Blast Management & Consulting

Quality Service on Time

Report: Blast Impact Assessment Proposed Twyfelaar Project Dagsoom Coal Mining (PTY) Ltd Project	
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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, *in situ* monitoring, post-blast monitoring and consulting as well as specialised projects. Blast Management & Consulting has been active in the mining industry since 1997 and work has been done at various levels for mining companies in South Africa, Botswana, Namibia, Mozambique, Democratic Republic of Congo, Sierra Leone and Côte d'Ivoire.

J D Zeeman holds the following qualifications:

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

Member: International Society of Explosive Engineers

iii. Independence Declaration

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

Legal Requirements

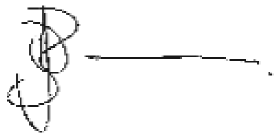
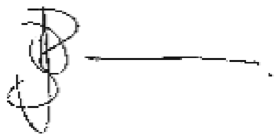
In terms of the NEMA 2014 EIA Regulations contained in GN R982 of 04 December 2014 (as amended by GN R 326 of 07 April 2017) all specialist studies must comply with Appendix 6 of the NEMA EIA Regulations, 2014 (as amended). Table 1 shows the requirements as indicated above.

Table 1: Legal Requirements for All Specialist Studies Conducted

Legal Requirement		Relevant Section in Specialist study
(1)	A specialist report prepared in terms of these Regulations must contain-	
(a)	details of-	
	(i) the specialist who prepared the report; and	I
	(ii) the expertise of that specialist to compile a specialist report including a curriculum vitae;	Section ii and 25
(b)	a declaration that the specialist is independent in a form as may be specified by the competent authority;	Section iii
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	Section 4
(d)	the date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Section 8
(e)	a description of the methodology adopted in preparing the report or carrying out the specialised process;	Section 6
(f)	the specific identified sensitivity of the site related to the activity and its associated structures and infrastructure;	Section 11
(g)	an identification of any areas to be avoided, including buffers;	Section 11
(h)	a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Section 11
(i)	a description of any assumptions made and any uncertainties or gaps in knowledge;	Section 9
(j)	a description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives on the environment;	Section 16
(k)	any mitigation measures for inclusion in the EMPr;	Section 16.13 & 17.4
(l)	any conditions/aspects for inclusion in the environmental authorisation;	Section 21
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Section 19
(n)	a reasoned opinion (Environmental Impact Statement)-	Section 24
	as to whether the proposed activity or portions thereof should be authorised; and	Section 24

Legal Requirement		Relevant Section in Specialist study
	if the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	Section 24
(o)	a description of any consultation process that was undertaken during the course of preparing the specialist report;	Section 12
(p)	a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	Section 12
(q)	any other information requested by the competent authority.	None

iv. Document Control:

Name & Company	Responsibility	Action	Date	Signature
C Zeeman Blast Management & Consulting	Document Preparation	Report Prepared	12/09/2019	
JD Zeeman Blast Management & Consulting	Consultant	Report Finalise	12/09/2019	
JD Zeeman Blast Management & Consulting	Consultant	Report Updated Editing	22/10/2019	

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List of Acronyms used in this Report

a and b	Site Constant
ANFO	Ammonium nitrate fuel oil
APP	Air Pressure Pulse
B	Burden (m)
BH	Blast Hole
BM&C	Blast Management & Consulting
Bs	Scaled Burden ($m^{3/2}kg^{-1/2}$)
D	Distance (m)
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	Latitude/Longitude
hddd°mm'ss.s"	Hours/degrees/minutes/seconds
M	Charge Height
m (SH)	Stemming height
Mc	Charge mass per metre column
N	North
NE	North East
NO	Nitrogen Monoxide
NO_2	Nitrogen Dioxide
NOx	Nitrogen Oxide
NOx’s	Noxious Fumes
NW	North West
P	Probability
POI	Points of Interest
PPD	Peak particle displacement
PPV	Peak Particle Velocity
PVS	Peak vector sum
RPP	Rock Pressure Pulse
S	South
SE	South East
SH	Stemming height (m)
SW	South West
T	Blasted Tonnage

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

List of Units used in this Report

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

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1 Executive Summary

Blast Management & Consulting (BM&C) was contracted as part of the Environmental Impact Assessment (EIA) team to perform a review of possible impacts with regards to blasting operations in the proposed Twyfelaar Coal Mining Project Northern access / block A box-cut area. Ground vibration, air blast, fly rock and fumes are some of the aspects as a result from blasting operations. The report concentrates on ground vibration and air blast and intends to provide information, calculations, predictions, possible influences and mitigations of blasting operations for this project.

The effects yielded by blasting operations was evaluated over an area as wide as 2500 m from the Twyfelaar Northern Access box-cut area. The range of structures observed consists of low-cost structures, brick and mortar houses, railway lines, cultivated fields and water resource related features. The location of structures around the Twyfelaar Northern Access box-cut area is such that the charge evaluated showed minimal possible influences due to ground vibration, air blast and fly rock. The closest structures observed are informal houses. These are located significant distance from the box-cut.

Ground vibrations predicted for the blasting operations in the box-cut area were relatively low. Levels predicted for infrastructure in the area investigated ranged between 0.5 mm/s and 1.9 mm/s. No specific mitigations are required for management of ground vibration.

Air blast predicted showed limited concerns for blasting at the box-cut. Levels predicted for the maximum charge ranges between 117 and 124 dB for all the POI's associated with housing considered. Levels are expected to be only a nuisance rather than damage causing. The predicted levels may contribute to effects such as rattling of roofs or door or windows that could lead to complaints. 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.

An exclusion zone for safe blasting was also calculated. The exclusion zone was established to be at least 233 m. The use of the normal practice observed in mines of 500 m exclusion zone could be considered. No infrastructure was observed within the 500 m boundary.

Closure of roads and considering the farming community around the box-cut area must also be considered.

The box-cut area is located such that no limited concerns – mainly air blast - were identified and addressed in the report.

Blasting operations during the operational is not expected to have any influence. Expected levels of ground vibration is less than 1 mm/s at the nearest house infrastructure to the underground area. There is no concern for influence from underground blasting operations on the identified house infrastructure surrounding the underground area.

2 Introduction

Dagsoom Coal Mining (Pty) Ltd (Dagsoom) currently has an approved Prospecting Right (reference number MP30/5/1/2/2/10236MR) which was authorised by the Department of Mineral Resources (DMR) and lapses on 05 May 2019. Dagsoom has submitted applications for Environmental Authorisation in terms of the National Environmental Management Act, 1998 (Act 107 of 1998) and a Mining Right Application in terms of the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA) to extract coal on Portions 1, 2 and 7 of the Farm Twyfelaar 298IT and on the Remaining Extent (RE) of the Farm Klipfontein 283IT. The farm is located near Sheepmoor town within the Msukaligwa Local Municipality, situated in the Highveld sub-region of the Gert Sibande District Municipality in the Mpumalanga Province.

The proposed Twyfelaar Coal Mining Project is a “greenfields” Project, meaning there is currently no mining activity on the proposed site. The proposed site is situated on the eastern escarpment of the Mpumalanga Highveld coalfield. Dagsoom proposes to extract the coal through underground mining by means of a mine adit. The Run of Mine (RoM) coal will be conveyed from the mine adit to the RoM stockpile alongside the RoM conveyor. Numerous wetlands and hillside seepage areas were identified around the hill and most of the potentially opencast mineable resource are therefore not mineable to limit the impacts of mining. The proposed mine will therefore be an underground mine, with all infrastructure around the mine access area on the eastern side of the project area on the farm Twyfelaar.
The proposed infrastructure required includes the following:

- Underground Mine accessed by adit;
- Access and haulage road;
- Adit;
- Two ventilation fans;
- Wash plant;
- Pollution control dam;
- Raw water pump station and process water pump station;
- Raw water pipeline and process water pipeline;
- Electricity supply;
- Potable water treatment plant and associated tanks;
- Sewage treatment plant;
- Reverse Osmosis plant;
- Two change houses;
- Offices and ablution facilities;
- Workshops and cable workshop;
- Refuel bay;
- Weighbridge and weighbridge control room; and
- Access control office.

The position for the mine access is selected based on the most appropriate position for a mine access, together with the associated surface infrastructure positioned outside the identified wetlands, but with a practical view on the seam access, mine layout, ventilation considerations, terrace for product handling and access road from the main road. The resource will be accessed through a box-cut (adit) on the side of the mountain and the C-lower seam will be accessed directly without any declines.

The coal reserves are scheduled to be mined with two continuous miners. Each production section will be mined at a rate of about 240 kilo tonnes per annum (ktpa) or 20 kilo tonnes per month (ktpm), which is the industry benchmark due to the low seam height to be mined. Stooping production rates may increase up to 30 ktpm due to less support requirements.

The total production for this mine is planned to be 480 ktpa or slightly higher during stooping operations with two continuous miner sections. The operating cost of the mine is also directly in relation to the production rate. This Life of Mine schedule allows a life of mine of between four and five years pending the decision whether or not to stoop the main development.

3 Objectives

The objectives of this document are outlining the expected environmental effects that blasting operations could have on the surrounding environment; 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 pieces of South African 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:

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

The guidelines and safe blasting criteria are based on internationally accepted standards and specifically criteria for safe blasting for ground vibration and recommendations on air blast published by the United States Bureau of Mines (USBM). There are no specific South African standards and the USBM is well accepted as standard for South Africa.

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 2500 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

The project is located on the farm Portion 1 of the Farm Twyfelaar 298 IT, Portion 7 of the Farm Twyfelaar 298 IT and Remaining Extent of the Farm Klipfontein 283 IT in the magisterial district Gert Sibande District Municipality. The project located approximately 8 km west of Sheepmoor town. Figure 1 shows a Locality Map of the proposed project area. Figure 2 shows the infrastructure layout of the proposed Twyfelaar Coal Mine Project. Figure 3 shows the Twyfelaar Northern underground access layout.

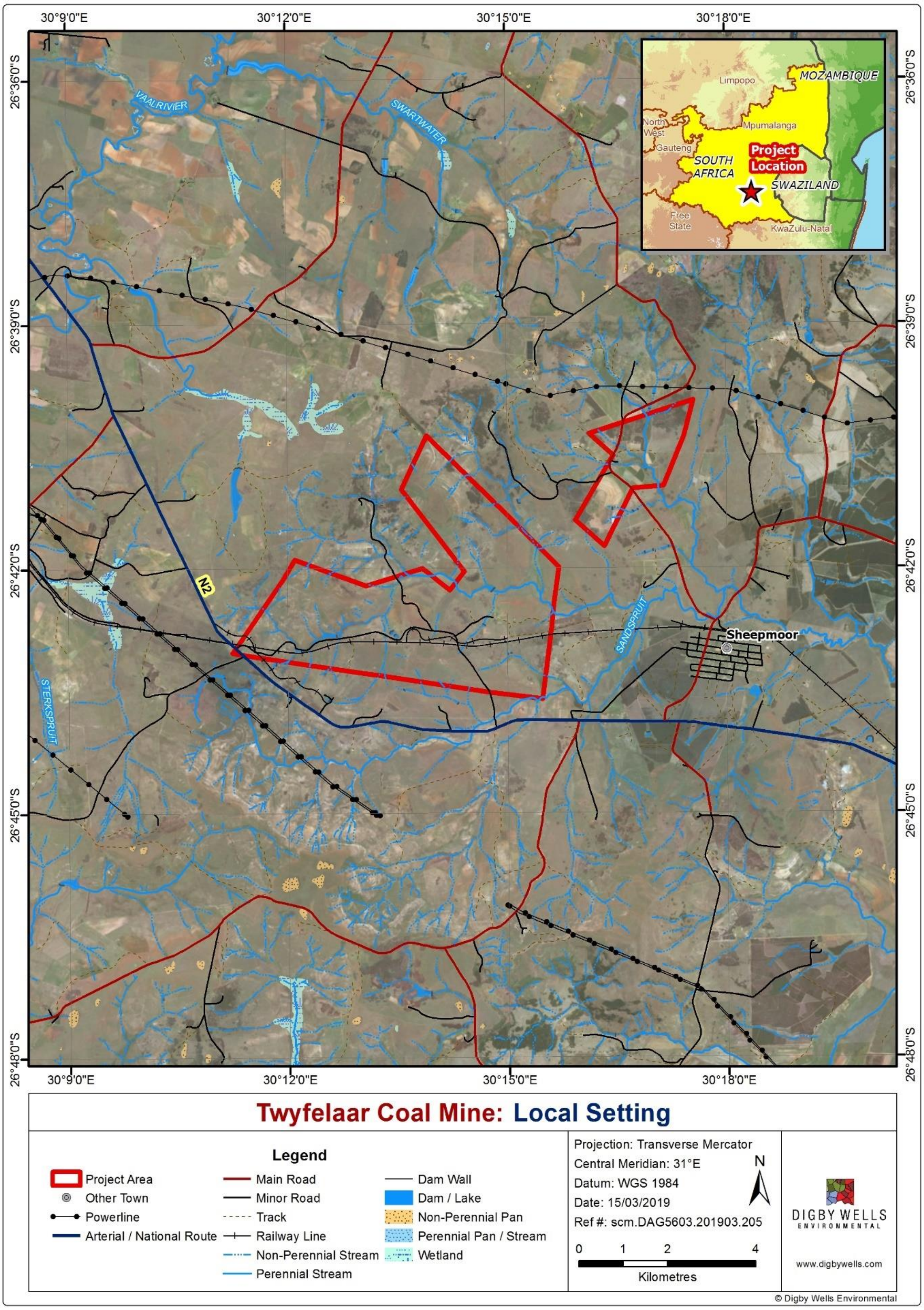


Figure 1: Locality Map of the proposed Project area

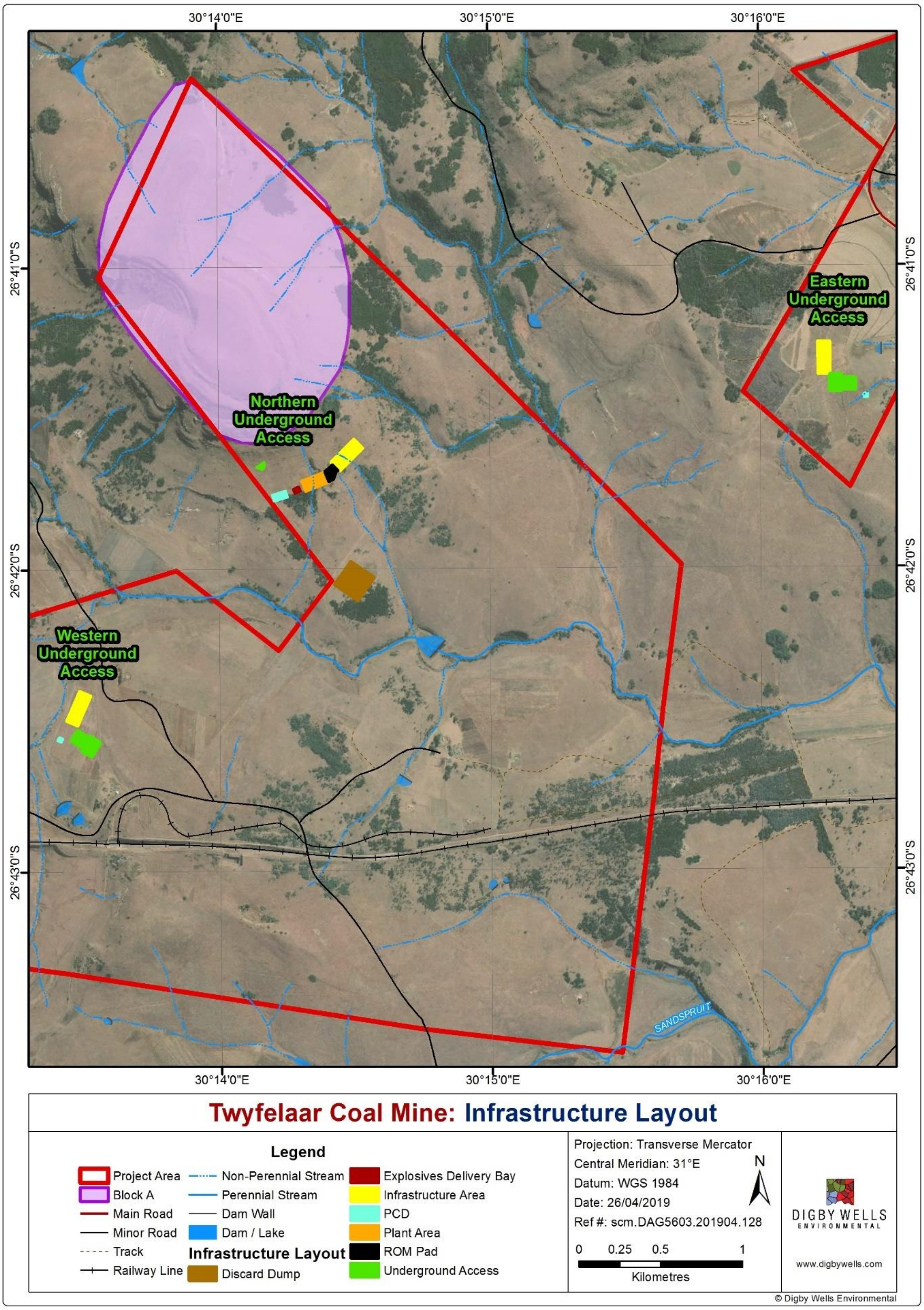


Figure 2: Infrastructure layout plan

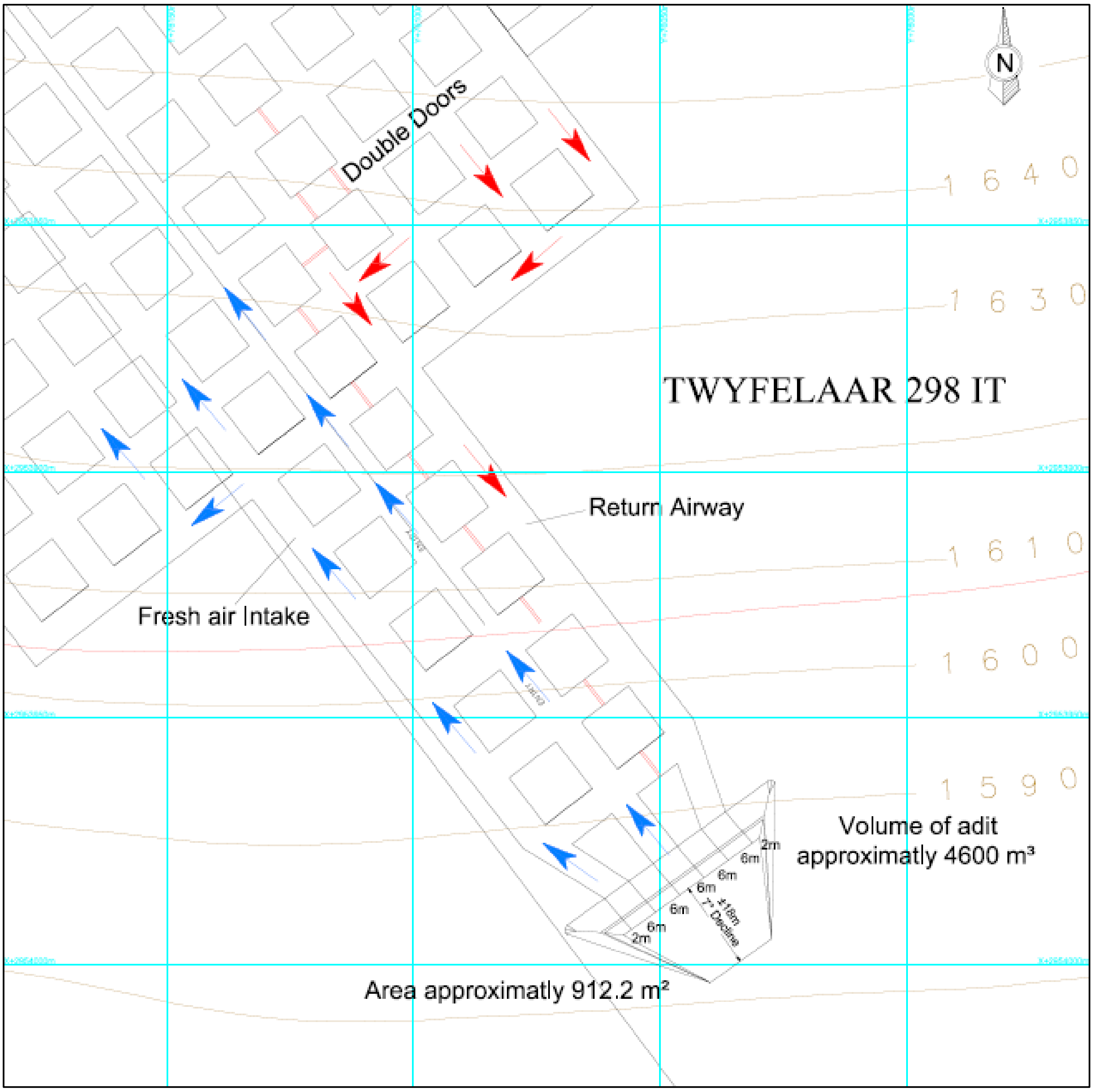


Figure 3: Twyfelaar Northern access plan

6 Methodology

The detailed plan of study consists of the following sections:

- Site visit: Intention to understand location of the site and its surroundings;
- Identifying surface structures / installations that are found within 2500 m from project site. A list of Point of Interests (POI's) are created that will be used for evaluation;
- Site evaluation: This consists of evaluation of the mining operations and the possible influences from blasting operations. The methodology is modelling – manual and software calculation - 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;

- Information from the bulk sample blasting done is used as guideline for expected drilling and blasting for the application area;
- Reporting: All data is prepared in a single report and provided for review.

7 Site Investigation

The site was visited on 03 September 2019. This site visit was done to get understanding of the location and the structures and installations surrounding the proposed Northern Access box-cut area.

8 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.

9 Assumptions and Limitations

The following assumptions have been made:

- The project is evaluated as a new operation with no blasting activities currently being done in section for application.
- 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 no data is available from this operation for a specific confirmation of the predicted values as no blasting activities is currently being done.
- No final box-cut blast design is not yet available. Data is based basic design parameters with information from scoping phase report. A generic box-cut blast design was applied.
- Blast Management & Consulting created a basic blast design.

- The work done is based on the author's knowledge and information provided by the project applicant.

10 Legal Requirements

The protocols applied in this document are based on the author's experience, guidelines elicited by the literature research, client requirements and general indicators provided in the various applicable South African acts. There is no direct reference in the consulted acts specifically with regard to limiting levels for ground vibration and air blast. There is however specific requirements and regulations with regards to blasting operations and the effect of ground vibration and air blast and some of the aspects addressed in this report. The acts consulted are: National Environmental Management Act No. 107 of 1998; Mine Health and Safety Act No. 29 of 1996; Mineral and Petroleum Resources Development Act No. 28 of 2002; and the Explosives Act No. 15 of 2003.

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. There are no specific South African standards and the USBM is well accepted as standard for South Africa. Additional criteria required by various institutions in South Africa was also taken into consideration, i.e. Eskom, Telkom, Transnet, Rand Water Board, etc.

In view of the acts consulted, the following guidelines and regulations are noted: (where possible detail was omitted and only some of the information indicated)

- MINE HEALTH AND SAFETY ACT 29 OF 1996

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

Precautionary measures before initiating explosive charges
4.7 The employer must take reasonable measures to ensure that when blasting takes place, air and ground vibrations, shock waves and fly material are limited to such an extent and at such a distance from any building, public thoroughfare, railway, power line or any place where persons congregate to ensure that there is no significant risk to the health or safety of persons.

General precautions
4.16 The employer must take reasonable measures to ensure that:

4.16(1) in any mine other than a coal mine, no explosive charges are initiated during the shift unless –

(a) such explosive charges are necessary for the purpose of secondary blasting or reinitiating the misfired holes in development faces;

(b) written permission for such initiation has been granted by a person authorised to do so by the employer; and

(c) reasonable precautions have been taken to prevent, as far as possible, any person from being exposed to smoke or fumes from such initiation of explosive charges;

4.16(2) no blasting operations are carried out within a horizontal distance of 500 metres of any public building, public thoroughfare, railway line, power line, any place where people congregate or any other structure, which it may be necessary to protect in order to prevent any significant risk, unless:

(a) a risk assessment has identified a lesser safe distance and any restrictions and conditions to be complied with;

(b) a copy of the risk assessment, restrictions and conditions contemplated, in paragraph (a) have been provided for approval to the Principal Inspector of Mines;

(c) shot holes written permission has been granted by the Principal Inspector of Mines; and

(d) any restrictions and conditions determined by the Principal inspector of Mines are complied with.

- MINERAL AND PETROLEUM RESOURCES DEVELOPMENT ACT 28 OF 2002

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

MINERAL AND PETROLEUM RESOURCES DEVELOPMENT REGULATIONS

67. Blasting, vibration and shock management and control

(1) A holder of a right or permit in terms of the Act must comply with the provisions of the Mine Health and Safety Act, 1996, (Act No. 29 of 1996), as well as other applicable law regarding blasting, vibration and shock management and control.

(2) An assessment of impacts relating to blasting, vibration and shock management and control, where applicable, must form part of the environmental impact assessment report and environmental management programme or the environmental management plan.

The current pit layouts indicate that private installations may be in proximity of the planned pit areas. The Mine Health and Safety Act has specific requirements regarding blasting within 500 m from private installations. This condition will be addressed in the recommendations as well.

11 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 box-cut area.
- An area 500 m to 1500 m around the box-cut 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 Twyfelaar Northern Access box-cut area for the Project. The specific influences will be determined through the work done for this project in this report.

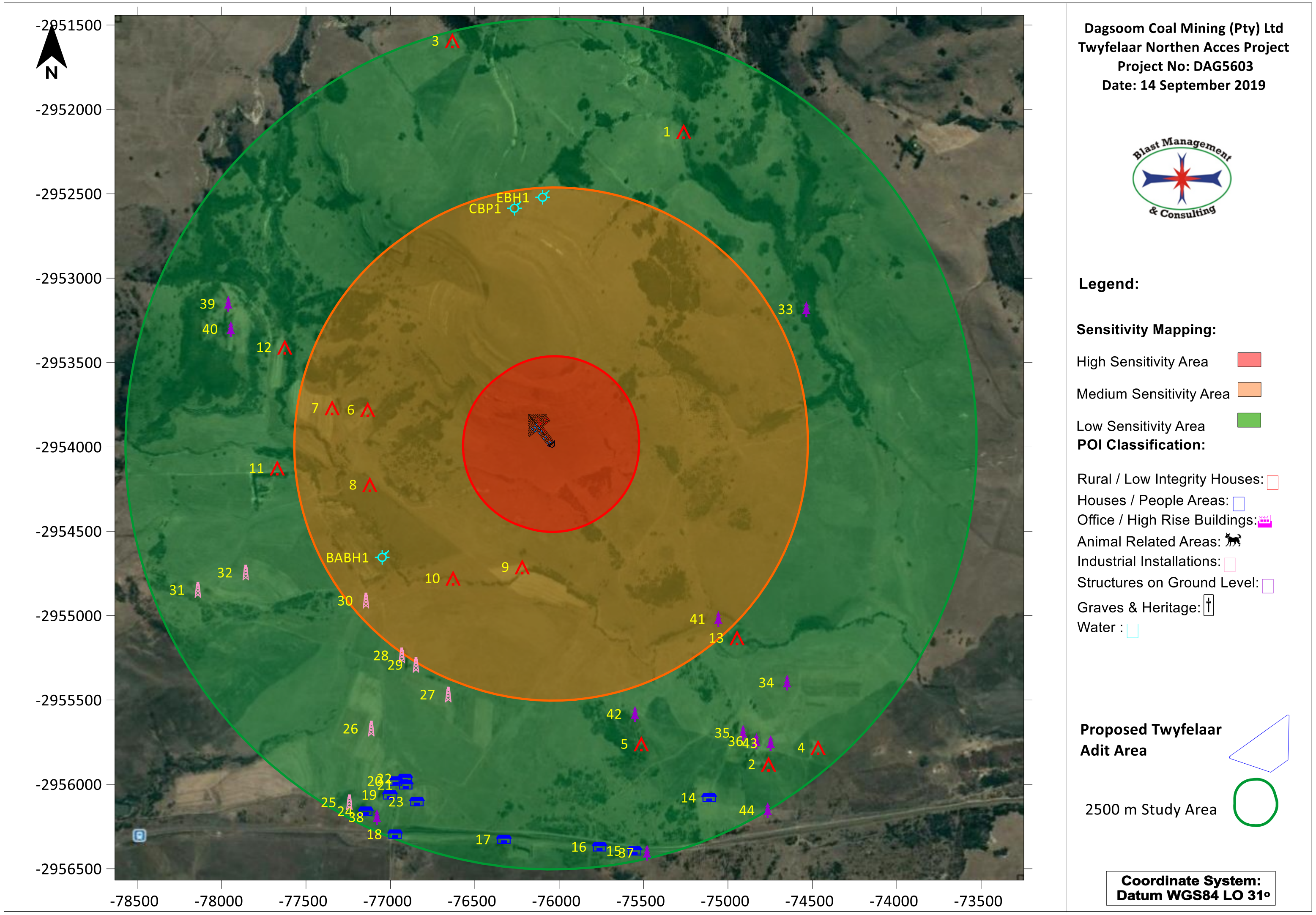


Figure 4: Identified sensitive areas for the proposed Twyfelaar Northern Access Box-cut area

12 Consultation process

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

13 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 from the blasting process. Based on the regulations of the different acts consulted and international accepted standards these effects are required to be within certain limits. The following sections provide guidelines on these limits. As indicated, there are no specific South African ground vibration and air blast limit standard.

13.1 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 used by BM&C.

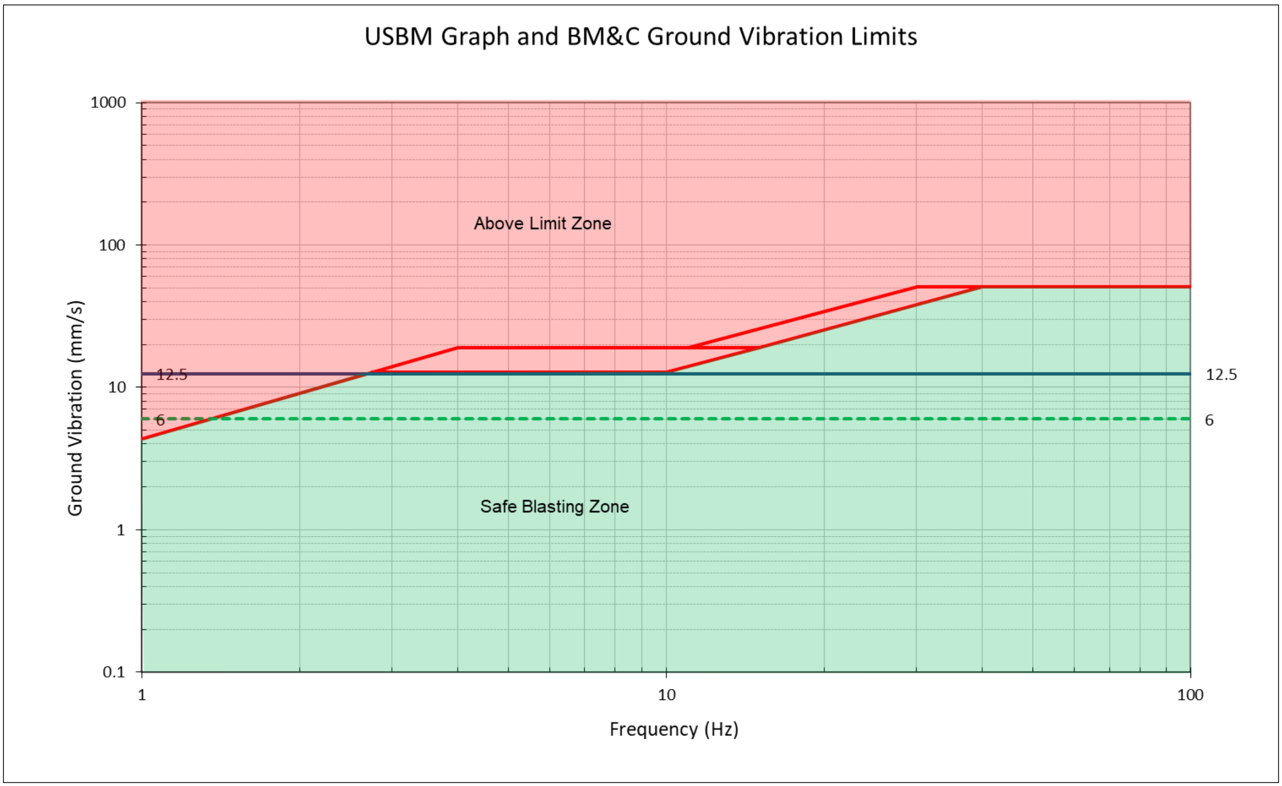


Figure 5: USBM Analysis Graph

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

- National roads/tar roads: 150 mm/s BM&C;
- Steel pipelines: 50 mm/s (Rand Water Board);
- Electrical lines: 75 mm/s (Eskom);
- Sasol Pipelines: 25 mms/s (Sasol);
- Railways: 150 mm/s BM&C;

- Concrete less than 3 days old: 5 mm/s [1];
- Concrete after 10 days: 200 mm/s [2];
- Sensitive plant equipment: 12 mm/s or 25 mm/s, depending on type. (Some switches could trip at levels of less than 25 mm/s.)[2];
- Waterwells or Boreholes: 50 mm/s [3];

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

- USBM criteria for safe blasting;
- The additional limits provided above;
- Consideration of private structures in the area of influence;
- Should structures be in poor condition, the basic limit of 25 mm/s is halved to 12.5 mm/s or when structures are in very poor condition limits will be restricted to 6 mm/s. It is a standard accepted method to reduce the limit allowed with poorer condition of structures;
- 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.

13.2 Ground vibration limitations and human perceptions

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

Ground vibration is experienced at different levels; BM&C considers only the levels that are experienced as “Perceptible”, “Unpleasant” and “Intolerable”. This is indicative of the human being’s perceptions of ground vibration and clearly indicates that humans are sensitive to ground

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

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

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

vibration and humans perceive ground vibration levels of 4.5 mm/s as unpleasant (See Figure 6). This guideline helps with managing ground vibration and the complaints that could be received due to blast induced ground vibration.
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.

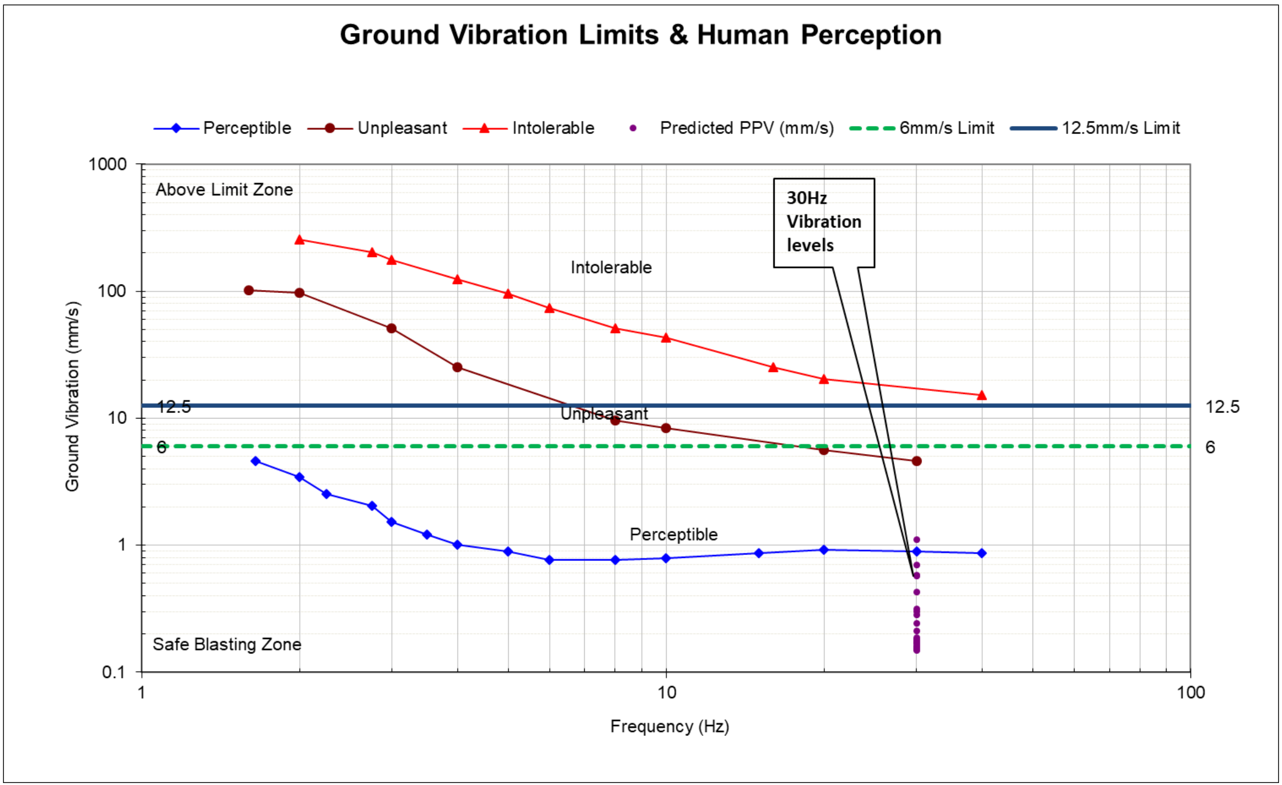


Figure 6: Human Perception Analysis

13.3 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 2). Levels given in Table 2 are at the point of measurement. The weakest points on a structure are the windows and ceilings.

Table 2: Damage Limits for Air Blast

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

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

13.4 Air blast limitations and human perceptions

Considering human perceptions and the misunderstanding about ground vibration and air blast, BM&C generally recommends that blasting be done in such a way that air blast levels are kept below 120dB. This will ensure fewer complaints regarding blasting operations. The effect 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.

13.5 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.

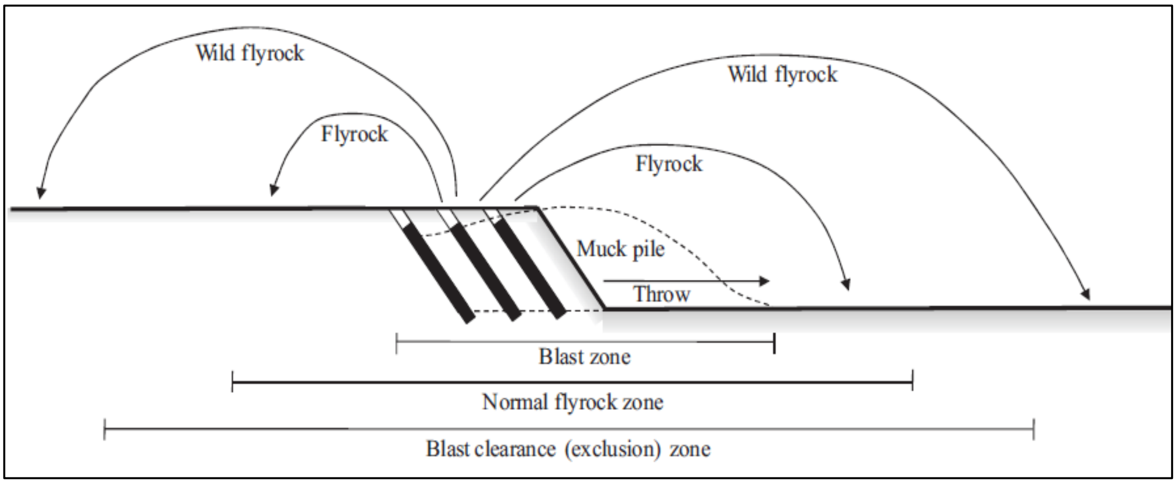


Figure 7: Schematic of fly rock terminology

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.

13.6 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.

13.7 Vibration impact on provincial and national roads

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

13.8 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 neighbourship. 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.

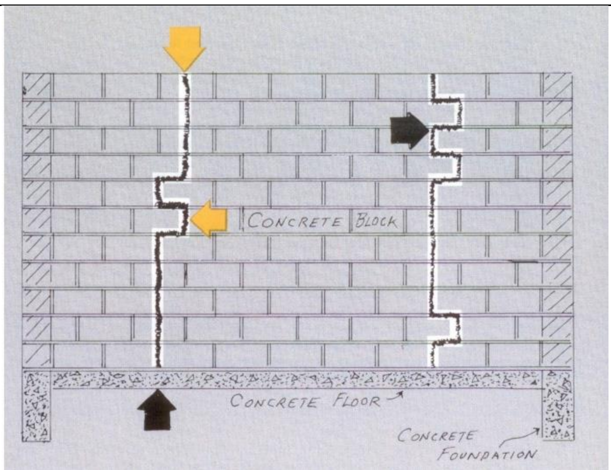
13.9 Cracking of houses and consequent devaluation

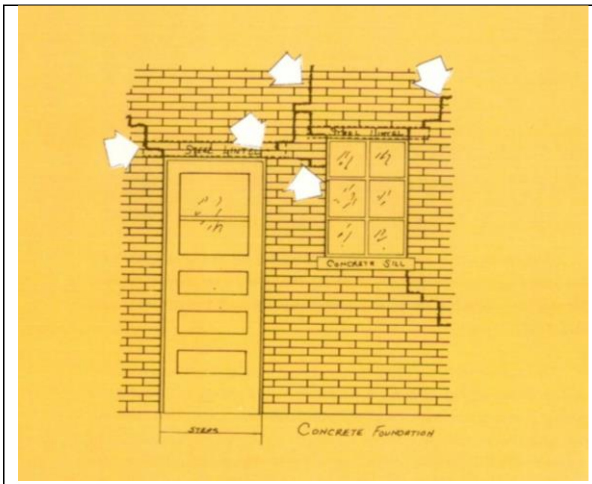
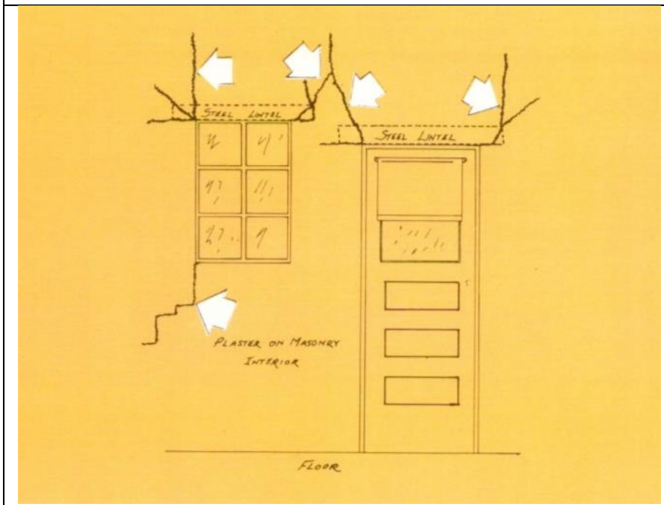
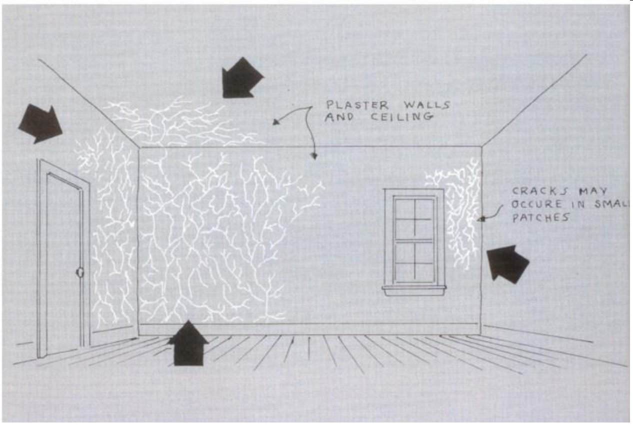
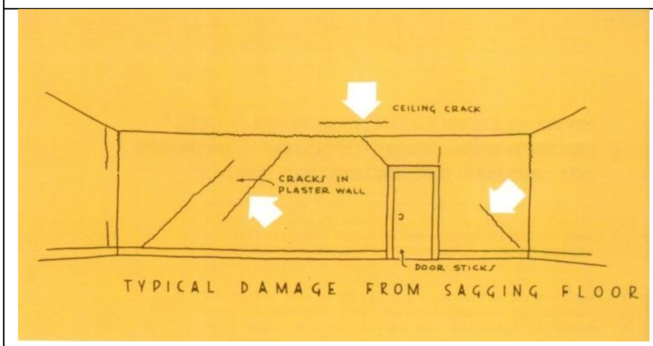
Houses in general have cracks. It is reported that a house could develop up to 15 cracks a year. Ground vibration will be mostly responsible for cracks in structures if high enough and at continued high levels. The influences of environmental forces such as temperature, water, wind etc. are more reason for cracks that have developed. Visual results of actual damage due to blasting operations are limited. There are cases where it did occur, and a result is shown in Figure 8 below. A typical X crack formation is observed.

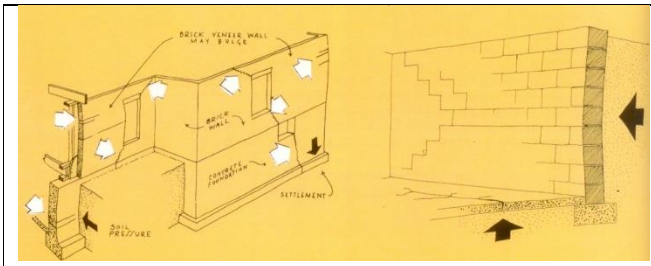
Figure 8: Example of blast induced damage.

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.

14 Baseline Results

The baseline information for the project is limited to observation of the current surroundings of the proposed project. There are currently no blasting operations being conducted that can be measured as part of a baseline study. The study area is evaluated as a “green fields” project.

14.1 Structure profile

As part of the baseline, all possible structures in a possible influence area are identified. The project area was reviewed using Google Earth imagery. Information sought during the review was to identify surface structures present in a 2500 m radius for the box-cut which will require consideration during modelling of blasting operations, e.g. houses, general structures, power lines, pipe lines, reservoirs, mining activity, roads, shops, schools, gathering places, possible historical sites, etc. A list was prepared of all structures in the vicinity of the box-cut area. The list includes structures and points of interests (POIs) within the 2500 m boundary – see Table 5 below. A list of structure locations was required in order to determine the allowable ground vibration limits and air blast limits. Figure 9 shows an aerial view of the box-cut 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 and High-rise buildings
4	Animal related installations and animal sensitive areas
5	Industrial buildings and installations
6	Earth like structures – no surface structure
7	Graves & Heritage
8	Water Borehole

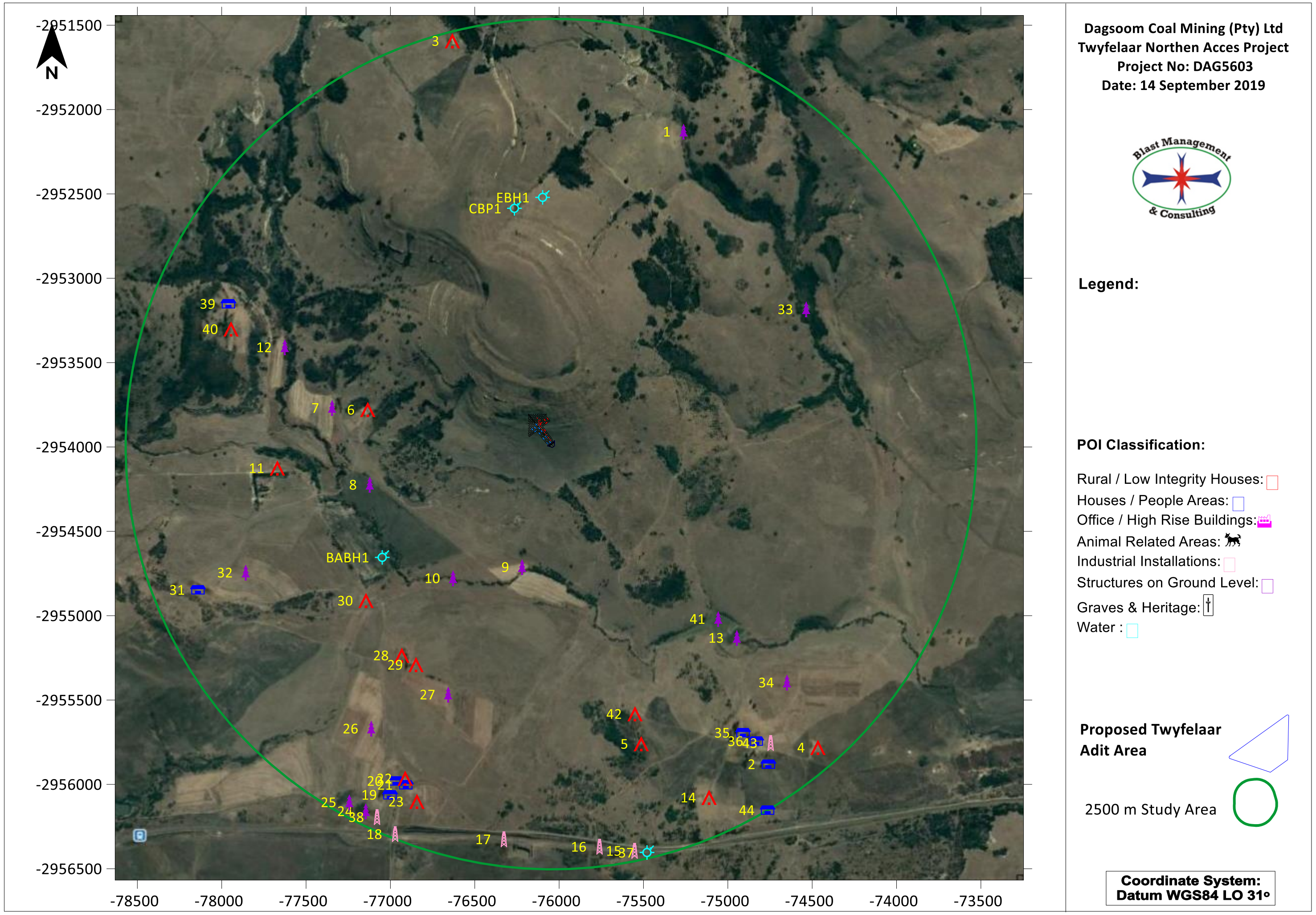


Figure 9: Aerial view and surface plan of the proposed Twyfelaar Northern Access Box-cut area with points of interest identified

Table 5: List of points of interest identified (WGS84 – LO 31°)

Tag	Description	Classification	Y	X
1	River	6	75262.1	2952130.7
2	Farm Building	2	74759.4	2955880.1
3	Rural Village	1	76632.8	2951593.0
4	Informal Housing	1	74465.9	2955781.4
5	Informal Housing	1	75513.4	2955759.4
6	Rural Village	1	77134.3	2953778.7
7	Cultivated Fields	6	77345.3	2953768.1
8	Cultivated Fields	6	77121.9	2954223.3
9	Cultivated Fields	6	76219.1	2954711.4
10	River	6	76628.5	2954777.7
11	Rural Village	1	77670.1	2954125.3
12	Cultivated Fields	6	77625.7	2953408.8
13	Dam	6	74946.0	2955131.0
14	Informal Housing	1	75111.3	2956077.6
15	Railway Line	5	75553.0	2956393.7
16	Bridge	5	75760.6	2956369.4
17	Railway Line	5	76327.4	2956325.3
18	Bridge	5	76972.0	2956294.5
19	Farmhouse	2	77002.6	2956061.5
20	Farm Buildings	2	76969.6	2955979.4
21	Farm Buildings	2	76909.0	2956002.3
22	Informal Housing	1	76912.4	2955964.4
23	Informal Housing	1	76842.9	2956101.6
24	Dam	6	77145.8	2956158.6
25	Dam	6	77243.1	2956105.7
26	Cultivated Fields	6	77113.3	2955668.9
27	Cultivated Fields	6	76657.1	2955467.3
28	Ruins	1	76932.5	2955235.3
29	Informal Housing	1	76848.6	2955290.7
30	Informal Housing	1	77144.8	2954910.5
31	Farm Buildings	2	78140.7	2954846.6
32	Cultivated Fields	6	77857.3	2954744.3
33	River	6	74535.4	2953183.5
34	Cultivated Fields	6	74649.1	2955395.7
35	Farm Buildings	2	74910.1	2955693.5
36	Farmhouse	2	74831.2	2955743.2
37	Weir	8	75479.1	2956404.3
38	Cement Dam	5	77079.4	2956193.6

Tag	Description	Classification	Y	X
39	Farm Building	2	77960.2	2953151.2
40	Ruins	1	77944.9	2953301.2
41	Marsh	6	75056.6	2955019.0
42	Informal Housing	1	75550.4	2955582.2
43	Cement Dam	5	74746.3	2955754.8
44	Farm Buildings	2	74764.2	2956152.3
BABH1	Artesian well	8	77048.5	2954654.9
BCPH1	Water supply borehole at Bambanani	8	80026.7	2956641.5
BCPH2	Dysfunctional water supply borehole	8	80491.1	2956377.7
CBP1	Spring	8	76265.0	2952586.0
EBH1	Exploration borehole	8	76097.7	2952521.1
KPR	Drinking water supply spring	8	72156.1	2951833.7
NBH1	Water supply borehole	8	77784.0	2957939.1
RPR (RBH)	Spring used for domestic uses.	8	72550.3	2952499.0
VRB	River fed by a spring	8	79415.2	2956439.3
WelBH1	Wind pump	8	80534.7	2948448.4
WBH1	Borehole	8	79078.6	2947895.4
ZW-Spring	Spring	8	76774.4	2950831.9

During the site visit the structures were observed and the initial POI list ground-truthed and finalised as represented in this section. Structures ranged from well-built structures, mining structures to informal building styles. Table 6 shows photos of structures found in the area.

Table 6: Structure Profile

Structure Photo	Description
	Brick and Mortar Structures

  	Rural Houses

  	Old Brick and Mortar Structure (with damage)

 	Informal Structures (corrugated)
	Railway Lines

	
	Bridges

	
	Weir
	Dam

	
	Farm House

	Cultivated Fields
	Livestock

 	Powerlines

15 Blasting Operations

Blast design forms the basis of all calculations done for impact assessment. A final blast design for the box-cut is not yet available and thus information used from scoping phase report was used to create generic blast design. Table 7 shows summary technical information of the blast design.

Table 7: Blast design technical information

Blast Information:	
B/H Diameter (mm)	115
Min Depth (m)	10.0
Maximum Depth (m)	10.0
Pattern	Square
Burden (m)	3.25

Spacing (m)	3.25
Average Depth (m)	10.00
Explosive Charge:	
Explosive Type	Emulsion
Explosive Description	Innovex 100
Explosive Density (1.0 - 1.25 g/cm^3)	1.15
Charging Regime:	
Linear Charge Mass (kg)	11.94
P/F Blasthole (kg/m$^{3)}$	0.80
Column Length (incl. Sub drill.)	7.1
Stemming Length (m) Control	2.90
Stemming Length (m) Required	2.90
Explosives Per B/H (incl. Sub drill) (kg)	84.809
Stemming: BH Diameter Ratio	25.0
Avg. Charge (kg)	85
BH / Delay	6.0
Multiple BH / Delay (kg)	509

The above information 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 115 mm diameter single blast hole and the maximum charge was determine from possible maximum blastholes detonating simultaneously. The maximum charge relates to the total number of blast holes that detonates simultaneously based on a blast layout, initiation and timing of the blast. In this case a shock tube type initiation system is considered and expected to have up to six blastholes detonating simultaneously yielding the maximum mass of explosives detonating at once. The minimum charge relates to 85 kg and the maximum charge (6 x 85kg) relates to 509 kg. These values were applied in all predictions for ground vibration and air blast.

Underground Coal Blast

Underground coal blasting consists of blast holes drilled into the face. A maximum of 800gr of permitted explosive is charged in a blast hole for underground coal mines in South Africa. The arrangement of blast holes drilled could typically be as shown in figure 6. The two rows of blast holes where blastholes in a row are initiated simultaneously yielding a total mass of explosives detonating at 3.2 kg. The expected ground vibration levels from underground blasting are 50% less than that of surface blasting for the same charge mass and distance. This is caused by mainly body waves generated from blasting underground instead of surface and body waves in surface blasting.

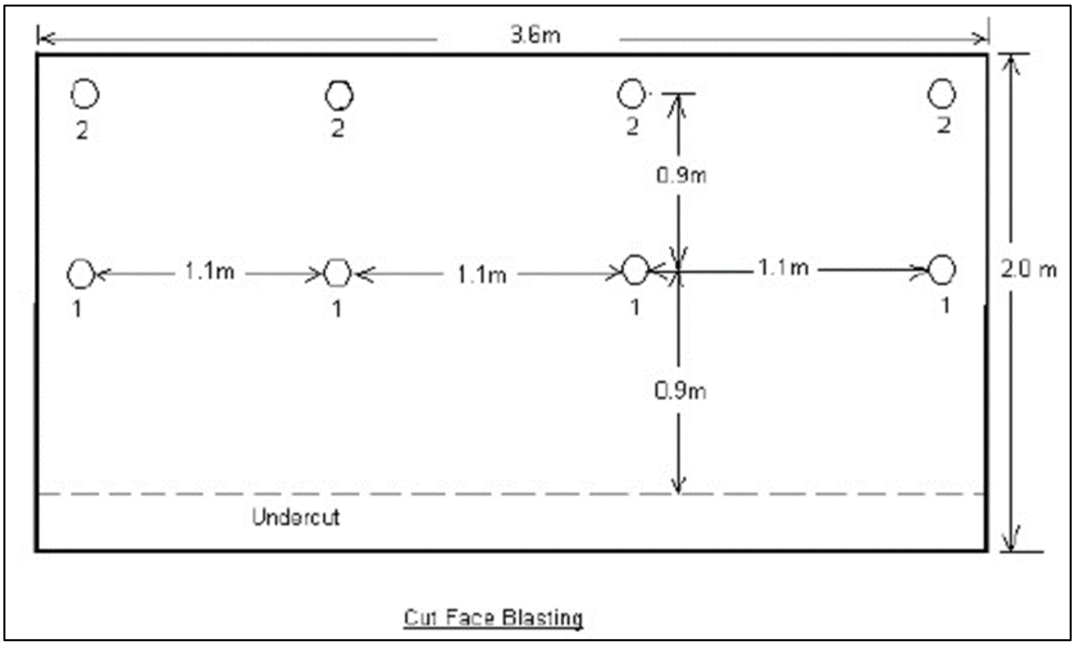


Figure 10: Underground coal blast round

15.1 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 from source (m)
E = Explosive Mass (kg)

Applicable and accepted factors a & b for new operations is as follows:
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. Structures 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 blast designs (surface blasts) presented on expected drilling and charging design, the following Table 8 shows expected ground vibration levels (PPV) for various distances calculated at the two different charge masses. The charge masses are 58 kg and 509 kg for the opencast area. The maximum charge mass expected from underground coal blasts are in the order of 3.2 kg. Table 9 shows expected levels of ground vibration for various distances from the underground blasting.

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

No.	**Distance (m)**	**Expected PPV (mm/s) for 58 kg Charge**	**Expected PPV (mm/s) for 509 kg Charge**
1	50.0	70.2	307.5
2	100.0	36.0	157.5
3	150.0	11.5	50.2
4	200.0	7.1	31.2
5	250.0	4.9	21.6
6	300.0	3.7	16.0
7	400.0	2.3	9.9
8	500.0	1.6	6.9
9	600.0	1.2	5.1
10	700.0	0.9	4.0
11	800.0	0.7	3.2
12	900.0	0.6	2.6
13	1000.0	0.5	2.2
14	1250.0	0.3	1.5
15	1500.0	0.3	1.1
16	1750.0	0.2	0.9
17	2000.0	0.2	0.7
18	2500.0	0.1	0.5

Table 9: Expected Ground Vibration at Various Distances from Charges Applied in this Study

No.	Distance (m)	Max Charge PPV (mm/s)
1	5.0	104.8
2	10.0	33.4
3	15.0	17.1
4	20.0	10.6
5	25.0	7.4
6	30.0	5.5
7	35.0	4.2
8	40.0	3.4
9	45.0	2.8
10	50.0	2.3
11	55.0	2.0
12	60.0	1.7
13	65.0	1.5
14	70.0	1.3
15	75.0	1.2
16	80.0	1.1
17	85.0	1.0
18	90.0	0.9
19	95.0	0.8
20	100.0	0.7

15.2 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:

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

Where:

P = Air blast level (mB)

D = Distance from source (m)

E = Maximum charge mass per delay (kg)

A = Constant - (37.1)

B = Constant - (-0.97)

The constants for A and B were then selected according to the information as provided in Figure 11 below. Various types of mining operations are expected to yield different results. The information provided in Figure 11 is based on detailed research that was conducted for each of the different types of mining environments. In this report, the data for "quarry face" was applied in the prediction or air blast because of box-cut operation.

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 11: 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 10 below is a summary of values predicted according to Equation 2.

Table 10: Air Blast Predicted Values

No.	Distance (m)	Air blast (dB) for 157 kg Charge	Air blast (dB) for 628 kg Charge
1	50.0	144.9	149.9
2	100.0	141.5	146.5
3	150.0	135.6	140.7
4	200.0	133.2	138.2
5	250.0	131.3	136.4
6	300.0	129.8	134.8
7	400.0	127.4	132.4
8	500.0	125.5	130.5
9	600.0	124.0	129.0
10	700.0	122.7	127.7
11	800.0	121.5	126.6
12	900.0	120.5	125.6
13	1000.0	119.6	124.7
14	1250.0	117.8	122.8
15	1500.0	116.3	121.3
16	1750.0	115.0	120.0
17	2000.0	113.8	118.8
18	2500.0	111.9	117.0
19	3000.0	110.5	115.4
20	3500.0	109.1	114.2

16 Construction Phase: Impact Assessment and Mitigation Measures

The area surrounding the proposed mining areas was reviewed for structures, traffic, roads, human interface, animal 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 15 is considered with regards to ground vibration and air blast.

Ground vibration and air blast was calculated from the edge of the box-cut 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 box-cut 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.

16.1 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 box-cut area at the minimum and maximum charge mass at specific distances from the box-cut 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 2500 m around the box-cut 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 areas. 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.

16.1.1 Minimum charge mass per delay – 58 kg – Twyfelaar Northern Access Box-cut

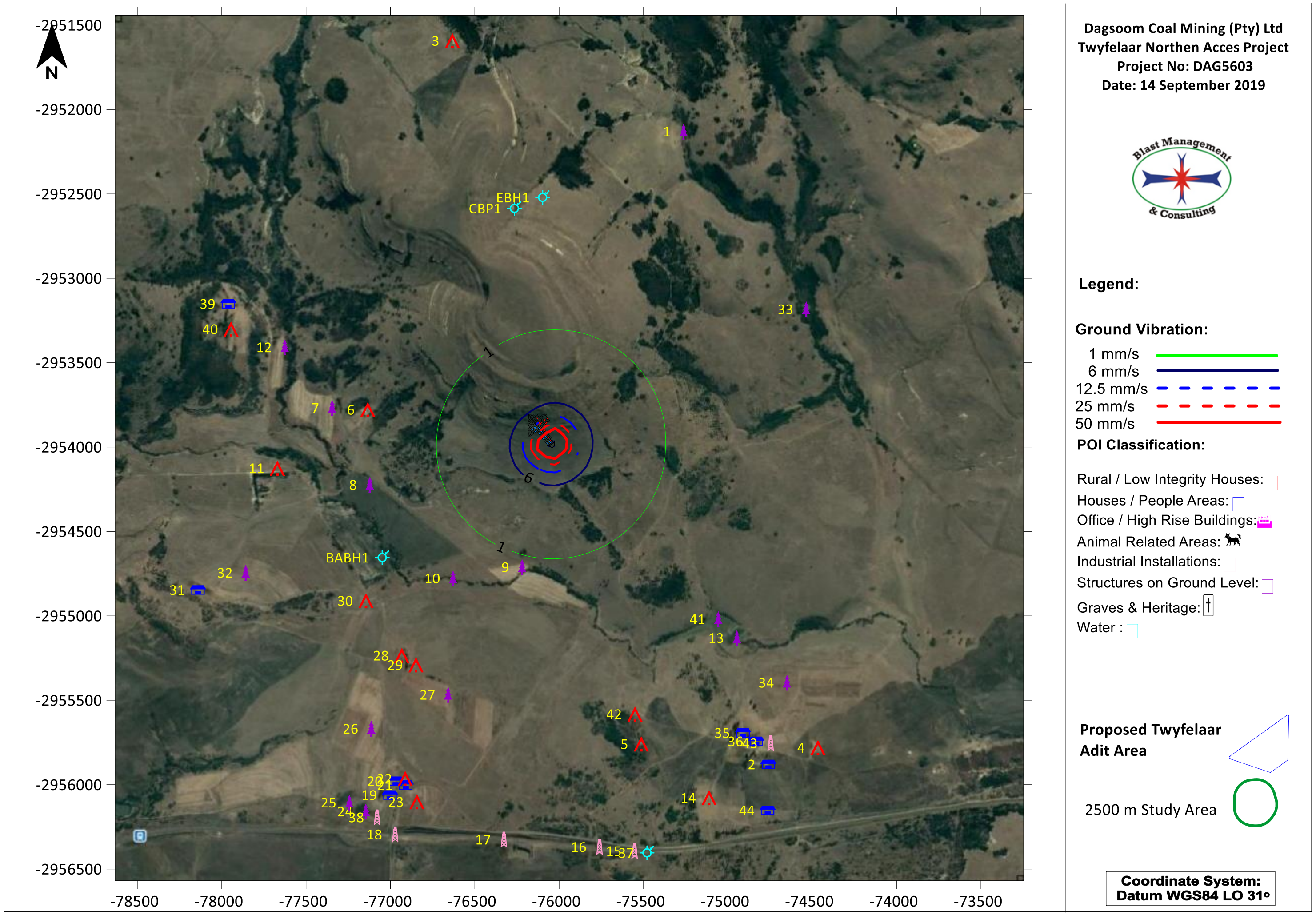


Figure 12: Ground vibration influence from minimum charge for Twyfelaar Northern Access Box-cut

Table 11: Ground vibration influence from minimum charge for Twyfelaar Northern Access Box-cut

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	River	200	1985	85	0.2	Acceptable	N/A
2	Farm Building	12.5	2272	85	0.1	Acceptable	Too Low
3	Rural Village	6	2446	85	0.1	Acceptable	Too Low
4	Informal Housing	6	2373	85	0.1	Acceptable	Too Low
5	Informal Housing	6	1833	85	0.2	Acceptable	Too Low
6	Rural Village	6	1086	85	0.4	Acceptable	Too Low
7	Cultivated Fields	200	1296	85	0.3	Acceptable	N/A
8	Cultivated Fields	200	1078	85	0.4	Acceptable	N/A
9	Cultivated Fields	200	730	85	0.8	Acceptable	N/A
10	River	200	963	85	0.5	Acceptable	N/A
11	Rural Village	6	1606	85	0.2	Acceptable	Too Low
12	Cultivated Fields	200	1662	85	0.2	Acceptable	N/A
13	Dam	50	1569	85	0.2	Acceptable	N/A
14	Informal Housing	6	2272	85	0.1	Acceptable	Too Low
15	Railway Line	150	2439	85	0.1	Acceptable	N/A
16	Bridge	50	2382	85	0.1	Acceptable	N/A
17	Railway Line	150	2339	85	0.1	Acceptable	N/A
18	Bridge	50	2472	85	0.1	Acceptable	N/A
19	Farmhouse	12.5	2269	85	0.1	Acceptable	Too Low
20	Farm Buildings	12.5	2180	85	0.1	Acceptable	Too Low
21	Farm Buildings	12.5	2177	85	0.1	Acceptable	Too Low
22	Informal Housing	6	2144	85	0.1	Acceptable	Too Low
23	Informal Housing	6	2245	85	0.1	Acceptable	Too Low
24	Dam	50	2418	85	0.1	Acceptable	N/A
25	Dam	50	2416	85	0.1	Acceptable	N/A
26	Cultivated Fields	200	1974	85	0.2	Acceptable	N/A
27	Cultivated Fields	200	1587	85	0.2	Acceptable	N/A
28	Ruins	6	1512	85	0.3	Acceptable	Too Low
29	Informal Housing	6	1513	85	0.3	Acceptable	Too Low
30	Informal Housing	6	1413	85	0.3	Acceptable	Too Low
31	Farm Buildings	12.5	2240	85	0.1	Acceptable	Too Low
32	Cultivated Fields	200	1939	85	0.2	Acceptable	N/A
33	River	200	1683	85	0.2	Acceptable	N/A
34	Cultivated Fields	200	1965	85	0.2	Acceptable	N/A
35	Farm Buildings	12.5	2033	85	0.2	Acceptable	Too Low
36	Farmhouse	12.5	2118	85	0.1	Acceptable	Too Low
37	Weir	100	2465	85	0.1	Acceptable	N/A
38	Cement Dam	50	2421	85	0.1	Acceptable	N/A
39	Farm Building	12.5	2070	85	0.2	Acceptable	Too Low
40	Ruins	6	1999	85	0.2	Acceptable	Too Low
41	Marsh	200	1411	85	0.3	Acceptable	N/A
42	Informal Housing	6	1653	85	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
43	Cement Dam	50	2177	85	0.1	Acceptable	N/A
44	Farm Buildings	12.5	2499	85	0.1	Acceptable	Too Low
BABH1	Artesian well	50	1182	85	0.4	Acceptable	N/A
BCPH1	Water supply borehole at Bambanani	50	4762	85	0.0	Acceptable	N/A
BCPH2	Dysfunctional water supply borehole	50	5024	85	0.0	Acceptable	N/A
CBP1	Spring	50	1397	85	0.3	Acceptable	N/A
EBH1	Exploration borehole	50	1443	85	0.3	Acceptable	N/A
KPR	Drinking water supply spring	50	4418	85	0.0	Acceptable	N/A
NBH1	Water supply borehole	50	4302	85	0.0	Acceptable	N/A
RPR (RBH)	Spring used for domestic uses.	50	3772	85	0.1	Acceptable	N/A
VRB	River fed by a spring	50	4145	85	0.0	Acceptable	N/A
WelBH1	Wind pump	50	7119	85	0.0	Acceptable	N/A
WBH1	Borehole	50	6791	85	0.0	Acceptable	N/A
ZW-Spring	Spring	50	3219	85	0.1	Acceptable	N/A

16.1.2 Maximum charge mass per delay – 509 kg – Twyfelaar Northern Access Box-cut

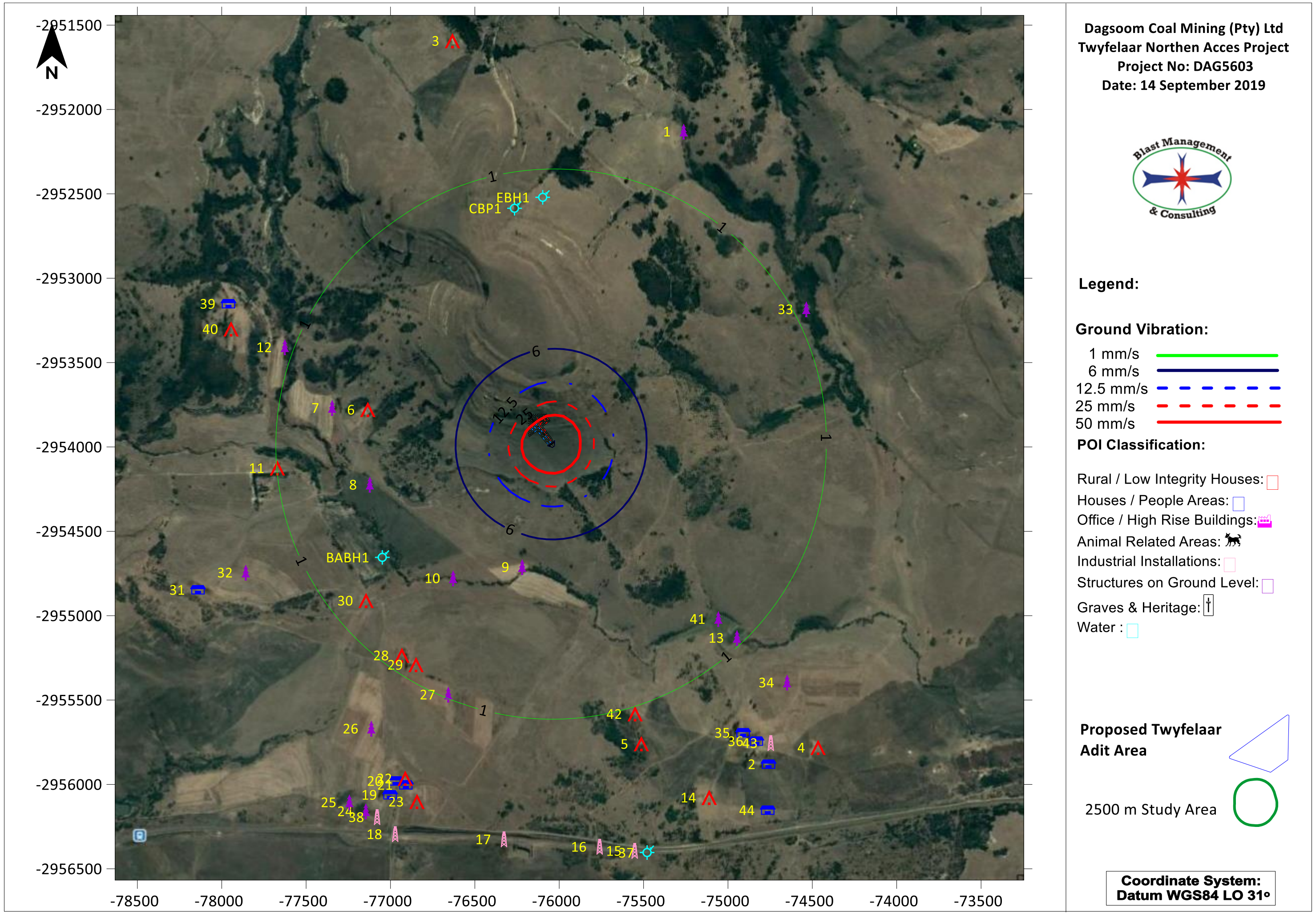


Figure 13: Ground vibration influence from maximum charge for Twyfelaar Northern Access Box-cut Area

Table 12: Ground vibration evaluation for maximum charge for Twyfelaar Northern Access Box-cut Area

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	River	200	1985	509	0.7	Acceptable	N/A
2	Farm Building	12.5	2272	509	0.6	Acceptable	Too Low
3	Rural Village	6	2446	509	0.5	Acceptable	Too Low
4	Informal Housing	6	2373	509	0.5	Acceptable	Too Low
5	Informal Housing	6	1833	509	0.8	Acceptable	Perceptible
6	Rural Village	6	1086	509	1.9	Acceptable	Perceptible
7	Cultivated Fields	200	1296	509	1.4	Acceptable	N/A
8	Cultivated Fields	200	1078	509	1.9	Acceptable	N/A
9	Cultivated Fields	200	730	509	3.7	Acceptable	N/A
10	River	200	963	509	2.3	Acceptable	N/A
11	Rural Village	6	1606	509	1.0	Acceptable	Perceptible
12	Cultivated Fields	200	1662	509	0.9	Acceptable	N/A
13	Dam	50	1569	509	1.0	Acceptable	N/A
14	Informal Housing	6	2272	509	0.6	Acceptable	Too Low
15	Railway Line	150	2439	509	0.5	Acceptable	N/A
16	Bridge	50	2382	509	0.5	Acceptable	N/A
17	Railway Line	150	2339	509	0.5	Acceptable	N/A
18	Bridge	50	2472	509	0.5	Acceptable	N/A
19	Farmhouse	12.5	2269	509	0.6	Acceptable	Too Low
20	Farm Buildings	12.5	2180	509	0.6	Acceptable	Too Low
21	Farm Buildings	12.5	2177	509	0.6	Acceptable	Too Low
22	Informal Housing	6	2144	509	0.6	Acceptable	Too Low
23	Informal Housing	6	2245	509	0.6	Acceptable	Too Low
24	Dam	50	2418	509	0.5	Acceptable	N/A
25	Dam	50	2416	509	0.5	Acceptable	N/A
26	Cultivated Fields	200	1974	509	0.7	Acceptable	N/A
27	Cultivated Fields	200	1587	509	1.0	Acceptable	N/A
28	Ruins	6	1512	509	1.1	Acceptable	Perceptible
29	Informal Housing	6	1513	509	1.1	Acceptable	Perceptible
30	Informal Housing	6	1413	509	1.2	Acceptable	Perceptible
31	Farm Buildings	12.5	2240	509	0.6	Acceptable	Too Low
32	Cultivated Fields	200	1939	509	0.7	Acceptable	N/A
33	River	200	1683	509	0.9	Acceptable	N/A
34	Cultivated Fields	200	1965	509	0.7	Acceptable	N/A
35	Farm Buildings	12.5	2033	509	0.7	Acceptable	Too Low
36	Farmhouse	12.5	2118	509	0.6	Acceptable	Too Low
37	Weir	100	2465	509	0.5	Acceptable	N/A
38	Cement Dam	50	2421	509	0.5	Acceptable	N/A
39	Farm Building	12.5	2070	509	0.7	Acceptable	Too Low
40	Ruins	6	1999	509	0.7	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	Marsh	200	1411	509	1.2	Acceptable	N/A
42	Informal Housing	6	1653	509	1.0	Acceptable	Perceptible
43	Cement Dam	50	2177	509	0.6	Acceptable	N/A
44	Farm Buildings	12.5	2499	509	0.5	Acceptable	Too Low
BABH1	Artesian well	50	1182	509	1.7	Acceptable	N/A
BCPH1	Water supply borehole at Bambanani	50	4762	509	0.2	Acceptable	N/A
BCPH2	Dysfunctional water supply borehole	50	5024	509	0.2	Acceptable	N/A
CBP1	Spring	50	1397	509	1.3	Acceptable	N/A
EBH1	Exploration borehole	50	1443	509	1.2	Acceptable	N/A
KPR	Drinking water supply spring	50	4418	509	0.2	Acceptable	N/A
NBH1	Water supply borehole	50	4302	509	0.2	Acceptable	N/A
RPR (RBH)	Spring used for domestic uses.	50	3772	509	0.2	Acceptable	N/A
VRB	River fed by a spring	50	4145	509	0.2	Acceptable	N/A
WelBH1	Wind pump	50	7119	509	0.1	Acceptable	N/A
WBH1	Borehole	50	6791	509	0.1	Acceptable	N/A
ZW-Spring	Spring	50	3219	509	0.3	Acceptable	N/A

16.2 Summary of ground vibration levels

The box-cut operation was 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 box-cut area. The influences will also vary with distance from the box-cut area. The model used for evaluation does indicate acceptable 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 2500 m from the box-cut area. In view of the minimum and maximum charge no specific damage inducing influences were predicted. There is not a high concentration of structures around the box-cut area. The nearest house structures are located further than 1000 m away and the type of blasting to be applied showed levels well within accepted norms. The ground vibration levels predicted ranged between 0.5 mm/s and 1.9 mm/s for all structures surrounding the box-cut area. The distances between structures and the box-cut area are a contributing factor to the levels of ground vibration expected and the subsequent possible low influences.

There are thirteen water related features identified within the project and only four within the evaluated 2500 m area. None which is close to the box-cut and thus no specific concern for damage due to ground vibration.

Mitigation of ground vibration was considered and discussed in Section 17.13. 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.

16.3 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 30 Hz frequency and plotted with expected human perceptions on the safe blasting criteria graph (see Figure 14 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 14 that up to a distance of 1985 m people may experience levels of ground vibration as perceptible. There are houses or settlements closer at 1985 m from the box-cut area. People may experience ground vibration as perceptible. At 730 m levels may be perceived as unpleasant. There are however no settlements closer than 730 m.

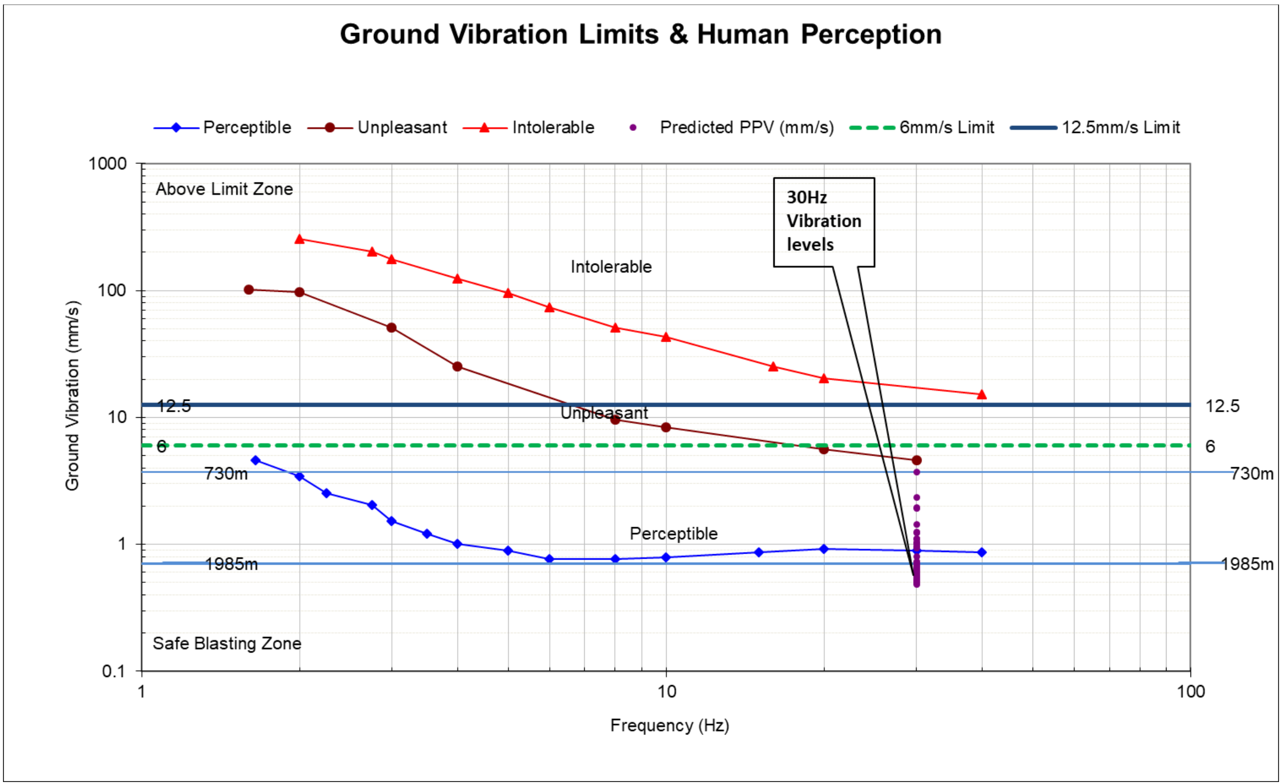


Figure 14: The effect of ground vibration with human perception and vibration limits

16.4 Vibration impact on roads

There are no roads in the vicinity of the project area that needs to be considered. There may be smaller gravel / farm roads in the area. There is no concern of impact from ground vibration regarding roads.

16.5 Potential that vibration will upset adjacent communities

Ground vibration and air blast generally upset people living in the vicinity of mining operations. The nearest settlement of people is Informal Housing approximately 1413 m from the planned box-cut operations. These buildings/structures are located such that levels of ground vibration predicted may be perceptible but with no significant impact probable.

Ground vibration levels expected from maximum charge has possibility to be perceptible up to 1985 m. It is certain that lesser charges will reduce this distance for instance at minimum charge this distance is expected to be 800 m.

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

16.6 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 2500 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.

16.7 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 areas 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"

16.7.1 Minimum charge mass per delay – 58 kg – Twyfelaar Northern Access Box-cut

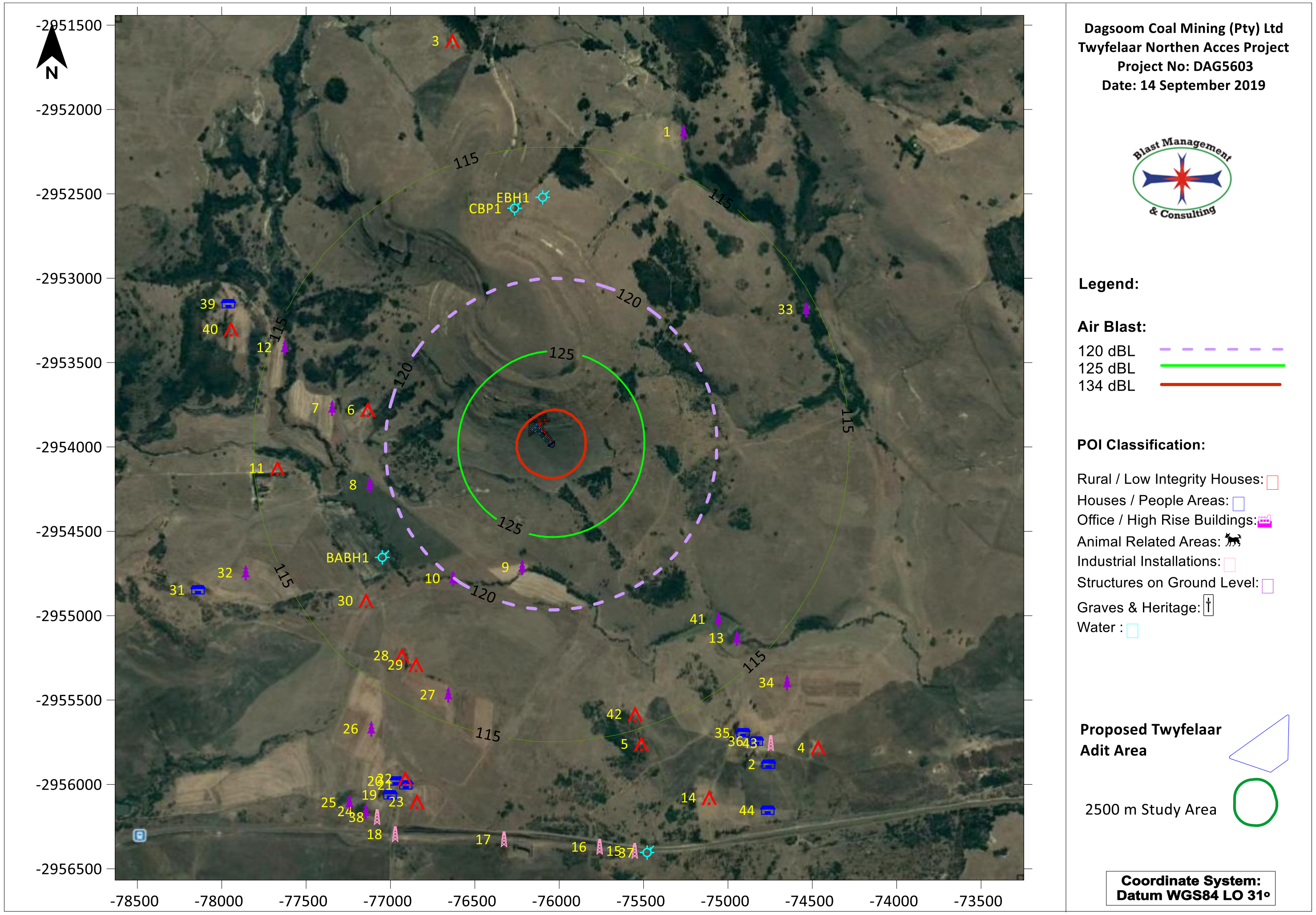


Figure 15: Air blast influence from minimum charge for Twyfelaar Northern Access Box-cut

Table 13: Air blast evaluation for minimum charge for Twyfelaar Northern Access Box-cut Area

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	River	1985	113.9	N/A
2	Farm Building	2272	112.8	Acceptable
3	Rural Village	2446	112.1	Acceptable
4	Informal Housing	2373	112.5	Acceptable
5	Informal Housing	1833	114.6	Acceptable
6	Rural Village	1086	119.0	Acceptable
7	Cultivated Fields	1296	117.5	N/A
8	Cultivated Fields	1078	119.0	N/A
9	Cultivated Fields	730	122.3	N/A
10	River	963	120.0	N/A
11	Rural Village	1606	115.7	Acceptable
12	Cultivated Fields	1662	115.4	N/A
13	Dam	1569	115.9	N/A
14	Informal Housing	2272	112.8	Acceptable
15	Railway Line	2439	112.1	N/A
16	Bridge	2382	112.4	N/A
17	Railway Line	2339	112.6	N/A
18	Bridge	2472	112.0	N/A
19	Farmhouse	2269	112.8	Acceptable
20	Farm Buildings	2180	113.2	Acceptable
21	Farm Buildings	2177	113.2	Acceptable
22	Informal Housing	2144	113.3	Acceptable
23	Informal Housing	2245	112.9	Acceptable
24	Dam	2418	112.3	N/A
25	Dam	2416	112.3	N/A
26	Cultivated Fields	1974	114.0	N/A
27	Cultivated Fields	1587	115.8	N/A
28	Ruins	1512	116.2	Acceptable
29	Informal Housing	1513	116.2	Acceptable
30	Informal Housing	1413	116.8	Acceptable
31	Farm Buildings	2240	112.9	Acceptable
32	Cultivated Fields	1939	114.1	N/A
33	River	1683	115.3	N/A
34	Cultivated Fields	1965	114.0	N/A
35	Farm Buildings	2033	113.7	Acceptable
36	Farmhouse	2118	113.3	Acceptable
37	Weir	2465	112.1	N/A
38	Cement Dam	2421	112.3	N/A
39	Farm Building	2070	113.5	Acceptable
40	Ruins	1999	113.9	Acceptable
41	Marsh	1411	116.8	N/A
42	Informal Housing	1653	115.4	Acceptable

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
43	Cement Dam	2177	113.2	N/A
44	Farm Buildings	2499	111.9	Acceptable
BABH1	Artesian well	1182	118.3	N/A
BCPH1	Water supply borehole at Bambanani	4762	106.6	N/A
BCPH2	Dysfunctional water supply borehole	5024	106.2	N/A
CBP1	Spring	1397	116.8	N/A
EBH1	Exploration borehole	1443	116.6	N/A
KPR	Drinking water supply spring	4418	107.2	N/A
NBH1	Water supply borehole	4302	107.4	N/A
RPR (RBH)	Spring used for domestic uses.	3772	108.5	N/A
VRB	River fed by a spring	4145	107.8	N/A
WelBH1	Wind pump	7119	103.2	N/A
WBH1	Borehole	6791	103.5	N/A
ZW-Spring	Spring	3219	109.8	N/A

16.7.2 Maximum charge mass per delay – 509 kg – Twyfelaar Northern Access Box-cut

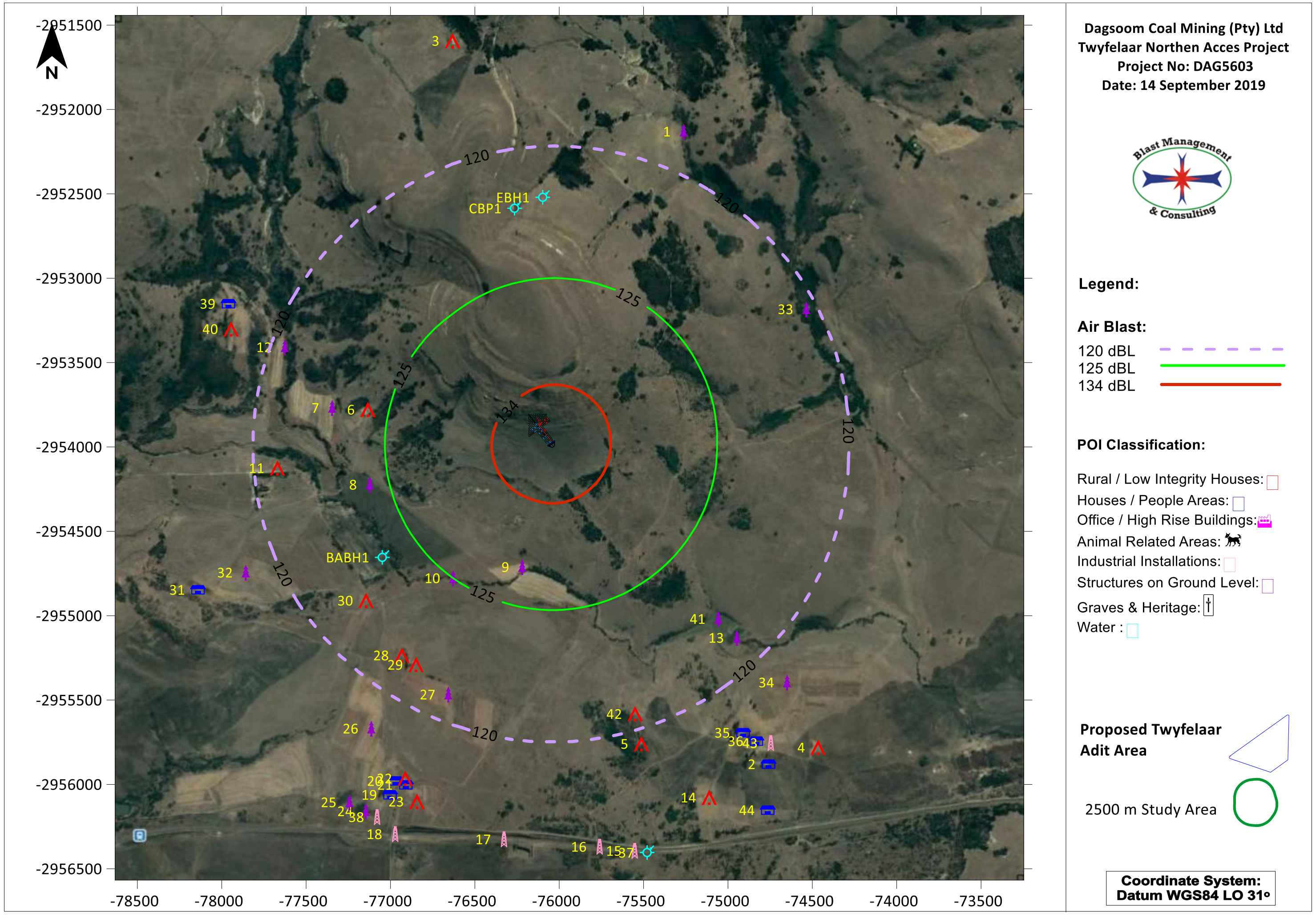


Figure 16: Air blast influence from maximum charge for Twyfelaar Northern Access Box-cut

Table 14: Air blast evaluation for maximum charge for Twyfelaar Northern Access Box-cut

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	River	1985	118.9	N/A
2	Farm Building	2272	117.8	Acceptable
3	Rural Village	2446	117.1	Acceptable
4	Informal Housing	2373	117.4	Acceptable
5	Informal Housing	1833	119.6	Acceptable
6	Rural Village	1086	124.0	Complaint
7	Cultivated Fields	1296	122.5	N/A
8	Cultivated Fields	1078	124.1	N/A
9	Cultivated Fields	730	127.3	N/A
10	River	963	125.0	N/A
11	Rural Village	1606	120.7	Complaint
12	Cultivated Fields	1662	120.4	N/A
13	Dam	1569	120.9	N/A
14	Informal Housing	2272	117.8	Acceptable
15	Railway Line	2439	117.2	N/A
16	Bridge	2382	117.4	N/A
17	Railway Line	2339	117.6	N/A
18	Bridge	2472	117.1	N/A
19	Farmhouse	2269	117.8	Acceptable
20	Farm Buildings	2180	118.1	Acceptable
21	Farm Buildings	2177	118.1	Acceptable
22	Informal Housing	2144	118.3	Acceptable
23	Informal Housing	2245	117.9	Acceptable
24	Dam	2418	117.3	N/A
25	Dam	2416	117.3	N/A
26	Cultivated Fields	1974	119.0	N/A
27	Cultivated Fields	1587	120.8	N/A
28	Ruins	1512	121.2	Complaint
29	Informal Housing	1513	121.2	Complaint
30	Informal Housing	1413	121.8	Complaint
31	Farm Buildings	2240	117.9	Acceptable
32	Cultivated Fields	1939	119.1	N/A
33	River	1683	120.3	N/A
34	Cultivated Fields	1965	119.0	N/A
35	Farm Buildings	2033	118.7	Acceptable
36	Farmhouse	2118	118.4	Acceptable
37	Weir	2465	117.1	N/A
38	Cement Dam	2421	117.3	N/A
39	Farm Building	2070	118.6	Acceptable
40	Ruins	1999	118.8	Acceptable
41	Marsh	1411	121.8	N/A
42	Informal Housing	1653	120.5	Complaint

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
43	Cement Dam	2177	118.1	N/A
44	Farm Buildings	2499	117.0	Acceptable
BABH1	Artesian well	1182	123.3	N/A
BCPH1	Water supply borehole at Bambanani	4762	111.6	N/A
BCPH2	Dysfunctional water supply borehole	5024	111.1	N/A
CBP1	Spring	1397	121.9	N/A
EBH1	Exploration borehole	1443	121.6	N/A
KPR	Drinking water supply spring	4418	112.3	N/A
NBH1	Water supply borehole	4302	112.5	N/A
RPR (RBH)	Spring used for domestic uses.	3772	113.5	N/A
VRB	River fed by a spring	4145	112.8	N/A
WelBH1	Wind pump	7119	108.3	N/A
WBH1	Borehole	6791	108.6	N/A
ZW-Spring	Spring	3219	114.9	N/A

16.8 Summary of findings for air blast

Review of the air blast levels indicates more possible impact than ground vibration for the blasting operation in the box-cut. Possible impact is not in the damaging ranges, but it is expected that air blast could lead to complaints. No POI's were identified where air blast could be problematic. None of the predicted levels are greater than the 134 dBL limit. Predicted for the maximum charge ranges between 117 and 124 dB for all the POI's associated with housing considered. These levels may contribute to effects such as rattling of roofs and/or door and/or windows with limited points that could lead to complaints.

The current accepted limit on air blast is 134 dBL. Damages are only expected to occur at levels greater than 134 dBL.

The possible negative effects from air blast are expected to be greater 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.

16.9 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 17 shows the results from the ISEE calculations for fly rock range based on a 115 mm diameter blast hole and 2.9 m stemming length. Based on these values a possible fly rock range with a safety factor of 2 was calculated to be 233 m. The absolute minimum unsafe zone is then the 233 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 always be implemented. The occurrence of fly rock can be mitigated but the possibility of the occurrence thereof can never be eliminated. Figure 18 shows the area around the box-cut pit that incorporates the 233 m unsafe zone.

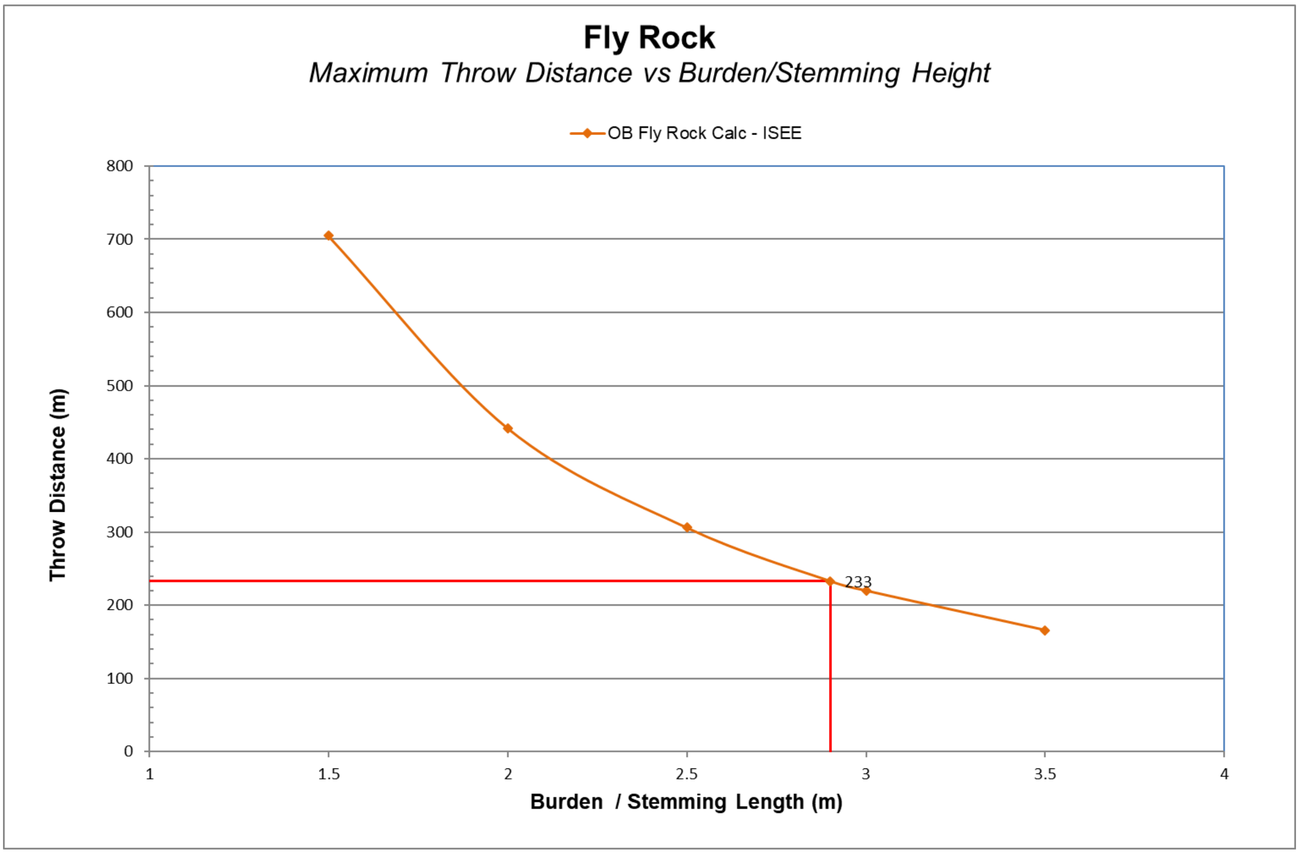


Figure 17: Fly rock prediction calculation

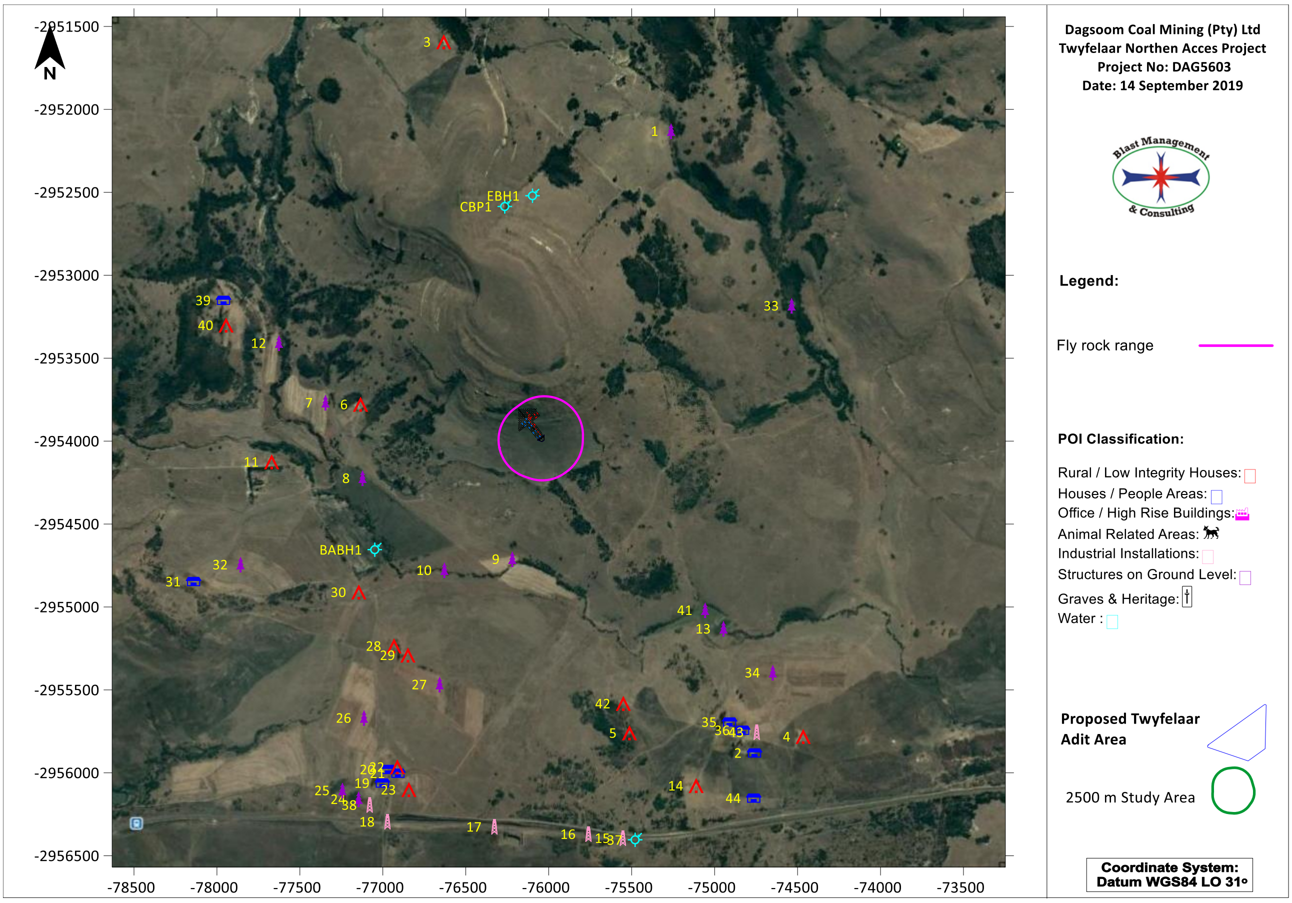


Figure 18: Fly rock prediction area

Review of the calculated unsafe zone showed no POI's that are within the unsafe zone. The nearest houses or settlements are 1086 m from the box-cut area.

16.10 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.

16.11 Water borehole influence

Thirteen water related features were identified – these include boreholes, springs rivers etc. Review of the location of these features in relation to the box-cut area none showed any concerns for damage due to blasting operations in the box-cut. Table 15 shows all the identified boreholes. Figure 19 shows the location of these features within the 2500 m evaluation area.

Table 15: Identified water related features for Twyfelaar Northern Access box-cut Area

Tag	Description	Y	X
37	Weir	75479.1	2956404.3
BABH1	Artesian well	77048.5	2954654.9
BCPH1	Water supply borehole at Bambanani	80026.7	2956641.5
BCPH2	Dysfunctional water supply borehole	80491.1	2956377.7
CBP1	Spring	76265.0	2952586.0
EBH1	Exploration borehole	76097.7	2952521.1
KPR	Drinking water supply spring	72156.1	2951833.7
NBH1	Water supply borehole	77784.0	2957939.1
RPR (RBH)	Spring used for domestic uses.	72550.3	2952499.0
VRB	River fed by a spring	79415.2	2956439.3
WBH1	Borehole	79078.6	2947895.4
WelBH1	Wind pump	80534.7	2948448.4
ZW-Spring	Spring	76774.4	2950831.9

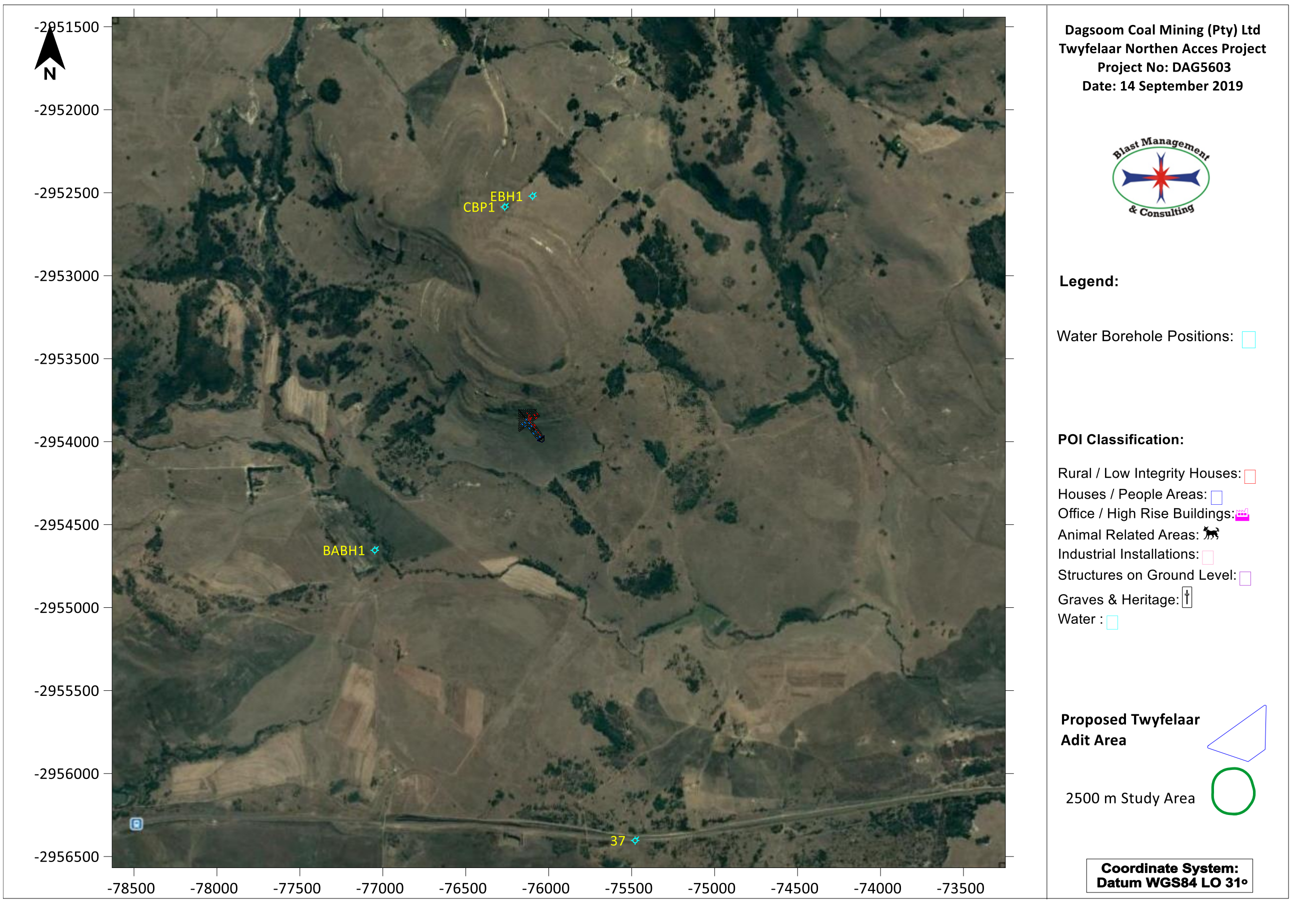


Figure 19: Location of the Water related features

16.12 Potential Environmental Impact Assessment: Construction Phase

Details of the impact assessment methodology used to determine the significance of blasting impacts are provided below.
The significance rating process follows the established impact/risk assessment formula:

Significance = Consequence x Probability x Nature

Where

Consequence = Intensity + Extent + Duration

And

Probability = Likelihood of an impact occurring

And

Nature = Positive (+1) or negative (-1) impact

Note: In the formula for calculating consequence, the type of impact is multiplied by +1 for positive impacts and -1 for negative impacts.

The matrix calculates the rating out of 147, whereby Intensity, Extent, Duration and Probability are each rated out of seven as indicated in Table 18: . The weight assigned to the various parameters is then multiplied by +1 for positive and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of the mitigation measure proposed in this report. The significance of an impact is then determined and categorised into one of eight categories, as indicated in Table 17: , which is extracted from Table 16. The description of the significance ratings is discussed in Table 18: .

It is important to note that the pre-mitigation rating takes into consideration the activity as proposed, i.e. there may already be certain types of mitigation measures included in the design (for example due to legal requirements). If the potential impact is still considered too high, additional mitigation measures are proposed.

Table 16: Impact Assessment Parameter Ratings

Rating	Intensity/Replaceability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	Positive Impacts (Nature = +1)			
7	Irreplaceable loss or damage to biological or physical resources or highly sensitive environments. Irreplaceable damage to highly sensitive cultural/social resources.	Noticeable, on-going natural and / or social benefits which have improved the overall conditions of the baseline.	International The effect will occur across international borders.	Permanent: The impact is irreversible, even with management, and will remain after the life of the project.	Definite: There are sound scientific reasons to expect that the impact will occur. >80% probability.
6	Irreplaceable loss or damage to biological or physical resources or moderate to highly sensitive environments. Irreplaceable damage to cultural/social resources of moderate to highly sensitivity.	Great improvement to the overall conditions of a large percentage of the baseline.	National Will affect the entire country.	Beyond project life: The impact will remain for some time after the life of the project and is potentially irreversible even with management.	Almost certain / Highly probable: It is most likely that the impact will occur. <80% probability.
5	Serious loss and/or damage to physical or biological resources or highly sensitive environments, limiting ecosystem function. Very serious widespread social impacts. Irreparable damage to highly valued items.	On-going and widespread benefits to local communities and natural features of the landscape.	Province/ Region Will affect the entire province or region.	Project Life (>15 years): The impact will cease after the operational life span of the project and can be reversed with sufficient management.	Likely: The impact may occur. <65% probability.
4	Serious loss and/or damage to physical or biological resources or moderately sensitive environments, limiting ecosystem function. On-going serious social issues. Significant damage to structures / items of cultural significance.	Average to intense natural and / or social benefits to some elements of the baseline.	Municipal Area Will affect the whole municipal area.	Long term: 6-15 years and impact can be reversed with management.	Probable: Has occurred here or elsewhere and could therefore occur. <50% probability.

Rating	Intensity/Replaceability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts** (Nature = +1)			
3	Moderate loss and/or damage to biological or physical resources of low to moderately sensitive environments and, limiting ecosystem function. On-going social issues. Damage to items of cultural significance.	Average, on-going positive benefits, not widespread but felt by some elements of the baseline.	Local Local extending only as far as the development site area.	Medium term: 1-5 years and impact can be reversed with minimal management.	Unlikely: Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur. <25% probability.
2	Minor loss and/or effects to biological or physical resources or low sensitive environments, not affecting ecosystem functioning. Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Low positive impacts experience by a small percentage of the baseline.	Limited Limited to the site and its immediate surroundings.	Short term: Less than 1 year and is reversible.	Rare / improbable: Conceivable, but only in extreme circumstances. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures. <10% probability.
1	Minimal to no loss and/or effect to biological or physical resources, not affecting ecosystem functioning. Minimal social impacts, low-level repairable damage to commonplace structures.	Some low-level natural and / or social benefits felt by a very small percentage of the baseline.	Very limited/Isolated Limited to specific isolated parts of the site.	Immediate: Less than 1 month and is completely reversible without management.	Highly unlikely / None: Expected never to happen. <1% probability.

Table 17: Probability/Consequence Matrix

Significance																																						
7	-147	-140	-133	-126	-119	-112	-105	-98	-91	-84	-77	-70	-63	-56	-49	-42	-35	-28	-21	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147
6	-126	-120	-114	-108	-102	-96	-90	-84	-78	-72	-66	-60	-54	-48	-42	-36	-30	-24	-18	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126
5	-105	-100	-95	-90	-85	-80	-75	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
4	-84	-80	-76	-72	-68	-64	-60	-56	-52	-48	-44	-40	-36	-32	-28	-24	-20	-16	-12	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84
3	-63	-60	-57	-54	-51	-48	-45	-42	-39	-36	-33	-30	-27	-24	-21	-18	-15	-12	-9	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63
2	-42	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
Probability 1	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Consequence

Table 18: Significance Rating Description

Score	Description	Rating
109 to 147	A very beneficial impact that may be sufficient by itself to justify implementation of the project. The impact may result in permanent positive change	Major (positive) (+)
73 to 108	A beneficial impact which may help to justify the implementation of the project. These impacts would be considered by society as constituting a major and usually a long-term positive change to the (natural and / or social) environment	Moderate (positive) (+)
36 to 72	A positive impact. These impacts will usually result in positive medium to long-term effect on the natural and / or social environment	Minor (positive) (+)
3 to 35	A small positive impact. The impact will result in medium to short term effects on the natural and / or social environment	Negligible (positive) (+)
-3 to -35	An acceptable negative impact for which mitigation is desirable. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in negative medium to short term effects on the natural and / or social environment	Negligible (negative) (-)
-36 to -72	A minor negative impact requires mitigation. The impact is insufficient by itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in negative medium to long-term effect on the natural and / or social environment	Minor (negative) (-)
-73 to -108	A moderate negative impact may prevent the implementation of the project. These impacts would be considered as constituting a major and usually a long-term change to the (natural and / or social) environment and result in severe changes.	Moderate (negative) (-)
-109 to -147	A major negative impact may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects. The impacts are likely to be irreversible and/or irreplaceable.	Major (negative) (-)

Table 19: Risk Assessment Outcome Construction Phase

Dimension	Rating	Motivation	Significance
Blasting operations in the proposed Twyfelaar Coal Mining Project Northern access / block A box-cut area			
Impact Description: Ground vibration impact on community houses			
Prior to Mitigation/Management			
Duration	2	Ground vibration may be perceptible during the blasting operations in the box-cut.	Negligible (negative) -16
Extent	3	Ground vibration may extend at low levels even to nearby settlements	
Intensity	2	Intensity is expected to be less than damaging but may be perceptible	
Probability	3	The probability of damage is low due to low levels of ground vibration	
Nature	Negative		
Mitigation/Management Actions			
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.			
Monitor ground vibration and air blast from blasting operations			

Post-Mitigation			
Duration	2	No specific mitigation required	Negligible (negative) -16
Extent	3	No specific mitigation required	
Intensity	2	No specific mitigation required	
Probability	3	No specific mitigation required	
Nature	Negative		
Dimension	**Rating**	**Motivation**	**Significance**
Blasting operations in the proposed Twyfelaar Coal Mining Project Northern access / block A box-cut area			
Impact Description: Air blast impact on community houses			
Prior to Mitigation/Management			
Duration	2	Air blast may be perceptible during the blasting operations in the box-cut.	Negligible (negative) -16
Extent	3	Air blast may extend to nearby settlements and be perceived as a nuisance and lead to complaints	
Intensity	2	Intensity is expected to be less than damaging but will be perceptible	
Probability	3	The probability of damage is low due to low levels expected	
Nature	Negative		
Mitigation/Management Actions			
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.			
Monitor ground vibration and air blast from blasting operations			
Post-Mitigation			
Duration	2		Negligible (negative) -16
Extent	3		
Intensity	2	Specific blast design with increased stemming length will assist in reducing effects.	
Probability	3		
Nature	Negative		
Dimension	**Rating**	**Motivation**	**Significance**
Blasting operations in the proposed Twyfelaar Coal Mining Project Northern access / block A box-cut area			
Impact Description: Fly rock impact on community houses			
Prior to Mitigation/Management			
Duration	2	Fly rock may be experienced during the blasting operations in the box-cut.	Negligible (negative) -10

Extent	2	Fly rock is expected to be limited to the immediate area around the box-cut.	
Intensity	2	No damaging effects expected at nearby settlements or houses.	
Probability	1	No houses are in proximity of the blasting area that could be negatively influenced.	
Nature	Negative		
Mitigation/Management Actions			
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.			
Monitor fly rock situation using video camera			
Post-Mitigation			
Duration	2	No specific mitigation required	Negligible (negative) -10
Extent	2		
Intensity	2		
Probability	1		
Nature	Negative		

16.13 Mitigations

In review of the evaluations made in this report it is certain there is no specific mitigations required. None of the identified POI's surrounding the box-cut area is influenced negatively with regards to possible damage. Recommendations are made for management of blast operations only.

17 Operational Phase: Impact Assessment and Mitigation Measures

During the operation extraction of coal may be done by conventional drilling and blasting sections or mechanical means. Mechanical means of extraction using continuous miners does not have any significant influence to consider. Conventional drilling and blast operations do require consideration of ground vibration effects. No air blast or fly rock is considered due to the mine being an underground operation during the operational phase. These effects do not have any influence on the surface environment.

17.1 Review of expected ground vibration

Presented herewith are the expected ground vibration levels at different distances from the underground mining area and discussion of relevant influences from underground blasting operations. 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 for the underground panel blasting at specific distances from the outline of the underground 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 30 m to 100 m around the underground mining area.

The simulation provided shows ground vibration contours only for a limited number of levels. The levels used are based on the minimum depth below anticipated up to 100 m from the edge of the underground area. 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"

Simulations for expected ground vibration levels are presented below.

17.1.1 Maximum charge mass per delay – 3.2 kg – underground panel blasting

Figure 20: Ground vibration influence from underground blasting operations

Table 20: Ground vibration influence from underground blasting

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
3	Rural Village	76632.8	2951593.0	6	165	0.3	Acceptable	Too Low
6	Rural Village	77134.3	2953778.7	6	660	0.0	Acceptable	Too Low

Note: only the nearest infrastructure is shown

17.2 Summary of ground vibration levels

Review of expected levels of ground vibration from underground blasting operations it's clear that levels expected are very low. There is no specific housing infrastructure close to the underground area. The nearest rural village is 165 m from the underground area. Expected levels of ground vibration is less than 1 mm/s. There is no concern for influence from underground blasting operations on the identified house infrastructure surrounding the underground area.

17.3 Potential Environmental Impact Assessment: Operational Phase

Details of the impact assessment methodology used to determine the significance of blasting impacts are provided section 16.12. Table 21 below shows impact assessment for the operational phase underground blasting operations.

Table 21: Risk Assessment Outcome Construction Phase

Dimension	**Rating**	**Motivation**	**Significance**
Blasting operations in the proposed Twyfelaar Coal Mining Project Underground Operations			
Impact Description: Ground vibration impact on community houses			
Prior to Mitigation/Management			
Duration	5	Underground blasting may occur for life of mine	Negligible (negative) -9
Extent	3	Very low levels are expected with limited reach	
Intensity	1	No damaging effects expected at nearby settlements or houses.	
Probability	1	No houses are in proximity of the blasting area that could be negatively influenced.	
Nature	Negative		
Mitigation/Management Actions			
None required			
Post-Mitigation			
Duration	5	No specific mitigation required	Negligible (negative) -9
Extent	3		

Intensity	1		
Probability	1		
Nature	Negative		

17.4 Mitigations

In review of the evaluations made in this report it is certain there is no specific mitigations required for the underground blasting operations. None of the identified POI's surrounding the underground area is influenced negatively with regards to possible damage.

18 Closure Phase: Impact Assessment and Mitigation Measures

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

19 Alternatives (Comparison and Recommendation)

The alternatives to consider will be very dependent on the hardness of the overburden. It is known that the coal for the area is soft enough to be mechanically excavated. If hard overburden can be mechanically removed it will reduce risk associated with blasting operations. No specific alternative mining methods are currently under discussion or considered for drilling and blasting.

20 Monitoring

A monitoring programme for recording blasting operations is recommended for the construction phase. 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.

One monitoring position was identified as possible location that will need to be considered. Monitoring positions are indicated in Figure 21 and Table 22 lists the positions with coordinates. Monitoring point / s can be re-defined with the first blast done and the monitoring programme defined.

Figure 21: Monitoring Positions suggested for the Twyfelaar Northern Access Box-cut area

Table 22: List of possible monitoring positions

Tag	Description	Y	X
6	Rural Village	77134.3	2953778.7

21 Recommendations

The following recommendations are proposed for the construction phase.

21.1 Regulatory requirements – MHSA Reg. 4.16(2)

Regulatory requirements indicate specific requirements for all non-mining structures and installations within 500 m from the mining operation. There are no external infrastructure or houses within 500 m from the box-cut. No actions will be required.

21.1 Regulatory requirements – MHSA Reg. 17.6(a)

No infrastructure or houses is observed within 100 m from the planned box-cut. The application of Mine Health and Safety act regulation 17.6(a) will not be applicable.

21.2 Blast Designs

Review of the planned blast design will be required. A detail design with blast planning will be required for efficient and safe mining of this box-cut. Blast designs should be reviewed prior to first blast planned and done. The geology for the box-cut area and the required drill depths should be confirmed. Due to stripping of topsoil that will take place there may be variances in required final depths and thus design applied to be confirmed.

21.3 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.

21.4 Safe blasting distance and evacuation

Calculated minimum safe distance is 233 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.

21.5 Photographic Inspections

The option of photographic survey of all structures up to 1500 m from the pit area is recommended. The mine will be operating for a significant number of years. This will give advantage on any negotiations with regards to complaints from neighbours on structural issues due to blasting. This process can however only succeed if done in conjunction with a proper monitoring program. It is expected that ground vibration levels will be significantly less than proposed limits at 1500 m, but this process will ensure record of the pre-blasting status of the nearest structures to the pit area. At 1500 m the expected level of ground vibration will be perceptible. Figure 22 shows extent of the range of 1500 m around the box-cut area with POI's identified. It must be noted that a point may represent a group of structures found in the vicinity of the point identified.

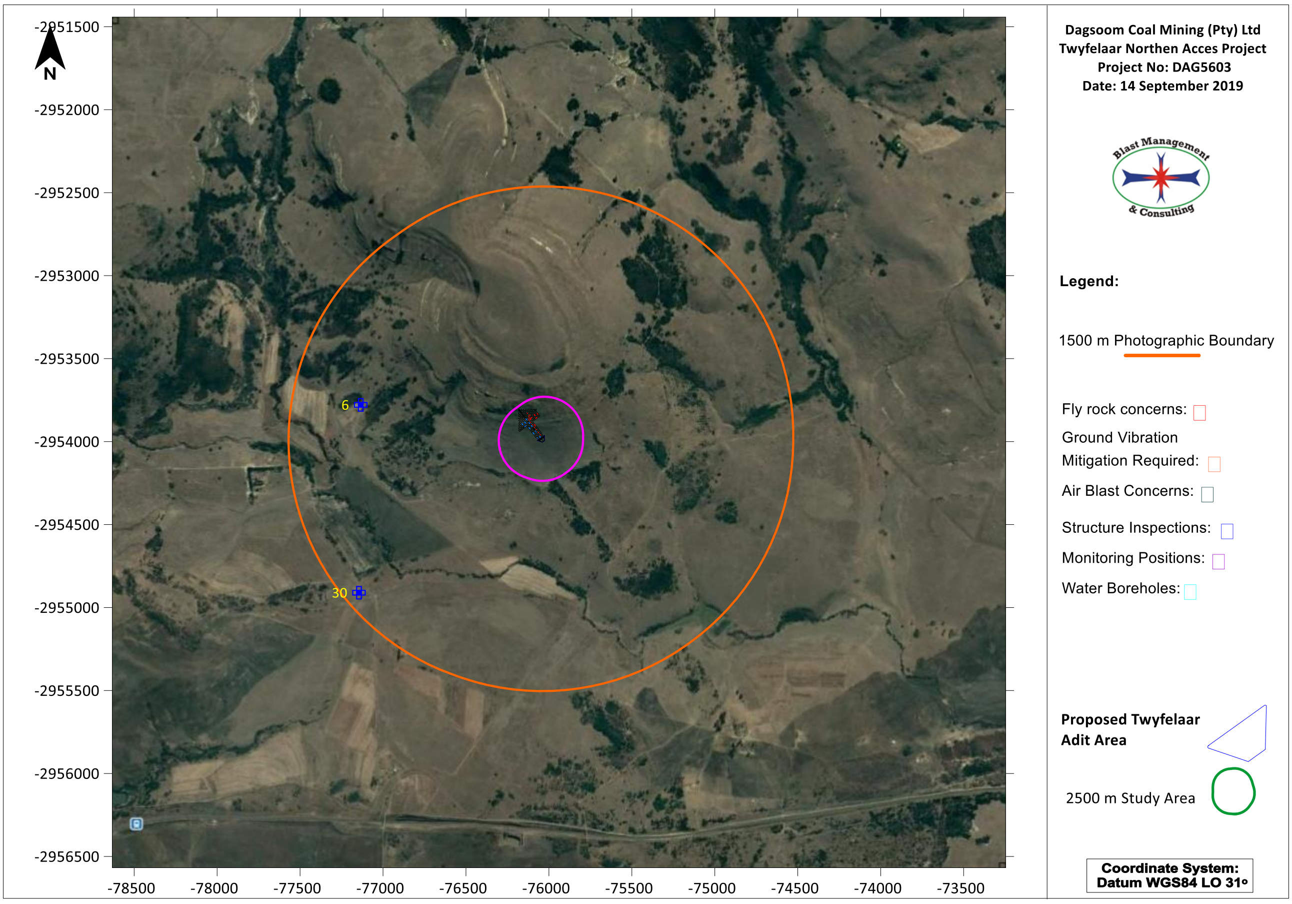


Figure 22: 1500 m area around the Twyfelaar Northern Access Box-cut identified for structure inspections.

Table 23: List of structures identified for inspections

Tag	Description	Y	X
6	Rural Village	77134.3	2953778.7
30	Informal Housing	77144.8	2954910.5

21.6 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 24.

Table 24: Recommended ground vibration air blast limits

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

21.7 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.

21.8 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.

21.9 Video monitoring of each blast

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

22 Knowledge Gaps

The data provided from client and information gathered was enough 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.

23 Reasoned Opinion

The author is of the opinion that with careful planning of blasting operations the project can be done safe and effective. A changed consideration of blast designs may be required.

24 Conclusion

Blast Management & Consulting (BM&C) was contracted as part of the Environmental Impact Assessment (EIA) team to perform a review of possible impacts with regards to blasting operations in the proposed Twyfelaar Coal Mining Project Northern access / block A box-cut area. Ground vibration, air blast, fly rock and fumes are some of the aspects as a result from blasting operations. The report concentrates on ground vibration and air blast and intends to provide information, calculations, predictions, possible influences and mitigations of blasting operations for this project.

The effects yielded by blasting operations was evaluated over an area as wide as 2500 m from the Twyfelaar Northern Access box-cut area. The range of structures observed consists of low-cost structures, brick and mortar houses, railway lines, cultivated fields and water resource related features. The location of structures around the Twyfelaar Northern Access box-cut area is such that the charge evaluated showed minimal possible influences due to ground vibration, air blast and fly rock. The closest structures observed are informal houses. These are located significant distance from the box-cut.

Ground vibrations predicted for the blasting operations in the box-cut area were relatively low. Levels predicted for infrastructure in the area investigated ranged between 0.5 mm/s and 1.9 mm/s. No specific mitigations are required for management of ground vibration.

Air blast predicted showed limited concerns for blasting at the box-cut. Levels predicted for the maximum charge ranges between 117 and 124 dB for all the POI's associated with housing considered. Levels are expected to be only a nuisance rather than damage causing. The predicted levels may contribute to effects such as rattling of roofs or door or windows that could lead to complaints. 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.

An exclusion zone for safe blasting was also calculated. The exclusion zone was established to be at least 233 m. The use of the normal practice observed in mines of 500 m exclusion zone could be considered. No infrastructure was observed within the 500 m boundary.

Closure of roads and considering the farming community around the box-cut area must also be considered.

The box-cut area is located such that no limited concerns – mainly air blast - were identified and addressed in the report.

Blasting operations during the operational is not expected to have any influence. Expected levels of ground vibration is less than 1 mm/s at the nearest house infrastructure to the underground area. There is no concern for influence from underground blasting operations on the identified house infrastructure surrounding the underground area.

25 Curriculum Vitae of Author

J D Zeeman was a member of the Permanent Force - SA Ammunition Core for period January 1983 to January 1990. During this period, work involved testing at SANDF Ammunition Depots and Proofing ranges. Work entailed munitions maintenance, proofing and lot acceptance of ammunition.

From July 1992 to December 1995, Mr Zeeman worked at AECI Explosives Ltd. Initial work involved testing science on small scale laboratory work and large-scale field work. Later, work entailed managing various testing facilities and testing projects. Due to restructuring of the Technical Department, Mr Zeeman was retrenched but fortunately was able to take up an appointment with AECI Explosives Ltd.'s Pumpable Emulsion Explosives Group for underground applications.

From December 1995 to June 1997 Mr Zeeman provided technical support to the Underground Bulk Systems Technology business unit and performed project management on new products.

Mr Zeeman started Blast Management & Consulting in June 1997. The main areas of focus are Pre-blast monitoring, Insitu monitoring, Post-blast monitoring and specialized projects.

Mr Zeeman holds the following qualifications:

1985 - 1987 Diploma: Explosives Technology, Technikon Pretoria

1990 - 1992 BA Degree, University of Pretoria

1994 National Higher Diploma: Explosives Technology, Technikon Pretoria

1997 Project Management Certificate: Damelin College

2000 Advanced Certificate in Blasting, Technikon SA

Member: International Society of Explosives Engineers

Blast Management & Consulting has been active in the mining industry since 1997, with work being done at various levels for all the major mining companies in South Africa. Some of the projects in which BM&C has been involved include:

Iso-Seismic Surveys for Kriel Colliery in conjunction with Bauer & Crosby Pty Ltd.; Iso-Seismic surveys for Impala Platinum Limited; Iso-Seismic surveys for Kromdraai Opencast Mine; Photographic Surveys for Kriel Colliery; Photographic Surveys for Goedehoop Colliery; Photographic Surveys for Aquarius Kroondal Platinum – Klipfontein Village; Photographic Surveys for Aquarius – Everest South Project; Photographic Surveys for Kromdraai Opencast Mine; Photographic inspections for various other companies, including Landau Colliery, Platinum Joint Venture – three mini-pit areas; Continuous ground vibration and air blast monitoring for various coal mines; Full auditing and control with consultation on blast preparation, blasting and resultant effects for clients, e.g. Anglo Platinum Ltd, Kroondal Platinum Mine, Lonmin Platinum, Blast Monitoring Platinum Joint Venture – New Rustenburg N4 road; Monitoring of ground vibration induced on surface in underground mining environment; Monitoring and management of blasting in close relation to water pipelines in opencast mining environment; Specialized testing of explosives characteristics; Supply and service of seismographs and VOD measurement equipment and accessories; Assistance in protection of ancient mining works for Rhino Minerals (Pty) Ltd.; Planning, design, auditing and monitoring of blasting in new quarry on new road project, Sterkspruit, with Africon, B&E International and Group 5 Roads; Structure Inspections and Reporting for Lonmin Platinum Mine Limpopo Pandora Joint Venture 180 houses – whole village; Structure Inspections and Reporting for Lonmin Platinum Mine Limpopo Section - 1000 houses / structures.

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

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