Blast Management & Consulting

Quality Service on Time

Blast and Vibration Assessment Report

Proposed Development of an Underground Coal Mine and Associated Infrastructure near Hendrina, Mpumalanga

Date:	7 June 2016
BM&C Ref No:	Digby Wells-Hendrina Reserve-EIAReport-160607V01
DMR Ref No:	MP30/5/1/2/2/10129MR
Signed:	
Name:	JD Zeeman

occur, neither the author nor his employees will assume liability for any alleged or actual damages arising directly or indirectly out of the recommendations and information given in this document.

i. Document Prepared and Authorised by:

JD Zeeman
Blast Management & Consulting (CK97 31139 / 23)
61 Sovereign Drive
Route 21 Corporate Park
Irene
South Africa

PO Box 61538
Pierre van Ryneveld
Centurion
0045

Cell: +27 82 854 2725 Tel: +27 (0)12 345 1445 Fax: +27 (0)12 345 1443

ii. Study Team Qualifications And Background

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

J D Zeeman holds the following qualifications:

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

Member: International Society of Explosive Engineers

iii. Independence Declaration

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

iv. Legal Requirements

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

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 23
(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 15
(k)	any mitigation measures for inclusion in the EMPr;	Section 15.12

Legal Requirement		Relevant Section in Specialist study
(l)	any conditions/aspects for inclusion in the environmental authorisation;	Section 20
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Section 19
(n)	a reasoned opinion (Environmental Impact Statement)-	Section 22
	as to whether the proposed activity or portions thereof should be authorised; and	Section 22
	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 22
(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

v. Document Control:

Name	Responsibility	Signature	Date
C Zeeman Blast Management & Consulting	Document Preparation		30/06/2016
JD Zeeman Blast Management & Consulting	Consultant		30/06/2016

Table of Contents

List of Acronyms used in this Report

a and b	Site Constant
ANFO	Ammonium nitrate fuel oil
APP	Air Pressure Pulse
B	Burden (m)
BM&C	Blast Management & Consulting
Bs	Scaled Burden ($m^{3/2}kg^{-1/2}$)
D	Distance (m)
D	Duration (s)
E	East
E	Explosive Mass (kg)
EIA	Environmental Impact Assessment
Freq.	Frequency
GRP	Gas Release Pulse
I&AP	Interested and Affected Parties
k	Factor value
L	Maximum Throw (m)
Lat/Lon	Latitude/Longitude
hddd°mm'ss.s"	Hours/degrees/minutes/seconds
M	Charge Height
m (SH)	Stemming height
M/S	Magnitude/Severity
Mc	Charge mass per metre column
N	North
NE	North East
NO	Nitrogen Monoxide
NO_2	Nitrogen Dioxide
NOx	Nitrogen Oxide
NOx's	Noxious Fumes
NW	North West
p_s	Air blast level (dB)
P	Air blast level (Pa (mB x 100))
P_o	Reference Pressure (2 x 10^{-5} Pa)
P	Probability
POI	Points of Interest
PPD	Peak particle displacement
PPV	Peak Particle Velocity
PVS	Peak vector sum
RPP	Rock Pressure Pulse

S	Scale
S	South
SE	South East
SH	Stemming height (m)
SW	South West
T	Blasted Tonnage
TNT	Explosives (Trinitrotoluene)
USBM	United States Bureau of Mine
W	West
WGS 84	Coordinates (South African)
WM	With Mitigation Measures
WOM	Without Mitigation Measures

List of Units used in this Report

%	percentage
cm	centimetre
dB	decibel
dBL	linear decibel
g	acceleration
g/cm^3	gram per cubic centimetre
Hz	frequency
kg	kilogram
kg/m^3	kilogram per cubic metre
kg/t	kilogram per tonne
km	kilometre
kPa	kilopascal
m	metre
m^3	metre squared
MJ	Mega Joules
MJ/m^3	Mega Joules per cubic meter
MJ/t	Mega Joules per tonne
mB	millibar
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

List of Figures

List of Tables

1 Executive Summary

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

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as a 1500 m radius from where blasting will take place. The range of structures observed and considered in this evaluation ranged between industrial structures, farm buildings, graves and heritage structures. The proposed surface infrastructure includes:

- Crushing and Screening Plant
- Overburden and Product Stockpiles
- Access and Service Roads (with weighbridge)
- Overland Conveyors
- Three Access Points to the Underground Reserve (one shaft area per Access Point)
- Three ventilation shafts (one per Access Point)
- Office Complex (change house, workshop, offices)
- Three Pollution Control Dams (PCDs) and Water Pipelines
- Five Aboveground Storage Tanks for the storage of diesel
- Three Waste Bins per Shaft
- Site Fencing located around the Conveyer Belt and each Mining Complex
- Diesel Generator and Sub-station
- Water Treatment Plant
- Package Sewage Treatment Plant

This project is a greenfields project with no existing blasting operations.

There are people and houses at close distances to the project area. The nearest house or building is found at a distance of 392 m for Shaft 1, 852 m for Shaft 2 and 1076 m for Shaft 3. There are Heritage - Farm Buildings/structures located at 272 m from the Shaft 1 area. Ground vibration mitigation will be required for these structures. Specific attention will be required for adjustments in the blasting operations to ensure expected levels of ground vibration and air blast are within the required limits. Ground vibration at structures and installations other than the identified problematic structures is well below any specific concern for inducing damage. There is a possibility that ground vibration may be unpleasant at the closest residential houses.

The nearest residential houses are located 852 m from the Shaft 2 boundary. The levels predicted do show low levels of ground vibration that could be experienced as unpleasant at the maximum charge on the human perception scale. The ground vibration levels predicted for all installations evaluated surrounding the decline shaft area ranged between 1.7 mm/s and 183.0 mm/s. Ground vibration levels at the nearest buildings where people may be present is 67.5 mm/s. These structures considered in the evaluation showed concern for possible damages.

Air blast predicted for the maximum charge ranges between 112.8 and 129.6 dB for all the POI's considered. No specific damages are expected from the levels calculated. Damages are only expected to occur at levels greater than 134 dB and 134 dB is only expected at distances closer than 250 m to the shaft area. The nearest buildings are 392 m from the shaft boundary. Infrastructure such as the N11 road is close but air blast does not have any influence on these installations. The levels at private houses or settlements are expected to be within limits and not damaging. Levels at the nearest houses may cause effects such as rattling of roofs or doors and could result in complaints from the owners.

An exclusion zone for safe blasting was also calculated. The exclusion zone was established to be at least 315 m. Normal practice observed in mines is a 500 m exclusion zone. The minimum distance recommended is 315 m. This distance may be greater but not less.

Seven boreholes were identified that could possibly be influenced due to excessive ground vibration at minimum and maximum charge. The expected levels of ground vibration for all of the boreholes inside the area evaluated are well within the limit applied for water boreholes.

The following recommendations are made and should be considered:

- There are structures and installations within 500 m from the shaft areas and specific regulatory authorisations for blasting within 500 m of these installations will be required.
- At time of developing the shafts the blast designs must be reviewed for improvements on the general design used in this report.
- A minimum safe clearance distance of 315 m must be applied.
- Farming activities and travelling on farm roads must be considered when areas are cleared prior to blasting operations.
- Ground vibration limits as recommended and presented should be adhered to.
- The use of a third party to monitor the blasting operations for ground vibration and air blast is recommended.

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

2 Introduction

Umcebo Mining (Pty) Ltd (Umcebo), a subsidiary of Glencore Operations South Africa (Pty) Ltd (Glencore) is proposing the development and operation of a new underground coal mine and associated infrastructure at a site situated approximately 10 to 22 kilometres (km) south east of Hendrina in the Mpumalanga Province of South Africa (the Hendrina Reserve Project).

Umcebo currently holds two Prospecting Rights (PRs), namely, MP 1265 PR and MP 1266 PR, located within the Ermelo Coal Field. The total extent of MP 1265 PR (referred to as Mooivley East and Mooivley West) is 3 923 hectares (Ha) and comprise the following farms and portions:

- Mooivley 219 IS – Potions 2, 4, 5 and Remaining Extent (RE) of the farm
- Tweefontein 203 IS – Portions 2, 15, 16, 17 and Portion of Portion 14
- Uitkyk 220 IS – Portions 2 and 3
- Orange Vallei 201 IS – Portions 1 and RE of the farm

The total extent of MP 1266 PR (referred to as Hendrina South) is 2 787 ha and comprises the following farm and portions:

- Elim 247 IS - RE of the farm
- Geluksdraai 240 IS – 1 and 2
- Orpenskraal 238 IS – RE of the farm
- Bosmanskrans 217 IS – Potions 1, 3, 4, 6, 8, 9 and RE of the farm

The project area proposed to be mined (underground) has a combined footprint of 6 714 ha and is located within the Steve Tshwete Local Municipality (STLM) and Msukaligwa Local Municipality (MLM).

The Hendrina Reserve Project is a greenfields project with none of the shafts developed yet. Thus no drilling and blasting operations have been or are currently being conducted. The Hendrina Reserve Project therefore has no specific contribution with regards to ground vibration, air blast or fly rock at the moment.

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

3 Objectives

The objectives of this document are to outline the expected environmental effects that blasting operations at the Hendrina Reserve Project have on the surrounding environment and to propose 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, project applicant requirements and general indicators in the various appropriate pieces of South African legislation. There is no direct reference in the following acts regarding requirements and limits on the effect of ground vibration and air blast and some of the aspects addressed in this report:

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

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

4 Scope of Blast Impact Study

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

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

   - Evaluation of expected blasting influence on national and provincial roads surrounding the blasting operations, if present
   - Evaluation of expected ground vibration levels on water boreholes if present within 500 m from blasting operations
   - Evaluation of expected air blast levels at specific distances from the operations and possible influence on structures
   - Evaluation of fly rock unsafe zone
   - Discussion on the occurrence of noxious fumes and dangers of fumes
   - Evaluation of the location of blasting operations in relation to surrounding areas according to the regulations from the applicable Acts
- Undertake an impact assessment and identify suitable mitigation measures

5 Study Area

The proposed area is situated on the Davel road approximately 10-22 km South East of Hendrina towards Ermelo in the Mpumalanga Province of South Africa. Three shaft areas are planned to access the underground operations. These are located at following coordinates (Lat/Lon WGS84):

- Shaft 1 - 26°15'19.79"S 29°46'27.37"E;
- Shaft 2 - 26°15'35.97"S 29°47'43.84"E
- Shaft 3 - 26°10'48.07"S 29°44'43.29"E.

Figure 1 shows a geographical locality plan of the Hendrina Reserve Project area. Figure 2 shows a view of the proposed layout for the mining area indicating the three shaft areas via decline shaft specifically.

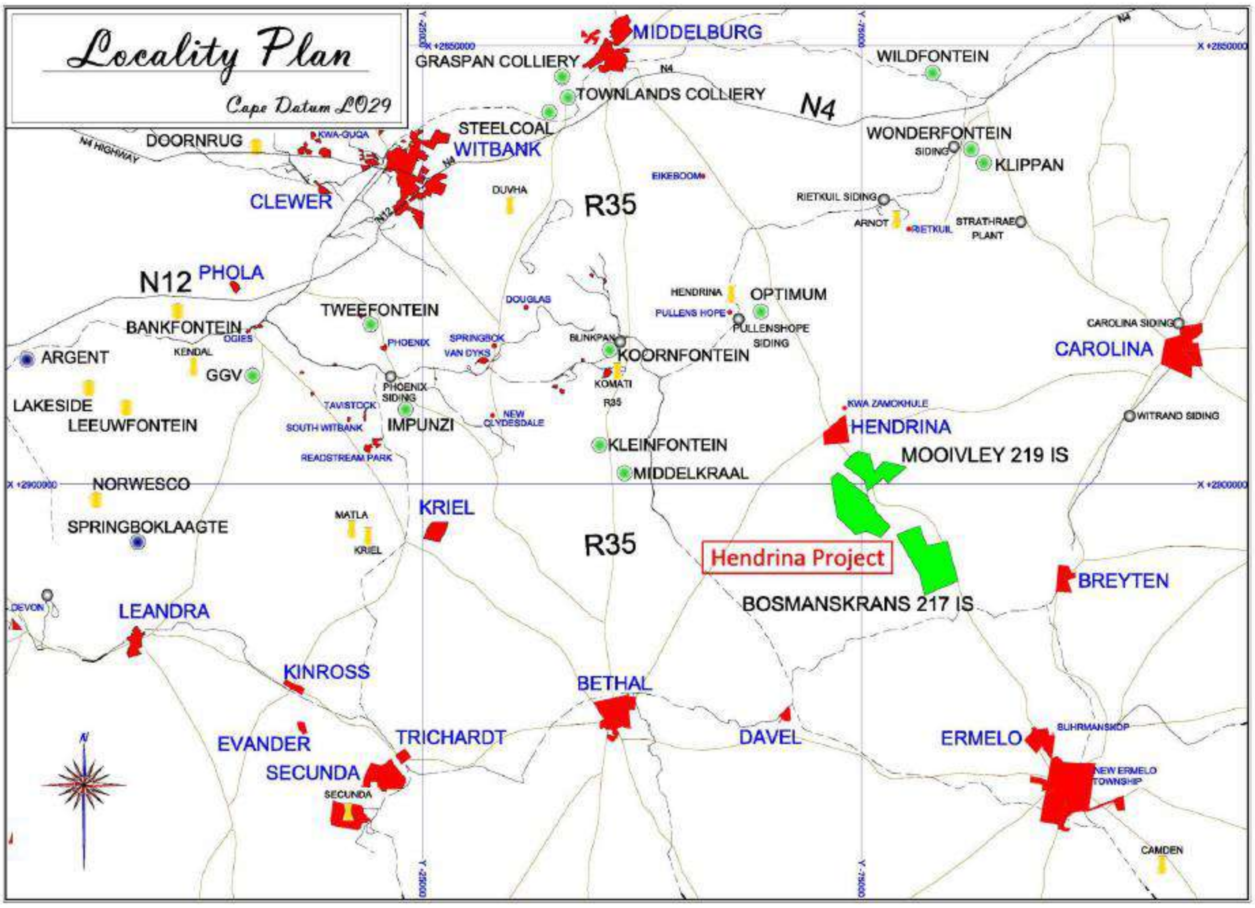

Figure 1: Locality of the project area

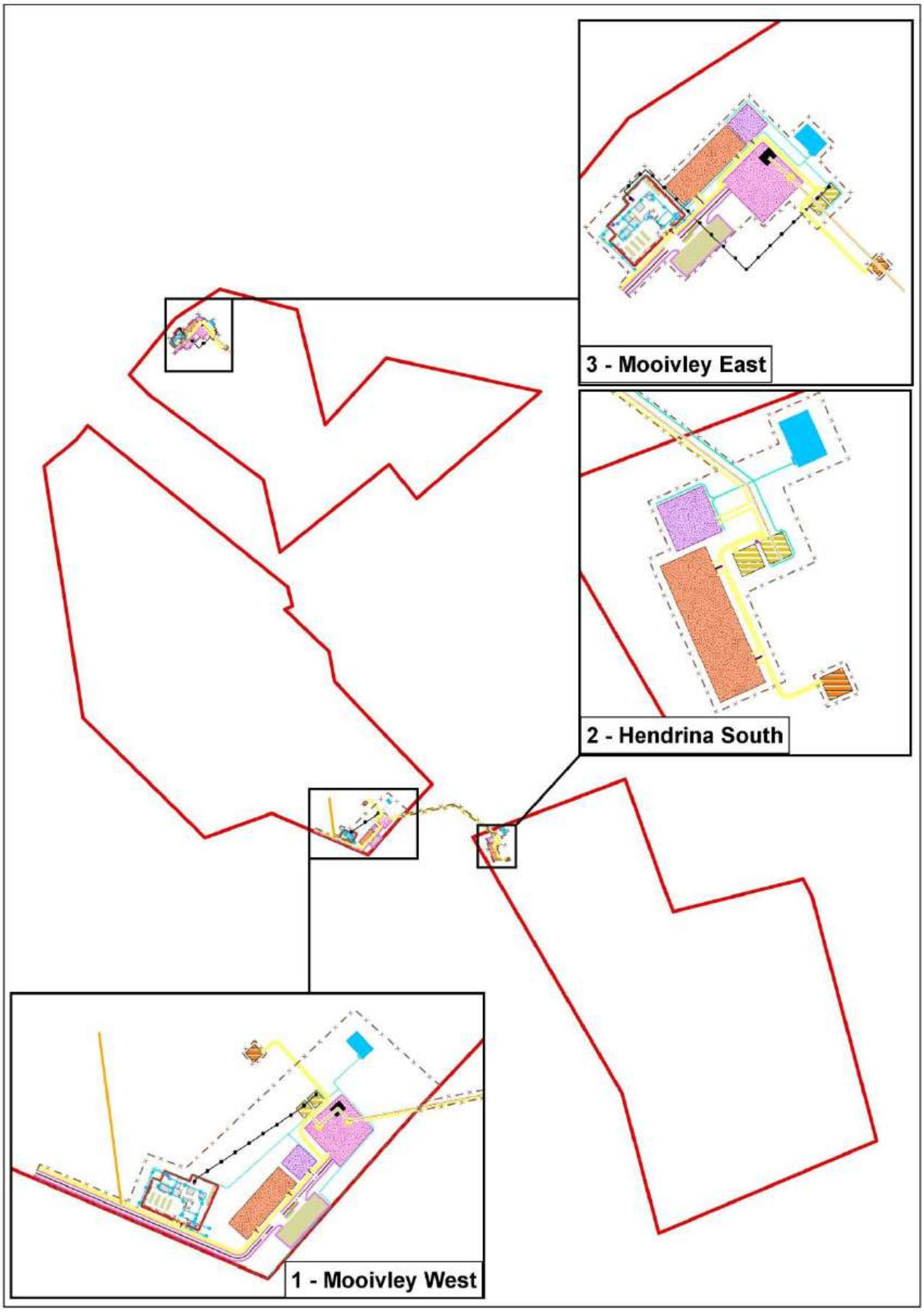

Figure 2: Proposed mining area layout

6 Methodology

The detailed plan of study consists of the following sections:

- Baseline influence: There are no blasting activities currently being done or no operations yet. The baseline is zero with no specific influence from blasting.
- Identifying surface structures/ installations that are found within reason from the project site. A list of Point of Interests (POI's) were created that will be used for the evaluation.
- Site evaluation: This entails an evaluation of the planned mining, drilling and blasting operations and the possible influences from the blasting operations. The methodology includes the modelling of the expected impacts based on the expected drilling and blasting information provided for the project. Various accepted mathematical equations were applied to determine the attenuation of ground vibration, air blast and fly rock. These values were then calculated over the distance investigated from the site and shown as amplitude level contours. Overlaying these contours on the location of the various receptors gave an indication of the possible impacts and the expected results of potential impacts. Evaluation of each receptor according to the predicted levels further gave an indication of the possible mitigation measures to be applied. The possible environmental or social impacts were addressed in the detailed EIA phase investigation.

7 Site Investigation

The site was visited and a structure identification was done on 12th April 2016. This site visit was done specifically to get an understanding of the location of the decline shaft areas for the project and identifying the structures and installations surrounding the proposed decline shafts.

8 Assumptions and Limitations

The following assumptions have been made:

- The project is a greenfields project with no drilling and blasting operations currently active.
- 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 confirmation of the predicted values as it is a greenfields site with no current blasting activities.
- A general decline shaft blast design was used to determine possible influences.

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

9 Legal Requirements

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

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

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 a standard for South Africa. Additional criteria required by various institutions in South Africa were also taken into consideration, i.e. Eskom, Telkom, Transnet, Rand Water Board, etc.

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

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

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

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

General precautions

4.16 The employer must take reasonable measures to ensure that:

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

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

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

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

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

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

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

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

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

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

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

Mineral and Petroleum Resources Development Regulations

67. Blasting, vibration and shock management and control

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

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

10 Sensitivity of the Project

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

- A highly sensitive area of 500 m around the mining area. Normally, this 500 m area is considered an area that should be cleared of all people and animals prior to blasting. Levels of ground vibration and air blast are also expected to be higher closer to the decline shaft area.
- An area 500 m to 1500 m around the shaft area can be considered as being a medium sensitive area. In this area, the possibility of impact is still expected, but is lower. The expected level of influence may be low, but there may still be reason for concern, as levels could be low enough not to cause structural damage but still result in a reaction by surrounding landowners/occupiers.
- An area greater than 1500 m is considered a low sensitivity area. In this area it is relatively certain that influences will be low with low possibility of damages or a reaction by surrounding landowners/occupiers.

Figure 3 and Figure 4 shows the sensitivity mapping with the identified POI in the surrounding areas for the three Shafts for the proposed Hendrina Reserve Project.

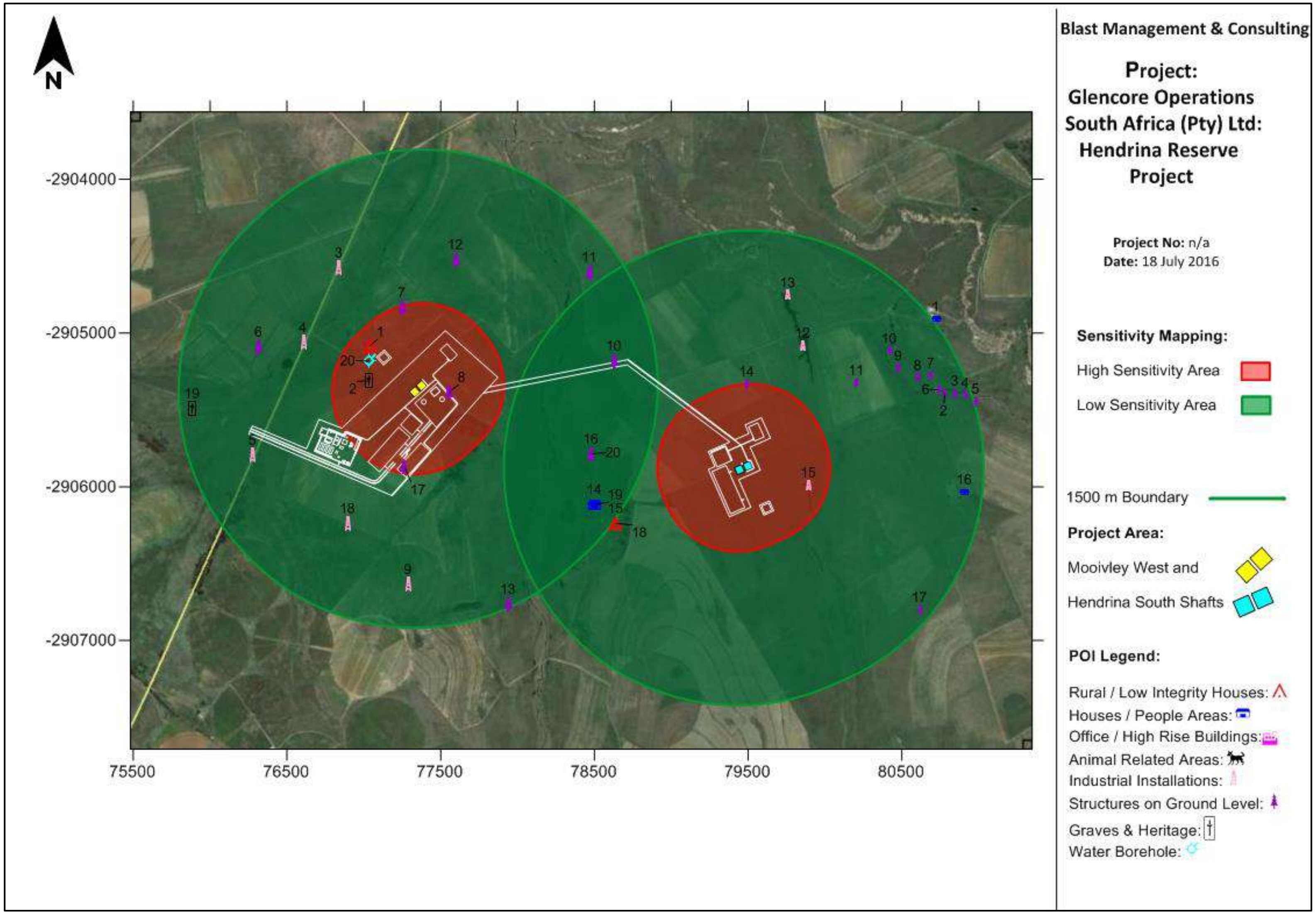

Figure 3: Identified sensitive areas for Mooivley West (Shaft No. 1) and Hendrina South (Shaft No. 2)

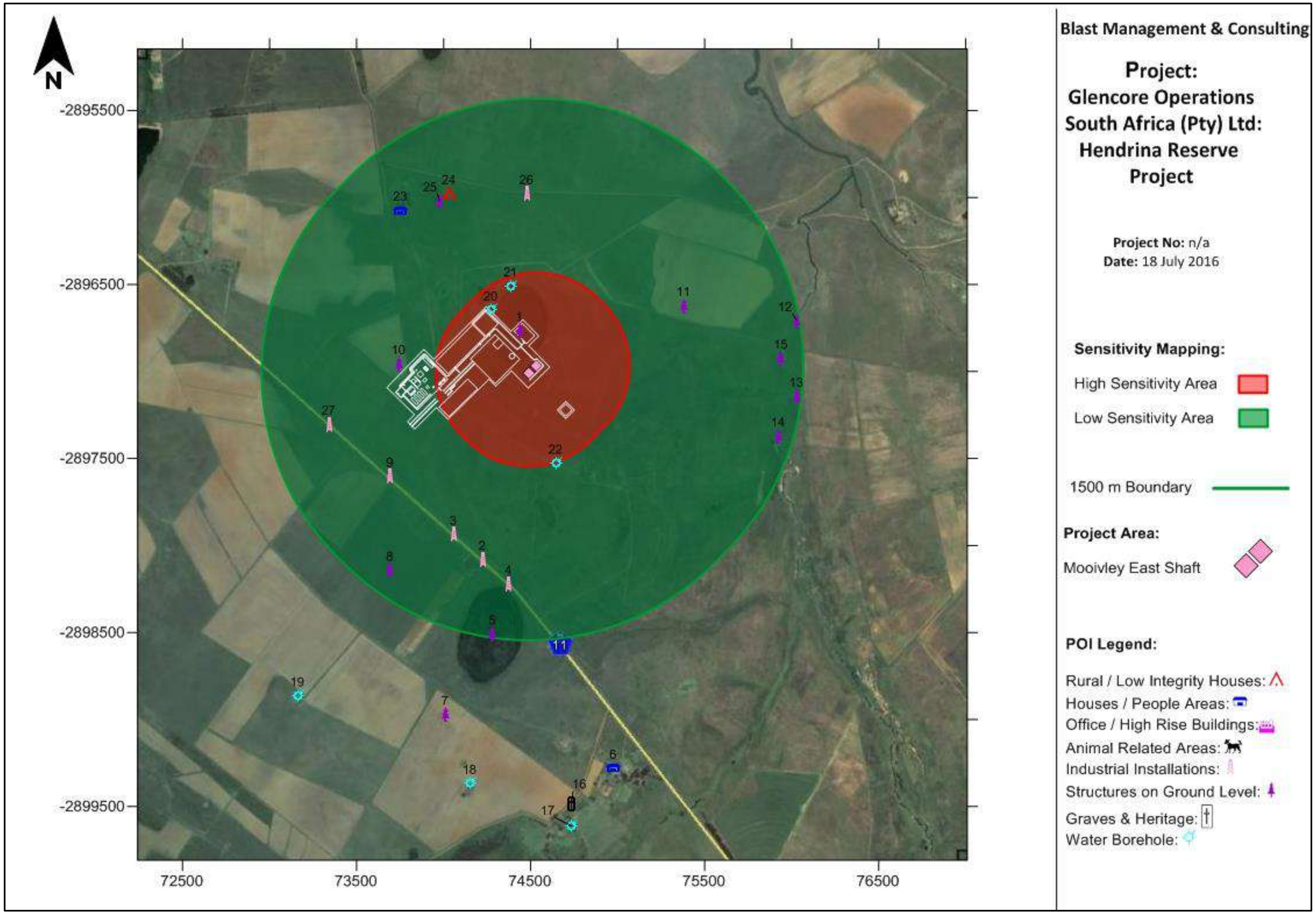

Figure 4: Identified sensitive areas for Mooivley East (Shaft No. 3)

11 Consultation Process

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

12 Influence from Blasting Operations

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

12.1 Ground Vibration Limitations on Structures

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

Currently, the USBM criteria for safe blasting are applied as the industry standard where private structures are of concern. Ground vibration amplitude and frequency is recorded and analysed. The data is then evaluated accordingly. The USBM graph is used for plotting of data and evaluating the data. Figure 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; and
- Analysed data displayed in the top half of the graph shows potentially unsafe ground vibration levels.

Added to the USBM graph is a blue line and green dotted line that represents 6 mm/s and 12.5 mm/s additional criteria that are used by BM&C.

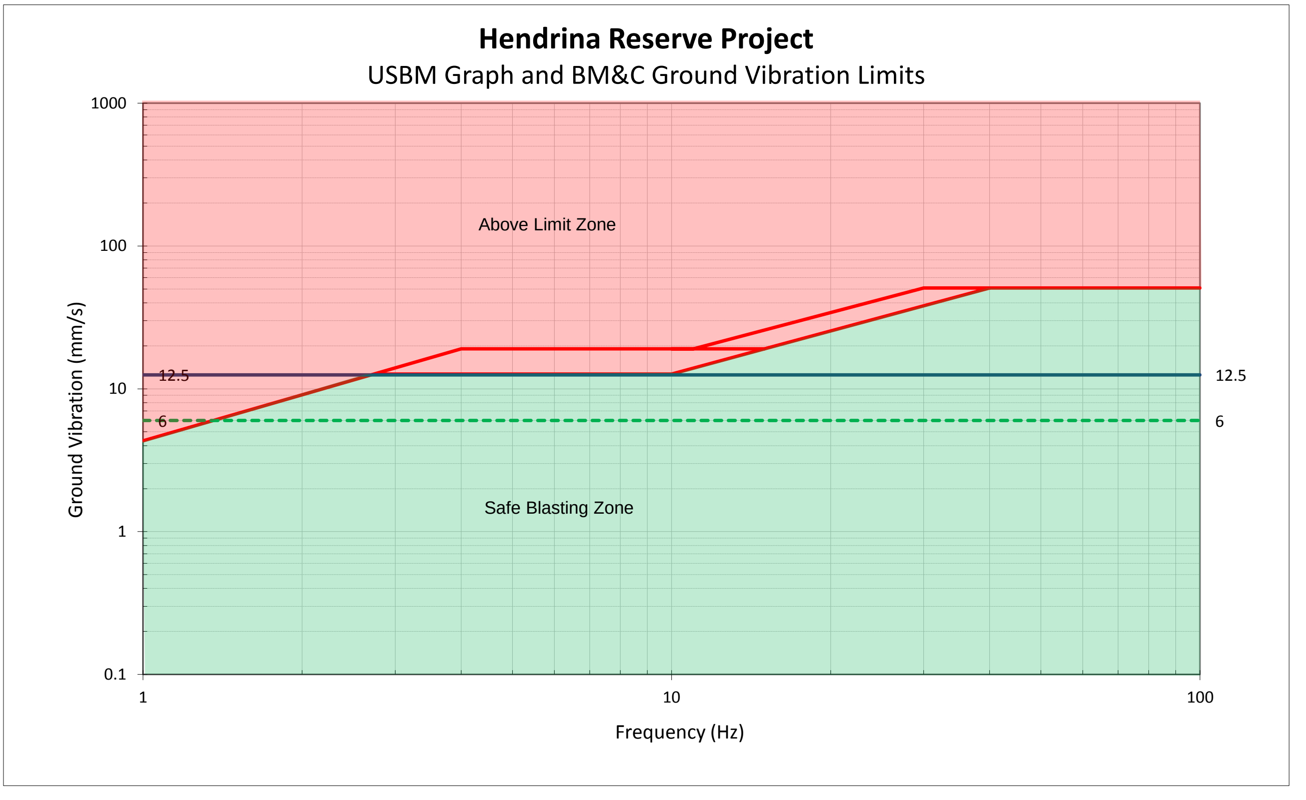

Figure 5: USBM Analysis Graph

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

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

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

12.2 Ground Vibration Limitations and Human Perceptions

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

Ground vibration is experienced at different levels; BM&C considers only the levels that are experienced as “Perceptible”, “Unpleasant” and “Intolerable”. This is indicative of the human being’s perceptions of ground vibration and clearly indicates that humans are sensitive to ground vibration and humans perceive ground vibration levels of 4.5 mm/s as unpleasant (See Figure 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 evaluation.

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

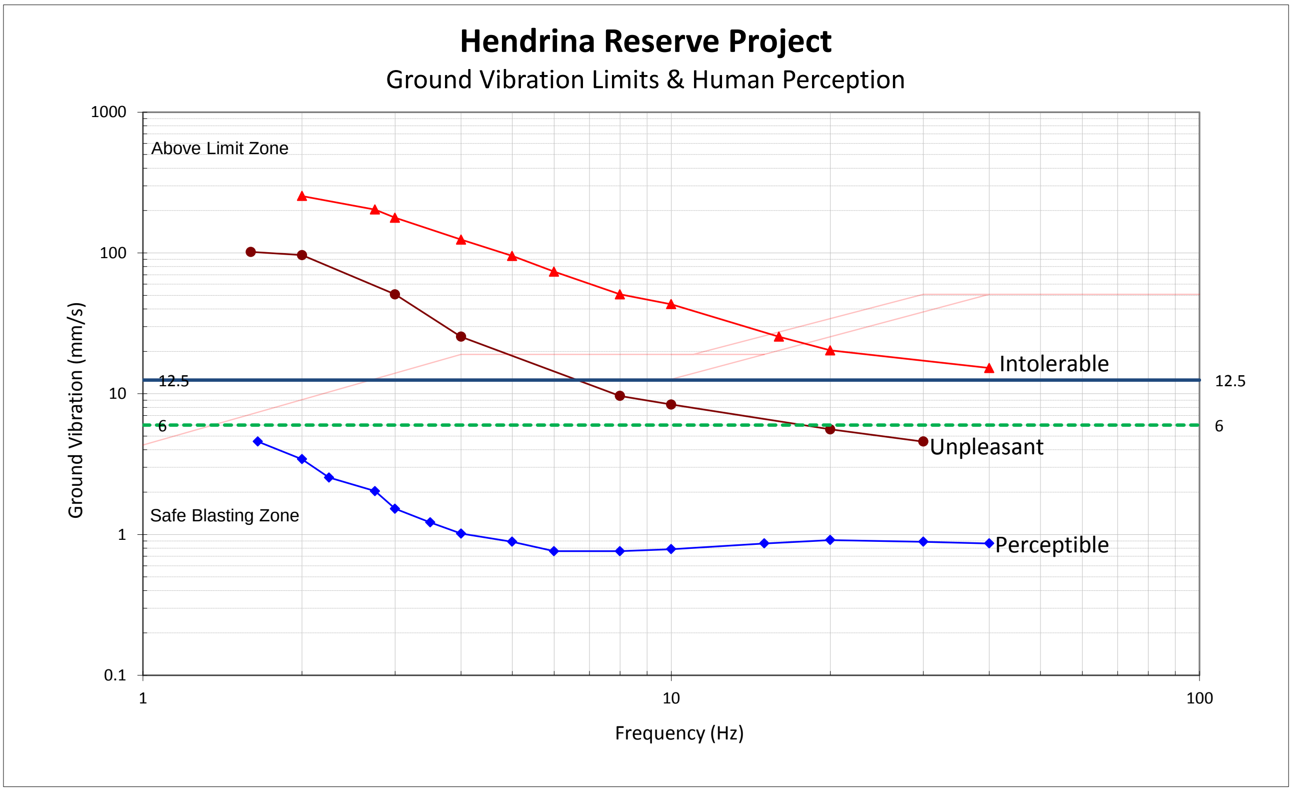

Figure 6: USBM Analysis with Human Perception

12.3 Air Blast Limitations on Structures

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

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

The general recommended limit for air blast currently applied in South Africa is 134 dB. This is based on work done by the USBM. The USBM also indicates that the level is reduced to 128 dB in proximity of hospitals, schools and sensitive areas where people congregate. Based on work carried out by Siskind *et al.* (1980), monitored air blast amplitudes up to 135 dB are safe for structures, provided the monitoring instrument is sensitive to low frequencies. Persson *et al.* (1994) have published estimates of damage thresholds based on empirical data (Table 2). Levels given in Table 2 are at the point of measurement. The weakest points on a structure are the windows and ceilings.

Table 2: Damage Limits for Air Blast

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

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

12.4 Air Blast Limitations and Human Perceptions

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

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

12.5 Fly Rock

Blasting practices require some movement of rock to facilitate the excavation process. The extent of movement is dependent on the scale and type of operation. For example, blasting activities at large coal mines are designed to cast the blasted material over a greater distance than in quarries or hard rock operations or a decline shaft as in this project. The movement should be in the direction of the free face. In a decline shaft situation the free face is the surface. The orientation of the blast and expected movement direction is important. Material or elements travelling outside of a planned or expected range would be considered fly rock. Figure 7 shows schematic of fly rock definitions.

Fly rock can be categorised as follows:

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

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

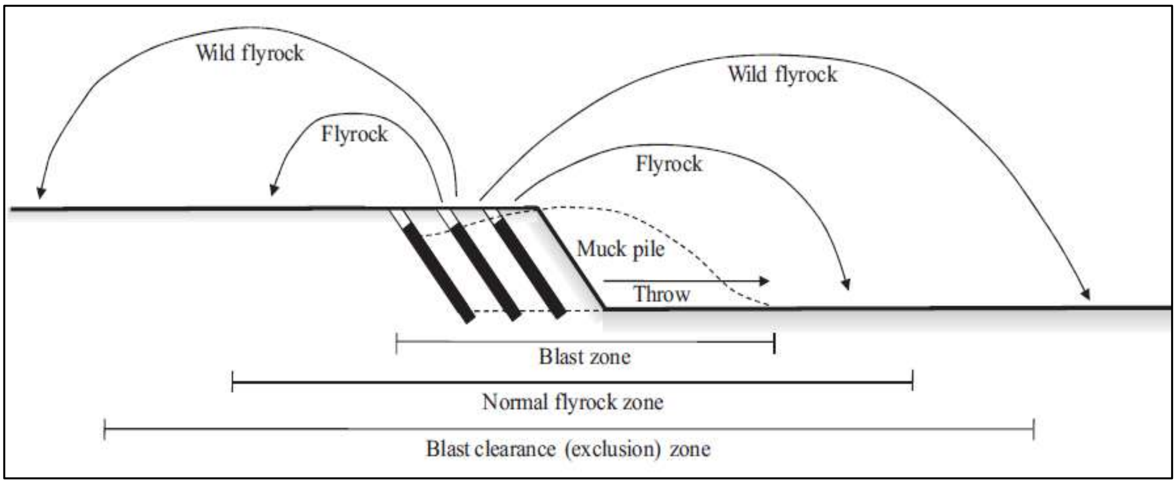

Figure 7: Schematic of fly rock terminology

Fly rock from blasting can result under the following conditions:

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

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

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

12.6 Noxious Fumes

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

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

13 Baseline Results

Baseline work for this report normally consists of two parts. The first part is monitoring of blasting operations if the mine is operational. The project is not currently active with any blasting operations being done. No specific monitoring was done. Baseline data is considered at zero level. The second part of baseline work done is familiarising oneself with the surroundings and the typical structures that are found in the area of the project. The information for this is presented below.

13.1 Ground Vibration and Air Blast Predictions

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

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

This project is a new planned operation with no specific blast designs available. A typical design was done for the development of the decline shaft in order to access the underground resource.

In this case a basic blast design was constructed for the development of the decline shaft. Blasts were designed using JKSimblast blast simulation software and simulate the outcomes for specific aspects. The simulation of the blast in the software was then used to obtain the best prediction possible. Blast was designed, charged (charged according to expected drill depths over the full development of decline and bulk area), standard timing of what can be expected was used and simulated. Table 3 shows the technical information for the design done. This is only the first top bench to be blasted with part of the decline to the level of the bench. Figure 8 below shows the decline shaft layout with blast holes. Figure 9 shows simulation timing contours with decks per delay from the typical timing applied.

Table 3: Blast design technical information

Blast Reference:	Blast01
Type of Blast:	Bulk
Bench Height (m):	15.0
Blasthole Depth - Minimum (m):	0.1
Blasthole Depth - Maximum (m):	15.0
Blasthole Diameter (mm):	115 & 165
Sub Drill Length (m):	0
Burden (m):	4.5
Spacing (m):	4.5
Drill Pattern:	Square
Quantity Blastholes:	1180
Rock Type:	Medium Hard Layered
Density (gr./cm^3):	2.64
Explosive Type:	Emulsion
In-hole Density (kg/m^3):	1.25
Total Explosives Quantity (kg):	186366
Charge Length - Minimum (m):	0.0
Charge Length - Maximum (m):	10.9
Charge per blasthole - Minimum (kg):	0.364
Charge per blasthole - Maximum (kg):	291.336
Stemming Length - Minimum (m):	0.05
Stemming Length - Maximum (m):	7.75
Type of Stemming:	Crushed Aggregate
Accessories Type:	Shocktube
Downhole delay (ms):	500

Surface Timing - Inter hole (ms):	17
Surface Timing - Inter row (ms):	42
Booster / Primer (gr.):	None
Delay Pattern:	V1
Maximum single charge (kg):	291.3
Powder Factor (kg/m^3):	0.82
Blast Volume / Size (m^3):	226 101.173
Free Face:	No
Charging Configuration	Single Deck
Max. No. of Decks / Blasthole	1
Cover or Not	**No**

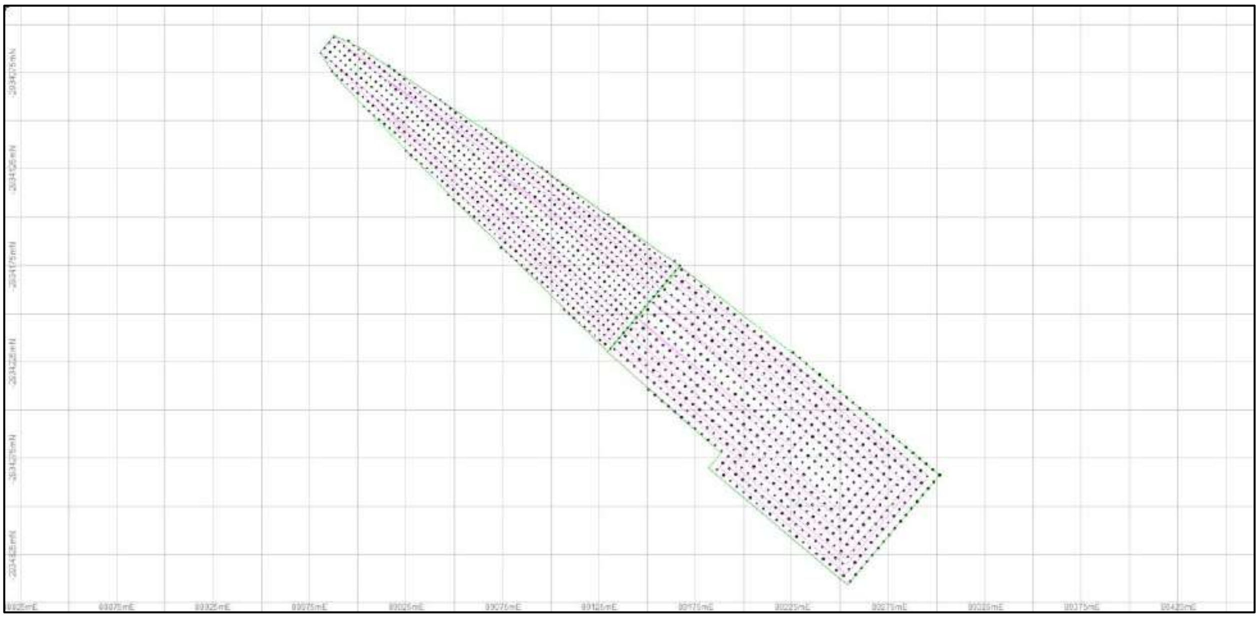

Figure 8: Decline shaft blast holes layout

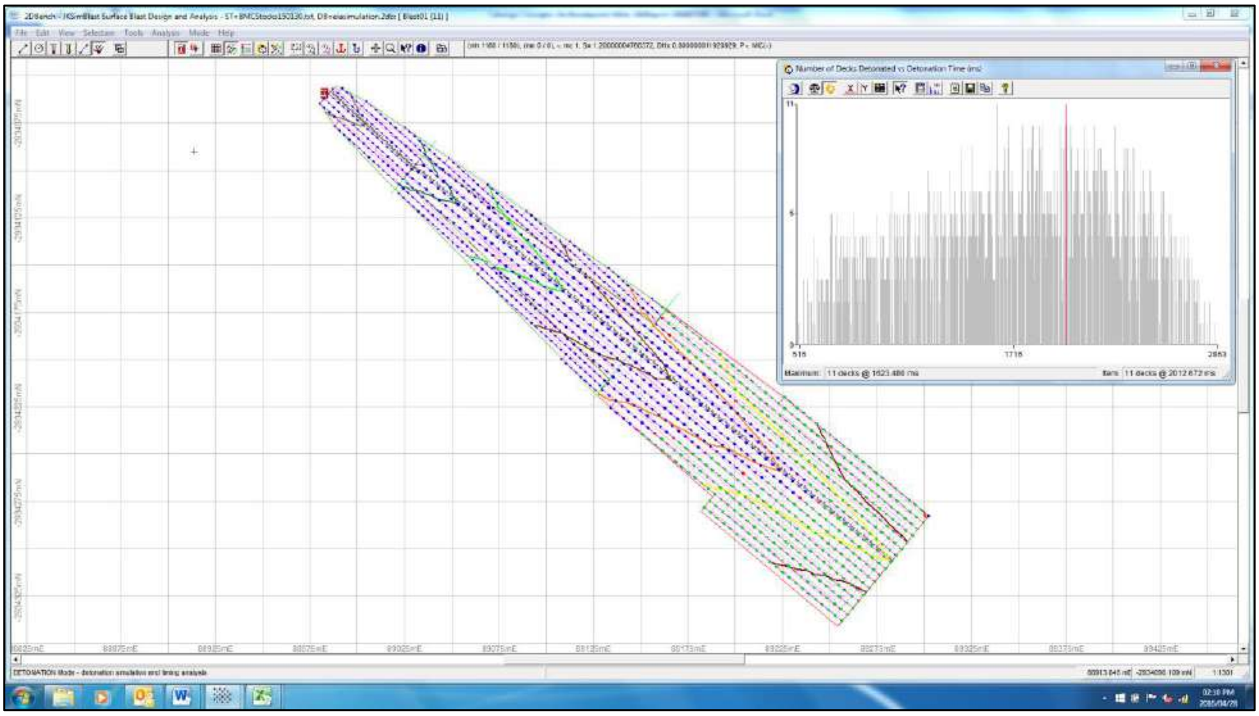

Figure 9: Simulation and decks per delay graph

The simulation work done provided information that is applied for predicting ground vibration and air blast. Evaluation of the blasting operations considered a minimum charge and a maximum charge. The minimum charge was derived from the deepest 165 mm diameter single blasthole and the maximum charge was extracted from the blast simulation in JKSimblast. The minimum charge relates to 291 kg and the maximum charge relates to 2402 kg. These values were applied in all predictions for ground vibration and air blast.

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

Equation 1:

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

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

a = 1143 and
b = -1.65.

Utilizing the abovementioned equation and the given factors, allowable levels for specific limits and expected ground vibration levels can then be calculated for various distances.

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

Equation 2:

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

Where:

P = Air blast level (mB)
D = Distance from source (m)
E = Maximum charge mass per delay (kg)
A = Constant
-B = Constant

The constants for A and B were then selected according to the information as provided in Figure 10 below. Various types of mining operations are expected to yield different results. The information provided in Figure 10[1] is based on detailed research that was conducted for each of the different types of mining environments. In this report the data for “Construction (Average)” was applied in the prediction or air blast.

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

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 10: 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.

Based on the designs presented on expected drilling and charging design, Table 4 shows expected ground vibration levels (PPV) for various distances calculated at the two different charge masses. A low charge mass and a maximum charge mass as worst case scenario. The charge masses are 291 kg and 2402 kg.

Table 4: Expected Ground Vibration at Various Distances from Charges Applied in this Study

No.	Distance (m)	Expected PPV (mm/s) for 291 kg Charge	Expected PPV (mm/s) for 2 402 kg Charge
1	50.0	193.8	1105.9
2	100.0	99.3	566.5
3	150.0	31.6	180.5
4	200.0	19.7	112.3
5	250.0	13.6	77.7
6	300.0	10.1	57.5
7	400.0	6.3	35.8
8	500.0	4.3	24.8
9	600.0	3.2	18.3
10	700.0	2.5	14.2
11	800.0	2.0	11.4
12	900.0	1.6	9.4
13	1000.0	1.4	7.9
14	1250.0	1.0	5.5
15	1500.0	0.7	4.0

Although the above equation 2 & 3 was applied for prediction of air blast levels, additional measures are also recommended to ensure that air blast and associated fly-rock possibilities are minimised as best as possible. As discussed earlier the prediction of air blast is very subjective. Following in Table 5 below is a summary of values predicted according to Equation 2 and Equation 3.

Table 5: Air Blast Predicted Values

No.	Distance (m)	Air blast (dB) for 291 kg Charge	Air blast (dB) for 2402 kg Charge
1	50.0	142.6	149.3
2	100.0	138.7	145.4
3	150.0	132.1	138.8
4	200.0	129.3	136.0
5	250.0	127.2	133.9
6	300.0	125.5	132.2
7	400.0	122.7	129.4
8	500.0	120.6	127.3
9	600.0	118.8	125.6
10	700.0	117.4	124.1
11	800.0	116.1	122.8
12	900.0	115.0	121.7
13	1000.0	114.0	120.7
14	1250.0	111.8	118.5
15	1500.0	110.1	116.8

13.2 Structure Profile

As part of the baseline, all possible structures in a possible influence area are identified. The site was reviewed using Google Earth imagery. Information sought during the review was to identify surface structures present in a 1500 m radius from the proposed shaft area, which will require consideration during modelling of blasting operations, e.g. houses, general structures, powerlines, pipelines, reservoirs, mining activity, roads, shops, schools, gathering places, possible historical sites, etc. A list was prepared of all structures in the vicinity of the three shaft areas. The list includes structures and POI within the 1500 m boundary – see Table 6 below. A list of structure locations was required to determine the allowable ground vibration limits and air blast limits. Figure 11 shows an aerial view of the decline shaft area and surroundings with POIs. The type of POIs identified is grouped into different classes. These classes are indicated as "Classification" in Table 7. The classification used is a BM&C classification and does not relate to any standard or national or international code or practice. Table 6 shows the descriptions for the classifications used.

Table 6: POI Classification used

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

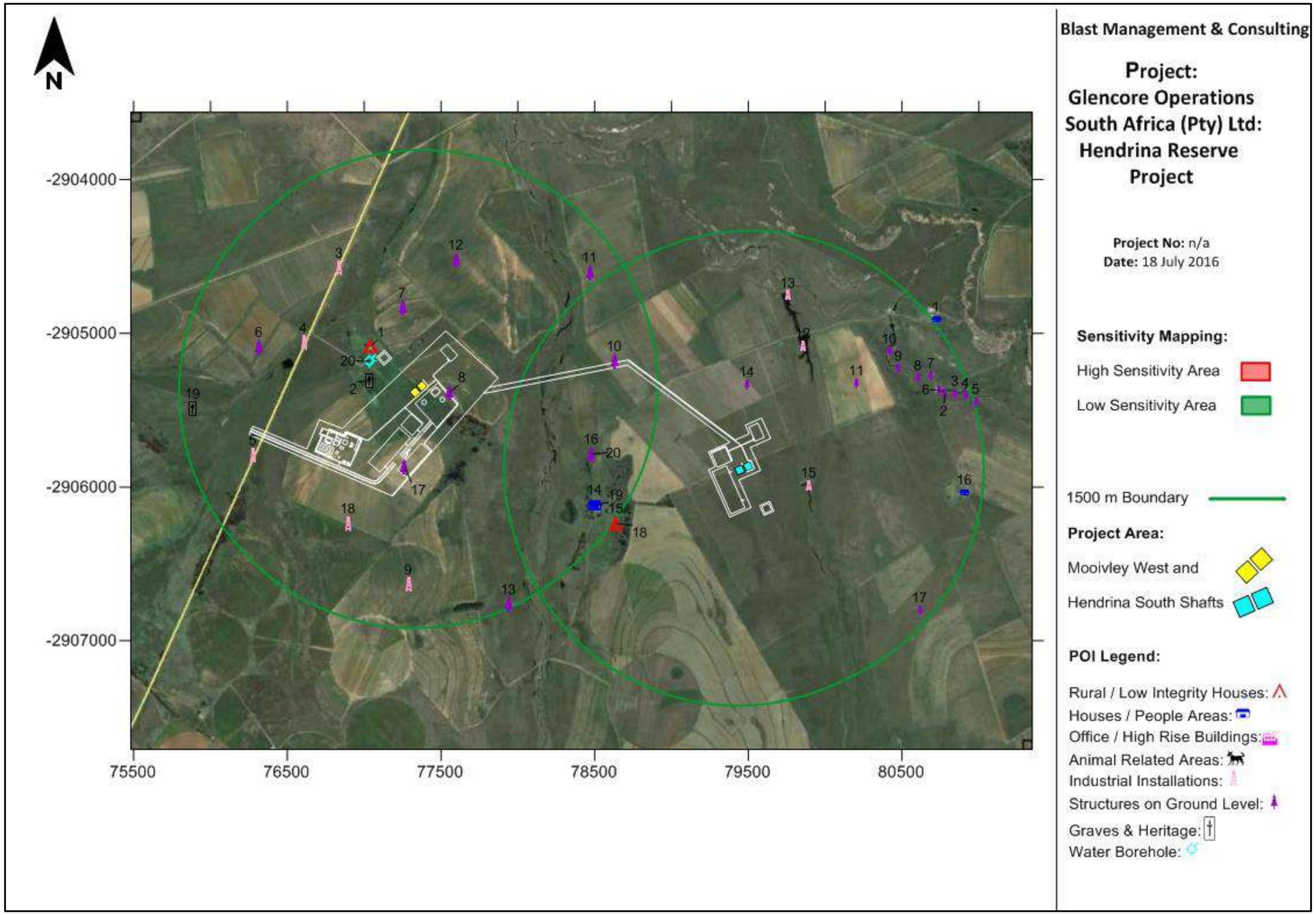

Figure 11: Aerial view and surface plan of the proposed Mooivley West (Shaft No. 1) and Hendrina South (Shaft No. 2) areas with points of interest identified

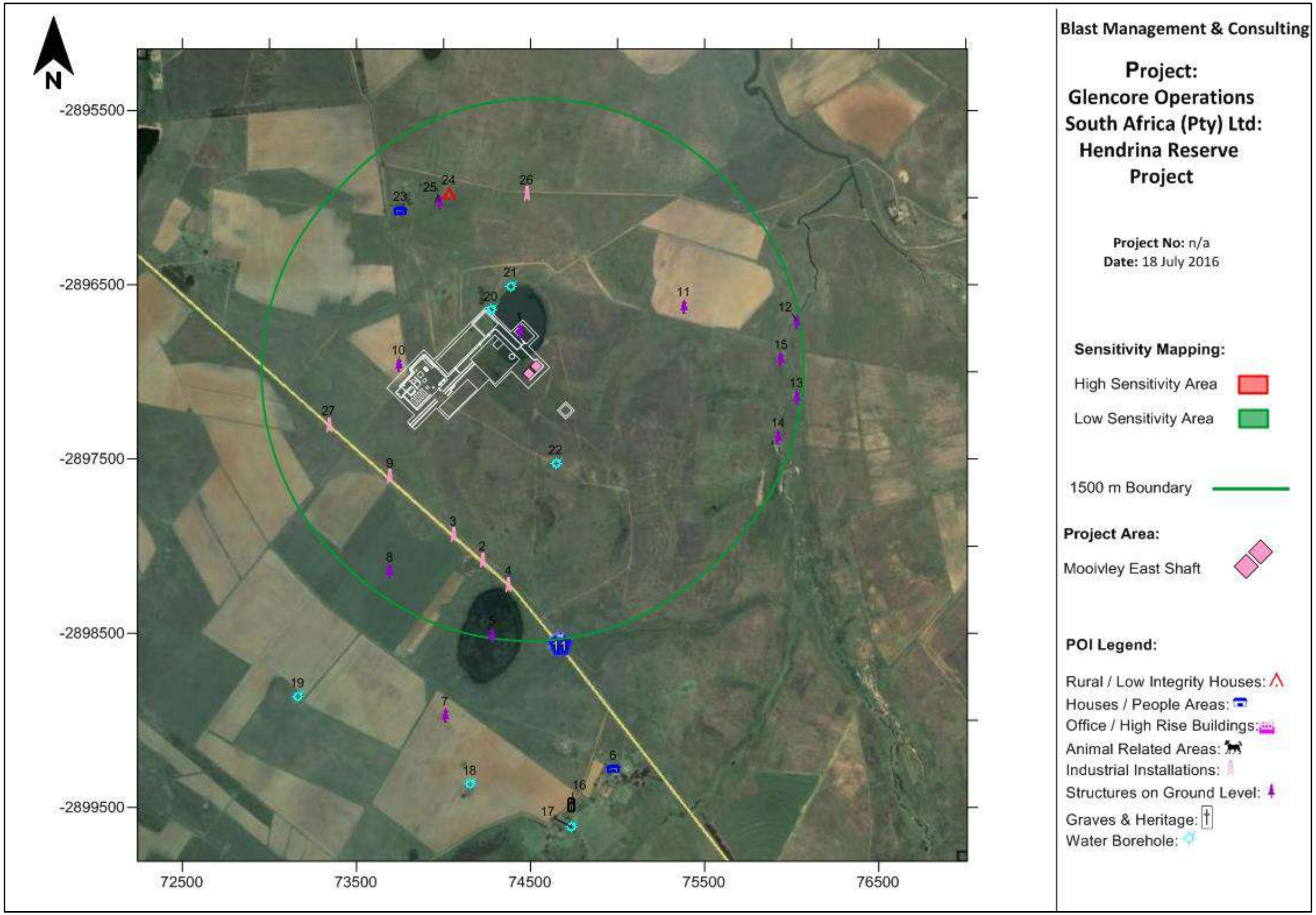

Figure 12: Aerial view and surface plan of the proposed Mooivley East (Shaft No. 3) area with points of interest identified

Table 7: List of POIs identified (WGS – LO 29º)

Tag	Description	Classification	Y	X
Mooivley West (Shaft No. 1)				
1	Informal Housing	1	-77040.18	2905083.36
2	Heritage - Farm Buildings/Structures	7	-77032.78	2905311.24
3	Davel Road	5	-76840.07	2904574.78
4	Davel Road	5	-76606.56	2905061.37
5	Davel Road	5	-76276.93	2905793.62
6	Cultivated Fields	6	-76317.05	2905090.20
7	Cultivated Fields	6	-77249.45	2904833.72
8	Cultivated Fields	6	-77554.40	2905384.54
9	Pivot Irrigation	5	-77289.72	2906635.93
10	Cultivated Fields	6	-78629.13	2905180.66
11	Cultivated Fields	6	-78470.71	2904603.07
12	Cultivated Fields	6	-77597.72	2904522.12
13	Pan	6	-77939.66	2906762.80
14	Farm Buildings/Structures	2	-78502.48	2906115.51
15	Informal Housing	1	-78639.55	2906238.40
16	Pan	6	-78478.81	2905786.33
17	Cultivated Fields	6	-77264.36	2905870.07
18	Pivot Irrigation	5	-76896.00	2906237.81
19	Burial Ground with graves (BGG-001)	7	-75885.59	2905489.48
20	Hydrocencus Borehole(MVLBH5)	8	-77033.57	2905182.14
Hendrina South (Shaft No. 2)				
1	Farm Buildings/Structures	2	-80723.77	2904909.13
2	Klein-Olifants River	6	-80777.94	2905394.45
3	Klein-Olifants River	6	-80845.83	2905389.98
4	Klein-Olifants River	6	-80916.07	2905403.65
5	Klein-Olifants River	6	-80982.99	2905443.68
6	Klein-Olifants River	6	-80741.87	2905370.61
7	Klein-Olifants River	6	-80691.04	2905274.06
8	Klein-Olifants River	6	-80606.93	2905288.83
9	Klein-Olifants River	6	-80478.66	2905226.86
10	Klein-Olifants River	6	-80421.44	2905115.21
11	Cultivated Fields	6	-80207.72	2905321.93
12	Dam	5	-79857.71	2905080.00
13	Dam	5	-79759.51	2904753.18
14	Cultivated Fields	6	-79493.04	2905330.85
15	Dam	5	-79895.46	2905987.67
16	Buildings/Structures	2	-80909.08	2906034.00
17	Cultivated Fields	6	-80617.54	2906798.75
18	Informal Housing	1	-78639.55	2906238.40
19	Farm Buildings/Structures	2	-78502.48	2906115.51
20	Pan	6	-78478.81	2905786.33

Tag	Description	Classification	Y	X
Mooivley East (Shaft No. 3)				
1	Pan	6	-74437.95	2896764.90
2	N11 Road	5	-74225.51	2898080.11
3	N11 Road	5	-74058.37	2897936.26
4	N11 Road	5	-74375.84	2898220.75
5	Pan	6	-74281.41	2898508.47
6	Farm Buildings/Structures	2	-74976.87	2899280.75
7	Cultivated Fields	6	-74010.89	2898971.49
8	Cultivated Fields	6	-73693.01	2898141.86
9	N11 Road	5	-73693.29	2897603.43
10	Cultivated Fields	6	-73743.18	2896956.69
11	Cultivated Fields	6	-75380.88	2896622.05
12	Klein-Olifants River	6	-76029.12	2896708.60
13	Klein-Olifants River	6	-76030.44	2897143.93
14	Klein-Olifants River	6	-75925.27	2897371.44
15	Klein-Olifants River	6	-75940.71	2896923.68
16	Burial Ground with graves (BGG-002)	7	-74733.04	2899482.12
17	Hydrocencus Borehole(ORJBH1)	8	-74734.80	2899609.99
18	Hydrocencus Borehole(ORJBH2)	8	-74152.46	2899367.99
19	Hydrocencus Borehole(ORJBH3)	8	-73161.75	2898864.31
20	Hydrocencus Borehole(VLBSP8)	8	-74272.98	2896646.65
21	Hydrocencus Borehole(VLBSP7)	8	-74386.74	2896510.02
22	DW drilled borehole(OVBH2)	8	-74645.82	2897527.76
23	Farm Buildings/Structures	2	-73754.21	2896073.93
24	Informal Housing	1	-74033.54	2895978.42
25	Pan	6	-73975.98	2896019.53
26	Road	5	-74479.45	2895978.86
27	N11 Road	5	-73341.96	2897303.12

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

Table 8 shows photos of the structures found in the area.

Table 8: Structure Profile

Structure Photo	**Description**
	Informal Housing
	Windmill

Structure Photo	Description
	Farming area and cattle grazing
	Farmstructure

Structure Photo	Description
	Cattle
	Mealie fields

Structure Photo	Description
	View over area for Shaft 2 & 3
	Windmill and water reservoir

Structure Photo	Description
	Corrugated iron store
	Buidlings with old roof

Structure Photo	Description
	Informal housing
	Olifants river

Structure Photo	Description
	Pan next to N11
	Cattle and birds at the Pan

Structure Photo	**Description**
	Fibre line next to N11
	Fibre pole with nots

Structure Photo	**Description**
	N11 National Road

14 Construction Phase: Blast and Vibration Assessment

The Hendrina Reserve Project area is evaluated in detail in the following sections. Establishment of a decline shaft to access each of the underground sections is considered for this report as part of the construction phase. The main mining operations will be undertaken through underground mechanical mining. As such, there is no operational phase evaluation done for this project in this report. The underground mine is the operational phase and mining will be done mechanically. No drilling and blasting is anticipated as part of the operational phase. Minor blasting may be required when a dyke is encountered but not expected to have any significant influence on surface.

This impact assessment evaluates the expected levels of ground vibration, air blast and fly rock during construction. The levels and distances are calculated for each influence. The predicted levels are plotted as amplitude contour maps and evaluated in relation to identified POI. Where exceedance of levels is expected mitigation measures are recommended and the impact assessment is done considering the pre- and post-mitigation measures.

In all cases ground vibration and air blast was calculated from the edge of the decline shaft outline and modelled accordingly. A worst case is then applicable with a calculation from the shaft edge.

14.1 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 decline shaft area.
- "Specific Limit" is the maximum limit for ground vibration at the specific structure or installation.
- "Predicted PPV (mm/s)" is the calculated ground vibration at the structure.
- The "Structure Response @ 10Hz and Human Tolerance @ 30Hz" indicates the possible concern and if there is any concern for structural damage or potential negative human perception respectively. Indicators used are "perceptible", "unpleasant", "intolerable" which stems from the human perception information given and indicators such as "high" or "low" is given for the possibility of damage to a structure. Levels below 0.76 mm/s could be considered to have low or negligible possibility of influence.

Ground vibration is calculated and modelled for a typical decline blast area to access each of the underground mining areas. The minimum and maximum charge mass at specific distances from the decline area is then used and modelled for influence. The charge masses applied are according to blast designs discussed in Section 14. 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 1500 m around the shaft area.

The simulation provided shows ground vibration contours only for a limited number of levels. The levels used are considered the basic limits that will applicable for the type of structures observed surrounding the decline shaft area. These levels are: 6 mm/s, 12.5 mm/s, 25 mm/s and 50 mm/s. This enables immediate review of possible concerns that may be applicable to any of the privately owned structures, social gathering areas or sensitive installations.
Data is provided as follows: Vibration contours; a table with predicted ground vibration values and evaluation for each POI. Additional colour codes used in the tables are as follows:

Vibration levels higher than proposed limit applicable to Structures / Installations is coloured "Mustard"
Vibration levels indicated as Intolerable on human perception scale is coloured "Yellow"
POI's that are found inside the shaft area is coloured "Olive Green"

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

- **Minimum charge mass per delay 291 kg – Mooivley West (Shaft No. 1)**

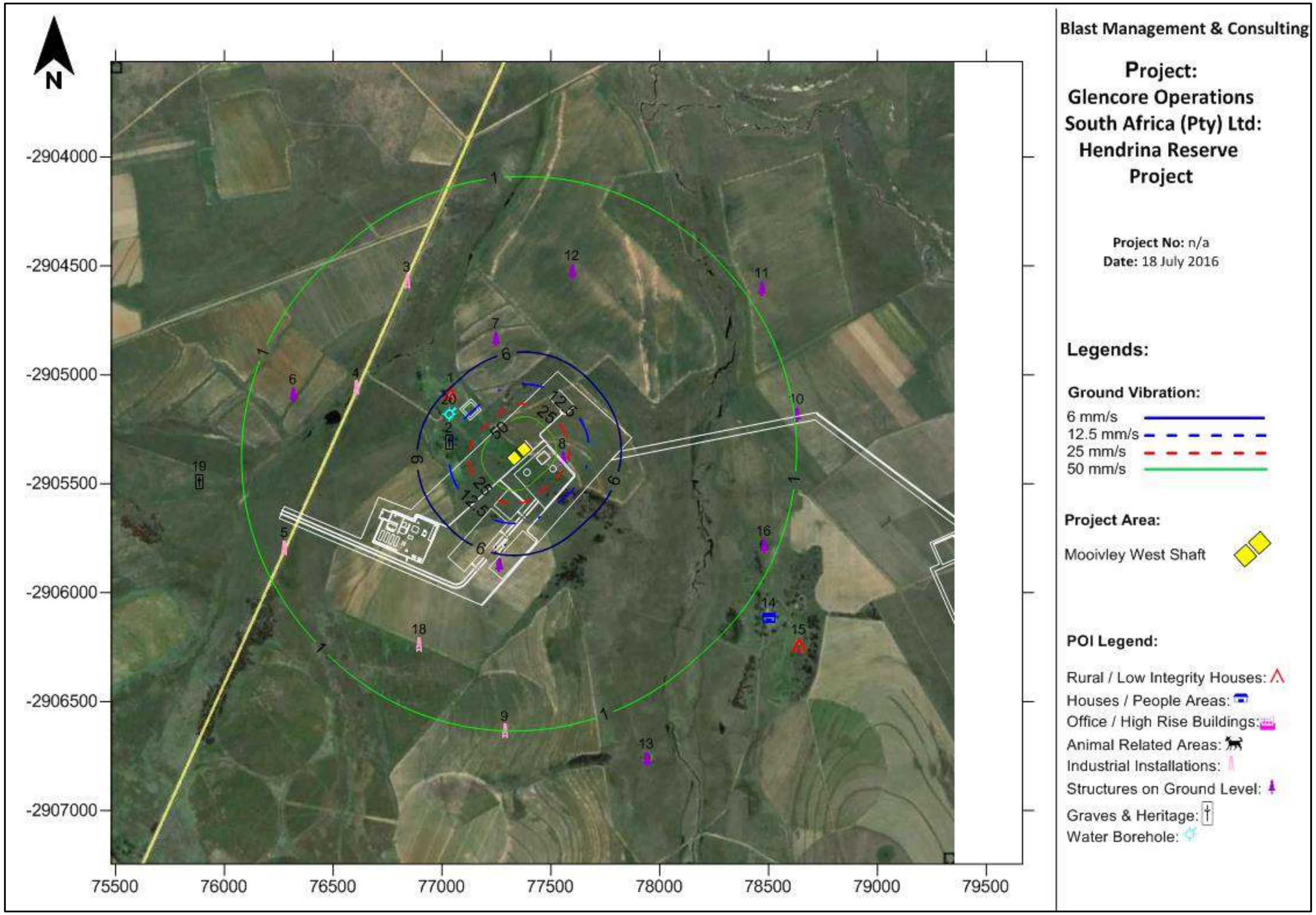

Figure 13: Ground vibration influence from minimum charge for Mooivley West (Shaft No. 1)

Table 9: Ground vibration evaluation for minimum charge for Mooivley West (Shaft No. 1)

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Informal Housing	6	392	6.5	Problematic	Unpleasant
2	Heritage - Farm Buildings/Structures	6	272	11.8	Problematic	N/A
3	Davel Road	150	908	1.6	Acceptable	N/A
4	Davel Road	150	760	2.2	Acceptable	N/A
5	Davel Road	150	1100	1.2	Acceptable	N/A
6	Cultivated Fields	150	1021	1.3	Acceptable	N/A
7	Cultivated Fields	150	490	4.5	Acceptable	N/A
8	Cultivated Fields	150	149	32.1	Acceptable	N/A
9	Pivot Irrigation	150	1219	1.0	Acceptable	N/A
10	Cultivated Fields	150	1229	1.0	Acceptable	N/A
11	Cultivated Fields	150	1293	0.9	Acceptable	N/A
12	Cultivated Fields	150	815	1.9	Acceptable	N/A
13	Pan	150	1477	0.7	Acceptable	N/A
14	Farm Buildings/Structures	25	1336	0.9	Acceptable	Perceptible
15	Informal Housing	6	1519	0.7	Acceptable	Too Low
16	Pan	150	1156	1.1	Acceptable	N/A
17	Cultivated Fields	150	457	5.0	Acceptable	N/A
18	Pivot Irrigation	150	928	1.6	Acceptable	N/A
19	Burial Ground with graves (BGG-001)	50	1415	0.8	Acceptable	N/A
20	Hydrocencus Borehole(MVLBH5)	50	329	8.7	Acceptable	N/A

- **Maximum charge per delay 2402 kg – Mooivley West (Shaft No. 1)**

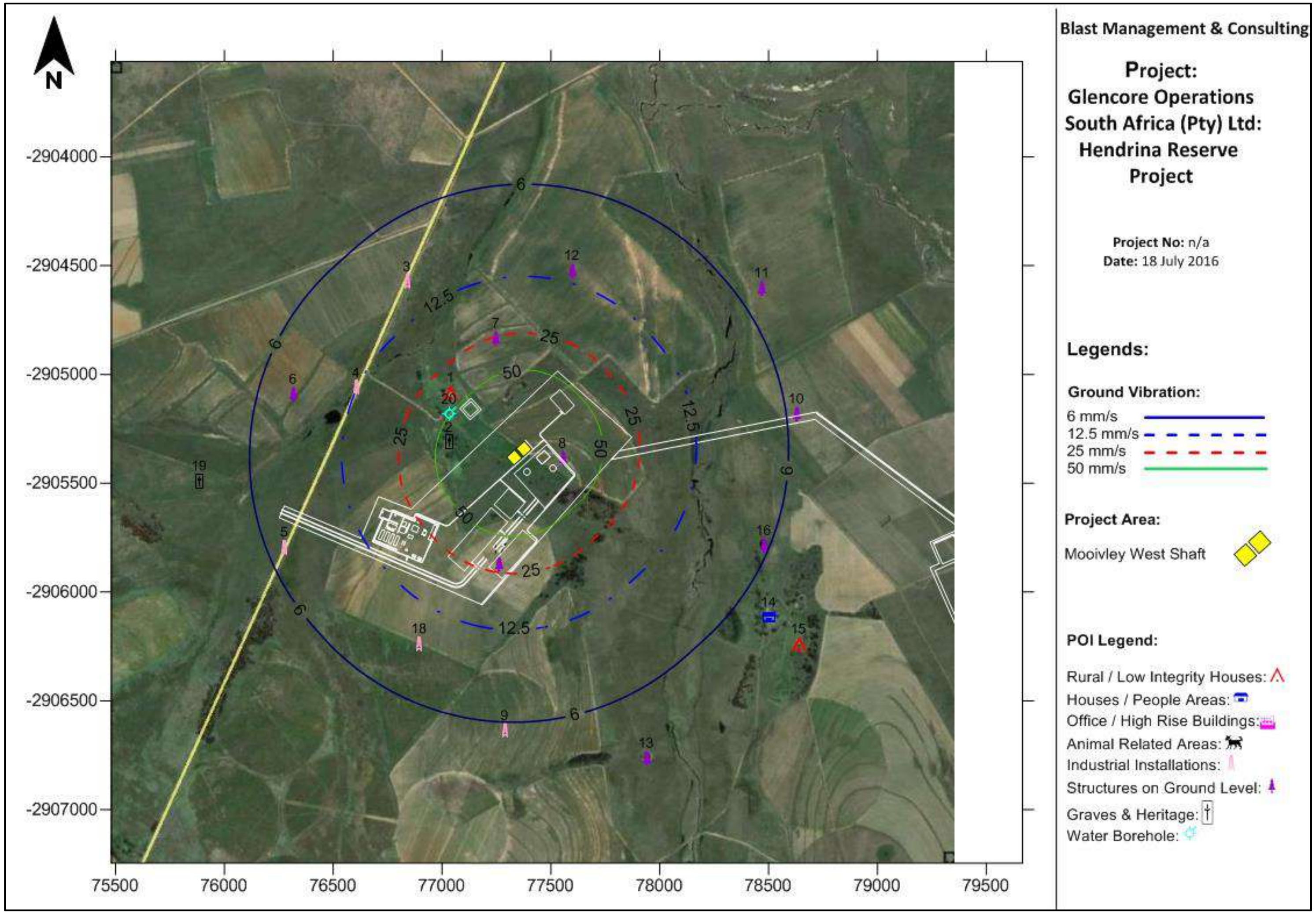

Figure 14: Ground vibration influence from maximum charge for Mooivley West (Shaft No. 1)

Table 10: Ground vibration evaluation for maximum charge for Mooivley West (Shaft No. 1)

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Informal Housing	6	392	37.0	Problematic	Intolerable
2	Heritage - Farm Buildings/Structures	6	272	67.5	Problematic	N/A
3	Davel Road	150	908	9.2	Acceptable	N/A
4	Davel Road	150	760	12.4	Acceptable	N/A
5	Davel Road	150	1100	6.7	Acceptable	N/A
6	Cultivated Fields	150	1021	7.6	Acceptable	N/A
7	Cultivated Fields	150	490	25.6	Acceptable	N/A
8	Cultivated Fields	150	149	183.0	N/A	N/A
9	Pivot Irrigation	150	1219	5.7	Acceptable	N/A
10	Cultivated Fields	150	1229	5.6	Acceptable	N/A
11	Cultivated Fields	150	1293	5.2	Acceptable	N/A
12	Cultivated Fields	150	815	11.1	Acceptable	N/A
13	Pan	150	1477	4.1	Acceptable	N/A
14	Farm Buildings/Structures	25	1336	4.9	Acceptable	Perceptible
15	Informal Housing	6	1519	4.0	Acceptable	Perceptible
16	Pan	150	1156	6.2	Acceptable	N/A
17	Cultivated Fields	150	457	28.7	Acceptable	N/A
18	Pivot Irrigation	150	928	8.9	Acceptable	N/A
19	Burial Ground with graves (BGG-001)	50	1415	4.5	Acceptable	N/A
20	Hydrocencus Borehole(MVLBH5)	50	329	49.4	Acceptable	N/A

- **Minimum charge mass per delay 291 kg – Hendrina South (Shaft No. 2)**

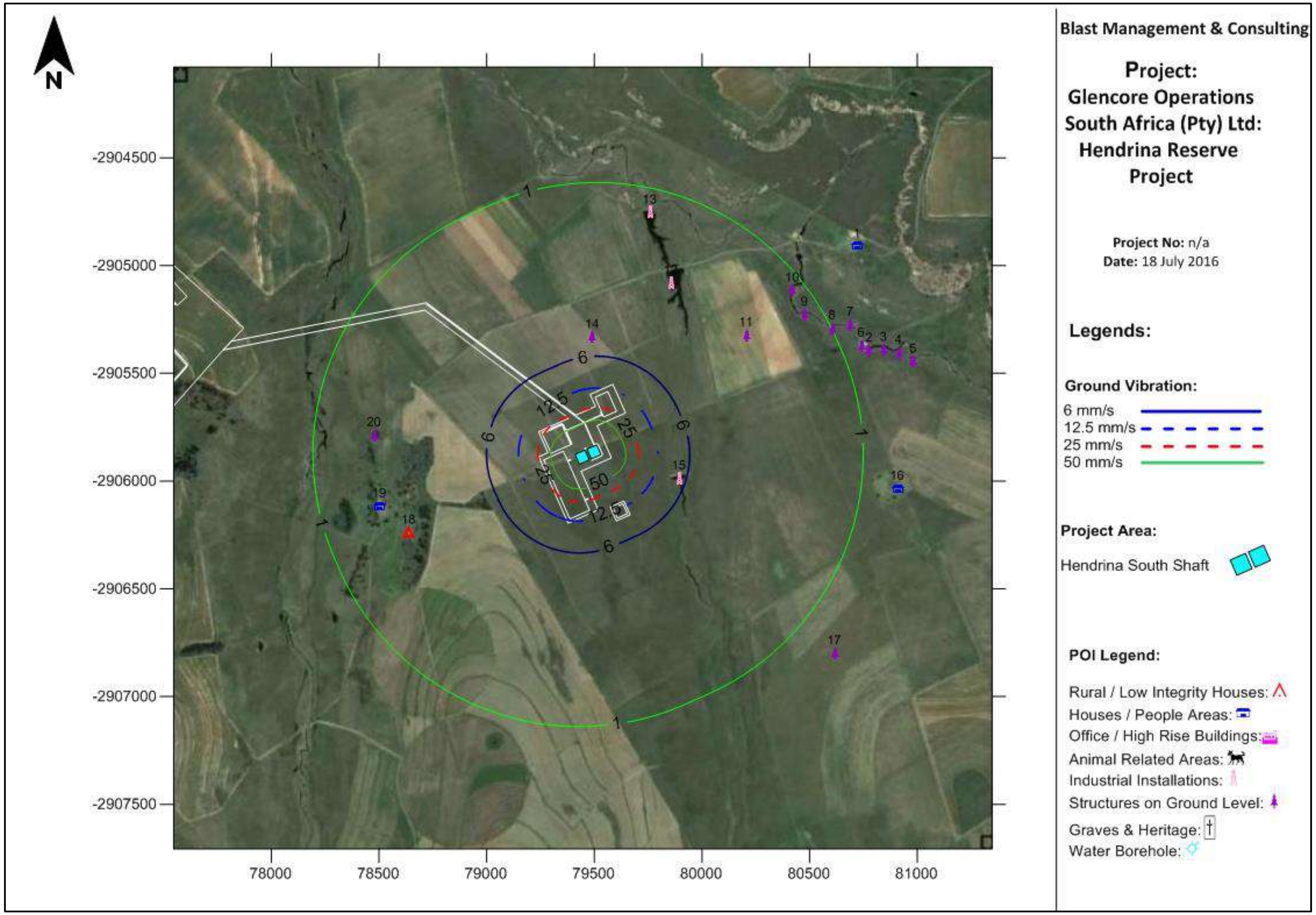

Figure 15: Ground vibration influence from minimum charge for Hendrina South (Shaft No. 2)

Table 11: Ground vibration evaluation for minimum charge for Hendrina South (Shaft No. 2)

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Farm Buildings/Structures	25	1524	0.7	Acceptable	Too Low
2	Klein-Olifants River	150	1337	0.9	Acceptable	N/A
3	Klein-Olifants River	150	1402	0.8	Acceptable	N/A
4	Klein-Olifants River	150	1464	0.7	Acceptable	N/A
5	Klein-Olifants River	150	1515	0.7	Acceptable	N/A
6	Klein-Olifants River	150	1312	0.9	Acceptable	N/A
7	Klein-Olifants River	150	1305	0.9	Acceptable	N/A
8	Klein-Olifants River	150	1223	1.0	Acceptable	N/A
9	Klein-Olifants River	150	1141	1.1	Acceptable	N/A
10	Klein-Olifants River	150	1158	1.1	Acceptable	N/A
11	Cultivated Fields	150	863	1.8	Acceptable	N/A
12	Dam	50	828	1.9	Acceptable	N/A
13	Dam	50	1107	1.2	Acceptable	N/A
14	Cultivated Fields	150	501	4.3	Acceptable	N/A
15	Dam	50	380	6.8	Acceptable	N/A
16	Buildings/Structures	25	1387	0.8	Acceptable	Perceptible
17	Cultivated Fields	150	1424	0.8	Acceptable	N/A
18	Informal Housing	6	852	1.8	Acceptable	Perceptible
19	Farm Buildings/Structures	25	939	1.5	Acceptable	Perceptible
20	Pan	150	936	1.5	Acceptable	N/A

- **Maximum charge mass per delay 2402 kg – Hendrina South (Shaft No. 2)**

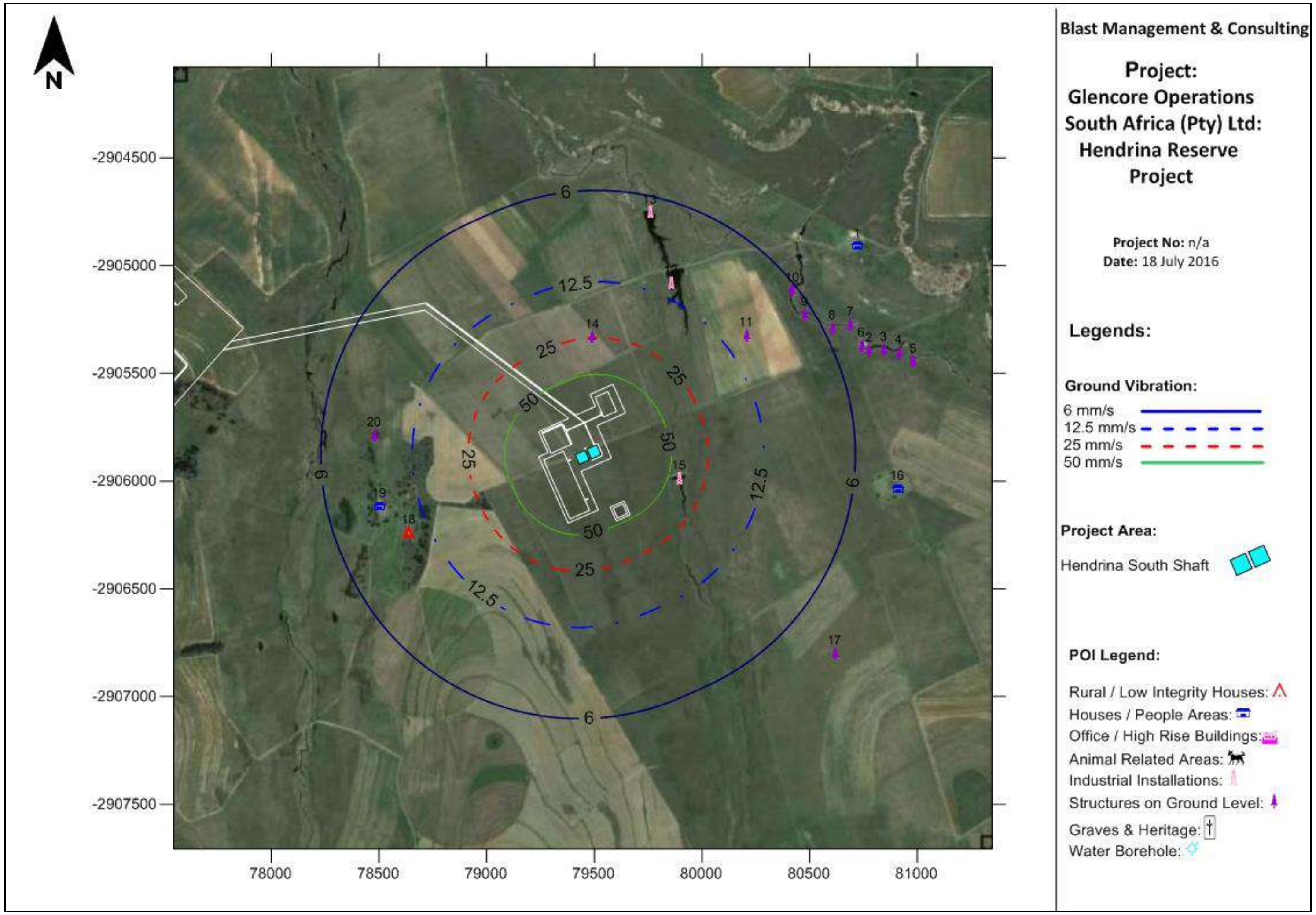

Figure 16: Ground vibration influence from maximum charge for Hendrina South (Shaft No. 2)

Table 12: Ground vibration evaluation for maximum charge for Hendrina South (Shaft No. 2)

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Farm Buildings/Structures	25	1524	3.9	Acceptable	Perceptible
2	Klein-Olifants River	150	1337	4.9	Acceptable	N/A
3	Klein-Olifants River	150	1402	4.5	Acceptable	N/A
4	Klein-Olifants River	150	1464	4.2	Acceptable	N/A
5	Klein-Olifants River	150	1515	4.0	Acceptable	N/A
6	Klein-Olifants River	150	1312	5.0	Acceptable	N/A
7	Klein-Olifants River	150	1305	5.1	Acceptable	N/A
8	Klein-Olifants River	150	1223	5.7	Acceptable	N/A
9	Klein-Olifants River	150	1141	6.3	Acceptable	N/A
10	Klein-Olifants River	150	1158	6.2	Acceptable	N/A
11	Cultivated Fields	150	863	10.1	Acceptable	N/A
12	Dam	50	828	10.8	Acceptable	N/A
13	Dam	50	1107	6.7	Acceptable	N/A
14	Cultivated Fields	150	501	24.7	Acceptable	N/A
15	Dam	50	380	38.9	Acceptable	N/A
16	Buildings/Structures	25	1387	4.6	Acceptable	Perceptible
17	Cultivated Fields	150	1424	4.4	Acceptable	N/A
18	Informal Housing	6	852	10.3	Problematic	Unpleasant
19	Farm Buildings/Structures	25	939	8.8	Acceptable	Unpleasant
20	Pan	150	936	8.8	Acceptable	N/A

- **Minimum charge mass per delay 291 kg – Mooivley East (Shaft No. 3)**

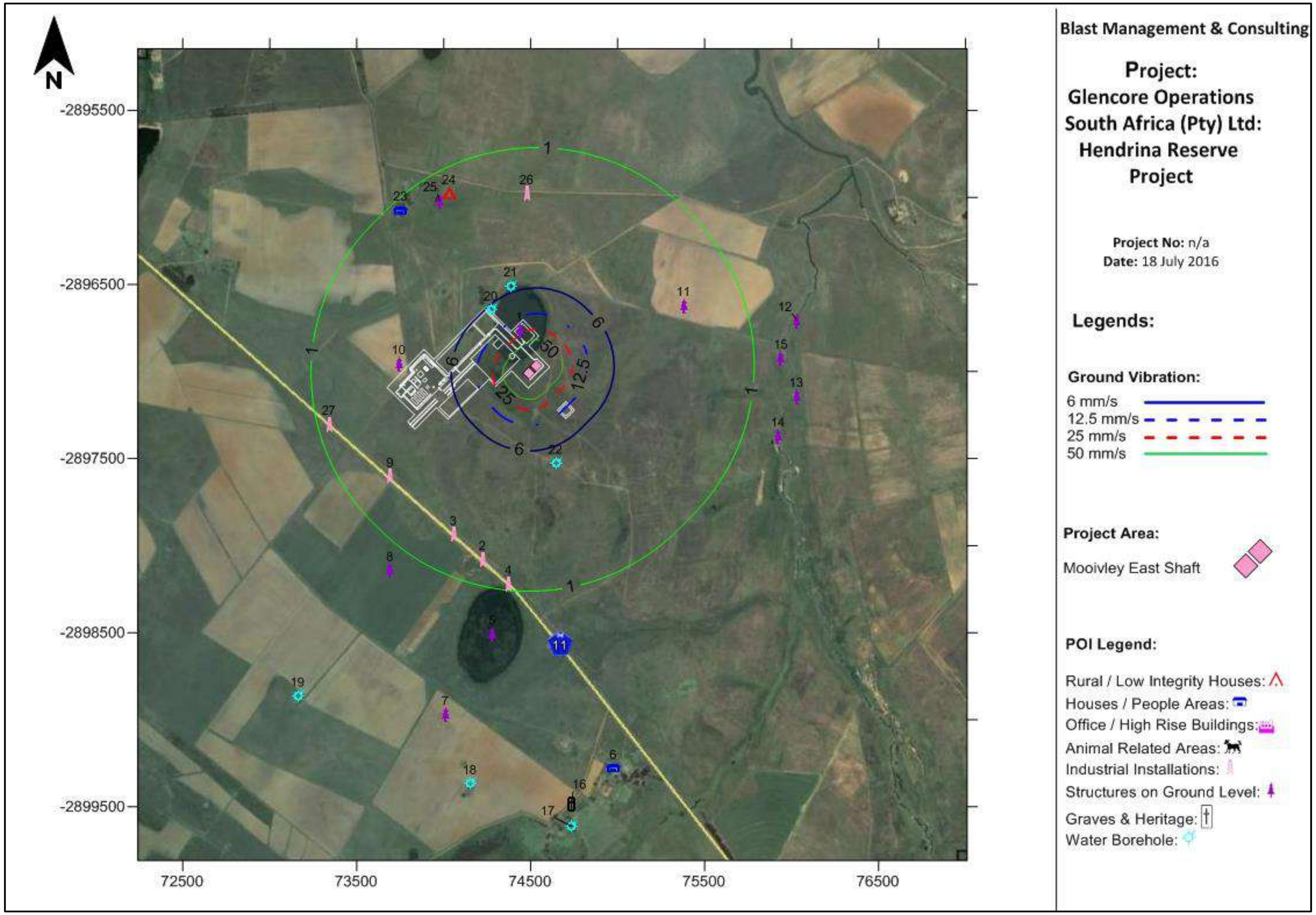

Figure 17: Ground vibration influence from minimum charge for Mooivley East (Shaft No. 3)

Table 13: Ground vibration evaluation for minimum charge for Mooivley East (Shaft No. 3)

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Pan	150	192	21.1	Acceptable	N/A
2	N11 Road	150	1069	1.2	Acceptable	N/A
3	N11 Road	150	991	1.4	Acceptable	N/A
4	N11 Road	150	1182	1.0	Acceptable	N/A
5	Pan	150	1479	0.7	Acceptable	N/A
6	Farm Buildings/Structures	25	2289	0.4	Acceptable	Too Low
7	Cultivated Fields	150	1986	0.4	Acceptable	N/A
8	Cultivated Fields	150	1356	0.8	Acceptable	N/A
9	N11 Road	150	966	1.5	Acceptable	N/A
10	Cultivated Fields	150	714	2.4	Acceptable	N/A
11	Cultivated Fields	150	883	1.7	Acceptable	N/A
12	Klein-Olifants River	150	1484	0.7	Acceptable	N/A
13	Klein-Olifants River	150	1473	0.7	Acceptable	N/A
14	Klein-Olifants River	150	1416	0.8	Acceptable	N/A
15	Klein-Olifants River	150	1373	0.8	Acceptable	N/A
16	Burial Ground with graves (BGG-002)	50	2450	0.3	Acceptable	N/A
17	Hydrocencus Borehole(ORJBH1)	50	2577	0.3	Acceptable	N/A
18	Hydrocencus Borehole(ORJBH2)	50	2348	0.3	Acceptable	N/A
19	Hydrocencus Borehole(ORJBH3)	50	2253	0.4	Acceptable	N/A
20	Hydrocencus Borehole(VLBSP8)	50	385	6.7	Acceptable	N/A
21	Hydrocencus Borehole(VLBSP7)	50	446	5.2	Acceptable	N/A
22	DW drilled borehole(OVBH2)	50	508	4.2	Acceptable	N/A
23	Farm Buildings/Structures	25	1158	1.1	Acceptable	Perceptible
24	Informal Housing	6	1076	1.2	Acceptable	Perceptible
25	Pan	150	1068	1.2	Acceptable	N/A
26	Road	150	954	1.5	Acceptable	N/A
27	N11 Road	150	1151	1.1	Acceptable	N/A

- **Maximum charge mass per delay 2402 kg – Mooivley East (Shaft No. 3)**

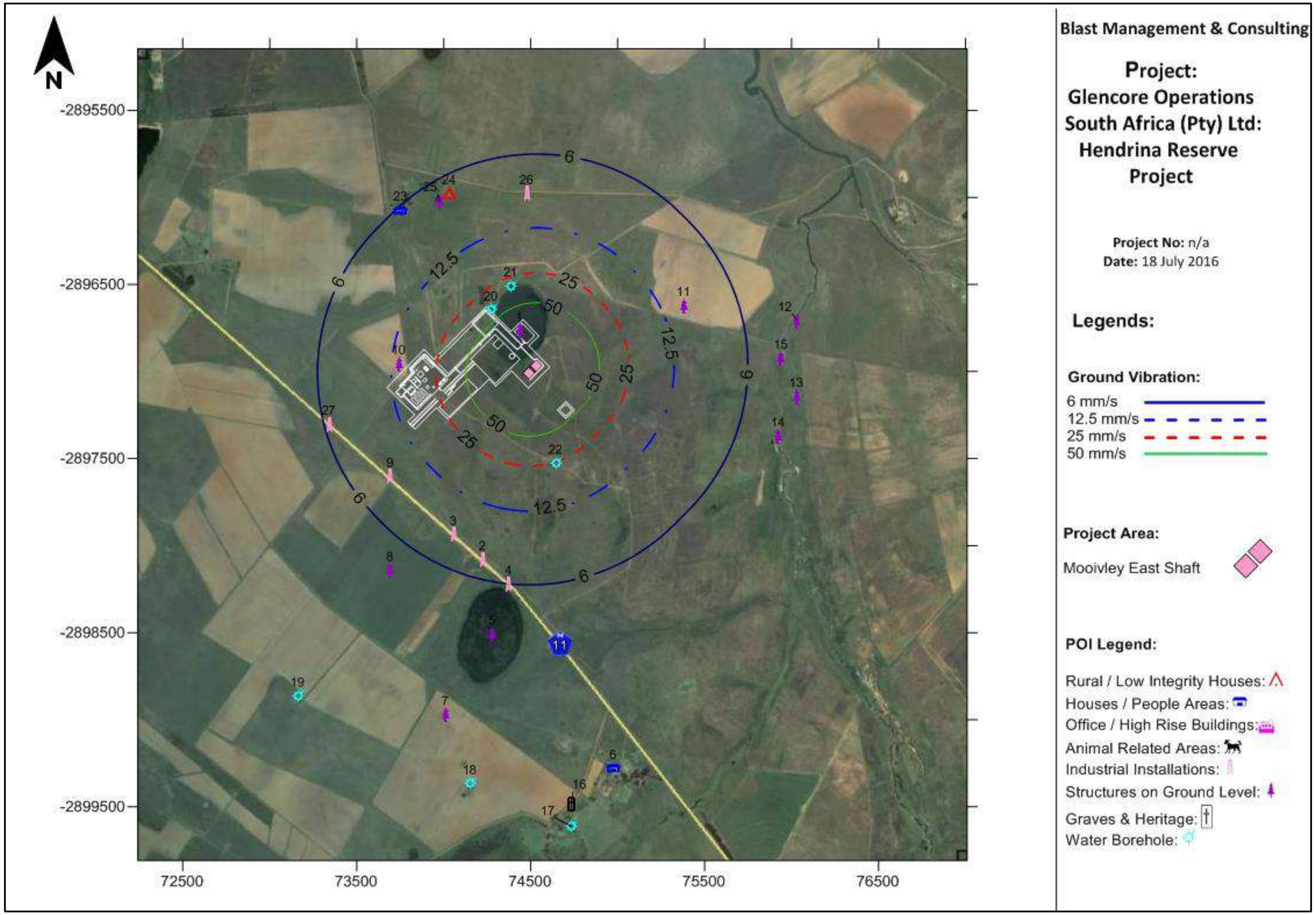

Figure 18: Ground vibration influence from maximum charge for Mooivley East (Shaft No. 3)

Table 14: Ground vibration evaluation for maximum charge for Mooivley East (Shaft No. 3)

Tag	Description	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Pan	150	192	120.6	Acceptable	N/A
2	N11 Road	150	1069	7.1	Acceptable	N/A
3	N11 Road	150	991	8.0	Acceptable	N/A
4	N11 Road	150	1182	6.0	Acceptable	N/A
5	Pan	150	1479	4.1	Acceptable	N/A
6	Farm Buildings/Structures	25	2289	2.0	Acceptable	Perceptible
7	Cultivated Fields	150	1986	2.5	Acceptable	N/A
8	Cultivated Fields	150	1356	4.8	Acceptable	N/A
9	N11 Road	150	966	8.4	Acceptable	N/A
10	Cultivated Fields	150	714	13.8	Acceptable	N/A
11	Cultivated Fields	150	883	9.7	Acceptable	N/A
12	Klein-Olifants River	150	1484	4.1	Acceptable	N/A
13	Klein-Olifants River	150	1473	4.2	Acceptable	N/A
14	Klein-Olifants River	150	1416	4.4	Acceptable	N/A
15	Klein-Olifants River	150	1373	4.7	Acceptable	N/A
16	Burial Ground with graves (BGG-002)	50	2450	1.8	Acceptable	N/A
17	Hydrocencus Borehole(ORJBH1)	50	2577	1.7	Acceptable	N/A
18	Hydrocencus Borehole(ORJBH2)	50	2348	1.9	Acceptable	N/A
19	Hydrocencus Borehole(ORJBH3)	50	2253	2.1	Acceptable	N/A
20	Hydrocencus Borehole(VLBSP8)	50	385	38.1	Acceptable	N/A
21	Hydrocencus Borehole(VLBSP7)	50	446	29.9	Acceptable	N/A
22	DW drilled borehole(OVBH2)	50	508	24.1	Acceptable	N/A
23	Farm Buildings/Structures	25	1158	6.2	Acceptable	Unpleasant
24	Informal Housing	6	1076	7.0	Problematic	Unpleasant
25	Pan	150	1068	7.1	Acceptable	N/A
26	Road	150	954	8.5	Acceptable	N/A
27	N11 Road	150	1151	6.3	Acceptable	N/A

14.2 Summary of Ground Vibration Levels

The shaft areas were evaluated for expected levels of ground vibration from future blasting operations. Review of the sites and the surrounding installations / houses / buildings showed that structures vary in distances from the three Shaft areas. The influences will also vary with distance from the specific area. The evaluation considered a distance up to 1500 m from the mining area.

The closest structures to Mooivley West (Shaft No. 1) are the Heritage Farm Buildings and Informal Housing. The planned maximum charge evaluated showed that it could be problematic in terms of potential structural damage and human perception. Cultivated Fields at POI 8 at 149 m is very close to the Shaft area.

Problematic structures identified at Hendrina South (Shaft No. 2) are only the Informal Housing at POI 18 at 852 m. Damages at these buildings are possible and humans could experience the levels of ground vibration as intolerable. The levels predicted at the Informal Housing at POI 18 and the Farm Buildings/Structures at POI 19 do show low levels of ground vibration that could be experienced as unpleasant at the maximum charge on the human perception scale.

Problematic structures identified at Mooivley East (Shaft No. 3) are the Informal Housing at POI 24 1076 m from the blasting operations. Ground vibration levels predicted are greater than allowed limit for the maximum charge and it could be problematic in terms of potential structural damage and human perception.

The distances between the structures and the 3 Shafts is the main contributing factor to the levels of ground vibration expected and the subsequent possible influences at POIs of concern. It is observed that for the different charge masses evaluated that levels of ground vibration will change as well. In view of the maximum charge specific attention will need to be given to specific areas where POIs of concern have been identified.

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

In view of the above it is believed that specific mitigations will be required near POIs that have been identified as possible concerns such as possible relocation of relevant households.

14.3 Ground Vibration and Human Perception

Considering the effect of ground vibration with regards to human perception, vibration levels calculated were applied to an average of 30Hz frequency and plotted with expected human perceptions on the safe blasting criteria graph (see Figure 19 below). Data applicable to human response only is plotted. The frequency range selected is the expected average range for frequencies that will be measured for ground vibration when blasting is done. From Figure 19 it can be seen that the ground vibration levels predicted is expected to be greater than the perceptible level but mostly less than the unpleasant level. People at the nearest farmhouse may experience ground vibration levels as unpleasant. These levels are only the levels that area associated with POI's where people may live or congregate.

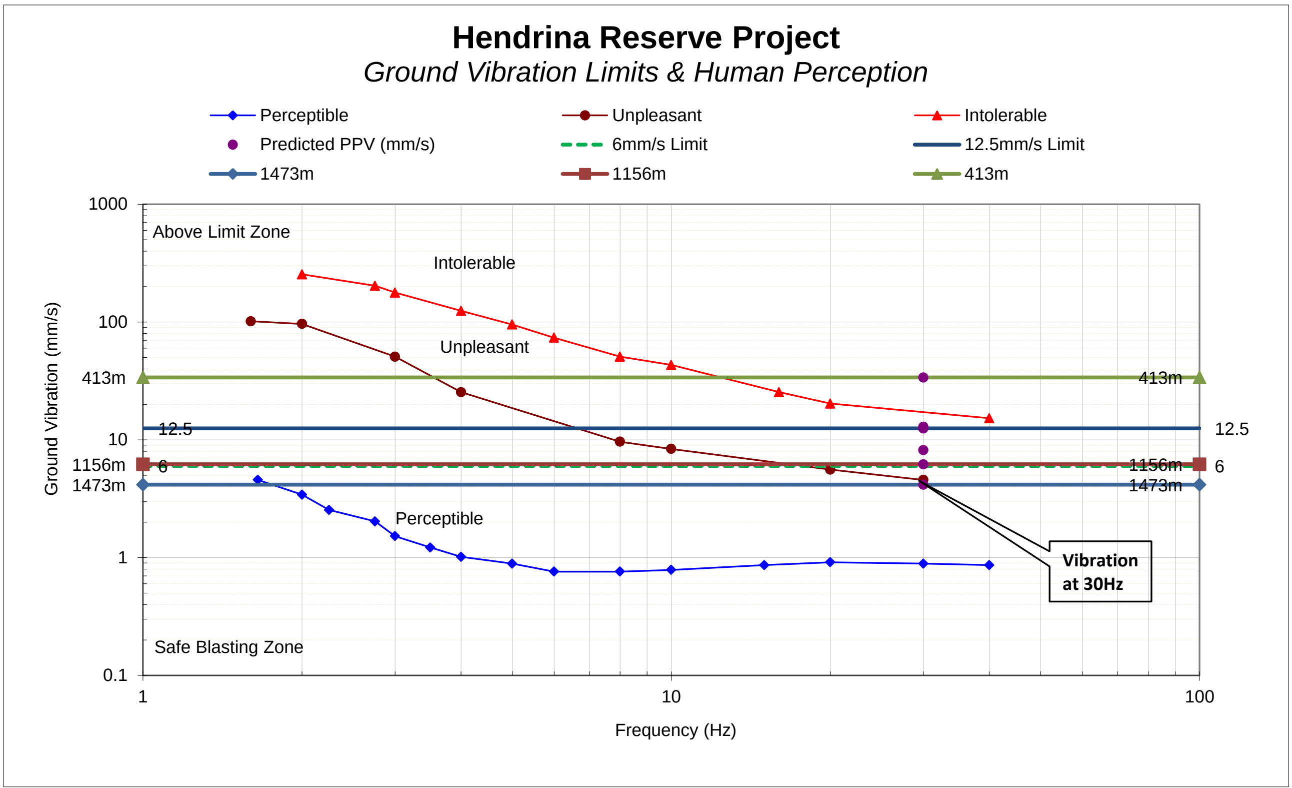

Figure 19: The effect of ground vibration with human perception and vibration limits

14.4 Vibration Impact on Roads

Two roads will be utilised to access the mining areas which include the N11 and Davel Road (Farm Road). The Davel Road branches off in a southern direction from the N11 driving from Hendrina. The Davel Road is located 760 m from the Shaft area and will be utilised to access Mooivley West and Hendrina South. Mooivley East will be accessed from the N11 which is 991 m from the Shaft area. The expected levels of ground vibration are well within the limits for these roads. No specific actions are required for these roads.

14.5 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 at Shaft 1 is Informal housing approximately 392 m, at Shaft No. 2, Informal Housing at 852 m and Shaft No. 3, Informal Housing at 1076 m from the planned operations. These settlements are located such that levels of ground vibration predicted may be perceptible and unpleasant and may be damaging.

People tend to react negatively on experiencing effects from blasting such as ground vibration and air blast. Proper and appropriate communication with neighbours about blasting, monitoring and actions done for proper control will be required.

14.6 Review of Expected Air Blast

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

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

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

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

- **Minimum charge per delay 291 kg – Mooivley West (Shaft No. 1)**

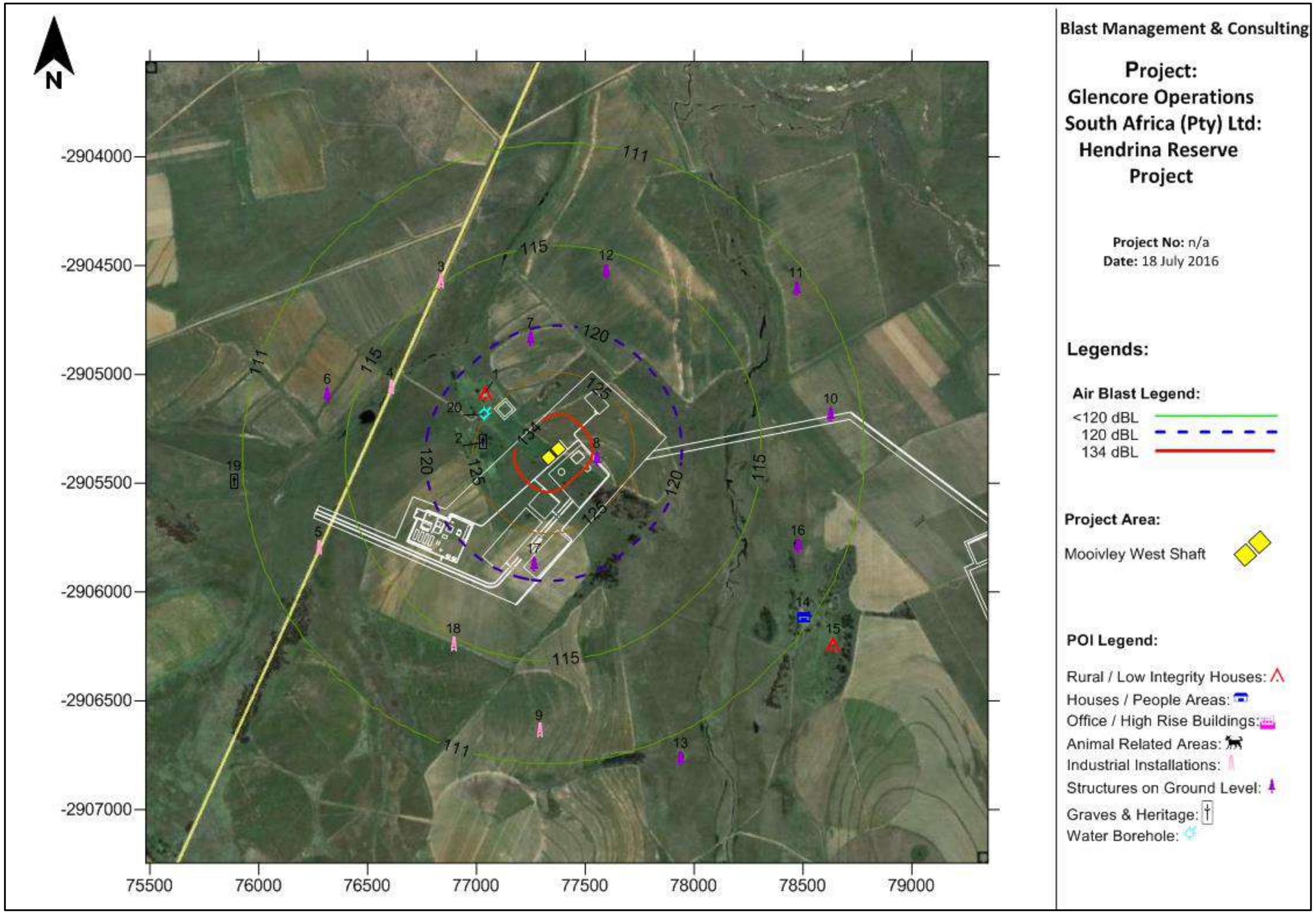

Figure 20: Air blast influence from minimum charge for Mooivley West (Shaft No. 1)

Table 15: Air blast evaluation for minimum charge for Mooivley West (Shaft No. 1)

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Informal Housing	392	122.9	Complaint
2	Heritage - Farm Buildings/Structures	272	126.4	N/A
3	Davel Road	908	114.9	N/A
4	Davel Road	760	116.6	N/A
5	Davel Road	1100	113.1	N/A
6	Cultivated Fields	1021	113.8	N/A
7	Cultivated Fields	490	120.7	N/A
8	Cultivated Fields	149	132.1	N/A
9	Pivot Irrigation	1219	112.1	N/A
10	Cultivated Fields	1229	112.0	N/A
11	Cultivated Fields	1293	111.6	N/A
12	Cultivated Fields	815	115.9	N/A
13	Pan	1477	110.2	N/A
14	Farm Buildings/Structures	1336	111.2	Acceptable
15	Informal Housing	1519	110.0	Acceptable
16	Pan	1156	112.6	N/A
17	Cultivated Fields	457	121.4	N/A
18	Pivot Irrigation	928	114.7	N/A
19	Burial Ground with graves (BGG-001)	1415	110.6	N/A
20	Hydrocencus Borehole(MVLBH5)	329	124.6	N/A

- **Maximum charge per delay 2402 kg – Mooivley West (Shaft No. 1)**

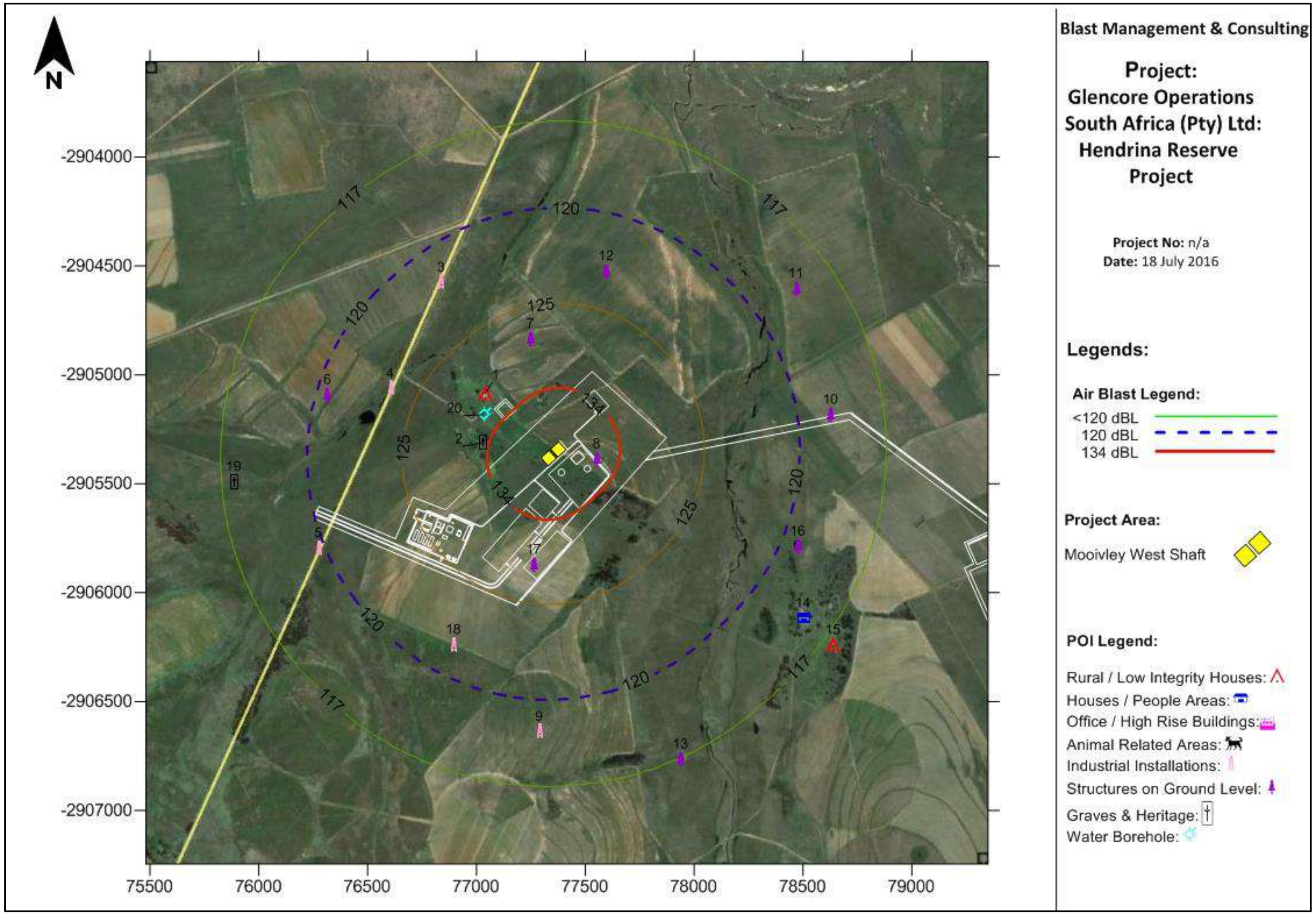

Figure 21: Air blast influence from maximum charge for Mooivley West (Shaft No. 1)

Table 16: Air blast evaluation for maximum charge for Mooivley West (Shaft No. 1)

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Informal Housing	392	129.6	Complaint
2	Heritage - Farm Buildings/Structures	272	133.1	N/A
3	Davel Road	908	121.6	N/A
4	Davel Road	760	123.3	N/A
5	Davel Road	1100	119.8	N/A
6	Cultivated Fields	1021	120.5	N/A
7	Cultivated Fields	490	127.5	N/A
8	Cultivated Fields	149	138.9	N/A
9	Pivot Irrigation	1219	118.8	N/A
10	Cultivated Fields	1229	118.7	N/A
11	Cultivated Fields	1293	118.2	N/A
12	Cultivated Fields	815	122.6	N/A
13	Pan	1477	117.0	N/A
14	Farm Buildings/Structures	1336	117.9	Acceptable
15	Informal Housing	1519	116.7	Acceptable
16	Pan	1156	119.3	N/A
17	Cultivated Fields	457	128.1	N/A
18	Pivot Irrigation	928	121.4	N/A
19	Burial Ground with graves (BGG-001)	1415	117.4	N/A
20	Hydrocencus Borehole(MVLBH5)	329	131.3	N/A

- **Minimum charge per delay 291 kg – Hendrina South (Shaft No. 2)**

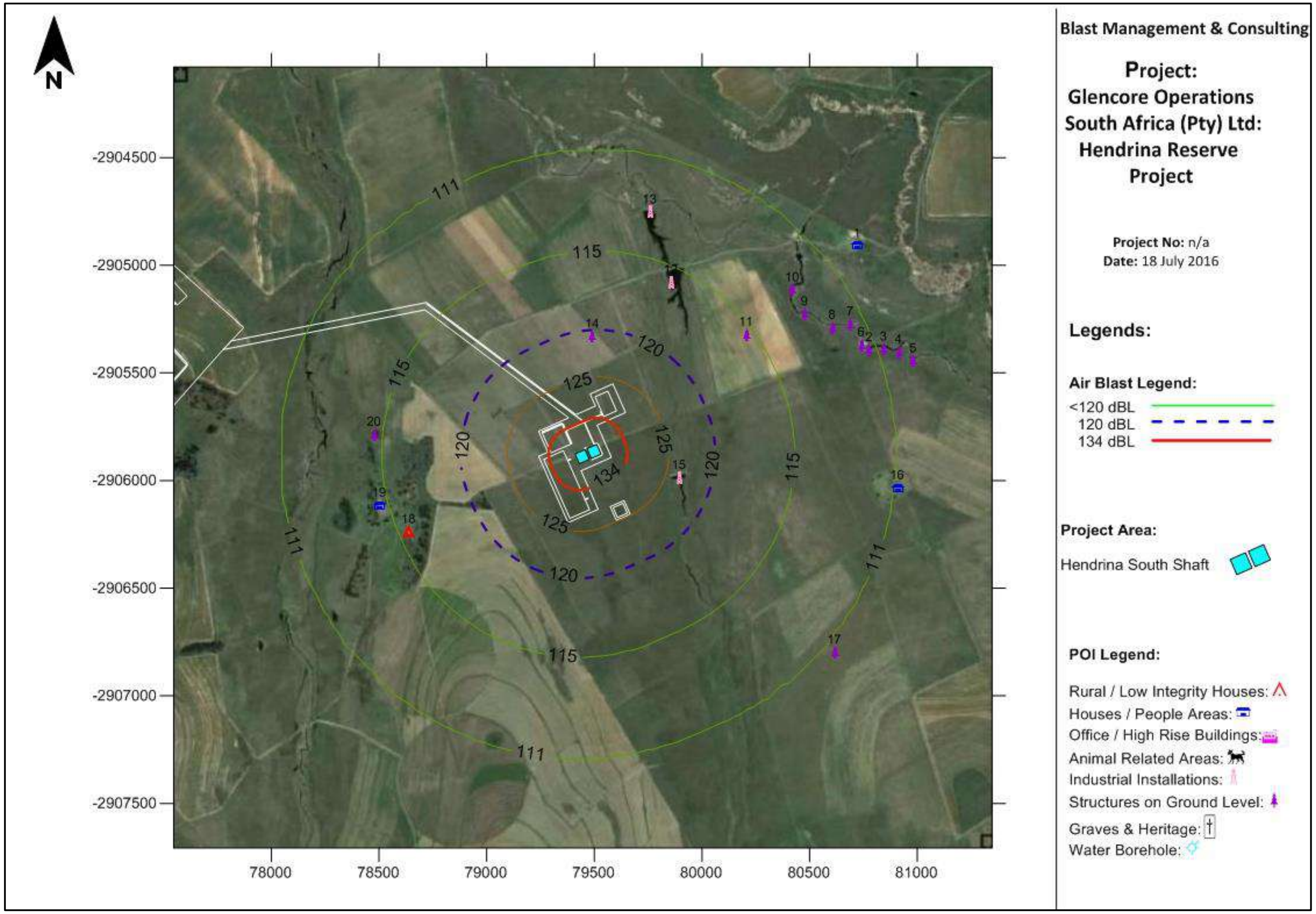

Figure 22: Air blast influence from minimum charge for Hendrina South (Shaft No. 2)

Table 17: Air blast evaluation for minimum charge for Hendrina South (Shaft No. 2)

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Farm Buildings/Structures	1524	110.0	Acceptable
2	Klein-Olifants River	1337	111.2	N/A
3	Klein-Olifants River	1402	110.8	N/A
4	Klein-Olifants River	1464	110.4	N/A
5	Klein-Olifants River	1515	110.1	N/A
6	Klein-Olifants River	1312	111.4	N/A
7	Klein-Olifants River	1305	111.5	N/A
8	Klein-Olifants River	1223	112.0	N/A
9	Klein-Olifants River	1141	112.8	N/A
10	Klein-Olifants River	1158	112.6	N/A
11	Cultivated Fields	863	115.3	N/A
12	Dam	828	115.8	N/A
13	Dam	1107	113.1	N/A
14	Cultivated Fields	501	120.5	N/A
15	Dam	380	123.2	N/A
16	Buildings/Structures	1387	110.9	Acceptable
17	Cultivated Fields	1424	110.6	N/A
18	Informal Housing	852	115.5	Acceptable
19	Farm Buildings/Structures	939	114.6	Acceptable
20	Pan	936	114.6	N/A

- **Maximum charge per delay 2402 kg – Hendrina South (Shaft No. 2)**

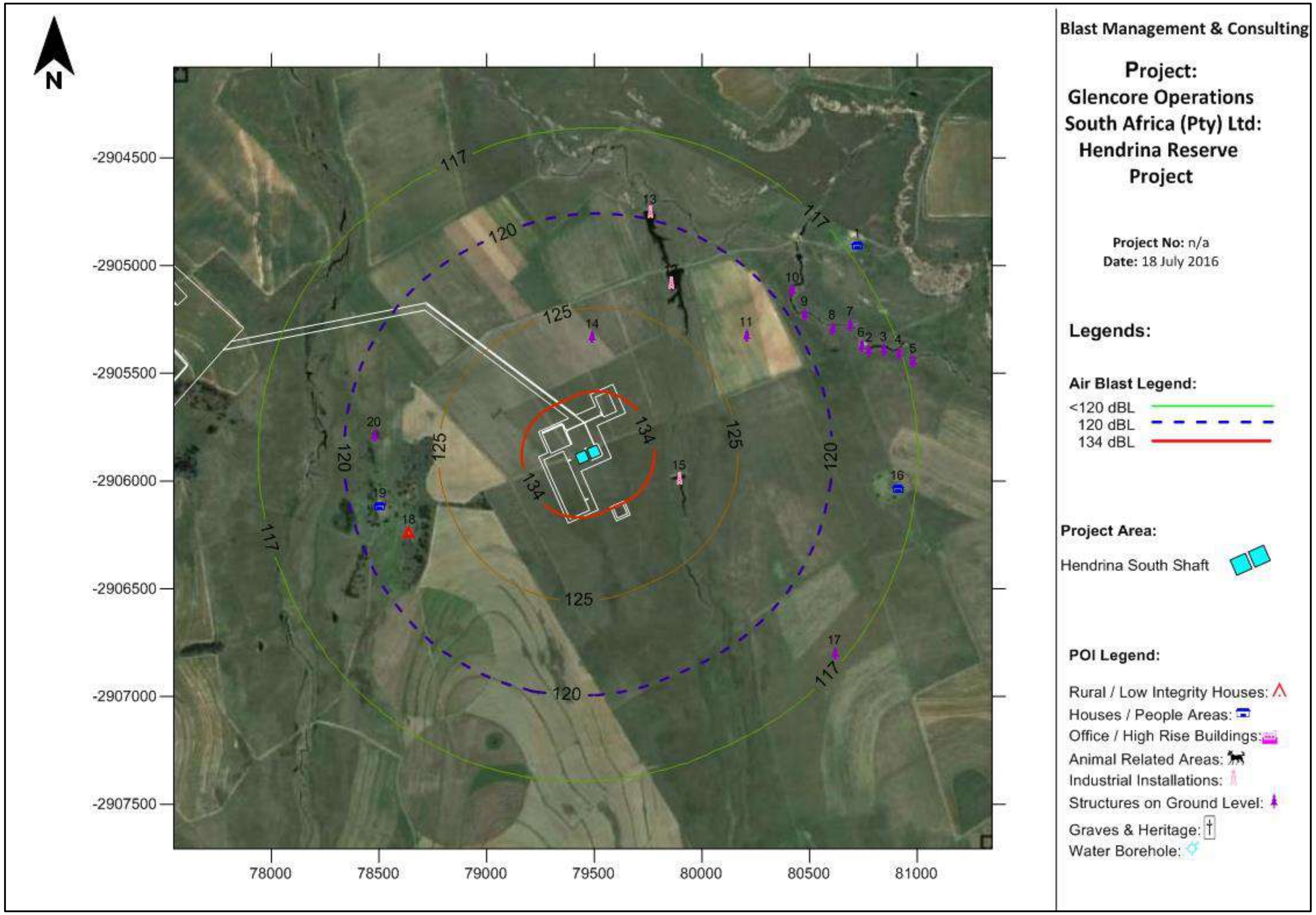

Figure 23: Air blast influence from maximum charge for Hendrina South (Shaft No. 2)

Table 18: Air blast evaluation for maximum charge for Hendrina South (Shaft No. 2)

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Farm Buildings/Structures	1524	116.7	Acceptable
2	Klein-Olifants River	1337	117.9	N/A
3	Klein-Olifants River	1402	117.4	N/A
4	Klein-Olifants River	1464	117.0	N/A
5	Klein-Olifants River	1515	116.7	N/A
6	Klein-Olifants River	1312	118.1	N/A
7	Klein-Olifants River	1305	118.1	N/A
8	Klein-Olifants River	1223	118.7	N/A
9	Klein-Olifants River	1141	119.4	N/A
10	Klein-Olifants River	1158	119.3	N/A
11	Cultivated Fields	863	122.1	N/A
12	Dam	828	122.5	N/A
13	Dam	1107	119.7	N/A
14	Cultivated Fields	501	127.3	N/A
15	Dam	380	129.9	N/A
16	Buildings/Structures	1387	117.6	Acceptable
17	Cultivated Fields	1424	117.3	N/A
18	Informal Housing	852	122.2	Complaint
19	Farm Buildings/Structures	939	121.3	Complaint
20	Pan	936	121.3	N/A

- **Minimum charge per delay 291 kg – Mooivley East (Shaft No. 3)**

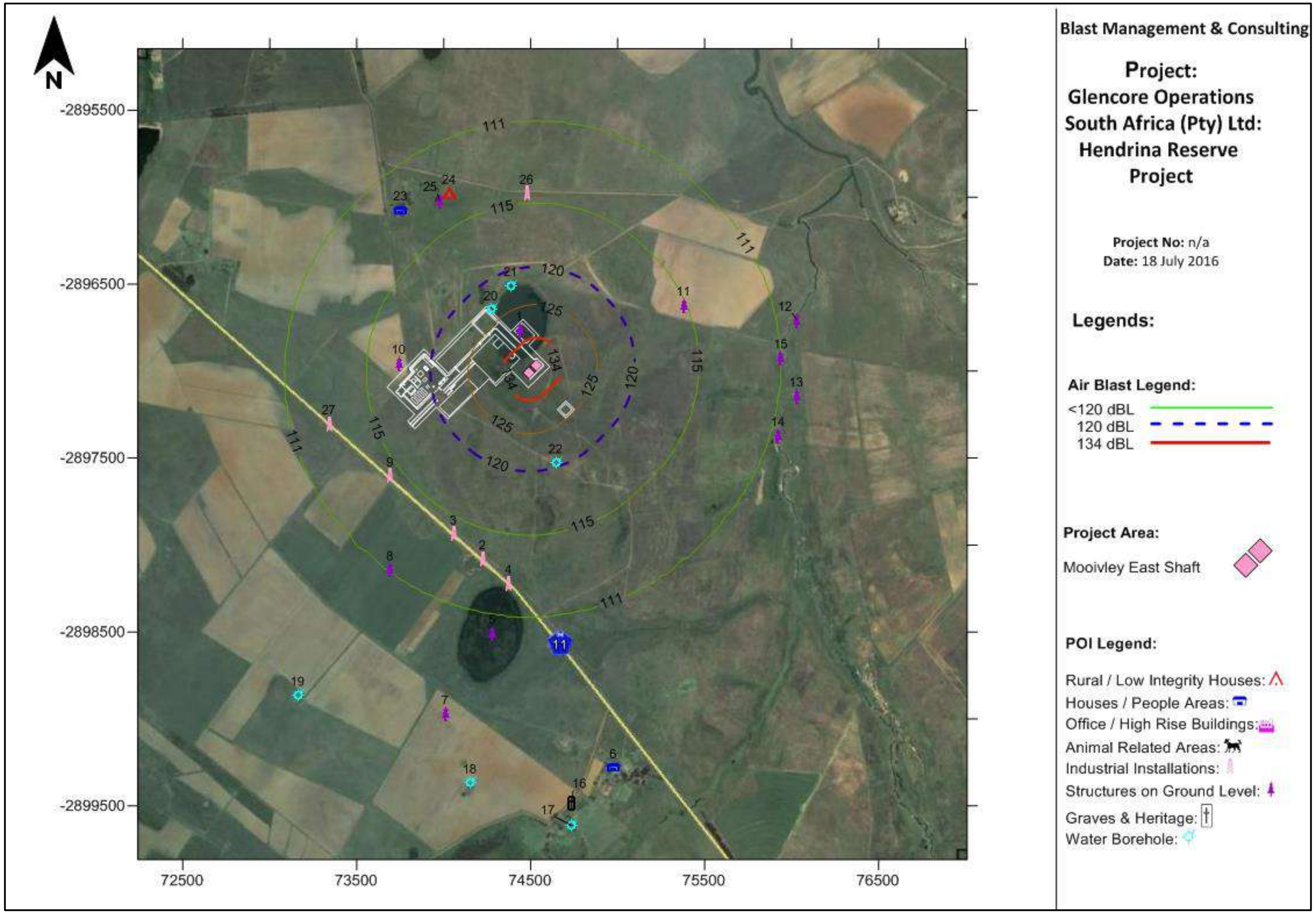

Figure 24: Air blast influence from minimum charge for Mooivley East (Shaft No. 3)

Table 19: Air blast evaluation for minimum charge for Mooivley East (Shaft No. 3)

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Pan	192	129.7	N/A
2	N11 Road	1069	113.3	N/A
3	N11 Road	991	114.1	N/A
4	N11 Road	1182	112.4	N/A
5	Pan	1479	110.2	N/A
6	Farm Buildings/Structures	2289	106.2	Acceptable
7	Cultivated Fields	1986	107.4	N/A
8	Cultivated Fields	1356	111.1	N/A
9	N11 Road	966	114.3	N/A
10	Cultivated Fields	714	117.2	N/A
11	Cultivated Fields	883	115.2	N/A
12	Klein-Olifants River	1484	110.2	N/A
13	Klein-Olifants River	1473	110.2	N/A
14	Klein-Olifants River	1416	110.6	N/A
15	Klein-Olifants River	1373	111.0	N/A
16	Burial Ground with graves (BGG-002)	2450	105.6	N/A
17	Hydrocencus Borehole(ORJBH1)	2577	105.1	N/A
18	Hydrocencus Borehole(ORJBH2)	2348	105.8	N/A
19	Hydrocencus Borehole(ORJBH3)	2253	106.2	N/A
20	Hydrocencus Borehole(VLBSP8)	385	123.1	N/A
21	Hydrocencus Borehole(VLBSP7)	446	121.7	N/A
22	DW drilled borehole(OVBH2)	508	120.4	N/A
23	Farm Buildings/Structures	1158	112.6	Acceptable
24	Informal Housing	1076	113.3	Acceptable
25	Pan	1068	113.3	N/A
26	Road	954	114.4	N/A
27	N11 Road	1151	112.7	N/A

- **Maximum charge per delay 2402 kg – Mooivley East (Shaft No. 3)**

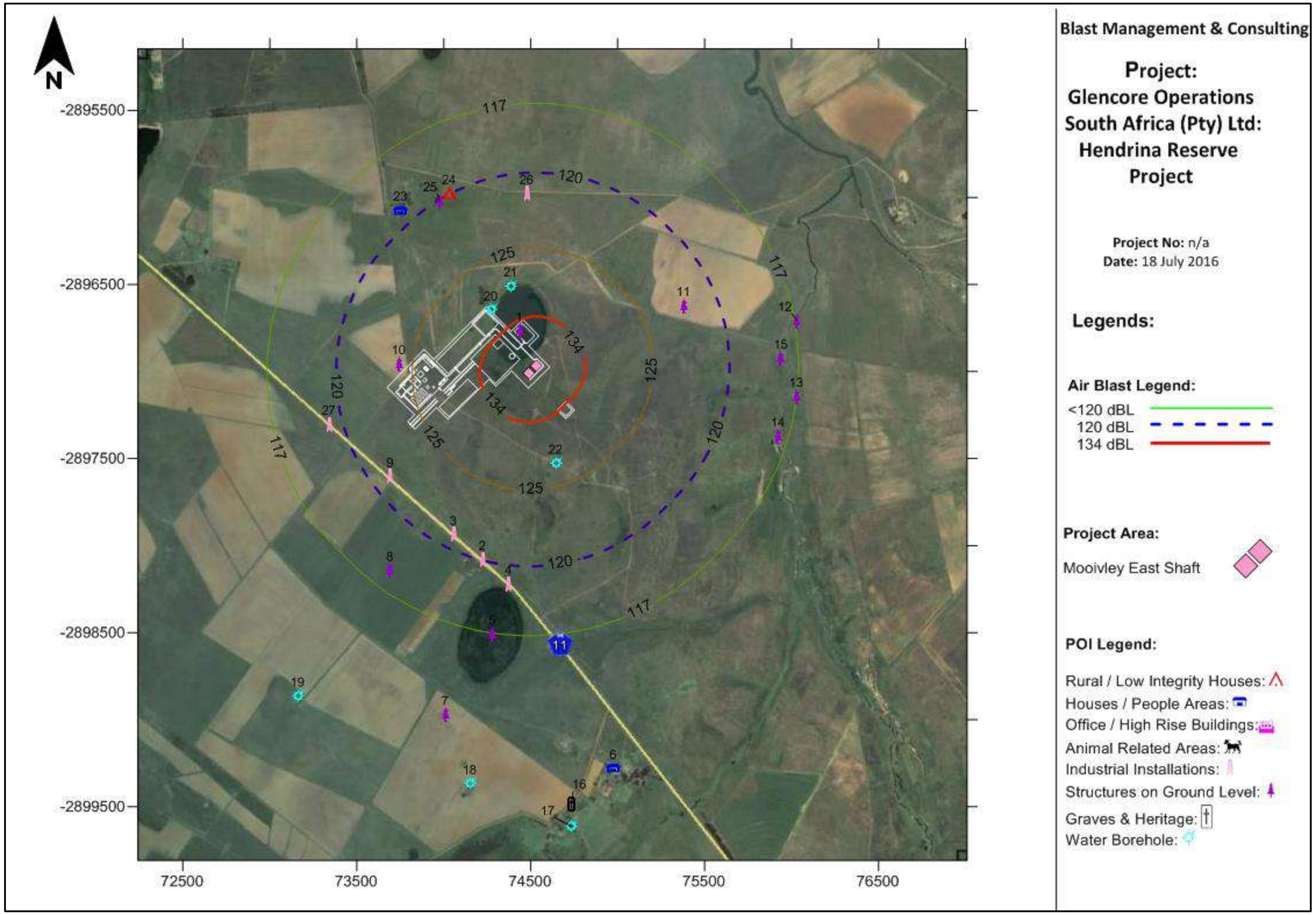

Figure 25: Air blast influence from maximum charge for Mooivley East (Shaft No. 3)

Table 20: Air blast evaluation for maximum charge for Mooivley East (Shaft No. 3)

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Pan	192	136.5	N/A
2	N11 Road	1069	120.0	N/A
3	N11 Road	991	120.7	N/A
4	N11 Road	1182	119.1	N/A
5	Pan	1479	117.0	N/A
6	Farm Buildings/Structures	2289	112.8	Acceptable
7	Cultivated Fields	1986	114.2	N/A
8	Cultivated Fields	1356	117.8	N/A
9	N11 Road	966	121.0	N/A
10	Cultivated Fields	714	123.9	N/A
11	Cultivated Fields	883	121.9	N/A
12	Klein-Olifants River	1484	116.9	N/A
13	Klein-Olifants River	1473	117.0	N/A
14	Klein-Olifants River	1416	117.4	N/A
15	Klein-Olifants River	1373	117.7	N/A
16	Burial Ground with graves (BGG-002)	2450	112.1	N/A
17	Hydrocencus Borehole(ORJBH1)	2577	111.7	N/A
18	Hydrocencus Borehole(ORJBH2)	2348	112.6	N/A
19	Hydrocencus Borehole(ORJBH3)	2253	113.0	N/A
20	Hydrocencus Borehole(VLBSP8)	385	129.8	N/A
21	Hydrocencus Borehole(VLBSP7)	446	128.4	N/A
22	DW drilled borehole(OVBH2)	508	127.1	N/A
23	Farm Buildings/Structures	1158	119.3	Acceptable
24	Informal Housing	1076	120.0	Complaint
25	Pan	1068	120.0	N/A
26	Road	954	121.1	N/A
27	N11 Road	1151	119.3	N/A

14.7 Summary of Findings for Air Blast

Review of the air blast levels indicates a reduced possibility of damage concerns but more complaint concerns than with ground vibration. Air blast predicted for the maximum charge ranges between 116.7 and 129.6 dB for Shaft 1, 116.7 and 122.2 for Shaft No 2 and 112.8 and 120.0 for Shaft No. 3 for all the POI's considered. This includes the nearest points such as the Farm House Buildings and Informal Housing. These levels may contribute to effects such as rattling of roofs or door or windows but are not expected to be damaging. As indicated above, there is a high probability that influence that could lead to complaints. The current accepted limit on air blast is 134 dB. Damages are only expected to occur at levels greater than 134dB. On prediction it is expected that air blast will be greater than 134 dB at a distance of 250 m and closer to the shaft boundary. There are no private structures in this area that are of concern. All private structures are further away. The nearest buildings are 392 m from Shaft 1 and 852 m from Shaft 2 boundary. Infrastructure such as Borehole (OVBH2) and cultivated fields are closer but air blast does not have any influence on these installations.

Complaints from air blast are normally based on the actual effects that are experienced due to rattling of roof, windows, doors etc. These effects could startle people and raise concern of possible damage.

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

14.8 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 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 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 26 shows the results from the ISEE calculations for fly rock range based on a 165 mm diameter blast hole and 4.13 m stemming length. Based on these values a possible fly rock range with a safety factor of 2 was calculated to be 315 m. The absolute minimum unsafe zone is then the 315 m. This calculation is a guideline and any distance cleared should not be less. The occurrence of fly rock can however never be 100 % excluded. Best practices should be implemented at all times. The occurrence of fly rock can be mitigated but the possibility of the occurrence there of can never be eliminated. Figure 27, Figure 28 and Figure 29 shows the areas around the Shafts 1, 2 and 3 declines that incorporates the 315 m unsafe zone.

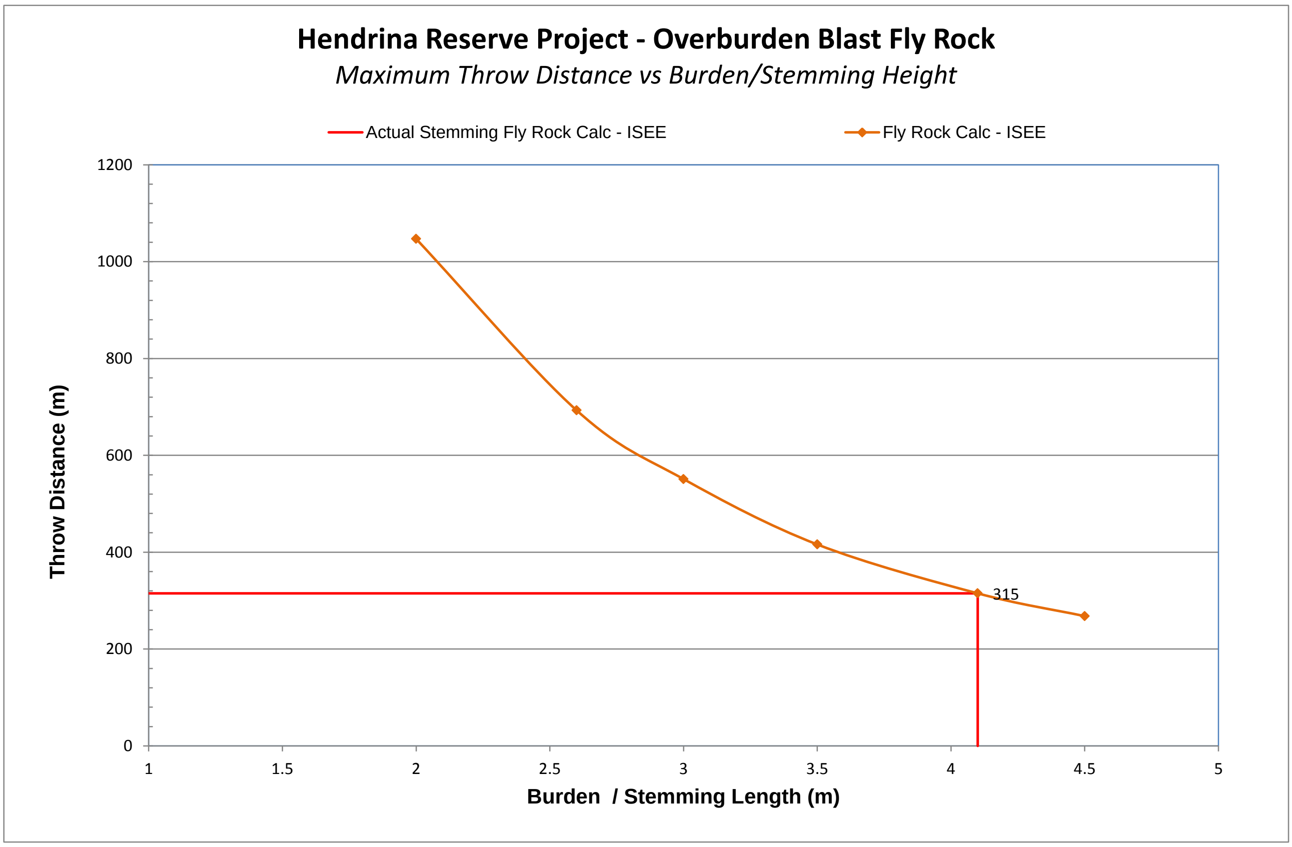

Figure 26: Fly rock prediction calculation

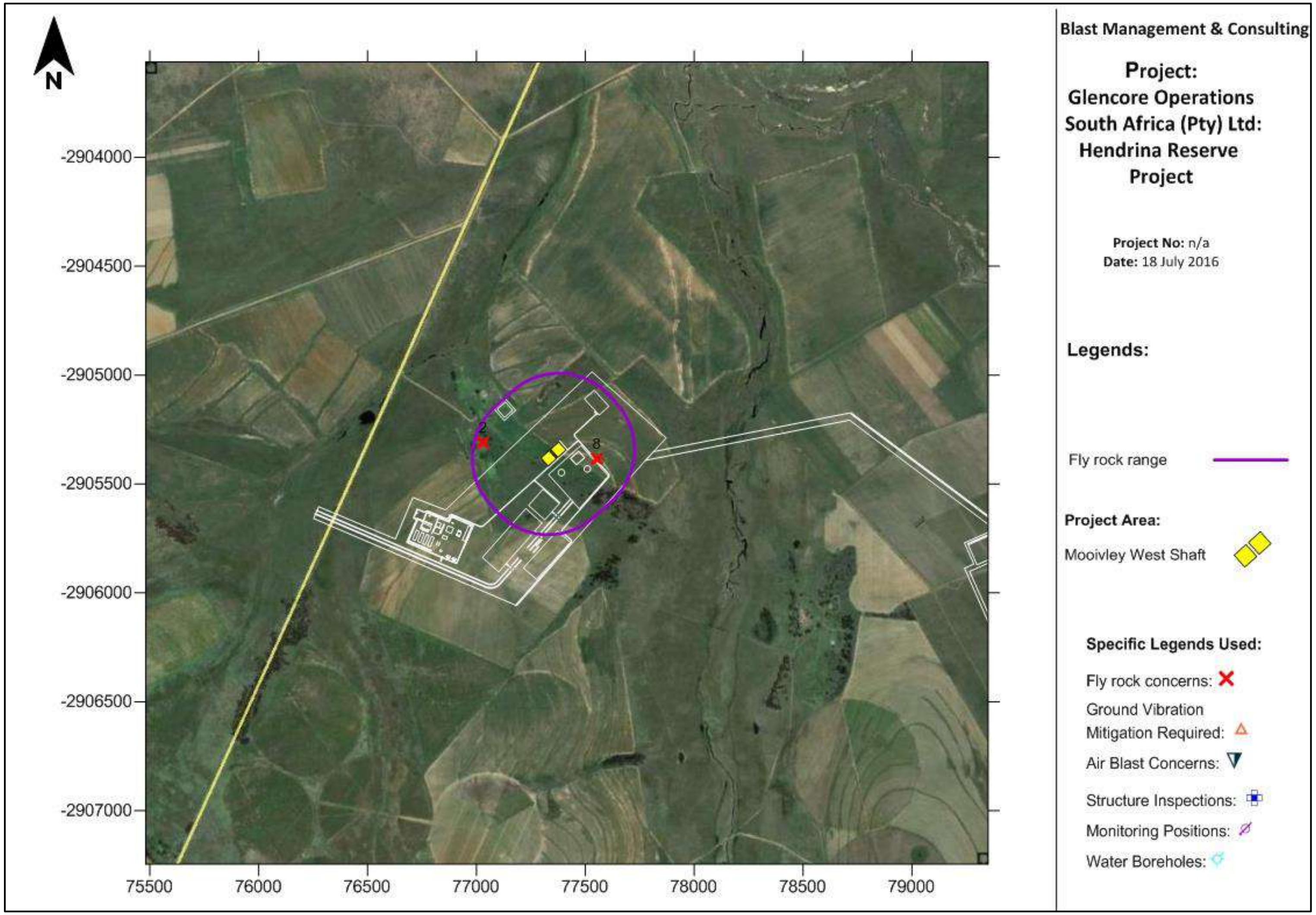

Figure 27: Predicted Fly rock Exclusion Zone for Mooivley West (Shaft No. 1)

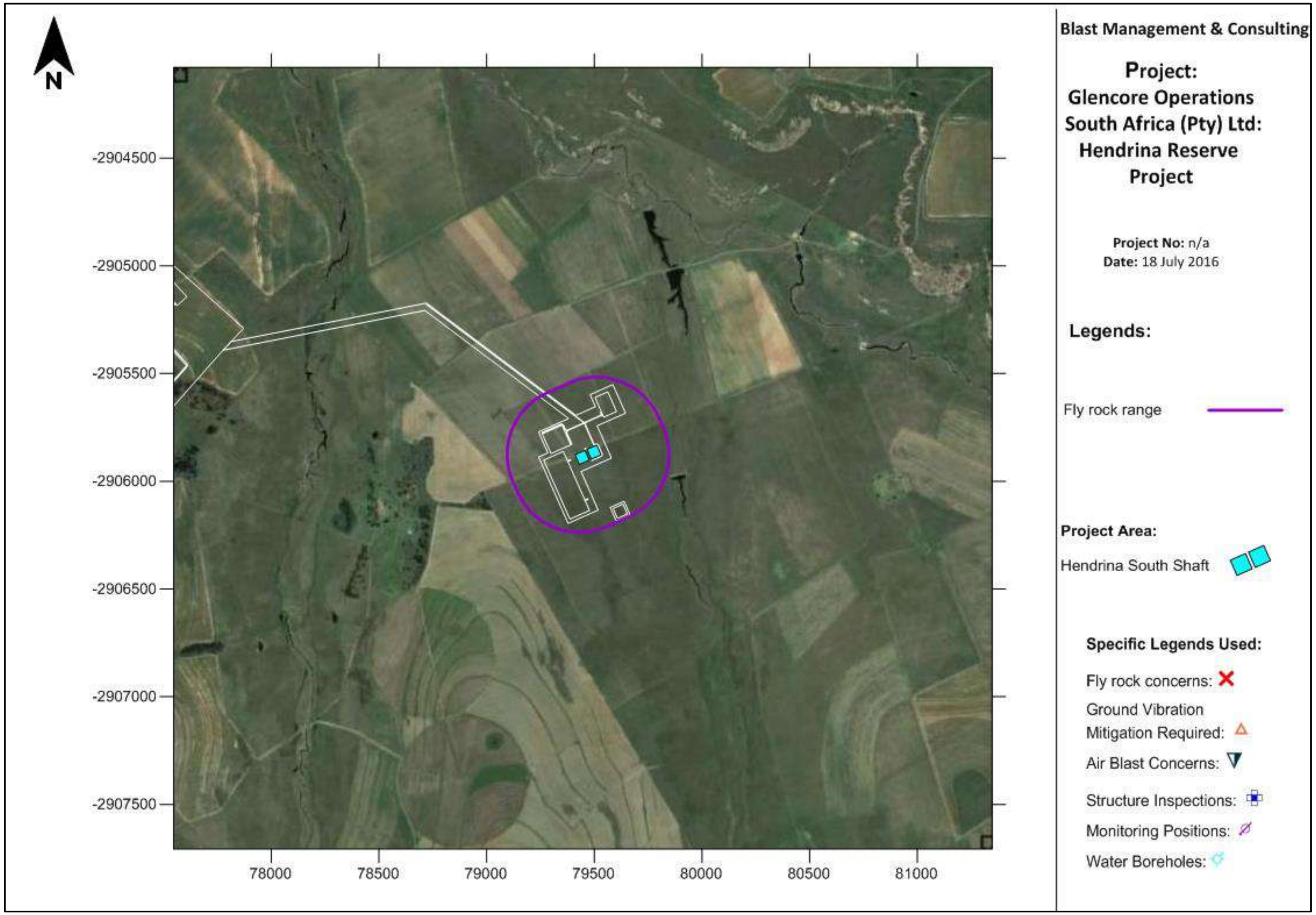

Figure 28: Predicted Fly rock Exclusion Zone for Hendrina South (Shaft No. 2)

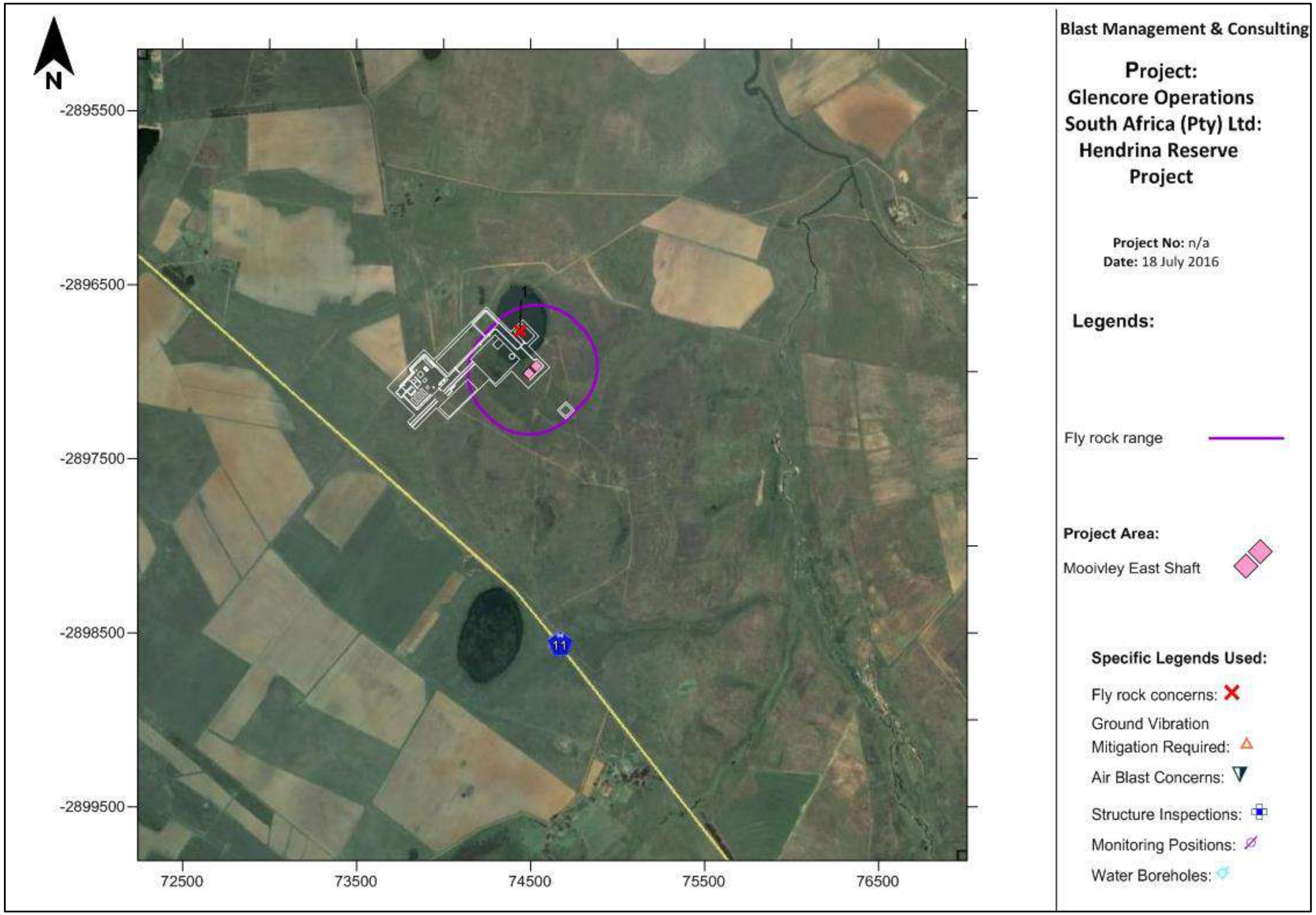

Figure 29: Predicted Fly rock Exclusion Zone for Mooivley East (Shaft No. 3)

Review of the calculated unsafe zone showed two POI's for shaft 1 and one POI for shaft 3 within the unsafe zone. This includes mainly the Heritage - Farm Buildings/Structures, cultivated fields and Pan closest to the shaft areas. Table 21 below shows the POI's of concern and coordinates.

Table 21: Fly rock concern POI's

Tag	Description	Y	X
Shaft 1			
2	Heritage - Farm Buildings/Structures	-77032.78	2905311.24
8	Cultivated Fields	-77554.40	2905384.54
Shaft 3			
1	Pan	-74437.95	2896764.90

Care must be taken during blasting that people should not be present in the cultivated fields.

14.9 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.

14.10 Water Borehole Influence

Boreholes for water were evaluated for possible influence from blasting. Seven boreholes were identified that could possibly be influenced due to excessive ground vibration at minimum and maximum charge. The expected levels of ground vibration for all of the boreholes inside the areas evaluated are well within the limit applied for water boreholes. Based on the maximum charge per delay it is calculated that any boreholes closer than 300 m to the shaft boundary could be problematic. The maximum allowable limit for boreholes will be achieved up to a distance of 300 m. Table 22 shows the identified boreholes. Figure 30 and Figure 31 shows the location of the boreholes in the area.

Table 22: Identified Boreholes

Tag	Description	-Y	-X	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)
Mooivley West (Shaft No. 1)						
20	Hydrocencus Borehole(MVLBH5)	-77033.57	2905182.14	50	329	49.4
Mooivley East (Shaft No. 3)						

Tag	Description	-Y	-X	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)
17	Hydrocencus Borehole(ORJBH1)	-74734.80	2899609.99	50	2577	1.7
18	Hydrocencus Borehole(ORJBH2)	-74152.46	2899367.99	50	2348	1.9
19	Hydrocencus Borehole(ORJBH3)	-73161.75	2898864.31	50	2253	2.1
20	Hydrocencus Borehole(VLBSP8)	-74272.98	2896646.65	50	385	38.1
21	Hydrocencus Borehole(VLBSP7)	-74386.74	2896510.02	50	446	29.9
22	DW drilled borehole(OVBH2)	-74645.82	2897527.76	50	508	24.1

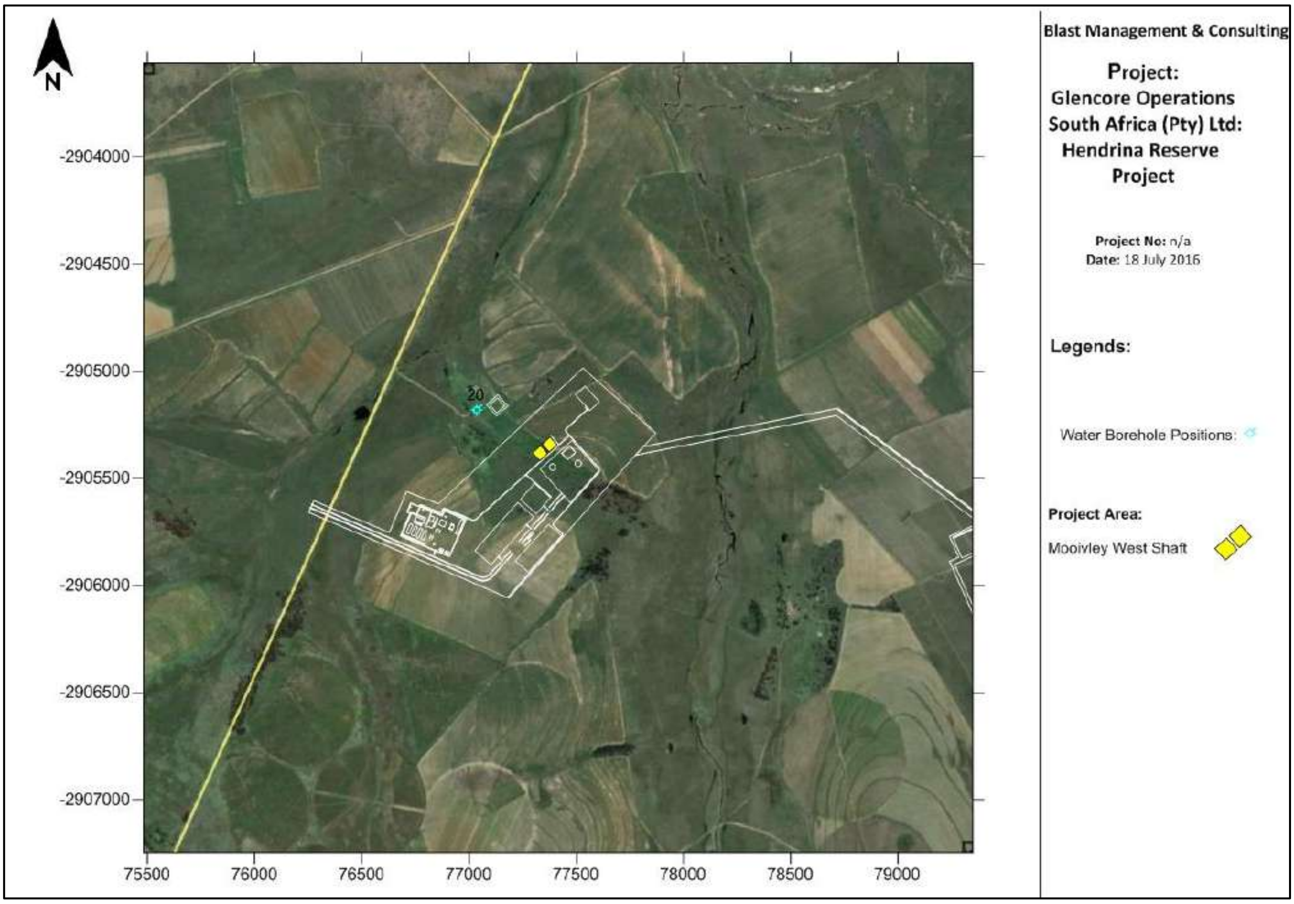

Figure 30: Location of the Borehole at Mooivley West (Shaft No. 1)

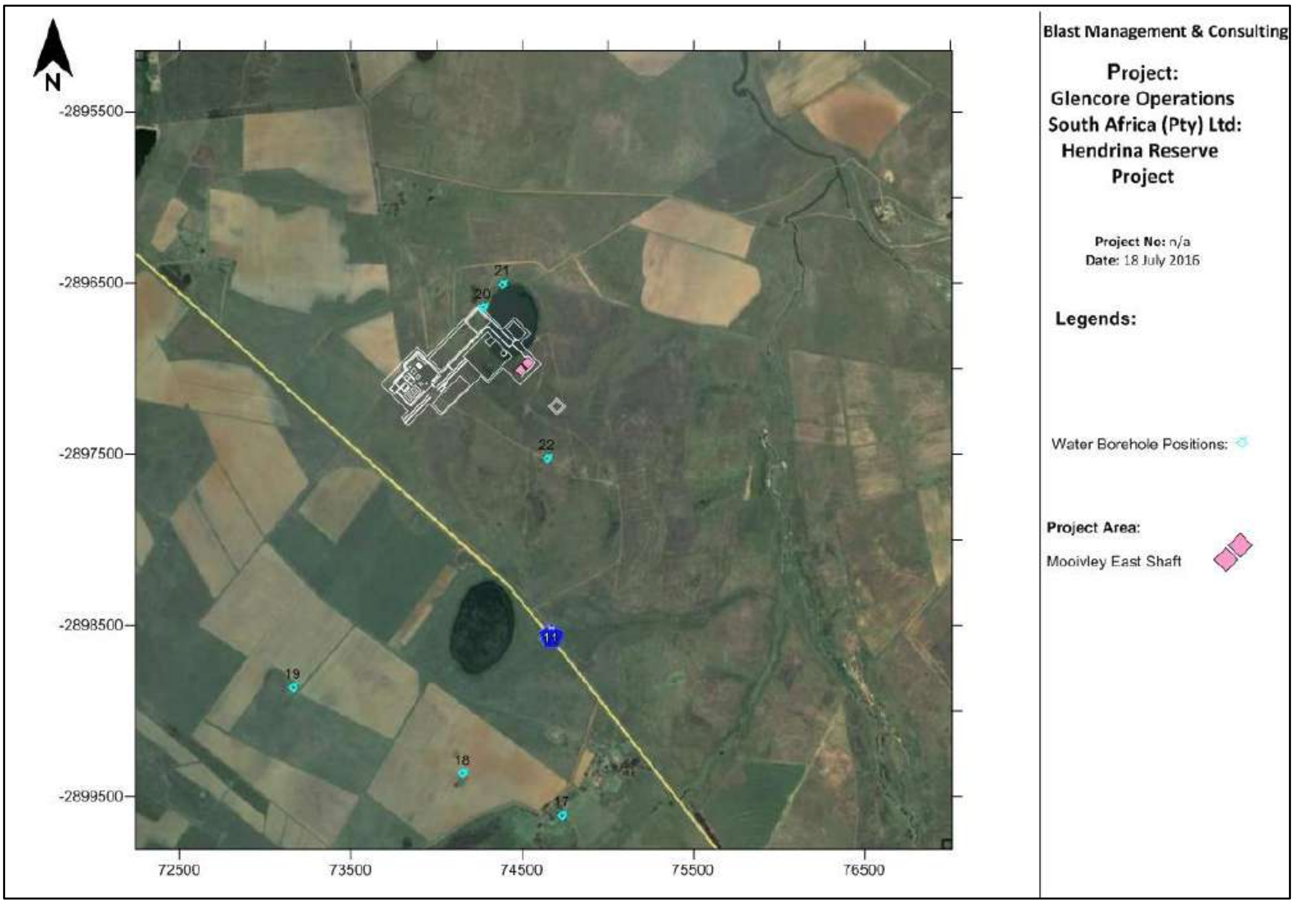

Figure 31: Location of the Borehole at Mooivley East (Shaft No. 3)

14.11 Environmental Impact Assessment

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

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

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 23. 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 24, which is extracted from Table 23. The description of the significance ratings is discussed in Table 25.

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 23: Impact Assessment Parameter Ratings

Rating	Intensity/Replace ability		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 definitely 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.	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.

Rating	Intensity/Replace ability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature=-1)	Positive Impacts (Nature=+1)			
	Irreparable damage to highly valued items.				
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.
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 of low sensitive environments, not	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

Rating	Intensity/Replace ability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature=-1)	**Positive Impacts (Nature=+1)**			
	affecting ecosystem functioning. Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.				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 24: Probability/Consequence Matrix

Significance

Probability																																						
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
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 25: 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) (-)

14.11.1 Assessment

Table 26: Risk Assessment Outcome before mitigation

No.	Impact	Intensity	Extent	Duration	Consequence	Probability	Nature	Significance Before Mitigation	
		Score	Score	Score	Score	Score	Score	Score	Magnitude
Construction Phase									
1	Ground vibration Impact on houses	4	3	1	8	7	-1	-56	Minor (negative) (-)
2	Ground vibration Impact on boreholes	4	3	1	8	7	-1	-56	Minor (negative) (-)
3	Ground vibration Impact on roads	1	3	1	5	1	-1	-5	Negligible (negative) (-)
4	Air blast Impact on houses	4	3	1	8	5	-1	-40	Minor (negative) (-)
5	Air blast Impact on boreholes	1	3	1	5	1	-1	-5	Negligible (negative) (-)
6	Air blast Impact on roads	1	3	1	5	1	-1	-5	Negligible (negative) (-)
7	Fly Rock Impact on houses	4	3	1	8	7	-1	-56	Minor (negative) (-)
8	Fly Rock Impact on boreholes	1	3	1	5	1	-1	-5	Negligible (negative) (-)
9	Fly Rock Impact on roads	4	3	1	8	2	-1	-16	Negligible (negative) (-)
10	Impact of Fumes - Houses	3	3	1	7	3	-1	-21	Negligible (negative) (-)

Table 27: Risk Assessment Outcome after mitigation

No.	Impact	Mitigation Measures	Intensity	Extent	Duration	Consequence	Probability	Nature	Significance after Mitigation	
			Score	Score	Score	Score	Score	Score	Score	Magnitude
Construction Phase										
1	Ground vibration Impact on houses	Reduce Charge Mass/Delay Reconsider blast initiation system - electronics, Relocate POI's of concern at least 500m away Implement a specific blast design	2	3	1	6	4	-1	-24	Negligible (negative) (-)
2	Ground vibration Impact on boreholes	Reduce Charge Mass per delay Relocate borehole Monitor borehole for changes to well and condition Implement a specific blast design	2	3	1	6	4	-1	-24	Negligible (negative) (-)

No.	Impact	Mitigation Measures	Intensity	Extent	Duration	Consequence	Probability	Nature	Significance after Mitigation	
			Score	Score	Score	Score	Score	Score	Score	Magnitude
Construction Phase										
3	Ground vibration Impact on roads	None	1	3	1	5	1	-1	-5	Negligible (negative) (-)
4	Air blast Impact on houses	Reduce Charge Mass/Delay Increase stemming length, controls put in place for management of stemming lengths and quality stemming material Relocate POI's of concern at least 500m away Implement a specific blast design	2	3	1	6	4	-1	-24	Negligible (negative) (-)
5	Air blast Impact on boreholes	None	1	3	1	5	1	-1	-5	Negligible (negative) (-)
6	Air blast Impact on roads	None	1	3	1	5	1	-1	-5	Negligible (negative) (-)
7	Fly Rock Impact on houses	Increase stemming length, use quality stemming material, controls put in place for management of stemming lengths Relocate POI's of concern at least 500m away Implement a specific blast design	2	3	1	6	4	-1	-24	Negligible (negative) (-)
8	Fly Rock Impact on boreholes	None	1	3	1	5	1	-1	-5	Negligible (negative) (-)
9	Fly Rock Impact on roads	Increase stemming length, use quality stemming material, controls put in place for management of stemming lengths Relocate POI's of concern at least 500m away Implement a specific blast design	2	3	1	6	2	-1	-12	Negligible (negative) (-)
10	Impact of Fumes - Houses	Use correct product, control product quality Prevent sleep time for charged blast holes, same day charge and blast Implement a specific blast design	3	3	1	7	3	-1	-21	Negligible (negative) (-)

14.12 Mitigation Measures

In review of the evaluations made in this report it is certain that specific mitigation will be required. There are specific ground vibration concerns on installations close to the shaft areas. There are concerns for the Informal Housing, Heritage Farm Buildings/structures, cultivated fields and boreholes.

Air blast and fly rock can be controlled using proper charging methodology irrespective of the blast hole diameter and patterns used. The only way to mitigate air blast is the design of the stemming length and stemming material. This will require changed blast design to ensure energy levels remain as expected but with increased stemming lengths and the use of proper stemming material. The used of a crushed product with size of 10 % of the blasthole diameter is the recommended material.

Specific impacts are expected at the following POI's identified.
Table 28 shows list of POI's that will need to be considered as defined above. Figure 32, Figure 33 and Figure 34 shows the location of these POI's in relation to the shaft areas.

Table 28: Structures at Shaft 1, Shaft 2 and Shaft 3 Area identified as problematic

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz
Mooivley West (Shaft No. 1)							
1	Informal Housing	-77040.18	2905083.36	6	392	37.0	Problematic
2	Heritage - Farm Buildings/Structures	-77032.78	2905311.24	6	272	67.5	Problematic
8	Cultivated Fields	-77554.40	2905384.54	150	149	183.0	Problematic
Hendrina South (Shaft No. 2)							
18	Informal Housing	-78639.55	2906238.40	6	852	10.3	Problematic
Mooivley East (Shaft No. 3)							
24	Informal Housing	-74033.54	2895978.42	6	1076	7.0	Problematic

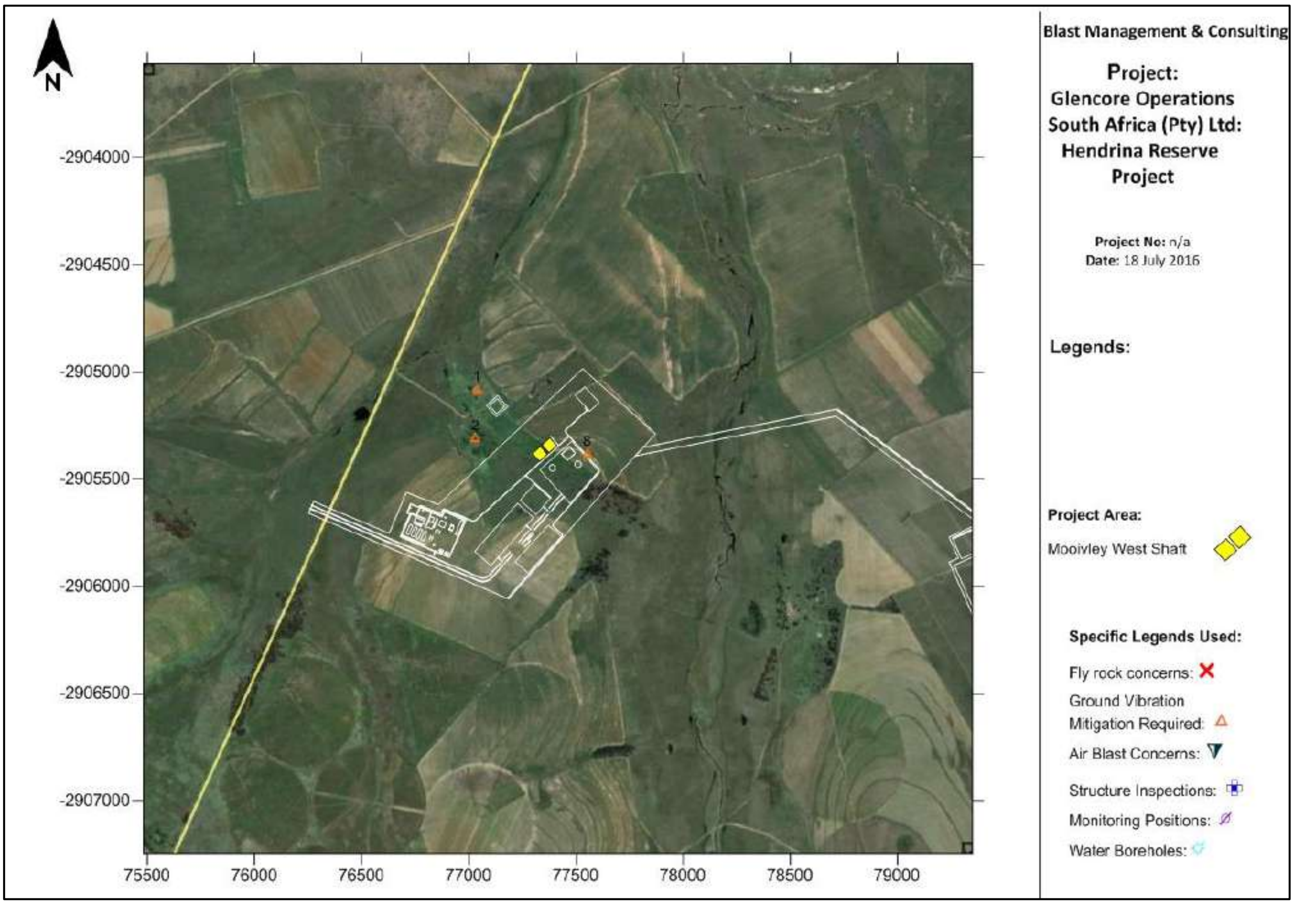

Figure 32: Structures identified where ground vibration mitigation will be required at Mooivley West (Shaft No. 1).

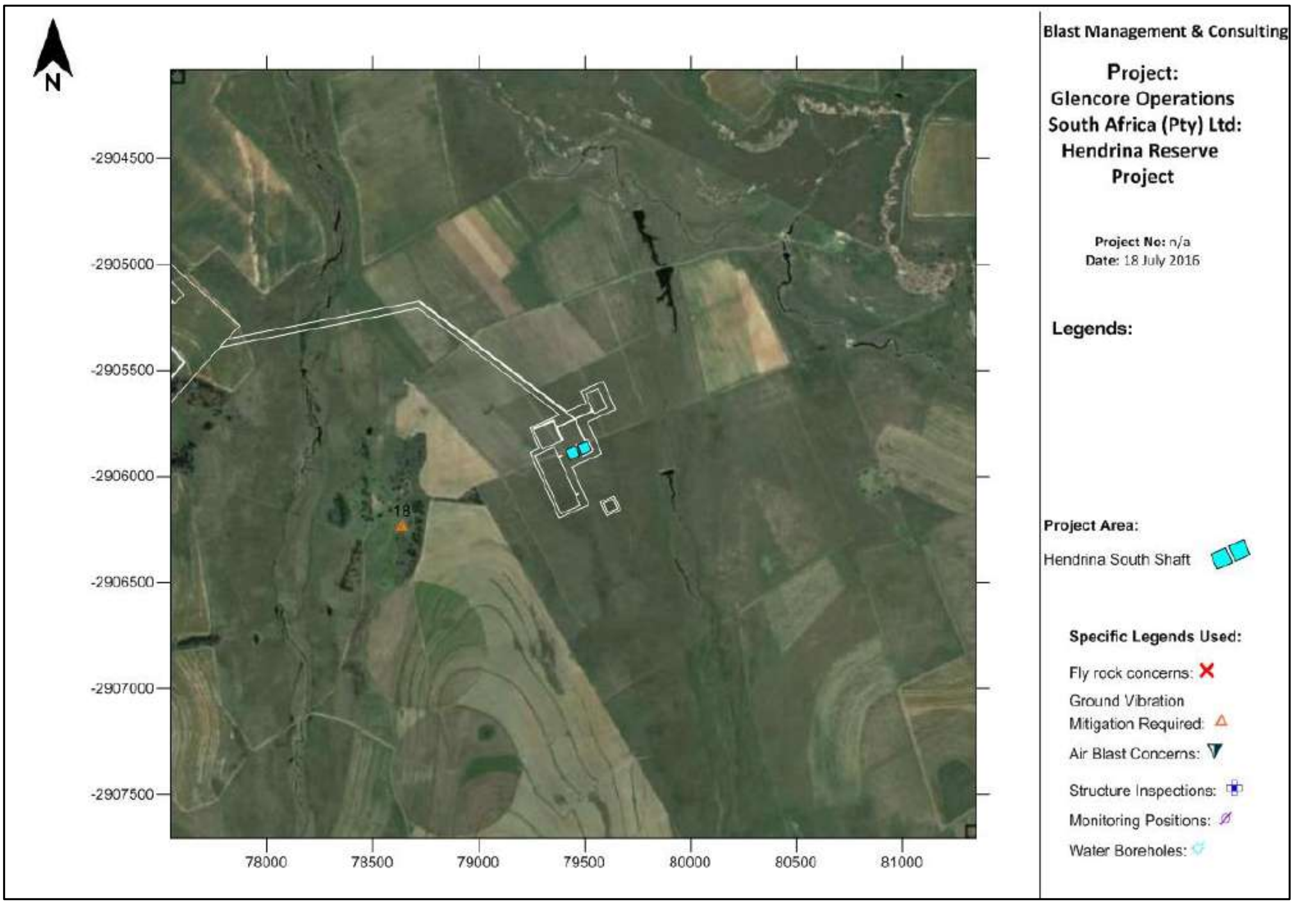

Figure 33: Structures identified where ground vibration mitigation will be required at Hendrina South (Shaft No. 2).

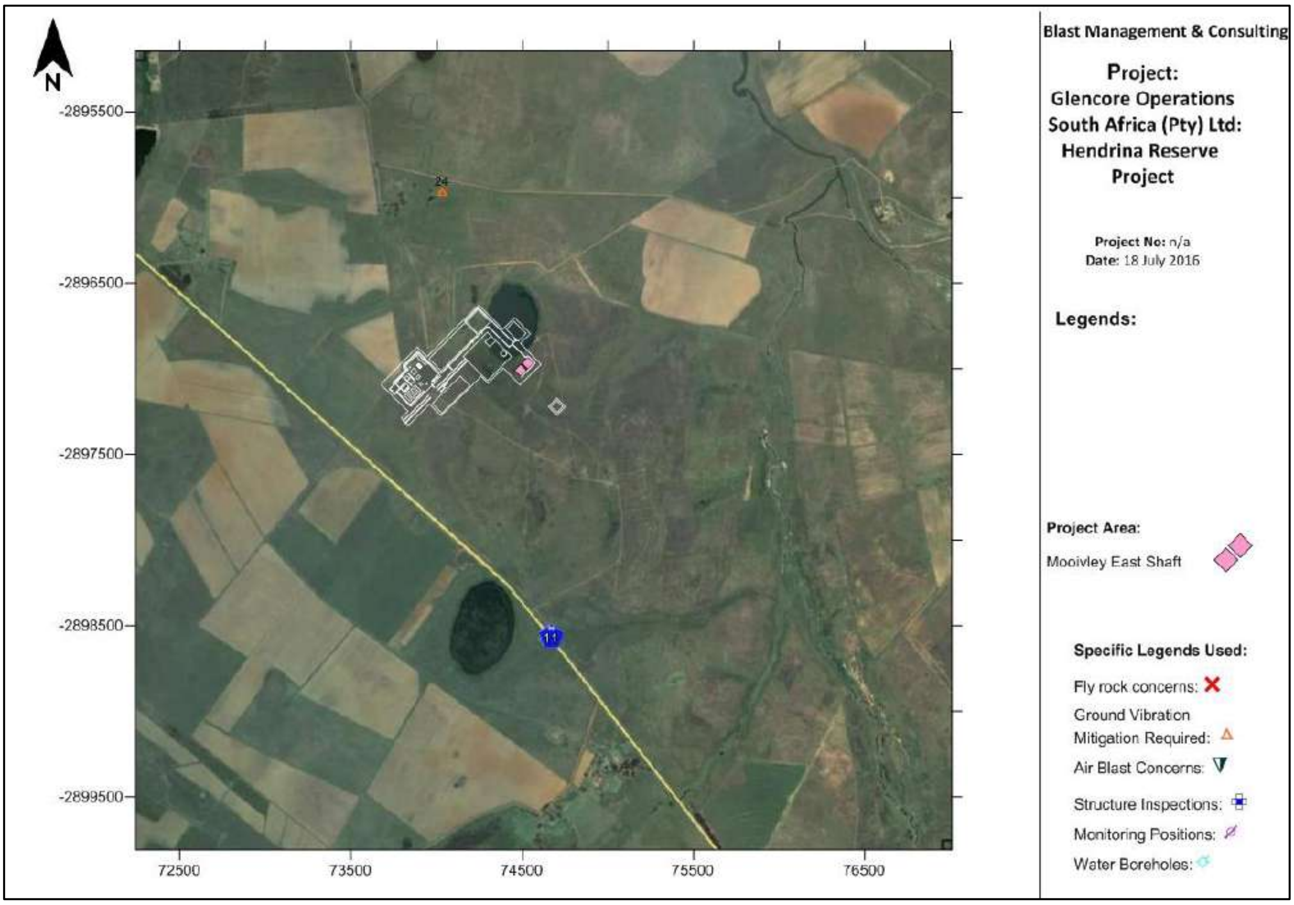

Figure 34: Structures identified where ground vibration mitigation will be required at Mooivley East (Shaft No. 3).

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

- Do blast design that considers the actual blasting and the ground vibration levels to be adhered too.
- Change the initiating system to facilitate less blast holes detonating simultaneously making using of electronic initiation that allow for single hole firing. The single blast hole charge mass showed no concerns. See section 14.1.
- Do design for smaller diameter blast holes that will use fewer explosives per blasthole.

Table 29 shows mitigation in the form of maximum charge mass allowed and minimum distance require for the maximum charge used in the evaluation. Firstly the maximum charge mass per delay that will satisfy the required limits for the actual distance between blast area and point of concern is shown. Secondly the minimum distance required to satisfy limits for the maximum charge used in evaluation. These factors are highlighted yellow.

Table 29: Mitigation measures for ground vibration

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
Mooivley West (Shaft No. 1)								
Maximum Charge allowed								
1	Informal Housing	-77040.18	2905083.36	6	392	265	6	Acceptable
2	Heritage - Farm Buildings/Structures	-77032.78	2905311.24	6	272	128	6	Acceptable
8	Cultivated Fields	-77554.4	2905384.54	150	149	1888	150	Acceptable
Minimum distance Required								
Tag	**Description**	**Y**	**X**	**Specific Limit (mm/s)**	**Distance (m)**	**Total Mass/Delay (kg)**	**Predicted PPV (mm/s)**	**Structure Response @ 10Hz**
1	Informal Housing	-77040.18	2905083.36	6	1179	2402	6	Acceptable
2	Heritage - Farm Buildings/Structures	-77032.78	2905311.24	6	1179	2402	6	Acceptable
8	Cultivated Fields	-77554.4	2905384.54	150	168	2402	150	Acceptable
Hendrina South (Shaft No. 2)								
Maximum Charge allowed								
18	Informal Housing	-78639.55	2906238.4	6	852	1250	6	Acceptable
Minimum distance Required								
18	Informal Housing	-78639.55	2906238.4	6	1179	2402	6	Acceptable
Mooivley East (Shaft No. 3)								
Maximum Charge allowed								
24	Informal Housing	-74033.54	2895978.42	6	1076		6	Acceptable
Minimum distance Required								
24	Informal Housing	-74033.54	2895978.42	6	1179	2402	6	Acceptable

15 Monitoring

A monitoring programme for recording blasting operations is recommended. This process will be mainly for the development of the different decline shafts. 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 improved relationships with the neighbours. Three crucial monitoring positions were identified for Shaft 1, four for Shaft 2 and two for Shaft 3. Monitoring positions are indicated in Figure 35, Figure 36, Figure 37 and Table 30 lists the positions with coordinates. These points will need to be re-defined with the initial first blast and consider the final blast design that will be applicable.

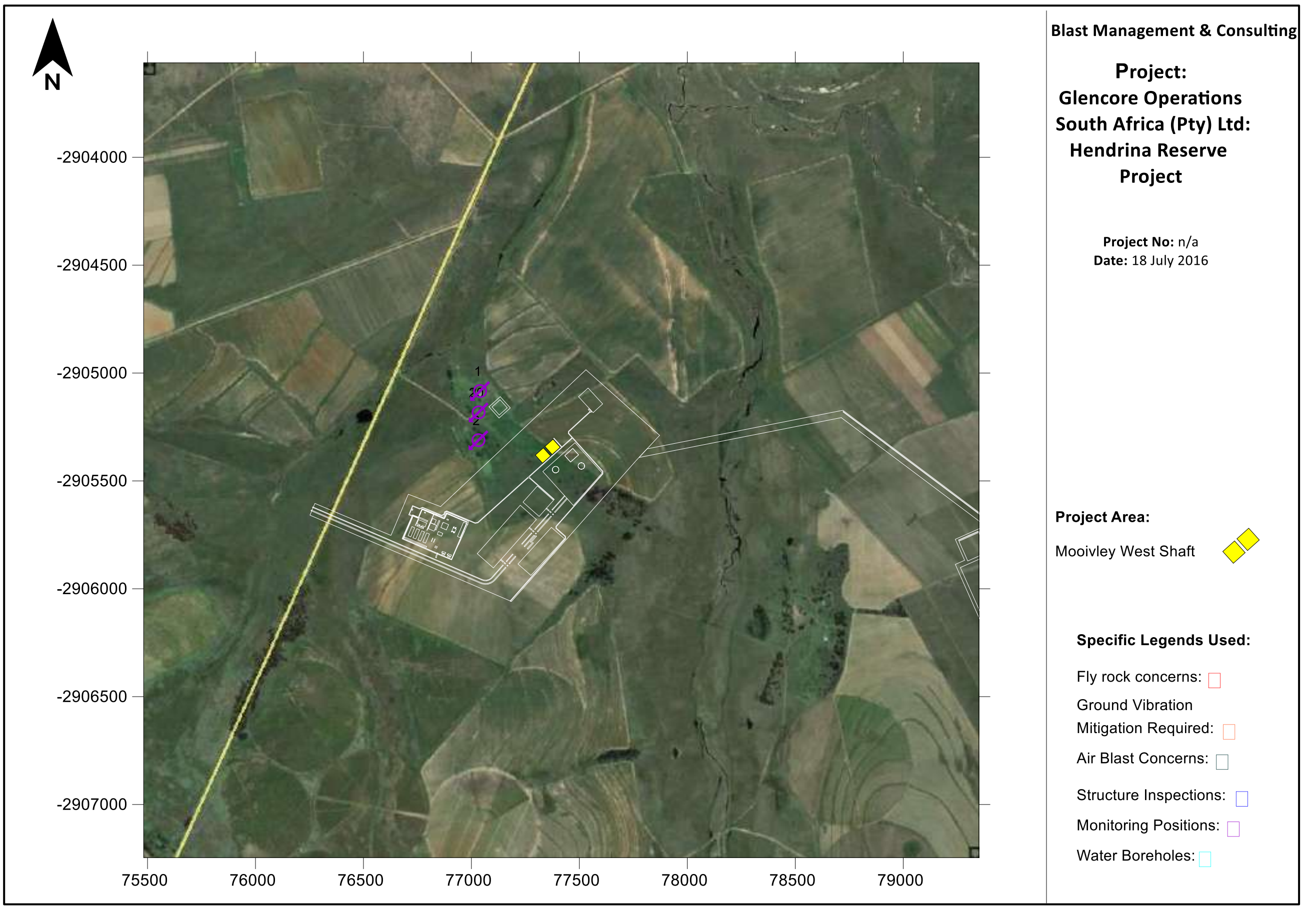

Figure 35: Monitoring Positions suggested for Mooivley West (Shaft No. 1).

Figure 36: Monitoring Positions suggested for Hendrina South (Shaft No. 2).

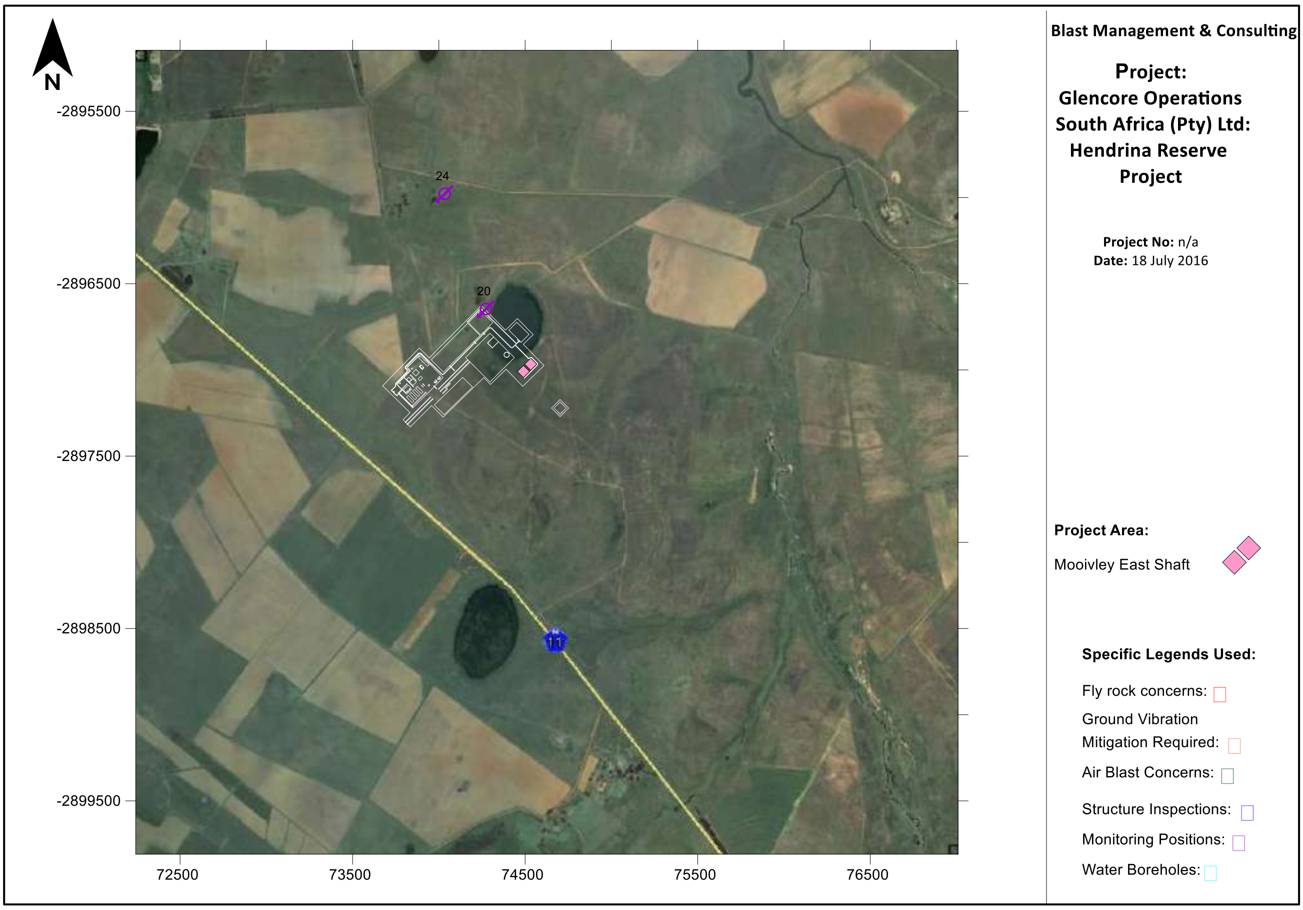

Figure 37: Monitoring Positions suggested for Mooivley East (Shaft No. 3).

Table 30: List of possible monitoring positions

Tag	Description	Y	X
Mooivley West (Shaft No. 1)			
1	Informal Housing	-77040.18	2905083.36
2	Heritage - Farm Buildings/Structures	-77032.78	2905311.24
20	Hydrocencus Borehole(MVLBH5)	-77033.57	2905182.14
Hendrina South (Shaft No. 2)			
12	Dam	-79857.71	2905080.00
15	Dam	-79895.46	2905987.67
18	Informal Housing	-78639.55	2906238.40
19	Farm Buildings/Structures	-78502.48	2906115.51
Mooivley East (Shaft No. 3)			
20	Hydrocencus Borehole(VLBSP8)	-74272.98	2896646.65
24	Informal Housing	-74033.54	2895978.42

16 Recommendations

16.1 Regulatory requirements

Regulatory requirements indicate specific requirements for all non-mining structures and installations within 500 m from the mining operation. The Buildings/structures at Shaft 2 and the N11 Road and Borehole (OVBH2) at Shaft 3 are observed within the 500 m. The mine will have to apply for the necessary authorisations as prescribed in the various acts. Table 31 shows list of these installations. Figure 38, Figure 39 and Figure 40 below shows the 500 m boundary around the shaft areas. The location of non-mining installations is clearly observed.

Table 31: List of possible installations within the regulatory 500 m

Tag	Description	Y	X
Mooivley West (Shaft No. 1)			
1	Informal Housing	-77040.18	2905083.36
2	Heritage - Farm Buildings/Structures	-77032.78	2905311.24
7	Cultivated Fields	-77249.45	2904833.72
8	Cultivated Fields	-77554.40	2905384.54
17	Cultivated Fields	-77264.36	2905870.07
20	Hydrocencus Borehole(MVLBH5)	-77033.57	2905182.14
Hendrina South (Shaft No. 2)			
15	Dam	-79895.46	2905987.67
Mooivley East (Shaft No. 3)			
1	Pan	-74437.95	2896764.90
20	Hydrocencus Borehole(VLBSP8)	-74272.98	2896646.65
21	Hydrocencus Borehole(VLBSP7)	-74386.74	2896510.02

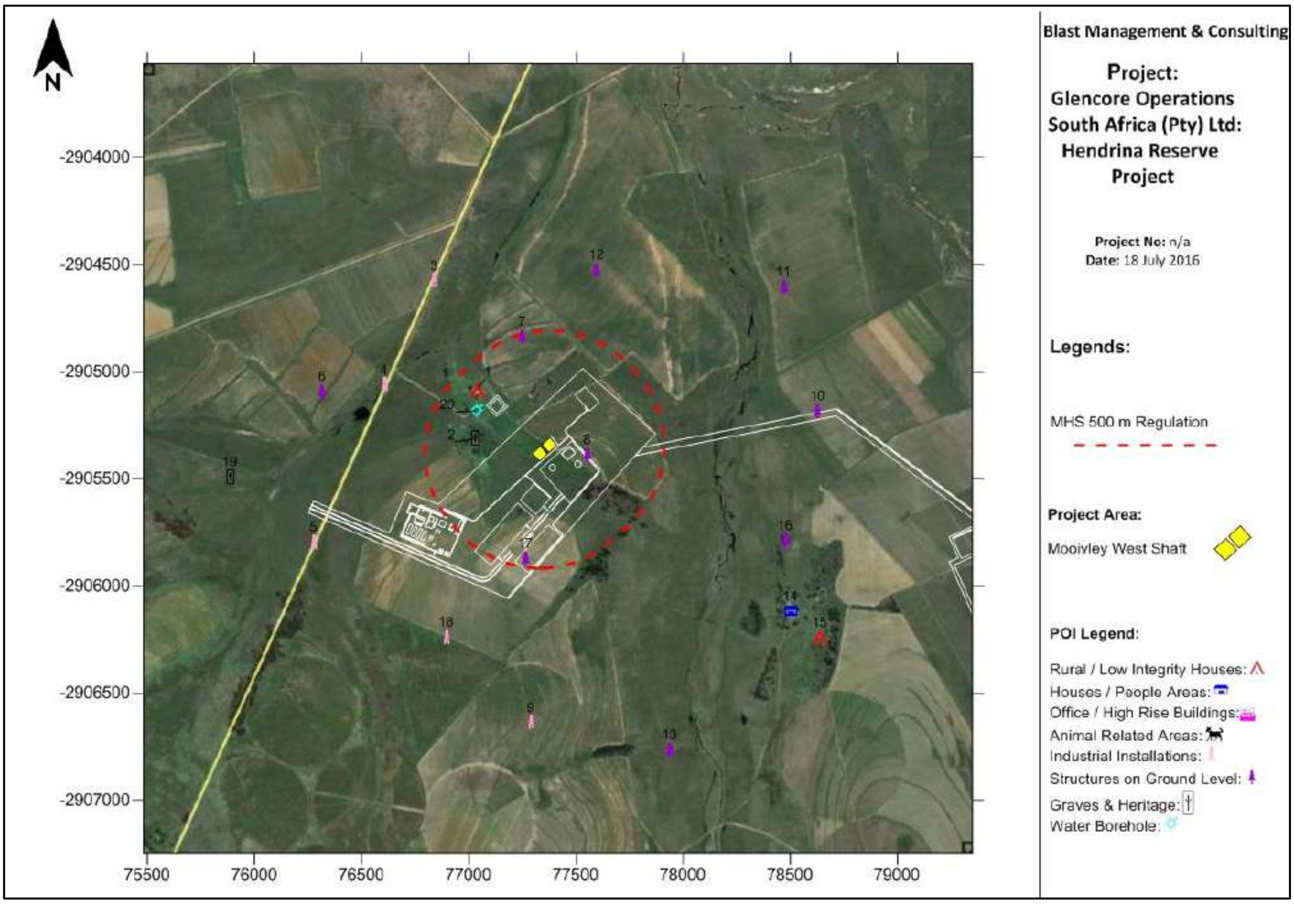

Figure 38: Regulatory 500 m range for Mooivley West (Shaft No. 1)

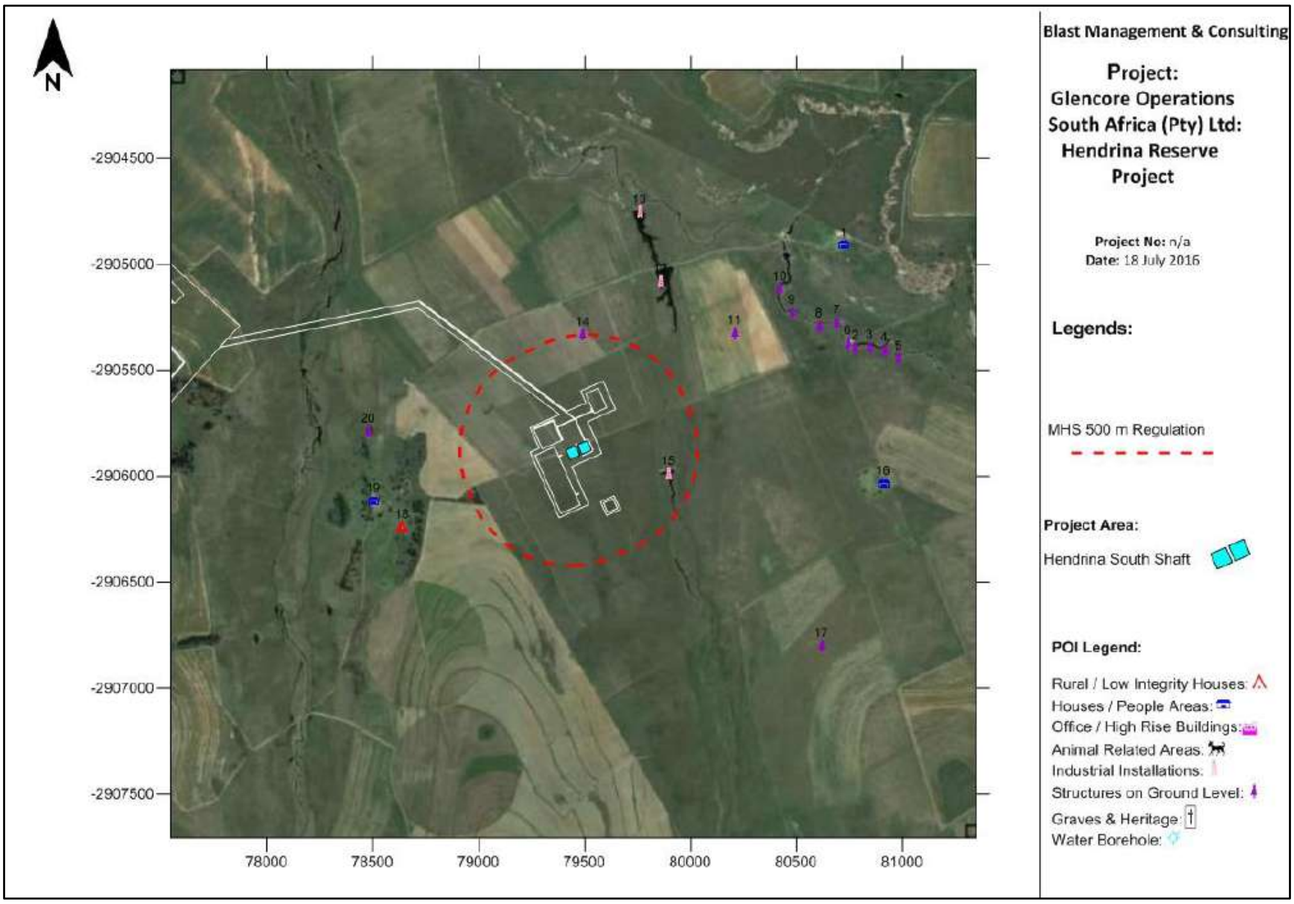

Figure 39: Regulatory 500 m range for Hendrina South (Shaft No. 2)

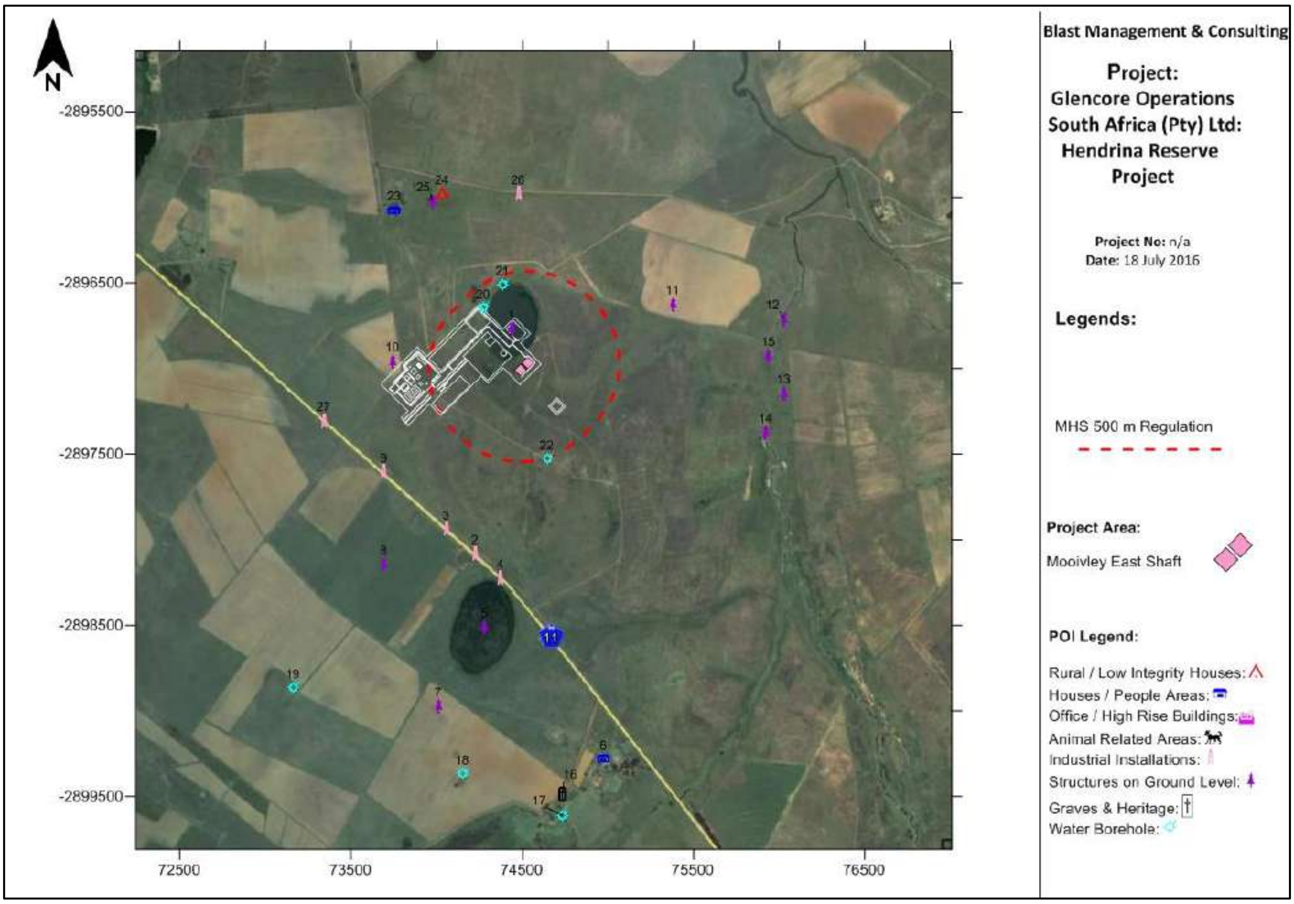

Figure 40: Regulatory 500 m range for Mooivley East (Shaft No. 3)

16.2 Blast Designs

The blast designs used in this report forms part of the initial consideration of blasting operations. It is highly recommended that this blast design be reviewed and a detail blasting code of practice be prepared and accepted for the development of the shaft areas. Designing of blasts must consider the location of the blast and location of surface structures. The expected levels of ground vibration and air blast must be considered and calculated for the nearest surface structures. The design must consider final pattern, charging configurations and timing taken into account.

16.3 Safe Blasting Distance and Evacuation

The calculated minimum safe distance is 315 m. This is the estimated area that must be cleared at least around a blast before firing. General evacuation used in the mining industry is at least 500 m from any blast. The final blast designs that may be used will determine the final decision on safe distance to evacuate people and animals. This distance may be greater pending the final code of practice of the mine and responsible blaster’s decision on safe distance. The blaster has a legal obligation concerning the safe distance and he needs to determine this distance.

16.4 Road Closure

Two roads will be utilised to access the mining areas which include the N11 and the Davel Road (Farm Road). The Davel Road branches off in a southern direction from the N11 driving from Hendrina. The Davel Road is located 760 m from the Shaft area and will be utilised to access Mooivley West and Hendrina. Mooivley East will be accessed from the N11 which is 991 m from the Shaft area. The expected levels of ground vibration are well within the limits for these roads. No specific actions are required for these roads. These roads are also located at distances far enough that road closure controls will not be required.
There may be smaller general farm tracks and roads not specific shown here that must be considered during blasting operations.

16.5 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 32.

Table 32: 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	

16.6 Blasting Times

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

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

16.7 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.

17 Knowledge Gaps

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

18 Conclusion

BM&C was contracted as part of EIA to perform an initial review of possible impacts with regards to blasting operations on the proposed Hendrina Reserve located in the Mpumalanga Province of South Africa. Ground vibration, air blast, fly rock and fumes are some of the aspects resulting from blasting operations.

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as 1500 m. The project was found to have people or houses at close distances to the project area. The nearest house or buildings is found 392 m for Shaft 1, 852 m for Shaft 2 and 1076 m away for Shaft 3. The Heritage - Farm Buildings/Structures is closest at 272 m from the Shaft 1 area. Ground vibration mitigation will be required for these structures. Specific attention will be required for adjustments in the blasting operations to ensure expected levels of ground vibration and air blast are within the required limits. Ground vibration at structures and installations other than the identified problematic structures is well below any specific concern for inducing damage. There is a possibility that ground vibration may be unpleasant at nearest houses.

The nearest public houses are located 852 m from the Shaft 2 decline shaft boundary. The levels predicted do show low levels of ground vibration that could be experienced as unpleasant at the maximum charge on the human perception scale. The ground vibration levels predicted for all installations evaluated surrounding the decline shaft area ranged between 1.7 mm/s and 183.0 mm/s. Ground vibration levels at the nearest buildings where people may be present is 67.5 mm/s. These structures considered in the evaluation showed concern for possible damages.

Air blast predicted for the maximum charge ranges between 112.8 and 129.6 dB for all the POI's considered. No specific damages are expected from the levels calculated. Damages are only expected to occur at levels greater than 134 dB and 134 dB is only expected at distances closer than 250 m to the decline shaft area. The nearest buildings are 392 m from the decline shaft boundary. Infrastructure such as the N11 road is close but air blast does not have any influence on these installations. The levels at private houses or settlements are expected to be within limits and not damaging. Levels at nearest houses may cause effects such as rattling of roofs or doors and cause complaints.

An exclusion zone for safe blasting was also calculated. The exclusion zone was established to be at least 315 m. Normal practice observed in mines is a 500 m exclusion zone. The minimum distance recommended is 315 m. This distance may be greater but not less.

Seven boreholes were identified that could possibly be influenced due to excessive ground vibration at minimum and maximum charge. The expected levels of ground vibration for all of the boreholes inside the area evaluated are well within the limit applied for water boreholes.

Recommendations were made that should be considered:

- There are structures and installation within 500 m from the shaft areas and specific regulatory authorisations for blasting within 500m of these installations will be required.
- At time of developing the shafts the blast designs must be reviewed for improvements on the general design used in this report.
- A minimum safe clearance distance of 315 m must be applied.
- Farming activities and travelling on farm roads must be considered when areas are cleared prior to blasting operations.
- Ground vibration limits were recommended and presented.
- The use of third party to monitor the blasting operations for ground vibration and air blast is recommended.

The impact assessment indicated that there is no reason that this operation cannot continue if the recommendations provided are adhered to.

19 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.

20 References

1. 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.
2. BME Training Module – Vibration, air blast and fly rock, Module V, Dated 5 August 2001.
3. 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.
4. Dowding C.H., Construction Vibrations, 1996, Prentice Hall, Upper Saddle River, NJ 07458.
5. Farnfield Dr R., Client Report: Air Overpressure from Le Maitre Flash Report, Dated: 27 April 2007.
6. Hawkins J., 9 May 2000, Impacts of Blasting on Domestic Water Wells, Workshop on Mountaintop Mining Effects on Groundwater.
7. ISEE Blasters Handbook, 18th Edition, Little, January 2011, Ohio USA
8. Mechanical vibration and shock – Vibration of buildings – Guidelines for the measurement and evaluation of their effects on buildings, SABS ISO 4886:1990.
9. Oriard, L.L., 1999, The Effects of Vibration and Environmental Forces: A guide for Investigation of Structures, International Society of Explosives Engineers, Cleveland, Ohio, USA.
10. Persson P.A., Holmberg R. and Lee J., 1994, Rock Blasting and Explosives Engineering, Boca Raton, Florida: CRC Press.
11. Richards A. B., Moore A.J., Terrock Consulting Engineers Pty Ltd., 2002, Fly rock Control – By Chance or Design, Paper Presented at ISEE Conference – New Orleans.
12. Rowland, J.H.(III), Mainiero R., and Hurd D.A.(Jr.), Factors Affecting Fumes Production of an Emulsion and Anfo/Emulsion Blends.
13. Sapko M., Rowland J., Mainiero R., Zlochower I., Chemical and Physical Factors that Influence no Production during Blasting – Exploratory Study.
14. Scott A., Open Pit Blast Design, 1996, Julius Kruttschnitt Mineral Research Centre, The University of Queensland.
15. Siskind D.E., Stachura V.J., Stagg M.S. and Kopp J.W., 1980. Structure Response and Damage Produced by Air blast From Surface Mining. US Bureau of Mines RI 8485.