Reg. Number: 2007/149565/23
VAT No: 4580 2410 34
Phone Number: 013 932 5110
Fax Number: 013 932 4185
Web: www.bigcrock.co.za
Email: pierre@bigcr.co.za
Physical Address:
52 Church Street
Bronkhorstspruit
1020
Postal Address
PO Box 2615
Bronkhorstspruit
1020

CC No:2007/149565/23 VAT No: 4580 2410 34

Date: 22th of September 2019 *Report number 2009-006ECO - MJ*

Project Reference: Koppie Colliery

ROCK ENGINEERING REPORT – BLAST AND GROUND VIBRATION ASSESSMENT – KOPPIE COLLIERY

This report was compiled for:

ECO ELEMENTUM (PTY) LTD
WORLD BANK OFFICE PARK,
442 RODERICKS ROAD,
LYNNWOOD, PRETORIA
0081

This report was compiled by:

MARICA PRETORIUS (ROCK ENGINEERING DEPARTMENT MANAGER)
***B. TECH (NC)*, COMCSC (COAL)**

This report was reviewed by:

MORNÈ W PRETORIUS (ROCK ENGINEERING PRACTITIONER)
B. TECH (NC), COMCSC (COAL) COMRMC (OPEN PIT)
MSANIRE, MSACNASP, MSAIMM, MGSSA

Table of Contents

Executive Summary

The proposed mining area falls on the boundary between the Witbank and Highveld Coalfield known for its economic contribution to the mining sector. The proposed underground bord and pillar workings will be primarily be developed with continuous miners, blasting will only be used in stone works, i.e mining through dykes and faults.

The occasional underground blasting is not expected to affect the overlying surface structures. The bord and pillar development beneath surface structures will have a greater effect in terms of ensuring the stability of the surface structures. By ensuring that both blasting and development is conducted on a proper design the stability of the surface structures can be ensured.

1. Introduction

Eco Elementum requested Big C Rock Engineering CC to assist in conducting a Blast and Ground Vibration Assessment as part of an Environmental Impact assessment for the proposed Underground workings of Koppie Colliery, which is located in the Mpumalanga Province.

This report will assess the ground vibration and air blast velocity to provide guidance and mitigating measures to prevent damages caused by ground vibrations and air blasts to different surface structures (buildings, roads, rivers & streams, etc.).

2. Location

The proposed underground mining operation is located on a portions of the farms Koppie 228 IS and Uitgedacht 229 IS situated 13 kilometres north of the town of Bethal in the Mpumalanga Province. The proposed mining area location and outlines are illustrated below in Figure 1 (Reference Google Earth Imagery Date 7/26/2020).

The proposed underground mining operation is located on the boundary between the Witbank and Highveld coalfields. The underground mining methods as per the “Mining Rights Application” is bord and pillar mining that will be conducted with continuous miners. Stone development with drill and blast mining methods will only be conducted in areas where development through dyke areas is required or “sub-decline” developments or inclines between the No. 4 Coal seam and No. 2 Coal seam. The proposed box-cut will also be developed with drill and blasting methods.

The most notable infrastructure that needs to be considered is perennial streams that occur in the project area as well as public roads and farm dwellings area that occurs in the project area.

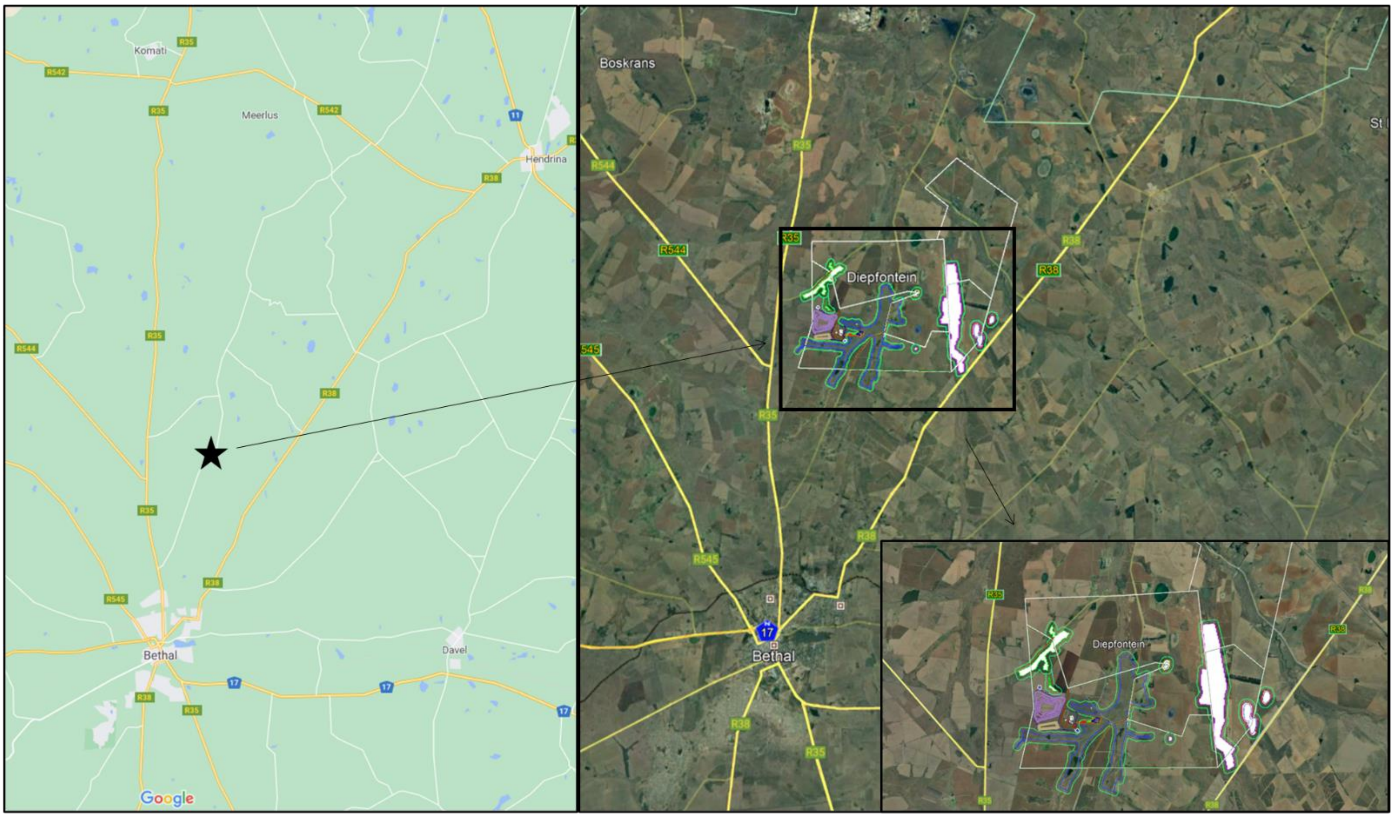


Figure 1: Illustration of the location of the mine

3. Sensitive receptors

The sensitive receptors for the proposed mining area includes all surface structures noted in Regulation 4.16 (2) of the Mine Health and Safety Act of 1996 which states that:

No blasting operations are carried out within a horizontal distance of 500 meters 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) Written permission has been granted by the Principal Inspector of Mines; and

d) Any restrictions and conditions determined by the Principal Inspector of Mines are complied with.

The sensitive receptors identified on the mining property are illustrated in Figure 2 below, they include the following and are not limited to:

- Farm buildings, related structures (dams and kraals) and small settlements
- Water catchment areas and perennial streams (Joubertsvlei Spruit and Diepsloot Spruit), small dams etc. (All indicated in Figure 2 with a green buffer line)
- Powerlines
- All National and District public roads

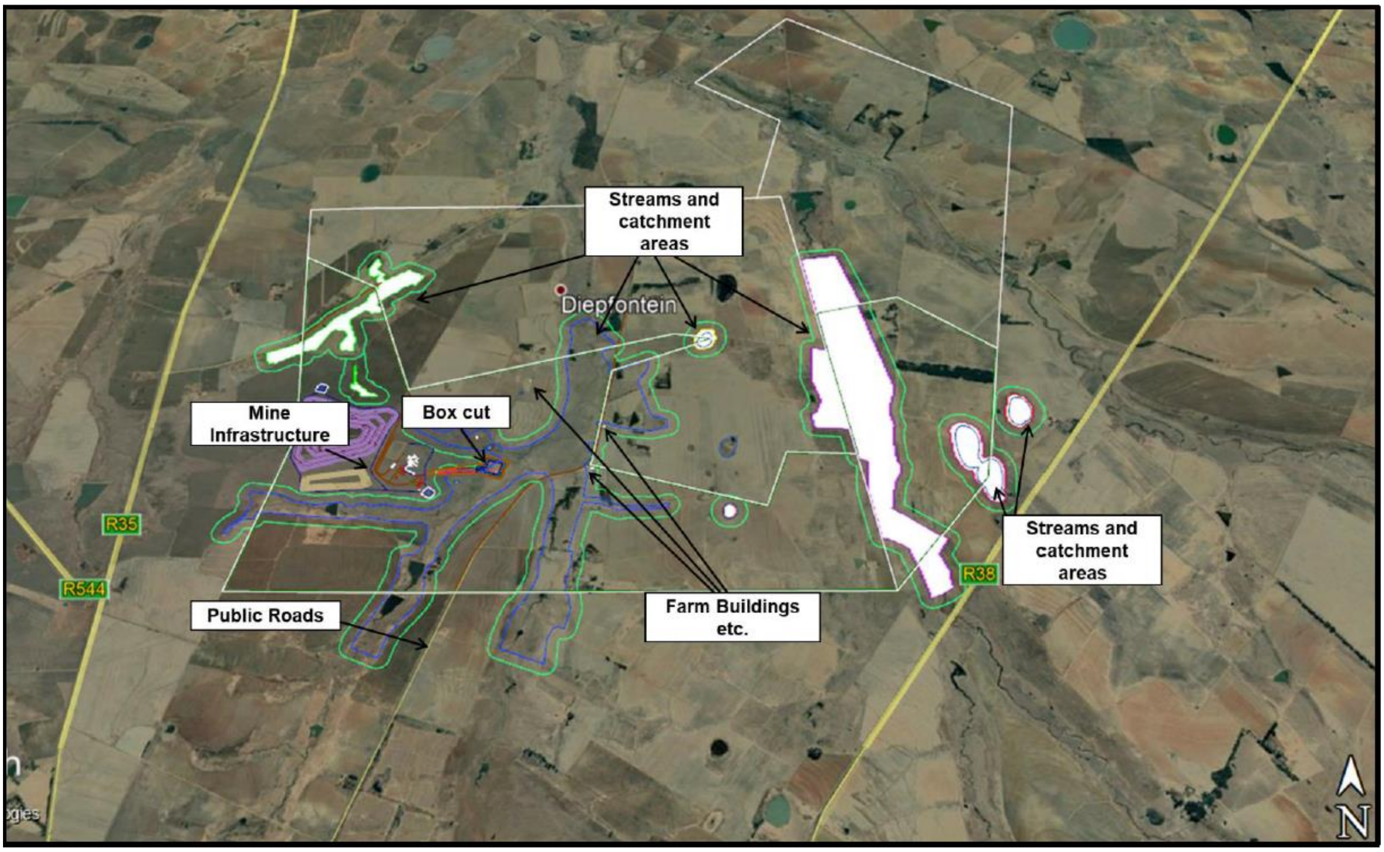


Figure 2: Illustration of sensitive receptors in relation to the proposed underground layout

4. Summary of the Geology

Overburden Geology

The topography of the mining area comprises of flat rolling hills and valleys. The Joubertsvlei Spruit and Diepsloot Spruit drains in a northerly direction.

The mining area is located south east of the paleo-high and pre-karoo ridge, Smithfield Ridge, that forms the divide between the Witbank and Highveld Coalfields. Areas situated in close proximity to these paleo-high areas can expect thinning of the coal seams as well as increased occurrence of joints due to differential compaction.

The area is affected by dolerite intrusions in the form of dolerite sills, dolerite stringers and devolatilized coal.

Several coal seams are present in the mining area, illustrated in a generalized stratigraphic column of the mining area in Figure 3. The most prevalent coal horizons in the area is the No. 4 Coal Seam and the No. 2 Coal Seam.

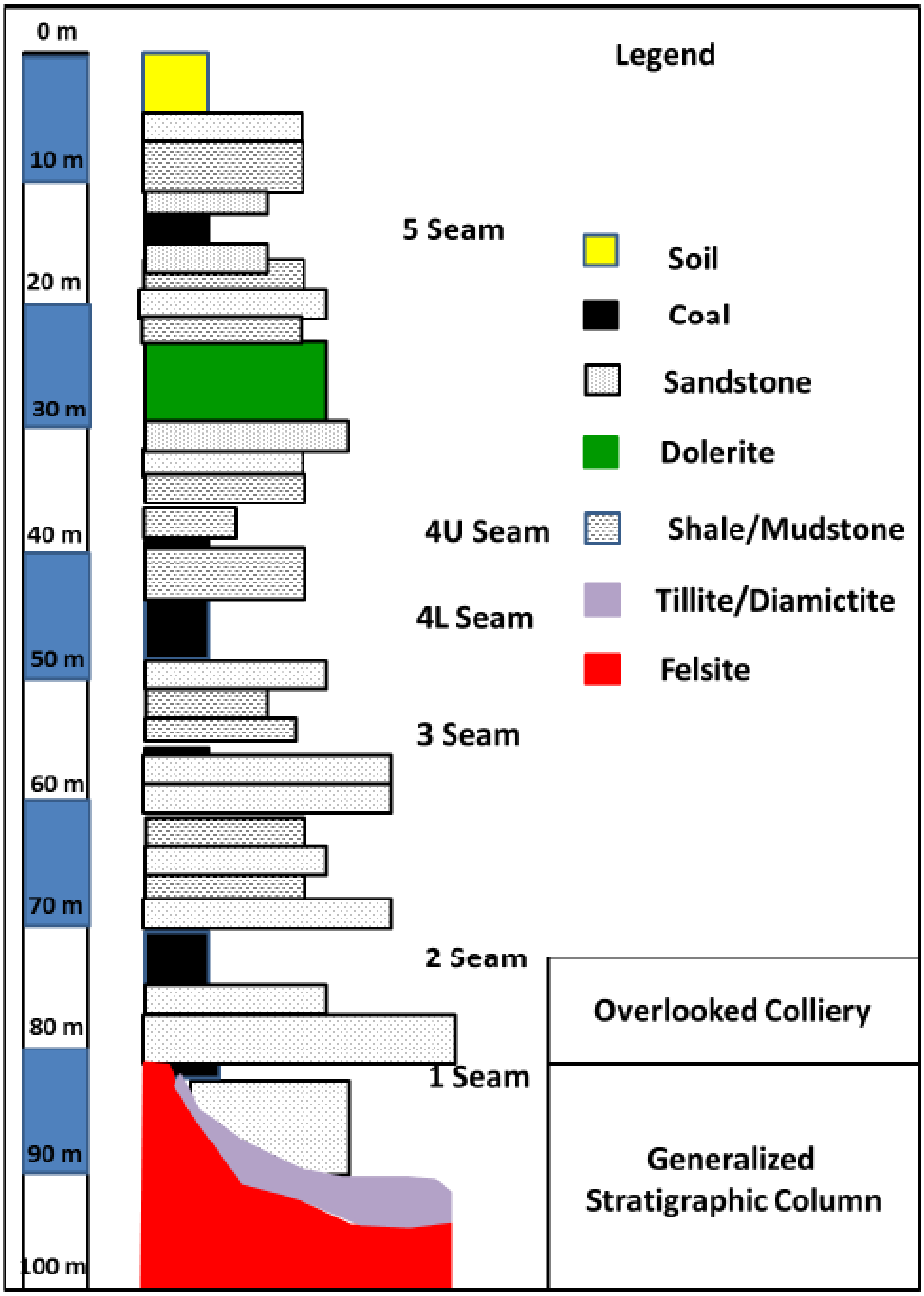


Figure 3: Generalized stratigraphic column

The basement rocks of the mining area are Rooiberg felsite and granite. Diamictite and Dwyka sediments overlies the basement, which is in turn overlain by sediments of the Vryheid Formation. The sediment deposits consist of siltstone, sandstone and coal.

Minable Seams

The No. 4 Coal Seam and No. 2 Coal Seam is viable in the mining area, the depth and thicknesses are summarized as follows:

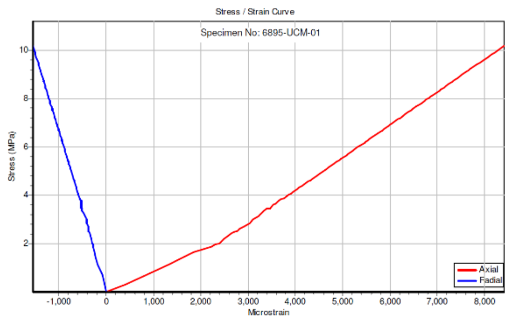
Seam	Thickness	Minimum Depth	Maximum Depth
No. 4 Lower Seam	1.65m	58.96m	118.8m
No. 2 Lower Seam	2.58m	89.35m	132.72m

Geotechnical

There are currently no information available on the geotechnical strength properties of the strata in the mining area. The following data illustrated in Table 1 will be used in this investigation which indicates the laboratory determined mechanical properties of some rock types.

UCS: *laboratory strength (the maximum stress that a material can resist without failing) tests of a rock sample.*

Young's Modulus: *The relationship between stress and strain of a material when a force is exerted on the material. Example graph>>>>>>>>>>>>>>>>*



Rock Type	UCS (MPa)	UTS (MPa)	Young's Modulus (GPa)	Density (kg/m^3)
Sandstone	75	5	13	2480
Shale	75	5	15	2480
Siltstone	70	6	1	2480
Mudstone	40	5	7	2480
Dolerite	190	14	100	3000
Coal	25	5	5	1500

Table 1: Illustration of the general laboratory tested strength of different materials.

5. Discussion

The effect that the proposed underground workings will have on the stability of the overlying surface structures will be determined by the stability of the underground workings itself (where instability may result in subsidence) and to a lesser extent the blasting practices implemented (vibrations). Note that blasting will not be used as the primary development method and will only be used in areas where dykes, faults and other stone work will be required.

***Subsidence** can be defined as the downward movement of the surface lying above an underground excavation such as bord and pillar workings. The extent of subsidence is affected by the mining depth, mining height, panel width, mining method and overburden composition.*

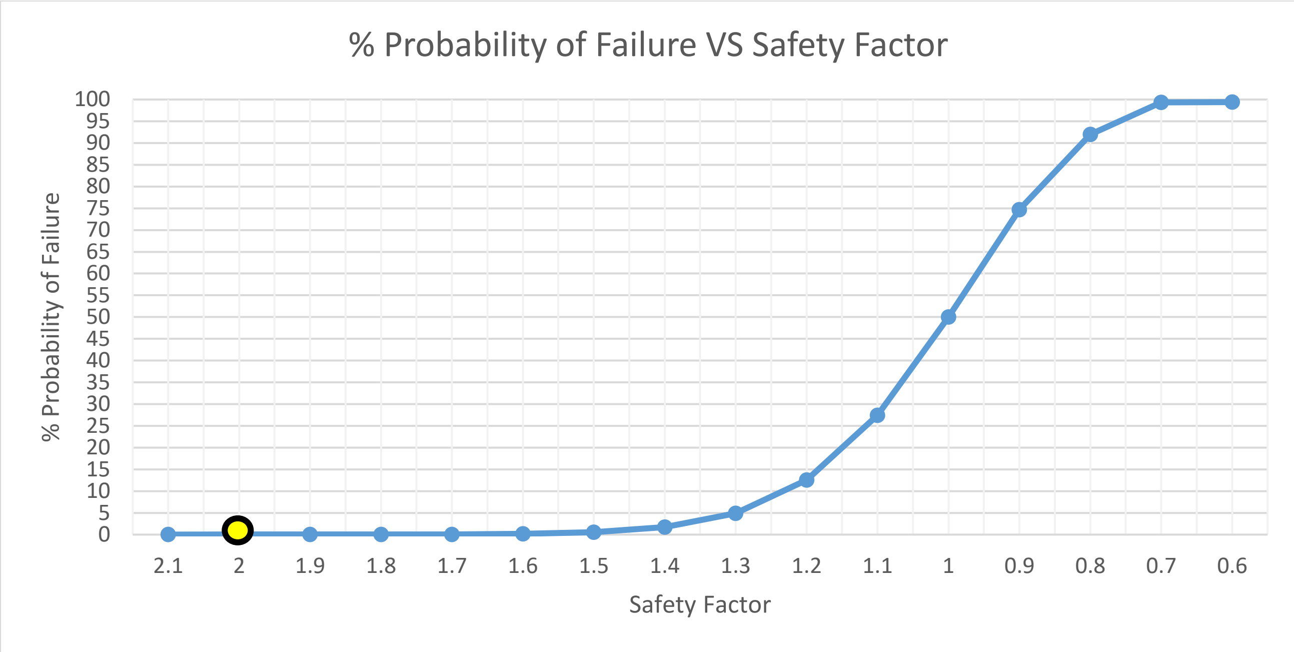
Subsidence = 0.39 x mining height x (width to height ratio) ^0.32

5.1. Stability of the underground workings

The stability of the underground workings is primarily dependent on the underground pillar design which should ensure long term pillar stability. In shallow mining areas (areas less than 40m below surface)(Madden and Canbulat, 2005) the pillar stability in collaboration with intersection and bord stability will determine if the resultant subsidence will affect the overlying surface structures. By ensuring pillar and roof stability, subsidence can be prevented and thus the stability of the overlying surface structures be ensured.

Based on the anticipated mining depths illustrated in the geology section of this report, mining will not be conducted in shallow mining areas. The following minimum criteria will apply for mining below surface structures:

- Mining below surface structures may not be conducted in shallow mining areas (areas less than 40m below surface).
- Ensure to develop pillars below surface structures according to primary panel safety factor design criteria (being in excess of 2). Research conducted in 1976 Salamon and Oravecz **recommended a safety factor of 2.0** for the design of main development pillars (Van der Merwe 2006). Hill (2005) suggests that pillars designed for long life in excess of 5 years such as primary development pillars should be designed with a margin of 20 percent in addition to the minimum design, the reason being that at some stage it can be assumed that the pillars will be subjected to full tributary area loading. Hill (2005) further recommended that pillars that required for the permanent protection of critical surface features must be designed to have a minimum probability of failure of 1 in a million pillars. The probability of failure is illustrated below in Graph 1.



Graph 1: Illustration of the probability of failure

> ***The Pillar Safety Factor (PSF)*** *can be defined as the pillar strength divided by the pillar load. The PSF is a prediction of the probability of a stable geometry used in the pillar design of underground Coal workings.*

- The **pillar width to mining height ratio should be at least 3** below surface structures. After Wagner (1974) investigated coal strength he determined that the modulus of elasticity was a true material property independent of geometry which indicated that post failure behaviour of a pillar is a structure property and not an inherent material property. I.e. larger width to height ratio equals increased stability.

> ***The Pillar width to Mining Height ratio (W:H)*** *is an indication of the strength of a pillar core.*

- Pillar extraction or any form of higher extraction (including bottom and top coaling) must not be attempted or conducted beneath vital surface structures. Any form of higher extraction increases the risk of failure which increases the risk of subsidence which can damage the infrastructure on surface.
- Since pillar extraction or any higher form of extraction is not allowed beneath surface structures it is not anticipated that the critical mining span (*The mined out span at which expected total roof collapse will occur*) will be exceeded since the maximum mined open spans will not exceed that of the support design which is typically maximum 6m for bords and 9.4m for intersection diagonal distances.
- All pillar and support designs must be conducted according to the site specific conditions and strengths. By incorporating site specific designs the site specific conditions can be catered

for. Therefore future drilling projects must include geotechnical strength analysis techniques to ensure that site specific strength parameters of the roof, floor and coal are incorporated into the designs.

- By using a continuous miner to create roadways in the proposed underground bord and pillar working, less damage to the pillar sides and roof will occur as opposed to blasting.
- It must be noted that water can be diverted by means of gravity from overlying water bodies (streams, dams pans etc.) to the underground workings through discontinuities. The effect of weathering in these areas is sometimes extensive, which resultantly affects the competency of the rock material and also the stability of the workings. This can only be determined once underground mining has commenced in affected areas.
- Ensure that barrier pillars are included into the mine layout and designs. This will furthermore increase stability of the underground workings and allow for compartmentalization in case of a catastrophic event.

Hill (1996) conducted an investigation into the development of sinkholes in the Witbank-Highveld Coalfields, during which he determined that the main contributing factors for sinkhole formation is:

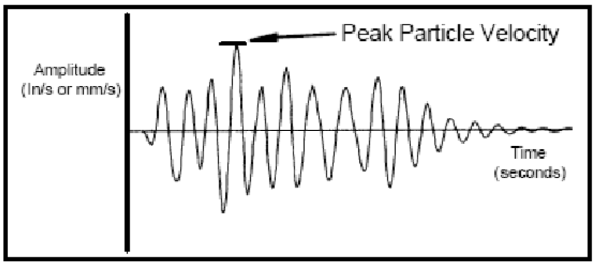
- It is unlikely that sinkholes will occur when the depth exceeds 40m below surface.
- Sinkholes are more likely to form in areas where sandstone layers account for less than 30% of the overburden.
- Large spans and intersections are more likely to result in failure.
- Blast vibrations, especially large overburden opencast blasts may cause failures.

5.2. Ground Vibrations Assessment -effect of blasting

A blast design has not been conducted for the underground workings yet. It is not foreseen that blasting will be conducted on a daily basis at the underground workings. However since this report anticipates the worst case scenario the effect of blasting is included herein.

The effect that blasting conducted in the underground operation may have on the overlying surface structures is dependent on the amount of ground vibrations that will be generated when conducting drill and blast operations (also known as stone works) through dyke and fault areas. The ground vibrations are determined by the Peak Particle Velocity (PPV) that will be generated during a blast.

The PPV is the maximum ground motion amplitude experienced by a particle subjected to ground vibration or is defined as the speed at which a particle of ground/soil vibrates as the wave passes through a particular section. PPV is measured in meters per second (m/s) or millimetres per second (mm/s).



Explosives are used to break rock through the shockwaves and gases yielded from the explosion. Ground vibration is a natural result from blasting activities. The far field vibrations are inevitable, but undesirable by products of blasting operations. The shockwave energy that travels beyond the zone of rock breakage is wasted and could cause damage and annoyance. The following factors influences the magnitude of ground vibration (Rangasamy, 2018):

- The charge mass per delay,
- The delay period,
- Distance from the blast,
- Rock mass and
- Geometry of the blast.

The factors influencing ground vibrations can be controlled by a planned design and proper blast preparation (Rangasamy, 2018):

- The larger the charge mass per delay the greater the vibration energy yielded.
- The distance between the blast and the point of interest.
- The geology of the blast medium and surroundings also influences the magnitude of vibrations. High density materials have highs shockwave transferability where low density materials have low transferability of the shockwave.

5.2.1. Ground Vibrations Limit Criteria

South African legislation does not dictate the specified maximum allowable ground vibration limits. However several studies within South Africa has investigated vibration limits. The vibration limits suggested by Rorke (2011) for civil and engineering structures will be used in this report:

Structure	**PPV mm/s limit**	**Description**
Eskom Power Lines	<75 mm/s	Conservative value since the steel structure of pylons and concrete foundation blocks can both withstand significantly higher values.

Public Roads	<150 mm/s	Desegregation of road material will start to appear at vibration amplitudes above 150mm/s
Pipelines (water and Transnet)	<50 mm/s	Blasting near pressurized steel pipelines has taken place safely at PPV's of >50 mm/s in South Africa.
Conveyors	< 200mm/s	A steel conveyor structure will withstand very high vibrations and the concrete plinths will remain undamaged by ground vibrations up to 200mm/s.

Criteria – Civil Surface structures (Rorke 2011)

Furthermore the United States Bureau of Mines (Siskind et al, 1980) Criteria is used for civil infrastructure such as buildings and houses:

Type of Building	Ground vibration limit
General houses of proper construction	25 mm/s
Houses of lesser proper construction	12.5 mm/s
Rural buildings	6 mm/s

Criteria – Buildings (USBM)

The aim of the underground blasting design will therefore be to ensure that less than 6mm/s vibrations are generated on surface to ensure that even the weakest of structures (rural buildings) are not damaged by underground blasting.

5.3. Predicted Ground Vibrations

Since a blast design has not been conducted for the underground workings the following example are used to illustrate the effect of underground blasting on surface.

The PPV can be calculated by using the following formula:

$$v = k(w^b D^n)^m$$

v – peak particle velocity (mm/s)

w – weight of explosives (kg)

D – distance from the blast (m)

k – equation constant

m, n, b - constants

For the type of evaluation at hand value of -0.33 should be used for "b" whilst 1 will be a suitable value for "n". The constants "k" and "m" are on-site, specific measurements. However since these measurements has not been conducted the values derived at other mines in the Witbank area will be used for the analysis. The values derived by Naismith will be used in this investigation:

m – -1.38

k – 417

Example

A typical underground blast has a 25kg charge weight per delay. The following table illustrates the PPV's for various distances using the above said input parameters:

Peak Particle Velocity (m/s)	Distance (m)	Charge per delay (Kg)
PPV	**D**	**E**
195.97	5	25
75.29	10	25
43.03	15	25
28.93	20	25
21.26	25	25
16.53	30	25
13.36	35	25
11.12	40	25
9.45	45	25
8.17	50	25
6.35	60	25
5.13	70	25
4.27	80	25
3.14	100	25

The depth below surface where mining will be conducted is in excess of 58m, therefore blast vibrations on surface structures is very low (6mm/s to 8mm/s) when blasting id conducted directly underneath surface structures. It can be seen in the table that very little vibrations are expected on surface, if any.

When a blast design is compiled for stone works it must ensure that the PPVs does not exceed 6mm/s when blasting is conducted within 100m of surface structures. Underground mining operations use far less weight per charge/delay than opencast mining operations.

Different velocities for different materials

Barton created the well-known rock mass classification system called the Q Index and combined the information to determine an empirical relationship between the Q Index and the seismic P wave velocity. The wave velocity can be calculated with the following calculation:

$V_p = 3.5 + Log_{10} Q_c$ where $Q_c = (Q.\sigma_c)/100$

The Q Index rating calculated for dolerite is 76 whilst the Q Index rating for coal is 0.71. The uniaxial compressive strength for dolerite is 190 MPa whilst coal's compressive strength lies in the vicinity of 25 MPa according to Van der Merwe and Madden.

Rock Material	Q Index	UCS Strength	Q_c	P wave Velocity
Dolerite	76	190 MPa	144.4	5.66 $km.s^{-1}$
Coal	25	25 MPa	0.18	2.76 $km.s^{-1}$

The outcome of the calculations indicates that the velocity for the Dolerite is higher than that of Coal i.e. the velocity will be transferred through the dolerites at a higher rate than for coal. If, however, the charge is detonated in coal, the wave velocity for coal (2.76 km. s^{-1}), will travel through the dolerite as well. Conversely, if the charge is detonated within dolerite, the wave velocity will decrease, once it reaches coal, or any material with a lower stiffness (sandstone, shales, etc). it is not anticipated that blasting will be conducted in the coal but rather in dolerite or fault areas (coal roof or coal floor).

Additional factors

Additional factors that influences the wave propagation of the ground vibrations is:

- Discontinuities – which reflects or diverts the waves in different directions. In rock such as shale or laminated material which tends to be highly laminated with multiple beddings the wave transfer will be poor.
- Stiffness of the material generally represented by the Young's modulus of the material. The stiffer the material the better the transfer of the wave. In areas where dolerite (stiff material) is present the wave will therefore be transferred better through the material than with coal or shale (Lower young's modulus).
- The transfer of waves between different strata layers. Some velocity is lost between the discordance planes of the layers. In other words in a sedimentary environment such as the mining area the discordance planes is ample therefore transfer of the energy waves between layers are lost and the velocity is therefore low.

The following ground vibrations mitigating measures should be included into a sound blast design (Thompson 2005):

- Small amount of explosive charge per delay should be used
- The delays between the rows must not strengthen the shockwave, i.e. single hole firing with electronic detonators.
- Blast parallel to the main joint set
- Use a pre-split or other highwall control drilling method to isolate the main blast-block from the rest of the rock mass, i.e. create a second free face.

6. Risk Assessment

Based on the above interpretations of the findings the following risk assessment was conducted to illustrate the risk of roof failure and pillar failure that may result in subsidence. The risk matrix used in the investigation are as follows:

Risk (R) = Probability (P) x Consequence (S) x Exposure (E)

Probability (P)	Certain that it will occur	5
	Likely that it will occur	4
	Possible that it will occur	3
	Rare that it will occur	2
	Very unlikely that it will occur	1
Severity (S)	Minor property loss	1
	Causing multiple injuries or property loss that result in production loss for the neighbouring party	2
	Causing fatalities to at least 1 person and or damage to equipment of less than R1 mil	3
	Causing multiple fatalities and or significant property loss of more than R1 mil	4
	Causing fatalities, injuries or significant damage to neighbouring properties and civilians resulting in the production and money loss in the macro environment.	5
Exposure (E)	Continuous exposure	5
	Frequent exposure	4
	Occasionally exposed	3
	Rarely exposed	2
	Very rarely exposed	1
Risk Level	High risk – high probability of occurring, immediate action needed	>60
	Substantial Risk – medium probability of occurring action needed.	>40-60
	Low Risk – low probability of occurring	0-40

Risk Matrix: Risk rating for the probability of subsidence to occur

Appendix 1: Baseline Risk Assessment – Underground Workings beneath Surface Structures										
Hazards	**Hazard Consequences**	**Initial Risk Value**				Eliminate → Control → Minimize → PPE → Monitor	**Final Risk Value**			
		P	**S**	**E**	**R**		**P**	**S**	**E**	**R**
Pillar Stability	**Insufficient design resulting in pillar failure and subsidence.**	3	4	5	60	1. Ensure to design pillars according to the guidelines set apart for South African Coal mines for the protection of surface structures. The minimum recommended safety factor is 2. 2. Pillar safety factor calculations must be conducted according to site specific formulas. 3. Pillars in shallow mining areas (<40m below surface) may not be developed beneath critical surface structures i.e. no mining beneath surface structures in shallow mining areas. 4. Pillars below surface structures must be designed with increased safety factors (>2) which considers the life of the pillar. 5. Adhere to the shallow mining guidelines set apart by the Chamber of Mines Research organization. 6. Ensure to monitor pillar stability underground, reassess the pillar design (re-design) annually to determine compliance. 7. Ensure rock engineering involvement throughout the mining process, including geotechnical logging and strength analysis of site specific strata layers. 8. Do not conduct any form of pillar extraction or higher percentage extraction in areas where the protection of the surface is vital without a written investigation from the rock engineering practitioner which ensures surface stability.	2	3	3	18

Roof Stability	**Excessive spans resulting in roof failures that can extend to surface resulting in subsidence.**	3	3	5	45	1. Ensure that the bord widths and intersection diagonal distances are designed according to the site-specific strength parameters (uniaxial tensile strength, young's modulus and uniaxial compressive strength, slake durability and Duncan swell tests) of the immediate roof strata. Incorporate a factor of safety of at least 2 in support design strategies. 2. Ensure to support in time according to a site-specific support design which must be compiled according to site specific geotechnical strength parameters (impact splitting data must be included). 3. Ensure to mine according to the designed maximum allowable parameters. 4. Do not exceed the maximum allowable design parameters. Offline mining must not be tolerated. In areas where offline mining has occurred implement remedial measures where the spans have been exceeded. 5. Implement monitoring devices to monitor roof deflection with remedial measures in the case of activation. 6. Ensure rock engineering involvement throughout the mining process.	2	3	2	12
Shallow Mining (<40m below surface)	**Increased risk of subsidence.**	1	4	5	20	1. Ensure that pillars are designed in accordance with at least the minimum required site specific shallow mining guidelines which adheres to the guidelines as set apart by the Chamber of Mines for mines situated below 40m from surface. 2. Support design must take into consideration the depth of weathering and shallow mining specific strength parameters for the immediate roof strata as well as long term stability of roof support. The depth of weathering must be determined by the geologist or during geotechnical logging. 3. Do not open spans beneath surface structures that needs to be protected unless a rock engineering practitioner has assessed the conditions, gives measures to ensure long term (>100 years) surface stability, etc. 4. Do not open intersections beneath surface structures. 5. Ensure rock engineering involvement throughout the mining process. 6. Monitoring devices must be implemented in every intersection in normal shallow mining areas where surface structures are not present to assist with monitoring roof conditions. 7. Monitor pillar, bord and intersection dimensions in normal shallow mining areas where surface structures are not present to ensure that the designed parameters are followed. Implement remedial measures where required.	1	4	3	12

Underground Blasting	**Blasting practices resulting in excessive ground vibrations causing damage to surface structures.**	3	4	2	24	1. Ensure that a proper blast design is compiled for the underground operation that incorporates site specific parameters and characteristics of the material that will be blasted. 2. Ensure that the blast design in close proximity to surface structures adheres to the minimum PPVs <6mm/s. (PPV = Peak Particle Velocity). 3. Do not blast within 60m of surface structures. 4. Ensure to monitor blasting PPVs during blasting operations both underground and on surface. If required redesign to ensure adherence to the minimum allowable PPVs. 5. Ensure that a qualified blaster (blast engineer) is appointed to conduct the blast design.	2	3	2	12
Higher percentage extraction (pillar extraction, secondary extraction etc.)	**Pilar failures or roof failures resulting in surface subsidence.**	4	5	5	10 0	1. Do not conduct pillar extraction or any form of higher extraction beneath surface structures in especially shallow mining conditions. 2. Do not conduct pillar extraction or any form of higher extraction beneath surface structures in deeper lying areas without a proper investigation by a qualified experienced rock engineering practitioner who must give guidelines as to how ensure surface stability. 3. Do not conduct pillar robbing or barrier mining. 4. Ensure rock engineering involvement throughout the mining process.	2	4	2	16

7. Conclusion

Stability of the overlying surface structures can be ensured by implementing the risk assessment and the associated control measures. Monitoring the implementation of the measures from start of mining is key to ensuring not only the long term stability of the surface structures but also the stability of the underground workings.

Once mining commences a proper operational blast design and code of practice must be compiled, implemented, monitored, evaluated and improved. Alternative blasting techniques such as Electronic Detonation can also be implemented, which has a much lower impact in terms of vibrations.

8. References

VAN DER MERWE, J. N. AND MADDEN, B. J. Rock Engineering for underground coal mining – Second Edition. South African Institute of Mining and Metallurgy. 2010.

HILL, D. 2005. Coal Pillar Design Criteria for Surface Protection, in Aziz, N (ed). Coal 2005: Coal Operators Conference. University of Wollongong & the Australasian Institute of Mining and Metallurgy, 2005, 31-38.

WAGNER (1974) AND COOK ET AL (1971) in VAN DER MERWE, J. N. AND MADDEN, B. J. Rock Engineering for underground coal mining. South African Institute of Mining and Metallurgy. 2002.

RANGASAMY, T, (2018) Certificate in Rock Mechanics Part 3.4: Surface Mining (Hard and Soft Rock). Middindi Consulting (PTY) LTD.

RORKE, A.J., 2011, Blasting Impact Assessment for the proposed New Largo Colliery based on New Largo Mine Plan 6.

VAN DER MERWE, N., (1993). Revised strength factor for coal in the Vaal Basin. South African Institute of Mining and Metallurgy, vol. 93, no 3. pp. 71-77. March.

CANBULAT, I AND MADDEN, B.J. Shallow depth mining considerations. The South African Institute of Mining and Metallurgy 3rd Southern African Rock Engineering Symposium. October 2005.