Assessment of Environmental Impact of Blasting Associated with the Proposed Highthorn Development, Northumberland

BANKS MINING

_____

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

QUALITY MANAGEMENT

Report Title: Assessment of Environmental Impact
of Blasting Associated with the Proposed
Highthorn Development, Northumberland

Client: Banks Mining

Report Number: R15.8783/3/DW

Issue Date: 19 August 2015

Prepared By: **Checked By:**

Daniel Williams **David Johnson**
Consultant **Director**

Vibrock Limited
Shanakiel
Ilkeston Road, Heanor
Derbyshire, DE75 7DR
Tel: +44 (0) 1773 711211
Fax: +44 (0) 1773 711311
Email: vibrock@vibrock.com
Web: www.vibrock.com

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

CONTENTS

TABLES

FIGURE

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

1.0   INTRODUCTION

1.1   At the request of Banks Mining, Vibrock Limited, an independent firm of environmental consultants, was commissioned to undertake a blast induced vibration study of proposals for the Highthorn development located to the east of Widdrington Station, Northumberland.

1.2   It is understood that this report will accompany the application for planning permission to be submitted to Northumberland County Council.

1.3   This study benefits from a site inspection undertaken on 26 June 2015.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

2.0   SITE DESCRIPTION

2.1   The proposed development area is located to the east of Widdrington Station and to the north west of Cresswell in Northumberland. A number of isolated residential properties lie around the site boundary. Parts of the site are likely to contain hard bands of overburden material (rock) which will need to be fractured to enable it to be excavated from the mining void. This rock is fractured using controlled explosive charges.

2.2   The optimum blast design may vary from blast to blast and will necessarily be decided by the site operator with reference to the site specific conditions and in order to comply with the recommended vibration criteria.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

3.0   EFFECTS OF BLASTING

3.1   When an explosive detonates within a borehole stress waves are generated causing very localised distortion and cracking.   Outside of this immediate vicinity, however, permanent deformation does not occur.   Instead, the rapidly decaying stress waves cause the ground to exhibit elastic properties whereby the rock particles are returned to their original position following the passage of the stress waves. Such vibration is always generated even by the most well designed and executed of blasts and will radiate away from the blast site attenuating as distance increases.

3.2   With experience and knowledge of the factors which influence ground vibration, such as blast type and design, site geology and receiving structure, the magnitude and significance of these waves can be accurately predicted at any location.

3.3   Vibration is also generated within the atmosphere where the term air overpressure is used to encompass both its audible and sub-audible frequency components.   Again, experience and knowledge of blast type and design enables prediction of levels and an assessment of their significance. In this instance, predictions can be made less certain by the fact that air overpressure levels may be significantly influenced by atmospheric conditions. Hence the most effective method of control is its minimisation at source.

3.4   It is important to realise that for any given blast it is very much in the operator's interest to always reduce vibration, both ground and airborne to the minimum possible in that this substantially increases the efficiency and hence economy of blasting operations.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

4.0 BLAST VIBRATION TERMINOLOGY

4.1 Ground Vibration

4.1.1 Vibration can be generated within the ground by a dynamic source of sufficient energy. It will be composed of various wave types of differing characteristics and significance collectively known as seismic waves.

4.1.2 These seismic waves will spread radially from the vibration source decaying rapidly as distance increases.

4.1.3 There are four interrelated parameters that may be used in order to define ground vibration magnitude at any location. These are:-

Displacement - the distance that a particle moves before returning to its original position, measured in millimetres (mm).

Velocity - the rate at which particle displacement changes, measured in millimetres per second (mms^{-1}).

Acceleration - the rate at which the particle velocity changes, measured in millimetres per second squared (mms^{-2}) or in terms of the acceleration due to the earth's gravity (g).

Frequency - the number of oscillations per second that a particle undergoes measured in Hertz (Hz).

4.1.4 Much investigation has been undertaken, both practical and theoretical, into the damage potential of blast induced ground vibration. Among the most eminent of such research authorities are the former United States Bureau of Mines (USBM), Langefors and Kihlström, and Edwards and Northwood. All have concluded that the vibration parameter best suited as a damage index is particle velocity.

4.1.5 Studies by the USBM have clearly shown the importance of adopting a monitoring approach that also includes frequency.

4.1.6 Thus the parameters most commonly used in assessing the significance of an impulsive vibration are those of particle velocity and frequency which are related for sinusoidal motion as follows:-

$$PV = 2 \pi f a$$

where
$$PV = \text{particle velocity}$$
$$\pi = \text{pi}$$
$$f = \text{frequency}$$
$$a = \text{amplitude}$$

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

4.1.7   It is the maximum value of particle velocity in a vibration event, termed the peak particle velocity, that is of most significance and this will usually be measured in three independent, mutually perpendicular directions at any one location in order to ensure that the true peak value is captured. These directions are longitudinal (or radial), vertical and transverse.

4.1.8   Such maximum of any one plane measurements is the accepted standard worldwide and as recommended by the British Standards Institution and the International Standards Organisation amongst others. It is also the basis for all the recognised investigations into satisfactory vibration levels with respect to damage of structures and human perception.

4.1.9   British Standard 7385 states that there is little probability of fatigue damage occurring in residential building structures due to blasting. The increase of the component stress levels due to imposed vibration is relatively nominal and the number of cycles applied at a repeated high level of vibration is relatively low. Non-structural components (such as plaster) should incur dynamic stresses which are typically well below, i.e. only 5% of, component yield and ultimate strengths.

4.1.10 All research and previous work undertaken has indicated that any vibration induced damage will occur immediately if the damage threshold has been exceeded and that there is no evidence of long term effects.

4.2   Airborne Vibration

4.2.1   Whenever an explosive is detonated transient airborne pressure waves are generated.

4.2.2   As these waves pass a given position, the pressure of the air rises very rapidly to a value above the atmospheric or ambient pressure. It then falls more slowly to a value below atmospheric before returning to the ambient value after a series of oscillations. The maximum pressure above atmospheric is known as the peak air overpressure.

4.2.3   These pressure waves will comprise of energy over a wide frequency range. Energy above 20 Hz is perceptible to the human ear as sound, whilst that below 20 Hz is inaudible, however, it can be sensed in the form of concussion. The sound and concussion together is known as air overpressure which is measured in terms of decibels (dB) or pounds per square inch (p.s.i.) over the required frequency range.

4.2.4   The decibel scale expresses the logarithm of the ratio of a level (greater or less) relative to a given base value. In acoustics, this reference value is taken as 20×10^{-6} Pascals, which is accepted as the threshold of human hearing.

4.2.5   Air overpressure (AOP) is therefore defined as:-

$$\text{AOP, dB} = 20 \, \text{Log} \, \frac{\text{(Measured pressure)}}{\text{(Reference pressure)}}$$

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

4.2.6   Since both high and low frequencies are of importance no frequency weighting network is applied, unlike in the case of noise measurement when an A - weighted filter is employed.

4.2.7   All frequency components, both audible and inaudible, can cause a structure to vibrate in a way which can be confused with the effects of ground vibrations.

4.2.8   The lower, inaudible, frequencies are much less attenuated by distance, buildings and natural barriers. Consequently, air overpressure effects at these frequencies can be significant over greater distances, and more readily excite a response within structures.

4.2.9   Should there be perceptible effects they are commonly due to the air overpressure inducing vibrations of a higher, audible frequency within a property and it is these secondary rattles of windows or crockery that can give rise to comment.

4.2.10   In a blast, airborne pressure waves are produced from five main sources:-

(i)   Rock displacement from the face
(ii)   Ground induced airborne vibration
(iii)   Release of gases through natural fissures
(iv)   Release of gases through stemming
(v)   Insufficiently confined explosive charges

4.2.11   Meteorological factors over which an operator has no control can influence the intensity of air overpressure levels at any given location. Thus, wind speed and direction, temperature and humidity at various altitudes can have an effect upon air overpressure.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

5.0   VIBRATION CRITERIA

5.1   Introduction

5.1.1   When defining damage to residential type structures the following classifications are used:-

Cosmetic or threshold   -   the formation of hairline cracks or the growth of existing cracks in plaster, drywall surfaces or mortar joints.

Minor   -   the formation of large cracks or loosening and falling of plaster on drywall surfaces, or cracks through bricks/concrete blocks.

Major or structural   -   damage to structural elements of a building.

5.1.2   Published damage criteria will not necessarily differentiate between these damage types but rather give levels to preclude cosmetic damage and therefore automatically prevent any more severe damage.

5.2   United States Bureau of Mines

5.2.1   The comprehensive research programme undertaken by the United States Bureau of Mines (USBM) (R.I. 8507, 1980) determined that vibration values well in excess of 50 mms^{-1} are necessary to produce structural damage to residential type structures. The onset of cosmetic damage can be associated with lower vibration levels, especially at very low vibration frequencies, and a limit of 12.7 mms^{-1} is therefore recommended for such relatively unusual vibration. For the type of vibration associated with open pit blasting in this country, the safe vibration levels are seen to be from 19 - 50 mms^{-1}.

5.2.2   A further USBM publication (Bureau of Mines Technology Transfer Seminar, 1987) states that these safe vibration levels are "….for the worst case of structure conditions….", and that they are "….independent of the number of blasting events and their durations", and that no damage has occurred in any of the published data at vibration levels less than 12.7 mms^{-1}.

5.2.3   Any doubt that such low levels of vibration are perfectly safe should be dispelled by considering the strain induced within a residential type property from daily environmental changes and domestic activities. This is confirmed within the 1987 USBM publication which quotes that daily changes in humidity and temperature can readily induce strain of the order that is equivalent to blast induced vibration of from 30 - 75 mms^{-1}. Typical domestic activities will produce strain levels corresponding to vibration of up to 20 mms^{-1} and greater.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

5.2.4 It is for this reason that many domestic properties will exhibit cracks that may be wrongly attributed to blasting activities. There are many additional reasons why properties will develop cracks, for example:-
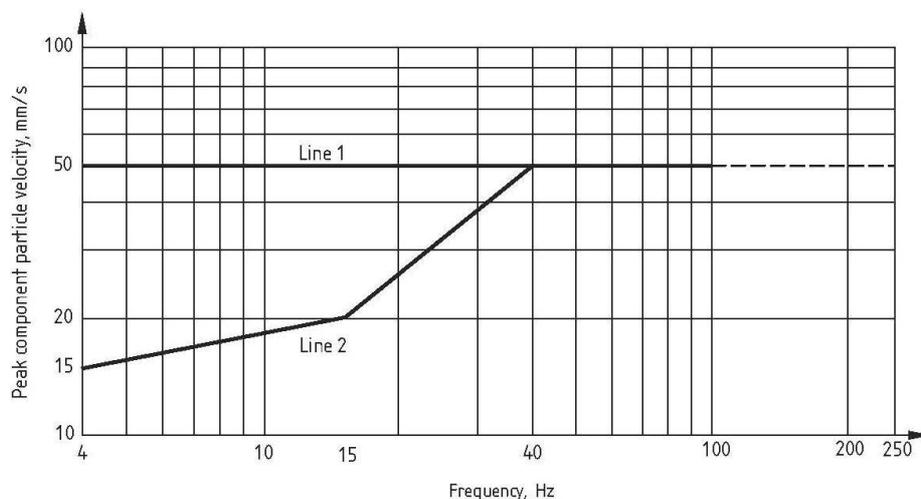
a) Fatigue and ageing of wall coverings;
b) Drying out of plaster finishes;
c) Shrinkage and swelling of wood;
d) Chemical changes in mortar, bricks, plaster and stucco;
e) Structural overloading;
f) Differential foundation settlement - particularly after times of prolonged dry spells.

5.3 British Standard 7385-2: 1993 - Evaluation and Measurement for Vibration in Buildings: Guide to Damage Levels from Groundborne Vibration

5.3.1 The British Standards Institution's structural damage committee have investigated impulsive vibration with respect to its damage potential. They contacted some 224 organisations, mainly British, and found no evidence of any damage at levels less than those recommended by the USBM. The investigation culminated in British Standard 7385: Part 2: 1993.

5.3.2 British Standard 7385 gives guide values to prevent cosmetic damage to property. Between 4 Hz and 15 Hz, a guide value of 15 - 20 mms^{-1} is recommended, whilst above 40 Hz the guide value is 50 mms^{-1}. These vibration criteria reconfirm those of the USBM:

Line	Type of Building	Peak component particle velocity in frequency range of predominant pulse	
		4 Hz to 15 Hz	**15 Hz and above**
1	Reinforced or framed structures	50 mms^{-1} at 4 Hz and above	50 mms^{-1} at 4 Hz and above
	Industrial and heavy commercial buildings		
2	Unreinforced or light framed structures	15 mms^{-1} at 4 Hz increasing to 20 mms^{-1} at 15 Hz	20 mms^{-1} at 15 Hz increasing to 50 mms^{-1} at 40 Hz and above
	Residential or light commercial buildings		
Note 1 – values referred to are at the base of the building			
Note 2 – for line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) is not to be exceeded			

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

Transient vibration guide values for cosmetic damage (BS 7385-2: 1993, pg 6)

5.3.3   All research and previous work undertaken has indicated that any vibration induced damage will occur immediately if the damage threshold has been exceeded and that there is no evidence of long term effects.

5.3.4   Whilst cosmetic damage levels range from 15 to 50 mms^{-1}, according to BS 7385: Part 2, "Minor damage is possible at vibration magnitudes which are greater than twice those given for cosmetic damage, and major damage to a building structure may occur at values greater than four times the tabulated values". Hence vibration levels necessary for structural damage within property are accepted to be around 200 mms^{-1} and above.

5.4   BS 5228-2: 2009 + A1: 2014, Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration

5.4.1   Damage threshold criteria for transient vibration within British Standard 5228-2: 2009 + A1: 2014 is guided by the tabulated levels contained within BS 7385-2: 1993.

5.5   Planning Practice Guidance to the National Planning Policy Framework (2014)

5.5.1   In March 2014 the Planning Practice Guidance was issued by the Government as a framework for assessing the environmental impacts of mineral extraction in England.

5.5.2   The guidance document states that the environmental impact of blasting operations should be assessed but does not provide an assessment framework or guidance on relevant planning conditions. The British Standards and other documents detailed within this report however provide relevant guidance which is in line with the vibration criteria detailed within the former Mineral Planning Guidance notes MPG 9 and 14, archived in March 2014.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

5.5.3   The former MPG 9 and 14 stated that planning conditions should provide for limits on the timing of blasts and on ground vibrations received at sensitive properties, for monitoring to ensure that the limits are not exceeded and for methods to be employed minimising air overpressure.

5.5.4   Acceptable ground vibration criteria within the former MPG 9 and 14 suggested a range of between 6 to 10 mms^{-1} at a 95% confidence level measured at sensitive property, with no individual blast to exceed 12 mms^{-1}.

5.6   The Environmental Effects of Production Blasting from Surface Mineral Workings, DETR (Vibrock Limited)

5.6.1   These same criteria are also recommended within the 1998 Department of the Environment Transport and The Regions research publication, The Environmental Effects of Production Blasting from Surface Mineral Workings.

5.6.2   This same DETR publication also notes that "It would appear that over the years conditions have become progressively more stringent. No doubt this is as a result of MPAs seeking to reduce the number of complaints and by operators seeking to resolve issues more quickly. However, a reduction in complaints will not necessarily follow".

5.6.3   Indeed, one of the principal findings of the study which led to this publication is "Once the threshold of perception had been crossed the magnitude of vibration seemed to bear little relation to the level of resulting complaint".

5.6.4   An explanation of the necessity to use explosives and the likely effects as perceived by a site's neighbours can allay the concern of a significant proportion of those inhabitants of neighbouring property. It is invariably the case that an operator will consider the perception threshold level prior to the design of each and every blast at a particular site.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

5.7   Air Overpressure

5.7.1   Comprehensive investigations into the nature and effects of air overpressure with particular reference to its damage potential have been undertaken by the United States Bureau of Mines (R.I. 8485, 1980).

5.7.2   The weakest parts of most structures that are exposed to air overpressure are windows. Poorly mounted, and hence pre-stressed windows might crack at around 150 dB (0.1 p.s.i.) with most cracking at 170 dB (1.0 p.s.i.). Structural damage can be expected at 180 dB (3.0 p.s.i.).

5.7.3   The recommendations by the United States Bureau of Mines are as follows:-

Instrument Response	Maximum Recommended Level (dB)
0.1 Hz high pass	134
2.0 Hz high pass	133
5.0 or 6.0 Hz high pass	129
C- Slow	105 dB (C)

5.7.4   This set of criteria is based on minimal probability of the most superficial type of damage in residential-type structures, the single best descriptor being recommended as the 2 Hz high pass system (R.I. 8485, 1980).

5.7.5   Guidance on air overpressure levels are contained within BS 6472-2: 2008, which states the previously discussed research by USBM. According to BS 6472-2: 2008, "air overpressure levels measured at properties near quarries in the United Kingdom are generally around 120 dB(lin), which is 30 dB(lin) below, or only 3% of, the limit for cracking pre-stressed poorly mounted windows". The British Standard further suggests that due to the variable effects of the weather conditions at the time of any blast, the aim should always be to minimise air overpressure at source by giving careful consideration to blast design and implementation.

5.7.6   Guidance contained within the previously mentioned 1998 DETR publication and the former MPG 9 and 14 does not recommend an air overpressure limit, rather the operator should submit methods to minimise air overpressure to the Mineral Planning Authority.

5.7.7   With a sensible ground vibration limitation the economics of safe and efficient blasting will automatically ensure that air overpressures are kept to reasonable levels.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

5.8   Perception Levels

5.8.1   The fact that the human body is very sensitive to vibration can result in subjective concern being expressed at energy levels well below the threshold of damage.

5.8.2   A person will generally become aware of blast induced vibration at levels of around 1.5 mms^{-1}, although under some circumstances this can be as low as 0.5 mms^{-1}. Even though such vibration is routinely generated within any property and is also entirely safe, when it is induced by blasting activities it is not unusual for such a level to give rise to subjective concern. Such concern is also frequently the result of the recent discovery of cracked plaster or brickwork that in fact has either been present for some time or has occurred due to natural processes.

5.8.3   It is our experience that virtually all complaints regarding blasting arise because of the concern over the possibility of damage to owner-occupied properties. Such complaints are largely independent of the vibration level. In fact, once an individual's perception threshold is attained, complaints can result from 3% to 4% of the total number of blasts, irrespective of their magnitude.

5.9   British Standard 6472–2: 2008 - Guide to evaluation of human exposure to vibration in buildings: Part 2: Blast-induced vibration

5.9.1   This document discusses how and where to measure blast-induced vibration and gives maximum satisfactory magnitudes of vibration with respect to human response. Satisfactory magnitudes are given as 6 to 10 mms^{-1} at a 90% confidence level as measured outside of a building on a well-founded hard surface as close to the building as possible.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

5.9.2   Maximum satisfactory magnitudes of vibration with respect to human response for up
to three blast vibration events per day are detailed within Table 1 of BS 6472-2: 2008:

Place	Time	Satisfactory magnitude[A] (ppv mms^{-1})
Residential	Day [D]	6.0 to 10.0 [C]
	Night [D]	2.0
	Other times [D]	4.5
Offices [B]	Any time	14.0
Workshops [B]	Any time	14.0

A)   The satisfactory magnitudes are the same for the working day and the rest day unless
otherwise stated;

B)   Critical working areas where delicate tasks impose more stringent criteria than human
comfort are outside the scope of this standard;

C)   With residential properties people exhibit a wide variation of tolerance to vibration. Specific
values are dependent upon social and cultural factors, psychological attitudes and the
expected degree of intrusion. In practice the lower satisfactory magnitude should be used
with the higher magnitude being justified on a case-by-case basis;

D)   For the purpose of blasting, daytime is considered to be 08h00 to 18h00 Monday to Friday
and 08h00 to 13h00 Saturday. Routine blasting would not normally be considered on
Sundays or Public Holidays. Other times cover the period outside of the working day but
exclude night-time, which is defined as 23h00 to 07h00.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

6.0   PREDICTION AND CONTROL OF VIBRATION LEVELS

6.1   Ground Vibration

6.1.1   The accepted method of predicting peak particle velocity for any given situation is to use a scaling approach utilising separation distances and instantaneous charge weights. This method allows the derivation of the site specific relationship between ground vibration level and separation distance from a blast.

6.1.2   A scaled distance value for any location may be calculated as follows:-

Scaled Distance,	SD	=	$DW^{-\frac{1}{2}}$ in $mkg^{-\frac{1}{2}}$

where

D	=	Separation distance (blast to receiver) in metres
W	=	Maximum Instantaneous Charge (MIC) in kg
		i.e. maximum weight of explosive per delay interval in kg

6.1.3   For each measurement location the maximum peak particle velocity from either the longitudinal, vertical or transverse axis is plotted against its respective scaled distance value on logarithmic graph paper.

6.1.4   An empirical relationship derived by the USBM relates ground vibration level to scaled distance as follows:-

$$PV = a\,(SD)^{b}$$

where

PV	=	Maximum Peak Particle Velocity in mms^{-1}
SD	=	Scaled Distance in $mkg^{-\frac{1}{2}}$
a,b	=	Dimensionless Site Factors

6.1.5   The site factors a and b allow for the influence of local geology upon vibration attenuation as well as geometrical spreading. The values of a and b are derived for a specific site from least squares regression analysis of the logarithmic plot of peak particle velocity against scaled distance which results in the mathematical best fit straight line where

	a	is the peak particle velocity intercept at unity scaled distance
and	b	is the slope of the regression line

6.1.6   In almost all cases, a certain amount of data scatter will be evident, and as such statistical confidence levels are also calculated and plotted.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

6.1.7   The statistical method adopted in assessing the vibration data is that used by Lucole and Dowding. The data is presented in the form of a graph showing the attenuation of ground vibration with scaled distance and results from log - normal modelling of the velocity distribution at any given scaled distance. The best fit or mean (50%) line as well as the upper 95% confidence level are plotted.

6.1.8   The process for calculating the best fit line is the least squares analysis method. The upper 95% confidence level is found by multiplying the mean line value by 1.645 times 10 raised to the power of the standard deviation of the data above the mean line. A log - normal distribution of vibration data will mean that the peak particle velocity at any scaled distance tends to group at lower values.

6.1.9   From the logarithmic plot of peak particle velocity against scaled distance, for any required vibration level it is possible to relate the maximum instantaneous charge and separation distance as follows:-

Maximum Instantaneous Charge (MIC) = $(D/SD)^2$

Where D   =   Separation distance (blast to receiver) in metres
      SD   =   Scaled Distance in $mkg^{-\frac{1}{2}}$ corresponding to the vibration level required

6.1.10 The scaled distance approach assumes that blast design remains similar between those shots used to determine the scaling relationship between vibration level and separation distance and those for which prediction is required. For prediction purposes, the scaling relationship will be most accurate when calculations are derived from similar charge weight and distance values.

6.1.11 The main factors in blast design that can affect the scaling relationship are the maximum instantaneous charge weight, blast ratio, free face reflection, delay interval, initiation direction and blast geometry associated with burden, spacing, stemming and subdrill.

6.1.12 Although the instantaneous explosive charge weight has perhaps the greatest effect upon vibration level, it cannot be considered alone, and is connected to most aspects of blast design through the parameter blast ratio.

6.1.13 The blast ratio is a measure of the amount of work expected per unit of explosive, measured for example in tonnes of rock per kilogramme of explosive detonated (tonnes/kg), and results from virtually all aspects of a blast design, i.e. hole diameter, depth, burden, spacing, loading density and initiation technique.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

6.1.14 The scaled distance approach is also strictly valid only for the specific geology in the direction monitored. This is evident when considering the main mechanisms which contribute to ground motion dissipation:-

(i)   Damping of ground vibrations, causing lower ground vibration frequencies with increasing distance.
(ii)   Discontinuities causing reflection, refraction and diffraction.
(iii)   Internal friction causing frequency dependent attenuation, which is greater for coarser grained rocks.
(iv)   Geometrical spreading.

6.1.15 In practice similar rates of vibration attenuation may occur in different directions, however, where necessary these factors should be routinely checked by monitoring, especially on sites where geology is known to alter.

6.1.16 Where it is predicted that the received levels of vibration will exceed the relevant criteria, the operator will have to reduce the maximum instantaneous explosive charge weight. One method of achieving such a reduction is to deck the explosives within the borehole. This technique splits the column of explosives in two, separated by inert material. If blasting is required at closer distances than that where double decking would be a successful strategy, other charge reduction methods would have to be employed. These could be more complex decking strategies or changes to the blast geometry and / or the use of smaller diameter boreholes.

6.2   Airborne Vibration

6.2.1   Airborne vibration waves can be considered as sound waves of a higher intensity and will, therefore, be transmitted through the atmosphere in a similar manner. Thus meteorological conditions such as wind speed, wind direction, temperature, humidity and cloud cover and how these vary with altitude, can affect the level of the air overpressure value experienced at a distance from any blast.

6.2.2   If a blast is fired in a motionless atmosphere in which the temperature remains constant with altitude then the air overpressure intensity will decrease purely as a function of distance. In fact, each time the distance doubles the air overpressure level will decrease by 6dB. However, such conditions are very rare and it is more likely that a combination of the factors mentioned above will increase the expected intensity in some areas and decrease it in others.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

6.2.3   Given sufficient meteorological data it is possible to predict these increases or decreases. However, to be of use this data must be both site specific and of relevance to the proposed blasting time. In practice this is not possible because the data is obtained from meteorological stations at some distance from the blast site and necessarily at some time before the blast is to be detonated. The ever changing British weather therefore causes such data to be rather limited in value and its use clearly counter productive if it is not relevant to the blast site at the detonation time. In addition, it would not normally be safe practice to leave charged holes standing for an unknown period of time.

6.2.4   It is because of the variability of British weather that it is standard good practice to control air overpressure at source and hence minimise its magnitude at distance, even under relatively unfavourable conditions.

6.2.5   Such control is achieved in a well designed and executed blast in which all explosive material is adequately confined. Thus particular attention must be given to accurate face profiling and the subsequent drilling and correct placement of explosive within any borehole, having due regard to any localised weaknesses in the strata including overbreak from a previous shot, clay joints and fissured ground.

6.2.6   Stemming material should be of sufficient quantity and quality to adequately confine the explosives, and care should be taken in deciding upon the optimum detonation technique for the specific site circumstances.

6.2.7   Although there will always be a significant variation in observed air overpressure levels at a particular site it is possible to predict a range of likely values given sufficient background information and/or experience. In this respect, past recordings may be analysed according to the cube root scaled distance approach to provide a useful indication of future levels.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

7.0   BLAST INDUCED VIBRATION MEASUREMENTS

7.1   Blast vibration data monitored at opencast coal sites working similar strata to that at Highthorn has been accessed from the Vibrock database.

7.2   The resulting regression line formed from this data has been used in order to be able to predict the anticipated future vibration levels at the various adjacent vibration sensitive locations and also to establish the likely allowable instantaneous charge weights when operations approach such features.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

8.0 DISCUSSION

8.1 Interpretation of the regression curve has been undertaken for the adjacent structures and services listed in Table 3 and Figure 1.

8.2 Table 1 gives the allowable instantaneous explosive charge weights in order to comply with the recommended site vibration criterion at residential property of 6 mms^{-1} at the given separation distances.

8.3 The closest residential properties are Highthorn to the south of the development and the properties at Hemscott Hill to the east of the development area at separation distances of 180 m and 440 m respectively from the area of excavation.

8.4 Table 2 gives the allowable instantaneous explosive charge weights in order to comply with the recommended site vibration criterion at electricity pylons and telegraph poles of 50 mms^{-1} at the given separation distances. A maximum instantaneous charge weight of 50 kg could be used 66 metres from such infrastructure whilst complying with the recommended vibration criterion.

8.5 Table 3 details the predicted vibration levels when blasting in the proposed extraction area and employing an instantaneous explosive charge weight of 50 kg, again at the nearest possible distance of approach to the locations given. A maximum instantaneous explosive charge weight of 50 kg has been used in the predictions based on our experience of similar operations in the area. The MIC will however be determined on a blast by blast basis with reference to the site specific conditions in order to comply with the recommended vibration criterion.

8.6 The predicted maximum vibration levels given will only occur when blasting at the nearest possible distance of approach to the respective locations.

8.7 As such, the vast majority of blasting events within the extraction area will be significantly below the levels given.

Houndalee Cottages East

8.8 Utilising a maximum explosive charge weight of 50 kg the maximum likely predicted vibration level from blasting operations at the closest approach is 1.6 mms^{-1}.

8.9 Such a magnitude of vibration is well within the relevant British Standard guidance for the prevention of cosmetic damage and human exposure of blast induced vibration, and well within the recommended vibration criterion of 6 mms^{-1} at 95% confidence level.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

Stonecroft

8.10   The property of Stonecroft is located to the north of the proposed development. When blasting operations are at the closest approach, a maximum likely vibration level of 0.8 mms^{-1} is predicted, well within the recommended site vibration criterion.

High Chibburn

8.11   Considering the utilisation of instantaneous explosive charge weights of up to 50 kg, a maximum likely vibration level of 0.9 mms^{-1} is predicted at the closest of potential blasting operations to the property.

Druridge Farm Cottages

8.12   Druridge Farm Cottages are located to the north east of the proposed development area. At the closest approach of the workings, a maximum likely vibration level of 1.1 mms^{-1} is predicted, well within the recommended site vibration criterion.

Hemscott Hill

8.13   The properties at Hemscott Hill are located some 440 metres to the east of the closest of potential blasting operations. At the closest approach, a most likely vibration level of 1.9 mms^{-1} and a maximum likely 2.6 mms^{-1} is predicted.

8.14   Although vibration of such magnitude may be perceptible, it is well within the relevant British Standard guidance for the prevention of cosmetic damage, and within the accepted guide values in relation to the human exposure to blast vibration levels.

Blakemoor Farm

8.15   Blakemoor Farm is located to the south east of the proposed development area at Highthorn. The maximum likely vibration level predicted from the closest of potential blasting operations is 0.9 mms^{-1}, which is within the recommended site vibration criterion of 6 mms^{-1}.

Ellington Caravan Park

8.16   Ellington Caravan Park is located to the south of the proposed development area. Blasting operations at the closest distance of approach are predicted to generate a most likely level of 0.7 mms^{-1} and a maximum likely level of 0.9 mms^{-1}, which is well within the relevant British Standard criterion and the recommended site vibration criterion of 6 mms^{-1}.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

Highthorn

8.17   The residential property at Highthorn is the closest residential receptor to the proposed development. When blasting within 258 metres of the property, a reduction in the anticipated maximum instantaneous explosive charge weight, in line with Table 1, will be required in order to attain the recommended vibration criterion of 6mms^{-1} at a 95% confidence level.

Widdrington Station

8.18   The closest residential receptor in Widdrington Station is predicted to receive a most likely vibration level of 0.5 mms^{-1} and a maximum likely vibration level of 0.7 mms^{-1}, which is within the recommended site vibration criterion.

Electricity Pylons and Telegraph Poles

8.19   It is anticipated that any electricity pylons and telegraph poles which cross the site will be re-routed. When blasting in close proximity to such infrastructure however blasts should be designed to comply with a vibration criterion of 50 mms^{-1}, a vibration criterion which has previously been successfully applied to such infrastructure. Reference should be made to Table 2 in order to attain the recommended criterion.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

9.0 CONCLUSIONS

9.1 A criterion for restricting vibration levels from production blasting has been recommended in order to address the need to minimise annoyance to nearby residents. Accordingly, Vibrock recommends a vibration criterion of 6 mms^{-1} for 95% of events as a satisfactory magnitude for vibration from blasting at the Highthorn development.

9.2 All blasts at Highthorn shall be designed in order to comply to a vibration criterion of 6 mms^{-1} peak particle velocity at a 95% confidence level as measured in any of the three planes of measurement.

9.3 All vibration will be of a low order of magnitude and would be entirely safe with respect to the possibility of the most cosmetic of plaster cracks as detailed within British Standard 7385-2: 1993.

9.4 Vibration will also be within those levels recommended for blast induced vibration and human perception as being satisfactory within the previously discussed British Standard Guide BS 6472-2: 2008.

9.5 With such low ground vibration levels accompanying air overpressure would also be of a very low and hence safe level, although possibly perceptible on occasions at the closest of properties.

9.6 At any telegraph poles and electricity pylons adjacent to the development a vibration criterion of 50 mms^{-1} shall apply.

9.7 The vibration predictions contained within this report shall be supplemented by site specific test blast data to verify the predicted levels and allowable maximum instantaneous explosive charge weights.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

10.0 RECOMMENDATIONS

10.1   The following recommendations are presented in order to minimise the vibration impact of blasting operations at Highthorn to nearby residents.

Ground Vibration - Inhabited Property

10.2   We recommend that a ground vibration limit is chosen that not only is perfectly safe for the integrity of structures, but also takes into account the physiological effects on adjacent neighbours. As such we recommend a vibration limit of 6 mms^{-1} peak particle velocity at a 95% confidence level. The limit of 6 mms^{-1} at a 95% confidence level is successful current practice at numerous similar open pit workings within the United Kingdom and also agrees with the relevant British Standards 6472-2: 2008 and BS 7385-2: 1993 and the former MPG 9 and 14.

Air Overpressure

10.3   Our considerable past experience of air overpressure measurement and control leads us to the firm conclusion that it is totally impracticable to set a maximum air overpressure limit, with or without an appropriate percentile of exceedances being allowed, simply because of the significant and unpredictable effect of variable weather conditions. This point is recognised by the DETR publication The Environmental Effects of Production Blasting from Surface Mineral Workings and British Standard 6472-2: 2008.

10.4   With a sensible ground vibration limitation the economics of safe and efficient blasting will automatically ensure that air overpressures are kept to reasonable levels.

10.5   We therefore recommend that in line with the current best accepted modern practice in the extraction industries that safe and practical measures are adopted that ensure the minimisation of air overpressure generated by blasting at source, considering such factors as initiation technique. The mineral operator should submit methods to minimise air overpressure to the Mineral Planning Authority for approval.

Monitoring and Control

10.6   The mineral operator should design blasting operations taking into account the findings of this report.

10.7   It is recommended that blast vibration monitoring is conducted at adjacent properties and utilities in line with a monitoring strategy agreed with the MPA. The results of such monitoring should be used to update the initial test blast regression line. The regression line should be interpreted so that for each blast the correct maximum instantaneous explosive charge weight for adjacent structures and services is utilised.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

11.0 REFERENCES

1.   BS ISO 4866: 2010. Mechanical vibration and shock – Vibration of fixed structures – Guidelines for the measurement of vibrations and evaluation of their effects on structures. British Standards Institution.

2.   BS 6472-2: 2008. Guide to evaluation of human exposure to vibration in buildings, Part 2: Blast-induced vibration. British Standards Institution.

3.   BS 7385: 1993 Evaluation and measurement for vibration in buildings: Part 2. Guide to damage levels from groundborne vibration. British Standards Institution.

4.   BS 5228-2: 2009 + A1:2014, Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration.

5.   Planning Practice Guidance to the National Planning Policy Framework, 2014, Department for Communities and Local Government.

6.   Minerals Planning Guidance Note No. 9, 1992 Planning and Compensation Act 1991: Interim Development Order Permissions (IDOS) - Conditions. Department of the Environment, Welsh Office.

7.   Minerals Planning Guidance Note No. 14, 1995 Environment Act 1995: Review of Mineral Planning Permissions. Department of the Environment, Welsh Office.

8.   The Environmental Effects of Production Blasting from Surface Mineral Workings, Vibrock Report on behalf of the DETR, 1998.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

TABLE 1

ALLOWABLE MAXIMUM INSTANTANEOUS EXPLOSIVE CHARGE WEIGHTS – INHABITED PROPERTY AT HIGHTHORN DEVELOPMENT

From the regression line the corresponding scaled distance value for a vibration criterion of 6 mms^{-1} at a 95% confidence level is 36.44 mkg$^{-\frac{1}{2}}$.

This gives rise to the following allowable maximum instantaneous charge weights at the given blast/receiver separation distances:-

Blast/Receiver Separation Distance (metres)	Allowable Maximum Instantaneous Charge Weight, kg to comply with 6 mms^{-1} at 95% confidence level
180 (Highthorn)	24
200	30
250	47
258	50
300	67
350	92
400	120
440 (Hemscott Hill)	145
450	152
500	188
550	227
600 (Houndalee Cottages East)	271

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

TABLE 2

ALLOWABLE MAXIMUM INSTANTANEOUS EXPLOSIVE CHARGE WEIGHTS – WOODEN ELECTRICITY PYLONS AND TELEGRAPH POLES AT HIGHTHORN DEVELOPMENT

From the regression line the corresponding scaled distance value for a vibration criterion of 50 mms^{-1} at a 95% confidence level is 9.28 mkg$^{-\frac{1}{2}}$.

This gives rise to the following allowable maximum instantaneous charge weights at the given blast/receiver separation distances:-

Blast/Receiver Separation Distance (metres)	Allowable Maximum Instantaneous Charge Weight, kg to comply with 50 mms^{-1} at 95% confidence level
50	29
66	50
70	56
90	94
110	140
130	196

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

TABLE 3

PREDICTED VIBRATION LEVELS
PROPOSED DEVELOPMENT AREA AT HIGHTHORN

Considering a maximum instantaneous charge weight of 50 kg utilised in the area of excavation at the nearest distance of approach to the location considered, the predicted vibration levels are as follows:-

Location	Closest Approach Distance (m)	Vibration Level Peak Particle Velocity (mms^{-1})	
		Mean (50%)	Maximum (95%)
1	600	1.2	1.6
2	930	0.6	0.8
3	910	0.7	0.9
4	770	0.8	1.1
5	440	1.9	2.6
6	850	0.7	0.9
7	890	0.7	0.9
8	180	4.4*	6.0*
9	1000	0.5	0.7

<u>Locations</u> (see Figure 1)

1.   Houndalee Cottages East
2.   Stonecroft
3.   High Chibburn
4.   Druridge Farm Cottages
5.   Hemscott Hill
6.   Blakemoor Farm
7.   Ellington Caravan Park
8.   Highthorn
9.   Widdrington Station

* Maximum instantaneous explosive charge weights reduced in order to comply to vibration criteria.

Assessment of Environmental Impact of Blasting Associated
with the proposed Highthorn Development, Northumberland
19 August 2015

FIGURE 1

PREDICTION LOCATIONS

1. Houndalee Cottages East
2. Stonecroft
3. High Chibburn
4. Druridge Farm Cottages
5. Hemscott Hill
6. Blakemoor Farm
7. Ellington Caravan Park
8. Highthorn
9. Widdrington Station