Macraes Phase III Vibration and Air Blast Assessment

Oceana Gold (New Zealand) Limited

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ORICA
MINING
SERVICES

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Basic Overview

Name: Oceana Gold (New Zealand) Limited (referred to as OceanaGold in this report).

Orica Mining Services has been requested to complete a study of the blasting related environmental effects of their planned mine and submit its report to site.

On site reports:

- Bernie O'Leary
- Alison Paul

Legal contacts:

- Stephen Christensen
- Maree Baker

Brief

Assess the effects of blasting, in particular air blast and vibration, of the proposed Macraes Phase III Project on the Macraes village, the nearest houses to the proposed operation not owned by OceanaGold and the historic buildings in Golden Point Reserve. The assessment will need to be applied to each of the pits proposed to be mined. The preparation of a brief of evidence based on the report is required to be in accordance with the Environment Court Code of Conduct.

1.1 Executive Summary

Predictive models for ground vibration and air blast over-pressure effects from blasting have been established based on historic blast monitoring data and the monitoring results from 6 test holes fired in November 2010.

The following conclusions can be drawn from the predictive modelling work:

- Blast related ground vibration is highly correlated to the maximum mass instantaneous explosives charge weight (MIC) fired in each blast and the distance to the monitoring point
- The closest distance for blasting near the historic buildings within the Golden Point Reserve is proposed to be approximately 750m. At a typical MIC of 630kg, the predicted ground vibration (measured as a peak particle velocity) is less than 5 mm/s.
- The nearest non-company owned building is in the Macraes village and is approximately 1,200m from the nearest open pit. Again, at a typical MIC of 1,600kg, the predicted ground vibration is expected to be less than 5 mm/s.
- Provided peak particle velocity generated from blasting is less than 10mm/s as predicted, then adverse effects from ground vibration are expected to be minor.
- Air blast from blasting is difficult to predict and is affected by a number of factors. These include the MIC, distance from the monitoring point but also temperature, cloud cover, humidity, shielding effects of the open pit walls, stemming depth and quality, presence of groundwater and the nature of the intervening topography.
- These factors will need to be taken into account for all blast designs and provided these are favourable, and then air blast overpressure of less than 120dBL is expected. Effects from air blast overpressure that is less than 120dBL are expected to be minor.

1.2 Introduction

OceanaGold's Macraes Mine has requested collection of information for predicting blast induced ground vibration and air blast from their blasts at Frasers Pit. There is currently one monitor used at the site in accordance with the current consents. It is desirable to predict the vibration and air blast at the closest environmentally sensitive locations prior to blasting proposed as part of Macraes Phase III.

OceanaGold have requested Orica Mining Services to provide a vibration and air blast prediction model for blasting in Frasers pit which can also be used for further predictions. Orica used the actual recorded values and create a statistical tool (which can include more complex models after more data collection) and then moved onto measuring waveforms; a single hole site law; ground p-wave velocity and blast design parameters. From these results a site based law can be created for the remaining areas of interest using the collected seed wave.

The main points of interest identified for a predictive model were The Golden Point Historic Reserve and at the Macraes town, both being the closest public owned building locations. The current statistical analysis uses actual data from the area but does not define these points specifically. Further testing using single hole firing was used to assist with predicting the vibration and air blast at these locations. These predictions can be either projected out to further locations or used as the maximum level for blasts. More specific point measurements can be done if required.

The current consented blasting hours have been set as: Monday to Friday 9am to 5:30pm, Saturday and Sunday 10am to 4:30pm. Blast details are recorded, stored on site and are available to council on request. These are typically set and agreed upon as part of the mines initial set up but in some cases but may be discussed as part of a full review of variations in mine and lease conditions with the relevant regulatory body.

The current consent conditions limit vibration to 5mm/sec at the frequency range of 3-12Hz. This allows for 5% of the total number of blasts over 12 months being up to but not exceeding 10mm/sec. These limits are based on the Australian and New Zealand Environment Council's (ANZEC) "Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration" (1990). The frequency range has been set but there are only very rare occasions that the blast will be in this range. Typically they will be around 20 to 120 hertz. Initial parameters that have been set are based around the standards as outlined in the Australian Standard (AS 2187.2—2006) which outline the structural damage for buildings according to the blasting practices. Note that people in the houses would expect to feel some vibration at firing time but a level of 10 mm/s ppv is widely accepted as being well below the threshold of structural damage to houses *(see AS 2187 – 2 2006 appendix J extracts).* The limitations do change for different structures and can be more stringent depending on the construction and building type or limitations.

Overpressure limits are set to 115 dBL; this allows for 5% of the total number of blasts over 12 months to be up to but not exceeding 120 dBL.

1.3 Geology

The geology of the site consists of mainly Psammite on the hanging wall as well as the footwall. The hanging wall Psammite is inter-layered with softer layers of Pelite which will alter the effect of the vibration. The area of interest to the west of the mine is made up of Psammite with some overlying Cretaceous Sediment and Miocene Volcanics. The rock types should have only a minor effect on the overall vibration when firing in the Frasers and Frasers South pits. When blasting on the eastern side of the major fault that strikes north south overall vibration results may decrease slightly. These effects should not be significant.

1.4 Modelling

Orica Mining Services has constructed a model based on a statistical linear regression type process. This is an analysis of the current data along with additional data sets used to create information that can be used to: predict the blasting parameters; set site rules; and give the ability to predict the results from a blast at a point. The following results show the basic information gathered from previous records (pre 2005) where the mass instantaneous charge (MIC), distance from the shot to the location, and the result was recorded and easily accessible.

1.4.1 Ground Vibration

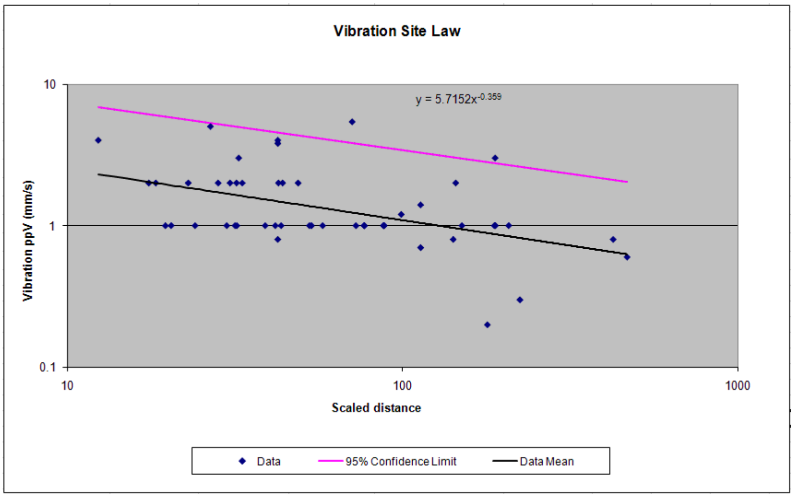

Figure 1: Ground Vibration vs. Scaled Distance using Historic Data

The information in Figure 1 is shown on a logarithmic scale which can be used to display and simply identify the trends of the data. The scaled distance is calculated as the distance (measured in metres) from the blast to the monitoring point divided by the square root of the MIC (measured in kg of explosives charge weight fired instantaneously). The historical data shows a large variation in close data points, using linear regression (see appendix 1) on the information the R square (R^2) value determines the lines "best fit" where the closer to 1 the more accurate the prediction, according to the data. In the case of the initial information, the R^2 value is 0.194 showing that the data is not statistically valid, this is mostly due to the data being collected from a significant distance and a lack of overall spread enabling both far and near points to create a more accurate data spread. The relationship derived in *Figure 1* was not ultimately used for modelling purposes. The more refined relationship shown in Figure 2 was used. More collection points were used at close range and input into the data set to create the following *Figure 2.* The information was also inspected and unreliable data removed.

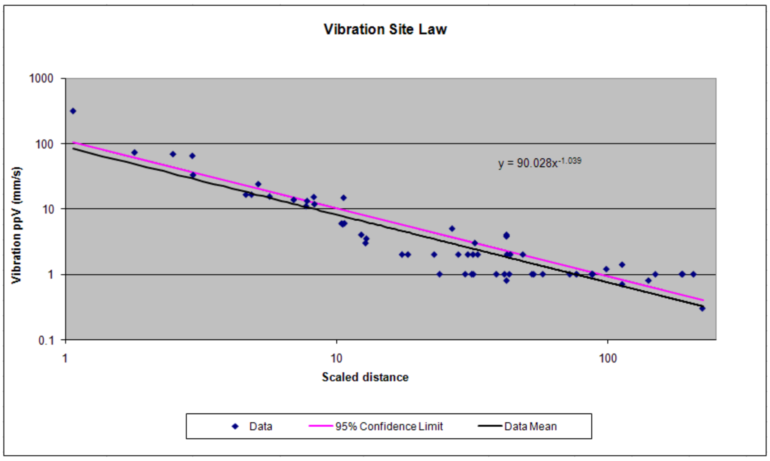

Figure 2: Ground Vibration vs. Scaled Distance using Historic Data and Nov 2010 Test Hole Data

The additional information as well as the data inspection allowed the model to be refined to a more accurate level. This shows an R^2 value of 0.843 which is statistically valid for this type of vibration model to show a confident result.

1.4.2 Air Blast

Air blast data is more difficult to manage due to the general nature of air blasts which are difficult to predict due to the variables that are involved. The following data has been compiled using all of the available data.

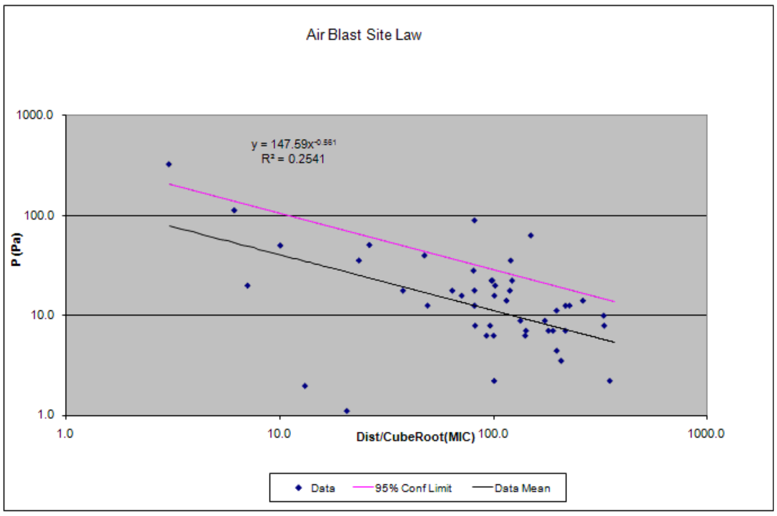

Figure 3: Air Blast P (Pa) vs. Scaled Distance

As shown the air blast data is limited but indicates a trend, note that the regression R^2 value is 0.254 and shows that the data cannot be used reliably. The air blast data suggests that the statistical approach is limited; reduction in overpressure should be controlled through the quality control and assurance phase in blast designing and charging operations in the field. The scaled distance formula for this relationship in *Figure 3* is the distance from the blast divided by the cube root of the MIC.

1.4.3 Modelling Results – Ground Vibration

The Macraes blasting patterns are broken down into two main drill patterns; these are determined based on the presence of ore. They are mined in a similar way using excavators but the ore shots require a significantly finer fragmentation and so they are blasted using a pattern designed with a smaller burden, spacing (and typically) hole diameter. This ensures that the ore is broken to a finer size to reduce additional crushing requirements for further milling in the gold extraction process.

The waste blasts that do not require finer fragmentation can be blasted with a more efficient and cost effective pattern using a larger burden, spacing and hole diameter. This increases the overall charge weight per hole and typically increases the MIC based on similar depths and number of holes initiating during any window of time (typically determined as 8ms). Using the information shown in *Figure 2* the ground vibration will be higher for the waste blasts due to the increased charge weight and overall MIC.

The closest distance proposed for blasting near the historic buildings in the Golden Point Historic Reserve is approximately 750m. Using the waste blast scenario below at the closest point the following results were noted.

Table 1 shows the basic shot parameter using single hole firing in a waste blast.

Diameter of Drill Hole	0.20m
Hole Depth	16.00m
Stemming Length	2.00m
Charge Weight / Metre (1.25g/cm)	39.27kg
Resulting Charge Weight	550.00kg

The modelled results show that the result for this scenario would give a ground vibration of 2.5mm/s, using a 95% confidence limit the result would be shown as 4.7mm/s which is still within acceptable limits.

The closest non-company owned house is in the Macraes Village and is 1200m away from the proposed open pit. The modelled ground vibration at this distance using the same blasting scenario is 1.5mm/s with a 95% confidence limit giving 2.9mm/s.

Ground vibration levels can be controlled and reduced by modifying the blast design parameters. The two main methods where the distance is a set value in decreasing the overall vibration is to load a smaller charge weight per hole by reducing the diameter and/or increasing the stemming and the second is to reduce the MIC within the 8ms window. The first method reduces the amount of product per hole and the second ensures holes have enough time between hole initiations. The stemming length and quality will also affect the airblast as outlined in the next section.

Macraes Mine currently uses both electronic and pyrotechnic detonators, in using pyrotechnic detonators there is a “cap scatter” which refers to the variation in the accuracy of the detonator to fire at the assigned time. The electronic detonator allows the hole timing to be more specific (typically sub millisecond) and allows additional control of the vibration and airblast according to the MIC.

Using quality control in the design, loading and initiation of the shots ground vibration can be controlled at Macraes Gold Mine to achieve less than 5mm/s, there is expected to be no structural damage to these buildings as a result of blasting.

1.4.4 Modelling Results – Air Blast

Air blast is not as easy to define due to its additional complexities, note that the air blast limits are extremely difficult to predict due to the slight changes in temperature, ground layout, cloud cover, humidity, pit geometry, local topography, stemming quality, ground water content/amount or any one of a number of other factors can influence the air blast results. Previous site records have been used to see what types of results have been collected and show extreme variations; the data cannot be used due to the lack of meteorological data available to define external variables.

Through additional modelling, data processing and statistical variation the results at the closest point to the structures indicate that the results would be 124 dBL at a maximum using the model. This was compared with other standard models used in construction blasting showing that the result would be 123.5dBL indicating that the model is relatively reliable. According to the Australian Standard AS2187.2-2006 Appendix J, the limit for damage from air blasting is 133 dBL, this covers the limitations for a buildings weaker structures that may be damaged, windows, etc.
Human comfort levels are classified as follows: 95% of blast less than 115 dBL and 100% less than 120 dBL at a site that is blasting more than 20 times for the life of the project. If it is less than 20 blasts then 95% of blast less than 120 dBL and 100% less than 125 dBL. The model indicates that the air blast should be within the appropriate levels using the MIC noted for the vibration limits, this can be reduced further with increased confinement leading to further reduce the MIC in the crucial zones close to structure. Depending on the mining method the number of blasts will vary but the process in the area is manageable with planning.

Air blast can be additionally controlled/reduced through effective depth of burial which is currently 1.4 (se*e Appendix 1 table 2 Depth of Burial)*. Structure, plains of weakness and stem quality will affect the blast but is able to be managed to reduce overall overpressure. This process of improving stemming quality greatly increases the confinement by using the aggregate shape and size to lock in the energy rather than allow it to "rifle" out of the hole as occurs with some poorer stemming that may not lock in place. Lower grade stemming may "bridge" in the hole which is where it self supports and does not fill the entire length, this is typically due to clay content, oversize pieces or a combination of both. By reducing these potential risks the likelihood of air blast can be significantly decreased.

1.5 Conclusion

The results are in line with previous reports showing that it is extremely unlikely that a ground vibration of 10mm/s would ever be exceeded at the consent monitoring points using the current blasting methods. With overpressure, there have been some instances where previous blasts have been at the limits. Careful blast design (with environmental predictions), through execution of each blast and environmental monitoring will alleviate environmental exceedances. Some areas of the pit will need to have a reduced MIC and others will be able to be increased due to distance and topography. The vibration frequency can be controlled by the initiation timing and along with some shielding techniques to reduce the vibration results if required. These can be specifically mapped in more detail when additional data can be collected.

As an overall conclusion, provided blasting operations continue in a controlled manner similar to the current fashion, adverse effects from ground vibration and air blast are expected to be no more than minor.

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Appendix 1

Linear Regression: The Regression analysis tool performs linear regression analysis by using the "least squares" method to fit a line through a set of observations. You can analyze how a single dependent variable is affected by the values of one or more independent variables. For example, you can analyze how an athlete's performance is affected by such factors as age, height, and weight. You can apportion shares in the performance measure to each of these three factors, based on a set of performance data, and then use the results to predict the performance of a new, untested athlete.

Australian Standard 2187.2 – 2006

APPENDIX J TABLE J4.5(A)

GROUND VIBRATION LIMITS FOR HUMAN COMFORT CHOSEN BY SOME REGULATORY AUTHORITIES (see Notes following Table J4.5(B))

Category	**Type of blasting operations**	**Peak component particle velocity (mm/s)**
Sensitive site*	Operations lasting longer than 12 months or more than 20 blasts.	5 mm/s for 95% blasts per year 10 mm/s maximum unless agreement is reached with the occupier that a higher limit may apply
Sensitive site*	Operations lasting for less than 12 months or less than 20 blasts.	10 mm/s maximum unless agreement is reached with occupier that a higher limit may apply
Occupied non-sensitive sites, such as factories and commercial premises	All blasting	25 mm/s maximum unless agreement is reached with occupier that a higher limit may apply. For sites containing equipment sensitive to vibration, the vibration should be kept below manufacturer's specifications or levels that can be shown to adversely affect the equipment operation

- Sensitive site includes houses & low rise residential buildings, theatres, schools, etc occupied by people.

TABLE J4.5 (B)

RECOMMENDED GROUND VIBRATION LIMITS FOR DAMAGE CONTROL OF DAMAGE TO STRUCTURES (see Note 1)

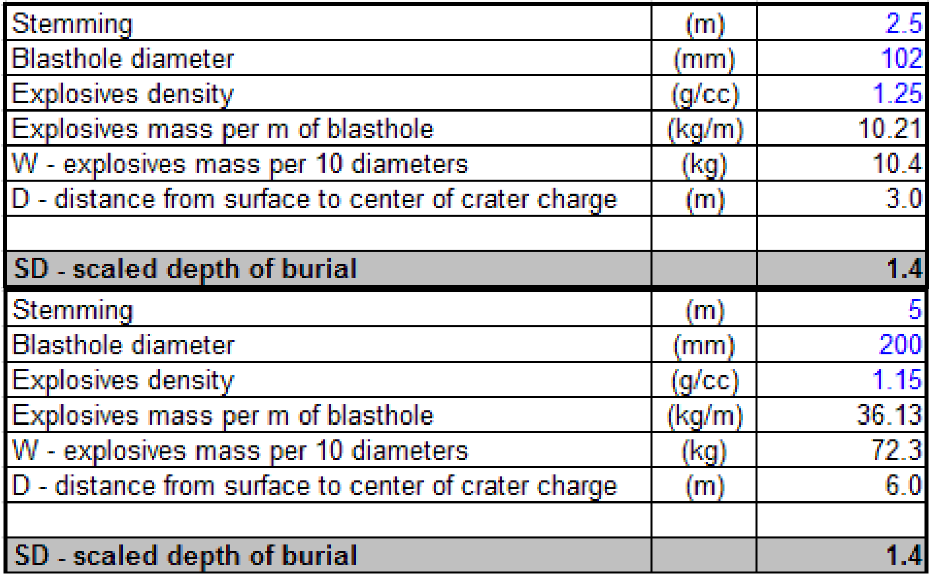
Category	**Type of blasting operations**	**Peak component particle velocity (mm/s)**
Other structures or architectural elements that include masonry, plaster and plasterboard in their construction	All blasting	Frequency dependent damage limit criteria Tables J4.4.2.1 and J4.4.4.1
Unoccupied structures of reinforced concrete or steel construction	All blasting	100 mm/s maximum unless agreement is reached with the owner that a higher limit may apply
Service structures, such as pipelines, power lines and cables	All blasting	Limit to be determined by structural design methodology.

NOTES:

1 Tables J4.5 (A) and J4.5 (B) do not cover high-rise buildings, buildings with long-span floors, specialist structures such as reservoirs, dams and hospitals, or buildings housing scientific equipment sensitive to vibration. These require special considerations that may necessitate taking additional measurements on the structure itself, to detect any magnification of ground vibrations which might occur within the structure. Particular attention should be given to the response of suspended floors.

Depth of Burial

Table 2 shows two of the current practice at Macraes.



Stemming	(m)	2.5
Blasthole diameter	(mm)	102
Explosives density	(g/cc)	1.25
Explosives mass per m of blasthole	(kg/m)	10.21
W - explosives mass per 10 diameters	(kg)	10.4
D - distance from surface to center of crater charge	(m)	3.0
SD - scaled depth of burial		**1.4**
Stemming	(m)	5
Blasthole diameter	(mm)	200
Explosives density	(g/cc)	1.15
Explosives mass per m of blasthole	(kg/m)	36.13
W - explosives mass per 10 diameters	(kg)	72.3
D - distance from surface to center of crater charge	(m)	6.0
SD - scaled depth of burial		**1.4**

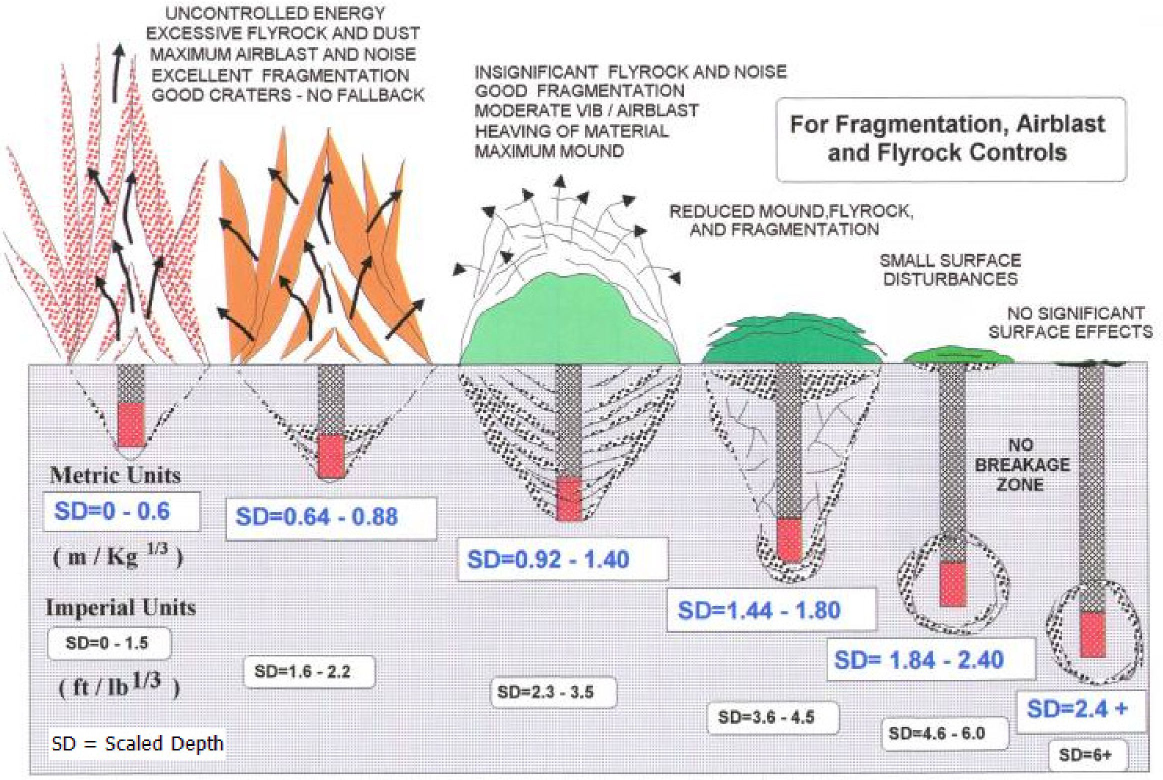
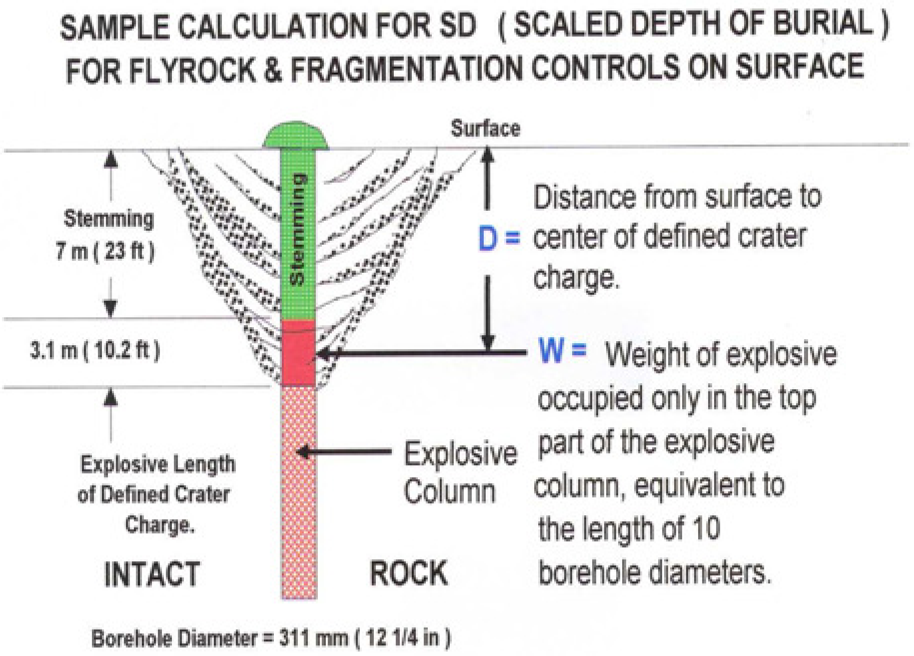
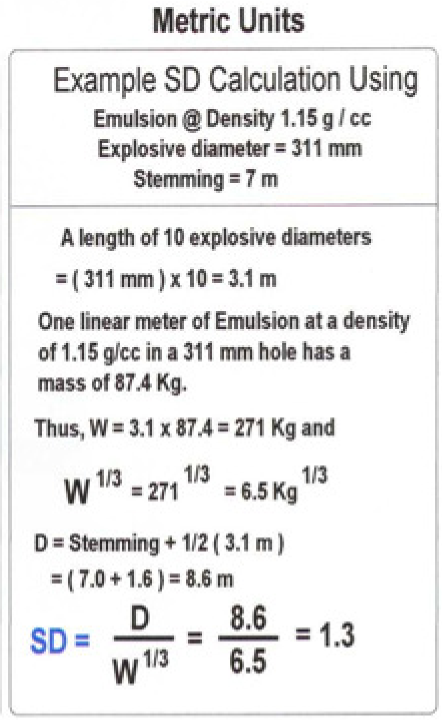


Figure A2 Signifigance of Scaled Depth of Burial (SD) - Metric & Imperial Units

Figure 4:Scaled depth of burial for different holes





Metric Units

Example SD Calculation Using

Emulsion @ Density 1.15 g / cc
Explosive diameter = 311 mm
Stemming = 7 m

A length of 10 explosive diameters

= (311 mm) x 10 = 3.1 m

One linear meter of Emulsion at a density of 1.15 g/cc in a 311 mm hole has a mass of 87.4 Kg.

Thus, W = 3.1 x 87.4 = 271 Kg and

$$W^{1/3} = 271^{1/3} = 6.5\ \mathrm{Kg}^{1/3}$$

D = Stemming + 1/2 (3.1 m)
= (7.0 + 1.6) = 8.6 m

$$SD = \frac{D}{W^{1/3}} = \frac{8.6}{6.5} = 1.3$$

SD = Scaled Depth (in this case)

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Figure 5: Calculation of Scaled Depth

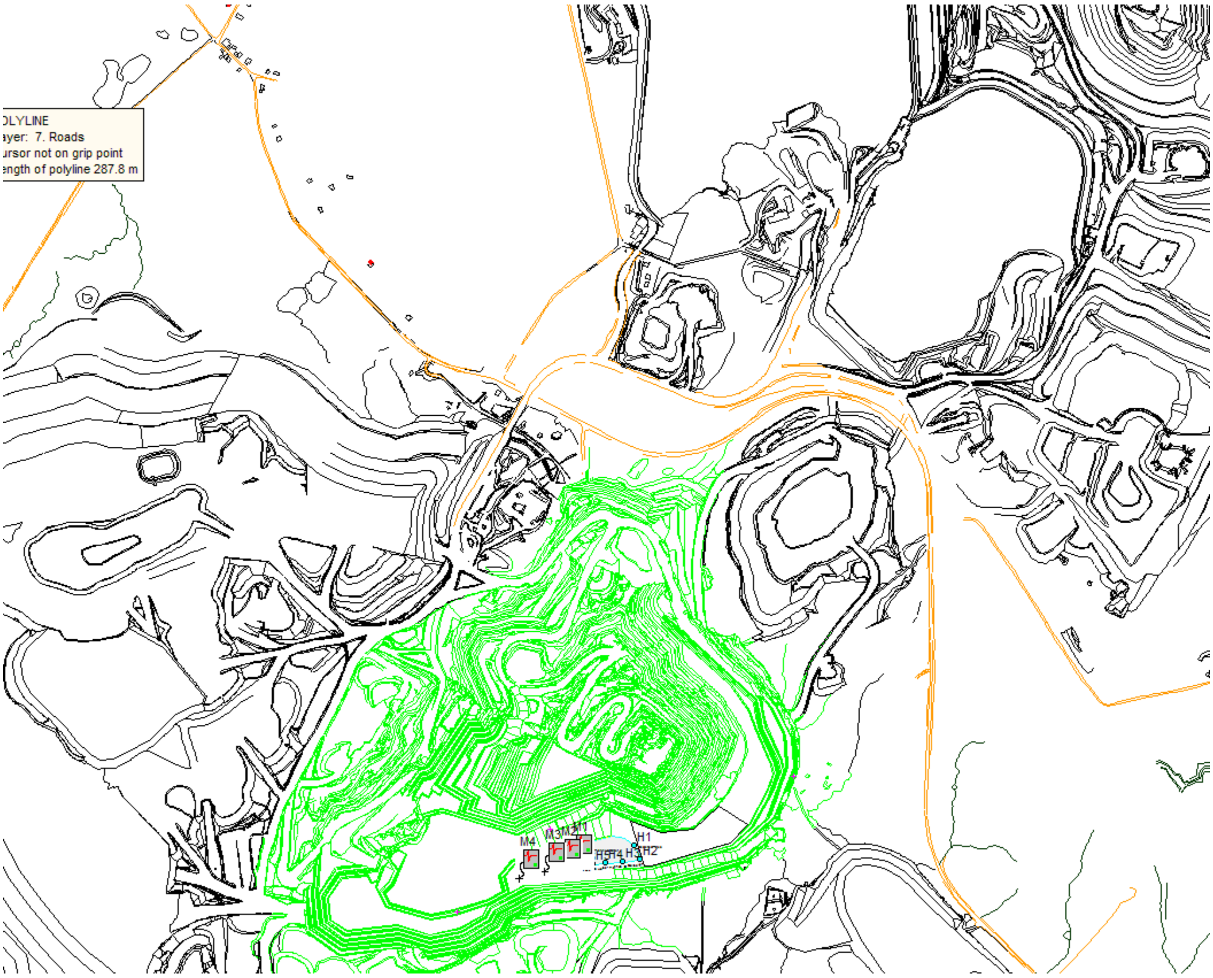

Figure 6: Current mine design with the testing area at the bottom right of the figure.