September 27, 2019

Attention: Rise Grass Valley Inc.

Subject: Environmental Factors of Blasting Report for the Proposed Idaho-Maryland Gold Project Nevada County, CA

EXECUTIVE SUMMARY

Precision Blasting Services (PBS) has been retained by Rise Grass Valley Inc. (Rise) to provide a description of the proposed blasting at the Idaho Maryland Mine (IMM) and potential environmental impacts from the blasting. This report includes an overview of vibration and blasting ground vibration, the effects of ground vibration on various structures, methodology for determining ground borne vibration levels, proposed IMM blasting activities, the total magnitude of ground vibration expected from IMM blasting at various depths and horizontal distances, and air overpressure. In addition, a monitoring program has been recommended to establish background levels, record ground vibration, and model the ground vibration. PBS has determined that potential impacts of drilling and blasting to the surrounding community will be negligible. The impact from exposure of persons to or generation of excessive ground vibration created by blasting will be less than significant.

The U.S. Bureau of Mines (USBM) and Office of Surface Mining, Reclamation, and Enforcement (OSMRE) have both developed recommendations for ground vibration levels to prevent damage to residential structures. The estimated ground vibration from IMM blasting activities are typically less than 10% of these limits and present no risk of damage to any nearby receptors. The author recommends that blasting vibrations at the location of receptors on surface be kept below a threshold of 0.4 in/s to minimize annoyance and complaints. Maximum predicted blast vibrations at IMM will typically be less than 50% of this 0.4 in/s threshold level and should not cause concerns amongst the local community.

<u>The anticipated impact from drilling and blasting surrounding the proposed Idaho-Maryland Mine is negligible, and in almost all situations will be unnoticeable and undetectable.</u>

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1.0 ORIGIN OF VIBRATION LIMITS

In the past 100 years the blasting industry has quickly transformed how it views ground vibration and air overpressure levels with the development of rigorous standards to prevent damage to structures and minimize annoyance of neighbors. A great deal of the work towards the development of these standards was completed by the U.S. Bureau of Mines (USBM) and is now enforced by the Office of Surface Mining, Reclamation, and Enforcement (OSMRE) in regard to mine blasting. Various state departments of transportation, departments of natural resources, and the U.S. Army Corp of Engineers (USACE) enforce standards and practices for construction blasting situations.

Due to the difficulty in quantifying blast vibration data, many independent researchers, universities, and government bodies have conducted research programs independent of the USBM. These studies have demonstrated that the USBM limits are much too conservative. Numerous international governments have come up with less controlling standards than ones adopted by the USBM without seeing additional damage done by blasting operations. In recent years, OSMRE has developed a modified Z-curve that is now used as the federal regulation for blasting vibration near residential structures.

1.1 Basic Mechanics of Ground Vibration

Seismic waves are waves that travel through the earth. These waves represent the transmission of energy through the solid earth. Seismic waves can be naturally generated or occur from man-made sources. A common natural occurring source of seismic waves is earthquakes. Common sources of man-made seismic waves include explosions, blasting, pile driving, and mechanical excavation of rock. When these man-made seismic waves are perceptible, that is when they can be felt, they are referred to as "vibration".

Seismic waves are divided into two large classes, body waves and surface waves. Body waves travel through the mass of the rock, penetrating down into the interior of the rock mass. There are two kinds of body waves: compressional waves and shear waves. The compressional wave (P wave) is a push-pull type wave that produces alternating compression and dilatation in the direction of wave travel, such as occurs in a stretched spring. The shear wave (S wave) is a transverse wave that vibrates at right angles to the direction of wave travel. The motion of a shear wave can be seen in a rope that is strongly flexed at one end. The rope moves up and down, but the wave travels outward toward the other end. Liquids do not transmit shear waves.

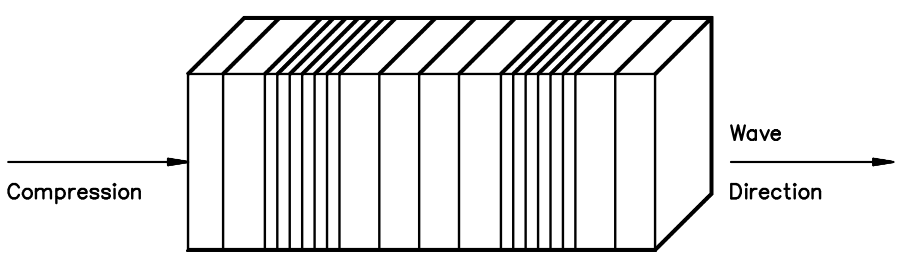

Figure 1 - Compressional Body Wave (P-Wave)

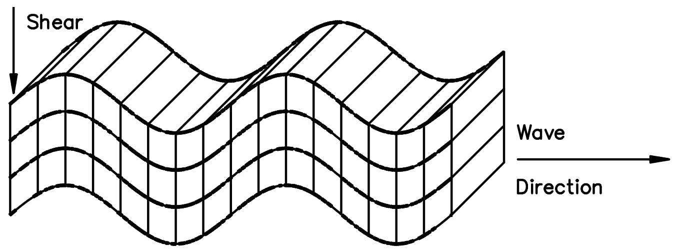

Figure 2 - Shear Body Wave (S-Wave)

Surface waves (L wave) travel over the surface of rock mass but do not travel through it. The depth to which the rock mass is affected by the wave motion is approximately one wavelength. Surface waves are generated by body waves that are restrained by physical and geometrical conditions from traveling into the interior of the rock mass. Surface waves produce the largest ground motions and are the large energy carriers. Surface waves have two components, the Raleigh and the Love waves. Raleigh and Love waves are measured by a seismograph and are the main component of vibration when discussing ground vibration from blasting activities. The ground vibration from these surface waves are recorded as the velocity of motion, or how many inches per second (in/s) the ground is moving.

1.2 Seismographs

Ground vibration is monitored using a measurement device known as a Seismograph, which is specially built to measure the high frequencies of blasting ground vibration. To measure the entire motion of the blast, a seismograph will record ground vibration in three different directions giving three distinct wave traces which are typically referred to as Vertical, Longitudinal, and Transverse. This measurement is the velocity of the blast and the maximum on any of these three wave traces is the peak particle velocity (PPV).

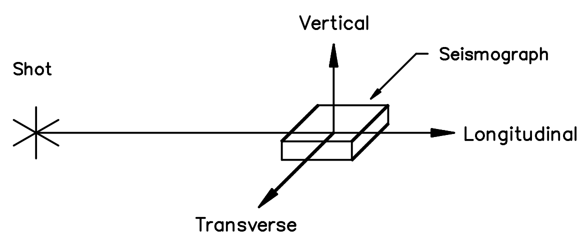

Figure 3 - Vibration Components of a Seismograph

In addition to this, the seismograph comes with a special microphone which is capable of picking up the low (inaudible) frequency noise that is generated from the blast. This noise is typically called air overpressure and is measured in either PSI or decibels. The printout from a seismograph has four distinct curves that show the three directions of ground vibration and the one waveform of air overpressure. An example of this can be seen in figure four.

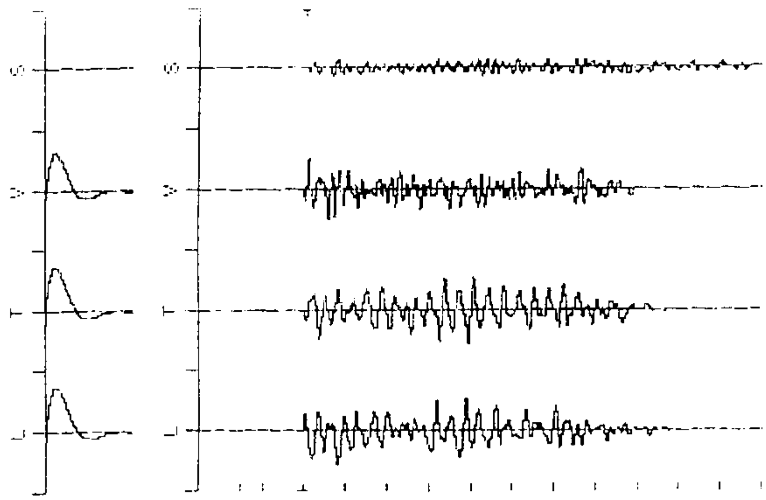

Figure 4 - Example of a Vibration Record (In descending order: Sound, Vertical, Transverse, Longitudinal)

1.3 Development of Standards for Blasting Ground Vibration

The first major research project conducted in the United States on blasting vibration was Bulletin 442 (Thoenen & Windes, 1942) which looked at the relationship between blasting and blast vibrations. This study examined numerous blasts and began the investigation into topics such as damping, structural damage from vibrations, frequency dependency on vibration, resonance vibration, delayed blasting, and numerous other factors. The researchers used statistical analysis to develop a chart that showed the danger and caution zones for damage correlating frequency and displacement.

Attempts were also made to look at accelerations and its correlation to damage. While many topics were discussed in Bulletin 442 two major conclusions were made by the researchers:

1. The vibration from a blast can be predicted with a relationship of size of the shot (which was classified as the charge weight per delay) and distance to the structure (now known as scaled distance).
2. “The vibration of a structure at resonance does not in itself cause damage because of the restraining effect of damping inherent in the building” (Thoenen & Windes, 1942).

Due to the increase of blasting near homes and more populated areas, the USBM commissioned an additional study to further develop a few of the topics covered in Bulletin 442. This additional study was published as RI 6561 (Duvall, Johnson, Meyer, & Devine, 1963) and examined delayed blasting and the relationship between charge weight, distance, and peak particle velocity of the blast. This relationship would be termed the ‘scaled-distance’ and takes the form of:

$$V = K * w^{b} * D^{-n}$$

Where: V = Scaled Distance

K = Site Specific, Time Specific Constant

w = Charge Weight per Delay

D = Distance

b,n = Site-Specific Constants

In addition, the researchers began looking deeper into the effects of delayed blasting using short period delay detonators (blasting caps) versus instantaneous blasting and determined the following conclusions:

- When a single hole was fired, it would produce a value of 'K'.
- When multiple holes were fired in the blast, but delayed by at least 9ms between each other, then the value of 'K' would only increase by 42% from a single hole.
- Firing multiple holes on the same delay period, or firing the entire blast on the same delay period, would produce significantly larger 'K' values then the single hole or delayed blasting.

Furthermore, the researchers concluded that the vibration for delays was independent of the time period or delay used, as long as a minimum delay of 9ms was used – ultimately this transformed into the 8-millisecond rule which states that all explosives fired within 8ms are counted as a single charge (and single charge weight).

Following this study, Bulletin 656 (Nicholls, Johnson, & Duvall, 1971) was released which studied the relationship between ground vibration, air overpressure, and damage to residential structures. This study concluded that damage to structures is unlikely if vibration levels, specified by the peak particle velocity (maximum velocity in any of the three orthogonal directions), remained below 2.0 in/s and the air overpressure remained below 0.5 PSI. In addition to this, human complaint factors were studied and it was determined that less than 8% of people would complain about blasting activities if the peak particle velocity was below 0.4 in/s. The study also concluded that, except in the case of abnormal stemming, the air overpressure was not a significant producer of damage if the vibration was maintained below 2.0 in/s. This study was also the first to recommend a minimum scaled distance (feet per pounds$^{1/2}$) of 50 without the use of a seismograph, which still shows up in many state regulations today. Bulletin 656 also established various classes of damage from ground vibration, which are:

Threshold of damage (4 in/s)
- opening of old cracks
- formation of new cracks
- dislodging of loose objects

Minor damage (5.4 in/s)
- fallen plaster
- broken windows
- fine cracks in masonry
- no weakening structure

Major damage (7.6 in/s)
- large cracks in masonry
- shifting of foundation-bearing walls
- serious weakening of structure

The next major study published by the USBM was RI 8485 (Siskind, Stachura, Stagg, & Kopp, 1980) which looked deeper into the effects of air overpressure on structure response and damage to residential structures. This was one of the largest air overpressure studies conducted to this point and looked at numerous factors such as measuring devices, scaled distances with absence of monitoring, damage and annoyance, and situations leading to higher levels or frequencies. This limited the air overpressure (from a regulatory standpoint) from the previous 140 dB to the chart below, which includes the ability of the measuring device. These levels were stated to be equal to one another after accounting for the lower frequencies. Exceedance of the air overpressure levels in Table 1 would typically be considered significant and require mitigation.

Table 1 - Air Overpressure Limits based on Instrumentation Frequency

Air Overpressure Level	Measuring Device Frequency
134 dB	0.1 hZ
133 db	2 hZ
129 db	6 hZ
105 db	C-Slow

Following this study one of the most famous USBM vibration studies was published, RI 8507 (Siskind, Stagg, Kopp, & Dowding, 1989), which compiled previous ground vibration and residential damage with research done during the program to make the vibration standards that are still prominent in today's blasting industry. This study analyzed the relationship between peak particle velocity and frequency taking into consideration resonance of structures and midwalls. This study suggested that structures had a resonance frequency of 4–12 hZ and that midwalls resonated between 10-25 hZ, contrary to what was claimed in Bulletin 442. This new data, combined with damage data falling between 0.5 in/s and 2.0 in/s (for a 95% confidence level), the recommendation made was that any blast with a frequency below 40 hZ had a limit of 0.75 in/s (modern homes) or 0.50 in/s (old homes) and any blast that had a frequency above 40 hZ could sustain a vibration level of 2.0 in/s without causing damage.

To aid mine operators, the USBM developed the Z-Curve method to identify blast level ranges which utilized peak particle velocity (PPV), displacement, and frequency. This Z-Curve, while slightly modified, is still the main regulatory curve utilized in the United States and is still the curve utilized used in all court cases dealing with vibration damage to residential structures. It is one of the most conservative damage predictors in the world, and as long as ground vibration is maintained below this level, damage to residential structures is highly unlikely.

Numerous tests have been completed analyzing the relevance the USBM standards and exposure to repetitive vibrations. One of these tests was completed by Dr. Walter in which an 8ft x 8ft room was built on a shake table and vibrated for 365 days for 24 hours a day at 10-15 hZ (building resonance) for 0.05 to 0.16 in/s. No damage occurred even with this extended, repeated vibration for levels under the Z-Curve (Konya & Walter, 1991). The USACE also conducted similar testing with a room at 26-30 hZ (midwall resonance) with vibration levels ranging from 0.1 to 4.0 in/s with no damage occurring until the 6th run at 4.0 in/s. All tests showed that the levels implemented by the USBM are extremely conservative and, if the limits are held, damage will not occur.

The development of this damage criteria began looking at only a single number from the thousands of vibration samples taken during a blasting event, this number was the maximum peak particle velocity of any of the three wave traces for ground vibration. This single number is what was correlated to damage and has stood until today as the indicator of potential damage. It is important to note that the Z-Curve and other ground vibration standards are extremely conservative and that exceeding the curve does not mean that damage will occur but that there is a possibility that damage could occur.

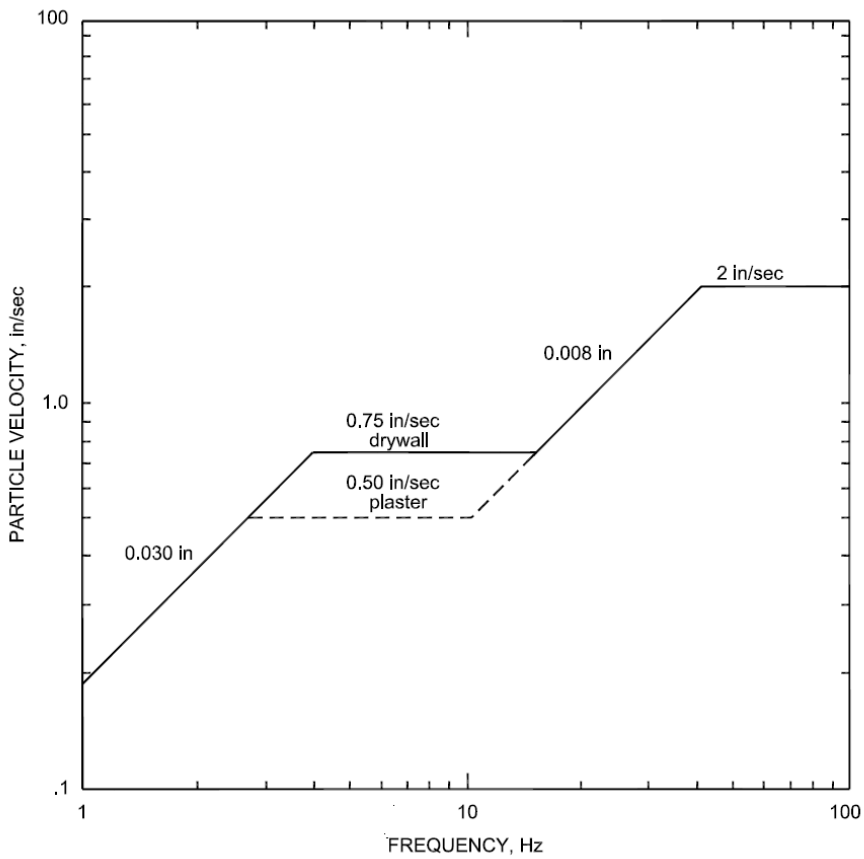

Figure 5 - USBM Z-Curve

Non-residential structures such as commercial and industrial buildings are typically built to a much higher standard than a normal residential structure. Due to higher building standards, non-residential structures can withstand much higher levels of ground vibration. Therefore, if the Z-curve is followed for non-residential structures then no damage will occur. The IMM is expected to have ground vibration at much lower levels than would be of any concern on the Z-Curve. The ground vibration from the anticipated blasting at IMM could then be looked at as an issue of public perception instead of damage to any structures.

1.4 Human Perception of Ground Vibration

The human body can detect lower levels of ground vibration than those levels discussed above that could damage structures. The human body has been reported by numerous agencies, including the USBM and the State of California (California Department of Transportation, 2013), to distinctively perceive ground vibration as low as 0.1 inch per second, with some people being able to sense lower levels yet. This can explain why some people may feel ground vibration from blasting even at larger distances, yet this ground vibration is nowhere near damaging.

The reason the general public may perceive this as worrisome is due to the fact that it is an A-Cultural Vibration. An A-Cultural Vibration is something that occurs that people are not used to; for example, a person living near a train does not worry that when the train passes by and causes their house to shake from ground vibration that their house will be destroyed. This is because the train is a cultural, or normal, vibration they experience. Vibration produced by a blast, however, is unique and one does not expect it, therefore an individual may key in on the vibration to a much larger extent.

As discussed previously, Bulletin 656 showed that if ground vibration from blasting was kept below 0.4 in/s, less than 8% of the population were concerned enough to complain. This 0.4 in/s is then used as the threshold for annoyance amongst the community. In addition to this, studies were completed by the USBM to determine the ground vibration levels and frequencies that people noticed and raised concerns.

Depending on the frequency range, ground vibration did not become noticeable to cause concern until approximately 1 inch per second of peak particle velocity (PPV). This would indicate that if human perception was a major concern then keeping ground vibration to a PPV limit below 1.0 in/s would ensure that the majority of humans were not worried about the ground vibration and its potential effects.

The Konya Vibration Scale was developed and has been used with Department of Transportation and Federal Highway Administration projects, for the last 30 years (Konya, 2015) to explain ground vibration levels. This vibration scale assigns vibration classes from a Class 1, which is extremely low levels of ground vibration, to Class 20, which is extremely high levels of ground vibration.

As shown in Table 2, the vibration class is related to peak particle velocity of the blast and translates to a similar cultural vibration. This is used by first determining what the expected peak particle velocity of the blast may be, for example if the expected PPV is 0.128 in/s, this equates to a Vibration Class (VC) of 8. A VC8 is the same vibration as the garbage disposal running in a house or someone slamming a door.

If the ground vibration of a site is kept below a VC10, equivalent to a ground vibration of 0.512 in/s, then the human population should never have any concerns to damage in their house as this does not lead to even non-visible damage to existing cracks and it is well below the typical movement a house experiences just from daily environmental temperature changes.

Table 2 - Vibration Classes to Cultural Vibration

ACTIVITY	VIBRATION SCALE, CLASS 1 TO 20																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
WALKING	X	X	X	X	X															
TRAIN NEARBY	X	X	X	X	X	X														
WALKING ON WOOD FLOOR	X	X	X	X	X	X	X													
PILE DRIVING, PUNCH BARGE	X	X	X	X	X	X	X	X												
GARBAGE DISPOSAL	X	X	X	X	X	X	X	X	X											
JUMPING	X	X	X	X	X	X	X	X	X											
DOOR SLAMS	X	X	X	X	X	X	X	X	X											
POUNDING NAILS	X	X	X	X	X	X	X	X	X	X										
DAILY ENVIRONMENTAL CHANGE	X	X	X	X	X	X	X	X	X	X	X	X								
RIDING IN AUTOMOBILE	X	X	X	X	X	X	X	X	X	X	X	X	X							
PEAKPARTICLE VELOCITY (IPS) (THRESHOLD VALUES)	0.001	0.002	0.004	0.008	0.016	0.032	0.064	0.128	0.256	0.512	1.024	2.048	4.096	8.192	16.38	32.77	65.54	131.07	262.14	524.29

1.5 Vibration Tolerance for Sensitive Electrical Equipment

Concerns about ground vibration and the effects it can have on sensitive electrical equipment such as microscopes, computers, and other systems has existed since electrical equipment first came out. When considering sensitive electrical equipment, three classifications exist: military, industrial, and commercial. The military equipment is the most robust and must be combat tested. The standards for military equipment are typically about 2g of acceleration at 20 to 40 Hz of frequency. Recent work has shown that computers for industrial and commercial settings could withstand ground vibration between 2g and 3g of acceleration (Holmberg, Ekman, & Sandstrom, 1983). Telephone equipment has also been shown to withstand over 0.6 inches per second of ground vibration on the unit, which correlated to approximately 2.0 inches per second on the ground (Dowding, 1985). This was without any vibration dampening equipment installed. If vibration dampening equipment is utilized on electrical equipment then the equipment is affected less by the ground vibration. In this situation, it is likely that the equipment could easily tolerate the ground vibration standards developed by the USBM in the Z-Curve for residential structures.

2.0 PREDICTION OF GROUND VIBRATION

The prediction of ground vibration for an underground mine that will conduct blasting can be accomplished utilizing modelling of proposed blasting practices with industry accepted models. These models are developed to be extremely conservative and overestimate the ground vibration. There are various formulas that have been developed over time to estimate ground vibration. The formula most applicable to underground mining is the Cubed-Root Scale Distance formula.

2.1 Cubed-Root Scaled Distance Formula

It has been proposed since the early 1960s that ground vibration from underground mines propagate at a different rate than surface waves. The ground vibration from underground mines is typically well below what a surface mine would produce because the body waves decay much more rapidly than surface waves. The surface waves cannot be produced until these body waves have reached the surface from an underground blast. This has led to a large overestimation of underground mine vibrations as the scaling for surface operations is $(1/d)^{0.5}$ whereas scaling for underground blasting is $(1/d)^{1}$. While no full, comprehensive model exists for all underground blasting operations, a cubed-root scaling model (Ambraseys & Hendron, 1968) has been developed to account for this faster decay in ground vibration.

This method of scaling ground vibration uses the cubed-root scaled distance (CRSD) which takes the form of:

$$CRSD = \frac{d}{\sqrt[3]{w}}$$

Where: CRSD = Cubed-Root Scaled Distance

d = distance (ft)

w = Weight of Explosive per 8ms Delay (lbs)

The distance (d) to a structure will be the total direct path distance which can be calculated using the following equation:

$$d = \sqrt{d_v^2 + d_h^2}$$

Where: d = True Distance from Blast to Structure (ft)

d_v = Distance from Blast to Structure in Vertical Direction (ft)

d_h = Distance from Blast to Structure in Horizontal Direction (ft)

The equation for the prediction of ground vibration is then:

$$PPV\left(\frac{in}{s}\right) = 360 * CRSD^{-1.6}$$

Where: PPV = Peak Particle Velocity (in/s)

CRSD = Cubed-root Scaled Distance

As the cubed-root scaled distance has more practical significance for the Idaho-Maryland Mine, the cubed-root scaled distance equation will be used for the prediction of ground vibration at the IMM. Table 3 contains a comparison of Cubed-Root Scaled Distance (CRSD) to Peak Particle Velocity (PPV).

Table 3 - Cubed-Root Scaled Distance to Peak Particle Velocity

Cubed Root-Scaled Distance	Peak Particle Velocity (in/s)
50	0.69
60	0.51
70	0.40
80	0.32
90	0.29
100	0.23

2.2 Ground Vibration from Drilling

The mining industry utilizes two methods of drilling to develop boreholes or drill holes, these methods are percussion and rotary drilling. Percussion drilling is completed by striking a drill bit into the rock and applying small amounts of rotation to the drill bit with every strike. The total movement of the drill head is very small per hit and the borehole that is developed is slightly larger than the drill diameter. Rotary drilling is the process of cutting a borehole with a drill bit in which the rock is cut or crushed by a high speed rotation drill system.

The drilling of bore holes will have only local effects within a few feet of the location of the drill. There is no vibration or effect of drilling except for the local zone around the drill hole. This vibration or effects of drilling cannot be detected feet away from the drill and no impact to the community would exist from these drilling activities.

3.0 THRESHOLDS OF SIGNIFICANCE FOR BLASTING VIBRATIONS

As described in the preceding section, the thresholds to determine a potential impact from blasting are based on recommendations from the USBM and OSMRE, studies by Konya and Konya, experience and technical knowledge of the author.

The U.S. Bureau of Mines (USBM) and Office of Surface Mining, Reclamation, and Enforcement (OSMRE) have both developed recommendations for ground vibration levels to prevent damage to residential structures.

The USBM recommended a peak particle velocity threshold level of 0.4 in/s if complaints and claims are to be kept below 8% of the potential number of complainants. The author recommends that blasting vibrations at the location of receptors on surface be kept below this threshold to minimize annoyance and complaints.

A summary of the thresholds of significance for impacts from blasting vibrations can be summarized as follows:

PPV < OSMRE Z-Curve	Damage to residential structures unlikely
PPV < 0.40 in/s	No significant concerns about public annoyance
PPV < 0.05 in/s	Blasting vibrations not typically detectable on blasting seismograph

4.0 GROUND VIBRATION FROM PROPOSED UNDERGROUND BLASTING AT THE IDAHO-MARYLAND MINE

The maximum ground vibration from underground blasting at the IMM will be analyzed using the Cubed-Root Scaled Distance prediction equation.

To understand what types of ground vibration would be expected it is important to identify and define the type of blast design that will be used for underground development. The type of blast design utilized is based on the purpose of the blast area. The following section identifies the two main blast design methods to be used at the Idaho Maryland Mine; Drift Development and Long-hole Stoping. Based on the blast designs identified, typical blast guidelines are established and analyzed to identify ground vibration levels.

4.1 Project Description

In order to provide access to the gold ore and an extensive network of tunnels and raises will be constructed throughout the life of the mine. These tunnels are constructed in the non-mineralized rock which at the mine is typically meta-andesite volcanic rocks. The tunnels are constructed in 10-foot advances per blast (a “round”) as previously described. The broken rock is then moved to surface, the tunnel is supported with rock bolts and screen, and then the process starts again to continue advancing the tunnel and a number of tunnels would be under construction throughout the mine area at all times during the life of the mine.

New underground tunnels and raises would be created as necessary to access potential ore veins or provide the necessary underground infrastructure to transport rock and provide ventilation and escape routes. Rise has approximately 2,800 acres of underground mineral rights. The location, size, and depth of new underground workings would depend on surface and underground drilling and mineral testing.

It is expected that mine development in non-mineralized “barren” rock will result in the production of approximately 500 tons per a day (182,500 tons per year) of barren rock or 5 drift rounds blasted per day.

In some cases where ore widths are narrow, drifting alone would be used for ore production. However, the use of longhole stope blasting is more productive than drift mining and would be used whenever possible.

Generally, mining of a block of ore by long hole stoping commences by driving horizontal tunnels, using similar techniques as described above, along the length of an ore vein. Horizontal tunnels are driven through orebody on vertical spacing of approximately 50 feet. Ore production by drifting is assumed to be 20% of total production or approximately 200 tons per day of ore requiring approximately 2 drift round per day.

Therefore, is it assumed that on average 7 drifts round blasts will be required per day. Blasting of drift rounds is normally done between shifts and therefore, on average, 3 to 4 drifts rounds would be blasted every 12 hours between shift changes.

Ore production through long hole blasting is assumed to produce 800 tons per a day of ore. Longhole stoping of a block of ore is done in several blasts. The initial blast is smaller and used to create enough void for subsequent blasts. This initial blast is called a slot blast. Once the slot blast is completed and the broken ore removed the remainder of the block of ore can be blasted. A longhole stope blast may typically be 3,300 tons assuming dimensions of 100 feet in length, a stope height of 40 feet, and an ore width of 10 ft. Due to the larger amounts of ore produced per blast, longhole stope blasts are less frequent than drift round blasts and might typically take place once every 3-4 days. Longhole stope blasts would be completed within seconds.

The IMM deposit has been extensively mined to 1600 feet below surface. However, it is possible that gold ore exists in the upper levels of the mine. Therefore, it is assumed that mining by drift rounds and longhole blasts could take place as shallow as 500 feet below ground surface.

As part of the project construction, IMM will be developing a service shaft which will be completed using raise blasting techniques. This will have blasting occur up to the contact between the rock mass and the overburden soils, estimated to be approximately 50 ft below surface. This shaft blasting is not continuous throughout the project and therefore will create temporary ground vibration.

4.2 Typical Blast Design

4.2.1 Drift Development – Lateral Tunneling

A tunnel created by drilling and blasting underground is termed a “drift” in the mining industry. Drift development blasting is used to develop new or modify existing mine working. There is an extensive network of existing drifts (mine workings or tunnels) in the IMM developed by historic operators. Existing drifts may be enlarged to accommodate modern mining equipment. In addition, new drifts will be developed to access new working areas in undeveloped ore zones or create passageways for moving broken rock, ventilation, or other services.

A drift is created by advancing the working face in short segments which are termed “rounds” in the mining industry. At the IMM, a drift round is anticipated to be approximately 12 ft long. The actual advance per round is always less than the depth of the drilled holes and it is assumed that a 12 ft drift round will result in an advance of the drift of 10 ft per blast.

The round commences by drilling a number of parallel holes in the face of the drift. To create enough void for the rock to be fragmented by explosives, one or several of the holes in the center of the drill hole pattern are enlarged and used as void or “relief” holes (open holes not loaded with explosives) and a number of closely spaced holes around these “relief” holes are loaded with explosives. This is called the “cut” of the drift round. The explosives in the cut are initiated first which fragments and ejects the rock in the cut to create a larger void in the face of the drift. The remaining holes are then initiated in a series of delays to progressively enlarge the blast until the final dimensions and profile of the drift is created. A number of different parallel cut patterns (or “burn cuts”) are used by underground miners which are similar but vary in the number and size of relief holes used. A lesser used technique to create a cut uses angled holes (a “V cut”) and would likely produce similar levels of ground vibration as they utilize similar weights of explosives as a parallel cut. An example of a basic drill pattern design and sequence of delay timing (shown in red numbers) for drift rounds is displayed in Figure 8.

As displayed in Figure 6, the blasting of a drift round progresses as follows;

1) The cut holes surrounding the relief holes are initiated first with each hole on a different delay timing to progressively fragment the rock and create the cut.
2) The holes surrounding the cut are initiated after the cut holes have detonated and progressively fragment the rock to enlarge the blasted area of the round. As the void area increases, several of the holes can be initiated on the same delay timing.
3) The lifter holes at the floor of the drift are fired last in order to create the finished floor profile and “lift” the fragmented rock to allow easier loading of the broken rock. Typically, a number of the lifter holes are initiated on the same delay timing.

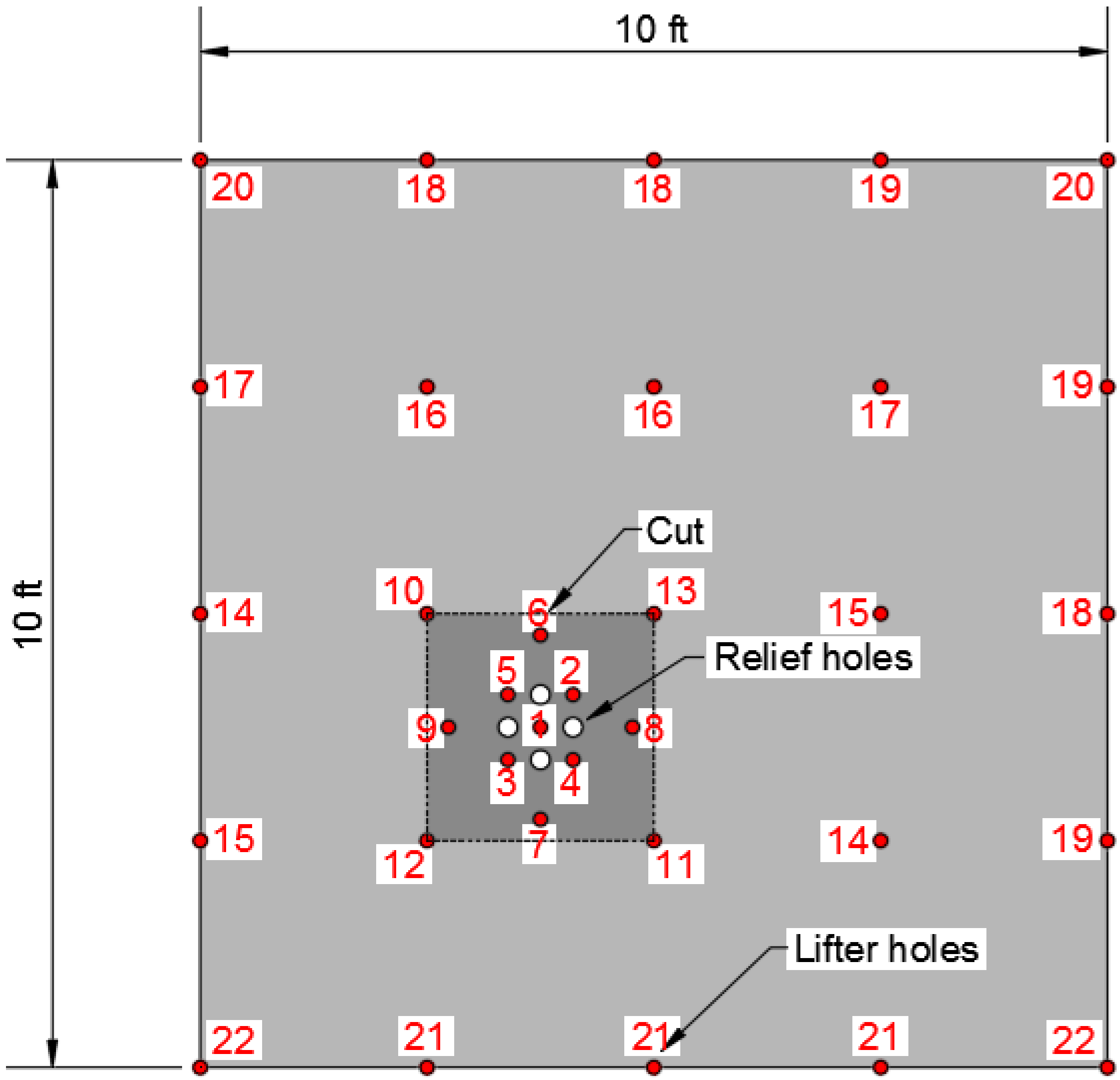

Figure 6 - Example of a Drift Round – Looking at face of drift

The preliminary round design will utilize 1.75" diameter drill holes approximately 12ft in length. Approximately 10ft of the hole will be loaded with explosives. In some situations, such as blasting the holes along the floor, the mine may blast more than one hole per 8ms delay. For this reason, it can be considered that up to four holes may be detonated at a single time. Drift round blast would be completed in seconds.

The two main types of explosive material used in underground mining are ANFO (ammonium nitrate and fuel oil) and emulsion, also mainly comprised of ammonium nitrate. ANFO is a widely used bulk industrial explosive which is pneumatically loaded (blown in under pressure). Emulsion is a packaged explosive that is water resistant and has a higher bulk density which is typically used in wet mining conditions.

For the case of pneumatically loaded ANFO, assuming that it is blown in at an air pressure of 40 PSI, it would have a specific gravity of 1.0. If four holes are detonated in one delay, with 10 ft of each hole being loaded with ANFO explosive, the total weight of explosive (charge weight) per delay would be 41.7 lbs of explosive. At a distance of 500 ft this would produce a CRSD of 144, which would produce a PPV of 0.13in/s.

For the case of emulsion, the highest density emulsion (booster-sensitive) will be considered which has a specific gravity of 1.25. If four holes are detonated in one delay, with 10 ft of each hole being loaded with emulsion explosive, the total weight of explosives (charge weight) per delay would be 52.1 lbs of explosive. At a distance of 500 ft this would produce a CRSD of 134 which would produce a PPV of 0.14 in/s.

4.2.2 Raise Development – Vertical Tunneling

A raise is a vertical tunnel which is used to connect lateral tunnels or drifts. Raises are constructed as ventilation airways, ore passes, ladder or hoist passageways, or slots (voids) for longhole stope blasts. When raises are constructed by drill and blast methods in an underground mine they are typical done using hand held pneumatic powered drills rather than the large machine mounted hydraulic drills used in drifting. Therefore, the drill hole diameters are smaller and the hole lengths shorter than drift rounds. A raise round is drilled and blasted similar to a drift round as previously described. Assuming a typical hole diameter of 1.25”, a loaded hole length of 8 ft, and the blasting of four holes in one delay the charge weight per delay using emulsion can be calculated as 21.3 lbs per delay. At a distance of 500 ft this would produce a CRSD of 180, which would produce a PPV of 0.09 in/sec..

4.2.3 Long-hole Stope Blasting

Generally, mining of a block of ore commences by driving horizontal tunnels, using drifting techniques as described above, along the length of an ore vein. Horizontal tunnels are driven through orebody on vertical spacing of approximately 50 feet. Once the tunnels are completed, a pattern of drill holes are drilled between the two levels. These long holes are then loaded with explosives and detonated to fragment the ore so that it can be transported to the shaft and then to surface. The mining of these blocks of ore is termed “stoping” in the mining industry and the mined areas between the drifts are termed “stopes”.

Long-hole blasting utilizes longer boreholes which extend from the previously developed drift into the rock mass. The holes are typically larger in diameter and two to five times longer than the holes used in drift development. The stope blasting is similar to holes being blasted in a quarry, with long holes that are drilling into the rock which break to a free face or a slot. The preliminary long-hole stoping design will utilize 2.5” diameter drill holes. The long holes would be loaded with either ANFO or emulsion. As previously identified, emulsion is heavier and therefore will always have a larger weight of explosive if used in the same drill hole as ANFO.

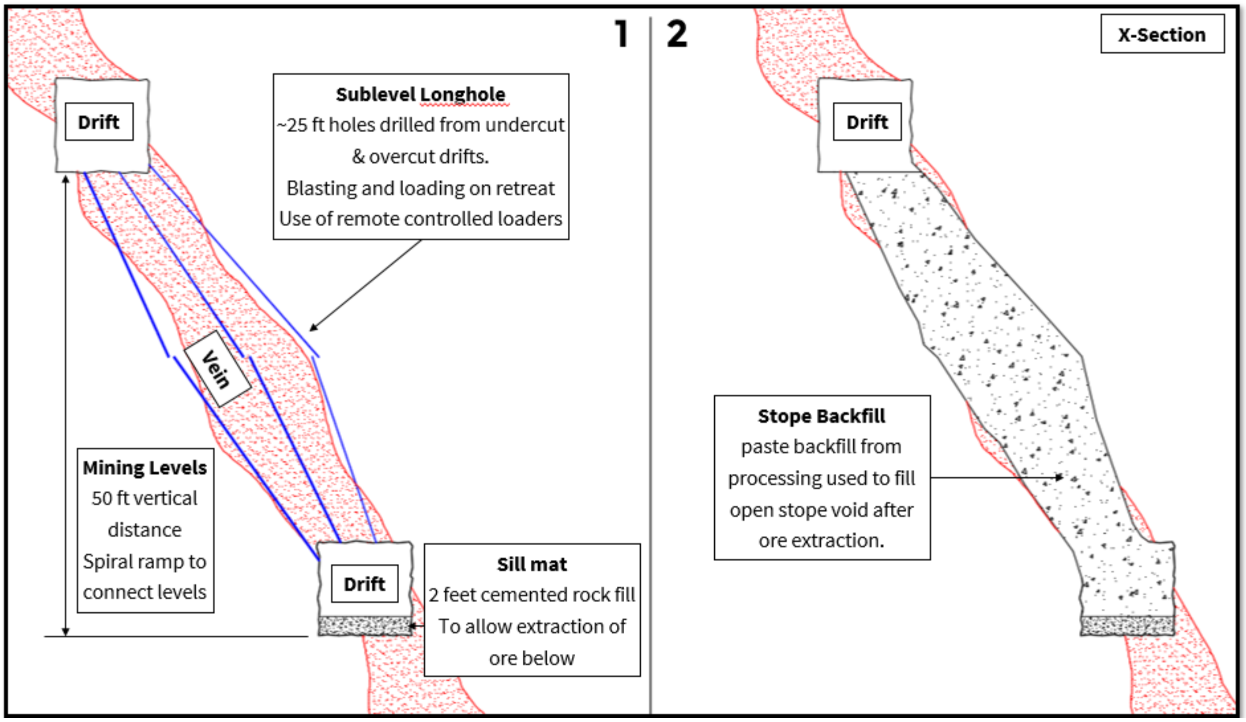

Figure 7 - Example of a Longhole blast – Looking in cross section

For long-hole stope blasting, it can be assumed that some stopes will extend up to 50 ft in height. If an emulsion product with a specific gravity of 1.25 was used to load 50 ft of hole for a stope blast, the total weight of explosives (the charge weight) per hole would be 133 lbs of explosive. At a distance of 500 ft from the blast, this would have a CRSD of 98, which would produce a PPV of 0.23 in/s.

Figure 7 shows a cross section of a typical longhole drill pattern and stope geometry. If the holes were drilled from both the overcut and undercut drift the holes would be approximately half the length and therefore half the charge weight. In this case, 2 holes could be fired on the same delay and result in the same vibration levels as for single holes with 50 ft lengths.

In terms of scaled distance, the lower the scaled distance, the larger the anticipated ground vibration. As explained in the preceding sections, the drift rounds (burn cuts) will always have a larger scaled distance value than the stope rounds due to the difference in weight of explosives (charge weight) which means that the drift round blasts will have a lower PPV than the long hole stope blasts, resulting in less vibration. As such, the environmental factors considered for the typical IMM operation are mostly driven by longhole stope blasting, with the understanding that the drift rounds will produce significantly lower ground vibration.

4.3 Maximum Ground Vibration

The Idaho-Maryland Mine has a large area of underground mineral rights and the blasting operations will occur in various mineralized zones throughout the mineral property. As such, it is important to consider the maximum ground vibration from various locations and depths that could occur to the surrounding area and receptors. The receptors located directly above the area that is being blasted have the least horizontal distance of separation from the blast area and therefore the least amount of rock that the ground vibration is attenuated through, at a specific depth. As a result, these receptors have the greatest chance of being negatively impacted by a blast. To understand what the ground vibration may be at the nearest receptors, the analysis will initially quantify the distance between the blast and the surface (the closest distance) to determine anticipated ground vibration levels from blasting at different mine levels.

The maximum ground vibration from underground blasting at the IMM will be analyzed using the Cubed-Root Scaled Distance prediction equation. Table 5 and Table 6 detail the anticipated peak particle velocities from the various blasting levels using the drift and long hole blasting techniques that IMM will employ as outlined in Section, assuming the receptor is located vertically above the blast location (no horizontal displacement). Emulsion explosive product has been assumed as it produces the largest weight of explosives (charge weight) per hole. This has been segmented based on the anticipated mining levels, beginning at 500 ft and every 100 ft below that. The datum to ground has been set as the Brunswick Shaft; however, many of the surrounding structures which the mine may be mining below are located at a higher elevation relative to the Brunswick Shaft and thus have lower ground vibration levels than shown below. Any field indicated with the symbol “NT” has an anticipated ground vibration below that which is typically detectable on a typical blasting seismograph (PPV < 0.05 in/s) and as such, is viewed as having no ground vibration effects.

As shown in Table 4 and Table 5, all vibrations calculated for blasting of both drift round and long-hole stopes, respectively, are well below the USBM recommendations and levels where structural damage to buildings is possible.

Drift development blasts at the shallowest depth considered of 500 ft would be barely perceivable to the general population and undetectable by instrumentation below 900 ft depth.

Larger longhole stoping blasts at the shallowest depth considered of 500 ft would be 0.23 in/s, which is also well below the threshold level of vibration (0.4 in/s) that less than 8% of the population complains about. The calculated ground vibration is considered insignificant. At depths below 800 ft, the ground vibration becomes unnoticeable to the general population.

Untraceable vibration would occur at a depth of approximately 1500 ft. At depths below 1500 ft it would be expected that ground vibration would be unnoticeable.

Table 4 - Anticipated Peak Particle Velocities for Development Round Blasting based on Vertical Distance from Receptor

Mine Level	**Weight of Explosive (lbs)** Emulsion Explosive	**Receptor Distance from Blast (ft)**	**Cubed-Root Scaled Distance**	**Peak Particle Velocity (in/s)** *NT = Not Traceable
500	52.1	500	144.2	0.14
600	52.1	600	173.0	0.11
700	52.1	700	201.9	0.08
800	52.1	800	230.7	0.07
900	52.1	900	259.5	0.06
1000	52.1	1000	288.4	0.05
1100	52.1	1100	317.2	NT
1200	52.1	1200	346.0	NT
1300	52.1	1300	374.9	NT
1400	52.1	1400	403.7	NT
1500	52.1	1500	432.6	NT
1600	52.1	1600	461.4	NT
1700	52.1	1700	490.2	NT
1800	52.1	1800	519.1	NT
1900	52.1	1900	547.9	NT
2000	52.1	2000	576.7	NT
2100	52.1	2100	605.6	NT
2200	52.1	2200	634.4	NT
2300	52.1	2300	663.3	NT
2400	52.1	2400	692.1	NT
2500	52.1	2500	720.9	NT
2600	52.1	2600	749.8	NT
2700	52.1	2700	778.6	NT
2800	52.1	2800	807.4	NT
2900	52.1	2900	836.3	NT

Table 5 - Anticipated Peak Particle Velocities for Long Hole Blasting based on Vertical Distance from Receptor

Mine Level	**Weight of Explosive (lbs)** Emulsion Explosive	**Receptor Distance from Blast (ft)**	**Cubed-Root Scaled Distance**	**Peak Particle Velocity (in/s)** *NT = Not Traceable
500	133	500	98.0	0.23
600	133	600	117.5	0.18
700	133	700	137.1	0.14
800	133	800	156.7	0.11
900	133	900	176.3	0.09
1000	133	1000	195.9	0.08
1100	133	1100	215.5	0.07
1200	133	1200	235.1	0.06
1300	133	1300	254.7	0.05
1400	133	1400	274.3	0.05
1500	133	1500	293.9	NT
1600	133	1600	313.5	NT
1700	133	1700	333.0	NT
1800	133	1800	352.6	NT
1900	133	1900	372.2	NT
2000	133	2000	391.8	NT
2100	133	2100	411.4	NT
2200	133	2200	431.0	NT
2300	133	2300	450.6	NT
2400	133	2400	470.2	NT
2500	133	2500	489.8	NT
2600	133	2600	509.4	NT
2700	133	2700	528.9	NT
2800	133	2800	548.5	NT
2900	133	2900	568.1	NT

It is also important to determine the ground vibration that may be experienced at nearby structures that are located in the vicinity of, although not directly above, the blasting activities. To analyze this, both the vertical distance and horizontal distance must be considered to determine at what range the vibration is no longer perceivable and at what distance the vibration will no longer be felt.

When considering both horizontal and vertical distance, the actual distance to a structure will be the total direct path distance.

Appendix A contains a supporting table detailing stope blasting ground vibration based on vertical and horizontal displacement from the blast source. Stope blasting vibration charts are presented in Appendix B to illustrate the vibration perception considering both the depth of the blast and the horizontal displacement. A detailed table is presented in Appendix C which shows expected vibration levels from the drift rounds at specified vertical and horizontal distances from a receptor.

4.4 Expected Ground Vibration at Identified Structures

Sensitive receptors, including houses, businesses, industrial structures, and supporting equipment, surround the Idaho-Maryland Mine at varying distances. PBS has investigated receptors around the IMM. The following three identified receptors are used as real examples and does not represent the only surrounding receptors. The Stope Blasting Ground Vibration table in Appendix A can be utilized for anticipated vibrations for other receptors not specifically mentioned.

4.4.1 Analog Devices

Analog Devices (previously Linear Technologies), located on Crown Point Circle, has previously indicated that they work with sensitive electronic equipment and microscopes placed on vibration dampeners. It is likely that this equipment could withstand vibration levels well in excess of 0.5 in/s without causing harm (this is an extremely conservative estimate with the background contained earlier in this report). Although, the Mine anticipates that the shallowest depth of underground mining and blasting in this vicinity may occur on 1000 ft Level. It is possible that this may occur directly below Analog Devices therefore no horizontal offset has been assumed. Table 6 displays the calculated ground vibration predictions which are expected to remain well below the 0.1 in/s that is perceivable. Underground blasting on the 1400 ft Level and levels below will be untraceable (NT). There are no anticipated or noticeable effects expected at Analog Devices from underground blasting at the Idaho-Maryland Mine.

Table 6 - Linear Technologies (Analog) Ground Vibration Predictions

Mine Level	Weight of Explosive (lbs)	Vertical Distance From Blast (ft)	Horizontal Distance From Blast (ft)	True Distance from Blast (ft)	Cubed-Root Scaled Distance	Peak Particle Velocity (in/s)
1000	133	1026.5	0	1026.5	201.10	0.07
1100	133	1126.5	0	1126.5	220.69	0.06
1200	133	1226.5	0	1226.5	240.28	0.06
1300	133	1326.5	0	1326.5	259.87	0.05
1400	133	1426.5	0	1426.5	279.46	NT
1500	133	1526.5	0	1526.5	299.05	NT
1600	133	1626.5	0	1626.5	318.64	NT
1700	133	1726.5	0	1726.5	338.23	NT
1800	133	1826.5	0	1826.5	357.82	NT
1900	133	1926.5	0	1926.5	377.41	NT
2000	133	2026.5	0	2026.5	397.01	NT

4.4.2 Sierra Nevada Memorial Hospital

The Sierra Nevada Memorial Hospital has been classified as a sensitive receptor in the area which may contain sensitive equipment and desire to have controls on ground vibration during typical operations. PBS has worked on many projects which involved blasting next to working hospitals, including blasting foundations for hospital expansions next to existing hospitals. The ground vibration was never an issue and was typically set to the USBM Z-Curve limits for residential structures. For the proposed means and methods of underground mining at the Idaho-Maryland Mine, there are no risks of ground vibration to the hospital, as shown in Table 7. The hospital is expected to have no instances of recordable ground vibration.

Table 7 - Sierra Nevada Memorial Hospital Ground Vibration Predictions

Mine Level	Weight of Explosive (pounds)	Vertical Distance From Blast (feet)	Horizantal Distance From Blast (feet)	True Distance from Blast (feet)	Cubed-Root Scaled Distance	Peak Particle Velocity (in/s)
500	133	398.5	3300	3323.973864	651.19	NT
600	133	498.5	3300	3337.439475	653.83	NT
700	133	598.5	3300	3353.833963	657.04	NT
800	133	698.5	3300	3373.114622	660.82	NT
900	133	798.5	3300	3395.232282	665.15	NT
1000	133	898.5	3300	3420.131905	670.03	NT
1100	133	998.5	3300	3447.753218	675.44	NT
1200	133	1098.5	3300	3478.031376	681.37	NT
1300	133	1198.5	3300	3510.897642	687.81	NT
1400	133	1298.5	3300	3546.280058	694.74	NT
1500	133	1398.5	3300	3584.104107	702.15	NT
1600	133	1498.5	3300	3624.293345	708.25	NT
1700	133	1598.5	3300	3666.770002	714.78	NT
1800	133	1698.5	3300	3711.455543	721.71	NT
1900	133	1798.5	3300	3758.271178	729.03	NT
2000	133	1898.5	3300	3807.138328	736.73	NT

4.4.3 Downtown Grass Valley

Downtown Grass Valley was also analyzed due to the presence of older buildings and larger populations in the area. An extremely conservative approach was taken to analyze this taking into account the actual elevation of the mine compared to the shaft for vertical distances, as shown in Table 8. However, the mine plan does not plan to blast within 200 ft vertically and 6000 ft horizontally of downtown.

Regardless, even with an extremely conservative approach, the mining activities are so far away from the downtown area that no ground vibration is expected. All levels of the mine, in the worst case scenario produce NT. It is highly unlikely for anyone in downtown Grass Valley to perceive the ground vibration or for the ground vibration to cause any damage.

Table 8 - Downtown Grass Valley Ground Vibration Predictions

Mine Level	Weight of Explosive (lbs)	Vertical Distance From Blast (ft)	Horizantal Distance From Blast (ft)	True Distance from Blast (ft)	Cubed-Root Scaled Distance	Peak Particle Velocity (in/s)
500	133	169.5	6000	6002.39371	1175.91	NT
600	133	269.5	6000	6006.049471	1176.63	NT
700	133	369.5	6000	6011.366754	1177.67	NT
800	133	469.5	6000	6018.341154	1179.03	NT
900	133	569.5	6000	6026.96692	1180.72	NT
1000	133	669.5	6000	6037.236971	1182.74	NT
1100	133	769.5	6000	6049.142935	1185.07	NT
1200	133	869.5	6000	6062.675173	1187.72	NT
1300	133	969.5	6000	6077.822822	1190.69	NT
1400	133	1069.5	6000	6094.573837	1193.97	NT
1500	133	1169.5	6000	6112.915037	1197.56	NT
1600	133	1269.5	6000	6132.832156	1198.47	NT
1700	133	1369.5	6000	6154.309892	1199.69	NT
1800	133	1469.5	6000	6177.331969	1201.22	NT
1900	133	1569.5	6000	6201.881186	1203.05	NT
2000	133	1669.5	6000	6227.939487	1205.18	NT

5.0 TEMPORARY GROUND VIBRATION FROM CONSTRUCTION OF SHAFT RAISE AT THE IDAHO-MARYLAND MINE

The current mine plan includes an additional raise from underground to develop a new shaft at the site. Construction blasting of the shaft raise will commence from an underground drift and move upward towards the surface using similar blasting methods as described for raise development (vertical tunneling). This shaft would result in temporary blasting activities closer to the surface than the drift and stope development analyzed above. The details of expected ground vibration of the shaft have been described below.

5.1 Typical Shaft Round

The proposed shaft would have a breakthrough of approximately 50 ft below the ground surface due to the large amount of overburden above the rock. The shaft is expected to be approximately 18 ft x 12ft in area. If the shaft is constructed with drill and blast methods, blasting would be similar to the analysis presented in Section 4.1.2. The shaft will likely be developed using drill holes up to 1.25" diameter with a total of 8ft of explosive product loaded in the hole in each blast. It is assumed that up to five holes will fire on a single delay, for a total of 26.6 lbs of explosive being detonated per delay. This is made using the higher specific gravity of emulsion products, as was previously completed for the stoping analysis.

5.2 Ground Vibration from Shaft Round

The closest residence to the service shaft location on surface is greater than 900 ft horizontally. Based on the assumed charge weight per delay, the blasting vibrations will be undetectable at the nearest residence during the majority of construction of the raise from underground. For the final raise rounds taken as the raise approaches the surface the development of the shaft will be considered similar in manner to a construction blast, and the ground vibration of the shaft can then be calculated using the Konya and Konya prediction model for construction blasting (Konya & Konya, 2016). This equation is:

$$PPV\left(\frac{in}{s}\right) = 51 * \frac{d}{\sqrt{w}}^{-1.15}$$

Where: PPV = Peak Particle Velocity (in/s)

d = Distance from Blast (ft)

w = Weight of Explosive per 8ms Delay (lbs)

The highest levels of ground vibration will be that produced from the breakthrough round, as this has the least amount of vertical distance between the blast and the surface. While this round will be 50 ft below surface it will be blasted to the surface. This is an extremely conservative estimate both in the magnitude of estimating the ground vibration and assuming there is no vertical relief.

The ground vibration from this single shot would not be expected to cause damage to industrial structures adjacent to the raise breakthrough round or residences in the area. At maximum, the ground vibration at the nearest receptor is expected to be 0.13 in/s which is well below the 0.4 in/s recommendation for human perception.

6.0 AIR OVERPRESSURE

Air overpressure is an inaudible, low frequency pressure wave that moves through the air after a blast has occurred. This is typically recorded in decibels (dB), which is a logarithmic scale where the sound level doubles for every 6 dB. In some operations, there has been concern about air overpressure from blasting; however, the USBM stated that if the ground vibration was kept below the recommendations of the USBM, as per the Z-Curve described in RI8507, in almost all situations the air overpressure would be below the recommendations for maximum air overpressure. There are means and methods to predict the air overpressure from blasting, specifically that using the Konya and Konya Air Overpressure Prediction Formula (Konya & Konya, 2015). The equation for prediction of Air Overpressure is:

$$AP\ (dB) = -17.81 * \log(CRSD) + 170.34$$

Where: AP = Air Overpressure in decibels

CRSD = Cubed-Root Scaled Distance

Air overpressure is caused by numerous factors including the explosive detonation, movement, and collapse of a mine face which are in open air. In underground mining, especially the type proposed at the Idaho-Maryland Mine, there would be no air overpressure produced on the surface. The blast would not cause this pressure wave to form or an audible sound produced. The air overpressure from the underground blasting at the propose mine would be zero.

The single breakthrough round from the shaft may produce air overpressure of 126 dB, which is approximately 50% of the USBM recommendations (which are shown in Table 1 of this report (Siskind, Stagg, Kopp, & Dowding, 1989).

7.0 GROUND VIBRATION MONITORING PROGRAM

A ground vibration monitoring program for any mine is critical to determine the actual levels of ground vibration experienced and models should be developed on a monthly basis to determine how the ground around the mine is actually transmitting ground vibration. The models used in this report are extremely conservative and typically greatly overestimate the ground vibration experienced at the site. As such, PBS has recommended a ground vibration monitoring plan that the mine can follow to monitor and model the ground vibration from the site.

7.1 Site-Specific Seismograph Set-Up During Blasting

The mine should employee between 8 to 10 seismographs during the blasting of levels above the 1000 ft level. These seismographs should be placed at:

- One at the Brunswick Shaft
- One at each of the four corners of the Mine Property
- One in the Whispering Pines Industrial Park.
- Two at nearby residences
- Two travelling seismographs which can change location depending on the weekly/monthly mining plan

After the mine has stopped blasting at the proposed shaft and above the 1000 ft level, it is likely that only 5 seismographs would be required. One should be located at the Brunswick shaft and one in each of the four corners of the mine property. This would collect relevant data throughout the entire operation to understand how the ground is transmitting vibration in these areas.

7.2 Site-Specific Modelling of Ground Vibration

Once operations commence, it is recommended that IMM hire a blast consultant to assist with the development of a 95% confidence level equation for the site-specific ground vibration. This consultant would take the data acquired by the seismographs set-up on the mine, run a linear regression and log-log confidence model to develop an equation that the mine can use to modify blasting, as needed, to ensure vibration levels remain at acceptable levels. This equation would take the form of the equations previously used in this report.

8.0 OVERVIEW OF THE SECURITY OF EXPLOSIVES

The explosive industry is regulated by numerous agencies including the:

- Department of Transportation (DOT),
- Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF),
- Department of Homeland Security (DHS),
- Mine Safety and Health Administration (MSHA),
- Office of Surface Mining, Reclamation, and Enforcement (OSMRE)
- Environmental Protection Agency (EPA), and
- various State and Local Regulations.

The Idaho-Maryland Mine would require an ATF license to purchase and store explosives and would then be able to purchase explosives from an explosive manufacturer or explosive distributor. These manufacturers and distributors would be responsible for producing a quality explosive product and delivering the explosive to the mine in special explosive transportation trucks which meet the DOT regulations for transporting explosive products. IMM would then transport this explosive underground and place into an approved storage location. IMM is required to follow all MSHA regulations for the use of explosive products underground, The California Health and Safety Code, and the California Department of Industrial Relations.

9.0 CHEMICAL COMPOSITION OF EXPLOSIVES

The mine will utilize both ANFO (ammonium nitrate and fuel oil) and Emulsion. Both of these explosive products utilize ammonium nitrate as their main component. ANFO has the addition of fuel oil to it in a ratio of 94% ammonium nitrate and 6% fuel oil. ANFO is not water resistant and will dissolve if it comes into contact with any water. Since IMM may encounter groundwater within certain areas of the underground workings a mine would likely use an emulsion product when water is encountered.

Emulsion products vary in the industry on exact percentages of ingredients but contain ammonium nitrate, water, oil, emulsifier, and small percentages of hardeners or thickeners. These are mixed together to produce a slurry which can be pumped into packages or boreholes. The emulsion product is water resistant, it will not break down and will reliable perform in water.

10.0 CONCLUSION

The proposed blasting methods at the Idaho-Maryland Mine (IMM) have been thoroughly analyzed in this report to include drift, raise, and stope rounds that may be used on-site. This report has utilized extremely conservative methods of determination of potential ground vibration and all levels are likely largely overestimated. The mine is likely to produce much lower ground vibration levels than those mentioned in this report. The U.S. Bureau of Mines (USBM) and Office of Surface Mining, Reclamation, and Enforcement (OSMRE) have recommendations for ground vibration limits to prevent damage to residential structures. The proposed blasting at IMM would never approach these levels and a majority of blasting will have ground vibration less than 10% of these Z-Curve recommendations. The USBM recommended a peak particle velocity of 0.4 in/s as a threshold level if complaints and claims are to be kept below 8% of the potential number of complainants. The ground vibration from the proposed blasting at IMM is well below this recommendation and is typically less than half of this level.

Based on this analysis, it highly unlikely the mine would cause damage to structures in the area. Regular drift round blasting will be undetectable below 900 feet depth or distance and barely perceivable at 500 feet depth. The largest longhole blasts, occurring once every 3-4 days on average will be undetectable below 1400 feet depth or distance from a receiver. The maximum ground vibration that the mine would produce to nearby receptors is 0.23 in/s. This maximum calculated vibration considers a rare scenario where a longhole blast is done directly underneath a receptor at 500 feet depth. This maximum vibration of 0.23 in/s is similar to a Vibration Class 9, which is like running a garbage disposal in the house; with the exception that this blasting ground vibration would last only seconds. Table 9 summarizes the maximum ground vibration that would be produced from long hole blasts, based on the mine level, assuming blasting occurred directly below a receptor (no horizontal displacement). Blasting on mine levels below 1400 ft would produce no traceable ground vibration on the surface.

Table 9 – Summary of Maximum Ground Vibration, from longhole stope blasting, assuming no Horizontal Displacement

Mine Level	Peak Particle Velocity (in/s)
500	0.23
600	0.18
700	0.14
800	0.11
900	0.09
1000	0.08
1100	0.07
1200	0.06
1300	0.05
1400	0.05

In addition, identified structures (receptors) in the surrounding area have been analyzed to determine potential risk. Analog Devices may experience ground vibrations up to a maximum of 0.07 in/s which is below the limit that humans can feel. The Sierra Nevada Memorial Hospital would experience no ground vibration. Downtown Grass Valley would experience no ground vibration.

The community will experience no ground vibration from the drilling activities at the mine. The drilling produces no longstanding ground vibration and has no effects a few feet from the hole being drilled.

The community will experience no significant air overpressure from blasting at IMM. The underground blasting will not produce any air overpressure on the surface. The single breakthrough round of the shaft may produce air overpressure up to 25% of the USBM recommendation at the closest receptor.

The anticipated impact from drilling and blasting surrounding the proposed Idaho-Maryland Mine is negligible, and in almost all situations will be unnoticeable and undetectable by seismographs.

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APPENDIX A – LONG HOLE STOPE BLASTING GROUND VIBRATION

Table 10 - Stope Blast Anticipated Ground Vibration

Mine Level	Weight of Explosive (lbs)	Vertical Distance from Blast (ft)	Horizontal Distance from Blast (ft)	True Distance from Blast (ft)	Cubed-Root Scaled Distance	Peak Particle Velocity (in/s)
500	133	500	0	500.00	97.95	0.23
500	133	500	50	502.49	98.44	0.23
500	133	500	100	509.90	99.89	0.23
500	133	500	150	522.02	102.27	0.22
500	133	500	200	538.52	105.50	0.21
500	133	500	250	559.02	109.52	0.20
500	133	500	300	583.10	114.23	0.18
500	133	500	350	610.33	119.57	0.17
500	133	500	400	640.31	125.44	0.16
500	133	500	450	672.68	131.78	0.15
500	133	500	500	707.11	138.53	0.13
500	133	500	600	781.02	153.01	0.12
500	133	500	700	860.23	168.53	0.10
500	133	500	800	943.40	184.82	0.09
500	133	500	900	1029.56	201.70	0.07
500	133	500	1000	1118.03	219.03	0.06
500	133	500	1100	1208.30	236.72	0.06
500	133	500	1200	1300.00	254.68	0.05
500	133	500	1300	1392.84	272.87	0.05
500	133	500	1400	1486.61	291.24	NT
500	133	500	1500	1581.14	309.76	NT
500	133	500	2000	2061.55	403.87	NT
600	133	600	0	600.00	117.54	0.18
600	133	600	50	602.08	117.95	0.17
600	133	600	100	608.28	119.17	0.17
600	133	600	150	618.47	121.16	0.17
600	133	600	200	632.46	123.90	0.16
600	133	600	250	650.00	127.34	0.15
600	133	600	300	670.82	131.42	0.15
600	133	600	350	694.62	136.08	0.14
600	133	600	400	721.11	141.27	0.13
600	133	600	450	750.00	146.93	0.12
600	133	600	500	781.02	153.01	0.12
600	133	600	600	848.53	166.23	0.10
600	133	600	700	921.95	180.62	0.09

Mine Level	Weight of Explosive (lbs)	Vertical Distance from Blast (ft)	Horizontal Distance from Blast (ft)	True Distance from Blast (ft)	Cubed-Root Scaled Distance	Peak Particle Velocity (in/s)
600	133	600	800	1000.00	195.91	0.08
600	133	600	900	1081.67	211.91	0.07
600	133	600	1000	1166.19	228.46	0.06
600	133	600	1100	1253.00	245.47	0.05
600	133	600	1200	1341.64	262.84	0.05
600	133	600	1300	1431.78	280.50	NT
600	133	600	1400	1523.15	298.40	NT
600	133	600	1500	1615.55	316.50	NT
700	133	700	2000	2118.96	415.12	NT
700	133	700	0	700.00	137.13	0.14
700	133	700	50	701.78	137.48	0.14
700	133	700	100	707.11	138.53	0.13
700	133	700	150	715.89	140.25	0.13
700	133	700	200	728.01	142.62	0.13
700	133	700	250	743.30	145.62	0.12
700	133	700	300	761.58	149.20	0.12
700	133	700	350	782.62	153.32	0.11
700	133	700	400	806.23	157.95	0.11
700	133	700	450	832.17	163.03	0.10
700	133	700	500	860.23	168.53	0.10
700	133	700	600	921.95	180.62	0.09
700	133	700	700	989.95	193.94	0.08
700	133	700	800	1063.01	208.25	0.07
700	133	700	900	1140.18	223.37	0.06
700	133	700	1000	1220.66	239.13	0.06
700	133	700	1100	1303.84	255.43	0.05
700	133	700	1200	1389.24	272.16	0.05
700	133	700	1300	1476.48	289.25	NT
700	133	700	1400	1565.25	306.64	NT
700	133	700	1500	1655.29	324.28	NT
700	133	700	2000	2118.96	415.12	NT
800	133	800	0	800.00	156.73	0.11
800	133	800	50	801.56	157.03	0.11
800	133	800	100	806.23	157.95	0.11
800	133	800	150	813.94	159.46	0.11
800	133	800	200	824.62	161.55	0.11
800	133	800	250	838.15	164.20	0.10
800	133	800	300	854.40	167.38	0.10

Mine Level	Weight of Explosive (lbs)	Vertical Distance from Blast (ft)	Horizontal Distance from Blast (ft)	True Distance from Blast (ft)	Cubed-Root Scaled Distance	Peak Particle Velocity (in/s)
800	133	800	350	873.21	171.07	0.10
800	133	800	400	894.43	175.22	0.09
800	133	800	450	917.88	179.82	0.09
800	133	800	500	943.40	184.82	0.09
800	133	800	600	1000.00	195.91	0.08
800	133	800	700	1063.01	208.25	0.07
800	133	800	800	1131.37	221.64	0.06
800	133	800	900	1204.16	235.90	0.06
800	133	800	1000	1280.62	250.88	0.05
800	133	800	1100	1360.15	266.46	0.05
800	133	800	1200	1442.22	282.54	NT
800	133	800	1300	1526.43	299.04	NT
800	133	800	1400	1612.45	315.89	NT
800	133	800	1500	1700.00	333.04	NT
800	133	800	2000	2154.07	422.00	NT
900	133	900	0	900.00	176.32	0.09
900	133	900	50	901.39	176.59	0.09
900	133	900	100	905.54	177.40	0.09
900	133	900	150	912.41	178.75	0.09
900	133	900	200	921.95	180.62	0.09
900	133	900	250	934.08	182.99	0.09
900	133	900	300	948.68	185.85	0.08
900	133	900	350	965.66	189.18	0.08
900	133	900	400	984.89	192.95	0.08
900	133	900	450	1006.23	197.13	0.08
900	133	900	500	1029.56	201.70	0.07
900	133	900	600	1081.67	211.91	0.07
900	133	900	700	1140.18	223.37	0.06
900	133	900	800	1204.16	235.90	0.06
900	133	900	900	1272.79	249.35	0.05
900	133	900	1000	1345.36	263.57	0.05
900	133	900	1100	1421.27	278.44	NT
900	133	900	1200	1500.00	293.86	NT
900	133	900	1300	1581.14	309.76	NT
900	133	900	1400	1664.33	326.05	NT
900	133	900	1500	1749.29	342.70	NT
900	133	900	2000	2193.17	429.66	NT
1000	133	1000	0	1000.00	195.91	0.08

Mine Level	Weight of Explosive (lbs)	Vertical Distance from Blast (ft)	Horizontal Distance from Blast (ft)	True Distance from Blast (ft)	Cubed-Root Scaled Distance	Peak Particle Velocity (in/s)
1000	133	1000	50	1001.25	196.15	0.08
1000	133	1000	100	1004.99	196.88	0.08
1000	133	1000	150	1011.19	198.10	0.08
1000	133	1000	200	1019.80	199.79	0.08
1000	133	1000	250	1030.78	201.94	0.07
1000	133	1000	300	1044.03	204.53	0.07
1000	133	1000	350	1059.48	207.56	0.07
1000	133	1000	400	1077.03	211.00	0.07
1000	133	1000	450	1096.59	214.83	0.07
1000	133	1000	500	1118.03	219.03	0.06
1000	133	1000	600	1166.19	228.46	0.06
1000	133	1000	700	1220.66	239.13	0.06
1000	133	1000	800	1280.62	250.88	0.05
1000	133	1000	900	1345.36	263.57	0.05
1000	133	1000	1000	1414.21	277.05	NT
1000	133	1000	1100	1486.61	291.24	NT
1000	133	1000	1200	1562.05	306.02	NT
1000	133	1000	1300	1640.12	321.31	NT
1000	133	1000	1400	1720.47	337.05	NT
1000	133	1000	1500	1802.78	353.18	NT
1000	133	1000	2000	2236.07	438.06	NT
1100	133	1100	0	1100.00	215.50	0.07
1100	133	1100	50	1101.14	215.72	0.07
1100	133	1100	100	1104.54	216.39	0.07
1100	133	1100	150	1110.18	217.49	0.07
1100	133	1100	200	1118.03	219.03	0.06
1100	133	1100	250	1128.05	220.99	0.06
1100	133	1100	300	1140.18	223.37	0.06
1100	133	1100	350	1154.34	226.14	0.06
1100	133	1100	400	1170.47	229.30	0.06
1100	133	1100	450	1188.49	232.83	0.06
1100	133	1100	500	1208.30	236.72	0.06
1100	133	1100	600	1253.00	245.47	0.05
1100	133	1100	700	1303.84	255.43	0.05
1100	133	1100	800	1360.15	266.46	0.05
1100	133	1100	900	1421.27	278.44	NT
1100	133	1100	1000	1486.61	291.24	NT
1100	133	1100	1100	1555.63	304.76	NT

Mine Level	Weight of Explosive (lbs)	Vertical Distance from Blast (ft)	Horizontal Distance from Blast (ft)	True Distance from Blast (ft)	Cubed-Root Scaled Distance	Peak Particle Velocity (in/s)
1100	133	1100	1200	1627.88	318.91	NT
1100	133	1100	1300	1702.94	333.62	NT
1100	133	1100	1400	1780.45	348.80	NT
1100	133	1100	1500	1860.11	364.41	NT
1100	133	1100	2000	2282.54	447.17	NT
1200	133	1200	0	1200.00	235.09	0.06
1200	133	1200	50	1201.04	235.29	0.06
1200	133	1200	100	1204.16	235.90	0.06
1200	133	1200	150	1209.34	236.92	0.06
1200	133	1200	200	1216.55	238.33	0.06
1200	133	1200	250	1225.77	240.14	0.06
1200	133	1200	300	1236.93	242.32	0.06
1200	133	1200	350	1250.00	244.88	0.05
1200	133	1200	400	1264.91	247.80	0.05
1200	133	1200	450	1281.60	251.07	0.05
1200	133	1200	500	1300.00	254.68	0.05
1200	133	1200	600	1341.64	262.84	0.05
1200	133	1200	700	1389.24	272.16	0.05
1200	133	1200	800	1442.22	282.54	NT
1200	133	1200	900	1500.00	293.86	NT
1200	133	1200	1000	1562.05	306.02	NT
1200	133	1200	1100	1627.88	318.91	NT
1200	133	1200	1200	1697.06	332.46	NT
1200	133	1200	1300	1769.18	346.59	NT
1200	133	1200	1400	1843.91	361.23	NT
1200	133	1200	1500	1920.94	376.32	NT
1200	133	1200	2000	2332.38	456.93	NT
1300	133	1300	0	1300.00	254.68	0.05
1300	133	1300	50	1300.96	254.87	0.05
1300	133	1300	100	1303.84	255.43	0.05
1300	133	1300	150	1308.63	256.37	0.05
1300	133	1300	200	1315.29	257.68	0.05
1300	133	1300	250	1323.82	259.35	0.05
1300	133	1300	300	1334.17	261.37	0.05
1300	133	1300	350	1346.29	263.75	0.05
1300	133	1300	400	1360.15	266.46	0.05
1300	133	1300	450	1375.68	269.51	0.05
1300	133	1300	500	1392.84	272.87	0.05

Mine Level	Weight of Explosive (lbs)	Vertical Distance from Blast (ft)	Horizontal Distance from Blast (ft)	True Distance from Blast (ft)	Cubed-Root Scaled Distance	Peak Particle Velocity (in/s)
1300	133	1300	600	1431.78	280.50	NT
1300	133	1300	700	1476.48	289.25	NT
1300	133	1300	800	1526.43	299.04	NT
1300	133	1300	900	1581.14	309.76	NT
1300	133	1300	1000	1640.12	321.31	NT
1300	133	1300	1100	1702.94	333.62	NT
1300	133	1300	1200	1769.18	346.59	NT
1300	133	1300	1300	1838.48	360.17	NT
1300	133	1300	1400	1910.50	374.28	NT
1300	133	1300	1500	1984.94	388.86	NT
1300	133	1300	2000	2385.37	467.31	NT
1400	133	1400	0	1400.00	274.27	0.05
1400	133	1400	50	1400.89	274.44	0.05
1400	133	1400	100	1403.57	274.97	0.05
1400	133	1400	150	1408.01	275.84	NT
1400	133	1400	200	1414.21	277.05	NT
1400	133	1400	250	1422.15	278.61	NT
1400	133	1400	300	1431.78	280.50	NT
1400	133	1400	350	1443.09	282.71	NT
1400	133	1400	400	1456.02	285.24	NT
1400	133	1400	450	1470.54	288.09	NT
1400	133	1400	500	1486.61	291.24	NT
1400	133	1400	600	1523.15	298.40	NT
1400	133	1400	700	1565.25	306.64	NT
1400	133	1400	800	1612.45	315.89	NT
1400	133	1400	900	1664.33	326.05	NT
1400	133	1400	1000	1720.47	337.05	NT
1400	133	1400	1100	1780.45	348.80	NT
1400	133	1400	1200	1843.91	361.23	NT
1400	133	1400	1300	1910.50	374.28	NT
1400	133	1400	1400	1979.90	387.88	NT
1400	133	1400	1500	2051.83	401.97	NT
1400	133	1400	2000	2441.31	478.27	NT

APPENDIX B – LONG HOLE STOPE BLASTING VIBRATION CHARTS

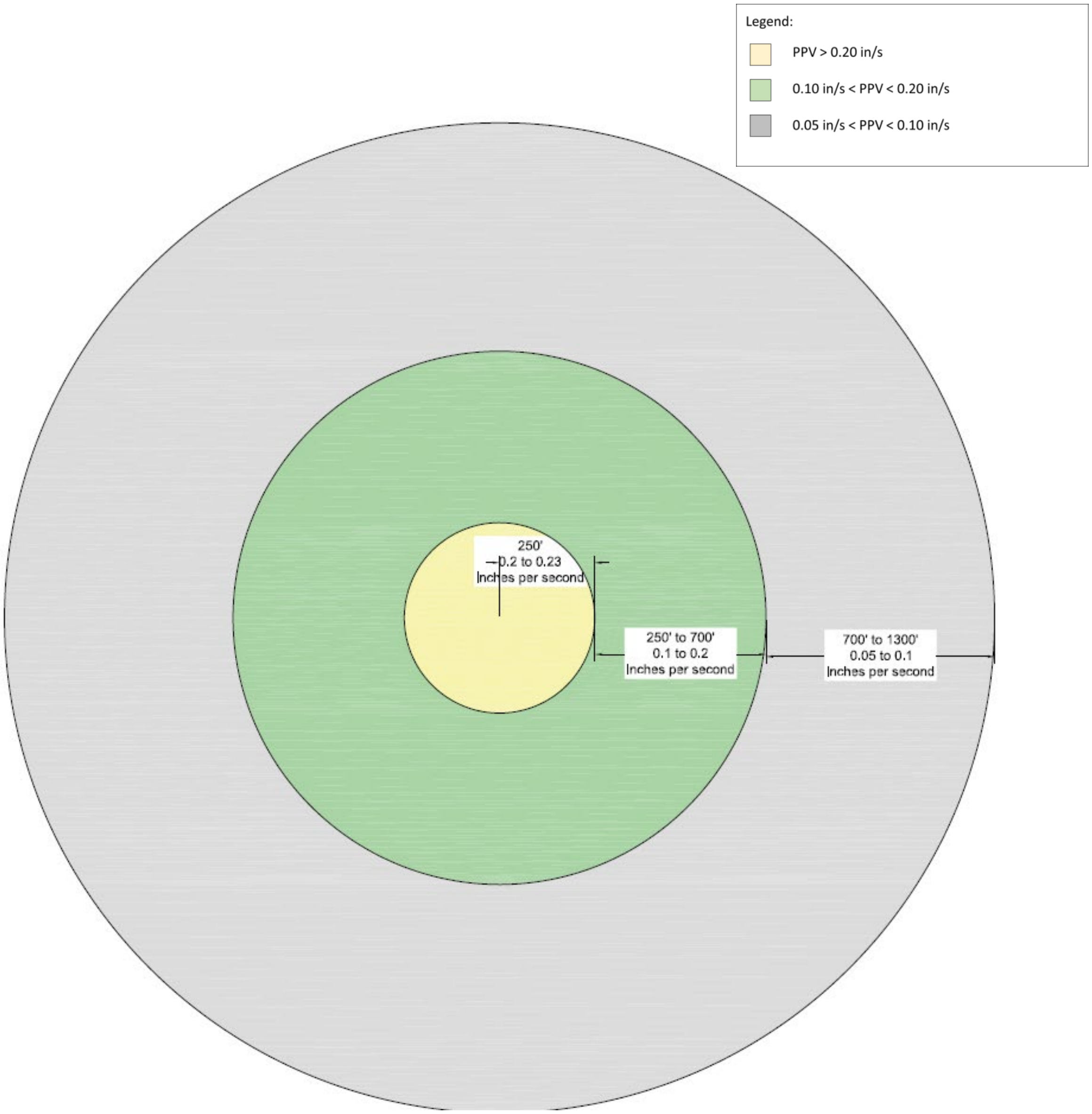

Figure 8 - 500 Foot Mine Depth to Horizontal Distances

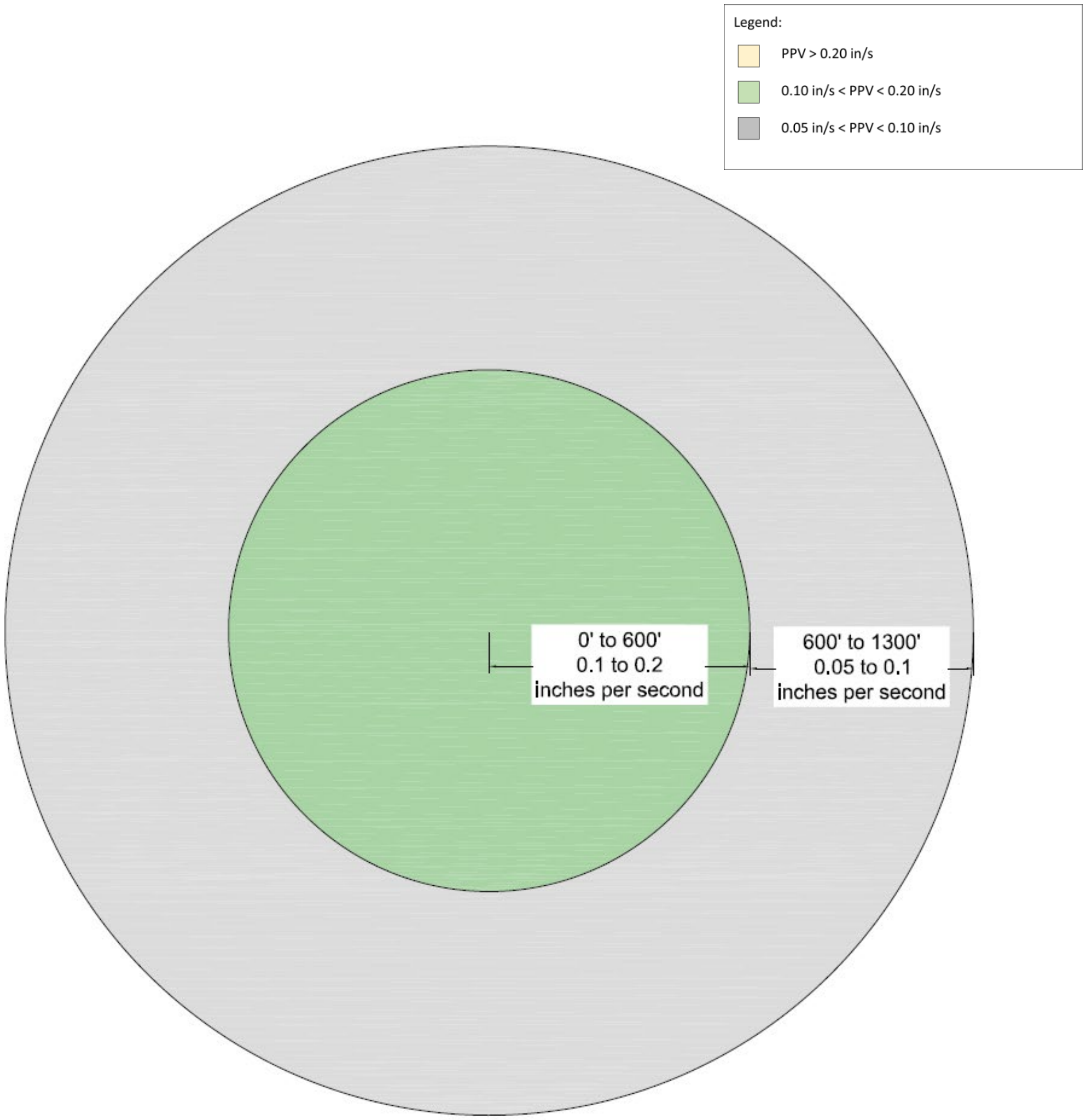

Figure 9 - 600 Foot Mine Depth to Horizontal Distances

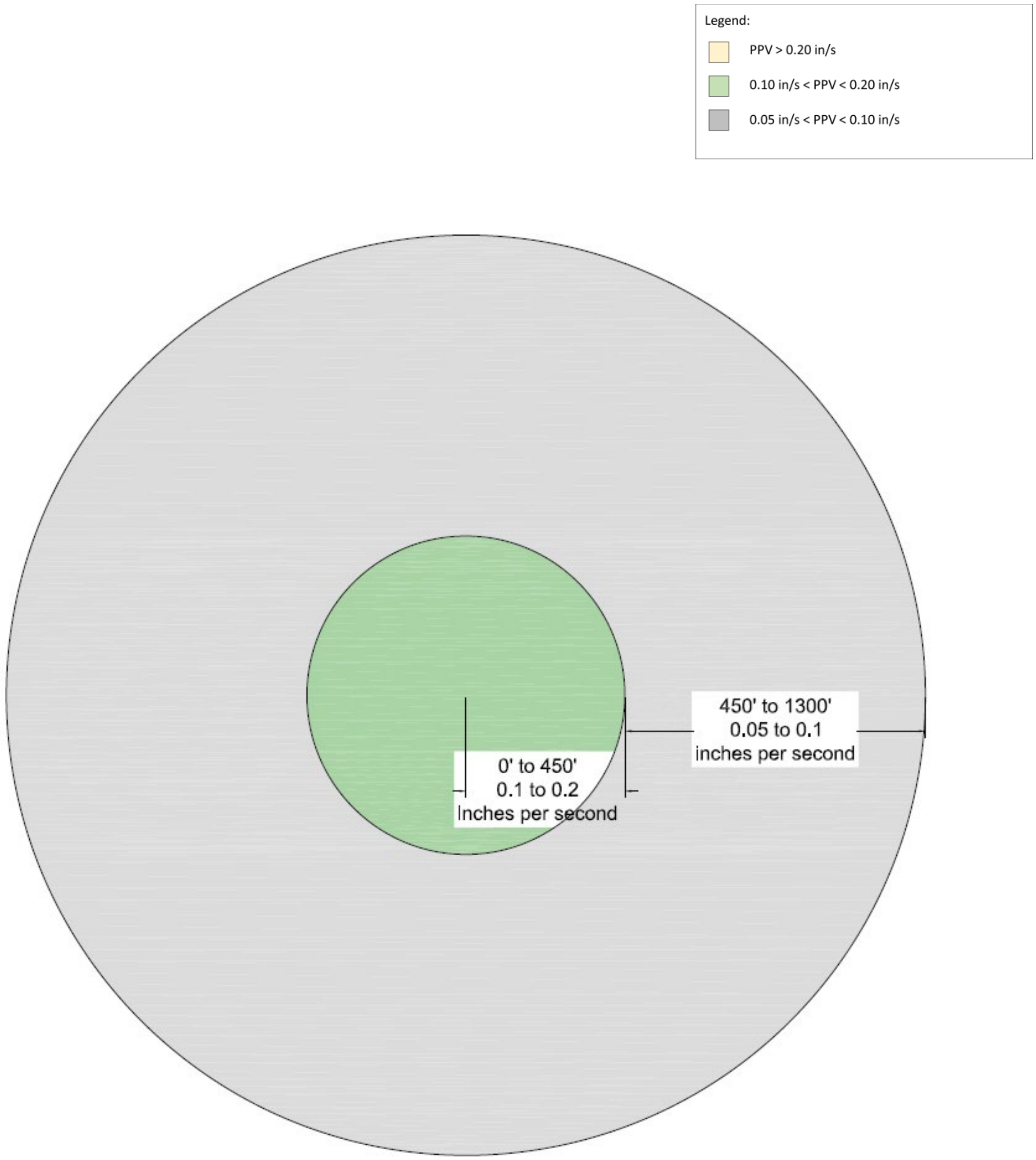

Figure 10 - 700 Foot Mine Depth to Horizontal Distances

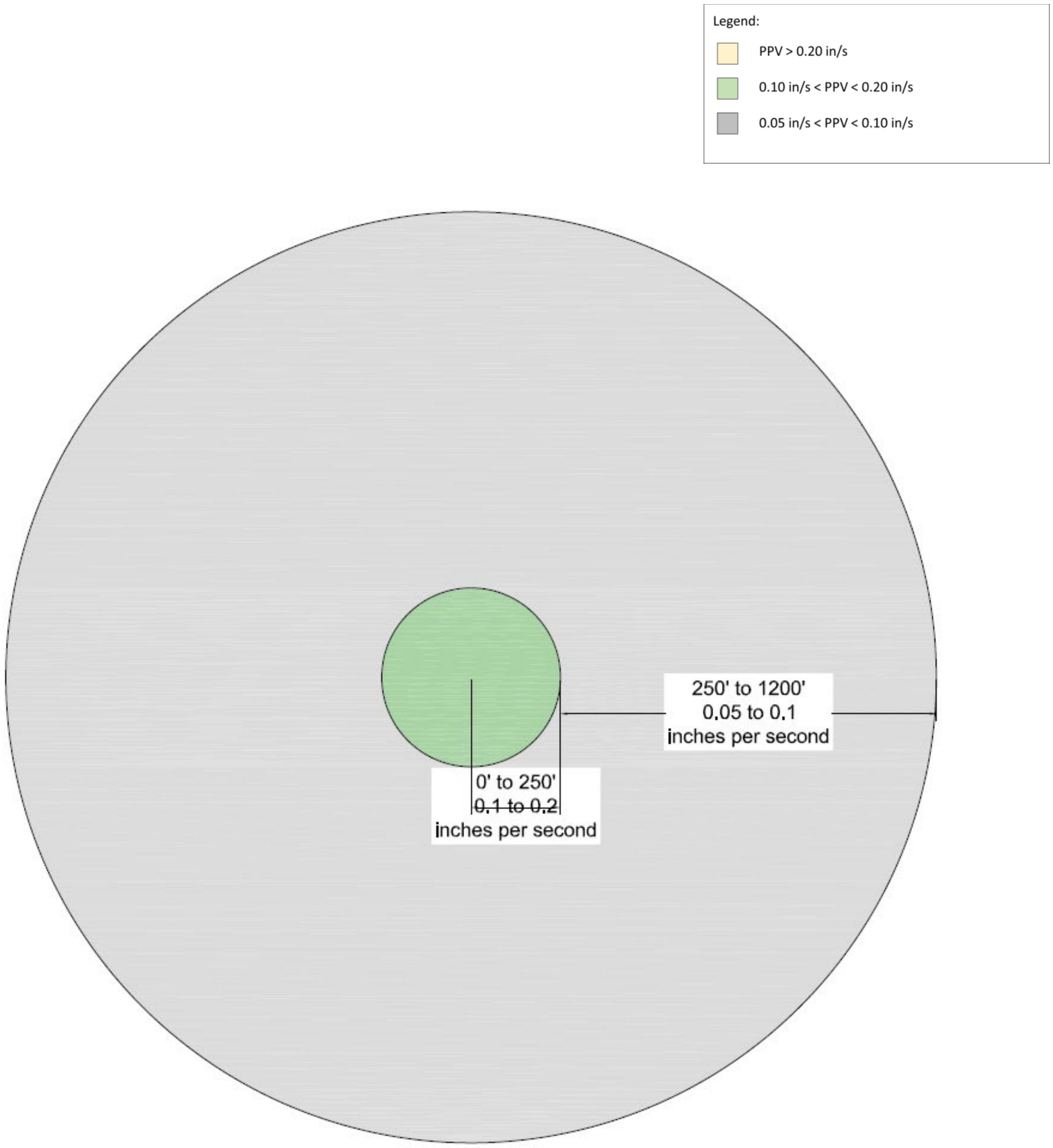

Figure 11 - 800 foot Mine Depth to Horizontal Distances

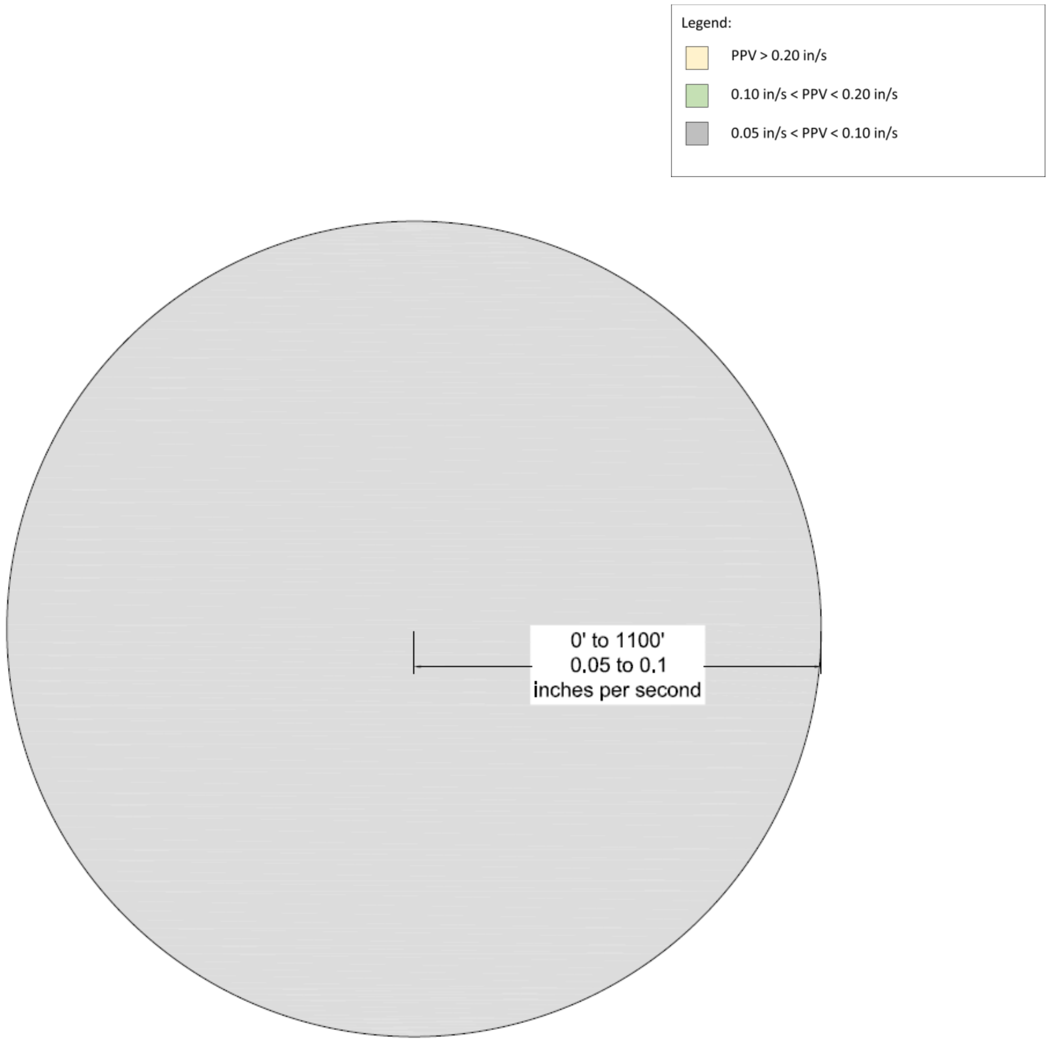

Figure 12 - 900 Foot Mine Depth to Horizontal Distances

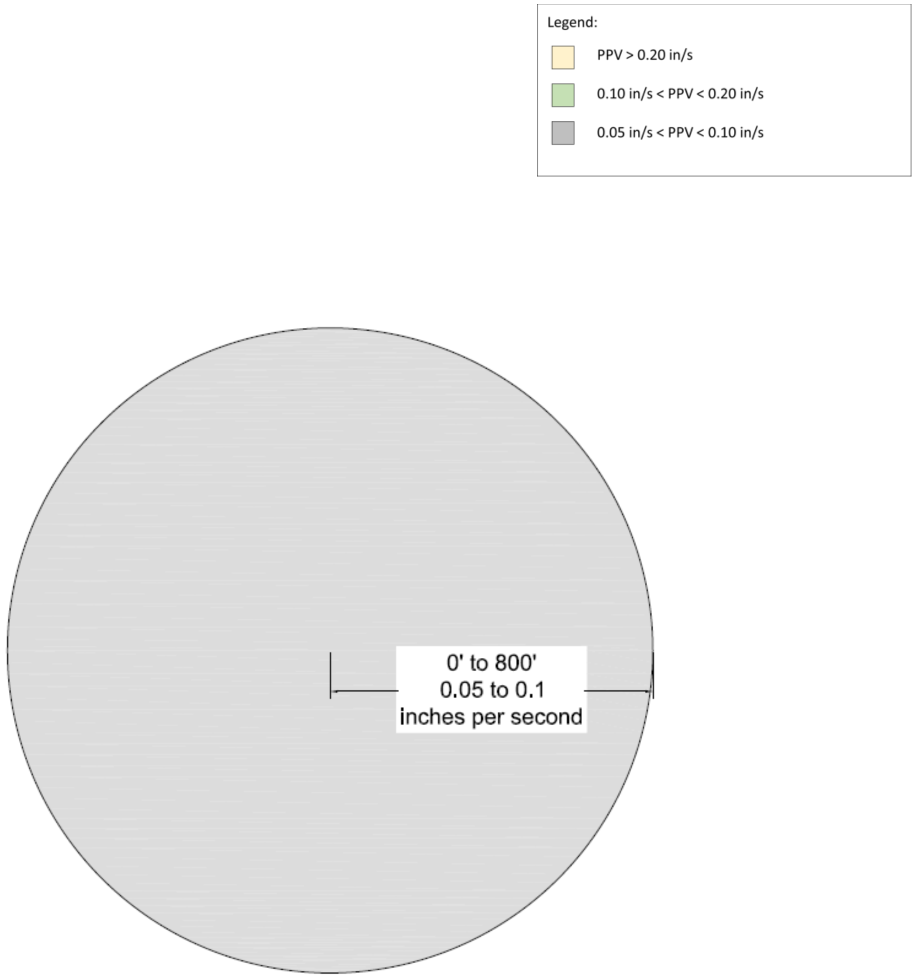

Figure 13 - 1000 foot Mine Level to Horizontal Distance

APPENDIX C – DRIFT ROUND ANTICIPATED GROUND VIBRATION

Table 11 - Anticipated Ground Vibration from Drift Rounds

Mine Level	Weight of Explosive (lbs)	Vertical Distance From Blast (ft)	Horizontal Distance From Blast (ft)	True Distance from Blast (ft)	Cubed-Root Scaled Distance	Peak Particle Velocity (in/s)
500	52.1	500	0	500.00	133.87	0.14
500	52.1	500	50	502.49	134.54	0.14
500	52.1	500	100	509.90	136.52	0.14
500	52.1	500	150	522.02	139.77	0.13
500	52.1	500	200	538.52	144.18	0.13
500	52.1	500	250	559.02	149.67	0.12
500	52.1	500	300	583.10	156.12	0.11
500	52.1	500	350	610.33	163.41	0.10
500	52.1	500	400	640.31	171.44	0.10
500	52.1	500	450	672.68	180.11	0.09
500	52.1	500	500	707.11	189.32	0.08
500	52.1	500	600	781.02	209.12	0.07
500	52.1	500	700	860.23	230.32	0.06
500	52.1	500	800	943.40	252.59	0.05
500	52.1	500	900	1029.56	275.66	NT
500	52.1	500	1000	1118.03	299.35	NT
500	52.1	500	1100	1208.30	323.52	NT
500	52.1	500	1200	1300.00	348.07	NT
500	52.1	500	1300	1392.84	372.93	NT
500	52.1	500	1400	1486.61	398.03	NT
500	52.1	500	1500	1581.14	423.34	NT
500	52.1	500	2000	2061.55	551.97	NT
600	52.1	600	0	600.00	160.65	0.11
600	52.1	600	50	602.08	161.20	0.11
600	52.1	600	100	608.28	162.86	0.10
600	52.1	600	150	618.47	165.59	0.10
600	52.1	600	200	632.46	169.34	0.10
600	52.1	600	250	650.00	174.03	0.09
600	52.1	600	300	670.82	179.61	0.09
600	52.1	600	350	694.62	185.98	0.08
600	52.1	600	400	721.11	193.07	0.08
600	52.1	600	450	750.00	200.81	0.07
600	52.1	600	500	781.02	209.12	0.07
600	52.1	600	600	848.53	227.19	0.06
600	52.1	600	700	921.95	246.85	0.05

Mine Level	Weight of Explosive (lbs)	Vertical Distance From Blast (ft)	Horizontal Distance From Blast (ft)	True Distance from Blast (ft)	Cubed-Root Scaled Distance	Peak Particle Velocity (in/s)
600	52.1	600	800	1000.00	267.74	0.05
600	52.1	600	900	1081.67	289.61	NT
600	52.1	600	1000	1166.19	312.24	NT
600	52.1	600	1100	1253.00	335.48	NT
600	52.1	600	1200	1341.64	359.22	NT
600	52.1	600	1300	1431.78	383.35	NT
600	52.1	600	1400	1523.15	407.82	NT
600	52.1	600	1500	1615.55	432.55	NT
700	52.1	700	2000	2118.96	567.34	NT
700	52.1	700	0	700.00	187.42	0.08
700	52.1	700	50	701.78	187.90	0.08
700	52.1	700	100	707.11	189.32	0.08
700	52.1	700	150	715.89	191.68	0.08
700	52.1	700	200	728.01	194.92	0.08
700	52.1	700	250	743.30	199.02	0.08
700	52.1	700	300	761.58	203.91	0.07
700	52.1	700	350	782.62	209.54	0.07
700	52.1	700	400	806.23	215.86	0.07
700	52.1	700	450	832.17	222.81	0.06
700	52.1	700	500	860.23	230.32	0.06
700	52.1	700	600	921.95	246.85	0.05
700	52.1	700	700	989.95	265.05	0.05
700	52.1	700	800	1063.01	284.62	NT
700	52.1	700	900	1140.18	305.28	NT
700	52.1	700	1000	1220.66	326.82	NT
700	52.1	700	1100	1303.84	349.10	NT
700	52.1	700	1200	1389.24	371.96	NT
700	52.1	700	1300	1476.48	395.32	NT
700	52.1	700	1400	1565.25	419.09	NT
700	52.1	700	1500	1655.29	443.20	NT
700	52.1	700	2000	2118.96	567.34	NT
800	52.1	800	0	800.00	214.20	0.07
800	52.1	800	50	801.56	214.61	0.07
800	52.1	800	100	806.23	215.86	0.07
800	52.1	800	150	813.94	217.93	0.07
800	52.1	800	200	824.62	220.79	0.06
800	52.1	800	250	838.15	224.41	0.06
800	52.1	800	300	854.40	228.76	0.06

Mine Level	Weight of Explosive (lbs)	Vertical Distance From Blast (ft)	Horizontal Distance From Blast (ft)	True Distance from Blast (ft)	Cubed-Root Scaled Distance	Peak Particle Velocity (in/s)
800	52.1	800	350	873.21	233.80	0.06
800	52.1	800	400	894.43	239.48	0.06
800	52.1	800	450	917.88	245.76	0.05
800	52.1	800	500	943.40	252.59	0.05
800	52.1	800	600	1000.00	267.74	0.05
800	52.1	800	700	1063.01	284.62	NT
800	52.1	800	800	1131.37	302.92	NT
800	52.1	800	900	1204.16	322.41	NT
800	52.1	800	1000	1280.62	342.88	NT
800	52.1	800	1100	1360.15	364.17	NT
800	52.1	800	1200	1442.22	386.15	NT
800	52.1	800	1300	1526.43	408.69	NT
800	52.1	800	1400	1612.45	431.73	NT
800	52.1	800	1500	1700.00	455.17	NT
800	52.1	800	2000	2154.07	576.74	NT
900	52.1	900	0	900.00	240.97	0.06
900	52.1	900	50	901.39	241.34	0.06
900	52.1	900	100	905.54	242.45	0.06
900	52.1	900	150	912.41	244.29	0.05
900	52.1	900	200	921.95	246.85	0.05
900	52.1	900	250	934.08	250.09	0.05
900	52.1	900	300	948.68	254.00	0.05
900	52.1	900	350	965.66	258.55	0.05
900	52.1	900	400	984.89	263.70	0.05
900	52.1	900	450	1006.23	269.41	0.05
900	52.1	900	500	1029.56	275.66	NT
900	52.1	900	600	1081.67	289.61	NT
900	52.1	900	700	1140.18	305.28	NT
900	52.1	900	800	1204.16	322.41	NT
900	52.1	900	900	1272.79	340.78	NT
900	52.1	900	1000	1345.36	360.21	NT
900	52.1	900	1100	1421.27	380.54	NT
900	52.1	900	1200	1500.00	401.62	NT
900	52.1	900	1300	1581.14	423.34	NT
900	52.1	900	1400	1664.33	445.62	NT
900	52.1	900	1500	1749.29	468.36	NT
900	52.1	900	2000	2193.17	587.21	NT
1000	52.1	1000	0	1000.00	267.74	0.05

Mine Level	Weight of Explosive (lbs)	Vertical Distance From Blast (ft)	Horizontal Distance From Blast (ft)	True Distance from Blast (ft)	Cubed-Root Scaled Distance	Peak Particle Velocity (in/s)
1000	52.1	1000	50	1001.25	268.08	0.05
1000	52.1	1000	100	1004.99	269.08	0.05
1000	52.1	1000	150	1011.19	270.74	0.05
1000	52.1	1000	200	1019.80	273.05	0.05
1000	52.1	1000	250	1030.78	275.98	NT
1000	52.1	1000	300	1044.03	279.53	NT
1000	52.1	1000	350	1059.48	283.67	NT
1000	52.1	1000	400	1077.03	288.37	NT
1000	52.1	1000	450	1096.59	293.60	NT
1000	52.1	1000	500	1118.03	299.35	NT
1000	52.1	1000	600	1166.19	312.24	NT
1000	52.1	1000	700	1220.66	326.82	NT
1000	52.1	1000	800	1280.62	342.88	NT
1000	52.1	1000	900	1345.36	360.21	NT
1000	52.1	1000	1000	1414.21	378.65	NT
1000	52.1	1000	1100	1486.61	398.03	NT
1000	52.1	1000	1200	1562.05	418.23	NT
1000	52.1	1000	1300	1640.12	439.13	NT
1000	52.1	1000	1400	1720.47	460.65	NT
1000	52.1	1000	1500	1802.78	482.68	NT
1000	52.1	1000	2000	2236.07	598.70	NT
1100	52.1	1100	0	1100.00	294.52	NT
1100	52.1	1100	50	1101.14	294.82	NT
1100	52.1	1100	100	1104.54	295.73	NT
1100	52.1	1100	150	1110.18	297.24	NT
1100	52.1	1100	200	1118.03	299.35	NT
1100	52.1	1100	250	1128.05	302.03	NT
1100	52.1	1100	300	1140.18	305.28	NT
1100	52.1	1100	350	1154.34	309.07	NT
1100	52.1	1100	400	1170.47	313.39	NT
1100	52.1	1100	450	1188.49	318.21	NT
1100	52.1	1100	500	1208.30	323.52	NT
1100	52.1	1100	600	1253.00	335.48	NT
1100	52.1	1100	700	1303.84	349.10	NT
1100	52.1	1100	800	1360.15	364.17	NT
1100	52.1	1100	900	1421.27	380.54	NT
1100	52.1	1100	1000	1486.61	398.03	NT
1100	52.1	1100	1100	1555.63	416.51	NT

Mine Level	Weight of Explosive (lbs)	Vertical Distance From Blast (ft)	Horizontal Distance From Blast (ft)	True Distance from Blast (ft)	Cubed-Root Scaled Distance	Peak Particle Velocity (in/s)
1100	52.1	1100	1200	1627.88	435.86	NT
1100	52.1	1100	1300	1702.94	455.95	NT
1100	52.1	1100	1400	1780.45	476.71	NT
1100	52.1	1100	1500	1860.11	498.03	NT
1100	52.1	1100	2000	2282.54	611.14	NT

APPENDIX D – ANTHONY KONYA M.S. QUALIFICATIONS

EDUCATION

Missouri University of Science and Technology - Rolla, Missouri

- Doctorate of Philosophy (Ph.D.) in Explosive Engineering
  - Research in Precision Presplitting and Overbreak Control
  - Additional Coursework in Rock Blasting, Construction Blasting, Explosive Testing and Instrumentation
  - Graduation December 2019

Missouri University of Science and Technology - Rolla, Missouri

- Master of Science in Explosive Engineering
  - Research in Precision Presplitting and Overbreak Control
  - Additional Coursework in Construction Methods and Project Management
- Graduate Certificate in Explosive Engineering
- Graduate Certificate in Financial Engineering

Missouri University of Science and Technology - Rolla, Missouri

- B.S. in Mining Engineering
  - Graduated with Distinction in Mining Engineering
  - Summa Cum Laude
  - Outstanding Undergraduate Research Award

FUNDED RESEARCH

1. Analysis of Environmental Effects of Precision Presplitting for Construction Blasting, Funded by Precision Blasting Services
2. Optimization of Underground Salt Blasting with the Utilization of an Undercut, Funded by Cargill Inc.
3. Development of Chemical Formulations for Emulsion Gassing for a Dynamic Manufacturing System, Funded by Energia Kft
4. Development of Low Viscosity Emulsion Products, Funded by Energia Kft and Lubrizol
5. The Investigation of the Mechanics of Precision Presplitting Formation, Funded by Precision Blasting Services
6. Analysis of Near Field Air Overpressure from Stemming Ejection in Surface Blasting, Funded by Precision Blasting Services
7. Impacts of Underground Blast Vibration on Surface and Underground Structures, Funded by Precision Blasting Services
8. Investigation into Air Overpressure Generation from Unconfined Explosive Charges Underground, Funded by Precision Blasting Services

COURSES AND SEMINARS

1. Underwater Blasting (Exp Eng 5001). Spring 2019. Missouri S&T. Instructor.
2. Specialty Uses of Energetic Materials (Exp Eng 5721). Spring 2019. Missouri S&T. Instructor.
3. Blasting Design and Technology (Exp Eng 5622). Spring 2019. Missouri S&T. Graduate Teaching Assistant.

4. MSHA Certification 8-Hour New Miner Refresher. Spring 2019. Missouri S&T. Instructor.
5. Introduction to Mine Health and Safety (Min Eng 2126). Fall 2018. Missouri S&T. Instructor.
6. Principles of Explosive Engineering (Exp Eng 5612). Fall 2018. Missouri S&T. Graduate Teaching Assistant/Instructor.
7. Introduction to Mine Health and Safety (Min Eng 2126). Spring 2018. Missouri S&T. Instructor.
8. MSHA Certification 8-Hour New Miner Refresher. Spring 2018. Missouri S&T. Instructor.
9. Specialty Uses of Energetic Materials (Exp Eng 5721). Spring 2018. Missouri S&T. Instructor.
10. Blasting Design and Technology (Exp Eng 5622). Spring 2018. Missouri S&T. Graduate Teaching Assistant.
11. Introduction to Mine Health and Safety (Min Eng 2126). Spring 2017. Missouri S&T. Instructor.
12. MSHA Certification 8-Hour New Miner Refresher. Spring 2017. Missouri S&T. Instructor.
13. Graduate Level Mine Health and Safety Training. Fall 2017. Missouri S&T. Instructor.
14. Principles of Explosive Engineering (Exp Eng 5612). Fall 2017. Missouri S&T. Graduate Teaching Assistant.
15. MSHA Certification 8-Hour New Miner Refresher. Spring 2016. Missouri S&T. Instructor.

BOOKS AND BOOK CHAPTERS

1. Konya, A.J. & Konya, C.J., Dr. (2017) Effects of Hole Stemming Practices on Energy Efficiency of Comminution In A. Kwame (Ed.) *Energy Efficiency in the Minerals Industry: Best Practices and Research Directions*. Springer.

PEER REVIEWED PUBLICATIONS

1. Konya, A. J., & Konya, C. J., Dr. (2015). Airblast Prediction Equations for Construction Blasting. International Society of Explosive Engineers 41st Proceedings.
2. Konya, C. J., Dr., & Konya, A. J. (2015). Precision Presplit Design. 8th Blasting Symposium (Istanbul, Turkey).
3. Konya, A. J., & Konya, C. J., Dr. (2016). Precision Presplitting Optimization. 42nd International Society of Explosive Engineers Proceedings.
4. Konya, A. J. (2016). Basics of Salt Blasting. 42nd International Society of Explosive Engineers Proceedings.
5. Konya, A.J. & Konya, C.J., Dr. (2017, February). Precision Presplitting – Explosive Variations with Spacing. 43rd International Society of Explosive Engineers Proceedings
6. Konya, A.J. & Konya, C.J., Dr. (2017, February). Precision Presplitting. Society for Mining, Metallurgy, and Exploration Proceedings.
7. Konya, A.J.; Konya, C.J., Dr. (2018, January). Predicting Vibration Through Linear-Regression Modeling. 44th Annual Conference on Explosivess & Blasting Technique Proceedings. San Antonio, Texas.
8. Konya, A.J.; Konya C.J., Dr. (2018, February). Modelling and Prediction of Underground Blast Vibrations. 2018 Society of Mining, Metallurgy, and Exploration Conference Proceedings. Minneapolis, Minnesota.

9. Konya, A.J.; Worsey, P.N., Dr (2018, February). Design Philosophy for Modern Underground Blast Design. 2018 Society of Mining, Metallurgy, and Exploration Conference Proceedings. Minneapolis, Minnesota.

TECHNICAL PUBLICATIONS

1. Konya, C. J., Dr., & Konya, A. J. (2015). Precision Presplit Design. 8th Blasting Symposium (Istanbul, Turkey). - *Invited Speaker*
2. Konya, A. J. (2015, December). Avery Island Blasting Optimization. Cargill Snowglobe.
3. Konya, A. J. (2015, December). Project Management: Locker Room Renovation. Cargill Snowglobe.
4. Konya, A. J. (2015, December). Project Management: Avery Steam Hoist Guarding. Cargill Snowglobe.
5. Konya, A. J. (2016, March). Six Sigma Blasting. Quarry Management.
6. Konya, A.J. "Undercutter Blast Design". Underground Blasting. By Dr. Calvin Konya. Montville: Academy of Blasting and Explosive Technology, 2016. Print.
7. Konya, A.J. & Konya, C.J., Dr. (2016, May). Precision Presplitting – The Basics. Rock Products.
8. Konya, A.J. & Konya, C.J., Dr. (2016, June). Precision Presplitting – Design Aspects. Rock Products.
9. Konya, A.J. & Konya, C.J., Dr. (2016, August). Precision Presplitting – Variable Spacing. Rock Products.
10. Konya, A.J. & Konya, C.J., Dr. (2017, January). Field Testing of ANFO Explosives. Rock Products
11. Konya, A.J. & Konya, C.J., Dr. (2017, February). Field Testing of Emulsion Explosives. Rock Products
12. Konya, A.J. & Konya, C.J., Dr. (2017, February) Increasing Blast Burdens with Bottom Charges. Coal Age
13. Konya, A.J. (2017, March). Special Report - Six Sigma Drilling and Blasting. Aggregates Manager.
14. Konya, A.J. & Konya, C.J., Dr. (2017, April). Field Testing of AN Blend Explosives. Rock Products
15. Konya, A.J. & Konya, C.J., Dr. (2017, April). Breaking the Top Burden of Blasts. Coal Age
16. Konya, A.J. & Konya, C.J., Dr. (2017, May). Improving Explosive Efficiency with Stemming. Pit and Quarry
17. Konya, A.J. & Konya, C.J., Dr. (2017, May). Breaking the Top Burden of Blasts. Engineering and Mining Journal
18. Konya, A.J.; Konya, C.J., Dr.; & Worsey, P., Dr. (2017, June). Modern Underground Blasting Methods. Engineering and Mining Journal
19. Konya, A.J.; Konya, C.J., Dr.; & Worsey, P., Dr. (2017, August). Modern Design of Burn Cuts. Engineering and Mining Journal
20. Konya, A.J.; Konya, C.J., Dr.; & Worsey, P., Dr. (2017, September). Modern Design of V-Cuts. Engineering and Mining Journal
21. Konya, A.J. & Konya, C.J., Dr. (2017, September). The Utilization of Used Oil and Explosives. Rock Products
22. Konya, A.J.; Konya, C.J., Dr.; & Worsey, P., Dr. (2018, January). Modern Design of Fan Cuts. Engineering and Mining Journal
23. Konya, A.J.; Konya, C.J. (2018, March). Modern Design of Sinking Cuts. Rock Products
24. Konya, A.J.; Konya, C.J. (2018, March). Blasting Practices to Control Pit Floors and Correct Toes. Quarry Management.

25. Konya, A.J.; Konya, C.J. (2018, April). Six Sigma Blasting. Engineering and Mining Journal.
26. Konya A.J.; Konya, C.J. (2018, April). Stemming for Large Blastholes. Coal Age.
27. Konya, A.J. (2018, May). Downstream Impacts of Drilling and Blasting. Mining Mirror.
28. Konya, A.J.; Konya, C.J. (2018, May). Rhythmic Timing Practices. Pit and Quarry.
29. Konya, A.J.; Konya, C.J. (2018, June). Tronadura – Implementacion de un plan de Six Sigma (*In Spanish*). Equipo Minero.
30. Konya, A.J.; Konya, C.J. (2018, August). Technology vs. Sales – The Ongoing Battle in the Blasting Business. Engineering and Mining Journal.
31. Konya, A.J.; Konya, C.J. (2018, September) Technology vs. Sales – The Ongoing Battle in the Blasting Business. Coal Age.
32. Konya, A.J.; Worsey, P.; Sibley, A. (2018, October) Safety: Drilling and Blasting – Training Tomorrow's Leaders. Pit and Quarry.
33. Konya, A.J.; Konya, C.J.; Worsey, P. (2018, December). Blast Casting Optimization. Coal Age.
34. Konya, A.J.; Konya, C.J. (2019, January). Powder Factor: The Ineffective Design Tool. Engineering and Mining Journal.
35. Konya, A.J.; Konya, C.J. (2019, January). The Mechanics of Rock Breakage – Revisited: Part 1. Pit and Quarry
36. Konya, A.J.; Konya, C.J. (2019, January). Selecting Borehole Diameter for Optimal Fragmentation. Rock Products.
37. Konya, A.J.; Konya, C.J. (2019, February). The Mechanics of Rock Breakage – Revisited: Part 2. Pit and Quarry – *Accepted for Publication*
38. Konya, A.J.; Konya, C.J. (2019, March). The Mechanics of Rock Breakage – Revisited: Part 3. Pit and Quarry – *Accepted for Publication*
39. Konya, A.J.; Konya, C.J. (2019, March). Controlling Pit Floors using Modern Blasting Techniques. Rock Products.
40. Konya, A.J.; Konya, C.J. (2019, April). The Mechanics of Rock Breakage – Revisited: Part 4. Pit and Quarry.

TECHNICAL PRESENTATIONS

1. Konya, A. J., & Konya, C. J., Dr. (2015). Airblast Prediction Equations for Construction Blasting. Lecture Presented at the 41st Annual Conference on Explosive and Blasting Technique.
2. Konya, A. J. (2015, April). Air Overpressure Prediction. Lecture presented at Best in the West, Spearfish, South Dakota.
3. Konya, C. J., Dr., & Konya, A. J. (2015). Precision Presplit Design. 8th Blasting Symposium (Istanbul, Turkey). – *Invited Speaker*
4. Konya, A. J. (2016, May). Undercutting Blast Design. Lecture presented during Underground Blasting Optimization Course at The Academy of Blasting and Explosive Technology, Montville, Ohio.
5. Konya, A. J., & Konya, C. J., Dr. (2016). Precision Presplitting Optimization. Lecture Presented at the 42nd Annual Conference on Explosive and Blasting Technique.
6. Konya, A. J. (2016). Basics of Salt Blasting. Lecture Presented at the 42nd Annual Conference on Explosive and Blasting Technique.
7. Konya, A.J. & Konya, C.J., Dr. (2017, February). Precision Presplitting – Explosive Variations with Spacing. Lecture Presented at the 43rd Annual Conference on Explosive and Blasting Technique.
8. Konya, A.J. & Konya, C.J., Dr. (2017, February). Precision Presplitting. Lecture Presented at Society for Mining, Metallurgy, and Exploration.

9. Konya, A.J. (2017, March) Environmental Effects of Construction Blasting. Lecture to the Alaska Department of Transportation. Juneau, Alaska.
10. Konya, A.J. (2017, March) Overbreak Control for Construction Blasting. Lecture to the Alaska Department of Transportation. Juneau, Alaska.
11. Konya, A.J. (2017, July) Fragmentation from Surface Blasting. Lectures presented to Oldcastle Materials Private Seminar at the Academy of Blasting and Explosives Technology, Montville, Ohio.
12. Konya, A.J. (2017, July) Environmental Effects of Surface Blasting. Lectures presented to Oldcastle Materials Private Seminar at the Academy of Blasting and Explosives Technology, Montville, Ohio.
13. Konya, A.J. (2017, June) Mass Blast Design for Underground Stopes. Lecture presented to Mount Rock Powder Underground Blasting Conference, Manilla, Philippines.
14. Konya, A.J. (2017, June) Environmental Effects of Underground Blasting. Lecture presented to Mount Rock Powder Underground Blasting Conference, Manilla, Philippines.
15. Konya, A.J. (2017, June) Burn Cut Design. Lecture presented to Mount Rock Powder Underground Blasting Conference, Manilla, Philippines.
16. Konya, A.J. (2017, June) Stope Blasting Design and Ring Drilling. Lecture presented to Mount Rock Powder Underground Blasting Conference, Manilla, Philippines.
17. Konya, A.J. (2017, October) Environmental Effects from Surface Coal Blasting. Lecture presented to Teck Coal Corporate Training Program. Sparwood, Canada.
18. Konya, A.J. (2017, October) Overbreak Control. Lecture presented to Teck Coal Corporate Training Program. Sparwood, Canada.
19. Konya, A.J. (2017, October) Environmental Effects of Constructino Blasting. Lecture presented to Oregon Department of Transportation. Portland, Oregon.
20. Konya, A.J. (2017, October) Overbreak Control. Lecture presented to Oregon Department of Transportation. Portland, Oregon
21. Konya, A. J. (2018, January). Modern Vibration Prediction Techniques. Lecture presented at MSHA Academy, Beckley, West Virginia.
22. Konya, A.J.; Konya, C.J., Dr. (2018, January). Predicting Vibration Through Linear-Regression Modeling. Lecture Presented at the 44th Annual Conference on Explosive and Blasting Technique. San Antonio, Texas.
23. Konya, A.J.; Konya C.J., Dr. (2018, February). Modelling and Prediction of Underground Blast Vibrations. Lecture Presented at 2018 Society of Mining, Metallurgy, and Exploration Conferenc. Minneapolis, Minnesota.
24. Konya, A.J.; Worsey, P.N., Dr (2018, February). Design Philosophy for Modern Underground Blast Design. Lecture Presented at 2018 Society of Mining, Metallurgy, and Exploration Conference. Minneapolis, Minnesota.

REPRESENTATIVE PROJECTS

Isabella Dam Blast Consulting– 2019 (Isabella, California)

Isabella Dam is a large spillway construction project on the Isabella Dam which is contracted out by the USACE. I have been hired by RJH Consultants (the contracted consulting company by the USACE) to serve as a blasting consultant on the project which is to include blasting specifications review, analysis of pre-blast and post-blast plans, analysis on contractors means and methods, etc.

Teck Coal, Fording Valley N-Factor Blast Design – 2019 (Sparwood, Canada)

Fording Valley is a large surface coal mine which is located North of Sparwood, Canada operated by Teck Coal. I am currently working with them conducting a two-factor testing program (which has been coined as a N-Factor Blast Design by Anthony Konya) to determine the interrelationships between multiple variables in the blast design to minimize the risk of flyrock. This is to allow the mine to blast up to and immediately next to the Fording River without rock entering the waterway.

Panama Canal Lawsuit – 2018/2019 (Panama)
The Panama Canal is the largest lawsuit that has ever been tried in rock blasting. Due to the ongoing nature of the case full details cannot be released at this time, however I was retained by the Panama Canal Authority to review specifications, all blast notices, blast reports, blast videos, and inspection reports. Along with this, I was requested to develop reports of contractors blasting performance, graphics and charts to show problems that occurred during blasting, and develop the defense of the Panama Canal Authority to refute contractors change order claims after review of all blasts on project.

Sergeant Stone Ground Vibration Consulting – 2018/2019 (Cadez, Ohio)
Sergeant Stone is a Limestone Quarry located near Cadiz, Ohio for which I provided ground vibration consulting services in the development of ground vibration models. These models were to predict ground vibration from nearby blasts to a nearby proposed pipeline which would reduce the ore reserves of the mine to develop proper compensation models from oil company.

Chickamauga Lock Expansion Ground Vibration and Blast Design Consulting – 2018/2019 (Chattanooga, Tennessee)
The Chickamauga Lock Expansion is a USACE heavy construction project which is expanding the locks on the Chickamauga river to increase barging capacity. During the first stage of the project I was retained by the drill and blast contractor as the ground vibration consultant where I developed ground vibration models to predict ground vibration from various blasting scenarios. During the second part of the project I was hired by the USACE to conduct on-site investigations of the contractors blasting and act as a blast consultant for the Corp.

MERA Emulsion Plant Design and Commissioning – 2018 (Mongolia)
This project involved the design and build of an emulsion plant which had the ability to produce cap sensitive and booster sensitive product, packaged and bulk, chemically gassed and microsphere sensitized, and cross-link hardened emulsions. The second stage was the commissioning of the plant in the Gobi Desert in Mongolia. During the initial design and build of the plant I acted as an explosive engineer assisting with emulsion formulations, plant drawings and layout, and other engineering tasks in the design and build. During the commissioning phase of the project I was the project superintendent where the plant was erected, tested, finalized, and commissioned on-site. Over the 6-week timeframe I led a crew of 2 Hungarian explosive specialists, 4 North American engineers, and 15 Mongolian laborers which included the use of translators for a total of three different languages. The plant was fully installed and finalized with all products being produced.

Saudi Comedat Blast Design Consulting – 2018 (Saudi Arabia)
Saudi Comedat operated the Al Jalamid Mine in Northern Saudi Arabia on the Iraq border. This phosphate mine is the largest surface operation in Saudi Arabia and I provided blast consulting services firing 8 test blasts over a 3 week period which incorporated over 1 million

tons of total broken material. This was to reduce the oversize from the phosphate products, where the oversize was cut into 1/3 of pre-visit level, and to improve overburden blasting for increased heave and fragmentation. All objectives where achieved and I was then retained for the remainder of 2018 to provide distance blast consulting services for optimization of the blasting program.

Teck Coal, Fording Valley Ground Vibration Consulting – 2018 (Sparwood, Canada)
The Fording Valley Mine which is operated by Teck Coal north of Sparwood, Canada is a complex open pit coal mine which has vertical dipping beds of coal. I provided ground vibration consulting services to the mine to develop surface ground vibration prediction models to ensure safety of a tailing dam which was located immediately next to the Lake Mountain Pit.

MD355 Underground Ground Vibration Consulting – 2018 (Maryland)
The MD355 project is an underground construction project in Maryland which involved the development of one tunnel and connection into a perpendicular tunnel. The existing tunnel had strict vibration limits imposed to preserve concrete. I provided ground vibration consulting in the development of numerous underground to underground ground vibration prediction models, review of project specifications, and analysis of the seismograph layout and set-up. Additionally, I provided blast design consulting for pattern improvements to underground tunneling rounds to reduce ground vibration.

Escobal Mine Historical Structure Response Analysis to Ground Vibration [Tahoe Resources] – 2018 (Guatemala)
I provided ground vibration consulting services to the Escobal Mine in Guatemala which included a combination of structural analysis of ancient Xinca burial mounds, response analysis of the ancient Xinca structures, and then development and prediction of ground vibration at the structures to determine potential risks and failure mechanisms.

Alaska Department of Transportation Specification Development and D&B Training – 2017 (Juneau, Alaska)
I provided training to the Alaska Department of Transportation on environmental effects of rock blasting and overbreak control techniques for engineers, project managers, specification writers, and inspectors. This training focused on how to manage and review contractor documents and properly write specifications on these topics. Following the training I reviewed and rewrote the state DOT blasting specifications. Since completion Alaska has reported much better blasting, vibration control, and overbreak control while successfully completing numerous projects.

Oregon Department of Transportation Drill and Blast Training – 2017 (Portland, Oregon)
I provided training for the Oregon Department of Transportation on environmental effects of rock blasting and overbreak control techniques for engineers, project managers, specification writers, and inspectors. This training focused on how to manage and review contractor documents and properly write specifications on these topics.

Teck Coal Corporate Training and D&B Audit – 2017 (Sparwood, Canada)
Teck Coal contracted training and consulting services for their Canadian operations in the Rocky Mountains. While there I helped plan and time blasts while conducting site audits at LCO and EVO mines. In addition, I provided training on environmental effects of rock blasting

and overbreak control techniques for engineers, blasters, and corporate supply chain members.

Mount Rock Powder Underground Blast Design Training – 2017 (Manilla, Philippines)
I was contracted to go to the Philippines to provide three days' worth of training to Mount Rock Powder, the mines they service, and Austin Powder training on Underground Blast Design including burn cuts, V-cuts, fan cuts, stoping, ring blasting, mass blasting, etc.

Escobal Mine Ground Vibration Consulting [Tahoe Resources] – 2017 (Guatemala)
An underground silver mine in Guatemala which faced severe problems with ground vibration upsetting the locals. Part one of project included analyzing over 7,000 seismograph reports and completing modified USBM regression analysis and a review of all blasting reports and data from June 2015 to present day. Part two included development and field testing of new models using 10+ seismographs including differences in geologic domain and cardinal direction.

Mission Hospital Ground Vibration Consulting – 2016/2017 (Ashville, North Carolina)
A construction project for construction of a new section of Mission Hospital where blasting was taking place in a downtown urban environment. I received and analyzed blasting and seismograph reports to develop 95% confidence models ground vibration and air overpressure models for each blast. Models were used for blast design by blasting team, KESCO, to blast within 20 feet of hospital and not exceed vibration limits on project.

Cordull Hull Capitol Utility Connector Ground Vibration Consulting – 2016 (Nashville, Tennessee)
A construction project in downtown Nashville to create new underground utility tunnels where blasting was taking place a few dozen feet under an urban environment and the capitol building. I received and analyzed data to develop 95% confidence level ground vibration models; when these proved inadequate because of large standard error from various underground blast designs I developed a new modeling procedure for statistically significant envelope lines which were used on project to design new blasts. In addition, I developed new blast designs and timing parameters which significantly decreased the ground vibration.

Victor Mine, DeBeers Diamonds Blast Design Consulting – 2016 (Ontario, Canada)
A surface diamond mine in Northern Canada which faced problems with explosives, fragmentation, and blast design. Site audit of mine and emulsion manufacturing plant were conducted, including post blast investigation to determine causes of problems and ways to improve blasting operations on-site. Major problems were identified with explosives and cause of large volumes of NO_x.

Avery Island Salt Mine, Cargill Blast Design Developments – 2015 (Avery Island, Louisiana)
An underground salt mine in Louisiana that looked to improve fragmentation and face advance while lowering blasting costs. Utilization of kerf blasting was used, I was responsible for data collection, interpretation, and bi-weekly reporting of both engineering reports (to improve design) and supervisor reports (to breakdown individual employee performance and coaching

opportunities). In addition, I was responsible for developing new blasting patterns which succeeded in reducing costs by over 30% at the mine. For this I was awarded the Cargill Diamond Crystal Achiever Award, the highest award Cargill gives for an improvement to its entire company.

Nordex Emulsion Plant Design and Consulting – 2015 (Kirkland Lake, Canada)
A previously built emulsion plant was in operation by Nordex in Canada (originally built by Precision Blasting Services in 2007) and I was hired to go to the site to review equipment conditions, provide consulting on manufacturing improvements, and design additional processes/formulations to develop new emulsions.

Kentucky Locks (Grand Rivers, Kentucky) and Folsom Dam (Folsom, California) Ground Vibration Consulting – 2015
Two USACE projects for construction of lock and dam. I worked under Dr. Calvin J. Konya, analyzing all blasting data and seismograph information to develop site specific ground vibration and air overpressure equations. Upon completion of this, data was combined with other construction projects to develop a "Construction Blasting" ground vibration and air overpressure equations for both Precision Presplitting and Production blasting.