Blasting Impacts Assessment for Proposed Idaho-Maryland Mine

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BLASTING CONCERNS AND IMPACTS

From a preliminary review of the mine Idaho-Maryland Mine site, it appears that the following concerns and issues might arise from the planned use of explosives for planned development and production blasting.

1. Security of explosive materials.
2. Vibration impacts to neighboring structures including but not limited to residential property, canals, roadways, pipes and other utilities.
3. Vibration and noise disturbance impacts to humans and animals.
4. Control of fumes.
5. Nitrate and ammonia contamination of soil by blasting chemicals.

POTENTIAL EFFECTS OF PROPOSED ROCK BLASTING

Two distinct phases of blasting would occur at the Idaho-Maryland Mine. The first phase of blasting would occur in a development tunnel that would begin at a portal located on the existing Idaho-Maryland Mine property. This 15%-down-sloping exploration and development tunnel would initially head eastward and make two slight south turns until it terminates at an existing shaft located on the New Brunswick Mine Site. The horizontal alignment of the tunnel is shown in Figure C-1. A second phase of production mining blasting would occur after diamond drilling work is done to delineate the ore body for mine planning purposes. The host rock for the development tunnel and production mining areas is very hard metavolcanic rock with compressive strengths exceeding 24,000 psi. Using mechanical methods to create the excavations needed for this mining is not feasible in rock with this hardness.

The scale of blasting and size of charges used in the development tunnel would be much smaller than those used in production mining. For the purpose of helping readers have a clear understanding the findings of this blast-effects evaluation, this section includes brief technical reviews of development tunnel blasting methods and the physical science and terms used to characterize ground vibration and other effects of blasting.

Development Tunnel Mining

When blasting methods are used to mine tunnels, the drilling and blasting work is much more technical than imagined by casual observers. Tunnel alignments are guided by lasers, many small holes using carefully delay-sequenced detonators are used to break rock to typically advance the tunnels in four to 12-foot segments, and complex ventilation and ground support systems are used to ensure the work is done safely. The general scheme of advancing tunnels using blasting methods is shown in Figure C-2.

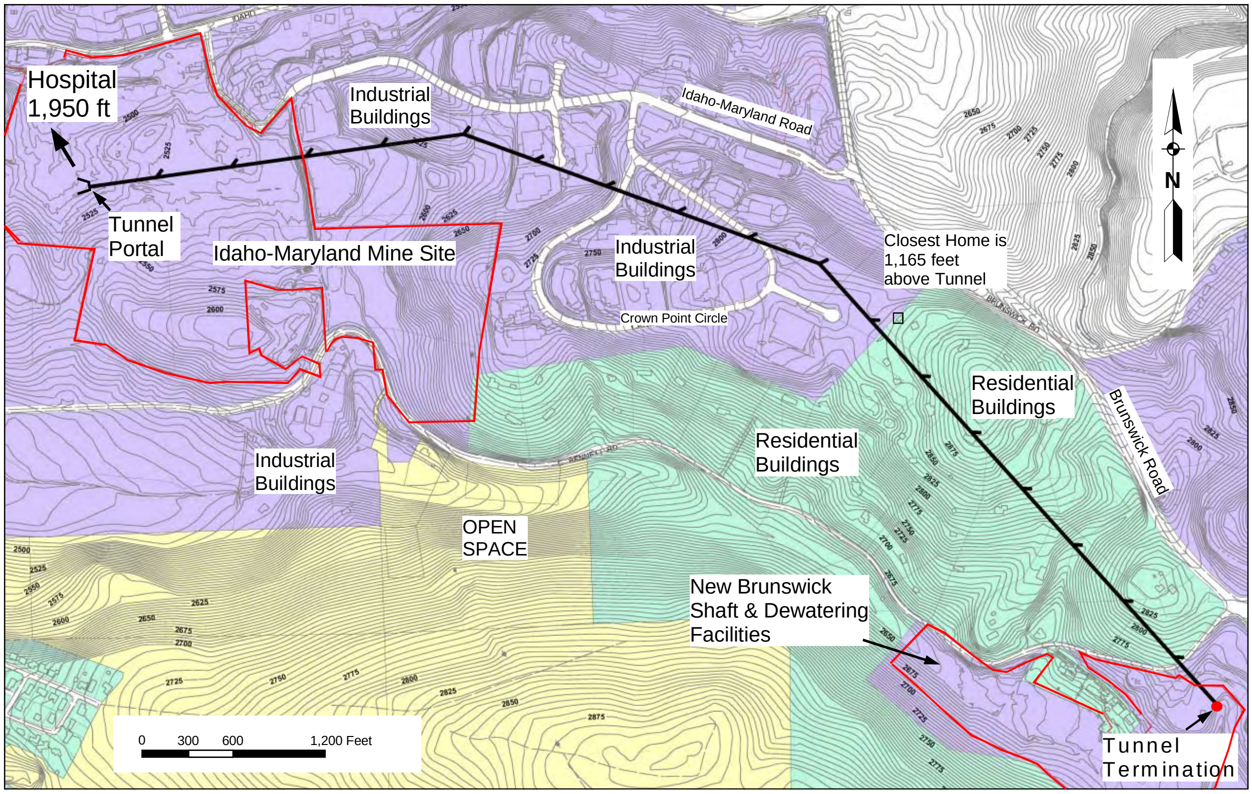


Figure C-1 –Idaho-Maryland Mine Development Tunnel Site Location Map

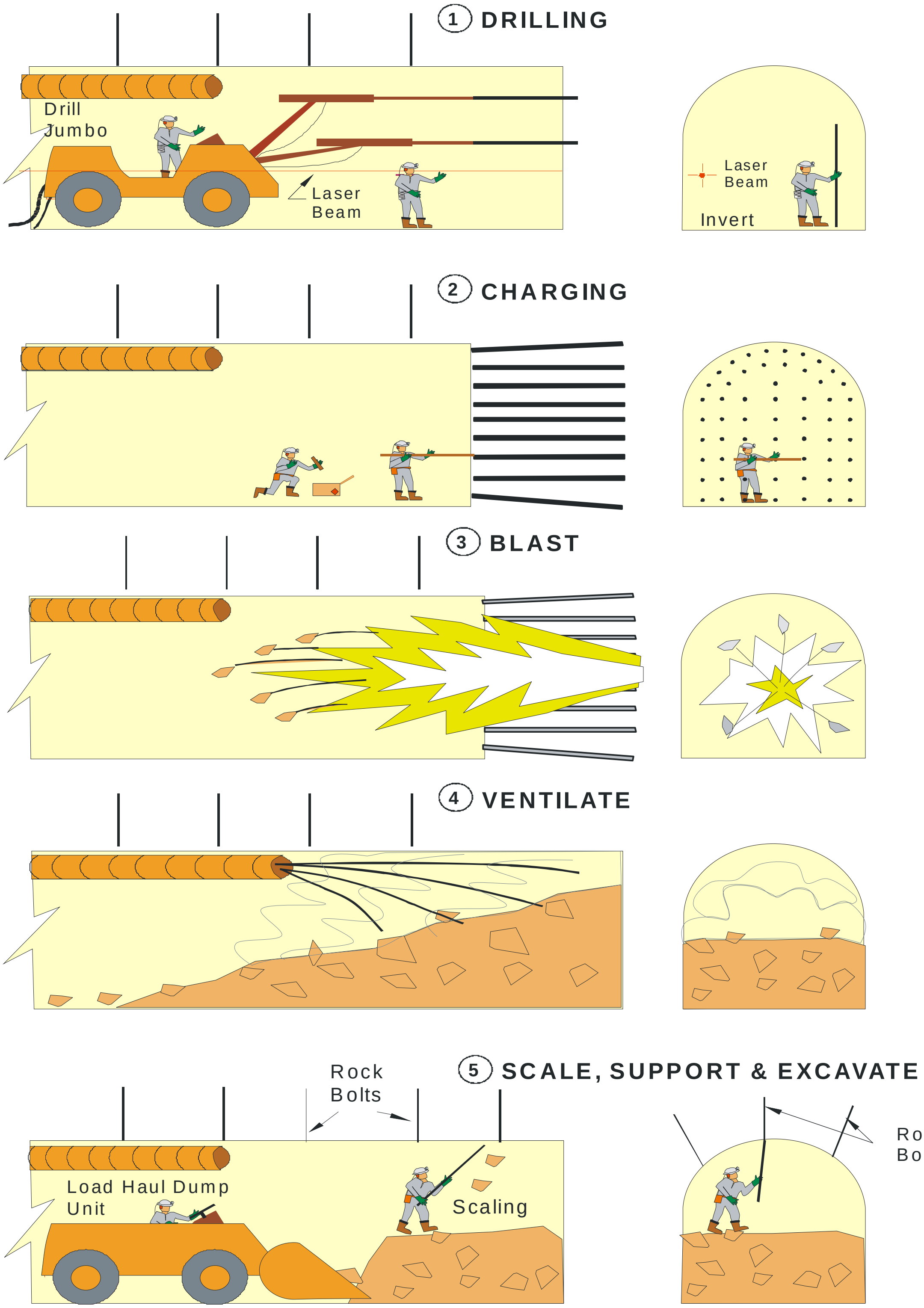


Figure C-2. General Methods of Drill-Blast Tunneling Work

When explosive charges detonate in rock, they are designed so that most of the energy is used in breaking and displacing the rock mass. However, some of the energy can also be released in the form of transient stress waves, which in turn cause temporary ground vibration. Detonating charges also create rock movement and release of high-pressure gas, which in turn induce air-overpressure (noise), airborne dust, and audible blast noise.

In the very-near zone, crushing usually occurs in the rock around the charge. The extent of this compressive and shear failure zone is usually limited to one or two charge radii. Beyond the plastic crushing zone, the rock or ground is temporarily deformed by elastic strain waves. For some distance, tangential strain intensity exceeds the rock’s strength and new fractures are created. Based on research by the US Bureau of Mines (RI 7901, 1983), radial cracks extend no farther than 26 charge radii. These radial cracks are created when strain created tangentially to the compressive stress waves exceeds the rock’s tensile strength. Since all blasting in the development tunnel will be done hundreds of feet away from all structures and facilities of concern, there is no risk that direct ground cracking or rupturing could have any impact whatsoever on these properties and improvements (beyond the immediate tunnel excavation zone).

Vibration Ground Waves

Within and beyond the cracking and rupture zone, stress waves spread through the rock mass and along the ground surface. Some waves pass through the “body” of the rock mass. Primary compression waves and shear waves are examples of body waves. Other surface vibration waves travel along the ground surface similar to the way waves travel along the surface of water. In an ideal isotropic and homogenous rock mass, wave energy would travel evenly in all directions. However, most rock masses are far from ideal, so wave energy is reflected, refracted and attenuated by various geological and topographical conditions. Typical blast-induced elastic waves that emanate through rock and soil are shown in Figure C-3.

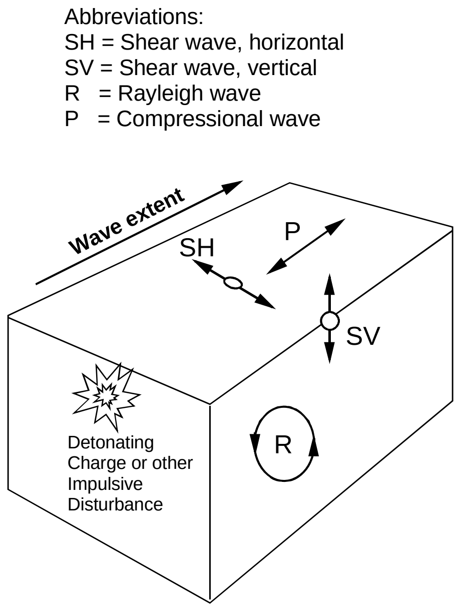


Figure C-3. Typical Vibration Waves

The elastic properties of rock and soils control initial vibration intensity and the rate of attenuation as energy disperses into ground with distance. When seismic waves pass through the ground, ground particles oscillate within three-dimensional space. Soon after blasting has stopped, vibration energy dissipates and the ground particles become still.

The physical nature of ground vibration and the intensity of ground motion can be measured in several ways. These measures include:

- Particle displacement
- Particle velocity
- Particle acceleration
- Vibration frequency

Displacement is a measure of ground particle travel distance or location with respect to time. Particle velocity measures the speed of movement and acceleration is the rate of velocity changes. Vibration frequency is a measure of how many oscillations a ground particle makes per second of time. Frequency is reported in units of Hertz (Hz), which is equivalent to cycles per second. For damage prevention and human/animal response purposes, the key measure best related to the kinetic energy of the motion is particle velocity. Frequency of motion is also an important measurement because secondary motion stimulated in structures built in the ground can be amplified when the frequency of the ground motion matches the natural frequency of buildings and other structures.

For measurement and control purposes, special seismographs are used to measure particle velocity and frequency. These instruments create time-intensity plots like the one shown in Figure C-4.

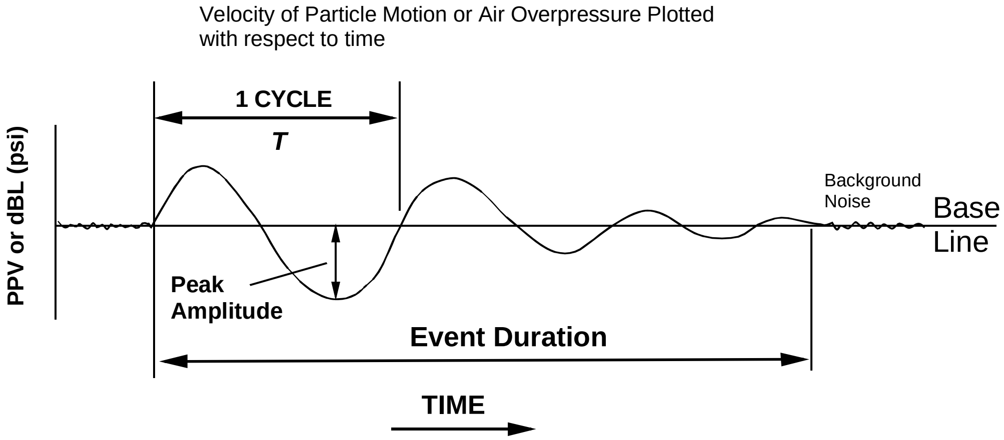


Figure C-4. Idealized Vibration or Air Overpressure Time—Intensity History Plot

Vibration Perception and Damage Criteria

The average person is quite sensitive to ground motion, and levels as low as 0.50 mm/s (0.02 in/s) can be detected by the human body when background noise and vibration levels are low. A curve plotting intensities of ground motion and motion frequencies that will not cause cosmetic cracking in drywall and plaster-lath walls are shown in Figure C-5. Vibration intensity is expressed as Peak Particle Velocity (PPV), which is simply the maximum speed that the ground moves while it temporarily shakes. Since ground-shaking speeds are very small, it is measured in inches per second (in/s). Frequency of motion or cycles per second is a measure of how many times a particle of ground moves back and forth (or up and down) in one second of time. Frequency is expressed in units of Hertz (Hz).

The “safe limits” published by the US Bureau of Mines (USBM) in Report of Investigations (RI) 8507, are specifically intended to protect typical wood frame homes. Significantly higher PPV limits, ranging from 2.0 to 5 in/s, are used to protect buried pipes, commercial property and other heavy civil structures.

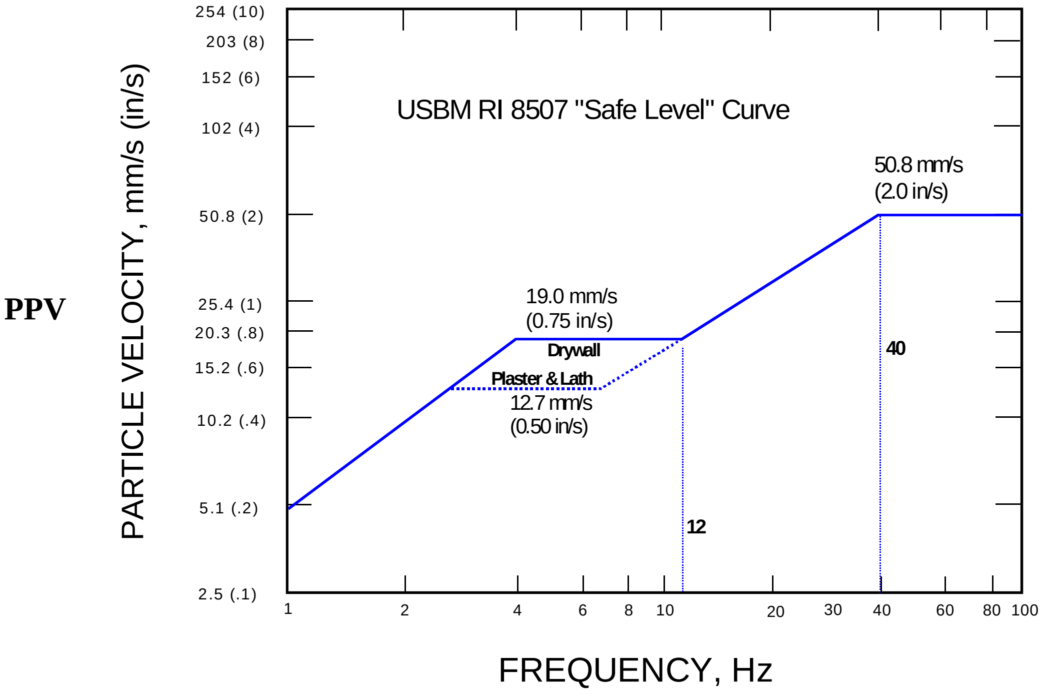
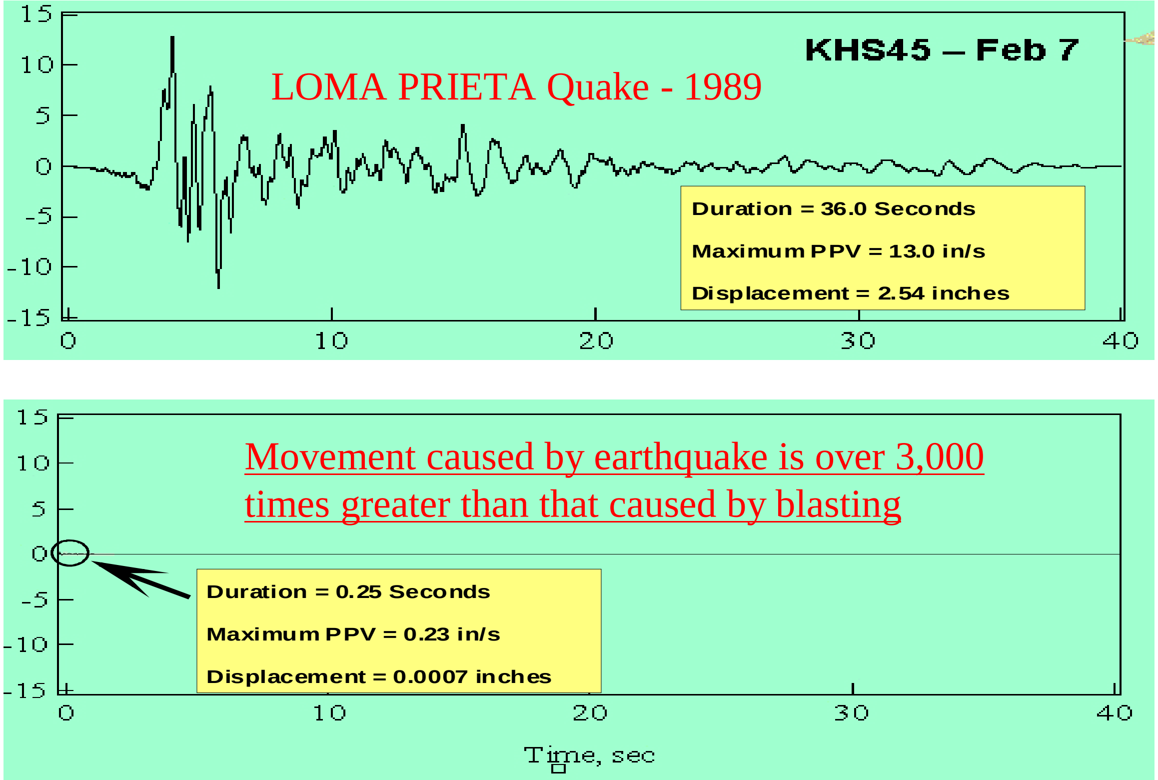


Figure C-5. USBM "Safe Level" vibration curve from RI 8507

Earthquake Shaking Versus Blasting Vibrations

The motion caused by typical rock blasting charges is EXTREMELY different than the motion caused by earthquakes. For terms of comparison, the seismic design criteria for dam structures typically specify a 2% chance that a 0.18g earthquake event might occur in a 50-yr period. The resulting PPV caused by an earthquake occurring at a typical frequency of 1 Hz would be **11.0 in/s** [(0.18 x 32.2 x 12) / (2 x 3.14 x 1)]. The particle displacement would be **1.75 inches**! [11.0 / (2 x 3.14 x 1)]. The displacement created by typical blast charges is hundreds of times less. In other words, unlike earthquakes, the high-frequency motion created by small charges is quite small because due to the extremely high frequency the particles are changing direction so quickly they are effectively "running in place."

For purposes of comparison, a scaled comparison of the ground motions created by a typical rock blast at the Idaho-Maryland Mine and the Loma Prieta earthquake of 1989 are shown in Figure C-6.



LOMA PRIETA Quake - 1989

Duration = 36.0 Seconds

Maximum PPV = 13.0 in/s

Displacement = 2.54 inches

Movement caused by earthquake is over 3,000 times greater than that caused by blasting

Duration = 0.25 Seconds

Maximum PPV = 0.23 in/s

Displacement = 0.0007 inches

Figure C-6. Comparison of Ground Vibration Caused by Earthquakes and Rock Blasting

Blast Noise (Air-Overpressure)

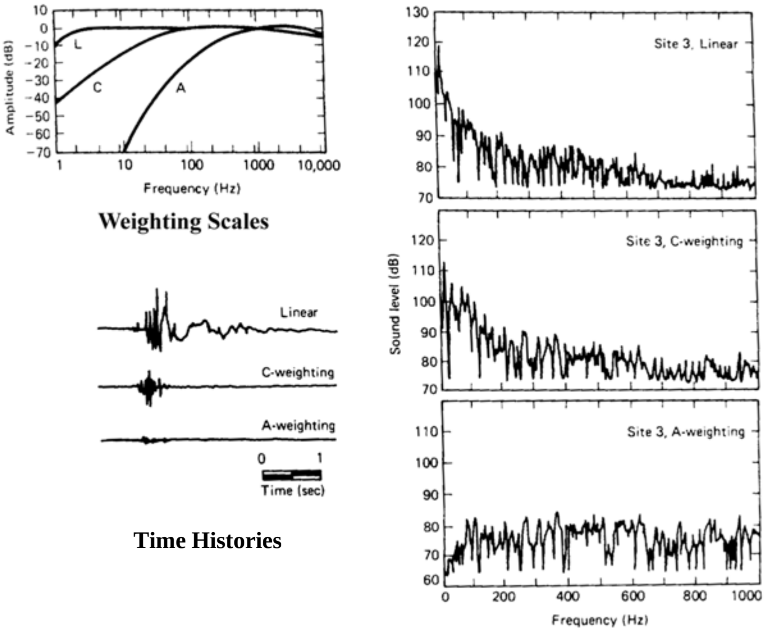
Because blasting will occur at and near the surface when the tunnel portal is developed and when the tunnel is started, noise or air pressure waves from the blasting will effect nearby structures and occupants. These effects can be controlled, but they will be felt and will most certainly be an important control issue. The control of airborne blast energy will be most important for the tunnel blasting, where burn cuts utilizing open holes can release high air-pressure waves or impulsive noise energy to the atmosphere. The term “Blast noise” is a misleading because the largest component of blast-induced noise occurs at frequencies below the threshold-of-hearing for humans (16 to 20 Hz). Hence, the common industry term for blast-induced noise is “air-overpressure”. As its name implies, air-overpressure is a measure of the transient pressure changes. These low-intensity pulsating pressure changes, above and below ambient atmospheric pressure, are manifested in the form of acoustical waves traveling through the air. The speed of sound varies in different materials, depending on the density of the medium. For instance, pressure waves travel at the speed of 4,920 ft/s (1,500 m/s) in water, whereas, in air they typically travel at a lesser speed of 1,100 ft/s (335 m/s) because air has a lower density.

When calculating maximum overpressure values, the absolute value of the greatest pressure change is used — regardless of whether it is a positive or negative change. The frequency of the overpressure (noise) is determined by measuring how many up-and-down pressure changes occur in one second of time. Blast noise occurs at a broad range of frequencies and the highest-energy blast noise usually occurs at frequencies below that of human hearing (<20 Hz).

Air-Overpressure Measurement Scales

When measurements include low frequency noise (2 Hz and higher) with a flat response, they are called "linear scale" measurements. Air-overpressure measurements are typically expressed in decibels (dB) units and when the scale is linear, the unit designation is “dBL.” Regular acoustical noise measurements taken for the purpose of monitoring compliance with local noise ordinances almost always use weighted scales that discriminate against low frequency noise. Thus for a similar noise source, A-weighted and C-weighted scales will usually record significantly lower levels of noise. Differences between decibel scale measurements for individual blasts will vary depending on their unique frequency-intensity spectrums. Since full-range recording of blast-induced noise can only be done with linear (2-Hz response) instruments, it is imperative that all compliance specifications for blast-induced noise be expressed in “Linear” scale decibels (dBL).

In a study by USBM, researchers measured blast-induced noise at a common location using A-weighted, C-weighted and Linear Microphones. The comparable measurements taken about 800 feet from a blast, shown in Figure C-7, show that a linear peak noise of 120 dBL equates to only 112 dBC and 85 dBA.



Weighting Scales

Time Histories

After Siskind and Summers, (1974)

Fourier Frequency Spectra

Figure C-7. Effects of Weighted Filtering on Air-overpressure Records

The regulatory limit defined by USBM, in State of California regulations, for air-overpressure measured with 2-Hz response seismographs is 133-dBL (0.014 psi). Damage to old or poorly glazed windows does not occur until air-overpressure reaches about 150 dBL. More importantly, since the decibel scale is a logarithmic ratio, the actual overpressure at 150 dBL is 0.092 psi, versus 0.013 psi at 133 dBL. Therefore, the actual pressure at the 133 dBL limit, is over seven times (0.0917/0.0129) lower than the threshold damage level at 150 dBL. The relationships between actual overpressure expressed in psi and decibel scale measurements are shown in the following Equation JJ. NOTE: Due to the logarithmic ratios used to decibel values, seemingly small changes in decibel readings can equate to large changes in absolute overpressure (psi).

$$dB = 20\,Log_{10}\left({}^{P}\!/_{P_o} \right) \quad or \quad P = P_o\,10^{\left({}^{dB}\!/_{20} \right)}$$

Equation JJ

Where: dB = decibels, P = overpressure (psi), P_o = Threshold of Human Hearing Pressure (20 microPascals or 2.9 x 10^{-9} psi).

Rock Drilling Noise

When hydraulic rock drills are used for the tunneling work near the surface, it is very likely that airborne A-scale noise levels may exceed nighttime noise limits mandated by the City of Grass Valley. Hence the contractor doing the drill blast work may be restricted from doing nighttime drilling work until the tunnels have advanced hundreds of feet under the ground. Once drilling work is isolated underground, some secondary audible noise created by the vertical component of ground vibrations would be caused by the drilling. This vibration and the secondary noise it creates typically occur within a narrow band frequency range between 70 and 125 Hz. During quiet periods of the day, the resulting drill noise heard by occupants of building located within 500 or so vertical feet from the tunnel may sound like a neighbor across the street is using a hammer drill. Historical drill noise data is limited, however it is known that the maximum level of noise induced in homes 15 meters above the Ramsgate Project in England did not exceed 46 dBA. Also, at the Sodra Lanken Metro Project is Stockholm Sweden, it is reported that the contractor had difficulty meeting 55 dBA-daytime and 35 dBA-nighttime noise restrictions for relatively shallow (< 30 m) roadway tunnel blasting work.

While living in a home located several hundred feet directly above an operating hard rock nickel mine, during quiet periods of the day, the author recalls hearing rock drills that sounded like a very distant and “tinny” whining-like noise.

Drilling operations for production mining occurring at depths greater than 1,300 feet from surface will not be noticeable.

Blast Vibration Intensity Predictions

It is standard practice to use scaling relationships to predict vibration intensities at various distances. These relationships, based on similitude theory, are used to develop empirical relationships between ground vibration particle velocity, charge weight, and distance. Distance is scaled by dividing it by the square root of the maximum charge weight firing at any time within a blast. This single scaled distance variable can than be used to predict vibration intensity (PPV). The scaling relationship between peak-particle-velocity (PPV) and scaled distance (D_s) is shown below in Equation YY.

$$PPV = K\left(D/\sqrt{W} \right)^m \qquad or \qquad PPV = K\left(D_s \right)^m \qquad \text{Equation YY}$$

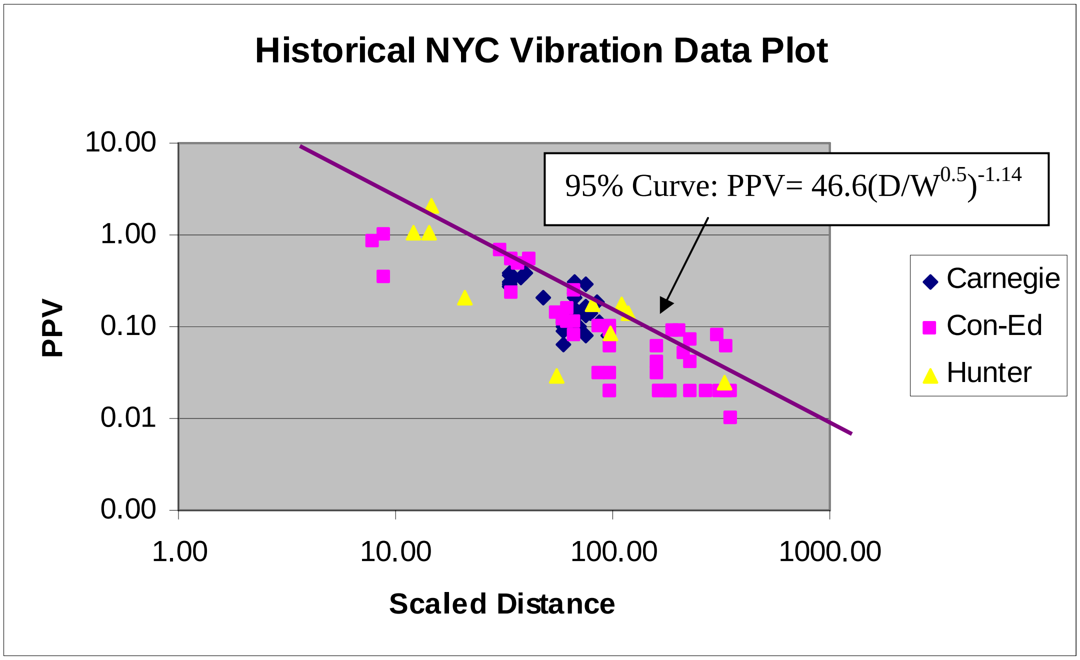
Where: PPV = Peak Particle Velocity (in/s)
D = Distance (ft)
W = Maximum Charge-weight-per-delay (lb)
K = Rock Energy Transfer Constant (K-Factor)

m = Decay Constant
D_s = Scaled Distance ($m\text{-}kg^{-0.5}$)

Site-specific constants, ***K*** and ***m***, can be determined by performing a regression analysis of multiple peak particle velocity (PPV) and D_s data pairs. In simple terms, for any given site, ***K*** is a measure of how much vibration energy is transferred to the ground near the explosive charge and ***m*** defines how fast the energy attenuates with distance.

A sample regression curve that was recently prepared to support blasting controls for an upcoming subway project in New York City is shown in Figure C-8. When plotted in log-log scale, the exponential relationship between scaled distance and PPV generally follows a straight line with a negative slope (***m***) -- usually around –1.6, and Y-intercept (***K***) values varying between 960 and 26, as defined by Oriard (1972). The ***K*** value (amount of energy at the source) is higher when charges are more confined and/or rock has a high stiffness ratio (Young's modulus of elasticity).

Figure C-8. PPV Data from Blasting at Carnegie Hall



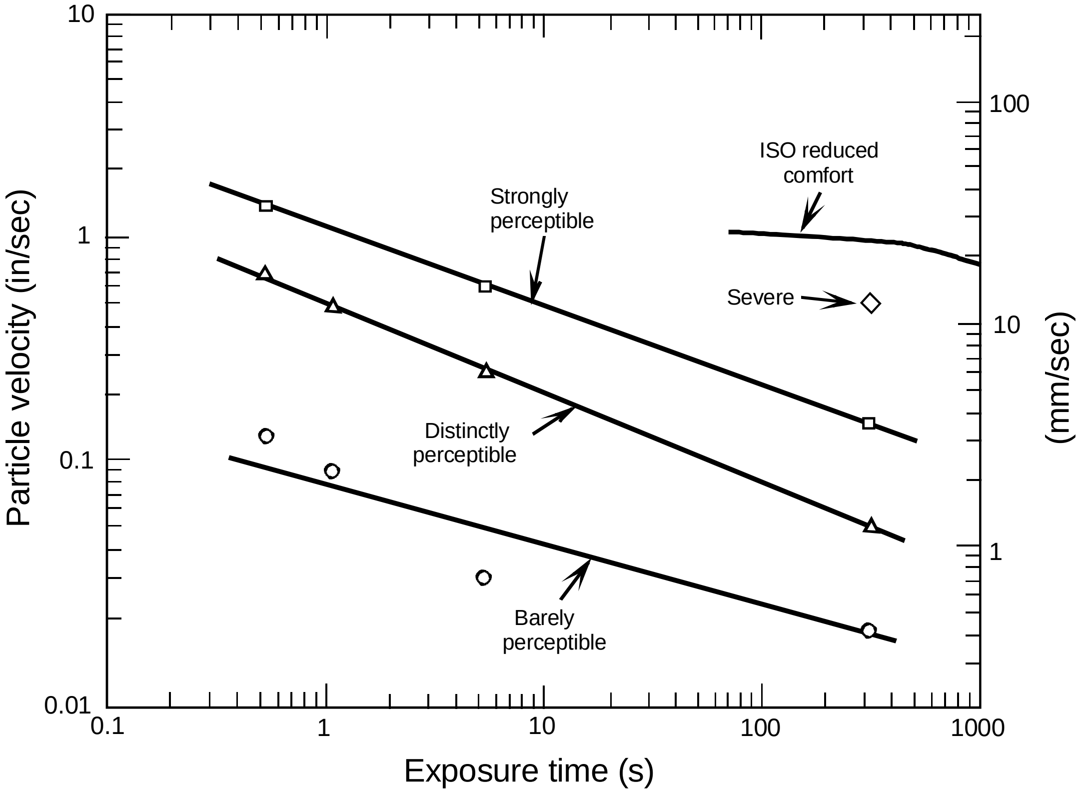
Historical NYC Scaled Distance—PPV Data from Blasting at Carnegie Hall, the Con-Edison Shaft at 36th Street and 1st Avenue and foundation blasting at Hunter College at between 38th and 39th Streets (NOTE: the 95% curve means that 95 percent of the time, predicted values will be lower than the value calculated).

When site-specific historical data is not available, the K factor value can be estimated based on physical rock properties and degree of blast confinement. From the author's past experience, for blasts in the metavolcanic rock formations at the Idaho-Maryland Mine Site, a prediction equation with a ***K*** factor of 240 can be used to predict vibration intensities (PPV) at various locations of concern. With this cautiously high K-factor, predicted levels of vibration will likely be higher than actual values measured at similar scaled distances. The resulting prediction equation, which is used in the following site-specific evaluations of this report, is shown in Equation YYY.

$$PPV = 240\left(D/\sqrt{W}\right)^{-1.6} \qquad \text{Equation YYY}$$

3.6 Human Response to Transient Vibrations

In addition to concerns about vibration damage, under certain conditions, humans and animals can be startled or annoyed by blast-induced ground vibration. Research has also shown that the human response to transient vibration--like those caused by blasting--varies depending on exposure time and the intensity of the motion. Response curves defining how humans respond to transient vibrations based on these variables are shown in Figure C-9.



Human response to transient pulses of varying duration after Wiss and Parmalee (1974)

Figure C-9. Human Response to Transient Vibration

POTENTIAL SPECIFIC IMPACTS OF DEVELOPMENT AND PRODUCTION BLASTING AT THE IDAHO-MARYLAND MINE SITE

In the following sections, potential effects of blasting are analyzed and where appropriate, practical and proven mitigation measures are recommended. For purposes of estimating blast effects, the author made calculations based on a 2-inch diameter charge, which is the largest sized hole typically used for development tunnel blasting.

Chemical Contamination of Ground Water and Surface Water

Most commercial explosives contain 70 to 94% ammonium nitrate, by weight. If significant amounts of explosives are spilled or incompletely detonated, rainwater will cause some amount of ammonia and nitrate to leach out and go onto into the ground. Over time, leached ammonia and nitrates will penetrate into ground water and can possibly be washed by rainwater over the ground surface and into surface and ground water resources. The U.S. EPA ambient water quality criterion is 0.02-mg/L free-ammonia and the drinking water criterion for nitrate as nitrogen ($NO_3^{-}N$) is 10-mg/L. The key to controlling this issue is preventing loss of explosive material to the ground, and more importantly to blasted rock that is conveyed and placed in surface waste areas. If this is not done, over time, rainwater will leach remnant explosive material from shot rock and release ammonia and nitrates to ground water and nearby water resources. Best control is maintained when only cartridged explosives are used in lieu of flowable pumped emulsions or pneumatically placed Ammonium Nitrate – Fuel Oil (ANFO) charges.

At the Idaho-Maryland Mine site, if normal industry standards of care concerning clean-up procedures are used to recover any spilled explosives materials like ANFO or pumped emulsion explosives, and charges are adequately primed to ensure complete detonation, losses of ammonia and nitrates to ground water or flowing surface water will not exceed regulated levels.

Since there is 900 feet of distance between the closest fork of Wolf creek and the near surface portal the mining areas, the development blasting could certainly be done without creating water contamination problems if rigorous no-explosives-lost-to-ground practices are employed by the tunnel development contractor. Ongoing explosive loss management efforts will likely be needed during production mining operations, particularly if adjacent creeks are contain native trout or other sensitive species where nitrate limits are much lower than US drinking water quality standards. Explosive loss management programs that prevent misfires resulting in remnant un-detonated portions of charges or spilled bulk explosives in mined waste rock later spoiled on surface will depend on the location of waste rock dumps and on how the mine plans to treat and control future mine water exposed to production blasting activities. This water pollution issue has caused severe disruptions to some North American mines and in one case, development work at the Montanore base metal was halted due to this pollution issue. However, other mines like the Stillwater Platinum Mine also located in Montana have implemented strict controls to successfully limit nitrate and ammonia levels in the adjacent trout bearing Stillwater River. Many mines in Canada have also implemented successful controls.

Security of Explosive Materials

In this day and age, it is quite normal and expected for residents to express concerns about the security of explosive materials. To ensure that explosive materials are indeed properly secured during transport and use, industry groups and government agencies have cooperatively developed laws and standard practices used in all operations throughout the United States.

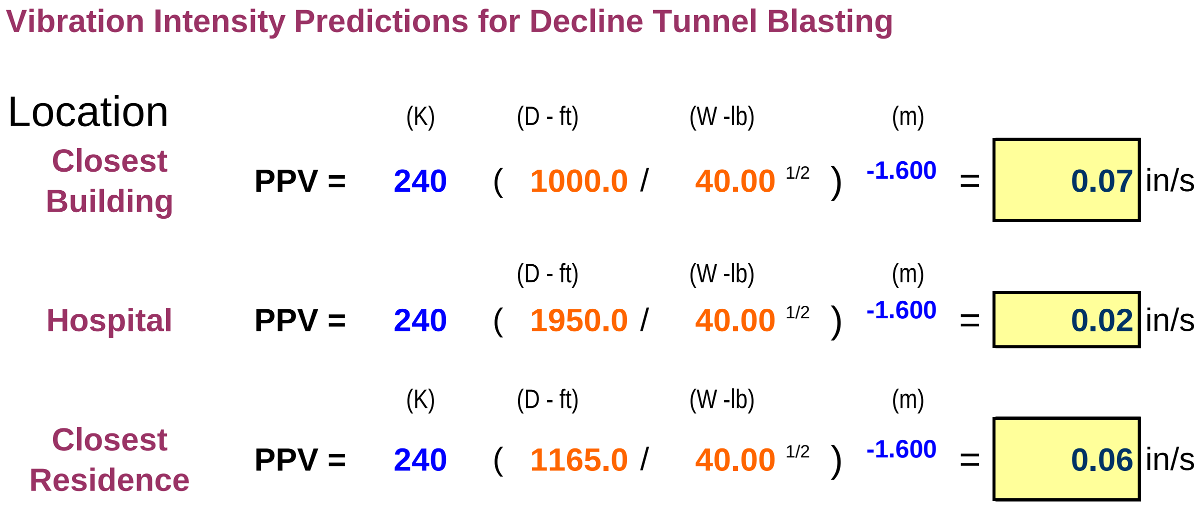
As required by Department of Transportation (DOT) rules, explosive materials would be delivered in specially built vehicles marked with United Nations (UN) hazardous materials placards. Explosives and detonators are delivered in separate vehicles or they are separated in compartments meeting DOT rules within the same vehicle. Vehicles must have at least two 10-pound Class-A fire extinguishers and all sides of the vehicles display placards displaying the United Nations Standard hazard code for the onboard explosive materials. Drivers must have commercial driver licenses (CDL) with Hazmat endorsements, and drivers must carry bill-of-lading papers detailing the exact quantities and code dates of transported explosives or detonators. Once explosives are delivered to the blasting site, the licensed blaster-in-charge is responsible for directly overseeing their security. The blaster-in-charge must have adequate experience and successfully pass a licensing test verifying their knowledge of blasting methods, rules and safety procedures. In the State of California, CalOSHA administers the testing and licensing of blasters and the California Highway Patrol establishes safe explosive transport routes and oversees all DOT rules enforcement.

During recent years there have been several well-publicized thefts of explosives from magazines in Northern California. Once underground magazines are established, the risk of break-in theft will be minimal. However, during the initial development blasting for the planned access tunnel, the tunnel contractor plans to establish a temporary magazine site on the Idaho-Maryland Mine site property. When and if this is done, the contractor must comply with US Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) table-of-distance requirements (CFR 27, U.S. Department of Justice, Alcohol, Tobacco, Firearms and Explosives Division Part 555) that restrict explosive quantities based on distance from occupied buildings and public roadways. Contract and mine employees must also now comply with the security requirements of the Safe Explosives Act (Title XI, Subtitle C of Public Law 107-296, Interim Final Rule), implemented in March 2003. These requirements require background checks for all persons that use, handle or have access to explosive materials; and responsible persons on a now required federal explosives license must submit photographs and fingerprints with the application to ATF.

At some locations, local police or fire authorities in California are mandating 24-hour security and/or the use of motion-detector and alarmed double wire fencing security measures before approving surface explosive storage permits. In any case, if comprehensive explosive security measures are developed and rigorously enforced, theft of explosive materials can be prevented.

Impacts to Neighboring Homes, Commercial Property and Other Structures

If it is assumed that the maximum charge of explosive-per-delay in the access tunnel is limited to 40 pounds or less, the intensities of ground motion at the nearest occupied building at a distance of 1,000 feet, the hospital at 1,950 feet, and the closest home when the tunnel is below it at a distance of 1,165 feet would likely not exceed values shown in Table C-1.



Vibration Intensity Predictions for Decline Tunnel Blasting

Location (K) (D - ft) (W -lb) (m)

Closest Building: $PPV = 240\ (1000.0 / 40.00^{1/2})^{-1.600} = \boxed{0.07}$ in/s

(D - ft) (W -lb) (m)

Hospital: $PPV = 240\ (1950.0 / 40.00^{1/2})^{-1.600} = \boxed{0.02}$ in/s

(K) (D - ft) (W -lb) (m)

Closest Residence: $PPV = 240\ (1165.0 / 40.00^{1/2})^{-1.600} = \boxed{0.06}$ in/s

Table C-1 – Maximum Tunnel Blasting Vibration Levels

The 40-lb charge-per-delay limit is not overly restrictive and the anticipated levels of ground motion would be barely perceptible to occupants of all buildings at locations of concern.

If the maximum charge-per-delay used in future mine production blasting, at expected distances greater than 1,300 feet below the ground surface, does not exceed 200 pounds–per-delay, the intensity of ground motion would likely not exceed 0.17 in/s [240 $(1{,}300 / 200^{1/2})^{-1.6}$]. Motion of this level will not cause damage but it would certainly be felt by occupants of buildings. To minimize disturbance to surface residents, it would be wise to restrict all mine production blasting to daytime hours between 8:00 AM and 8:00 PM when residents are not sleeping. This should also be done for the near-surface (< 1,000 feet from portal) tunnel blasting where air-overpressure effects would certainly irritate residents during nighttime hours.

Ground motion at these levels not exceeding 0.2 in/s will not damage buildings, buried utilities, rock slopes, or any other facilities. Motion at this level will also not disturb animals. For comparison, a person walking on the ground or floor of a structure will often generate motion exceeding 0.15 in/s and normal temperature and humidity changes create much higher strains in building materials.

Hours of work for near surface tunnel drilling work may also be restricted by drilling noise depending on measured A-scale noise levels and local Grass Valley noise ordnance restrictions. Once the tunnel has advanced to depths greater than 500 feet, drill noise transmitted to the ground surface through the ground would likely not be noticeable to occupants of surface buildings so drilling work could occur 24 hours a day.

To ensure compliance and risk management purposes, for all blasts, IMMC should measure ground motion at the nearest occupied building and at least one other location of concern. Seismographs and procedures used for these measurements should be in full conformance to the standards developed by the Vibration Section of the Society of Explosives Engineers (ISEE). These standards are included in Attachment KK.

Air-overpressure

If reasonable blast design controls, including the use of charge stemming and other measures, are employed to control tunnel blast effects at and near the surface, air-overpressure intensity measured 50 feet from the blast round would typically not exceed 150 dBL. Using the extrapolation prediction formula shown in Figure C-10, the peak overpressure at nearest occupied buildings located about 1,000 feet from the portal would be around 116 dBL. Air-overpressure at nearest occupied homes located over 4,000 feet from the noise source at the portal would likely attenuate rapidly to less than 104 dBL. Air-overpressure at these levels will not be damaging and the impact on structures is less than that caused by a 20-mph wind gust.

$$OP_x = OP_1 - 20 \log_{10} (R_x / R_1)$$

Where:
OP_x = Over-pressure at Distance X (dB)
OP_x = Reference Over-pressure at Distance R_1 (dB)
R_1= Reference Over-pressure Distance (ft)
R_x = Extrapolated Overpressure Distance (ft)

Note: psi = $2.9 \times 10^{-9} \times \log_{10}$ (dB/20), dB = 20 log (psi/2.9×10^{-9})

Distance (ft) **R_1**	**OP_1**	**OP_x**	**Decibel Reduction**	**Absolute Pressure**	**Reduction Factor**
20	**150 dB**		**none**	**0.09171 psi**	**none**
R_x					
100		136.0 dB	1.1 times	0.01834 psi	5 times
500		122.0 dB	1.2 times	0.00367 psi	25 times
1000		116.0 dB	1.3 times	0.00183 psi	50 times
2000		110.0 dB	1.4 times	0.00092 psi	100 times
4000		104.0 dB	1.4 times	0.00046 psi	200 times
6000		100.5 dB	1.5 times	0.00031 psi	300 times

Figure C-10. Attenuation of Tunnel Blast Noise (Overpressure) with Distance

Depending on topography of the portal site and the visible exposure of windows and walls of the Sierra Nevada Hospital buildings, located about 2,000 feet northwest of the tunnel portal, it is possible that secondary vibration and window rattling caused by low frequency air-overpressure pulses could be heard within the hospital. Although this energy will not be damaging, it may cause concern. This and other specific impacts to the hospital and medical activity at the hospital are discussed in a separate section that follows. As done at the TRI-MET light rail tunnel project in Oregon (Revey, 1995), once the decline tunnel has advanced a few hundred feet, heavy reinforced tunnel doors might be installed to mitigate air-overpressure levels and allow extended blasting hours.

Impacts on the Sierra Nevada Hospital

During the past three years, blasting at tunnel projects was successfully done near hospitals in Garfield Heights, Ohio and in Wauwatosa, Wisconsin. For the blasting in Wisconsin, engineers representing the Metropolitan Milwaukee Sewer District (MMSD), recognizing that blasting effects might impact activities like laser eye surgery procedures at the Medical Center Eye Institute, prohibited blasting between 7:00 a.m. and 3:00 p.m. However, a provision was included in the specifications that would allow blasting to occur during these hours if the contractor could submit a signed letter from the director of the clinic that authorized daytime blasting subject to agreed restrictions.

Understanding that it would be extremely beneficial to the project schedule for blasting work to occur during daytime hours, the contractor building the tunnels and their blasting consultant developed a specialized blasting plan that would keep ground motions at the Medical Center, located 2,700 feet away, below 0.02 in/s, which is less than the human perception threshold.

A detailed presentation outlining all of the planned blast design and control measures was presented to the Director Medical Center and key staff members. After all concerns were addressed, it was agreed to allow a series of daytime test blasts that would confirm whether or not blast-induced vibration and air-overpressure would be noticeable. The Director of the Medical Center provided a letter authorizing the daytime blasting with the proviso that if blasting effects were noticed, the blasting would stop. To allow comparison of blast-induced energy to existing background noise and vibration at the Medical Center and Eye Institute, it was also agreed that it would be wise to determine levels of background noise and vibration at areas of concern. Monitoring locations were suggested by the staff of the Medical Center and background levels were determined. The test blasts, and all subsequent full scale blasts were executed as planned without any concerns being expressed by the Medical Center.

Similar issues, that could be similarly controlled, may arise when blasting is planned within 1,950 feet of the Sierra Nevada Hospital facilities. At this point, it would be very wise to investigate what activities occur at the hospital and to learn any concerns that the staff may have regarding medical procedures, experiments, and impacts on patients residing therein.

Once these issues and concerns are identified, appropriate blasting controls and appropriate drilling and blasting hours might be determined.

CONCLUSION

Despite the fact that many issues and challenges involving the planned use of explosives and blasting methods for the development and mining work at the Idaho-Maryland mine have been identified, there are proven technologies and management methods that can be applied to safely and successfully mitigate potential impacts from blasting at this mine.

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ATTACHMENT KK

ISEE BLAST
MONITORING
STANDARDS

INDUSTRY BLAST MONITORING STANDARDS

The following standards should be applied when measuring blast-induced vibration and air-overpressure (noise). These standards are based on the best practices recommended by The Vibration Section of the International Society of Explosives Engineers – 1999.

Part 1. General Guidelines

1. Operators: Only personnel who have successfully completed a proper training course should operate monitoring equipment.

2. Calibration: The instrument manufacturer should annually calibrate recording units and sensors. Documenting certificates should be kept on file and copies should be provided to appropriate persons upon request.

3. Event Record Keeping: Hard copy reports and electronic file-copies of all event-monitoring records should be maintained for all blasts. Operating notes should be programmed into the instruments, which should be printed monitoring records. These notes at a minimum should include the operator’s name, date, time, place and other pertinent data specific to the monitoring location.

4. Trigger Levels: When employing instruments to operate in auto-trigger-mode, trigger levels should be set low enough to record blast effects. If expected levels of blast noise or vibration do not exceed minimum trigger levels, the instrument should be attended by an operator and turned on manually.

5. Documenting Monitor Location: In addition to event reports, an accurate method should be used to determine the monitoring location for later reference. Acceptable methods are 1) plotting numbered locations on scaled maps; 2) defining location with GPS northing, easting and elevation values; and 3) noting the name of the structure and the measured distance (+/- 1 ft) where the seismograph was placed relative to at least two identifiable reference points. Any person should be able to locate and identify the exact monitoring location at a future date.

6. Distance to Blast: The horizontal distance from the seismograph to the blast should be known to at least two significant digits. For example, a blast within 1000 feet would be nearest tens of feet and a blast within 10,000 feet would be measured to the nearest hundreds of feet. Where the vertical-to-horizontal ground slope ratio exceeds 2.5 to1, slant distances or true distance should be used and recorded in the monitoring records.

7. Processing Time: When instruments are used in auto-trigger and continuous-recording mode to record the effects of multiple blasts, the time between successive blasts shall be at least one (1) minute and seismographs shall be set to NOT automatically print out event records. These procedures should ensure that instruments have adequate time to save event data for each blast and reset to monitoring mode before subsequent blasts occur.

8. Memory Management: The instrument operator should know the memory or record capacity of the seismograph and ensure that adequate memory is available to store the event data from the blast(s) planned during that operating day.

9. Waveform Data: Instruments shall be set to save full waveform data for all monitored blast and digitally saved event files shall contain this data for use in further analyses if needed.

10. Instrument Setup Time: Equipment operators should allow ample time for proper setup of the seismograph, transducers and microphones. At least 15 minutes of time should be allotted for each setup location.

11. Securing cables: In order to prevent false triggering caused by wind-blown cables, the operator should secure suspended or freely moving cables from the wind or other extraneous sources.

Part II. Ground Vibration Monitoring

A. Sensor Placement

The sensor should be placed on or in the ground on the side of the structure towards the blast. A structure can be a house, pipeline, telephone pole, etc. Measurements on driveways, walkways, and slabs are to be avoided where possible.

1. Location relative to the structure: The sensor should be placed within 10 feet of the structure or less than 10% of the distance from the blast, whichever is less.

2. Soil density evaluation: The operator should avoid placing velocity transducers in loose or low-density soils. The density of the ground should be greater than or equal to the sensor density.

3. Sensor Level: Transducers should be placed so they are level or nearly level.

4. Sensor Orientation: Sensor blocks should be oriented so the arrow indicating the longitudinal direction is aimed at the blast location.

5. Monitoring when Access to Nearest Structure is not Accessible: Where access to a structure is not available, the transducers should placed at the accessible location closest the structure of concern and in line with the blast.

B. Sensor coupling

1. Sensor Coupling Methods: Based on expected acceleration determined from Chart 1, to avoid decoupling errors, the operator shall use the following methods to couple vibration transducers to the ground or structure.

    a. Less than 0.2 g: No burial or attachment is necessary.

   b. Between 0.2 and 1.0 g: Transducer should be attached to the ground with a spike or covered with a sand bag.
   c. Greater than 1.0 g: Transducer should be buried, bonded to the ground or structure with stiff clay or putty, or some other method that should achieve firm attachment.

TABLE 1 – Acceleration intensity (g's) based on estimated particle velocities and frequencies

	Maximum Frequency (Hz or cycles-per-second)										
	4	10	15	20	25	30	40	50	100	150	200
PPV (in/s) at Acc. (g) ≥ **0.2**	3.08	1.23	0.82	0.62	0.49	0.41	0.31	0.25	0.12	0.08	0.06
PPV (in/s) at Acc. (g) ≥ **1.0**	15.38	6.15	4.10	3.08	2.46	2.05	1.54	1.23	0.62	0.41	0.31

2. Sensor Burial: When velocity transducers are buried the operator should employ the following methods.

   a. Excavate a hole that is no less than three times the height of the sensor (ANSI S2.47-1990, R1997).
   b. If possible, spike the sensor to the bottom of the hole.
   c. Firmly compact soil around and over the sensor.

3. Attaching Sensors to bedrock or hard Structural Surfaces:

   a. Bolt, clamp or use epoxy or putty to firmly couple the sensor to the hard surface.
   b. The sensor may be attached to the foundation of the structure if it is located within +/- 1-foot of ground level (USBM RI 8969). This should only be used if burial, spiking or and bagging is not practical.

4. Other sensor placement methods: Use other methods as described below if disturbance of the ground is not possible.

   a. Cover transducers with sand bags loosely filled with about 10 pounds of sand. When placed over the sensor the sandbag profile should be as low and wide as possible with a maximum amount of firm contact with the ground.
   b. A combination of both spiking and sandbagging gives even greater assurance that good coupling is obtained.

C. Programming considerations

Site conditions dictate certain actions when programming the seismograph.

1. Ground motion trigger level: The PPV-trigger-level should be programmed low enough to trigger the unit from blast vibrations and high enough to minimize the occurrence of false events. The level should be slightly above the expected background vibrations for the area. A good starting level is 0.05 in/s.

2. Dynamic range and resolution: If PPV is expected to exceed 10 in/s or frequency is expected to exceed 250 Hz, special sensors approved by the Vibration Specialist should be used to measure blast effects. In these cases, the Vibration Specialist should also determine a digital sampling rate that should provide accurate recordings.

3. Recording duration: Set the record time for 2 seconds longer than the blast duration plus 1 second for each 1100 feet from the blast.

Part III Air-overpressure Monitoring

The following procedures should be used as possible when setting up instruments to measure blast-induced noise.

A. Microphone placement

The microphone should be placed along the side of the structure nearest the blast.

1. The microphone should be covered with a windscreen and mounted near the velocity transducers.

2. The preferred microphone height is 3 feet above the ground or within 1.2 inches of the ground. Other heights may be acceptable for practical reasons. (ANSI S12.18-1994, ANSI S12.9-1992/Part2) (USBM RI 8508)

3. If practical, the microphone should not be shielded from the blast by nearby buildings, vehicles or other large barriers. If such shielding cannot be avoided, the horizontal distance between the microphone and shielding object should be greater than the height of the shielding object above the microphone.

4. If placed too close to a structure, the airblast may reflect from the house surface and record higher amplitudes. Structure response noise may also be recorded. Placing the microphone near a corner of the structure can minimize reflection of over-pressure energy. (RI 8508)

B. Programming considerations

Site conditions dictate certain actions when programming the seismograph to record air-overpressure.

1. Trigger level: When only an airblast measurement is desired, the trigger level should be low enough to trigger the unit from the airblast and high enough to minimize the occurrence of false events. The level should be slightly above the expected background noise for the area. A good starting level is 120 dB.
2. Recording duration: When only recording airblast, set the recording time for at least 2 seconds more than the blast duration. When ground vibrations and air-overpressure measurements are desired on the same record, follow the guidelines for ground vibration programming (Part II C.3).