EXPLOTECH

Specialists in Explosives, Blasting and Vibration
Consulting Engineers

Blasting Impact Analysis
Lafarge Navan Quarry Extension
Part Lots 9 and 10, Concession 5, former geographic township of Cumberland, City of Ottawa

Submitted to:

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EXECUTIVE SUMMARY

Explotech Engineering Ltd. was retained in April 2013 to provide a Blast Impact Analysis for the proposed Lafarge Navan Quarry extension operation located on Part Lots 9 and 10, Concession 5, former geographic township of Cumberland, City of Ottawa.

Vibration levels assessed in this report are based on the Ministry of the Environment, Conservation and Parks Model Municipal Noise Control By-law (NPC 119) with regard to guidelines for blasting in Mines and Quarries. We have assessed the area surrounding the proposed license area with regard to potential damage from blasting operations and compliance with the aforementioned by-law document. In addition, we have reviewed blast and/or vibration reports collected at the existing licenced quarry for the 2016 - 2020 blasting campaigns.

We have inspected the site and reviewed the available site plans. Explotech Engineering Ltd. is of the opinion that the planned mineral extraction extension on the site can be carried out safely and within Ministry of the Environment, Conservation and Parks guidelines as set out in NPC 119 of the By-Law.

Recommendations are included in this report for blasting operations to be carried out in a safe and productive manner and to suitably manage and mitigate the possibility of damage to any buildings, wells, structures or residences surrounding the property.

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INTRODUCTION

The proposed Lafarge Navan Quarry extension operation is located on the East side of the existing licensed and operating Navan Quarry (Licence 4185, 4144 and 10699). The legal description for the subject property is Part Lots 9 and 10, Concession 5, former geographic township of Cumberland, City of Ottawa.

This Blast Impact Analysis is based on the Ministry of the Environment, Conservation and Parks (MECP) Model Municipal Noise Control By-law (NPC 119) with regard to guidelines for blasting in mines and quarries. We have additionally assessed the area surrounding the proposed license with regard to potential damage from blasting operations.

Given that quarry operations are currently underway on the adjacent Lafarge licenced properties and all blasts conducted are monitored for ground vibrations and overpressure, site-specific blast monitoring data is available for the area. The site specific data has been incorporated into this assessment to confirm predictable values. It is a recommendation of this report that a vibration monitoring program be continued on this site, including within the Navan extension lands, and that the program be maintained for the duration of all blasting activities to permit timely adjustment to blast parameters as required.

While not specifically required as part of the required scope of the Blast Impact Analysis under the Aggregate Resources Act, this report reviews the topics of flyrock and residential water wells. Details related to residential water wells are addressed in the hydrogeological report prepared by Golder Associates while specific flyrock control is addressed at the operational level by Lafarge given significant influences related to blast design, geology and field accuracy.

Recommendations are included in this report for blasting operations to be carried out in a safe and productive manner and to suitably manage and mitigate the possibility of damage to any buildings, wells, structures or residences surrounding the property.

EXISTING CONDITIONS

The current licensed area for the Lafarge Navan Quarry (Licences 4185, 4144 and 10699) is described as Lots 7 to 10, Concession 6, former geographic Township of Cumberland, City of Ottawa. This property is bounded by private properties fronting on Colonial Road to the South and vacant farm fields to the North West and East. The lands surrounding the licence are sparsely populated with the areas of closest and densest development lying immediately to the South.

The licenced area for the proposed Navan Quarry extension lands encompasses a total area of approximately 28.4HA. The associated extraction area is approximately 21.1HA when allowing for setbacks and sterilized areas.

The proposed Lafarge Navan Quarry extension is located immediately East of the existing licence on Part Lots 9 and 10, Concession 5, former geographic Township of Cumberland, City of Ottawa. The extension lands are bounded by farm fields to the East and North, the existing Navan quarry to the West, and residential properties located on Colonial Road to the South. The closest sensitive receptors located within 1500m of the proposed limit of extraction are listed in Table 1 below as well as in the Sensitive Receptor Overview contained in Appendix A:

Sensitive Receptor Address	Sensitive Receptor or Non Sensitive Receptor	Distance to Receptor (m)	Direction from Extraction Limits
1949 Colonial Rd	Sensitive	1,365	Southwest
2002 Colonial Rd	Sensitive	1,155	Southwest
2027 Colonial Rd	Sensitive	1,070	Southwest
2067 Colonial Rd	Sensitive	930	Southwest
2083 Colonial Rd	Sensitive	875	Southwest
2093 Colonial Rd	Sensitive	820	Southwest
2139 Colonial Rd	Sensitive	665	Southwest
2156 Colonial Rd	Non-Sensitive	560	Southwest
2182 Colonial Rd	Sensitive	445	Southwest
2203 Colonial Rd	Sensitive	430	Southwest
2206 Colonial Rd	Sensitive	330	Southwest
2210 Colonial Rd	Non-Sensitive	340	Southwest
2264 Colonial Rd	Non-Sensitive	160	Southwest
2348 Colonial Rd	Sensitive	115	South

Sensitive Receptor Address	Sensitive Receptor or Non Sensitive Receptor	Distance to Receptor (m)	Direction from Extraction Limits
2353 Colonial Rd	Sensitive	200	South
2452 Colonial Rd	Sensitive	110	South
2454 Colonial Rd	Sensitive	60	South
2455 Colonial Rd	Sensitive	230	South
2462 Colonial Rd	Non-Sensitive	110	South
2473 Colonial Rd	Sensitive	190	South
3043 Dunning Rd	Non-Sensitive	1,525	Northeast
3085 Dunning Rd	Sensitive	1,530	Northeast
3094 Dunning Rd	Sensitive	1,395	Northeast
3105 Dunning Rd	Non-Sensitive	1,500	Northeast
3128 Dunning Rd	Sensitive	1,345	Northeast
3160 Dunning Rd	Sensitive	1,305	Northeast
3178 Dunning Rd	Sensitive	1,265	Northeast
3264 Dunning Rd	Sensitive	1,060	Northeast
3305 Dunning Rd	Sensitive	1,120	Northeast
3315 Dunning Rd	Sensitive	1,075	Northeast
3338 Dunning Rd	Sensitive	935	East
3374 Dunning Rd	Sensitive	885	East
3519 Dunning Rd	Sensitive	850	East
3636 Dunning Rd	Sensitive	965	Southeast
3676 Dunning Rd	Sensitive	750	Southeast
3686 Dunning Rd	Sensitive	1,085	Southeast
3709 Dunning Rd	Sensitive	1,200	Southeast
3714 Dunning Rd	Sensitive	1,165	Southeast
3738 Dunning Rd	Sensitive	1,455	Southeast
3548 Heuvelmans Rd	Sensitive	230	South
3785 Heuvelmans Rd	Sensitive	1,090	South
3800 Heuvelmans Rd	Sensitive	1,200	South
2182 Giroux Rd	Sensitive	970	Northwest
2215 Giroux Rd	Sensitive	980	Northwest
2226 Giroux Rd	Sensitive	895	Northwest
2570 Giroux Rd	Sensitive	1,490	Northeast
3365 Rockdale Rd	Non-Sensitive	1,290	West
3540 Rockdale Rd	Non-Sensitive	1,500	Southwest

Table 1: Closest Sensitive Receptors

PROPOSED MINERAL EXTRACTION

As per the Aggregate Resources Act Extraction Plan (Refer to Appendix A), the proposed initial Phase 1 quarry operations will commence at the East face of the existing licence extraction limit and will retreat East into the Northern part of the extension lands. This will eliminate the need for a sinking cut and provide the maximum distance separation to neighbouring receptors. Phase 1 will be extracted to a final floor elevation of 95masl and given existing topography of 106-109masl, it is anticipated that Phase 1 extraction will take place in 1 – 2 benches.

Phase 2 is located to the South of Phase 1 and could retreat Southerly from Phase 1 and/or utilize the East face of the existing licence extraction limit and retreat Easterly across the extension lands. Phase 2 will be extracted to a final floor elevation of 86masl and given existing topography of 105masl, it is anticipated that Phase 2 extraction will take place in 1 – 2 benches.

Similarly to Phase 2, Phase 3 is located immediately South of Phase 2 and could also retreat Southerly from Phase 2 and/or utilize the East face of the existing licence extraction limit and retreat Easterly across the extension lands. Phase 3 will be extracted to a final floor elevation of 80masl and given existing topography of 102masl, it is anticipated that Phase 2 extraction will take place in 1 – 2 benches.

Phase 4 is located to the South of Phase 3 and will retreat Southerly from Phase 3 to the Southern extraction limits. Phase 4 will be extracted to a final floor elevation of 71.5masl and given existing topography of 96-100masl, it is anticipated that Phase 4 extraction will take place in 1 – 2 benches.

As quarry operations migrate across the property, the closest sensitive receptors to the required blasting operations will vary. While initial mineral extraction in the proposed licence area will occur approximately 775m from the closest sensitive receptors to the blast location, the quarry face along the South limits of extraction will come within 60m of the closest property located on Colonial Road (Refer to Table 1 above).

Limestone Quarries in Ontario normally employ 76 to 150mm diameter blast holes which, for a 7–20m bench, would employ 30kg to 390kg per hole. Given that all blasting in the extension lands will shoot to an existing open face eliminating the requirement for a sinking cut, blasts can be designed to fire one hole per period.

Current practice at the Lafarge Navan operation employs 100mm diameter blast holes with a typical load per delay of 115kg. While current practices would be acceptable for the initial blasting in the extension area, calculations contained within this report suggest modifications to current blast designs will be necessary as operations progress towards adjacent receptors. Fortunately, given advanced initial separation distances between blasting operations and neighbouring receptors, there exists ample opportunity for data collection and analysis prior to any required blasting in closer proximity to the adjacent homes.

BLAST VIBRATION AND OVERPRESSURE LIMITS

The Ontario MECP guidelines for blasting in quarries are among the most stringent in North America.

Studies by the U.S. Bureau of Mines have shown that normal temperature and humidity changes can cause more damage to residences than blast vibrations and overpressure in the range permitted by the MECP. The limits suggested by the MECP are as follows.

Vibration	12.5mm/s	Peak Particle Velocity (PPV)
Overpressure	128dB	Peak Sound Pressure Level (PSPL)

The above guidelines apply when blasts are being monitored. Cautionary levels are slightly lower and apply when blasts are not monitored on a routine basis. It is a recommendation of this report that all blasts at the operation be monitored to quantify and record ground vibration and overpressure levels employing a minimum of two (2) digital seismographs, one installed at the closest receptor behind the blast, or closer, and one installed at the closest receptor in front of the blast, or closer.

BLAST MECHANICS AND DERIVATIVES

The detonation of explosives within a blast hole results in the development of very high gas and shock pressures. This energy is transmitted to the surrounding rock mass, crushing the rock immediately surrounding the borehole (approximately 1 borehole radius) and permanently distorts the rock to several borehole diameters (5-25, depending on the rock type, prevalence of joint sets, etc).

The intensity of this stress wave decays quickly so that there is no further permanent deformation of the rock mass. The remaining energy from the detonation travels through the unbroken material in the form of a pressure wave or shock front which, although it causes no plastic deformation of the rock mass, is transmitted in the form of vibrations.

Particle velocity is the descriptor of choice when dealing with vibrations because of its superior correlation with the appearance of cosmetic cracking. As such, for the purposes this report, ground vibration units have been listed in mm/s.

In addition to the ground vibrations, overpressure, or air vibrations, are generated through the direct action of the explosive venting through cracks in the rock or through the indirect action of the rock movement. In either case, the result is a pressure wave which travels though the air, measured in linear decibels (or dBL) for the purposes of this report.

VIBRATION AND OVERPRESSURE THEORY

Transmission and decay of vibrations and overpressure can be estimated by the development of attenuation relations. These relations utilize empirical data relating measured velocities at specific separation distances from the vibration source to predict particle velocities at variable distances from the source. While the resultant prediction equations are reliable, divergence of data occurs as a result of a wide variety of variables, most notably site-specific geological conditions and blast geometry and design for ground vibrations and local prevailing climatic conditions for overpressure.

In order to circumvent this scatter and improve confidence in forecast vibration levels, probabilistic and statistical modeling is employed to increase conservatism built into prediction models, usually by the application of 95% confidence lines to attenuation data.

The attenuation relations are not designed to conclusively predict vibration levels at a specific location as a result of a specific blast design, application of this probabilistic model creates confidence that for any given scaled distance, 95% of the resultant velocities will fall below the calculated 95% regression line.

While the data still provides insight into probable vibration intensities, attenuation relations for overpressure tends to be less reliable and precise than results for ground vibrations. This is due primarily to wider variations in variables outside of the influence of the blast design which impact propagation of the vibrations. Atmospheric factors such as temperature gradients and prevailing winds (refer to Appendix B) as well as local topography can all serve to significantly alter overpressure attenuation characteristics.

Our experience and analysis demonstrates that blast overpressure is greatest when blasting towards receptors, and blast vibrations are greatest when retreating towards the receptors.

VIBRATION LEVELS AT THE NEAREST SENSITIVE RECEPTOR

The most commonly used formula for predicting PPV is known as the Bureau of Mines (BOM) prediction formula or Propagation Law. We have used this formula to predict the PPV's at the closest house for the initial operations.

$$PPV = k\left(\frac{d}{\sqrt{w}}\right)^{e}$$

Where, PPV = the predicted peak particle velocity (mm/s)

K, e = site factors

d = distance from receptor (m)

w = maximum explosive charge per delay (kg)

The value of K and e are variable and influenced by many factors (i.e. rock type, geology, thickness of overburden, etc.). As such, these site factors are developed empirically through the measurement of vibration characteristics at the specific operations of interested.

The portion of the BOM prediction formula contained within the parentheses is referred to as the *Scaled Distance* and represents another important PPV relation. It correlates the separation distance between a blast and receptor to the energy (usually expressed as explosive weight) released at any given instant in time. The two most popular approaches are square root scaling and cube root scaling:

$$\left(SDSR = \frac{R}{\sqrt{W}}\right) \qquad \left(SDCR = \frac{R}{\sqrt[3]{W}}\right)$$

Where, SDSR = Scaled distance square root method

SDCR = Scaled distance cube root method

R = Separation distance between receptor site and blast (m)

W = Maximum explosive load per delay period (kg)

Historically, square root scaling is employed in situations whereby the explosive load is distributed in a long column (i.e. blasthole) while cube root scaling is employed for point charges. In accordance with industry standard, square root scaling was adopted for ground vibration analysis for the purposes of this report.

For a distance of 815m (the standoff distance to the closest sensitive receptor for the initial Phase 1 blasting, namely 2348 Colonial Road) and a maximum explosive load per delay of 128kg (101mm diameter hole, 15m deep, 2m surface collar and 1 hole per delay), we can calculate the maximum PPV at the closest building using the following formulae:

Imperial Equations:

Oriard 50% Bound (2002)	$v = 160(\frac{D}{\sqrt{W}})^{-1.6}$
Oriard 90% Bound (2002)	$v = 242(\frac{D}{\sqrt{W}})^{-1.6}$
Quarry Production Blast (Bulletin 656 – 1971)	$v = 182(\frac{D}{\sqrt{W}})^{-1.82}$
Typical limestone Quarry (Pader report – 1995)	$v = 52.2(\frac{D}{\sqrt{W}})^{-1.38}$
Typical Coal Mine (RI8507 1980)	$v = 133(\frac{D}{\sqrt{W}})^{-1.5}$

Metric Equations:

General Blasting (Dupont)	$v = 1140(\frac{D}{\sqrt{W}})^{-1.6}$
Construction Blasting (Dowding 1998)	$v = 1326(\frac{D}{\sqrt{W}})^{-1.38}$
Agg. Quarry Blasting (Explotech 2005)	$v = 5175(\frac{D}{\sqrt{W}})^{-1.76}$
Agg. Quarry blasting (Explotech 2003)	$v = 7025(\frac{D}{\sqrt{W}})^{-1.85}$

The equations described above accommodate for a range of geological conditions. The proposed blast parameters were applied to the formulae to estimate a range of the potential vibrations to be imparted on the closest sensitive receptor behind the blast. As discussed in previous sections, the MECP guideline for blast-induced vibration is 12.5 mm/s (0.5 in/s). Appendix C demonstrates that the maximum (ie worst-case) calculated value for the vibration intensities imparted on the closest sensitive receptor based on all equations is 3.62mm/s for the initial blasting, well below the MECP guideline limit. All blasts will be monitored for overpressure and ground vibrations with blast designs adjusted in response to readings on site in order to confirm consistent compliance with established limits.

All vibration calculations and tables going forward will utilize the formula providing the worst case scenario for all geological conditions (Construction Blasting (Dowding 1998)).

An ***example*** of this calculation is as follows:

For a distance of 815m (the standoff distance to the closest sensitive receptor for the initial Phase 1 blasting behind the blast, namely 2348 Colonial Road) and a maximum explosive load per delay of 128kg (101mm diameter hole, 15m deep, 2m surface collar and 1 hole per delay), we can calculate the maximum PPV at the closest sensitive receptor as follows:

$$ppv = 1326\left(\frac{815}{\sqrt{128}}\right)^{-1.38} = 3.62mm/s$$

As discussed in previous sections, the MECP guideline for blast-induced vibration is 12.5 mm/s (0.5 in/s). The calculated 95% predicted PPV (based on the proposed blasting data discussed above) would be 3.62mm/s, well below the MECP guideline limit. It is understood that as separation distance to the receptors decreases, adjustments to blast designs may be necessary to maintain compliance with the guideline limits.

Similarly, the above equation used to calculate PPV can be reformatted to find an approximation of the distance at which a vibration velocity of 12.5mm/s would occur if all blasting parameters are kept the same as used in the equation above:

$$12.5 = 1326\left(\frac{d}{\sqrt{128}}\right)^{-1.38} = 332.24m$$

The above result suggests that design modifications to the above preliminary design would be required once blasting operations encroach to within 335m of the properties to the South. Fortunately, vibration data will be continually collected and analyzed as the sensitive receptors are approached in order to confirm the requirement for any design modifications. An abundance of design modifications are available which would readily maintain vibration intensities below guideline limits.

Given the separation distances that will be involved at the Navan Quarry Extension, Table 2 below provides initial guidance on maximum loads per delay based on various separation distances. The following maximum loads per delay were derived from the equation for ground vibrations listed above and are based on a maximum intensity of 12.5mm/s:

Separation distance between sensitive receptor and closest borehole (meters)	Maximum recommended explosive load per delay (Kilograms)
500	290
450	235
400	185
350	140
300	105
250	70
200	45
150	25
100	11
60	4.25

Table 2: Maximum Loads per Delay to Maintain 12.5mm/s at Various Separation Distances

It is noteworthy that the above values are typically conservative and are intended as a guideline only as the ground vibration attenuation equation is based on a calculated 95% regression line. Actual loads employed shall be based on the results of the monitoring program in place and adjusted as necessary.

The closest separation distance between a sensitive receptor and any blast over the life of the license is 60m. While blasting at this separation distance is feasible from a technological perspective, given current blasting technology and

techniques, market economics will dictate the feasibility of extracting rock at lesser separation distances. Monitoring and changes in blasting designs will be required in order to confirm all blasts are within MECP guidelines when blasting comes closer to adjacent sensitive receptors.

Similarly to the paragraph above, the closest separation distance between a non-sensitive receptor (namely 2462 Colonial Road) and any blast over the life of the license is 90m. Using the above equation and keeping the same blasting parameters with a suggested limit of 50mm/s, the calculation would suggest that once blasting encroaches to 122m removed from the non-sensitive receptors, modifications may be required.

OVERPRESSURE LEVELS AT THE NEAREST SENSITIVE RECEPTOR

It is unusual for overpressure to reach damaging levels, and when it does, the evidence is immediate and obvious in the form of broken windows in the area. However, overpressure remains of interest due to its ability to travel further distances as well as cause audible sounds and excitation in windows and walls.

Air overpressure decays in a known manner in a uniform atmosphere, however, a uniform atmosphere is not a normal condition. As such, air overpressure attenuation is far more variable due to its intimate relationship with environmental influences. Air vibrations decay slower than ground vibrations with an average decay rate of 6dBL for every doubling of distance.

Air overpressure levels are analyzed using cube root scaling based on the following equation:

$$P = k\left(\frac{d}{\sqrt[3]{w}}\right)^{e}$$

Where, P = the peak overpressure level (psi – imperial, Pa, dB - metric)
K, e = site factors
d = distance from receptor (ft – imperial, m - metric)
w = maximum explosive charge per delay (lbs – imperial, kg - metric)

The value of K and e are variable and are influenced by many factors (i.e. rock type, geology, thickness of overburden, environmental conditions, etc.). As such, these site factors are developed empirically through the measurement of overpressure characteristics at the specific operations of interested.

As discussed in previous sections, the MECP guideline for blast-induced overpressure is 128dBL. For a distance of 765m (i.e. the standoff distance to the closest sensitive receptor in front of the blast for the initial Phase 1 blasting, namely 2206 Colonial Road) and a maximum explosive load of 128kg (101mm diameter hole, 15m deep, 2m surface collar and 1 hole per delay), we can calculate the overpressure at the nearest receptor in front of the blast using the following equations:

Imperial Equations:

USBM RI8485 (Behind Blast)	$P = 0.056(\frac{D}{\sqrt[3]{W}})^{-0.515}$
USBM RI8485 (Front of Blast)	$P = 1.317(\frac{D}{\sqrt[3]{W}})^{-0.966}$
USBM RI8485 (Full Confined)	$P = 0.061(\frac{D}{\sqrt[3]{W}})^{-0.96}$
Construction Average (Oriard 2005)	$P = 1(\frac{D}{\sqrt[3]{W}})^{-1.1}$

Metric Equations:

Ontario Quarry - dB (Explotech)	$P = 159(\frac{D}{\sqrt[3]{W}})^{-0.0456}$
Limestone - dB (Explotech)	$P = 206(\frac{D}{\sqrt[3]{W}})^{-0.1}$
Ontario Quarry - Pa (Explotech)	$P = 1222(\frac{D}{\sqrt[3]{W}})^{-0.669}$

Appendix C demonstrates that the maximum calculated value for the overpressure intensities imparted on the closest sensitive receptor based on all equations is 126.54 dB(L) for the initial blasting below the MECP guideline limit. For initial blasting, all blasts should be scheduled on days with favourable weather conditions to assist in mitigating overpressure levels. All blasts will be monitored for overpressure and ground vibrations with blast designs adjusted in response to readings on site in order to maintain consistent compliance with established limits.

Based on the above calculation and the assumed blast parameters, and the conservatism built into the equations, overpressures from blasting operations can remain compliant with the MECP NPC 119 guideline limit of 128dBL. The design method of retreat has been planned so as to direct overpressures generated as

much as practicable in the direction of vacant lands. All overpressure calculations and tables going forward will utilize the formula providing the worst case scenario for all geological conditions (Ontario Quarry – Pa (Explotech)).

We reiterate that air overpressure attenuation is far more variable due to its intimate relationship with environmental influences and as such, the equation employed is less reliable than that developed for ground vibration. Overpressure monitoring performed on site shall be used to guide blast design as it pertains to the control of blast overpressures. As demonstrated in Appendix B, prevailing winds during quarry operational periods are predominantly out of the South and West, a condition which will assist in attenuating overpressures at the receptors in front of the blasting throughout the phasing of the extension licence.

As discussed in previous sections, the MECP guideline for blast-induced overpressure is 128dBL. For a distance of 765m in front of the blast (i.e. the standoff distance to the closest sensitive receptor for the initial Phase 1 blasting, namely 2206 Colonial Road) and a maximum explosive load of 128kg (101mm diameter hole, 15m deep, 2m surface collar and 1 hole per delay), we can calculate the PSPL at the nearest receptor as follows:

$$P = 1222\left(\frac{765}{\sqrt[3]{128}}\right)^{-0.669} = 126.54dB(L)$$

Similarly, the above equation used to calculate PSPL can be reformatted to find an approximation of the distance at which an overpressure of 128 dB(L) would occur. If all blasting parameters are kept the same as above, a distance of 600m from the closest sensitive receptor in front of the blast would have a calculated overpressure of 128db(L). Once again, the on-site monitoring program will accurately delineate the overpressure intensities and provide guidance for the timing for any design changes. For the initial blasting, when a distance from blast to sensitive receptor in front of the blast is <600m, decking could be employed on site and half the explosive load/delay to 64kg/delay, which would achieve a calculated overpressure of 126.6dB(L).

Given the intimate correlation between overpressure and environmental conditions as stated previously, care must be taken to avoid blasting on days when weather patterns are less favourable. Extraction directions have been selected so as to minimize overpressure impacts on adjacent receptors.

Table 3 below can be used as an initial guide showing maximum loads per delay based on various separation distances for receptors in front of the blast face. The

following maximum loads per delay are derived from the air overpressure equation above and are based on a peak overpressure level of 128dB(L):

Separation distance between sensitive receptor and closest blasthole (meters)	Maximum recommended explosive load per delay (Kilograms)
900	440
800	310
700	205
600	130
500	75
400	38
300	16
200	4.5
100	0.6

Table 3: Maximum Loads per Delay to Maintain 128dB(L) at Various Separation Distances for Receptors in Front of the Face

We note that the above values are conservative and are intended as a guideline only as the air overpressure attenuation equation is based on a calculated 95% regression line. Actual loads employed shall be based on the results of the monitoring program in place.

ADDITIONAL CONSIDERATIONS OUTSIDE OF THE BLAST IMPACT ANALYSIS SCOPE

The following headings are addressed for general information purposes and are not strictly required as part of the scope of the Blast Impact Analysis as required under the ARA to ensure compliance with MECP NPC-119 guidelines. The hydrogeological study prepared by Golder Associates as part of the licence application will address residential water wells in detail. Flyrock control is addressed at the operational level given significant influences related to blast design, geology and field accuracy which render concrete recommendations related to control inappropriate at the licencing phase.

FLYROCK

Flyrock is the term used to define rocks which are propelled from the blast area by the force of the explosion. This action is a predictable and necessary component of a blast and requires that every blast have an exclusion zone established within which no persons or property which may be harmed are permitted.

Government regulations strictly prohibit the ejection of flyrock off of a quarry property. The regulations regarding flyrock are enforced by the Ministries of Natural Resources and Forestry, Environment, Conservation and Parks and Labour. In the event of an incident where flyrock does leave a site, the punitive measures include suspension / revocation of licences and fines to both the blaster and quarry owner / operator. Fortunately, flyrock incidents are extremely rare due to the prevalence of professionally designed and implemented blasting programs as well as rigorous prosecution of such events. It is in the best interest of all, stakeholders and non-stakeholders, to ensure that dangerous flyrock does not occur. Through proper blast planning and design, it is possible to control and mitigate the possibility for flyrock.

THEORETICAL HORIZONTAL FLYROCK CALCULATIONS

Flyrock occurs when explosives in a hole are poorly confined by the stemming or rock mass and the high pressure gas breaks out of confinement and launches rock fragments into the air. The three primary sources of fly rock are as follows:

- **Face burst:** Lack of confinement by the rock mass in front of the blast hole results in fly rock in front of the face.

- **Cratering:** Insufficient stemming height or weakened collar rock results in a crater being formed around the hole collar with rock projected in any direction.

- **Stemming Ejection:** Poor stemming practice can result in a high angle throw of the stemming material and loose rocks in the blasthole wall and collar.

The horizontal distance flyrock can be thrown (L_H) from a blast hole is determined using the expression:

$$L_H = \frac{V_o{}^2 Sin2\theta_0}{g} \qquad [1]$$

where:

V_o = launch velocity (m/s)

θ_0 = launch angle (degrees)

g = gravitational constant (9.8 m/s^2)

The theoretical maximum horizontal distance fly rock will travel occurs when θ_0 = 45 degrees, thereby yielding the equation:

$$L_{H\max} = \frac{V_o{}^2}{g} \qquad [2]$$

The normal range of launch velocity for blasting is between 10m/s - 30m/s. To calculate the launch velocity of a blast the following formula is used:

$$V_o = k\left(\frac{\sqrt{m}}{B}\right)^{1.3} \qquad [3]$$

where:

k = a constant

m = charge mass per meter (kg/m)

B = burden (m)

By combining equations 2 and 3 and taking into account the different sources of fly rock, the following equations can be used to calculate the maximum fly rock thrown from a blast:

Face burst: $$L_{H\max} = \frac{k^2}{g} * \left(\frac{\sqrt{m}}{B}\right)^{2.6}$$

Cratering: $$L_{H\max} = \frac{k^2}{g} * \left(\frac{\sqrt{m}}{SH}\right)^{2.6}$$

Stemming Ejection: $$L_{H\max} = \frac{k^2}{g} * \left(\frac{\sqrt{m}}{SH}\right)^{2.6} Sin2\theta$$

where:
θ = drill hole angle
L_{hmax} = maximum flyrock throw (m)
m = charge mass per meter (kg/m)
B = burden (m)
SH = stemming height (m)
g = gravitational constant
k = a constant

For flyrock calculation purposes, we have applied the current blasting parameters used in the Navan Quarry which utilize 101mm (4”) diameter holes on a 3.0m x 3.0m (10’x 10’) pattern, with total depths of up to 20m (80’) and a collar length of 2m (8’).

The range for the constant k is 13.5 for soft rocks and 27 for hard rocks. Given the proposed licence area is predominantly limestone, we have applied a k value of 21. The explosive density is assigned to be 1.2 g/cc for emulsion products and the drill hole angles are assumed to be 90 degrees (i.e. vertical).

Based on a free face blast, maximum anticipated horizontal flyrock projection distances are calculated as follows in Table 4:

Table 4 – Maximum Flyrock Horizontal		
Collar **Lengths** (m)	**Maximum Throw Face Burst** (m)	**Maximum Throw Cratering and Stemming Ejection** (m)
1.5	48	302
2.0	48	143
2.5	48	80
3.0	48	50
3.5	48	33

Different collar lengths are displayed in the table above to account for over or under loaded holes. As demonstrated with these various collar lengths, any deviation, no matter how slight, can greatly affect these maximum values. The current proposed initial blasting parameters have the potential to send flyrock 143m assuming all holes achieve the designed collar lengths of 2.0m.
Blast mats or sand can be placed on top of the shot to further reduce the distance for potential flyrock.

Through proper blast design and diligence in inspecting the geology before every blast, flyrock can readily be maintained within the quarry limits. It may be necessary to increase collars and adjust designs accordingly when blasting along the perimeter to accommodate the reduced distance to receptors and to ensure flyrock remains within the property limit. The operational plan for the quarry has been designed to retreat towards the closest receptors thereby projecting flyrock and overpressures away from the receptors.

RESIDENTIAL WATER WELLS

Possible impacts to the water quality and production capacity of groundwater supply wells is a common concern for residents near blasting operations. Complaints related to changes in water quality often include the appearance of turbidity, water discolouration and changes in water. Complaints regarding water production most often involve loss of quantity production, air in water and damage to well screens and casings. A review of research and common causes of these problems indicates that most of these concerns are not related to blasting and can be shown to be the direct impact of environmental factors and poor well construction and maintenance.

There is an intuitive belief that blasting operations have dramatic and disastrous impacts on residential water wells for large distances around such operations. Unfortunately, there is no scientific basis for such claims. Outside of the immediate radius of approximately 20-25 blasthole diameters from a loaded hole, there is no permanent ground displacement. As such, barring blasting activity within several meters of an existing well, the probability of damage to residential wells is essentially non-existent.

Despite the scientific support for the above conclusion, numerous studies have been performed to verify the validity of this statement. These studies have investigated the effects of blasting on varied well configurations and in varied geological mediums to ensure results could be readily extrapolated to all blasting operations. The conclusion of these studies has confirmed that with the exception of possible temporary increases in turbidity, blasting operations did not result in any permanent impact on wells outside of the immediate blast zone of the blast until vibrations levels reached exceedingly high intensities. Applying universally accepted threshold levels for ground vibrations eliminates the possibility for any long term adverse effects on wells in the vicinity of blasting operations.

In a study by Froedge (1983), blast vibration levels of up to 32.3mm/s were recorded at the bottom of a shallow well located at a distance of 60 meters (200 feet) from an open pit blast. There was no report of visible damage to the well nor was there any change in the water pumping flow rate. This study concluded that the commonly accepted limit of 50mm/s PPV level is adequate to protect wells from any damage. We reiterate, the current guideline limit for vibrations from quarry and mining operations is 12.5mm/s.

REVIEW OF HISTORICAL NAVAN QUARRY DATA

A vibration and overpressure monitoring program has been in place for all blasts conducted at the Lafarge Navan Quarry in recent years. As part of this analysis, Lafarge has provided copies of vibration data summaries collected from 2016 – 2020. For continuity, summaries of the historical data collected and supplied by Lafarge are included in Appendix C to this report.

2016 – 2020 DATA

Vibration monitoring conducted from 2016 – 2020 has included the installation of seismographs at the following locations:

- 2083 Colonial Road
- 2182 Colonial Road
- Scale House

All vibration monitoring was performed by either the blasting contractor or the quarry owner. A review of the data supplied confirms that for 2016 through 2020 inclusive, one (1) blast exceeded the MECP guideline limit of 128dB set for air overpressure. Table 5 below lists the blast that exceeded the overpressure limit:

Table 5: Exceedances of NPC 119 Recorded During 2016-2020 Blasting Operations

Date	***Time***	***Sensitive Receptor***	***Limit Exceeded***	***Value of Exceedance***
April 17, 2017	14:50	2083 Colonial Road	**>128dB(L)**	***148.2dB(L)

***The reported overpressure of 148.2dB is not consistent with the blasting parameters contained in the reviewed blast report for this day. Based on our overpressure calculations, a maximum load per delay well exceeding 500kg would be required to produce the above overpressure. A review of the vibration event report confirms the overpressure sensor was malfunctioning/damaged and reporting false readings at the time of installation and this reading is thereby not valid.

Using the conservative calculation equations contained in this report based on a worst case scenario where the front of the blast is directed towards 2083 Colonial Road with an explosive load of 100kg (two holes/delay) at a distance of 630km, the calculated overpressure would be 127.19dB(L).

RECOMMENDATIONS

It is recommended that the following conditions be applied for all blasting operations at the proposed Lafarge – Navan Quarry Extension areas:

1. All blasts shall be monitored for both ground vibration and overpressure at the closest privately owned sensitive receptors adjacent the site, or closer, with a minimum of two (2) instruments – one installed in front of the blast and one installed behind the blast.

2. In order to safeguard the structural integrity of non-sensitive receptors, we recommend that vibrations at these properties be maintained below 50mm/s (>40Hz) in accordance with research performed by the United States Bureau of Mines (USBM RI8507).

3. The guideline limits for vibration and overpressure shall adhere to standards as outlined in the MECP Model Municipal Noise Control By-law publication NPC 119 (1978) or any such document, regulation or guideline which supersedes this standard.

4. In the event of an exceedance of NPC 119 limits or any such document, regulation or guideline which supersedes this standard, blast designs and protocol shall be reviewed prior to any subsequent blasts and revised accordingly in order to return the operations to compliant levels.

5. Orientation of the aggregate extraction operation will be designed and maintained so that the direction of the overpressure propagation will be away from structures as much as possible.

6. Blast designs shall be continually reviewed with respect to fragmentation, ground vibration and overpressure. Blast designs shall be modified as required to ensure compliance with current applicable guidelines and regulations.

7. Blasting procedures such as drilling and loading shall be reviewed on a yearly basis and modified as required to ensure compliance with industry standards.

8. Detailed blast records shall be maintained in accordance with current industry best practices.

The blast parameters described within this report are supported by the modeling in the attached appendices. As the quarry progresses and as site-specific data is collected from the on-going operation, the blast parameters can be refined, as necessary, to ensure continual compliance with MECP Guidelines.

CONCLUSION

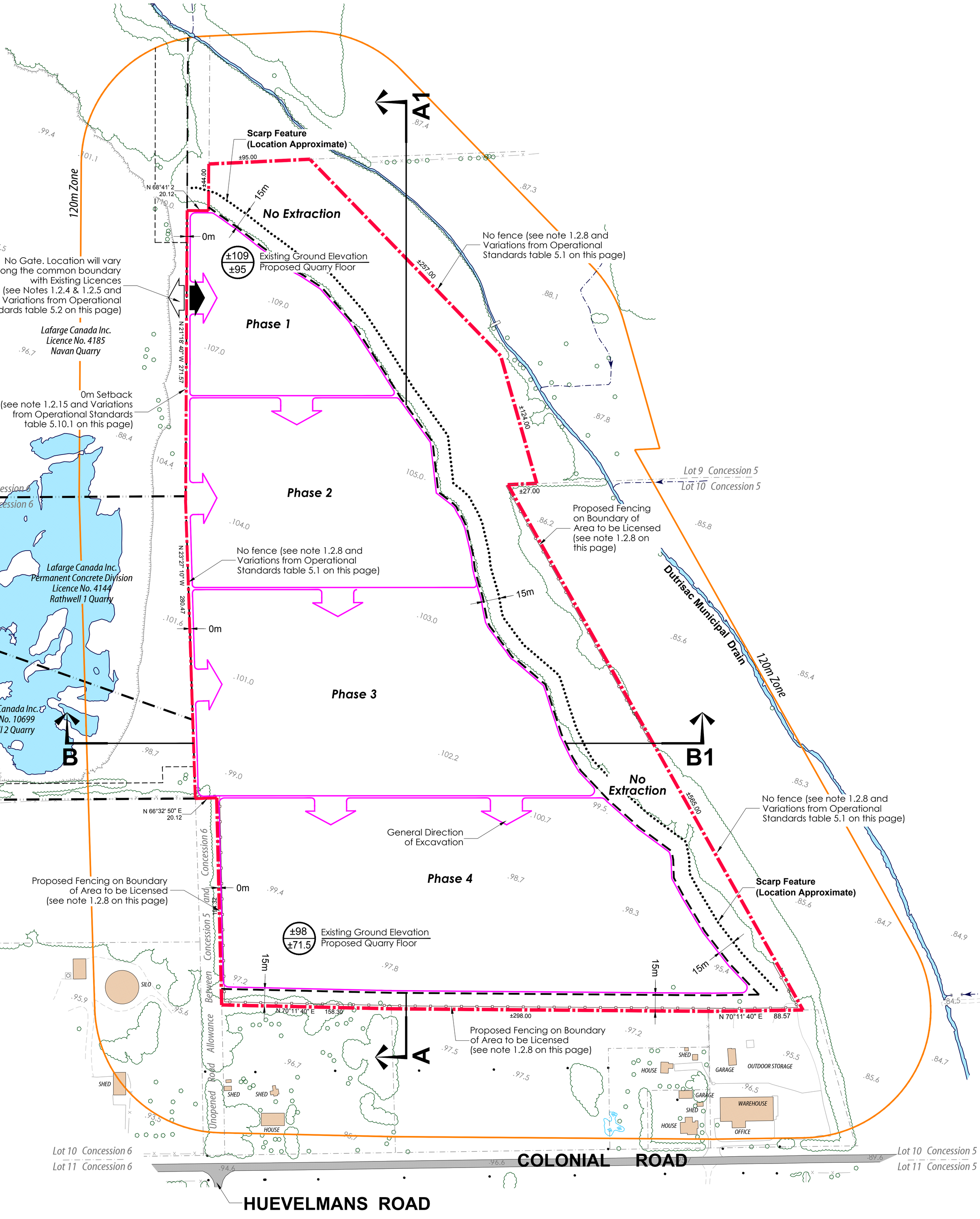
The blast parameters described within this report will provide a good basis for the initial blasting operations at this location. As site specific blast vibration and overpressure data becomes available, it will be possible to refine these parameters on an on-going basis.

Blasting operations required for operations at the proposed Lafarge – Navan Quarry Extension site can be carried out safely and within governing guidelines set by the Ministry of the Environment, Conservations and Parks.

Modern blasting techniques will permit blasting to take place with explosives charges below allowable charge weights ensuring that blast vibrations and overpressure will remain minimal at the nearest receptors.

APPENDIX A

SEQUENCE OF OPERATIONS



Sensitive Receptor Overview

Boundary of Area to be Licensed

Sensitive Receptors

#4420 Municipal Address

north

GIROUX ROAD

#2182 #2215 #2226

#2570 #3085 #3094 #3128 #3160 #3178

DUNNING ROAD

#3264 #3305 #3315 #3338 #3374

COLONIAL ROAD

#3540 #1949 #2027 #2067 #2083 #2093 #2139 #2203 #3548

#2002 #2156 #2206 #2182 #2264

ROCKDALE ROAD

HUEVELMANS ROAD

(REGIONAL ROAD #28)

#2348 #2353 #2452 #2454 #2455 #2473 #3519

#3636 #3676 #3686 #3739 #3714

APPENDIX B

EXPLOTECH

Lafarge – Navan Quarry Extension

PREVAILING METEOROLOGICAL CONDITIONS

Medians provided by Environment Canada
Canadian Climate Normals 1971-2000
Ottawa MacDonald – Cartier International A

Date	Wind Direction	Wind Velocity Km/h	Temperature (Deg Celcius)
January	W	15	-10.8
February	W	14.2	-8.7
March	W	14.7	-2.5
April	W	15.3	5.7
May	S	12.7	13.4
June	S	11.5	18.3
July	S	10.4	20.9
August	S	9.9	19.5
September	S	11.1	14.3
October	S	12.6	7.8
November	W	13.8	1.0
December	W	14.0	-7.1

APPENDIX C

Ground Vibrations

Imperial Equations

Equation 1	Equation 2	Equation 3	Equation 4	Equation 5
Oriard 50% Bound (2002)	Oriard 90% Bound (2002)	Typical Production Blast (Bulletin 656 – 1971)	Typical limestone Quarry (Pader report – 1995)	Typical Coal Mine (RI8507 1980)
$v = 160\,(\frac{D}{\sqrt{W}})^{-1.6}$	$v = 242(\frac{D}{\sqrt{W}})^{-1.6}$	$v = 182\,(\frac{D}{\sqrt{W}})^{-1.82}$	$v = 52.2(\frac{D}{\sqrt{W}})^{-1.38}$	$v = 133(\frac{D}{\sqrt{W}})^{-1.5}$

Metric Equations

Equation 1	Equation 2	Equation 3	Equation 4
DuPont General (1968)	Construction Blasting (Dowding 1998)	Agg. Quarry Blasting (Explotech 2005)	Agg. Quarry blasting (Explotech 2003)
$v = 1140\,(\frac{D}{\sqrt{W}})^{-1.6}$	$v = 1326(\frac{D}{\sqrt{W}})^{-1.38}$	$v = 5175(\frac{D}{\sqrt{W}})^{-1.76}$	$v = 7025(\frac{D}{\sqrt{W}})^{-1.85}$

D (m)	W (Kg)	PPV1 (mm/s)	PPV2 (mm/s)	PPV3 (mm/s)	PPV4 (mm/s)	PPV5 (mm/s)	PPV1 (mm/s)	PPV2 (mm/s)	PPV3 (mm/s)	PPV4 (mm/s)
815	128	**1.2**	**1.8**	**0.5**	**1.2**	**1.7**	**1.2**	**3.6**	**2.8**	**2.6**

Air Overpressure

Imperial Equations

Equation 1	Equation 2	Equation 3	Equation 4
USBM RI8485 (Behind Blast)	USBM RI8485 (Front of Blast)	USBM RI8485 (Full Confined)	Construction Average
$P = 0.056\,(\frac{D}{\sqrt[3]{W}})^{-0.515}$	$P = 1.317\,(\frac{D}{\sqrt[3]{W}})^{-0.966}$	$P = 0.061\,(\frac{D}{\sqrt[3]{W}})^{-0.96}$	$P = 1\,(\frac{D}{\sqrt[3]{W}})^{-1.1}$

Metric Equations

Equation 1	Equation 2	Equation 3
Ontario Quarry (Explotech 2013)	Limestone (Explotech 2011)	Ontario Quarry (Explotech 2012)
$P = 159(\frac{D}{\sqrt[3]{W}})^{-0.0456}$	$P = 206\,(\frac{D}{\sqrt[3]{W}})^{-0.1}$	$P = 1222\,(\frac{D}{\sqrt[3]{W}})^{-0.669}$

D (m)	W (Kg)	OP1 (dB)	OP2 (dB)	OP3 (dB)	OP4 (dB)	OP1 (dB)	OP2 (dB)	OP3 (dB)
765	128	**119.11**	**123.24**	**96.87**	**113.93**	**126.45**	**124.66**	**126.54**

BLAST REPORT SUMMARY

Blast#	Date	Time	Weather	Wind From	Wind Velocity	Max Kg /Delay	Hole Dia. (in.)	# Of Rows	# Of Holes	Avg. % Water	Ave Hole Depth	Total Tons	Location	Monitor 1 (mm/s)	Monitor 1 (dbl.)	Monitor 1 Distance	Monitor 2 Location	Monitor 2 (mm/s)	Monitor 2 (dbl.)	Monitor 2 Distance
16001	Jun 23/16	11:30AM	Partly cloudy	West	<20	127.80	4	5	226	50.00	14.00	104222.0	2083 Colonial	4.45	119	674.0				
16002	Jul 7/16	11:30	Partly cloudy	West	<20	130.50	4	5	225	50.00	14.00	101455.0	2083 Colonial	6.4	115.9	674.0				
16003	Aug 10/16	11:00	Sunny	West	<20	12.5	4	5	204	50.00	14.00	91771.0	2083 Colonial	5.4	112.3	674.0				
16004	Aug 12/16	13:00	Partly cloudy	NW	<20	152.9	4	4	126	100.00	14.00	55817.0	2083 Colonial	3.4	114.8	674.0				
17001	Jan 12/17	14:30	Rain	NW	<20	51.2	3.5	10	162	100.00	7.60	24617.0	2083 Colonial	DNT	DNT	670.0	Scale House	7.13	122.5	495.0
17002	Jan 18/17	16:00	Rain	NW	<20	55.30	3.5	10	273	100.00	7.60	41485.0	2083 Colonial	DNT	DNT	670.0	Scale House	12.64	130.0	500.0
17003	Jan 23/17	15:00	Cloudy	NW	0	52	3.5	6	173	100.00	7.60	25377.0	2083 Colonial	1.7	118.6	673.0				
17004	Jan 25/17	15:30	Cloudy	W	0	51.3	3.5	6	284	100.00	7.60	43156.0	2083 Colonial	2.4	114.0	674.0				
17005	Feb 2/17	15:30	Cloudy	W	<20	55.7	3.5	8	253	100.00	7.60	37230.0	2083 Colonial	2.2	117.6	676.0				
17006	Feb 22/17	15:00	Cloudy	W	<20	48.60	3.5	6	185	100.00	7.60	28112.0	2083 Colonial	2.5	114.2	676.0				
17007	Mar 3/16	14:30	Snow	NW	<20	50.1	3.5	8	167	100.00	7.60	24161.0	2083 Colonial	DNT	DNT	754.0				
17008	Mar 31/17	12:15	Cloudy	SE	<20	0.00	3.5	9	75	100.00	7.60	10029.0	2083 Colonial	DNT	DNT	750.0				
17009	Apr 6/17	13:45	Rain	NW	>20	52.00	3.5	4	228	100.00	7.70	34783.0	2083 Colonial	3.5	116.1	631.0				
17010	Apr 17/17	14:50	Cloudy	W	>20	51.2	3.5	4	175	100.00	7.90	27570.0	2083 Colonial	3.6	148.2	630.0				
17011	Apr 27/17	12:09	Sunny	W	<20	51.90	3.5	10	202	60.00	7.90	31824.0	2083 Colonial	4.3	112.0	566.0				
17012	Jun 7/17	14:10	Sunny	W	<20	119.50	4	4	109	80.00	13.80	48874.0	2083 Colonial	5.2	113.5	645.0				
18002	Jun 19/18	11:44	Sunny	NW	<20	126.60	4	5	104	90.00	13.70	32213.0	2083 Colonial	5.4	112.6	569.0				
18003	Aug 3/18	11:45	Cloudy	SE	<20	133.50	4	6	106	90.00	13.70	32225.0	2083 Colonial	10.6	106.0	555.0				
18004	Aug 14/18	14:06	Cloudy	N	<20	56.30	3.5	4	266	50.00	7.90	42066.0	2083 Colonial	3.0	115.0	846.0				
18005	Aug 17/18	11:58	Cloudy	NE	<20	58.60	3.5	4	240	80.00	7.90	37321.0	2083 Colonial	3.0	115.2	813.0				
18006	Aug 24/18	13:44	Partly cloudy	SW	<20	54.00	3.5	4	230	85.00	7.90	35740.0	2083 Colonial	2.8	111.5	824.0				
18007	Aug 28/18	14:19	Partly cloudy	SW	<20	62.10	3.5	3	215	5.00	8.20	35287.0	2083 Colonial	4.5	111.5	597.0				
18008	Sep 19/18	14:00	Cloudy	W	<20	64.30	3.5	3	215	50.00	8.50	36063.0	2083 Colonial	5.0	115.4	665.0				
18009	Sep 28/18	11:48	Cloudy	W	<20	133.70	4	6	105	90.00	13.70	31921.0	2083 Colonial	9.6	115.4	536.0				
18010	Oct 5/18	13:00	Partly cloudy	W	<20	64.20	3.5	4	236	100.00	8.50	39465.0	2083 Colonial	6.4	114.8	668.0				
18011	Oct 11/18	13:03	Rain	NE	<20	52.60	3.5	4	214	100.00	7.60	31953.0	2083 Colonial	DNT	DNT	840.0	Scale House	70.82	128.7	125.0
18012	Oct 16/18	13:12	Partly cloudy	NW	>20	65.40	3.5	4	195	90.00	8.80	33633.0	2083 Colonial	4.9	115.7	633.0				
18013	Oct 18/18	13:00	Partly cloudy	W	<20	132.90	4	7	107	60.00	14.00	33891.0	2083 Colonial	9.2	112.8	510.0				
18014	Oct 25/18	14:00	Partly cloudy	NW	>20	54.90	3.5	5	240	10.00	7.60	35757.0	2083 Colonial	1.8	114.2	850.0				
18015	Nov 5/18	14:30	Rain	W	>20	129.30	4	9	119	100.00	14.20	54949.0	2083 Colonial	9.7	117.8	525.0				
18016	Nov 8/18	14:04	Partly cloudy	W	<20	54.60	3.5	8	252	90.00	7.60	37127.0	2083 Colonial	2.5	115.6	886.0				
18017	Nov 19/18	14:03	Cloudy	SW	<20	67.90	3.5	6	209	90.00	9.50	38256.0	2083 Colonial	4.6	106.5	635.0				
18018	Nov 23/18	10:00	Sunny	SE	<20	65.30	3.5	5	214	90.00	9.50	40329.0	2083 Colonial	4.9	113.5	563.0				
18019	Dec 12/18	15:29	Sunny	W	<20	62.50	3.5	7	249	50.00	9.20	45435.0	2083 Colonial	3.9	114.0	530.0				
18020	Dec 19/18	15:31	Cloudy	SW	<20	30.00	3.5	10	279	50.00	6.10	33939.0	2083 Colonial	DNT	DNT	855.0				
19001	Jan 15/19	11:42	Cloudy	NE	<20	67.30	3.5	10	161	20.00	9.50	30341.0	2083 Colonial	3.9	110.2	517.0				
19002	Mar 7/19	13:27	Partly cloudy	W	<20	80.50	3.5	2	168	20.00	10.40	34263.0	2083 Colonial	DNT	DNT	502.0	Scale House	7.32	119.2	420.0
19003	Mar 14/19	14:30	Cloudy	SW	<20	74.10	3.5	4	200	20.00	10.40	40455.0	2083 Colonial	2.5	108.0	479.0				
19004	Mar 21/19	13:00	Cloudy	W	<20	74.80	3.5	4	155	80.00	10.10	30323.0	2083 Colonial	DNT	DNT	479.0	Scale House	7.12	119.7	438.0
19005	Mar 28/19	13:15	Cloudy	SW	>20	61.60	3.5	4	144	95.00	9.00	25127.0	2083 Colonial	DNT	DNT	477.0				
19006	Apr 4/19	13:06	Partly cloudy	NW	>20	73.30	3.5	4	155	95.00	10.40	31992.0	2083 Colonial	4.7	113.5	605.0				
19007	Apr 29/19	11:59	Partly cloudy	N	>20	70.50	3.5	4	132	100.00	9.80	25666.0	2083 Colonial	DNT	DNT	607.0	Scale House	21.09	120.7	363.0
19008	May 13/19	12:52	Cloudy	NW	<20	73.00	3.5	6	149	100.00	10.10	28717.0	2083 Colonial	DNT	DNT	613.0	Scale House	25.37	122.1	220.0
19009	May 17/19	11:55	Cloudy	W	<20	71.30	3.5	8	170	50.00	9.20	31020.0	2083 Colonial	DNT	DNT	716.0	Scale House	48.81	123.5	130.0
19010	May 30/19	11:58	Partly cloudy	NW	<20	65.70	3.5	4	187	50.00	9.40	34450.0	2083 Colonial	2.3	111.2	716.0				
19011	Jun 6/19	11:55	Sunny	NW	<20	65.60	3.5	5	209	50.00	9.80	39665.0	2083 Colonial	2.7	110.2	716.0				

BLAST REPORT SUMMARY

Blast#	Date	Time	Weather	Wind From	Wind Velocity	Max Kg /Delay	Hole Dia. (in.)	# Of Rows	# Of Holes	Avg. % Water	Ave Hole Depth	Total Tons	Location	Monitor 1 (mm/s)	Monitor 1 (dbl.)	Monitor 1 Distance	Monitor 2 Location	Monitor 2 (mm/s)	Monitor 2 (dbl.)	Monitor 2 Distance
19012	Jun 13/19	11:55	Cloudy	SE	>20	65.20	3.5	4	199	50.00	9.20	35582.0	2083 Colonial	2.3	112.3	718.0				
19013	Jul 4/19	11:55	Partly cloudy	SW	<20	70.60	3.5	5	190	50.00	9.80	35971.0	2083 Colonial	2.6	107.5	722.0				
19015	Jul 30/19	11:55	Cloudy	SW	<20	198.30	3.5	3	63	100.00	20.10	25290.0	2083 Colonial	5.3	111.8	444.0				
19017	Aug 16/19	13:00	Sunny	SE	<20	157.00	3.5	4	98	20.00	20.40	39907.0	2083 Colonial	7.0	111.2	429.0				
19018	Aug 27/19	11:15	Partly cloudy	S	<20	155.30	3.5	3	91	20.00	19.80	35932.0	2083 Colonial	5.9	109.2	434.0				
19019	Aug 29/19	11:58	Partly cloudy	SW	<20	149.00	3.5	4	108	70.00	20.70	44626.0	2083 Colonial	7.4	112.8	427.0				
19020	Oct 18/19	15:32	Partly cloudy	W	<20	112.50	3.5	3	61		19.80	24086.0	2083 Colonial	7.1	error	424.0				
19021	Oct 25/19	13:00	Partly cloudy	SW	<20	112.30	3.5	6	80	20.00	20.10	32099.0	2083 Colonial	6.7	115.0	421.0				
19022	Nov 6/19	12:06	Partly cloudy	NW	<20	111.50	3.5	3	56	60.00	20.70	23139.0	2083 Colonial	DNT?	DNT?	424.0				
19023	Nov 26/19	13:00	Cloudy	W	<20	120.60	3.5	5	105	10.00	20.70	43386.0	2083 Colonial	8.5	117.9	420.0				
19024	Dec 2/19	12:00	Partly cloudy	SW	<20	2.3? (~120)	3.5	3	77	10.00	20.70	31816.0	2083 Colonial	7.9	114.8	417.0				
19025	Dec 12/19	13:28	Partly cloudy	NW	<20	70.70	3.5	4	135	100.00	9.80	25471.0	2083 Colonial	DNT	DNT	738.0				
19026	Dec 17/19	13:27	Partly cloudy	W	<20	153.00	3.5	3	68	10.00	20.40	27691.0	2083 Colonial	6.4	113.5	414.0				
20-001	Jan 28/20	14:56	Cloudy	NW	20.00	54.00	3.25	5	287		6.90	35399.0	2083 Colonial	<2	124.3	911.4				
20-002	Feb 11/20	14:35	Cloudy	SW	10.00	52.00	3.25	6	231		8.40	31225.0	2083 Colonial	<2	<115	933.3				
20-003	Feb 21/20	14:36	Sunny	SW	30.00	56.00	3.25	8	252		8.40	32451.0	2083 Colonial	<2	<115	952.6				
20-004	Feb 26/20	14:22	Snow	NE	15.00	45.00	3.5	5	139		8.40	18727.0	2083 Colonial	<2	<115	960.0				
20-005	Mar 11/20	10:10	Partly cloudy	S	5.00	52.00	3.5	7	260		8.50	36710.0	2083 Colonial	<2	<115	881.1				
20-006	Mar 19/20	13:35	Cloudy	NE	10.00	54.00	3.25	7	234		8.80	31973.0	2083 Colonial	<2	<115	965.2				
20-007	Mar 30/20	14:46	Rain	NE	10.00	56.00	3.25	9	257		8.80	35019.0	2083 Colonial	<2	<115	965.2				
20-008	May 4/20	13:57	Cloudy	NW	30.00	199.00	3.5	6	108		20.70	44742.0	2083 Colonial	6.2	122.6	399.0	2182 Colonial	4.37	117.5	538.3

APPENDIX D

EXPLOTECH

Specialists in Explosives, Blasting and Vibration
Consulting Engineers

Robert J. Cyr, P. Eng.

Principal, Explotech Engineering Ltd.

EDUCATION

Bachelor of Applied Science,
Civil Engineering, Queen's University

PROFESSIONAL AFFILIATIONS

Association of Professional Engineers of Ontario (APEO)
Association of Professional Engineers and Geoscientists of BC (APEG)
Association of Professional Engineers, Geologists and Geophysicists of Alberta
Association of Professional Engineers and Geoscientists of New Brunswick
Association of Professional Engineers of Nova Scotia
Association of Professional Engineers and Geoscientists Manitoba
Professional Engineers and Geoscientists Newfoundland and Labrador
Northwest Territories and Nunavut Association of Professional Engineers (NAPEG)
International Society of Explosives Engineers (ISEE)
Ontario Stone Sand & Gravel Association (OSSGA)
Surface Blaster Ontario Licence 450109

SUMMARY OF EXPERIENCE

Over thirty five years experience in many facets of the construction and mining industry has provided the expertise and experience required to efficiently and accurately address a comprehensive range of engineering and construction conditions. Sound technical training is reinforced by formidable practical experience providing the tools necessary for accurate, comprehensive analysis and application of feasible solutions. Recent focus on vibration analysis, blast monitoring, blast design, damage complaint investigation for explosives consumers and specialized consulting to various consulting engineering firms.

PROFESSIONAL RECORD

2001 – Present	-Principal, Explotech Engineering Ltd.
1996 – 2001	-Leo Alarie & Sons Limited - Project Engineer/Manager
1993 – 1996	-Rideau Oxford Developments Inc. – Project Manager
1982 – 1993:	-Alphe Cyr Ltd. – Project Coordinator/Manager

EXPLOTECH

Specialists in Explosives, Blasting and Vibration
Consulting Engineers

Mark Morelli, B.Eng.

Explotech Engineering Ltd.

EDUCATION

Bachelor of Engineering,
Civil Engineering, Carleton University

PROFESSIONAL AFFILIATIONS

International Society of Explosives Engineers (ISEE)

SUMMARY OF EXPERIENCE

A technician working for Explotech Engineering Ltd., Mark holds a Bachelor of Engineering degree in Civil Engineering and has strong technical, leadership, interpersonal, communication, and presentation skills. Recent focus on blast monitoring, data management, scheduling, job estimations, vibration analysis, damage complaint investigation and attenuation anlysis.

PROFESSIONAL RECORD

2006 – Present - Technician, Explotech Engineering Ltd.

2003 – 2004 - Labourer, Hydracorp Canada Ltd.

2002 – 2003 - Labourer, Quad Construction

APPENDIX E

EXPLOTECH

Blasting Terminology

ANFO:	Ammonium Nitrate and Fuel Oil – explosive product
ANFO WR:	Water resistant ANFO
Blast Pattern:	Array of blast holes
Body hole:	Those blast holes behind the first row of holes (Face Holes)
Burden:	Distance between the blast hole and a free face
Column:	That portion of the blast hole above the required grade
Column Load:	The portion of the explosive loaded above grade
Collar:	That portion of the blast hole above the explosive column, filled with inert material, preferably clean crushed stone
Face Hole:	The blast holes nearest the free face
Overpressure:	A compressional wave in air caused by the direct action of the unconfined explosive or the direct action of confining material subjected to explosive loading.
Peak Particle Velocity:	The rate of change of amplitude, usually measured in mm/s or in/s. This is the velocity or excitation of the particles in the ground resulting from vibratory motion.
Scaled distance:	An equation relating separation distance between a blast and receptor to the energy (usually expressed as explosive weight) released at any given instant in time.
Sensitive Receptor:	Sensitive land use may include recreational uses which are deemed by the municipality or provincial agency to be sensitive; and/or any building or associated amenity area (i.e. may be indoor or outdoor space) which is not directly associated with the industrial use, where humans or the natural environment may be adversely affected by emissions generated by the operation of a nearby industrial facility. For example, the building or amenity area may be associated with residences, senior citizen homes, schools,

	day care facilities, hospitals, churches and other similar institutional uses, or campgrounds.
Spacing:	Distance between blast holes
Stemming:	Inert material, preferably clean crushed stone applied into the blast hole from the surface of the rock to the surface of the explosive in the blast hole.
Sub-grade:	That portion of the blast hole drilled band loaded below the required grade
Toe Load:	The portion of explosive loaded below grade

EXPLOTECH

References

Building Research Establishment, (1990), *"Damage to Structures From Ground-Borne Vibration",* BRE Digest 353, Gaston, Watford, U.K.

Crum S. V., Siskind D. E., Pierce W. E., Radcliffe K. S., (1995) *"Ground Vibrations and Airblasts Monitored in Swedesburg, Pennsylvania, From Blasting at McCoy Quarry",* Contract Research Rept. By the United States Bureau of Mines for the Pennsylvania Department of Environmental Resources, 120 pp.

Dowding C.H., (1985), *"Blast Vibration, Monitoring and Control"*, Prentice-Hall Canada Inc., 297 pp.

Dowding C.H., (1996), *"Construction Vibrations"*, Prentice-Hall, Upper Saddle, N.J., USA, 610 pp.

Du Pont Company, (1980), *"Blaster's Handbook"* Wilmington, Delaware, United States of America

Fletcher L.R., D'Andrea D.V., (1986) *"Control of Flyrock in Blasting"*, Proceedings of the Twelfth Annual Conference on Explosives and Blasting Technique, International Society of Explosives Engineers

Froedge D. T., (1983) *"Blasting Effects on Water Wells",* Proceedings of the Ninth Annual Conference on Explosives and Blasting Technique, International Society of Explosives Engineers

Kopp J.W., (1994) *"Observation of Flyrock at Several Mines and Quarries"*, Proceedings of the Twentieth Annual Conference on Explosives and Blasting Technique, International Society of Explosives Engineers

Matheson G. M., Miller D. K., (1997) *"Blasting Vibration Damage to Water Supply, Well Water Quality and Quantity",* Proceedings of the Twenty-Third Conference on Explosives and Blasting Technique, International Society of Explosive Engineers

Moore A.J., Richards A.B., (2005), *"Golden Pike Cut-Back Flyrock Control and Calibration of a Predictive Model"*, Terrock Consulting Engineers, Eltham, Victoria, Australia.

Nicholls H., Johnson C., Duvall W., (1970), "*Blasting Vibrations and their Effects on Structures",* United States Department of the Interior, Bureau of Mines, Bulletin 656

Oriard L.L., (1989) *"The Scale of Effects in Evaluating Vibration Damage Potential"* Fifteenth Conference on Explosives and Blasting Technique, International Society of Explosive Engineers

Oriard L.L., (2002) *"Explosives Engineering, Construction Vibrations and Geology"* International Society of Explosive Engineers, Clevland, Ohio, United States of America

Robertson D. A., Gould J. A., Straw J. A., Dayton M. A., (1980) *"Survey of Blasting Effects on Ground Water Supplies in Appalachia",* United States Department of the Interior, Bureau of Mines, Contract No. J-0285029

Rose R., Bowles B., Bender W. L., (1991) *"Results of Blasting in Close Proximity to Water Wells at the Sleeper Mine",* Proceedings of the Seventeenth Annual Conference on Explosives and Blasting Technique, International Society of Explosive Engineers

Roth J., (1979) *"A Model for Determination of Flyrock Range as a Function of Shot Conditions"*, United States Department of the Interior, Bureau of Mines, Report OFR 77-81

Siskind D.E., Stagg M.S., Kopp J.W., Dowding C.H., (1980), *"Structural Response and Damage Produced by Ground Vibration from Surface Mine Blasting",* United States Bureau of Mines RI 8507.

White,T.J., Farnfield,R.A., Kelly,M., (1993), "*The Effect of Low Level Blast Vibrations and the Environment on a Domestic Building"*, Proceedings of the Ninth Annual Symposium on Explosives and Blasting Research, International Society of Explosives Engineers.

Wright D.G., Hopky G. E., (1998) *"Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters",* Canadian Technical Report of Fisheries and Aquatic Sciences 2107