REPORT

Blast Impact Assessment

St. Marys Cement, Proposed Thomas Street Quarry Extension

Submitted to:

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Distribution List

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Executive Summary

St. Marys Cement Inc. (Canada) (SMC), a division of Votorantim Cimentos North America (VCNA), is proposing to expand their existing Thomas Street Quarry in St. Marys, Ontario west, onto the adjacent property (the “Site”). Blasting is part of the routine operations of a quarry in order to extract the limestone bedrock.

This report provides an assessment of the potential effects of the ground and air vibrations that will be produced by the proposed quarry’s blasting operations on adjacent receptors such as residences, structures, bedrock strata, water wells and fish spawning depressions. This report also reviews the provincial and federal guidelines for the assessment of environmental impacts from blasting. Finally, this report provides recommendations for blasting design and monitoring.

Blasting operations on the Site can readily be carried out in compliance with existing provincial and federal environmental guideline limits with respect to ground and air vibrations. These effects are subject to recommended limits of 12.5 mm/s and 128 dBL respectively, as established by the Ontario Ministry of the Environment, Conservation and Parks (MECP) and outlined in Noise Pollution Control (NPC) publication 119 of the Model Municipal Noise Control By-Law, for operations where monitoring of these effects is carried out as a matter of routine. All blasting and monitoring would occur in accordance with the Aggregate Resources Act prescribed conditions so as to comply with the provincial guidelines. Blasting operations are also subject to a ground vibration limit of 13 mm/s at identified spawning depressions around the proposed quarry as established by the Department of Fisheries and Oceans (DFO) for the use of explosives in or near Canadian fisheries waters.

SMC provided vibration monitoring data from the existing quarry monitoring. Our analysis indicates that the majority of the Site may be excavated using the blast parameters currently used for extraction of the limestone bedrock at the quarry. The quarry would put in place and maintain a blast monitoring program during extraction of the entire quarry. The blasting operations within the Site would have no impact on the integrity of adjacent water wells.

By maintaining ground and air vibration levels during blasting operations at the Site within the recommended provincial guideline limits, there would not be any noticeable cumulative effect on adjacent structures associated with the blasting operations within the proposed extension.

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APPENDICES

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by St. Marys Cement Inc. (Canada) (SMC), a division of Votorantim Cimentos North America (VCNA), to prepare an application for a Category 2, Class A, Quarry Below Water licence under the Aggregate Resources Act (ARA) for their westward extension of the current operations at the Thomas Street Quarry in St. Marys, Ontario (the "Site"). Blasting is part of the routine operations of the quarry in order to extract the limestone bedrock. This report consists of a blast impact assessment for the Site to provide technical support for the application to the Ministry of Natural Resources and Forestry (MNRF). The approximate limits of the Site are shown on Figure 1.

1.1 Site Overview

St. Marys, also known as Stonetown, is situated within Perth County, Ontario at the junction of the Thames River and Trout Creek. The Site is located at 4608 Perth Rd Line 5, about 2 kilometres (km) southwest of the Town of St. Marys, approximately 25 metres (m) north of the Thames River, and immediately west of Thomas Street Quarry. The Site is legally described as Lot 29, Concession Thames Blanshard / Perth S; PIN 53278-0038 (LT) and consists of a rectangular parcel of land approximately 46.2 hectares (114.2 acres) in area.

The Site is currently used for agricultural purposes (i.e. farmland), as seen on Figure 1, with one farmhouse, two outbuildings, and two silos in the southern portion of the property. A small wooded area is present in the centre of the Site.

1.2 Study Overview

The blasting impact assessment addresses the environmental effects from future blasting operations within the proposed areas of the Site. The impact assessment specifically addresses whether the applicable Ontario Ministry of Environment, Conservation and Parks (MECP) guideline (NPC-119) with respect to ground and air vibration effects can be met at the nearest sensitive Point(s) of Reception (POR(s)). Historical blast monitoring results were reviewed as part of this study.

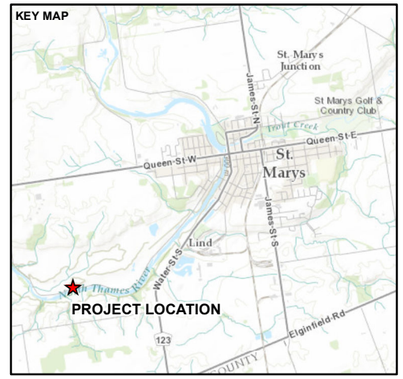
The investigation involved an initial site visit to view the existing property, as well as a review of the ground and air vibration monitoring results from blasting operations at other limestone quarries in southern Ontario.

The following report is an assessment of the potential effects from blasting operations for the proposed quarry. Specifically, this report assesses the potential effects of ground and air vibration levels that could be produced by the proposed extensions blasting operations on neighbouring receptors, such as residences, structures, water wells and fish spawning depressions, and whether these effects meet the applicable recommended provincial and federal guidelines.

LEGEND

- Point of Reception
- Watercourse
- Waterbody
- Site Boundary

KEY MAP



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REFERENCE(S)

1. BASEDATA - MNRF LIO, OBTAINED 2018
2. IMAGERY - SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
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3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE

CLIENT
ST. MARYS CEMENT INC. (CANADA)

PROJECT
THOMAS STREET QUARRY EXPANSION

TITLE
POINTS OF RECEPTION

CONSULTANT
GOLDER

YYYY-MM-DD	2020-06-02
DESIGNED	SO
PREPARED	SO
REVIEWED	PN
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
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This impact assessment specifically addressed whether the applicable MECP guidelines, with respect to ground and air vibration effects from quarry blasting operations, could be met at the nearest PORs. This report addresses the following topics:

- Review of existing provincial and federal guidelines for the assessment of environmental impacts from blasting;
- Recommendations for the continued control of ground and air vibration effects;
- The potential impact of the blasting operations on bedrock strata and adjacent water wells; and
- The long-term impact of the blasting operations on surrounding structures.

2.0 PROPOSED QUARRY EXTRACTION AND BLAST PROCEDURE

The proposed extension will operate as a continuation to the existing quarry. There will be no processing on the Site. Blasted aggregate will be transported by quarry trucks to the existing processing plant. Shipping to market will be status quo as it will utilize the existing entrance / exit and established haul routes.

The quarry is anticipated to operate throughout the year.

Blasting procedures on the Site would be carried out in a manner similar to those currently being carried out within the existing quarry as summarized in Table 1. APPENDIX A provides a glossary of terms relating to blast design and Figure A-1 illustrates a typical bench blast design. Golder anticipates that blasting will occur from one to two times per week at peak production levels. The duration of each blast would generally be less than about one to two seconds.

The blasting at the existing quarry is divided between two geological units that have different properties and, consequently, different markets. The blasts for Canadian Building Materials (CBM), a division of SMC, supply an aggregate market whereas the SMC blasts are for a cement market. The differences in the blast parameters for CBM and SMC are shown in Table 1.

Table 1: Blast Design Details – Thomas Street Quarry

Parameter	Details [1)]	
Name	CBM Blasts	SMC Blasts
Hole Diameter	102 mm	102 mm
Bench Height	10.4 – 13.7 m	7.9 – 19.5 m
Sub-drill	0.0 m	0.0 m
Depth of Hole	10.4 – 13.7 m	7.9 – 19.5 m
Blast Pattern	4.3 x 3.7 m	4.0 x 4.0 m to 4.9 x 4.9 m
Stemming Length	1.8 – 2.1 m	2.1 - 3.6 m
Explosive Product	Titan XL 1000 G	Titan XL 1000 G

Parameter	Details [1)]	
Explosive Type	Gassed Bulk Emulsion	Gassed Bulk Emulsion
Explosive Density	1.20 g/cc	1.20 g/cc
Explosive Weight per Hole	86 – 128 kg	53 – 188 kg
Number of Holes per Delay	1	1
Explosive Weight per Delay	86 – 128 kg	53 – 188 kg
Powder Factor	0.52 – 0.62 kg/m^3	0.34 – 0.51 kg/m^3
Approximate # Holes Per Blast	24 – 55	23 - 60
Rock Tonnage per Blast	13,000 - 25,000 tonnes	12,000 – 56,000 tonnes

1) Based on blast reports provided by SMC for blasts at the Thomas Street Quarry from January 23 to December 13, 2017.

All explosives used for the purposes of blasting will be brought to the Site on the day of each blast. No explosives will be stored on the Site at any time.

3.0 IMPACT IDENTIFICATION

The environmental effects most often associated with blasting operations are ground vibrations and air concussion.

The intensity of ground vibrations, which is an elastic effect measured in units of peak particle velocity, is defined as the speed of excitation of particles within the ground resulting from vibratory motion. For the purposes of this report, peak particle velocity (PPV) is measured in mm/s.

While ground vibration is an elastic effect, one must also consider the plastic or non-elastic effect produced locally by each detonation when assessing the effects on the bedrock strata and local water wells. The detonation of an explosive produces a very rapid and dramatic increase in volume due to the conversion of the explosive from a solid to a gaseous state. When this occurs within the confines of a borehole it has the following effect:

- The bedrock in the area immediately adjacent to the explosive product is crushed. As the energy from the detonation radiates outward from the borehole, the bedrock between the borehole and quarried face becomes fragmented and is displaced while the bedrock behind the borehole is fractured.
- Energy not used in the fracturing and displacement of the bedrock dissipates in the form of ground vibrations, sound and air concussion. This energy attenuates rapidly from the blast site due to geometric spreading and natural damping.

Air vibrations, or airblast is a pressure wave travelling through the air produced by the direct action of the explosive on air or the indirect action of a confining material subjected to explosive loading. Air vibrations from surface blasting operations consist primarily of acoustic energy below 20 Hz, where human hearing is less acute (Siskind et al., 1980), while noise is that portion of the spectrum of the air vibration lying within the audible range

from 20 to 20,000 Hz. It is the lower frequency component (below 20 Hz) of air vibration, that which is less audible, that is of interest as it is often the source of secondary rattling and shaking within a structure. For the purposes of this report, air vibration is measured as decibels in the Linear or Unweighted mode (dBL). This differs from noise (above 20 Hz) which is measured in dBA.

Both ground and air vibration effects produced at private structures adjacent to surface or underground mining operations are subject to guidelines contained in NPC 119 of the Model Municipal Noise Control By-Law, dated August 1978, published by the Ontario Ministry of Environment (now Ministry of Environment and Climate Change (MOECC)). The guideline limits for ground and air vibration levels at the nearest sensitive receptor to the quarry property are 12.5 mm/s and 128 dBL respectively. These limits apply under conditions where monitoring of the blasting operations is routinely carried out, which will be the case for the proposed extension. A copy of Publication NPC-119 is contained in Appendix B.

Transmission and decay of ground and air vibrations 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.

Seventeen (17) sensitive receptors for the Site have been identified. Since there are clusters of residential structures in several areas, these are representative receptors for the various areas around the quarry. These are listed in APPENDIX C and displayed on Figure 1. Separation distances, from the receptor to the extraction limit, shown in APPENDIX C are based on a 15 m extraction setback on the Site and a 30 m setback from Perth Road Line 5 within the Quarry property limits.

The detonation of explosives in or near water can produce compressive shock waves which initiate damage to the internal organs of fish in close proximity and may result in the death of the fish. Ground vibrations induced at active spawning beds may adversely impact incubating eggs. In an effort to mitigate potential impacts on fish populations, Fisheries and Oceans Canada (DFO) developed the Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky, 1998). The limits set out in the document are as follows:

- Maximum water overpressure – 100 kPa; and
- Maximum PPV at active spawning beds – 13 mm/s.

4.0 VIBRATION ATTENUATION MODELS

4.1 Current Blast Vibration Monitoring

Both ground and air vibration levels lose energy and dissipate with increasing distance from the blast source. The rate at which these effects attenuate or dissipate from a particular site are dependent on geologic and environmental conditions, topography and the particulars of the blast design. The intensity of ground and air

vibration effects from any surface blasting operation are primarily governed by the distance between the receptor and the blast and the maximum weight of explosive detonated per delay period within the blast. Vibration monitoring results were provided by SMC for blasts between January 11, 2017 and December 13, 2017.

The blast vibration monitoring results for 46 blast carried out on the existing quarry were provided to Golder and included data from two (2) sites. Forty-four (44) blasts were monitored at 4608 Thomas Street and two (2) blasts were monitored at the St. Marys Cement Plant located on the Thomas Street Quarry site.

4.2 Ground Vibration Model

The rate ground vibrations attenuate from a blast site is dependent on a number of variables. These include the characteristics of the blast (delay timing, type of explosive, etc.), topography of the site, as well as the characteristics of the bedrock and/or soil materials. The rate ground vibrations decay or attenuate from a blast site can be expressed by the Scaled Distance, which is defined as:

$$Scaled\ Distance\ (SD) = \left(\frac{D}{\sqrt{W}}\right)$$

where D= the distance (m) between the blast and receptor

W= the maximum weight of explosive (kg) detonated per delay period

The ground vibration level is given by:

$$PPV = K(SD)^{-e}$$

where PPV = Peak Particle Velocity (mm/sec)

SD = Scaled Distance (m/kg$^{1/2}$) as defined above

K, e = Site factors typically derived from monitoring

Based on the data provided by SMC, the 95% confidence line for the Thomas Street Quarry is given by the following:

$$PPV = 1234\left(\frac{D}{\sqrt{W}}\right)^{-1.399}$$

where D= the distance (m) between the blast and receptor

W= the maximum weight of explosive (kg) detonated per delay period

That model is proposed for the estimation of blast vibrations from the proposed PQC expansion and is plotted on Figure 2. The calculated SD for a peak ground vibration level of 12.5 mm/s would be equal to 26.6 m/kg$^{1/2}$.

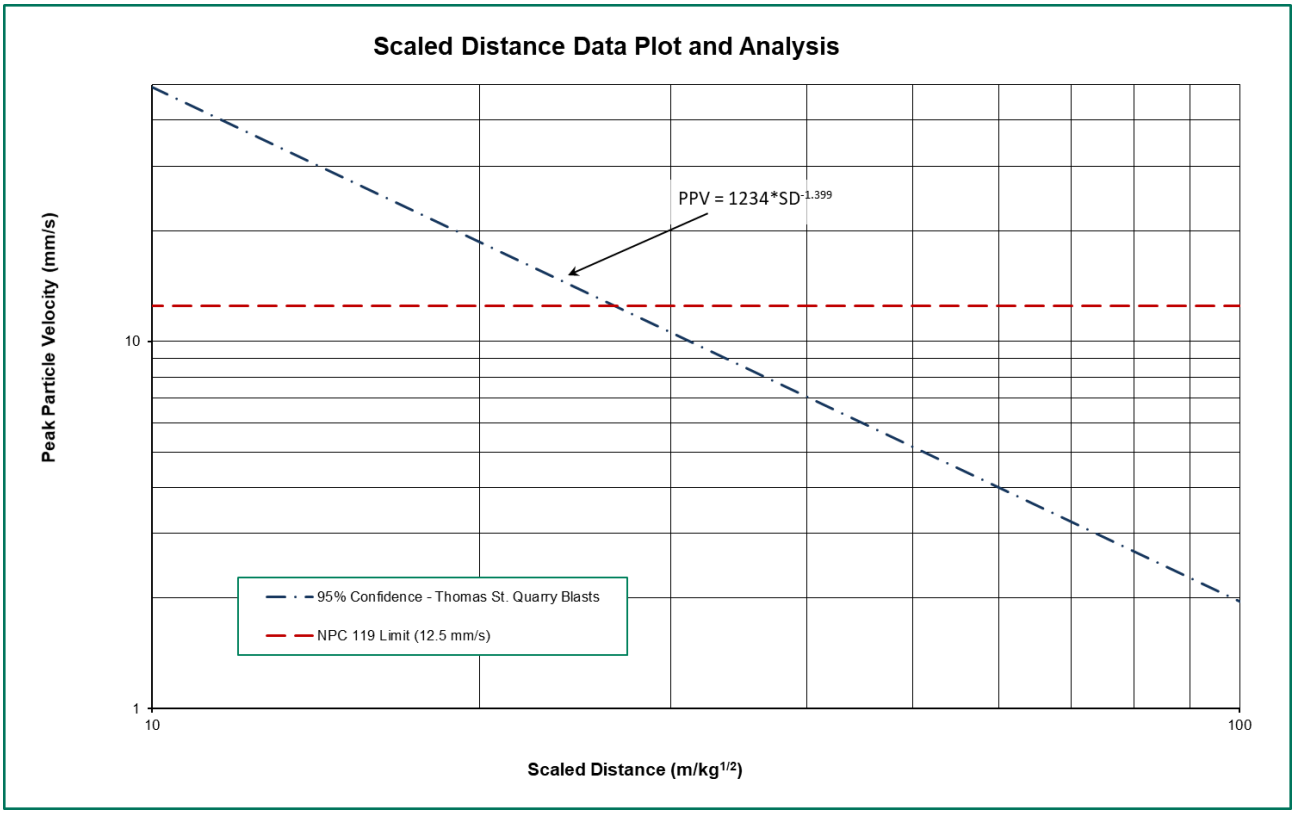


Figure 2: Proposed Ground Vibration Attenuation Model

The purpose of this equation is not so much to predict what a given vibration level would be at a particular location for a given blast, but to indicate that the peak vibration would fall below the level indicated by the equation for a given distance and maximum explosive weight. The equation is, therefore, a useful blast design tool in establishing maximum charge weights for various distances from a blast site for a given maximum ground vibration level.

4.3 Air Vibration Model

Blasting for the quarry operations on the Site will result in air vibrations. This section describes the attenuation (i.e., reduction in intensity) of air vibrations from blasting.

Air overpressure attenuates from a blast site as the distance to the receptor increases (Siskind, 2005). Air vibrations attenuate from a blast site at a slower rate than ground vibrations. The distribution of air vibration energy from a blast is strongly influenced by the prevailing weather conditions during the blast. For example, wind can increase downwind levels by 10 to 15 dBL above what would otherwise be measured (Dowding 1985). Low cloud ceilings and temperature inversions also contribute to air vibrations propagating further than would typically be the case. Other factors influencing air vibration distribution from a blast include orientation of the blast face, local topography and vegetation, length of collar and type of stemming material, differences in explosive types and variations in burden distance.

The rate air vibrations decay or attenuate from a blast site can be expressed by the Scaled Distance, which is defined as:

$$Scaled\ Distance\ (SD) = \left(\frac{D}{\sqrt[3]{W}}\right)$$

where D is the distance (m) between the blast and receptor

W maximum weight of explosive (kg) detonated per delay period.

The air vibration level is given by:

$$PSPL = K(SD)^{-e}$$

where PSPL= Peak Sound Pressure Level (dBL)

SD= Scaled Distance (m/kg$^{1/3}$) as defined above

K, e = Site factors typically derived from monitoring, or provided within published literature

Where no site-specific data is available, the model factors can be estimated based on literature derived models or models based on applicable experience. The air vibration data provided by SMC had a limited range of Scaled Distance and yielded clustered data, which made it unreliable for the development of an air vibration attenuation model. As such, air vibration attenuation characteristics were estimated based on data collected by Golder at several limestone quarries in Southern Ontario and shown by the following equation:

$$PSPL_{dBL} = 163.3 - 21.32 \log\left(\frac{D}{\sqrt[3]{W}}\right)$$

The model above is plotted on Figure 3. The calculated SD for a peak ground vibration level of 128 dBL would be equal to 45.5 m/kg$^{1/3}$.

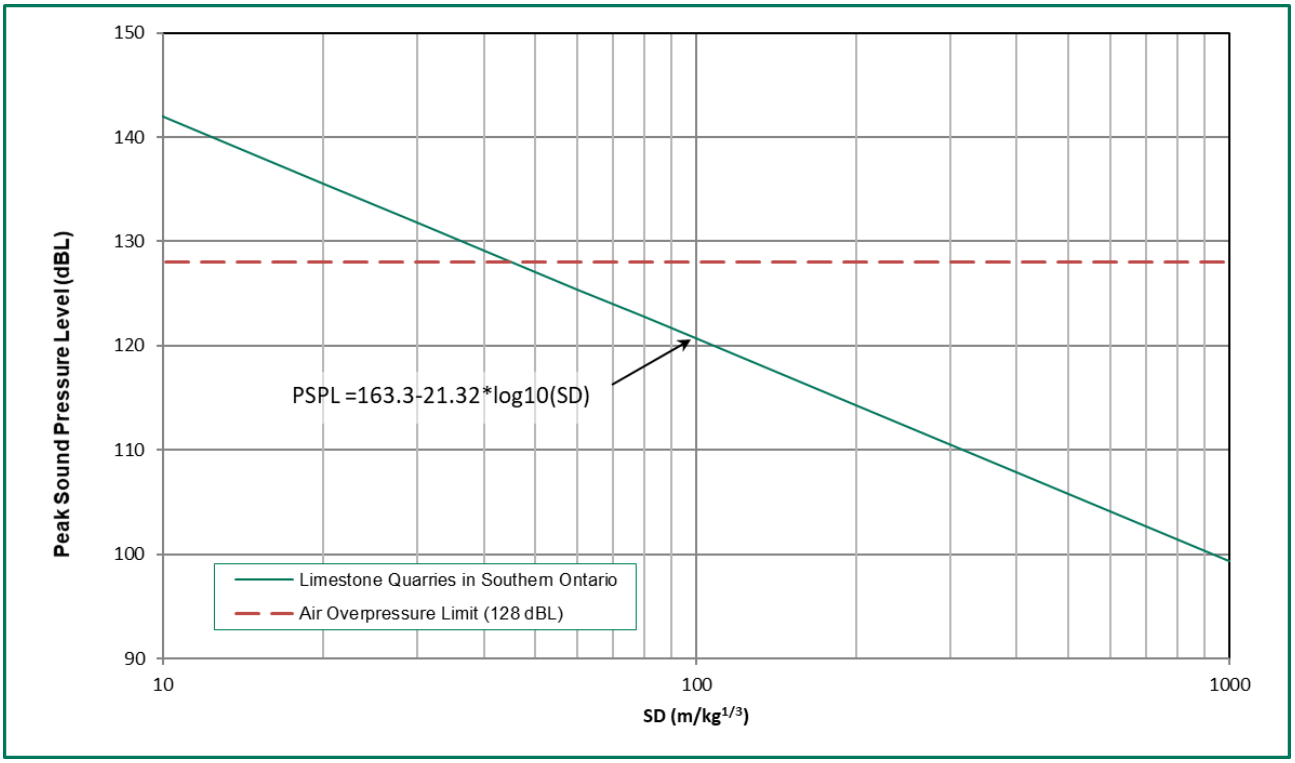


Figure 3: Proposed Air Vibration Attenuation Model.

5.0 IMPACT ASSESSMENT

5.1 Vibration Predictions

5.1.1 Ground Vibration Prediction

The prediction of peak ground vibration levels is carried out at differing distances from a blast based on an expected maximum explosive weight per delay period. The ground vibration levels from the Site are expected to be below the limits for blasts with an average burial of explosives. Figure 4 shows the estimated ground vibration amplitudes for the proposed blast design at a range of distances from the blast.

Assuming a single hole per delay period, the maximum explosive weight per delay of 188 kg, as seen in Table 1. The MECP guideline limit of 12.5 mm/s may be complied with for all blasting beyond a minimum distance of about 365 m from adjacent receptor residences.

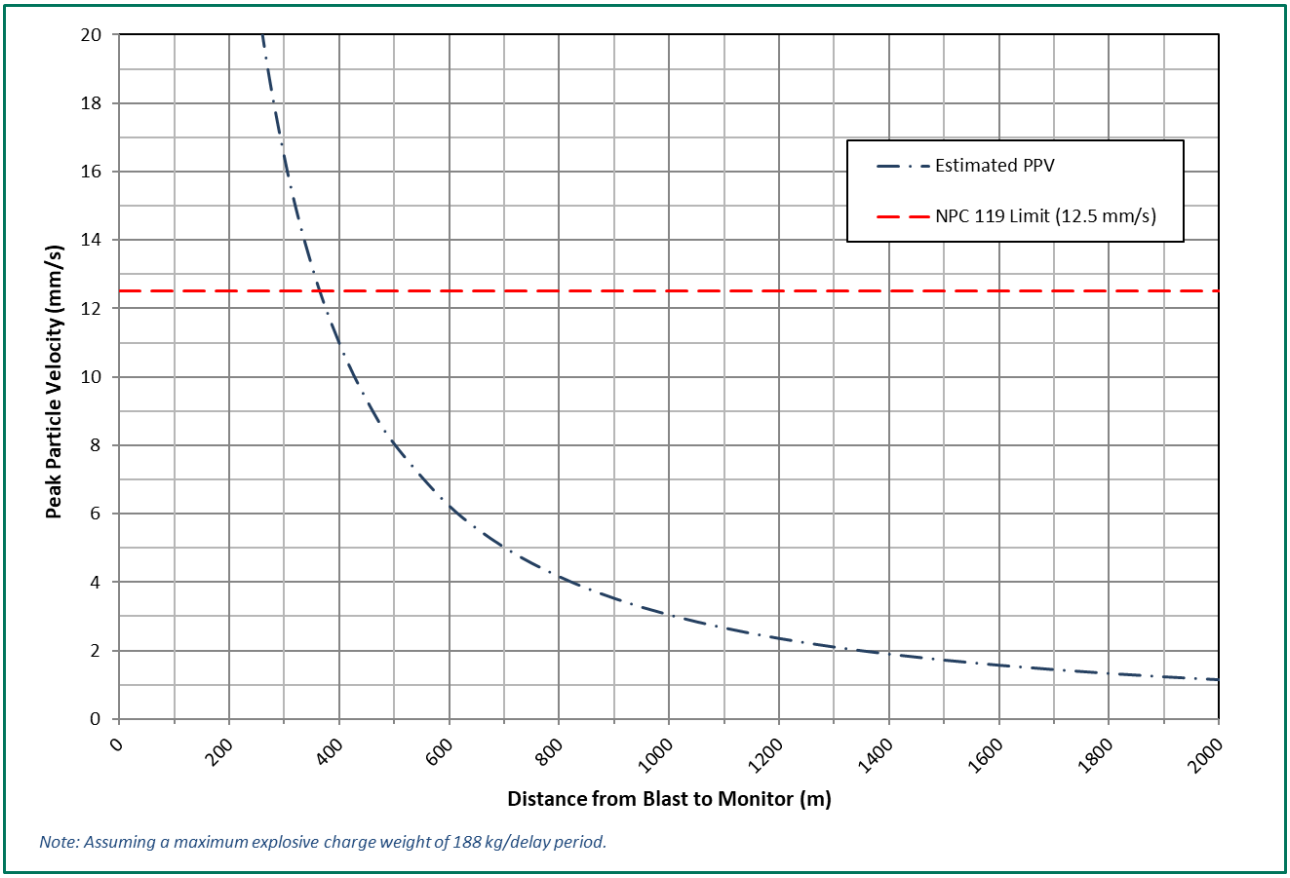


Figure 4: Estimated Maximum Ground Vibration for the Proposed Blast Design at a Range of Distances

Table 2 illustrates the maximum allowable explosive weight that may be detonated per delay period for maintaining a peak ground vibration level of 12.5 mm/s at varying distances from the blast.

Table 2: Maximum Explosive Loads to Comply with NPC 119 Ground Vibration Limit

Distance [1] (m)	Max. Explosive Charge Weight (kg) [2]
200	57
300	127
400	226
500	353
600	509
700	693
800	905

1) Distance between the blast and the sensitive receptor.

2) Assuming the attenuation model proposed above.

5.1.2 Air Vibration Prediction

The prediction of peak ground vibration levels is carried out at differing distances from a blast based on an expected maximum explosive weight per delay period. The ground vibration levels from the Site are expected to be below the limits for blasts with an average burial of explosives. Figure 5 shows the estimated ground vibration amplitudes for the proposed design at a range of distances from the blast.

Assuming a single hole per delay period, the maximum explosive weight per delay of 188 kg, the MECP guideline limit of 128 dBL may be complied with for all blasting beyond a minimum distance of about 260 m from adjacent receptor residences.

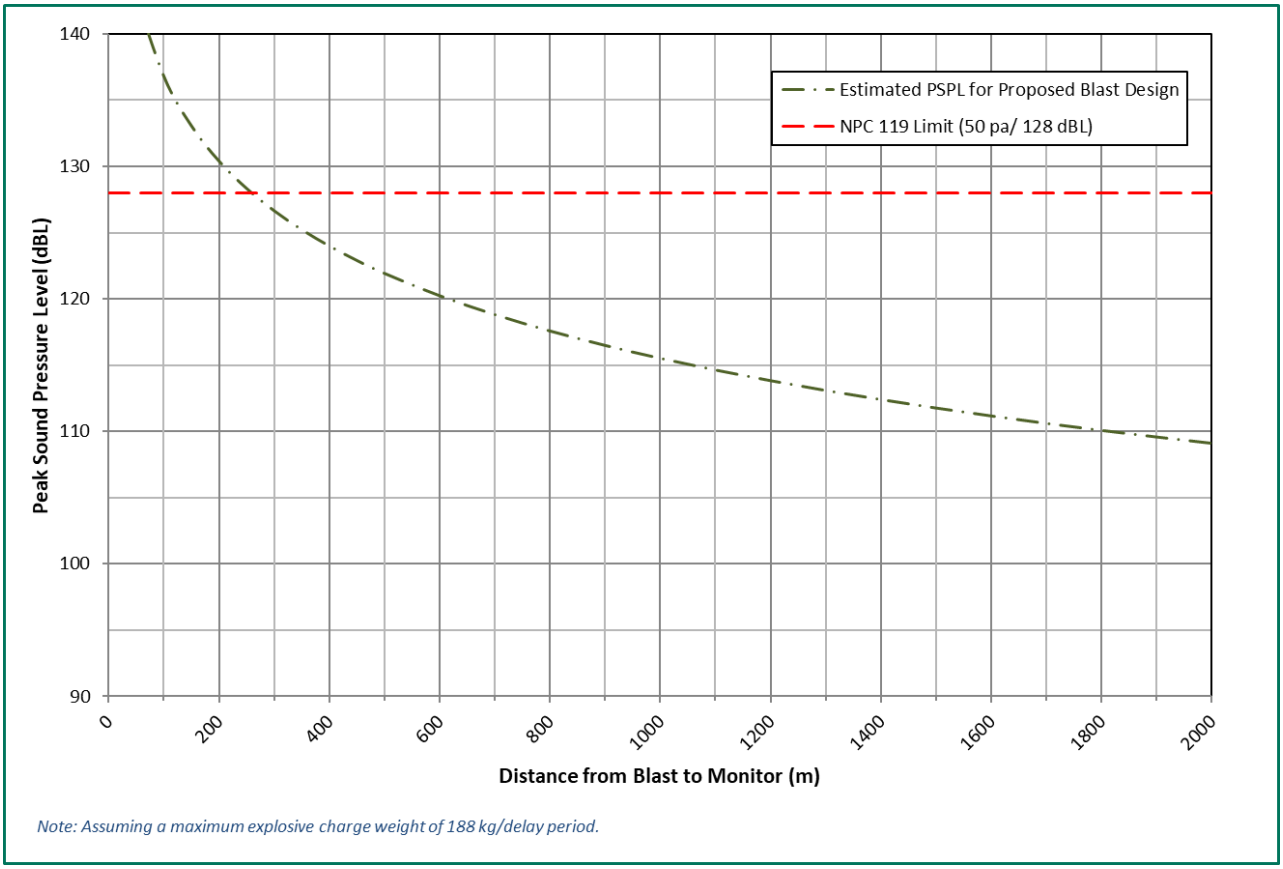


Figure 5: Estimated Maximum Air Vibration for the Proposed Blast Design at a Range of Distances

Table 3 illustrates the maximum allowable explosive weight that may be detonated per delay period for maintaining a peak ground vibration level of 128 dBL at varying distances from the blast.

Table 3: Maximum Explosive Loads to Comply with NPC 119 Air Vibration Limit

Distance [1] (m)	Max. Explosive Charge Weight (kg) [2]
200	57
300	127
400	226
500	353
600	509
700	693
800	905

1) Distance between the blast and the sensitive receptor.

2) Assuming the attenuation model proposed above.

5.1.3 Vibration Prediction Summary

Site-specific SD plots are commonly used as a blast design tool since maximum peak ground vibrations levels can reasonable be predicted at specific distances from a blast. Based on the regression models developed in Section 4.0, Table 4 shows the maximum suggested explosive loads (MICs) for various distances from the blast site based on the provincial guideline limits of 12.5 mm/s and 128 dBL respectively. This is shown graphically on Figure 6.

Table 4: Summary of Maximum Explosive Loads to Comply with NPC-119

Distance [1] (m)	Max. Explosive Charge Weight (kg) [2]	
	PPV = 12.5 mm/s SD = 23.3 m/kg$^{1/2}$	PSPL = 128 dBL SD = 45.5 m/kg$^{1/3}$
200	57	81
300	127	272
400	226	645
500	353	1,259
600	509	2,176
700	693	3,456
800	905	5,159
900	1,145	7,345
1,000	1,413	10,075

1) Distance between the blast and the sensitive receptor.

2) Assuming the attenuation models proposed above.

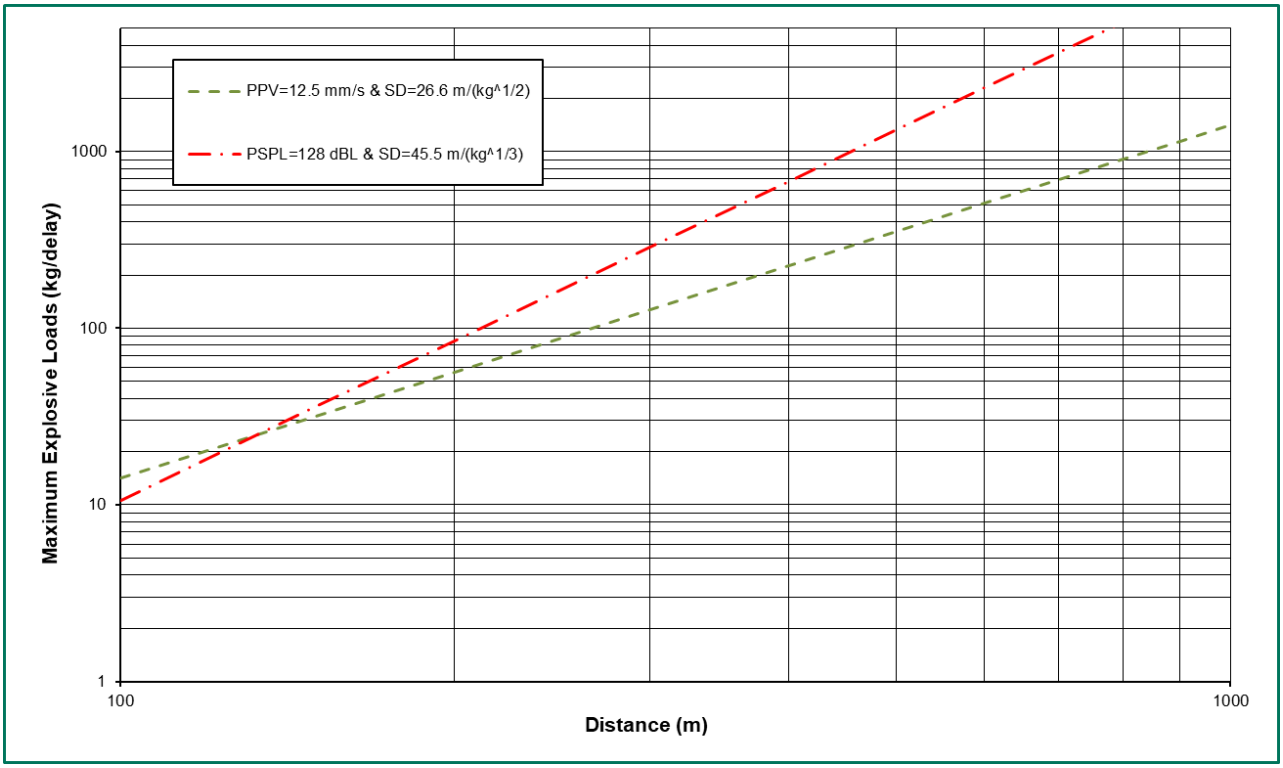


Figure 6: Maximum Explosive Charge Weights to Comply with NPC-119 Ground and Air Vibration Limits

The results demonstrate that the ground vibration limit of 12.5 mm/s becomes the more restrictive guideline when determining the maximum explosive loads beyond 133 m from the Thomas Street Quarry's blasting operations. While the air vibration limit of 128 dBL would tend to dictate the maximum loads inside 133 m, implementing blast design changes to reduce ground vibration intensities typically also results in a corresponding reduction in air vibration effects.

5.2 Compliance With NPC-119

All blasting at the Site would be carried out such that ground and air vibration effects would comply with the recommended provincial guideline limits of 12.5 mm/s and 128 dBL respectively. It is evident from the regression equations discussed in Section 4.0 that the distance from the blast and the amount of explosive detonated per delay period are the principal parameters in controlling ground and air vibration effects. The current maximum explosive charge load is approximately 188 kg (see Table 1). The maximum explosive loads given on Figure 7 for limiting peak ground and air vibration levels to 12.5 mm/s and 128 dBL respectively, indicate that the provincial guideline may be complied with for all blasting beyond a distance of about 265 to 365 m, respectively, from adjacent residential properties.

The closest separation distance between a sensitive receptor and any blast over the life of the Site is 250 m. When blasting approaches to within about 370 m of adjacent residences, depending on bench height, it may become necessary to reduce the maximum explosive weight detonated (MIC) within the blast. Any one or combination of the following operations would achieve this:

1) Reduce the borehole diameter with a corresponding reduction in the drill pattern parameters.

2) Introduce additional decked charges within each borehole, as illustrated on Figure B-1 (APPENDIX B).

3) Reduce the borehole length (depth) by reducing the bench height.

For example, a reduction in the borehole diameter from 102 mm to 89 mm would effectively reduce the explosive weight per hole, assuming the same loading and blast procedures, by approximately 24%. Adding an additional deck to the explosive column could further reduce the maximum explosive weight per delay by about another 60%. Additional decking and reductions in bench heights, as identified above, could achieve further reductions in maximum explosive weights. This would allow extraction of those areas within the proposed extension closest to off site receptors.

As it is the intention of the SMC to continue monitoring all blasts for the Site, the attenuation curves discussed previously could be used in conjunction with the monitoring data collected at adjacent properties to dictate when changes to the blast procedure become necessary when approaching adjacent residences. Although a reduction in the maximum instantaneous explosive load is anticipated as blasting approaches the extraction boundary, the ground and air vibration guideline limits contained within NPC-119 would continue to be maintained.

5.3 Blast Effects on Bedrock and Water Wells

As discussed previously, under typical blasting conditions stresses introduced into the bedrock by the explosive detonation and the accompanying gas pressures create and extend fractures within the bedrock around each borehole. Fracture development is usually limited to a distance of about 20 to 30 times the borehole diameter. In the case of the blast procedures given for the proposed extension, this would be limited to an area immediately around each blast. The gas pressures within the hole may extend micro-cracks or existing natural discontinuities within the bedrock, such as joints or bedding planes. Studies on crack development within bedrock from blast detonations (Keil et al., 1977) indicate that peak ground vibration levels of 300 to 600 mm/s are required to create micro-cracks or open existing discontinuities. Golder's experience within the limestone of Southern Ontario indicates that such values would not be anticipated beyond a distance of about 5 to 10 m from the blast, depending on such parameters as blasthole diameter and the type of explosive product. The creation or extension of fractures within the bedrock would remain confined to an area immediately around the blast site. This is the principal reason why each blast is made up of a pattern of holes. The explosive in each hole has only sufficient energy to fracture the bedrock around that particular hole.

Several studies have been carried out to investigate the effects of blasting on ground water wells (Froedge, 1983). These studies have concluded that:

1) When blast-induced ground vibrations are less than about 25 mm/s maximum resultant particle velocity, the response of the well is limited to a slight temporary variation in water level on the order of 3 to 6 cm either up or down. The specific capacity of the water well is unchanged based on drawdown tests.

1) Vibration measurements made at the surface and at the bottom of the observation wells indicate the vibration levels are always lower at the bottom of the well.

2) All of the data collected indicates that a ground vibration limit of 50 mm/s peak particle velocity is adequate to protect the wells from any significant damage. There is a possibility that temporary turbidity may be caused at lower levels periodically, although not at any constant threshold level.

The research consistently indicates that blast vibrations below 25 mm/s should have no adverse effects on nearby wells. As the maximum provincial guideline vibration limitation at the nearest residence is only half of this value,

at 12.5 mm/s, the ground vibrations produced from the quarry's blasting operations would have no effect on the neighbouring water wells.

5.4 Repeated Vibration Effects on Structures

Blast vibrations characteristically produce temporary transient strains within the various materials that makeup a residential structure. These strains would typically have durations of no more than one or two seconds for each blast as the vibration passed the structure. While the blasting may introduce these temporary strains a few times each week for one or two seconds, Table 5 shows the strain levels produced in a household by changes in temperature and humidity (environmental changes), as well as those produced by regular household activities (Dowding, 1985), which take place on a recurring and significantly more frequent basis. These strain levels are compared to equivalent levels of ground vibration produced from blasting operations. It is evident from Table 5 that routine household activities and environmental changes can produce strains within a structure that are well in excess of those produced by blasting.

Table 5: Strain Levels Induced by Household Activities, Environmental Changes and Blasting

Loading Phenomena	Site[a)]	Microstrain Induced by Phenomena (μin/in)	Corresponding Blast Vibration Level[b)] (mm/s)
Daily environmental changes	K_1 K_2	149 385	30.0 76.0
Household Activities 1. Walking 2. Jumping 3. Door slams 4. Pounding nails	 S_2 S_2 S_1 S_{12}	 9.1 37.3 48.8 88.7	 0.8 7.1 12.7 22.4

a) K_1 and K_2 were placed across a taped joint between two sheets of gypsum wallboard.

b) Blast equivalent based on envelope line of strain versus ground vibration.

Source: Dowding (1985)

Several studies have also been carried out to look at the long-term effects of repeated blasting on structures (Stagg et al., 1984, Siskind et al., 1980). These studies concluded that repeated blasting over several decades, producing peak vibration levels well in excess of the provincial guideline limit, were required to cause cosmetic threshold cracking to occur. By ensuring that blasting continues to remain within the provincial guideline limits, there would not be any noticeable cumulative effect associated with the blasting operations from the proposed quarry.

5.5 Effect on Canadian Fisheries Waters

Information provided to Golder as well as Golder's observations while on the Site have not indicated that there is fish habitat near the Site. There is no indication that there are any spawning beds in the area. There has not been any concern that the existing Thomas Street Quarry has negatively impacted the fish or habitat in the Thames River to date. As such, the proposed blasting operations at the Site are not anticipated to have an adverse effect on them.

6.0 RECOMMENDATIONS

In keeping with the blasting practices that have already been established within the Thomas Street Quarry, Golder recommends that the procedures be continued during the extraction of the Site:

- Monitor all quarry blasts at the closest residences for ground and air vibration effects to ensure compliance with the current MECP guideline limits. The vibration monitoring shall be carried out by an independent third-party engineering firm with expertise in blasting and monitoring.
- Blasting shall be carried out by persons experienced, trained and qualified to conduct blasting operations.
- Blasting should be scheduled so that it occurs routinely during a specific period of time each day where possible.
- Prohibit drilling and blasting on Sundays and all Statutory holidays.
- When blasting within approximately 370 m of adjacent residences, the quarry shall regularly review their blast procedures in conjunction with the blast monitoring results to assess if it is necessary to modify blast design parameters of the blasts. If there are regular exceedances of the vibration limits, blast design parameters will be modified to reduce the maximum explosive weight detonated (MIC) per delay period. Any one or combination of the following operations would achieve this:

  1) Reduce the borehole diameter with a corresponding reduction in the drill pattern parameters.

  2) Introduce additional decked charges within each borehole.

  3) Reduce the borehole length (depth) by reducing the bench height.

- Blasting procedures such as drilling and loading shall be reviewed annually and modified as required to ensure compliance with industry standards.
- Maintain a record of all blasting details including a seismic record of the ground and air vibration monitoring results. The blast details and monitoring results should be made available to the MNRF and the MECP, upon written request. The MECP (1985) recommended that the body of the blast reports should include the following information:

  - Location, date and time of the blast;
  - Dimensioned sketch including photographs, if necessary, of the location of the blasting operation, and nearest point of reception;
  - Physical and topographical description of the ground between the source and the receptor location.
  - Type of material being blasted;
  - Sub-soil conditions, if known;
  - Prevailing meteorological conditions including wind speed in m/s, wind direction, air temperature in ^{o}C, relative humidity, degree of cloud cover and ground moisture content;
  - Number of drill holes;
  - Pattern and pitch of drill holes;

- Size of holes;
- Depth of drilling;
- Depth of collar (or stemming);
- Depth of toe-load;
- Weight of charge per delay;
- Number and times of delays;
- The result and calculated value of Peak Pressure Level in dBL and Peak Vibration Velocity in mm/s;
- Applicable limits; and
- The excess, if any, over the prescribed limit.

- The initial series of regular production blasts at the start of extraction/blasting within the Site boundaries should be monitored at a minimum of five locations at varying distances from each blast to refine the ground and air vibration attenuation characteristics are within the estimated levels discussed in this report. This would entail establishing monitoring stations between the blast site and neighbouring receptors (residents). The site-specific attenuation data developed during this monitoring period should then be used to better define ground and air vibration effects at the nearest receptors.

7.0 TECHNICAL NOTES

The following is a summary of the guidelines and procedure to be followed during the extraction at the proposed Thomas Street Quarry extension:

1) All quarry blasts shall be monitored for ground and air vibration levels at the closest residences effects to ensure compliance with the current MECP guideline limits.

4) Blasting shall be carried out by persons experienced, trained and qualified to conduct blasting operations.

5) Blasting shall be scheduled so that it occurs routinely during a specific period of time each day where possible.

6) No drilling and blasting shall occur on Saturdays, Sundays and all Statutory holidays.

7) Results of the blast details and monitoring results shall be kept for all blasts and made available to the MNRF and the MECP, upon written request.

8) Blasting procedures shall be reviewed annually and modified as required to ensure compliance with industry standards.

8.0 CONCLUSIONS

Based on the foregoing considerations, it is Golder's opinion that blasting operations may be performed at Site in compliance with the current quarry blasting guidelines published by the MECP (NPC-119). This should be

confirmed with the results of the monitoring program given that the analysis is based on largely on literature values, results from other quarries, and limited site data. All blasting and blast monitoring would occur in accordance with the *Aggregate Resources Act (*Ontario Ministry of Natural Resources and Forestry, 2017*)* prescribed conditions in order to ensure compliance with the provincial guidelines.

The CVs for the report signatories are displayed in APPENDIX D.

9.0 REFERENCES

Dowding, C.H., 1985. “Blast Vibration Monitoring and Control”, 297 pp.

Froedge, D.T., 1983. “Blasting Effects on Water Wells”, Proc. Ninth Conf. on Explosives and Blasting Technique, Int. Soc. of Explosives Engineers.

Keil, L.D., Burgess, A.S., Nielson, N.M., Koropatrick, A., 1977. “Blast Vibration Monitoring of Rock Excavation”, Canadian Geotechnical Journal, Volume 14.

Ontario Ministry of Environment, 1978. “Model Municipal Noise Control By-Law, NPC-119”, Final Report, August 1978.

Ontario Ministry of Environment, 1985, "Guidelines on Information Required for Assessment of Blasting Noise and Vibration”, December 1985.

Ontario Ministry of Natural Resources and Forestry (MNRF), 2017. “Aggregate Resources Act of Ontario, R.S.O. 1990, Chapter A.8” amended 2017.

Siskind, D. E., 2005. “Vibrations from Blasting”, International Society of Explosives Engineers, 120 pp.

Siskind, D.E., Stagg, M.S., Kopp, J.W., Dowding, C.H., 1980. “Structure Response and Damage Produced by Ground Vibration from Surface Mine Blasting”, U.S.B.M. Report RI8507.

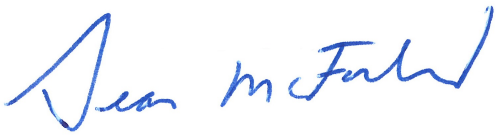
Stagg, M.S., Siskind, D.E., Stevens, M.G., Dowding, C.H., 1984. “Effects of Repeated Blasting on a Wood-Frame House”, U.S.B.M. Report RI8896.

Wright, D.G., Hopky, G.E., 1998. “Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters”, Can. Tech Rep. Fish Aquati. Sci. 2107.

Signature Page

Golder Associates Ltd.

Daniel Corkery
Associate, Senior Blasting Consultant



Sean McFarland, Ph.D., P.Geo.
Principal

DJC/HM/SM/jl

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APPENDIX A

Definition of Blasting Terms and Glossary of Blasting Terms

DEFINITIONS OF BLASTING TERMS

Figure A-1 illustrates blasting terminology used in this report.

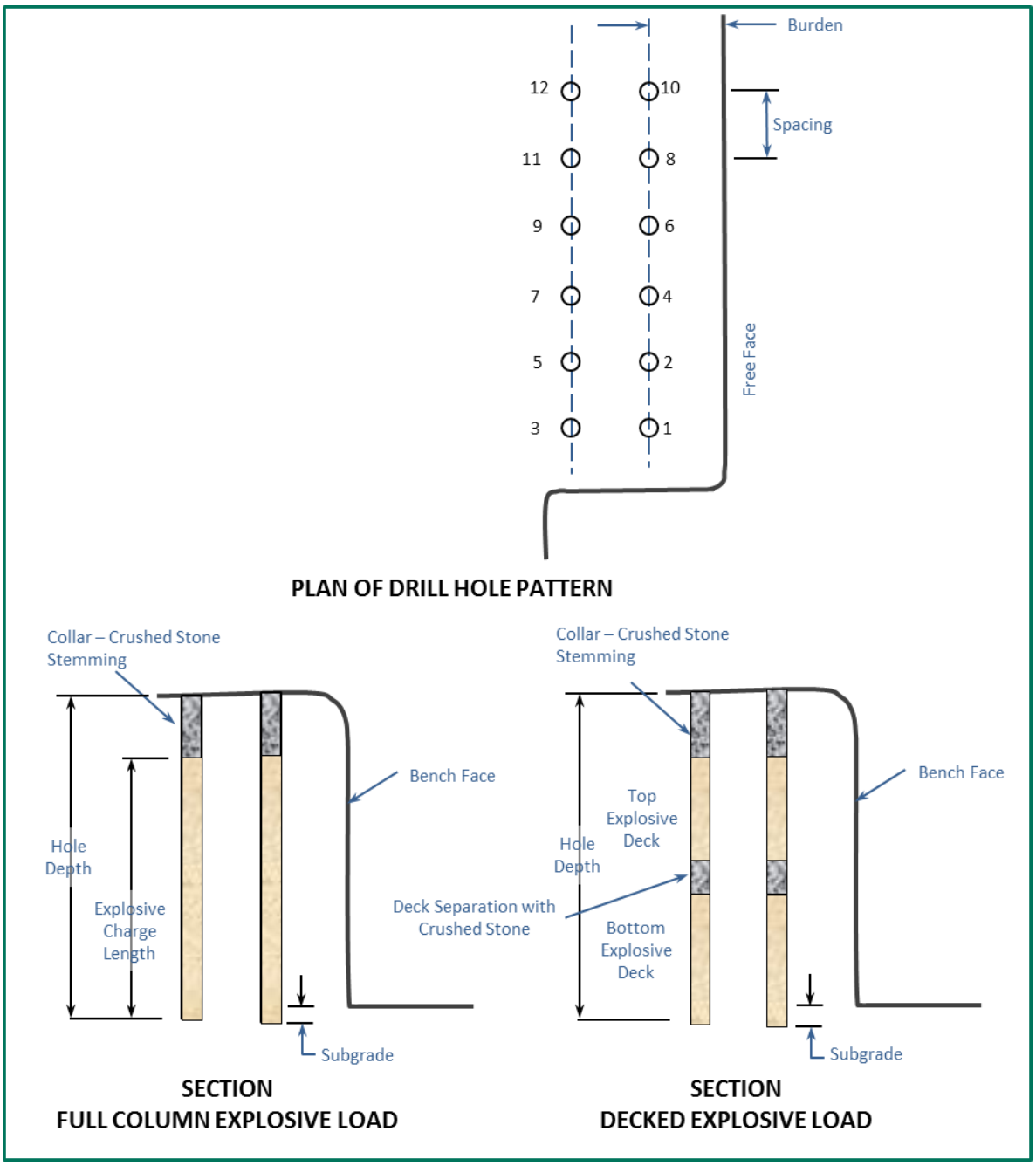

Figure A-7: Definition of Blasting Terms

GLOSSARY OF TERMS

The following is a glossary of blasting terms that were used in this report.

Bench Height	-	This is the vertical distance from the top of the bench to the floor or to the top of the next lower bench.
Blast	-	The operation of rending (breaking) rock by means of explosives.
Blast Area	-	The area of a blast within the influence of flying rock missiles, gases and concussion.
Blast Hole	-	A hole drilled in rock or other material for the placement of explosives.
Booster	-	This is an explosive unit containing a suitable firing device that is used for the initiation of an entire explosive charge.
Burden	-	Generally considered the distance from an explosive charge to the nearest free or open face.
Collar	-	This is the mouth or opening of a borehole.
Deck	-	In blasting a portion of a blast hole loaded with explosives that are separated from the main charge by stemming.
Detonation	-	This is an explosive reaction that moves through an explosive material at a velocity greater than the speed of sound in the material.
Detonator	-	This is any device containing any initiating or primary explosive that is used for initiating detonation. This includes blasting caps.
Electronic Detonator	-	This is a detonator that provides better precision for delays. They are that are variably and individually programmable.
Explosive	-	This is a chemical mixture that reacts at high speed to liberate gas and heat and thus cause development of tremendous pressures.
Flyrock	-	Rocks propelled from the blast area by the force of an explosion.
Free Face	-	The bench face to which the blast will move. It is also any rock surface exposed to air.
Highwall	-	Nearly vertical face at the edge of a bench, bluff or ledge on a surface excavation.
Initiation	-	The act of causing and explosive material to detonate or deflagrate.
ISEE	-	International Society of Explosives Engineers.
MIC	-	Maximum Instantaneous Charge is the maximum weight of explosive (kg) detonated at any instant in time.
Muckpile	-	The pile of broken material resulting from a blast.
Powder Factor	-	The weight of explosive per unit volume or weight of rock moved.
Spacing	-	This is the distance between boreholes or charges in a row.

Stemming	-	The inert material, such as drill cuttings or crushed stone, used in the uncharged portion (or elsewhere) of a blasthole so as to confine the gaseous products formed on explosion.
Subdrill	-	This is the portion of the blastholes beyond the planned grade lines or below floor level.

APPENDIX B

Publication NPC-119, Model Municipal Noise Control By-Law, Final Report, 1978

PUBLICATION NPC-119
Blasting

1. Scope

This Publication refers to limits on sound (concussion) and vibration due to blasting operations.

2. Technical Definitions

The technical terms used in this Publication are defined in Publication NPC-101 – Technical Definitions.

3. Measurement Procedures

All measurements of peak pressure level and vibration velocity shall be made in accordance with the “Procedure for Measurement of Sound and Vibration due to Blasting Operations” set out in Publication NPC-103 – Procedures, section 5.

4. Concussion – Cautionary Limit

Subject to section 5 the peak pressure level limit for concussion resulting from blasting operations in a mine or quarry is 120 dB.

5. Concussion – Peak Pressure Level Limit

If the person in charge of a blasting operation carries out routine monitoring of the peak pressure level, the peak pressure level limit for concussion resulting from blasting operations in a mine or quarry is 128 dB.

6. Vibration – Cautionary Limit

Subject to section 7, the peak particle velocity limit for vibration resulting from blasting operations in a mine or quarry is 1.00 cm/s.

7. Vibration – Peak Particle Velocity Limit

If the person in charge of a blasting operation carries out routine monitoring of the vibration the peak particle velocity limit for vibration resulting from blasting operations in a mine or quarry is 1.25 cm/s

APPENDIX C

Nearest Receptors to the Proposed Thomas Street Quarry Extension

NEAREST RECEPTORS TO THE THOMAS STREET QUARRY EXTENSION

Receptor ID	Receptor Name	Distance (m) [1)]
POR001	4650 Perth Rd 5 Line	240
POR002	4691 Perth Rd 5 Line	1660
POR003	4782 Perth Rd 5 Line	1010
POR004	4769 Perth Rd 5 Line	930
POR005	1801 Perth Rd 139	780
POR006	1930 Perth Rd 139	980
POR007	1952 Perth Rd 139	850
POR008	1957 Perth Rd 139	780
POR009	524 Elgin St. W.	1230
POR010	462 Water Street South	1850
POR011	500 Water Street South	1480
POR012	1760 Perth Rd. 123	1050
POR013	1730 Perth Rd. 123	1000
POR014	4546 Perth Rd 3 Line	580
POR015	4585 Perth Rd 3 Line	550
POR016	4642 Perth Rd 3 Line	600
POR017	1407 Perth Rd 127	930

1) *Separation distance to the nearest point of extraction.*

APPENDIX D

CVs of Report Signatories

St. Catharines

Senior Hydrogeologist and Principal

As a Senior Hydrogeologist with Golder, Dr. McFarland has more than 30 years of professional experience and a broad background in conducting, managing and directing aggregate waste management, mining, power, oil and gas, and ground management and protection projects. He served as the project director for work programs for proposed mines, aggregate operations and industrial facilities.

He has a broad background in licensing and permitting of pits and quarries. This includes the licensing for the expansion of the Lafarge Dundas Quarry, the expansion of the Lafarge Woodstock Quarry, the expansion of the Nelson Aggregate Quarry, the RW Tomlinson license application, the St. Mary's cement Bonis Quarry, the ongoing expansion of the Port Colborne Quarry, and the Lafarge Goodwood Pit and other sites. He is also involved in numerous PPTW applications for pits and quarries. In addition, he has extensive experience in site selection studies and resource evaluations for aggregate sites.

Sean acted as the Project Director and Senior Hydrogeologist for the 2014 and 2015 annual landfill monitoring reports for the Vale Port Colborne site and for 8 landfill monitoring programs in Niagara Region. He was the Project Manager and Senior Hydrogeologist for the extensive Adams Mine landfill project, which involved the successful permitting of a 20 million tonne hydraulic containment engineered landfill facility, within a 200 m deep former open pit mine, following hydrogeological investigations collected over an 8-year period that involved extensive monitoring well installation, electronic instrumentation and testing, pump test analyses and groundwater flow modelling. He has also been an expert witness for hydrogeology at Environmental Assessment (EA) and Ontario Municipal board (OMB) hearings and has been involved in extensive contaminated site investigations including legal disputes.

Additional project experience includes hydrogeological assessments for the low level radioactive (LLRWM) facility concepts of waste management for the Canadian federal government Siting Task Force Secretariat (STFS) in limestone bedrock beneath the Great Lakes, and fractured and faulted Precambrian granitic gneiss at the Chalk River Nuclear Reactor site in northern Ontario, Canada. Further project experience in fractured rock includes the proposed Steetley Landfill, in limestone bedrock of the Niagara escarpment, including an extensive EA level hydrogeological investigation, over a 5-year period, and the existing Brow Landfill including an EPA level investigation, a long-term monitoring program and remediation.

Education

PhD Osgoode Hall Law School, York University, 2013

LLM Osgoode Hall Law School, York University, 2005

MBA Centre for Innovative Management, Athabasca University, 2001

M.Sc. Earth Sciences, Brock University, 1997

B.Sc. Geological Sciences (Honours), University of Toronto, 1985

Certifications

Professional Geoscientist, P.Geo., Ontario

Certified Professional Accountant, CPA, Ontario

Certified Management Consultant, CMC

Project Management Professional, PMP

Languages

English – Fluent

Employment History

Golder Associates Ltd. – Mississauga, Ontario

Senior Geoscientist and Principal (1987 to Present)

Hydrogeologist then Senior Hydrogeologist (1987-present)
Managing Principal, Vice President, Canada (2005-2014)
Associate - 1997 appointment
Principal - 2003 appointment

Geologist and Hydrogeologist (1985 to 1987)
Characterization of proposed and existing metal and industrial mineral facilities and impact assessments for industrial facilities.

Regina Associates Ltd. – Kingston, Ontario
Geoscientist (1983 to 1987)

Characterization of proposed and existing metal and industrial mineral facilities in Ontario, Nova Scotia, Newfoundland, British Columbia and the Northwest Territories; and hydrogeological impact assessments for industrial facilities.

PROJECT EXPERIENCE – AGGREGATE INDUSTRY

Aggregate Resource Evaluation Regional Municipality of Peel, ON	Project Manager and geologist for evaluation of sand and gravel and bedrock resources in the Regional Municipality of Peel, Ontario for the provincial Ministry of Municipal Affairs and Housing (MMAH). The project was carried out as part of the development of the official plan for the Region.
Region of Peel Regional Municipality of Peel, ON	Technical advisor for ARIP (Aggregate Resource Inventory Paper) report for the Regional Municipality of Peel. The project involves and evaluation of shale and gravel, limestone and shale resources in the Region and was submitted to the Ontario Geological Survey for publication as a government document ARIP Paper.
Navan Quarry Navan, ON	Project Manager and geologist for evaluation of sand and gravel and bedrock resources in the Regional Municipality of Peel, Ontario for the provincial Ministry of Municipal Affairs and Housing (MMAH). The project was carried out as part of the development of the official plan for the Region.
Brockville Quarry Brockville, ON	Project Manager and hydrogeologist for hydrogeological evaluation of the Permanent Lafarge Brockville Quarry. The results of the evaluation were used to negotiate the liability of the quarry to alleged water well interference associated with quarry expansion with the Ontario Ministry of the Environment.
Dufferin Aggregates ON	Project Director and senior hydrogeologist for numerous aggregate projects at quarries and sand and gravel pits within Ontario including resource evaluations, hydrogeological investigations and environmental assessments.
Due Diligence Studies Southern Ontario	Project Manager and senior hydrogeologist for due diligence studies as part of the potential purchase of aggregate companies and operating pits and quarries in Ontario.
Site Selection Studies Southern Ontario	Project Director for site selection studies for development of quarries and sand and gravel operations in Ontario.
Lafarge - North Quarry Flamborough, ON	Project Director for hydrogeological program at the Lafarge (formerly Redland) Quarry Operations in Flamborough, Ontario, to meet the regulatory requirements of the Ontario Ministry of the Environment.

Proposed Halminen Quarry Buckhorn, ON	Project Manager for a private application for a license for a proposed limestone quarry near Buckhorn, Ontario. The project involved management of multi-disciplinary project team public meetings, and application for a Class A licence under the Aggregate Resources Act.
Votorantim Cimentos Bowmanville, ON	Project Director for the development of a limestone/dolostone mine under Lake Ontario. The work programs involve drilling and testing of a 275m deep borehole under the lake, development of an underground mine plan, preparation of an EA document for regulatory approvals and public participation programs.
Milton Limestone Quarry Peer Review Milton, ON	Project Director for the peer review of the hydrogeological and adaptive management plan report for the proposed Dufferin Aggregates Milton Quarry expansion. The work program involved meetings with the hydrogeological consultant and legal counsel and attendance at Ontario Municipal Board hearings.
SAROS Study Greater Golder Horseshoe, ON	Evaluation of supply and demand of aggregate resources in the Greater Golden Horseshoe for the MMNR (Ministry of Natural Resources and Forestry). The project includes resource estimates for 25 quarries and 120 pits and unlicensed sand and gravel resources in the study area.
Nelson Quarry Expansion Burlington, ON	Project Director for the proposed Nelson Quarry extension including extensive borehole drilling and monitoring well installations, water quality sampling, a surface water program, groundwater flow modeling, impact assessments, preparation of an Adaptive Management Plan (AMP), reporting and acting as an expert witness at an Ontario Municipal Board hearing.
Lafarge South Quarry Expansion Dundas, ON	Project Director for a hydrogeological and hydrological work programs in support of a license application for the expansion of the Lafarge South Quarry near Dundas, Ontario (ongoing). The work program involves borehole drilling and monitoring well installations, geophysical borehole logging, water quality sampling and analyses, hydrological analyses of streams and wetlands, a karst assessment, a water well survey, geological and hydrogeological interpretation, groundwater flow modeling, agency interaction and attendance at public meetings.
Lafarge Fonthill Pit PTTW Renewal Fonthill, ON	Project Director for a hydrogeological work program in support of a Permit to Take Water (PTTW) application for the Lafarge, The work program included interpretation of pumping wells records, evaluation of drawdown in water wells related to pumping, water quality analyses and preparation and submission of a report in support of the permit application.
Lafarge North Quarry Expansion Dundas, ON	Project Director for a hydrogeological work program conducted in support of a license application for the expansion of the Lafarge North Quarry. The work program involved borehole drilling and monitoring well installations, pumping tests, groundwater flow modelling, a water well survey, an impact assessment of potential effects on water wells and an adjacent provincially significant wetland, agency interaction and preparation of a report submitted in support of the license application. The application was approved with an Ontario Municipal Board hearing.

Lafarge PTTW Monitoring Programs ON	Project Director for hydrogeological monitoring programs for a portfolio of more than 50 pits and quarries in Ontario. The programs involved water level and water quality monitoring, evaluation of pumping records, effects assessments and preparation and submission of monitoring reports for compliance with the permits.
RW Tomlinson Quarry License Application Brechin, ON	Project Co-director for the hydrogeological work program for a hydrogeological work program performed in support of a license application for a dolostone quarry in the Carden Plain. The work program involved borehole drilling and monitoring well installation, geophysical borehole logging, packer testing, well response testing, pump testing, water quality sampling, groundwater flow monitoring, an impact assessment including potential effects on surrounding water wells and an adjacent wetland, development of a monitoring program preparation of a report in support of the application and agency interaction.
Proposed Lafarge Glen Morris Pit ON	Project Director and senior hydrogeologist for the hydrogeological work program in support of a license application for the proposed Glen Morris Pit. The work program included borehole drilling, monitoring well installations, groundwater level monitoring and the provision of data and preparation of a hydrogeological report.
Lafarge Wellington Quarry PTTW and ECA Renewal ON	Project Director and senior hydrogeologist for the Lafarge Wellington Quarry Renewal. The field program involved borehole drilling, packer testing, monitoring well installations, groundwater level monitoring, a field pumping test, development of a water budget and groundwater quality sampling. A hydrogeological impact assessment was developed to assess the potential impacts of quarry groundwater level drawdown related to quarry dewatering activities on surrounding private water wells and municipal wells. The work program included the modification of the regional source water protection to incorporate site data to assess the potential affects on the Guelph municipal wells.
Lafarge Regan Resource Drilling ON	Project Manager and senior geoscientist for resource drilling at the Lafarge Regan site using some drilling techniques. The results of the work program were provided to Lafarge for their resource assessment.
Lafarge Hagersville Quarry Hagersville, ON	Senior Hydrogeologist for the assessment of quarry dewatering and pumping for the Lafarge Hagersville Quarry as part of the PTTW monitoring program.
Arbour Farms License Application ON	Senior Hydrogeologist for the Arbour Farms license application for a pit below water. The work program included borehole drilling, installation of monitoring wells, groundwater level monitoring and assessment of potential affects on an adjacent water course. Three-dimensional groundwater flow and heat transport modeling was completed to assess the potential thermal impacts on the surrounding surface water courses.

Rankin Construction Port Colborne Quarry Extension
Port Colborne, ON

Project Director for a multi-disciplinary work program for a license application for an extension of the Port Colborne Quarry. The work program involved hydrogeological, hydrological, blasting, noise, air, natural environment, planning, agricultural and archaeological studies and a resource estimate. Senior Hydrogeologist for the hydrogeological work program that involved borehole drilling, monitoring well installations, groundwater quality sampling and analysis, an impact assessment and a monitoring and response program for potential impacts on surrounding water wells.

Lafarge Goodwood Pit Extension
Goodwood, ON

Project Director and senior hydrogeologist for a license application for the Lafarge Goodwood Pit extension, for a Category 1 Class EA pit below water. The objective of the work program was to characterize the existing hydrogeological and hydrological conditions in the vicinity of the site, including the depth and elevation of the water table and assess potential affects of the operational and rehabilitation scenarios. The work program involved borehole drilling, monitoring well installations, groundwater level monitoring, development of a water budget and a hydrogeological impact assessment.

Lafarge Woodstock Quarry Expansion
Woodstock, ON

Project Director and senior hydrogeologist for the hydrogeological investigation of the Woodstock quarry for support of a license amendment. The field program involved borehole drilling, packer testing, monitoring well installations, groundwater quality sampling and analysis, a field water well survey and development of a water budget. An impact assessment was conducted to assess the potential affect of quarry related groundwater level drawdown on surrounding water wells and surface water courses.

CRH Resource Evaluation and Due Diligence
ON

Project Manager and senior geoscientist for a resource evaluation of a property near Orangeville, Ontario for potential acquisition for quarry development. The work program included borehole drilling, geological logging of the rock core, monitoring well installations to determine the depth of the water table, aggregate quality testing and reporting.

Limestone and Sandstone Resource Evaluation and Due Diligence
Regional Municipality of Peel, ON

Project Director and senior hydrogeologist for a resource evaluation for a property developer for potential acquisition of an existing quarry near Mississauga. The work program involved borehole drilling, core logging, aggregate quality testing and reporting.

Stouffville Resource Drilling
Stouffville, ON

Project Manager and senior hydrogeologist for the resource drilling at Lafarge Stouffville Quarry. The drilling was conducted using a sonic drill rig with continuous core sampling. The results were provided to the Lafarge geologist for the resource assessment.

Lakeridge Resource Drilling
ON

Project Manager and senior geoscientist for the resource drilling at the Lafarge Lakeridge site. The drilling was conducted using sonic coring and the results provided to the Lafarge geologist for development of a resource assessment.

Votorantim Thomas Quarry License Application ON	Senior hydrogeologist for the hydrogeological component of the Votorantim Thomas Quarry Extension license application. The work program involved borehole drilling, packer testing, geophysical borehole logging monitoring well installations and groundwater quality sampling and analysis. Three-dimensional groundwater flow monitoring was conducted to assessment the potential hydrogeological impacts of the quarry.
Lafarge Pinkney Pit #3 ON	Senior Hydrogeologist for the hydrogeological work program for the Lafarge Pinkney Pit #3 license application. The work program involved borehole drilling, monitoring well installations and a hydrogeological impact assessment.
Lafarge Mosport Resource Drilling ON	Project Manager and senior geoscientist for the sonic borehole drilling at the Lafarge Mosport Pit. The results of the resource drilling were provided to the Lafarge geologist as part of the site resource assessment.
Lafarge Goodwood Resource Drilling ON	Project Manager and senior geoscientist for sonic borehole drilling of the resource near the Lafarge Goodwood Pit. The results of the drilling were provided to the Lafarge geologist for a resource assessment.
APAO (Aggregate Producers Association of Ontario) Water Consumption Study ON	Project Director for a study for the APAO to determine the consumption of water associated with pits and quarries.
Lafarge Sunningdale Pit Monitoring Program ON	Senior Hydrogeologist for the Lafarge Sunningdale Pit Monitoring Program. The work program includes hydrogeological monitoring, an assessment of potential impacts and preparation of an annual monitoring report.
Votorantim Resource Assessment ON	Project Manager and senior geoscientist for a resource assessment at a Votorantim Quarry in central Ontario. The work program involved borehole drilling and borehole geophysics were used to identify and correlate the geological formations and members at the site.
Cox Construction Monitoring Well Network Wellington County, ON	Project Manager and senior hydrogeologist for borehole drilling and monitoring well installations at a property in Wellington County to provide baseline date for potential future licensing as a quarry. The wells were installed in the thick sequence of Amabel Formation at this locates. Groundwater level monitoring was performed to determine the depth to water table.
Cox Construction Resource Evaluation and Due Diligence ON	Project Director for a drilling program to evaluate to the limestone resource for potential acquisition of a property for development. The work program involved borehole drilling, geological logging of the rock core, monitoring well installations, aggregate quality testing and reporting.

PROJECT EXPERIENCE – WASTE MANAGEMENT

Adams Mine Kirkland Lake, ON	Project Hydrogeologist and Project Manager for the hydrogeological assessment of the Adams Mine near Kirkland Lake, Ontario over a five-year period as part of the proposed development of 20 million tonne engineered landfill facility for solid non-hazardous waste. The facility will receive waste from the Greater Toronto Area (GTA) via a rail line system. The landfill facility incorporates a hydraulic containment design, which prevents outward migration of contaminants from the landfill, which reduces environmental impacts and long-term operating costs. Provided expert witness testimony in an environmental assessment (EA) hearing.
Brow Landfill Dundas, ON	Project Hydrogeologist then Project Manager for hydrogeological assessment for landfill expansion of the existing Redland Quarries Inc. (formerly Steetley Quarry Products Ltd.) solid industrial waste Brow Landfill in Flamborough, Ontario. Subsequent work included ongoing groundwater and surface water quality monitoring and preparation monitoring reports submitted to the MOE, followed by development of a closure plan and an ongoing compliance monitoring program.
South Quarry Landfill Flamborough, ON	Project Hydrogeologist for hydrogeological assessment of the proposed Redland Quarries Inc. (formerly Steetley Quarry Products Ltd.) South Quarry in Flamborough, Ontario for the proposed development of an engineered landfill facility. Participated in environmental assessment (EA) hearings and assisted with the preparation of final arguments with legal counsel.
Siting Task Force Secretariat Chalk River, ON	Project Hydrogeologist, then Project Manager for geological and hydrogeological characterizations of the Chalk River Nuclear laboratories property, near Chalk River, Ontario for siting of a proposed facility for the disposal of low-level nuclear waste for the federal Siting Task Force Secretariat (STFS).
Siting Task Force Secretariat Port Hope, ON	Project Hydrogeologist then Project Manager for geological and hydrogeological characterization of the Lakeshore site in Port Hope, Ontario, for the federal Siting Task Force Secretariat (STFS). The work was carried out as part of the feasibility level I study for dispose of low-level waste in engineered caverns beneath Lake Ontario and the Cameco Uranium fuel processing facility in Port Hope.
Interim Waste Authority Regional Municipality of Peel, ON	Project Hydrogeologist for geological and hydrogeological characterization comparative evaluation of five short-listed sites for siting of an engineered landfill facility as part of the provincial Interim Waste Authority (IWA) landfill site selection process for the Region of Peel.
Guelph-Wellington County WMMP Wellington County, ON	Project Hydrogeologist for geological and hydrogeological characterization of five candidate sites and identification of a preferred site in Wellington County for siting of an engineered municipal landfill facility, as part of the joint City of Guelph - County of Wellington Waste Management Master Plan (WMMP).
Model City Landfill Lewiston, NY	Project Hydrogeologist for hydrogeological investigation of the Model City hazardous waste landfill, near Lewiston, New York, carried out as part of landfill expansion.

Welland-Wainfleet WWMP Townships of Welland and Wainfleet, ON	Project Hydrogeologist for the identification of preferred sites for development of a municipal landfill facility, as part of the Welland-Wainfleet Waste Management Master Plan (WMMP).
Brock South Landfill Pickering, ON	Project Hydrogeologist for assessment of the proposed Brock South Landfill near Pickering, Ontario, to assess the suitability of the site for development of an engineered municipal landfill facility for Metropolitan Toronto.
Redland Queenston Quarry Queenston, ON	Project Hydrogeologist for hydrogeological assessment of the Redland Quarries Inc., Queenston Quarry to determine the suitability of the site for disposal of waste rock saline shale, from the construction of the proposed diversion tunnels of the Sir Adam Beck III hydroelectric generating facility in Niagara Falls, Ontario.
Fly Ash Disposal Facility ON	Project Hydrogeologist for hydrogeological investigations at four quarries located near Hagersville, Cayuga, Smithville and Milton to determine their suitability for development an engineered landfill for disposal of fly ash from the Ontario Hydro Lakeview Power Generating Station.
Mohawk Street Landfill Brantford, ON	Project Hydrogeologist for assessment of groundwater and surface water quality impacts at the municipal Mohawk Street Landfill in Brantford, Ontario.
Vale Industrial Landfill Port Colborne, ON	Project director for the preparation of an annual report for the groundwater monitoring program for an industrial waste landfill at a former nickel refinery. The work program included interpretation of groundwater flow directions and water quality trends, evaluation of the extent of the leachate plume, and an impact assessment.
Vale Industrial Refinery Landfill Monitoring Port Colborne, ON	Project Director and senior hydrogeologist for an evaluation of the effectiveness of the purge well system at a former nickel refinery and the development of mitigation and rehabilitation measures for well clogging. The work program involved step drawdown pumping tests, longer term pumping tests, hydraulic analysis of pumping test data, assessment of the decline of well efficiency due to scaling and bio fouling and the development of a work program for well rehabilitation and maintenance including acidification.
Municipal Landfill Annual Monitoring Programs Niagara Region, ON	Project Director for the annual monitoring program for 8 landfills in bedrock and escarpment settings in Niagara Region. The work program involves field water quality sampling, groundwater level monitoring, and provision of progress and annual reports.
Proposed Walker Ingersoll Landfill ON	Senior Hydrogeologist for the hydrogeological investigation for the proposed Walker Landfill near Ingersoll, Ontario. The field program involved borehole drilling, monitoring well installations, packer testing, geophysical borehole logging, downhole flow profiling, groundwater quality sampling and analysis, a karst study and a water well survey. Three-dimensional groundwater flow modeling was conducted to assess the potential impacts of the landfill.

PROJECT EXPERIENCE – SHALE INDUSTRY

Canada Brick Mississauga, ON	Specialist for assessment of geological controls upon shale quality at the Canada Brick Britannia Road quarry site. The work was carried out in conjunction with quality control estimate of shale reservoir on the property.
Canada Brick Halton Region, ON	Project Manager for a hydrogeological work program in support on an application for a license for the Hanson Brick Tremaine Quarry in Halton Region, Ontario.
Brampton Brick Limited Halton and Peel Region, ON	Project Director for a hydrogeological and surface water program in support of a license application for a proposed shale quarry for a brick manufacturer. The work programs involved borehole drilling and monitoring well installations, surface water flow monitoring, water quality sampling, groundwater flow modelling and preparation of an Adaptive Management Plan (AMP).
Hanson Brick Limited Halton Region, ON	Project Director for the assessment of the potential gas migration from a landfill to an adjacent brick manufacturing facility containing a brick kiln. The program identified potential risks and a monitoring and response program.

PROJECT EXPERIENCE – MINING

Stanleigh Mine Elliot Lake, ON	Project Hydrogeologist for assessment of the Rio Algom Stanleigh Mine near Elliot Lake, Ontario. The project included development of a three-dimensional flow model of a low-level radioactive waste tailings facility in Precambrian bedrock of the Canadian Shield. The model was used to develop estimates of seepage rates from the facility and was submitted to the Atomic Energy Control Board (AECB) as part of the regulatory approvals process.
Voisey's Bay Mine Labrador	Technical specialist for hydrogeological modelling at the Voisey's Bay Mine site involving development of three-dimensional groundwater flow models of a proposed tailings basin, mine waste rock disposal facility, and an open pit mine at the Voisey's Bay Mine Site in Labrador. The modelling was carried out for the Voisey's Bay Nickel Company (VBNC) as part of the hydrogeological assessment of the mine. The work was subject to regulatory review and presented as evidence at an environmental assessment hearing.
Baley Gold Mine Baley, Russia	Project Hydrogeologist for an Environmental Impact Assessment (EIA) as part of a feasibility study for mine expansion. The hydrogeological component included evaluation of potential for water quality impacts for an open pit mine and tailings basin, reduction of flow in stream and interference with the municipal water well supply.
Asacha Gold Mine Kamchatka, Russia	Project Hydrogeologist of the proposed Asacha Gold Mine in northeastern Russia. The assessment focused upon chemical water quality and streamflow impacts associated dewatering of an underground mine and construction of a tailings basin. The results of the assessment formed part of the mine feasibility study.

Timmins Mine Water Study Timmins, ON	Project Hydrogeologist for assessment of flooding of an extensive array of underground mine working beneath the City of Timmins. The assessment included evaluation of the potential impacts arising from the discharge of water from the flooded mine workings at surface within the city.
Cigar Lake Mine Saskatchewan	Project Hydrogeologist for assessment of potential groundwater inflows into proposed shaft in northern Saskatchewan for the Cigar Lake Mining Corporation (CLMC). The results of the assessment were used as the basis for the engineering design at the shaft.
Denison Mines Elliot Lake, ON	Project Hydrogeologist for an assessment of low-level nuclear waste tailings basin at the Denison Mines near Elliot Lake, Ontario. The hydrogeology study included assessment of seepage of uranium-impacted groundwater from the basin.
MaCassa Mines Kirkland Lake, ON	Project Hydrogeologist for hydrogeological assessment at the Lac Minerals MaCassa Mine tailing basins in Precambrian bedrock near Kirkland Lake, Ontario. The work was carried out to evaluate the potential impacts during operation and following decommissioning of the facility.

PROJECT EXPERIENCE – CONTAMINATED INDUSTRIAL SITES

ICI Nobel, ON	Hydrogeological assessment of groundwater and surface water quality at the former ICI explosives and war productions plant near Parry Sound, Ontario for ICI Canada. The program included assessment of groundwater and surface water quality impacts and removal of buried underground fuel storage tanks. The results of the investigations were submitted to the Ontario Ministry of the Environment as part of the site decommissioning.
Ford Motor Company North York, ON	Dewatering of a groundwater collection gallery and discharge of the contaminated (chlorinated solvent) wastewater to the municipal sewer system (under special conditions), at the Ford Motor Company Plant in North York, Ontario.
Shell Oil North York, ON	Dewatering of a groundwater collection gallery and discharge of the contaminated (chlorinated solvent) wastewater to the municipal sewer system (under special conditions), at the Ford Motor Company Plant in North York, Ontario.
Beaver Lumber Cole Harbour, NS	Excavation of underground storage tank (fuel oil) at the Beaver Lumber store at Cole Harbour, Nova Scotia. The results of the investigation favoured Beaver Lumber, by indicating that damage to the store was due to lack of delivery of the fuel supplier rather than leakage from the site fuel storage tank.
ICI Surfactants Oakville, ON	Hydrogeological impact assessment of cadmium concentrations in groundwater at the ICI Surfactants (formerly Atkemix) site in Oakville, Ontario. The results of the monitoring were submitted to the Ministry of Environment and Energy for regulatory purposes.

Bata Footwear
Batawa, ON

Participation in the hydrogeological investigation of chlorinated solvent contamination of a bedrock limestone aquifer at the Bata Footwear plant site in Batawa, Ontario. The results of the hydrogeological impact assessment were submitted to the Ministry of Environment and Energy and used during subsequent legal proceedings to determine financial liability of Bata Footwear for the groundwater contamination.

Niagara Recycling Centre
Niagara Falls, ON

Project Director and senior hydrogeologist for the annual operational and monitoring programs for a hydrogeological work program involving groundwater contaminated with chlorinated solvents at the Niagara Recycling Centre related to prior industrial land use. The work program involved operation of the groundwater injection remediation system, assessment of subsurface contamination and preparation of annual monitoring reports.

Rankin Construction Fill Management Plan
Port Colborne, ON

Project Director and senior geoscientist for the development of a fill management plan for Pit 1 at the Rankin Construction Port Colborne Quarry. The program included a plan to take excess fill from the area to fill Pit 1. This included a sampling and reporting program to meet MECP requirements.

PROJECT EXPERIENCE – OIL & GAS

Assessment of Natural Gas Storage Potential
Lake Erie, ON

Project Manager for an assessment of the potential for natural gas storage on Crown Lands beneath Lake Erie. The study involved the assessment of natural gas reservoirs to evaluate their suitability for use as gas storage facilities. Estimated available storage volumes were provided for each of the reservoirs.

Assessment of Natural Gas Storage Potential
Southwestern Ontario

Project Manager for an evaluation of the hydrocarbon resources in Southwestern Ontario for the Petroleum Resources Centre of the Ministry of Natural Resources. The study included the interpretation and mapping of pool boundaries for major pools, calculations of in place and recoverable reserves, tabulation of reservoir characteristics, and estimation of potential hydrocarbon resources in the Ordovician strata of southern Ontario.

PROJECT EXPERIENCE – MUNICIPAL GROUNDWATER STUDIES

Groundwater Study for the County of Victoria
ON

Project Director and senior hydrogeologist for a large-scale groundwater study for the County of Victoria with funding from the Provincial Water Protection Plan (PWPP). The work program involved a groundwater resource assessment, evaluation of existing groundwater usage, contamination assessment, development of management options and protection strategies, and an economic evaluation.

Groundwater Study for the City of Stratford
ON

Project Director and senior hydrogeologist for a Groundwater Study for the City of Stratford involving an assessment of groundwater resources, source of contamination, pump testing of deep wells in limestone bedrock, and development of groundwater management options and protection strategies.

Simcoe and South Simcoe Groundwater Studies
ON

Provided specialist hydrogeological services for both the North Simcoe Groundwater Study and South Simcoe Groundwater Study. The work program involved a characterization of the hydrogeology of the study areas and numerical groundwater modelling of Well Head Protection Areas for municipal wells (WHPAs).

PROJECT EXPERIENCE – KARST

Nelson Quarry Extension
ON

Project Director and Senior Hydrogeologist for karst assessment of the proposed Nelson Quarry extension that involved mapping of the Amabel Formation along the exposed cliff faces of the Mount Nemo outlier, identification of karstic springs in the Medad Valley and associated water courses, mapping of karst features along more than 1 km of exposed quarry faces. Examination of surface karst features including sinkholes and internal drainage were mapped in the area of the quarry. An ERI (Electrical Resistivity Imaging) survey was conducted over a linear distance to identify potential anomalies that could represent karstic features. Boreholes were drilled into the karstic features to evaluate karstic conditions. The boreholes were video logged along the length of the hole to evaluate karstic features such as solution enlarged fractures and voids. The flow in the boreholes were pumped and logged during an impeller flow meter to assess inflow into boreholes from potential karstic features. An array of 8 wells and a pumping well were drilled to conduct a tracer test using fluorescein dye. The dye was injected into the wells and the travel time and dye concentrations were recorded to evaluate karstic flow paths and velocities. The results were incorporated in a report submitted as part of the regulatory approvals process and presented and defended at an Ontario Municipal Board hearing.

Proposed Redland Quarries Landfill
ON

Project Hydrogeologist for a karst study as part of a geological and hydrogeological evaluations of a proposed hydraulic containment engineered landfill facility in a quarry near Dundas, Ontario. The karst study involved examination and evaluation of karstic features in the vicinity of the quarry including solution-enhanced weathering and extensive network of surficial dolostone plain, and examination of epi-karst on more than 1 km of quarry faces including solution enlarged and materialized vertical joints. The results of groundwater level monitoring results were evaluated for patterns indicative of presence of karst including rapid rises in groundwater levels (‘spiking’). Pump tests were analysed to evaluate the drawdown and recovery responses characteristic of karst.

Proposed Dundas Quarry Extension
ON

Project Director and Senior Hydrogeologist for a karst assessment as part of a hydrogeological work program for the approval of an application for a large dolostone quarry near Dundas, Ontario. The work program involved an ERI surface geophysical survey along more than 500 m of line to test for potential karstic anomalies. Boreholes were drilled in the areas of identified anomalies to evaluate the potential presence of karst. The faces of the quarries were also examined for layers of karstic groundwater inflow. The results of the karst study have been peer reviewed and are currently being used in support of the license application for quarry expansion.

Karst Remediation
Hamilton, ON

Senior Hydrogeologist for a karst assessment of a remediated industry site in the area of the Eramosa Karst Conservation Area in Hamilton, Ontario. The work program involved a review of literature on karst in the area. An inspection of the karstic features includes sinkholes, internal drainage and inferred subsurface karstic flow pathways was undertaken in areas around the site. A report in support of a property transaction was provided to regulatory authorities and agencies.

Brow Landfill Monitoring Program
ON

Project Hydrogeologist for an assessment of leachate seepage from an industrial solid waste landfill along karstic flow pathways including epi-karst, solution weathered vertical joints and horizontal fracture networks. The assessment involved monitoring of the flow rates from leachate springs and water quality of springs.

Hydrocarbon Reserve Evaluation
Southwestern Ontario

Project Director and Senior Geologist/Hydrogeologist for the estimation of hydrocarbon reserves in Southern Ontario for the Petroleum Resource Centre of Ontario Ministry of Natural Resources. The work program involved extensive analysis of karstic reservoirs formed and dolomitization from solution weathering and collapse along vertical joints and horizontal sub horizontal fracture networks. Prepared a report summarizing the study and provided to the MNR as a commercial publication.

PROJECT EXPERIENCE – LAND DEVELOPMENT AND INFRASTRUCTURE

Peer Review, Town of Caledon
Caledon, ON

Peer review of the hydrogeological work program for a proposed residential development in Palgrave for the Town of Caledon planning department. The work program involved review of hydrogeological reports, discussions with the Town and preparation of a peer review reports with recommendations.

Peer Review, Town of Caledon
Caledon, ON

Peer review of the hydrogeological and geotechnical work program for a proposed residential development in Beaverhall for the Town of Caledon planning department. The work program involved review of hydrogeological reports, discussions with the Town and preparation of a peer review reports with recommendations.

Niacon Construction
Niagara-on-the-Lake, ON

Hydrogeological assessment of the potential impacts associated with the development of an infrastructure for a zipline facility along the Niagara river at Thompsons Point. The work program involved an evaluation of the potential for reduction of groundwater seepage along the Niagara Gorge and related environmental effects. A report was prepared that was submitted to agencies as part of the regulatory approvals process.

Time Developments
Niagara Falls, ON

Senior hydrogeologist for the hydrogeological assessment of the existing conditions and potential impacts associated with the development of a condominium adjacent to the Niagara River in Niagara Falls. The work program involved borehole drilling, monitoring wells installation, groundwater level monitoring and assessment of groundwater levels and flow directions. The results of the work program were incorporated into a geotechnical and hydrogeological report.

Time Developments Niagara Falls, ON	Phase 1 and Phase 2 Environmental Site Assessments (ESA) for regulatory approval for condominium development on River Road in Niagara Falls, Ontario. The work program involved test pitting and surface sampling as well as collection and analysis of soil and water samples and evaluation of potential soil and water contamination.
AECOM Oakville, ON	Hydrogeological assessment of the excavation and construction of a water pumping station in till and bedrock adjacent to a surface water course. The work program involved borehole drilling, monitoring well installations, hydraulic conductivity testing and a hydrogeological assessment of impacts on surrounding private wells associated with construction dewatering.
Geranium Homes Woodview Development ON	Hydrogeological assessment in support of approval for a proposed residential development involving borehole drilling, monitoring well installations, hydraulic conductivity testing, groundwater level monitoring, determination of groundwater levels and flow directions and a hydrogeological impact assessment involving a water balance to evaluate reduction in infiltration and potential interference with surrounding water wells and effects on an adjacent provincially significant wetland. Participated in meetings with the TRCA as part of the approvals process. A report was prepared in support of the approvals process.
Geranium Homes Altona Development ON	Hydrogeological assessment in support of approval for a proposed residential development. The work program involved borehole drilling, monitoring well installations, groundwater level monitoring, development of a water balance and a hydrogeological impact assessment. A report was prepared in support of the application.

Education

B.Sc. (Hons) Geological Sciences and Chemistry (Hon.), Brock University, Canada, 1983

Languages

English – Fluent

Golder Associates Ltd. – Mississauga

Senior Mining / Vibration Consultant

Daniel Corkery is an Associate and Senior Blasting / Vibration Consultant with Golder Associates.

Daniel has 34 years of professional experience, 30 years in blasting. His experience includes work in quarry, open pit, underground, construction, demolition and marine blasting. Daniel has conducted several comprehensive studies for open pit blasting operations which involved modelling the vibration, air and water overpressure, flyrock, wall control and fragmentation. He has prepared Blast Impact Assessment for proposed operations as well as extensions to existing quarries and open pit mines across Canada and internationally.

Daniel has provided testimony before an arbitration hearing assessing the blasting techniques to produce armour stone at an existing rock quarry. He provided expert testimony regarding potential impact of blasting operations during permitting hearing for a proposed expansion of an aggregate quarry in Southern Ontario. He provided expert opinion on the blasting practices of a contractor and the potential for nitrate impact on the local groundwater. Daniel provided expert opinion on the potential cause of flyrock at an aggregate quarry near Halifax, Nova Scotia.

Employment History

Golder Associates Ltd. – Mississauga, Ontario

Associate, Senior Blasting / Vibration Consultant (2014 to Present)

Responsible for the blast consulting projects in various sectors of the blasting industry. These include blast impact assessments, blast design, compliance and near-field vibration monitoring, fragmentation analyses, pre-construction surveys and environmental control. Responsible for design, oversight and senior review of vibration monitoring control projects for construction operations across Canada.

Golder Associates Ltd. – Sudbury, Ontario

Senior Mining Consultant / Geologist (2003 to 2014)

Responsible for blast impact assessments, blast design, compliance and near-field vibration monitoring, fragmentation analyses, pre-construction surveys, data collection and analysis and report preparation for projects in various sectors of the blasting industry. Responsible for geological and mineral assessment compilations, geological mapping as well as site supervision, logging and data analysis for geological and geotechnical drilling programs.

Explotech Engineering Ltd. – Sudbury, Ontario

Senior Blasting Consultant / Geologist (1989 to 2003)

Involved in underground, quarry, construction, demolition and marine blasting, as well as blasting operations for pipeline and hydroelectric power plant operations. Handled blast monitoring, blast performance, vibration analysis, and investigations of blast damage complaints. Conducted near-field underground blast vibration monitoring for optimization of development and stope blasts as well as timing

assessments of prototype detonators. Conducted VOD measurements for blasting at quarries and mining operations. Provided geological interpretations for blasting in complex terrain.

Geocanex Ltd. – Toronto, Ontario
Project Geologist (1985 to 1989)

Responsible for the coordination and execution of exploration projects, predominantly in Northwestern Ontario, Canada. Responsible for crew of up to 10 geologists, engineers and technicians. Projects typically involved the integration of geophysical and geochemical surveys with geological mapping and subsequent diamond drilling projects. Managed diamond drilling projects and prepared summary reports.

PROJECT EXPERIENCE – CONSTRUCTION VIBRATION MONITORING

Urban Infrastructure Construction Monitoring
Ontario, Canada

Designed and oversaw vibration monitoring projects for a range of construction operation types and assessment of the potential impact of the vibrations. This included operations adjacent infrastructure as well as heritage and historic structures.

Traffic Vibration Impact Studies
Ontario, Canada

Implementation, analysis of traffic vibration impact studies in the Sudbury and Cochrane regions, Ontario.

PROJECT EXPERIENCE – OPEN PIT AND QUARRY BLASTING

Expert Opinion and Testimony
Canada

Provided expert testimony at an Ontario Municipal Board hearing regarding the potential impact of blasting operations at a proposed expansion of an aggregate quarry in Southern Ontario.

Provided expert opinion to the Ontario government on blast practices for a road construction project related to the potential for release of nitrates to the local groundwater. The work included a review of documents including blasting design reports and logs.

Provided expert opinion on the potential cause of flyrock at an aggregate quarry near Halifax, Nova Scotia. The work included a site visit, a review of documents (including drilling and blasting logs and as-built reports) and preparation of a summary report of findings.

United States

Provided testimony before an arbitration hearing assessing the blasting techniques to produce armour stone at an existing rock quarry. The work included a site visit, review of extensive documentation (including drilling and blasting logs and as-built reports), preparation of a summary report on finding.

Drilling and Blasting Audit
Northwest Territories, Canada

Carried out a drill and blast audit of the surface and underground operations at a diamond mine in Northwest Territories, Canada. The work entailed a review of the drilling and blasting practises. Recommendations were provided for blasting optimization and mitigation of nitrate losses to the environment.

Nunavut, Canada

Carried out a drill and blast audit including data review, site observations, discussions of the conceptual blast designs for the various types of blasts at the mine and recommendations regarding optimization of the blast designs.

Quebec, Canada	Conducted a study to assess the wall control practices and the resulting final wall at an open pit gold mine in western Quebec.
General Blasting Requirements Minnesota, United States	Carried out a review of the blasting requirements, ROM fragmentation distribution prediction and drillability assessment an open pit project in north-eastern Minnesota.
Quebec, Canada	Carried out a study to assess the practicality of mining an open deposit overlooking existing infrastructure at an operating open pit mine. The study included assessments of the potential impact from flyrock, vibrations and the estimated fragmentation size distribution of possible blast designs. A follow-up study provided a calibration of the flyrock, vibrations and the estimated fragmentation size distribution models for current nearby pit. Recommendations regarding blast design were provided.
Armenia	Provided ongoing blast consultation services for the construction operation prior to the open pit development at a gold mine in Armenia.
Fragmentation Assessments Mexico	Preparation of a fragmentation prediction report for Wheaton Mineral's Los Filos Project, Guerrero, Mexico. Analysis and report preparation for a blast fragmentation prediction at the Peñasquito Silver Project in Zacatecas State, Mexico.
Riprap Assessments Quebec, Canada	Assessment of blast fragmentation and size distribution for riprap at a) the CA-606 Quarry and b) the Canal D'Amenée, Rupert Diversion Project, James Bay, Quebec. Assessment of blast fragmentation and size distribution for riprap at the CF4 Quarry, Eastmain-1 Hydroelectric Project, Quebec.
Explosive Performance Ontario, Canada	Conducted VOD measurements and analysis for an explosive's distributor at an Oakville quarry as part of an explosive assessment/troubleshooting study. Provided explosive VOD measurement and analysis for production blasts at a graphite near Kearney, Ontario.
Blast Vibration Monitoring and Analysis Canada	Blast vibration monitoring and analysis for an investigation of blast induced pore pressure beneath the dike at Diavik Diamond Mines Inc.'s open pit diamond operation in Northwest Territories. Blast monitoring and the development of a blast vibration regression analysis for the open pit operation in Timmins. Blast and vibration monitoring and analysis for Rainbow Concrete Industries' quarries in North Bay and Maley Drive in Sudbury, Ontario. Prepared a blast vibration attenuation analysis for a quarry operator in Bruce Mines. Established vibration and overpressure attenuation curves in preparation of the expansion of a large open pit in Timmins, Ontario.

PROJECT EXPERIENCE – BLAST IMPACT ASSESSMENTS

Blast Impact on Heritage Structures Nova Scotia	Provided a review of proposed blasting near a heritage structure in Halifax, Nova Scotia. The work included a site visit, a review of documents (including proposed blast design) and a provision of a summary report (including best practises and recommended blast vibration limits for heritage structures).
NWT and Nunavut, Canada	Identification and quantification of nitrate sources related to the blasting at the surface and underground operations at a diamond mine in Northwest Territories, Canada.
	In support of a feasibility study, carried out a study to assess the potential impact of mining an open deposit. The study included assessments of the potential impact from vibrations, flyrock, water overpressure on fish, the estimated fragmentation size distribution of possible blast designs as well as the relative costs for drilling and blasting the proposed designs.
Open Pit Environmental Impact Ontario, Canada	Carried out a study to assess the potential impact of mining a proposed open pit deposit adjacent residential and industrial areas in Timmins, Ontario. The study included assessments of the potential impact from vibrations, flyrock, air and water overpressure, and the estimated fragmentation size distribution of possible blast designs.
	Prepared a blast vibration impact assessment as a part of a larger Environmental Impact Assessment for a proposed open pit operation near the town of Atikokan.
	Prepared a blast vibration impact assessment as a part of a larger Environmental Impact Assessment for a proposed operation in the “Ring of Fire” in Northern Ontario.
	Prepared a blast vibration impact assessment as a part of a larger Environmental Impact Assessment for a proposed open pit operation near the town of Dubreuilville.
British Columbia, Canada	Carried out a study to assess the potential impact of mining a proposed open pit coal deposit adjacent an existing natural gas coal mine in Southeastern British Columbia. Recommendations for blast designs and mitigation strategies were provided.
	Provided an assessment of the potential impact of open pit coal blasting on nearby tailings embankment. Recommendations for vibration limits, mitigation strategies and response frameworks were provided.
Northwest Territories, Canada	Assessed the potential impact of construction blasting on a tailings embankment at an existing mining operation. Provided analysis and guidance regarding recorded blast vibrations at the embankment and adjacent grout curtain.

Blast Impact on Tailings Embankments
Australia

Prepared a blast impact assessment for the blasting operations to be carried out adjacent an active mine tailings storage facility for the Solomon Hub Iron mine in Western Australia.

Prepared a blast impact assessment for the blasting operations to be carried out adjacent a mine tailings embankment for Rio Tinto's Yandicoogina mine in Western Australia. The project entailed the development of a mitigation strategy, blast design review and assistance with the development of a site-specific attenuation model.

Ireland

Prepared a stability review and assessment of the potential impact of blasting on the embankments and raises associated nearby residue disposal area at the Aughinish Alumina refinery, Ireland.

Nitrate Mitigation Studies
Canada

Identification and quantification of nitrate sources related to the blasting at the surface and underground operations at a diamond mine in Northwest Territories, Canada.

Data collection, analysis and report preparation for an investigation of ammonium nitrate loss to the mine discharge water at Diavik Diamond Mines. Identification and quantification of nitrate sources related to the blasting at the open pit operations at an iron mine in Labrador, Canada. The study also included recommendations for measures to mitigate the nitrate losses from blasting.

Conducted an audit of current blasting practices and explosives handling procedures at diamond mine in the Northwest Territories, Canada that identify the nature and potential magnitude of nitrogen compound sources and developed an implementation plan to address the recommendations from the audit.

Quarry Environmental Impact
Ontario, Canada

Prepared Blast Impact Analysis reports for quarry operations across Ontario in support of the permitting of new quarries or extension of existing quarries. This included reporting and technical representation for blasting issues at a public information session.

Participated in Public Information Session for a number of operations Ontario to discuss the blasting impact related to a proposed quarry expansion.

Attended a "Community Advisory Panel" for a number of quarries in Ontario as a blasting consultant to discuss the blasting impact related to ongoing quarry blasting operations.

PROJECT EXPERIENCE – CIVIL BLASTING

Urban Blasting
Ontario, Canada

Provided vibration monitoring and consulting services for numerous blasting operations in urban settings and in close proximity to existing infrastructure. This included blast design and recommendations for risk mitigation.

Blast Monitoring and Consulting
Ontario, Canada

Blast monitoring and consulting for blasting contractor during the expansion of the sewage treatment facility in Fort Francis, Ontario.

Blast monitoring and consulting to TransCanada Pipelines Limited for the construction and upgrading of natural gas pipelines across Ontario. This included both mainline and station blasting operations.

Blast monitoring and consulting to CentraGas (now Union Gas) for operations associated with the installation of main natural gas service lines in Sudbury, Ontario.

Blast monitoring and consulting for installation or upgrading of several hydro generating stations in Ontario, Canada. These include the following projects: Great Lakes Power's High Falls Rehabilitation Project, Wawa; Ontario Hydro's Matabitchuan Power Station Rehabilitation, North Cobalt; Ontario Hydro's Big Chute Generating Station Redevelopment, Port Severn; Ontario Hydro's Sluiceway Safety Upgrading at the South Falls GS, Bracebridge; E.B. Eddy's Paper Plant Power Plant Installation, Espanola; and Conwest Ltd.'s Black River Power Plant Generating Station Installation, Heron Bay.

Highway Construction
Britsh Columbia, Canada

Provided support for the slope reprofiling blasting operations for the highway through Yoho National Park. The work included a drill and blast audit and ongoing support of the blasting operations regarding safety, blast designs, submissions and wall control strategies.

Ontario, Canada

Blast consulting to the Ontario Ministry of Transportation during road construction blasting operation on Highway 69, south of Sudbury. Responsibilities included the assessment of results of wall control blasting and quality assurance report on the vibration monitoring program conducted by the blasting contractor's blasting consultant.

Assessment and recommendations for wall control blasting operations conducted for the twinning of Highway 69 near Parry Sound, Ontario.

Blast Specifications and Audits
Ontario, Canada

Carried out a study to evaluate the potential effects of blasting, a vibration audit of the site preparation blasting operations and preparation of a performance specification for the pre-split blasting conducted for the installation of the No. 4 Air Separation Unit, Inco/Vale Smelter Complex, Copper Cliff, Ontario.

Assisted in the preparation of blasting specifications for the surface site preparations required during the mine infrastructure development at a project near Falconbridge, Ontario.

Geotechnical mapping (surface and underground), logging, analysis blast damage assessment for the Sudbury Sewer Tunnel Project, Sudbury, Ontario.

Saskatchewan, Canada

Assisted in the preparation of blasting specifications for the blasting operations required during the installation of a natural gas pipeline in La Ronge, Saskatchewan.

PROFESSIONAL AFFILIATIONS

Member, International Society of Explosives Engineers (ISEE)

Member, Canadian Institute of Mining and Metallurgy

PUBLICATIONS

Conference Proceedings

Corkery, D., N. Lauzon and D. Sprott. 2010. *Reducing Ammonium Nitrate Loss to Mine Discharge Water.* CIM Mine Operators Conference. Sudbury, Ontario, Canada.

Corkery, D. and R. Wing. 1993. *Controlled Study of the Effects of Temperature and Humidity Versus Blasting Vibrations on Homes*. Nineteenth Annual Conference on Explosives and Blasting Technique, International Society of Explosive Engineers., Canada.

Cameron, A., D. Corkery, B. Forsyth, T. Gong and G. MacDonald. 2007. *An Investigation of Ammonium Nitrate Loss to Mine Discharge Water at Diavik Diamond Mines*. Explo 2007, Blasting: Techniques and Technology, Australian Institute of Mining and Metallurgy., Australia.

Journal Articles

Corkery, D.J., E.G. Lorek and H.R. Williams. A study of Joints and Stress Release Buckles in Palaeozoic Rock of the Niagara Peninsula, Southern Ontario. *Canadian Journal of Earth Sciences*, 25 (1985)

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