REPORT

BLAST IMPACT ASSESSMENT

Port Colborne Quarries Inc., Port Colborne Quarry, Proposed Extension

Submitted to:

Rankin Construction Inc.
222 Martindale Road
PO Box 1116
St. Catharines, ON L2R 7A3
Attn: Shawn Tylee, C.E.T.
Manager of Procurement and Corporate Affairs

Submitted by:

Golder Associates Ltd.
6925 Century Avenue, Suite #100 Mississauga, Ontario, L5N 7K2 Canada

+1 905 567 4444

1771656

July 2020

Distribution List

1 PDF Copy - Rankin Construction Inc.

1 PDF Copy - Golder Associates Ltd., Mississauga

Executive Summary

The Port Colborne Quarries Inc. (PCQ) is proposing to establish an extension to Pit 3 of their existing aggregate quarry in the Port Colborne, Ontario. 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 within the proposed Port Colborne Quarry Pit 3 Extension 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.

PCQ provided vibration monitoring data from the existing quarry monitoring. However, the limited range of separation distances from the blasts to the nearest monitoring locations resulted in data that was clustered and not appropriate for the development of attenuation models. As such, ground and air vibration attenuation characteristics were estimated based on blast monitoring data collected by Golder Associates Ltd. (Golder) at other limestone quarry operations in Southern Ontario. The results indicate that the majority of the proposed Port Colborne quarry Pit 3 Extension 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 proposed quarry would have no impact on the integrity of adjacent water wells.

By maintaining ground and air vibration levels during blasting operations at the proposed Pit 3 Extension 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 quarry.

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

PCQ, a division of Rankin Construction Inc. (Rankin) is proposing an extension to Pit 3 of their existing Port Colborne Quarry in order to continue mining of the aggregate resources.

In order to satisfy the requirements of the Ontario Aggregate Resources Act (ARA) with regard to a Category 2, Class "A" Quarry Below Water license application certain plans and studies are required to identify the effects of the proposed quarry and studies are required to identify land use impacts of the proposed quarry and to mitigate such effects so that established MECP thresholds are met. Blasting is part of the routine operations of a quarry in order to extract the limestone bedrock. In this regard, PCQ requested that Golder aid in the development of a blast impact assessment (referred to in the ARA as a Blast Design Report) for the proposed Pit 3 Extension property (Site).

1.1 Port Colborne Quarry Pit 3 Extension

The existing Port Colborne Quarry is located in the City of Port Colborne within the Regional Municipality of Niagara. The existing quarry is bounded by Second Concession Road to the north, Highway 140 to the west, Main Street East (Highway 3) to the south, and 200 metres west of Carl Road to the east. The Site is situated directly east of the existing quarry and remains between Second Concession Road to the north and Highway 3 to the south and extends approximately 410 - 790 metres east of Carl Road (see Figure 1). The Port Colborne Quarry Extension is located in Part of Lots 18 and 19 Concession 2, Humberstone Township, Regional Municipality of Niagara and comprises 108.25 hectares (267.49 acres). The property is bisected bordered by Second Concession Road to the north, Main Street East to the south, the existing Port Colborne quarry to the west and agricultural fields and Humberstone Speedway to the west.

1.2 Required Land Use Approvals

In order for extraction to occur on the subject lands, the following approvals are required:

- Amendment to the Region of Niagara Official Plan 2014, to designate the lands as Licensed Pits and Quarries.
- Amendment to the City of Port Colborne Official Plan 2017, to redesignate the lands from Agricultural to Mineral Aggregate Operation.
- Amendment to the City of Port Colborne Zoning By-Law 6575/30/18, to rezone the lands from Agricultural (A) to Mineral Aggregate Operation (MAO).
- Application to the Ministry of Natural Resources, under the Aggregate Resources Act for a Class A Category 2 Licence (Quarry Below Water).

1.2.1 Region of Niagara Official Plan (ROP) 2014

Policy 6.C.13 of the Region of Niagara ROP states: "Where a new pit or quarry or an extension to an existing licensed pit or quarry are to be located outside a Possible Aggregate Area, an amendment to this Plan is required." As the subject lands are not within a Possible Aggregate Area, a Regional Official Plan Amendment through the Region of Niagara is required to identify the subject lands on Schedule D4 - Mineral Resources.

1.2.2 City of Port Colborne Official Plan (OP) 2017

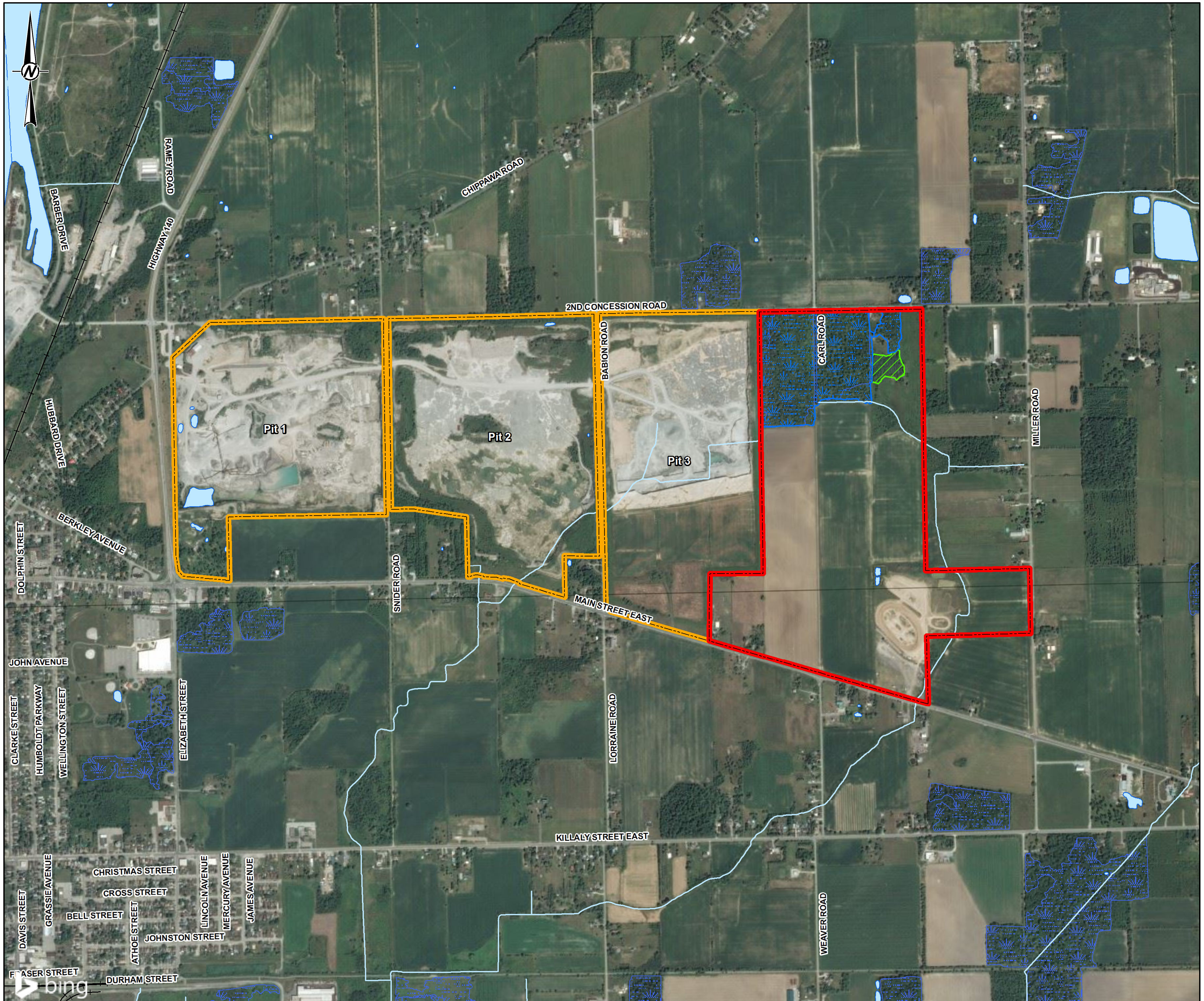
Policy 10.2 of the City of Port Colborne OP states: "The establishment of a new or an expansion to an existing mineral aggregate operation shall require an amendment to this Plan…" Therefore, an Official Plan Amendment through the City of Port Colborne is required.

1.2.3 City of Port Colborne Zoning By-Law No. 6575/30/18:

The lands are currently zoned (A) Agricultural within the City's Comprehensive Zoning By-Law. Extraction and related uses are not a permitted use. Therefore, the lands must be rezoned to (MAO) Mineral Aggregate Operations in order to permit extraction and all the permitted accessory uses. This requires an amendment to the City's Zoning By-Law No. 6575/30/18.

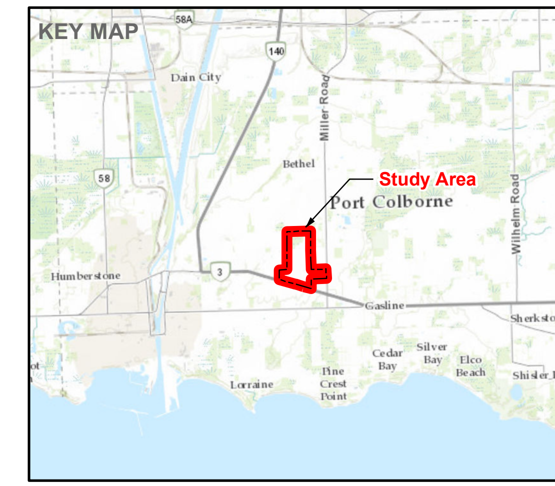
1.2.4 Aggregate Resources Act

In addition to the above Planning Approvals, PCQ also requires approval for a Class A Category 2 (Quarry Below Water) License under the Aggregate Resources Act as processed through the Ministry of Natural Resources and Forestry.



LEGEND

- Roads
- Railway
- Watercourse
- Wetland
- Woodland
- Waterbody
- Proposed Quarry Extension
- Property Boundary



0 500 1,000

1:15,000 Meters

NOTE(S)

REFERENCE(S)
1. BASE DATA: MNRF LIO 2016
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
© 2020 MICROSOFT CORPORATION © 2020 MAXAR ©CNES (2020) DISTRIBUTION AIRBUS DS
3. PROJECTION: TRANSVERSE MERCATOR NAD 1983 UTM ZONE 17N

CLIENT
RANKIN CONSTRUCTION

PROJECT
PROPOSED PORT COLBORNE QUARRY EXTENSION

TITLE
SITE LOCATION PLAN - BLAST IMPACT

CONSULTANT

GOLDER

YYYY-MM-DD	2020-07-14
DESIGNED	PR
PREPARED	PR
REVIEWED	DC
APPROVED	SM

PROJECT NO.	CONTROL	REV.	FIGURE
1771656	0006		1

PATH: S:\Clients\Rankin_Construction\Port_Colborne_Quarry\99_PROJ\1771656_1970065_Ontario_ESA\40_PROD\0006_BlastingImpact\1771656-0006-CH-0001.mxd PRINTED ON: 2020-07-14 AT: 9:03:39 PM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

25mm

1.3 Overview of the Study

The blasting impact assessment addresses the environmental effects from future blasting operations within the proposed Pit 3 extension areas of the Port Colborne Quarry. The impact assessment specifically addresses whether the applicable Ontario MECP guidelines with respect to ground and air vibration effects can be met at the residential properties nearest to the proposed extension. Historical blast monitoring results were reviewed as part of this study.

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 quarry’s 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.

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.

This report addresses the following topics:

- Reviews of the 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.

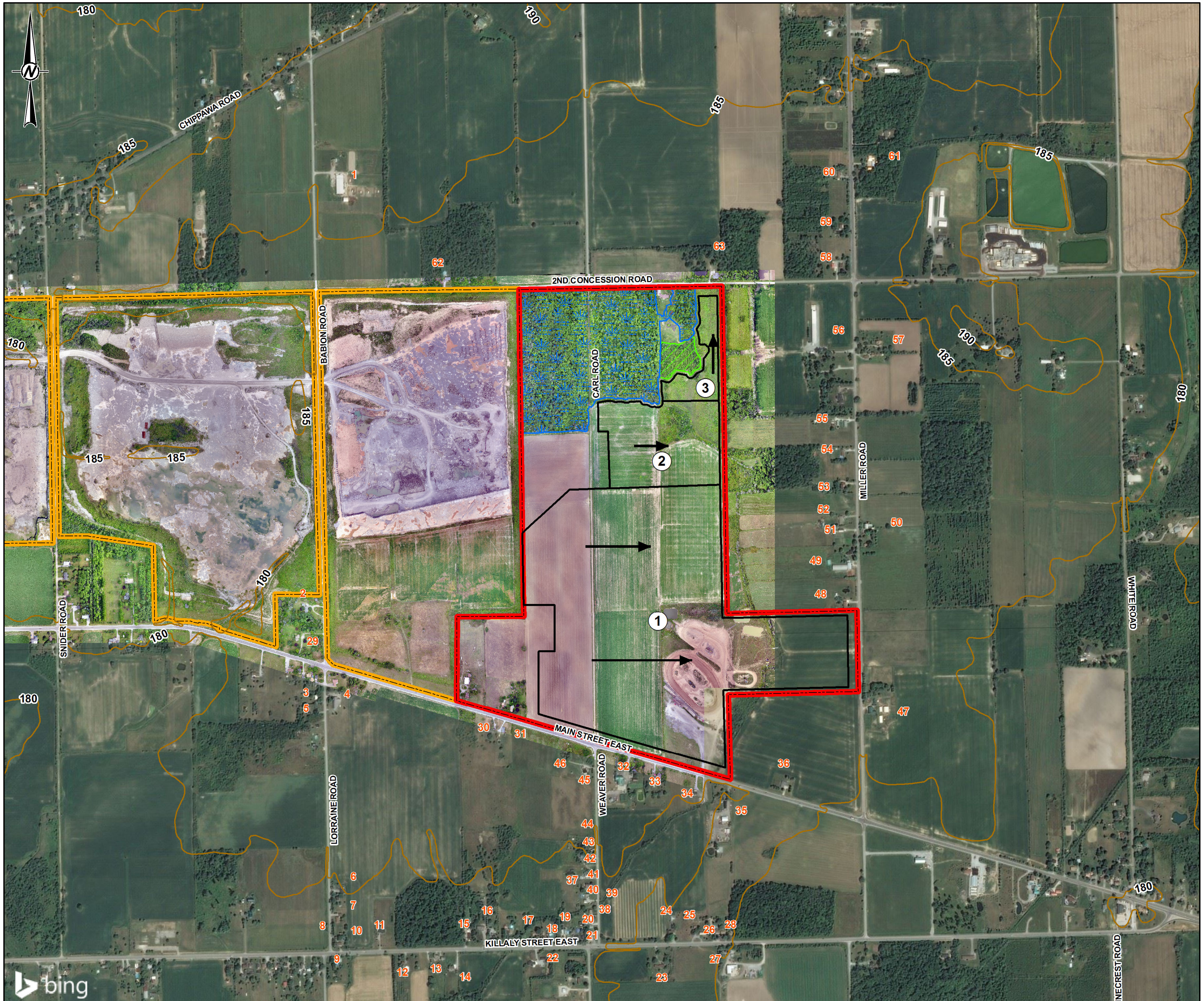
2.0 PROPOSED QUARRY EXTRACTION AND BLAST PROCEDURE

The proposed extension will operate as a continuation to the existing quarry. The proposed quarry will not result in an increase in permitted production levels.

Site preparation and extraction in the Pit 3 Extension will commence when Pit 3 of the existing quarry is nearing completion. Initially, there will be no processing at the Site. Initially, blasted aggregate will be transported by quarry trucks to the main existing processing facility within Pit 1. Eventually (during Phase 1 of Pit 3 Extension), the processing facility will be relocated to within the existing Pit 3 site. . Shipping to market will be status quo as it will utilize the existing entrance / exit and established haul routes. A new entrance will be eventually established onto Miller Road, and/or directly onto Highway 3. The proposed phasing for the extension area is shown in Figure 2.

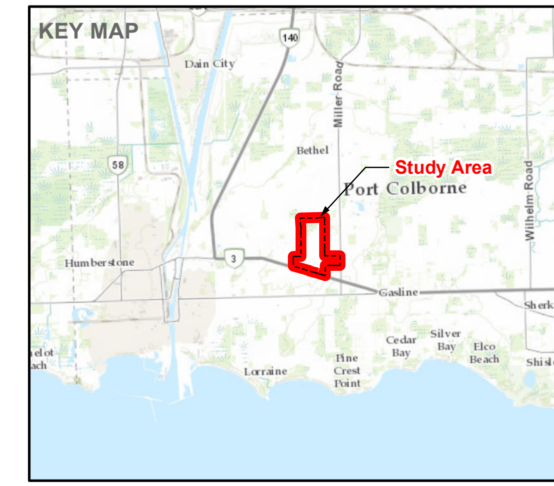
The quarry is anticipated to operate throughout the year.

Blasting procedures within the proposed extension 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. We anticipate that blasting will occur from two to five times per week in each cell at peak production levels. The duration of each blast would generally be less than about one second.



LEGEND

63	Sensitive Receptor
1	Excavation Phase
	Excavation Direction Arrow
	Contours
	Wetland
	Woodland
	Approximate Excavation Phasing Boundary
	Proposed Quarry Extension
	Property Boundary



0 0.4 0.8

1:12,000 Kilometers

NOTE(S)

REFERENCE(S)
1. BASE DATA: MNRF LIO 2016
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
© 2020 MICROSOFT CORPORATION © 2020 MAXAR ©CNES (2020) DISTRIBUTION AIRBUS DS
3. PROJECTION: TRANSVERSE MERCATOR NAD 1983 UTM ZONE 17N

CLIENT
RANKIN CONSTRUCTION

PROJECT
PORT COLBORNE QUARRY EXTENSION

TITLE
SENSITIVE RECEPTOR LOCATION PLAN

CONSULTANT

GOLDER

YYYY-MM-DD	2020-07-14
DESIGNED	PR
PREPARED	PR
REVIEWED	DC
APPROVED	SM

PROJECT NO.	CONTROL	REV.	FIGURE
1771656	0006		2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

25mm

The blasting at the quarry is divided between two geological units that have different properties and, consequently, different markets. The lower unit, the Falkirk Member of the Bertie Formation, is typically excavated on a 5 m bench (internally known as the Brown Bench). The overlying members of the Bertie Formation, which are exposed within the quarry, are typically excavated in a 10 m bench (internally known as the Grey Bench). The differences in the blast parameters, divided on lithology, are shown in Table 1.

Table 1: Blast Design Details - Port Colborne Quarry Pit 3

Parameter	Details [1)]	
Bench Name	Gray Bench	Brown Bench
Depth of Hole	7.6 - 10.5 m	4.9 – 5.2
Blast Pattern	3.05 x 3.05 to 3.35 x 3.35 m	2.44 x 2.44 m
Approximate # Holes Per Blast	50 – 100	78 - 200
Diameter of Holes	102 mm	102 mm
Subdrill	0.0 m	0.0 m
Collar Length	1.52 - 1.68 m	1.52 m
Stemming	19 mm (3/4 in) Clear Stone	19 mm (3/4 in) Clear Stone
Explosive Product	Hydromite 4400 Bulk	Hydromite 4400 Bulk
Explosive Type	Emulsion Blend / ANFO Blend (Chemically Sensitized)	Emulsion Blend / ANFO Blend (Chemically Sensitized)
Explosive Weight per Hole	51 – 98 kg	28 – 37 kg
Number of Holes per Delay	1 - 3	1 - 4
Rock Tonnage per Blast	12,000 - 28,000 tonnes	6,200 – 15,600 tonnes
Potential Number of Blasts per Week	1 - 3	

[1)] Based on blast reports provided by Rankin from March to May 2017.

All explosives used for the purposes of blasting will be brought to site on the day of each blast. No explosives will be stored on site at any time. The proposed Pit 3 Extension would not result in an increase in permitted production levels.

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, Conservation and Climate Change (MECP)). 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 quarry. A copy of Publication NPC-119 is contained in APPENDIX B.

Sixty-three (63) sensitive receptors near the Site have been identified. These are listed in APPENDIX C, Table C1 and displayed in Figure 2. Separation distances, from the receptor to the extraction limit, shown in Table C1 are based on a 15 m extraction setback within the Quarry property limits and a 90 m setback from Hwy 3 within the Quarry property limits.

The DFO has established a set of guidelines for the use of explosives in or near Canadian fisheries waters (1998). These guidelines set out that “No explosive may be used that produces or is likely to produce, a peak particle velocity greater than 13 mm/s in a spawning bed during egg incubation”. Under conditions where these guidelines could not be met the proponent would be required to prepare a mitigative plan outlining additional procedures for protecting fish and their habitat.

4.0 IMPACT ASSESSMENT

4.1 Compliance with NPC-119

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 PCQ for blasts between March 2, 2017 and May 11, 2017.

The blast vibration monitoring results provided to Golder included data from two (2) sites. The location at the corner of Babion and Hwy 3 is located behind the blast face which means that the quarry was retreating toward that location. The monitoring location at the Henderson Farm located in front of the blast face which means that the quarry was retreating away from that location.

4.1.1 Ground Vibrations

4.1.1.1 Ground Vibration Models

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

$\mathrm{K, e}$ = Site factors typically derived from monitoring

Where no site-specific data is available, the factors K and e can be estimated based on similar conditions.

Attenuation measurements should be made with an array of logarithmically spaced seismographs positioned in a straight line away from the blast (Siskind, 2005). If the range of scaled distances is too small, the PPV data will become grouped or clustered. Siskind (2005) recommends that, in such a case, a propagation equation should not be computed because the statistical reliability of the slope will be poor. This was the case with the data provided by PCQ. The monitoring locations were intended for compliance monitoring rather than the development of an attenuation model. As such, attenuation characteristics were estimated based on blast monitoring data collected by Golder at other limestone quarry operations in Southern Ontario. Where appropriate site-specific data is not available, it is industry practice that models be provided from similar operations until such time as data can be collected to confirm those models. Attenuation rates based on blast monitoring data collected by Golder from several currently active limestone quarries in Southern Ontario are given in the following equation:

$$PPV = 770\left(\frac{D}{\sqrt{W}}\right)^{-1.29}$$

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 Pit 3 Extension and is plotted on Figure 3.

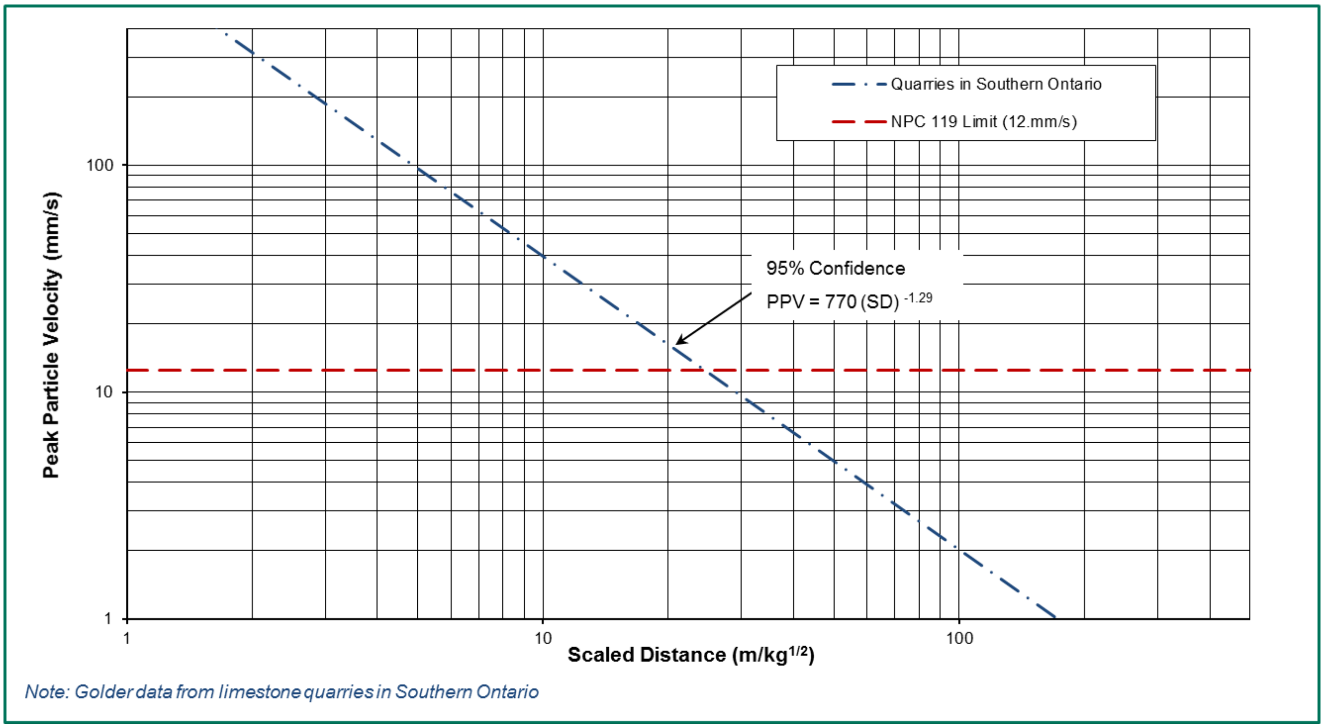
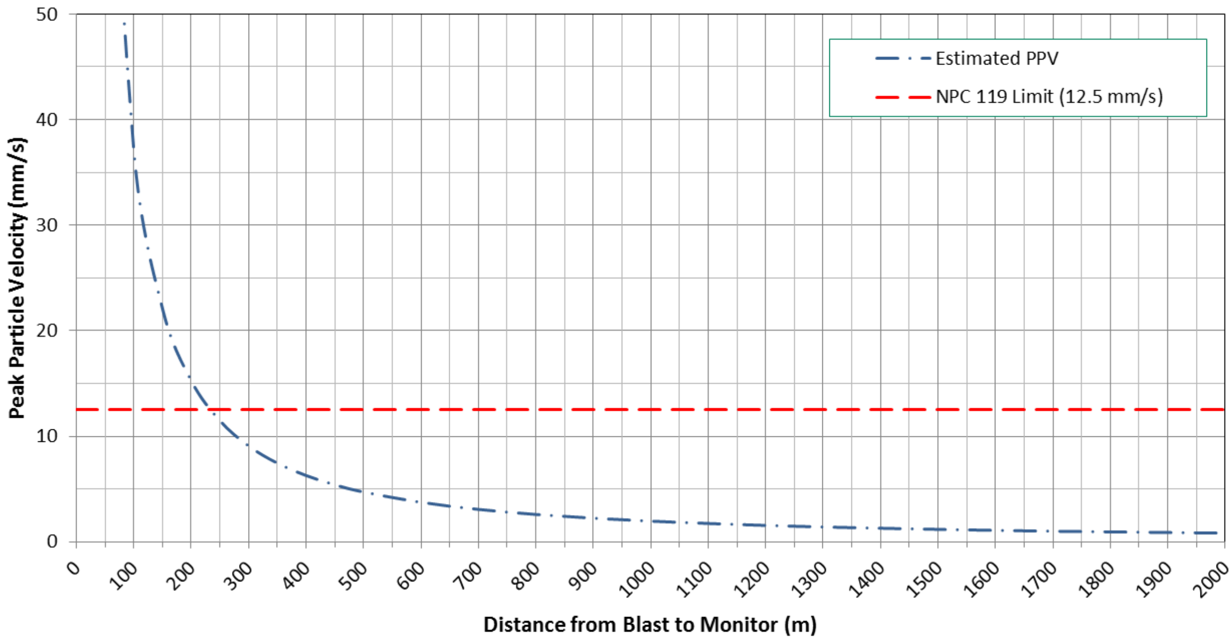


Figure 3: Proposed Ground Vibration Attenuation Model

4.1.1.2 Ground Vibration Predictions

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 92 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 233 m from adjacent receptor residences.



Note: Assuming 92 kg/borehole and one hole per delay

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)]
150	38
200	67
250	105
300	151
350	206
400	269
450	340
500	420

[1)] Distance between the blast and the sensitive receptor.

[2)] Assuming the attenuation model proposed above.

Any blasting within about 233 m of adjacent private residences may necessitate a reduction in the maximum explosive weight detonated per delay period so that the peak ground vibration levels could be maintained below 12.5 mm/s. Any one or combination of the following operations would reduce the maximum explosive weight per delay:

1. Reducing the borehole diameter with a corresponding reduction in the drill pattern (see Table 1).
2. Introduce decked charges within each borehole, as illustrated on Figure A-1.
3. Reduce the borehole length (depth) by reducing the bench height.

4.1.2 Air Vibrations

4.1.2.1 Air Vibration Models

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

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

Wmaximum 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

$\mathrm{K, e}$ = Site factors typically derived from monitoring, or provided within published literature

As discussed in Section 4.1.1.1, data provided by PCQ had a limited range of Scaled Distance and yielded clustered data, which made it unreliable for the development of an air vibration attenuation model. The air vibration data compiled by Golder from limestone quarries in Southern Ontario have been used in this study and are shown in the following equation:

$$PSPL = 172.6\left(\frac{D}{\sqrt[3]{W}}\right)^{-0.079}$$

The model above is plotted on Figure 5.

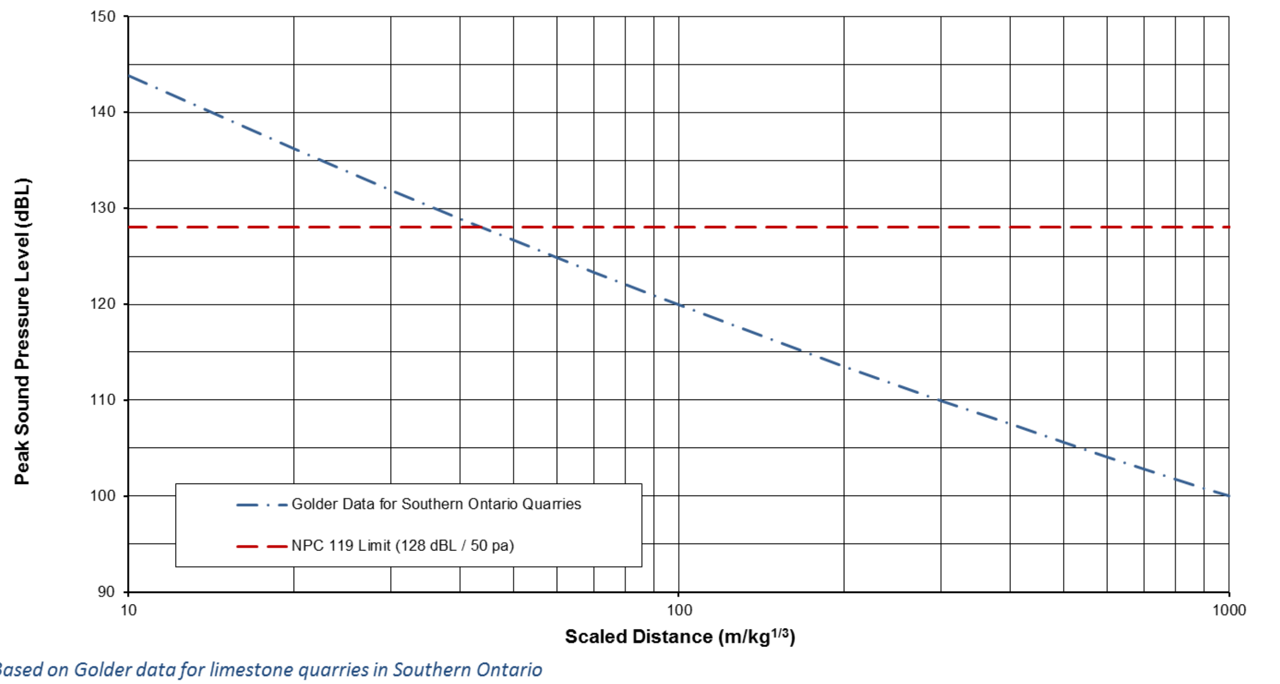


Figure 5: Proposed Air Vibration Attenuation Model.

Golder's experience and analysis also demonstrates that air vibrations are greatest when blasting toward the sensitive receptors.

4.1.2.2 Air Vibration Predictions

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 6 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 92 kg, the MECP guideline limit of 128 dBL may be complied with for all blasting beyond a minimum distance of about 284 m from adjacent receptor residences.

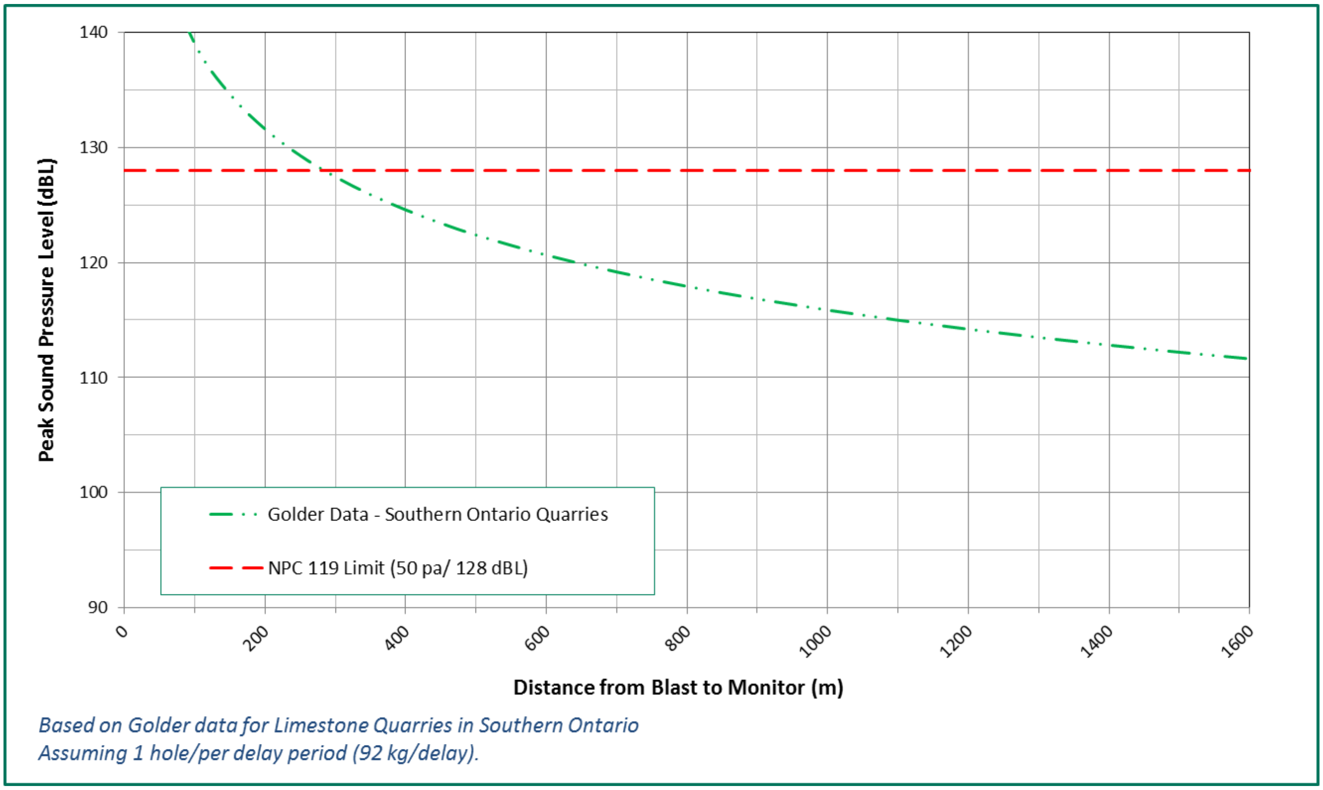


Figure 6: Estimated Maximum Air Vibration for the Proposed Blast Design at a Range of Distances

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 [2)] (kg)
150	40
200	94
250	183
300	317
350	548
400	751
450	1070
500	1467

[1)] Distance between the blast and the sensitive receptor.

[2)] Assuming the attenuation model proposed above.

Reducing the maximum explosive weight per delay period for maintaining the ground vibration limit, as discussed previously, would by consequence also reduce the air vibration effects.

4.1.3 Summary

The closest separation distance between a sensitive receptor and any blast over the life of Pit 3 Extension is 30 m (Receptor #48). The termination point for the blasting operations will be governed by the results of the on-site monitoring program.

4.2 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 quarry, 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.

2) 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.

3) 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.

4.3 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 4 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 4 that routine household activities and environmental changes can produce strains within a structure that are well in excess of those produced by blasting.

Table 4: 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. Heel drops 3. Jumping 4. Door slams 5. Pounding nails	 S_2 S_2 S_2 S_1 S_{12}	 9.1 16.0 37.3 48.8 88.7	 0.8 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.

4.4 Effect on Canadian Fisheries Waters

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, the 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.

A review of publicly available background data on fish communities did not indicate the presence of fish communities in the area in or around the proposed quarry extension. While a fish community survey was not carried out, Golder’s environmental team carried out a fish habitat survey of the property. It was found that the Mitchell Drain, has habitat features of fish-bearing watercourses. This information is documented in the Environmental Impact Study (EIS).

The underwater overpressure limit only tends to become a measurable indicator when blasting or explosives are used immediately adjacent to or within the water body itself.

Based on the ground vibration attenuation rates discussed previously in Section 4.1.1.2, peak ground vibration levels would be expected to fall below the DFO guideline limit of 13 mm/s at a distance of about 226 m from the blasting operations. In the event that spawning depressions are identified within about 250 m of the blasting operations, maintaining compliance with the DFO guidelines could be achieved by ensuring that blasting occurred outside identified spawning periods. When blasting on site is to take place employing blast parameters which suggest vibrations in excess of 10 mm/s (75% of DFO 13mm/s limit) imparted on an active spawning bed, an additional seismograph shall be installed at the location of the closest spawning bed, or closer to the blast, to confirm compliance with the DFO guideline limit for ground vibrations of 13 mm/s.

The rerouting or assessment of the Michner Drain is not included in our scope of work at this point.

5.0 RECOMMENDATIONS

As part of the ongoing blasting operations for the extraction of the proposed quarry we recommend the following:

- The initial series of test blasts, occurring with approximately one month of the commencement of blasting shall be monitored at a minimum of five locations at varying distances from each blast to refine the ground and air vibration attenuation characteristics and confirm that MECP - NPC 119 of the Model Municipal Noise Control By-Law is being met. This will entail establishing monitoring stations between the blast site and neighbouring receptors [residences] during the sinking cut and development of the initial bench face. The site-specific attenuation data developed during this monitoring period shall then be used to better define ground vibration and air concussion effects at the nearest receptors.
- Routine monitoring of all blasting operations shall be carried out in the vicinity of the closest receptor to the proposed blasting operations. As extraction continues within the quarry and blasting operations move, the actual monitoring site shall be routinely and regularly reviewed so that the closest receptor is always being monitored for ground and air vibration effects.
- 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 shall be made available to the Ministry of Natural Resources and the MECP upon written request.
- Prohibit blasting on Saturdays, Sundays and all Statutory holidays.
- When blasting within approximately 300 m of adjacent residences, the quarry shall regularly review their blast procedures in conjunction with the blast monitoring results to assess when it is necessary to reduce the maximum explosive weight detonated per delay period within the blast. The termination point for the blasting operations will be governed by the results of the on-site monitoring program.
- Detailed blast records shall be maintained. The MOE (1985) recommended that the body of the blast reports shall 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 ºC, 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.

No perimeters berms are necessary for the purposes of blasting.

6.0 CONCLUSIONS

Based on the foregoing considerations, it is our opinion that the proposed PCQ Pit 3 Extension, located in the town of Port Colborne, can readily be operated within the current quarry blasting guidelines published by the Ontario Ministry of Environment, Conservation and Parks and the Department of Fisheries and Oceans. All blasting and monitoring would occur in accordance with the Aggregate Resources Act prescribed conditions so as to comply with the provincial guidelines.

REFERENCES

Dowding, C. H., 1985. “Blast Vibration Monitoring and Control”, Prentice-Hall, 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, Final Report”, August, 1978.

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

Oriard, L. L., 1999. “The Effects of Vibrations and Environmental Forces”.

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.

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

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., PGeo
Principal

DJC/SM/mp

https://golderassociates.sharepoint.com/sites/32998g/deliverables/phase 2000 blasting/final-16jul2020/1771656-r-rev2-blast impact assessment-16jul2020.docx

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.

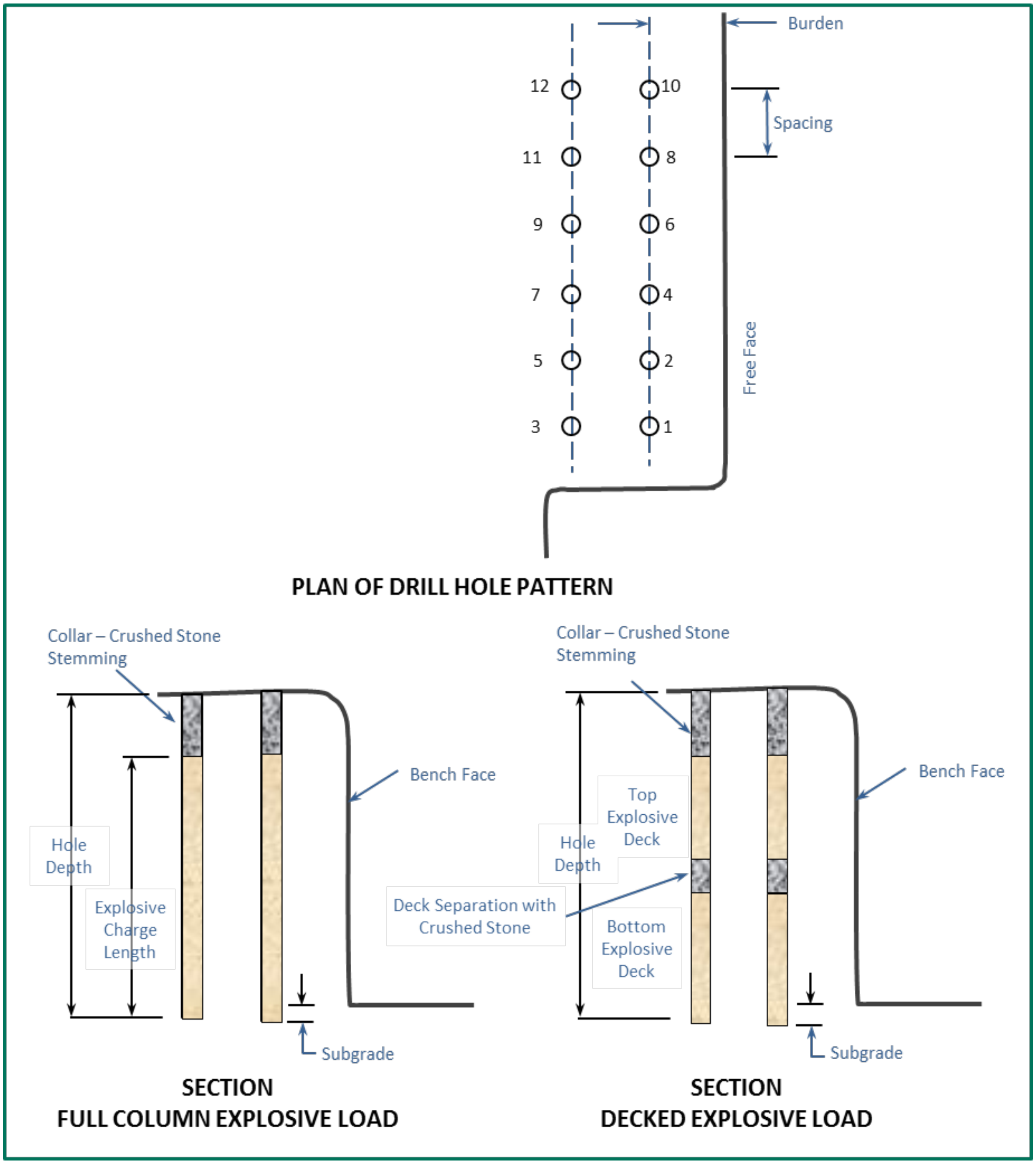


Figure A-1: Definition of Blasting Terms

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.
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.

APPENDIX C

Nearest Receptors to the Port Colborne Quarry Pit 3 Extension

NEAREST RECEPTORS TO THE PORT COLBORNE QUARRY EXTENSION

Table C1: Nearest Sensitive Receptors to the Proposed Port Colborne Extension

Receptor ID	Receptor Address	Owner Name	Distance (m) 1) 2)
1	2199 Babion Rd.	Henderson, Janet Elaine; Henderson, David Marshall	1060
2	1540 Babion Rd.	Scace, Lynne; Scace, Wesley	640
3	1386 Lorraine	Dennis, Wayne	700
4	1413 Lorraine	Phillips, Janet Margaret	630
5	1368 Lorraine	Rottier, Mathew	690
6	1085 Lorraine	Watson, Carol Ann	810
7	1051 Lorraine	Horpenuk, Sophie	740
8	896 Killaly	Hurkmans, Sally Marjorie; Hurkmans, Robert William	870
9	1007 Killaly	Zarb, Tiffany; Quesnelle, Andrew	980
10	1014 Killaly	Lee, Erin Margaret; Lee, Derek	930
11	1096 Killaly	Fehrman, Amy Lee; Fehrman, Paul Allan	830
12	1133 Killaly	Bankert, Roy	880
13	1193 Killaly	Ribau, Jeffrey	800
14	1233 Killaly	Pagliaro, Bonnie Lynn; Pagliaro, Carlo	820
15	1246 Killaly	Shibley, Chad William	700
16	1288 Killaly	Long, Catherine Margrit; Long, Mark Christopher	680
17	1374 Killaly	Burke, Michael	680
18	1384 Killaly	Ecker, Mary Ellen; Phillips, Charles Milton	670
19	1446 Killaly	Gillespie, Karra Jean; Gillespie, Evan John	660
20	1458 Killaly	Smith, Rose Marie; Smith, Reginald Garfield	650
21	1470 Killaly	Carter, Brenda Elizabeth; Carter, Douglas Phillip	620
22	1379 Killaly	Vandebeld, Ronald Simon; Vandebeld, Grace Elizabeth	755
23	1627 Killaly	Spiece, Angie Teresa; Spiece, Corey John	660
24	1640 Killaly	Jacques, Louann Mary; Jacques, Timothy Maurice	540
25	1704 Killaly	Bankert, Catherine Jessie; Bankert, Ralph Edward	550
26	1728 Killaly	Carter, Brianne; Chiarle, Bryan	510
27	1739 Killaly	Toepp, Doris; Toepp, Rudolf; Toepp, Marc Rudolf	580
28	1740 Killaly	Wall, Raven; Wall, Hannah Michelle	520
29	991 Hwy 3	Huffman, Carole; Huffman, John Wayne	740
30	1305 Hwy 3	Crawford, Margaret; Crawford, David	150
	1305 Hwy 3 (sliver)	Hennigar, Vernon; Hennigar, Annette	
31	1331 Hwy 3	Hennigar, Annette Cecilia; Hennigar, Vernon Charles	110`
32	1577 Hwy 3	Fehrman, Amy Lee; Fehrman, Paul Allan	100
33	1627 Hwy 3	Van Boom, Maria; Poulsen, Arnold	80
34	1695 Hwy 3	Wagner, Edith Gail	100
35	1751 Hwy 3	Ruston, James Daryl	90

Receptor ID	Receptor Address	Owner Name	Distance (m) 1) 2)
36	1838 Hwy 3	Fehrman, Amy Lee; Fehrman, Paul Allan; Fehrman, Mark David	220
37	1054 Weaver Road	Hobbs, Marjorie; Hobbs, Edward	480
38	1030 Weaver Road	Morin, Angel Joyce; Brown, Robert William	560
39	1080 Weaver Road	Wright, Rose Marie; Wright, Timothy James	525
40	1094 Weaver Road	Have, Marsha Elayne; Shave, Harry Albert	490
41	1110 Weaver Road	Van Schaik, Thomas Albert	455
42	1142 Weaver Road	Babin, Ryan Wade; Arbour, Melinda Joy	420
43	1152 Weaver Road	Butters, Barbara Katherine; Butters, Larry R.	385
44	1162 Weaver Road	Landry, Henry	350
45	1266 Weaver Road	Ladd, Kevin Wilfred; Ladd, Sharon Lynn	120
46	1284 Weaver Road	Ladd, Kevin Wilfred	120
47	1359 Weaver Road	Blake, Lynn Marlene	70
48	1498 Miller Road	Noel, Tina Louise; Noel, Marc Raymond	30
49	1580 Miller Road	Danner, Christine	190
50	1591 Miller Road	Demeo, Paivi; Demeo, Giuseppe	220
51	1630 Miller Road	Dyck, Elisabeth Peters; Dyck, Abram Klassen	260
52	1682 Miller Road	Jarry, Nicole Therese; Jarry, Terry Alain	280
53	1732 Miller Road	Bury, Laurie; Bury, Alexander	360
54	1778 Miller Road	Heitman, Debra Ann; Fabi, David George	360
55	1826 Miller Road	Vince, Terrance Andrew; Vince, Jennifer Lynn	360
56	1864 Miller Road	Bowman, Douglas Murray	280
57	1903 Miller Road	Mittlestead, Barbara Arline; Mittlestead, Scott John	490
58	2024 Miller Road	Dimitrov, Donna; Dimitrov, Matej	380
59	2084 Miller Road	Huffman, Audrey Fern; Huffman, Raymond Arthur	430
60	2168 Miller Road	Rodgers, Helen Elaine	520
61	2187 Miller Road	Vanderlaan, Marie; Vanderlaan, Jack	620
62	1246 2nd Concession Rd.	Forsey, Cynthia Lynn	640
63	1740 2nd Concession Rd.	Kosmas, Irene; Kosmas, Nikolas	60

1) *Separation distance to the nearest point of extraction.*
2) *Separation distances are based on a 15 m extraction setback within the Quarry property limits, a 30 m setback from Hwy 3 within the Quarry property limits.*

APPENDIX D

Curriculum Vitae

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 / Vibration Blasting Consultant with Golder Associates.

Daniel has been involved in blasting and vibration assessment since 1989. 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
British 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)

golder.com