Specialists in Explosives, Blasting and Vibration
Consulting Engineers

Blast Impact Analysis
Brechin Quarry
Part of Lots 11, 12 and 13, Concession 1
Township of Ramara, County of Simcoe

Submitted to:

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EXECUTIVE SUMMARY

Explotech Engineering Ltd. was retained to provide a Blast Impact Analysis for the proposed Brechin Quarry located on Part of Lots 11, 12 and 13, Concession 1, (former geographic Township of Mara), Township of Ramara, County of Simcoe.

Vibration levels assessed in this report are based on the Ministry of the Environment, Conservation, and Parks Model Municipal Noise Control By-law (NPC119) with regard to Guidelines for Blasting in Mines and Quarries. We have assessed the area surrounding the proposed Aggregate Resources Act licence with regard to potential damage from blasting operations and compliance with the aforementioned by-law document.

We have inspected the property and reviewed the available site plans. Explotech is of the opinion that the planned aggregate extraction on the proposed property can be carried out safely and within MECP guidelines as set out in NPC 119 of the By-Law.

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

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INTRODUCTION

LCP Quarry Limited has applied for a Class A Licence for the property legally described as Part of Lots 11, 12 and 13, Concession 1, (former geographic Township of Mara), Township of Ramara, County of Simcoe. The proposed name for the operation is the Brechin Quarry. This Blast Impact Analysis assesses the ability of the proposed licence to operate within the prescribed blast guideline limits as required by the Ontario Ministry of the Environment, Conservation, and Parks (MECP).

While not specifically required as part of the scope of the Blast Impact Analysis under the Aggregate Resources Act, this report also covers the topics of blast impact on adjacent fish habitats, residential water wells, flyrock, and rail (train tracks) for general informational purposes only. Potential impacts on the nearby waterbodies are discussed to confirm compliance with applicable guidelines, as well as potential impacts. Exhaustive details related to residential water wells are addressed in the hydrogeological report prepared by Azimuth Environmental. Specific flyrock control is addressed at the operational level given significant influences related to blast design, geology, and field accuracy. Potential impacts and recommended controls are discussed as they relate to the Canadian National Railway (CN).

The land surrounding the proposed Brechin Quarry is a mixture of rural, industrial, highway, commercial, and agricultural land use areas. The site is currently zoned as ‘rural’ and ‘agricultural’. The proposed Brechin Quarry operation is bound by wetland, woodlots and properties fronting onto Concession 2 to the Northwest, wetlands, woodlots, and properties fronting onto Ramara Road 47 to the West, wetlands, and woodlots fronting onto Concession 1 to the South and woodlots, residential properties and commercial properties fronting onto Highway 12 to the East. The site is located adjacent to two existing licenced mineral aggregate operations. The Mara Limestone Aggregates Limited Quarry (Licence 3717) is located immediately south of the site and the Lafarge Canada Inc. Brechin Quarry (Licence 3582) is located north-east of the site. The property will be accessed via a proposed haulage road off of Concession 2.

This Blast Impact Analysis has been prepared based on the Ministry of the Environment, Conservation, and Parks (MECP) Model Municipal Noise Control By-law with regard to Guidelines for Blasting in Mines and Quarries (NPC 119). We have additionally assessed the area surrounding the proposed licence with regard to potential damage from blasting operations.

Excavation and blasting operations have not been undertaken on site in the past and as such, site-specific blast monitoring data is not available. We have therefore applied data generated across a spectrum of quarries and construction projects which provides a conservative approximation of anticipated vibration levels from the operation. It has been our experience that this data represents a conservative starting point for blasting operations. It is a recommendation of this report that a vibration monitoring program be initiated on-site upon the commencement of blasting operations and maintained for the duration of all blasting activities to permit timely adjustment to blast parameters as required. Ultimately, the quarry will be required to operate to the MECP guideline limits for ground vibration and overpressure based on actual measurements taken during blast times.

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

EXISTING CONDITIONS

The licence area for the proposed Brechin Quarry encompasses a total area of approximately 151.4HA and an extraction area of approximately 91.5HA when allowing for setbacks and sterilized areas. The site is broken into two (2) distinct extraction phases. Each phase will be extracted in two (2) sub-phases (Refer to Appendix A Operational Plan). The Phase 1A extraction area of the licence area involves excavation of the Northeast quadrant of the proposed licence. The Phase 1B area of the licence area involves excavation of the Northwest quadrant of the proposed licence. The Phase 2A area lies at the Southern quadrant of the proposed licence area and involves extraction in a Westerly direction. The Phase 2B area of the licence involves excavation of the remainder of the Southern quadrant of the quarry. All phases of the licence involve excavation of up to three (3) lifts to a proposed maximum extraction depth of 202masl.

The topography of the proposed licence area is lowest on the Eastern and Western boundaries at an elevation in the order of 232masl rising towards the Southern corner of the proposed extraction limits at an elevation in the order of 244masl.

The lands surrounding the proposed licence area are largely characterized by woodlots, commercial operations, and rural residential properties with the closest sensitive receptors lying East of the limits of extraction along Highway 12, and to the Northwest along Concession 2 and Ramara Road 47. The Mara Limestone Aggregates Limited Quarry (Licence 3717) is located immediately south of the site and the Lafarge Canada Inc. Brechin Quarry (Licence 3582) is located north-east of the site. The closest separation distance between sensitive receptors and the extraction limit over the life of the quarry operations are listed in Table 1 below.

Table 1: Closest Sensitive Receptors within 500m

Receptor Label	Address	Closest Straight Line Distance to Receptor (m)	Direction from Quarry
R1	1399 Highway 12	430	East
R2	1544 Highway 12	150	East
R3	1554 Highway 12	150	East
R4	1569 Highway 12	370	East
R5	1570 Highway 12	150	East
R6	1645 Highway 12*	150	East
R7	1842 Highway 12	600	Northwest
R8	2101 Concession 1	590	East
R9	2401 Concession 2	250	West
R10	2549 Concession 2	730	Northwest

Table 1: Closest Sensitive Receptors within 500m			
Receptor Label	**Address**	**Closest Straight Line Distance to Receptor (m)**	**Direction from Quarry**
R11	2239 Ramara Road 47	1000	West
R12	2409 Ramara Road 47	970	Northwest

*** Commercial properties**

PROPOSED AGGREGATE EXTRACTION

The proposed initial quarry operations will commence with a sinking cut at the North limit of the Phase 1A extraction area. The sinking cut is denoted in Appendix A as Phase 1A – Sinking Cut. Initial blasting will be located approximately 600m from the closest sensitive receptor in front of the blast, namely 1842 Highway 12, and approximately 720m from the closest sensitive receptor behind the blast, 1570 Highway 12. Extraction will retreat from the sinking cut in a general Southern direction to a proposed maximum extraction depth of 202masl. Based on the existing Phase 1A elevations, this phase of extraction will take place in 3 benches.

Extraction in Phase 1B will leverage the existing Phase 1A Western boundary face. Blasting shall commence at the Phase 1A/Phase 1B interface thereby eliminating the need for a sinking cut. Phase 1B will then retreat in a Western direction to a proposed maximum extraction depth of 202masl. Based on the existing Phase 1B elevations, this phase of extraction will take place in 3 benches.

Extraction in Phase 2A will leverage the existing Phase 1A/Phase 1B interface thereby eliminating the need for a sinking cut. Phase 2A will then retreat in a Western direction to a proposed maximum extraction depth of 202masl. Based on the existing Phase 2A elevations, this phase of extraction will take place in 3 benches.

Extraction in Phase 2B will leverage the existing Phase 2A boundary face. Blasting shall commence at the Phase 2B / Phase 2A interface thereby eliminating the need for a sinking cut. Extraction will retreat in a general Southern direction to a proposed maximum extraction depth of 202masl. Based on the existing Phase 2B elevations, this phase of extraction will take place in 3 benches.

As quarry operations migrate across the property, the closest sensitive receptors to the required blasting operations will vary with the governing structures and approximate closest separation distances being as follows:

Northern corner: 1842 Highway 12 – R7 – 600m
Eastern face: 1570 Highway 12 – R5 – 150m
Southeast corner: 1399 Highway 12– R1 – 430m
Western corner: 2401 Concession 2 – R9 – 250m

The closest separation distance between a sensitive receptor and any blast over the life of the quarry is 150m. Blasting at this separation distance can be achieved through the decking of the bench as the blasting approaches the sensitive receptor. The on-site monitoring program will govern the number of decks implemented as the blasting approaches the sensitive receptors.

Quarries in Ontario normally employ 76 to 152mm diameter blast holes which, for a maximum 12m bench and a 1.8m collar, would employ 56kg to 222kg of explosive load per hole. The choice of hole diameter will govern the maximum number of holes to be fired per period for the sinking cut. Once the quarry is opened up, subsequent blasts can be designed to minimize the number of holes fired per period.

BLAST VIBRATION AND OVERPRESSURE LIMITS

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

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

Vibration___________12.5mm/sec Peak Particle Velocity (PPV)

Overpressure_______128 dB Peak Sound Pressure Level (PSPL)

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

BLAST MECHANICS AND DERIVATIVES

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

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

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

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

VIBRATION AND OVERPRESSURE THEORY

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

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

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

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

Our experience and analysis demonstrates that blast overpressure is greatest when blasting toward receptors, and blast vibrations are greatest when retreating in the direction of the receptor.

GROUND VIBRATION LEVELS AT THE NEAREST SENSITIVE RECEPTOR

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

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

Where, PPV = the calculated peak particle velocity (in/s-imperial, mm/s-metric)

K, e = site factors

d = distance from receptor (ft-imperial, m-metric)

w = maximum explosive charge per delay (lbs-imperial, kg-metric)

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

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

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

Where, SDSR = Scaled distance square root method
SDCR = Scaled distance cube root method
R = Separation distance between receptor site and blast (ft, m)
W = Maximum explosive load per delay period (lbs, kg)

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

For a distance of 720m (i.e. the standoff distance to the closest existing sensitive receptor behind the blast for the initial blasting) and a maximum explosives load per delay of 56kg (76mm diameter hole on a 2.74m x 2.74m pattern, 12m deep, with a column load of 10.2m, 1.8m collar and 1 hole per delay), we can calculate the maximum PPV at the closest building using the following formulae:

Imperial Equations:

Oriard 50% bound (2002)

$$v = 160\left(\frac{D}{\sqrt{W}}\right)^{-1.6}$$

Oriard 90% Bound (2002)

$$v = 242\left(\frac{D}{\sqrt{W}}\right)^{-1.6}$$

Quarry Production Blast
(Bulletin 656 – 1971)

$$v = 182\left(\frac{D}{\sqrt{W}}\right)^{-1.82}$$

Typical limestone Quarry
(Pader report – 1995)

$$v = 52.2\left(\frac{D}{\sqrt{W}}\right)^{-1.38}$$

Typical Coal Mine
(RI8507 1980)

$$v = 133\left(\frac{D}{\sqrt{W}}\right)^{-1.5}$$

Metric Equations:

General Blasting
(Dupont)

$$v = 1140\left(\frac{D}{\sqrt{W}}\right)^{-1.6}$$

Construction Blasting
(Dowding 1998)

$$v = 1326\left(\frac{D}{\sqrt{W}}\right)^{-1.38}$$

Agg. Quarry Blasting
(Explotech 2005)

$$v = 5175\left(\frac{D}{\sqrt{W}}\right)^{-1.76}$$

Agg. Quarry blasting (Explotech 2003) $$v = 7025\left(\frac{D}{\sqrt{W}}\right)^{-1.85}$$

The equations described above accommodate for a range of geological conditions and blasting methodologies. The proposed parameters were applied to the formulae to estimate a range of the potential vibrations imparted on the closest sensitive receptor behind the blast. As discussed in previous sections, the MECP guideline for blast-induced vibration is 12.5mm/s (0.5 in/s). Appendix C demonstrates that the maximum calculated value for the vibration intensities imparted on the closest sensitive receptor based on all equations is 2.4mm/s for the initial blasting, below the MECP guideline limit. All ground vibration calculations and tables going forward will utilize the formula providing the worst case scenario for all geological conditions. All blasts will be monitored for overpressure and ground vibrations with blast designs adjusted in response to readings on site in order to ensure consistent compliance with established limits.

Given the separation distances to the various sensitive receptors adjacent the proposed quarry, Table 2 below provides initial guidance on maximum loads per delay based on various separation distances until such time as a site specific equation is developed. The following maximum loads per delay were derived from the equation for ground vibrations listed above (Agg. Quarry Blasting – Explotech 2005) and are based on a maximum intensity of 12.5mm/s:

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

Separation distance between sensitive receptor and closest borehole (meters)	Maximum recommended explosive load per delay (Kilograms)
600	382
550	321
500	267
450	215
400	170
350	130
300	96
250	66
200	45
150	24
100	11

The closest separation distance between a sensitive receptor and any blast over the life of the license is 150m. While blasting at this separation distance is feasible, monitoring and changes in blasting designs will be required in order to confirm all blasts are within MECP guidelines when blasting comes closer to adjacent sensitive receptors.

OVERPRESSURE LEVELS AT THE NEAREST SENSITIVE RECEPTOR

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

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

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

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

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

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

As discussed in previous sections, the MECP guideline for blast-induced overpressure is 128dBL. For a distance of 600m (i.e. the standoff distance to the closest existing structure in front of the blast for the initial blasting) and a maximum explosives load per delay of 56kg (76mm diameter hole on a 2.74m x 2.74m pattern, 12m deep, with a column load of 10.2m each, 1.8m surface collar and 1 hole per delay), we can calculate the overpressure at the nearest receptor in front of the blast using the following equations:

Imperial Equations:

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

Metric Equations:

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

Appendix C demonstrates that the maximum calculated value for the overpressure intensities imparted on the closest sensitive receptor based on all equations is 126.3dB(L) for the initial blasting, below the MECP guideline limit. All blasts will be monitored for overpressure and ground vibrations with blast designs adjusted in response to readings on site in order to ensure consistent compliance with established limits.

Based on this calculation and the assumed blast parameters, overpressures from the initial blasting operations will remain compliant with the MECP NPC 119 guideline limit of 128dBL. The design method of retreat has been planned so as to direct overpressures generated as much as practicable in the direction of vacant lands. All overpressure calculations and tables going forward will utilize the formula providing the worst-case scenario for all geological conditions.

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

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

Table 3 below can be used as an initial guide showing maximum loads per delay based on various separation distances for receptors in front of the blast face. The following maximum loads per delay are derived from the air overpressure equation above (Ontario Quarry – dB – Explotech 2012) and are based on a peak overpressure level of 128dB(L):

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

Separation distance between sensitive receptor and closest blasthole (meters)	Maximum recommended explosive load per delay (Kilograms)
500	77
450	56
400	39
350	26
300	16
250	9

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

ADDITIONAL CONSIDERATIONS OUTSIDE OF THE BLAST IMPACT ANALYSIS SCOPE

The following headings are addressed for general information purposes and are not strictly required as part of the scope of the Blast Impact Analysis as required under the ARA to assess compliance with MECP NPC-119 guidelines. Considerations for aquatic species in the adjacent waterbodies are further addressed in the Natural Environment report prepared by Azimuth Environmental. The hydrogeological study prepared by Azimuth Environmental as part of the license application addresses residential water wells in detail. Flyrock control is addressed at the operational level given significant influences related to blast design, geology and field accuracy which render concrete recommendations related to control inappropriate at the licencing phase.

BLAST IMPACT ON ADJACENT FISH HABITATS

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, ultimately resulting in the death of the organism. Additionally, ground vibrations imparted on active spawning beds have the ability to adversely impact the incubating eggs and spawning activity. In an effort to alleviate adverse impacts on fish populations as a result of blasting, the Department of Fisheries and Oceans (DFO) developed the Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters (1998). This publication establishes limits for water overpressure and ground vibrations which are intended to mitigate impacts on aquatic organisms while providing sufficient flexibility for blasting to proceed. Specifically, water overpressures are to be limited to 100kPa and, in the presence of active spawning beds, ground vibrations at the bed are to be limited to 13mm/s.

The Natural Environment study prepared for the application indicates that there are fish habitats in watercourses adjacent the quarry location. The fish species identified in the Natural Environment study noted to occupy the adjacent watercourses could be utilizing any of the vegetation that proliferates through the system as spawning beds. During active spawning season, vibration monitoring will be required at the shoreline adjacent the closest spawning area, or closer to the blast, in order to ensure compliance with DFO limits for ground vibration.

Table 4 below is presented as initial guidance showing maximum permissible loads per delay based on various separation distances from spawning beds. The following maximum loads per delay are derived from the equation for ground vibrations listed earlier in this report and are based on a maximum vibration intensity of 13.0mm/s as experienced at the active spawning habitat:

Table 4: Maximum Loads per Delay to Maintain 13.0mm/s at Various Separation Distances	
Separation distance between possible spawning bed and closest borehole (meters)	**Maximum recommended explosive load per delay (Kilograms)**
500	278
450	225
400	178
350	136
300	100
250	70
200	45
150	25
100	11

The generation of suspended solids within the watercourse as a result of the blasting activities will be negligible and grossly subordinate to suspended solids generated as a result of spring runoff and rain activity.

RESIDENTIAL WATER WELLS

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

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

Despite the scientific support for the above conclusion, numerous studies have been performed to verify the validity of this statement. These studies have investigated the effects of blasting on varied well configurations and in varied geological mediums to permit conclusions to be readily extrapolated to diverse blasting operations. The conclusion of these studies has confirmed that with the exception of possible temporary increases in turbidity, blasting operations did not result in any permanent impact on wells outside of the immediate blast zone (20-25 blasthole diameters) of the blast until vibrations levels reached exceedingly high intensities. Applying universally accepted threshold levels for ground vibrations eliminates the possibility for any long term adverse effects on wells in the vicinity of blasting operations.

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

Rose et al. (1991) studied the effect of blasting in close proximity to water wells near an open pit mine in Nevada, USA. Blasts of up to 70 kilograms of explosives per delay period were detonated at a distance of 75 meters (245 feet) from a deep water well. There was no reported visible damage to the well. Fluctuations in water level and flow rate were evident immediately after the blast. However, the well water level and flow rate quickly stabilized.

The U.S. Bureau of Mines conducted a study (Robertson et al., 1990) to determine the changes in well capacity and water quality. This involved pumping from wells before and after nearby blasting. One experiment with a well in sandstone showed no change in well capacity after blasts induced PPV's at the surface of 84mm/s and there was no change in water level after PPV's of 141mm/s, well above the current guideline limit of 12.5mm/s.

Matheson et al. (1997) brought together available information on the most common complaints, the possible causes of the complaints and the relation between blasting and the complaint causes. This study yet again reaffirmed the fact that the attribution of well problems to blast sources are unfounded.

The MECP vibration limit of 12.5mm/s effectively excludes any possibility of damage to residential water wells. Based on available research and our extensive experience in Ontario quarry blasting, blasting at the Brechin Quarry will induce no permanent adverse impacts on the residential water wells on properties surrounding the site.

FLYROCK

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

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

THEORETICAL HORIZONTAL FLYROCK CALCULATIONS

We have analyzed theoretical flyrock projection distances based on a quarry operating in the dry.

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

- **Face burst:** Lack of confinement by the rock mass in front of the blast hole results in fly rock in front of the face.
- **Cratering:** Insufficient stemming height or weakened collar rock results in a crater being formed around the hole collar with rock projected in any direction.
- **Stemming Ejection:** Poor stemming practice can result in a high angle throw of the stemming material and loose rocks in the blasthole wall and collar.

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

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

where: V_o = launch velocity (m/s)
θ_0 = launch angle (degrees)
g = gravitational constant (9.8 m/s^2)

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

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

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

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

where: k = a constant
m = charge mass per meter (kg/m)
B = burden (m)

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

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

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

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

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

For calculation purposes, we have utilized the initial blasting parameters: 76mm (3”) diameter holes on a 2.74m x 2.74m (9’ x 9’) pattern, with total depths of up to 12m (39.4’) and a collar length of 1.4m (4.6’) to 2.2m (7.2’).

The range for the constant k is 13.5 for soft rocks and 27 for hard rocks. Given dolostone bedrock in the area, we have applied a k value of 20. The explosive density is assigned to be 1200 kg/m^3 for emulsion products and the drill hole angles are assumed to be 90 degrees (i.e. vertical).

The maximum horizontal throw for the flyrock using a varied collar is shown in Table 5 below.

Table 5 – Maximum Flyrock Horizontal		
***Collar* Lengths** (m)	**Maximum Throw Face Burst** (m)	**Maximum Throw Cratering and Stemming Ejection** (m)
1.4	27	154
1.6	27	108
1.8	27	80
2.0	27	61
2.2	27	47

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

CANADIAN NATIONAL (CN) RAILWAY

The Canadian National (CN) Railway runs parallel to the proposed quarry East of Highway 12 (refer to Appendix A). The MECP guideline for blast-induced vibration (12.5mm/s) does not apply to railways as they are not classified as sensitive receptors. The CN Railway carries a vibration limit of 100mm/s as measured along the centreline of the tracks.

Applying the equation from *Predicated Vibration Limits at the Nearest Sensitive Receptor*, for a distance of 640m (the standoff distance to the railway for the initial blasting) and a maximum explosives load per delay of 56kg (76mm diameter hole on a 2.74m x 2.74m pattern, 12m deep, with a column load of 10.2m, 1.8m surface collar and 1 hole per delay, we can calculate the maximum PPV utilizing the equations stated in section 'Ground Vibration Levels at the Nearest Sensitive Receptor.'

The maximum calculated value for the vibration intensities imparted on the Guelph Junction Railway (based on the proposed blasting data discussed above) is 2.9mm/s utilizing the worst-case equation for the initial blasting, well below the 50mm/s railway standard. As the blasting operations retreat towards the CN Railway, blast designs and parameters must be adjusted accordingly to remain compliant with the 50mm/s railway vibration standard.

RECOMMENDATIONS

It is recommended that the following conditions be applied for all blasting operations at the proposed Brechin Quarry:

1. An attenuation study shall be undertaken by a competent independent blasting consultant during the first 12 months of operation in order to obtain sufficient quarry data for the development of site specific attenuation relations. This study will be used to confirm the applicability of the initial guideline parameters and assist in developing future blast designs.

2. All blasts shall be monitored for both ground vibration and overpressure at the closest sensitive receptors adjacent the site, or closer, with a minimum of two (2) digital seismographs – one installed in front of the blast and one installed behind the blast. Monitoring shall be performed by and independent third party engineering firm with specialization in blasting and monitoring.

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

4. In the event that calculations suggest the vibrations at the closest portion of the rail line will exceed 2/3 of the applicable limit, an additional vibrations monitor shall be installed at the closest portion of the rail line.

5. Vibrations imparted on the rail line shall be maintained below industry best practices for structures of this nature or railway owner corporate policy.

6. When blasting on site is to take place employing blast parameters which suggest vibration in excess of 10mm/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 DFO guideline limit for ground vibration of 13mm/s.

7. Orientation of the aggregate extraction operation shall be designed and maintained so that the direction of the overpressure propagation and flyrock from the face shall be away from structures as much as possible.

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

9. Once blasting progress encroaches to within 250m of any offsite sensitive receptor, a formal review of accumulated blast records including vibration data and blast designs shall be undertaken. This review shall identify what modifications to blasting protocol and procedures are required to address the reduced separation distance.

10. Clear crushed stone shall be used for stemming.

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

12. Detailed blast records shall be maintained. The MECP (1985) recommends that the body of blast reports shall include the following information:

    - Location, date and time of the blast.
    - Dimensional sketch including photographs, if necessary, of the location of the blasting operation, and the 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 time of delays.

- The result and calculated value of Peak Pressure Level in dB and Peak Particle Velocity in mm/s.
- Applicable limits and any exceedances.

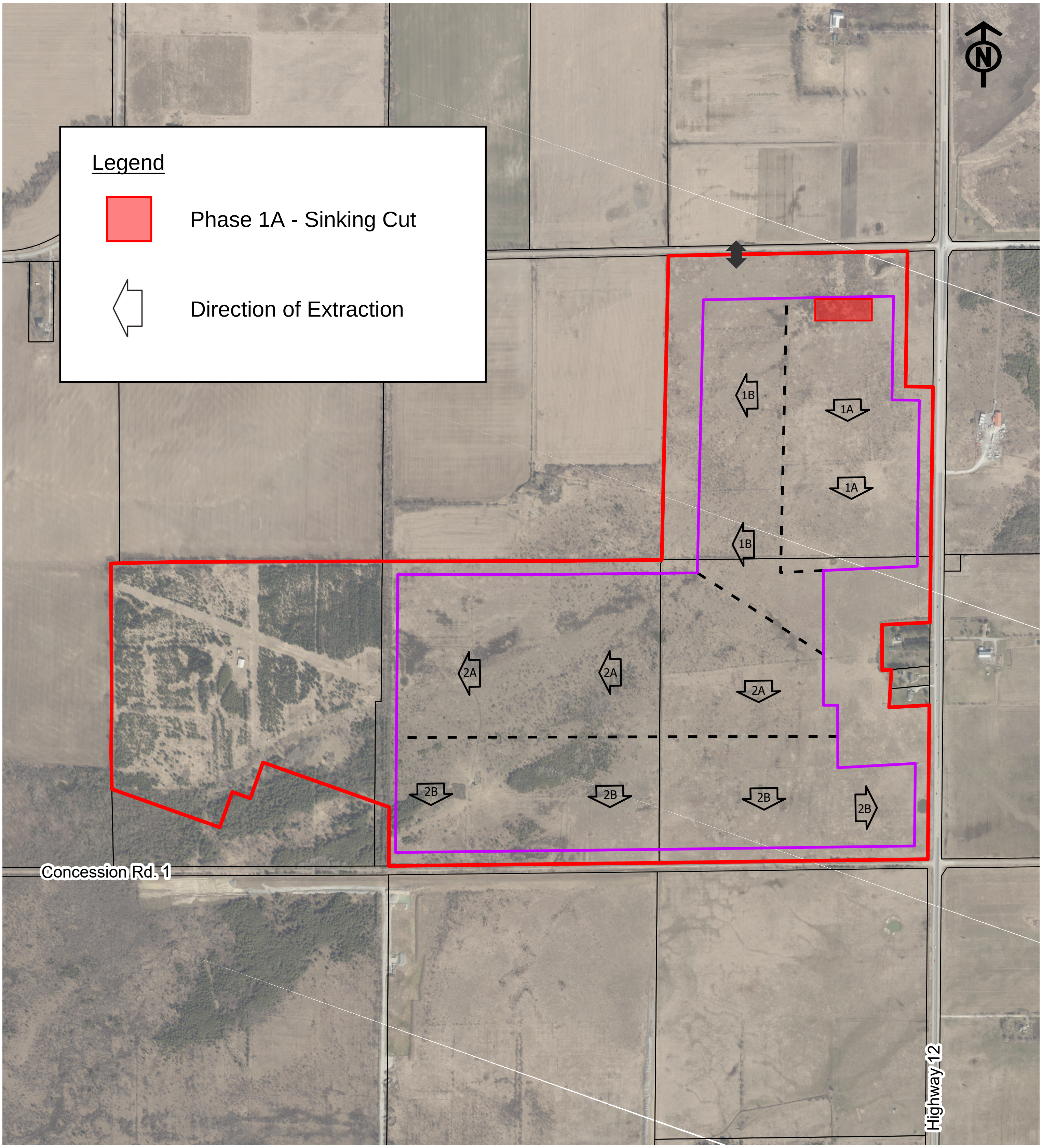
CONCLUSION

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

Blasting operations required for operations at the proposed Brechin Quarry site can be carried out safely and within governing guidelines set by the Ministry of the Environment, Conservation and Parks (MECP).

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

Appendix A



BRECHIN QUARRY SIMPLIFIED OPERATION SCHEMATIC

Proposed Brechin Quarry

Part of Lots 11&12, Concession 1
Township of Ramara
County of Simcoe

LEGEND

- Subject Lands and Proposed Licence Boundary
- Proposed Limit of Extraction
- Phasing Area
- Proposed Entrance / Exit
- Parcel Fabric

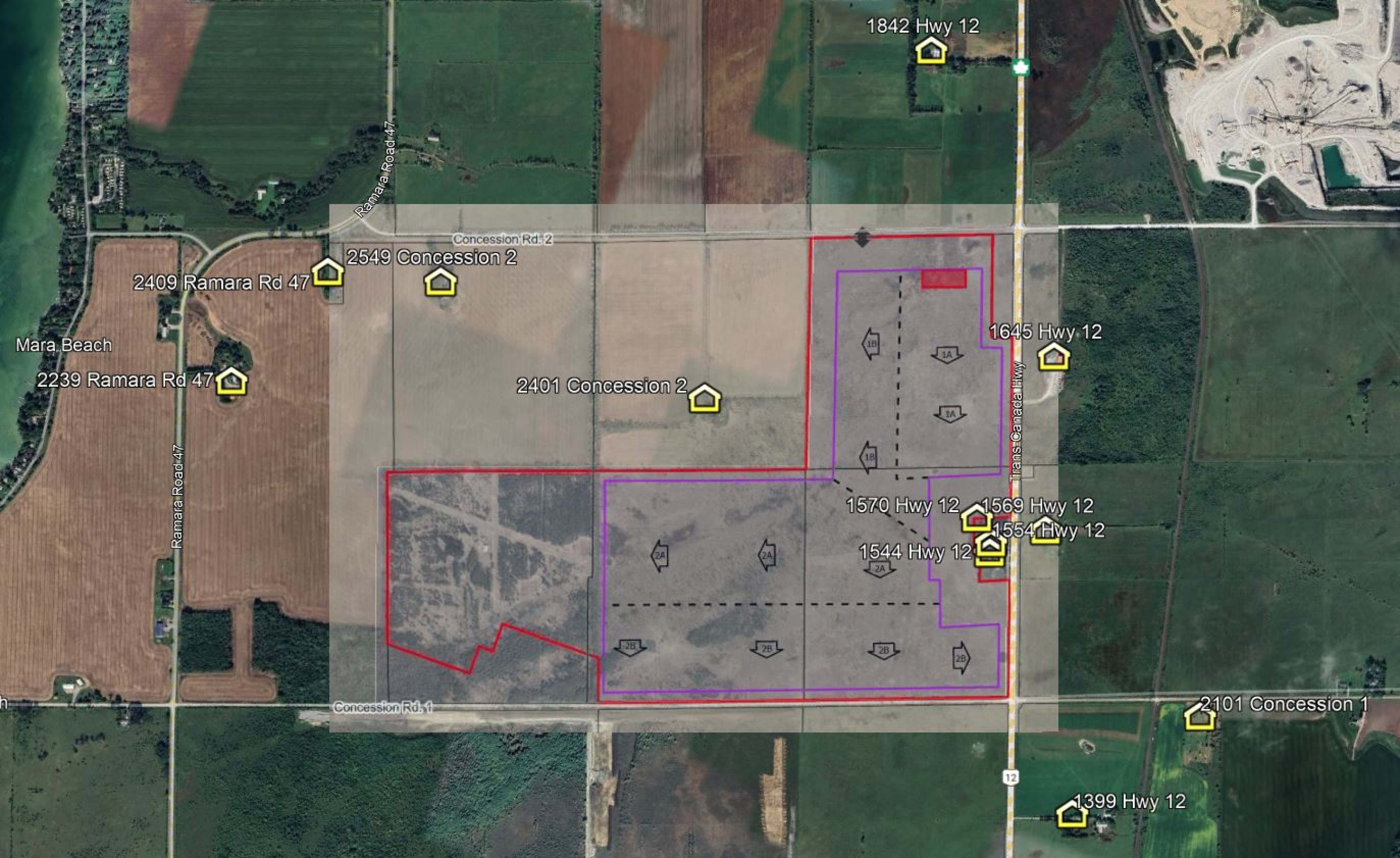
DATE December 2023

SOURCES 2022 Ortho Photography County of Simcoe GIS

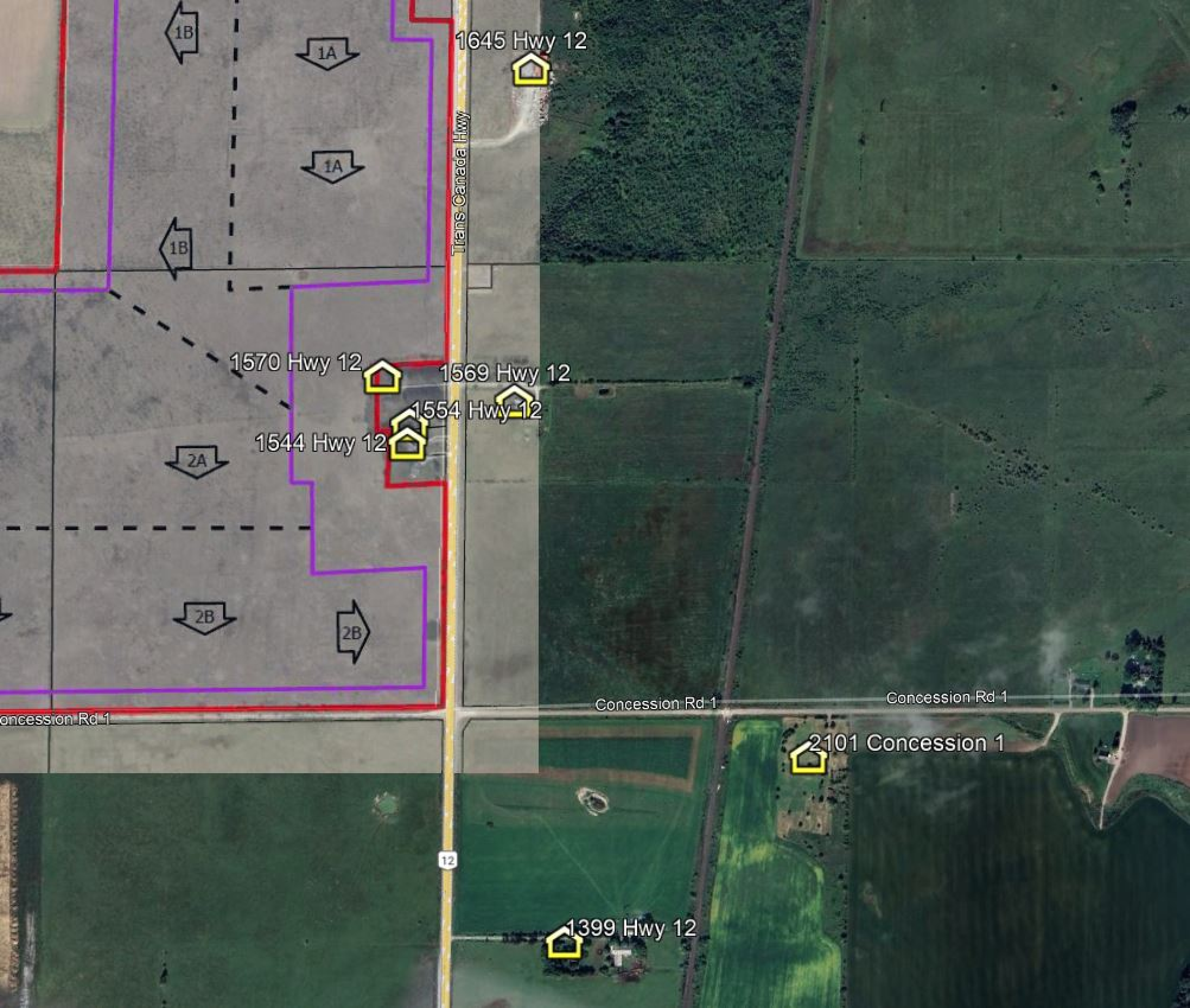
0 75 150 300
Meters

12135B - Planning Report Figures

MHBC PLANNING URBAN DESIGN & LANDSCAPE ARCHITECTURE



1842 Hwy 12
Concession Rd. 2
2549 Concession 2
2409 Ramara Rd 47
Ramara Road 47
Mara Beach
2239 Ramara Rd 47
2401 Concession 2
1645 Hwy 12
Trans Canada Hwy
1B
1A
1A
1B
1570 Hwy 12
1569 Hwy 12
1554 Hwy 12
1544 Hwy 12
2A
2A
2A
2B
2B
2B
2B
Ramara Road 47
Concession Rd. 1
2101 Concession 1
12
1399 Hwy 12


1B
1A
1A
1B
1645 Hwy 12
Trans-Canada Hwy
1570 Hwy 12
1569 Hwy 12
1554 Hwy 12
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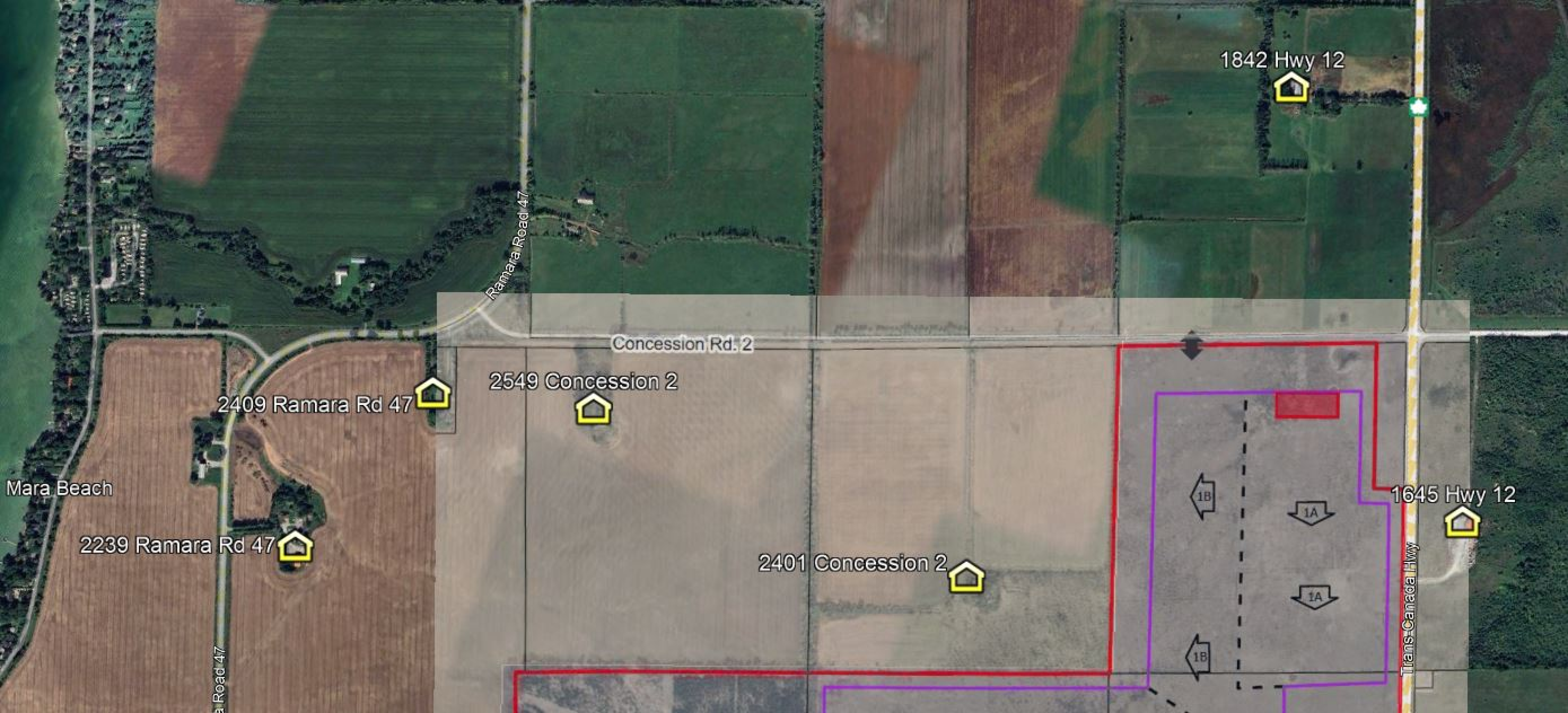
2A
2B
2B
Concession Rd 1
Concession Rd 1
Concession Rd 1
2101 Concession 1
12
1399 Hwy 12



1842 Hwy 12
Ramara Road 47
Concession Rd. 2
2549 Concession 2
2409 Ramara Rd 47
Mara Beach
2239 Ramara Rd 47
1645 Hwy 12
1B
1A
1A
1B
2401 Concession 2
Trans-Canada Hwy
Ramara Road 47

Appendix B

EXPLOTECH

Brechin Quarry

PREVAILING METEOROLOGICAL CONDITIONS

Medians provided by Environment Canada

Date	Wind Direction**	Wind Velocity (Km/h)**	Temperature (Deg Celsius)*
January	S	12.4	- 8.4
February	NW	12.6	- 6.8
March	NW	12.7	- 1.8
April	NW	13.3	6.0
May	NW	11.5	12.5
June	NW	10.0	17.7
July	NW	9.1	20.3
August	S	8.9	19.2
September	S	9.5	14.8
October	S	11.1	8.2
November	S	11.9	2.0
December	S	12.2	- 4.4

** Data is not available specifically for the proposed quarry location.
Nearest weather stations is Lindsay, Ontario* and Egbert, Ontario**

** Data is based on averaged climate normals gathered 1981 – 2010 for Lindsay, Ontario and 1991 – 2020 for Egbert, Ontario.

Appendix C

Ground Vibrations

Imperial Equations

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

Metric Equations

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

D (m)	W (Kg)	PPV1 (mm/s)	PPV2 (mm/s)	PPV3 (mm/s)	PPV4 (mm/s)	PPV5 (mm/s)	PPV1 (mm/s)	PPV2 (mm/s)	PPV3 (mm/s)	PPV4 (mm/s)
720	56	**0.8**	**1.2**	**0.3**	**0.8**	**1.1**	**0.8**	**2.4**	**1.7**	**1.5**

Air Overpressure

Imperial Equations

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

Metric Equations

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

D (m)	W (Kg)	OP1 (dB)	OP2 (dB)	OP3 (dB)	OP4 (dB)	OP1 (dB)	OP2 (dB)	OP3 (dB)
600	56	**119.0**	**123.0**	**96.6**	**113.6**	**126.3**	**124.3**	**126.3**

Appendix D

Andrew Campbell, P.Eng.

Explotech Engineering Ltd.

EDUCATION

Bachelor of Engineering,
Mechanical Engineering, Carleton University

PROFESSIONAL AFFILIATIONS

Association of Professional Engineers of Ontario (APEO)
International Society of Explosive Engineers (ISEE)

SUMMARY OF EXPERIENCE

An engineer working for Explotech Engineering Ltd., Andrew holds a Bachelor of Engineering degree in Mechanical Engineering and has strong analytical, technical, and interpersonal skills. A proven leader in collaborative environments, Andrew is comfortable managing projects, specifying details, and communicating internally and externally. Recent focus on blast designs, blast impact analyses, vibration analysis, damage complaint investigation, blast monitoring, and job estimations.

PROFESSIONAL RECORD

2018 – Present	- Engineer, Explotech Engineering Ltd.
2013 – 2018	- Technician, Explotech Engineering Ltd.
2012 – 2012	- Ride Technician, Canada's Wonderland

Robert J. Cyr, P. Eng.

Principal, Explotech Engineering Ltd.

EDUCATION

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

PROFESSIONAL AFFILIATIONS

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

SUMMARY OF EXPERIENCE

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

PROFESSIONAL RECORD

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

EXPLOTECH

Specialists in Explosives, Blasting and Vibration
Consulting Engineers

Mitch Malcomson, P.Eng.

Consulting Engineer, Explotech Engineering Ltd.

EDUCATION

Bachelor of Engineering,
Civil Engineering with Concentration in Business Management,
Carleton University

PROFESSIONAL AFFILIATIONS

Association of Professional Engineers of Ontario (APEO)
Association of Professional Engineers and Geoscientists of BC (APEG)
International Society of Explosives Engineers (ISEE)
Ontario Stone Sand and Gravel Association (OSSGA)

SUMMARY OF EXPERIENCE

A Consulting Engineer and Project Manager for Explotech Engineering Ltd., Mitch holds a Bachelor of Engineering degree from Carleton University in Civil Engineering with a Concentration in Business Management. Mitch has strong analytical, technical, business and leadership skills. As a Project Manager, Mitch is responsible for operational strategies, scheduling and contract procurement. As a Consulting Engineer, the technical responsibilities include detailed blast designs, blast investigations and reviews, implementation of vibration monitoring programs, development of monitoring equipment/ technologies and building assessments for construction and the drilling and blasting portions of mining, quarrying and construction projects across Canada.

PROFESSIONAL RECORD

2008 – Present - Consulting Engineer / Project Manager, Explotech Engineering Ltd.

Michael Tobin, P.Eng.

Explotech Engineering Ltd.

EDUCATION

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

PROFESSIONAL AFFILIATIONS

Association of Professional Engineers of Ontario (APEO)
International Society of Explosives Engineers (ISEE)

SUMMARY OF EXPERIENCE

An engineer working for Explotech Engineering Ltd., Michael holds a Bachelor of Applied Science degree from Queen's University in Geological Engineering. Michael has strong analytical, technical, and interpersonal skills. Recent projects have focused on blast monitoring, vibration analysis, job estimation, damage complaint investigation and blast design.

PROFESSIONAL RECORD

2021 – Present - Engineer, Explotech Engineering Ltd.

2017 – 2021 - Technician, Explotech Engineering Ltd.

Appendix E

EXPLOTECH

Blasting Terminology

ANFO:	Ammonium Nitrate and Fuel Oil – explosive product
ANFO WR:	Water resistant ANFO
Blast Pattern:	Array of blast holes
Body hole:	Those blast holes behind the first row of holes (Face Holes)
Burden:	Distance between the blast hole and a free face
Column:	That portion of the blast hole above the required grade
Column Load:	The portion of the explosive loaded above grade
Collar:	That portion of the blast hole above the explosive column, filled with inert material, preferably clean crushed stone
Face Hole:	The blast holes nearest the free face
Overpressure:	A compressional wave in air caused by the direct action of the unconfined explosive or the direct action of confining material subjected to explosive loading.
Peak Particle Velocity*:*	The rate of change of amplitude, usually measured in mm/s or in/s. This is the velocity or excitation of the particles in the ground resulting from vibratory motion.
Scaled distance:	An equation relating separation distance between a blast and receptor to the energy (usually expressed as explosive weight) released at any given instant in time.
Spacing:	Distance between blast holes
Stemming:	Inert material, preferably clean crushed stone applied into the blast hole from the surface of the rock to the surface of the explosive in the blast hole.
Sub-grade:	That portion of the blast hole drilled band loaded below the required grade
Toe Load:	The portion of explosive loaded below grade

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