March 5, 2014

WEST OTTAWA LAND HOLDINGS LTD.

Ground Vibration Attenuation Analysis of Huntley Quarry Blasting

Submitted to:
West Ottawa Land Holdings Ltd.
225 Metcalfe Street
Ottawa, Ontario
K2P 1P9
Attn.: Jeff Parkes
V.P. Planning & Development

Report Number: 13-1127-0133

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1.0 INTRODUCTION

West Ottawa Land Holdings Ltd. (WOLHL) intends to develop property near Karson Aggregates’ (Karson) Huntley Quarry located north of Stittsville, Ontario. WOLHL retained Golder Associates Ltd. (Golder) to assess the potential blast-induced ground and air vibration from the nearby rock quarry on the proposed development (the development). The purpose of this report is to provide a summary of the existing blast monitoring data, review the applicable ground and air vibration limits and estimate appropriate standoff distances from the quarry and the development. The analysis and results presented in this document are intended to provide sufficient information to the City of Ottawa to allow for appropriate planning and zoning for the proposed commercial and light industrial development.

2.0 CRITERIA – GROUND AND AIR VIBRATION LIMITS

The ground and air vibration effects produced at Points of Reception (PORs) as defined by the Ontario Ministry of the Environment (MOE) (i.e., dwellings, hotels, schools etc.) adjacent to mines and quarries are subject to guidelines contained in Noise Pollution Control (NPC) publication 119 of the Model Municipal Noise Control Bylaw, dated August 1978, published by the MOE. Under conditions where monitoring of the blasting operations is routinely carried out, NPC 119 stipulates that the ground and air vibration limits at the nearest POR to the quarry will be 12.5 mm/s and 128 dBL, respectively.

However, it is Golder’s understanding that many of the structures to be developed by WOLHL are not PORs. Specifically, proposed structures nearest to the existing quarry will not meet the definition of a POR in accordance with MOE guidelines. The Ontario Provincial Standard Specification (OPSS) 120, General Specification Use of Explosives, covers the requirements for the use of explosives and has been developed for use in provincial- and municipal-oriented contracts. Where blasts are not covered by NPC 119, the OPSS is often used in blasting contracts. The Peak Particle Velocity (PPV) limits specified by OPSS 120 are shown in Table 1.

<table>
<thead>
<tr>
<th>Element</th>
<th>Frequency (Hz)</th>
<th>PPV (mm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structures and Pipelines</td>
<td>≤ 40</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>&gt; 40</td>
<td>50</td>
</tr>
<tr>
<td>Concrete and Grout &lt; 72 hours from placement</td>
<td>N/A</td>
<td>10</td>
</tr>
</tbody>
</table>

Generally, empirical observations related to cracking in structures have been with single component peaks. The use of the Peak Vector Sum (PVS) (i.e., vector resultant of all components combined) provides a large factor of safety. Standard practice is to apply vibration limits to the PPV of the largest single component on the seismograph record rather than the PVS. Additionally, MOE publications NPC 119 and NPC 103 adopt the use of PPV rather than PVS. In our review of the vibration monitoring data, the PPV of the largest single component (i.e., transverse, vertical, longitudinal) of the monitoring record was used.

The OPSS 120 does not provide limits for air vibration limits. As a result, many contracts will use the NPC119 limit of 128 dBL or 134 dBL as recommended in United States Bureau of Mines (USBM) RI8485 (Siskind et al.,...
for large scale surface mining operations. The cracking of windows has been found to be the first indication of air vibration damage from blasts (Siskind, 2005). Most studies discussed within the USBM RI8485 report suggest that 140 dBL is a reasonable threshold for glass and plaster damage. It is suggested in that study that 134 dBL was a worst-case safe-level for blast induced air vibration. An air vibration limit of 134 dBL is used within this document.

Ground vibration guidelines are typically established for blasting sites to prevent damage to adjacent facilities or infrastructure. Exceeding these levels does not in itself imply that damage has occurred but only increases the potential that damage might occur. Siskind and Stagg (1993) suggested a PPV limit for Class B or better steel pipelines (or Class 6 or better PVC pipelines) at 127 mm/s. However, many pipeline companies in Canada (including TransCanada Pipelines and Union Gas) impose a more conservative limit of 50 mm/s. Ground vibration limits for stronger materials, such as concrete, may be set as high as 150 to 200 mm/s, while peak ground vibration levels of 300 to 600 mm/s are required to create micro-cracks or open existing discontinuities in bedrock (Keil et al., 1977). Richards and Moore (2007) provided a review of the damage potential from blast-induced vibrations from open pit coal mines. Table 2 provides a summary of PPV limits proposed for a variety of infrastructure types.

### Table 2: Vibration Limits for Various Infrastructure Types

<table>
<thead>
<tr>
<th>Infrastructure Type</th>
<th>PPV Limit (mm/s)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Transmission Towers *</td>
<td>100</td>
<td>Concrete footings</td>
</tr>
<tr>
<td>Wooden Hydro Poles *</td>
<td>240</td>
<td></td>
</tr>
<tr>
<td>Electrical Sub-stations *</td>
<td>10 – 30</td>
<td>Depending on switch type. Manufacturer should be consulted.</td>
</tr>
<tr>
<td>Railway Tracks *</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Buried Pipelines **</td>
<td>127</td>
<td></td>
</tr>
<tr>
<td>Underground Fibre Optics Line *</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Concrete and grout &lt;72 hours from placement ***</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Mine Plant and Industrial Buildings *</td>
<td>100</td>
<td>Unoccupied structures of reinforced concrete or steel construction</td>
</tr>
</tbody>
</table>

* * Suggested by Richards and Moore (2007)
** Siskind and Stagg (1993)
*** OPSS 120

### 3.0 METHODS

#### 3.1 Existing Blast Monitoring

Austin Powder Limited (Austin) monitors the blast vibrations from the Huntley Quarry in order to ensure that the blasts remain within the NPC 119 Guidelines. Austin also conducted an attenuation study behind the blasts in order to establish the potential blast vibration at the proposed development. Austin provided Golder with the monitoring results from 17 blasts conducted from April 25, 2013, to September 10, 2013, which were recorded by Austin staff. The vibration monitoring records consisted of 2 sets of data:

- Compliance monitoring at locations in front of the blasting; and
Monitoring locations behind or beside the closed end of the blasts which would most likely represent those to be recorded at the WOLHL development.

The data provided by Austin has been reprocessed and assessed for the purposes of this assessment. Specifically, the data has been presented as PPV in accordance with standard practice in Ontario.

3.2 Ground Vibration Modelling

The rate at which ground vibrations attenuate or decrease with increased distance from a blast source depends on a variety of conditions, including the type and condition of the bedrock being blasted, depth and composition of the earth covering deposits (soil), and the general topography.

The impact of blast vibrations on structures is related to both the amplitude and dominant frequency of the vibration as well as the type and configuration of the structure. The PPV is the most commonly used measure of the intensity of the ground vibration due to blasts. Two of the most important variables that affect a blast PPV are the distance from the source (seismic waves attenuate with distance) and the maximum explosive charge weight per delay period. The most common method of normalizing these two factors is by means of plotting the scaled distance (SD) against the PPV and is given by the following:

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

Where $SD = \text{scaled distance (m/kg}^{0.5}\text{)}$ between the blast and receptor; and, $\text{K, e = are site specific constants.}$

The scaled distance is given by:

$$SD = \frac{D}{\sqrt{W}}$$

Where $D = \text{distance (m) between the blast and receptor};$ and, $W = \text{maximum weight of explosive (kg) detonated per delay period.}$

3.3 Air Vibration Modelling

Blasting for the quarry will result in air vibrations. 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 the local topography and vegetation, length of collar and type of stemming material, differences in explosive types and variations in burden distance.

Because the Peak Sound Pressure Level (PSPL) is given by the following:
PSPL = M \times \ln(SD) + b

Where SD = scaled distance (m/kg^{0.33}) between the blast and receptor; and
M, b = are site-specific constants.

The cube root scaled distance is given by:

\[ SD = \frac{D}{\sqrt[3]{W}} \]

Where D = distance (m) between the blast and receptor; and,
W = maximum weight of explosive (kg) detonated per delay period.

### 4.0 RESULTS

#### 4.1 Monitored Ground Vibration Levels

The results of the ground vibration monitoring for the Huntley Quarry are presented on Figure 1 as a plot of the PPV against the SD.

The ground vibration records exhibit a degree of scatter that is inherent in all SD plots. Factors responsible for these variations include the geologic conditions of the bedrock (type and structure), different wave types, errors in blast initiation timing, degree of confinement, and differences in blast efficiencies.
It must be noted that Golder did not observe the blast vibration monitoring conducted by Austin. As such, we are unable to verify the equipment or methodology used to carry out the monitoring.

The ground vibration attenuation characteristics for the entire data set as well as that for the monitoring behind the blasts are summarized in Figure 2. These represent the estimated 95% confidence lines, which provide a means to predict the maximum vibration for a given explosive charge weight per delay and given distance from the source to the target location. The purpose of the equations is not so much to predict what a given vibration level would be at a particular location for a given blast, but to indicate the probability that the peak vibration would fall below the level indicated by the equation for a given distance and maximum explosive weight. The equations are therefore a useful blast design tool in establishing maximum explosive charge weights per delay for various distances from a blast site for a given maximum ground vibration level.

\[
PPV = 1243 (\frac{D}{\sqrt{W}})^{-1.32}
\]
for all the vibration monitoring data received; and

\[
PPV = 814 (\frac{D}{\sqrt{W}})^{-1.14}
\]
for the vibration monitoring conducted behind the blasts.
4.2 Monitored Air Vibration Levels

The results of the air vibration monitoring for the Huntley Quarry are presented on Figure 3 as a plot of the Peak PSPL against the SD.

![Figure 3: Air Vibration Monitoring for the Huntley Quarry Blasts](image)

The equations for estimating the PSPL using the 95% confidence lines shown in Figure 4 can be expressed as:

$$PSPL = -8.963 \times \ln(SD) + 167.5$$

for the vibration monitoring conducted behind the blasts.
4.3 Predicted Ground Vibration Levels

Information from Karson indicates that the current permissible explosive charge weight per delay is 126 kg. Figure 5 shows the estimated ground vibration amplitudes for blasts carried out over a range of distances (from the blasts to the nearest receptor) and assuming a maximum explosives charge weight per delay of 126 kg. It also displays the various ground vibration limits discussed.

The ground vibration monitoring results and an assumed maximum explosive charge weight per delay of 126 kg suggest that the following standoff distances behind the blasts would be required to remain below the OPSS 120 limits:

- OPSS 120 (≤ 40 Hz) – 290 m; and
- OPSS 120 (> 40 Hz) – 130 m.

Figure 4: Estimated Air Vibration Attenuation from the Vibration Monitoring for the Huntley Quarry
As discussed above, the two key parameters that will affect the PPV at nearby structures are distance and explosives charge weight per delay. Changes to the latter will require discussions between WOLHL and Karson.

Figure 6 shows the estimated 12.5 mm/s and 20 mm/s ground vibration contours for blasts at the Huntley Quarry assuming a maximum explosives charge weight per delay of 126 kg recorded behind the blast. The contours are based on blasts at the eastern limit of extraction (i.e., closest distance between the quarry limit of extraction the proposed WOLHL development). This illustrates that at standoff distances of less that 290 m the ground vibration levels may exceed 20 mm/s and at standoff distances less than 438 m they may exceed 12.5 mm/s.
**Figure 5**

*Estimated Ground Vibration Contours for Locations Behind the Blasts*

**Legend**
- **Licensed Boundary**
- **Limit of Extraction**
- **Estimated Ground Vibration Contours for Locations Behind the Blasts**
  - 15.0 mm/s (138 m)
  - 3.0 mm/s (286 m)

**KARSON HUNTLEY QUARRY**
License No. 4079

**KARSON WILSON FARM PIT & QUARRY**
License No. 4106

NOTE:
This figure is to be read in conjunction with the accompanying Goldar Associates Ltd. report No. 13-1127-0133.

**Reference**
Data from West Ottawa Land Holdings Ltd. and Karson Group Ltd.
Land Information Ontario (LIO) data produced by Goldar Associates Ltd. under licence from Ontario Ministry of Natural Resources. © Queens Printer 2016.

**Scale:** 1:5,000

**Site Plan**
From West Ottawa Land Holdings Ltd. and Karson Group Ltd.
4.4 Predicted Air Vibration Levels

Figure 7 shows the estimated air vibration amplitudes for blasts carried out over a range of distance (from the blasts to the nearest receptor) and assuming a maximum explosives charge weight per delay of 126 kg. It also displays the various air vibration limit discussed.

The air vibration monitoring results and an assumed maximum explosive charge weight per delay of 126 kg suggest that the standoff distances behind the blasts would be required to remain to at least:

- 410 m for the 128 dBL limit; and
- 210 m for the 134 dBL limit.

![Figure 7: Estimated PSPL at a Given Distance for Monitoring Behind the Blast](image)

5.0 DISCUSSION

Based on the vibration monitoring data provided to Golder behind the blasts at the Huntley Quarry and the current blasting operations, the recommended standoff distances from the blasts are as follows:

- For ground vibrations to meet OPSS 120 ground vibrations limits:
  - ≤ 40 Hz – 290 m; and
  - > 40 Hz – 130 m.
- For air vibrations to meet air vibration limit of 134 dBL – 210 m.
These results are based on the understanding that the development will primarily include commercial and light industrial type facilities. Based on discussion with WOLHL, the potential for sensitive locations, as defined by the MOE are possible, however, these locations will be no closer than approximately 500 m. At this distance, the predictions provided in this report suggest that the limits specified in NPC 119 will be met as a minimum setback distance of less than 438 m will be required to ensure compliance with the MOE guideline.

In addition, consideration must be given to the allowable zoning of the development. Appendix A includes the IP - Business Park Industrial Zone provisions. At a distance of approximately 438 m, vibration levels associated with blasts from the quarry will comply with MOE limits (i.e., < 12.5 mm/s and < 128 dBL). Therefore, no restrictions related to PORs as defined by the MOE are required. At distances less than 438 m, PORs should not be allowed unless changes to the blasting operations at the quarry are employed. This may include lower charge weight per delay or other modified blasting practices to lower off-site vibration levels. These levels should be verified through monitoring of the modified blasting practices. Examples of restricted uses as defined by the MOE include:

- Daycares;
- Hotels;
- Places of assembly; and
- Medical facilities.

At distances between 290 m and 438 m, the predicted ground vibration levels will vary between 20 mm/s and 12.5 mm/s. If we assume a 30 m quarry blasting setback, which has been confirmed within the quarry operator's licence, and the 26 m Right of Way between properties, there is a total of 56 m natural setback from the WOLHL site boundary. Thus, at distances between 234 m and 382 m onto the WOLHL property, the predicted ground vibration levels will vary between 20 mm/s and 12.5 mm/s. Vibration levels within this setback are predicted to meet OPSS 120 criteria, but may exceed MOE limits. Based on these results, additional zoning restrictions should be considered. These restrictions must include any POR as identified above and the following:

- Printing plant;
- Technology industry;
- Research and development centre; and
- Production studio.

The restrictions listed above should be reviewed on an individual case-by-case basis, as sensitivity to vibration varies significantly and restricting all uses that may fall into the above categories may not be appropriate. Understanding the type of vibration sensitivity that is required by various pieces of equipment is imperative to understanding the potential affects that blast vibrations may cause.

For distances less than 290 m from a blast, one additional restriction should be considered in addition to all of the above. The potential for office use within a setback of 290 m should be reviewed to establish whether or not the proposed office type is suitable.
As is typical practice for quarry operators in Ontario, notification of blasting operations will be critical to mitigating potential complaints from the blasting ground and air vibrations within the development. In addition to these notifications, a warning clause is recommended to be included in all development agreements, offers/agreements of purchase, sale or lease agreement. Sample wording is given below, which can be modified as needed.

“Purchasers / tenants are advised that due to the proximity of the adjacent Karson Huntley Quarry, ground and air vibration levels associated with the blasting operation of the quarry may at times be perceptible.”

Lastly, Golder also recommends that the results of this report be provided to all future builders and architects to ensure that ground and air vibration levels have been considered in the design of all structures. The consideration of ground and air vibration levels early in the design of any future structure will allow for building elements to reduce vibration effects.

6.0 CLOSURE

Golder Associates Ltd. was retained by West Ottawa Land Holdings Ltd. to assess the potential blast-induced ground and air vibration from the nearby rock quarry on the proposed commercial and light industrial development. Based on the results presented in this report and restricting some of the approved uses within specific setback distances as identified in Section 5.0 of this report and shown on Figure 6, the proposed development can meet ground and air vibration limits specified in OPSS 120, United States Bureau of Mines RI8485 and MOE publication NPC 119.

If you have any further questions or concerns, please feel free to contact the undersigned.
APPENDIX A
IP – Business Park Industrial Zone Provisions
Purpose of the Zone

The purpose of the IP – Business Park Industrial Zone is to:

(1) accommodate mixed office, office-type uses and low impact, light industrial uses in a business park setting, in accordance with the Enterprise Area designations of the Official Plan or, the Employment Area or the General Urban Area designation where applicable;

(2) allow in certain Enterprise or General Urban Areas, a variety of complementary uses such as recreational, health and fitness uses and service commercial (e.g. convenience store, personal service business, restaurant, automobile service station and gas bar), occupying small sites as individual occupancies or in groupings as part of a small plaza, to serve the employees of the Enterprise, Employment or General Urban Area, the general public in the immediate vicinity, and passing traffic;

(3) prohibit retail uses in areas designated as Enterprise Area but allow limited sample and showroom space that is secondary and subordinate to the primary use of buildings for the manufacturing or warehousing of the product;

(4) prohibit uses which are likely to generate noise, fumes, odours, or other similar obnoxious impacts, or are hazardous; and

5) provide development standards that would ensure compatibility between uses and would minimize the negative impact of the uses on adjacent non-industrial areas.

In the IP Zone:

Permitted Uses
(1) The following uses are permitted subject to:

   (a) the provisions of subsections 205(3) to (6);  

          automobile dealership  
          automobile rental establishment  
          broadcasting station  
          day care  
          drive-through facility  
          emergency service  
          hotel  
          light industrial uses  
          medical facility  
          office  
          place of assembly  
          printing plant  
          production studio  
          research and development centre  
          service and repair shop  
          small batch brewery, see Part 3, Section 89  
          technology industry  
          training centre  
          warehouse  

(2) The following additional uses area permitted subject to:

   (a) the provisions of subsections 205(3) to (6);  

   (b) the cumulative total gross floor area for these uses not exceeding 2,999 m²;  
       (OMB Order #PL080959, issued September 18, 2009)  

   (c) each use not exceeding 300 square metres of gross floor area; and  

   (d) the provisions of subsection 205(2)(c) not applying to recreational and athletic facility and park;  

          animal care establishment  
          animal hospital  
          automobile service station  
          bank  
          bank machine  
          car wash  
          convenience store
TABLE 205 - IP ZONE PROVISIONS

<table>
<thead>
<tr>
<th>I ZONING MECHANISMS</th>
<th>II PROVISIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Minimum lot area</td>
<td>750 m²</td>
</tr>
<tr>
<td>(b) Minimum lot width</td>
<td>No minimum</td>
</tr>
<tr>
<td>(c) Maximum lot coverage</td>
<td>55%</td>
</tr>
<tr>
<td>(d) Minimum front yard and corner side yard</td>
<td>6 m</td>
</tr>
<tr>
<td>(e) Minimum interior side yard</td>
<td>(i) abutting a residential or institutional zone 6 m</td>
</tr>
<tr>
<td></td>
<td>(ii) all other cases 3 m</td>
</tr>
<tr>
<td>(f) Minimum rear yard</td>
<td>6 m</td>
</tr>
<tr>
<td>(g) Maximum floor space index</td>
<td>2, unless otherwise shown on the zoning maps</td>
</tr>
</tbody>
</table>
### Maximum building height

<table>
<thead>
<tr>
<th>(i) within 20 m from a residential or institutional zone</th>
<th>11 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>(ii) in all other cases</td>
<td>22 m, or as shown otherwise by a suffix or on a schedule</td>
</tr>
</tbody>
</table>

### Minimum width of landscaping

<table>
<thead>
<tr>
<th>(i) abutting a residential or institutional zone</th>
<th>3 m; may be reduced to one metre if a 1.4 metre high opaque screen is provided</th>
</tr>
</thead>
<tbody>
<tr>
<td>(ii) abutting a street</td>
<td>3 m</td>
</tr>
<tr>
<td>(iii) in all other cases</td>
<td>No minimum</td>
</tr>
</tbody>
</table>

### Accessory display and sales area

- Accessory **display and sales area** must be within the same building as the use to which it is accessory and must not exceed 25% of gross floor area.

### Outdoor storage

- Outdoor storage is prohibited.

### Other applicable provisions


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**Medical facility** means a **place** where a medical doctor, dentist or other legally qualified health care practitioner has his or her practice, and includes a medical or dental laboratory. *(clinique)*

**Office** means a **place** used by an agency, business or organization for:

1. the transaction of administrative, clerical, data processing or management business;
2. the practice of a profession other than a **medical facility**; or
3. the provision of government or social services and other similar services. *(bureau)*

**Place of assembly** means a **place** designed and used to accommodate gatherings of people such as clubs, reception halls, conference centres, legion halls, assembly halls and lodges, and for events such as trade shows, banquets, and political or other conventions. *(lieu de rassemblement)*
Research and development centre means a place used for systematic research, data collection and manipulation, or technical or scientific development of information or new products, and may include a research laboratory; but excludes industrial and manufacturing operations other than those required as part of the research. (centre de recherche-développement)
As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

For more information, visit golder.com