APPRAISAL OF THE MINING ASPECTS OF REPORTS

Prepared as Part of the
Hidden Quarry Rezoning Application
To the
Guelph/Eramosa Township Council

WILLIAM HILL MINING CONSULTANTS LIMITED
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Foreword

This written appraisal of five reports dealing with the Hidden Quarry (HQ) was prepared by William Hill Mining Consultants Limited. The appraisal was written by William Hill with the help and support of professionals in the Concerned Residents Coalition (CRC); as well as professionals who have extensive knowledge in mining and geology. On October 21, 2013 William Hill gave a Power Point Presentation to the Guelph/Eramosa Township (GET) Council titled Mining Explained. The presentation gave the Council an opportunity to become better informed on drilling and blasting in open pit mines.

William Hill is a resident of GET on the sixth line. He owns a cash crop farm 700 metres north and slightly west of the HQ. The property also abuts the eastern boundary of the town of Rockwood.

William Hill has been actively involved in the mining industry continuously since 1949 and from 1958 as a Mining Engineer. The title of Professional Engineer of Ontario was assigned to him over 40 years ago. His professional career has taken him to projects in close to fifty countries. He continues to serve the industry as a Mining Consultant, as a Mining Company Director and he has mining interests in Latin America.

William Hill has extensive knowledge of open pit mines - his field of specialty – in almost all types of rock and mineral. The mining work has involved the drilling and blasting and transport of rock totaling well over one billion tonnes. In one mine alone the daily tonnage moved was close to 500,000 tonnes per day. Other operations involved as little as three men, a compressor, a drill and several wheel barrows. This experience is particularly applicable for commenting on the proposed operations of the HQ. The reason for the foregoing statement is that the HQ is actually an open pit mine involving drilling and blasting just as it is done in thousands of such operations throughout the world.The term quarry usually connotes a more innocuous (sand and gravel) type of operation.

Over the years William Hill has developed a love and respect for the mining industry and has benefited from being involved in its growth: However, it has also given him the knowledge to recognize that mining should only be carried out in suitable locations. Paramount consideration, in determining whether the environment is suitable, must be given to location, particularly with respect to the surrounding residents - in this case those of the Rockwood area.

Also in determining the environment, consideration should be given to the physical setting particularly with respect to geology. The dolomitic rock in the area is not suitable for drilling and blasting because geological time will likely have produced irregularities in the rock, such as crevices and cavities, which could contribute to possible dangers with blasting such as personal and highway injuries, fatalities and damages to property.

Appraisal of the Mining-Related Aspects of Reports
Prepared as Part of the
Hidden Quarry Rezoning Application
To the
Guelph/Eramosa Township Council

Introduction

Early in 2013, citizens in and around the town of Rockwood became aware that James Dick Construction Limited (JDC) had applied for a rezoning permit from the Guelph/Eramosa Township Council (GET). This would allow for the extraction of aggregate, both sand and gravel near surface and dolomite in bedrock below the water table. The property planned to be exploited lies in the first 100 acre lot north of Highway7 and east of the 6th Line of Eramosa Township.

The proposal was accompanied by several reports of studies and plans prepared for the exploitation of the aggregate resources. This report presents a review of those reports but covers only the material which is related directly to the mining (quarrying) operations in the Hidden Quarry project**.**

Summary

The GET posts a complete set of reports submitted by JDC as well as reports commissioned by consultants as peer reviews on its web site.

William Hill Mining Consultants Limited (WHMC) reviewed five of these reports concentrating on the mining-related aspects contained in them drawing on knowledge of the problems associated. The opinion of WHMC with respect to the reports is summarized as follows.

All five of the reports fall short of providing adequate coverage of the subject. In doing so, the problems which may arise from the implementation of the HQ project, as proposed, have been inadequately presented to Council and could potentially lead to faulty decision-making.

Conclusions

The dangers posed by flyrock in proximity of people, homes, structures, Highway 7 and side roads are absent in all reports.

The problems typically associated with blasting shock waves have been dealt with inadequately.

The protection of the Northwest Wetland, the Allen Wetland and the Northeast wetland is probably inadequate in view of their proximity to blasting.

The proposed protection of the Brydson Creek may not be sufficient to assure its existence because the planning for its preservation is flawed.

Re**commendation**

GET should commission a review of the five reports as well as this one. The new study should be carried out by independent qualified engineers with extensive experience in mining, particularly with knowledge in rock mechanics and blasting in open pits.

Preamble

This appraisal can be divided into two parts with appendices.

The first part presents the results of a review by William Hill Mining Consultants Limited (WHMC) of reports dealing with the rezoning application for the Hidden Quarry (HQ) presented to the Guelph/Eramosa Township (GET) Council. These reports can be accessed through the GET website under Hidden Quarry. The first part of the appraisal -

1. Cuesta/Burnside – Cuesta Planning Consultants Inc (Cuesta) "Planning Report #1, Zoning By-law Amendment, January 29, 2013" and "ZBA Hidden Quarry, January 11, 2013" by Burnside and Associates Limited (Burnside
2. "Blasting Impact Analysis, November 12, 2012"- Explotech Engineering Limited (EEL).
3. "Planning Report, September, 2012 "- Stovel and Associates Inc (Stovel).
4. "Level l and ll Hydrogeological Investigation, September, 2012" – Harden Environmental Services Ltd. (Harden).

The second part of the appraisal covers what WHMC considers to be omissions and shortcomings of the EEL Report. These are dealt with in two sections:

5. Flyrock
6. Blasting Vibrations

Appendices in the last pages of this report include;
1. Actual examples of flyrock experiences at other sites.
2. Illustrations.

1. Cuesta /Burnside

In its application for rezoning of the Hidden Quarry (HQ) property, James Dick Construction Limited (JDC) submitted several documents prepared by experts to the Guelph/Eramosa Township Council (GET).

GET retained the services of Cuesta and Burnside to review the documentation on its behalf. Peer-review reports prepared by Cuesta and Burnside were presented to Council on January 29th, 2013. These reports were reviewed by WHMC. WHMC is qualified to comment on parts relating directly with the mining (quarrying) aspects of the reports.

Unfortunately, the Cuesta and Burnside reports provide very little in the way of mining material for comment. Given this gap in its analysis, it appears that the proposal for mining had been either tacitly accepted, as being adequate, or else simply ignored. It is clear the problems, and dangers posed by the mining proposal have not been fully understood by the GET consultants. As a consequence, Council may have received inadequate analysis and advice. The consultants should have recognized their lack of understanding about the subject and sought out the advice of experienced mining consultants.

WHMC asserts that three reports presented to council by JDC should have received far more detailed and critical attention by Cuesta/Burnside. They are:

1. ,The “Blast Impact Analysis” by EEL dated November 19, 2012,
2. The “Planning Report” by Stovel dated September 2012, and
3. The Hydrogeological Investigation by Harden dated September 2012.

WHMC has reviewed this collective material and presents opinions in sections 2, 3 and 4 which follow.

2. Blasting Impact Analysis

Introduction

This section of the report presents an appraisal of the report titled "Blast Impact Analysis" for JDC by EEL. This appraisal has been prepared to address deficiencies in the review process by the consultants Cuesta and Burnside retained by GET.

Commentary

The omission of any reference to the potential dangers posed by flyrock in the EEL report is the most significant observation identified by WHMC in this appraisal.
(The mechanics and dangers of flyrock are explained in section 4. of this report)

Conclusions and Recommendations

The primary conclusion is the EEL report does not present accurate and credible facts on which to base a re-zoning decision for the HQ property as it does not touch in any way on the potential dangers of flyrock.

GET Council should direct JDC to commission a new report by qualified consulting engineers on the impact of blasting. **This report must include a detailed study of the impact of flyrock.**

Report Analysis

This appraisal covers the facts as presented in the Explotech (EEL) presentation dated November 19, 2012 with reference to the page being analyzed.

Page 3, paragraph 4

"*Given that the mining operations have not been undertaken in the past on this property, site specific blast monitoring data is not available. We have therefore applied data generated at a variety of quarries across Ontario which present similar material characteristics*"

At a minimum, EEL should have provided the names and locations of the quarries referred to in this paragraph.

In WHMC's search of quarries in Ontario there does not appear to be another property which presents the unique characteristics of the proposed Hidden Quarry. That is, the HQ is planned to be mined:

- Under the water table,
- From the surface of bedrock,
- In a fragile rock structure (Karst topography),
- In an urban setting that includes 19 structures and houses within what could be typically deemed an Exclusion Zone by several countries.), and
- Abutting both Highway 7 and the Sixth Line over a length of 1.5 km.

Furthermore EEL goes on to recommend:

"*this data represents a conservative starting point for blasting operations - vibration monitoring program be initiated on site upon commencements of blasting operations - to permit timely adjustments to the blast parameters as required*"

EEL appears to be suggesting that with experiment and experience they may be able to arrive at safe blasting parameters. In other words, the pit may be a testing ground in order to determine if safe mining is achievable, at the expense of the neighbouring property owners.

<u>Page 4, paragraph 4</u>

"*The properties immediately surrounding the proposed license area are largely characterized by farmland and sparse residential development*".

This statement is, at best, misleading.

It would appear to indicate that EEL does not give importance to the relatively close proximity of 19 residences or structures within 440 metres of the license area. In many other jurisdictions that distance would constitute an "exclusion zone", Exclusion zones are established around blast sites for the safety of people and livestock. They are intended to minimize the risk of any injuries due to flyrock. Extending the radius out a further 500 metres could include an additional 30 homes and be close to 250 homes and structures which could be affected.

<u>Pages 6 and 7</u>

A table presents the distance from the pit boundaries to the 45 closest receptors. With some exceptions, the measurements appear to be reasonable. Of particular note is the distance from the pit to the nearby Mushroom Farm (Receptor 19).

The table makes a reference to a distance of 165 metres, when, in actual fact, the distance is 80 metres. There are 19 receptors listed as being closer than 440 metres. These receptors all fall within an area that could be subject to vibrations either close to or in excess of limits permitted by the Ministry of Environment (MOE).

<u>Page 15</u>

This section of the report titled “Predicted Vibration Levels at the Nearest Sensitive Receptor” EEL suggests the vibration levels even at the closest receptor will be lower than the 12.5mm/second as allowed by the Ministry of the Environment (MOE).

EEL has applied a formula developed by the US Bureau of Mines (BOM) to predict vibration levels at different distances from the blasts. The use of the formula results in the theoretical measurement of vibrations termed Peak Particle Velocity (PPV). The formula is based on the distance from the blast to receptors, the maximum charge per delay of explosives and two site-specific factors termed “k and e” which are “***based on monitoring performed in an Ontario quarry with similar material characteristics***”. No mention is made of the name or location of the example quarry. It would be of interest to know what quarry is referenced and which are the similar characteristics.

The BOM formula is almost universally accepted in the mining industry and equally widely used in predicting the effect on buildings. Acceptable limits are usually a maximum PPV of 12.5 mm/second.

The example used by EEL states:

“*for a distance of 425 m (i.e. the closest standoff distance for initial operations at the proposed quarry) and a maximum explosive load per delay of 150 kg…The calculated 95% predicted PPV (based on the proposed blasting data discussed above) would be 10.1mm/second, below the MOE guidelines limit*”.

This statement is misleading as the closest receptor, (see page 6 of the EEL report), is approximately 80 metres from the blast not 425 metres (also the starting point of extraction). If the same formula as used by EEL is applied with the distance corrected to 80 metres, the resulting PPV is over 250 mm/second, which is far in excess of any allowable limit for structures and could result in extensive damage and injuries.

Applying the formula with the factors used by EEL, the PPV of 12.5 mm/second could be exceeded at any receptor closer than 375 metres from a blast. This means that 18 receptors may potentially receive vibrations from blasting in excess of MOE guidelines.

Predictions of PPV

In many cases, the theoretical PPV as calculated using the BOM formula is not always replicated in the actual blasts carried out in the field. PPV can be measured at the actual blasting sites employing instrumentation similar to those used for measuring earthquakes. The results are often used to determine “site-specific factors” for a given location.

An example of the difference between actual and theoretical PPVs, (using the BOM formula) can be found in a peer review by Golder Associates on the report prepared by EEL for the County of Renfrew in April 2007 for the proposed extension to the Miller Braeside Quarry.

In its review, Golder presented a table comparing 11 PPV values at various distances as calculated by EEL, to actual measured blasting results over the same intervals in the field. The comparison of the results showed a marked difference with the actual values exceeding the EEL theoretical by a wide margin perhaps close to 90%.

The results of the comparison could lead to the conclusion that the “K and e” “site specific factors” assigned to measure the PPV values may have required some modification. In other words the formula for PPV estimation is not always 100% dependable due to the difficulty of deriving reliable “K and e” site-specific factors.

3. Planning Report

This section presents an appraisal of the report titled Planning Report prepared for JDC by Stovel and Associates. (Ref. F1)

This report is difficult to appraise in that it omits for the most part in depth reference to the subject of greatest importance – that is detail on the the extraction method. Reference is only made in statements such as ***“Extraction below the water table involves drilling and blasting of dolostone resources. Once the dolostone has been broken up, the raw aggregate will be removed by an excavator or dragline –“***

However, it is the opinion of WHMC the basic design of the proposed HQ operations is flawed in that it provides inadequate protection for the Brydson Creek, the wetland on the northwest corner, the Allen wetland and the wetland adjacent to the northeast corner of the property. Each of these inadequacies is discussed in the following sections.

Figure 1: HQ Site Plan

<u>Brydson Creek</u>

The Brydson Creek flows through the HQ property from north to south exiting under Highway 7 near the southeastern corner. The stream flows intermittently depending on precipitation. It was reported that the stream disappears into the ground within the HQ property during dry spells. It is clearly visible from Highway 7 flowing in the southeastern part of the HQ property except during spells of dry weather. The stream is an important contributor to the Blue Springs Water Basin at the top of the Grand River Watershed.

The plan for development includes provision for a 40-meter right of way (20-meter setbacks on either side of the creek). This would allow water to flow undisturbed in its channel through the pit - much like a big aqueduct. This involves mining the rock in two pits – one on each side leaving a pillar of dolomite 30m high plus overlying gravels and sand with a depth of up to 8m on top holding the stream bed.

The writer has had experience in this type of procedure. In one occasion, a pit in Cerro de Pasco (in central Peru) required a similar structure to remain in place to provide access for trucking. There it was demonstrated that the problem with this idea is that the pillar remains intact when blasting approaches from the first pit.

However, when the opposite wall of the pillar is similarly impacted by blasting shock waves, the structural integrity of the rock in the pillar is compromised. As well, the overlying gravel may not be able to sustain the vibrations from the blasts. The result is that the flow of the creek, both at surface and underground, may be dried up completely with water percolating into the pit.

The flow of water in the Brydson Creek appears to have already been compromised by the drainage of the wetland (close to the middle of the HQ property in the course of the stream) through a dug channel which appears to have been excavated for that purpose. The wetland is now termed as a "depression". The drainage of that wetland and its effect on the water table may have contributed to the lack of capability of the stream to flow constantly.

The Wetlands

The Northwest Wetland

The Wetland on the northwest corner bounded on the west by the 6th Line is a resource protected by law and cannot be compromised. It is the nesting area for several different types of ducks and Canada geese, as well as the breeding area for numerous turtles and numerous other forms of wildlife.

This wetland is defined technically as a "perched lake". A perched lake is a a body of water underlain by an "aquiclude". An aquiclude is defined as the impermeable layer of rock or stratum that acts as a barrier to the flow of water. This aquiclude permits the water in the wetland to exist at ground level several metres above the water table and close to ten metres above the water table near to Highway 7. It should be noted the final pit design may leave water levels in the pit considerably lower than the wetland which could require a totally impervious barrier.

JDC proposes to build a barrier around the wetland to leave it intact. (The description of the barrier is provided in section #4 - Hydrogeological Report)

Unfortunately, it may likely be impossible to protect the area considering that the pit will be mined right up to its barrier. Again, the blasting shock wave vibrations -- no matter how carefully controlled –will probably compromise the integrity of the barrier and aquiclude underlying the pond. The fragile rock under the aquiclude barrier will probably be weathered and contain cavities, faults, clay seams, porous gravels etc. which over the centuries since the last ice age have been filled with gravels and clays to form an impermeable barrier. Blasting shock waves could have the effect of destabilizing those features and create drainage channels allowing the waters to percolate out of the wetland and eventually dry it up.

Local readers may recall the mill pond in Eden Mills. The writer's children learned how to swim in it in the 1970s. The pond has now dried up, although the dam remains intact. After being in existence for over a century, likely the pond was drained as a result of the failure of the underlying aquiclude.. It is possible that the traffic of heavy trucks on the road close to the dam could have been a contributing factor in causing the vibrations which led to the destruction of that underlying barrier

The Allen Wetland and The Northeast Wetland

The Allen Wetland is located to the north of the of the HQ property and is the source of the Brydson Creek. The Northeast Wetland is located adjacent to the proposed eastern pit. Although both these wetlands may be affected by the blasting in both pits no mention is made with respect to their protection in the planning, as in the Northwest Wetland. The Northeast Wetland is a perched water feature and, once again, its aquiclude might be adversely affected by blasting.

4. Hydrogeological Investigation Report (Ref. F1)

This section presents an appraisal of the report titled Level 1 and 2 Hydrogeological Assessment prepared by Harden for JDC. The Harden report appears to be excellent in almost all aspects, except in its proposed provision for the protection of the three wetlands and the Brydson Creek (tributary B). Insufficient attention has been given to the effects of blasting and other mining activity. It's believed the proposed protection falls far short of what is required and may be impossible to accomplish with any assurance of success. Each water feature is discussed in the following paragraphs.

The Brydson Creek

The Brydson Creek (tributary B) flows through the HQ property entering at its northern boundary close to the eastern boundary and exits south under Highway 7 close to its eastern boundary. At the mid-point in the property there exists a "depression" . Aerial photographs indicate a sink hole occupying what was once likely a wetland. The depression appears to have been drained by a "man dug" channel. To the north of the depression the stream occupies the southern extension of the (Provincially Significant Wetland) Allen Wetland. It continues to the north on the Allen Farm and eventually the De Grandis pond. The draining of the depression has contributed to the draining of the wetland in the HQ property and is probably contributing factor for the reported loss of water into the ground during periods of low precipitation.

The proposal for the HQ is to protect the creek from further damage by providing a 20m buffer zone on both banks.

The first problem with this proposal is that even a very light explosive charge (Example: 150kg in a three inch hole at 20m) could result in a PPV of 2200mm/sec or 175 times the allowable limit set by the MOE guidelines. These estimates of PPV were derived using the BOM formula as in the EEL report. Even at double the distance, the PPV may still be close to 50 times the allowable 12.5mm/sec. The threatening PPV values have all been calculate using EEL site-specific constants which appear to be too conservative considering the blasting will be under water.

It may be argued the limits of PPV are specifically meant for structures. In the case of the Brydson Creek, there is an overlying 8 m of sand and gravel which may compound the problem and suffer much more than a building. The gravels may probably shake and lose stability. The stream bed may lose its capability for containing the water flow and could be completely lost into the ground even in periods of high precipitation. This may also have an adverse effect on the Allen Wetland to the north.

The second problem is associated with the blasting shockwaves when they are reflected back in tension from the opposite side of the 40m set backs. These could crack the rock pillar and eventually render it incapable of supporting the stream bed and its underlying gravels.

The Northwest Wetland

The proposed plan for protecting the wetland in the northwest corner of the HQ is similar to that for the Brydson Creek -- that is providing a 20m setback from the wetland. As a further protection "*A hydraulic barrier will be constructed in the location shown on Figure 4.2 to prevent the draw of overburden water into the excavation. – The barrier is constructed by digging a trench downgradient of the wetland and replacing the sand and gravel with silt. – The barrier will be keyed into the silt/till layer."*

The report goes on to cite examples of the successful use of the proposed method. The method could be effective provided the right setting is prevalent. The writer has had experience in the (mostly) successful containment of concentrator tailings ponds (very finely ground mine waste after treatment of ore). However, many such structures did not always withstand earthquake shock waves, sometimes even mild shocks.

The examples stated in the Harden report are "*the Reid's Heritage Homes pit in Puslinch Township*" and at "*Warnock Lake adjacent to the Caledon Sand and Gravel pit".* Both sites are gravel and sand operations. The differences in water level on both sides of the barrier are insignificant compared to those present in the HQ pit plan.

However, using these sites as a means of comparison is largely inappropriate. Neither site makes use of holes drilled 30 meters under water or explosives.

The proposal, as it stands, may likely be ineffective in protecting the wetland. The barrier could be destroyed by vibrations of blasts as close as 20m.

The underlying aquiclude may be compromised. The underlying rock could be shaken and natural water courses reopened. This may drain the overburden water table down to bedrock water level several metres below. The wetland will likely be drained.

The Allen Wetland and the Northeast Wetland

These two features are conspicuously absent in proposals for protection in the Harden report. However:

> If the Brydson Creek protection measures fail, then the Allen Wetland could be drained not long afterward.
>
> The northeast wetland, a perched water body, is close to the proposed east pit, and may also be drained under the strain of blasting vibrations.

5. Flyrock (Ref. F2 & F3)

Flyrock is generally defined as “the undesired propulsion of rock fragments through the air beyond the normal blast zone by the force of the detonations of explosives being employed to fragment the rock”.

In general flyrock is caused by two main factors – either too little or too much confinement. Confinement, also referred to as burden, is the amount of rock placed in the way of the intended direction in which the broken rock should be thrown.

In most pits, including the HQ, the intended direction of throw is horizontal. If too little confinement is provided in the horizontal direction the blast blows out causing flyrock to be thrown at a low angle. In the HQ the lateral blow out should not be a problem because the pit filled with water will dampen the blast.
In the HQ any flyrock will be propelled by the relative amount of confinement in the lateral direction as compared to the vertical. The result of too much lateral confinement is the tendency for blow outs in the vertical direction. This type of blow out is relatively low in frequency and generally arises from geological conditions. Karst type of weathering, which is present in the Rockwood area, could probably pose a serious problem with flyrock because of the difficulty in knowing where the problem may arise.

There are recorded instances where particles of flyrock as large as one cubic foot (described in one report as being roughly the size of a “microwave oven”). have been propelled as far as 1.2 kilometers from the blasting site with a potentially enormous destructive capacity.

More commonly, rocks about the size of a baseball are propelled at speeds measured at up to 600 km/hour at point of impact. These too may have devastating consequences including property damage, **injuries and fatalities**.

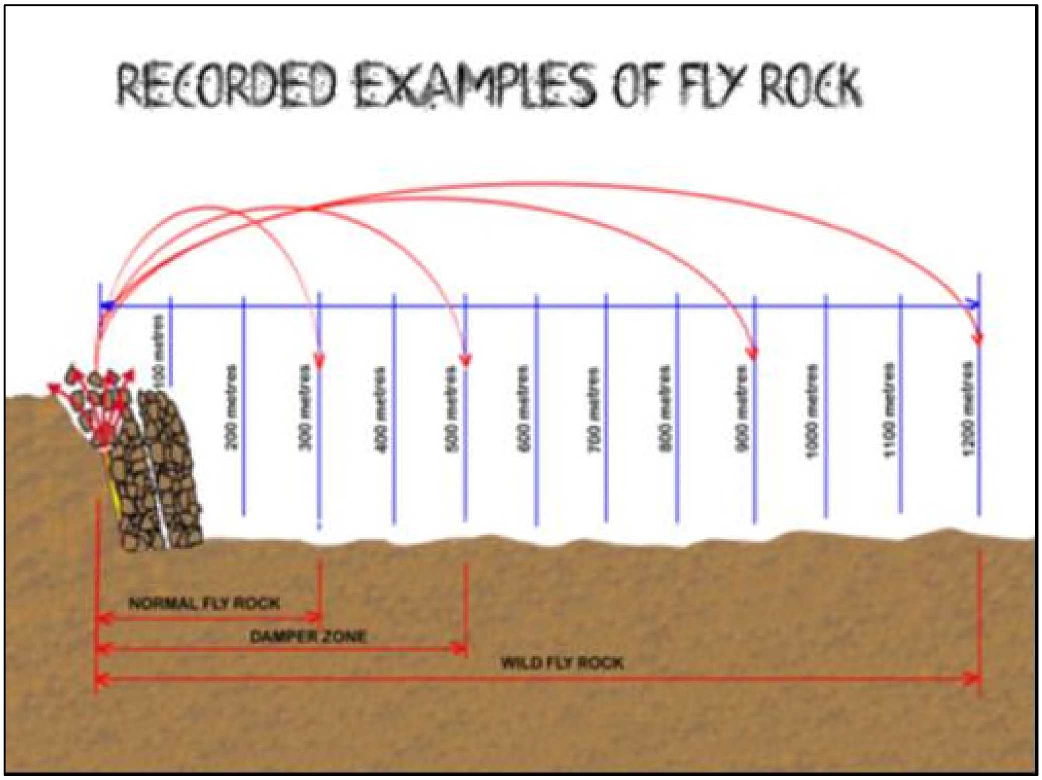

Figure 2: Range of Fly Rock

The distance of particle travel was analyzed in the United Kingdom, covering a five year period. The range is illustrated in the table that follows. The distribution indicated below shows that “normal flyrock” could be assumed to affect an area extending outwards 300m in all directions from the blast. To mitigate risk, an exclusion zone could probably be reasonably set at 500m.

Figure 3: Fly Rock Danger Zones at Hidden Quarry

Distance (m) from blast	Number of instances	percent of total	cumulative %
100	17	20	20
200	22	26	46
300	25	29	75
400	7	8	84
500	8	9	93
600	2	2	95
700	3	4	99
800	1	1	100
total	85	100	

There are, broadly speaking, two types of flyrock. The first simply called “flyrock”, is the undesired but statistically expected fragment of rock which is expected to fall within a prescribed area of exclusion – typically between 300-500m from the blast. When blasting, preparations are made to evacuate all personnel to a safe distance beyond the blasting area.

The second sometimes termed “wild flyrock” (with ranges up to 1200m) is statistically rare but can occur with disastrous and sometimes tragic results.

The severity of flyrock incidents is illustrated in Mine Safety and Health Administration (MSHA) statistics for a period covering 1978 to 1998. During that time, there were 281 injuries in the US caused by flyrock. Roughly half of the injuries were the result of “wild flyrock”. 16% of the injuries resulted in fatalities.

Numerous publications by blasting experts state that flyrock can be controlled for the most part, but should never be eliminated or ruled out entirety.. All too often, the human element comes in to play with common mistakes like the use of too much explosive or the placement of the explosive too close to the rock surface.

The most important factor, influencing the launching of flyrock, is the geology of the area where mining is carried out. With rigorous control and diligence human factors can be reduced, but geological conditions and rock structure variations often remain beyond technical control.

It is well known that limestone and dolomite which underlie the area of the proposed quarry are prone to dissolving and as a result produce irregularities such as sink holes, enlarged faults and fissures and even caves. A review of the aerial photographs around the HQ reveals traces of no fewer than ten sink holes including two on the HQ property itself. Areas with these characteristics are termed to have Karst Topography.

The process for Karst weathering is often referred to as “carbon dioxide cascade”. This is explained as follows;

1. As rain falls through the atmosphere it picks up Carbon Dioxide which dissolves in the droplets.
2. Once the rain hits the ground it percolates through the ground and picks up more Carbon Dioxide to form a weak solution of Carbonic Acid.
3. The infiltrating water naturally exploits any cracks or crevices in the underlying rocks.
4. Over long periods of time, the rock is dissolved by the acid waters leading to the propagation of solution cavities and widening cracks.

Visual evidence of this phenomenon is prevalent in the Rockwood Conservation Area.

The problem which most likely be encountered in drilling and blasting in this geological environment is that if a drill hole is inadvertently located too close to a cavity or enlarged fissure the blast will likely take the path of least resistance -- that is, into the cavity. This could result in cratering at surface and the ejection of rocks at velocities exceeding 500km/hour. (Ref F4 & F5)

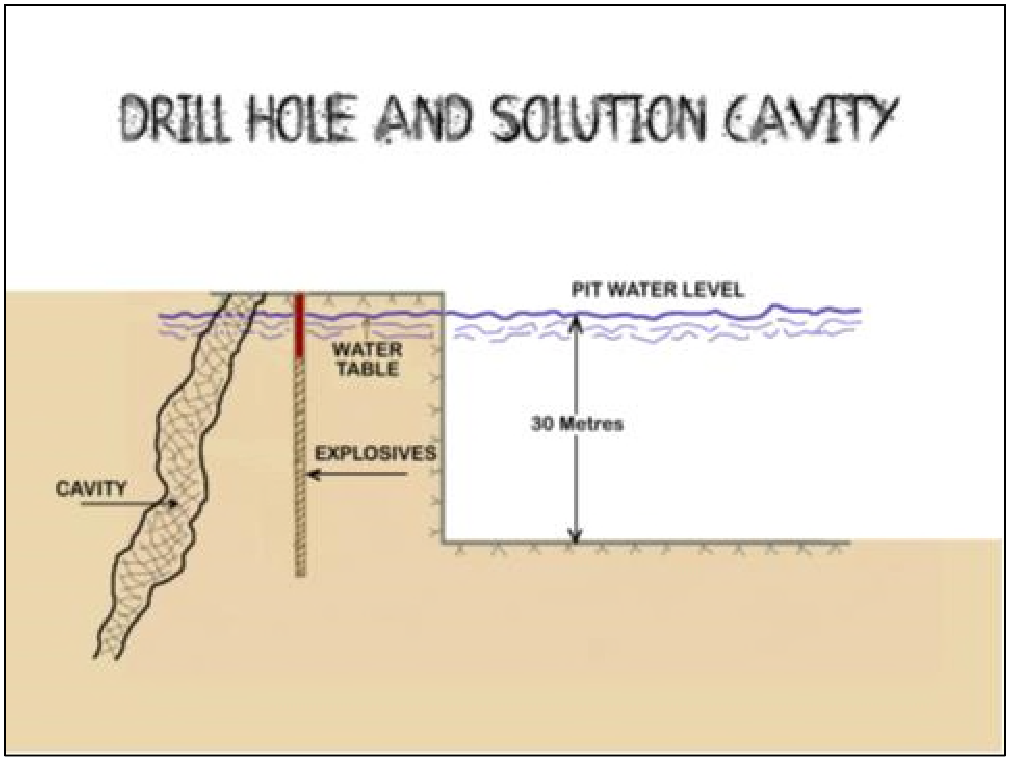

Figure 4: Drill Hole and Solution Cavity

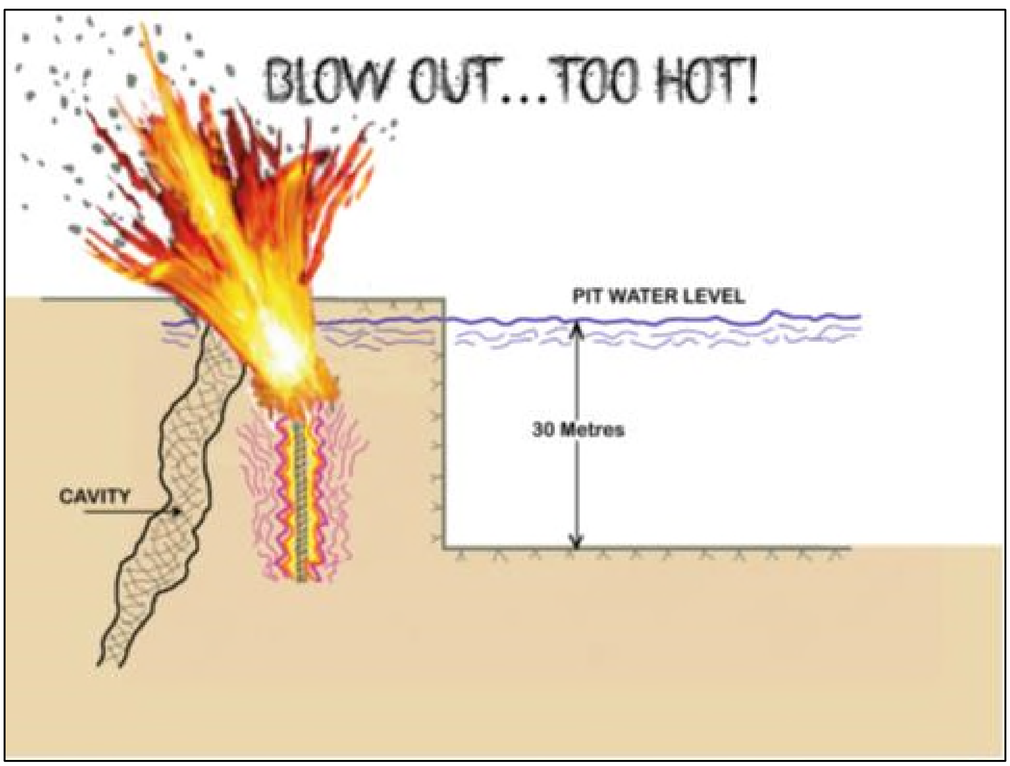

Figure 5: Drill Hole Blow Out

A tragic reminder of what can happen as a result of geological conditions – occurred in Campbell County, Tennessee on June 4, 1993.

> "A 16 year old passenger, in a car driven by his parent on Interstate I-75 was fatally injured by flyrock originating from an overburden blast in a nearby coal mine…(The official report stated)…***The blaster, apparently was unaware of the presence of an 8-ft thick layer of clay"***"

During the proposed 17-year life of the HQ project there could be 20,000 to 50,000 individual holes blasted which may provide ample opportunity to cause injuries and deaths as well as property damage including vehicles on Highway 7 and neighbouring side roads.

The only solution available to reduce the risk (even with rigorous control) of human injury or death and damage to property is to set blast clearance through the aforementioned exclusion zones. These exclusion zones establish minimum distances from inhabited buildings and roads to the blast sites.

In Scotland and Wales the minimum distance is set at 500m after a "tragic accident" in Burnfoot Moor in 1998. Western Australia has established a minimum limit of 400m. If these same regulations were applied in the HQ case, mining would likely not be permitted at the site.

In the US, the Federal Office of Surface Mining (OSM) regulations specify that "flyrock shall not be cast from the blasting site –

- More than half the distance to the nearest dwelling or other occupied structure,
- Beyond the area of control required under 30 816.66(6) CFR (exclusion zone), or
- Beyond the permit boundary".

If the OSM regulations were adopted, it is possible that none of the proposed HQ operating area would be permitted for blasting as the closest structure is only 80m from the boundary.

Exclusion zones also very deliberately apply to highways. If the HQ is allowed to proceed there will be approximately 1.5km of Highway 7 within what could be deemed the exclusion zone. There occurred a fatal flyrock occurrence in a car traveling on I-75 and also one on the M1 in the UK at greater distances than the HQ property is from Highway 7.

During its 17-year operating life the HQ will probably have blasted up to 40,000 separate explosive charges (drill holes) each with between roughly 150kg and 700kg. It is impossible to estimate the probability that some of them may propel flyrock – but, considering the history of open pit mines there is a chance that some may.

6. Blasting Vibrations

Unlike flyrock, blasting vibrations transmitted through the ground are difficult to quantify. Flyrock is quite easy to identify -- if a rock crashed through a house roof at blast time it is hard to argue about its origin. With blasting vibrations on the other hand, the impact is usually measured by the use of instrumentation similar to seismographs used for earthquakes.

Vibrations can be quite noticeable and are similar to the feeling of an earthquake. The problems usually associated with blasting vibrations include cracked basement walls and floors, drywall cracks, broken windows, floor tile loosening and a host of others. Psychological problems are even more difficult to quantify but can be worse as people react in their own individual way to the unpleasant sudden jarring caused by blasting.

Figure 6: Milton Quarry Shockwave Impact Superimposed on Hidden Quarry Site

According to the Explotech Study (EEL), blasts will occur between 12 and 20 times per year. This implies that each blast may require roughly up to 30,000 kg of explosives. The quantities are very large considering the urban setting.

When starting new mines the only method known to WHMC of theoretically estimating blasting vibrations is by the use of the US Bureau of Mines (BOM) formula for estimating Peak Particle Velocity (PPV). This in effect measures the displacement of the ground by shock waves in terms of milimetres per second. Readings of less than 12.5mm/s are considered acceptable by many regulatory agencies including the MOE in Ontario. When readings exceed 12.5mm/s, damage to buildings and structures may occur.

The mathematical equation for estimating PPV is shown as follows;

$PPV = K(D/\sqrt{W})^{-x}$ Where

PPV = velocity in milimetres per second
K = constant relating to the particular site
D = distance from the blast in metres
W = maximum charge per delay in kilograms
x = constant relating to the particular site

When considering W it is important to point out that although the blast could have a total amount of explosives of up to 30,000kg, each hole is blasted separately by the use of millisecond delays. These delayed detonations allow each hole, with up to 700kg of explosives, to be blasted independently at intervals of a few thousandths of a second between each. This results in a much lower individual shock wave (PPV) but a longer overall blasting impact time.

Note the underlined "relating to the particular site". The prediction of the theoretical PPV for a particular site is entirely dependent on the chosen K and x constants - at best, a good guess. The only way to truly and reliably determine those constants is through experience.

A three-stage process is often used:.

1. Charges are set with known weights of explosives
2. The shockwaves are measured at various distances by instrumentation, and
3. The K and x constants are derived from stages 1 and 2.

An example of the difference between the actual and the theoretical PPV (using the BOM formula) is illustrated in a peer review by Golder Associates on the report prepared by EEL for the County of Renfrew in April 2007 for the proposed extension to the Miller Braeside Quarry. In the review, Golder presented a table comparing 11 PPV values at various distances as calculated by EEL, to actual measured blasting results over the same intervals in the field. The comparison of the results showed a marked difference. The actual values exceeded the EEL theoretical numbers by an average of 91%.

Another case provides an example of the inadequacy of the BOM formula (unless the cite-specific constants are chosen correctly) can be found in the difference between actual PPV per blast measurements compared to formula estimates in Miramar City, Florida. 74 seismograph readings (taken by an independent government agency) at Miramar City were compared to the theoretical results derived by using the BOM formula and the EEL site-specific constants. The results of actual readings are far in excess of the theoretical, by an average difference of close to 100%. These results are shown in the following chart (which is shown in full, in the section covering the Miramar experience later in this report),

Distance metres	Seismograph readings	Actual Miramar PPV mm/s	Predicted EEL PPV mm/s	ratio Miramar/EEL
1150	10	4.8	3.3	1.5
1440	18	4.0	2.2	1.8
2240	33	2.7	1.0	2.7
3100	13	1.9	0.8	3.3

In the EEL report on the HQ the site specific constants were arbitrarily chosen **"*Based on monitoring performed in an Ontario quarry with similar material characteristics…In the absence of data for the proposed aggregate extraction operation, these data are used for initial prediction purposes"*.**

The use of an arbitrary selection of site specific constants could result in an inadequate assessment of PPV for the HQ. Moreover, the determination of PPV by EEL is only for "***initial prediction purposes***". The PPV calculations could turn out to be too low by half? Is the "***Ontario quarry with similar material characteristics"*** applicable to the HQ considering the following condition;

- Mined under the water table.
- In virgin weathered rock (Karst type weathering).
- Drill holes over 30m in depth.
- Urban setting.

The writer has reviewed publications on several quarries in Ontario but has not turned up one with all the unique features of the HQ.

The BOM formula used by EEL assumes that 150kg of explosives will be used in drill holes of 3in diameter and has based its estimate that at "***425m i.e. the closest stand off distance…the maximum PPV at the closest building***" will be 10.1mm/s. It bears repeating the closest receptor at the HQ is less than 100m from the proposed pit – not 425m.

Furthermore it is unlikely, based on the EEL report, that 3in drill holes will be used exclusively. Rather, a substantial amount of the drilling will be carried out using 6in drill holes using charges of up to 550kg. If 100m is applied as the closest standoff distance, the PPV may actually be 128mm/s possibly resulting in injuries and in damage to the structure. If 6in holes are used, the PPV could be 31.6mm/s at 425m. Using the BOM formula, the 16 residences surrounding the HQ may be subjected to blasting shock waves with PPV values of over the MOE guidelines. This is far in excess of the MOE recommended allowable PPV limits. The southern part of Rockwood 1km from the HQ may be subjected to values of PPV estimated at 7mm/s which, while not necessarily damaging are at best uncomfortable to humans and for some bordering on psychologically devastating

Understanding that shock waves likely may have undesirable effects, it's worth looking at the recent experiences of three other communities.

1. The Lac – Milton Quarry (Ref. F6)
2. Guelph - also involving James Dick Construction Ltd.
3. The City of Miramar, Florida

1. The Lac Quarry in Milton operated a drill and blast operation for many years on the escarpment to the west of Milton. The pit was closed down after repeated complaints by the neighbouring residents. The operators tried multiple means to alleviate problems, but had little success with any. It is important to mention the affected residences were located about 1km to the west of the pit blasts. That's about the same distance between the HQ and the southern part of Rockwood. The PPV values were, in fact, below the 12.5mm/s allowable limit but were so disturbing that eventually the pit was closed down.

2. The Dolime Quarry in Guelph operated by JDC has been in the news in recent years not only because of water problems but also because of neighbouring residents' complaints regarding blasting. The closest residences, on College Ave. to the south, appear to be located roughly 400 metres from the blasting sites. Other populated areas to the east and to the north are farther away.

It should be pointed out that almost all the residences were built well after the mine started production in the 1800s. However, it appears the blasting norms in Guelph may have changed, and if so there may exists a case for complaining.

3. Miramar City is located just north of Miami in Dade County, Florida. Quarries similar to the proposed HQ are being mined close to its city limits. The similarity was drawn to our attention in a Power Point presentation to council by JDC (March 25, 2013). In its presentation JDC indicated that a Florida quarry, (shown in one of their slides), was mined under the water table and had been carried out without incident for many years. JDC stressed the suitability of the mining method for use in the proposed HQ. WHMC followed up on the reference

to Florida and uncovered revealing data on blasting in pits filled with water, particularly with respect to blasting vibrations.

Ample information is available on “Google” relating to blasting in Florida, and more particularly in Dade County, close to Miami. The information is found under the title “Blasting Problems” followed by –In “Dade County” or “Doral” or “Palm Springs” or “Miramar City” (Miramar) etc. Most of the information involves complaints by residents “over 9000 feet away” (2.7km) regarding blasting damages from seismic shock waves, but also provides significant information and ample data on blasting vibrations in an under water setting.

The writer had experience in under water blasting in the early 1960s when employed by Compania Minera Santa Fe in an iron ore mining operation in Chanaral, Chile. The ore was shipped by freighters. To compete in an increasingly tight market, larger ships had to be used and, as a consequence, the port had to be deepened. The work involved drilling and blasting both on shore and under water. The residences and businesses in the town of Chanaral were as close as 75m requiring meticulous control of each blast. This necessitated procedures to measure the blasting vibrations. There was in fact a distinct difference in the shock wave recordings between the blasts on land and those under water. The under water blasts registered much higher values using identical explosive charges.

Problems with quarries in Dade County and particularly Miramar go back almost twenty years. Complaints by home owners regarding vibrations resulting in damages succeeded in having the quarries close to Miramar shut down. Operations east of the city limits, in Dade County were allowed to continue. These operations -- although farther away -- continued to cause problems in Miramar with numerous complaints resulting in compensation. The shock waves experienced were in excess of the allowable limits. Ultimately, regulatory PPV limits were increased to the equivalent of 12.5mm/s. Complaints continued, prompting local authorities to carry out a study using seismograph readings to determine the extent of the problems.

It has been reported ***“The city placed seismographs – after hearing complaints from residents that the blasts at nearby quarries were causing leaks in their pools, shattering glass and breaking floor tiles[in] the closest neighborhood to the quarries”*** This part of the city was 9000 feet or 2.7 km away, roughly the same distance between the proposed HQ and the rail crossing on Main Street in Rockwood. Seventy-four of the seismograph readings from Miramar were assembled on a spread sheet separated into 14 groups of similar distance ranging from 1000 to 3500 metres from the blasts along with the average actual PPV for each group. These values were then compared to the theoretical PPV derived using the EEL constants and the BOM equation. It is evident that the theoretical values understate the magnitude of the PPV with the magnitude of the discrepancy increasing with the distance from the blast.

distance Metres	Seismograph Readings	Miramar average PPV mm/s	Calculated EEL - BOM PPV mm/s	Actual ratio of PPV Miramar/EEL
1040	1	5.1	3.9	1.3
1131	3	4.0	3.3	1.2
1267	6	4.7	2.7	1.7
1349	6	4.3	2.4	1.7
1437	6	4.0	2.2	1.8
1539	6	3.7	1.9	1.9
1832	4	3.2	1.4	1.2
2112	5	3.1	1.1	2.8
2417	17	2.5	.9	2.9
2603	7	2.2	.8	2.9
2760	2	2.8	.7	4.1
2864	3	2.1	.5	3.3
3152	7	1.5	.2	2.8
3584	1	1.3	.4	3.0
total readings	74			
weighted	Average	3.1	1.5	2.1

The similarity between the quarries in Dade County and the HQ appear to provide a reason to believe the EEL choice of site-specific constants for the HQ may not be totally justified. The rational for using site specific factors which are applicable in Dade County rather than those based on ***“an Ontario Quarry with similar characteristics”*** are presented in the following paragraphs.

It appears that blasting under water has entirely different shock wave characteristics compared to those created by normal blasting into an open air face.

Another example of the impact of water was provided in WWII by the “Dam Busters”. The air raids destroyed the German dams in the Ruhr Valley by dropping bombs close to and on the water side of the dams, with huge (and disastrous) success..

The same phenomenon appears to take place when explosives charges are backed by water in the quarries in Florida. The most important factor derived from the Dade County blast vibrations, in terms of PPV readings in their geological environment, is the magnitude of the shock waves which are noticeably greater than those of ***“an Ontario Quarry with similar characteristics”*** . It appears that the fact that blasting, is carried out under the water table and that the surrounding area is underlain by a shallow water table, provides a very efficient medium for transmitting shock waves.

The reason for the greater efficiency is that fault planes or cavities in the rock are filled with water-saturated and compacted debris. This allows waves to travel relatively unimpeded. If the same fault planes and cavities are dryer they act as shock absorbent impediments, thus dampening the vibrations. This effect is particularly accentuated in the initial distances from the blasts. In water-free pits, the surrounding area is drained for the most part to below the pit floor causing a very marked dampening of shock waves in the initial few hundred metres from the pit.

A comparison is made in the following chart of the actual PPV recorded in Miramar (column 3) with values estimated using the EEL site-specific factors (column 4). In addition the highest PPV in each range at Miramar are presented in the second column. The results of PPV values estimated in a study by independent specialists commissioned by Dade County are presented in column #5. It is interesting to note that there appear to be no residences closer than one kilometer to the mining operations.

AVERAGE RANGE METRES	MIRAMAR HIGHEST PPV mm/s	MIRAMAR AVERAGE PPV mm/s	EEL ESTIMATED PPV mm/s	DADE COUNTY ESTIMATED PPV mm/s
1150	6.5	4.6	3.3	
1450	5.0	4.0	2.2	8.9
2250	4.4	2.7	1.0	4.1
3100	2.8	1.9	0.6	2.5
AVERAGE	4.7	3.3	1.8	

It is important to point out that the explosives charges, in all the Miramar and Dade County figures shown on the charts were less than the quantity compared to those used in the EEL Blasting Impact Study.

In summary it appears that the HQ blasting operations may have a greater adverse effect than indicated by the estimates of EEL. In estimating the impact of blasting WHMC believes that explosives charges will not all be 150kg per drill hole but rather, some will be closer to 550kg, (as proposed by EEL using 6in drill holes rather than 3in holes). The smaller sized hole based on the experience of WHMC may be impractical for drilling of 33m depths as well as more difficult to control.

An estimate of the impact of the blasting at the HQ is summarized in the following paragraphs.

Structures within a radius of 500m from the HQ may suffer vibrations with a PPV (based on the EEL site specific constants) in excess of the permissible 12.5mm/s. The effect could be cracked basements and pools, cracked plaster and broken windows, damage to glass and crockery from falling off shelves etc. Older stone houses may also be damaged or perhaps even destroyed as cement will have deteriorated with age.

Structures within a radius of 1000m -- using the Miramar experience -- may also be subjected to vibrations of perhaps greater than permissible in Ontario. Although the damages will not be as great as those closer to the blasting, there may still be extensive cracking and breakage.

Within a radius of 1500m the houses nearest the HQ could still be close to the permissible limits. Those homes could be rattled and sustain lesser damage. If the formula used by the Dade County independent consultants is employed in the calculations then the vibrations from shock waves will be greater still.

Respectfully submitted

William Hill Mining Consultants Limited

William Hill P. Eng.
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Appendices

Flyrock

Examples of flyrock incidents are presented in most cases in brief as follows

1. The first example of flyrock is taken from the personal experience of the writer, William Hill P Eng.

In 1963 the William Hill was working in the McCune Open Pit of Cerro de Pasco Corporation (CDP) in Peru. Underground mining had been carried out at that time for close to 400 years and the city of Cerro De Pasco was built up close to the mine shafts. Upon starting the open cast operations the city was close to the eastern border of the pit because of the location of the ore body. The closest distance from the mining operations to habitations was less than 100m, consequently every blast was monitored with great care. The open pit operations had been relatively successful for an extended period of time, probably more than a year, with only minor complaints regarding some damage from flyrock, noise and vibration which was easily taken care of (remembering that this was a company town – only one employer) by help with the repairs. Guards were sent into the populated area during each blast and warning sirens were placed in all areas where there was the remotest chance of flyrock falling.

In 1963 a catastrophic event took place. One drill hole blew upward causing a huge explosive noise and a serious propagation of flyrock. The damage, by a stroke of good luck, caused only minor injuries (probably because the people, accustomed by lesser events, took shelter) but resulted extensive damage in more than 300 houses, some up to 300m from the blast. The outcome of that blast was that a large portion of the city was moved to a safer location with an expenditure in today's dollars close to $50 million.

Other examples of fly rock incidents are summarized in the following brief paragraphs (detail information on each reference is available for the most part on Google).

2. Burlington, Vermont. "In September 2008 – detonated a blast that threw flyrock several hundred yards and resulted in damages estimated to be a million dollars to aircraft, vehicles, buildings and the grounds at the Burlington International Airport"

3. On June 11, 2007 in West Lebanon, New Hampshire – a quarry blast resulted in flyrock being thrown 3000 feet into an industrial park – the same blast

also sent flyrock about 4000 feet landing on the airport property including the runway" "flyrock as big as a bucket"

4. In a study of a serious blasting problem researched by the Department of Mining Engineering of the University of Belgrade reference is made to the following.
"Some of the fly rock traveled a distance of 600 metres and had speeds estimated at 600 km per hour. Rocks up to 200 kg were projected over a distance of 300 metres".

Flyrock Fatalities

Most fatalities attributed to flyrock involve operators of mines principally because the mines or quarries are generally situated in remote areas with sparse population. There are cases which illustrate that flyrock is dangerous to people who are not associated with the operations. Examples of these are as follows;

5. (Repeated for emphasis) "A sixteen year old passenger in a car driven by his parents on interstate I – 75 was fatally injured by flyrock originating from an overburden blast in a nearby coal mine".

6. A resident in the vicinity of a coal mine unknowingly drove up a trail and parked his ATV about 35m from the blast area and was killed by flyrock.

7. "fly rock from a limestone quarry traveled about 300m and fatally injured a resident who was mowing grass in his yard".

8. September 2011, Shawinigan Lake Gravel Pit. A 50 year old woman observing the pit lost her arm to flyrock. "Debris flew 400m".

A few examples of fatalities by flyrock mostly near the working area are listed as follows

9. In a report by the US Department of Labour, regarding a coal mine in Kentucky, 2007. A fatal accident occurred killing a miner with 20 years experience. "The fly rock that struck the victim traveled approximately 1500 feet (483m) into an area where miners parked their personal vehicles – the rock passed over a 20m high embankment" Pieces of rock "16 x 20 inches (50kg) also hit close to where the man had been standing".

10. An equipment operator with seven years experience at the mine was in his pickup guarding the access to the pit 270m the blast. Fly rock entered by the windshield and killed the operator.

11. “A foreman was fatally injured when fly rock struck the roof his ¾ ton truck. The impact caused the roof to bend downward and strike the foreman’s head. The Upon firing the shot, a sandstone rock weighing 8.5 pounds traveled 50m and hit the roof of the cab”.

12. “a blaster was fatally injured by fly rock weighing 14 pounds traveling over a 200 foot highwall - about 600 feet from the blast holes”.

13. Preparing a logging road outside of the pit area. “The blast projected flyrock about 300m and fatally injured the victim. Several boulders were scattered near the accident site”. “The MSHA investigation determined that a blown out shot caused the fly rock”.

14. A visitor and drill/blast helper were 50m from the blast. The drill/blast helper was killed and the visitor was injured.

15. “A blaster was fatally injured by a 1ft 5in by 2ft, 11 in by 8.5 in fly rock (MSHA 1992). The blaster positioned himself under a Ford 9000, 2 ½ ton truck while detonating the shot. A fly rock traveled 250m.

16. “A crane operator was fatally injured when fly rock struck him on the back. During the blast the victim and the blaster were standing on a top bench 40m from the nearest blast hole. The blast holes were covered with blasting mats”. ‘Upon initiation of the blast one of the holes threw fly rock toward the victim”.

17. In a report by the Department of Mining Engineering, Indian School of Mines, Dhanbad, flyrock from secondary blasting is discussed.
“A study of blasting has revealed that more than 40% of fatal and 20% of serious accidents resulting due to fly rock (Mishra 2003)”
A boulder 3m by 1.5m by1.6m – two holes of 45 mm diameter, spaced 0.6 m apart and 1.5m deep were drilled and blasted. Fly rocks (2) were ejected 550m causing damage to a building but narrowly missing the occupants.