POTENTIAL IMPACTS OF THE PROPOSED HIDDEN QUARRY ON GROUNDWATER

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The Application

In 2016, James Dick Construction Limited (JDCL) re-submitted an application for re-zoning of 39.4 hectares (98.8 acres) of Paris Moraine land bordered by 6th Line and Highway 7 in Guelph/Eramosa Township (GET). The application requests that portions of the site be re-zoned from "Agricultural Zone" & "Environmental Protection Zone" to "Extractive Industrial Zone" & "Environmental Protection Zone" to permit operation of a mineral aggregate extraction operation employing underwater blasting. The recent Wellington County Official Plan Amendment (2018) designates the majority of the site as "Greenland" and "Core Greenland". The latter includes Tributary B, which crosses the site and connects wetlands and springs above the site with downstream Brydson Creek and the Blue Springs Creek Wetland Complex and Natural Heritage System (Figure 1).

Quarry Operations

If approved, quarrying would proceed in two 'lifts' within each of three distinct phases, on a total of 24.5 ha (hectares) of the site (Figure 2), beginning at the northern boundary (Stovel, 2019). In the first lifts, a total of 21.07 ha of the forest and other vegetation will be stripped from the site (GWS, 2012), followed by the sand, gravel and rock overburden, yielding over 3 million tonnes for storage and later use (see table below). Strangely, this quantity of material is considered as "minimal" by the proponent.(Stovel, 2019).

Phase	Material	Depth, m.	Years	Tonnes (total)	Tonnes/Yr	Tonnes/Day	Blasts/Yr
Lift 1	Overburden	8 – 9 (1)	> 1	> 3,000,000 (4)	--	--	--
Lift 2	Bedrock	22 – 28 (1)	17 – 20 (2)	12,000,000(3)-14,000,000(2)	700,000 (2)	6,000 (2)	15 – 30 (2)

Sources: (1) Stovel, 2019; (2) Explotech, 2014; (3) Stovel, 2016; (4) Calculated; '--' = Not Available.

During the second lift in each phase, blasting of the dolomite bedrock (dolostone) will occur above and below the groundwater table, but mainly in the subaqueous environment (i.e., within the groundwater). Assuming an operational year of 8 months, this will involve up to 1 blast per week, each involving multiple boreholes filled with explosive. Upon quarry completion, the initial habitat will have been destroyed and replaced by two large, steep-walled ponds: a West Pond of 13.9 ha and an East Pond of 3.5 ha (Figure 2; Stovel, 2019).

A Processing Plant area is to be located in the southern portion of the West Pond in an area also scheduled for bedrock extraction (Stovel, 2019). The aggregate washing plant will be capable of using 2,500,000 litres of groundwater per day (Harden (2016b) if a Permit to Take Water (PTTW) is issued by the MOECP. An estimated 195,000 litres/day of this will be lost through dust control of roads, plus 75,000 litres/day by evaporation and entrainment in the shipped aggregate. The remainder will be discharged back into the quarry via silt pond(s). The wash pond in the bedrock will have a surface area of 3,250 m^2 and will store 76,000,000 litres. While blasting of bedrock will be restricted to weekdays, operations in the plant area, including extraction, processing, loading,

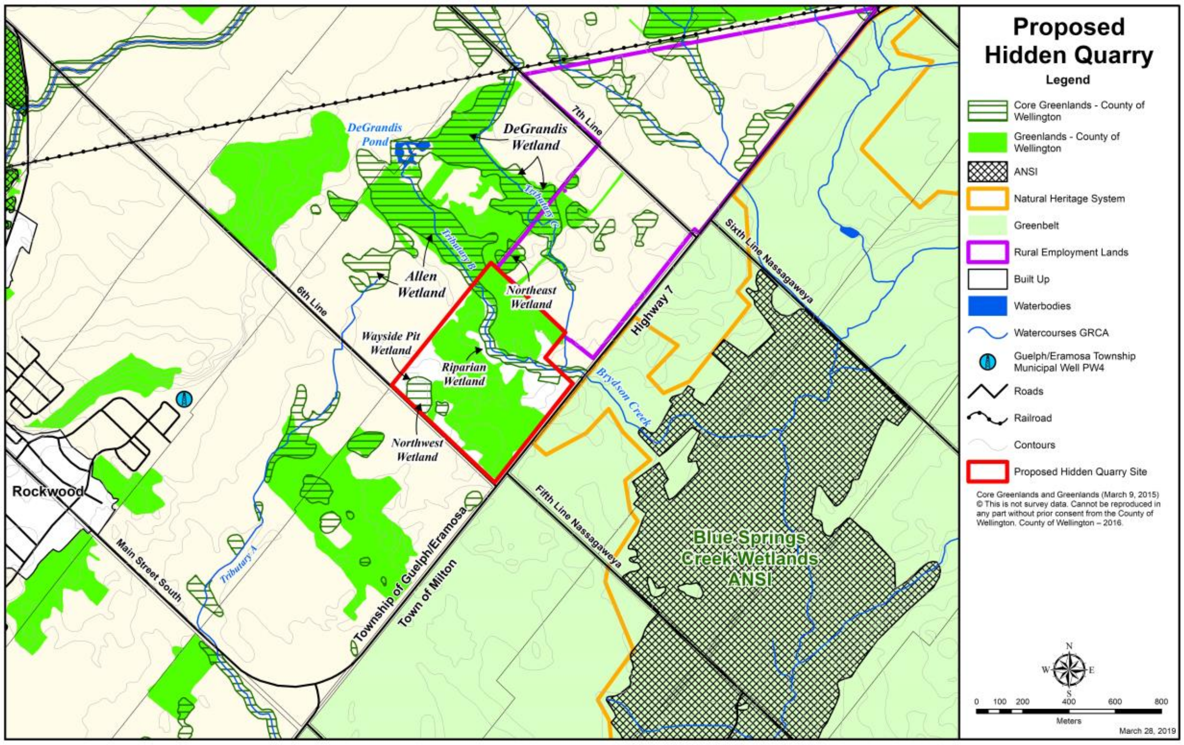

Figure 1

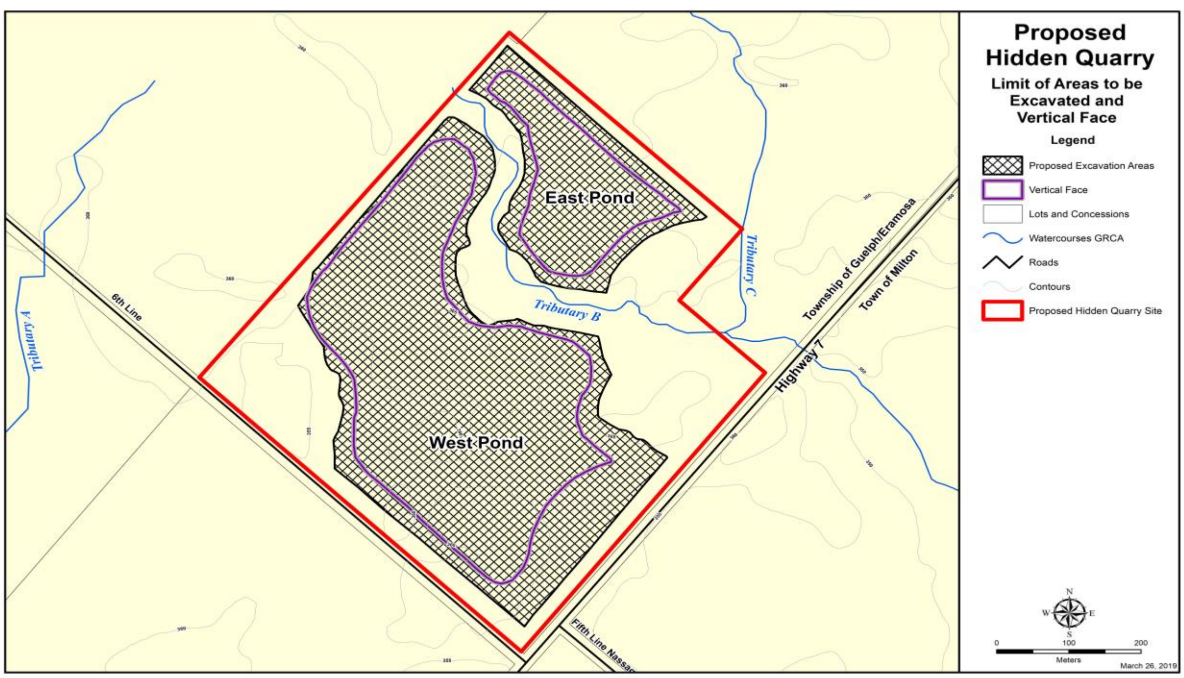

Figure 2

and shipping will be carried out six days a week (Stovel, 2019).

This proposed quarry operation has raised concerns about its potential impacts. In fact, even the proponent's hydrogeologist stated that: "First, the mining process introduces chemical explosives to the sub-aqueous environment to break the rock apart." and: "Secondly, the water body created will be susceptible to biological contamination introduced by wildlife (Harden, 2012)". This was mirrored by the concern of MOECC (2013) in their review of the proposal: "…extraction below the groundwater without dewatering - also has the potential to have a detrimental effect on the groundwater quality since chemical explosives, in a water-proof emulsion form, are brought in the sub-aqueous environment to break the rock." and that "…the quarry pond to be created by the aggregate extraction activities will be susceptible to biological contamination introduced by wildlife." These and other potential groundwater impacts are discussed in the following sections.

Bedrock Characteristics

After reviewing the quarry proposal, the site conditions, and the borehole logs, Cowell (2016) concluded that: "There is no question that the aquifer associated with the proposed quarry is a karst aquifer…With discrete, selected fractures (conduits) for groundwater to follow, the flow of water in a karst aquifer is unpredictable. Hence, any development with the potential to block conduits or re-direct flows among conduits can have profound impacts on connecting surface water features and water supplies." and "Changes in final water levels and changes to pathways inside the aquifer can be expected (ibid)".

Karst systems have very low self-purification capabilities, so that once the filtration and water purification abilities of the overlying soil and vegetation is removed, the water in the aquifer becomes paricularly vulnerable to contamination by pollutants, including pathogens (Kresic *et al*., 1992; Langer, 2001; Green *et al*., 2006). These can be carried long distances without being filtered due to high flow velocities (Assad & Jordan, 1994; Hobbs & Gunn, 1998; Green *et al*., 2006). Groundwater and its associated contaminants can travel several hundred metres in karst systems, whereas in porous rock, it is much slower and usually less than a metre per day (Green *et al*., 2006; Green *et al*., 2012).

The primary process in karst formation is a complex interaction of a number of processes which involve the dissolving action of weak acids in precipitation and soil seepage on calcareous bedrock such as limestone and dolomite. Over time, weaknesses in the bedrock allow penetration by the water and expansion of the fractures by dissolution (Cowell, 2019). This produces a landscape characterized by features such as epikarst* (see Explanatory Notes) vertical shafts, sinkholes, sinking (losing) streams, springs, complex and variable subsurface drainage systems and caves (BC, 2001). It is noteworthy that in British Columbia, karst terrain is recognized as a sensitive and valuable resource that can be highly susceptible to disturbance. Industrial activities, such as rock quarrying or forestry, if not properly conducted, can lead to: excessive soil erosion; destruction of surface and subsurface karst features; changes in groundwater flows; and contamination, sedimentation, or clogging of underground and surface streams (Ekmekci, 1993; BC, 1997).

The Hidden Quarry proposal raises concerns about potential impacts on groundwater in three areas: physical, chemical and biological, which are all interrelated and dependent on the nature of the bedrock aquifer under the site and in the surrounding area. The aquifer's characteristics are very important to groundwater flow and the potential transfer of pollutants. Hydrogeologically, the bedrock aquifer of the area consists of fractured and porous material, with the majority of the flow being in the fractures (Frind, 2018), "…and velocities in fractures are much faster than velocities in the averaged bulk [porous] medium (Frind, 2017)". Groundwater flow rate at a well downstream of the East Pond of the proposed Hidden Quarry averaged 69 metres/day, based on hydraulic conductivity (Harden, 2017a).

Physical Impacts

Quarry-related water table changes have been found to be more extensive than for gravel pits (Hobbs & Gunn, 1998: Blackport & Golder, 2006). Furthermore, Laurila (in Jermakka *et al*., 2015) noted that quarrying under the groundwater table may have more significant effects than when taking place above it, with the scale of effects being dependent on water flow, rock properties (cracks, conductivity, etc.) and links to other aquifers. Wellington County Official Plan Amendment (OPA) ***Policy 4.9.3*** (2018) states:

> *"Groundwater resources occur throughout the County and are not confined to the Greenland system. Groundwater needs to be protected to promote public health, and as an essential resource for urban an rural water supplies, agricultural production and the maintenance of the Greenland system. It is the intent of this plan that all development and site alteration shall be subject to the following policies to ensure water quality and quantity are not negatively affected. Specifically, it is the County's intent that the development of public and private uses will not:*
> - *Negatively impact groundwater recharge or discharge*
> - *Impair groundwater or surface water quality*
> - *Negatively impact municipal groundwater supply*

Groundwater flowing through the proposed Hidden Quarry area is the source of numerous nearby and down-gradient water wells, as well as Brydson Spring, Brydson Creek and the Blue Springs Creek system. It also sustains a number of Provincially Significant Wetlands (PSWs). "Quarrying either above or below the water table in extensive karstic areas can cause significant changes to both surface and subsurface flow as major flow conduits are intercepted and cut off (Blackport & Golder, 2006)".

Overburden Water Levels and Wetlands

The water table at the site is often in the overburden, so that its removal may also result in passive water level changes (Hunter, 2017a). In fact, recent modelling for JDCL (Harden, 2017b) predicts a drawdown of 3.0 metres in the overburden adjacent to the Northwest Provincially Significant Wetland (PSW) and 2.0 metres next to the Northeast PSW, which is just offsite (Figure 1). As a result, Blackport (2017) predicted that the greatest potential impact of the quarrying operation was likely under the Northwest PSW, home to a species at risk, and Burnside (2018) expressed concern about the impact of overburden removal on the Northeast PSW. These concerns contradict the proponent's claim that: "There will be no significant effects on wetlands onsite or offsite (JDCL, 2017)" and that extraction in the eastern portion of the site will not affect Allen Wetland hydrology since there is a "…substantial unsaturated zone beneath the wetland" and there is no connection to the bedrock. This seems to be strange reasoning, since surface water, soil water and groundwater interact as a single unit (Frind, 2018).

Bedrock Aquifer Levels
There is significant potential for impacts from the proposed quarrying (e.g., 0.9 metres/day drawdown during extraction) on groundwater resources in the surrounding area (Burnside, 2013b). Predicted impacts on wells were 1.6 metres at the residential well closest to the site, plus an additional decrease of 1.6 m when water levels are at their natural low (Harden, 2013a; 2014c). Predicted groundwater drawdown due to the quarrying has increased from 2.5 metres (Harden, 2014a) to a 4.5 metre drawdown in the sinking cut along the northern edge (Harden, 2017b). Since the proposed quarry site is part of a larger area which includes wetlands, woodlands and wildlife habitat, changes in crucial environmental factors such as groundwater level and flow have the potential for major adverse impacts around the property, including wells essential for agriculture and livestock (De Grandis, 2016). This includes the Allen and De Grandis springs and their associated ponds and wetlands. Drawdown in the underlying Gasport (bedrock) aquifer is predicted to be at least 3.5 metres (Harden, 2017b). Hydrological analysis on behalf of CRC (Hunter, 2017b) indicates that: the bedrock surface water table decrease could be as much as 6 metres in the northwest and northeast corners of the quarry extraction areas; about 3 metres adjacent to the Allen PSW; about 3 metres where Tributary B enters the quarry site. An increase in water level of 2 to 3.5 metres is predicted at the southwest corner.

Burnside (2015b), felt that the predicted changes in bedrock water levels as a result of the quarry could have a significant adverse impact on the upgradient De Grandis well, The spring-fed ponds on the De Grandis property are an important source of water for the downstream Allen PSW and for Tributary B, which connects with Brydson Creek south of Highway 7 (Figure 1).

Chemical Impacts

Contamination by Overland Flow
Due to the 5 to 9 metres of groundwater gradient from the northwest to the southeast at the site (Harden, 2013b & 2014c), bedrock extraction will result in leveling-out in the created ponds and induce passive water level drawdowns on the upgradient side, thereby increasing the capture zone and flow through the quarry (Hunter, 2017b) and the potential for surface contaminants input. Langer (2001) cautioned that: "Unless measures are taken to control runoff and sedimentation, deterioration of ground water is likely." In fact, Wellington County OPA ***Policy 4.9.5.9*** (2018) requires:

> *"To the extent that the aquifer vulnerability is changed as a result of a new or expanding aggregate operation, the potential for overland flow of surface water originating from adjacent lands onto the excavated area must be minimized such that it does not pose additional risk to groundwater quality."*

The proponent's hydrogeologist stated: "There will be no overland flow from adjacent lands into the quarry; therefore agricultural based contaminants cannot flow into the open excavation." but then essentially claimed the opposite in the same communication: "The site will continue to be a recharge area and through the creation of the excavation will capture runoff resulting in greater recharge at the site (Harden (2016c)". In fact, agricultural operations are located up-gradient of the site and these have previously been cited as sources of nitrogen to the groundwater: "…the quarry is being developed in an area that is already susceptible to contamination from the ground surface (Harden, 2014a)". Overland inputs have the potential to be a direct source of biological and chemical pollutants into bedrock groundwater and migrate downgradient in bedrock fractures (Burnside, 2015a). There is also the potential for contaminants input to the quarry ponds from Tributary B through shallow overburden groundwater flow (Woerns, 2019), or directly, should its supporting bedrock structure collapse due to blasting shockwaves. Samples from this tributary have contained elevated numbers of bacteria and of nitrogen concentrations, likely related to agricultural operations.

Contamination of Municipal and Residential Wells

GET's hydrogeologists have repeatedly expressed the opinion that the quarrying activities will result in constant mixing of the water from a variety of previously unconnected zones in the bedrock, and that the existing secure water quality in the deep bedrock aquifer will be changed to a surface water source under the influence of bacteria and viruses for an unknown distance around the quarry (Burnside (2013a ; 2014a; 2015a). This could result in the local deep aquifer serving nearby municipal wells such as GET Municipal Well #4 (PW4) being designated as a GUDI* source (Burnside, 2013b; Hunter, 2016; Frind, 2017). "Once the quarry is finished, there will be a large surface body directly in contact with the bedrock fracture system which may allow rapid movement of pathogens towards bedrock wells downgradient of the site (Burnside, 2013b)".

CRC's hydrologist has pointed out that the 2017 Tier 3 report on Water Budget and Risk Assessment Program fails to address the actual water table drawdown from PW4 that extends to the quarry site, thereby creating a possible connection between this municipal well and the quarry (Frind (2018). He stated that: "The Tier Three 2017 model by Matrix does not take the quarry into account, so the WHPAs [Wellhead Protection Areas] are only valid as long as the quarry does not exist." The Matrix model employed a 2 metre drawdown due to pumping of wells as the threshold for impact. Had a 0.5 metre threshold been used, the WHPAs would extend into the quarry site, as well as the Allen, De Grandis and Brydson Springs (Frind, 2018). Although the effect of bedrock extraction was not simulated in recent modeling for JDCL, it did predict a water level change of about 0.20 metes in the bedrock aquifer at the PW4 wellhead (Harden, 2017b). Note that a pumping test of PW4 in 2015 resulted in a small drawdown at two quarry wells. Note also that the WHPAs are based on a porous medium model instead of a karstic model, which can underestimate time of travel and area to be protected. This can lead to a false sense of security regarding protection from contamination of wells, such as occurred in Walkerton, Ontario in 2000 (Green *et al*., 2006).

A moratorium was placed on below-water limestone mining within 0.5 miles (800 metres) of the Northwest Wellfield in Florida's Biscayne aquifer which is a water source for 1.5 million citizens. This was in response to the high flow velocity in the karst aquifer (366 m/day in a dye tracer test) and concern over the potential for pathogens such as *Giardia* and C*ryptosporidium* to migrate into groundwater from the open lakes formed by subaqueous quarrying to a depth of 25 metres (Green *et al*., 2006). This situation is very similar to CRC's present concerns about groundwater contamination resulting from the proposed Hidden Quarry operations.

Harden (2014b) stated that: "…there is a system of interconnected fractures at depth" and "We agree, based on the observations, that it is possible that there is an anisotropic response* with preferential flow from the northwest direction." CRC's hydrogeologist is of the opinion that creation of the quarry in the local dolostone bedrock environment will result in a new preferential recharge flow pathway for contaminants and pathogens from the quarry ponds to the Rockwood production wells PW3 and PW4 (Hunter, 2016). Blackport & Golder (2006) indicated that aggregate extraction below the water table may modify capture areas of a municipal well or well field located in the same aquifer, as is the case with the proposed Hidden Quarry and PW4.

Blasting Agents

Explosives used in the underwater blasting can introduce nitrogen and other contaminants to the bedrock and groumdwater. In their review of nitrogen compounds at mines and quarries, Jermakka *et al*. (2015) observed that: "Explosives are mentioned as the single most significant risk to groundwater quality in extraction operations, and also considered as a possible factor influencing the quality of nearby surface waters." In his review of the proposal for Halton Region, Jambakhsh (2016) expressed concern regarding the potential for migration of explosive-related contaminants into the groundwater.

ANFO is a common explosive (blasting agent) composed of a mixture of ammonium nitrate and fuel oil in a ratio of 94.5% and 5.5%, respectively, but these percentages can vary somewhat by manufacturer. The fuel oils used are a complex mixture of hydrocarbons (alkanes, cycloalkanes, aromatics and olefins), with the most commonly employed being No. 2 Fuel oil and No. 2 Diesel fuel (Brochu, 2010). A water-resistant ANFO-WP, called Hydromite 4400 is referenced for use at the proposed quarry (Harden, 2014c).

Ammonium and nitrate are quite water soluble and therefore there is a direct relationship between ammonia and nitrate concentrations in water and the amount of un-detonated explosives in the rock through which the water flows (Revey, 1996). Additionally, improper handling, spillage, blasthole loading, and disposal of explosives can result in site contamination (Forsyth *et al*., 1995).

Under ideal conditions, combustion products of ANFO detonation consist mainly of carbon dioxide, nitrogen and water. However, "Explosions are not 100% efficient and some residue may remain to dissolve in the water in the quarry (Harden, 2014b)." The detonation of ANFO is often incomplete in a wet environment (e.g., the proposed Hidden Quarry bedrock), leaving behind by-products of un-reacted blasting agent such as nitrate, nitrite, and ammonia, as well as carbon monoxide, carbon dioxide and methane. Under certain exposure conditions, heterogeneities can occur in the ANFO mixtures, leading to non-ideal detonations, or decreased detonation velocity (Brochu, 2010). Other causes of incomplete combustion include premature rock movement caused by earlier detonations which can cut off portions of the charge, or pre-compression failures when hole-to-hole shock pressures are too high (Revey, 1996). Poor design or execution are the most common causes of misfires, and blast monitoring has shown that 10 to 20 % of blastholes misfire in a given blast operation (Forsyth *et al*., 1995). Weathered karst bedrock exists at the proposed Hidden Quarry. This can lead to accumulations of blasting material in fissures when pumped into drill holes, undesirable accumulations of explosives, and uncontrolled explosions leading to flyrock (Hill, 2015). Furthermore, with blasthole depths exceeding 10 metres and blast events consisting of multiple blastholes, as at the proposed Hidden Quarry, drill hole deviation ("wandering") from the vertical is possible, with an increased potential for misfires or blowouts (Hill, 2015).

Confinement of bulk explosives to control migration in rock beyond the blast hole into aquifers is important in saturated ground, particularly in layered rock mass strata (Jambakhsh, 2016). The rate of nitrate leaching from explosives varies dramatically with the product's composition. In tests, 50% of ANFO and about 25% of the water resistant ANFO [ANFO-WP] was leached within an hour of exposure to water (Revey, 1996). In the field, a study conducted in an underground metal mine in which groundwater flows through the bedrock and dewatering is not employed, found that 12 to 28% of the nitrogen in the ANFO explosive was leached out.(Morin & Hutt, 2009). These percentages are much higher than results from other mines, and the authors suggest that the difference was related to the "wetter" environment at that mine (ibid). It is not surprising that Jermakka *et al* (2015) suggested that: "One important means of controlling ANFO-originated nitrogen discharges to water is to avoid explosion work in wet conditions."

The Ontario Drinking Water Standard for Nitrate is 10 mg/litre (parts per million, or ppm) as Nitrate-nitrogen and 1 mg/L for Nitrite-nitrogen (MOECC, 2018). Nitrate can be reduced to nitrite in the gastro-intestinal tract of warm-blooded animals, and when reaching the bloodstream, react with haemoglobin to form methaemoglobin, which impairs oxygen transport, particularly in infants (Forsyth *et al*., 1995; Revey, 1996; USEPA). Nitrite was not detected in groundwater samples. However, Nitrate concentrations ranged from ND (not detected) to 5.2 mg/litre in 2013 and 2014 Hidden Quarry area groundwater samples, while Tributary B contained 0.80 to 4.64 mg/litre (Harden, 2014c; 2014e). The latter is above the 3 mg/L guideline for the protection of freshwater aquatic life (CCME, 2012). Ammonia Nitrogen includes both unionized Ammonia (NH_3) and ionized Ammonium (NH_4+) forms. The former is highly toxic to aquatic organisms, particularly to salmonids such as rainbow and brook trout. Concentrations of ammonia ranged from ND to 0.160 mg/L in groundwater samples from the site (Harden, 2014c; 2014e). The guideline for the protection of freshwater aquatic life is 0.019 mg/L (CCME, 2010). Ammonium (NH_4+), which is less toxic than ammonia, was not detected in any of the site groundwater samples or in Tributary B samples.

Calculation of the potential nitrogen loading by blasting to Hidden Quarry groundwater was attempted by the proponent's hydrogeologist using estimated annual nitrogen loadings, assuming Hydromite 4400 ammonium nitrate content of 82%, and Dolime (Guelph Limestone) Quarry information (Harden, 2014b). Results ranged from 0 to 894 kg Nitrogen loading per year (Harden, 2014a; 2014b; 2014c), However, Hydromite is listed as containing 85 to 95% ammonium nitrate (Austin, 2015) and the calculations failed to take into account that the depth of blasting and explosive charge per hole differs significantly between the two quarries (see table below). Furthermore, the Dolime Quarry is actively dewatered, resulting in a much greater dilution rate than at the proposed Hidden Quarry (Hunter, 2015; 2017a).

Quarry	**Blasting Depth, metres**	**Blasting Charge/ hole, kg**	**PTTW Volume, litres/day**		**Explosive Used, kg/year**	**Nitrogen conc'n, mg/L**	**Nitrogen Loss, %**
			Dewatering	***Aggegate Washing***			
.Dolime (Guelph)	approx.10 (2)	< 100 (2)	13,750,000 (6)	3,270,000 (6)	--	0.76-0.89 (2)	--
Hidden Quarry	22 - 28 (1)	136 – 545(5)	0	2,500,000 (4)	136,665 (3)	--	--
Gamebridge	--	--	2,880,000 (6)	--	60,875-103,480(3)	3.11-6.72 (3)	2.28 (3)

Sources: (1) Stovel, 2019; (2) Harden, 2014b; (3) Harden, 2014c; (4) Harden, 2016b; (5) Explotech, 2019; (6) MOECC, 2017; "--" = Not Available.

The proponent has claimed that: “Aggregate extraction is a very clean activity and test results from other extraction sites confirm that there are no chemical contaminants degrading the quality of ground or surface water (JDCL, 2017)”. Contrary to this claim, between 2009 and 2013, the average nitrogen concentrations in JDCL’s Gamebridge Quarry dewatering discharge water were from 3.11 to 6.72 mg/litre, several times higher than the quarry water background value of 1.4 mg/litre (Harden, 2014 b). Even though nitrogen loss was calculated as only 2.28% of the total used, it was still sufficient to adversely affect water quality.

Blasting Agent By-Products
In addition to ammonium nitrate, other constituents listed in the Specific Data Sheet for the HEET and Hydromite explosives include Aluminum, No. 2 Diesel Fuel, Light and Medium Petroleum Distillates, Polyolefin Alkanolamine Ester Emulsifier, Glass Microspheres and Plastic Microspheres and water (Austin, 2015). Many of these are considered to be irritants, toxicants, flammable, or cancer-causing (ibid) depending on their concentration and/or exposure route.

The fuel oil components of ANFO, such as Diesel Fuel, are moderately volatile and water soluble, and exhibit moderate to high acute toxicity, depending on the specific hydrocarbon components (Brochu, 2010). Of these, the aromatic compounds can exhibit acute or chronic toxicity, depending on the concentration and length of exposure. The lighter molecular weight aromatics have moderate water solubilities in the mg/L (ppm) range. For example,the solubility of benzene in fresh water is 1,780 mg/L (EUGRIS).and the Ontario drinking water Standard for benzene is 0.001 mg/L (= 1 ug/L, or ppb) (MOECC, 2018). A Dolime Quarry pond water sample collected in 2012 contained 0.11 ug/L benzene. Gaseous reaction products from incomplete detonation of the explosive can include nitrite as well as phthalates, aliphatic hydrocarbons and benzene (Jermakka *et al*., 2015). As noted above under nitrogen loadings, the depth of rock blasting (drill holes) and amount of explosive used at the Hidden Quarry would be nearly three times deeper and up to six times greater, respectively, than at the Dolime Quarry, thereby allowing for greater potential contact of explosive-related materials with groundwater.

Fortunately, benzene’s volatility and evaporation from a water body is relatively fast, with times to reach half of the original concentration (half-lives) of 2.7 and 5 hours, respectively (Nagpal, 2007). Benzene is highly biodegradable under aerobic (oxygen-rich) conditions with a half-life of 16 to 58 days (Nagpal, 2007; Lawrence, 2006). However, it can be relatively persistent in bedrock groundwater where volatilization is not a viable process and oxygen is often depleted. Even a concentration half-life of 28 days under anaerobic conditions (Lawrence, 2006) is longer than the probable transit time of groundwater in the fractured rock of the proposed Hidden Quarry site to downgradient areas.

Spills
Loss or spillage of materials within the quarry extraction area may reach groundwater and be carried downstream to contaminate residential wells, Brydson Creek and Blue Springs Creek. Potential contaminants which could be present on a regular basis on the site include: gasoline, diesel fuel, motor oil, grease, lubricants, coolants, brake and transmission fluids, degreasing agents, solvents, and road de-icing compounds (Harden, undated).

Biological Impacts
Wildlife, including waterfowl, will have ready access to the two created ponds. The proponent’s

environmental consultant claimed that waterfowl will not be important users of the ponds, stating: "… waterfowl nesting and brood rearing in the quarry during the spring and summer months should be minimal. The greatest waterfowl use of the area will likely occur during the fall migration although the number of birds should still be relatively low (GWS, 2014)." Geese are often observed on quarry ponds in large numbers, even in winter, where they provide a staging area, so there is a very real potential for groundwater contamination by waterfowl year-round. Furthermore, the attractiveness of the ponds for nesting and rearing of young now seems to be enhanced in the recent Site Plans (Stovel, 2019) which specify the creation of littoral and wetland habitat in some areas of the quarry that will encourage waterfowl use.

Waterfowl using water bodies for feeding, resting, or nesting can be significant contributors of viable bacteria and pathogens, as well as nutrients such as nitrogen and phosphorus. Inputs can vary with the species and density of waterfowl, their diets and feeding habits, water body dilution capacity, and time of year (Fleming & Fraser, 2001). Groundwater samples from the site did not contain any detectable *E. coli* and only one sample contained Total Coliforms in 2014 at 14 CFU (Colony-forming units)/100 mL (Harden, 2014g). The Ontario Drinking Water Standard for both Fecal Coliforms and *E. coli*. is 'Not Detectable'

As noted previously, fractured dolostone is present at the proposed Hidden Quarry site. Sampling of 22 wells in a regional fractured dolostone aquifer in south Wellington County indicated a high vulnerability to contamination by sewage-derived human enteric viruses, although they were present at very low concentrations (Allen *et al*., 2017). The cool groundwater temperatures of these aquifers can promote virus longevity and infectivity, while the rapid groundwater velocities can increase virus transport from upstream sources to downstream areas and users. No Ontario water quality Standard is currently available for enteric viruses, but USEPA rules require that systems using surface water or ground water under the direct influence of surface water achieve a 99.99% removal or inactivation.

Summary and Conclusions

There are a number of concerns about the extraction of bedrock from the proposed Hidden Quarry site by using underwater blasting with explosives. These include physical, chemical and biological effects: water level decreases in the overburden, aquifer, adjacent wells and wetlands due to quarrying, contamination of groundwater during blasting by ammonium nitrate and fuel oil, and/or its combustion by-products, and contamination of the groundwater withdrawn to wash the crushed rock, or by spills of contaminants. Additionally, waterfowl and other wildlife using the open ponds created by the operation will introduce nutrients, bacteria, and other pathogens. Creation of the quarry in the local dolostone bedrock environment threatens to create a new preferential recharge flow pathway from the quarry ponds and contaminants to Rockwood production well PW4 and to surrounding wells and downstream tributaries. There have been numerous inconsistencies and contradictions in statements of the proponent's consultants regarding the potential for adverse impacts of the proposed quarry.

With these concerns in mind, it is important to note Wellington County ***Policy 4.9.7*** (2018) concerning the Paris and Galt Moraine Area:

> *"…they* [the moraines] *function as a support for hydrologic processes and features that influence groundwater and surface water resources at regional and local scales."*

and that **Policy Objectives *4.9.7.1*** are intended to

> *"…Protect moraine processes and features in order to maintain and where possible enhance groundwater and surface water resources; and Promote stewardship activities that maintain, restore or enhance these resources.*

and ***Policy Direction 4.9.7.2***: On lands in the Paris and Galt Moraines Policy Area on Schedule 'B' that lie outside of Wellhead Protection Area, the following shall apply:

> "*Large scale development proposals including intensive recreation, mineral aggregate operations, new rural employment area designations and urban boundary expansions will be required to demonstrate that ground and surface water functions will be maintained and where possible, restored and enhanced."*

These and a number of other County Official Plan policy requirements cited have not been met by the proponent and furthermore, there is evidence that the moraine land may lie within a Wellhead Protection Area that includes GET Municipal Well PW4. The potential for damage to the Paris Moraine groundwater system and processes is too great for this proposal to be approved. Aggregate may be required for some infrastructure projects, but the need for water is universal.

Explanatory Notes *

epikarst = a thick layer (often 15-30 m) of bedrock extending from the bottom of the soil zone, characterized by extreme fracturing and enhanced solution, where significant water storage and transport occur.

GUDI = Groundwater Under Direct Influence of Surface Water.

anisotropic response = preferred flow direction is other than in the direction of the gradient.

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