

August 10, 2020 Supplement to April 24, 2020 Flyrock and Other Impacts from Quarry Blasting Operations

(see <https://intval.com/articles/Flyrock-and-Other-Impacts-from-Quarry-Blasting-Operations.pdf>)

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SECTION I

The Incidence and Dangers of Flyrock Occasioned by Blasting

According to a January 2020 article appearing in the Journal of Mining and Environment (JME),¹

[I]n China, flyrock is the reason of about 27% of surface mine disaster events [p. 1]² [emphasis added]

...Flyrock...is one of the most hazardous phenomena in the drilling and blasting operation of surface mines. This phenomenon is defined as driving rock fragments beyond a desired area, which can result in human injuries, fatalities, and structure damages [p. 1].³

There can be many reasons for the flyrock phenomenon occurring ranging from deviations in the blast pattern design or their implementation, explosive use, and known or unknown ground conditions [p. 1].

According to a 2003 paper prepared on behalf of the International Society of Explosives (ISEE),⁴ flyrock accounted for 21.5% of all blasting injuries in surface mining in the United States from 1994 to 2001. According to records of Mine Safety and Health Administration (MSHA),⁵

1 out of 10 accidents happened because of flyrock that landed outside the blast area. Accidents happened not just to blasters but also to people guarding the blast area, contractors sitting in their trucks, miners waiting to go back to work, neighbors working in their own yards, and even to people driving on the highway. [emphasis added]

If you are a mile away or even only 500 yards away, you may be able to see flyrock coming but it is too fast to avoid. And if one piece of rock flies, there will likely be others with it.

A case study of a flyrock incident presented in an April 2020 article of J. Inst. Eng. India Ser. D⁶ addresses the comparative dangers of flyrock occasioned by blasting and identifies some of the underlying causes of flyrock:

In blasting operations, flyrock (uncontrolled flying fragment) is one of the main causes of accident. The other blasting impacts to the surroundings such as ground vibration, noise (air overpressure/air-blast), fumes and dust can hardly cause direct injury and fatality to human, although they may cause structural damage and nuisance to the nearby residential houses and habitats.

¹ Norouzi Masir et al., *Journal of Mining & Environment*, Published online, retrieved 2-May-20 http://jme.shahroodut.ac.ir/article_1666_85bf4cbae3cc897226cce579c31233b3.pdf.

² Fan L, Shen, w. and Li, Y. "The causes of flyrock and safety precautions in demolition blasting," *Engineering Blasting of China* 8 (1): 35-38.

³ Monjezi, M., Bahrami, A., Varjani, A.Y. and Sayadi, A.K. (2011). "Prediction and controlling of fly rock in blasting operations using artificial neural network." *Arab J Geosci* 4; 421-425.

⁴ H. Verakis and T. Lobb, "An Analysis of Blasting Accidents in Mining Operations," *International Society of Explosives Engineers*, 2003.

⁵ "Toolbox Safety Talks: Blast Safety, <http://www.cfins.com/wp-content/uploads/2019/01/blasting-safety-toolbox-complete.pdf>.

⁶ C. Sawmliana, Panchanan Hembram, R.K. Singh, S. Banerjee, P.K. Singh and P. Pal Roy, "An Investigation to Assess the Cause of Accident due to Flyrock in an Opencast Mine: A Case Study," *J. Inst. Eng. India Ser. D*, retrieved 12-May-2020 <https://doi.org/10.1007/s40033-020-00215-4>.

The accident due to flyrock remains one of the major contributors of fatal and serious accidents in opencast mines. The ‘Danger Zone’ as given in Coal Mine Regulations [1] has already been increased from 300 to 500 m in the new Coal Mines Regulation [2] [Reg. 196 (2) (b)] to avert flyrock-related accidents in opencast coal mines. [emphasis added]

There are many reasons for flyrock causes and associated accidents during blasting in opencast mines. Overcharging of holes with explosive, less stemming length, improper stemming, less burden, undercut, overcut/break-back/end-back due to previous blasting, presence of loose material in the strata, cavities, improper initiation sequence among others are the common causes of flyrock in bench blasting. The reasons for accident due to flyrock also include failure to evacuate the area, failure to take shelter, failure to communicate, taking unsafe shelter, etc.

According to Dr. Kiger, a now-retired Civil and Environmental Engineering professor at the University of Missouri,⁷ flyrock is a significant concern to both quarry workers and nearby residents, as identified in his response to a proposed rezoning to permit a quarry:⁸

“Flyrock” is rock that is ejected from the blast site in a controlled explosion in mining operations. The term refers to rock that flies beyond the blast site, potentially causing injuries to people and damage to property. This is considered a significant issue in mining. Indeed, between 1994 and 2005, 32 miners were injured by flyrock.⁹ Flyrock can vary in mass from marble-sized to car-sized. [emphasis added]

At quarry blasting operations flyrock is a constant hazard not only to the workers at the quarry, but also to nearby homes and residents. Flyrock can be produced when the holes filled with explosive intersects a naturally occurring fracture or soft loose material in the rock being quarried. This fault in the rock provides a path for the shock wave generated by the detonation wave in the explosive to escape and propel a part of the surface rock into the air. The shock wave is moving at a very high speed so it can propel the flyrock great distances. Note that a shock wave is defined as a disturbance in the atmosphere moving at a speed greater than the speed of sound (1,100 feet per second at sea level).

The shock wave will be very disturbing to anyone within one to two miles of the blast (there are more than 100 homes within 0.75 miles of the proposed quarry pits in Alvaton). The escaped shock wave might even crack windows in this area. The shock wave is very similar to the sonic boom generated by a jet airplane when it “breaks the sound barrier.” I have reviewed the reports by two geologists provide[d] by the clients which state that preliminary geologic mapping suggests that there are pervasive schist interlayers within the granite body with pervasive intergranular fractures. As stated above, such fracturing increases the likelihood for blasting to produce flyrock at the proposed quarry.

Another way these unwanted events of flyrock and/or blast shock waves often occur is when the drill hole encounters a void, or open crack at the depth of the explosive. The explosive material is

⁷ Dr. Kiger is a nationally and internationally recognized expert in explosion effects and blast resistant structural design. He has authored or co-authored over 100 technical papers and reports, and is the principal author of the US Army Technical Manual “Fundamentals of Protective Construction”, TM5-855. He previously chaired the American Society of Civil Engineers (ASCE) Technical Committee on Shock and Vibratory Effects; is a Past President of the WV Section of ASCE, and is a member of the National Research Council’s Committee for Oversight and Assessment of Blast Effects and Related Research. In 1985, Dr. Kiger was recognized as the US Army Corps of Engineers Researcher of the year for his work in explosion resistant structural analysis and design; and in 2008, he was awarded a Lifetime Achievement Award in Shock and Vibration “for outstanding contributions and leadership in the community.”

⁸ Rezoning denied and upheld on appeal. https://flintriverkeeper.org/wp-content/uploads/2019/05/Randall_etal_v_Meriwether_County_etal_Final_Order.pdf.

⁹ The National Institute for Occupational Safety and Health, *Mining Topic: Blasting and Explosives* (last accessed October 17, 2018), available at www.cdc.gov/niosh/topics/explosives.html.

most often in the form of slurry¹⁰ and is pumped into the blast hole. If there is a void or open crack too much explosive can collect and the resulting blast will blow out producing a shock wave into the atmosphere and, potentially, flyrock.¹¹

Predicted Versus Actual Flyrock Distance

In a case study of the July 15, 2015 flyrock incident at a construction site in Johor, Malaysia that propelled flyrock up to a distance of 200 metres killing one worker and injuring two others, it was determined that blast design was only 69% accurate in predicting flyrock distance.

In this study five empirical models are used to compare the incidents. It was found that none of the existing formulas could accurately predict flyrock distance. Analysis shows that the gap between predicted and actual flyrock distance can be reduced by including blast design and geological conditions in forecasts. Analysis revealed only 69% of accuracy could be achieved if blast design is the only parameter to be considered in flyrock projection and the rest is influenced by the geological condition.¹²

Repeated Quarry Blasting

In Miller Paving Ltd. v. McNab/Braeside (Township),¹³ Dr. Kiger addressed the high probability of damage to neighbouring structures (homeowners' property) resulting from repeated blasting, even at low ground-vibration levels.



¹⁰ "Slurry" is defined as "an explosive material containing substantial portion of a liquid, oxidizers, and fuel, plus a thickener, [p. 12]" according to Geotechnical Engineering Manual Gem-22, Revision #4, August 2015, <https://www.dot.ny.gov/divisions/engineering/technical-services/technical-services-repository/GEM-22b.pdf>.

¹¹ Dr. Sam Kiger, P.E., Professor Emeritus, Civil & Environmental Engineering, University of Missouri, "Proposed Granite Quarry in Alvaton, Meriwether County, GA," October 20, 2018.

¹² Edy Tonnizam Mohamad, Chang Shiang Yi, Bhatawdekar Murlidhar, Rosli Saad, "Abstract: Effect of Geological Structure on Flyrock Prediction in Construction Blasting," *Geotechnical and Geological Engineering*, Issue 4/2018.

¹³ *Miller Paving Ltd. v. McNab/Braeside (Township)*, PL130785, OMB, October 27, 2015 <http://www.omb.gov.on.ca/e-decisions/pl130785-Oct-27-2015.pdf>.

[Quarry blasting is done by drilling blast holes behind the working face of the quarried material to blast it loose for harvesting. The hole size, spacing, and amount of explosive are designed by an experienced blaster. The explosive most often used is ANFO (Ammonium Nitrate and Fuel Oil). When the explosive is detonated a detonation wave moves through the explosive at a speed of about 18,000 feet per second changing the solid material to a gas at a very high rate. This detonation wave and rapidly expanding gas will create a cavity, crushing, cracking and moving the surrounding material. It will also introduce 2 types of waves into the earth around the explosion. First a surface, or Rayleigh wave, that will damp out and disappear in a relatively short distance. And second a body wave that will travel great distances in the bedrock (under any barrier). It is this body wave that will move through the bedrock and cause the earth above the bedrock to vibrate and shake homes, even at large distances from the explosions. **There is no way to mitigate or block the movement of these body waves.**] [evidence presented by Dr. Kiger in connection with an Application for Rezoning and Special Use Permit for a proposed Granite Quarry in Alvaton, Meriwether County, GA]¹⁴ [emphasis added]

In the...1980 report [prepared for the US Bureau of Mines] by Siskind et al,¹⁵ the authors establish 0.5 in/sec (12.7 mm/s) as the “threshold” for damage to structures, and they define “threshold” as a 5% probability of cosmetic damage. The probability of damage to a home may be relatively small in any single blasting event. However, numerous opportunities for an unlikely occurrence (like damage to the home) will result in a very likely occurrence of damage. For example, if the probability of damage (P_d) in any single blasting event is 0.05, or 5 percent, then the probability of not being damaged (P_u) is 95 percent. One can use the probability law of independent events to calculate the probability of damage occurring at least once in 100 events....[F]or example see... “Introduction to Probability and Statistics” Third Edition, 1964, by Henry L Alder and Edward B Roessler; published by W.H. Freeman and Company. Thus, assuming the probability of damage is the same for each event, 0.05, then the probability of not being damaged at least once in 100 events is:

$$P_{u-100} = (0.95)^{100} = 0.006$$

¹⁴ On October 23 2018, the Meriwether County Board of Commissioners (CBC) denied the request to rezone the property and grant a special use permit for a blasting quarry. The appeal of the CBC ruling to deny the rezoning was upheld by the Superior Court in *Luther H. Randall, III, et al., v. Meriwether County, Georgia, et al.* File No. 18CV0270 [May 1, 2019]. In upholding the decision of the Board of Commissioners, the Superior Court made a number of observations, including the following: “The proposed zoning for use as a granite quarry [is] unsuitable in view of the many residences within .75 miles [1,207 metres] of the proposed quarry pits....The applicant failed to reliably demonstrate that the proposed zoning as a granite quarry will not adversely affect the existing use or usability of the adjacent and nearby residential property owners. Evidence from experts (real estate appraiser, geologists, noise control engineer, blasting expert) indicated that: (a) the applicants did not reliably demonstrate that the proposed quarry will not decrease the value of adjacent residential properties; (b) there is a potential for negative impacts to drinking water wells in the area of the property; (c) the application provided no details on how surface water will be reliably collected and properly concentrated to enter the quarry holes; (d) the applicant’s noise study is not reliable and underestimates sound emission by more than 20 dB in several cases; (e) blasting at the quarry has a high likelihood of damaging many of the more than 100 residential structures within one to two miles of the proposed granite pits over the life of the proposed operation and will significantly degrade the quality of life for those residents affected; and, (f) the application has no information on how the quarry operation will be reclaimed when its reserves are exhausted....The proposed use will generate additional traffic, noise, blasting, dust, and other operational processes not consistent with the surrounding properties or the Low Density Residential Zoning [p. 9-11].” https://flintriverkeeper.org/wp-content/uploads/2019/05/Randall_et_al_v_Meriwether_County_et_al_Final_Order.pdf.

¹⁵ D.E. Siskind, M.S. Stagg, J.W. Kopp, and C.H. Dowding, “Report of Investigations 8507: Structure Response and Damage Produced by Ground Vibration From Surface Mine Blasting,” (1980), prepared for US Bureau of Mines. Online at <http://www.osmre.gov/resources/blasting/docs/USBM/RI8507BlastingVibration1989.pdf> [RI 8507].

And the probability of the structure being damaged in 100 explosions is 1 minus the probability that it is not damaged, thus:

$$P_{d-100} = 1 - 0.006 = 0.994$$

This implies that the probability of damage in 100 events is about 99 percent, meaning damage is almost certain if the homes are subjected to these blast induced ground vibrations numerous times. Thus, even though damage is unlikely to result from any single blasting event, some damage in the form of cracking of walls, ceiling, tile, concrete, nail popping, loosening of framing joints, etc. becomes very likely over time with numerous repetitions of blast-induced ground vibrations. And once damage occurs (like cracking, nails pops, or framing joints loosening) that damage will rapidly increase with repeated exposure to the vibrations, even at lower levels of vibrations.

In recognition of the fact that damage to residential homes can occur even at low ground-vibration levels, other countries have set much more stringent limits on allowable peak ground vibrations....[R]egulatory agencies in Leicestershire County, UK have established the upper limit on allowable peak particle velocity as 0.24 in/sec (6.096 mm/sec); in Australia the common limit is 0.2 in/sec (5.08 mm/sec) and it is 0.001 in/sec (0.00254 mm/sec) for historical buildings and monuments for frequencies less than 15 Hz [hertz].

Janet Bradley, legal counsel for the Township of McNab-Braeside, argued that buffers (setbacks) are often the only effective means of eliminating adverse effects between incompatible land uses. Bradley prevailed in advancing the Township's position that the buffers be provided within the boundary limits of the ownership or control of the landowner needing the buffers (i.e., *Miller Paving*, the quarry operator).

*Often distance is the only effective way to mitigate the [adverse] effects of industry on its neighbours....Bradley contended buffers should be on the properties of the parties needing it for their operations (not extending into people's back yards)...[p. 4].*¹⁶

A private for-profit company such as a quarry operator does not possess a legal right to externalize buffer (setback) requirements that diminish the utility and value of neighbouring properties, the owners of which do not participate in the anticipated profits from the quarry operation or receive any financial compensation.

In *Fontaina Scott v. Mountaineer Grading Co.*,¹⁷ Dr. Kiger explained the *dimensional changes* homes undergo daily and seasonally, and how they can be magnified or exacerbated by subsequent blast induced vibrations.

All homes undergo daily and seasonal changes due to things like humidity variations and changing temperatures, like the sun moving from one side of the home to the other (the warm side will expand relative to the cooler side); or seasonal variations of temperature and humidity. For example[,] most of us have experienced a 'sticking door' or a door that will not close (or easily open) during certain times of the year. These environmental effects will cause strains in the walls, ceilings, structural framing, tile covered surfaces,...etc. These strains are known by engineers as prestrains, that is strains that exist before an event like a blast induced ground vibration. The prestrain condition may be such that a very small vibration will push the item, like a wall panel, a framing connection, or piece of tile, over its strain limit and result in a crack or loosening of a structural frame connection. Once a crack is initiated the crack will grow at a much lower level of vibrations than was required to initiate the crack. This is because of the stress concentration that exist at the crack tip; envision for example a small crack in an automobile windshield where even a

¹⁶ "Quarry expansion, but no asphalt plant in Braeside: Opponent," Arnprior Chronicle, March 25, 2015, <https://issuu.com/arnpriorchronicleguide/docs/arnprior032615>.

¹⁷ *Fontaina Scott v. Mountaineer Grading Co.*, Putnam Co. Civ. Act. No. 09-C-286.

small bump from ones hand can cause the crack to grow. Thus, even low levels of repeated occurrences of blast induced ground vibrations can cause significant damage to a home over time. For example[,] the German vibration standard is 0.16 ips [inches per second] for buildings with visible damage and cracks in masonry. See for example Table 1 in “Vibration Criteria for Historic and Sensitive Buildings” by Konon and Schuring.¹⁸

*The fact that these prestrain conditions can produce a condition in the home such that damage to a home will occur at even very low levels of vibrations is acknowledged in BOM [Bureau of Mines] RI 8507¹⁹ in their Conclusion 7 of page 68; Conclusion 7 is pasted below. This conclusion agreed to by the 4 experts that authored RI 8507, clearly states that “...**there may be no absolute minimum vibration threshold...**”; that is, when inevitable prestrain conditions are present in a home, any blast induced ground vibrations might cause damage to the home.*

7. All homes eventually crack because of a variety of environmental stresses, including humidity and temperature changes, settlement from consolidation and variations in ground moisture, wind, and even water absorption from tree roots. Consequently, there may be no absolute minimum vibration damage threshold when the vibration (from any cause, for instance slamming a door) could in some case precipitate a crack about to occur.

In Bureau of Mines RI 8507 they suggest a maximum allowable ground vibration peak particle velocity of 0.5 inches per second (ips) at which there is a 0.5 percent probability of damage. However, the standards in many countries are much lower....[R]egulatory agencies in Leicestershire County, UK have established the upper limit on allowable peak particle velocity (ppv) as 0.24 ips; in Australia the common limit is 0.2 ips and it is 0.001 for historical buildings and monuments for frequencies less than 15 Hz. Note that frequencies less than 15 Hz are very likely in blast induced ground vibrations of large distances from the blasts. The Australian standard for historical buildings of 0.2 mm/sec (0.001 ips) implies that if a building is really important the allowable vibrations to prevent damage is extremely low. Therefore, standards in reality represent an economic decision. Since at almost any vibration level some homes might be damaged, but for the mine to operate at an economic level, some probability of damage is tolerated. The level of 0.5 ips widely adopted in the US is far greater than the standards adopted in other countries. [see Table 2, R. Pesch and A. Robertson, “Drilling and Blasting for Underground Space”, Wollongong, NSW, 3-4, September 2007.]

The size of the blast induced ground vibration waves shaking the homes are large in comparison to the footprint dimensions of a typical home. The length of the ground vibration wave train is the duration of the blast induced vibration shaking at the homes, typically about 3 to 4 sec, times the speed of the ground wave, typically about 800 ft per sec. Thus, for a typical blasting event with multiple individual explosions the ground vibration wave train is about 3,000 ft long. These ground vibrations at long distances, i.e. more than 1,000 ft, have a dominate frequency of the ground vibration equal to about 8 or 10 Hz (cycles per sec); for a frequency of 10Hz a single cycle of the ground shaking is 80 ft in length (one cycle is up down and back up) so that the leading edge of the home is picked up then pulled down while the back of the home is being picked up; this up and down of the front and then back of the house occurs repeatedly for the full 3 to 4 second duration of the ground vibration; in this example that would be about 30 to 40 complete cycles (10 cycles per second for 3 or 4 seconds). When these repeated distortions of the house matches the natural frequency of the house, the motions will be amplified and damage to the house will be significantly increased.

In 2016, Dr. Kiger was contacted by a reporter in connection with an article about a family's 10-year exposure to the adverse effects endured as a consequence of blasting at a nearby surface coal mine in Appalachia, and the homeowners' failed attempts to hold the coal mine

¹⁸ Konon and Schuring, “Vibration Criteria for Historic and Sensitive Older Buildings” ASCE Preprint 83-501; American Society of Civil Engineers (ASCE), Houston, Texas, October 17-19, 1983.

¹⁹ US Bureau of Mines RI 8507, “Structural Response and Damage Produced by GroundVibration From Surface Mine Blasting”, 1980.

operator accountable for the damages to their home.²⁰ The coal mine operator contends that all blasts are conducted within regulatory limits and, therefore, the blasting cannot cause structural damage, despite the apparent damage to the homeowners' residence (persistent drywall cracks in nearly every room, windows and doors out of alignment, and slanting of the floor toward the centre of the home, where the dining room floor has settled lower than the hallway floor). According to Dr. Kiger, the regulatory blasting standards are based primarily on a 1989 study of new residential structures in Indiana, which are not representative of the older homes typical in Appalachia:

"These more fragile homes [in Appalachia] are much more susceptible to damage from blasting-induced ground vibrations," he wrote. "In many other countries, the experts established a much lower threshold for damage."

In a 2010 report prepared for a court case involving blast complaints in Mingo County, W.Va., Kiger compared the blasting limits from the Indiana study to Australian standards for historical buildings, which designate a vibration level 500 times lower than the acceptable level for surface mine blasts in the United States. "Therefore, standards really represent an economic decision," Kiger stated in the report.

Homeowners Awarded Damages Caused by Vibrations and Shockwaves from Blasting

In *Cann v. Carl B. Potter Ltd.*,²¹ blasting in bedrock to a depth of 50 to 60 feet in 1975 for the construction of a public highway and installation of sanitary and storm sewers, and water lines caused damage to a dwelling about 600 feet (183 metres) to 700 feet (213 metres) away. "[A]s a result of escaping vibrations and shock waves, the plaintiffs' property was damaged and the plaintiffs suffered injury, loss and damage." The dwelling, built on bedrock with a thin cover of soil, was constructed in 1959, with a rear addition constructed in 1962. Before the property was purchased in 1972, the homeowners conducted a thorough inspection of the dwelling looking for defects, *noting only a hairline crack of two to three inches on a living room plaster wall.*

No pre-blast report was ever made of the Cann residence by the blasting company. At first the Canns felt light tremors, but as the blasting got closer to the dwelling the tremors became more pronounced. According to the Canns, after the blasting in 1975 "the house was shaken up and...cracks in the plaster [appeared] at various places in the house." The Canns kept records of the time when the sound of blasting was heard and the noticeable effects to the dwelling. The effects on the dwelling were documented by Mr. Cann, and confirmed by a neighbour:

[P]laster dust fell from the plastered walls and pictures moved on the walls and fell from the walls. He gave these records to one, Kaiser, who was an adjuster acting for his insurance company, and these records were never returned....After he found that the first record had been lost, he kept later records...A neighbour...kept records of blasting times and dates and of the severity of tremors felt by her.

Mr. Cann produced Exhibit 2, indicating the location of the various cracks in the plastered walls of the house and...where there were cracks in the foundation wall and in the fireplace and in the

²⁰ Molly Moore, "Blasted: Homeowners near mine seek recourse for property damage," *The Appalachian Voice*, February 18, 2016, <https://appvoices.org/2016/02/18/blasting-homeowners-property-damage-coal/>.

²¹ *Cann v. Carl B. Potter Ltd.*, 1980 CarswellNS 292, 42 N.S.R. (2d) 682, 77 A.P.R. 682.

chimney, and the concrete base of the chimney. He found water was entering the basement from the outside.

In his evidence on behalf of the homeowners,

Dr. Potyondy [professional engineer] particularly stressed the relative displacement of the two sections of the cracked foundation wall. This indicated to him that the wall was subject to a lateral force and that blasting nearby probably caused this movement. He also expressed the opinion that the damage to the chimney and fireplace was consistent with damage caused by blasting nearby.

The homeowners' other expert, Mr. Yurkew, also a professional engineer, in his April 9, 1976 report,

[described] the cracks which he saw throughout the house and the way in which the mantelpiece had pulled away from the south wall of the house...[and] the cracks in the brickwork of the fireplace chimney. He...concluded that any movements which were evident at the time of his inspection must...be the result of extraneous forces.

Mr. Yurkew prepared a second report on March 10, 1980, pursuant to a follow-up visit and inspection of the house. After being assured in March 1980 that the house was built on bedrock, while maintaining the opinion that the damage observed was caused by lateral force from blasting, Mr. Yurkew abandoned,

the theory put forward in his report of April 9, 1976, with regard to densification of the soil and settlement of the foundations...[para. 29].

Mr. Jacques' company was retained to conduct a pre-blast survey, and it was determined that the pre-blast survey should stop at 500 feet, which excluded the Cann house some 600 feet distant, putting budgeting constraints (economic considerations) of a private company before the safety and well-being of the public.

Mr. Jacques' firm was retained by the Public Service Commission, and the City of Halifax, had regard to the possible areas in which houses could be damaged by blasting operations and gave consideration to matters of cost. I take this to mean that there were some budget constraints which determined that the pre-blast survey should stop at the 500 ft. distance and that, if one had regard only to the possibility of damage from blasting, one would extend the area beyond the 500 ft. and would probably include the Cann house at a distance of 600 ft [para. 34].

Rejecting the evidence presented on behalf of the defendant and ruling in favour of the homeowners, the trial court judge said:

It has been established to my satisfaction, by a preponderance of evidence, that the damage complained of by the plaintiffs occurred during the period when the defendant company was carrying on its blasting operations in the vicinity of the Cann house and ceased when those blasting operations ceased. In view of that finding, I cannot accept the opinion of the witness, J.W. Cowie, that the damage was caused by humidity changes and thermal changes in the house. If his opinion were correct, one would expect not only that some of the damage complained of would have occurred long before October, 1975, as he said it did, but also that such changes would continue to occur after April, 1976, and there is no evidence that this, in fact, happened [para. 51].

The trial court also found the defendant liable without negligence having to be proved, stating,

the defendant company is liable to the plaintiffs without the necessity of proving negligence on the part of the defendant company. The defendant company was in occupation of the construction site at Kearney Lake Road and Dunbrick Street and conducted blasting operations thereon by the use of explosives, causing vibrations to escape from the site, which vibrations caused the damage complained of by the plaintiffs at their residence [para. 57].

The homeowners were entitled to recover damages basing their cause of action on nuisance or on *Rylands v. Fletcher* (1868), L.R. 3 H.L.333 (para. 59). The trial court's ruling was upheld by the Nova Scotia Court of Appeal.²²

Homeowner Awarded Damages Caused By Blasting Operations

In *Jones v. Consolidation Coal Co.*,²³ the appeals court upheld the trial court's judgment awarding the homeowners \$14,850 in property damages incurred as a result of the defendant's blasting at a distance of 2,000 feet (610 metres) from the home.

At trial, plaintiffs, Ronald and Shirley Jones, testified that they bought their home, outbuildings, and 20 acres near Sparta, Illinois, from Shirley's mother over 20 years ago. They paid \$17,000 for the two-story house, a barn, two machine sheds, two small sheds, and the acreage. Plaintiffs remodeled and added to the house after they purchased it.

They experienced no damage to their home prior to 1978. In the early summer and fall of 1978, defendant conducted blasting operations at its Burning Star No. 3 Mine, approximately one-fourth mile from plaintiffs' residence. Plaintiffs testified that they felt strong vibrations from the periodic blasting at the mine. They began to notice damage to their residence and outbuildings after the blasting. The damage included: cracking plaster and fireplace, separation of paneling and a kitchen counter top from the wall, sagging kitchen floor, and water damage. In addition, they noticed cracking in the concrete floors of their garage and barn. Plaintiffs contacted defendant and their insurance agent about the damage. They asked Roy McKinley, a local contractor, to give them an estimate of the cost of repair. Plaintiffs effected some repairs to their residence prior to trial.

Clarence Clasen, plaintiffs' insurance agent, testified that he had been in plaintiffs' residence several times between 1971 and 1978. Prior to 1978, he did not notice significant cracking or water damage. He visited the Jones residence during or shortly after 1978 and observed cracking at various locations throughout the home and separation of the kitchen cabinet from the wall. He also noticed cracking of the masonry in a milkhouse attached to plaintiffs' barn.

Plaintiffs' neighbor, Larry Phelps, testified that he had been to plaintiffs' residence prior to and after the damage to the residence. He observed no damage prior to 1978; however, after 1978 he noticed cracking plaster and separation of the kitchen cabinet from the wall.

Clarence Welty testified that he lived approximately 2 1/2 miles east of plaintiffs' house. During the summer of 1978, he felt vibrations from the blasts at defendant's mine and noticed cracks forming in his house.

Roy McKinley, a retired carpenter, testified that he had bid hundreds of repair jobs during the period of time that he worked as an independent contractor. In November of 1978, he gave plaintiffs an itemized estimate...of the cost of repair work for their residence. The written estimate of \$16,350 was later admitted as evidence and included \$4,500 for tearing up the cracked concrete floor in plaintiffs' garage and replacing it with a new floor. McKinley acknowledged that the cost of replacing the floor was "expensive" and that he had, in the past, used caulk to fill cracks in "outside concrete." He stated that a car could probably be parked on the concrete, but driving a car in and out of a

²² *Cann v. Carl B. Potter Ltd.*, 1980 CarswellNS 291, 42 N.S.R. (2d) 681, 77 A.P.R. 681.

²³ *Jones v. Consolidation Coal Co.*, 174 Ill. App.3d 38 (1988) 528 N.E.2d 33, https://scholar.google.com/scholar_case?case=4697769657346115593&q=%22ground+vibration%22&hl=en&scisbd=2&as_sdt=2006.

garage with a cracked floor would eventually result in more extensive cracking. McKinley stated that the concrete would eventually "break up" and it would have to be replaced.

The three issues (unsuccessfully) argued by the defendant on appeal were

- 1) That the court erred in awarding damages based on the cost of repair where repairs were made and on no evidence of actual cost of repair was introduced
- 2) That the cost of removing and replacing the plaintiff's cracked concrete garage floor entails an unreasonable destruction of the structure and results in cost to defendant disproportionate to the benefit to the plaintiffs
- 3) That the judgment was against the manifest weight of the evidence

In respect of issue 1) the appeals court dismissed the defendant's argument in part because there was no proof of the existence of a repair bill. As for issue 2), it was argued by the defendant based on the testimony of their appraiser, Thomas Rheinecker. Rheinecker testified,

that the plaintiff's outbuildings were worth nothing, hence the decrease in value was less than the cost of repair....Rheinecker...[also testified] that effecting the repairs sought would only increase the value of the property \$3,000 to \$4,000.

The court rejected the appraiser's testimony as to the value of the outbuildings characterizing the testimony "as inherently improbable and unworthy of belief." The court also was not convinced that "an injured homeowner should be relegated to a diminution in value standard where structures are damaged," while citing the following in support of its position:

In Myers v. Arnold (1980), 83 Ill. App.3d 1, 403 N.E.2d 316, the court noted that the diminution in value rule may be inadequate and unfair in some instances. The court stated:

"Allowing a plaintiff to recover the lesser of the cost of repair or the diminution in market value may be appropriate where the interest which has been harmed is purely financial, as where the land was purchased as a business investment with an eye towards speculation or where it is held solely for production of income. However, the same measure of damages may be painfully inadequate when the land is held for a personal use such as a family residence and the harm may be corrected with a reasonable expenditure even though the expenditure exceeds the amount the land has diminished in value. In the latter case, **the full repair cost will come much closer to restoring what was actually lost and will not require the injured party to correct the harm with funds from his own pocket.**"

Myers, 83 Ill. App.3d at 7, 403 N.E.2d at 321. [emphasis added]

The Restatement (Second) of Torts would go even further. The comments to section 929 indicate that

"if a building such as a homestead is used for a purpose personal to the owner, the damages ordinarily include an amount for repairs, even though this might be greater than the entire value of the building. So, when a garden has been maintained in a city in connection with a dwelling house, the owner is entitled to recover the expense of putting the garden in its original condition even though the market value of the premises has not been decreased by the defendant's invasion." (Restatement (Second) of Torts § 929, comment b (1979).)

On issue 3) the defendant's ground vibration and structural response expert referenced "peak particle velocity" (PPV) as a standard formula that measures the intensity of vibration and movement, and concluded that the damage sustained by the homeowners was not the result of the defendant's blasting operation:

Clark cited studies for the proposition that, as PPV approaches two inches per second [ips], there is a 6% probability of failure in dry wall and plaster. According to defendant's records, PPV never rose above 1.1 [inches per second] during the relevant time frame. At the time, government regulations required restriction of PPV readings to under 2.0 [ips]. The regulation has since been changed to 1.0 [ips]. Clark inspected the damage to plaintiffs' property and concluded that it could not have been caused by blasting. In his opinion, the damages were caused by construction defects, natural causes, and aging.

Raymond Taucher, an administrative assistant for the defendant in 1978, testified that he had inspected the reported homeowners' damage after the 1978 blast,

but did not believe it was the result of blasting. Taucher testified that the closest point, the defendant' mining operation was 2,000 feet [610 metres] from the plaintiffs' residence.

The appeals court was not persuaded by Clark's expert testimony or the argument that mere "temporal proximity" is insufficient to establish a cause and effect relationship.

...[T]he testimony of an expert must be judged by the same rules of weight and credibility applicable to other witnesses. ([Presswood v. Morris \(1979\), 70 Ill. App.3d 513, 388 N.E.2d 844.](#))... [N]o particular significance [is attached] to the fact that defendant produced an expert witness while plaintiffs presented only lay witnesses. As for defendant's claim that mere "temporal proximity" of blasting and damage is insufficient to establish a cause and effect relationship, we find this argument to be without merit given the evidence presented in this case.

In [Arras v. Columbia Quarry Co. \(1977\), 52 Ill. App.3d 560, 367 N.E.2d 580](#), this court held evidence similar to that in the case at bar relevant and admissible to establish a cause and effect relationship. In Arras, plaintiffs' neighbor, Anna Dugar, testified that the water in her well disappeared after the explosion in defendant's quarry, just as water in plaintiffs' well had disappeared. This court held that the alleged effect of the same blast on other wells in the vicinity would be admissible. The only relevancy the Dugan testimony had was to prove that defendant's blasting damaged plaintiffs' well. As in Arras, Clarence Welty testified that he experienced cracking in his home during the period of blasting, just as cracks had formed in plaintiffs' home. We hold that the lay testimony presented by the plaintiffs was sufficient to establish a causal connection between the blasting and the damage to plaintiffs' residence. This court cannot substitute its opinion for the finding of the trier of fact unless its holding is against the manifest weight of the evidence. ([Scheduling Corp. of America v. Massello \(1987\), 151 Ill. App.3d 565, 503 N.E.2d 806.](#)) We cannot say that an opposite conclusion is clearly evident in the case at bar.

Homeowners Allowed to Pursue Claim Against Blasting Quarry for Trespass and Mental Anguish

In *Dockins v. Drummond Co., Inc.*,²⁴ the homeowners claimed that Drummond, the quarry operator, engaged in repeated blasting within 1,500 feet (457 metres) that damaged their home and caused them to suffer mental anguish. Summary judgment of the trial court in favour of the quarry operator on the claims of "wantonness," as related to trespass, and mental anguish were reversed on appeal.

The Dockinses presented evidence that Drummond had blasted within 1,500 feet of their home. The Dockinses testified that they repeatedly contacted Drummond (12 to 14 times) to complain about the blasting and the damage to their home. The Dockinses also presented evidence that Drummond had received from the Surface Mining Commission two notifications of violations for

²⁴ *Dockins v. Drummond Co., Inc.*, 706 So. 2d 1235 (Ala. Civ. App. 1997), https://scholar.google.ca/scholar_case?case=1739173338660306567&q=Dockins+v+Drummond&hl=en&sa_sdt=2006.

"exceeding air blast limits" during the blasting at issue. "Wantonness in the context of a claim for trespass is an invasion of the plaintiff's property with knowledge of the violation of the plaintiff's rights in his or her property." [citations omitted]

Therefore, we conclude that the Dockinses presented substantial evidence in support of their claim that Drummond had wantonly continued its blasting operations. The summary judgment is reversed insofar as it relates to the wantonness claim.

The Dockinses next argue that the trial court improperly entered summary judgment on their claim for damages for mental anguish. Drummond argues that mental anguish damages are not recoverable in an action alleging damage resulting from blasting, absent a physical injury. The Dockinses concede that they were not physically injured by the blasting; however, they argue that a physical injury is not required in order to recover mental anguish damages in a blasting case.

Our supreme court has held that damages for mental anguish are allowed in an action alleging "culpable tortious conduct," regardless of the absence of a physical injury. *Taylor v. Baptist Medical Center, Inc.*, 400 So.2d 369, 374 (Ala.1981)....Our supreme court has further held that, "[i]n order to recover damages for mental distress where the tort results in mere injury to property, the trespass to property must be committed under circumstances of insult or contumely." *Harris v. Birmingham Hide & Tallow Co.*, 589 So.2d 150, 151 (Ala.1991). The Dockinses allege that Drummond continued its blasting with knowledge that it was causing damage to the Dockinses' property. Therefore, we conclude that the Dockinses are entitled to submit to the jury their claim for mental anguish damages, if they present substantial evidence that they suffered mental anguish caused by the blasting.

Homeowners Unable to Sell Homes at Full Value Due to Blasting at Nearby Quarry²⁵

Residents of the Grandview, a neighborhood of 22 homes located roughly 750 feet (229 metres) to 1,700 feet (518 metres) from McGee's West River Road quarry operation, have complained blasting at the quarry has damaged their homes, reduced their property value and disrupted their lives. In July 2017, Cheri and Pietro Nicolosi, who live near the quarry, filed a law suit claiming that blasting at the quarry damaged their home, caused problems with their water and caused them emotional distress. The law suit names the City of Augusta, McGee Construction and Maine Drilling and Blasting, the firm which blasts rock for McGee, and seeks compensation for damages and to have McGee's permit to blast and extract rock at the quarry site revoked.²⁶

Grandview neighborhood residents said blasting at a quarry operation [of McGee Construction on West River Road] in a pit adjacent to their neighborhood has made it impossible to sell their homes at their full value and caused cracks in their homes' floors and walls, and it makes them anxious before and angry after blasts that can occur up to 10 times a year. [emphasis added]

They asked the city, as they have before, to take action to protect their neighborhood. Councilors are considering a proposal to reduce the size of blasts in quarries in the city. [emphasis added]

Roland Maheux, who lives with his wife, Anna, on Edwards Street, about 760 feet [232 metres] from the blasting area of the McGee Construction-owned pit off West River Road, described a Sept. 29 blast as violent and said he literally could see the walls of his home moving and could feel shaking throughout the home. He said his home has evidence of

²⁵ Keith Edwards, "Augusta quarry's neighbors attribute house damage to blasting," November 17, 2016, <https://webcache.googleusercontent.com/search?q=cache:afY3Ta1nC4EJ:https://www.centralmaine.com/2016/11/17/augusta-quarrys-neighbors-attribute-house-damage-to-blasting/+&cd=1&hl=en&ct=clnk&gl=ca>.

²⁶ <https://cprcengage.com/asce/app/document/23793269;jsessionid=1rflrik19uox31kihxpxi8mg7l>.

structural fatigue including cracks in walls and floors, and steps that are slowly creeping farther away from his home. He said he thinks at least some of that damage “is a result of the pounding my house has taken (from blasting in the quarry) over the last 14 years.” [Over 14 years there have been 140 blasts at the McGee Construction quarry] [emphasis added]

He said he gets anxious before every blast. And he said when a violent blast happens, he reacts so strongly to the potential damage to his home that he used to go outside after some of them and yell and scream. [emphasis added]

Other neighborhood residents said they also think cracks and other damage to their homes has been caused by blasting at the pit. [emphasis added]

Patrick Street resident Gary Leighton said he and his wife have tried twice over the last six years to sell their home but have been unable to do so. He said he thinks the blasting, as well as publicity and the resulting stigma attached to it, has hurt their ability to sell their home, even though it is beautiful home with a big yard and good neighbors. [emphasis added]

“Our hope is that a resolution can finally be reached so those of us who want to sell can do so, and those who want to remain can enjoy our neighborhood,” Leighton said. [emphasis added]

Last week councilors heard a presentation from the technical supervisor for Gardiner-based Maine Drilling and Blasting, the firm contracted to blast rock in a quarry owned by McGee Construction off West River Road in Augusta. He spoke about blasting and when it does and does not present a potential danger to property.

City officials are considering proposed changes to the city blasting ordinance that would reduce the standards for allowable blasts in quarries in Augusta to just 15 percent of the city’s current standards, which are already tighter than state blasting standards. Blasting and construction company officials said last week that standard would be so low it wouldn’t be economically feasible to continue blasting rock for construction projects. [emphasis added]

Industry representatives said last week they would work with the city staff to come up with a potentially new standard as a compromise that would reduce the vibrations coming from blasts but still allow the companies to operate their quarries.

Matt Nazar, development director for the city, said that has not yet happened....

...Lou Craig, a Grandview resident, said he believes blasting at the McGee pit has damaged his home, including causing a massive horizontal break he said will cost him thousands of dollars to fix.

He said he’s filed a claim with Maine Drilling and Blasting over the damage....

City Manager William Bridgeo said the city is working with an independent expert to have the presentation made by Smith, and other information presented to the city, analyzed. He said councilors would discuss those findings at a future meeting, likely Dec. 8....

The proposal for tighter rules was made in response both to ongoing complaints from residents of the Grandview neighborhood and to a city official describing a blast he observed from inside a home as startling and alarming. The Grandview neighborhood is next to a McGee Construction-owned pit and quarry operation that blasts rock up to 10 times a year off West River Road. Nazar has attended roughly 40 blasts at quarry operations, mostly in the McGee pit, over the last 10 years. During a recent blast, Nazar was in the home of Maheux, and he said the blast was “startling” and felt much more significant than blasts of similar size he observed outside. [emphasis added]

Smith said that blast was not damaging to buildings despite what Nazar felt. He said it is a natural human reaction to be surprised by blasts. Nazar said that blast and the other blasts he’s observed at the West River Road pit this year were well below allowable standards for ground vibration contained in the city’s blasting ordinance. He said data indicated the blast was only 20 percent to

25 percent of the maximum allowable blast. So if the city wants to address neighbors' concerns by reducing the blasts' impact, the city's allowable standards would have to be lowered dramatically.

Disputes between the pit owner and neighbors about the effect of blasting there go back many years, and the city's current mining and blasting rules were formed after a lengthy process involving multiple interested parties.

Homeowners Near Quarry Forced to Sell Their Homes at a Loss

The noise, dust and dirt from a nearby quarry in Estey's Bridge, New Brunswick, have forced homeowners to resell their homes for less than they paid, as reported in a May 28, 2019, CBC news release.²⁷ The Royal Road quarry operated by Mira Construction Limited opened in December 2014. About 40 homes are affected by the Mira Quarry, and about 100 trucks are in the area each day. "There's so much dust, dirt and noise that you cannot be outside", and "you've...lost total enjoyment of your property."²⁸

PA's Rick DeSaulniers threatens to oppose budget if nothing is done about truck traffic at Estey's Bridge.

The uncertainty and instability of a minority government is working out just fine for a group of rural residents near Fredericton who are upset about noise and dust from a quarry close to their homes.

They say the pivotal role of their MLA, Rick DeSaulniers of the People's Alliance, has finally got them some attention from the provincial government after almost five years.

"This is the first time that an MLA has really gone to bat for us," says Gerry McQuinn, an Estey's Bridge resident who says his property is plagued by noise and dust from the quarry just across the Nashwaaksis Stream.

"We needed somebody to step up and be forceful for the government to look at it," McQuinn said as the rumble of trucks echoed across his backyard. "So I guess it worked."

Last month, DeSaulniers threatened to vote against the Progressive Conservative government's budget estimates for the Department of Environment and Local Government.

That got him a meeting with Premier Blaine Higgs and, according to the department, stepped-up monitoring of the quarry owned by Mira Construction Ltd.

"I have a significant amount of clout," said DeSaulniers. "I took a calculated risk. ... Obviously, the position I'm in there has caused the government to pay attention."

Judith Seymour, the chair of the Estey's Bridge local service district, says she's not optimistic the situation will get better, but at least the first-term Alliance MLA has the government's attention.

"Rick's got us a meeting with the minister and a meeting with the premier, which is something the local service district couldn't get in five years. We couldn't even get an answer to a letter."

The quarry was approved without an environmental impact assessment by the Progressive Conservative government of David Alward just before the 2014 election. [emphasis added]

It's across from the stream behind McQuinn's property. Trucks driving in and out of the quarry cross a small bridge built over the stream, leading to dirt and debris falling through the open bed into the waterway. [emphasis added]

McQuinn and other residents have catalogued at-risk species, including salmon parr, wood turtles and butternut trees. He said the trucks also make noise from early in the morning until the evening, and dust regularly settles on his property. [emphasis added]

²⁷ Jacques Poitras, "Quarry opponents finally get government's ear when MLA flexes 3rd-party muscle," <https://www.cbc.ca/news/canada/new-brunswick/minority-government-quarry-dust-rural-new-brunswick-1.5152489>.

²⁸ <https://www.cbc.ca/news/canada/new-brunswick/esteyes-bridge-quarry-1.4381771>.

People in the area who have sold their homes have been forced to accept resale prices lower than what they originally paid, he said. [emphasis added]

"It's very taxing on us. It's very demoralizing that somebody won't help us out."

The previous Liberal government turned down another company's proposal for a second quarry in the area in 2017, but Environment Minister Jeff Carr said in the legislature last month it's impossible to undo Mira's approval.

"Will we ever be able to eliminate the situation? I don't see it happening, to be honest."

No one from Mira Construction responded to a CBC News request for an interview....

"I care a great deal about what's going on with these people, their health, their well-being, the frustration and the stress," he said. "Five, six years of this is too much. It's gone on too long. These folks need to get some kind of justice." [emphasis added]

After trying to get a meeting with Higgs on the issue, since Christmas, DeSaulniers warned Carr in an April 17 committee session that "if we don't get some action ... then I may very well vote against this budget for this department."

Carr responded that his department would "ratchet up and turn the screw on the approval to operate" and if the company didn't follow the conditions of that approval, "we will shut them down." He also asked for the research that local residents had done. [emphasis added]

Defeating departmental estimates would not have triggered an election but would have bogged down the legislative process and embarrassed the Tories.

"It was a calculated risk I took and it worked," DeSaulniers said, adding that "within minutes," someone from Higgs's office contacted the Alliance. "Our chief of staff said we set a record" for a response, he added.

Higgs and Carr met with DeSaulniers and local residents. Environment Department spokesperson Erika Jutras said it has adopted several new measures, including having the department:

- Visit the site "several times per week" and respond to resident complaints.
- Work with Public Health to evaluate potential health impacts in the area.
- Order Mira Construction to conduct a noise study and develop a "prevention and control plan."

Jutras said the province will also continue to test water in the Nashwaaksis Stream and require the company to do its own testing. It also told the Department of Public Safety about complaints about speeding trucks and rocks falling off trucks....

So far there's been no actual reduction in the noise and dust levels, though, and McQuinn doesn't have a lot of faith things will change. Shutting down the quarry would probably lead Mira to sue the province, he said.

The new steps are "more or less window dressing for us, thinking that they're going to cure all our problems, which they cannot."

The quarry's approval to operate from the department is up for renewal later this year, but Seymour is not optimistic that stricter conditions will be added....

DeSaulniers said that in the end, the only option may be for the province to buy out the affected properties — something he said he'll use his clout to push for. [emphasis added]

Neighbouring Homeowner Reluctantly Settles Lawsuit Against Blasting Quarry for Damages to House

A family residing near a quarry was forced to settle a claim for damages to their property, reportedly for an amount less than the cost to repair, as the family could not afford to fight the lawsuit in Federal Court. The homeowners had purchased the property in 2009, with

the realtor assuring them that the quarry, dormant at the time of the purchase, would not restart operations.²⁹

After a long year of mediation, negotiations and \$20,000 in lawyer fees, Poultney residents Kristin and Jeff Silverman have settled their lawsuit with Hilltop Slate, Jeffrey M. Dunster and K-D Stone Inc., and said they're moving their young family out of Vermont.

"By moving in with my parents, in Hampton, we will be homeless, and kids can decide where to go to school," Kristin Silverman said. "If you don't have the money to go to court, you're dead in the water."

When the Silvermans bought their home at 1276 York St. Extension in Poultney nine years ago [February 17, 2009, for \$142,000], their real estate agent told them it was unlikely anyone would resume mining the old quarry abutting their property, which hadn't been used since the 1950s, Silverman said....

But last year [2017], Hilltop Slate decided to mine the quarry, and the Silvermans say the result was a ruined foundation spitting rock and mortar onto their basement floor as it began to crumble and buckle beneath the home, among other issues....[emphasis added]

After enduring damage to their home that they said was a result of the blasting and mining just 100 feet from their home, the Silvermans filed a three-count lawsuit in January requesting \$150,000 for claims of negligence, \$150,000 for being a nuisance and a sum equal to three times the value of their home due to gross negligence, according to the lawsuit filed by Burlington lawyer A.J. LaRosa.

According to court documents, the town of Poultney also issued a cease-and-desist letter to the quarry on the grounds that their blasting endangered the highway. [emphasis added]

The lawsuit states Hilltop had mineral rights to the quarry and had active operations there between June 2017 and January 2018, and had transferred the right to operate the quarry to Dunster and/or K-D Stone Inc.

The Silvermans went into mediation Oct. 12 with the hope that Hilltop would do what many quarries do when there's at risk of damaging neighboring property with quarrying activities — buy them out, Silverman said. Silverman could not disclose the amount of the settlement due to confidentiality. Hilltop Slate and K-D Stone Inc. didn't respond to calls seeking comment.

Silverman said the quarrying company wasn't interested in buying their property, and taking the case to federal court would require \$60,000 more in legal fees, something the Silvermans couldn't afford....

Silverman said the settlement wouldn't be enough to cover the damage to their home, and they couldn't see the point in paying to repair the damage anyway, given the fact that Hilltop would resume work in the quarry.

"You're powerless," Silverman said. "Quarries have endless resources and attorneys. Normal people like us don't."

Now, Silverman said they're working with PNC Holding LLC, who will send out an assessor to evaluate the property for which they still owe \$120,000, and they'll probably be forced into foreclosure or a short sale of the home.

"I blame Vermont for it," Silverman said. "It's the Act 250 exemption. The government doesn't care."

According to Act 250, Criterion 10, for a quarry to apply for a permit to operate, the quarry must adhere to the town plan and zoning laws, unless the quarry was registered by Jan. 1, 1997, in which case the quarry would be exempt from all Act 250 requirements. The requirements include

²⁹ Kate Barcellos, "Poultney family settles quarry lawsuit," October 26, 2018, https://www.rutlandherald.com/news/local/poultney-family-settles-quarry-lawsuit/article_659e9166-4eba-5077-988a-1ae32f8a6fb8.html

town zoning setback requirements from adjacent properties which, for Poultney at the time, was “200-foot setback of all pits, dumps and buildings to any residential building or property line.”

“We’re trying to protect residents who have a quarry operating (near them) so they can enjoy their property line,” Rep. Patty McCoy, R-Poultney, said at a Poultney planning commission meeting earlier that year. “There has to be a way that we protect pre-existing homes.”

Silverman said throughout the legal battle, she was contacted many times by other homeowners who have experienced damage to their homes as a result of quarrying and advised anyone interested in buying a home in Vermont do their due diligence, especially if there is a quarry property nearby, regardless of whether their real estate agent tells them it’s non-operational. [emphasis added]

“It’s crazy to me that this many people are affected, and nobody can help,” Silverman said. “There’s this big push to move to Vermont, but do they know what they’re getting into?”

A letter by Kristin Silverman³⁰ posted online sometime after the settlement provides additional details as to the adverse impacts endured while residing near an operational blasting quarry:

My family lived on the property happily until almost 9 years later. One early morning I was sitting in my kitchen when I smelled the overwhelming smell of diesel and heard machinery. When I went out to explore, I found an excavator operated by Hilltop Slate, working under 60 feet from my backyard. When I went to the Tarans about this they too were surprised.

You see what my husband and I were blind to was a thing called, “Mineral Rights”. Although the Tarans owned the property, everything you could see, Hilltop (Daniel Boone) owned the mineral rights, everything under the ground.

They worked all hours of the day. If the light was there so were they. Weekends. Sometimes as early as 5:30 in the am....

We went to the Town of Poultney hoping they could help/protect us in some way. They repeatedly told us it was a civil matter.

We went to the EPA, MSHA, even Bill Burke in Rutland at the Act 250 office. Everyone was sympathetic but no one could help.

We even met with a group of local quarry owners. Although they agreed Daniel Boone and Hilltop were not operating in a way that these owners manage their quarries, they admitted there was largely nothing that could be done except sue Hilltop. These same quarry owners said that if we were their neighbor they would have bought us out and have been done with it.

At first Hilltop was an annoyance (noise, diesel fumes, fast cars, litter on our property, etc). Eventually they began blasting. At times this was under 90 feet from our well head. The sludge pumped through our well repeatedly clogged the filters and at one point was so bad we lost water for a number of days and were forced to move in with my parents for a time. My children had to give up their beloved chickens because we could no longer provide water for them on a constant basis. My mother did our laundry. [emphasis added]

My mother did our laundry. There was no warning that came with the blasting. One day there was a loud noise. That was how it started. Never a horn or signal, neighborly knock for a “heads-up”. Nothing. Sometimes when I was in the yard you could hear someone from near the pit yell, “Clear” just as an explosion was detonated. Blasting wasn’t occasional. It happened sometimes daily for a period. Sometimes on weekends. [emphasis added]

³⁰

<https://legislature.vermont.gov/Documents/2020/WorkGroups/House%20Natural/Bills/19-0040/Written%20Testimony/Slate%20Quarries/W~Kristin%20Silverman~19-0040.%20Statement%20re-%20Slate%20Quarries~4-22-2019.pdf>

Some of these blasts sent “fly rock” (rock from the blast) the size of my husband[‘]s foot into the road and onto our property. Someone from the quarry would drive up the road after the blast pushing the “fly rock” back towards the pit. Our well was damaged and our foundation buckled in towards our fuel tanks. Our 165 foot deep well was damaged (although Shawn Camara claimed my well was not deep enough and that blasting “hydrates” wells) according to an engineer that we hired. Our foundation that had stood strong for nearly 200 years was now in danger of knocking over the fuel tanks. [emphasis added]

Fearing for our safety and our home, we did seek litigation against Hilltop Slate. Because of the monetary amount of the law suit, it was going to be handled in Federal Court. When we finally got to mediation with Hilltop and our lawyers, we realized we were “out of our league”. I am a teacher. My husband is a factory worker at Hubbardton Forge. We had already spent tens of thousands in lawyers, engineers, tests, etc. Coming up with upward of \$50,000 was not a possibility. [emphasis added]

We settled. Not for enough to fix the house. We paid back most of the money we borrowed from friends and relatives. We fixed the problem with the fuel tanks. We put the house on the market for what we owe. We are looking into the foreclosure process because the damage and location of our property to the quarry have made the property worthless. [emphasis added]

This process has taken 2 years. We stand to lose everything we worked and saved for. [emphasis added]

Flyrock Continues to be the Most Dangerous Aspect of Rock Blasting Operations

As noted in Mwafulirwa’s July 2014 Dissertation, there is a need for research work on flyrock as it remains the most dangerous aspect of blasting operations.³¹

As a general recommendation, research work in reducing fly-rocks from rock blasting operations should continue because even today, the danger associated with fly-rocks is very high and fly-rocks still remain as the most dangerous aspect of rock blasting in the mining and construction industry [p. 175].

Raina et al.³² expressed similar concerns over the dangers of flyrock and the need for additional research of flyrock.

Flyrock can result in injuries or even fatalities as well as damage to properties and/or equipment, here referred to as “object(s) of concern”. Flyrock is a concern for both researchers and blasting engineers as it is a random phenomenon. However, it has received relatively little attention from

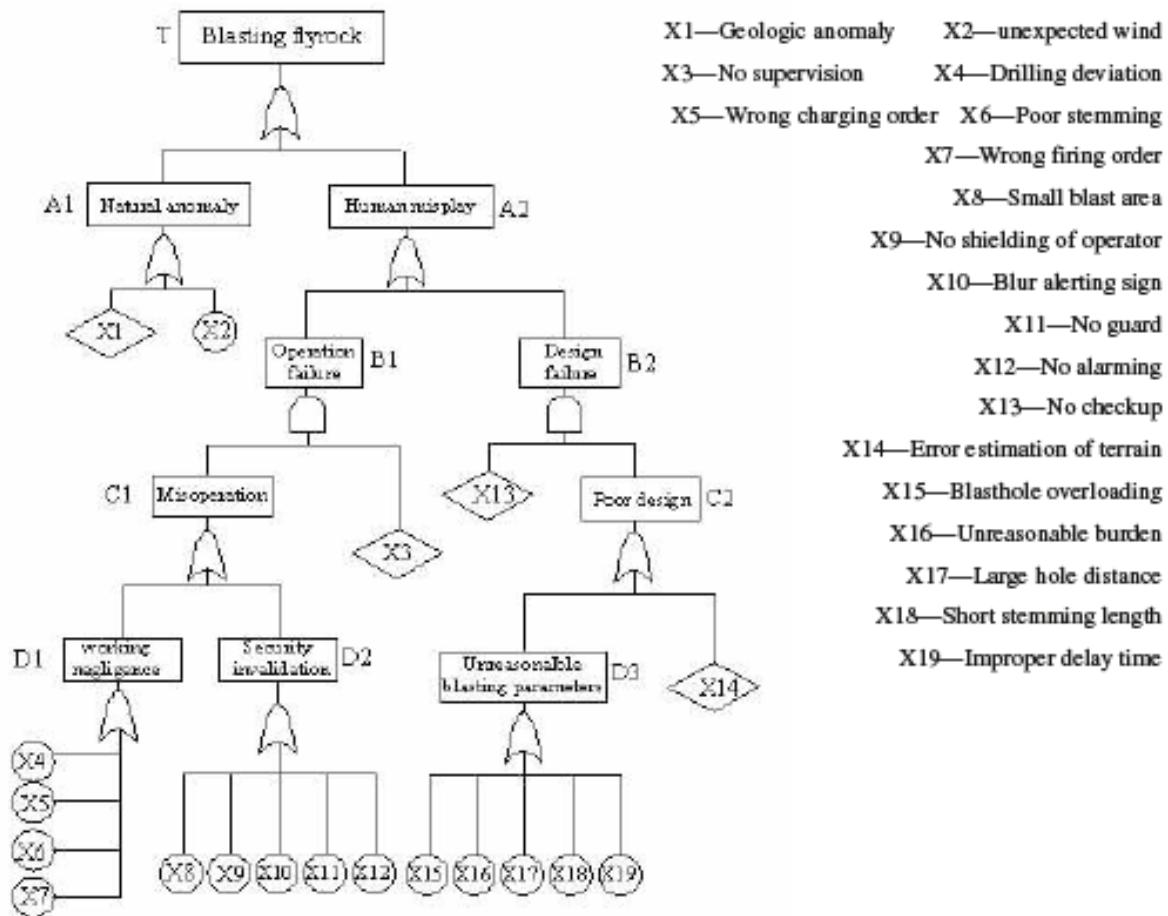
³¹ Khwima Yauma Mwafulirwa, “Methodology for Characterizing the Efficacy of Blasting in Open-Pit Mines; Video and Image Analysis,” July 2014 Dissertation, University of Porto – Faculty of Engineering, Portugal, [file:///C:/Users/Windows%207%20PC/Downloads/Methodology for Characterizing the Efficacy of Blasting in Open Pit Mines.pdf](file:///C:/Users/Windows%207%20PC/Downloads/Methodology%20for%20Characterizing%20the%20Efficacy%20of%20Blasting%20in%20Open%20Pit%20Mines.pdf).

³² A. K. Raina, A. K. Chakraborty, P. B. Choudhury and A. Sinha, “Flyrock danger zone demarcation in opencast mines,” *Bulletin of Engineering Geology and the Environment* (2011) 70: 163-172, https://d1wqxts1xzle7.cloudfront.net/50489185/s10064-010-0298-720161122-8304-1q8k9eq.pdf?1479861280=&response-content-disposition=inline%3B+filename%3DFlyrock+danger+zone+demarcation+in+openc.pdf&Expires=1597071244&Signature=bNTVEvpN5wN-k3I2Stblu2ITcGoNGXf2M09B8G4H05lirzNsPWJoR-7KrGhD-2U1Ywi6hqGIDv~~FzPsgz0vyvEAmd392Nex3d6e9bM0LptgiLkhonnL4zIrhCyTZka16waFg80kPwgT15yVAxAYSX5laqPdNsbtQYpNzq5ZWpfNS-ppKRUuyuMSoFVUVxeN0PxuF475iZwlo9XB056fk1oGIaQJcN~FrtbYVBILCglaOBAnhWnzzPyeBaxu5NJI33f8Gk9Nkgd~XoweUpmU5sfkt5UGGtsxX7zRGvhCicjkH2SOjYxljX-6ek1xZ4hRiydlwpWNfz2fpcEruKpwtA_&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA

researchers due to the complex nature of the interaction between the blast design and rock parameters. To date, most research has focused on the prediction of the maximum throw of flyrock and the initial velocity of the rock fragment projected from the blast face. Such workers as (Bajpayee et al. 2004; Raina et al. 2006; Bhowmik et al. 2004) detailed the major reasons for and control of flyrock with an exhaustive literature survey [p. 163-164].

Fault-Tree Risk Analysis of Flyrock Accidents in Blasting Operations

The events or risk factors in blasting operations that contribute to flyrock accidents are depicted in the following fault-tree prepared by Zhou et al:³³



The fault-tree labels flyrock as T (the top event), and the underlying events or risk factors potentially responsible for flyrock accidents are labelled A, B, C and D. The occurrence of flyrock is complicated by the inherent variability of blasting operations. Each underlying event in the fault tree describes some failure involving some controllable or uncontrollable aspect of the blasting operation. Flyrock accidents can be caused by a singular event (risk factor) or a combination of events (risk factors). The numerous controllable and

³³ Zilong Zhou, Xibing Li, Xiling Liu and Guoxiang Wan, "Safety Evaluation of Blasting Flyrock Risk with FTA Method," *School of Resources and Safety Engineering, Central South University, Changsha 410083, Hunan, China*, <https://miningandblasting.files.wordpress.com/2009/09/safety-evaluation-of-blasting-flyrock-risk-with-ftha-method.pdf>.

uncontrollable risk factors involved in blasting operations that cause flyrock accidents are summarized as follows:

2.1 Poor Design of Blasting Parameters The efficiency of blasting is determined by the precise blasting to the design contour. Inaccuracies in the design of blasting patterns can cause large deviations from expectation and result in flyrock occurrence. They include:

- a) **Blasthole Overloading** The consumption of explosives, i.e. the quantity of explosives consumed in kg/m³ of rock mass is governed by a host of factors, such as physicomechanical properties of rock, cross sections of workings, proper charging of blast hole, etc. Any of the factors can lead to the excessive charging. When the blasthole overloading occurs, it generates tremendous amount of energy to form flyrock.
- b) **Unreasonable Burden** Due to irregularity of bench slopes, the design of reasonable burden is always challenging. Too short a burden distance wastes energy and always causes the release of energy at the weakest side only. While too great a burden distance creates oversize boulders and results in the vertical shooting of boulders.
- c) **Too Short Stemming** Stemming provides confinement and prevents the escape of high-pressure gases from the blasting hole. In general, the stemming length should be not less than 25 times the blast hole diameter. When the designed length of the stemming is too short, the high-pressure gases would shoot out the stemming and solid substance around the hole top directly.
- d) **Improper Delay Time** Short delay blasting is one of the popular methods in practice, which can produce less seismic impact of blasting, less noise, less shock wave, and less flyrock. The determination of proper delay time is the key of success. However, when the delay time is too long, the unloading effect disappears and lots of fly-rocks appear.

2.2 Operation Negligence All the construction and operations are done by people, and then the misplay is unavoidable. The operation negligence usually is the main reason of blasting accidents including flyrock events. It has many kinds of manifestation, such as:

- a) **Inaccurate Drilling** For the invisibility characteristic of soil and rock material, the accurate positioning of the drilling angle is impossible in practice. Different operators may drill holes with completely different angles and length even at the same position, then the drilling deviation changes the designed blasting patterns insensibly.
- b) **Poor Stemming Quality** Stemming material quality is another factor lead to the occurrence of flyrock. When poor quality stemming with lower cost is used, there is fissure left between stemming and hole wall. Then there is not enough power to hold back the escape of high-pressure gases from releasing.
- c) **Wrong Firing Sequence** Firing pattern must be performed so that each hole or group of holes, gets as favorable confinement and throw conditions as possible. When the firing sequence is deliberately reversed, the flyrock accident is on the way.

2.3 Blast Area Security The blast area should be determined by considering geology, blasting patterns, blasting experience of operator, delay systems, type and amount of explosive material, and type and amount of stemming. A lot of empirical formulas have been suggested to determine the blast area. However, the exact determination of the blast area is never an easy thing. Even carrying out the most exact calculation of the blast area, an unintentional invader can make all the effort nothing and become the victims. Besides the unwitting invaders, the informed people sometimes are curious to the detonation phenomenon and may approach the site nearly. So the blast area must be all-clear before blasting and all the access roads leading to the blasting site be guarded while blasting.

2.4 Unknowable Natural Conditions A common problem in geotechnical projects is the lack of knowledge and accurate technology to identify and recognize the specific anomaly or weakness in the rock structure, which can lead to the subsequent flyrock problem. The rock structure and rock properties may vary considerably from location to location even within the same blast area. The

discontinuity of joints and fissures can cause very high explosive concentration in the hole. The wind also can assist in the producing of flyrock. When the wind direction is in accord with the designed throwing direction, the flyrock can travel distance two times than normal

Tragically, the risks of flyrock are too often taken into account long after a blasting operation has been established, and is most often the result of a catastrophic flyrock event resulting in personal property damage, real property damage, personal injury or death, or a combination thereof.³⁴ ***"Flyrock is an accident that needs to be considered before it happens [p. 13]."***³⁵ [emphasis added]

Incidents of Flyrock Go Unreported to Avoid Disclosure of Legal Responsibility

According to Raina *et al.*,³⁶ one of the major reasons flyrock incidents go unreported is to avoid disclosure legal responsibility:

...[Flyrock] is known to have resulted in accidents ranging from serious injuries, fatalities, and damage to property – belonging and not belonging to the owner of the mine (Jenkins and Floyd, 2000; Rehak, et al., 2001; Bajpayee et al. 2002; Fletcher and D'Andrea, 1987; Verkis, 2011). Flyrock incidents still continue to happen (McKenzie, 2009; Amini et al. 2011; Stojadinovic, et al., 2011; Rezaei, et al., 2011; Kricak, et al. 2012).

One of the major constraints in the prediction of flyrock is non-reporting of such incidents (Davies 1995) for obvious legal reasons [p. 900]..

Incidents of Flyrock Uninvestigated and Lack of Regulatory Oversight

According to an August 17, 2009 newspaper article,³⁷ only 4 of 36 flyrock incidents were investigated by the Office of Surface Mining [OSM] Charleston Field Office during January 2004 to December 2007:

...a...[March 2009] report from the guys at the OSM Charleston Field Office outlines significant problems in the way the West Virginia Department of Environmental Protection [WVDEP] is regulating blasting. The 18-page report focuses on citizen complaints about "flyrock" — rocks and boulders from blasts that literally fly off mine sites into nearby communities....

—Detailed investigations by WVDEP are performed in few of the flyrock incidents the agency becomes aware of. OSM praised the WVDEP Office of Explosives and Blasting for its investigation reports. But, OSM found, OEB was involved in only 4 of 36 flyrock events during the period examined, from January 2004 to December 2007.

When WVDEP's Division of Mining and Reclamation performed its own investigations (rather than referring the matters to OEB), "the actions were inconsistent because of inspector's varying degrees of expertise or guidance on procedure."

³⁴ Blanchier, A., "Quantification of the Levels of Risk of Flyrock," *Proceedings of the Thirty-Ninth Conference on Explosives and Blasting Technique* (pp. 17-20), St. Louis, MO: ISEE.

³⁵ Jackson, Brett Christopher, "Total Cost Optimization For Contour Blasting In The Appalachia Region," (2015). *Theses and Dissertations-Mining Engineering*. 20. https://uknowledge.uky.edu/mng_etds/20.

³⁶ Avtar Krishen Raina, V.M.S.R. Murthy and Abhay Kumar Soni, "Relevance of Shape of Fragments on Flyrock Travel Distance: An Insight from Concrete Model Experiments Using ANN," *EJGE*, Vol. 18 [2013], Bund. E, 899-907, <http://www.ejge.com/2013/Ppr2013.079alr.pdf>.

³⁷ Ken Ward Jr., "OSM finds WVDEP lax in policing flyrock," *Clarkson Gazette-Mail*, <http://blogs.wvgazettemail.com/coaltattoo/2009/08/17/have-a-blast-osm-finds-wvdep-lax-in-policing-flyrock/>.

OSM recommended that OEB “should investigate every flyrock event in detail to determine or require the company to determine the most likely cause(s) in order to devise a site-specific remediation plan.”

— WVDEP inspectors who cited companies for flyrock incidents **typically ordered mine operators to clean up the off-permit material, instead of determining the cause and proposing corrective measures** to prevent repeat incidents.

— OSM said that monetary fines for flyrock violations were “too low for the seriousness of the violations.” **During the period examined, the median penalty was \$1,200.**

— Staffing issues “are a possible impediment” to strong flyrock enforcement. At the time of the OSM review, there were six blasting inspectors for the entire state. **OSM was authorized to have 17 positions, but at the time of the report had five vacancies....**

— WVDEP does not track performance of the mine operator and contract employees it certifies to perform blasting at strip mines. **Because of this, OSM was unable to identify the blasters or companies responsible for some flyrock problems.** OSM said, “Having the ability to identify habitual offenders for enforcement purposes is critical to initiating suspension or revocation proceedings.”

Finally, OSM cautioned WVDEP that “**blasting is the single most frequently occurring event at mines that has the potential to cause injury, death or property damage.**”

OSM continued:

Due to the significant danger of flyrock, it is recommended that in all cases, OEB institute the cessation of blasting activity in the area where flyrock originates and adjacent areas until an investigation is completed and prescribed changes are implemented by the company to ensure there is a reasonable expectation that flyrock will not occur again from the same cause.

WVDEP’s response to that recommendation?

OEB does not feel it is necessary to issue an [imminent harm cessation order] or cease blasting on all flyrock cases. It is the inspector’s call as to whether or not the individual incident warrants an IHCO. However, OEB will take multiple incidents into consideration in determining if blasting should cease.

Blasting Operations Are Dangerous and Must Pay Their Own Way - No Amount of Damage to Neighbouring Properties is “Reasonable”

As concluded by the Indiana Supreme Court in *Enos Coal Mine v. Schuchart et al.*,³⁸ there is no logical reason not to extend strict liability for property damage from vibrations simply because there is no physical trespass as in falling debris from an explosion on nearby land. The appeals court ruled that the common law principle of liability in trespass applies equally where damage is caused only by vibration, commenting, in part, by way of analogy, as follows:

In these days of nuclear explosions, the breaking of sound barriers by airplanes and missiles, violent explosions from artillery and gunnery practice (to mention but a few of the advances of science), nearby buildings and property can be shattered or destroyed as effectively as by an earthquake without any physical invasion of the property.

The United States Supreme Court has recognized these modern problems in holding that property owners are entitled to compensation for deterioration in property values caused by noise and vibration of jet planes in the use of air space near an airport. *Griggs v. Allegheny County (1962), 369 U.S. 84, 82 S.Ct. 531, 7 L.Ed.2d 585.*

³⁸ *Enos Coal Mining Company v. Schuchart et al.*, 243 Ind. 692 (1963) 188 N.E.2d 406, https://scholar.google.com/scholar_case?case=5259210695212382453&q=%22a+little+damage+is+reasonable%22&hl=en&as_sdt=2006.

It is argued that the owner of property may make the fullest use of his property so long as he does not trespass upon other property or damage it by his negligent acts. On the other hand, there is also the principle that one may not use his property so as to injure the property of another. This conflict in the general principles of law is the result of the historical difference between an action in trespass and an action on the case. An examination of this historical development affords no logical reason for the original difference.

The court cited *Wendt v. Yant Construction Co. (1933)*, 125 Neb. 277, 249 N.W. 599, as being in accord with the general principle that if damage is inflicted there ordinarily is liability for one's acts without regard to fault regardless of whether the damage is caused from blasting that projects rocks or by concussion:

"The weight of authority sustains the position that there is no distinction in liability for damage to property from blasting which projects rocks or by concussion."

The court also argued that while certain business operations are "necessary" for the promotion of industrial development, if they have adverse impacts on neighbouring properties the homeowners are entitled to be compensated by the business owners. Adverse impacts (minor or extensive) caused without the consent of the neighbouring homeowners are compensable regardless of whether the business operation is legally permissible and operating in compliance with regulatory limits.

It is also urged that in business and industry certain operations are "necessary" for the encouragement of industrial development and that even though such business activities cause some injury to neighboring properties, a "reasonable use" is permissible. From our viewpoint, this is to say that "a little damage" is "reasonable" and legal, but too much damage is "unreasonable" and wrong. What is or is not "reasonable" is an uncertain yardstick. Although it is a standard of conduct in some cases because of the lack of a better one, it is to be avoided, so far as possible, because of its vagueness and lack of certainty.

A business should bear its own costs, burdens, and expenses of operation, and these should be distributed by means of the price of the resulting product and not shifted, particularly, to small neighboring property owners for them to bear alone. We can understand no sensible or reasonable principle of law for shifting such expense or loss to persons who are not involved in such business ventures for profit. Industrial development is to be encouraged, not at the expense of private individuals without their consent, but by the price of the resulting product in the industry itself. If there is a public interest in such development, the only equitable and just way to distribute such expense or cost would be through the equitable use of public funds.

"Blasting operations are dangerous and must pay their own way." 2 Harper and James, Torts § 14.6, p. 814 (1956).

"The individual citizen may be deprived of his home or other property by the proper exercise of the power of eminent domain; but it ought not to be said that it can be lawfully destroyed without compensation in the interest of a mere business enterprise, simply because such enterprise is of great magnitude and general public interest." Watson v. Mississippi R.P. Co. (1916), 174 Iowa 23, 34, 156 N.W. 188.

Miramar Quarries a Source of Frustration for 6,300 Residents Impacted by Blasting

Residents of the City of Miramar have long been plagued by the adverse impacts of blasting, with over 6,300 residents signing a petition to have the quarry blasting stopped.

The Miramar City Commission has asked Gov. Ron DeSantis to order a temporary stop to rock mine blasting during the state of emergency called for the COVID-19 pandemic.

The commission acted following a flood of complaints from homeowners who claimed the blasting caused cracks in their pools, patios, walls, floors and ceilings and even the foundations of their homes — as well as fraying their nerves. A recent petition issued to stop the blasting has the backing of more than 6,300 signers from Miramar, Pembroke Pines, Doral and other nearby communities in Miami-Dade and Broward. [emphasis added]

Complaints began to mount about the same time that DeSantis signed the COVID-19 state of emergency order on April 1[, 2020] that ordered nonessential businesses to close, according to Miramar Mayor Wayne Messam. Laid-off workers were home to hear the daytime blasts. [emphasis added]

The resolution's author, Commissioner Yvette Colbourne, told commissioners during the April 15 meeting that she sent the resolution to other affected cities to join the appeal to the governor.

Residents' beef is with White Rock Quarries in northwest Miami-Dade County. The company's Hialeah plant has been operating since the 1980s, long before suburban sprawl surrounded the facility....

Blasting has been an issue since the mid-1990s when new communities sprang up near the plant including Sunset Lakes, Sunset Falls, Riviera Isles, Huntington, Nautica and County Club Ranches. Homeowners complained that the blasting was hurting their properties. [emphasis added]

The Florida Fire Marshal's Office oversees quarry operations, monitoring blasting activities and restricting blasting to weekday daylight hours. Seismologists also measure the explosions to make sure they remain within permit limits.

Broward County prohibits blasting, but Miami-Dade County allows it. Miramar now also outlaws blasting within city limits, though allowed it when the far western communities were being developed.

While there's been a lot of talk over the years, blasting continues and most likely will continue until the quarry's permits are not renewed or canceled. Permits are active for one year and must be renewed pending inspection by the Fire Marshal.

Given the experiences of homeowners, Mayor Messam questioned whether state rules on blasting are adequate to prevent damage. He said the limits were developed elsewhere in the nation, not Florida where just inches under sandy soil lays a porous plateau of limestone. [emphasis added]

"While we did a study and found that they are working with required limits, at the end of the day, if residents experience damage, they should be paid," he said. [emphasis added]

An attempt to compensate homeowners was established in 2003 by then-Gov. Jeb Bush, who signed into law a measure to provide communities with state mediation to hear damage complaints, Messam said. "However, the state assigned the Department of Administrative Hearings (DOAH) to hear and rule on the complaints... If the DOAH sides with the quarry, the complainant must pay all [litigation] costs, including those of the quarry."

Messam said that in mid-March [2020] he noticed a spike in complaints on neighborhood websites, like Next Door. Some examples:

- Will Pen, of Silver Isles, wrote: "FYI I have lived in Silver Isles for 18 years. I have filed lawsuits since these blasts have caused the interior pipes of my pool to crack and thus cause major leaks. Cracks on exterior walls that have been certified as caused by this.... nothing, nada...."
- Henry Abdelnour, Silver Isles: "I've been living in Miramar for 15 years now. Those blasts were happening way before I moved in. They occur every day on workdays between 11 a.m. and 2 p.m. You just need to get used to them because there is nothing you can do. Sometimes they stop for a little while but not right now. Unfortunately, your complaints won't go anywhere."

- Debra Briggs, Silver Lakes: “This has been going since we moved here in 1996. I had to put laminate on my floors because my beautiful expensive tile had cracks throughout my home. I am pissed beyond belief and they do nothing!!”
- Sean Emmett, Sunset Lakes: “We feel it in our home and in my office, which is on the fourth floor of one of the buildings in Flagler Station adjacent to the Turnpike just south of NW 106th St. Some of the blasts are so bad that the office building sways from side to side for up to 10 seconds and our desks and computer monitors shake...Our local government officials granted the developers permission to build our homes knowing this could become an issue. Unfortunately, we are up against the might of the quarry operators who have support in Tallahassee and deep pockets to pay lawyers to defend them...”

If the proposed moratorium on blasting takes place, Messam wants to work out some solution to the noise and damages.

“The issue ultimately comes down to the Legislature to put regulations and laws in place,” Messam said. “And the more scientific than political we are, the more effectively we can all work. The current statutes make it very difficult.”³⁹

Formation of Sinkholes

According to the US Geological Survey, the formation of sinkholes can have catastrophic consequences.

It is a frightening thought to imagine the ground below your feet or house suddenly collapsing and forming a big hole in the ground. Sinkholes rarely happen, but when they strike, tragedy can occur. Sinkholes happen when the ground below the land surface cannot support the land surface.

A sinkhole is an area of ground that has no natural external surface drainage--when it rains, all of the water stays inside the sinkhole and typically drains into the subsurface. Sinkholes can vary from a few feet to hundreds of acres and from less than 1 to more than 100 feet deep. Some are shaped like shallow bowls or saucers whereas others have vertical walls; some hold water and form natural ponds....Typically, sinkholes form so slowly that little change is seen in one's lifetime, but they can form suddenly when a collapse occurs. Such a collapse can have a dramatic effect if it occurs in an urban setting.

Sinkholes form in what geologists call “karst terrain.” Karst terrain is a region where the bedrock can be dissolved by ground water.

Sinkholes are common where the rock below the land surface is limestone, carbonate rock, salt beds, or rocks that can naturally be dissolved by groundwater circulating through them. As the rock dissolves, spaces and caverns develop underground. ***Sinkholes are dramatic because the land usually stays intact for a while until the underground spaces just get too big. If there is not enough support for the land above the spaces, then a sudden collapse of the land surface can occur. These collapses can be small...or they can be huge and can occur where a house or road is on top.*** [emphasis added]

New sinkholes have been correlated to land-use practices, especially from groundwater pumping and from construction and development practices. Sinkholes can also form when natural water-drainage patterns are changed and new water-diversion systems are developed. Some sinkholes form when the land surface is changed, such as when industrial and runoff-storage ponds are created. The substantial weight of the new material can trigger an underground collapse of supporting material, thus causing a sinkhole. [emphasis added]

³⁹ Ann Henson Feltgen, “Miramar asks governor for temporary halt to blasting during COVID-19 pandemic,” April 24, 2020, <https://www.floridabulldog.org/2020/04/miramar-asks-governor-temporary-halt-blasting-amid-covid-19/>.

The overburden sediments that cover buried cavities in the aquifer systems are delicately balanced by groundwater fluid pressure. The water below ground is actually helping to keep the surface soil in place. Groundwater pumping for urban water supply and for irrigation can produce new sinkholes in sinkhole-prone areas. If pumping results in a lowering of groundwater levels, then underground structural failure, and thus, sinkholes, can occur.

The sudden and sometimes catastrophic subsidence [is] associated with localized collapse of subsurface cavities (sinkholes)... This type of subsidence is commonly triggered by ground-water-level declines caused by pumping and by enhanced percolation of ground water. Collapse features tend to be associated with specific rock types, such as evaporites (salt, gypsum, and anhydrite) and carbonates (limestone and dolomite). These rocks are susceptible to dissolution in water and the formation of cavities. Salt and gypsum are much more soluble than limestone, the rock type most often associated with catastrophic sinkhole formation. Evaporite rocks underlie about 35 to 40 percent of the United States, though in many areas they are buried at great depths. Natural solution-related subsidence has occurred in each of the major salt basins in the United States. **The high solubilities of salt and gypsum permit cavities to form in days to years, whereas cavity formation in carbonate bedrock is a very slow process that generally occurs over centuries to millennia. Human activities can expedite cavity formation in these susceptible materials and trigger their collapse, as well as the collapse of pre-existing subsurface cavities.**⁴⁰ [emphasis added]

In 1994, a New Windsor Maryland man [Robert W. Knight] was killed when his van fell in a [sink]hole that opened on Rt. 31. The site was near a limestone rock quarry [Redland Genstar Inc., operator of Medford quarry].⁴¹

As reported in the Baltimore Sun on December 1, 1998,⁴² the widow of Robert W. Knight reached an out-of-court settlement with the quarry operator.

Redland Genstar Inc. has settled a multimillion-dollar lawsuit by the widow of a Westminster city employee killed in 1994 after his van plunged into a sinkhole on the road to New Windsor.

Jury selection was to begin yesterday for an estimated three-week trial, but instead the attorneys met privately with Carroll County Circuit Judge Raymond E. Beck Sr.

Robert W. Knight was driving to New Windsor about 2 a.m. March 31, 1994, to get food during his shift at Westminster Wastewater Treatment Plant. A sinkhole 45 feet wide and 18 feet deep had opened on Route 31, a state road northeast of Medford Road.

Emergency crews worked more than two hours to free him from the van, and Knight was flown to Maryland Shock Trauma Center in Baltimore, where he died five hours after the accident.

Nancy Lee Knight filed a \$13 million lawsuit in 1996 against Genstar, operator of the nearby Medford quarry, and the state of Maryland, alleging negligence and wrongful death....

Knight settled her claim against the state of Maryland Nov. 17 for \$50,000, and the state was dismissed as a defendant. The amount was the maximum that could be recovered under the 1984 Maryland Tort Claims Act and the much older doctrine of sovereign immunity, according to court papers and the assistant attorney general handling the case....

In her claims against the state, Knight had said state officials in the Department of the Environment and the State Highway Administration were negligent in regulating the Medford quarry and in maintaining Route 31.

⁴⁰ <https://www.usgs.gov/media/images/karst-landscapes-are-more-prone-have-land-subsidence-and-sinkholes>.

⁴¹ <https://www.wusa9.com/article/news/local/maryland/new-sinkholes-in-frederick-put-focus-on-hazardous-geology-in-region/65-557172801>.

⁴² Sheridan Lyons, The Baltimore Sun, "Settlement reached in sinkhole death Worker's van plunged into Route 31 opening," December 1, 1998, <https://www.baltimoresun.com/news/bs-xpm-1998-12-01-1998335117-story.html>.

Sinkholes occur naturally in some limestone and marble formations, where water dissolves the rock and creates cavities that then collapse.

***Because quarries dig below the water table and must pump out water, the lawsuit alleged that this process had weakened the rock under the road and caused the ground to collapse in front of Knight's van.* [emphasis added]**

***The Knight lawsuit had been looked at as a possible test of the "sphere of influence" of quarry operations. A state law passed in 1991 holds mining companies liable for property damage caused by such activity within a specific area but does not presume that they are at fault.* [emphasis added]**

***Genstar had previously denied that the area where the sinkhole occurred is within its sphere of influence.* [emphasis added]**

Sinkholes and Water Problems

Alabama A&M & Auburn Universities maintain a public website devoted to addressing issues concerning *Karst Conditions (Sinkholes) and Water Problems*:⁴³

Can pumping of ground water cause land subsidence?

Definitely. As water is pumped from underground formations in major aquifers where the water is not replaced on a regular basis, the load bearing strength is weakened and over time the overburden materials can cause relatively large land areas to subside or settle under the force of gravity. This can ruin building foundations, rupture buried gas and water lines and cause other problems. Land subsidence has occurred in a number of areas across Texas due to excessive pumping of ground water, including the Houston-Galveston area during recent years.

Does open-pit quarrying in karst areas increase the likelihood of sinkhole formation?

Yes. Open-pit quarrying in some types of bedrock may not increase the formation of sinkholes, but the likelihood that open-pit quarrying in karst bedrock will increase the formation of sinkholes is near 100 percent. As a quarry is dug deeper below ground level or expanded in size, a greater volume of water must be pumped continuously to prevent pond formation in the bottom of the pit. Increased quarrying and pumping causes a cone of depression to expand throughout any surrounding surface aquifer system linked to the pit. Over time, underground fractures may begin to form, causing water to be emptied even from voids and caverns below the surface water aquifers. Not only will shallow wells surrounding the quarry begin to dry up, but surface streams fed from ground water may also dry up during low rainfall periods. And worst of all, accelerated sinkhole formation is likely as soil overburden and fractured materials begin to collapse into underground voids that were once full of water. If blasting is used in a quarry, the vibration and shock waves can accelerate the formation of bedrock fractures, which may lead to soil piping and the eventual collapse of the above materials into underground caverns. Any quarrying activity that intersects with or changes underground water levels or flow patterns can lead to sinkhole problems and even to nearby flooding if surface to ground water flow patterns are temporarily or permanently interrupted.

Am I more likely to get a sinkhole on my property because a neighbor of mine recently got a sinkhole on his property, and if so, how can I locate where a sinkhole is most likely to occur?

Not necessarily. Karst terrain, where sinkholes most commonly occur, generally has an underlying limestone type bedrock that is honeycombed with cavities and crevices of varying size. There may be several cavities or none in the bedrock under your property. If there is a sinkhole very near your property, there is more reason for concern because sinkholes sometimes occur in sets. Periodic surface inspection of your property for any sinking or soft areas might be prudent. But, the only way to be certain there are no cavities or voids under your property that could at some time result in the development of a sinkhole, is to get a geological bedrock density inspection. This means contacting a company with certified geologists who can use one of several types of instruments to survey and

⁴³ <https://ssl.acesag.auburn.edu/natural-resources/water-resources/faq/subject.php?code=116>.

map the location of any voids in the geology below your property. One such company is GeoModel, Inc. The URL for their web site is <http://www.geomodel.com> and their email address is geomodel@geomodel.com.

Can a sinkhole under the foundation of a home be repaired so there is no risk for future damage?

Not really, because few things in life are 100 percent risk free. Since sinkholes are natural systems, as are floods, tornadoes, and hurricanes, there can be no guarantee that a repaired sinkhole will not cause future problems. However, engineering companies have used techniques varying from simple injection of grout into sinkholes to more advanced systems of engineered reinforced plugs, pins, and porous concrete that have been very successful.

Can altering surface drainage and flow around or into sinkholes affect groundwater supplies in karst terrain?

Yes. Man-made changes to drainage on the surface or to sinkholes may easily alter the rate at which the underlying aquifer receives its normal recharge. Vegetation slows runoff from storms and allows water to percolate into the soil. However, runoff from impermeable materials (e.g. cement drains, asphalt roads or parking lots, and roofs of structures) may rapidly be funneled through specific sinkholes into an aquifer. Artificially filled sinkholes may become blocked inputs. Increasing the rate of runoff and/or blocking sinkhole inputs may result in temporary flooding, unless runoff is diverted away from its natural sink point (thereby altering the recharge to yet another sink point). This may drastically affect the amount of groundwater available for use in the immediate vicinity.

Can collapses and formation of sinkholes in karst landscapes be avoided?

No, not completely. Dissolution of water soluble carbonate rocks (limestone, dolomite and marble) below the land surface will lead to formation of below ground caverns. These openings or fractures that form in the bedrock will allow water to penetrate until connecting channels often form underground. After some time (a few years to thousands of years), mechanical failure of the overburden will occur and soil material will collapse to form sinkholes. Greater rainfall and storm water flow through cracks will accelerate the process, as will other events such as mining operations, increased ground water pumping and more frequent and heavier traffic loads on the overburden.

Can excessive pumping of underground water cause a sinkhole to form?

Yes. Many sinkholes have formed due to de-watering of underground voids. The soil arch over a void is often partially supported by the buoyancy of the water table. When the water is removed and the soil material above the void becomes wet from heavy rainfall, it may collapse. A number of adjacent voids may coalesce to form a large void. Patterns of pumping from high yield wells over extended periods of time can result in large and rapid drawdown of the water table and the emptying of voids and also the creation of solution voids due to ground water flow patterns. Water table drawdowns can cause voids to develop along solution channels, eventually leading to sinkhole formation at a distance from the well itself.

Can locations for potential sinkholes be accurately predicted in karst areas?

No, not completely. Most sinkholes form where there are open voids below the ground surface due to solution of water soluble minerals (carbonates) in karst areas. After a time mechanical failure will cause rocks and overburden, including soil, to eventually collapse to form sinkholes in many unexpected locations across karst landscapes. Large voids and deep caves can be detected throughout karst terrain with the proper geophysical instruments, but shallow and smaller voids are more difficult to detect, even with test drilling. Soil piping may go unnoticed for years and then cause sudden catastrophic collapse into large underground voids. Actions that cause the emptying of underground voids and caves of water can cause the land surface above to collapse without warning.

Can pumping of ground water cause land subsidence?

Definitely. As water is pumped from underground formations in major aquifers where the water is not replaced on a regular basis, the load bearing strength is weakened and over time the overburden materials can cause relatively large land areas to subside or settle under the force of gravity. This can ruin building foundations, rupture buried gas and water lines and cause other problems. Land subsidence has occurred in a number of areas across Texas due to excessive pumping of ground water, including the Houston-Galveston area during recent years.

Does open-pit quarrying in karst areas increase the likelihood of sinkhole formation?

Yes. Open-pit quarrying in some types of bedrock may not increase the formation of sinkholes, but the likelihood that open-pit quarrying in karst bedrock will increase the formation of sinkholes is near 100 percent. As a quarry is dug deeper below ground level or expanded in size, a greater volume of water must be pumped continuously to prevent pond formation in the bottom of the pit. Increased quarrying and pumping causes a cone of depression to expand throughout any surrounding surface aquifer system linked to the pit. Over time, underground fractures may begin to form, causing water to be emptied even from voids and caverns below the surface water aquifers. Not only will shallow wells surrounding the quarry begin to dry up, but surface streams fed from ground water may also dry up during low rainfall periods. And worst of all, accelerated sinkhole formation is likely as soil overburden and fractured materials begin to collapse into underground voids that were once full of water. If blasting is used in a quarry, the vibration and shock waves can accelerate the formation of bedrock fractures, which may lead to soil piping and the eventual collapse of the above materials into underground caverns. Any quarrying activity that intersects with or changes underground water levels or flow patterns can lead to sinkhole problems and even to nearby flooding if surface to ground water flow patterns are temporarily or permanently interrupted.

How can overdrafting of groundwater cause problems?

Special problems may result from the excessive use of groundwater. Overdrafting occurs when people draw water out of an aquifer faster than nature can replenish it. The most obvious problem created is a shortage of water. Overdrafting, however, can also create significant geotechnical problems. Although not an issue, at many locations around the world, overdrafting has caused land subsidence and formation of sinkholes. This can produce severe engineering difficulties. Parts of Mexico City, for instance, have subsided as much as 10 meters in the past 70 years, resulting in a host of problems in its water supply and sewer system. Land subsidence may also occur when the water table is lowered by drainage. In the early 1970s, for example, an entire residential subdivision in Ottawa Canada subsided when a collector sewer was constructed nearby. The subsidence seriously damaged the residents' property. [See Pugliese et al. v. National Capital Commission et al.; Beaver Underground Structures Ltd. et al.; Third Parties Dunn et al. v. Regional Municipality of Ottawa-Carleton et al., 17 O.R. (2d) 129, Ontario CA, August 1977; Supreme Court of Canada upheld the ruling of the Ontario Court of Appeal.]

In *Pugliese et al. v. National Capital Commission et al.*, the homeowners claimed their properties sustained damages totaling approximately \$2 million:

The one hundred and seventy-one plaintiffs in the Pugliese action, who are the owners of one hundred and one residential properties in the Township of Nepean in the Regional Municipality of Ottawa-Carleton, and the four plaintiffs in the Dunn action, who are the owners of two residential properties in the same part of the municipality, claim that the ground water table below their properties was substantially lowered by the construction of a collector sewer on lands of the National Capital Commission located nearby, and that their homes and lands were seriously damaged by the resulting subsidence. There is also a claim that properties involved both in the Pugliese action and in the Dunn action were damaged as a result of drilling and blasting operations. [emphasis added]

As a result of the dewatering the ground water table was lowered in the lands adjacent to and in the general vicinity of the LCS [Lynwood Collector Sewer]. At the location of the LCS it was lowered to at least the invert elevation of the LCS. The lowering of the ground water table caused the

underlying clay strata to consolidate and the underlying loose sand and silt strata to compress. This resulted in a differential settlement over the base of the foundations of the plaintiffs' homes. The damages suffered by the plaintiffs included severe cracking and faulting to the floors, foundations, walls, ceilings and fireplaces of their residential structures, including depressed exterior foundation walls, sloping floors to depressed walls, brick or stone veneer cracked or pulled away from walls and severe distortions of door and window frames. Subsidence of the plaintiffs' lands also occurred with cracking to the curbs, laneways, sidewalks and landings. Damages amounting in the aggregate to approximately two million dollars are claimed, based on nuisance, negligence or breach of statutory duty.

The depth of the limestone bedrock was erratic and varied from a near ground surface elevation to a depth much in excess of fifty feet. The ground water table before construction was commenced for the LCS was generally at a depth of approximately four to fourteen feet below the ground surface. The LCS was to be constructed by a tunnelling operation, and the invert of the LCS was to be installed approximately forty feet below the ground surface. Beaver and Cosentino had the option of controlling the ground water conditions either by the use of compressed air during tunnelling operations, or by dewatering in advance of tunnelling operations. Commencing in the summer of 1974 and continuing until the winter of 1975-76, they adopted a dewatering system of pumping from deep drainage wells. The total quantity of water pumped by Beaver and Cosentino greatly exceeded the daily maximum which was permitted under the "Permits to Take Water" issued by the Ministry of the Environment under The Ontario Water Resources Act, R.S.O. 1970,

With the concurrence of all parties, the Ontario Court of Appeal agreed to determine the matter on a stated question of law related to the homeowners' claims (other than those related to blasting operations) as if it were an appeal from a determination under Rule 124 (Ontario Rules of Practice). The Court of Appeal concluded as follows:

1. *An owner of land does not have an absolute right to the support of water beneath his land not flowing in a defined channel, but he does have a right not to be subjected to interference with the support of such water, amounting to negligence or nuisance.*
2. *Such an owner does have a right of action

 - (a) in negligence for damages resulting from the abstraction of such water, or
 - (b) in nuisance for damages for unreasonable user of the lands in the abstraction of such water.*
3. *Such an owner does not have a right of action under The Ontario Water Resources Act for damages for subsidence arising from the pumping of water in excess of the amounts set out in permits issued under that Act.*

The Supreme Court of Canada⁴⁴ upheld the Ontario Court of Appeal ruling, varying the judgment, in part, to read as follows:

In an action by an owner of land in negligence or nuisance from the pumping of ground water not flowing in a defined channel for any damage resulting from the abstraction of such water, no right of another owner to pump such water avails as a defence in respect of any pumping exceeding the quantity authorized under The Ontario Water Resources Act".

In reference to the fine for pumping water in excess of that permitted under *The Ontario Water Resources Act*, the Supreme Court of Canada stated,

...I do not view the enactment for the protection of the land owners from damage by excessive pumping as creating a duty but as a limitation of whatever right existed of doing it with impunity.

⁴⁴ N.C.C. et al. v. Pugliese et al., 1979 CanLII 32 (SCC), [1979] 2 SCR 104, <<http://canlii.ca/t/1tx79>>, retrieved on 2020-07-12.

How adequate is the enforcement by penalty when this is \$200 a day and the damage is probably in excess of \$2,000,000[?]

The Supreme Court of Canada found that the pumping violation in that Act was considered a *nuisance* when causing damage to other properties, as well as a *negligent act*. The homeowners were entitled to sue the defendants in *nuisance* and in *negligence*.

How does groundwater move through karst terrain (sinkhole areas)?

Unlike in other types of terrain, groundwater in karst regions is channelized within the natural underground system of interconnected pipes or tunnels that collectively transmit water from input (recharge) points to output (discharge) points. Recharge in karst terrain occurs in two ways. First, rainwater may percolate through the soil and into fractures in the soluble rock over large areas of the countryside. This is known as diffuse recharge. Secondly, surface flow may enter caves or sinkholes directly. This is called discrete recharge. Both mechanisms occur simultaneously in most karst regions. Discharge from the ground to the surface occurs in several different ways. Karstic groundwater is released from natural springs as cave streams exit from openings or as seeps as water emerges from the ground over wide areas. Spring flow may range from a few to thousands of gallons per minute. A significant quantity of water may also be withdrawn from wells drilled to obtain water for domestic, commercial, agricultural, or other industrial uses. The natural subsurface flow in karst terrain can be very complex. It is often difficult to ascertain exactly where water entering a karstic aquifer flows and where it eventually emerges on the surface. In practice, paths of travel are determined by introducing tracers, such as dyes, into input points and observing where they resurface.

How should I manage a sinkhole on my personal property?

That depends on the age of the sinkhole and the role it plays in local water flow patterns. New relatively small sinkholes that form due to mining operations lowering the water table can be filled with local soil material. It is not a good recommendation though to fill old sinkholes with impervious material, especially if such sinkholes are established components of the local drainage system. Filling such sinkholes can lead to flooding problems and formation of additional, and sometimes, much larger sinkholes. It is a good idea however, to maintain overall stability of a sinkhole on your property. A good conservation practice is to establish a natural vegetated buffer zone around such sinkholes to maintain the quantity and quality of recharge water entering the aquifer there. Thought should be given to the size of the drainage area and proximity to sources of contamination when assessing vulnerability of the sinkhole and the size of buffer needed.

If I get a sinkhole on my property will it keep getting bigger and bigger over time?

Usually no. The size of most sinkholes stabilize after a period of time. When an underground cavity enlarges to the point that its ceiling can no longer support the weight of overlying sediments, the earth suddenly collapses into the cavity. A circular hole typically forms and grows over a period of time that typically will last from a few minutes to a few hours. Slumping of the sediments along the sides of the sinkhole may take several days to completely stop. Unless stabilized with vegetation or rocks, water erosion of the edge of a sinkhole may continue for years in a climate that gets regular rainfall. If a sinkhole becomes an active conduit for surface water flow directly to subsurface water channels, it is not likely to stabilize and will likely continue to grow in size over time.

Is ground water more susceptible to pollution in areas with sinkholes?

Yes. Pollution of groundwater resources is always a problem in karst terrain with sinkholes. Sinkholes are natural funnels that can convey toxic substances directly into the below ground plumbing system. Sinkholes have long been used as dumps for waste materials. The dumping of solid wastes, such as dead animals, garbage, and refuse into sinkholes is a major hazard to groundwater resources. Liquid wastes dumped into sinkholes can enter a groundwater system undiluted through the underground drainage routes or conduits. Sinkhole dumping is just one way of contaminating karstic groundwater. Many karstic aquifers are now contaminated by fertilizers and

pesticides applied to fields overlying carbonate rock, leakage from municipal landfills sited in these areas, leaky septic systems and sewage lines, seepage from accidental chemical spills, and other contaminated effluent along transportation and urban corridors. An excellent practice to follow is to never put anything in a sinkhole that you would not want in your drinking water. Be cautious in using potential pollutants in karstic terrain because the overburden above many of these aquifers may not have the capacity to filter contaminated water before it reaches the groundwater and the cavernous system of the aquifer has little capacity to filter contaminated groundwater before it reaches discharge sites. Most states now have special codes prohibiting the dumping of any kind of wastes into or adjacent to sinkholes.

Sinkholes Swallow Property and Trees

According to a May 15, 2014 article,⁴⁵ sinkholes continue to swallow property and trees in Opelika, Alabama.

Sinkholes are swallowing property in Opelika. One homeowner says he's lucky he took a break from cutting the grass when he did, otherwise he may have sunk 20 feet into the ground along with a large tree in his front yard.

Heavy rain is doing more than just flooding streets and overflowing creeks in Opelika, it's causing tall trees to be sucked into the ground. Jerome Hamby was cutting the grass Wednesday afternoon when the ground gave away right in the place where he was about to resume work after a short break.

"I praise the lord that I came to take a break, because if I was out there - I was just cutting around that - you know what I mean? If I was out there cutting, I would probably be in that hole with the tree."

Sinkholes are becoming a recurring problem for this part of Opelika near Lee Road 704. Hamby says a road in his neighborhood was forced to close because of the ground caving in. He says the problem is partly due to drilling at a nearby rock quarry. [emphasis added]

"Well, they say they're going to shut this thing down in August, and they tell me then that it should do away with the sink holes in this community."

This is the second time a large sink hole has done damage to his property in recent years. He wants to move, but the offers he's getting on his house are less than he paid for it. [emphasis added]

"It's a shame, I'm going on 76, you work all your life to have a home and then you deal with this. And believe me, it puts a lot of stress on you. A lot of stress. Until then, he'll have to hire professionals to help him pull a tree out from deep in the ground that once stood high above his property. [emphasis added]

On May 16, 2014, a follow-up article elaborated on the problem of sinkholes in Opelika, and in Alabama.⁴⁶

Despite popular belief, sinkholes are not unusual in Alabama and they can come in all sizes.

"There are major land areas in Alabama that have the same issues because they contact the underground geology that's water soluble and when some of that gets dissolved it leave[s] large holes of water.

Sinkholes are very common," explains Dr. James. Hairston,- AU Professor Emeritus/ Retired and ACES Water Program Coordinator.

⁴⁵ WTVM, "Homeowner narrowly escapes sinkhole that swallows tree," May 15, 2014, updated July 25, 2014, <https://www.wtvm.com/story/25523713/opelika-sinkhole-swallows-trees-whole/?autostart=true>.

⁴⁶ WTVM, "Experts say sinkholes are not uncommon in Alabama," May 16, 2014, updated July 27, 2014, <https://www.wtvm.com/story/25532311/experts-say-sinkholes-are-not-uncommon-in-alabama/>.

Sinkholes are frequently associated with urban development in karst landscapes.

***Mining or quarrying and high water withdrawal can lead to some types of sinkholes and is what Hairston believes happened yesterday in Opelika.* [emphasis added]**

A quarry is in operation just down the street from Hamby's property.

***"They call it a cone of depression. The deeper the sinkhole gets, you have a cone forming away from the line quarry where the water starts dropping," says Hairston.* [emphasis added]**

In 2007, Lee County sued and reached a settlement with the then owners of the rock quarry, where the quarry will pay for and repair any sinkhole related damages in a given area on public and private property.

"They say they're going to shut this thing down in August and they tell me then that it should do away with the sinkholes in this community," says Hamby.

***"You have that [sinkhole] potential anywhere close to a quarry," explains Hairston.* [emphasis added]**

The closing of the quarry and the factors leading up to the closing of the quarry were reported by the Opelika Observer on September 9, 2014.⁴⁷

The limestone quarry that has made its home in Lee County for over a century will soon close its doors. As previously reported by the "Observer," the quarry on Alabama Highway 166 in Opelika will be closed by the end of the year.

MidSouth Aggregates, Inc., and its holding company, Oldcastle Materials, Inc., made the decision to close the quarry that has been in operation since as early as the mid-1800s for various reasons. Community rumors spoke of an imbalance of revenue and cost of production, and others blamed the numerous sinkholes around Lee County and the cost of repairing them for the closing.

In 2007 the city of Opelika and Lee County brought a lawsuit against the owner of the quarry, MidSouth Aggregates, as well as its holding company, Oldcastle Materials, Inc. The case was eventually settled outside of court. According to the Lee County Commission, there were eight items in the settlement. The quarry agreed to the following:

- pay for and repair sinkhole-related damages, present and future. They will repair damage on public and private property, with a financial cap of \$1.6 million;
- make significant road repairs, at its expense (Lee Road 148 had been closed because of sinkholes);
- conduct initial sinkhole susceptibility testing and weekly inspections, at its expense;
- provide defense and indemnification of Lee County, at its expense;
- agree to the continuing jurisdiction of the Lee County Circuit Court;
- stay in strict compliance with operating restrictions and its Alabama Department of Environmental Management discharge permit limits;
- provide a \$5 million performance bond, which will remain in effect for seven years after closure if the quarry closes; and
- repay Lee County \$2 million for legal fees.

Tom Aley, president of Ozark Underground Laboratory in Missouri, was heavily involved in the litigation process of the 2007 lawsuit. His company was hired to evaluate the validity of the claims brought against the quarry and Oldcastle Materials, Inc.

Aley worked extensively in Opelika, accessing [sic] the formation of sinkholes and the drying up of the Spring Villa area surrounding the quarry.

⁴⁷ Rebecca Martin, Opelika Observer, "Quarry closure examined," September 9, 2014, <https://opelikaobserver.com/quarry-closure-examined/>.

"In my opinion, once the quarry has ceased its operations, the spring that has been dry for so many years will flow again," Aley said. "The timeline of course depends a great deal on the amount of rainfall Opelika gets, but I look for the flow to resume within a couple of years."

Justin Hardee, Lee County engineer, said MidSouth Aggregates and Oldcastle Materials have dutifully upheld their settlement responsibilities. The highway department reported a sinkhole under the asphalt of Lee County Road 148 in April of this year, and Hardee said the quarry took care of the problem in accordance with the settlement agreement.

"The closing of the quarry is a bittersweet thing for the highway department," Hardee said. "It employed county residents and also provided our department with a great deal of the materials we use in road construction and repair. We are, however, looking forward to the safety concerns the sinkholes caused not being an issue."

The quarry will officially close later this fall.

In the 2007 law suit, the city of Opelika brought an action against Hanson Aggregates Southeast Inc. and Oldcastle Materials Inc., "alleging that violations at their facilities were damaging the health and properties of their neighbors," as reported by Lawyers and Settlements.com.⁴⁸ The location of the sinkholes caused by the quarry and the settlement reached are described as follows:

The civil suit against Oldcastle Materials and former quarry operator Hanson Aggregates Southeast alleged that deep drilling from the quarry, located between Alabama Highway 166, just south of Opelika, is responsible for numerous sinkholes and an overwhelming loss of spring water in the surrounding area.

As part of a settlement reached, though pending approval from the Opelika Utilities Board and the Lee County Circuit Court where Judge Jacob Walker III presides, the quarry companies will pay [sic] the city...\$1.1 million. Under the deal, Oldcastle will install, at its own expense, an 8-inch waterline from the fire hydrant near Brown Tool & Mold Company to the westerly most entrance of Spring Villa Park. The length of said waterline is approximately 5,000 feet, and it will serve Spring Villa Park. Further, Oldcastle will repair, at its own expense, all existing and future sinkholes and sinkhole-related damages to properties, easements and rights-of-way owned by the city and the Opelika Utilities Board. If the bridge crossing Little Uchee Creek suffers sinkhole-related damages, Oldcastle will repair the bridge at its own expense; and will indemnify the city and the utilities board from future claims and liability arising from sinkhole-related damages. [OPELIKE AUBURN NEWS: QUARRY SINKHOLES]

Quarry Dewatering Causes Sinkholes on Neighbouring School Campus

In *Solebury School v. Commonwealth of Pennsylvania DEP and New Hope Crushed Stone & Lime Co.* (NHCS),⁴⁹ the DEP ruled in favour of the Solebury School, finding that the sinkholes were caused by dewatering at NHCS' quarry. The case summary that follows has been prepared by Miano and Keays:⁵⁰

This case study involves a private boarding school [on 90 acres] located in a rural area and a [215.75-acre] limestone quarry [with extraction confined to 141 acres] located directly next to the school. The school and the quarry are located in karst terrain.

⁴⁸ Quarry Sinkholes, October 17, 2007, <https://www.lawyersandsettlements.com/settlements/09711/quarry-sinkholes.html>.

⁴⁹ *Solebury School v. Commonwealth of Pennsylvania Dep't of Envtl. Prot. and New Hope Crushed Stone & Lime Co.*, No. 2011-136-L, 2014 WL 4087592, (Environmental Hearing Board July 31, 2014), https://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1053&context=sinkhole_2018.

⁵⁰ Steven T. Miano and Peter V. Keays, "When Sinkholes Become Legal Problems," 15th Sinkhole Conference, https://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1053&context=sinkhole_2018.

Mining has been occurring on the quarry property [NHCS] since the 19th Century, but it wasn't until the 1960s that mining began at depth, which required the dewatering of the quarry pit. The state regulatory agency issued the quarry its first mining permit in the mid-1970s. Although the permit approves mining to a depth of -200' MSL [mean sea level], the agency has required the quarry to apply for separate "depth corrections" in order to mine progressively closer to that depth. In July 2011, the agency issued the quarry a depth correction allowing it to mine to a depth of -170' MSL; the previous depth correction, issued in 2007, allowed the quarry to mine to -120' MSL. Following the issuance of the most recent depth correction, the quarry was pumping 2-4 million gallons of water per day from the quarry pit.

In 1989, collapse sinkholes began to open on the school's campus. The sinkholes ranged from several feet across to nearly a quarter an acre, most exceeding 20 feet across. Between 1989 and 2014 at least 29 sinkholes opened on the school's campus, and at least 10 sinkholes opened on neighboring properties, the largest of which was 150 feet long, 75 feet wide, and 15-20 feet deep. Over the course of this time period, wells on the school's campus began to go dry. Deeper wells were drilled, only to dry up a few years later. In addition, the creek that historically ran across the campus and the quarry property ran dry; what little flow remained was sporadic and was drained by a swallet that formed on the quarry's property, not far from the school's property line. [emphasis added]

The sinkholes presented an enormous danger to the safety of the students, faculty, staff, and visitors, and posed a potentially existential problem for the school. Around the time that the quarry applied for its most recent depth correction in 2008, the school retained two experts—a licensed professional engineer and a Ph.D. in geology—to investigate the potential cause or causes of the sinkholes, and to make recommendations as to how future sinkholes might be prevented. Based on the investigation of these experts, which revealed that the dewatering of the quarry pit was causing the sinkholes and that deepening the quarry pit would promote continued sinkholes on the campus, the school opposed issuance of the depth correction. The agency limited its review to the marginal impact of adding 50 feet to the quarry, as opposed to the continuing impact of the ongoing dewatering of the quarry (an approach that was later held to be improper and unlawful). After concluding that the school failed to show that the depth correction would exacerbate the sinkhole problem, the agency issued the depth correction in 2011. The school appealed the depth correction to a state administrative court. [emphasis added]

Not surprisingly, the issue of causation was at the heart of the school's appeal, which was ultimately resolved in the school's favor after a two-week trial, most of which was focused on conflicting expert testimony. The court ultimately concluded that—because the quarry's dewatering had substantially lowered the groundwater under the school, which, given the underlying karst features, resulted in the sinkholes—the quarry's dewatering of the quarry pit is the "overriding cause" of the sinkholes.⁵¹ At trial, the quarry and the agency's experts offered several alternate theories of sinkhole causation, including flooding caused by heavy precipitation and the school's development activities on its campus, which the court rejected. The court found that continued dewatering will further depress groundwater levels below the school, and—crediting the opinions of the school's expert witnesses—found that "dewatering of the quarry is directly resulting and will continue to result in the hazardous formation of collapse sinkholes."⁵² [emphasis added]

The court anchored its legal conclusions on various provisions of the state's noncoal surface mining act and related regulations. Citing the stated purpose of the act, which includes "preventing and eliminating hazards to health and safety,"⁵³ the court pointed to the requirement that no permit may be issued unless the applicant affirmatively demonstrates, among other things, "that it will ensure the protection of the quality and quantity of surface water and groundwater, both within the permit area and adjacent areas,

⁵¹ Environmental Hearing Board July 31, 2014).

⁵² Solebury School v. DEP at *16.

⁵³ Solebury School v. DEP at *21 (quoting 52 P.S. § 3302).

as well as the rights of present users of surface water and groundwater.⁵⁴ Citing a number of statutory and regulatory provisions, the court affirmed that the agency not only has the authority to deny the depth correction “if continued mining is causing unavoidable and serious harm to health and safety,” but also the “duty to ensure that mining can be performed without undue risk to health, safety, and welfare.”⁵⁵ The court ruled that by issuing the depth correction the agency acted unlawfully and unreasonably by enabling a serious hazard to continue unabated. The court also rejected the standard for reviewing the quarry’s application, stating that “the question is not whether the limited subject of the revision can be safely accomplished,” but rather “whether the project as a whole, as revised, can be safely accomplished.”⁵⁶ Invoking a statutory provision that declares “any condition that creates a risk of...subsidence, cave-in, or other unsafe, dangerous or hazardous condition”⁵⁷ to be a public nuisance, the court ruled that the quarry is creating a public nuisance. The court also invoked the agency’s statutory duty to abate and remove public nuisances.⁵⁸ [emphasis added]

In the wake of the court’s decision, the agency required the quarry to begin reclamation and to submit a reclamation plan and timeline that was driven by the time needed to restore the groundwater and abate the nuisance, rather than the time needed to extract the remaining mineable reserves. The quarry’s failure to comply resulted in the issuance of an order that imposed various requirements and restrictions upon the quarry, most notably, a daily pumping limit of 500,000 gallons. That order was recently upheld by the court.⁵⁹ [emphasis added]

This case exemplifies the critical role that expert witnesses can play in sinkhole litigation. As the court wrote: “the School assembled a top-notch team of experts for evaluating the karst geology of the [basin] and the hydrogeologic connection between the quarry’s dewatering and the sinkhole development on the School’s campus, the key issues in the case.”⁶⁰ **This case also illustrates that statutes and regulations and the permitting process can be powerful tools that a party can use to combat sinkholes, even in cases where the government agency entrusted with enforcing those laws fails to do so.** [emphasis added]

Quarry Dewatering Causes Neighbouring Homes to Sink

In *Henderson v. Wade Sand & Gravel Co., Inc.*,⁶¹ the Alabama appeals court overturned the trial court’s ruling, which had rejected the homeowners’ claims against the quarry for damages to their houses caused by dewatering at the quarry a half-mile (805 metres) away.

The plaintiffs' houses were constructed roughly fifty years ago, and are located in a residential neighborhood. In 1977, the land on which their houses are situated began to sink, large sinkholes appeared, and their houses began to break up. Investigation disclosed that the sinking of their property was due to the activities of defendant, Wade Sand and Gravel Company, which operated a quarry one-half mile north of plaintiffs' homes. In the course of its operations, the quarry, which began operating in 1957, periodically pumps water from the bottom of its pits, and empties it into a nearby creek. This resulted in ground water being leached from under plaintiffs' land, leaving large underground cavities. Heavy rains then caused water to flow through the empty cavities at an accelerated rate, destroying the

⁵⁴ *Solebury School v. DEP* at *21 (citing 25 Pa. Code § 77.457(a))

⁵⁵ *Solebury School v. DEP* at *22.

⁵⁶ *Solebury School v. DEP* at *24.

⁵⁷ 52 P.S. § 3311(b).

⁵⁸ See 52 P.S. § 3311(b); 71 P.S. § 510-17(3).

⁵⁹ *New Hope Crushed Stone and Lime Company v. DEP*, 1373 C.D., 2017 (Pa. Commw. Ct. 2018), <https://www.courtlistener.com/opinion/4517931/new-hope-crushed-stone-and-lime-company-v-dep/>.

⁶⁰ *Solebury School v. DEP* at *28.

⁶¹ *Henderson v. Wade Sand & Gravel Co., Inc.*, 388 So. 2d 900 (1980) Ala. Supreme Court, https://scholar.google.com/scholar_case?case=6837030642937266250&q=henderson+v+wade+sand+%26+gravel+co+inc&hl=en&as_sdt=2006.

structure of the land beneath plaintiffs' homes, and carrying away much subsoil and surface soil. [emphasis added]

At trial, the court denied the homeowners' request to present a study undertaken by the U.S. Geological Survey, which predicted the type of damage sustained.

In 1969, the U.S. Geological Survey began a study of the sinkhole problem in the Roberts Field area, which includes plaintiffs' homes and the quarry. The defendant [Wade Sand and Gravel Co.] cooperated in the study and was allegedly familiar with the contents of the report subsequently published. Plaintiffs contend that the study predicted that damage of the type complained of would occur if defendant continued to pump water from its pits.

The appeals court rejected the lower court's application of the "reasonable use" rule in a landowner's right to take water for a legitimate purpose (e.g., quarrying) with impunity, while causing neighbouring houses to become unsupported and to collapse.

We agree with the reasoning of this case, and conclude that the reasonable use rule was inappropriately applied in Sloss I & II. While the Sloss rule may have been acceptable, even beneficial, in an earlier era of lower population density and more primitive technology, it could produce disastrous results today. Carried to its logical extension, it would allow a quarry owner to willfully sink the City of Birmingham with impunity, provided that it was done in furtherance of a legitimate enterprise and that due care was exercised in the pumping. A rule which provides no check on a landowner's ability to utilize his land to the detriment of society cannot be tolerated. The appellee admits that "at some point a balance must be struck between annoyance and inconvenience to plaintiff and the right of defendant to do business," although they omit to specify when the point is reached. Accordingly, we hold that where a plaintiff's use of groundwater, whether it be for consumption or, as here, for support, is interfered with by defendant's diversion of that water, incidental to some use of his own land, the rules of liability developed by the law of nuisance will apply. [emphasis added]

A defendant is subject to liability under the law of nuisance for interference of a plaintiff's use of water, "either for (1) an intentional invasion when his conduct was unreasonable under the circumstances of the particular case, or (2) an unintentional invasion when his conduct was negligent, reckless or ultrahazardous." [underscoring added] *Henderson, supra*, at 903; *Labruzzo v. Atlantic Dredging one a lacy are if & Constr. Co.*, 54 So.2d 673, 675, 29 A.L.R.2d 1346, at 1351 (Fla.1951).

The case was remanded for further consideration by the trial court consistent with the opinion of the appeals court.

Homeowners File Law Suits Over Sinkholes That Rendered Subdivision Homes Unfit for Occupancy and Worthless

According to a February 15, 2019 press release,⁶² 14 luxury homes in a rural subdivision have been rendered unfit for occupancy after numerous sinkholes opened throughout the subdivision.

Residents of an upscale neighbourhood on British Columbia's Sunshine Coast will officially be barred from returning to their dream homes today.

⁶² "Fourteen 'dream' homes ordered evacuated as sinkholes open in Sechelt,"

Sinkholes throughout the subdivision have prompted the District of Sechelt to issue evacuation orders covering 14 properties.

The homes, with views overlooking Sechelt Inlet, are similar to others in a nearby subdivision valued at over \$1 million, although the BC Assessment Authority values most of the buildings in the Seawatch subdivision at zero. [emphasis added] [6657 Gale Ave N Sechelt assessed in 2020 for \$2 and 6636 Gale Ave N Sechelt assessed in 2020 for \$1]⁶³

An engineering report issued to the district says future sinkholes or landslides within the subdivision could damage infrastructure or buildings, and injury or death are possible consequences.

The district has informed residents by email that fences around the subdivision will be locked Friday afternoon and only RCMP and firefighters will be permitted inside after that.

A statement issued by the district says Concordia Seawatch Ltd. designed, built and sold the subdivision, despite engineering reports as early as 2006 describing the development of sinkholes. (CKAY, The Canadian Press) [emphasis added]

As reported in a follow-up article,⁶⁴ a dozen homeowners have launched a lawsuit against the District of Sechelt, the Province of B.C. and the developer.

In eight lawsuits filed last week, the Goids and other homeowners allege the geotechnical hazards underneath the subdivision were no mystery to the district when the development was approved in 2006. Court documents claim the district was negligent in approving their homes, and continually negligent by ignoring problems as they cropped up during construction.

Four lawsuits from other homeowners with similar claims have been filed in past months. No statements of defence have been filed.

Six months in, warning signs still stand around the deserted neighbourhood. Concrete medians block roads in and out of the area and two-metre-high construction fences circle empty houses. Goy said there's been reports of vandalism.

For the first five weeks after leaving home, the Goids house-sat, lucky to have friends who were on vacation. The couple has been renting in Sechelt since, and are still making payments — and paying taxes — on the house they can't live in.

"[The houses] have been rendered useless and worthless by a series of mistakes made with many different levels of governments over the years," Rod said.

All of the homeowners' lawsuits also name the province of B.C. and developer [Concordia Seawatch] as defendants, alongside the district. Residents say the province has extended the state of emergency keeping them from their homes on a weekly basis since February and claim the order extensions are an "abuse of power."

Various real estate agents are also named in several of the lawsuits. [emphasis added]

The neighbours have leaned on each other for comfort and communication, texting each other for updates. Rod said residents are not personally notified every time the order is extended — they have to drive to the neighbourhood to check if a new notice has been physically posted on-site, or search online once a week.

⁶³ Karin Larsen, "\$1 and \$2 property assessments confirm worst fears for residents of sinkhole-plagued neighbourhood," CBC News, January 3, 2020, <https://www.cbc.ca/news/canada/british-columbia/1-and-2-property-assessments-confirm-worst-fears-for-residents-of-sinkhole-plagued-b-c-neighbourhood-1.5414366>.

⁶⁴ Rhianna Schmunk, "12 homeowners in sinkhole-ridden B.C. neighbourhood sue over 'worthless' dream homes," Aug 22, 2019, <https://www.cbc.ca/news/canada/british-columbia/sechelt-sinkholes-homeowners-lawsuits-bc-1.5255774>.

They all know it could take years for their legal cases to wind through court, but Goy said the residents didn't know how else to move forward.

"I don't think anybody was looking to be adversarial in our neighborhood ... We were just looking for help."

Subsequently, the defendants filed responses, with the province stating that "it didn't cause or contribute to any loss or damage included in the Goy's claim, and extended the state of local emergency at the request of the district, and based on a geotechnical report highlighting the danger." As for the developer, "Concordia Seawatch, claims a geotechnical report it relied on from 2006 said the properties were expected to be safe, and that the district had other information it ought to have shared."⁶⁵

A review of the documents, filed with the law suits, by a CBC journalist⁶⁶ reveals the following chronology of events involving development of the subdivision:

1992 - *The earliest report on the city's website from Terra Engineering found "the property as a whole to be well suited to the type of residential development proposed" and that "if care is undertaken to prevent post-development storm water runoff from reaching unprotected slopes, the long term erosion potential of the surface is minimal." The final page reads: "There is no particular natural hazards of this site," but the report also recommends more testing.*

1993 – *Under a section titled "Geological Hazards," a Golder Associates report found "various types of existing and potential natural hazard which can affect development" and goes on to say "the assigning of probability levels to specific hazard events, or a series of events, can only be achieved by carrying out more detailed geotechnical and hydrological studies to determine appropriate hazard probability/magnitude relationships."*

1998 – *A development application was made, but the city notes it was "left uncompleted" in that year.*

2004 – *Geotactics Engineering prepared a report for the developer after one day on site and "an earlier report by Geotek Designs for part of the site was made available as background information." The report concluded that "the probability of occurrence of geotechnical hazards is estimated to be less than 10 percent in 50 years," but it also noted "several test pits should be excavated around the property to verify the subsurface conditions here" and that "each of the lots in Phase 1 should have an individual geotechnical assessment prior to final design and construction."*

2005 – *Sechelt district staff reported that in February, test pits were excavated to verify conditions at the "Shores" development. The report recommended council issue a development permit provided there are protections for banks and the shoreline, as well as "Registration of a Covenant on each of the lots in Phase 1 stating that a geotechnical assessment is required prior to the issuing of a Building Permit establishing building setbacks, storm runoff disposal and foundation construction specifications."*

2006 – *Geotactics Engineering wrote a follow-up report dated April 2006, mentioning the formation of four sink holes in the proposed subdivision area, "one of which was 10 feet in diameter and about eight feet deep." The report reads "On further investigation, the occurrence of sink holes in this area was found to be more common than previously believed" in other parts of Sechelt. Nonetheless, the*

⁶⁵ Rafferty Baker, "Province, district deny responsibility after 12 homeowners sue over sinkhole-riddled development," November 7, 2019, <https://www.cbc.ca/news/canada/british-columbia/sechelt-sinkhole-defendant-claims-1.5351050#:~:text=British%20Columbia-Province%20district%20deny%20responsibility%20after%202012%20homeowners%20sue%20over%20sinkhole,with%20denials%20and%20finger%2Dpointing>.

⁶⁶ Penny Daflos, <https://bc.ctvnews.ca/fair-warning-or-obstruction-duelling-claims-and-a-document-trail-in-sechelt-1.4299923>.

report concluded with the identical line from 2004: “**The probability of occurrence of geotechnical hazards is estimated to be less than 10 per cent in 50 years.**” A supplementary addition the following month claims “until a soil collapse occurs, the presence of a (potential) sink hole is generally undetectable. The occurrence is random.” The city imposes as “restrictive covenant against title” to the area, which includes the Geotactics report. [emphasis added]

2007 – Construction begins.

2008 – Thurber Engineering assessed the construction of retaining walls and slopes, but addressed the sink hole issue, noting the addition of rounded gravel to the existing sand could be an issue: “If water ingress occurs into the sand due to, for example, excessive lawn watering or broken water service, then any seepage through the sand that exits where there is rounded gravel backfill could cause internal erosion and piping with resultant formation of a sinkhole at the crest of the slope.”

2012 – The first sinkhole to affect a home at The Shore manifests. Thurber Engineering found a spring developed in May of that year, with a sinkhole collapsing without warning June 1 and “Additionally, there have been several instances of slope instability during and after construction.” But their conclusion was that “Given the low potential for internal erosion of the soils present at the site, we believe the most likely cause of the sinkholes is collapse of piping cavities.”

The city tried to address the issue by filling the hole with gravel while hiring consultants to assess the area with ground penetrating radar, land surveying equipment and aerial mapping. Thurber mentions several reports they reviewed but were not made public, including a 1997 report by Geotek Designs they quote as saying: “There are no indications of any threat of landslide.’ Geotek also states that ‘the land can safely be used for the use intended.’”

2013 – The District of Sechelt announces it has accepted a settlement offer of \$75,000 from Concordia Seawatch toward the community’s costs to investigate the sinkhole issue after council had approved “remedial action requirements.”

2015 – Another sinkhole forms, which renders a home uninhabitable; a lawsuit would follow. Thurber Engineering warns “identified voids and loose zones could develop into sinkholes in the future if measures ear [are] not taken to address the processes which contribute to sinkhole development.” **Urban Systems provides three solutions for dealing with the ongoing issue, the most comprehensive coming in at just shy of \$10 million. Urban Systems suggests a fourth option: “the closure of the subdivision, either partially or fully, and abandonment of infrastructure.”**

The District of Sechelt meets with Seawatch residents and tells them it won’t pay for a multi-million dollar solution, which doesn’t come with a guarantee of success and would require a 8.5 per cent property tax increase on all Sechelt residents to finance. [emphasis added]

Dec. 25, 2018 – Another sinkhole opens, 25 metres deep and four metres wide. Thurber Engineering suggests closing Seawatch Lane to vehicle traffic pending geotechnical assessment with warnings of the sinkhole hazard in the area. **Most chillingly, Thurber warns “Future sinkholes could damage existing infrastructure such as underground utilities, roads or sidewalks, or private property including buildings and retaining walls. Injury or even death is a possible consequence.”** [emphasis added]

February 2019 – The Seawatch subdivision is put on evacuation alert and begin packing their things.

Feb. 15, 2019 – The District of Sechelt declares a local state of emergency and the evacuation order is executed at 1 p.m. The same day, Ron Davis emails this statement to CTV News: “The developer of the Seawatch housing development, Concordia Seawatch Ltd., has great concern and compassion for the homeowners and families that are now being required to leave their homes. As the developer and others are currently involved in civil litigation relating to the Seawatch Development, we are not providing further comment at this time.” [emphasis added]

2020 – A trial claiming damages against the District of Sechelt and Concordia is slated to begin, stemming from a 2015 sinkhole.

Class Action Law Suit Against Quarry Operator For Past and Future Damages Settled

In 2003, a Circuit Court Judge of Munks Corner ruled that the settlement of a class-action lawsuit against Martin Marietta, operator of Berkeley Quarry, was fair.⁶⁷

Nearly two dozen Cross and Eutawville area residents began picketing Martin Marietta Materials' Berkeley Quarry last week, vowing to continue the protest until they get answers from company officials about payment for property damages they attribute to the blasting of limestone rock at the quarry....

In 2003, Circuit Court Judge Markley Dennis of Moncks Corner ruled that a class-action lawsuit brought against Martin Marietta by hundreds of area residents was fair. In the settlement, Martin Marietta agreed to pay \$1 million to be distributed among property owners with eligible claims, also known as "past claims" as defined in the 24-page settlement.

The settlement came after years of residents complaining about cracked driveways and foundations, discolored or "rusty" water, sinkholes and other property damages that could be attributed to the blasting of limestone rock at the Martin Marietta quarry in Cross, an active quarry for at least three decades. [emphasis added]

Protesters say the \$1 million settlement has been allocated but not fairly.

"Some of the people who got money shouldn't have gotten money because they live out of state ... and they just got property (land, not structures)," Wallace said.

Attorney Dawes Cooke of Charleston, the 2003 court-approved settlement administrator, told The Times and Democrat Thursday that "any property owner (within a five-mile radius of Martin Marietta) was entitled to make a claim ... "However, he said very little money has been awarded to landowners. He said he received a total of 675 "past claims," but some of the claims were rejected. [emphasis added]

Cooke said the \$1 million settlement fund was depleted last year [2008]. [emphasis added]

As part of the settlement terms, Martin Marietta agreed to annually replenish the Future Claims Fund with a maximum of \$100,000, "contingent upon the company having sufficient funds generated from five cents per ton of annual sales" at the local quarry, he said. [emphasis added]

From 2003 until April 2009, Cooke said he collected the "future claims" filed by Cross area residents, but protesters say they haven't been duly compensated for those "future claims" (meaning new damages allegedly caused by Martin Marietta's quarry work since the 2003 settlement). [emphasis added]

Martin Marietta is now handling the "future claims," says Paul Dominick, a Charleston attorney serving as legal counsel to the company.

In a prepared statement, Dominick said, "Future Claims must not be repetitive of prior claims, must be accompanied by supporting documentation and must be to compensate for damages caused by the Martin Marietta operations.

Dominick wrote that since taking over the claims process, "Martin Marietta has been working with class members to gather the appropriate documentation to support their Future Claims. All Future Claims will be reviewed by Martin Marietta within 60 days from Aug. 26."

He noted in the statement that since the settlement was reached in 2003, "Martin Marietta has gone beyond the requirements of the settlement agreement and spent a significant amount of time and

⁶⁷ Maratha Rose Brown, "'We need our money,' say picketing residents near MMM quarry," September 14, 2009, https://thetandd.com/news/we-need-our-money-say-picketing-residents-near-mmm-quarry/article_1075045c-1b39-54a2-9f0e-ac9b6c44c93f.html.

money in the Cross community drilling private wells and filling small holes on residents' properties without regard to whether the Martin Marietta operations impacted the properties."

The attorney said Martin Marietta "will continue to work with the class members and their counsel in the administration of the Future Claims fund."

Protester Carolyn Davis of 1467 County Line Rd. maintains that Martin Marietta has not kept its promise to the community.

Davis said her roof leaks, her yard contains numerous sinkholes and she's been forced to purchase bottled water for 33 years because of the "rusty water" produced by her inadequate well. She said Martin Marietta previously dug a new well for her but "it didn't work." [emphasis added]

"When the people blast at the quarry, pictures fall off the wall" of her home, Davis said. [emphasis added]

"I haven't received any money from them. My septic tank has sanked in, and I don't have good water yet," she added. [emphasis added]

Davis noted that prior to the development of the rock quarry, she didn't have any problems with her well and she wasn't faced with constant home repairs. [emphasis added]

J.W. Garrett, who lives about a mile from the Martin Marietta site, said when the quarry began operating about 35 years ago, "it didn't take them long to do the damage." The blasts at the quarry "feel like earthquakes," he said, adding that "a lot of people's wells went dry" when the quarry work began.... [emphasis added]

"We're certainly appreciative and realize the value of industries in Orangeburg County and what they contribute to our county in jobs and resources," [Orangeburg County Council Chairman] Wright told *The Times and Democrat*. ***"But citizens have their rights also in the democracy we live in to voice their opinions if they felt they were not treated fairly."***

Sinkholes Linked to Quarry Operations

This is a cautionary tale of a Stockertown quarry that has been identified as a major contributor to a rash of sinkholes responsible for disrupting traffic and damaging private property in Northampton County for years.⁶⁸

For the first time, a state official...publicly blamed a Stockertown quarry for contributing to a rash of sinkholes that has disrupted traffic and damaged property in parts of Northampton County for four years.

But Gary Hoffman, deputy secretary of operations for the state Department, stopped short of blaming Hercules Cement Co. for a sinkhole that damaged a northbound Route 33 Bridge in January [2004] and led to its \$3.5 million replacement as well as the state's decision to replace the southbound bridge.

Hoffman said it was PennDOT's fault the northbound bridge over the Bushkill Creek failed because the state did not take into account the geology when the space was built in the 1970s.

"We know that the quarry is unquestionably a contributor," Hoffman told residents and government officials at Memorial Library of Nazareth and Vicinity. "But to say it is 50 percent, 60% percent of the problem or 90 percent of the problem, I think none of us can say that." [emphasis added]

Hercules officials did not attend the meeting, which elected officials called to brief residents on an 8-month-old joint state and federal probe into the sinkholes and a new plan to slow sinkhole development in and around the Bushkill.

⁶⁸ <https://ei.lehigh.edu/envirosci/enviroissue/sinkholes/newspapers17.html>.

The sinkhole plan, which residents oppose and is being reviewed by the state Department of Environmental Protection and U.S. Army Corps of Engineers, calls for Hercules and PennDot to jointly line 850 feet of the creek, up to the state-owned land around the Route 33 bridges, with a synthetic material.

The state hopes the plastic membrane, which Hercules has a separate permit to use at two other stream locations further north, will stop creek water from draining into the ground and causing sinkholes. The lining would then reduce the amount of creek water flowing underground through sinkholes and into the quarry.

Hoffman said he knows the lining won't solve the overall sinkhole problem, but it's the best short-term solution to protect the bridges. He added the lining would help protect the creek if the Corps receives federal approval and local or state assistance to line more of the stream bed.

However, he said, if the joint plan is approved, PennDot would not begin its share of the work if studies show the lining would have a detrimental effect on residents downstream of Route 33.

Studies have shown that quarries can cause sinkholes when they pump groundwater out of their pits. The pumping creates a massive underground funnel called the "cone of depression" or "zone of influence." Groundwater is sucked up through the cone, which then buckles the surface above until a hole opens. [emphasis added]

Based on Hercules' own groundwater studies, which DEP uses as its official records, the quarry's cone is believed to cover 2.2 square miles, stopping on the east side of the northbound Route 33 bridge. The studies estimate Hercules' cone will grow an additional 1.3 miles when the quarry, now 300 to 330 feet deep, uses DEP's March 2003 approval to mine deeper. [emphasis added]

Although state officials previously acknowledged the size of Hercules' cone, no one said Hercules has contributed to the sinkholes, which began opening in 2000 when a Palmer Township family was forced from their home and the small Stockertown-Tamamy bridge was swallowed. [emphasis added]

DEP mining inspector Mike Menghini said...that although the state granted Hercules' a "conditional approval" to mine an additional 150 feet, the agency is now having second thoughts. [emphasis added]

We are not comfortable with them going deeper. We want them to go laterally," Menghini said. We could stop [the permit] if it shows an effect they cannot remediate, but then they can appeal that."

[Accelerated sinkhole formation in the study area by the infiltration of surface water through the beds and banks causes piping of soils and subsequent sinkhole formation at the ground surface near the stream. In order to prevent this infiltration, restoration activities that consider sealing the stream bottom or otherwise preventing the infiltrating water from piping or overburden soils are required. Bushkill Creek was historically stocked with brown trout but stocking no longer occurs due to the overall stream degradation due to human impacts. The significance of this project is that the restoration could improve the habitat conditions suitable for stocking to resume in this portion of the watershed. Fisheries officials indicate that future trout stocking plans could include Bushkill Creek if the habitat is restored.]⁶⁹

A review of potential groundwater impacts conducted by Terran Corporation⁷⁰ on behalf of Mad River Township Trustees and Village of Enon in connection with a proposed quarry application raised numerous concerns, some of which relate to *groundwater extractions and blasting*:

⁶⁹ "Congressional Fact Sheet," <https://ei.lehigh.edu/envirosci/enviroissue/sinkholes/factsheet.html>.

⁷⁰ Terran Corporation, May 15, 2017, <https://citizensagainstmining.org/wp-content/uploads/2017/03/Erdos-Ltr-Quarry-Model-Review-5-15-17-1.pdf>.

Blasting and groundwater extractions, in all cases, serve to reactivate and enhance karst, leading to sinkhole development (Lolcama et al., 2002). Quarry blasting may result in the destruction or disruption of groundwater flow paths, changes in the pattern of groundwater movement and changes in the quantity of water flowing through the karst system (Ekmeekci, 1993). There are documented occurrences of increases in turbidity of groundwater to wells and springs at limestone quarries that utilize blasting (Green et al., 2005). Any groundwater monitoring program designed for determining potential adverse effects of the proposed quarry operations in the carbonate aquifers beneath Mad River Township must pay special attention to the disturbances of blasting. How this will be assessed is completely missing in the current groundwater monitoring outline provided in the EAI report.

Should quarry operations create any adverse effects to existing groundwater wells, the stated remedial action options offered by Enon Sand & Gravel would include lowering of pumps, deepening of existing wells, or installation of replacement wells. These remedial actions might be plausible for some wells distant from the quarry whose water levels have not been lowered near the top of the Elkhorn shale. These remedial measures would not be successful for wells close to the quarry where essentially the entire thickness of the carbonate aquifer has been drained. There are no aquifers in the Elkhorn shale to deepen or replace the affected homeowner well. The proposed remedial measures would not be successful for well owners if the lower portion of the carbonate aquifer has minimal saturated porosity or lacks permeability. Also, these remedial measures would not address the taking of groundwater from owners whose groundwater levels have been lowered sufficiently to dry up springs on their property.

Missing from consideration in remedial measures of this permit application are remedies for property owners subjected to adverse water quality effects of the mining operations. Increased turbidity from blasting, bacterial or nitrate contamination resulting from accelerated induced recharge from lowered groundwater levels are two probable scenarios that need to be addressed.

Sinkhole in Quarry Zone of Dewatering Influence (ZOI) Leads to Condemned Dwelling, and Quarry Liability for Damages – Mass Sell-off of Homes Follows

As reported in the February 8, 2020 issue of The Frederick News-Post,⁷¹ a sinkhole caused a house to collapse, prompting officials to condemn it, and led to a mass sell-off of homes in the city of Frederick.

Jennifer Nelson was planning a funeral for a neighbor in September 2018 when she learned some concerning news.

A sinkhole had opened under her neighbor's house at 25 Hamilton Ave. in Frederick. Her home — the one she grew up in and purchased from her mother — at 27 Hamilton Ave. wasn't as damaged, but it raised concerns about whether her property was also at risk.

"On Sept. 11, 2018, our lives went from the normal hectic ... to being flipped upside down in a matter of minutes," Nelson told the House's Environment and Transportation Committee at a bill hearing this week. "A large sinkhole had opened up under my next door neighbor's home ... swallowing most of the house and the contents inside."

Nelson had cared for her elderly neighbor, helping him through hospice care before he died in August 2018. Because of her care, he gave her that house.

But roughly two weeks later, it was mostly destroyed by a sinkhole, which may have happened because of its position near a quarry, and the house sitting on karst terrain, a mixture of limestone and similar materials.

⁷¹ Steve Bohnel, "Del. Krimm introduces bill in response to sinkhole issue in Frederick," https://www.fredericknewspost.com/news/politics_and_government/levels_of_government/state/del-krimm-introduces-bill-in-response-to-sinkhole-issue-in-frederick/article_ca8fdccb-32da-5203-86f8-97143697fe92.html.

To combat issues like that, Del. Carol Krimm (D-Frederick) introduced a bill (House Bill 178) that would require real estate agents or homeowners to disclose that a property is prone to sinkholes opening up under their homes. [emphasis added]

More specifically, the bill notes that these properties are in “zones of dewatering influence” (ZOI), which means they have been marked by the state’s Department of the Environment as prone to sinkholes. [emphasis added]

Krimm noted in written testimony that since the ZOI was designated, 114 of 135 properties in Frederick have transferred ownership at least once. [emphasis added]

“Disclosure of this potential danger is necessary for informed decision making by a potential property purchaser, whether residential or non-residential,” Krimm wrote. “Sinkholes are a reality in Frederick, and in other communities with ZOI designations. There must be a duty to inform of the potential of such an occurrence for the safety of our residents, our business owners, and their patrons.” [emphasis added]

Tracy Coleman, deputy director of public works for the city of Frederick, told committee members that in cases of sinkholes opening up under homes — and lying in ZOIs — the Department of the Environment visits the site and determines if there is “proximate cause” involved with a nearby quarry. [emphasis added]

Coleman said in Nelson and her neighbor’s case, MDE determined the quarry was responsible for the sinkhole. Representatives from that quarry have appealed the decision, and it’s still in litigation, she said. [emphasis added]

Nelson, whose family has been relocated three times since the incident, declined to talk about the bill or case after the hearing, citing the litigation.

Bill Castelli, a senior vice president and lobbyist with Maryland Realtors, was in favor of the bill. But there are challenges to implementing it, he said, because the maps of ZOI from the MDE are not easy to find online. [emphasis added]

The disclosure should be akin to a “buyer notice” when someone sells their property, Castelli said. [emphasis added]

“We think it should be a simple disclosure that would catch the attention of the buyer and direct them to MDE to investigate it further, and then it would allow them to discover whether the property is in [the zone], or whether the property is out,” Castelli said. [emphasis added]

Jennifer Minnick, director of housing for Habitat of Humanity for Frederick County, said in written testimony that Habitat bought a property at 23 Hamilton Ave. without knowing whether it was in a zone of dewatering influence. [emphasis added]

Habitat helped Keysha Saxon, a single mother with three children, buy the house, noting it is handicap-accessible for her son, who uses a wheelchair.

“Where would Keysha and her family go if a sinkhole was discovered or in the process of forming? We cannot re-house them without having the funds to do so,” Minnick wrote.

She said after the hearing that it’s important for potential homeowners to know whether the risk of sinkholes exists, so they can look into buying insurance. [emphasis added]

Legislation Holding Quarry Operators Responsible for Well and Sinkhole Damages Within “Zone of Influence” Not Applied Retroactively⁷²

Medford Quarry's Wakefield Valley neighbors were told yesterday [April 9, 1996] that they may not look to the quarry owners to repair sinkhole damage or replace wells that went dry in the past five years -- a period when the mining industry fought a law that made it responsible for that kind of damage. [emphasis added]

Assistant Attorney General M. Rosewin Sweeney advised the Maryland Department of the Environment that quarry owners will become responsible for well and sinkhole damage caused by their operations only after the MDE adopts a "zone of influence [ZOI]" map outlining each quarry's area of responsibility.

C. Edmon Larrimore, head of the minerals, oil and gas division of the MDE's Water Management Administration, relayed the legal opinion to New Windsor-area residents at a hearing yesterday on the zone of influence [ZOI] proposed for Redland Genstar Inc.'s Medford quarry.

The Maryland Aggregates Association challenged the law soon after the 1991 General Assembly passed it and obtained an injunction that prevented state agencies from enforcing the law while it was under court challenge. The case ended in 1995 when the Supreme Court refused to hear a mining company's appeal.

The mining companies "bought four years of exemption by challenging the law," said New Windsor resident David T. Duree, chairman of the county Planning Commission.

The zone of influence [ZOI] outlined last night by MDE geologist Janine S. Mauersberg extends roughly from the branch of Turkeyfoot Run near Nicodemus Road on the south to 250 feet north of Little Pipe Creek on the north. On the east and west sides, it lies 300 feet beyond the edges of the limestone formation. Ms. Mauersberg called the line "conservative" because it extends beyond the water-bearing limestone into metabasalt, a harder, less porous rock.

The audience at the hearing ranged from residents who wanted their properties included in the zone to a developer [Powers Homes] who wanted his land removed.

Nicodemus Road resident Winston Griffin found the zone-of-influence line drawn through the center of his property, leaving it half in, half out.

"One of the headaches is that if you're on that line, the quarry is going to disavow any responsibility," he said. Mr. Griffin said he hasn't had problems with loss of well water but would like his entire property included in the zone.

Jeff Powers, president of Powers Homes, told the MDE officials that he would like his land excluded [from the ZOI]. "This is extremely detrimental to my development of the property," he said, adding that he believes the mining companies gain a limit on their liability through the law's application only to wells and sinkholes.

By holding quarries responsible unless they could prove damage did not result from their operations, the bill, sponsored by Richard N. Dixon, reversed a 1968 law that had made it difficult for nearby property owners to recover damages from mining companies. [emphasis added]

⁷² Donna R. Engle, The Baltimore Sun, “Quarry not held liable for damage Mining companies not responsible for drywells sinkholes,” April 10, 1996, <https://www.baltimoresun.com/news/bs-xpm-1996-04-10-1996101102-story.html>.

Ontario Karst Terrains

In 2013, at the request of MNR planning staff in the ministry's Southern Region, Ontario Geological Survey, provided a summary of some key geological investigation methods for addressing karst hazards in selected jurisdictions of Ontario.⁷³

One of the key objectives of this article is to address concerns of provincial staff involved in municipal land-use planning, specifically in eastern Ontario. The main purpose of this document is to provide a more comprehensive summary of the kinds of geoscience field work and data sets that could be integrated into field-based studies in order to address gaps in the current guidelines framework (e.g., Natural Hazards Technical Guidance documents for use with the current Ontario Provincial Policy Statement).

The mandate of the Ontario Geological Survey is to provide citizens and institutions of Ontario with accurate and objective earth science knowledge about Ontario, in order to sustain and support quality of life, economic prosperity, environmental quality, and public health and safety. The OGS does not comment on best practices or recommended approaches for reviewing and approving changes to land-use or development applications in karst terrains. [emphasis added]

Because karst is where you find it, concerns regarding structural collapse, and regulations and guidelines related to sinkhole hazards and subterranean caves are best addressed at the local or site specific level. Karst features presented in the OGS karst map (Brunton and Dodge 2008) and accompanying reports divided karst features into 3 main types:

- known karst,
- inferred karst, and
- potential karst.

Some of the main challenges concerning the production of comprehensive provincial policy statements and guidelines for conducting various forms of construction development and/or farming practices in karst terrains of Ontario include the fact that 1) the bedrock geology and nature of Quaternary sediments covering the Paleozoic bedrock vary across southern Ontario and 2) a number of the ministries involved in Provincial Policy Statement–decision making and in creating best practices documents have few or no Qualified Persons.

Because karst terrain development is tied to the interaction of aggressive waters and favourable rock types, it is essential that groundwater conditions and karst features are properly documented at both a local and regional scale. Solutionally aggressive waters associated with karstification are undersaturated in mineral phases of particular rock types (e.g., limestone, dolostone, gypsum) and enriched in carbon dioxide gas (slightly acidic), so dissolution of that material (rock) may arise until saturation in those mineral phases is achieved. Cave and spring precipitates (e.g., stalactites, stalagmites, tufa) result from supersaturation of groundwaters and resultant deposition of carbonate. Therefore, karstification involves both dissolution and precipitation geochemical processes associated with water–rock interactions. The presence of biological and/or organic compounds in soils and rock (e.g., bacterial activity and hydrogen sulphide and presence of organic compounds, such as oil, gas, and bitumen) also may increase carbonate solubilities and enhance karst terrain development.

Stage 1: Ministry Pilot Studies for Locally Based Karst Terrain Mapping

Stage 1 involves the compilation and use of available maps, satellite imagery, air photos and reports within a given study area to identify and delineate the location, distribution, physical characteristics of karst features and available data concerning surface water hydrology (drainage patterns on a seasonal basis) and groundwater quality. The Ontario Geological Survey has a

⁷³ F.R. Brunton, "Karst and Hazard Lands Mitigation: Some Guidelines for Geological and Geotechnical Investigations in Ontario Karst Terrains," *Earth Resources and Geoscience Mapping Section, Ontario Geological Survey*, December 2013, [file:///C:/Users/Windows%207%20PC/Downloads/FRB-2013-KarstHazard-Mitigation%20\(1\).pdf](file:///C:/Users/Windows%207%20PC/Downloads/FRB-2013-KarstHazard-Mitigation%20(1).pdf).

number of ArcGIS®-based data sets that could be integrated for a given development application or an application for a change in land-use planning. Data layers that should be included in such studies are the following: Karst, Bedrock topography, Physiography, Quaternary and Bedrock Geology, as well as hydrology and subsurface groundwater data. The complexity and associated costs of the initial desktop study of a geotechnical or engineering site investigation, only one component of which would be an examination of karst hazard concerns, would be dependent upon the nature of the development being proposed (i.e., ranging from a few thousand dollars for a single dwelling home with a septic system, to millions of dollars that would be required for the development of a nuclear facility).

Stage 2: Ministry Pilot Studies for Karst Terrain Mapping and Hazard Land Mitigation

Specific or Comprehensive Planning: address karst hazards directly by 1) field-based mapping of hazards (e.g., irregular surface drainage patterns and disappearing streams, presence of sinkholes, caves, solution-enhanced joints); 2) identifying compatible land-use activities; 3) establishing construction standards for development; 4) developing policies for addressing current inappropriate land uses; and 5) producing karst feature buffers that are specific to a given region and local set of land-use policies. This would involve restricting development around karst features through establishment of a fixed radius of no development or no storage of farm-related materials such as fertilizers or manure piles.

Structural Concerns: limit development that would require extensive blasting of carbonate or mixed carbonate–gypsum–evaporite bedrock, and/or intensive construction that would create excessive weight (large subdivisions, industrial parks) and/or alter drainage that could compromise underlying caves or buried sinkholes.

Surface Water and Groundwater Contamination Concerns: prevention of the construction of industrial point sources (e.g., chemical plants, dry cleaning facilities), waste lagoons, underground storage tanks, landfills and/or related changes in designation of land uses for either rural subdivision development (intensive septic system installations) or animal and crop agricultural uses. Land uses that drastically alter the position of local water tables and/or modify local drainage patterns, in association with inadequate storm-water management, may accelerate sinkhole subsidence and increase sinkhole and cave flooding in an unpredictable manner.

Geotechnical Studies: provide specific information relative to karst features through the identification and characterization of surface and deeper soils (overburden characterization – Quaternary geology studies), bedrock geology and an evaluation of local to regional hydrologic and hydrogeologic studies.

NEGATIVE ASPECTS OF LIVING IN KARST TERRAINS

- rapid drainage of rain and surficial waters may result in low water in wells during summer and reduced water supplies in late summer;
- rapid drainage or infiltration of waters into overburden and bedrock systems can transport waste contaminants from various sources (e.g., human, farm animal, nutrients, industrial) to groundwater drinking supplies;
- structural concerns, land subsidence and ground movements, resulting in property damage and possible threats to life—these are often induced by changes in land-use planning and redirection of surface waters and groundwater supplies.

Quarrying in Karst

According to Urich,⁷⁴ quarrying in a karst terrain has a number of adverse land use impacts, including the following:

2.7.1 Quarrying

In aesthetic terms, limestone quarrying is the most ‘obvious and, in both process and landform terms, the most dramatic anthropogenic impact on karst terrain’ (Gunn & Bailey 1991, 1993). The quarrying of limestone has both geomorphological and ecological impacts. The work of Gunn & Bailey (1991, 1993), Gunn & Hobbs (1999) and Hess & Slattery (1999) detailed these impacts in a British context. However, many of their findings are applicable to quarrying in any environment.

In essence, quarrying represents an intensification of the erosion process. In the case of Britain, the volume of material excavated would have taken up to 10 000 years to erode naturally. It is the rate of change that has dramatic and equally rapid impacts on hydrology and karst ecology. One of the more common impacts of quarrying is the drawdown of water in the subcutaneous zone surrounding the quarry. In some cases, this has led to doline formation. In other cases, the entire subcutaneous zone may be removed by quarrying activities and in such cases the impacts on local water resources and karst processes can be profound. When groundwater pumping is required to maintain a quarrying operation, the impacts typically affect a greater area than when pumping is not required. Groundwater drawdown can influence groundwater discharge from springs in the region of the quarrying operation, in terms of both quantity (seasonality) and quality of debouched water.

The stripping of forest cover and soil for quarry development destroys the karst ecology of the area earmarked for quarry development. Deposition of the spoils from these activities can also influence karst processes. The size and depth of the quarry has implications for the subsequent recolonisation of the environment by surrounding vegetation. With an increase in depth, it is correspondingly likelier that a different limestone composition will be exposed. Upon abandonment, the soil formed from this parent material could be significantly different from the surrounding environment, obviating the development of a complementary plant assemblage (Ruthrof 1997).

Gunn & Bailey (1991) assert that the size of a quarry is of less impact than its situation. They describe three possible locations for quarry development: on flat ground, along or into the side of a valley, or into a hill. Quarries developed in flat areas have less impact and this is restricted to the destruction of local karst features. Valleyside and hillside quarries are, however, favoured for their economy; it is easier and cheaper to work material laterally rather than vertically. Generally, hillside quarries have a greater geomorphological impact than valleyside operations. Cases of complete hill removal through quarrying have been documented (Stanton 1990; Urich et al. 2001).

⁷⁴ Peter B. Urich, “Land use in karst terrain: review of impacts of primary activities on temperate karst ecosystems,” Department of Conservation, Wellington New Zealand, June 2002, <https://www.doc.govt.nz/documents/science-and-technical/Sfc198.pdf>.

SECTION II – DOCUMENTED FLYROCK INCIDENTS

Flyrock 38

On April 5, 2017, at an opencast coal mine in Ramgarh District of Jharkhand State, a blaster's helper was killed after being struck by flyrock at a distance of 280 metres from the blast site.

The maximum possible travel distance of flying fragments based on different flyrock prediction models was 227 m. In the synonymous blast, only vertical throws of the flying fragments up to 70 m (approximate) height were observed. It was difficult to find out the exact cause of [the] flyrock incident. However, based on the detailed investigation, it was concluded that the possible cause of flying fragments travelling up to a distance of 280 m could be due to the presence of a weak zone in the rock strata.⁷⁵

Flyrock 39

On February 7, 2012, blasting at Moons Hill Quarry, Stoke St Michael, in the UK sent flyrock outside a danger zone toward employees and across a public road.

A Somerset company has been fined after a quarry blast sent rocks of up to 15 kilos flying outside a danger zone toward employees and across a public road. Falling rocks narrowly avoided hitting workers as they landed well outside the designated blast zone at Moons Hill Quarry...on February 7, 2012. [emphasis added]

Rocks also fell onto a public highway, exposing road users to unacceptable danger. [emphasis added]

Frome-based WCD Sleeman and Sons Ltd, who organised the blast, were prosecuted on February 27 after an investigation by the Health and Safety Executive (HSE) identified serious control failings.

Bristol Crown Court heard that workers acting as sentries outside the danger area were aware of rocks flying above their heads and landing all around them immediately after the blast. Rocks also landed in the processing plant area of the quarry, which is on the other side of a public road. [emphasis added]

HSE inspectors discovered that the blast had not been properly planned, that too much explosive was used in an area where the ground was already broken and measures put in place to reduce risks were inadequate.

Sleeman was fined £30,000 and ordered to pay £20,000 in costs after pleading guilty to breaching Section 3(1) of the Health and Safety at Work Act 1974. The court heard the firm was prosecuted after a similar offence in Devon when it was fined £20,000 with £17,000 costs in 2013. [emphasis added]

HSE inspector Catharine Pickett described the incident as “very serious” and put the public and employees at risk of death or injury. “Blasting operations at quarries are potentially very dangerous. The risks must be rigorously controlled by good engineering practice and in accordance with legal requirements. [emphasis added]

“Quarrying remains one of the most dangerous industries to work in with 3,250 injuries, including 27 fatalities, reported to HSE since 2000.” [emphasis added]

<http://www.hazardexonthenet.net/article/91111/UK-company-in-court-again-after-dangerous-quarry-blast.aspx>

⁷⁵ C. Sawmliana, Panchanan Hembram, R.K. Singh, S. Banerjee, P.K. Singh and P. Pal Roy, “An Investigation to Assess the Cause of Accident due to Flyrock in an Opencast Coal Mine: A Case Study,” *J. Inst. Eng. India Ser. D* (January-June 2020) 101(1):15-26.

Flyrock 40

In Pennsylvania in 1999, an equipment operator had stopped work clearing the crusher area near the blast site. He and his superintendent were parked in the usual spot, 800 ft [244 metres] away guarding the road. They were watching the blast. A baseball-sized piece of flyrock went through the windshield.

The victim died after surgery. He was only 32 years old. The supervisor was unharmed. Rocks flew 1,500 ft [457 metres] on that day.⁷⁶ [emphasis added]

Flyrock 41

[On August 15, 2019,] a Pangoula Farm woman on the outskirts of Harare died when a huge stone from a Lafarge quarry blast bore through the roof and struck her on the head. Shupikai Chitsana (36) who was in the kitchen died on the spot while her aunt was injured after a fly rock from Lafarge Cement quarry mine ripped through the roof and hit her in the head. [emphasis added]

...[T]he deceased is survived by her spouse and five children. [emphasis added]

After losing their mother due to irresponsible mining activities, the bereaved family was told by the government not to speak to anyone about the incident....

Lafarge Cement Corporate Affairs Manager Tawanda Njerere confirmed the incident and said investigations by the police and the Ministry of Mines and Mining Development are underway....⁷⁷

Flyrock 42

Blasting at *City Sand's* quarry on the outskirts of the City of St. John's, Newfoundland, led to a flyrock incident in 1988, which resulted in a temporary prohibition from blasting in certain parts of the 48-acre quarry on the outskirts of the City of St. John's, now in the Town of Paradise. A subsequent blast at the same quarry on July 3, 1998 resulted in flyrock that damaged two homes in the nearby Jane Heights subdivision (Elizabeth Park), and led to a permanent revision of the quarry's blasting plan to reduce the potential for flyrock.

From 1983, the Department of Mines and Energy [Newfoundland & Labrador] required a buffer zone of 300 meters between quarrying and a residential development. That requirement was a condition of the quarry leases issued to City Sand [and Gravel]....[T]he requirement of a 300 meter buffer zone was not a problem for City Sand in 1983 but became an issue in respect of residential development [of an infill 17-lot subdivision in Jane Heights approximately 225 metres from the quarrying activity] authorized [in 1985] for a nearby area, part of which was within 300 meters of the quarry's operations [para. 6].⁷⁸ [emphasis added]

Complaints respecting the effects of quarry blasting were received by Metro Board and provincial regulatory authorities from residents in Jane Heights in June 1986 and May 1988....The 1988 incident resulted in a temporary prohibition from blasting in certain parts of the quarry site. There were no further problems reported with further quarry blasting until July 3, 1998, when fly-rock caused damage to the garage of one resident of Jane Heights and to the roof of another [para 20].⁷⁹ [emphasis added]

In 1988, fly-rock from the blasting landed in the [300-metre] buffer zone. Blasting operations were subsequently prohibited in certain areas of the quarry....[On] July [3,] 1998, two Jane Heights residences were damaged as a result of fly-rock. City Sand was then required to

⁷⁶ <https://www.usgs.gov/special-topic/water-science-school/science/sinkholes>.

⁷⁷ <https://miningzimbabwe.com/woman-killed-in-lafarge-compound-after-cement-mine-blast/>.

⁷⁸ *City Sand and Gravel Limited and O.D. Holdings Limited v. Her Majesty the Queen in Right of Newfoundland, as represented by The Honourable Minister of Municipal and Provincial Affairs*, 2008 CanLII 1399 (SCC), <<http://canlii.ca/t/1vgkt>>, retrieved on 2020-07-10.

⁷⁹ *City Sand and Gravel Limited v. Newfoundland (Municipal and Provincial Affairs)*, 2007 NLCA 51 (CanLII), <<http://canlii.ca/t/1sfny>>, retrieved on 2020-07-11.

revise its blasting plan to minimize the potential for fly-rock. City Sand commenced an action in early 1998, claiming that the Respondent should be held liable in tort for damages to City Sand as a result of the significant costs incurred from the revised blasting plan. The Supreme Court of Newfoundland and Labrador, Trial Division, dismissed City Sand's action for damages, finding that no duty of care was owed by the Respondent to City Sand. The decision was unanimously upheld on appeal.⁸⁰ [Leave to appeal to the Supreme Court of Canada was denied.] [emphasis added]

The Buffers between the quarrying operations and the residential use or future urban development are intended to separate the two conflicting uses and to reduce the adverse effects of the quarrying operations on the other uses [par 17]. [emphasis added]

The buffer zone, by definition, is a neutral area designed to separate, in this instance, two inconsistent and adjoining uses. From an occupational health and safety perspective, it is a safety mechanism in the sense that should fly-rock or debris be ejected from the quarry site, as a result of blasting or other techniques, the likelihood of injury or damage to others is minimized. No evidence was placed before me to suggest the buffer zone is an area of usage to the plaintiff [City Sand and Gravel], that is granting the plaintiff [City Sand and Gravel] permission, in its operations, to eject rock or debris into this area and outside the boundaries of its leasehold realty property [para. 29]. [emphasis added]

City Sand understood from discussions with the Department of Mines and Energy, which issued the quarry leases, that there was a [300-metre] buffer zone around the quarry site. However, the quarry leases did not confer upon City Sand rights over property outside the quarry site [p.38]. [emphasis added]

A municipal authority reviewing a proposed residential development may owe a duty of care to future residents in respect of known hazards. Though City Sand emphasized that point, it did not acknowledge directly that its blasting, which entailed the inherent risk of fly-rock, exposed it also to liability in tort to those same residents. As City Sand had no right to eject fly-rock outside the quarry site, the respondent argued that Metro Board owed no duty of care to City Sand. The trial judge agreed – Trial Decision para. 56. I see no fundamental flaw in that position. City Sand carried on a legitimate but inherently dangerous operation. It constituted a danger to persons and property outside the quarry site. Prior to the development of Jane Heights, neither the owner of the land comprising that development, nor Metro Board, found it necessary to take legal action in respect of fly-rock landing outside the quarry site. City Sand could not however compel Metro Board to restrict development of adjacent land so that a public danger would not be created [para. 54].⁸¹ [emphasis added]

In my view, Metro Board in this case made a conscious policy decision to authorize the Jane Heights development. When, in June 1984, the development was found to be contrary to the Regional and Municipal Plans, Metro Board sought and obtained the approval of the Department and Minister to amend those plans via the Development Scheme. When the Development Scheme was adopted, Metro Board promptly amended its regulations in order to implement the Development Scheme and approved the development of Jane Heights. Throughout that process the decisions were taken at the highest level of Metro Board. The approval of the development was not "merely the product of an administrative direction, expert or professional opinion, technical standards or general standards of reasonableness"... The decision to allow additional residential development to the east of the proposed Outer Ring Road had financial, social and economic ramifications. Though not referenced in the Metro Board minutes, it is reasonable to infer that the

⁸⁰ Supreme Court of Canada Summary 32302 *City Sand and Gravel Limited, et al. v. Her Majesty the Queen in Right of Newfoundland, as represented by The Honourable Minister of Municipal and Provincial Affairs (Newfoundland & Labrador) & (Civil) (By Leave), file:///C:/Users/Windows%20PC/Documents/Supreme%20Court%20of%20Canada%20-%20SCC%20Case%20Information%20-%20Summary%20-%2032302%20City%20Sand%20and%20Gravel%20Flyrock.htm.*

⁸¹ *City Sand and Gravel Limited v. Newfoundland (Municipal and Provincial Affairs)*, 2007 NLCA 51 (CanLII), <<http://canlii.ca/t/1sfny>>, retrieved on 2020-07-11.

members of Metro Board were guided by such considerations. There was no evidence of improper factors entering into the deliberations of Metro Board [para. 51].⁸²

Buffer Zone Requirements for a Blasting Quarry Operation Increased

While *City Sand* was permitted to continue to carry out blasting operations based on a 300-metre buffer, which reduced the amount of onsite land available for extraction, there had been a growing awareness that a 300-metre buffer for the operation of a blasting quarry was insufficient to protect the health and safety of the public against “flyrock.” The concept of a buffer or buffer zone was in its early developmental stage when the problem of “flyrock” arose in 1988 between the *City Sand* quarry and the residents of the adjoining Jane Heights subdivision. (para. 64).⁸³

In 1996, in response to a growing awareness of “flyrock” as a public health and safety concern, the Department of Municipal and Provincial Affairs in its conditions for approval of a blasting quarry operation required that a 1,000-metre buffer zone be maintained from a cottage or residence.⁸⁴

In November 2018, *City Sand* announced that it would be closing the Paradise quarry, as, according to Larry O’Keefe, the quarry co-owner, “we’ve reached the back boundary of our property, which has a watershed behind us, so therefore we’re not allowed [to] continue going back into the ground, [a]nd with the construction of the [Outer] Ring Road 20-odd years ago [opened as a highway in 1998], it would make it unfeasible to construct our second lift of material.”

“The government had purchased land to the west of us, and [it] thought we would then be able to extract the rock from that piece of property.”

However, O’Keefe said, in the 1990s the zoning of the property changed from mineral workings to open space buffer — blocking City Sand and Gravel from using the land....

Mayor of Paradise, Dan Bobbett, said the town’s hands are tied by a municipal plan developed with an independent commissioner.

“It looked at all the growth in the Town of Paradise and looked at buffer zones, and in this particular one, we can’t do it because the commission basically said that you must obey these buffers,” Bobbett said. [emphasis added]

Residential homes are in close proximity to the blasting operation, he added. [emphasis added]

“In this case, the buffer zones are in place for the safety of our residents and we have to maintain those safety zones....”⁸⁵ [emphasis added]

Flyrock 43

On November 17, 2011, a blast at a quarry in Tremont, Maine, showered a nearby neighbourhood with flyrock that penetrated two (or possibly three) occupied homes, a workshop, a garage and a lobster boat, and caused extensive damage.

⁸² *City Sand and Gravel Limited v. Newfoundland (Municipal and Provincial Affairs)*, 2007 NLCA 51 (CanLII).

⁸³ *City Sand and Gravel Limited v. Newfoundland (Municipal and Provincial Affairs)*, 2007 NLCA 51 (CanLII).

⁸⁴ *City Sand and Gravel Ltd. et al. v. Newfoundland (Minister of Municipal and Provincial Affairs)*, 2005 NLTD 67 (CanLII), <<http://canlii.ca/t/fwvrv>>, retrieved on 2020-07-22, para. 20.

⁸⁵ Ariana Kelland, CBC News, November 8, 2018, <https://www.cbc.ca/news/canada/newfoundland-labrador/city-sand-gravel-closing-paradise-1.4896754>.

Bruce Rich was in his living room last week watching a movie, about meteors when rocks started falling from the sky around his house. [emphasis added]

But it wasn't rocks from space that pelted his home on Nov. 17, causing substantial damage. It was rocks from a quarry a few hundred yards east of his house, where a contractor had detonated explosives to blast away rock from a ledge. [emphasis added]

Rich, a lobster fisherman, said Friday that a large rock "as big as a TV tray" came through his bedroom wall, smashed through his bedroom door and came to rest in another bedroom. Debris from the blast also flew through a wall of his adjacent workshop, smashed five of his lobster traps and put rips and dents in his roof, which he said will have to be reshingled. [emphasis added]

On Friday, a shard of rock the size of a man's hand still protruded from an interior wall next to Rich's bedroom door.... [emphasis added]

He estimated that "thousands" of rocks of varying sizes sailed over the trees between his house and the quarry and landed on his Spruce Lane property. [emphasis added]

"It was raining rocks outside the window," Rich said. "The big one didn't hit where I was sitting or I would have been killed. I'm very upset." [emphasis added]

Danielle Neal, who with Jerry Harper lives next door to Rich, said Friday afternoon that rocks from the blast struck the house they live in. Rocks punctured the roofs of their house and garage, the body of an older truck inside the garage, and bent the frame of an all-terrain vehicle in their yard, demolishing it, she said. A large rock also smashed through the side of Harper's lobster boat, which is sitting on blocks outside their house. [emphasis added]

"It's fortunate no one got killed," Neal said. "I think there should be more regulation over [blasting]." [emphasis added]

Neal said she and Harper have consulted with an attorney to explore their options, but that they "don't know how far it's going to go." [emphasis added]

The contractor who set the blast said Wednesday that he has apologized to Rich, Neal and another nearby homeowner whose house also was hit, though to a lesser extent, by the flying debris. Drilling and Blasting of Exeter was blasting ledge at the quarry, which is owned by local contractor John Goodwin Jr. [emphasis added]

David Eastman of Northern Drilling and Blasting said Wednesday that his firm has been blasting in that same quarry on and off for a decade and has never had a problem before.

He said that on Nov. 17, he used 6,500 pounds of an "emulsion type" of explosive in the blast. He has licenses from the State Fire Marshal's Office and the federal Bureau of Alcohol, Tobacco and Firearms to transport and store the explosives, he said....

Eastman said he made sure Rich's house was sealed up right away and, on Monday, sent a carpenter to Rich's house to begin repairing the damage. Rich, however, sent the carpenter away before he could get to work, he said....

Rich said Friday that the carpenter showed up Monday before anyone from his insurance company had seen the damage. He said that he expects the same carpenter to come back next week to do an estimate, but that he expected to solicit estimates from other carpenters, too.

Rich said he has consulted with an attorney, but he has not decided what he will do. He has not ruled out filing a law suit against the contractor, he said. [emphasis added]

"I don't know yet," Rich said. "I can't sleep. My blood pressure is up and everything. I don't feel safe here no more." [emphasis added]

Inquiries made this week to state agencies about the incident suggest that Eastman's company might not face any regulatory penalties for damaging the homes.... [emphasis added]

Millard Billings, Tremont's town manager, said Friday that Tremont does not have any sort of blasting ordinance, but it might by next summer.

He said he has been asked by the town's Board of Selectmen to approach the planning board so a blasting ordinance can be drafted and submitted to voters for possible adoption at the annual town meeting in May. He said he plans to raise the issue with the planning board when it meets this coming Tuesday.

What kind of requirements the town might impose on blasting, Billings said, has not been determined. Town officials likely will consider requiring blasting contractors to be insured, to be properly licensed by the appropriate state and federal agencies, and perhaps to follow other precautions such as using protective blast mats.

"It depends how in depth they want to get into," Billings said.⁸⁶

Flyrock 44

As reported in a regulatory update of the Division of Mineral Mining (DMM), Virginia,⁸⁷

In October 2008, a volleyball size rock was thrown 1,700 feet [518 metres] hitting a MCC building located 100 feet from the jaw crusher operator's booth. The crusher was manned and operating at the time.

Flyrock 45

As reported in *Dept. of Energy v. Hobet Mine & Const.*, 358 S.E. 2d 823 (1987),⁸⁸ Burton N. Lay, an employee, was paralyzed after being struck by flyrock at a distance of 1,115 feet (340 metres), for which the operator of the mine was fined a nominal sum of \$1,000, a fine that was overturned on appeal. In a previous incident, flyrock had travelled in excess of 1,500 feet (457 metres).

This case arises from an accident at Hobet Mining Company's strip mine located in Boone County. Hobet was in the process of removing material known as innerburden to reach a coal seam at Hobet Mine No. 21. The ordinary procedure for removing innerburden is to drill holes into the strata, pack the holes with explosive charges, detonate the charges, remove the shattered material and repeat the process. After one such charge was detonated, Burton N. Lay was struck in the back by a piece of fly rock that had traveled 1,115 feet. His resulting injuries required extensive medical treatment and he is now permanently paralyzed from the mid-back down. [emphasis added]

The West Virginia Department of Mines investigated the accident. Their findings determined that the procedures used in setting and detonating the blast that injured Mr. Lay at Hobet No. 21 was the standard procedure at Hobet, and that Hobet had experienced fly rock traveling in excess of 1500 feet before. Nonetheless, Hobet continued to allow employees to place themselves in unsheltered positions at various distances from explosive charges while they were detonated. Based on these facts, the Department issued a notice of violation to Hobet for failing to maintain a safe blasting area as defined in West Virginia Administrative Rules and Regulations, Series III, § 3.32. [emphasis added]

Following a full evidentiary hearing before the Department of Mines Hearing Examiner, Hobet was assessed a fine of \$1000.00 for not maintaining a safe blast area. Hobet appealed to the Kanawha County Circuit Court. The circuit court, by final order on 10 May 1985, reversed the hearing

⁸⁶ Bill Trotter, "MDI homes pelted with rocks from errant quarry blast," November 25, 2011, <https://bangordailynews.com/2011/11/25/news mdi-home-pelted-with-rocks-from-errant-blasting/>.

⁸⁷ "Blasting Regulation Changes and Flyrock," Division of Mineral Mining, Created 2009, <https://www.dmm.virginia.gov/DMM/PDF/TRAINING/REFRESHER/lawchanges/ARBlastingRegChanges2009.pdf>.

⁸⁸ https://scholar.google.com/scholar_case?case=1714891186629936566&q=fly+rock&hl=en&as_sdt=2006

examiner's decision. The circuit court applied a higher standard of proof than that applied by the department and held that there must be a knowing violation.

Flyrock 46

A 2008 YouTube video posted online by WorkSafeBC describes a flyrock incident in Barnaby, which caused injury to a worker and damaged vehicles and equipment. One flyrock weighed 140 kilograms (309 pounds) and was propelled 250 metres.⁸⁹

At this site a blaster initiated a 100-hole open face blast. Flyrock flew up to 250 metres. 14 pieces of parked equipment and several vehicles were damaged. The force of the blast was so powerful that this 140 kilogram rock flew 250 metres all the way to the entrance of the construction site. A blaster must ensure that the danger area is clear of workers and is kept clear during the blasting operation but at this site five workers were put at risk by being allowed to stay within the danger area of the blast. One worker was struck by a small piece of flyrock and another worker suffered abrasions as he ducked for cover.....

Flyrock 47

A 2012 article *Environmental and Safety Accidents Related to Blasting Operation* authored by Kricak *et al.*,⁹⁰ includes an overview of the incidence of flyrock in various jurisdictions, and presents a case study of a flyrock incident in an unnamed andesite quarry in an unidentified location. The flyrocks, consisting of 3 rocks up to 50 centimetres (1.64 feet) in diameter, were propelled a distance of about 300 metres and caused extensive external and internal damage to a neighbouring home.

A field-scale investigation related to flyrock accident was conducted in an andesite quarry where rocks up to 50 cm in diameter were propelled almost 300 m from the center of blasting field causing extensive damages to the surrounding objects. The study revealed that accident occurred due to the existence of andesite alteration in one section of the blast field. The existence of this alteration caused a sliding of rock masses along the subsistent joint planes and thereby reduced burden for the second row of blastholes. Alterations involved small area of andesite masses that were not detected by previous geological exploration or visually observed prior to initiation of blastholes [p. 360]. [See Figures 1, 2 and 3 at page 361 for photos of property damage and flyrocks that caused the damage.]

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On July 15, 2015, blasting at a construction site in Johor, Malaysia, propelled flyrock a distance up to 200 metres from the blasting face, killing a nearby factory worker and injuring two other workers, and damaging several vehicles.

...[O]n the day the blasting, an unprecedented catastrophe occurred in which a part of the rock mass approximately 2,000 m³ from blasted granite flew away for a distance up to 200 m from the blasting face. From site survey, it was found that the size of the fly rock varied from 5 cm³ to 0.3 m³. Figure 1 shows the location of the areas involved. As a result of the explosion, unexpected fly rock covered surrounding area of the location. This unexpected accident killed a worker and injured two others. Workers involved were about 150 m to the west of the blasting location. Several vehicles

⁸⁹ "It Was Raining Rocks." <https://www.worksafebc.com/en/resources/health-safety/slide-shows/accident-snapshot-fly-rock-from-blasting?lang=en>.

⁹⁰ Lazar Kricak, Vladislav Kecojevic, Milanka Negovanovic, Ivan Jankovic and Dario Zekovic, *American Journal of Environmental Science*, 2012, 8 (4), 360-365, file:///C:/Users/Windows%207%20PC/Downloads/ajessp.2012.360.365%20(2).pdf.

were also destroyed and damaged. Some small fragments flew to a factory in southwest (about 50 m away). Figures 2 to 4 show the effect of the blasting [p. 16].⁹¹

...[I]t...[was] concluded that in present case study geological structure of rock-discontinuity of rock in west contributed to fly rock and blasting practice of blast design, communication, security arrangement, evacuation of persons from blasting zone, resulted into fly rock accident [p. 20].

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⁹¹ Edy Tonnizam Mohamad, Bhatawdekar Murlidhar, Danial Jahed Armaghani, Rosli Saad and Chang Shiang Yi, "Effect of Geological Structure and Blasting Practice in Fly Rock Accident at Johor, Malaysia," *Jurnal Teknologi, Sciences & Engineering*, 78: 8-6 (2016) 15-21, <file:///C:/Users/Windows%207%20PC/Documents/Effect%20of%20Geological%20Structure%20and%20Blasting%20March%202016%20Mohamad%20et%20al.%20a522b38e6c1a32fe5710c323e99ee69e459f.pdf>.