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Preventing the Potentially Deadly Consequences of Flyrock: Mandatory Minimum Setbacks and Separation Distances Required

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Abstract

Detonation of explosives is the principal method used in extracting rock in a quarry operation, and leads to a number of *adverse effects* on the environment and its inhabitants. The engineers associated with the aggregate industry and its explosives have been remarkably successful in concealing from the public, including land use planners, mortgage lenders, real estate brokers, real estate appraisers, etc., the existence and danger of *flyrock*, which is the ultimate *adverse effect* of a blasting quarry operation, and a significant health and safety issue. Flyrock is an unavoidable and unpredictable by-product of blasting rock, and because of the way in which flyrock is defined or characterized varies from jurisdiction to jurisdiction the incidence or frequency of flyrock is understated and underreported. Flyrock has the potential to damage personal and real property, and to injure, disable permanently or kill human and non-human life. The purpose of this research paper is to create public awareness of flyrock, to dispel the notion that flyrock can be eliminated by the use of empirical formulae, and to support the argument that the only effective remedy to protect the environment and health and safety of onsite quarry employees and offsite third parties is by way of permanent onsite setbacks and offsite separation distances.

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Keywords

Flyrock; Mining; Explosives; Public health; Environmental health

Introduction

As noted below, there is no standardized definition of flyrock, which complicates understanding the potential *adverse effects* associated with blasting rock. More disturbing is the absence of a definition of flyrock in jurisdictions such as Ontario, Canada, pursuant to the Aggregate Resources Act (ARA),[1] and the failure of engineers engaged in explosives to even mention flyrock in the preparation of a proponent-driven Blast design report (Blast Impact Assessment (BIA) report)[2]. Coupled with the lack of a definition of "blast area", Ontario's ARA, also undefined in BIAs, is incapable of protecting the public from the potentially deadly consequences of flyrock (Verikas, 2009), a task best left to local municipalities through the enactment and implementation of effective land use policies. Various definitions of flyrock are as follows:

- *"Flyrock is rocks propelled from the blast area by the force of an explosion."*[3]
- *"Flyrock means rock that is propelled through the air from a blast."*[4]
- *"Flyrock means any material propelled by a blast that would be actually or potentially hazardous to persons or property."*[5] [The Virginia Register of Regulations does not define "blast area."]
- *"Flyrock is anything that is thrown by a blast and lands outside the blast area."*[6]
- *"Flyrock can be gravel, rocks, tree trunks, construction materials, mud—even water [p. 3]."*[7]
- *"Flyrock is unwanted throw of rock fragments during bench blasting in mines and civil construction"* (Raina, Murthy and Soni, 2014)
- *"Flyrock is a rock fragment propelled from a blast face under the impact of explosive gases that travels beyond expected distances"* (Raina, Murthy and Soni, 2015).
- *"Flyrock, a rock fragment thrown to an excessive distance, is a random event and an ongoing problem in opencast bench blasting"* (Raina *et al.*, 2011).
- *"Flyrock – the fragments of rock thrown and scattered during blasting – is responsible for a large proportion of all blasting-related injuries and fatalities."*[8]
- *"Flyrock is defined as the rock propelled beyond the blast area by the force of an explosion."*[9]
- *"Flyrock is defined as blasted material cast into the air, or travelling along the ground, that is cast from the blasting site more than half the distance to the nearest dwelling, public building, school, church; commercial, community or institutional building; or any occupied structure; or that is cast beyond the permit boundary"* (Campbell, 2008).
- *"Throwing rock fragments from blasting at distances greater than the safe area, which can result in human injury, death and structural damage"* (Pimentel, 2022).

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1 *Ontario* Aggregate Resources Act, R.S.O. 1990, c. A.8, as amended, Available online at: https://www.ontario.ca/laws/statute/90a08 [accessed on December 18, 2022].

2 Aggregate resources of Ontario standards: A compilation of the four standards adopted by Ontario Regulation 244/97 under the *Aggregate Resources Act***.** https://files.ontario.ca/mnrf-aggregates-combined-standards-en-2020-08-27.pdf [accessed November 2, 2022]

3 International Society of Explosives Engineers (ISEE) Blaster's Handbook, General Definitions, https://www.dep.pa.gov/Business/Land/Mining/BureauofMineSafety/Training/BlastingTerms/Pages/default.aspx.

4 https://docs.legis.wisconsin.gov/code/admin_code/sps/safety_and_buildings_and_environment/301_319/307.pdf.

5 http://register.dls.virginia.gov/vol33/iss07/v33i07.pdf.

6 The National Institute for Occupational Safety and Health (NIOSH), Mining Product: Toolbox Training on Flyrock Awareness, December 2005, https://www.cdc.gov/niosh/mining/works/coversheet1824.html.

7 Workers Hazard Alert issued by the National Institute for Occupational Safety and Health (NIOSH), 2019

8 Mine Safety and Health Administration. Flyrock Dangers & Best Practices, Mar 24, 2016, https://www.msha.gov/news-media/announcements/2016/03/24/flyrock-dangers-best-practices.

9 IME [2007]. Glossary of Commercial Explosives Industry Terms. Safety Publication No. 12, Institute of Makers of Explosives, 1120 Nineteenth Street, NW, Suite 310 Washington, D.C. 20036-3605, pp. 16.

- *"Rock fragment projected in different directions beyond the expected and desired blast distances, due to design error and/or its application and/or the presence of adverse rock conditions that favor the escape of pressurized gases from the blast"* (Pimentel, 2022).
- *"Also called homing pigeons, this is nothing more than the launch [of flyrock] that usually reaches 5 to 10 times the distance of the normal launch, and occasionally much more"* (Pimentel, 2022).

What can be gleaned from the various definitions of *flyrock* is that flyrock can occur either onsite or off-site, or in both locations simultaneously, and launch in different directions, when blasting is undertaken at a quarry, and that neither onsite quarry employees nor third parties living, working or playing in the areas encompassing an operational quarry should ever be exposed to the potentially deadly consequences of being struck by flyrock. Further, as noted by Dataphyte, the majority of flyrock incidents are unreported or unnoticed:

> *[A 2021 investigation by] Dataphyte reviewed that globally, the majority of flyrock incidents go unreported or unnoticed, and in most jurisdictions, incidents of flyrock that do not leave the blast area or that do not cause injury or death within or outside the blast area are not officially reported* (Uthman, 2021).

And, even undetected flyrock that lands harmlessly beyond the lot boundaries of a blasting quarry operation has the potential to cause damage and harm:

> *A rock that lands harmlessly in a field may not appear to be a large issue. However, mowing and tilling become hazardous when rock is struck by farm equipment.*[10] *Rock through timber stands mar trees and potentially impact the market value.*[11]

As flyrock can be launched a considerable distance from the blast area, and in more than one direction,[12] safeguarding against the danger of flyrock from a proposed blasting quarry operation can only truly be achieved by imposing a permanent onsite setback (extraction limit or exclusion zone) of sufficient width within the boundary limits of a proposed blasting quarry operation. External separation distances are also required to prevent encroachment on sensitive or incompatible existing and future land uses during the expected life of a proposed quarry operation.

Flyrock incidents occasioned by blasting rock are not determined on the basis of excessive launch (travel distance), and that even the best blast designs can cause flyrock to launch a considerable distance due to a variety of interrelated reactions, unknown or unexpected conditions or human error (Kecojevic and

[10] In 2017, a Tasmanian family, Peter Guichelaar and his wife Sharon, who own a 377-hectare (932-acre) farm next to "The Gums" quarry, were still finding *flyrock* on their farm 13 years after blasting at the quarry had stopped. *The last blasting over 13 years ago generated so much flying rock that we are still collecting them .If a blast occurs during the growing crop, the whole crop is lost forever, since we cannot mow the paddock anymore due to severe damage to our mower. We recently had to replace a mower at a cost of $25,000 because of damage done by rocks that are still close [to] the border next to the quarry from the previous blast 13 years ago [p. 32].* https://www.flinders.tas.gov.au/client-assets/images/Council/Downloads/Agendas/2017.10/Annex%204B.%20A1.%20Representations.pdf.

[11] Controlling the Adverse Effects of Blasting, Module 8, https://www.osmre.gov/sites/default/files/inline-files/Module8.pdf, accessed on December 20, 2022.

[12] DGMS Circular No. 2 (31/01/2003), India, references an incident where a blast at an open cast coal mine launched projectiles (flyrock debris) a distance of about 412 metres in the reverse direction away from the face, and that hit a mechanical supervisor. In the interest of safety, and to prevent ejection of flying fragments, all places with a radius of 500 metres of the place of firing (blasting) must be treated as the danger zone. https://elibrarywcl.files.wordpress.com/2015/02/dgms-all-circular-2003.pdf.

Radomsky, 2005), incompetence[13] or negligence.[14] Flyrock can occur independently of movement of the blast, and that is why "there are no specific techniques to control or prevent flyrock," according to Pimentel (2022).[15] Because there is no way to control or prevent flyrock, there is no acceptable level of risk. Blasting in respect of aggregate extraction involving consolidated aggregate (solid rock) is typically associated with a quarry, which is defined as follows:

> *"Quarry" means land under water from which consolidated aggregate is being or has been excavated, and that has not been rehabilitated, but does not mean land or land under water excavated for a building or structure on the excavation site…[and usually involves blasting to break rock]. (Ontario Aggregate Resources Act, R.S.O. 1990, c. A.8, as amended)*

Like Ontario's ARA, as noted by Rehak *et al*. (undated), the United States Occupational Safety and Health Administration's (OSHA) Technical Manual does not address the prevention of flyrock or determination of blast area limits:

> *"…[T]here are no specific topics…which address the prevention of flyrock or blast area limits."*

According to Birch and Datson (2009), the most contentious environmental impact experienced by residents living adjacent to quarries and surface mines are those produced by blasting (Tetteh, 2018). Blasting is not an exact science, and every blast produces unique environmental effects (Vellone, undated). Of the numerous deleterious effects which can result from blasting rock with explosive charges, flyrock is considered the most dangerous of those listed below:

- Gases or toxic fumes generated by detonation of the explosive charge, which typically consist of carbon monoxide and nitrogen oxides, are a health risk (Mainiero, Harris and Rowland III, 2007).
- Dust generated from the fracturing of rock by blasting can cause eye and breathing problems, and, at high levels, can lead to silicosis, respiratory diseases, cancer and premature death (DiGiovanni, 2020), and safety issues due to poor visibility, disrupt both indoor and outdoor employment, social and recreational activities, and clog appliances and mechanical equipment such as HVAC systems.[16]
- Noise from blasting or repeated blasting, which is defined as annoying sounds, can be perceived by humans[17] (and non-humans, e.g., pets, livestock, wildlife[18]), and can cause a number of short- or

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[13] Black's Law Dictionary, *Centennial Edition (1891-1991)*, defines *incompetence* as "lack of ability, knowledge, legal qualification or fitness to discharge the required duty or professional obligation."

[14] Black's Law Dictionary, *Centennial Edition (1891-1991)*, defines *negligence* as "the omission to do something which a reasonable man [person], guided by those ordinary considerations which ordinarily regulate human affairs, would do, or the doing of something which a reasonable and prudent man [person] would not do."

[15] https://www.linkedin.com/pulse/flyrock-part-01-03-blasting-trainings/.

[16] *Hanna v. Brady*, 327 S.E. 2d (1985), NC App., https://scholar.google.ca/scholar_case?case=14374630816441889017&q=%22dust%22+AND+%22quarry&hl=en&as_sdt=2006.

[17] A vast number of complaints (St Marys Cement Community Relations Committee, September 11, 2018 meeting) lodged over a number of years by neighbouring homeowners at a considerable distance from the 556-acre Bowmanville quarry are related to blasting (i.e., noise and vibration) even though St Marys (Votorantim Cimentos) has an agreement with the nearby OPG Darlington Nuclear Generating Station, about 5 kilometres away, to ensure that St Marys' blasting "do[es] not result in ground movement greater than three millimetres per second [3mm/sec] [para. 66], which is far below the 12.5 mm/sec Peak Particle Velocity (PPV) guideline recommended by the *Ontario* Ministry of the Environment, Conservation and Parks (MOECP). (Record of Proceedings, Including Reasons for Decision, Dec 3 to Dec 6, 2012, Application to Renew Power Reactor Operating Licence), http://nuclearsafety.gc.ca/eng/the-commission/pdf/2012-12-03-Decision-OPG-DarlingtonNGS-e-Edocs4095954-final.pdf.. The closest residence is 250 metres from St Marys' quarry, which operates between 10 and 20 hours each day, and St Marys has refused to engage community members regarding shoreline erosion at Cedar Crest Beach, for which St Mary (Votorantim Cimentos) is responsible. (Clarington Resolution #C-276-19, Report CAO 006 19 – Cedar Crest Beach Update [Referred from June 17, 2019 General government Committee Meeting]).

[18] Veterinarian Dr. Lisa Dietrich (Public hearing, Troy Sand and Gravel blasting quarry application, Town of Nassau, NY, July 13, 2015) testified that "domestic animals are clinically affected by dust, allergens and other irritants that may result from blasting at the quarry, and suffer stress from anxiety related to equipment noise and blasting noise. We [the Town Board of Nassau] think that those same things could also cause safety concerns for the handlers of those animals. It is reasonably

long-term health issues such as stress, anxiety, hearing impairment, etc., and interfere with sleep, concentration, communications and use of indoor and outdoor amenity and workspace (Kulabako, 2016).[19]

- Airblast (or air vibration, air overpressure or airborne shockwave from blasting, in the form of concussion waves[20]) travels through the air at the speed of sound, and impacts structures through the roof, walls and windows, and can rattle or break windows, dislodge and damage wall-mounted art works or break fragile home furnishings (e.g., crystal, china, etc.).
- Ground vibration from a single blast or repeated blasts (even if subsequent blasts are of less intensity)[21] can cause damage to structures (Sayed-Ahmed and Naji, 2013) or site improvements, or worsen existing damage to structures or site improvements (even at a considerable distance),[22] or damage underground utilities such as gas pipelines and vaults.[23]
- Flyrock can cause injury or death to human and non-human life[24], and damage personal and real property, both onsite and offsite.
- Blasting that causes real property damage reduces property values (Kreder, 1949), which results in loss of homeowner- or investment-equity, and reduces a municipalities' realty tax base.

Blasting can also fracture underground caverns, rerouting natural water systems and displacing local species, according to Langer, a geologist who spent four decades with the U.S. Geological Survey (Carey, 2022).

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foreseeable that there could be impacts on domestic animals which could result in added expenses for the household, lower the animal's quality of life, and as related to agriculture, reduce farming and agri-tourism opportunities." The quarry application was denied by the Town of Nassau.

19 As reported by Kulabako (2016), the United States Census conducted in 2000 found that 30% of Americans complained of noise and 11% found it bothersome. Among those who complained, 40% found noise sufficiently bothersome to make them want to change their places of residence (U.S. Census Bureau, 2006).

20 The overpressure at several thousand feet from a blast can be similar to that of a sonic boom, whereas the duration of the pressure perturbation is several times longer for a blast than for a sonic boom. The damage and annoyance criteria developed from sonic boom research may reasonably be applied to quarry blasts. It was also found that in many instances the acoustic wave can be of greater significance than ground vibration induced by the same blast. Also see Taylor (1975).

21 In *Cage Brothers v. McCormack et al.*, 344 S.W.2d 203 (1961), the Texas appellate court held that repeated blasting at a limestone quarry had damaged four houses distant as far as 1,200 feet (366 metres) from the blasting area. One piece of "flyrock" weighing 85 pounds was launched 730 feet (223 metres). Dr. Tonn, the homeowners' expert testified that repeated blasting has a cumulative effect of causing cracks from initial blasts to widen or worsen, even if subsequent blasts are of a lesser intensity. https://scholar.google.ca/scholar_case?case=10141646206778100249&q=%E2%80%9Cblasting+damage%.

22 In *Birmingham Coal & Coke Company v. Charlotte Johnson et al.*, 10 So. 3d 993 (2008) vibrations from blasting at the surface coal mine damaged 10 houses. The distance to the 10 houses from the point of the blasting ranges from 2,875 feet (876 metres) to 4,779 feet (1,457 metres). Homeowners for each of the 10 houses were awarded damages either for diminution in value of their property or the cost to repair. The Alabama Supreme Court ruled in favour of the homeowners finding that "the plaintiffs proved by substantial evidence that the use of explosives in this case [was] under abnormally dangerous conditions and proximately caused severe damage[] to the plaintiffs' dwellings," while rejecting the defendant's defense that "the blasting was conducted to State regulations." https://scholar.google.ca/scholar_case?case=17351879806006460280&q=%E2%80%9Cblasting%E2%80%9D+AND+%E2%80%9Cemotional+distress%E2%80%9D&hl=en&as_sdt=2006.

23 In *Jones et al. v. Consolidated Coal Company*, 174 Ill. App. 3d (1988), 528 N.E. 2d 33, the Appellate Court upheld the lower court's award of $14,850 to the Jones for property damage from vibrations caused by blasting at Burning Star No. 3 mining operation, which at its closest point was 2,000 feet (610 metres) from the Jones' residence. In 1978, the Jones felt strong vibrations from the periodic blasting at the mine, and noticed damage to their residence and outbuildings. "The damage included cracking plaster and fireplace, separation of paneling and a kitchen countertop from the wall, sagging kitchen floor, and water damage. In addition, they noticed cracking in the concrete floors of their garage and barn."

24 On June 3, 1996, at Lochmaddy Sheriff Court in North Uist, McAulay Askernish Ltd was convicted under the Health and Safety Act for failing to ensure the safety of the villagers of Askernish in South Uist. A blast at the quarry in the village of Ashernish in South Uist, Scotland, launched flyrock debris almost a half-mile (805 metres) onto a row of council houses where families were watching the operation. While no humans were injured by the flyrock debris from the blast, falling rocks killed two sheep and injured another three that had to be put to death. https://www.heraldscotland.com/news/12120284.quarry-firm-fined-for-unsafe-blast/.

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Characterization and Unpredictability of Flyrock

Flyrock is an ever-present danger wherever blasting occurs, and, therefore, *flyrock* must be dealt with proactively and explicitly by municipal/regional planning authorities as part of an application to permit a blasting quarry operation. Flyrock has essentially three initiation mechanisms (Masir, Ataei and Motahedi, 2020; Ghasemi, Sari and Ataei,2012), which apply to each blast-hole and are described briefly as follows:

- *Face bursting:* This occurs when explosive charges intersect or are in close proximity to major geological structures or zones of weakness. The high-pressure gases of the explosives move along the least resistance paths and generate flyrock.
- *Cratering:* This occurs when the ratio of stemming height to blast-hole diameter is too small or the collar rock is weak, and causes flyrock to be launched.
- *Rifling:* This occurs when stemming materials are insufficient or absent. Blast gases move along the path of least resistance, and then the stemming materials, and sometimes the collar rock, are violently ejected as flyrock.

According to Jackson (2015), *"Flyrock…needs to be considered before…[an accident] happens [p. 13]," an approach which is consistent with the precautionary principle."* While Raina, Murthy and Soni (2015) identify a host of problems in attempting to accurately predict flyrock distance:

> *"Flyrock is one of the most contentious issues in bench blasting. Unlike ground vibrations, flyrock has the propensity to cause fatality and severe injuries. Although the kinematic equations present a basis for the estimation of flyrock distance, these suffer from the drawback of ignoring the post-release effects of trajectory motion in air. Predictive models that are based on such equations not only suffer from this anomaly, but also fail in flyrock distance prediction due to the gross approximations of initial velocity calculations and shape of the fragments* (Raina, Murthy and Soni, 2015)*."*

Flyrock and its environmental impacts[25] are characterized as follows:

> *Flyrock events historically have not been limited to blasting operations within the distances which require the submission and approval of an 'anticipated blast design'…prior to blasting. Rather, flyrock events occurred and impacted dwellings, vehicles, persons, animal life, and other physical structures thousands of feet from the blast site resulting in death and the destruction of property [p. 1].* [emphasis added]
>
> *"…[F]lyrock in blasting operations has a major impact on the external environment…due to the hazards involved and is more significant than vibrations and airblast….[E]ven if it is normal practice in these zones to take into account the impact of possible vibrations and even the effects of airblast when modeling the project, flyrock risks are not dealt with in initial studies, other than by way of integrating general safety distances. These risks are only sometimes taken into account much later in the operation and most often, following an accident or significant flyrock being recorded externally [offsite] [p.549]."* (Blanchier, 2012)
>
> *"Flyrock can be as large as a car. It is propelled with great force. Flyrock may come from high in the air, roll down a hillside, or come straight at you like a bullet. That is why the blaster places guards at entry roads around the area where rocks might fly—to keep people out and protect workers from death and injury. Yet people have still been killed inside [and outside] the blast area [p. 7]."*[26]

[25] *Environment*, in the broadest sense, is defined as "the conditions that surround someone or something: the conditions and influences that affect the growth, health, progress, etc., of someone or something," according to The Britannica Dictionary, https://www.britannica.com/dictionary/environment.

[26] "Tool Box Lesson A – What is Flyrock?" NIOSH, https://www.cfins.com/wp-content/uploads/2019/01/blasting-safety-toolbox-complete.pdf.

> *"Pearson et al. [1994] referenced flyrock weighing approximately three tons [6,000 pounds] thrown to a distance of 980 ft [299 metres]."* (Bajpayee, Verakis and Lobb, 2022)
>
> *"Flyrock [from surface mining blasting operations] contributes about 68% of total injuries worldwide*." (Nayak, Jain and Mahapatra , 2021)

The designated blast zone or blast area (exclusion zone) is confined within the boundaries of a quarry operation, and all of the *adverse effects*, including flyrock, associated with blasting must remain or be contained onsite:

> *"designated blast area" includes the danger area, which is the zone in which there exists a possibility of hazard to a person or property from flyrock, fume, air blast or ground vibrations, and is the area where the blaster has made arrangements to evacuate all persons whose safety might be threatened by the blasting operation." (Province of Newfoundland and Labrador, Department of Natural Resources)*[27]

As pointed out below there are numerous shortcomings involved in determining the size or extent of the onsite blast zone or blast area (exclusion zone) for a blasting quarry operation, which relate to health and safety and land use incompatibility.

- A theoretically determined *blast area* makes no provision for *safety factors* to protect onsite equipment from damage (safety factor of 2), and quarry employees from injury or death (safety factor of 4), as recommended by Richards and Moore (2002) and endorsed by Quarry (2014)[28], and ignores entirely land use incompatibility of adjoining public and private third-party real property, and the deleterious effects and potentially deadly consequences of blasting on those who live, work, play (e.g., golf, ski, fish, hike, cycle) or drive/walk in the surrounding area.
- Proponent-driven Blasting Impact Assessments (BIAs) prepared in Ontario do not address *flyrock* or *blast area* (onsite safety or exclusion zone), as the BIA is prepared solely for the benefit of the proponent, and is strictly confined to a superficial (generic) analysis of airblast and ground vibration under static environmental conditions, above and below ground. (The proponent has no legal right of trespass to conduct or commission any investigations or tests on publicly owned or privately owned third-party real property.)

Thus, *Flyrock* is an integral part of blasting rock. However, *flyrock* that is projected past an appropriately defined permanent onsite safety (exclusion) or blast zone is unacceptable:

> *"It is well known that rock and/or debris can be thrown over a kilometer [1,000 metres] from the blast site, and in a recent case, rocks travelled approximately 1.3 kilometres [1,300 metres]."*[29]

As reported by Trivedi, Singh and Raina (2014), *flyrock* is an inevitable consequence of blasting rock and can never be entirely eliminated:

> *"Due to the explosive force, rock fragments are propelled and thrust high into the air and beyond the safety limit of [the] blast area, thus termed as "flyrock". This is mainly due to the flaws presented in the blast design and also due to the misinterpretation of rock mass behavior. The phenomena of flyrock are always uncontrolled and can never be brought down to zero [p.*

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[27] https://www.gov.nl.ca/iet/files/Quarry-Permit-Standard-Terms-Conditions.pdf.

[28] The Terrock formula for predicting "flyrock" throw recommends onsite safety factors of "2" for equipment and "4" for quarry employees, which according to the publication "Quarry (2014)" is one of the better ones. https://www.quarrymagazine.com/2014/10/02/flyrock-prediction-from-mystery-to-science/. In a case study undertaken by Lwin and Auug (2019) of flyrock prediction for Kyaukpahto Gold Mine in Myanmar applying five formulas, the Terrorck formula resulted in the maximum flyrock distance for defining the blast area (exclusion zone).

[29] Explosives Information Bulletin no. 69, 27 February 2009, https://www.rshq.qld.gov.au/safety-notices/explosives/flyrock-incidents2.

> *26]."*[30] [Flyrock launched beyond the designated blast area is sometimes referred to as "wild flyrock."]

According to the Mine Health and Safety Council (MHSC) of South Africa, *flyrock* is the ultimate *adverse effect*, and must be avoided at all costs:

> *"Human response to flyrock is generally extreme. Apart from any consideration of damage, it is the only blasting-related hazard that can cause serious injury and death. It is the ultimate adverse effect of blasting and must be avoided at all costs."*[31] [Milestone 4, p. 31]

Flyrock is a Common Occurrence

According to the findings of an investigation of Hobet Mining & Construction Company (No. 21 Surface Mine) presented before the Federal Mine Safety and Health Review Commission (November 6, 1985)[32], flyrock is a common occurrence:

> *"Flyrock, meaning rock being propelled through the air outside of the immediate blast site, was common when bottom shots were blasted. In the two months prior to December 19, 1983, flyrock occurred in about 90 percent of the shots. On many occasions, it travelled in excess of 1000 feet [305 metres] from the site of the blast. Most of these instances involved shots of 150 holes or more. On a few occasions flyrock was propelled beyond the blasting crew into the woods, approximately 1400 or 1500 feet [427 or 457 metres] from the pit. These incidents also involved shots of 150 holes or more.* [Each detonated blast hole has the potential to generate flyrock, and the potentially deadly consequences of flyrock increases with the addition of each blast hole.]
>
> *When the crew saw flyrock coming, it was their practice to jump or dive under the equipment parked in the area. There was no standard procedure made known to the employees as to where they should go when flyrock was observed [p. 1810]."*

Ludwiczak (2002), a blasting and mining consultant, testified on behalf of Hobet, stating that he would expect flyrock to be launched about 300 feet (91.44 metres), and could not account for the flyrock travelling 1,115 feet (340 metres), the point at which Bart Lay, a mining employee, was struck and seriously injured.

> *"Based on the information given...[Ludwiczak], he stated that we would expect flyrock to be propelled about 300 feet [91.44 metres] from the December 19 [, 1983] shot. He was not able to account for the flyrock actually travelling 1115 feet [340 metres], but "guessed" that it may have resulted from a wet hole or crack in the strata or an upheaval of the rock [p. 1814]."*

The Blasting Report prepared by Tim Rath, an explosives engineer, on behalf of the Rivers application to permit a 93-acre blasting quarry operation in the Town of Moretown, Vermont, does not mention flyrock. It was only during cross examination (Cross Exam 12/15/2008)[33], when confronted with the issue of flyrock, Rath disclosed that

- where blasting operations are conducted in proximity to populated areas flyrock may be a hazard to people, structures, and equipment not on the blasting site;
- [f]ace burst, cratering, and stemming ejections are all types of blasting occurrences that can lead to flyrock;

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30 https://intval.com/articles/Flyrock-and-Other-Impacts-from-Quarry-Blasting-Operations.pdf.

31 https://mhsc.org.za/sites/default/files/public/research_documents/SIM140901%20Final%20Report.pdf.

32 *Secretary of Labor, Mine Safety and Health Administration (MSHA) v. Hobet Mining & Construction Company*, Nov 6, 1985, Docket No. WEVA 84-209, A.C. No. 46-04670-03520. On December 19, 1983, Bart Lay, a mine employee, was struck by flyrock at a distance of 1,115 feet (340 metres) from the blast, and sustained serious injuries and is paralyzed from the chest down.

33 Blasting and Flyrock Cross Exam of Rath 12/15/2008, http://www.killthealbionquarry.org/flyrock_danger.pdf.

- uncontrolled flyrock occurs when there is face burst, or cratering, or some other accident that happens and rock is thrown considerable distances;
- [m]any blasting accidents involving injury resulting from flyrock occur from excessive flyrock beyond the protected blast zone;
- voids in the ground located between the blast hole and the face can cause serious flyrock situations;
- [i]f a void, mudseam, crack or mis-drilled hole goes unnoticed when a blast is detonated, flyrock could result;
- [m]ost flyrock comes off of the face of a blast in what is called a face burst, but flyrock can travel in any direction or multiple directions from a blast;
- [b]ore tracking and laser profiling can identify anomalies in a hole but cannot identify those anomalies between the holes and the face;
- [e]ven a small crack in the rock connecting to a bore hole can produce flyrock;
- [a]n anomaly between holes or between the holes and the face could produce unexpected results, including flyrock;
- even where great care is taken to map and incorporate geology into blast design and implementation, cases may occur where adverse geologic conditions exist in the bank that are unknown and "Rivers…cannot guarantee that flyrock will not leave the Rivers parcel regardless of what precautions are taken to minimize the risk."

Rath further testified that "he was concerned for the safety of people living near the proposed quarry site during any blasts, and recommended that anyone within 1,500 feet (457 metres) of a blast remain inside or under cover during the blast." The thickness of burden is one of the variables used in determining the "throw" distance of rock[34], and as explained by Art Hendrickson (12/15/2008 Testimony), applying Rath's formulas, demonstrated how anomalies in the burden[35] actually become the face and the effect they have on the variability of flyrock throw (distance), showing "how dangerous a detonation can be."

> *"…[Hendrickson] gave a…demonstration with a measuring tape. He explained that the quarry wall and blast hole would be four stories high with a burden of eight feet in front of the blast holes. He extended his tape out 96 inches (8 feet) and stated at that distance the flyrock would go 32 feet. He shortened the tape [to] 47 inches and stated with that much burden the flyrock would go 311 feet. He shortened the tape 20 inches more and stated that with that much burden the flyrock would go 1,451 feet. He shortened the tape six inches more and stated that now the flyrock would go over 3000 feet [914 metres]."*

[34] "The selection of proper burden is one of the most important decisions made in any blast design. Of all the design dimensions in blasting, it is the most critical. If burdens are too small, rock is thrown a considerable distance from the face. Air blast levels are high, and the fragmentation may be excessively fine. If burdens are too large, severe backbreak and back shattering results on the back wall. Excessive burdens cause blastholes to geyser throwing flyrock considerable distances, vertical cratering and high levels of air blast will occur when blastholes relieve by blowing out. Excessive burdens cause over confinement of the blastholes, which result in significantly higher levels of ground vibration per pound of explosive used. Rock breakage can be extremely coarse, and bottom or toe problems can result. Of all the [blast] design variables, there is the least allowable error in the burden dimension [p. 89]. Rock Blasting and Overbreak Control, Section 6.1, U.S. Department of Transportation, Publication No. FHWA-HI-92-001, Prepared in 1991. NHI Course No. 13211. [bold added] https://www.fhwa.dot.gov/engineering/geotech/pubs/012844.pdf.

[35] The "burden" is the distance from a single row to the face of the excavation, or between rows in the usual case where rows are fixed in sequence. (National Parks Service Handbook for the Storage, Transportation and Use of Explosives, updated June 27, 2007). According to Ludwiczak (2002), "burden" is generally considered the distance from an explosive charge to the nearest free or open face. Technically, there may be an apparent burden and a true burden, the latter being measured always in the direction in which displacement of broken rock will occur following firing of an explosive charge.

On appeal, the Vermont Superior Court – Environmental Division[36], upheld the trial court's denial of Rivers' application to permit a blasting quarry, which followed two multi-day land use hearings and a Merits Decision issued on March 25, 2010.[37] As noted by the appeal court, residents (20 homes within 3,000 feet or 914 metres of the proposed quarry) would be exposed to the potentially deadly consequences of flyrock every time there was a blast, and would have to run for cover at least a dozen times a year for 33 years, the expected life of the proposed blasting quarry operation:[38]

> *"Rivers'…expert [Tim Rath] could not assure against fly rock occurring in such a manner as to cause damage or injury to the Rivers quarry neighbors. Rivers' expert continued his assessment of the project by recommending that neighbors seek shelter every time a blast is planned at the Rivers site, for the duration of its thirty-three-year life [p. 4]."*

As *flyrock* is an inevitable and uncontrollable by-product of quarry blasting,[39] and is not to leave the site, according to the *Ontario* Aggregate Resources Act (ARA), mandatory minimum setback (exclusion zone) of sufficient width is the only known remedy that can possibly eliminate *flyrock* from being launched off-site. On January 1, 2022, a licensee and permittee shall take all reasonable measures to prevent fly rock from leaving the site during blasting if a sensitive receptor [often code for human target] is located within 500 metres of the boundary of the site. (O. Reg. 466/20, s. 2(2))

"Reasonable" measures are undefined in the ARA, and it is foolhardy to leave that determination to the sole discretion of the blaster-in-charge on an adhoc or arbitrary basis before initiating each blast, given that there is zero tolerance for flyrock, a risk that is unmanageable.[40] The concern expressed by the ARA over sensitive receptors within 500 metres of the boundary of a quarry site infers that flyrock launched offsite is a "foreseeable" event, and why the ARA provision does not apply to property that is unimproved is illogical, as unimproved third-party lands would be precluded from any future development for the entire life of the quarry operation, which could remain operational for 100 years or more. Sterilizing private third-party land constitutes an unauthorized de facto taking without compensation.

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[36] *Rivers Dev. Conditional Use Appeal*, Docket No. 7-1-05 Vtec and *Rivers Dev. Act 250 Appeal*, Docket No. 68-307 Vtec,, August 17, 2010, State of Vermont Superior Court – Environmental Division, https://www.vermontjudiciary.org/sites/default/files/documents/Rivers%20Deveopment%20LLC%207-1-05%20Vtec%2068-3-07%20Vtec%20Decision%20on%20post-judgment%20motion%20to%20alter.pdf.

[37] The twenty Act 250 criteria and sub-criteria reviewed at trial are listed in the Merits Decision, at 4-5.

[38] Every blast hole is a separate detonation, which means that during every blast event there would be 62 chances for flyrock from face burst, cratering, or stemming ejection (Testimony of Art Hendrickson 12/15/2008).

[39] "There was…evidence that 'the fly rock' is uncontrollable and results in making unavailable a large area of the petitioner's land by its inability to conduct blasting operations within 800 feet [244 metres] of the new turnpike, para. 435]," *Lee Lime Corp. v. Massachusetts Turnpike Authority*, 337 Mass. 433 (1958) 149 NE 2d 905, https://scholar.google.ca/scholar_case?case=8453729559483718978&q=flyrock&hl=en&as_sdt=2006.

[40] On December 17, 2021, the reckless blaster-in-charge of an April 10, 2018, blasting incident at the Albury Quarry in Ettamogah was convicted and fined a total of $324,000 for three offences under the New South Wales Work Health and Safety Act (2011). After the flyrock incident, those present were asked to delete video footage of the blast, and the incident was not reported to the Regulator until September 7, 2018. Circumstances of the incident were not made known to the Regulator until video footage of the incident was received in November 2018. No exclusion zone had been set or sentries or blast guards assigned, despite having access to a 700-metre lead-in line on each reel to measure the distance between the blast and firing location. There were four people about 275 metres from the blast area and another eight, including the blaster, were about 320 metres away. The blast sent rocks flying into the air and three light vehicles and two excavators were struck by flyrock debris. One person was lucky to escape serious injury or death when a rock passed close by his head, then hit the boom of the excavator and cracked a hydraulic pipe. The blaster-in-charge violated several safety standards, including not using the correct type of explosive in all the blast holes and putting the firing location in the wrong place. Source: Australia's Mining Monthly, 10 January 2022, https://www.miningmonthly.com/sustainability/news/1424253/reckless-blaster-convictedhttps://www.miningmonthly.com/sustainability/news/1424253/reckless-blaster-convicted.

An appeal before the Supreme Court of Yukon (2012)[41] involved two *flyrock* incidents, where *flyrock* debris caused damage to a number of houses in the Lobird subdivision as far as 350 metres from the blast site, and penetrated the roof of one house, landing in the living room (Flyrock 120 – Nov 1, 2007 and May 6, 2008) (Waddell, 2009). The blast by blaster-in-charge of the May 6, 2008 had estimated the distance to the Lobird subdivision as 1,000 metres, when in fact the distance was only 350 metres away (Davidson, 2010). The expert blaster that testified on behalf of the Director of Occupational Health and Safety made the startling comment: *"Had it not been for the fly rock incident,…he would have considered the blast a success [para. 23]."* This is akin to saying "The operation was a success, but the patient died!"

Predictions of Flyrock Distance Not Accurate

All calculations relating to the throw or travel distance of flyrock are theoretical, and, as noted by van der Walt and Spiteri (2020), Raina, Murthy and Soni (2015)and Ghasemi, Sari and Ataei (2012), predictions of flyrock distance are not accurate and continue to confound explosives engineers and blasters for a variety of reasons:

- Several authors have proposed viable solutions based on assumed causative parameters and their impact as inputs….The testing methodologies used to measure the actual flyrock distance are not scientific and are highly dependent on the scrutiny of the researcher. In order to present results that are objective and uncriticizable, an accurate, quantitative and objective method of measuring the travel distance of flyrock is required (van der Walt and Spiteri, 2020).
- A problem in flyrock prediction is its random nature, as one cannot generate a flyrock while relying on chance. Modelling of random flyrock with regular variables poses a challenge to researchers. Attempts to predict flyrock using throw or heave prediction routines suffer from the perils of gross generalizations. "Since flyrock is a potential threat to property and life, one cannot risk under prediction (Raina, Murthy and Soni, 2015).
- Flyrock prediction is a complex issue in mining industry because at first many parameters influence flyrock phenomenon [sic] that can be divided generally into two categories; controllable and uncontrollable parameters. Second, most of these parameters accompany with uncertainty due to variability in blasting parameters (Ghasemi Sari and Ataei, 2012).

One of the most uncontrollable risk factors for flyrock is the natural environment.

- The presence of water, especially dynamic water, can contribute to the creation of weakness points in the rock or create pathways for the escape of gases, in the same way that rain can cause water to soak into the rock, reduce the efficiency of stemming, or even migrate through fractures, removing the friable filling material. It can still mask bench conditions, making it difficult to assess and perceive other risks (Quarry, 2014) and Flyrock (part 02 of 03, Linkedin, 2020[42])
- The presence of lightning and storms can cause premature blasts and generate flyrock.
- The wind can contribute to the intensification of flyrock when the wind direction is in accordance with the direction of release, and cause the flyrock to travel a distance up to twice as far as expected (Zhou *et al*., 2011).

[41] *Director of Occupational Health and Safety v. Government of Yukon, William R. Cratty and P.S. Sidhu Trucking Ltd*., 2012 YKSC 47 (CanLII), <https://canlii.ca/t/fs6vt>, accessed on 2021-10-23

[42] Flyrock (part 02 of 03), August 26, 2022. https://www.linkedin.com/pulse/flyrock-part-02-03-blasting-trainings/?trk=pulse-article.

Minimum Clearance Distance as Safety Zone Against Flyrock Based on Recorded Flyrock Distances and Experimental/Theoretical Estimation

According to GEO Report No. 260, Halcrow China Limited, 2002,[43] separation distance (or setbacks) is the only totally effective safety measure against *flyrock*:

> *"The only totally effective safety measure [against flyrock] is a minimum clearance distance, acting as a safety zone. In order to determine the required minimum clearance distance, it is necessary to ascertain the 'flying distance', (the distance to which flyrock may be thrown). The available [flyrock] data is of two types: reported instances and experimental/theoretical estimation."*

- *Recorded instances.* The data on recorded flyrock projection is based on published HSE and Mines & Quarries Division of GEO data. Both indicate significant numbers of rocks passing beyond 200 m. Very few (4 out of 80, or 5%) travelled beyond 300 m. Only one exceeded 450 m, and this travelled to 800 m. It should be noted that these numbers are the minimum number that occurred, being those that were reported. Numerous incidents at shorter ranges (up to 500 m) may not have travelled outside the quarry boundary or may not have caused injury and therefore were not treated as reportable incidents. In the UK, under-reporting by factors of 5 to 10 are considered possible below 500 m (Davis, 1995).
- [In the United Kingdom, over a five-year period, 85 flyrock incidents had been reported and documented: 25 incidents (29%) were between 200 and 300 metres; 15 incidents (17%) were between 300 and 500 metres; 5 incidents (6%) were between 500 and 700 metres; and only one incident (1%) exceeded 700 metres. Overall, 95% of the analyzed flyrock incidents occurred within 600 metres. p. 26[44]]
- *Experimental data.* Research on flyrock was undertaken by the Swedish Detonic Research Foundation (Lundborg *et al*., 1975). It was summarized in more accessible form by Hoek and Bray (1981) in their textbook "Rock Slope Engineering". It has been established that maximum 'flying distance' is about 540 m for a 200 mm diameter (about 15 kg) block. For fragments of 75 to 100 mm size (about 2.5 kg) the maximum range is 410 to 470 m.

From the foregoing, it is apparent that the only absolute guarantee for safety from flyrock is a large minimum clearance distance, the size of which depends on the blasthole diameter in use. The Safety Zone would need to extend 400 to 600 m from the blast. [emphasis added] [pp. 182-83]. A more recent study of discovered *flyrock* incidents undertaken by Sevelka (2021), where the *flyrock* distances are known, resulted in an analysis of 92 *flyrock* incidents. The results of the *flyrock* study, the most comprehensive and largest known of its kind, are as mentioned in subsequent sections.

An analysis of 92 *flyrock* incidents, where the distance from the blast is known, indicate that 91% (84) of the *flyrock* incidents occurred within 1,099 metres, and 97% occurred within 1,299 metres. The number of *flyrock* incidents within each interval, starting at between 300 and 399 metres, and the average distance travelled within each interval are summarized as follows:

- 20 (22%) of the flyrock incidents occurred between 300 and 399 metres (330 metres avg)
- 9 (10%) of the flyrock incidents occurred between 400 and 499 metres.(446 metres avg)
- 7 (8%) of the flyrock incidents occurred between 500 and 599 metres (515 metres avg)
- 7 (8%) of the flyrock incidents occurred between 600 and 699 metres (622 metres avg)
- 6 (7%) of the flyrock incidents occurred between 800 and 899 metres (802 metres avg)

[43] This report was prepared by Halcrow China Limited in August 2002 under Consultancy Agreement No. GEO 10/98 for the sole and specific use of the Government of the Hong Kong Special Administrative Region, https://www.cedd.gov.hk/filemanager/eng/content_475/er260links.pdf.

[44] https://intval.com/articles/Flyrock-and-Other-Impacts-from-Quarry-Blasting-Operations.pdf.

- 5 (5%) of the flyrock incidents occurred between 1200 and 1299 metres (1225 metres avg)
- 3 (3%) of the flyrock incidents occurred over 1300 metres (2307 metres average)

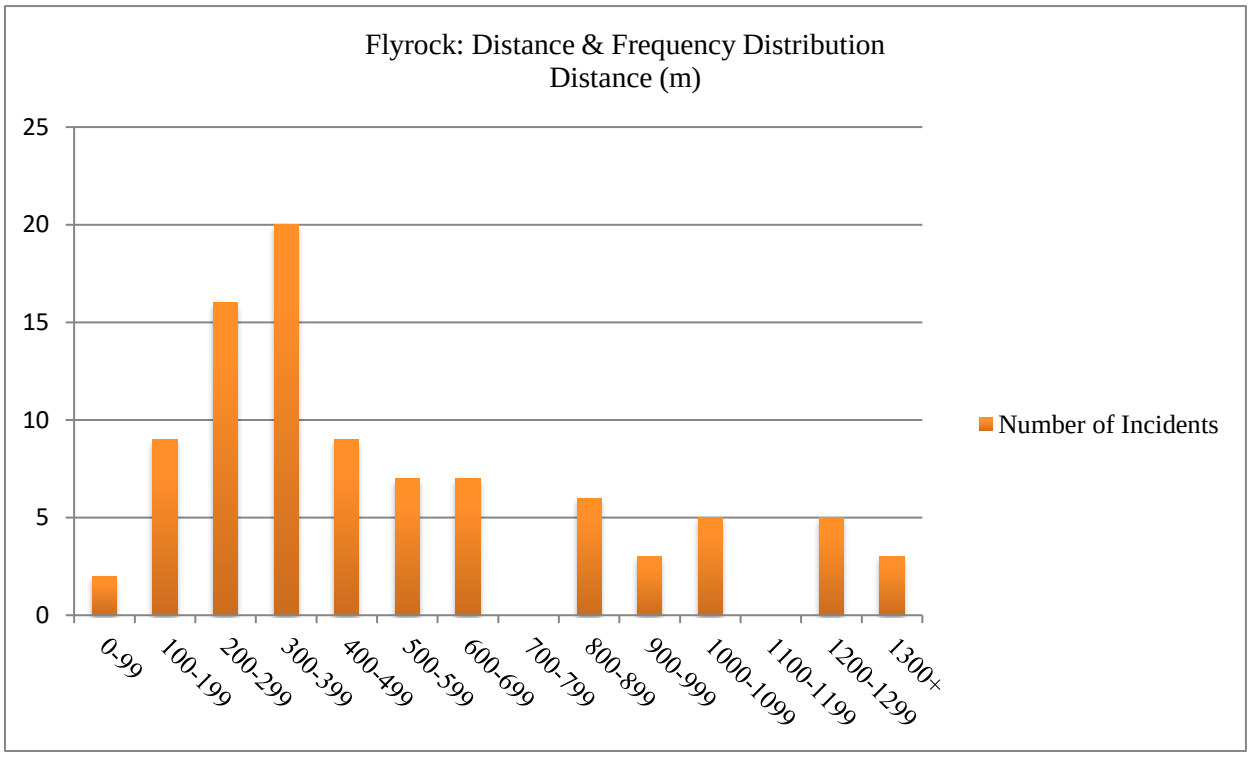

Figure 1: This graph summarizes the travel distances and frequency of 92 flyrock incidents where the travel distance from the blast site is known for each flyrock incident. The particulars of the flyrock incidents were obtained from a variety of online sources including news releases, formal investigations, published articles, journals, case law, etc.

At 80%, which accounts for the first 74 *flyrock* incidents in ascending order, *flyrock* reached a distance of 800 metres, and, at 90%, which accounts for the first 83 *flyrock* incidents in ascending order, *flyrock* reached a distance of 1,020 metres. On the basis of the most recent study of *flyrock* incidents (Sevelka, 2021), the designated blast area would have to be approximately 1,200 metres to effectively prevent 97% of *flyrock* incidents from leaving the boundaries of a blasting quarry site, equivalent to a 1,200-metre setback. A website produced and maintained by the mining and quarrying companies of Nova Scotia as an effort to assure the public that blasting does not have an adverse effect on neighbouring properties alludes to the fact that,

> *…[All] regulated blasting buffers in Nova Scotia are 800 metres, [making] the risk to groundwater or anything else [e.g. flyrock] is extremely low.*[45]

Examples of Flyrock's Deadly Consequences for Sensitive Receptors (Code for Human Targets) Onsite and Offsite

Listed below are samples of *flyrock* incidents at different blasting quarries at various geographic locations, which have killed onsite quarry employees and offsite residents in or outside their homes, offsite employees

[45] "Not Your Grandfather's Mining Industry," https://notyourgrandfathersmining.ca/faq. Retrieved on December 20, 2022.

and customers in places of business, children in schools, pedestrians during walking near quarries, and occupants in vehicles on roads near quarries.

- *Flyrock 6:* On March 22, 2016, a blast at a quarry launched *flyrock* debris 366 metres that penetrated a pickup truck striking and killing 42-year old Tracy Hockemeier, a quarry employee positioned 366 metres from the blast and preventing others from entering the blast area. Tracy leaves behind wife Megan and his four children: Trayton, 18; Marissa, 12; Trey, 10; and Sophie 9.
- *Flyrock 12:* On July 19, 2013, a blast at a quarry in Johor, Malaysia, showered *flyrock* debris as far as 1,000 metres that damaged 18 cars and 14 factories, injured 10 workers and residents in a housing estate, and struck and killed a worker in his 30s in a factory penetrated by numerous rocks at a distance of 500 metres. A team of 37 fire and rescue personnel carried out a search and rescue operation with the assistance of 16 policemen and Tenaga Nasional Berhad (TNB) employees before declaring the area safe for the public.[46]
- *Flyrock 34:* On June 4, 1993, a blast at a surface coal mine launched a large amount of *flyrock* debris approximately 91 metres that struck a car on Interstate 75, Tennessee, and 16-year old Brian Agujar, a passenger in the car driven by his parents, was killed as a result of the *flyrock* impact. The blaster was sent to prison for five months followed by five months of house arrest with electronic monitoring and a year of supervised probation. The superintendent of Sugar Ridge Coal Co. was sentenced to eight months, three months to be served in a halfway house followed by five months of home detention. (Prior *flyrock* incident occurred in April 1992 (Shea and Clark, 2020))
- *Flyrock 36:* On July 11, 1990, a blast at a quarry launched *flyrock* debris 283 metres that struck a resident who was mowing grass on his property, who later died on July 17, 1990 from head injuries.
- *Flyrock 38:* On April 5, 2017, a blast at a quarry launched *flyrock* debris 280 metres that struck and killed the blaster's helper.
- *Flyrock 40:* On December 21, 1999, a blast at a quarry in Lancaster County, Pennsylvania, launched *flyrock* debris that penetrated the windshield of a pickup truck and struck 32-year-old Lee Messner, a quarry equipment operator, at 244 metres, who subsequently died from his internal injuries, with *flyrock* debris also damaging a building at 457 metres from the blast. Messner left behind a wife and one child. (Prior *flyrock* incident occurred in 1996.)[47]
- *Flyrock 41:* On August 15, 2019, a blast at a LafargeHolcim quarry near Pangoula Farm, Zimbabwe, launched *flyrock* debris, some of which bore through the roof of a home and struck and killed 36-year old Shupikai Chitsana while in her kitchen, and her aunt was also struck by *flyrock*, but she survived her injuries while recovering in hospital. Shupikai leaves behind her five children and husband. LafargeHolcim's contractor Afri Mining did not follow established blasting procedures.
- *Flyrock 48:* On July 15, 2015, a blast at a construction site in Johor, Malaysia, launched *flyrock* debris 200 metres that struck and killed a factory worker, and seriously injured two others. *Flyrock* debris also struck a building at 50 metres, and damaged and destroyed several vehicles 150 metres from the blast site.
- *Flyrock 68:* May 27, 2020, a blast at a quarry launched *flyrock* debris that struck and killed 10-year old M. Nanhini, and that struck and injured her brother Soundarrajan.
- *Flyrock 74:* On July 16, 2007, *flyrock* fragments from a quarry blast at the Three Mile Mine in Pike County, Kentucky, were launched 483 metres and struck and killed 40-year old Bobby Messer, a quarry mechanic, and damaged the mechanic's truck. Messer is survived by his wife and three children.

[46] See posted video of quarry blast: https://www.facebook.com/Komuniti-Jalan-Bukit-Seri-Alam-736181443145111/videos/19-july-2013-quarry-explosion-tragedy-at-seri-alam-masai-johor19-july-2013-trage/877815032315084/.

[47] MSHA - Metal and Nonmetal Mine Fatal Accident Investigation Report: 12/21/1999.

- *Flyrock 86:* On December 4, 2013, a blast at Kansas Falls Quarry in Junction City, Kansas, launched *flyrock* debris, including a 96-pound boulder that struck and killed 63-year old Stephen Hetzler, an experienced blaster, standing 47 metres from the blast. Investigators determined the *flyrock* was travelling approximately 400 miles per hour (644 kilometres per hour).
- *Flyrock 94:* On December 13, 2017, a blast at a quarry Santa Elena, Cayo, Belize, showered *flyrock* debris over an area of 800 metres, striking and killing 71-year old Ronald Sutherland (an experienced Canadian blaster), injuring five people, wrecking 10 vehicles, significantly damaging 14 houses and causing minor damage to 20 other houses.[48]
- *Flyrock 100:* One July 16, 1997, a blast at a quarry launched one blasting expert, Skip Sibley, over a quarry ledge, leaving him seriously injured with face and chest burns, and another blasting expert, Joel Kanute, had his body impaled by *flyrock* debris, killing him instantly. Both were experienced blasters.
- *Flyrock 103:* In 2015, a blast at a quarry in Joma, Ghana, launched *flyrock* debris that struck and killed a baby on her mother's back, and "the child was ripped in half" by the force of the impact from the flying rock. The baby's mother and a motor rider were also struck by flyrock and sustained injuries.[49]
- *Flyrock 104:* On April 12, 2007, a blast at a quarry launched *flyrock* debris 300 metres that struck and killed a 12-year old boy standing in his courtyard.
- *Flyrock 114:* On February 28, 2021, a blast at a quarry in Senemal village of Lakhanpur Block, launched *flyrock* debris that struck 36-year-old Harekrishna Bhoi, a supervisor at the quarry. Bhoi died after being struck on the head by *flyrock* debris. [50]
- *Flyrock 121:* On September 19, 2011, a blast at a quarry near Perne in India, launched *flyrock* debris that struck 18-year-old Balu Namdeo Kolpe, a shepherd who was tending his sheep. Kolpe was struck in the head and "died on the spot."[51]
- *Flyrock 153:* On November 19, 2017, a blast at a quarry in Katombola, Southern Province, launched *flyrock* debris 50 metres that struck and killed an 11-year old boy on the spot (ripping his stomach, cutting his head and breaking his ribs) and seriously injured three other children, aged four and seven (Mukosha, 2017).
- *Flyrock 154:* On May 29, 2021, a blast at a quarry in Chittoor, launched *flyrock* debris 500 metres that struck and killed 25-year-old Jakir, a daily wager who had just completed loading mangoes into a trailer at a mango orchard abutting the quarry.[52]
- *Flyrock 155:* Sometime in the early 1990s, a blast at a quarry in Coboconk, Ontario, launched *flyrock* debris that penetrated the roof of a man's home, striking and killing the homeowner. A Coroner's Inquest followed. (Source: Retired Legal Counsel. This is the same *flyrock* incident cryptically alluded to during the MOE investigation of the two flyrock incidents at the Pakenham Quarry in 2009)
- *Flyrock 158:* On February 6, 2000, a blast at the Makkah Quarry, Saudi Arabia, launched *flyrock* debris that showered a nearby shopping district, killing an Egyptian passer-by and injuring five others.[53]

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[48] See posted video of quarry blast: https://www.facebook.com/News5Live/videos/twin-towns-rocked-by-huge-blast-explosion-at-quarry-this-evening/1491410510979815/.

[49] "Joma residents protest as CP's quarry operations kills baby," *3News*, August 15, 2015, Joma residents protest as CP's quarry operations kills baby | 3NEWS.

[50] "1 killed in Jharsuguda quarry blast," *the pioneer*, March 3, 2021, https://www.dailypioneer.com/2021/state-editions/1-killed-in-jharsuguda-quarry-blast.html.

[51] "Stone from quarry blast kills 18-year old," *The Times of India*, Sept 21, 2011, https://timesofindia.indiatimes.com/city/pune/stone-from-quarry-blast-kills-18-year-old/articleshow/10058714.cms.

[52] "One killed in quarry blast in Chittoor," *The Hindu*, May 29, 2021, One killed in quarry blast in Chittoor - The Hindu.

[53] "One Killed, Five Injured in Makkah Quarry Blast," *Kuwait News Agency (KUNA)*, 06/02/2000, https://www.kuna.net.kw/ArticlePrintPage.aspx?id=1058118&language=en.

- *Flyrock 159:* On June 21, 2021, a blast at a quarry in Thrissur, India, launched *flyrock* debris that struck and killed Abdul Naushad, the brother of the quarry owner, injured five others, and damaged several houses.[54]
- *Flyrock 160:* On March 14, 2018, a blast at a quarry in Kiyuni Sub County, Uganda, launched *flyrock* debris that penetrated a public school at a distance beyond 250 metres, and struck Sylvia Gwoliranye, a 14-year-old pupil at the school. Sylvia was struck in the head by the flyrock while seated in class, and eventually died after losing a lot of blood.[55]
- *Flyrock 161:* On September 4, 2020, a blast at a construction site at Gochas in the Hardap region of Namibia launched *flyrock* debris that struck 50-year-old Anna Ida Jaars in the head, killing her while sitting outside a house, at a distance of 700 metres from the bast site (Cloete, 2020).
- *Flyrock 162:* On March 27, 2020, a blast at KTH Quarry in Kampong Speu Province, Cambodia, launched a 5 kg rock that penetrated the roof of an onsite office, more than 70 metres from the blast site, and struck 20-year-old Chhoeun Sopheak, a company administrator, who succumbed to his injuries while being transported to a hospital.[56]
- *Flyrock 163:* On May 27, 2016, a blast at a stone quarry at Gaurhari village of Mahoba district, India, launched *flyrock* debris that showered and killed four quarry labourers, and critically injured one.[57]

As noted above, of 163 discovered *flyrock* incidents, 26 incidents of *flyrock* ended in loss of life (29 people were killed), resulting in a "kill" rate of 16%. An additional 36 people were injured in the 26 *flyrock* incidents that resulted in loss of life. The relatives of those innocent victims who have been killed by flyrock at the hands of the aggregate industry are devastated and left to mourn the loss of their loved ones; and surviving spouses are forced to raise their children as single parents and endure financial hardship and loss of companionship. Seeking compensation through the courts for the loss of a loved one can also be emotionally traumatizing, exhausting, time-consuming and costly, and the outcome uncertain. This devastating collateral damage is ignored and not taken into account when considering the potentially deadly consequences of flyrock.

Updated List of Known Flyrock Incidents in Various Jurisdictions

In addition to the abovementioned flyrock incidents, further research conducted on the internet using a number of search engines disclosed an additional 32 incidents of flyrock, which are briefly summarized below:

- *Flyrock 164:* On August 7, 2004, a blast from a quarry about a quarter-mile (402 metres) away launched *flyrock* weighing 90 pounds that penetrated the roof of a home at 74 Sleepy Hollow Road, Snowden, Washington, and caused about $15,000 to $20,000 in damage.[58] This was the second time that flyrock debris had impacted the property.
- *Flyrock 165:* On January 15, 2020, a blast at Cwt-y-Bugail Quarry in Llan Ffestiniog, Gwynedd, North Wales, resulted in rocks being ejected outside the danger zone and puncturing the roof of an

[54] "One killed, five injured in quarry blast in Thrissur," *Kaumudi Online*, 21 June 2021, https://keralakaumudi.com/en/news/news.php?id=576544&u=.

[55] "Stone from quarry hits, kills pupil inside class," *Daily Monitor*, March 15, 2018, https://www.monitor.co.ug/uganda/news/national/stone-from-quarry-hits-kills-pupil-inside-class-1745402.

[56] "Office Worker Killed After Quarry Blast," *Cambodia News English*, March 28, 2020, https://cne.wtf/2020/03/28/office-worker-killed-after-quarry-blast/.

[57] "Blast inside stone quarry kills 4 in India," *The Citizen*, May 27, 2016, https://www.citizen.co.za/news/news-world/1135041/blast-inside-stone-quarry-kills-4-in-india/.

[58] "Flying rock shatters wall in Snowden," *White Salmon Enterprise*, Sept 1, 2004, https://www.columbiagorgenews.com/archive/flying-rock-shatters-wall-in-snowden/article_7d1c6939-abe0-5860-8a01-c2c8737aa9a7.html.

occupied work shed at a distance of about 270 metres, and putting a hole in the outside pane of the manager's office skylight window.[59]

- *Flyrock 166:* In December 2020, a blast at RRC's quarry in Nigeria launched *flyrock* that penetrated the roof of 78-year-old Comfort Ajegunle's home and landed "just whiskers from her head on the bed where she lay" (Samad, 2021).
- *Flyrock 167:* On August 21, 2006, a blast at Aggregate Industries quarry in Swampscott, Massachusetts, launched *flyrock* debris that struck a car windshield with a passenger inside, and that was scattered around driveways, car exteriors and homes on Essex Street, Sunset Drive and Summit View (George, 2006a).[60] The blasting firm responsible for the flyrock incident was fired (George, 2006b).
- *Flyrock 168:* On July 26, 1994, blasting at the Rama Stone Quarry (Fowler Construction) in Township of Ramara, Ontario, launched *flyrock* weighing 8.5 pounds about 1,200 feet (366 metres), which landed on the front yard of the Spencer's property on Glenn Ellen Drive in Floral Park near Washago. "A similar incident damaged the roof of her neighbor's house seven years ago [c. 1987]" (Size, 1994).
- *Flyrock 169:* In March 2022, a 3-person road crew on the mid-Coast, B.C. was constructing a road to support harvesting operations. During one of the blasts, the swamper was hit at a distance of 240 metres from the blast by a piece of *flyrock* that weighed approximately 1.5 pounds, resulting in a broken femur and other injuries to his leg (Safety Alert, 2022).
- *Flyrock 170:* In 2013, during a blast in the South Pit of Isibonelo Colliery, South Africa, *flyrock* debris was launched 600 metres from the blast area and damaged overhead powerlines (Mashele, 2022).
- *Flyrock 171:* On June 4, 1993, a blast at the Balleese Wood quarry in Rathdrum, Ireland, launched *flyrock* boulders weighing 50 to 100 kilograms, more than a half-mile (805 metres) from the blast area onto a small neighbouring family farm.[61]
- *Flyrock 172:* On May 18, 2006, a blast at Rowe's Quarry, Malden, Massachusetts, launched *flyrock* debris that caused substantial damage to a number of parked vehicles, and the blasting company failed to report the flyrock incident in a timely manner (Matthew, 2006).
- *Flyrock 173:* On June 28, 2019, a blast at a construction site along I-93, Manchester, New Hampshire, launched *flyrock* debris that struck and damaged a number of nearby homes and vehicles (Siobhan, 2019).
- *Flyrock 174:* On July 30, 2001, a regular blast at a quarry launched *flyrock* debris that showered the nearby Cal State San Mancos University campus, damaging about 20 cars in the faculty-student parking lot, and campus buildings (Weisman, 2001).
- *Flyrock 175:* On May 14, 2021, a blast at the Magino mine in Finan Township, Ontario, launched *flyrock* debris that struck a passing motorist driving along the road adjacent to the mine property, and that landed on the road.[62]
- *Flyrock 176:* On July 25, 2022, blasting at the High Pointe 24 development in La Vergne, Tennessee, launched *flyrock* debris that smashed a car windshield and penetrated the roof of a home in the nearby Woodland Hills subdivision, with numerous previous complaints related to property

[59] "Quarrying company fined after blasting operation puts workers at risk, *HSE Media Centre*, November 25, 2021, https://press.hse.gov.uk/2021/11/25/quarrying-company-fined-after-blasting-operation-puts-workers-at-risk/.

[60] Derringer, George. "Quarry blast sends rocks flying at cars, homes," *WickedLocal.com*, Aug. 24, 2006. https://www.wickedlocal.com/story/swampscott-reporter/2006/08/24/quarry-blast-sends-rocks-flying/38563740007/.

[61] Seanad Éireann debate – Tuesday, 29 Jun 1993, Vol. 137 No. 3, https://www.oireachtas.ie/en/debates/debate/seanad/1993-06-29/6/.

[62] August 12, 2021 letter from Prodigy Gold Incorporated to Compliance and Enforcement Officer, Impact Assessment Agency, https://s22.q4cdn.com/115151820/files/doc_downloads/magino/incidents/Magino-Project-Fly-Rock-Incident-90-Day-Follow-Up-Report-SAC-1-FVFMY.pdf.

damage from vibrations from blasting despite blasting being conducted within regulatory limits (Langston, 2022).

- *Flyrock 177:* On June 21, 2004, blasting at the Radford Quarries of Boone, North Carolina, launched *flyrock* debris. Two or three of the rocks travelled approximately 996 feet (304 metres) and struck the High County Round Up Building. The rocks were between the size of a softball and basketball. Several smaller rocks struck the ground at various places around the building.[63]
- *Flyrock 178:* In February 2006, *flyrock* debris from a blast at the Wabush Mine, Newfoundland and Labrador, caused considerable damage to buildings and equipment, and two employees of a contractor on the site were exposed to "excessive flyrock."[64]
- *Flyrock 179:* On October 4, 2022, blasting at a new Veterans Administration Office on Brownsboro Road in Louisville, Kentucky, left craters in houses. Fragments of sediment and rock (*flyrock* debris) landed on Interstate 264, Watterson Expressway and onto nearby homes and property in the Crossgate subdivision. A massive rock went through the roof of Maria Moreno's home, which is located five minutes away from the site of the blast, landed in the kitchen and damaged her glass-top stove (Leavell, 2022).
- *Flyrock 180:* On September 28, 1999, a blast at Rapid City Quarry in North Dakota launched *flyrock* debris that struck a nearby home and vehicles, for which the owner of the quarry was fined a nominal sum of $1,000 by the Department of Environment and Natural Resources.[65]
- *Flyrock 181:* On June 22, 2005, a blast at Loughnane Concrete (Birr) Ltd. quarry in Ireland launched *flyrock* that extended outside the quarry boundary, for which the blaster was fined a nominal sum of €500.[66]
- *Flyrock 182:* On September 22, 1990, a blast at a coal mine in Walker County, Alabama, launched *flyrock* debris 275 metres that struck and killed the owner of a logging company in the process of preparing access roads for future logging operations outside of the mine property. Several large boulders scattered over an area near the victim were noticed (Bajpayee, 2004).
- *Flyrock 183:* On February 1, 1992, a blast at a coal mine in Mingo County, West Virginia, launched a 43-by 89- by 22-centimetre *flyrock* 229 metres that struck and seriously injured the blaster who was positioned under a Ford 9000, 2-1/2 ton truck within the blast area. He was treated for collapsed lungs, multiple rib injuries, fractured mandible, dislocated left shoulder, and serious head injuries (Bajpayee, 2004).
- *Flyrock 184:* On August 29, 1989, a blast at a coal mine in Webster County, West Virginia launched *flyrock* debris that struck a drill operator, causing minor injuries, and a 41-year old dozer operator, who was pronounced dead on arrival at a nearby hospital.[67]
- *Flyrock 185:* On October 12, 1990, a blast at a non-metal mine in Luna County, New Mexico, launced *flyrock* debris that struck and injured a visitor and drill/blast helper at a distance of 150 feet (45.7 metres) from the edge of the blast. They were transported to a nearby hospital, where the visitor was hospitalized for treatment of broken ribs and internal injuries, and the drill/blast helper was pronounced dead.[68]

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63 June 27, 2004 Memo from Orica to NCDENR, Division of Land Quality, https://edocs.deq.nc.gov/Stormwater/DocView.aspx?id=630064&page=3&dbid=0.

64 News Releases, "Charges Laid Resulting from Blasting Incident in Wabush," *Department of Government Services, Government of Newfoundland and Labrador*, 2008-02-26, https://www.releases.gov.nl.ca/releases/2008/gs/0226n04.htm.

65 http://www.gigablast.com/get?d=80584495513&strip=1&sentoff=36499&sentlen=275&q=quarry+blasting+causes+property+damage#gbsumoff.

66 https://www.hsa.ie/eng/topics/inspections/prosecutions/prosecutions_2007/

67 https://www.cdc.gov/niosh/mining%5C/UserFiles/works/pdfs/fadtf.pdf

68 https://www.cdc.gov/niosh/mining%5C/UserFiles/works/pdfs/fadtf.pdf

- *Flyrock 186:* On May 23, 1994, a blast at a limestone quarry in Madison County, Illinois, launched *flyrock debris* that despite the use of blast mats struck and killed a 21-year-old crane operator positioned 120 feet (36.6 metres) from the blast.[69]
- *Flyrock 187:* On February 15, 1999, a blast at a coal mine in Pike County, Kentucky, launched *flyrock* debris 100 feet (30.5 metres) that struck and killed a 55-year old man, unbeknownst to the blaster. The victim had parked his ATV at about 100 feet from the edge of the blast area and as he started walking toward the blast area he was struck by flyrock. Later, his body was found. The quarry operated on privately-owned land including land owned by the victim.[70]
- *Flyrock 188:* On January 12, 2016, a blast at a limestone quarry launched *flyrock* debris that penetrated the windshield of a pick-up truck travelling on a public road near the quarry site striking the driver and passenger, both of whom received minor injuries.[71]
- *Flyrock 189:* On July 22, 2014, a blast at Goldcorp's Hollinger Pit in Timmins, Ontario, launched *flyrock* that struck an employee's vehicle in the Hollinger parking lot (Timmins Today, 2014).
- *Flyrock 190:* On April 25, 1994, a blast at a coal mine in Greene County, Indiana, launched *flyrock* debris 72 metres that struck and killed a 34-year-old driller/loader.[72]
- *Flyrock 191:* On August 17, 2004, a routine blast at a Torrington Road rock-granite quarry in Winsted, Connecticut, launched *flyrock* debris consisting of thousands of rocks, large and small, which showered an area extending more than 300 metres from the blast site. The nearby Waste Management building was damaged, as rocks, some three times the size of a baseball, crashed through the building. Many vehicles, both personal and company, also sustained damage. One employee was hit in the leg by a rock. Beyond the Waste Management building, at 25 Lanson Drive, the nephew of Melissa and Charlton Webb had his face grazed by *flyrock* debris, and was lucky to have survived. The Webbs' barn and vehicle were also struck by rocks, as was Melissa's father-in-law's business a bit further down the road (Klimanowski, 2004).
- *Flyrock 192:* On September 27, 2017, a blast at a quarry at Bebi Betta, Pandavapura taluk, Mandya district, India, launched *flyrock* debris that struck and killed 35-year-old Narayana. The two other quarry employees, Shambu, 40, and Lokesh, 16, struck by *flyrock* sustained injuries and each one was transported to a local hospital for treatment. After inspecting the blast site, the Pandvapura police registered a case against the owner of the quarry.[73]
- *Flyrock 193:* On June 12, 2015, a blast at a quarry launched *flyrock* debris that struck a mine company vehicle at 440 feet (134 metres) from the site of the blast where two miners were tasked to keep anyone from entering the blast area. No one was injured, but the vehicle sustained damage.[74]
- *Flyrock 194:* On September 15, 1999, a blast at a quarry in Sau Mau Ping, China, launched *flyrock* debris in which "three men were injured, and 12 vehicles were damaged when rocks were hurled about 300 metres, outside the danger zone" of the quarry. Those injured were quarry worker Chan Fuk-hei, 47, security guard Choi Sheung-yin, 62, and dump truck driver Leung Hoi, 46. Chan was struck in the back by a rock "as big as a football" while seeking cover behind vehicles. Choi was hit by a piece of rock that shattered the window of the guardroom from which he watched the blast. Leung suffered eye injuries when a rock shattered the windscreen of his truck, outside the danger zone. "The man who detonated the blast…has 27 years' experience in blasting and said precautions had been taken" (SCMP Reporter, 1999).

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69 https://www.cdc.gov/niosh/mining%5C/UserFiles/works/pdfs/fadtf.pdf
70 https://www.cdc.gov/niosh/mining%5C/UserFiles/works/pdfs/fadtf.pdf
71 Flyrock Dangers & Best Practices, Mine Safety and Health Administration, https://www.msha.gov/news-media/announcements/2016/03/24/flyrock-dangers-best-practices. Retrieved on December 17, 2022.
72 https://static.compliancetrainingonline.com/docs/Blasting_Injuries_in_Surface_Mining.pdf.
73 "One killed, two injured in quarry blast," *DH Deccan Herald News*, Sep 29, 2017, https://www.deccanherald.com/content/635468/one-killed-two-injured-quarry.html.
74 DMM Safety Alert: Second Flyrock Incident in 2015, https://energy.virginia.gov/mineral-mining/documents/SAFETY/ALERTS/blastingflyrock/2015FlyrockSafetyAlert2.pdf.

- *Flyrock 195:* On August 24, 2022, a blast at the Hanson Aggregates limestone quarry (1685 Riverton Road) in Warren County, Vermont, launched *flyrock* debris that landed on both 340/U.S. 522 and Interstate 66 interchange, and in the parking lot in front of Dominion Health and Fitness (9816 Winchester Road), which was also struck by flyrock debris. The northbound and southbound lanes of U.S. 340/U.S. 522 just south of I-66 interchange as well as the eastbound ramp at exit 6 (Front Royal) of I-66 had to be closed while rocks and debris were cleared from the roadways. The Dominion Health and Fitness club sustained damage from the four rocks that penetrated the building while people were inside the gym, and was forced to close its business temporarily, and a number of vehicles in the parking lot were also damaged. A number of vehicles on the two highways were either struck by flyrock debris or drove over flyrock debris, and eight motorists sustained injuries. Emergency responders took one person to a nearby hospital and treated the others at the scene for minor injuries. The flyrock debris field extended for approximately a half-mile (805 metres) from the site of the blast (Bridges, 2022).

Of the additional 32 flyrock incidents discovered, seven or 21.9 percent resulted in death, accompanied by four people who were injured in the same seven flyrock incidents. The indicated kill rate of 21.9%, is higher than the corresponding rate of 16% for the initial 163 flyrock incidents previously discovered and analyzed. Combined, of the total 195 flyrock incidents discovered, 33 resulted in death, indicating an overall kill rate of 16.9%, and 40 people were injured in the same 33 flyrock incidents.

Setbacks in Land Use Planning and Protection of the Environment

In land use planning, a setback is the minimum distance which a building or other structure must be setback from a street, road or highway, a river or other stream, a shore or flood plain, or any other place deemed to need protection. Other things such as fences, landscaping, septic tanks, and various potential hazards (e.g., blasting quarry operations) or nuisances (e.g., noise, odour, vibrations) are regulated and prohibited by minimum setbacks for reasons of public policy (e.g., health, safety, welfare, privacy and environmental protection).

As a legal term, "environment" is broadly defined and includes all life forms, habitats, areas of the earth, ecosystems and organisms, as well as all land, marine and atmospheric resources.[75]
Setbacks are important in preventing (or containing onsite) the *adverse effects* (*Ontario* Provincial Policy Statement 2020, p. 139) associated with blasting quarry operations on the environment and its inhabitants:

a) impairment of the quality of the natural environment for any use that can be made of it;
b) injury or damage to property or plant or animal life;
c) harm or material discomfort to any person;
d) an adverse effect on the health of any person;
e) impairment of the safety of any person;
f) rendering any property or plant or animal life unfit for human use;
g) loss of enjoyment of normal use of property; and
h) interference with normal conduct of business.

Flyrock, ruled a contaminant by the Supreme Court of Canada in the *Castonguay* case (2013),[76] meets *Ontario* Environmental Protection Act's (EPA) definition of *contaminant* and the *adverse effects of flyrock*

[75] Bruce Pardy *Environmental Law: A guide to Concepts* (Butterworths, Toronto, 1996) at 99, cited at p. 23 of Dale Peter Scott's master's thesis, Victoria University of Wellington. https://researcharchive.vuw.ac.nz/xmlui/bitstream/handle/10063/5199/thesis.pdf?sequence=1.

[76] *Castonguay Blasting Ltd. v. Ontario (Environment)*, 2013 SCC 52 (CanLII), [2013] 3 SCR 323, <https://canlii.ca/t/g1038>, retrieved on 2022-08-26. In addition to being ruled a "contaminant," the Supreme Court of Canada noted that "fly-rock could easily have seriously injured or killed someone."

are not *trivial.*[77] The catalogued list of flyrock incidents, collectively, are shown to have caused all of the above-noted *adverse effects*, including death of human and non-human life. *Flyrock* launched offsite onto publicly-owned or privately-owned third-party property constitutes actionable "trespass" or "nuisance."[78]

A quarry can remain operational for 100 years or more adversely affecting five or more generations in the surrounding communities, and cause permanent and irreversible environmental damage. In Ontario, Canada, a provincial licence issued by the Ministry of Natural Resources and Forestry (MNRF) to permit aggregate extraction has no expiry date, and the blaster-in-charge at a quarry does not require a licence as proof of competency. The *working-from-home* and *home-based* economy spawned by the COVID-19 pandemic means that more residents and occupants of home-based businesses[79] in communities surrounding existing or new blasting quarry operations will be subjected to the potential *adverse effects* of *flyrock* (and the other adverse effects associated with a blasting quarry operation) on an ongoing and uninterrupted basis during the entire life of the quarry operation.

> *"The COVID-19 pandemic has changed the work location of thousands of Canadian workers. From April 2020 to June 2021, 30% of employees aged 15 to 64 who worked during the Labour Force Survey (LFS) reference week had performed most of their hours from home. In contrast, about 4% of employees did so in 2016.*
> *Of all Ontario workers—employees and self-employed—aged 15 to 64 who were working during the LFS reference week, 37% worked from home from April 2020 to June 2021."*[80]

An online survey released on October 11, 2022 by Hardbacon revealed that "80 per cent of Canadian remote workers would quit their job and look for a new one if their employer asked them to return to the office five days a week." There are significant out-of-pocket cost savings associated with working from home, which according to Hardbacon are estimated at $6,760 annually per employee, based on a year of 260 days (Szperling, 2022).

> *"On average, respondents estimate an average daily spend of $26 in out-of-pocket expenses related to going to the office. Annualized, this cost amounts to $6,760 per employee, based on a year of 260 working days…"*

In *Hoffman Mining Co. Inc. v. Zoning Hearing Bd.*, (2011),[81] Hoffman leased a 182.1-acre tract in Adams Township, Pennsylvania. On November 20, 2006, Hoffman submitted an application to the Zoning Board

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77 The EPA "Land Use Compatibility Definitions" defines "Trivial Impact" as "present or predictable contaminant discharges which are or are likely so minor that there would not be an "adverse effect." Flyrock is an inevitable by-product whenever and wherever blasting rock occurs (e.g., blasting quarry operation).

78 *Attorney General v. PYA Quarries Ltd*. [1958] EWCA Civ 1 (15 March 1958), https://www.bailii.org/ew/cases/EWCA/Civ/1958/1.html.

79 For example, the Town of Caledon Zoning By-law 2006-50, as amended, restricts *home occupation* to "no more than 25% of the *dwelling unit* area" and "permits one additional employee." "Home Occupation means an occupation or business which is conducted entirely within a *dwelling unit,* and which is clearly subordinate or incidental to the principal use of the dwelling unit for residential purposes, but does not include *any cannabis or industrial hemp use*" (Section 3-21, revised February 28, 2022). In the Caledon Official Plan, Chapter 6-42 (79.), consolidated April 2018, Home Occupation, shall mean any privately operated business which is limited in area, provides a service as an accessory use within a residential dwelling unit or under limited circumstances, an accessory building and is performed by one or more of the permanent residents of that dwelling unit and is compatible with the character of the residential setting or surrounding community. Such occupations may include but not limited to bed and breakfast establishments, professional and consulting services; instructional services; homecraft businesses; distribution sales offices or mail order sales; offices for trades or repair services; and, high technology uses. The incidental promotion and retailing of products specifically created on-site shall be permitted.

80 "Working from home: a new experiment for many Canadian workers." 2021-08-04, https://www150.statcan.gc.ca/n1/daily-quotidien/210804/dq210804b-eng.htm.

81 *Hoffman Mining Co. v. Zoning Hearing Bd. Of Adams Twp.* 32 A.3d 587 (Pa. 2011), https://scholar.google.ca/scholar_case?case=10693173978612087 46&q=hoffman+mining+company+inc+v+zoning+hearing+board+of+adams+township&hl=en&as_sdt=2006.

requesting a variance from Adams Township Zoning Ordinance to allow surface coal mining within 300 feet (91 metres) of residences. The Zoning Ordinance requires a 1,000-foot (305-metre) setback from residential structures. However, under Section 17.1 of the *Pennsylvania* Surface Mining Conservation and Reclamation Act (SMCRA) only a 300-foot (91-metre) setback is required.[82] The SMCRA is concerned with the methods by which the mineral (coal) is derived from the surface of the ground at all stages, whereas, the Zoning Ordinance merely contains a required minimum distance from which surface mining may be conducted next to a residential structure.

> *"…[T]he 'challenged [residential setback] provision of the Zoning Ordinance is a quintessential land use control logically connected to land use planning and is, therefore, not preempted by…[Section 17.1 of SMCRA [para. 592]."*

Hoffman's request for a variance from the township's 1,000-foot (305-metre) setback requirement was denied by the Zoning Board and upheld by the Supreme Court of Pennsylvania as the setback served to address "substantial health, safety and welfare issues."

> *"The Zoning Board found credible the residents' testimony regarding the following hazards of the proposed mining: debris and dust descending into the Village, due to the steep elevation of the proposed mining site; danger to children from open holding ponds 12-14 feet deep, adjacent to areas where they play; the residents' health issues, including asthma and other respiratory problems [para. 591]."*

The Court also found the required 1,000-foot (305-metre) setback not to be unique to Hoffman's 182.1-acre parcel of leased land, and that the property owner (Lessee) had not been deprived of all economic use of the land. The Court was unsympathetic to Hoffman's argument that the 1,000-foot (305-metre) setback from Village residences imposed by the township would deprive Hoffman of its ability to mine 88% of 220,000 tons of mineable coal, reducing potential profits by some $6,000,000.

> *"Hoffman asserts that because of the unique physical circumstances and conditions of the Property, the 1,000 foot setback would deprive it of its ability to mine 220,000 tons of mineable coal or 88% of the reserves on the Property. Because the setback would have that effect, Hoffman argues that it has shown that the Zoning Ordinance has denied it of the use of its property entitling it to a variance [para. 612]."*
>
> *"Testimony before the Board established that approximately 220,000 tons of coal with a market value of $30 per ton would be lost if the 1,000 foot setback was applied, amounting to an economic detriment of at least $6,000,000 [para. 613]."*

In *City Sand and Gravel Ltd. et al v. Newfoundland (Minister of Municipal Affairs)*, (2005),[83] St. John's Metropolitan Area Board Planner Stephen Jewczyk, "classified flyrock from blasting operations as a public danger" to the inhabitants in the Jane Heights subdivision near the 48-acre blasting quarry in the Town of Paradise, with the court finding as follows:

> *"On the issue of foreseeability, I am satisfied, based on Stephen Jewczyk's comments on discovery, as well as the ongoing evolution and growth of both the residential area and quarry operations, and the change in the size of the recommended buffer zones [increased from 300 metres to 1,000 metres] which took place between 1983 and 1996, that none of the parties foresaw any danger might be created [by flyrock from the quarry blasting (para. 58)]."*[84]

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[82] The setback requirement under *Ontario's* Aggregate Resources Act is 30 metres

[83] *City Sand and Gravel Ltd. et al. v. Newfoundland (Minister of Municipal and Provincial Affairs)*, 2005 NLTD 67 (CanLII), <https://canlii.ca/t/fwvrv>, retrieved on 2022-12-12.

[84] There have been three known flyrock incidents at the quarry, as identified in para. 58 of *His Majesty the King in Right of Newfoundland and Labrador v O.D. Holdings Limited and City Sand and Gravel Limited*, 2022 NLCA 60 (CanLII), <https://canlii.ca/t/jsvbs>, retrieved on 2022-12-12.

> *"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]."*[85]

According to the *Cessnock Development Control Plan* (2010) for the Cessnock City Local Government Area (LGA) in New South Wales, Australia,[86] policies addressing *encroaching development* and *separation distances* have been implemented to eliminate or avoid existing and future land use conflicts, as noted below:

- Where an application is received which is likely to result in a conflict with existing or likely future adjoining land uses, it will be the responsibility of the 'encroaching development' to provide the recommended buffer areas or satisfactorily reduce or remove the conflict through some other approved method.
- It will be generally required that where a physical separation is required it will be located on land in the ownership or control of the owner or operator of the encroaching development [4.2.4].
- Minimum separation distances refer to a measurement from the offending development to the property boundary of the affected land use unless otherwise stated [4.2.5].
- Appropriate site selection can avoid or reduce many of the environmental problems associated with proposals and:
    - reduce the need for technically based environmental mitigation measures and on-going management measures;
    - result in substantial savings in establishment and operational costs;
    - reduce levels of public concern; and
    - avoid potential delays in approval processes
- Site selection should therefore be based on the following principles:
    - is the land use permissible in the zone?
    - are environmentally sensitive areas avoided?
    - is the use compatible with nearby land uses?
    - do initial site investigations indicate that the site is fundamentally suitable for the use proposal?
- This is an essential step in locating developments which require buffers, and applicants may be required to provide an analysis of a number of sites to justify the preferred location, should that site not meet minimum separation guidelines [4.2.6].
- While compliance with the separation distances will assist in reducing conflicts, it will not guarantee that no conflict will occur, or that the proposal will be acceptable [4.2.8].

Quarries – Potential Conflicts

Potential conflicts include noise, dust, vibration, blast over-pressure, fly-rock from blasting, disruption and contamination of ground and surface waters. Potential for significant visual impact. Impacts on vegetation and habitat from clearing.

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[85] *City Sand and Gravel Limited v. Newfoundland (Municipal and Provincial Affairs),* 2007 NLCA 51 (CanLII), <https://canlii.ca/t/1sfnv>, retrieved on 2022-12-12. Leave to appeal to the Supreme Court of Canada denied.

[86] Part C: General Guidelines, Chapter 4: Land Use Conflict and Buffer Zones, file:///C:/Users/Windows%207%20PC/Downloads/Land-Use-Planning-_-Cessnock-DCP-2010-_-Part-C-General-Guidelines-_-CCC-website-doc.pdf.

[Category C] Land uses around which a buffer distance for residual emissions is required. These emissions include: noise; dust; vibration; odour; waste product whether liquid or gas; and can range from causing nuisance or discomfort to humans to being a risk to health and well-being. Examples include: coal mines; quarries:

- Minimum self-contained buffer of 1,000 metres from Category A [Sensitive Land Uses]…, which warrant protection from amenity reducing off-site effects from other land uses [e.g., Quarry]. These include all dwellings, caravan parks, community facilities, hospitals, pubs, serviced apartments, restaurants, schools, tourist facilities, seniors housing or other place of permanent or temporary occupation. [emphasis added]

In the 110-page 2015 decision of the Town of Nassau, New York, which denied the Troy Sand and Gravel application, the Town rejected the notion that private third-party offsite land could be used by the owner of the quarry site to mitigate a number of adverse impacts associated with a blasting quarry operation, commenting as follows:

- The Town considers use of private land to further mitigate fugitive dust impacts as unacceptable. As per this criteria, new land uses in Nassau are expected to perform to a level where no emissions of dust or other materials that could cause damage to the health of persons, animals, plant life or other forms of property are allowed. The anticipation that land beyond the quarry property would allow dust to settle indicates that this criteria cannot be met…The public record establishes ongoing concerns about fugitive dust and its implications on private property.
- Using 1,300 feet [including 300 feet or 91.44 metres onsite] as a[n external] buffer is in error because
    - It assumes another person's private property as mitigation;
    - Assumes that other private landowners will maintain their tree cover, when in fact those woodlands could be harvested; and
    - Assumes that no other lots or new homes will be created on private property closer than the 1,300' [396 metres]. This fact diminishes the use and enjoyment of those properties by non-mine landowners.

Setback requirements prohibiting quarrying uses, regardless of whether blasting is involved, are traditional land use regulations within a municipality's/planning board's jurisdiction.[87]

Municipal Setbacks and General Welfare Provisions – Case Law Commentary

The following commentary with respect to the powers enjoyed by municipalities under municipal jurisdiction appeared in a September 2010, Webinar presented by Laura Bowman, Staff Counsel, Environmental Law Centre:[88]

> *"An early municipal jurisdiction case over gravel pits was Uxbridge Township v. Timber Brothers Sand and Gravel Ltd., [1975].*[89] *In that case the Ontario Planning Act explicitly provided for the power for municipalities to make bylaws prohibiting pits and quarries in certain areas. Uxbridge Township had imposed a bylaw providing land uses and residential setbacks for pits and quarries. A further bylaw regulated the operation of pits including rehabilitation and safety requirements.*
> *The court interpreted this to allow only the prohibition of new pits, not the regulation of existing ones. The court considered that the Municipal Act in Ontario provided the power to regulate*

[87] *Tinicum Township v. Delaware Valley Concrete*, 812 A. 2d 758 (2002), Commonwealth Court of Pennsylvania, para. 764, https://scholar.google.ca/scholar_case?case=15752167703902735334&q=flyrock+and+%22setbacks&hl=en&as_sdt=2006.
[88] https://elc.ab.ca/media/7529/GravelPitsHandout.pdf.
[89] [1975] O.R. (2d) 484 (Ont. C.A.) Leave to appeal to Supreme Court of Canada Dismissed.

> *the "operation" of pits and quarries. The operator challenged an Uxbridge Township bylaw on (among other grounds) the basis that the province already regulated quarry rehabilitation and setbacks. The court found that the Municipality could provide additional setbacks:*
>
> > "The provincial legislation does no more than set the minimum set-back requirements or standards and in no way attempts to restrict the right of a municipality to enhance these standards. This the municipality may do provided it acts within its delegated legislative powers and does not enact provisions in by-laws which are inconsistent with statutory provisions. [emphasis added]"
>
> *The court held that municipal setbacks that were less than those provided for in provincial legislation, were invalid. The court allowed an injunction against the pit based on the other portions of the gravel regulation bylaw.*
> *The case was referenced by the Supreme Court of Canada in Spraytech* [2001][90] *specifically for the proposition that municipalities may regulate the environment more than the province does.*
> *The SCC went on to hold that general welfare provisions in municipal statutes, including in Alberta, authorize environmental regulation within a municipality relating to pesticides, notwithstanding the existence of provincial laws relating to the same subject."*

A proponent seeking municipal planning approval of an application to permit a new or expanding blasting quarry is responsible for ensuring *flyrock*, a common undisclosed and underreported occurrence (Davis, 1995), does not injure or kill onsite quarry employees or leave the boundaries of the site and cause harm to the environment or injure or kill human and non-human life offsite. In *City Sand and Gravel Limited v. Newfoundland (Municipal and Provincial Affairs)*, 2007,[91] in which the quarry operator had leased land restricting quarry operations to the leased land, the Supreme Court of Nova Scotia upheld the trial court's finding that creation of an (external) buffer zone "would not authorize City Sand to eject fly-rock outside the quarry site and onto land comprising the buffer zone [para. 42]."

> *[38] The quarry operation, apparently conducted in compliance with the requirements of regulatory authorities, involving blasting of rock face with the resultant inherent danger of fly-rock. Throughout the relevant period, the successive quarry leases under which City Sand derived its rights forbade quarrying within 300 meters of a residential development without ministerial approval. City Sand understood from discussions with the Department of Mines and Energy, which issued the quarry leases, that there was a buffer around the quarry site. However, the quarry leases did not confer upon City Sand rights over property outside the quarry.* [emphasis added]

On May 20, 1988, a blast at the City Sand and Gravel quarry launched *flyrock* debris offsite, which landed in the buffer zone, and resulted in complaints from nearby residents. A second *flyrock* incident occurred on July 3, 1998, causing damage to one resident's garage and the roof of another resident's house in the nearby Jane Heights subdivision. As noted below by the Court, City Sand and Gravel had no legal right of use to the offsite buffer.

> *"The buffer zone, by definition, is a neutral area designed to separate, in this instance, two inconsistent and adjoining land 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, that is, granting plaintiff [City Sand and Gravel Limited] permission, in its*

[90] *114957 Canada Ltee (Spraytech, Societe d'arrosage) v. Hudson (Town)*, 2 S.C.R. 241, 2001 SCC 40.
[91] *City Sand and Gravel Limited v. Newfoundland (Municipal and Provincial Affairs),* 2007 NLCA 51 (CanLII), <https://canlii.ca/t/1sfnv>, retrieved on 2021-10-03. Leave to appeal to the Supreme Court of Canada denied.

> *operations, to eject rock or debris into this area and outside the boundaries of its leasehold realty property [para. 56].”*[92]

The implication of the trial court’s observations is that the only way for a quarry operator to prevent *flyrock* from leaving the site is for the quarry operator to provide its own internal safety buffer, the equivalent of a setback. By 1996, it become clear that a 300-metre buffer for a blasting quarry was inadequate, and in 1996 the Department of Municipal and Provincial Affairs, in its conditions for approval of a blasting quarry, required a buffer zone of 1,000 metres from a cottage or residence.

In 2014, Austin Powder Ltd. pleaded guilty before the Justice of the Peace for failing to report to the *Ontario* Ministry of the Environment (MOE) “discharging flyrock” that resulted in off-site environmental impacts from blasting at the 98-acre Pakenham Quarry, licenced by Ministry of Natural Resources on March 22, 2006. The particulars of the offence are described as follows:

> *“Austin Powder Ltd. and Keith Taylor…at Pts E1/2 26 & 27, Concession 9, Township of Lanark did commit the offence of discharging or causing or permitting the discharge of a contaminant, to wit fly rock from quarry blasting operations, into the natural environment which caused or was likely to cause an adverse effect contrary to Sec. 14 (1) of the Environmental Protection Act, R.S.O. 1990, c. E. 19, as amended, thereby committing an offence under Sec 186 (1) of the said Act.”*

On July 20, 2009, and, again, on July 23, 2009, blasting at the Pakenham Quarry launched *flyrock* off-site, the details of which are described in the following press release. (The July 23, 2009 flyrock incident also struck the onsite quarry scale house 230 metres from the blast, which Austin Powder Ltd. failed to report to the Ministry of Labour.[93])

> *“According to the press release the official version of events is as follows: "In the first incident,[July 20, 2009] a small rock struck a worker at a neighbouring business on the arm. In the second incident, [July 23, 2009] rocks were observed flying well beyond the control area. A [quarry] scale house located 230 metres from the blast was struck by a number of rocks.*
> *Two [civilian] vehicles [occupied by passengers] held at a controlled stop along nearby Young Road on the edge of the quarry property located about 300 metres from the blast were also struck by rock resulting in extensive damage. There were no injuries even though the blast damaged property and impaired the safety of people"* (Dunn, 2014).

During the MOE investigation (Case File Number: 2283-83MN69), Explotech Engineering, retained by MOE in response to the July 23, 2009 *flyrock* incident, testified and concluded even though “it appears that blast procedures were followed and that while not probable, the potential exists for a recurrence,” and “strongly recommend[ed]” the “hazard zone” (i.e., safety or exclusion zone, the equivalent of a setback) be increased to 500 metres:

> *“We strongly recommend that the hazard zone be increased to 500m when firing any future blasts.”* (Source: Explotech Report, September 25, 2009)

Despite Explotech declaring that “while not probable the potential for [flyrock] reoccurrence exists”, unbeknownst to Explotech, only three days earlier on July 20, 2009, another flyrock incident had occurred

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92 *City Sand and Gravel Ltd. et al. v. Newfoundland (Minister of Municipal and Provincial Affairs)*, 2005 NLTD 67 (CanLII), <https://canlii.ca/t/fwvrv>, retrieved on 2021-10-03.

93 A third known flyrock incident at the Miller quarry occurred on September 10, 2022, as reported by the Moores, neighbouring homeowners, https://www.stcatharinesstandard.ca/local-arnprior/news/2022/01/07/inspection-reveals-violations-at-site-of-arnprior-blasting.html.

at the Pakenham Quarry. [emphasis added]. In a follow-up July 16, 2010 report prepared by Explotech, in response to the first *flyrock* incident of July 20, 2009, Explotech concluded that

> *"A review of the video of the July 20, 2009 blast clearly shows flyrock rifling from the toe area in two areas along the face of the blast. Based on additional witness and video evidence, it is our opinion that Austin Powder staff had to have been or ought to have been aware of flyrock being projected beyond the quarry boundaries. It is further evident that Austin personnel failed to verify that flyrock did not cause damage and failed to review their blasting procedures to ensure that the potential for flyrock was eliminated in subsequent blasts.*
> *…[T]he incident of July 20, 2009 should have served notice to Austin employees that the safety zone [i.e., setback] was not sufficient and that a review of the drilling and blasting operation was required."*

Both the blasting company, Austin Powder Ltd., and the quarry owner, Thomas Cavanagh Construction Ltd. argued unsuccessfully in their defence of not being aware of the reporting requirements under the *Ontario* Environmental Protection Act:

> *"Statements from company officials for both Thomas Cavanagh Construction Ltd. and Austin Powder Ltd. confirmed that they did not report the said incidents, had no knowledge that fly rock constitutes a contaminant or, that fly rock incidents, which may cause an adverse effect must, be reported to the Ministry of the Environment."*

Flyrock is an uncontrollable and inevitable by-product of blasting, as confirmed by Keith Taylor, General Manager, Austin Powder Company Ltd:

> *"90% of fly rock incidents are "unexplainable."* [emphasis added]

As Tim Rath, manager of Technical Services of Green Mountain Explosives, who testified in 2008 on behalf of the Rivers' Quarry Application Hearing (Town of Moretown, Vermont) cautioned:

> *"You can never say never. No matter how careful a blaster is there is no certainty a blast will not cause flyrock."* [emphasis added]

Conclusion

Detonation of explosives is the primary method used for fragmenting rock, an activity resulting into a number of adverse effects on the surrounding environment and its inhabitants. As concluded by the research conducted, the adverse effect from blasting rock which has the greatest potential for damage to personal or real property and to cause injury or death to human and non-human life is flyrock. Flyrock is the ultimate adverse effect and is an unavoidable by-product of blasting rock. While there are a number of formulas that can be applied in computing the "throw" distance of rock (flyrock), none are particularly accurate. Also, the lack of a standardized definition of *flyrock* is responsible for the understating and underreporting of flyrock incidents, which undermine the aggregate industry's assertion that flyrock is a "rare" event. Since flyrock cannot be eliminated, there is no level of acceptable "risk." The only effective remedy to shield against flyrock is the enactment and implementation of land use planning policies at the municipal level (e.g., comprehensive plan, official plan, zoning by-law/ordinance, municipal health, safety and welfare by-law/ordinance) that impose a permanent minimum onsite setback coupled with a permanent minimum external separation distance from incompatible, present and future, land uses. In Ontario, the ARA has no definition of "flyrock" or "blast area" (exclusion zone), and the "blaster-in-charge" does not require a licence demonstrating competency, all of which are a detriment to the environment and compromise the health and safety of onsite quarry employees and the people who live, work and play offsite in the communities surrounding a blasting quarry operation.

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Author's Declarations and Essential Ethical Compliances

Author's Contributions (in accordance with ICMJE criteria for authorship)
This article is 100% contributed by the sole author. He conceived and designed the research and analysis, collected the data, contributed to data analysis & interpretation, wrote the article, performed critical revision of the article/paper, edited the article, and supervised and administered the field work.

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Research involving human bodies (Helsinki Declaration)
Has this research used human subjects for experimentation? No

Research involving animals (ARRIVE Checklist)
Has this research involved animal subjects for experimentation? No

Research involving Plants
During the research, did the authors follow the principles of the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora? Not applicable

Research on Indigenous Peoples and/or Traditional Knowledge
Has this research involved Indigenous Peoples as participants or respondents? No

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