Imagine sitting in your living room when suddenly the earth shakes, walls crack, and the chimney crashes through the roof and lands in your lap. You are rushed to the emergency room, and your home suffers more than $100,000 in damages. This is what happened to Sandra Ladra in 2011 following a large earthquake near Prague, Oklahoma, that damaged roads and destroyed at least 14 homes. The 5.6-magnitude (M) quake was the largest recorded in Oklahoma history, and one of many unprecedented tremors that have hit the region in recent years. Scientists concluded that the event was facilitated by the operations of nearby oil and gas wastewater disposal wells, and Ladra sued the two companies believed to be responsible. The lawsuit has the oil and gas industry worried about an emerging liability issue: induced seismicity.

The development of unconventional sources of oil and gas using horizontal drilling and hydraulic fracturing has provided the United States with enhanced energy security, boosted the industrial economy, and decreased our imports from more unstable regions of the world. At the same time, unconventional production has become increasingly controversial as new environmental and social concerns emerge in the wake of shale development. Induced seismicity is perhaps the “most unexpected phenomenon” of America’s energy boom.

The number of earthquakes felt in the central and eastern United States has increased dramatically since around 2009. Myths surrounding the phenomenon abound, but the consensus from the scientific community is that the injection of wastewater fluids is the most likely culprit in

**Shattered Nerves: Addressing Induced Seismicity Through the Law of Nuisance**

by Lucas Satterlee

Lucas Satterlee is a 2016 J.D. candidate at the University of Denver Sturm College of Law.

**Summary**

The number of earthquakes felt in the central and eastern United States has increased dramatically; the scientific consensus is that injection of oil and gas wastewater fluids is the most likely culprit. Regulations and voluntary industry efforts are likely the best mechanisms to mitigate the risks associated with induced seismicity, but the common law remains relevant. This Article explores whether and to what extent a nuisance framework can be applied. Utilizing the law of nuisance to address induced seismicity is a novel concept, but the same basic rules used to assess liability when other human activities cause the earth to vibrate should apply. Proving causation is currently plaintiffs’ most challenging obstacle, but as the science becomes more developed, the chances of establishing the requisite link increase. The Article concludes that if reasonable precautions are not taken in the siting and operation of an injection well, companies can be held liable for creating a nuisance in the form of earthquakes.

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3. Matthew Weingarten et al., High-Rate Injection Is Associated With Increase in U.S. Mid-Continent Seismicity, 348 SCIENCE 1336 (2015) (finding that “high-injection wells (>300,000 barrels per month) are much more likely to be associated with earthquakes than lower-rate wells”).
4. Bustillo & Gilbert, supra note 2.
5. Id.
6. Hydraulic fracturing, or “fracking,” is the process of injecting a cocktail of mostly water, sand, and chemicals at high pressure into deep geologic strata to fracture hydrocarbon-bearing source rocks in order to provide permeable pathways to extract the oil and gas. Russell Gold, The Boom 30 (2014).
10. Seismicity in the region has ballooned from an average of approximately 20 per year (1970-2000) to over 100 per year (2010-2013). Peter Folger & Mary Tiemann, Cong. Research Serv., R43836, Human-Induced Earthquakes From Deep-Well Injection: A Brief Overview 4-6 (2015).
the increasing rates in seismicity.\textsuperscript{11} Hydraulic fracturing itself is unlikely to result in any significant levels of seismicity felt at the surface, but the rapid development of unconventional formations using this technique has contributed to the volume of wastewater that needs to be disposed of.\textsuperscript{12} The following analysis is limited to a discussion of induced seismicity resulting from wastewater disposal, not hydraulic fracturing.

The uptick in interest surrounding induced seismicity has drawn a varied response from lawmakers, regulators, and others. Regulations and voluntary industry efforts are likely the best institutional mechanism to mitigate the risks associated with induced seismicity, but the role of the common law remains relevant.\textsuperscript{13} The common law provides flexibility to address newly recognized harms, particularly where an industry’s political clouthamstrings regulators from being more aggressive.\textsuperscript{14}

Liability for induced seismicity may be found under several existing tort theories, but this Article is limited to a discussion of nuisance law. Section I presents general background information on the phenomenon known as induced seismicity in the context of Class II oil and gas wastewater disposal wells. Sections II-IV analyze the threshold issue of causation and apply existing nuisance law theory to induced seismicity. The Article concludes that in the right circumstances, wastewater well operators can be held liable for creating a nuisance in the form of damaging earthquakes.

I. Induced Seismicity and the Link to Oil and Gas Wastewater Disposal

The central United States has experienced a “dramatic increase” in seismicity over the past six years\textsuperscript{15} (see Figure 1). While most of these events are too small to be felt, several damaging earthquakes occurred in areas where historical levels of seismicity were minimal.\textsuperscript{16} Nowhere has this trend been more evident than in Oklahoma.\textsuperscript{17} In 2014, Oklahoma became the most seismically active state in the continental United States, enduring at least 5,415 earthquakes, which is more than it experienced in the previous 30 years combined.\textsuperscript{18} The Sooner State is on pace to double that number in 2015,\textsuperscript{19} as “the frequency and severity of these earthquakes are both on the rise.”\textsuperscript{20} The explanation for these events appears to be induced seismicity.\textsuperscript{21}

Induced seismicity is defined as earthquakes resulting from anthropogenic activity that “causes a rate of energy release, or seismicity, which would be expected beyond the normal level of historical seismic activity.”\textsuperscript{22} Over the decades, scientists have recognized an array of human activities known to cause earthquakes.\textsuperscript{23} The most infa

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\includegraphics[width=\textwidth]{figure1.png}
\caption{Increasing Rate of Earthquakes Beginning in 2009}
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\hline
Year & Number of M 3+ Earthquakes & Number of M 4+ Earthquakes & Number of M 5+ Earthquakes & Number of M 6+ Earthquakes & Number of M 7+ Earthquakes \\
\hline
1973-1983 & 500 & 200 & 50 & 5 & 1 \\
1984-1993 & 1000 & 400 & 100 & 10 & 5 \\
1994-2003 & 1500 & 600 & 150 & 15 & 5 \\
2004-2013 & 2000 & 800 & 200 & 20 & 5 \\
2014 & 2500 & 1000 & 250 & 25 & 5 \\
\hline
\end{tabular}
\caption{Number of Earthquakes by Magnitude}
\end{table}

\textsuperscript{12} Folger & Tiemann, \textit{supra} note 10, at 11.
\textsuperscript{14} Holly Doremus et al., \textit{Environmental Policy Law} 40 (6th ed. 2012).
\textsuperscript{15} Rubinstein & Mahani, \textit{supra} note 11, at 1.
\textsuperscript{16} In 2011 alone, multiple damaging earthquakes occurred: M5.6 Prague, OK; M3 Trinidad, CO; and M4.7 Guy-Greenbrier, AR. Rubinstein & Mahani, \textit{supra} note 11, at 1. For comparison, the 2015 earthquakes that devastated Nepal (4/25) and Afghanistan (10/26) were 7.8M and 7.5M, respectively, and some of the largest natural earthquakes ever recorded include Chile 1960 (M9.5); Alaska 1964 (9.2); Sumatra 2004 (9.1); and Japan (2011 (9.0); http://earthquake.usgs.gov/earthquakes/eventpage/us10003re5#general_summary; http://www.usgs.gov/blogs/features/usgs_top_story/magnitude-7-8-earthquake-in-nepal; http://earthquake.usgs.gov/earthquakes/world/10_largest_world.php.
\textsuperscript{17} Arkansas, Ohio, and Texas have also experienced damaging quakes with suspected links to wastewater from oil and gas operations. Richards, \textit{supra} note 13, at 3.
\textsuperscript{18} Bustillo & Gilbert, \textit{supra} note 2.
\textsuperscript{21} The U.S. Geological Survey (USGS) began warning in 2012 that the surge in earthquakes in Oklahoma was likely linked to disposal operations. Mike Soraghan, \textit{Sierra Club Threatens to Sue Drillers to Stop Oklahoma Earthquakes}, E&E NEWS, Nov. 3, 2015, http://www.eenews.net/stories/1060027316.
\textsuperscript{23} Human activities known to induce seismic events include impoundment of reservoirs, mining, withdrawal of fluids such as oil and gas, and injection
mous case of injection-induced seismicity involved a series of quakes that struck near Denver in the 1960s. The events were eventually linked to the underground injection of hazardous chemical wastes at the Rocky Mountain Arsenal defense plant. Prior to the 2011 earthquake that struck near Prague, Oklahoma, an M5.3 seismic event that hit Denver in 1967 was generally considered the largest human-induced earthquake in recorded history. There are similarities between the Rocky Mountain Arsenal earthquakes and recent events taking place in the central United States.

Induced seismicity has been observed in the oil and gas industry since at least the 1930s and can be attributed to three types of large-scale fluid injection used by the industry: wastewater disposal, hydraulic fracturing, and enhanced recovery. While each of these processes is capable of inducing seismic events, wastewater disposal is attributed to the “vast majority” of the recent increase, “including the largest and most damaging quakes.” For this reason, nuisance claims based on disposal activities are likely to be the most successful.

The basics of how human activities can cause earthquakes are fairly well-understood, and the primary driving mechanism of an injection-induced earthquake is increased fluid pressure.

The oil and gas industry injects a large portion of its wastewater into Class II disposal wells. Scientists at the U.S. Geological Survey (USGS) explain that most injection operations “do not appear to induce earthquakes . . . much less damaging ones.” Most of the tremors have been seismic (that is, not causing any appreciable seismic activity for quakes over M3), and most wells are in underground formations that have a “low risk of failure leading to damaging earthquakes” if the injection fluids do not migrate from the intended structure. However, induced seismicity associated with wastewater disposal “will become an increasingly important issue” as domestic energy resources continue to be developed.

If state regulators are slow to address induced seismicity in a meaningful way, some operators may ignore the risk. This risk of “inertia against regulation” is particularly high in places like Oklahoma and Texas, where the oil and gas industry makes up a large portion of the economy and has substantial influence over the state’s political agenda. Ultimately, regulation will probably have a more direct mitigation effect than litigation, but the common law provides supplemental deterrence. Until regulators and insurance markets catch up to the new geologic norm in the central United States, those injured by induced seismicity will rely on the common law for redress.

II. Common-Law Liability and Earthquake Lawsuits

The common law provides flexibility to address newly recognized harms. It is not subject to the same “political pressures and bureaucratic inertia” encountered in the regulatory process. Rather, it can provide an early response to new technologies and “where external forces demand change.” While causation still presents a difficult barrier for induced seismicity plaintiffs, the preponderance of the evidence standard enables juries to decide issues that may be an area of ongoing scientific uncertainty. Further, tort liability has an indirect deterrent effect on those causing the nuisance and may provide an incentive to mitigate the problem of induced seismicity where social command lags behind.
The battle over unconventional shale development is being fought in the courts on many fronts, and earthquake lawsuits are just beginning to enter the fray (see Figure 2). Over 20 such lawsuits have been filed since 2011, and more are just quietly in settlement, but the Ladra case has been watched closely by the industry and those immersed in the fracking debate nationwide. The district court dismissed the case for lack of jurisdiction, reasoning that the Oklahoma Corporation Commission (OCC) has exclusive jurisdiction over cases involving oil and gas operations. However, in June 2015, the Oklahoma Supreme Court reversed, and remanded the case for a determination on the merits. The court held that “district courts have exclusive jurisdiction over private tort actions when regulated oil and gas operations are at issue.”

Regardless of the eventual outcome, the Oklahoma Supreme Court’s unanimous decision paves the path for other landowners seeking compensation for injection-induced seismicity in Oklahoma. Another important case is Cooper v. New Dominion, LLC. The Oklahoma class action lawsuit seeks damages caused by the same defendants and earthquakes at issue in the Ladra case. Allowing these cases to proceed is a huge victory for the plaintiffs and others injured by injection-induced seismicity, but whether any of these landowners will ultimately succeed on the merits is far from clear. Proving causation and developing an appropriate litigation framework is the next step.

III. Legal Causation

Is there a relationship between the defendant’s injection activity and the plaintiff’s injuries? Even if the defendant’s injection activities played some role, should the inducer be liable for damage brought about by the tectonic forces of nature? When natural disasters strike, these so-called acts of God fall on a continuum. At one end of the spectrum are events caused by purely natural forces. At the other end are damaging forces induced by the “exercise of human will.” When human enterprise is thought to be responsible for inducing the events, the common law attempts to assess fault through the concept of “causation.”

Induced seismicity is still an area of ongoing research, but the general consensus from the scientific community is that a cause-and-effect relationship exists. Yet establishing...
Superseding Cause

The doctrine of superseding cause—an unforeseeable cause of independent origin—is likely to come up in a case of induced seismicity. The doctrine releases a defendant from liability where an unforeseen intervening force of nature supersedes the defendant’s tortious conduct. Ample scientific warning, public scrutiny, and the fact that injection-induced earthquakes have been observed since the 1960s suggest that the recent seismic events were foreseeable. An intervening force is not a superseding cause if the defendant’s inducing activity “put the force into motion,” and courts have held companies liable for “releasing or redirecting” a destructive force of nature. Therefore, because the tectonic force depends on the injection activities to lubricate the faults and produce the injury at the time it occurs, the force is unlikely to be considered a superseding cause that relieves defendants of liability.

General and Specific Causation

Plaintiffs must prove both general and specific causation, and “scientific uncertainty complicates both tasks.” For general causation, plaintiffs must prove that the type of injection operation used by the defendants is capable of causing the type of damaging tremors suffered by the plaintiffs. Putting forth evidence of general causation will not be as difficult, since the science supports the notion that wastewater injection can cause, and has caused, dam-

Circumstantial Evidence and Expert Testimony

The issue of causation is a question of fact to be determined by a jury, and establishing such a link will rely almost exclusively on circumstantial evidence. In cases involving property damage from earth vibrations caused by blasting operations, circumstantial evidence based on reasonable inferences is often sufficient to establish causation. The same probably holds true for injection-induced earthquakes. The corresponding timing of injection, close proximity of disposal wells to the epicenter, and low historic levels of natural seismicity are factors that weigh in favor of a causation finding.

This determination also involves a heavy dose of expert testimony, and plaintiffs are likely to depend heavily on recent scientific reports to establish a causal link. In both complaints, the plaintiffs in Ladra and Cooper cite recent

64. Cypser & Davis, supra note 62 at 565-66 (explaining that “large portions of the earth’s crust may exist for centuries at a level of strain near the point of failure,” but the inducer invites “the damage to occur at that point in time”).
65. Restatement (2d) of Torts §§440 (1965).
66. Id.
68. Id. at 560-61.
69. Dorems, supra note 14, at 89.
70. Id. at 62.
71. Hayes & Sellers, supra note 47.
72. Id.
73. Id.
74. Id.
75. Watson & Rorke, supra note 20.
76. Cypser & Davis, supra note 62, at 562.
78. Cypser & Davis, supra note 62, at 562. See also U.S. EPA, Minimizing and Managing Potential Impacts of Injection-Induced Seismicity From Class II Disposal Wells: Practical Approaches (2015) (noting that the historic absence of seismic activity “may be one indicator of induced seismicity if seismic events occur following activation of an injection well”), http://www.epa.gov/owater/aic/techdocs.htm#ntwg.
USGS studies for causation theories. USGS is the federal agency responsible for studying and monitoring earthquake activity in the United States, and it has established an ongoing project looking into hazards from induced seismicity. In April 2015, USGS issued a comprehensive assessment of induced seismicity, mapping our regions where such quakes have occurred and linking the recent seismic activity in the central United States to oil and gas wastewater disposal operations. The report specifically references the 2011 M5.6 earthquake in Prague, Oklahoma, and explains that deep injection of wastewater in the region “could trigger earthquakes with enough strength to damage nearby structures.” Other studies have reached similar findings and may be relied on by plaintiffs searching for evidence of legal causation.

Although the barriers are formidable, in the right circumstances—where scientific studies positively link seismicity to the defendant’s disposal wells—plaintiffs can prevail on causation. The scientific understanding of induced seismicity is still an area of great uncertainty and ongoing research, but as scientists continue to establish a more definite link and regulators require more active monitoring, the task will become easier.

IV. Nuisance Liability Framework

After proving causation, the next step is to develop an appropriate liability framework for induced seismicity. The potential field of candidates includes tort theories based on nuisance, negligence, trespass, and strict liability. All these theories might be applicable to induced seismicity, and the determination is a matter of state law. This Article is limited to a discussion of nuisance; however, since elements of negligence and strict liability inform modern nuisance law, it discusses those theories within the nuisance framework. Nuisance allegations have been among the most common actions brought against oil and gas companies in the wake of the domestic energy boom, but a court has not yet applied nuisance theory to induced seismicity. The contours of such a framework are not entirely clear, but looking to familiar concepts of tort liability involving concussion or vibration damage provides a useful aid.

The common law has assessed liability for damaging induced vibrations in the context of “rocket engine tests, pile driving, explosives, oil wells,” and other industrial activities that shake the earth. Although these tremors originate at the surface and are more easily attributed to anthropogenic activities than induced seismicity, the same basic legal principles apply. The damages to persons and property are “similar to those caused by explosives or machine vibrations.” In fact, in one case, the dynamite blasting vibrations complained of might have actually been small induced earthquakes. Most states recognize the right of a plaintiff to recover damages caused by vibrations under a nuisance theory. Such actions have been pursued against oil and gas operations. Compensatory damages are the primary remedy in a vibration nuisance case, but injunctive relief may also be awarded in certain circumstances. There are two distinct but similar causes of action for a nuisance: private nuisance and public nuisance.

83. Id. at 3.
84. Daniel D. McNamara et al., Efforts to Monitor and Characterize the Recent Increasing Seismicity in Central Oklahoma, 34:6 LEADING EDGE 628 (2015); Petersen et al., supra note 82; Matthew Weingarten et al. High Rate Injection Is Associated With Increase in U.S. Mid-Continent Seismicity, 368 SCIENCE 1356 (2015) (finding that the entire increase in earthquake rate is associated with fluid injection); Mark Zoback & F. Rall Walsh III, Oklahoma’s Recent Earthquakes and Saltwater Disposal, SCIENCE ADVANCES, June 18, 2015; Katie M. Keranen et al., Potentially Induced Earthquakes in Oklahoma, USA: Links Between Wastewater Injection and the 2011 Mw 5.7 Earthquake Sequence, GEOLGY, G34045.1 (2013) (concluding the Prague, OK, sequence was related to two nearby disposal wells); Daniel McNamara et al., Reactivated Faulting Near Cushing Oklahoma: Increased Potential for a Triggered Earthquake in an Area of United States Strategic Infrastructure, 42 GEOPHYSICAL RES. LETTERS, 8328 (2015). See also FOLGER & TIEMANN, supra note 10, at 7 (describing several studies linking wastewater injection to quakes in Arkansas, Ohio, and Texas).
85. The relationship between earthquake activity and the timing of injection, the amount and rate of fluid injected, and other factors are current research topics that require additional study. FOLGER & TIEMANN, supra note 10, at 1. See also Nicholson, supra note 80 (emphasizing that the USGS report acknowledges the difficulty of pinpointing how seismicity is induced).
86. Plaintiffs may recover under a strict liability theory in Colorado and Ohio. By contrast, Oklahoma and Texas do not recognize strict liability for concussion damage. Richards, supra note 13, at 32-33.
88. Cypser & Davis, supra note 62, at 553.
89. Id.
90. Id. at 583 (citing cases involving vibrations from heavy equipment, quarrying, mining, and storage of explosives).
91. In the 1970s, seismologists determined that earthquakes occurring in Dutchess County, NY, “were probably triggered” by the operation of a quarry, and “smaller quakes might have been mistaken for dynamite blasts.” Id. at 585-86.
92. In the 19th century, damages were awarded for private nuisance actions involving vibrations from railroad operations. Courts also determined that vibrations stemming from “pump drivers, pneumatic drills, wrecking balls, and other construction and wrecking equipment constituted a private nuisance.” Randy Sutton, Vibrations Not Accompanied by Blasting or Explosions As Constituting Nuisance, 103 A.L.R. 5th 157, §2(a) (2002).
93. See Transcontinental Gas Pile Line Corp. v. Gaulth, 198 F.2d 196 (4th Cir. 1952) (holding operator of gas compressor station liable for causing annoying vibrations in nearby area). In one case alleging nuisance for vibrations caused by nearby oil and gas operations, the defendants were unsuccessful in their attempts to overturn the judgment because jurors revealed they entertained the idea of induced earthquakes during deliberations, which were not part of the trial evidence. Hiner v. XTO Energy, Inc., No. 13-3443 (6th Cir. Oct. 3, 2014).
94. Traditionally, a plaintiff was entitled injunctive relief, but since the industrial revolution, courts have been more reluctant to enjoin “economically valuable” activities. Modern courts sometimes appoint a special master and use an equity-balancing analysis to determine if injunctive relief is warranted. DOREMES, supra note 14, at 56. Putative damages may also be awarded if the conduct is sufficiently wrongful. Id. at 57.
95. DOREMES, supra note 14, at 41 (noting that the “vast majority of such cases are for private nuisance, but a few actions have been brought as public nuisance cases”).
A. Private Nuisance—Balancing of Utilities Doctrine

A private nuisance involves an unreasonable and substantial interference with another’s use and enjoyment of land.96 Under the Restatement (Second) of Torts, the defendant’s actions must be: (a) intentional and unreasonable, or (b) unintentional and otherwise actionable under rules controlling liability for negligent or reckless conduct, or for abnormally dangerous conditions or activities.97 The acts leading to the invasion of another’s interest are deemed intentional “if they are substantially certain to produce harm, whether or not the actor desires the harm.”98 Since the great majority of injection wells do not cause seismic events, much less damaging ones, it is unlikely such actions are “substantially certain” to produce a damaging earthquake. However, induced seismicity can still be an unreasonable or negligent invasion.

In the nuisance context, the invasion is “unreasonable if the gravity of the harm outweighs the utility of the conduct or the harm is serious and the economic burden of compensation would not make the conduct infeasible.”99 Factors to consider in this analysis include the extent and character of the harm; social value of the plaintiff’s use of land and defendant’s conduct; suitability of each to the character of the locality; and the burdens on each party of avoiding the harm.100

1. Gravity of Harm—Extent and Character of the Harm

Nuisance law does not involve the protection of “slight inconvenience or ‘petty annoyance.’”101 The harm must be significant and implicate “something that is definitely offensive, seriously annoying or intolerable.”102 Numerous courts have found that induced vibrations were not of a sufficient degree to support an action for nuisance.103 In most instances of induced seismicity, the gravity of harm is probably low since most of these earthquakes are aseismic.104 However, where the quakes result in serious property damage or personal injury, the analysis becomes more complicated.105 Several earthquakes have caused significant property damage and, in the Ladra case, personal injury too.

Even without physical damage to real or personal property, vibrations have been found to constitute a nuisance in the absence of physical damage.106 Induced seismicity has the potential to shatter plenty of nerves if it is sufficiently annoying, inconvenient, or results in a loss of business or property value.107 The seismicity may be particularly discomforting if it occurs frequently or in swarms.108 An isolated seismic event may not be significant enough to warrant liability, but injection-induced earthquakes typically occur over a period of time, and “duration or recurrence of the interference” is a factor that weighs in favor of finding a nuisance.109 So far, none of the quakes have been catastrophic or involved fatalities,110 but that does not necessarily mean individual property owners should bear the externalized costs of the inducer’s operations. Therefore, where the seismicity results in significant personal or property damage, or occurs in swarms, the gravity of harm may be sufficient for nuisance liability.

2. Social Value of Disposal Well Operations

The situation in Oklahoma provides an interesting case study when it comes to balancing the gravity of harm against the social utility of the conduct. The Sooner State has experienced the greatest uptick in seismic activity and some of the most damaging quakes. At the same time, “Oil is the Oklahoma business,”111 a source of pride for many, and the state’s largest employer.112 Imposing the seismic externalities on individual property owners may seem like an “unjust way of forcing public investment in industrial growth.”113 However, because the industry is so intrinsically intertwined with the identity of the state, the significant benefit of engaging in oil and gas production (and the ancillary need to dispose of waste fluids) might support a finding of no nuisance.114 In states like Colorado or Ohio, where the economy is more diverse and less dependent on hydrocarbon extraction, the chances of overcoming the social utility factor are considerably greater.

3. Character of the Locality

Often expressed as “a pig in the parlor,” an activity might be a nuisance if its location is inconsistent with the character of the surrounding community.115 Sometimes, the industrial character of the area prevents a defendant’s operation

96. Id.
97. Restatement (2d) of Torts §822 (1979).
98. Doremus, supra note 14, at 41 (citing Restatement §825).
99. Id.
100. Id. (citing §§827-28).
103. See Sutton, supra note 92, at §2(a).
104. FOLGER & TEMANN, supra note 10, at 9.
106. Doremus, supra note 14, at 42.
107. Darlene A. Cypser, Colorado Law and Induced Seismicity 47 (1996) (unpublished manuscript) (on file with author), http://www.researchgate.net/publication/273789334_Colorado_Law_and_Induced_Seismicity (noting that vibrations can cause various physical and psychological reactions). See also Gold, supra note 6, at 31 (explaining that even when the earthquakes are not large, they become unsettling to residents “who are growing accustomed to feeling small rumbles under their feet”).
108. Cypser, supra note 107, at 47.
110. Rubinstein & Mahani, supra note 11, at 1.
111. Gold, supra note 6, at 170.
113. Doremus, supra note 14, at 42.
114. Shampton & Ritter, supra note 105, at 95.
115. Doremus, supra note 14, at 89.
from being considered a nuisance, and a plaintiff can only expect the “degree of quiet consistent with the standard of comfort prevailing in the locality of his dwelling.”116 Blasting operations conducted without proper precautions in a populated area may constitute a nuisance,117 and the site selection of an oil and gas well may be a nuisance if located out of place for its environment.118 Perhaps the site selection of an injection well can be considered a nuisance if precautionary seismic evaluations are not undertaken, or it induces earthquakes near sprawling suburbs. Colorado is undergoing a significant boom in population growth and urban sprawl, and shale development is increasingly encroaching on these communities.119 Where these conditions exist, disposal operations may not fit the character of the locality.

Further, a nuisance may exist even where the defendant’s operation occupied the area before the residences.120 For example, in State v. H. Samuels Co., the defendant operated a salvage business for nearly 50 years, but after the operation expanded to include additional products and capacity for storage, the Wisconsin Supreme Court held that it became a nuisance.121 Similarly, an injection well may have been disposing waste in the area for years without seismic problems until the recent boom in production increased the intake of wastewater capacity to the point where it now constitutes a nuisance.

4. Respective Burden of Avoiding Harm and Infeasibility of Paying Compensation

The ability of avoiding the harm lies primarily with the injection well operators. There is little that surrounding residents can do to abate the risk of induced seismicity. In places like Oklahoma, where there has been relatively little seismic activity in the past, most homeowners do not have earthquake insurance.122 Most of the negative effects associated with seismicity fall on the surrounding community, whereas damage to the well operator’s equipment and facilities is “minimal, or has not significantly impacted” operating costs.123

As far as the financial burden for avoiding the harm caused by induced seismicity, experience thus far shows that mitigating the risk “can be handled in a cost-effective manner.”124 However, to reduce their injection volumes, companies must cut production or spend money to ship waste further away for disposal.125 This might be particularly burdensome for smaller companies already struggling to survive since the price of oil fell dramatically in 2014.126 Companies have also expressed concern that the economic burden of paying compensation will make their operations infeasible.127 Defendants in the Ladra case told the court that allowing juries to decide liability “would invite economic catastrophe” by turning their injection wells into “legal liability pariahs.”128 However, a nuisance claim is only likely to succeed in rare circumstances, and companies should probably assume the risk of paying out compensation when it is warranted. As with all the factors used to determine unreasonableness, assessing the burden of avoiding harm and infeasibility of paying compensation depends on the situation of the particular defendant-company. The defendant will also be liable for a nuisance if its actions are considered abnormally dangerous or constitute a negligent invasion.

B. Private Nuisance Based on Negligent or Abnormally Dangerous Invasion

Nuisance law recognizes liability for acts that are unintentional but nonetheless actionable under a negligence or strict liability theory for abnormally dangerous activities.129 Strict liability only requires that the plaintiff prove causation, whereas negligence dictates that a standard of care was also breached by the defendant.130 Most jurisdictions where seismicity has been observed recognize vibration liability based on negligence, but only a few allow a defendant to be found guilty under a strict liability theory.131

I. Strict Liability—Abnormally Dangerous Conditions or Activities

Some jurisdictions consider blasting an abnormally dangerous activity and recognize liability for vibration damages without requiring any showing of fault.132 However, unlike blasting, which directly results in an explosion, the act of injecting wastewater merely induces tectonic forces that rarely cause damaging vibrations. The presence of a “clear, inherent threat of harm” associated with the concept of strict liability may be lacking since the
occurrence of injection-induced seismicity is infrequent and often unpredictable.\textsuperscript{133}

Courts are usually hesitant to apply strict liability to a new phenomenon, and this judicial reluctance is another reason why strict liability may not be the most viable theory.\textsuperscript{134} Therefore, even though the primary source of damage (that is, shock or vibration) is the same as with blasting, it is probably a stretch to consider wastewater injection an abnormally dangerous activity. Negligence provides a more viable avenue to establish nuisance liability and also helps the industry develop a standard of care to reduce the risk of induced seismicity.\textsuperscript{135}

2. Negligent Invasions Constituting Nuisance

In nuisance cases for vibration or concussion damages, some courts have required a showing of negligence, or at least considered it a critical factor in assessing liability.\textsuperscript{136} The degree of care required for conducting blasting operations is usually “reasonable care and skill with regard to the nature of the work and local conditions.”\textsuperscript{137} Therefore, well operators may be negligent in their site selection or injection activities if they knew or should have known of the potential to induce seismic activity.\textsuperscript{138} The standard of care might involve a “duty to take precautions against triggering damaging earthquakes.”\textsuperscript{139} Fulfilling such a duty would involve making sure the company has taken steps to mitigate the risks by conducting thorough site investigations and monitoring of seismic activity.\textsuperscript{140} If a company fails to conduct a reasonable investigation or acts in disregard of a known seismic risk, then it has breached its duty of care.

Even if long-held industry customs or standards do not require rigorous seismic evaluation and analysis, “conformity to such standards or customs is not a substitute for due care.”\textsuperscript{141} The industry may be reluctant to adopt new standards that cost additional time, effort, and money.\textsuperscript{142} Failure to adopt such measures in the face of increasing scientific evidence and warnings may warrant a finding of negligence.\textsuperscript{143}

Rather than acknowledge the link and take affirmative actions to address seismicity, some companies continue to assert that more study needs to be done to prove that they are contributing to the problem.\textsuperscript{144} There is evidence that oil companies pressured seismologists at the Oklahoma Geological Survey not to make any connection between the increase in seismicity and fracking-related wastewater injection wells.\textsuperscript{145} If these seismologists had been employed by the companies to conduct a study and were restrained from making a thorough investigation, the employer-operator might be liable for negligence under the doctrine of respondeat superior.\textsuperscript{146}

Like industry customs, state laws and regulations governing injection well disposal “set only minimum standards,” and are not conclusive regarding the proper standard of care.\textsuperscript{147} Regulators in states experiencing induced seismicity are starting to require seismic evaluations in the permitting process, and have implemented procedures to slow or shut down injection activities if seismicity is observed.\textsuperscript{148} Compliance with these requirements might be evidence that the company is acting reasonably or operating within the expected standard of care, but compliance is not an automatic bar to a finding of negligence.\textsuperscript{149}

Therefore, the fact that defendants are operating within the requirements of state-issued permits may not be enough to avoid liability. By contrast, a violation of state regulatory requirements might automatically subject the operator to liability based on its negligence, constituting a “nuisance per se.”\textsuperscript{150} In sum, wastewater injection is unlikely to be considered an abnormally dangerous activity, but well operations may constitute a nuisance under a negligence theory if the defendant failed to take proper precautions and ignored the risk.

C. Public Nuisance

Liability for injection-induced seismicity might also be found under a public nuisance theory if the invasion interferes “with the interests of the community or rights of the general public.”\textsuperscript{151} Although the basic analysis is the same as private nuisance, a public nuisance typically can only be brought by public authorities, or sometimes by a citizen who has suffered an injury “different in kind” from that endured by the public at large.\textsuperscript{152} If damaging seismic events are frequent and widespread over an entire community or threaten the viability of critical infrastructure, public nuisance theory may apply.

Beginning in September 2015, a series of earthquakes have struck within several miles of Cushing, Oklahoma,
where one of the largest crude oil storage hubs in the world is located.\textsuperscript{153} The massive storage complex, known as the Cushing Hub, is often considered “ground zero” for the world price of oil and is critical to the country’s economy and energy supply.\textsuperscript{154} The largest quake (M4.5) hit within a few miles of town and rattled the complex’s massive tanks.\textsuperscript{155} The threat of earthquakes raises new security concerns surrounding the Cushing Hub.\textsuperscript{156} After 9/11, U.S. government officials highlighted Cushing as a potential terrorist target, but a more domestic threat lurks just beneath the surface.\textsuperscript{157} Scientists predict the faults near Cushing could produce a large earthquake similar to the one that hit Prague in 2011 and has the potential to cause significant damage “to national strategic infrastructure” and the surrounding community.\textsuperscript{158} If such an event were to damage the hub’s network of pipelines and storage tanks, it could result in serious environmental damage, a temporary spike in oil prices, safety hazards such as fires, and disrupt the supply of oil to refineries across the country.\textsuperscript{159}

When it comes to protecting America’s energy security, experience demonstrates that “threats to reliability and security of supply can come in unexpected ways.”\textsuperscript{160} The common law is known for its adaptability, and the public nuisance doctrine has been invoked to protect “public health, safety, and even morality.”\textsuperscript{161} Allowing the government to abate a hazard with national security implications also seems appropriate. Courts recognize the importance of oil and gas storage facilities and the public interest they serve, and in doing so have held companies liable for a public nuisance when continued operation of nearby wells threatens the viability of such critical infrastructure.\textsuperscript{162} Companies that own tank capacity in Cushing have not yet taken steps to address earthquakes in their emergency or disaster plans.\textsuperscript{163} If they continue ignoring warnings

from scientists and national security officials, these companies and others that operate nearby disposal wells may find themselves liable for a public nuisance.

V. Conclusion

Utilizing the law of nuisance to address induced seismicity is a novel concept, but the same basic rules used to assess liability when other human activities cause the earth to vibrate should apply.\textsuperscript{164} If reasonable precautions are not taken in the siting and operation of an injection well, operators can be held accountable to those injured under a nuisance theory.\textsuperscript{165} Proving causation might be the most challenging obstacle for induced seismicity plaintiffs, but as the science becomes more developed, the chances of establishing the requisite link increase.\textsuperscript{166} If unabated, the magnitude and frequency of induced earthquakes may also increase, making it easier for plaintiffs to show the gravity of the harm outweighs the utility of the conduct.

In the 19th century, an illness sometimes described as “shattered nerves” was the focus of extensive debate among medical professionals trying to assess the cause and apply the proper remedy.\textsuperscript{167} Solving the problem of induced seismicity presents a similar challenge. Liability can fall under several tort theories, and this Article does not suggest that nuisance law is the best apparatus to address the problem. The law of nuisance “is a clumsy tool” and won’t provide a comprehensive solution to address the problem.\textsuperscript{168}

However, the deterrent effect of common-law liability should not be underestimated.\textsuperscript{169} Until regulatory efforts catch up and are adequate to address induced seismicity, litigation may fill the gap and catalyze the industry to engage in proactive mitigation measures.\textsuperscript{170} Even if these lawsuits are ultimately unsuccessful on the merits, “[b]ad press, public outcry, and fear from further liability all serve to prod industry self-improvement.”\textsuperscript{171} Domestic energy production provides great benefits to our economy and is critical to maintaining our modern way of life, but if humans are powerful enough to “mimic the wrath of God,” those responsible should also “mimic the mercy of God” by providing compensation to others who are injured by their industrial activities.\textsuperscript{172}

\textsuperscript{153} Phillips, supra note 19.
\textsuperscript{154} Cushing is the “gathering point for light, sweet crude known as West Texas Intermediate (WTI)” that serves as the reference point for futures traded on the New York Mercantile Exchange. Daniel Yergin, The Quest 161 (2012).
\textsuperscript{155} Phillips, supra note 19.
\textsuperscript{157} Phillips, supra note 19 (arguing that the threat of earthquakes could present a scenario “no less dangerous than a potential terrorist attack.”).
\textsuperscript{158} Daniel McNamara et al., Reactivated Faulting Near Cushing Oklahoma: Increased Potential for a Triggered Earthquake in an Area of United States Strategic Infrastructure, 42 Geophysical Res. Letters 8328 (Oct. 2015); Phillips, supra note 19 (explaining the potential of even larger quakes in the future); Wines, supra note 156 (explaining that “the Department of Homeland Security has gauged potential earthquake dangers to the hub and concluded that a quake equivalent to the record M 5.7 could significantly damage the tanks”).
\textsuperscript{159} Wines, supra note 156 (noting that the federal government has designated the hub “a critical national infrastructure”); Phillips, supra note 19 (arguing that “if even a couple of Cushing’s tanks had to shut down, or a pipeline were damaged, the impact could ripple through the market”).
\textsuperscript{160} See Yergin, supra note 154, at 719 (explaining that when “economies and technologies change, security concerns take new forms”).
\textsuperscript{161} Dorius, supra note 14, at 42.
\textsuperscript{163} Phillips, supra note 19.
\textsuperscript{164} Cypser, supra note 107, at 40.
\textsuperscript{165} Id. at 50.
\textsuperscript{166} FOLGER & TIEMANN, supra note 10, at 20.
\textsuperscript{167} Janet Oppenheim, Shattered Nerves: Doctor’s, Patients’, and Depression in Victorian England (1991) (discussing how doctors disagreed on whether the nervous breakdown was a physiological disorder or a moral weakness).
\textsuperscript{169} Richards, supra note 13, at 32-33.
\textsuperscript{170} Pidot, supra note 168, at 219.