Wastewater Injection Wells in North Texas Rarely Cause Earthquakes

Introduction

A series of low-magnitude earthquakes have occurred in North Texas in recent years, and several scientists have identified underground wastewater injection activities as a possible culprit. Although there are thousands of injection wells throughout the Barnett Shale region, academics and U.S. Geological Survey researchers have identified fewer than two dozen of the wells as possible sources of felt seismicity.

According to the Railroad Commission of Texas, there are three categories for underground injection of wastewater associated with oil and natural gas production: injection for secondary or enhanced recovery (in which the wastewater is returned to the reservoir from which it originated to "enhance" the flow of oil); disposal into non-producing rock formations; and disposal into the producing formation from which it originated (which differs from secondary recovery in that the injection is not designed to stimulate additional production).

The National Research Council has observed that all of these injection activities pose some risk of inducing seismicity, provided the right conditions are present, but that the overall risk is quite low.

To further quantify that risk, Energy In Depth reviewed recently published research on earthquakes in North Texas, identifying the well locations that some scientists suggest may be associated with seismic activity. EID then compared that information against state data on the number and location of injection wells throughout the Barnett Shale region.

Based on EID's analysis, over 99 percent of injection wells in the Barnett Shale have not been associated with felt seismic events. This finding is in line with many recent scientific studies indicating a low overall risk of induced seismicity, although additional research is ongoing. Moreover, given the complicated fault system and wide dispersion of injection wells in North Texas, any naturally occurring earthquake may have injection wells nearby – and such wells will immediately be subject to guilt by association. While an injection well can induce seismicity under certain circumstances, careful study and analysis is needed to determine actual causation.

Regulatory Structure for Underground Wastewater Injection

Wastewater generated from oil and natural gas production activities that is not recycled or reused to hydraulically fracture additional oil or natural gas wells must be managed under one of two federal laws – the Clean Water Act (CWA) or the Safe Drinking Water Act (SDWA). The CWA regulates wastewater that is discharged to surface waters. The SDWA regulates wastewater that is injected into disposal wells. More specifically, these injection wells are regulated under the SDWA's Underground Injection Control (UIC) program. Wells used for disposing of wastewater from oil and natural gas production – including hydraulic fracturing – are categorized as "Class II" by the U.S. Environmental Protection Agency.

Although UIC is a federally regulated program, the EPA often grants what's known as "primacy" to individual states if their regulatory programs meet a baseline of standards. This is done for a variety of reasons, the most important of which is the fact that state regulatory agencies have a longer history overseeing and managing oil and natural gas programs than does the EPA. In some cases, state programs on wastewater disposal are actually stronger than what direct EPA oversight would provide.

If granted primacy, a state regulatory agency – not the EPA – is in charge of the day-to-day oversight. Texas received primacy for its UIC program in 1982. Individual states have also joined together in recent

years to address concerns about induced seismicity from wastewater injection activities. The State Oil and Gas Regulatory Exchange, for example, formed an Induced Seismicity by Injection Working Group last year, which allows state regulatory agencies and geological surveys to share science and other research. The Working Group is currently developing science-based guidelines for state regulatory agencies to help prevent or mitigate induced seismicity.

North Texas Earthquakes: A Brief Review

According to researchers at Southern Methodist University, North Texas has experienced four seismic "clusters" since 2008, the latest of which occurred around the city of Irving in 2014. As SMU researchers have explained:

> *"The first [cluster] was an earthquake sequence centered near DFW airport in 2008 and 2009 with the largest magnitude of 3.3. A second sequence from 2009 into 2010 was near Cleburne, Texas with the largest magnitude of 2.8. A third set of events occurred near Azle, Texas beginning in the Fall of 2013 and continuing through 2014 with the largest magnitude of 3.6. In all of these cases earthquakes got smaller and further apart in time following the largest events. Additional focus areas of seismicity based on USGS locations exist NE of Cleburne, near Mineral Wells and in the Venus/Midlothian area but have not been well studied."*

University of Texas and SMU seismologists linked the DFW Airport seismic activity to a single injection well. UT and SMU released a separate report on the Cleburne sequence in 2013, finding that the earthquakes "may be related" to two nearby injection wells. Heather DeShon, a geophysics professor from SMU, said in 2014 that there are only three injection wells within 10 kilometers of the center of the Azle earthquakes (the SMU team's study of that cluster has not yet been released).

Research has only just begun on the Irving cluster, but there are no injection wells in close proximity to the Irving quakes, with the closest one being "more than 10 miles away," according to Dr. Craig Pearson, the state seismologist with the Railroad Commission. SMU says the distance to the nearest disposal well is around eight miles, which is still farther than the 10 km radius used to identify "nearby" wells for the Azle cluster.

A regional study in 2012 by Dr. Cliff Frohlich at the University of Texas identified 17 injection wells in the Barnett Shale region that he considered to be located "near earthquakes," or within a five kilometer radius of a known epicenter.

Frohlich's 2012 study was inclusive of the DFW Airport and Cleburne sequences, along with other seismic events that were identified from his more detailed analysis of USGS transportable array data. Altogether, the extensive research in North Texas has identified approximately 20 injection wells – out of thousands in the area – that have at least a spatial relationship to earthquake activity. Frohlich has also cautioned that it's "possible that some of these earthquakes have a natural origin," though he does not believe that's the case for all of the events.

It is possible that other seismic events in the region, which have not yet been identified or carefully studied, could be linked to injection activities in the future. This analysis, however, focuses on the earthquakes that have been extensively researched. The events in Irving, where research is only beginning, are included because they have been identified by SMU as part of the four prominent "clusters" of seismic activity in the area.

Injection Wells in the Barnett Shale

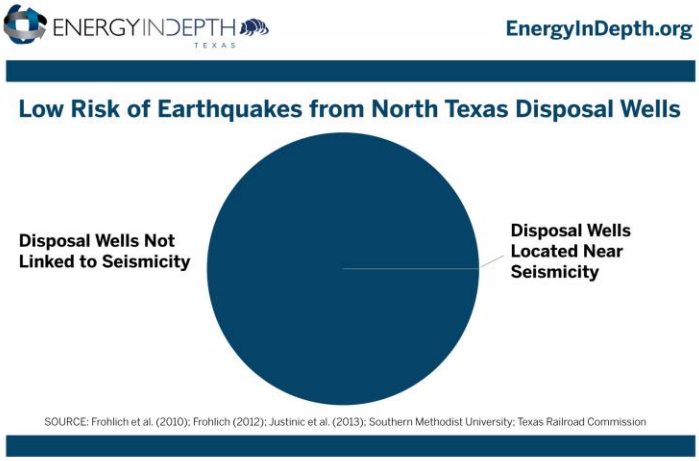
According to the Texas Railroad Commission, the Barnett Shale encapsulates a 25-county region across North Texas. The Commission also has a searchable database of the state's injection wells, which allows for county-by-county tabulations.

Injection wells in the Barnett Shale region, by county.
(CLICK FOR LARGER VIEW)

The database shows that there are over 14,000 injection wells in the official Barnett Shale region. Using the information from published research on regional seismicity, including the number of well sites in close proximity to epicenters, ***only 0.1 percent of injection wells throughout the Barnett Shale region have been identified as a possible cause of earthquakes***.

The Railroad Commission has noted, however, that the "vast majority" of injection wells in Texas are used for secondary or enhanced recovery, meaning the wells are used to inject wastewater into the formation where it originated to stimulate additional production. Of the 14,000 injection wells in the Barnett Shale, about 4,900 of them are classified for disposal.

If we assume all 20 of the wells having a spatial connection to seismicity are officially classified as being used for disposal, then 0.4 percent of the region's disposal wells have been suggested as possible sources of seismicity.



Over 99 percent of the nearly 4,900 disposal wells in the Barnett Shale region have not been associated with felt seismic events.

Since the four seismic clusters in North Texas have not occurred across the entire Barnett Shale region, it's also useful to compare the number of wells close to epicenters against the total number of wells in those counties where the clusters have been identified.

Frohlich (2012) identified six counties with earthquakes that have a spatial relationship to injection wells: Johnson, Hood, Tarrant, Denton, Wise, and Montague. Frohlich's study did not identify any earthquakes in Parker County, although one seismic event was identified in northwest Tarrant County. However,

subsequent events in the Azle/Reno area – located in Parker County – were within 10 kilometers of three injection wells.

According to the Railroad Commission, these seven counties are home to 571 disposal wells. Using this data, only about 3.5 percent of all of the disposal wells in this seven-county area are even being considered as possible sources of felt seismic events.

This figure may be less relevant in the broader discussion about the safety of injection activities, since it excludes thousands of wells operating in the Barnett region that have not been linked to earthquakes. But it does underscore that the vast majority of disposal wells – at least 95 percent – operate aseismically.

Scientists Confirm Low Risk of Seismicity

These findings corroborate what the broader scientific community has said about the generally low risk of seismicity from underground wastewater injection.

For example, a major report on induced seismicity from the National Research Council – part of the prestigious National Academies – concluded in 2012:

> *"Injection for disposal of wastewater derived from energy technologies into the subsurface does pose some risk for induced seismicity, but very few events have been documented over the past several decades relative to the large number of disposal wells in operation."*

The U.S. Geological Survey has noted that there are "roughly 40,000" underground wastewater disposal wells in the United States, and "only a small fraction of these disposal wells have induced earthquakes that are large enough to be of concern to the public."

A major report recently released by the U.S. Environmental Protection Agency, which was intended to help clarify induced seismicity for the purpose of better managing risks, concluded that "very few" of the tens of thousands of disposal wells in the United States have produced any notable seismic activity.

In studying the 2008-2009 earthquake cluster near DFW Airport, researchers at Southern Methodist University observed that there are hundreds of disposal wells operating in the production area, but very few of those wells were correlated with any observable seismicity. "If the DFW earthquakes were caused by saltwater injection or other activities associated with producing gas," the SMU team noted, "it is puzzling why there are only one or two areas of felt seismicity." It's worth noting that a separate research team, in a peer-reviewed journal article, found that seismicity was still ongoing at DFW Airport for at least two years after injection activities had stopped, highlighting further the possibility that naturally occurring stress changes in the subsurface could be driving the seismic events.

In reference to a 2013 study of the Cleburne cluster, SMU researcher and lead author Ashley Justinic told KERA News that the vast majority of injection wells do not cause earthquakes. "Yes, these events were near two injection wells," Justinic said, "but if you look at a map of all the injection wells across Texas, they're everywhere."

In his 2012 report, Dr. Cliff Frohlich from the University of Texas found that wells with high injection rates (i.e. greater than 150,000 barrels of water per month) were in close proximity to the seismic events his study identified. But he also added that these wells are "common" in the area, and that "almost 90% of these had no locatable earthquakes nearby."

Frohlich also published a report earlier this year that examined seismicity in North Dakota, the second largest oil producing state. Frohlich found only three small earthquakes that were situated near disposal wells, of which the state has nearly 500. Frohlich classified only one of these earthquakes as "probably induced or triggered."

The lack of any meaningful uptick in seismicity alongside new disposal wells has public policy implications, according to Frohlich. “Before we implement severe regulations or schemes to manage injection activity in a particular region,” Frohlich cautioned, “we need to do the homework -- survey the relationship between seismicity and injection activity there to determine what’s warranted.”

In California – a place well known for its earthquake activity – the state’s Oil and Gas Supervisor included “seismic activity” in a list of environmental concerns that “can be reduced to the level of less-than-significant,” based upon the findings of a peer-reviewed study from the California Council on Science and Technology.

The U.S. EPA observed in its report on induced seismicity that “there were approximately 2,700 active disposals wells in Louisiana, with no recent significant seismic events occurring as a result of the disposal activities.”

Although the Railroad Commission says it has “not identified a significant correlation” between earthquakes and injection practices in Texas, the agency updated its rules last year to require operators to monitor for seismic activity before an underground wastewater disposal well is put into operation. The rules also give the Commission the authority to shut down injection activities if they are linked to seismicity.

Irving Earthquakes

Research into the causes of the earthquakes in Irving, Tex., has only just begun, although a considerable gap has already emerged between what environmental activists – and some in the media – have suggested and what the scientific community has actually concluded.

One of the more notable (and inflammatory) pieces on Irving came from James Joiner, a correspondent at the Daily Beast. Joiner’s article ran under a headline that partially read, “Fracking’s Smoking Gun Is In Texas.” In addition to drawing not-so-subtle connections between Barnett Shale development and the seismic events in Irving, Joiner claimed that “Irving itself has more than 2,000 of these sites [gas wells] nearby, and some of the more than 216,000 state wide ‘injection wells’ responsible for disposing of fracking’s wastewater byproduct are in close proximity.”

The nearest disposal well to Irving is approximately eight to ten miles away, according to SMU and the Railroad Commission. Only two natural gas wells are anywhere near where the earthquakes occurred, and both have been inactive for years. Irving Mayor Beth Van Duyne has also noted, “we don’t currently have any fracking in Irving.”

But while some were busy blaming fracking for the Irving quakes, Dr. Brian Stump with Southern Methodist University cautioned against such speculation. “It’s premature to speculate on the cause of this current series of seismic events,” Stump said.

Early on, Mayor Van Duyne also advised against a rush to judgment. In stressing the importance of waiting for credible, scientific research to be completed, Van Duyne wrote in January: “What we won’t do is jump to irrational, unsupported conclusions.”

The mayor’s recommendation proved to be wise. A few weeks later, SMU scientists identified the source of the seismicity as being far deeper than where drilling or disposal activities typically occur. The scientists’ interim report, published last month, concluded that the earthquakes likely occurred in what’s known as the “basement rock,” whereas production and disposal activities in the area are “generally confined to the sedimentary units overlying the basement rocks.”

SMU’s findings do not necessarily rule out a man-made cause for the seismic events, but they do indicate that the rush to blame Irving’s earthquakes on fracking was based on speculation, not science.

Michael Brudzinski, a seismologist who has studied induced earthquakes in Ohio, was also skeptical of linking hydraulic fracturing to the Irving earthquakes. "It's hard to believe that fracking that took place many years ago would be resulting in earthquakes today," Brudzinski said, referring to two nearby gas wells that ceased production in 2012. According to KERA News, Brudzinski "says it appears North Texas seismologists looking for clues will have to drop fracking as a credible suspect."

Not Fracking or 'Frackquakes'

The scientific consensus is that fracking rarely if ever induces felt seismic events. The EPA's recent risk assessment of induced seismicity observed that hydraulic fracturing "has a low likelihood of inducing significant seismicity," owing to its short duration and comparatively low "pressure footprint."

But critics of drilling still suggest fracking is a major threat, using their own interpretation of the scientists' findings to call for restrictions or even bans on hydraulic fracturing.

Frack Free Denton – the campaign that led the effort to ban fracking in Denton, Tex. – promoted letters to the editor that claimed earthquakes were a reason to support banning hydraulic fracturing. Sharon Wilson, a North Texas organizer for Earthworks – a Washington, DC-based environmental group that has pledged a "war on fracking" nationwide – promoted coverage of the SMU/UT Cleburne study when it was released in 2013 and suggested the researchers linked the earthquakes to fracking.

Jim Schermbeck with Downwinders at Risk, an anti-fracking group in the Dallas area that has touted its ability to "parachute into a community and start an effective campaign," has written that North Texas earthquakes are "directly linked to fracking itself." Schermbeck believes the earthquakes in Azle are "an opportunity to organize and win deep behind enemy lines."

The Lone Star Chapter of the Sierra Club – which is "opposed to fracking, period" – has claimed that "earthquakes, tremors and sinkholes" are on the "list of possible negative consequences" of fracking in Texas. Last year, two staffers from Earthworks penned an op-ed on North Texas seismicity under the headline "Frackquakes," a term the organization has encouraged others to use on social media. The left-wing blog ClimateProgress has parroted that term as well.

The activist group 350.org has also blamed fracking for earthquakes in Dallas County, claiming Dr. Frohlich's 2012 report showed "earthquakes linked to fracking."

Earthworks promotes the term "frackquake" as a way to describe seismicity in North Texas. Scientists have said the term is inaccurate and not appropriate for describing earthquakes in the DFW area. SOURCE: Earthworks

But scientists – some of whom have authored the most extensive research on North Texas seismicity – disagree with the activists' claims.

When SMU published its findings on the DFW Airport earthquake cluster in 2010, it included a separate callout box under the header, "THE STUDY EMPHASIZES," which read:

> *"Wastewater injection in a single disposal well — and **not the drilling, hydrofracturing or natural gas extraction** — is a plausible cause of the minor earthquakes." (emphasis added)*

The same research team, in its report with UT researchers on the Cleburne cluster in 2013, observed "there has been no evidence that hydrofracturing, drilling, or natural gas production played any role in the [seismic] events." An NBC News story on the report noted that the researchers "did rule out drilling rigs themselves and a technique known as hydrofracturing – or fracking" as a cause of the seismicity.

Dr. Cliff Frohlich from the University of Texas, whose 2012 study on Barnett Shale-area seismicity has been used by anti-drilling groups to claim that fracking causes earthquakes, stressed that he did not evaluate fracking in his report, but focused rather on the underground disposal of wastewater.

SMU researchers have even directly challenged the notion that the term "frackquake" should be used at all. A page addressing frequently asked questions about SMU's earthquake research in North Texas includes this section:

> ***Is it accurate to describe the earthquakes that have been occurring in North Texas as "frackquakes?"***
>
> *No. Hydraulic fracturing or "fracking" is the process of creating fractures in subsurface rock formations by injecting fluid into cracks to create larger underground fissures, allowing more oil and gas to flow out of rock formations, from where it can be extracted. The largest resulting seismic activity from hydraulic fracturing is typically hundreds to thousands of times smaller than the smallest earthquake that human beings can feel. In examining all reports worldwide, there have been only a few instances where hydraulic fracturing did appear to directly trigger a felt earthquake out of tens of thousands of successful operations. Such instances are very, very rare and have not, to our knowledge, happened in the North Texas area. In the roughly 35,000 shale gas wells in the U.S., only two case studies are known (Shemeta et al, 2012 National Research Council). The other documented hydraulic fracturing events include the M3.5 in Horn River, Canada, a M2.3 in Blackpool, UK in 2011, and the event in Basel, Switzerland in 2006.*
>
> *Sometimes the waste fluids from producing oil and gas wells (those that use fracking to reach "tight gas", as well as those that don't) are disposed of by injection wells drilled below any fresh water aquifer. The wastewater disposal is a separate process from the fracking operation itself and may occur away from the fracked well. Injection of wastewater can occur in oil fields unrelated to fracking.*

The U.S. Geological Survey has made a similar observation:

> *"Many questions have been raised about whether hydraulic fracturing — commonly known as 'fracking'— is responsible for the recent increase of earthquakes. USGS's studies suggest that the **actual hydraulic fracturing process is only very rarely the direct cause of felt earthquakes**. While hydraulic fracturing works by making thousands of extremely small 'microearthquakes,' they are, with just a few exceptions, **too small to be felt**; none have been large enough to cause structural damage." (emphasis added)*

The USGS has also observed: "Hydraulic fracturing, commonly known as 'fracking,' does not appear to be linked to the increased rate of magnitude 3 and larger earthquakes."

The Lawrence Berkeley National Laboratory, meanwhile, has emphasized that injection-related seismicity "should not be confused with hydrofracturing."

> *"[H]ydofracturing is such a small perturbation that it is **rarely, if ever, a hazard** when it is used to enhance permeability in oil and gas or other types of fluid extraction activities. To our knowledge, hydrofracturing to intentionally create permeability **rarely creates unwanted induced seismicity large enough to be detected** on the surface with very sensitive sensors, let alone be a hazard or annoyance." (emphasis added)*

Dr. Mark Zoback, a professor of geophysics at Stanford University – and a member of the National Academy of Engineering – who has published extensive research on induced seismicity, recently told the *Dallas Morning News*, "I really think bans on hydraulic fracturing are political statements rather than risk management tools." In terms of actually addressing seismic risk, Zoback says, "the goal is to identify and avoid potentially active faults during wastewater injection."

Conclusion

Although the scientific community has stressed many times that the risk of any given disposal well inducing an earthquake is low, this should not be construed to suggest that citizen complaints should be dismissed or ignored. For those who live in areas experiencing earthquakes, the fact that underground wastewater disposal has a low risk of inducing such events may not adequately address concerns. Presenting that information in and of itself, though perhaps helpful as an educational tool, has no impact on the frequency of the seismic events.

The purpose of this report, however, is to help quantify the risk of induced seismicity based on data and a review of the scientific literature. Addressing concerns about seismicity must begin by identifying all of the variables where the earthquakes occurred. If individual injection sites are suspected of inducing seismic events, then the proper way to address that situation is by focusing on conditions at that individual site. Pressure, volume, and reservoir permeability are all potential factors that can influence induced seismicity, but these variables often vary from region to region, and in fact may differ considerably in two parts of the same geological basin. Scientists have also observed that natural seismicity may occur in close proximity to an injection well, further underscoring the need for careful scientific assessments that help the public understand the cause of any given seismic event or "cluster."

Broad regulatory measures premised on the assumption that every injection well poses the same risk may not effectively address the specific conditions that contributed to a particular seismic event. Effective risk management requires addressing problems where they occur, not expending resources to fix problems where they do not exist. For example, a ban on injection activities after a naturally-occurring seismic event may not be an appropriate response, since underground injection was not the culprit. Additionally, policies that restrict or even prohibit wastewater injection over a broad region will also restrict economic activity, threatening jobs and other opportunities for growth – and potentially in places where such a policy may be unnecessary.

As the data in this report show, the overwhelming majority of injection wells in North Texas have not been linked to felt seismic events, although additional scientific research is ongoing. With industry, environmental groups, scientists and policymakers continuing to study this issue, it is important that all interested parties focus on identifying solutions that will address concerns, and avoid overreaching measures that may do more harm than good.