

Human-induced earthquakes and high pressure natural gas transmission pipelines

An examination of earthquakes and other geohazards near pipelines and Hum reports

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Introduction

Many activities are known to induce earthquakes. This study examines earthquakes that occurred near high pressure natural gas transmission pipelines. Additionally, many of these earthquakes occur near reports of excessive low frequency noise (LFN) pollution often referred to as the Hum. Natural gas transmission pipelines are currently not widely recognized as a source of anthropogenic earthquakes. This study demonstrates that there is a correlation between these elements. There is likely a correlation between sinkholes and landslides as well. The sonic pollution from natural gas transmission pipelines should be studied further.

Most activities that are known to result in human-induced earthquakes are invasive and destructive. The Human-Induced Earthquake Database (HiQuake)¹ lists 14 categories of activities. All of these involve removing, adding, or moving materials on the earth's surface or subsurface. Examples of these activities are fracking, mining, construction, and wastewater impoundment. It could be reasoned that passive human activities typically would not release enough energy into the environment to induce earthquakes. High pressure inter/intra state natural gas transmission pipelines don't remove or add material. Instead, they sit just below the surface and transmit high-pressure natural gas. Regardless of their seemingly passive presence there is evidence that these systems induce earthquakes.

Do natural gas transmission pipelines have enough power to induce earthquakes? The capacity of the connected compressor stations is comparable to a small power generation plant. The compressor stations are situated every 40 to 100 miles along the pipeline. The operating pressure is between 200 and 1,500 psig. The equipment is like the equipment used in fracking operations, which is known to induce earthquakes.

A 1997 research paper² may explain how natural gas transmission pipelines release large amounts of sonic energy. The research examines LFN and vibration in the environment. It describes how under

¹ Data products for this study were accessed through The Human-Induced Earthquake Database (*HiQuake*), (www.inducedearthquakes.org). Last accessed April 2, 2022.

² Krylov, Victor V. 2013. "Investigation of Environmental Low-frequency Noise". May 1997

certain operating conditions; an underground natural gas pipeline can result in a phenomenon like a sonic boom. The conditions that this might occur is determined by the relationship between the velocity of radiating Rayleigh ground waves and the velocity of sound traveling in a pipeline. Based on typical operating pressures, it is theorized that these conditions might occur often. It is plausible that this effect or a related phenomenon is releasing excessive sonic energy of the magnitude needed to induce earthquakes.

The mechanism that natural gas transmission pipelines induce earthquakes may be soil liquefaction or vibration compaction of loose soils. If susceptible soils are exposed to strong and regular pressure waves, it may shift and become unstable. Sound waves reverberating in deep cavities could be a contributing factor. This same effect may be inducing landslides, mudslides, and sinkholes. Sinkholes have been occurring in unexpected places and at increasing rates. Many of these unexpected occurrences have been linked to leaking sewage and water infrastructure. Natural gas transmission pipelines may also be contributing to the increasing rates of sinkholes. Landslides and mudflows have been exacerbated by climate change and extreme weather events. Here too LFN pollution may be contributing. In later sections we look at a few examples where sinkholes and mudslides occur near natural gas pipelines. For example, sections of the 2018 mudslide in Santa Barbara County, CA initiated less than 100 feet from a pipeline.

If natural gas transmission pipelines can induce geohazards, what impacts do they have on wildlife and humans? There are reports of the Hum over much of the world. The reports are often similar, described as low rumble coming from outside, like an idling diesel truck. Gas Pipeline Syndrome (GPS) theory is the phenomena and conditions of the studied theory that gas transmission pipelines are responsible for generating LFN that can travel miles and cause health and wellbeing problems for those that live around them. By defining GPS in this way, it is intended to differentiate from other unsupported theories of sources of the Hum and related environmental pollution. The Hum can cause insomnia, anxiety, tinnitus and vibroacoustic disease.

LFN can travel long distances without attenuating and it spreads out in all directions. These factors makes it difficult to identifying the source. Articles on the Hum often proposed that it is the result of various industrial equipment, heat pumps, exhaust fans, and other common mechanical equipment. This has resulted in the Hum being framed as an unsolvable mystery. Confusing matters further, only a small percentage of people are aware of the Hum's presence. If natural gas transmission pipelines release enough sonic energy to induce geohazards than they may also be generating widespread LFN. Many of the locations examined in the following sections have all three of these elements present in the same location: Hum reports, geohazards, and natural gas transmission pipelines.

Natural gas transmission pipelines exist throughout much of the world and often in populated areas. We need to understand what impacts these systems have on wildlife and health.

Method

The approach is to exam where earthquakes or other geohazards have occurred and see if they are coincident with natural gas transmission pipelines and Hum reports. Table 1 provides a summary of the data sources used.

Table 1: Data Sources

Data	Source	Description	Website
Earthquake locations and details	United States Geological Survey (USGS) Earthquake map	Web tool with map that can filter by date ranges, magnitudes, and locations	https://earthquake.usgs.gov/earthquakes/map/
Natural gas transmission pipeline locations	National Pipeline Mapping System (NPMS)	Web tool with map of transmission pipelines by county	https://www.npms.phmsa.dot.gov/
Hum reports and location	The World Hum Map and Database	Interactive map and downloadable data set	https://thehum.info/
Identified human-induced earthquakes	The Human-Induced Earthquake Database (HiQuake)	Interactive map and downloadable data set	www.inducedearthquakes.org
Santa Barbra County debris field locations	Santa Barbra County READY	Interactive map of debris field from January 2018 land slide	https://readysbc.org/maps/

Earthquakes that were examined occurred from 1980 through 2021 with a magnitude of greater 2.5 or greater. The period and ranges could be expanded in the future. However, these ranges were sufficient for identifying induced earthquakes.

Earthquake locations are plotted on the NPMS maps. The county-level maps allow for quick identification of the earthquakes that occurred near the natural gas pipelines. There wasn't a specific threshold distance that was used to categorize the earthquakes as near a pipeline or not. The area maps and county maps in the following sections show both categories of earthquakes. There are only a few earthquakes that do not occur near pipelines in these areas. These occurred at a distance of 3.5 miles or more from pipelines. The earthquakes that are near pipelines were around 1.6 miles or less from a pipeline. Many of these earthquakes were less than a mile from a pipeline. The earthquakes that at further distances were disregarded from the examination.

Hum reports are overlaid with the natural gas pipelines and earthquakes. Most of the Hum reports are near the natural gas pipelines and in some instances very close to earthquakes. All of the earthquakes being considered were compared to the HiQuake database. None of these have been identified as a human-induced earthquake.

The Santa Barbra County mudslide was examined because it is the most notable United states mudslide in recent history.

Northern Illinois

There have been seven earthquakes with a magnitude of 2.5 or greater since 1980 through 2021 in northern Illinois. Aside from these earthquakes, this region has had little seismic activity during this period. The next closest earthquake is about 120 miles to the east in Indiana. Figure 1 shows the Midwest with a cluster of Northern Illinois earthquakes highlighted. The highlighted cluster of earthquakes are the area of focus in this section.



Figure 1: Midwest earthquakes greater than M2.5, 1980 through 2021, highlighted area of focus

The epicenters of five of these seven earthquakes are within 1.1 miles of a natural gas transmission pipeline. Upon closer examination, these earthquakes appear to have a correlation with their proximity to the pipelines. The other two earthquakes are over 3.5 miles from pipelines don't appear to have a direct correlation. The distinction between what is close to a pipeline and what is not, is apparent when looking at the county level transmission pipeline maps. These earthquakes either seemingly sat right on a pipeline (1.1 miles or less) or were at some location with no apparent correlation to the pipeline. Figure 2 shows the earthquakes in this region. The yellow dots are the earthquakes that are close to pipelines (1.1 miles or less). The earthquakes are assigned numbers to reference across figures.

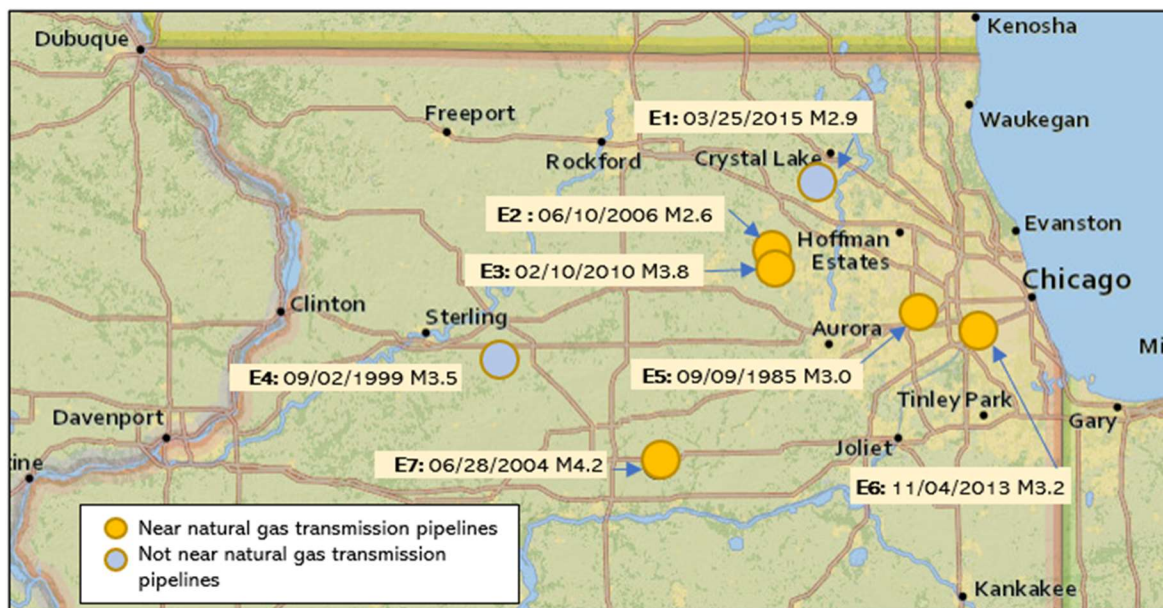


Figure 2: Epicenters in Northern Illinois and proximity to natural gas transmission pipelines

Two of these earthquakes (E2 and E3) are near each other and along the same pipeline. Figure 3 shows Kane County and these earthquakes. Additionally, there are three Hum reports (red dots) in this county, numbered for reference.

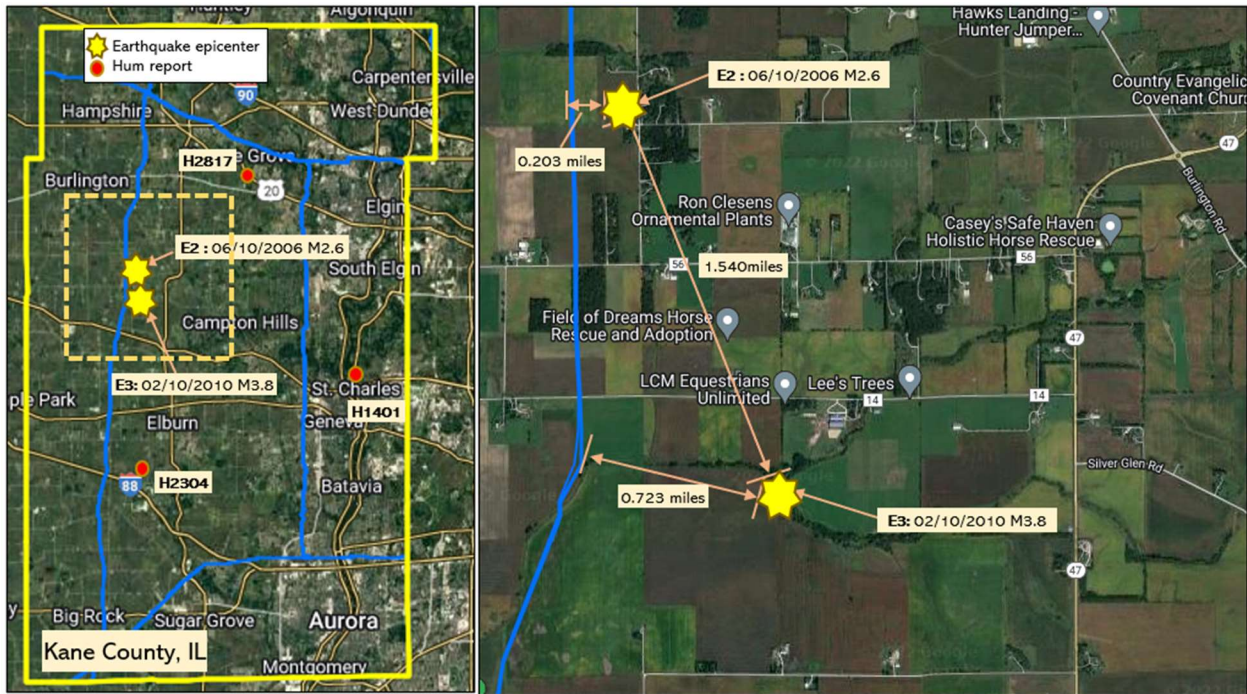


Figure 3: Kane County earthquakes, gas transmission pipelines and Hum reports

Much of Kane county is rural. E2 occurred in 2006 about 0.2 miles from a pipeline corridor. In 2010 there was a second earthquake only 1.5 miles from the first earthquake. The epicenter is about 0.7 miles from the same pipeline corridor. Additionally, there is a Hum report (H2304) that is only a couple miles away along the same pipeline. This Hum report describes the experience as follows: “Like an engine running or the bass from music playing in another room”. All three Hum reports in this county report that the sound causes anxiety and insomnia. H2817 adds that it causes a sense of vibration, ear discomfort and headaches. Additionally, these reports state that it is more noticeable or worse at night.

DuPage County is show below in Figure 4, with one earthquake and six Hum reports. E5 occurred in a fork of two pipelines, with the closer being about 1.0 miles away. This area is suburban with some commercial zoning nearby. While none of the Hum reports are in the immediate area, there are several scattered throughout the county.

H1413 describes the sound like this: “Diesel idle sound. Low rumble. Variable in duration and strength. Low bass sound to me sounds like a train engine or rumble.” H1512 stated that his hearing test was fine, but that he is currently going to doctor to address possible tinnitus.

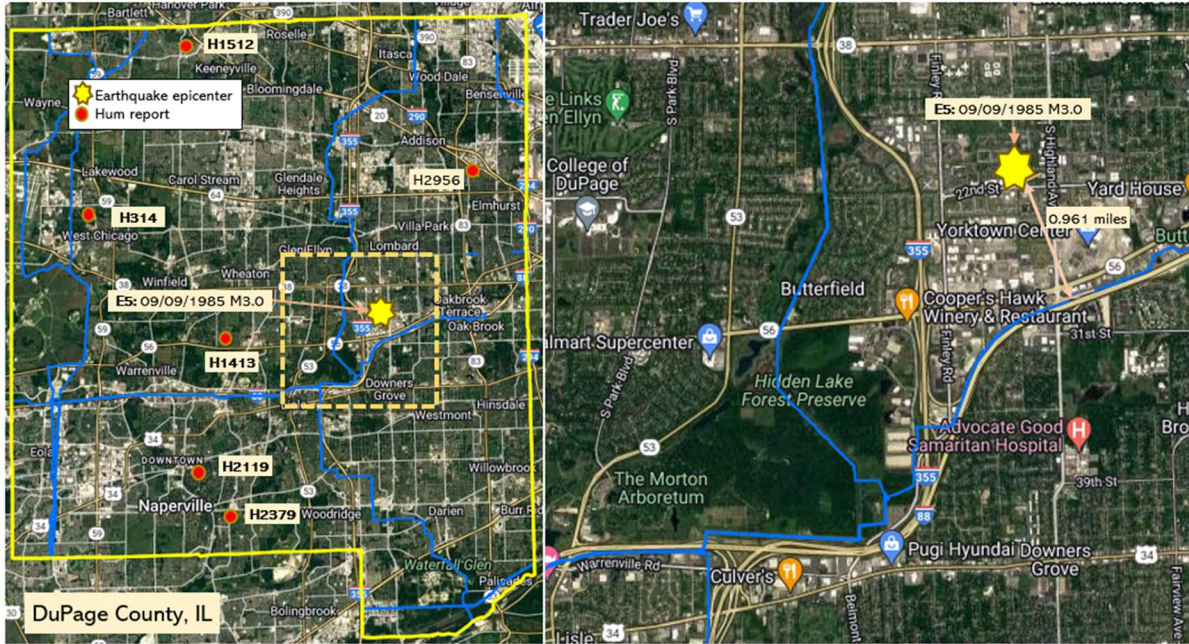


Figure 4: DuPage County earthquake, gas transmission pipelines and Hum reports

Cook County had an earthquake in 2013 with an epicenter directly on a natural gas transmission pipeline corridor. Figure 5 shows Cook County with three Hum reports near E6. Figure 6 shows a closeup of E6 with H1867 not far away. This area is urban with some industrial activity and possibly a quarry. A quarry might be one of the known activities to induce an earthquake. It is possible that in this instance the quarry contributed to the earthquake. However, with the epicenter sitting directly on a pipeline, it suggests that the pipeline was a significant contributor. H1867 describes the sound as a constant pulsing drone that is loudest during the night. If the quarry was singularly responsible, it seems unlikely that there would be activity during the night.

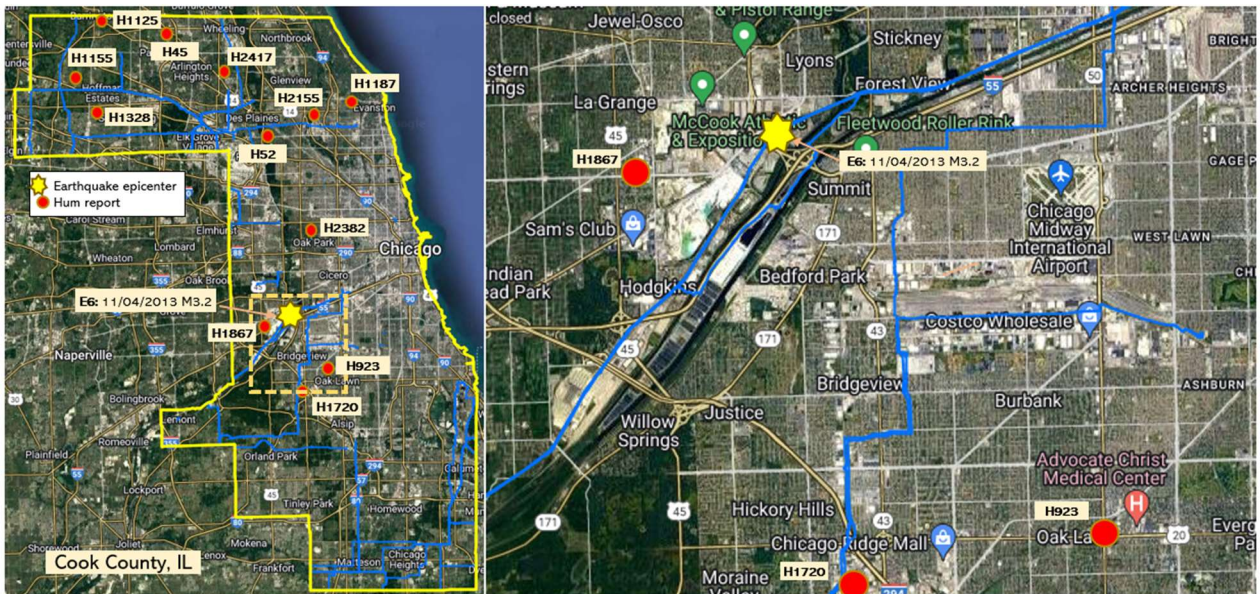


Figure 5: Cook County earthquake, gas transmission pipelines and Hum reports

H923 describes the Hum like this: “a low grumble. I imagine shifting plates in the earth when I hear it, and it only grows louder”. A Hum report in the Lake County directly north of Cook County (not shown) states the following: “I believe the sound may also be resonating through the ground as it can be loud in my basement”. These reports describe a sensation of ground vibrations. It seems likely that these Hum reports are resulting from the same thing that induced this earthquake.

Below, Figure 6 shows a close up of E6 sitting directly on the pipeline. There actually are multiple pipelines in this area. H1867 is remarkably only 1.3 miles from the pipeline and 1.8 miles from E6.

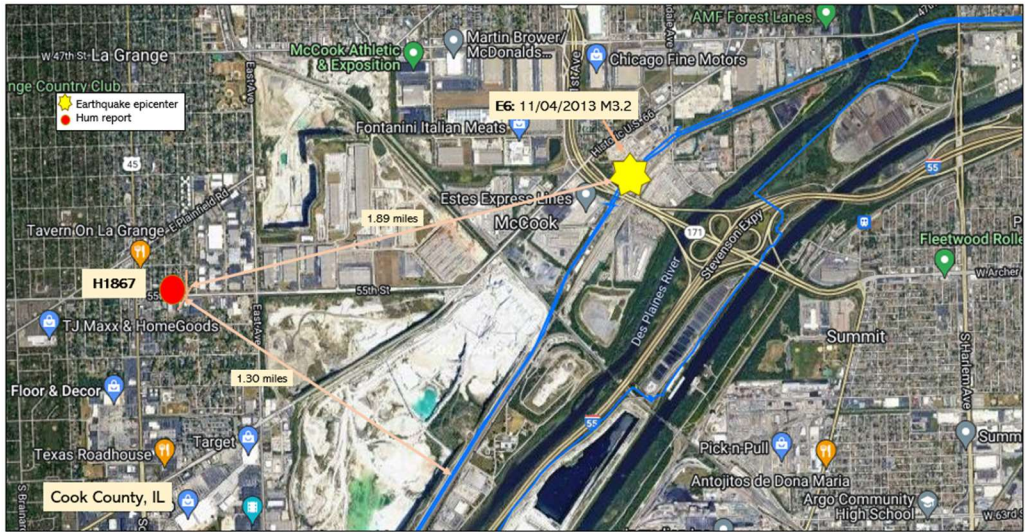


Figure 6: E6 and H1867 in Cook County and gas transmission pipelines

LaSalle County is mostly rural. There was one earthquake in this county that occurred a little over one mile from a pipeline. Looking at the county level map, it is apparent that this earthquake occurred near a pipeline. If this were an isolated event, it might be a coincidence. However, when considering all the earthquakes in this region, it is easy to see that there is a correlation.

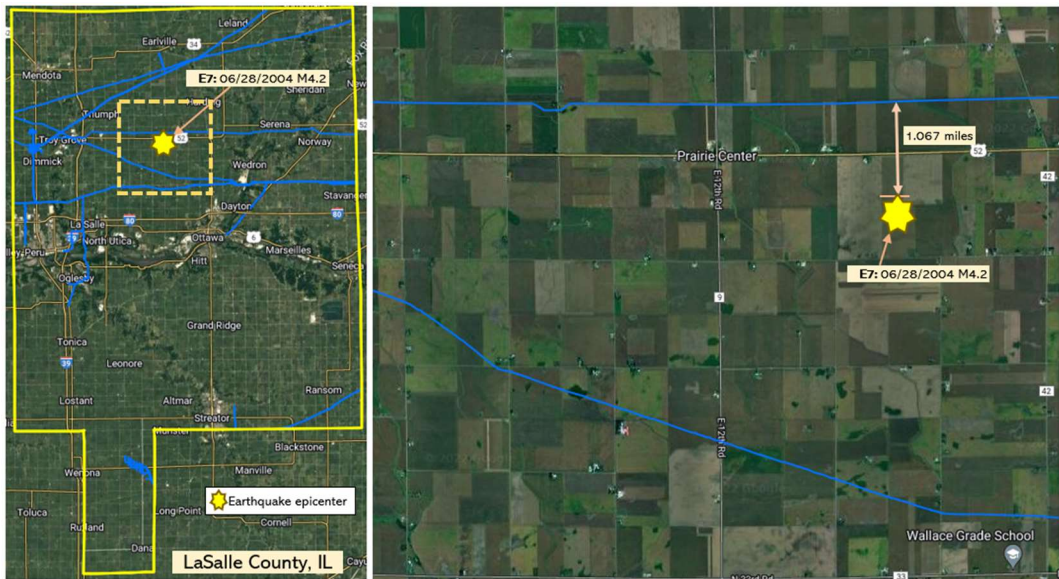


Figure 7: LaSalle County earthquake and gas transmission pipelines

Denver metropolitan area, CO

The Denver metropolitan area had six earthquakes between 1980 and 2022. Figure 8 shows the earthquakes that have occurred in this area. Four of these occurred along a stretch of the same pipeline (yellow markers). Two of these did not appear to be near high pressure gas transmission pipelines.

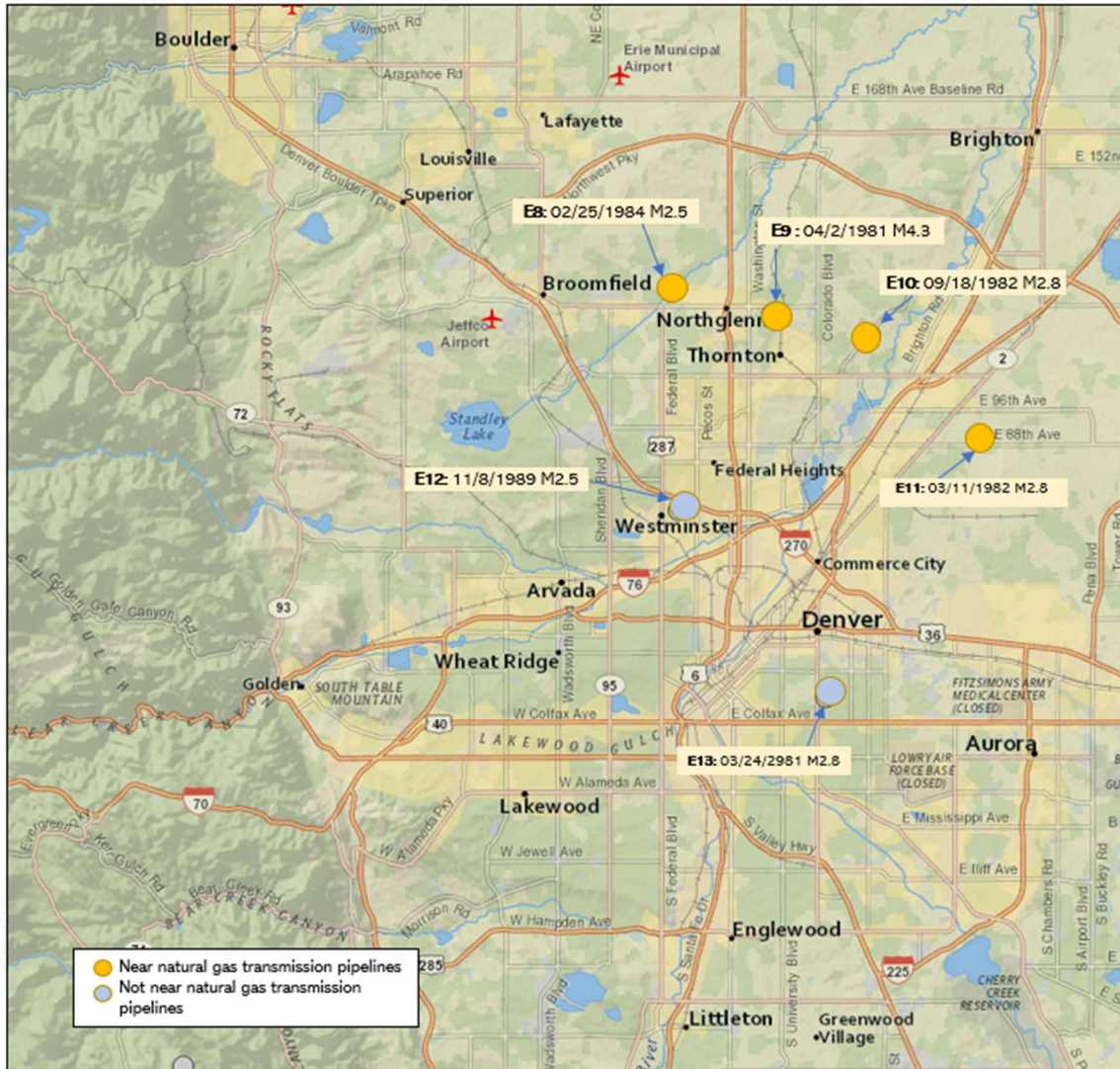


Figure 8: Epicenters in Denver metropolitan area and proximity to natural gas transmission pipelines

Figure 9 shows the pipelines in Adam's County where the four earthquakes near pipelines occurred.

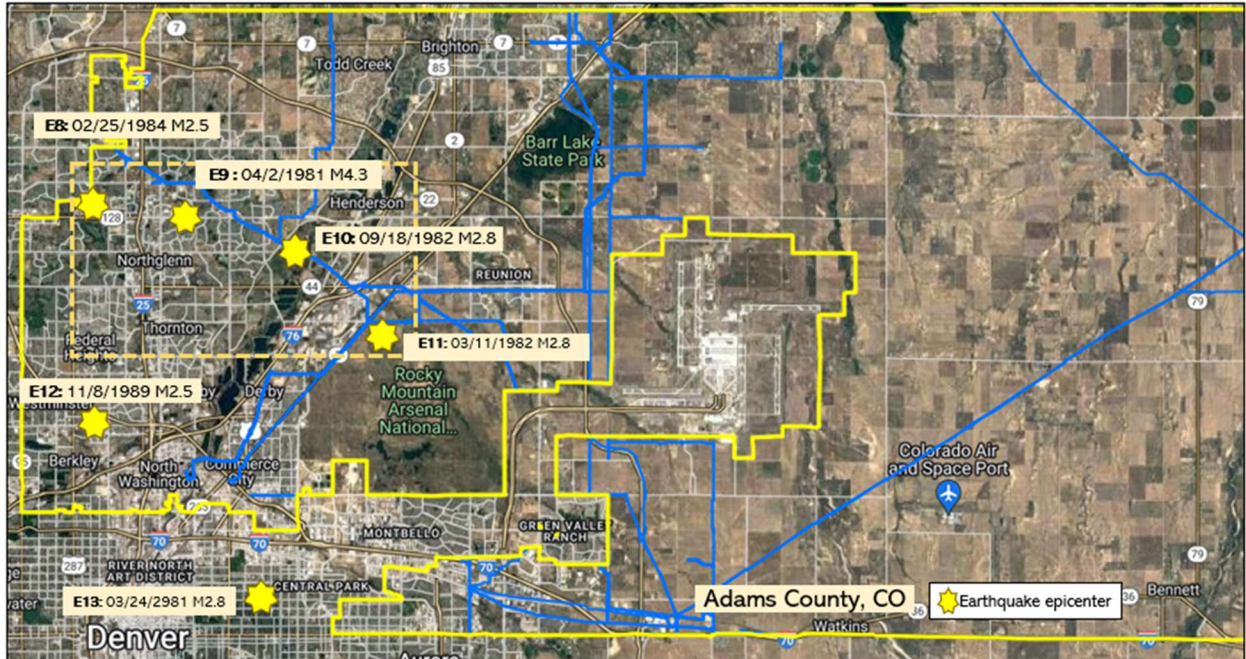


Figure 9: Adams County earthquakes and gas transmission pipelines

Figure 10 shows the four earthquakes that are near the pipeline. E10 occurred almost directly on top of the pipeline and E11 was only 0.5 miles away. E 8 is the furthest from the pipeline at about 1.6 miles away. It is noted that E8 occurs near the termination of two high pressure gas lines. This suggests that there are city gates here. City gates regulate the natural gas to a lower pressure. City gates are suspected of generating sound.

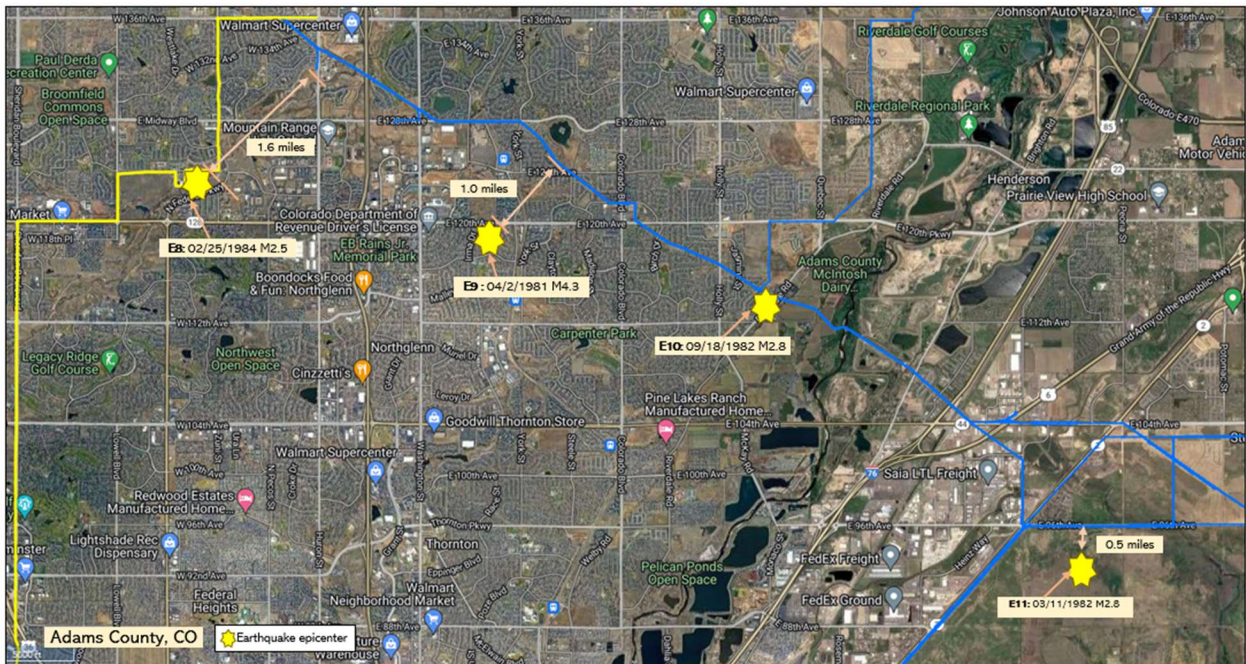


Figure 10: Adams County earthquakes near gas transmission pipelines

There are no Hum reports directly in Adams County. However, the Denver metropolitan area has many Hum reports. The following descriptions are used: “very low audible vibration that pulses intermittently”, “a low frequency hum more like a vibration but in my mind, it seems audible”, and “a low reverberation seemingly coming from outside house”.

Earthquakes in other locations

There are three more examples shown in this section. These are in remote areas, with little human activity. These examples show that these epicenters are very near the pipeline when looking at the county level map. E14 in Nebraska shows center pivot irrigation is used. It is plausible that extracting large amounts of ground water could play a role in inducing earthquakes. However, this earthquake occurred only 0.37 miles from a pipeline.

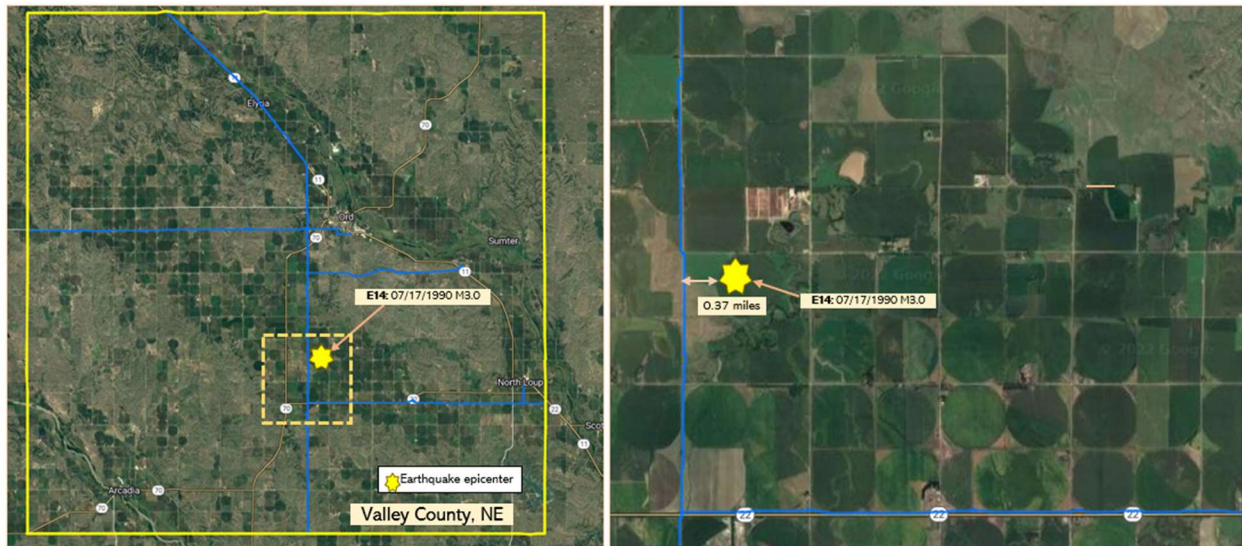


Figure 11: Valley County earthquake and gas transmission pipelines

Figure 12 shows E15 about 0.31 miles from a high pressure natural gas transmission pipeline. Like the other counties, by reviewing the county map, it is apparent that this earthquake occurred almost on top of a pipeline. Much of the county does not have pipelines, and there aren't earthquakes in these areas.

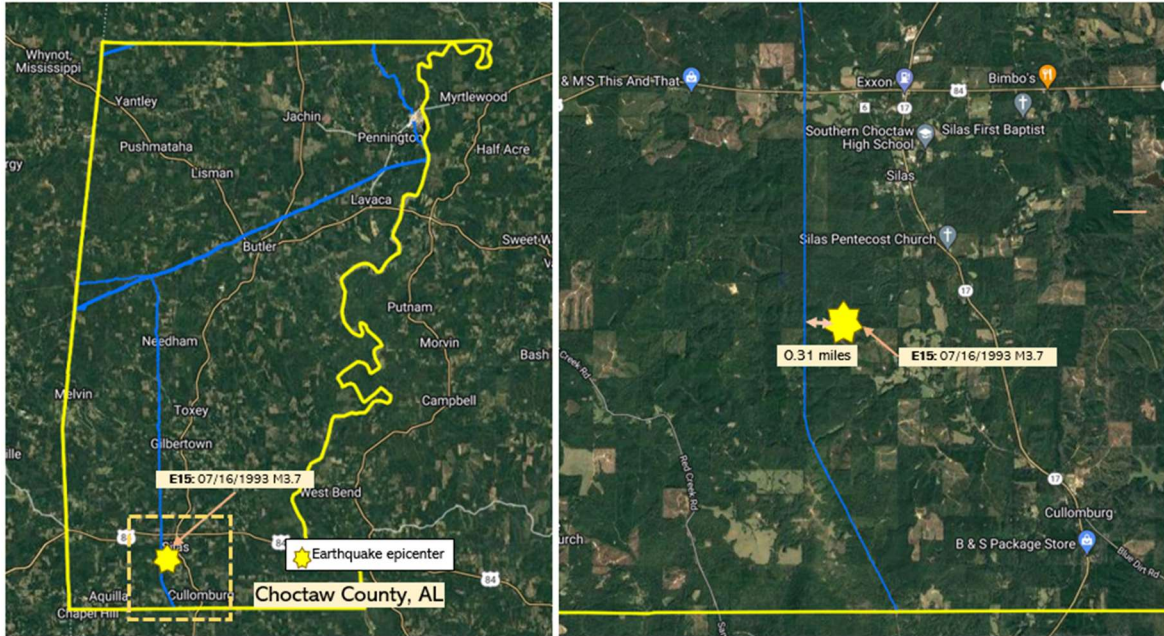


Figure 12: Choctaw County earthquake and gas transmission pipelines

Sumter County Alabama only has a gas pipeline passing through the southern portion. E16 occurred only about a mile from this pipeline.

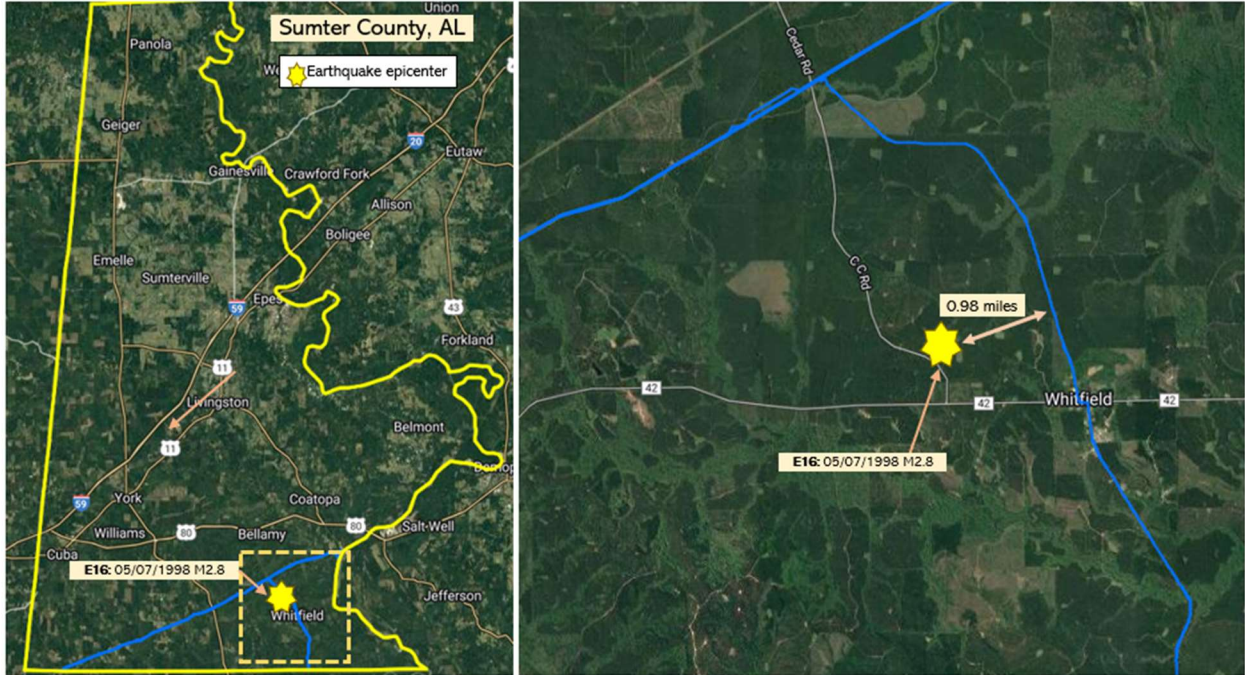


Figure 13: Sumter County earthquake and gas transmission pipelines

Santa Barbra County Mudslides

Montecito in Santa Barbra County had severe mudslides on January 9th, 2018. This event is attributed to a combination of the recent Thomas Fire and extremely heavy rain. The heavy rain carried mud and debris down the watersheds. Flash flooding combined with soil and debris run off from higher elevations

overwhelmed creeks. Mudslides formed as the force of the flood and debris overwhelmed the strength of the ground. Figure 14 shows where these mudslides occurred.



Figure 14: Santa Barbara County debris flow

There might be another factor that contributed to this devastating event. A natural gas transmission pipeline is located near the top of many of the debris flow areas. Many of these begin within a couple hundred feet of the pipeline. Figure 15 shows a section of the mudslides that formed along the pipeline. There are more mudslides to the east of this section with a similar correlation.

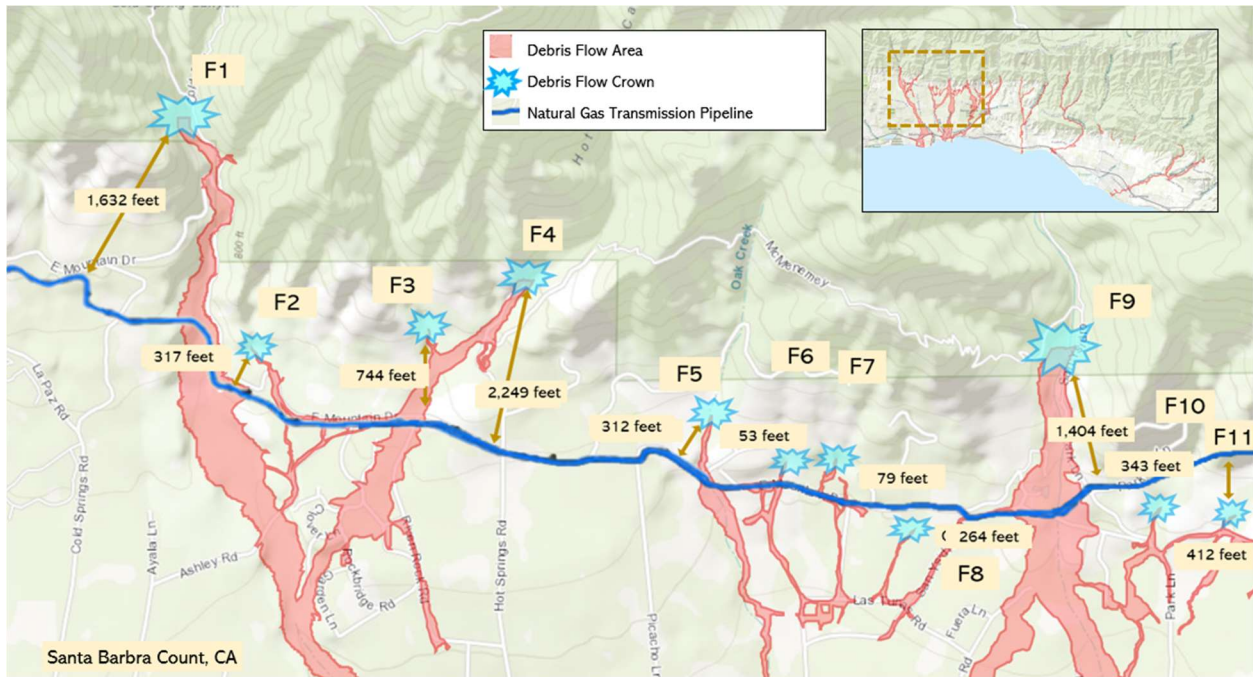


Figure 15: Santa Barbara debris flow and gas transmission pipeline

Typically, these events occur directly on the steep slopes where the ground is more likely to give way. In this event, many of the crowns are below steep slopes, where the ground should be more stable. The smaller debris flows (F2, F3, F5, F6, etc.) are within 500 feet of a gas transmission pipeline. This suggests that the pipeline may have played a critical role in destabilizing this ground. Only the larger mudslide (F1, F4, and F9) are higher up the range and further from the natural gas pipeline. The location of the crowns of the larger mudslides might have been determined by the locations of the basins. Although it is also possible, that these initially started at lower elevations along the pipeline and moved higher as the ground eroded. These flows are along established creeks which would have had greater volume of water and debris flowing.

The conditions for mudslides were all present for this event. However, with the mudslide crowns being so close to the natural gas pipeline, this likely contributed to the event. The role that the pipeline had on this event and other mudslides should be investigated further.

Sinkhole, USGS Website Photo

The USGS Water Science School offers information about many aspects of water and geology. They have a webpage dedicated to sinkholes. Sinkholes occur when rock below the surface is dissolved by groundwater. Eventually a cavern is formed. The sinkhole is created when the ground above the cavern becomes unstable and suddenly collapses. On the USGS webpage³ describing the natural processes that take place to create a sink hole there is a picture of a sinkhole, shown in Figure 16. This image shows a drainage pipe just above a sinkhole. The focus of this image and the webpage is about how water causes sinkholes. However, there is a natural gas pipeline marker present at this site as well (see yellow arrow). The webpage makes no mention of natural gas pipelines. It is possible that this marker is for a high pressure pipeline and may be a missing piece of what caused this sinkhole. If water dissolves and removes rock, adding regular low frequency sonic energy might expedite the process by weakening the soil. Future investigations of sinkholes should consider natural gas pipeline infrastructure.



Figure 16: Sinkhole Webpage on USGS Website showing water with gas pipeline marker in view

Conclusions

There is evidence that natural gas transmission pipelines induce earthquakes and other geohazards. Hum reports are often present in the same locations. Of the areas investigated in this study, only a

³ <https://www.usgs.gov/special-topics/water-science-school/science/sinkholes>, accessed on 4/24/2022

handful of the earthquakes were not located near a pipeline. Northern Illinois and Denver were selected for investigation because there are many Hum reports and some but not a lot of seismic activity. The very first earthquake that was examined was E6, which sits directly on a pipeline with a Hum report a short distance away. After reviewing more earthquakes, it seemed more likely than not to find a gas pipeline present.

For the other locations presented, they were selected for examination because of their apparent isolation from human activity and isolation from other seismic activity. Here too, gas pipelines are present. There are other earthquakes that were identified but not featured in this study. If a systematic review of earthquakes was conducted, it would probably reveal many more occurring in close proximity to pipelines.

The track of mudslides in Santa Barbara County occurred along a pipeline. Many of the crowns were less than 100 feet from the pipeline and on relatively level ground instead of higher up the slope on steeper surfaces. This suggests that the pipeline contributed to the event.

If natural gas transmission pipelines are releasing enough sonic energy to induce earthquakes, then they are likely also causing harm to wildlife and people. Hum reports describe a significant reduction in quality of life and health problems. There is no reason to think that the harm would be limited to those that are aware of this LFN pollution. Given the scale of these systems, there is a potential for this damage to affect most aspects of modern life. This problem needs to be studied further!

About the Author

I live with my family in Milwaukee, WI. I am a mechanical engineer primarily focused on energy efficiency. I first realized that something wasn't right in 2016, after moving into a new apartment in San Francisco. My walls rattled every night until 10:30 PM or so and started promptly again in the early morning. Like many others, I went through a slow process of ruling out potential sources. After moving several times and years later, I realized that the source of my apartment's walls rattling is the same as the Hum. This problem is causing immeasurable harm and needs to be addressed.

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