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Man-Made Earthquakes

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POSTED ON JULY 12, 2013 AT 9:30 AM

LAST UPDATE 10:32 AM BY: [WILLIAM ELLSWORTH \(ELLSWORTH@USGS.GOV\)](#), [JESSICA ROBERTSON \(JROBERTSON@USGS.GOV\)](#), AND [CHRISTOPHER HOOK \(703-648-4460\)](#)

The number of earthquakes has increased dramatically over the past few years within the central and eastern United States. More than 300 earthquakes above a magnitude 3.0 occurred in the three years from 2010-2012, compared with an average rate of 21 events per year observed from 1967-2000.

This increase in earthquakes prompts two important questions: Are they natural, or man-made? And what should be done in the future as we address the causes and consequences of these events to reduce associated risks? USGS scientists have been analyzing the changes in the rate of earthquakes as well as the likely causes, and they have some answers.

USGS scientists have found that at some locations the increase in seismicity coincides with the injection of wastewater in deep disposal wells. Much of this wastewater is a byproduct of oil and gas production and is routinely disposed of by injection into wells specifically designed and approved for this purpose.

Review Article on Injection-Induced Earthquakes

[U.S. Geological Survey](#) geophysicist William Ellsworth reviewed the issue of injection-induced earthquakes in a [recent study published in the journal *Science*](#). The article focused on the injection of fluids into deep wells as a common practice for disposal of wastewater, and discusses recent events and key scientific challenges for assessing this hazard and moving forward to reduce associated risks.

What is Induced Seismicity?

Although it may seem like science fiction, man-made earthquakes have been a reality for decades. It has long been understood that earthquakes can be induced by impoundment of water in reservoirs, surface and underground mining, withdrawal of fluids and gas from the subsurface, and injection of fluids into underground formations.

What is Wastewater Disposal?

Water that is salty or polluted by chemicals needs to be disposed of in a manner that prevents it from contaminating freshwater sources. Often, it is most economical to geologically sequester such wastewaters by injecting them underground, deep below any aquifers that provide drinking water.

Wastewater can result from a variety of processes related to energy production. For example, water is usually present in rock formations containing oil and gas and therefore will be co-produced during oil and gas production. Wastewater can also occur as flow back from hydraulic fracturing operations that involve injecting water under high pressure into a rock formation to stimulate the movement of oil and gas to a well for production.

When wastewater disposal takes place near faults, and underground conditions are right, earthquakes may be more likely to occur. Ellsworth's research showed. Specifically, an earthquake can be triggered by the well-understood mechanism of raising the water pressure inside a fault. If the pressure increases enough, the fault may fail, releasing stored tectonic stress in the form of an earthquake. Even faults that have not moved in millions of years can be made to slip and cause an earthquake if conditions underground are right.

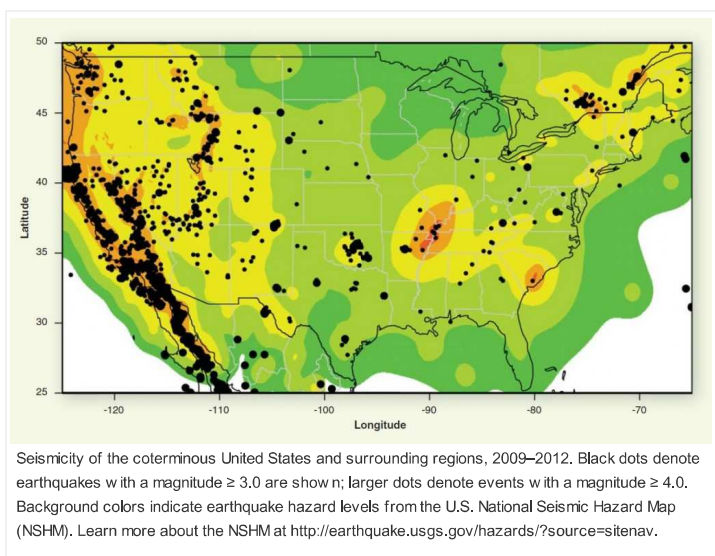
While the disposal process has the potential to trigger earthquakes, not every wastewater disposal well produces earthquakes. In fact, very few of the more than 30,000 wells designed for this purpose appear to cause earthquakes.

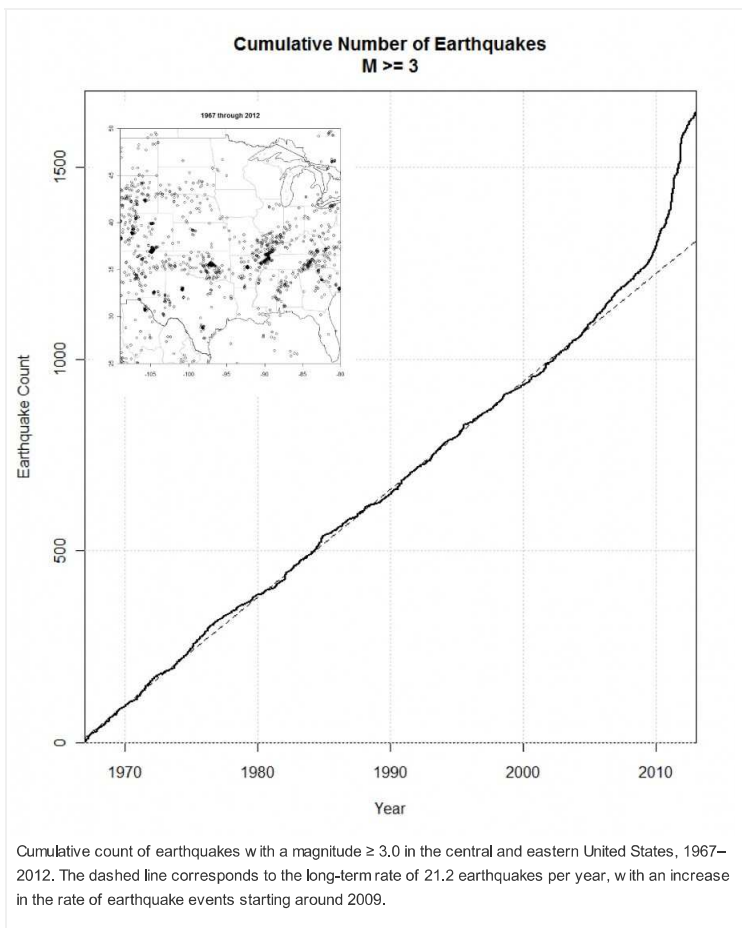
Hydraulic Fracturing

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 rarely felt and are too small to cause structural damage. As noted previously, wastewater associated with hydraulic fracturing has been linked to some, but not all, of the induced earthquakes.

Unknowns and Questions Moving Forward

USGS scientists are dedicated to gaining a better understanding of the geological conditions and industrial practices associated with induced earthquakes, and to determining how seismic risk can be managed.





One risk-management approach highlighted in Ellsworth's article involves the setting of seismic activity thresholds for safe operation. Under this "traffic-light" system, if seismic activity exceeds preset thresholds, reductions in injection would be made. If seismicity continued or escalated, operations could be suspended.

The current regulatory framework for wastewater disposal wells was designed to protect drinking water sources from contamination and does not address earthquake safety. Ellsworth noted that one consequence is that both the quantity and timeliness of information on injection volumes and pressures reported to the regulatory agencies is far from ideal for managing earthquake risk from injection activities.

Thus, improvements in the collection and reporting of injection data to regulatory agencies would provide much-needed information on conditions potentially associated with induced seismicity. In particular, said Ellsworth, daily reporting of injection volumes, and peak and average injection pressures would be a step in the right direction, as would measurement of the pre-injection water pressure and tectonic stress.

Importance of Understanding Hazards and Risks

There is a growing interest in understanding the risks associated with injection-induced earthquakes, especially in the areas of the country where damaging earthquakes are rare.

For example, wastewater disposal appears to have induced the magnitude-5.6 earthquake that struck rural central Oklahoma in 2011, leading to a few injuries and damage to more than a dozen homes. Damage from an earthquake of this magnitude would be even worse if it were to happen in a more densely populated area.

Start with Science

As the use of injection for disposal of wastewater increases, the importance of knowing the associated risks also grows. To meet these challenges, the USGS hopes to increase research efforts to

understand the causes and effects of injection-induced earthquakes.

More Information

The USGS has [FAQs online](#) that provide additional details and background on induced seismicity. You can also learn more by [reading a story](#) by the Department of the Interior on this topic.



House damage in central Oklahoma from the magnitude 5.6 earthquake on Nov. 6, 2011. Research conducted by USGS geophysicist Elizabeth Cochran and her university-based colleagues suggests that this earthquake was induced by injection into deep disposal wells in the Wilzetta North field. Learn more about that research at: <http://geology.gsapubs.org/content/early/2013/03/26/G34045.1.abstract>. Photo Credit: Brian Sherrod, USGS.



Oilfield waste arrives by tanker truck at a wastewater disposal facility near Platteville, Colo. After removal of solids and oil, the wastewater is injected into a deep well for permanent storage underground. This disposal process has the potential to trigger earthquakes, but very few wastewater disposal wells produce earthquakes. No earthquakes are associated with injection at the site in this photograph. Photo taken on Jan. 15, 2013. Photo Credit: William Elsworth, USGS

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o **New Interactive Flooding Warning Tools**



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o **PAGER System to include more Information ts**



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