

About Induced Seismicity Consortium and Areas of Study

1. What is the Induced Seismicity Consortium?

The Induced Seismicity Consortium (ISC) is a collaborative effort of many scientists from the Southern California Earthquake Center (SCEC), the USC Department of Civil and Environmental Engineering (CEE), and the Petroleum Engineering Program at the University of Southern California (USC) along with industry geologists, national laboratories who work together to develop science-based understanding of the risk of induced seismicity.

2. Has hydraulic fracturing caused earthquakes in California?

No. A report published in 2013 by the National Academies of Science concludes that hydraulic fracturing does not pose a high risk for inducing felt seismic events. This finding was confirmed by a study recently completed by the USC Induced Seismicity Consortium that reviewed 30 years of seismic data in California and found no correlation between wells that have been fractured and induced seismic activity. These studies also show little or no correlation between oil field activity in general and seismic activity.

The USC Induced Seismicity Consortium consists of representatives from the science community, industry, regulatory and government agencies, and NGOs.

The study compared seismic activity recorded by the Northern California Earthquake Center and the Southern California Earthquake Center and activities performed by energy companies on wells within the state, as reported by the California Division of Oil, Gas, and Geothermal Resources and on the FracFocus website. Seismic records provided the latitude and longitude of the epicenter of seismic activity, as well as the magnitude and the depth of that seismic activity. DOGGR and FracFocus data bases were used to display the location of each well, the type of each well (e.g. oil producer, water flood injector, steam flood injector, water disposal, gas source, etc.), the type of activity performed (drilling, producing, injecting, completing, stimulating, abandoning), and the position within the well where that activity took place (depth). A comparison of these data was made and displayed on maps that included the position of known geological faults and outlines of oil fields and geothermal areas.

Composite maps for each DOGGR District were generated showing the distribution of active wells and the distribution of recorded seismic events. The researchers performed statistical analysis of the data recorded between 1980 and June 2013. For example, for District 6 (northern California), there were 303,609 seismic events recorded. Within the area where oil and gas activities had taken place (Sacramento Basin, away from known

fault zones, depths less than 6 kilometers), there were 210 seismic events. Of those events, only 3 had magnitudes greater than 3, none greater than 4.

3. What is induced seismicity and how commonly does it occur?

Induced seismicity by definition is seismic activity that is human-caused (anthropogenic). Seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time. The vast majority of earthquakes are natural, caused by deep seated stresses that result in the fracturing of rock in the earth's crust. Examples of processes that are believed to have produced anthropogenic events in the past include subsurface wastewater injection, geothermal energy generation, reservoir impoundment (behind a dam), and very rapid oil production. Any subsurface action will result in some levels of seismicity; however much of this seismicity is very low magnitude, is rarely felt, and is only detectable by specialized instruments. In most reviewed cases of induced seismicity, almost all events had magnitudes ranging from negative 2.0 to positive 2.0 on the earthquake magnitude scale. Earthquakes with magnitude 2.0 and below are typically characterized as microseismicity, and not felt.

4. What are examples or causes of induced seismicity?

The main causes of induced seismicity are changes in the pressure associated with fluids in the pores of rocks, also known as pore pressures. Seismicity can be induced as a result of increases in fluid volume within a given volume of rock, thermal expansion and contraction of the volume, and rapid chemical alteration of the host rock. Induced seismicity is not caused by just injecting fluids but is triggered by increased pore pressure in the rock that causes it to break or that reduces natural friction on a fault.¹ Researchers are still in the process of understanding the detailed causes of induced seismicity, but know that fluid pressures have a role in seismicity.² The U.S. Department of Energy (DOE) explains that "pore pressures act against the weight of rock and forces holding the rock together; if the pore pressures are low, then only the imbalance of natural in situ earth stresses will cause an occasional earthquake. If, however, pore pressures increase, then it would take less of an imbalance to cause an earthquake."³

¹ http://www.gwpc.org/sites/default/files/events/white%20paper%20-%20final_0.pdf

² U.S. Department of Energy, 'Induced Seismicity Primer':
http://esd.lbl.gov/research/projects/induced_seismicity/primer.html

³ U.S. Department of Energy, 'Induced Seismicity Primer':
http://esd.lbl.gov/research/projects/induced_seismicity/primer.html

Examples of induced seismicity include wastewater disposal by injection into deep, very hard geologic formations.⁴ Injecting fluids increases pore pressure in those formations and, unless it can be balanced by fluid withdrawals, could induce seismic activity. Additional causes of induced seismicity could include chemical changes from injection and mining.⁵

5. Does induced seismicity from wastewater injection differ in California than in other states?

Oil companies are required by federal law to examine whether water injection will affect nearby faults. Their analysis is required to be reviewed by state regulators. The injection wells used in California are not the same type of injection disposal wells that have been linked to earthquakes in other states like Ohio, Oklahoma, Texas, and Arkansas.⁶ In California operations, water is being re-injected back into the formation after separating the oil out.⁷ In California, the zones into which the water is being injected are depleted reservoirs consisting of porous sandstone. In the mid-west and east, injection often is into very old, low porosity rocks, with little storage capacity. After a short period of injection, pore pressure increases significantly as the pore space is filled. Once it is totally filled, additional injected water can break the rock, causing an induced seismic event. UC Santa Barbara geophysicist Craig Nicholson finds that “very little of the state’s [California] earthquake activity can be tied in any way to reinjection...there’s not a connection like there is in the central and eastern United States.”

Further, the USGS finds that “although the disposal process has the potential to trigger earthquakes...very few of the more than 30,000 wells designed for this purpose appear to cause earthquakes.”⁸

⁴ Ozarks Public Radio, ‘USGS: Oka Fracking Has Increased Chance of ‘Damage Quake’’:
<http://ksmu.org/npr/usgs-okla-fracking-has-increased-chance-damaging-quake>

⁵ U.S. Department of Energy, ‘Induced Seismicity Primer’:
http://esd.lbl.gov/research/projects/induced_seismicity/primer.html

⁶ Energy in Depth California, ‘Earthworks Study Makes Shaky Assumptions on California Earthquakes,’<http://energyindepth.org/california/earthworks-study-shaky-assumptions-california-earthquakes/>

⁷ Energy in Depth California, ‘Earthworks Study Makes Shaky Assumptions on California Earthquakes,’<http://energyindepth.org/california/earthworks-study-shaky-assumptions-california-earthquakes/>

⁸ USGS ‘Man-Made Earthquakes Update’ http://www.usgs.gov/blogs/features/usgs_top_story/man-made-earthquakes/

6. Can hydraulic fracturing cause induced seismicity?

According to the U.S. DOE, hydraulic fracturing is “rarely, if ever, a hazard when used to enhance permeability in oil and gas or other types of fluid-extraction activities.”⁹

Hydraulic fracturing is a well-established, advanced means of extracting oil and natural gas from sub-surface shale formations. The method includes injecting fluid into sub-surface, which increases permeability in the shale and helps extraction of fluids (like oil and gas).¹⁰ While the technique has been questioned about potential adverse environmental consequences including increased seismic activity, only two cases of hydraulic fracturing are believed to have actually induced noticeable events; both were below magnitude 3.0, resulting in minimal effect and neither occurred in California.

USGS studies find that “only very rarely” is hydraulic fracturing the direct cause of felt earthquakes. The “microearthquakes” that hydraulic fracturing creates are too small to be felt or cause structural damage.¹¹

7. How do we know if an earthquake was caused by induced seismicity?

Felt induced seismicity is very rare. In those circumstances, experienced seismologists can only determine whether an earthquake is natural, triggered or induced after extensive analysis of data from the earthquake and potential anthropogenic triggers. More information is needed to improve researchers’ understanding of the “triggering” mechanisms of injection and production-related induced seismicity as well as how those can relate to naturally occurring earthquakes.¹²

Studies by USC and the California Institute of Technology comparing earthquakes measured by the Southern and Northern California Earthquake Centers and oil field production and injection records indicates that there is no significant correlation between earthquakes and oil and gas field operations. Natural earthquake epicenters are typically below five kilometers of depth, while oil field operations are conducted at depths shallower than two kilometers, most less than one kilometer.

⁹ U.S. Department of Energy, ‘Induced Seismicity Primer’:
http://esd.lbl.gov/research/projects/induced_seismicity/primer.html

¹⁰ U.S. Department of Energy, ‘Induced Seismicity Primer’:
http://esd.lbl.gov/research/projects/induced_seismicity/primer.html

¹¹ USGS ‘Man-Made Earthquakes Update’ http://www.usgs.gov/blogs/features/usgs_top_story/man-made-earthquakes/

¹² U.S. Department of Energy, ‘Induced Seismicity Primer’:
http://esd.lbl.gov/research/projects/induced_seismicity/primer.html

8. Are there any documented cases of injuries or property damage caused by induced seismicity?

There are no documented cases in California of injuries or property damage caused by induced seismicity. In the case of induced seismic activity in Oklahoma, there has been documented property damage caused by shaking that resulted from waste water injection into hard rocks adjacent to mapped faults.

According to the National Research Council's Committee on the Induced Seismicity Potential in Energy Technologies Report, (found at http://www.nap.edu/catalog.php?record_id=13355), virtually all induced seismicity attributed to energy development is small in magnitude, and unable to be felt. The committee also found that hydraulic fracturing does not pose a high risk for seismic events that can be felt.

9. Can induced seismicity affect groundwater?

The U.S. Environmental Protection Agency (EPA) is the federal agency responsible for investigation into and regulation of groundwater quality in relation to hydraulic fracturing processes. Injection associated with hydraulic fracturing has not been associated with the pollution of ground water. EPA and others are actively studying potential environmental effects of hydraulic fracturing. The Shale Gas Information Platform finds that groundwater contamination can happen through spillage or leakage.¹³ Details of the injection and groundwater pollution continue to be areas of active research.

10. Where can I find information about induced seismicity?

<http://earthquake.usgs.gov/research/induced/>

http://esd.lbl.gov/research/projects/induced_seismicity/

[Induced Seismicity FAQ EOS Draft 5 5](#)

[14.docxhttp://www.nap.edu/openbook.php?record_id=13355&page=37](http://www.nap.edu/openbook.php?record_id=13355&page=37)

¹³ <http://www.shale-gas-information-platform.org/what-are-the-risks.html>

11. What are the relevant federal, state, non-governmental organizations, and trade associations that have information about induced seismicity and how can they be contacted?

NATIONAL

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Web Information: http://esd.lbl.gov/research/projects/induced_seismicity/

CALIFORNIA

- Southern California Earthquake Consortium (SCEC)
<http://www.scec.org/>
Thomas Jordan
- California Department of Conservation
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DOGGR and State Water Resources Control Board

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