UNDERSTANDING SEISMICITY ASSOCIATED WITH SALTWATER DISPOSAL WELLS

BACKGROUND

The underground disposal of produced waters from oil and natural gas (O&G) operations has proven to be a safe and environmentally reliable means of managing this water. Currently, there are nearly 180,000 Class II Underground Injection Control (UIC) wells regulated by U.S. Environmental Protection Agency (EPA) under the Safe Drinking Water Act and delegated to 31 state agencies. These wells, used for salt water disposal, enhanced oil recovery, and hydrocarbon storage, serve a vital role by supporting the responsible and sustainable development of O&G resources. These O&G Class II UIC wells are a subset of the more than 740,000 permitted UIC wells nationwide which serve the needs of many different industries and governmental entities.

During the last few years, there has been an increase in earthquakes in the central United States, including areas where oil and natural gas operations and activity have experienced substantial growth. In response, state regulators have taken a range of actions to reduce potentially induced earthquakes. Industry, academia, and governmental entities have initiated research to better understand the science and mechanisms associated with the observed events.

In 2014 and 2015, a major initiative undertaken by the StatesFirst Initiative, renamed The State Oil and Gas Regulatory Exchange ("Exchange") in 2018, a collaboration between the Interstate Oil and Gas Compact Commission (IOGCC) and Groundwater Protection Council (GWPC), was established to investigate the seismicity issue. This effort brought together technical experts from multiple interested parties to produce a summary of the current knowledge for managing the potential risk and informing stakeholders, including the public and media. This hallmark effort culminated in a September 2015 publication "Potential Injection-Induced Seismicity Associated with Oil and Gas Operations." Ever improving, in March of 2021, a third edition was released titled, "Potential Induced Seismicity Guide: A Resource of Technical and Regulatory Considerations Associated with Fluid Injection" ("the Exchange Guide"). In addition to providing updated science surrounding seismicity induced by the injection of fluids in Class II disposal wells, the 2021 Guide expanded on topics including seismicity induced by hydraulic fracturing and Carbon Capture, Use and Storage (CCUS). It focuses on four main topics: 1) Understanding induced seismicity; 2) Assessing potential injection-induced seismicity; 3) Risk management and mitigation strategies; and 4) Considerations for external communication and engagement.

The Guide concludes that the majority of well operations in the United States do not pose a hazard for induced seismicity; however, under some geologic and operational conditions, a limited number of disposal wells and hydraulic fracturing operations have been determined to be responsible for induced earthquakes with felt levels of ground shaking.

The hydraulic fracturing process creates fractures and micro-seismic events in deep hydrocarbon reservoir rocks. The micro-seismic events cause no damage and cannot be felt on the earth's surface or even detected without sophisticated instruments. Under certain unique and limited geologic conditions hydraulic fracturing may induce an earthquake felt at the surface of the earth but such earthquakes have only rarely been noted. Vibrations created by trucks driving on the road, trains, and other common events are many times more powerful than what can felt from the distant and very small seismic events that typically happen with hydraulic fracturing activities.

This document addresses only permitted disposal wells. **Figure 1** is a photograph of a typical disposal site.

Source: ALL Consulting

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American Petroleum Institute

The American Petroleum Institute (API) and a number of its member companies participated in all three report editions and continue to support the collaborative efforts of the Exchange. API believes that risk management should be based on sound science that accounts for operational scope, geological setting, and local conditions. API encourages the continued enhancement of approaches to better assess and manage induced seismic risk. Using long-established seismological methods, it is difficult to clearly differentiate between induced and natural earthquakes. Evaluation of potentially induced seismicity requires integration of multiple technical disciplines and skill sets, and collaboration among seismologists, reservoir engineers, geotechnical engineers, geologists, hydrogeologists, and geophysicists. The Exchange continues to state that mitigation of the risks associated with potentially induced seismicity are best managed at the state level, with specific considerations at regional and sometimes local levels. A national approach is infeasible and likely ineffective, due to variability in local geology and surface conditions. These conditions include factors such as population density, building conditions, infrastructure, critical facilities, and seismic monitoring capabilities. Scale and distance matter in the discussion of induced seismicity.

UNDERSTANDING INDUCED SEISMICITY

Earthquakes are caused by slippage along critically stressed faults due to the release of stored elastic stress. A critically stressed fault means that existing shear forces are nearly sufficient to overcome natural friction. The vast majority of earthquakes are tectonic (natural), but under some circumstances, seismicity can be induced by human activities.

A U.S. National Academy of Sciences report indicates that induced seismicity has been documented since at least the early 1900s. The report states that seismicity has been attributed to a broad range of human activities, including enhanced geothermal projects, mining, underground fluid injection, oil and natural gas extraction, the impoundment of large amounts of water in reservoirs or behind dams, construction, and underground nuclear tests.

The EPA stated that for UIC Class II disposal wells to cause seismicity, there must be a critically stressed fault in proximity to a disposal operation and the disposal operation must change the effective stresses acting on the fault. Under these unique conditions, as pore pressure increases from injection of wastewater, the effective stress on the fault may be altered, triggering the earthquake and the corresponding release of accumulated strain energy. Hence, the triggering mechanism is actually associated with changes in the stresses acting on the fault; noting it is not accurate to say that the injected water has "lubricated" the fault causing it to slip.

The Exchange Guide contains a more thorough discussion of the geomechanics and cause and effect associated with potentially induced seismicity. In particular, Appendix A, titled "Relevant Earthquake Science," presents a general discussion of earthquake science.

SEISMIC DETECTION AND MONITORING

A decade ago, there were a limited number of seismic monitoring networks. When an earthquake occurred, this sparse recording network led to shortage of information about the surface location and depth of the seismic event. More recently, seismic monitoring capabilities have expanded and are providing more sensitive detection capabilities over larger areas. The increasing number of seismic arrays has allowed seismologists to more accurately pinpoint the location and depth of the seismic events, and improved the accuracy of calculating the magnitude of the earthquake. This enhanced capability has been beneficial to state regulatory agencies and government, academic, and industry researchers.

The United States Geological Survey (USGS) reports earthquake magnitude using a modified Richter scale. The magnitude value is important to seismologists comparing earthquake properties regionally and even globally. Magnitude is only indirectly related to what is felt at the surface, which is referred to as earthquake intensity. In recent years the USGS has developed "shake maps" which are posted on-line and show the approximate intensity of prior earthquakes. Generally, the farther from the earthquake hypocenter, the weaker the intensity. Earthquakes below magnitude 2.5 are not typically felt by humans except in exceptional circumstances.

SITING NEW DISPOSAL WELLS

HAZARD ASSESSMENT, SITE CHARACTERIZATION, AND OPERATIONAL CONSIDERATIONS SHOULD BE INTEGRAL DURING THE PLANNING PROCESS OF SITING NEW DISPOSAL WELLS.

The process should include a thorough geological and geophysical evaluation including the following:

- Examination of current and historical seismic activity in the area, including shallow and basement seismic events and the lateral and vertical proximity of the proposed disposal well to the events;
- Examination of available fault maps;
- Evaluation of the proximity of population centers, public structures, and sensitive infrastructure;
- Understanding the quality and utility of existing regional seismic networks; and
- Development of a seismic activity response plan that reflects the local conditions and risk exposures.

RESPONSE TO POTENTIALLY INDUCED SEISMICITY EVENTS

In the event that an existing disposal well is in the proximity of an earthquake, the operator should be prepared to fully cooperate with the regulatory agency having jurisdiction. Together the agency and operator can define and implement an agreed upon well mitigation strategy. It is important to note that applicable regulations can differ between states.

The data used to define mitigation practices is similar to the data used to site a new disposal well. The review should also include current operating data (i.e., injection volume and pressure, daily rates and pressure measurements) and the estimated location and depth of the earthquake (including how accurate the location and depth have been identified).

RESOURCES

In 2018, the StatesFirst Initiative was renamed The State Oil and Gas Regulatory Exchange (Exchange). In March of 2021 the Exchange published its third edition of the report on induced seismicity titled Potential Induced Seismicity Guide: **A Resource of Technical and Regulatory Considerations Associated with Fluid Injection**

(https://76df3998-d2d3-4c50-b713-68d19a2fa19e.filesusr.com/ugd/2c9022_a8086011c7eb40bd832d7b18d4bd93a6.pdf)

Myths and Facts on Wastewater Injection, Hydraulic Fracturing, Enhanced Oil Recovery, and Induced Seismicity. Rubinstein, Justin L. and Mahani, Alireza Babaie. 4, s.l. : Seismological Research Letters, 2015, Vol. 86.

(https://pubs.geoscienceworld.org/ssa/srl/article-abstract/86/4/1060/315450/Myths-and-Facts-on-Wastewater-Injection-Hydraulic?redirectedFrom=fulltext)

NRC, National Research Council. Induced seismicity potential in energy technologies. s.l.: **The National Academies Press, 2012.**

(Induced Seismicity Potential in Energy Technologies | The National Academies Press (nap.edu))

USEPA. Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches. Washington, DC. : Underground Injection Control National Technical Workgroup, U.S. Environmental Protection Agency, 2015.

(https://www.epa.gov/sites/default/files/2015-08/documents/induced-seismicity-201502.pdf)

SUMMARY

This document is a synopsis of the subject of induced seismicity related to disposal wells. Induced seismicity is a complex issue for which the base knowledge is changing rapidly and continues to evolve. Companies that operate disposal wells should be prepared to assess, mitigate, and minimize the potential for induced seismicity by using tools, knowledge, and expertise summarized in the Exchange Guide.

The science surrounding induced seismicity is advancing as research continues to be pursued across academic, governmental, and industrial research institutions. Ongoing collaboration between the oil and natural gas industry, regulators, academia, non-governmental organizations, and other experts will continue to advance the understanding of the complex subsurface physics associated with induced seismicity.

Source: http://www.api.org/~/media/Files/Oil-and-Natural-Gas/Hydraulic-Fracturing/seismicity-and-saltwater-wells.pdf

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ADDITIONAL INFORMATION RESOURCES

United States Geological Survey
Earthquake Hazards Program
https://earthquake.usgs.gov/research/induced/

U.S. Department of Energy
Lawrence Berkeley National Laboratories
http://esd1.lbl.gov/research/projects/induced_seismicity/

Groundwater Protection Council
Induced Seismicity Resources
http://www.gwpc.org/resources/induced-seismicity-resources

Stanford University
Stanford Center for Triggered and Induced Seismicity
https://scits.stanford.edu/

University of Texas Bureau of Economic Geology
TexNet / Center for Integrated Seismicity Research
http://www.beg.utexas.edu/texnet
http://www.beg.utexas.edu/cisr

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