Induced Seismicity from Oil and Gas Wastewater Injection

Prepared by Kathryn Mutz, Natural Resources, LLC for the University of Colorado Collaboratory for Induced Seismicity and the Intermountain Oil and Gas BMP Project

SUMMARY
This interactive map illustrates state and federal laws and regulations that can manage induced seismicity caused by disposal of oil and gas production fluids (wastewater) into Class II Underground Injection Control (UIC) wells.

ABOUT INDUCED SEISMICITY FROM WASTEWATER INJECTION AND THE DATA
Disposal of oil and gas wastewater by injection has caused hundreds of small earthquakes and several larger, damaging earthquakes in multiple states. Disposal of these fluids by injection is regulated under the federal 1974 Safe Drinking Water Act (SDWA) and its amendments. This dataset and map provides a cross-sectional comparison and a partial longitudinal (over time) comparison of federal law and the law of seven states with significant oil and gas development (Arkansas (AR), Colorado (CO), Kansas (KS), Ohio (OH), Oklahoma (OK), Pennsylvania (PA), and Texas (TX)).

While the SDWA, and most of the state law that controls Class II UIC wells, is intended to protect underground sources of drinking water from contamination, our dataset focuses on the subset of state and federal laws that can be used to avoid the hazards of induced earthquakes and the risks associated with them. Hazards can be addressed with proper well siting, construction, operations, and adaptive management strategies. Risks to the public can be ameliorated or redirected through siting decisions, involving the public in decision making, internalizing the environmental, social and administrative costs of disposal wells, and compensating impacted individuals for damages. In this dataset, these regulatory issues are addressed through questions regarding:

• Regulatory Authority;
• Well Permitting and Siting;
• Well Construction and Operations; and
• Public Participation, Financial Assurances, and Liability.

Some findings from the dataset include:
• All eight jurisdictions surveyed allow oil and gas operations to dispose of wastewater by injection (see Question 1). EPA classifies disposal wells for oil and gas production waste as Class II injection wells under the UIC program implementing the federal SDWA. All of the subject states except PA have primary responsibility (primacy) for regulating this underground disposal of wastewater (see Question 2). Four states (AR, CO, OK, and TX) have regulations specific to commercial disposal wells (see Question 3).

• In order to properly site well operations, all eight jurisdictions require applicants to submit information on subsurface features of the proposed injection site with their permit applications (see Question 4). Applications must include information on aquifers and geologic strata at the proposed well location and must identify the location of nearby wells. Half of the jurisdictions (AR, OH, TX, and EPA) specifically require identification of area faults. In addition, OK and CO administrative procedures require identification of faults. TX is the only state with regulations requiring information on historic earthquakes and depth to bedrock.

• Only a few states surveyed have regulatory or policy restrictions that go beyond protecting water quality to explicitly address seismicity-related issues when siting an injection well. Some have specific restrictions; others have general, more comprehensive siting criteria (see Question 5). Examples include:
  o AR created an injection well moratorium area related to the Guy-Greenbrier Earthquake Swarm, and can also restrict siting based on proximity to faults, proximity to other injection wells, and proximity to seismic events.
  o OH regulations require short setbacks from certain structures, i.e., the state does not allow UIC wells within designated distances from various categories of buildings and transportation infrastructure.
  o None of the jurisdictions specifically restrict well siting based on the depth of injection despite the fact that injection into basement rock has been implicated in induced seismicity in OK, CO, and KS. OH policy, however, is to prohibit all injection into the Precambrian basement to avoid drilling near any possible fault lines in the crystalline rock.
  o More generally, CO regulations allow UIC permit denial with reasonable cause to believe that the proposed disposal well could result in a significant adverse impact on the environment or public health, safety and welfare.
  o AR can determine zones suitable for disposal injection based on overall suitability of the zone as a disposal injection interval, specifically with respect to underground sources of drinking water and oil and gas resources.

• For constructing and operating wells, all eight jurisdictions have requirements for casing and cementing wells (Question 6) and testing for mechanical integrity (Question 7). All jurisdictions also regulate the fluid injection process (see Question 8). While all jurisdictions have restrictions on injection pressure based on fracture gradient of the underlying rock, only a few address the volume or rate of injection in their regulations.

• Regarding monitoring for seismicity, only OH requires operators, on a case-by-case basis, to prepare a plan for monitoring seismic activities near wells (see Question 9). AR, CO,
OK and PA have, through administrative actions, required some operators to monitor their wells for seismicity. And all of the jurisdictions use some type of state or federal seismic monitoring network to track seismicity and attempt to discern location and cause.

- All of the jurisdictions require some type(s) of monitoring, record keeping, and reporting to verify operator compliance with permit requirements (see Question 10). All jurisdictions require monitoring and reporting of injection parameters – fluid volume or injection rate and injection pressure. Frequency of data collection and reporting varies among the jurisdictions from daily to annual compilation and monthly to annual reporting. Two states (AR and OK) have special rules for monitoring and reporting on seismically active areas or commercial disposal wells.

- All jurisdictions have authority to require operators to take corrective action under certain circumstances (see Question 11). These actions may include modifying or halting operations. All jurisdictions except OK can revoke a permit, although TX is the only state that specifically provides for revoking a permit if a well is contributing to seismic activity. And OH only provides for revoking an unused permit. Though none of the jurisdictions can specifically shut-in a well due to seismicity, all but KS have agency discretion when there is potential harm to the public or an emergency situation exists. KS can revoke a permit for just cause after a hearing or take necessary remedial action after emergency adjudicative proceedings.

- All jurisdictions require public notice and opportunities for public hearings regarding permit applications for Class II wells and all but AR have additional regulations regarding public comments or protests (see Question 12). Opportunities for public participation are more limited after the permit has been approved. Only CO, KS, and PA have public notice requirements that might apply to seismicity issues during operations, although AR regulations may require a hearing prior to some permit amendments.

- All jurisdictions require the operator to post financial assurances for injection wells – generally surety bonds or approved substitutes (see Question 13). All jurisdictions also specify the dollar amount or a calculated amount for these bonds, but only AR and CO have specific bond amounts for injection wells. AR, CO and OK can increase the standard amount for the bond for specified reasons.

- Most states have fixed fees for injection well permits which may be in addition to a basic well drilling permit fee. Permit fees can also differ for commercial and non-commercial wells (AR and OK). Some states have fixed annual operations fees (AR, KS, OK, and TX), while OH operation fees are adjusted for the volume injected and the source of the fluid (out-of-state fluids costing more) (see Question 14). KS adjusts fees to cover administrative costs, including inspection, investigation, enforcement, and monitoring.

- Only a few jurisdictions address, even tangentially, liability or the burden of proof regarding the cause of an earthquake or liability for damages (see Questions 15-16). Two states (CO and OH) require operators to hold liability insurance and AR may require them to do so. In contrast, TX does not believe that it has statutory authority to require an operator to purchase insurance.
NAVIGATING THE DATA

There are two ways to navigate the data using the interactive map: by clicking the Filter tab or the Explore tab — for each option, the data can be visualized in a map and table format or in jurisdiction profiles.

Filter
The dataset homepage will default to the Filter tab. Here, users may answer a series of questions to learn more about the characteristics of the laws. Answering more than one question will show all the jurisdictions that meet the combined criteria. Criteria selected will be listed above the questions, and can be removed by clicking the white X or by clicking “Reset” above the questions.

Explore
Users can access Explore by clicking the Explore tab in the bar above the questions. Using Explore, users will see the answers to one question across all jurisdictions.

The primary questions in this dataset are:

1. Does the jurisdiction allow for the disposal of oil and gas production fluids through injection wells?
2. Has the Environmental Protection Agency (EPA) delegated primacy of the Underground Injection Control (UIC) Program under the Safe Drinking Water Act to the jurisdiction, enabling it to regulate Class II disposal wells?
3. Does the jurisdiction distinguish between commercial and non-commercial wells when regulating Class II disposal wells?
4. What subsurface features does the jurisdiction consider when permitting a Class II disposal well?
5. For what reasons does the jurisdiction restrict the siting of Class II disposal wells?
6. Must operators case and cement Class II disposal wells?
7. When must operators demonstrate mechanical integrity of Class II disposal wells?
8. Does the jurisdiction restrict injection pressure, injection rate, or total volume of fluids?
9. Does the jurisdiction require the operator to monitor for seismicity near Class II disposal wells?
10. What must operators monitor during operation of Class II disposal wells?
11. Can the jurisdiction change requirements for Class II disposal wells after they are permitted?
12. Does the jurisdiction require public participation opportunities for Class II disposal wells?
13. Does the jurisdiction require a financial assurance for Class II disposal wells?
14. Does the jurisdiction charge a permit or operations fee for Class II disposal wells?
15. Does the jurisdiction address liability issues for determining the cause of seismicity or damage from it?
16. Does the jurisdiction require operators to carry liability insurance?

DISPLAYING THE RESULTS

There are two display modes once criteria have been selected by using either the Filter or Explore tab — Map display mode and Profiles display mode.
Map Display
LawAtlas.org dataset homepages default to the map display mode. When querying the data using the Filter tab, all jurisdictions that meet the criteria selected will display in one tone of yellow. Those jurisdictions that do not meet the criteria selected will be colored gray. When querying the data using the Explore tab, the map will illuminate with colors from yellow to red that are associated with the various answer choices (the color-coding is defined by the key to the left of the map).

Below the map, a table will appear. Using the Filter or Explore tab to navigate the questions will change the display:

- Using the Filter tab, you can select an unlimited number of criteria and the applicable jurisdictions that meet the combined criteria will be displayed in the table below.
- Using the Explore tab, you can isolate a single criterion and the applicable jurisdictions will appear in the table below.

Profiles Display
The Profiles display presents the results of the criteria selected in a text-based format for each applicable jurisdiction. Using the Filter tab, jurisdictions that meet the criteria selected will display. Using the Explore tab, jurisdictions that meet the criterion selected will display. If no criteria are selected, the full profiles for each state will appear under both Filter and Explore.

Profile Legend
Within each Profile box, above the questions and answers, there are additional options and information useful in exploring the law:

<table>
<thead>
<tr>
<th>$$$</th>
<th>Toggle Legal Text – Selecting this option will show all the legal text used to answer questions for this jurisdiction.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Toggle Full Place Profile – Selecting this option will show all questions and answers for this jurisdiction, regardless of what was selected using the Filter or Explore tabs.</td>
</tr>
<tr>
<td></td>
<td>Toggle Size – Selecting this option will make the profile larger, but will not change the information displayed.</td>
</tr>
</tbody>
</table>

Legal Text History – This interactive timeline displays when changes in the law have occurred within a jurisdiction. Using the arrows to the left or right, users may explore how the law has changed over time as new amendments to the law have been enacted. The timeline will change from gray to a shade of yellow when the jurisdiction passed its first relevant law or when the project’s research began, whichever is more recent. Each change in the law after that is marked by a break in the timeline.
Map and Profile Legend
There are a few symbols to be aware of in both Map and Profiles display modes:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S$</td>
<td><strong>Section Symbol</strong> – Clicking this symbol will open a window that displays excerpts from the law that correspond to the question and answer.</td>
</tr>
<tr>
<td>$⚠️$</td>
<td><strong>Caution Note</strong> – Clicking on this symbol will open a small window that displays text that describes important caveats about the question and answer.</td>
</tr>
</tbody>
</table>

DATASET RESOURCES
Each dataset homepage includes the following resources available for download:

- **Data**: The Data file exports in CSV format and may contain two tabs. The “Statistical Data” tab contains the legal variables coded in the dataset, displayed as values defined in the accompanying Codebook. The “Summary Data” tab contains the legal variables coded in the dataset in text form, as well as the accompanying citations and any caution notes that may be included. Note: if there is only one tab available for download it will be the “Statistical Data” as described above.

- **Codebook**: The Codebook defines all of the coded variables in the dataset. The Codebook lists the question, question type, variable name, variable value and variable label. The Codebook should be used in conjunction with the Statistical Data extract.

- **Research Protocol**: The Research Protocol is a comprehensive document that outlines the entire methodology of the project, including the scope, inclusion and exclusion criteria, data collection methods, definitions, coding scheme decisions, as well as the quality control process.

- **Summary Report**: The Summary Report provides a snapshot of important findings from the dataset.

ADDITIONAL INFORMATION
This policy surveillance project is one of several projects of a National Science Foundation-funded Colorado Collaboratory for Induced Seismicity (CCIS). The CCIS, at the University of Colorado at Boulder, is developing the geoscience, social science and engineering understanding, models and methods needed to quantify risks associated with injection-induced seismicity and to evaluate strategies for sustainably managing and mitigating these risks. CCIS is probing the mechanisms by which injection wells induce earthquakes, the potential for these earthquakes to cause damage to the built environment, and the social and economic impact of induced earthquakes, expanding our knowledge of the complex interactions of the natural, built and human environments in the creation and management of induced seismicity.

Three websites provide additional detail regarding findings from the data, information on the CCIS, and/or links to additional information on induced seismicity and its regulation:
Intermountain Oil and Gas BMP (Best Management Practices) webpage at: http://www.oilandgasbmps.org/resources/IS.php

Colorado Collaboratory for Induced Seismicity website at: https://www.colorado.edu/research/induced-seismicity/

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

A more detailed summary comparison of the law regarding induced seismicity and oil and gas wastewater disposal is available in “Induced Seismicity from Oil and Gas Wastewater Injection: A Comparison of State and Federal Law Regarding Class II Underground Injection Control Wells”, available at: http://www.oilandgasbmps.org/docs/GEN472_Mutz_IS_Law_Comparison.pdf

This more detailed document is based on the LawAtlas dataset, but also compares the management of Class II injection wells citing to agency forms, agency actions and policies, and recent legislative and regulatory proposals.

This collection of laws does not provide legal advice nor does it address enforcement of laws, administrative policies, case law, or any other sources of law. Should you have a specific question about these laws in your state, please contact an attorney in your jurisdiction.