National Risk Assessment Partnership: Induced Seismicity Working Group

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USGS map displaying 21 areas impacted by induced earthquakes as well as the location of fluid injection wells that have and have not been associated with earthquakes.
Working Group Goals

- Identify sites and operations that lead to low-risk—i.e. minimal hazard, minimal damage.
- Develop techniques to quickly identify and manage seismicity problems if they should appear.
- Share recommended practices with the CCS community.
<table>
<thead>
<tr>
<th>Tools</th>
<th><strong>Short-term seismic forecasting tool</strong></th>
<th>Available on EDX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Ground motion prediction tool</strong></td>
<td>Available on EDX</td>
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<tr>
<td></td>
<td><strong>State-of-stress assessment tool</strong></td>
<td>New / available on EDX</td>
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<tr>
<td></td>
<td><strong>Probabilistic seismic risk assessment (PSRA) tool</strong></td>
<td>New / in beta-testing</td>
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<tr>
<td>Reports</td>
<td><strong>CO₂ seismic risk assessment review</strong></td>
<td>IJGGC Special Issue</td>
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<tr>
<td>Reports</td>
<td>Numerous technical papers</td>
<td>NRAP Publication List</td>
</tr>
<tr>
<td>Reports</td>
<td><strong>Seismicity recommended practices</strong></td>
<td>In progress</td>
</tr>
<tr>
<td>Capabilities</td>
<td><strong>Induced seismicity simulator (RSQSim)</strong></td>
<td>Mature</td>
</tr>
<tr>
<td>Capabilities</td>
<td>Coupled hydromechanical reservoir simulators</td>
<td>Mature</td>
</tr>
<tr>
<td>People</td>
<td><strong>Broad discipline expertise</strong></td>
<td>Seismicity Working Group</td>
</tr>
</tbody>
</table>
# State-of-Stress Assessment Tool (SOSAT)

<table>
<thead>
<tr>
<th>Input data available</th>
<th>Joint probability for $\sigma_H$ and $\sigma_h$</th>
<th>Probability of activating critically-oriented fault</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Pore pressure</td>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
</tr>
<tr>
<td>• Overburden density</td>
<td></td>
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<tr>
<td>• Regional stress indicators</td>
<td><img src="image3.png" alt="Graph" /></td>
<td><img src="image4.png" alt="Graph" /></td>
</tr>
<tr>
<td>• Geodetic data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Local measurement of $\sigma_h$</td>
<td><img src="image5.png" alt="Graph" /></td>
<td><img src="image6.png" alt="Graph" /></td>
</tr>
</tbody>
</table>

State-of-Stress Assessment Tool (SOSAT)

- Available on EDX
- [https://edx.netl.doe.gov/organization/nrap-tools](https://edx.netl.doe.gov/organization/nrap-tools)

Carbon Storage Recommended Practices


Goal: Develop recommended practices guidelines relevant for carbon storage.

Carbon Storage Recommended Practices

Seismicity Protocol: Primary Steps

Step 1  Perform a preliminary screening evaluation.

Step 2  Implement an outreach and communication program.

Step 3  Review and select criteria for ground vibration and noise.

Step 4  Establish seismic monitoring.

Step 5  Quantify the hazard from natural and induced seismic events.

Step 6  Characterize the risk of induced seismic events.

Step 7  Develop risk-based mitigation plan.

Four key drivers for update:

1) Update with lessons learned since 2012

2) Strengthen risk analysis components using NRAP insights

3) Ensure relevance for carbon storage operations

4) Add specificity
Step 1: Preliminary Seismic Risk Screening Evaluation

**Purpose**
The purpose of this step is to broadly assess the probability of success of candidate site locations before investing substantial resources into the planning and construction of a project. The preliminary seismic risk screening evaluation is based on simple bounding methods and acceptability criteria with the goal of determining go/no-go decision points for future planning.

**Recommendations**

1.1) Preliminary Classification of Site-Specific Seismic Risk

1.1.1) A preliminary site-specific seismic risk assessment shall be completed which qualitatively classifies seismic risk into one of four general categories. This assessment shall include, but is not limited to:

1.1.1.1) A review of local, state, and federal laws and regulations;
1.1.1.2) An initial estimation of the *Radius of Influence* of potential seismic events;
1.1.1.3) A listing of the potential impacts to within the *Radius of Influence*;
1.1.1.4) Lower and upper bound estimates of the potential impacts;
1.1.1.5) An assessment of local stakeholder risk tolerance; and
1.1.1.6) A final assessment of the overall site risk, based on factors (1.1.1.1) – (1.1.1.5).

**Explanation and Commentary**

[4 – 5 pages of technical content, including References]
Lessons Learned

- We need to do a better job integrating our risk assessment methods into existing industry practice
  - Essential for engagement and tech transfer
  - Recommended Practices should help here

- We have a diverse set of stakeholders, with different but equally important needs
  - Operators:
    - Writing permits
    - Day-to-day site management
  - Regulatory authority
    - Evaluating permits
    - Regional-scale management
  - Public
    - Context for evaluating risks and benefits
Synergy Opportunities

- **Always looking for partners with microseismic data**
  - CO$_2$ is most relevant, but other injection operations can be good analogs

- **Always valuable to hear about specific needs from stakeholders**
  - Allows us to maximize technical impact

- **NRAP is focused on a narrow component (risk assessment) of a very large problem (seismicity)**
  - Eager to engage with broader community, particularly other DOE-funded initiatives
Thanks
Program Goal No. 4

- Develop Best Practice Manuals for monitoring, verification, accounting, and assessment; site screening, selection and initial characterization; public outreach; well management activities; and risk analysis and simulation.

Benefit Statement

- An understanding of induced seismicity is essential for effective risk management of storage sites.

- This project seeks to develop:
  - An open toolkit to support seismic characterization and management.
  - Support best-practices to minimize risk while supporting the growth of the CO$_2$ storage industry.
## Significant Accomplishments in FY19

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Active pressure management study</td>
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</tbody>
</table>
| 2 | State-of-stress assessment tool (SOSAT)  
Probabilistic seismic risk assessment tool (RiskCat) |
| 3 | Recommended practices document |
| 4 | Numerous journal publications / conference presentations |
Phase II Workscope

- **Task 3.1 - Real-time Hazard Forecasting**
  - **Focus:** Improve Short-Term Seismic Forecasting (STSF) tool by testing new forecasting methods and improving tool usability.

- **Task 3.2 - Active Seismicity Management**
  - **Focus:** Study effectiveness of different techniques (e.g. pressure control) for managing seismicity at problematic sites.

- **Task 3.3 - Probabilistic Seismic Risk Assessment**
  - **Focus:** Transition NRAP workflow to a practical industrial workflow by partnering with stakeholders in the seismic risk consulting world.

- **Task 3.4 - Fault Leakage (Deferred to FY20+ due to resource limitations)**
  - **Focus:** Targeted monitoring and active mitigation of fault leakage (through, e.g., hydraulic barriers).

- **Task 3.5 - Seismicity Management Protocol (Re-prioritized for FY18-FY19)**
  - **Focus:** Best-practices protocol for CO₂ seismicity management, supported by a suite of tools to help stakeholders implement a practical workflow.