Welcome!!

National Risk Assessment Partnership Workshop:

NRAP Tools for Geologic Carbon Storage Risk-Based Decision Making

Held in Conjunction with the

Ground Water Protection Council
2021 Annual Forum

September 29, 2021
Overview of the National Risk Assessment Partnership and NRAP Phase II Products

Robert Dilmore, NETL

September 29, 2021
NRAP leverages DOE’s capabilities to quantitatively assess and manage long-term environmental risks amidst significant geologic uncertainty and variability.
The NRAP Team (April 2019)
Integrated R&D Approach for Commercial-Scale Deployment

- **2017**: Large Capture Pilots Initiated
- **2017**: Initiating Storage Feasibility for Integrated CCS
- **2020**: R&D Completed for Carbon Capture 2nd Generation Technologies
- **2022**: Commercial-scale storage complexes characterized
- **2025**: Integrated CCS Projects initiated
- **2030**: Advanced technologies available for broad commercial-scale deployment

"New target for the United States to achieve a 50-52 percent reduction from 2005 levels in economy-wide net greenhouse gas pollution in 2030”
~ Biden Administration, 4/2021
"Given the urgency and the scale on the climate change front, and the huge opportunity and need for [carbon capture, utilization and storage], we all need to do more," Turk said Tuesday. "This is really a make-it-or-break-it opportunity and window on the CCUS front."

David Turk,
Deputy Secretary, US DOE

Source: Clark, L; Richards, H.; Anchondo, C. What Biden's 2030 climate target means for energy. E&E News April 22, 2021
NRAP’s approach for rapid prediction of whole-system risk performance

A. Divide system into discrete components

B. Develop detailed component models that are validated against lab/field data

C. Develop reduced-order models (ROMs) that rapidly reproduce component model predictions

D. Link ROMs via integrated assessment models (IAMs) to predict system performance

E. Exercise whole system model to explore risk performance

Adapted from Bromhal et al. 2014; Pawar et al. 2017
NRAP Phase I (2010 – 2016)

Risk Assessment & Uncertainty Quantification

How big might the risks be from a GCS operation?

- Pioneered hybrid methods for quantifying complex systems (physics coupled to empirical, e.g., machine learning)
- Developed computational tools for quantifying storage post injection
- Developed foundation for strategic (risk-based) monitoring (e.g., DREAM tool; no-impact thresholds)

(Benson, 2007)
Integrated Decision Support for GCS Site Risk Mgmt

- Risk-based AoR
- Monitoring Design Evaluation
- Performance-based Closure Assessment
- Risk Management and Site Closure Evaluation
- Conformance assessment and uncertainty reduction

Metrics for Plume Stability

- Risk-based AoR
- Groundwater aquifers
- Atmosphere

- Potential Migration Pathways
  - Wells, surface splits
  - Fractures and intermediate results

- Sensors

- Monitoring Design Evaluation

- Performance-based Closure Assessment

- Conformance assessment and uncertainty reduction

https://gitlab.com/NRAP/OpenIAM
How can a risk-based approach help inform stakeholder decision making?

How can risks be managed at a GCS site?

Supporting risk-based decisions at GCS sites

Leakage Risk Management and Containment Assurance

- Conformance assessment and uncertainty reduction
- Metrics for Plume Stability
- Risk Management and Site Closure Evaluation

Induced Seismicity Risk Management

- Probabilistic seismic risk analysis
- Short-term seismicity forecasting
- State of Seismic Characterization

Risk-Based Monitoring Network Design

- Plume Generations
- Plume Tracer Location
NRAP Foundational Research and Community Data

• NRAP Phase II - Virtual Special Issue *International Journal of Greenhouse Gas Control* - (September 2020)

• Community Datasets
  – Kimberlina (*initial release March 2020*)
  – FutureGen 2.0 (*initial release October 2020*)

• [https://www.osti.gov/](https://www.osti.gov/)

~450 publications, 14,300 citations; h-index 66

https://edx.netl.doe.gov/nrap/
NRAP Phase II Tools

Leakage Risk/Containment Assurance
- NRAP Open-Source Integrated Assessment Model (NRAP-Open-IAM) - Beta Release May 2020

Induced Seismicity Risk
- Short-term Seismic Forecasting Tool (STSF) – Revision Expected 12/2021
- State of Stress Analysis Tool (SoSAT) – Beta release October 2018
- Probabilistic Seismic Risk Assessment Tool (RiskCat) - Beta release April 2020

Monitoring Design and Optimization
- Designs for Risk Evaluation and Management (DREAM 2.0) - Beta Release March 2020
- Microseismic monitoring design optimization tool – Beta release October 2020

NRAP Tools Available at: https://edx.netl.doe.gov/nrap/tools-main/
New NRAP Phase II Tools User Forum on EDX

https://edx.netl.doe.gov/workspace/forum/nrap-tools

Requires EDX account and permission to access NRAP tools workspace
Quality Assurance

- NRAP Quality Assurance Plan
- QA for individual and coupled components
- Benchmark tests
NRAP Application Catalog on EDX
N. Huerta, D. Appriou, D. Bacon (PNNL); P. Morkner (NETL); T. Jones, A. Barkhurst (MATRIC)

• Summary of 16 studies including
  • Prototype tool testing/method development
  • Site characterization
  • Analog studies

• Link to relevant publications

NRAP released a set of open-source computational tools designed to help evaluate the performance of geological carbon storage sites and to assess risks across a project's life cycle. The NRAP tools enable stakeholders and operators to rapidly explore the behavior of the storage complex and to evaluate containment effectiveness and quantify leakage risk, assess geomechanical risks and manage induced seismicity, and develop risk-based monitoring strategy for uncertainty reduction.

https://edx.netl.doe.gov/nrap/application-catalog/
Validating NRAP tools and approaches

Prototype testing / method development
1. NRAP-IAM-CS Used to Estimate AoR and Impact of Legacy Well Leakage
2. Application of WLAT and DREAM for Risk-Based Monitoring Design
3. Coupling of NRAP-Open-IAM and DREAM for Risk-based Monitoring Design and PISC Period Determination at the FutureGen 2.0 site
4. Probabilistic Risk-based AoR Determination at FutureGen 2.0 Site
5. Application of NRAP-Open-IAM to the Kimberlina Site
6. Application of SOSAT for State-of-stress Analysis at the FutureGen 2.0 Site
7. Evaluating Probability of Containment Effectiveness at FutureGen 2.0 Site

Analog studies
1. Oklahoma Wastewater Injection as Analog for CO₂ Sequestration
2. Statistical Analysis of the Induced Basel 2006 Earthquake Sequence

Preliminary site-characterization
1. Application of NRAP-IAM-CS for Preliminary Risk Assessment for GCS Candidate Site Selection
2. Application of NRAP-IAM-CS at Rock Springs Uplift Site
3. Application of NRAP-IAM-CS to Illinois East Sub-Basin CarbonSAFE
4. Application of the Aquifer Impact Model to the Decatur Site
5. State of Stress Analysis of the Farnsworth Site
6. Application of NRAP-Open-IAM to Illinois Christian (Macon) County CarbonSAFE
7. Application of NRAP-Open-IAM and SOSAT at Existing Oil Fields in IMCSC CarbonSAFE
Recommended Practices for Risk Management

**Induced Seismicity Risk Management**

1. **Step 1** Perform a preliminary screening evaluation.
2. **Step 2** Implement an outreach and communication program.
3. **Step 3** Review and select criteria for ground vibration and noise.
4. **Step 4** Establish seismic monitoring.
5. **Step 5** Quantify the hazard from natural and induced seismic events.
6. **Step 6** Characterize the risk of induced seismic events.
7. **Step 7** Develop risk-based mitigation plan.

**Leakage Risk Management and Containment Assurance**

Drafts Released March 8, 2021
Feedback still being accepted
Comments to: NRAP@netl.doe.gov
Task 6: Addressing critical risk-related questions

Recommended Practices Containment Assurance and Leakage Risk Management (Thomas et al., DRAFT)

- Planning and Execution of Risk-based GCS Site Characterization
- Characterization of State of Stress and Geomechanical Conditions
- Developing a Risk-based AOR
- Risk-based Strategic Monitoring
- Assessing GCS System Conformance
- Evaluating Mitigation Scenarios to Inform Risk Management Decisions (under development)
- Defining a Risk-based Period of Post-injection Site Care in Support of Site-Closure Decision-making

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NRAP Products and Stakeholder Engagement

INSIGHTS

PROTOCOLS/Workflows

TOOLS

RESEARCH

DEV

OPS

01 PLAN

02 CODE

03 BUILD

04 TEST

05 RELEASE

06 DEPLOY

07 OPERATE

08 MONITOR

Engaging with Key Stakeholders

DOE CarbonSAFE

DOE-FE Regional Initiatives

DOE-FE SMART Initiative

Industry Best Practices

International CCUS RD&D Community

Regulatory Context

Bourne et al., 2014
SMART Initiative

Science-informed Machine Learning to Accelerate Real Time (SMART) Decisions in Subsurface Applications

Real-Time Visualization
“CT” for the Subsurface

Rapid Prediction
Virtual Learning

Real-Time Forecasting
“Advanced Control Room”

Transforming decisions through clear vision of the present and future subsurface.

Technical Team

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Thank you!

Comments and Questions:
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Sign up for NETL EDX: https://edx.netl.doe.gov/user/register