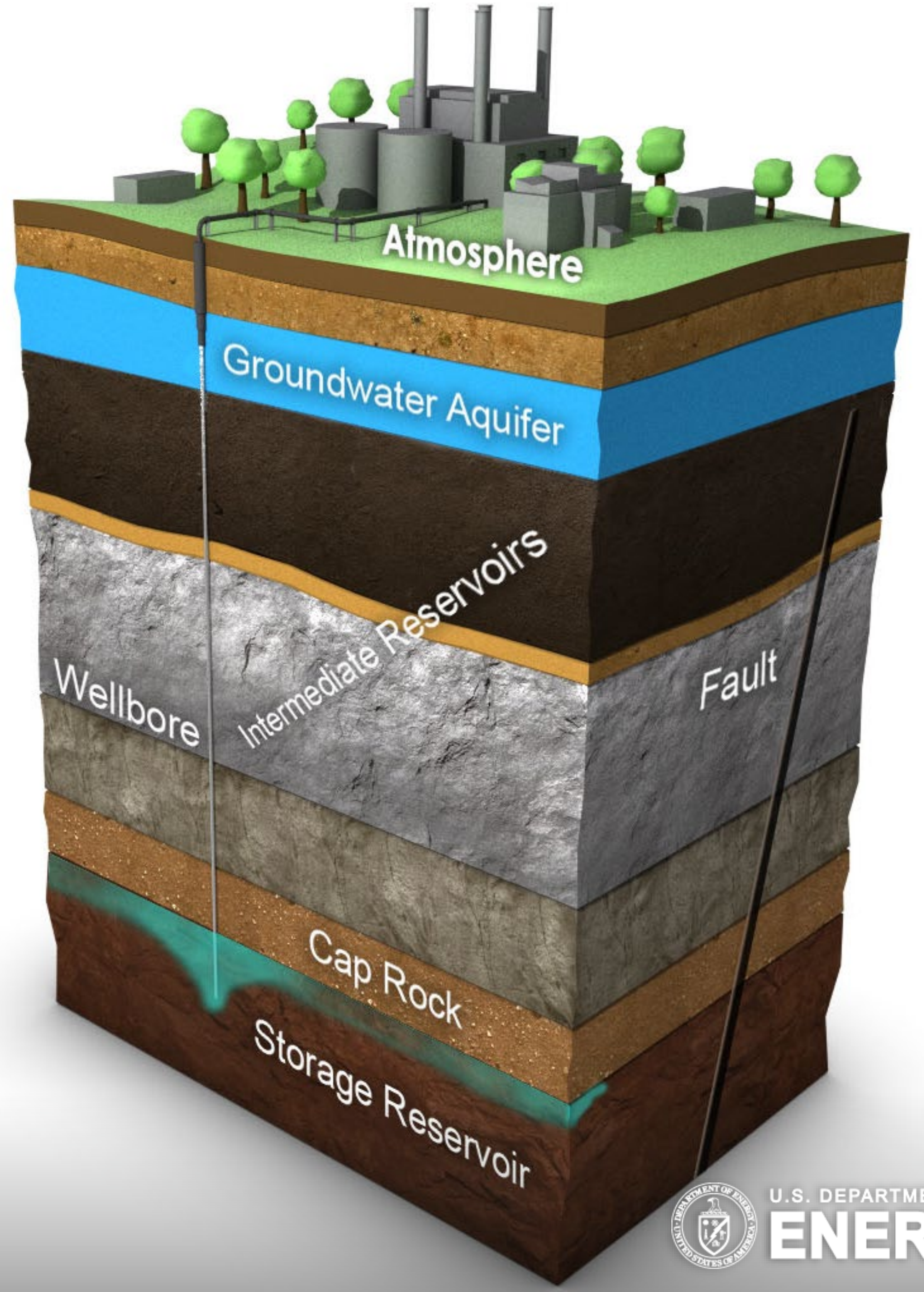
Task 5: Developing a Tool to Quantify Liability of Geologic Carbon Storage

David Morgan
National Energy Technology Laboratory

2023 Carbon Management Research Project Review Meeting
August 31, 2023

NRAP
National Risk Assessment Partnership



NATIONAL ENERGY TECHNOLOGY LABORATORY | BERKELEY LAB | Lawrence Livermore National Laboratory | Los Alamos NATIONAL LABORATORY | Pacific Northwest NATIONAL LABORATORY | U.S. DEPARTMENT OF ENERGY

Disclaimer

This project was funded by the U.S. Department of Energy, National Energy Technology Laboratory, in part, through a site support contract. Neither the United States Government nor any agency thereof, nor any of their employees, nor the support contractor, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Contributors to NRAP Phase 3 Task 5

- David Morgan (NETL, Task 5 lead)
- Kola Bello (NETL)
- Jeff Burghardt (PNNL, USM development lead)
- Gabe Creason (NETL)
- Robert Dilmore (NETL, NRAP lead)
- Erika Gasperikova (LBNL, Task 4 lead, RAMP development lead)
- Tim Grant (NETL)
- Nicolas Huerta (PNNL)
- Guoxiang (Gavin) Liu (NETL)
- Kayla Kroll (LLNL, Task 2 lead, ORION development lead)
- Mackenzie Mark-Moser (NETL)
- Curtis Oldenburg (LBNL)
- Pejman Rasouli (PNNL)
- Megan Smith (LLNL)
- Brian Strazisar (NETL)
- Veronika Vasylkivska (NETL, NRAP Open-IAM development lead)
- Derek Vikara (NETL)
- Travis Warner (NETL)
- Kyle Wilson (PNNL)

Task 5 Focus

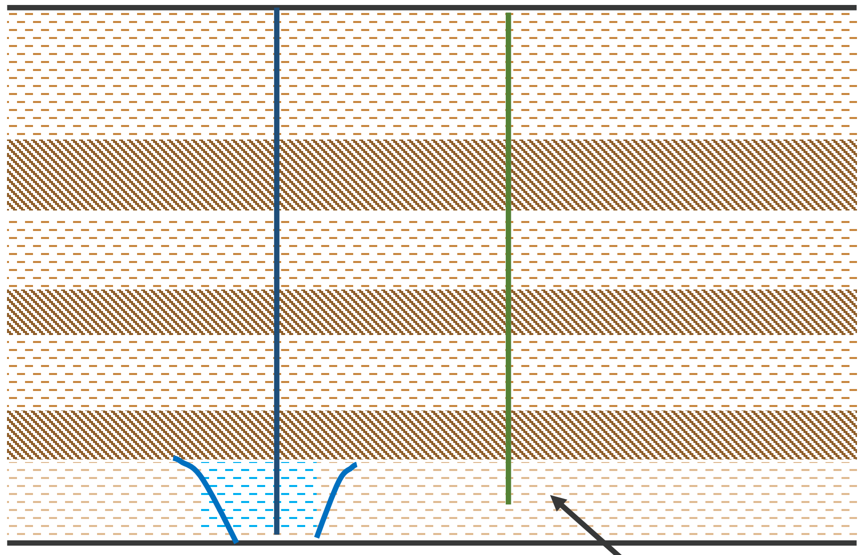
- **Problem:** What is the liability from responding to potential adverse events at a CO_2 saline storage site?
- **Analysis framework**
  - Liability is the cost of responding to a potential adverse event
  - Of the set of **potential adverse events**, this project focuses on:
    - *Potential leakage of CO_2 and/or brine* from storage formation into or toward an underground source of drinking water (USDW) or into the air
    - *Potential induced seismic incidents*
  - Remedial responses to adverse events and costs
    - *Operational response*: Altering "baseline or normal" operations (e.g., halting CO_2 injection)
      - Operational response costs may be small; revenues from CO2 injection can be drastically reduced
    - *Extrinsic response*: Actions taken outside "normal" operations (e.g., intensive localized monitoring to detect leak, re-plugging a leaking legacy well)
      - Extrinsic response costs are not part of normal operations
    - *Penalty response*: Regulatory or contractual costs associated with not injecting CO_2.
      - Penalty response costs are new costs and may be significant
  - Operational and extrinsic responses are **basis for Emergency and Remedial Response (ERR) Plans**
    - The cost of implementing the ERR Plan are the costs of implementing extrinsic responses and the costs of implementing some aspects of operational responses
    - The cost of implementing the ERR Plan is needed to determine costs for financial instruments for addressing financial responsibility (e.g., cost of insurance)

Implementing Analysis Framework

- **Starting point: Python version of FECM/NETL CO_2 Saline Storage Cost Model (CO2_S_COM_py)**
  - Provides revenues, costs and financial performance for all aspects of a CO_2 saline storage project
  - Includes addressing the requirements of Class VI injection well regulations (e.g., monitoring and financial responsibility)
- **CO2_S_COM_py modifications**
  - Working to include links to NRAP tools
    - NRAP Open-IAM for risk of CO_2 and brine leaks
      - Open-IAM is an integrated assessment model (i.e., IAM) that combines component models related to leakage
    - ORION for risk of induced seismic incidents
      - ORION is the Operational Forecasting of Induced Seismicity toolkit
    - RAMP for the design of an adaptive monitoring program and analysis of the effectiveness of this program at determining leaks
      - RAMP is the Risk-based Adaptive Monitoring Plan (RAMP) tool
  - Working to add links to other relevant tools (i.e., SMART Unified Simulation Module (USM))
    - USM is machine learning tool that calculates the evolution of the CO_2 plume and pressure front over time
  - Working to add technical performance and costs of remedial responses to adverse events

Leakage Scenario and Remedial Responses

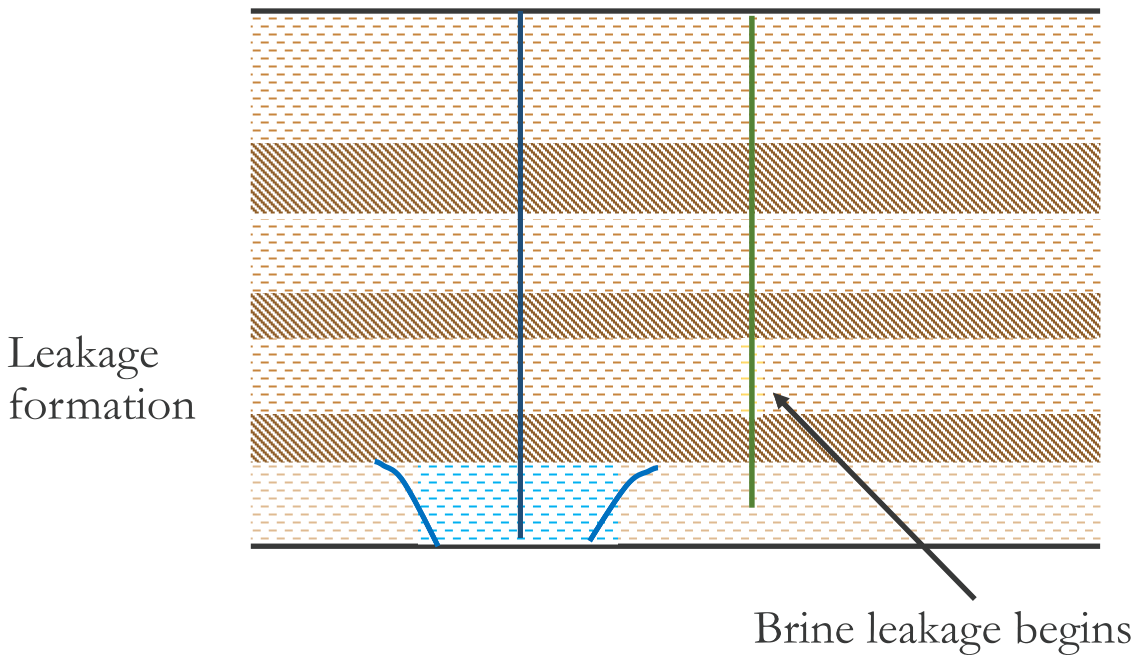
- CO_2 injection begins at time t_0 and CO_2 plume and pressure front expand with time
  - Note: Plume and pressure front data come from NRAP Open-IAM or SMART USM



Note: Vertical dimension is highly exaggerated.

Leakage Scenario and Remedial Responses

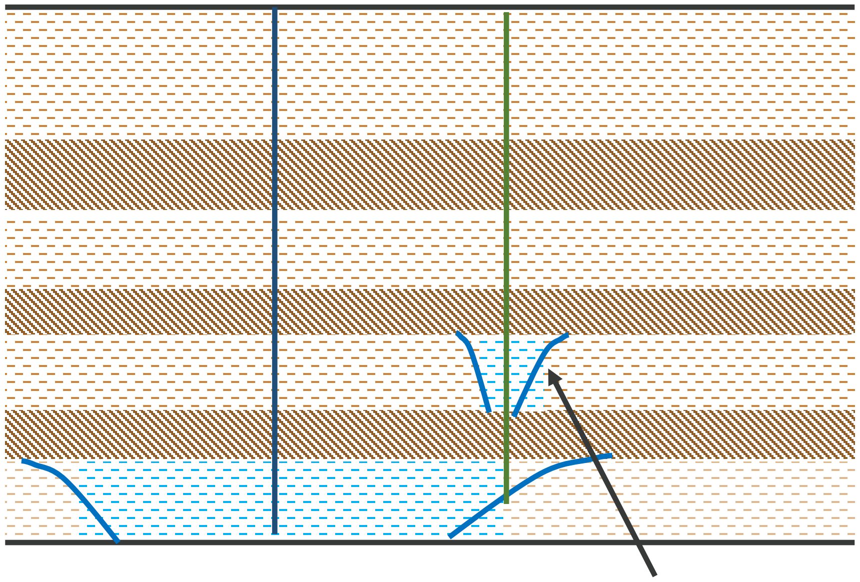
- **At later time t_1, pressures in formation at the source of a potential leakage pathway exceed a threshold and leakage begins**
  - Leakage is into a formation above the caprock (leakage formation)
  - Leaked fluid is initially brine and later a mixture of brine and CO_2
  - Note: Leakage locations and flow rates calculated by NRAP Open-IAM



Note: Vertical dimension is highly exaggerated.

Leakage Scenario and Remedial Responses

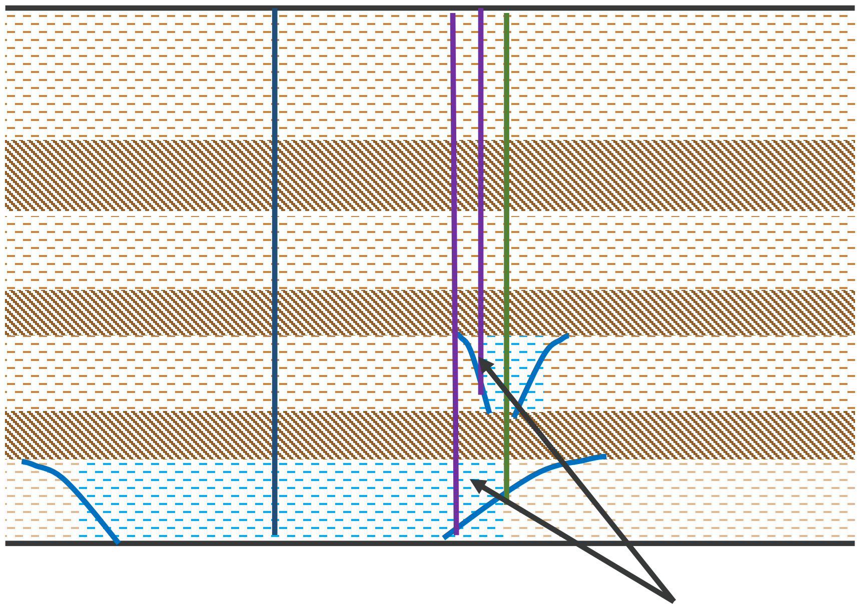
- **At still later time t_2, leak is detected or suspected**
  - Note: Initial monitoring program comes from RAMP and time when leak is detected comes from RAMP



Note: Vertical dimension is highly exaggerated.

Leakage Scenario and Remedial Responses

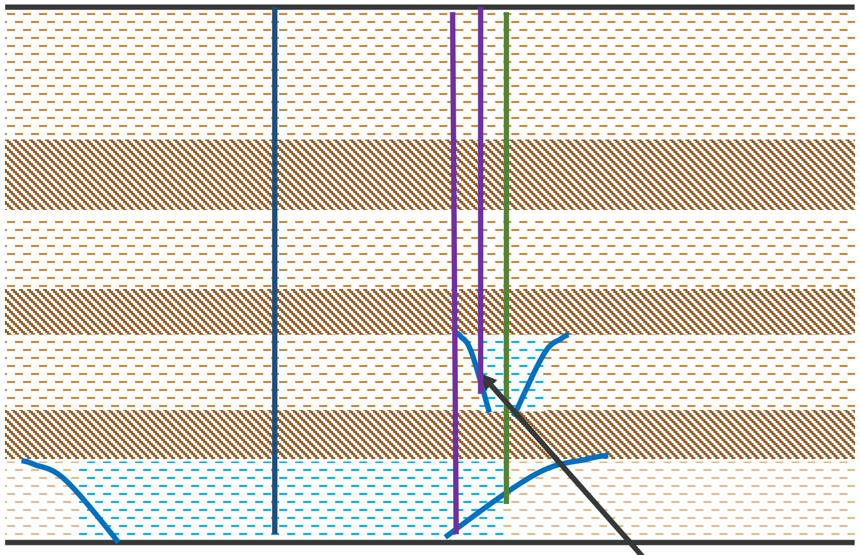
- **Remedial response to leak is initiated**
  - Intensive monitoring program is implemented and confirms existence (or likelihood) of leak
    - May involve installation of additional monitoring wells into leakage formation and storage formation as close to the leak source as possible
  - CO_2 injection stops
  - Intensive monitoring is continued to find source of leak:
    - Leakage due to improperly plugged legacy well
    - Faults or fractures in caprock
  - Note: Follow up intensive monitoring program is specified by user as part of remedial response to leak



Note: Vertical dimension is highly exaggerated.

Leakage Scenario and Remedial Responses

- **Additional remedial response actions (RRA, example):**
  - RRA1: Legacy well is source
    - Location of legacy well is found and well is re-plugged
    - Monitoring of pressures in storage formation and leakage formation confirm leak is stopped
    - CO_2 injection resumes
    - Pressure in leakage formation continues to decline after CO_2 injection resumes
    - Note: Remediation of brine and CO_2 released into leakage formation may be necessary

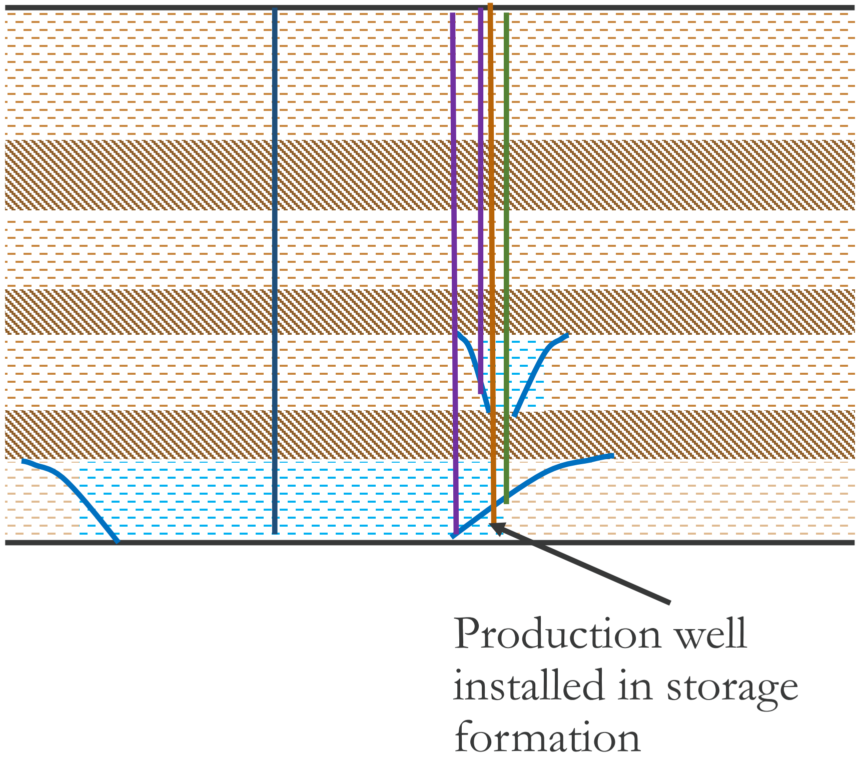


Pressure in leakage formation declines with time

Note: Vertical dimension is highly exaggerated.

Leakage Scenario and Remedial Responses

- **Additional remedial response actions (RRA, example):**
  - RRA2: 1) Legacy well is source but well cannot be plugged or plugging is not effective or 2) leakage through faults or fractures in caprock is source
    - Production well is drilled into storage formation as close as possible to source of leak
    - Fluid is produced and pressures are monitored in storage formation and leakage formation to determine if leak has been stopped
    - Produced fluid is treated and disposed
    - CO_2 injection resumes
    - Rate of produced fluid may need to be increased to offset the pressure increase from the CO_2 injection
    - Fluid production will need to continue for a period of time after
    - Note: Remediation of brine and CO_2 released into leakage formation may be necessary



Note: Vertical dimension is highly exaggerated.

Relevant Posters Presented Tuesday

- **"A framework for linking quantitatively assessed risks and costs for geologic carbon storage (GCS) to consider impact of contingency plans at a GCS site"**

  Travis Warner, Derek Vikara and David Morgan (NETL)

- **"Decision Support for Aquifer Impact Remedial Response of CO2 and Brine Leakage (NRAP)"**

  Pejman Rasouli, Kyle Wilson, Nicolas J Huerta, Ashton Kirol, Eusebius J Kutsienyo and Delphine Appriou (PNNL)

Thank you!

Comments and Questions:

NRAP@NETL.doe.gov

NRAP Website: https://edx.netl.doe.gov/nrap/