Class II to Class VI Operations - Insights from Simulation-Based Investigation of a CO_2-EOR to Dedicated Storage Scenario

Guoxiang Liu, Robert Dilmore, Brian Strazisar, Gregory Lackey
U.S. Department of Energy, National Energy Technology Laboratory, Pittsburgh, PA, 15236

NRAP
National Risk Assessment Partnership

Motivation and Objectives

The objective of this study is to develop and demonstrate a workflow to quantitatively assess the evolution of potential leakage risk when transitioning CO_2 flood enhanced oil recovery (CO_2-EOR) to a phase of increased storage and to consider the implications of that assessment for stakeholder decision making (whether the site can justify continued operation within the bounds of Class II permit or otherwise). Work presented herein is part of a larger effort under the National Risk Assessment Partnership (NRAP) that includes:

- ❑ Develop a conceptual & numerical simulation workflow that enables a risk assessment of transition to Class VI status.
- ❑ Conduct numerical simulation of a realistic CO_2-EOR field site transitioning from oil and gas production business as usual to dedicated CO_2 storage under a set of relevant injection/production scenarios.
- ❑ Develop and test a prototype reduced-order model to forecast CO_2, brine, and hydrocarbon leakage through wells.
- ❑ Explore influence of scenario responses for pressure and saturation, estimated area of review, forecasted potential leakage, and cumulative CO_2 storage can support stakeholder decision making for Class II to Class VI transition.

Model and Scenario Description

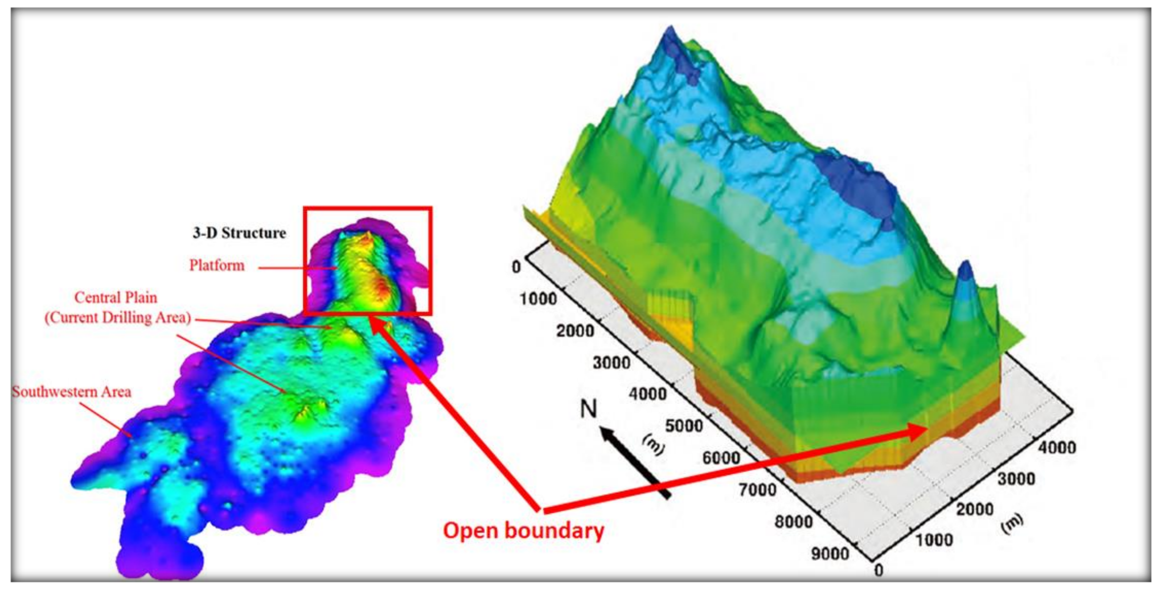
To explore this workflow, we use a previously-published model of a mature and actively operated unit in the Midland Basin of West Texas. The model used as the basis for these simulations is modified from that developed previously by Han and colleagues (2010) and, as such, is considered to be credible. Model and simulations of operational scenarios are not, however, explicitly representative of a real site.

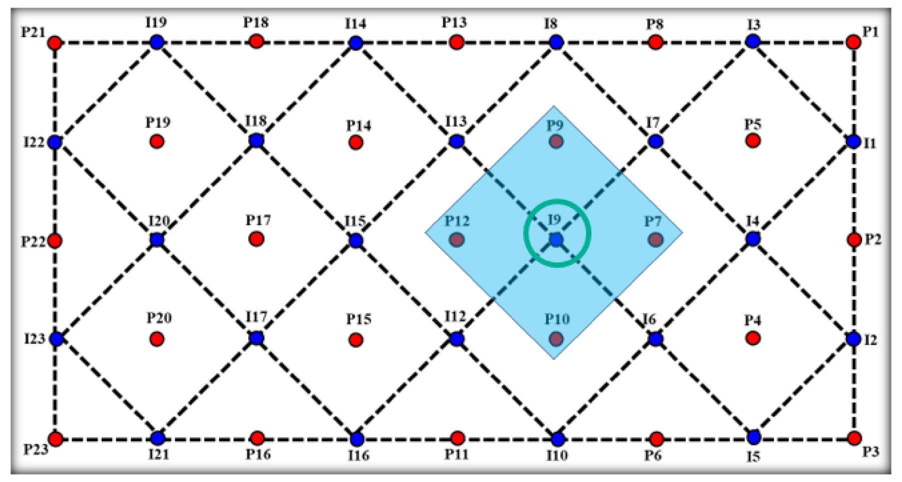
Model characteristics:

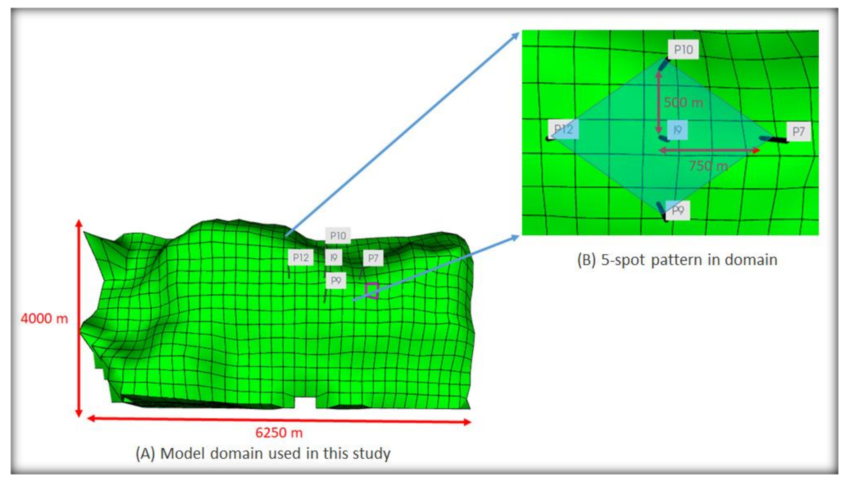
- Bounded on three sides and above and below the targeted interval with no-flow boundaries; one lateral boundary is treated as open with a Carter-Tracy aquifer model
- Depth: 1830 to 2280 meters
- Range of interval thickness: 150 to 250 meters
- Range of permeability and porosity: 10 to 1980 mD and 0.02 (2%) to 0.18 (18%)

The site has seen production through a period of primary hydrocarbon production, subsequent secondary (water flood) recovery, and period of tertiary water-alternating-gas CO_2-EOR that continues until the initiation of new operational paradigm (simulation year 2025, as described in the next panel). EOR was carried out using a typical 40-acre five spot pattern of injection/production wells.

Schematic of model domain used in this study – based on previous work by Han et al. (2010) and abstracted from a carbonate reef unit in Midland Basin, West Texas.







(A) Model domain used in this study

Operational Scenario Description

Operational scenarios designed to explore key elements of leakage risk in transition between EOR and storage:

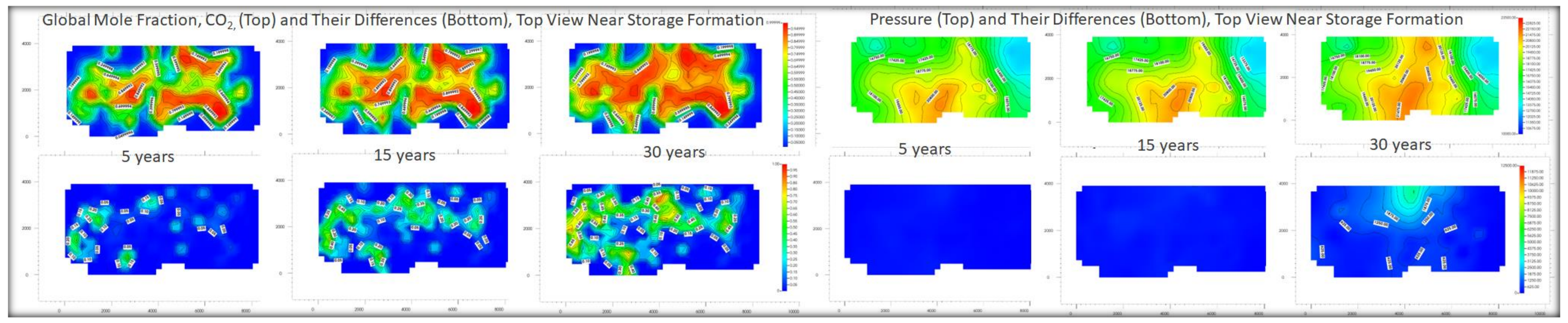
a) Continue WAG CO_2-EOR injection for 30 years (business-as-usual case); 50 years post-injection observation
b) Discontinue operations at the site with observation for 80 years
c) Discontinue WAG CO_2-EOR and inject CO_2 for 30 years (single injector, no production), 50 years post-injection
d) Limited WAG CO2-EOR operations before 2025 (shut-in wells producing < 10 bbls/day); 30-year CO_2 injection and 50-year post-injection as in Case C.

Cases		Injection Start (Year)	Stop of active operations	Operation Description	Wells	End of Post-Injection Observation
Case A	Business-as-usual	2025	2055 (30 years)	CO2-EOR, WAG with pressure constraint	45, (22 injectors, 23 producers)	2105 (50 years post-EOR)
Case B	No operations	2025	N/A	No injection or production		2105
Case C	Dedicated CO_2 storage	2025	2055 (30 years)	1 MT/year injection target, pressure constraint	Single injection well, I9	2105 (50 years post-injection)
Case D	Dedicated CO_2 storage with previous depletion to lower BHP	2025	2055 (30 years)	1 MT/year injection target, pressure constraint	Single injection well, I9	2105 (50 years post-injection)

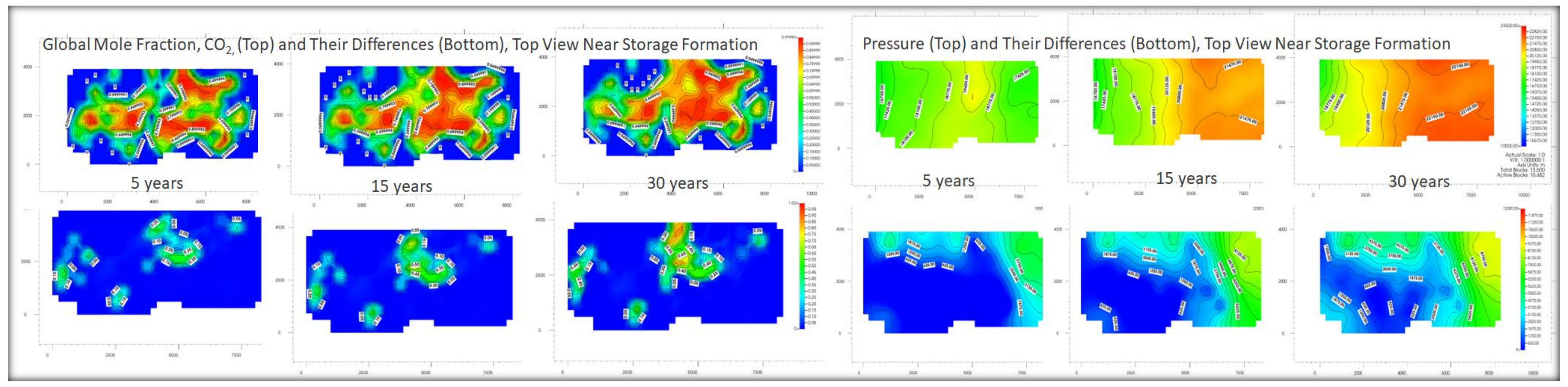
Preliminary Simulation Results

Preliminary reservoir simulation results showing time-series pressure and saturation evolution (absolute and change over operational period) for select scenarios. These will be used as the basis for quantifying potential leakage risk, consideration of area of review, and comparison of relative storage and risk performance between operational scenarios.

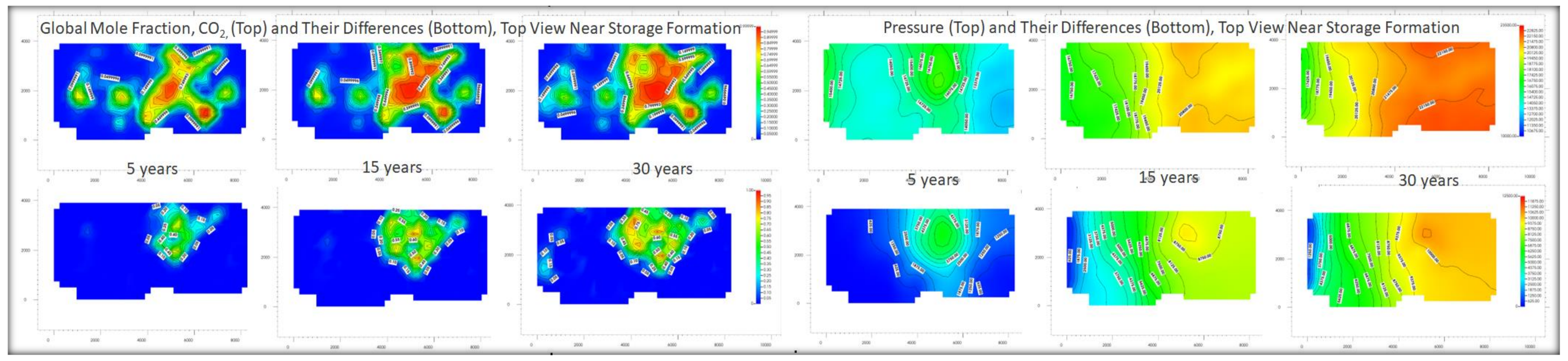
Case A



Case C

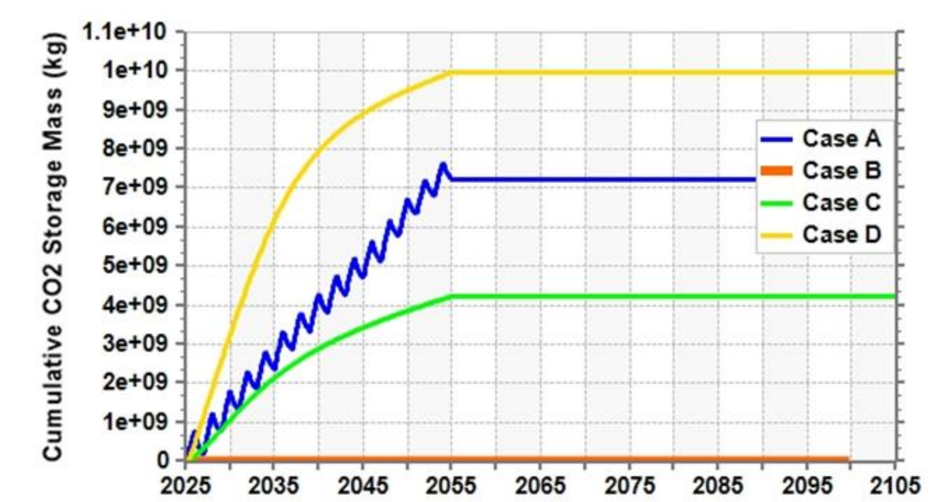


Case D



Preliminary Results (cont.)

Cumulative mass of CO_2 stored for each of the four scenarios considered.



Discussion and Next Steps

Preliminary Observations

- ➢ Storage in EOR business as usual (Case A) is of the same order of magnitude as the bounding dedicated storage scenarios (Cases C and D).
- ➢ Substantially higher pressure observed in Case C as compared to Case A suggests that dedicated storage after CO_2-EOR operations will result in greater potential leakage
- ➢ Substantial, broadly distributed CO_2 saturation across the model domain may have implications for AoR in Class II to Class VI transition, but solubility trapping in aqueous and hydrocarbon phases must be considered.
- ➢ The level of the initial reservoir depletion plays a significant role in permitting higher injection rates and storage capacity for dedicated CO_2 injection, as shown in comparison between Cases C and D.

Next Steps

- ➢ Refine reservoir simulation and expand set of operational scenarios, as needed,
- ➢ Apply simulation pressure and saturation results to calculate area of review,
- ➢ Apply simulation results together with credible representations of well integrity to estimate potential leakage risk,
- ➢ Consider implications for Class II to Class VI transition,
- ➢ Incorporate methods developed through this study into workflows within the NRAP-Open-IAM for risk assessment of transition and Class II to Class VI decision support.

Reference:
1. IEA, The Role of CO_2 Storage, Technical Report, 2019
2. EIA, The Distribution of U.S. Oil and Natural Gas Wells by Production Rate, December 2022
3. Han, W.S., McPherson, B.J., Lichtner, P.C., Wang, F.P., American Journal of Science, April 2010, 310 (4) 282-324; DOI: https://doi.org/10.2475/04.2010.03
4. Nunez-Lopez, V. and Moskal, E., https://doi.org/10.3389/fclim.2019.00005
5. EPA, Draft Underground Injection Control (UIC) Program Guidance on Transitioning Class II Wells to Class VI Wells, Draft Underground Injection Control (UIC) Program Guidance on Transitioning Class II Wells to Class VI Wells (epa.gov).

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