Risk Based Approach to Site Closure

National Risk Assessment Partnership

Nicolas Huerta

National Energy Technology Laboratory

U.S. Department of Energy

National Energy Technology Laboratory

Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting

August 13-16, 2018

Presentation Outline

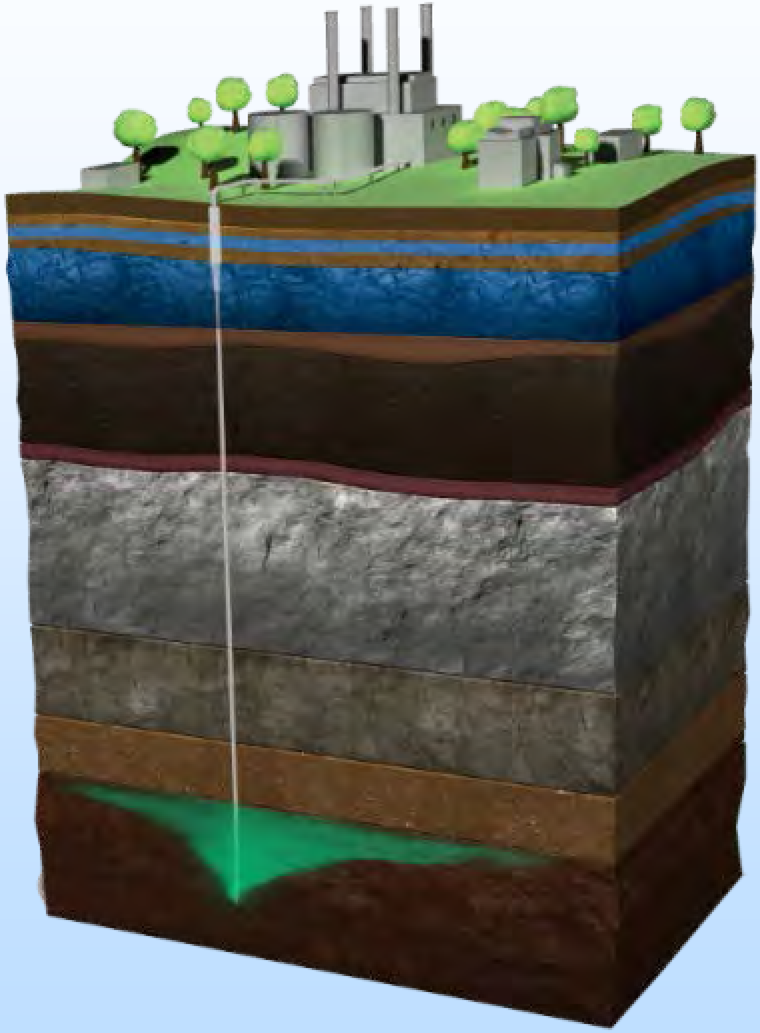
- NRAP Phase II, Task 6, and selected topic
- Introduce case studies
- Well integrity risk module
  - Approach
  - Workflow
  - Well Events
  - Example
- Summary

National Risk Assessment Partnership (NRAP)

- NRAP leverages DOE’s capabilities to help quantify uncertainties and risks necessary to remove barriers to full-scale CO_2 storage deployment.

- NRAP involves five DOE national laboratories: National Energy Technology Laboratory, Los Alamos National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and Pacific Northwest National Laboratory.

- The motivating goal of NRAP is to build methods and tools and improve the science base to quantify key environmental risks at geologic carbon storage sites, in the context of system uncertainty, particularly those associated with potential release of CO_2 or brine from the storage reservoir, and potential ground-motion impacts due to large volume injection of CO_2.



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

Using NRAP's expertise and tools to address site closure

Selected topic: Enabling geologic carbon storage project site closure using a case studies approach to develop performance-based and risk-based criteria

Technical approach

- Design five case studies based on actual sites with significant background data
- Target key ***aspects/considerations*** that operators and regulators will need to deal with to close a site
- Use NRAP tools and expand capabilities if needed
- Hold regular coordination meetings between teams
  - Ensure individual projects are moving toward a unified goal
  - Discuss issues and share tools/codes
- Develop five manuscripts for peer-reviewed journals
- Develop one summary report that pulls out cross-cutting observations, lessons learned, and proposes a workflow for a performance-based criteria for site closure.

Timeline

- **Summer 2017:** Topic selected
- **Fall 2017:** Developed workplan and formed teams
- **Spring 2018:** Received additional guidance, resources, and an accelerated timeline
- **8/17/18:** Present status at Stakeholders Group meeting
- **11/23/18:** Complete draft manuscripts of individual case studies
- **12/14/ 18:** Complete combined report of findings

Considerations/aspects of a storage site

- Operational scenarios and site properties (wells, scale of injection…)
- Conformance and performance
- Risk and risk uncertainty evolution
- Plume characterization and stability
- Value of information or data-worth from monitoring during and post-injection
- Rule-based vs. performance-based method
- Storage type (greenfield vs. brownfield)

- Lead to a performance-based approach for a large variety of realistic situations

King Island Virtual Storage Project (LBNL)

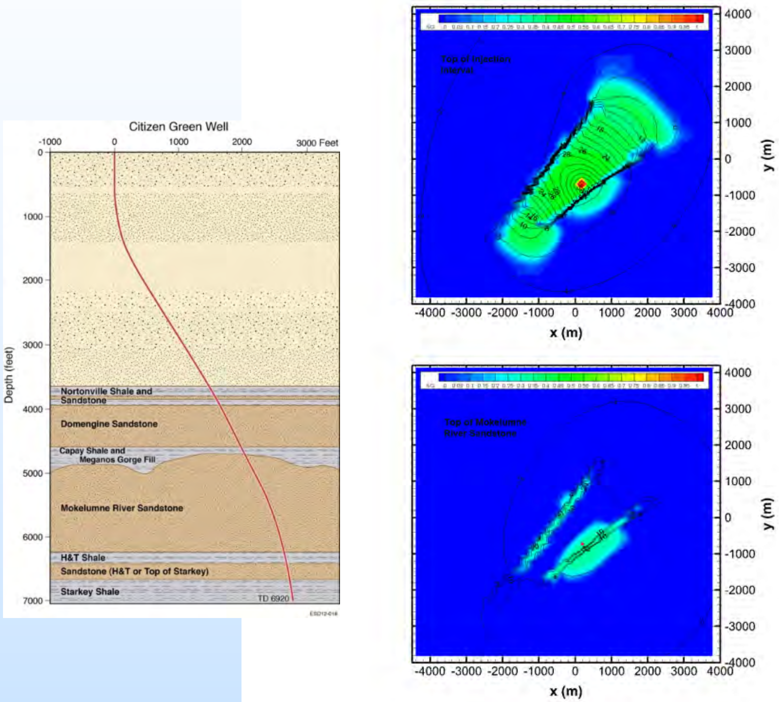
Objective: Demonstrate the lowering of uncertainty in model-based risk-related plume-growth forecasts over time as more monitoring data become available.

Motivation: Use a well-known site to demonstrate the value of monitoring strategies to minimize monitoring costs and demonstrate plume stability.

Potential Insights: CO_2 and pressure plume extent forecasts evolve over time as monitoring provides input to adjust and better constrain model output.

Technical Approach/Strategy:

- Simulate site based on very little data (pre-injection)
- Update models progressively over time based on synthetic monitoring data
- Carry out data-worth analysis of various monitoring strategies to minimize monitoring and its cost.



Left: Generalized lithology at King Island; the Mokelumne River Sandstone is the targeted storage formation. **Right:** Distributions of CO_2 (color map) and pressure change (contour lines) at the top of the injection interval (upper frame) and the top of the storage formation (lower frame) at 20 years, the end of the injection period. The injection well is shown as a red dot.

Kimberlina Case Study (LLNL)

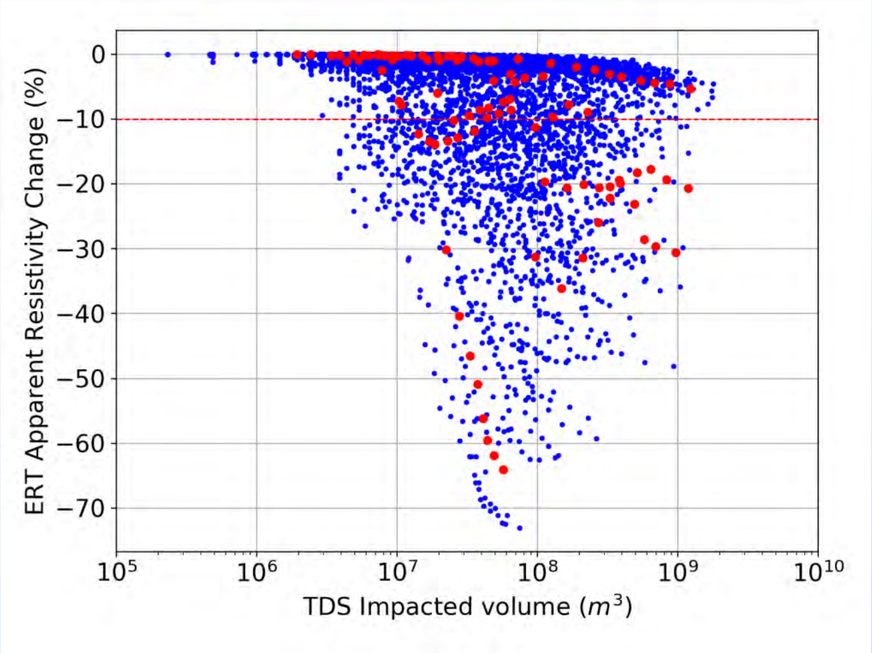
Objective: Illustrate how monitoring data can be used to inform the site care and reduce risk uncertainty.

Motivation: Site closure determination needs to be informed by measurements and an understanding of leakage risk to drinking waters.

Potential Insights: Performance metrics that define monitoring plans for post-injection site care.

Technical Approach/Strategy:

- To integrate groundwater risk with geophysical and pressure methods to detect leakage for select simulations.
- Use iterative approach, updating parameter ranges with monitoring data and recalculate risk using the **Open-IAM**.
- Compare results against well leakage and reservoir CO_2 saturation and pressure profiles to tie to performance metrics (e.g., groundwater impacts, reservoir pressure and CO_2 plume stability).



Rock-Springs Uplift (RSU) Case Study (LANL)

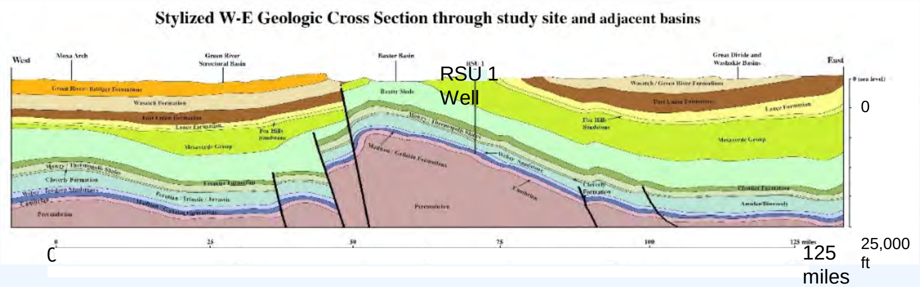
Objective(s): Evaluate plume stability and risk associated with a heterogeneous, stratigraphically dipping reservoir.

Motivation: Decisions regarding site closure will be site-specific, but plume stability and leakage risk tools and metrics can be generalized for use across potential GCS sites.

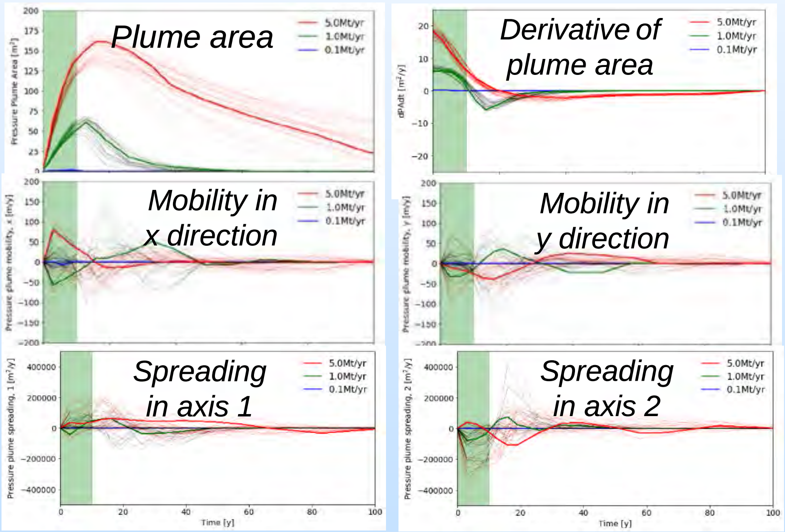
Potential Insights: Operational guidance on plume stability and leakage risk metrics to support site closure determination.

Technical Approach/Strategy

- Create plume stability metrics based on moment analysis; implement in **Open-IAM**.
- Evaluate plume stability metrics on suite of RSU simulations with 17 injection scenarios, 2 model domains, and 29 permeability realizations.
- Evaluate correlation between plume stability metrics and risk of leakage.



RSU ensemble plume stability analysis



FutureGen 2.0 Case Study (PNNL)

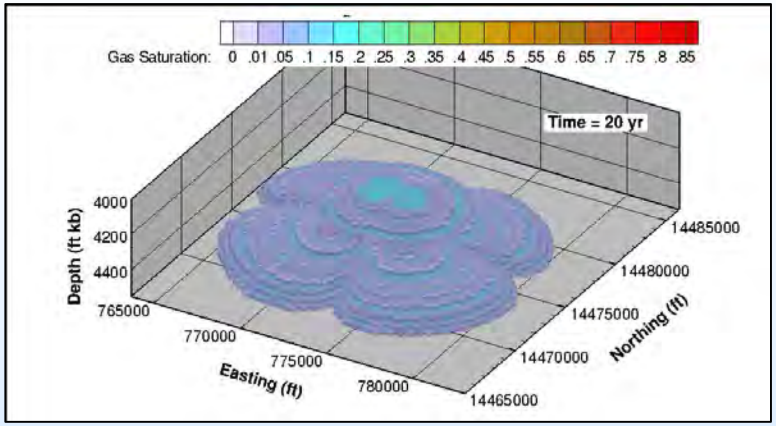
Objective(s): Determine a performance-based post injection site closure (PISC) period for the FutureGen 2.0 (FG 2.0) project.

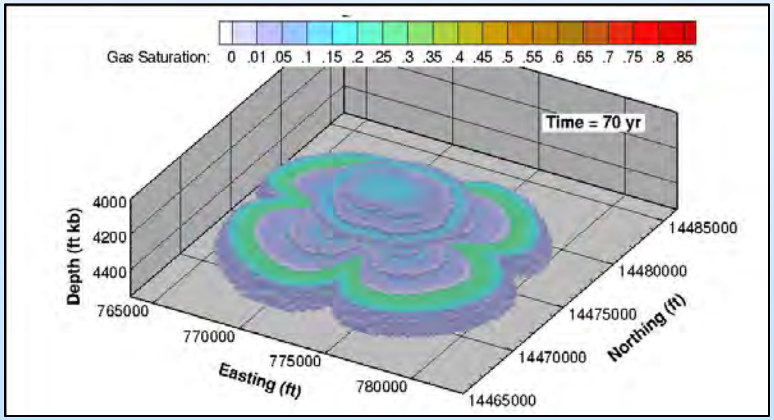
Motivation: FG 2.0 received Class VI permit based on default PISC period of 50 years. What would be required to obtain a permit with a performance-based PISC period?

Potential Insights: Inform the Class VI permitting process; evaluate metrics of plume/site stability; design suitable monitoring strategy.

Technical Approach/Strategy

- Utilize NRAP's **Open-IAM** to evaluate risk evolution over time to overlying USDW
  - Perform additional reservoir simulations using STOMP-CO2e
  - Develop new aquifer ROM
  - Create Python workflow for creating system model
- Use NRAP's **DREAM** tool to design an adaptive monitoring network for the FG 2.0 site



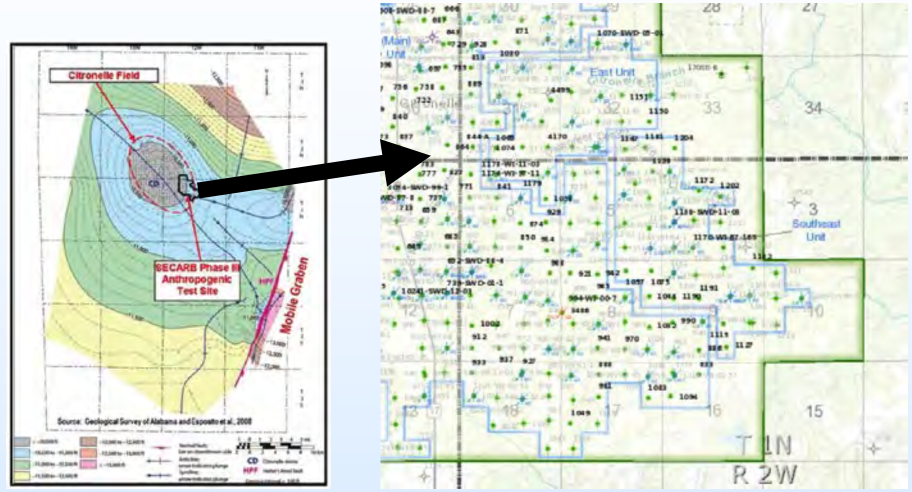


Citronelle Case Study (NETL)

Objective(s): Demonstrate how to represent non-endangerment at a site with many wells.

Motivation: Citronelle site has a long history of oil and gas production and is an ideal candidate for carbon storage. Closing a site with many wells remains a significant hurdle for full-scale deployment.

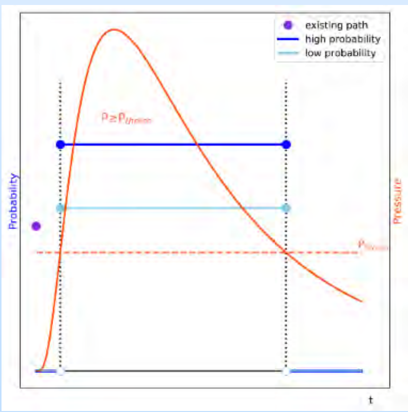
Potential Insights: Improving our understanding of well-related risks to develop strategies to demonstrate non-endangerment.



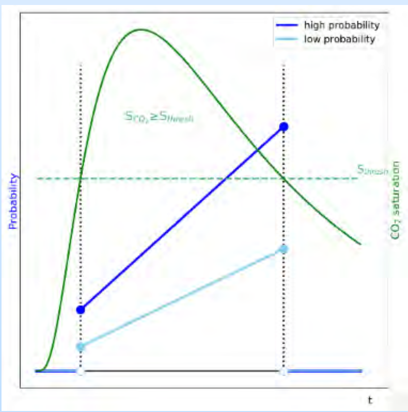
Technical Approach/Strategy

- Update **Open-IAM** with robust well integrity risk capability
  - Describe well risks as events/incidence
  - Relate risk types to driving forces and well properties to estimate probability for an event to occur
  - Describe monitoring approaches to estimate probability to detect a well integrity event/incident
- Develop several scenarios that show how operators can use the wells' risk profiles during a project's life to reduce uncertainty and facilitate site closure.

Mechanical failure



Corrosion failure



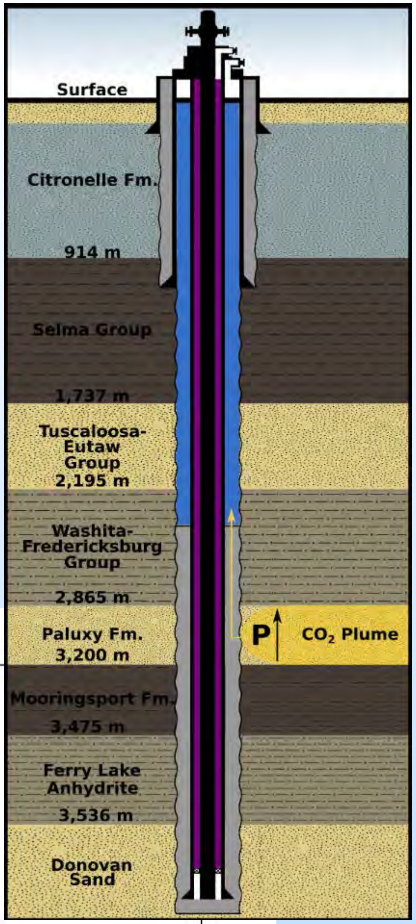
Enhancing the Open-IAM with the Well Integrity Risk Module

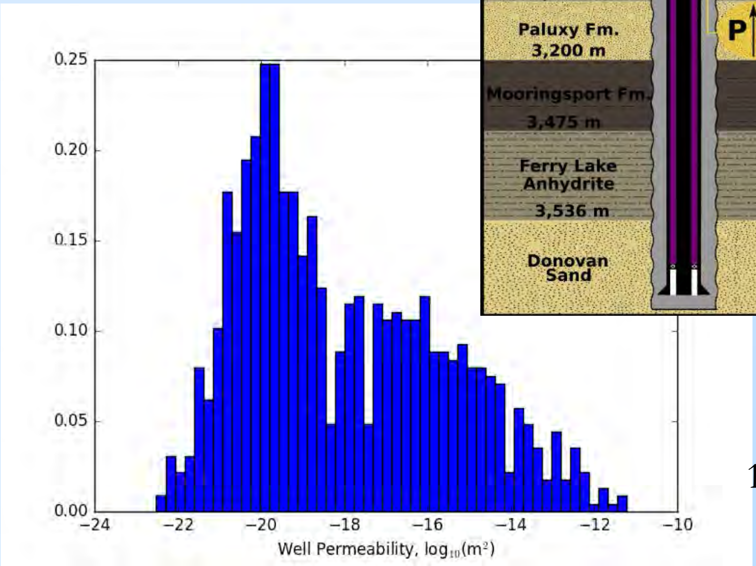
- Moving away from current approach: All wells have fixed permeability sampled from a probability distribution or assigned by user

- Developing an **Event/Incident Based** stochastic approach that allows for more complex relationships to be established for:
  - Probability for event to occur
  - Probability for leak path magnitude
  - Impact estimation
  - Probability to detect impact

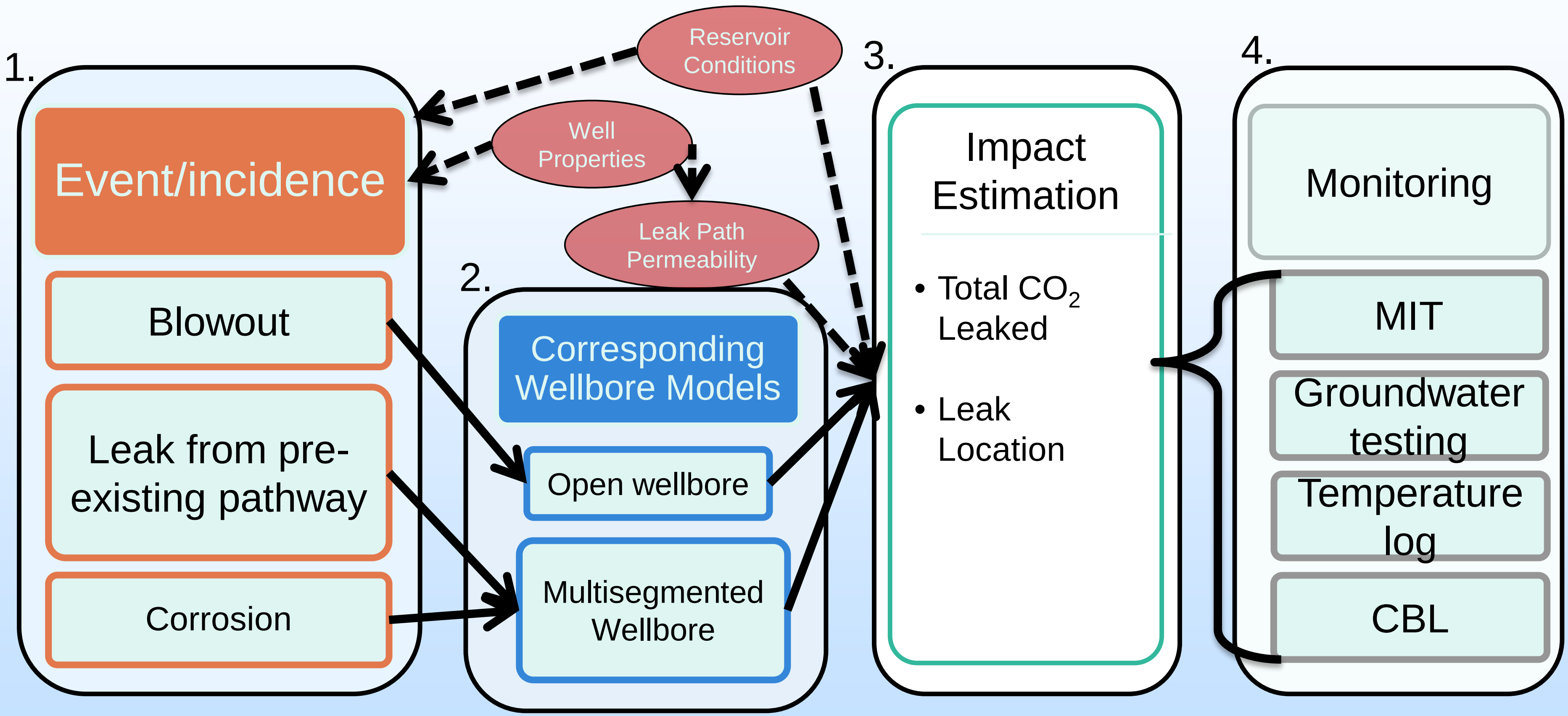
- Using events, well properties, reservoir conditions, and functional relationships to allow for time-evolving probabilities

- Inherent assumptions in our approach:
  - There may be causal relationships why wells leak
  - Driving forces affect a particular type of event
  - A well's history plays a role in its well integrity





Well Integrity Risk Module Framework



Example event descriptions

Blowout

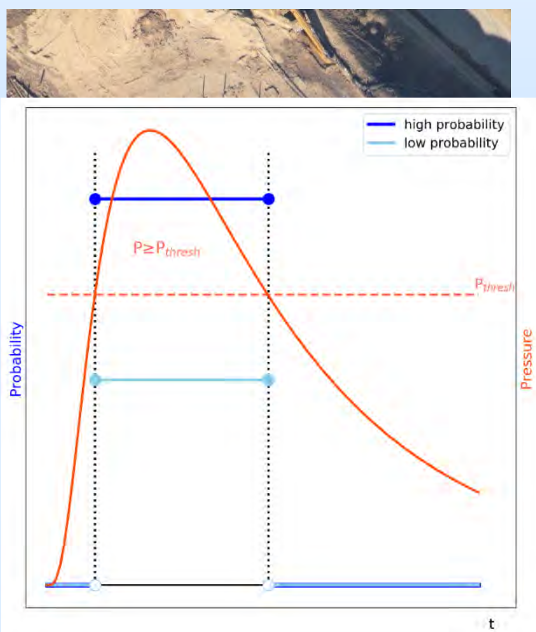
- Catastrophic failure
- Resulting from high reservoir pressure
- Risk highest during injection

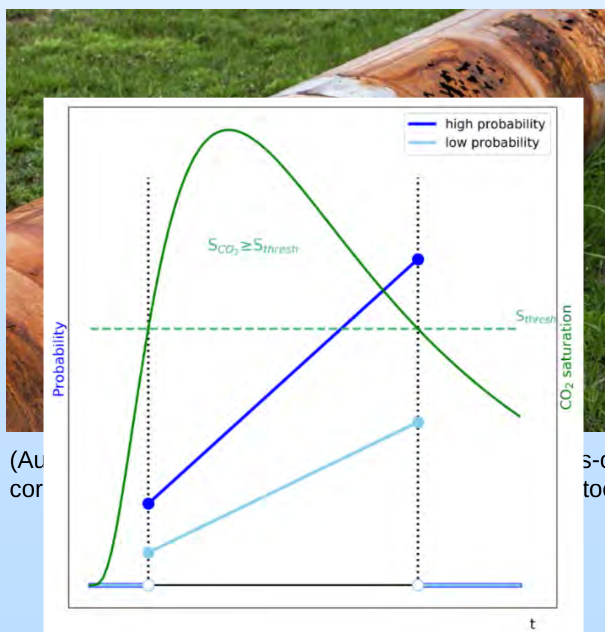
Corrosion

- Requires CO_2 saturation > threshold
- Chemical (CO_2, H_2S presence)
- Mechanical (pressure/temperature)
- Leak paths can develop over time

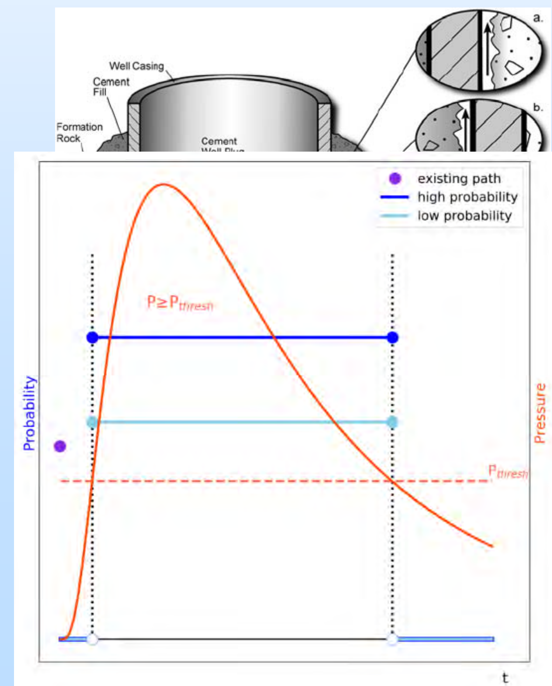
Existing Leak Path

- Poor cement bond/placement
- Thread leaks between casing joints
- Associated with poor construction

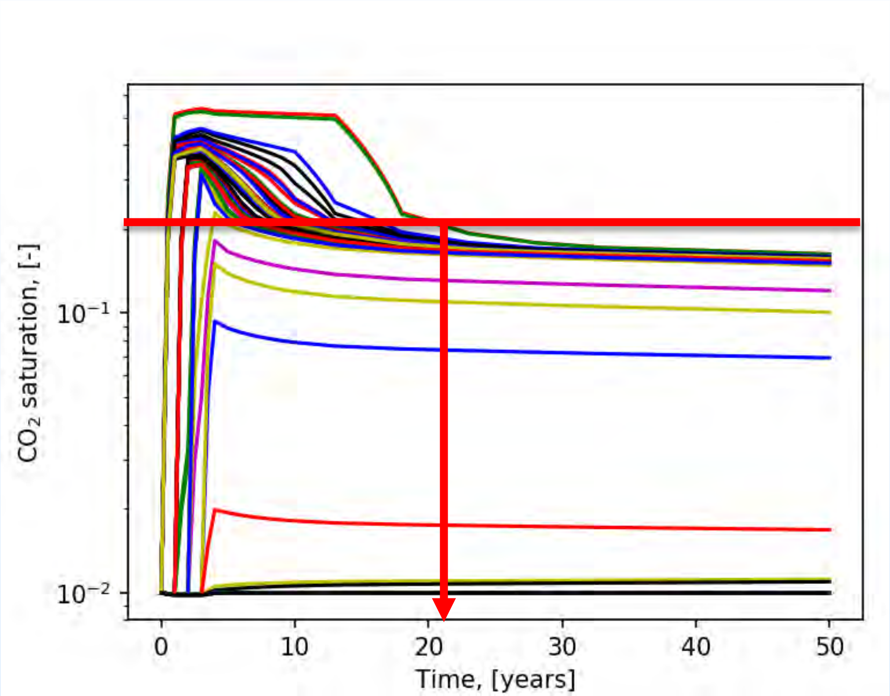


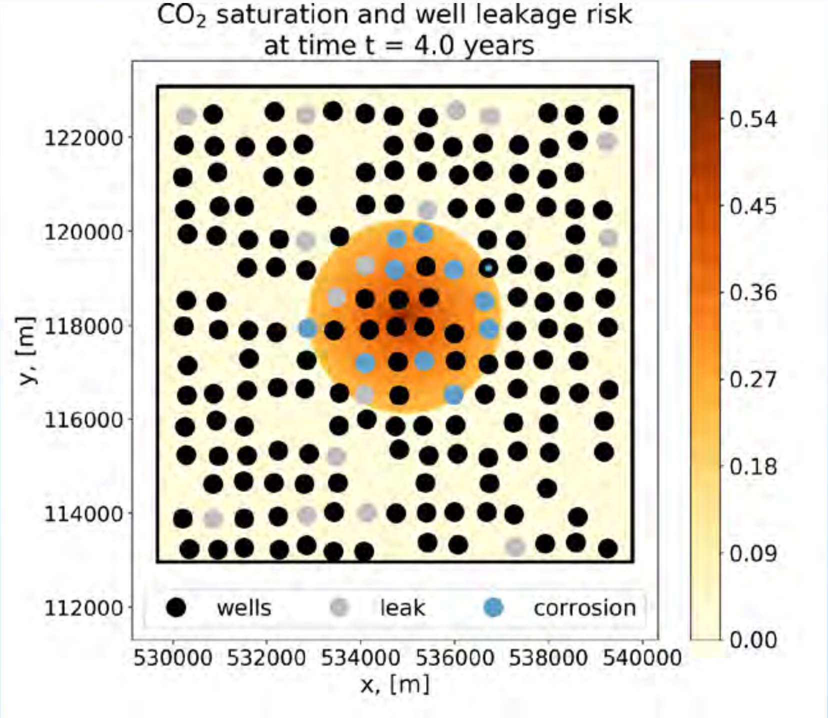


(Au
cor
s-of-
tock/



Constraining well integrity risks to support site closure





- Using this approach we can demonstrate an understanding for specific well integrity risks
- This allows an operator to make decisions on monitoring for longer periods versus recompleting or plugging a well to reduce a risk

Accomplishments to Date

- Each case study has selected a site, an approach, and defined the aspects/considerations they will focus on.
- Preliminary results being presented this week.

Lessons Learned

- The accelerated timeline has had an impact on the productivity of other NRAP priorities.
  - We have partially mitigated this by continuing to develop other NRAP tools and methods within the scope of the Task 6 effort (e.g., Open-IAM upgrades, Aquifer ROMS, modeling of monitoring, DREAM tool)
- Some uncertainty with how the different approaches will lead to a unified product
  - Attempting to mitigate this by having regular coordination meetings
  - Sharing tools and products when possible
  - Starting the compiled report early to have a framework to guide individual works

Synergy Opportunities

- Since these case studies are based on actual fields, collaboration with field operators would improve the products.
- These approaches involve both regulatory and financial decisions and so there is an opportunity for future collaboration to frame our work with those considerations.

Project Summary

- We are using a case study approach to develop scenarios that demonstrate how a performance- or risk-based approach may be used to close a site.
- In choosing different sites and slightly different approaches we are attempting to:
  - Capture as many of the important considerations for a site as possible
  - Converge on a single workflow that can be used to demonstrate site closure
- We will begin crafting both the individual study reports and the combined report to meet our CY2018 milestones/deliverables.

Team

- LANL: Rajesh Pawar, Dylan Harp
- LBNL: Christine Doughty, Curt Oldenburg
- LLNL: Susan Carroll, Xianjin Yang, Kayyum Mansoor
- NETL: Nicolas Huerta, Veronika Vasylkivska, Seth King, Andrew Wentworth, Greg Lackey, Robert Dilmore
- PNNL: Christopher Brown, Diana Bacon

Appendix

– These slides will not be discussed during the presentation, but are mandatory.

Benefit to the Program

- Identify the program goals being addressed.
- Insert project benefits statement.
  - See Presentation Guidelines for an example.

Project Overview

Goals and Objectives

- Describe the project goals and objectives in the Statement of Project Objectives.
  - How the project goals and objectives relate to the program goals and objectives.
  - Identify the success criteria for determining if a goal or objective has been met. These generally are discrete metrics to assess the progress of the project and used as decision points throughout the project.

Organization Chart

- Describe project team, organization, and participants.
  - Link organizations, if more than one, to general project efforts (i.e., materials development, pilot unit operation, management, cost analysis, etc.).

- Please limit company specific information to that relevant to achieving project goals and objectives.

Gantt Chart

- Provide a simple Gantt chart showing project lifetime in years on the horizontal axis and major tasks along the vertical axis. Use symbols to indicate major and minor milestones. Use shaded lines or the like to indicate duration of each task and the amount of work completed to date.

Bibliography

– List peer reviewed publications generated from the project per the format of the examples below.

- Journal, one author:
  - Gaus, I., 2010, Role and impact of CO_2-rock interactions during CO_2 storage in sedimentary rocks: International Journal of Greenhouse Gas Control, v. 4, p. 73-89, available at: XXXXXXX.com.
- Journal, multiple authors:
  - MacQuarrie, K., and Mayer, K.U., 2005, Reactive transport modeling in fractured rock: A state-of-the-science review. Earth Science Reviews, v. 72, p. 189-227, available at: XXXXXXX.com.
- Publication:
  - Bethke, C.M., 1996, Geochemical reaction modeling, concepts and applications: New York, Oxford University Press, 397 p.