Well Integrity Work Within the National Risk Assessment Partnership

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NETL

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 1-3, 2017

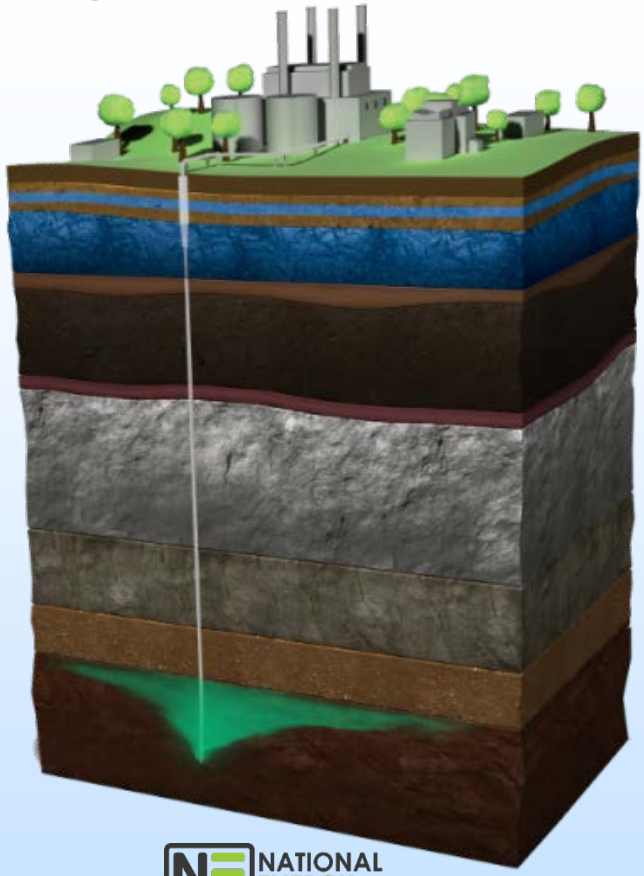
NRAP Phase II Structure

Technical Tasks:

1. **Containment Assurance**
   - Well integrity research
2. Induced Seismicity Risk
3. Strategic Monitoring for Uncertainty Reduction
4. Validation of Risk Assessment Tools and Methodologies Using Synthetic and Field Data
5. Addressing Critical Questions Related to Assessment and Management of Environmental Risk at CO_2 Storage Sites

Well integrity group's mission:

- Continue to advance science base for understanding well leak behavior
- Develop tools and techniques to quantify leak rate and leak probability



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Presentation Outline

Topic I: Experimental work

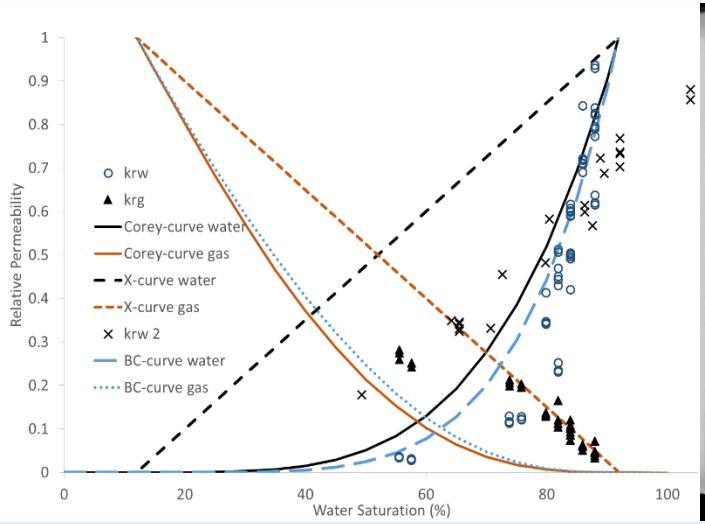
Topic II: Detailed simulations

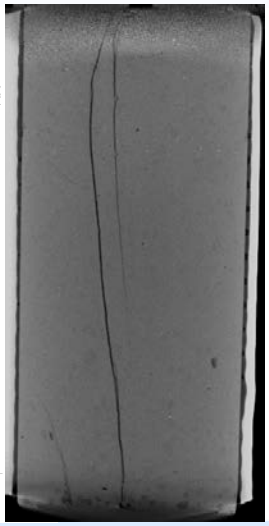
Topic III: Reduced-complexity models

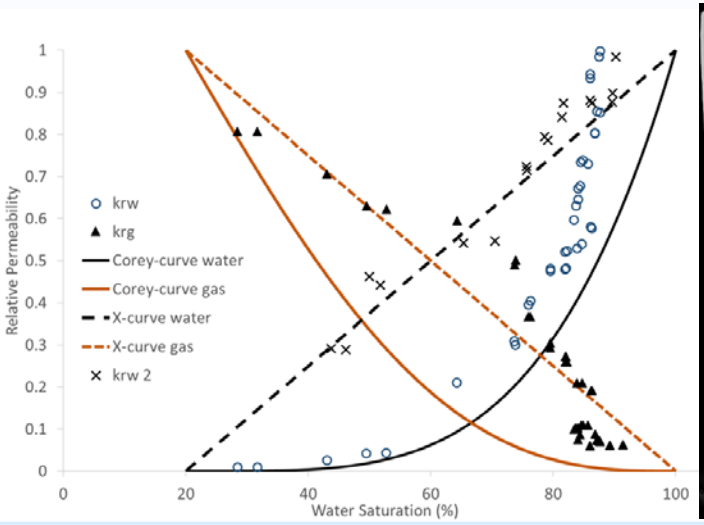
Experimental work

- **Current work**
  - **Assessing the relative permeability of fracture flow**
- **Future**
  - **Fracture relative permeability experiments at conditions**
  - **Casing-cement corrosion studies to determine if they will exhibit self-reinforcing behavior**

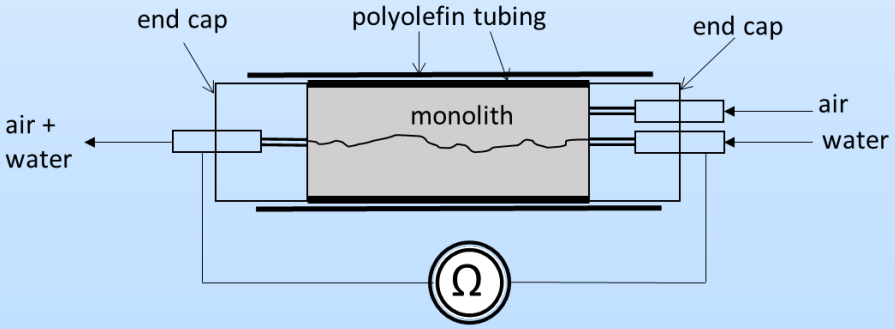
What is the appropriate multi-phase flow model to use for well leaks?







- Current well leak ROMs use either X-curve or Corey type questions
- Preliminary experiments show that gas may be more like X-curve and water flow may be more like Corey type

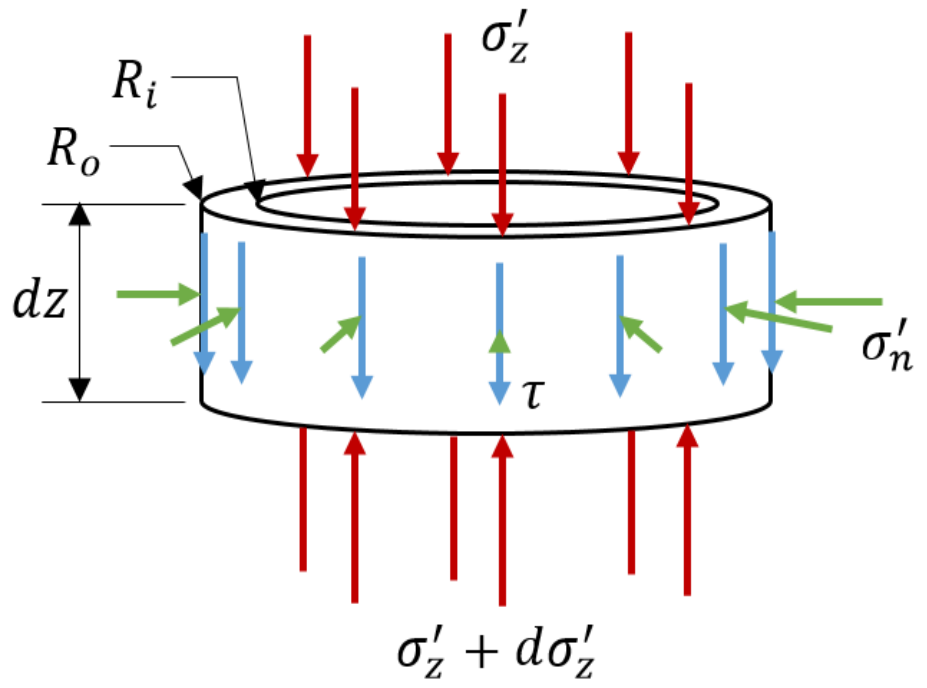


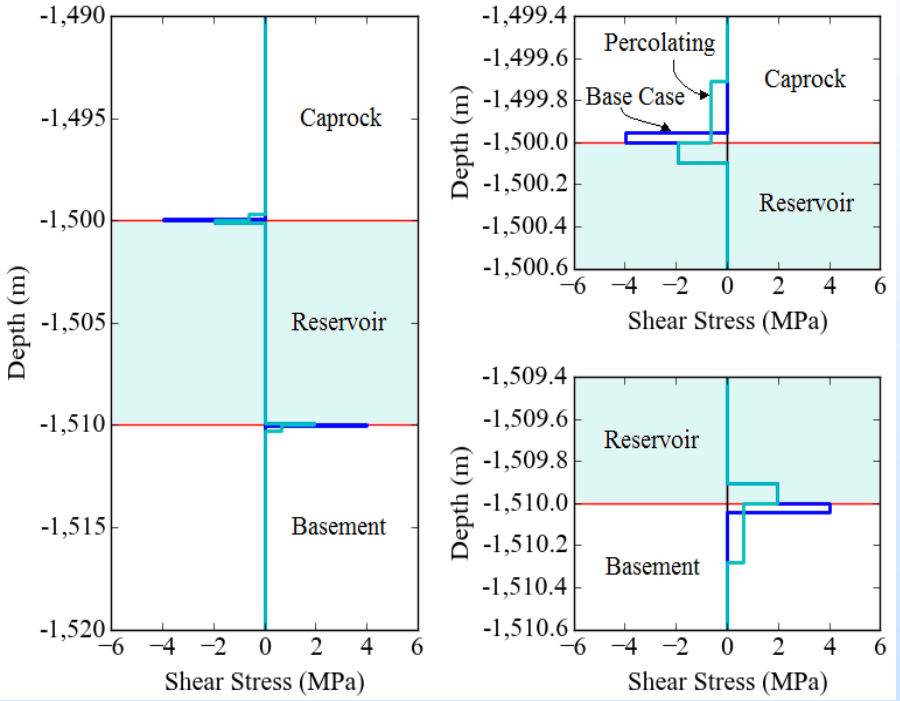
K. Rod, W. Um, C. Brown (PNNL)

Detailed simulations

- **Current**
  - **Mechanical failure between well system interfaces**
  - **Detection and mitigation of leakage from plugged and abandoned wells**
  - **Geochemical and geomechanical multiphase leakage model**
- **Future**
  - **Cross-flow simulations**

Debonding along the well system interfaces

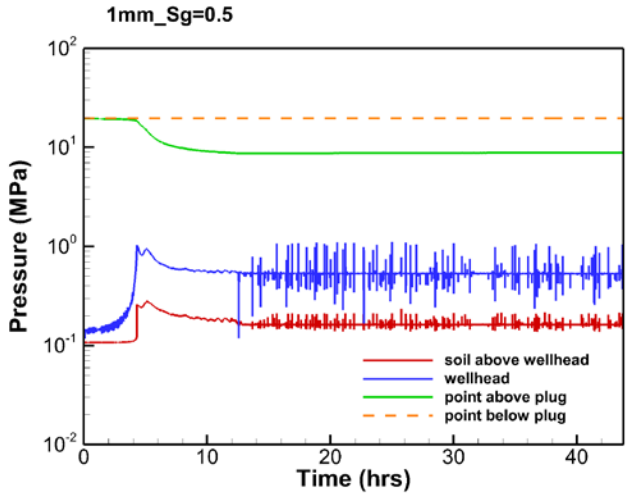


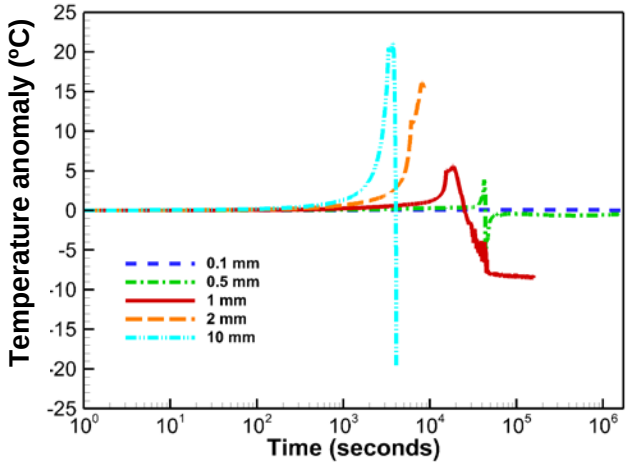


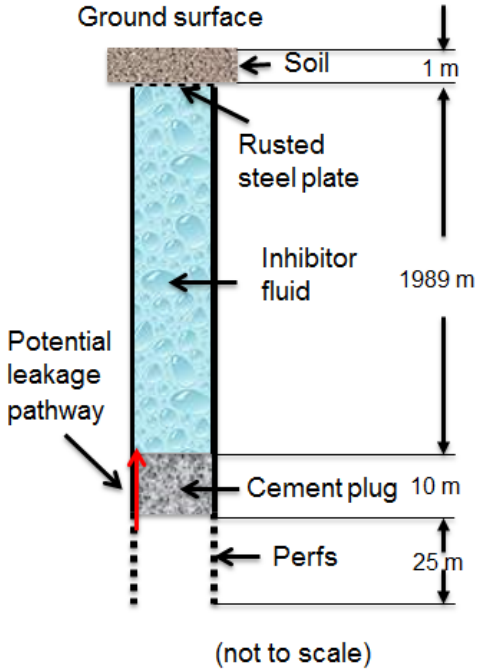
- Uses a simple analytic model for mechanics and failure
- Study shear-stress induced failure and propagation along well system interfaces

L. Frash, B. Carey (LANL)

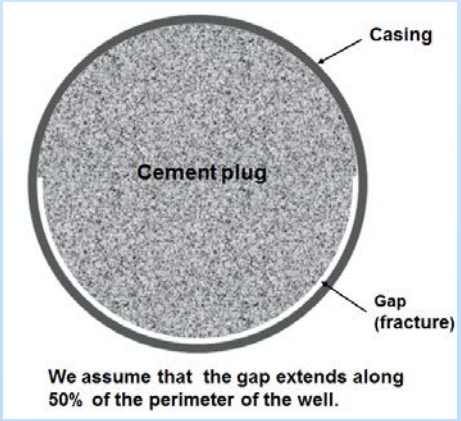
Detection and mitigation of leakage from plugged and abandoned wells







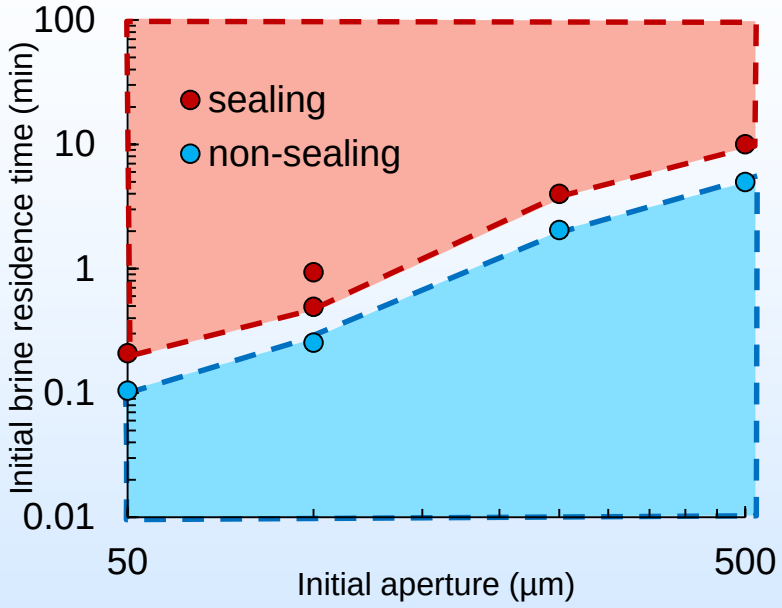
- Using drift-flux approach (T2Well) to simulate multi-phase flow up a failed plug and through a fluid-filled casing
- Model produces signals (P, T, S_{gas}) that can be used to detect small leaks



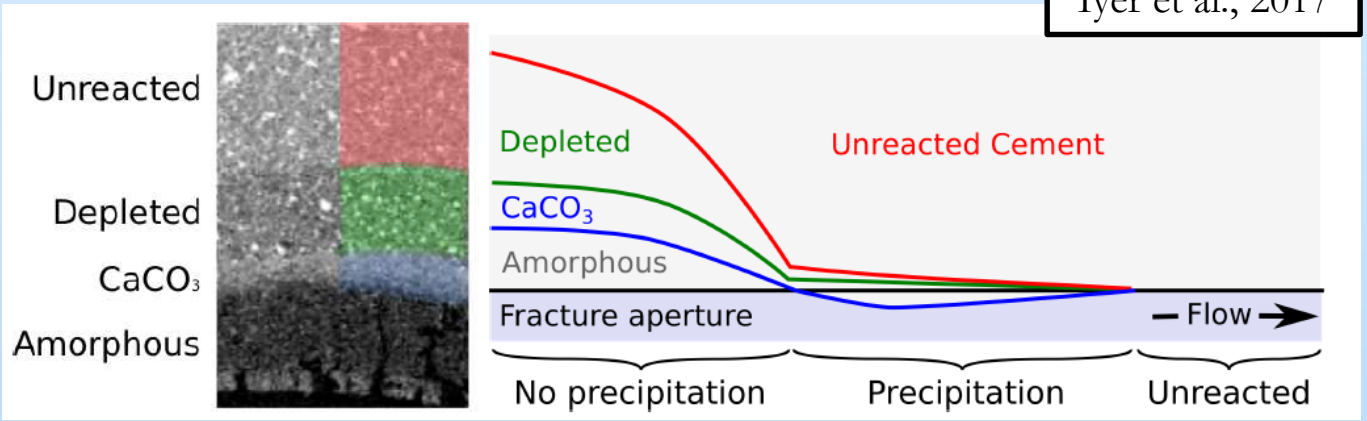
L. Pan, C. Oldenburg (LBNL)

Geochemical and geomechanical multiphase leakage model

- Well leak model developed to simulate leakage over time and consider:
  - Multiphase brine and CO_2 flow
  - Geochemical reactions
  - Geomechanical alteration
- Leveraging this model to build several approaches for leak risk assessment

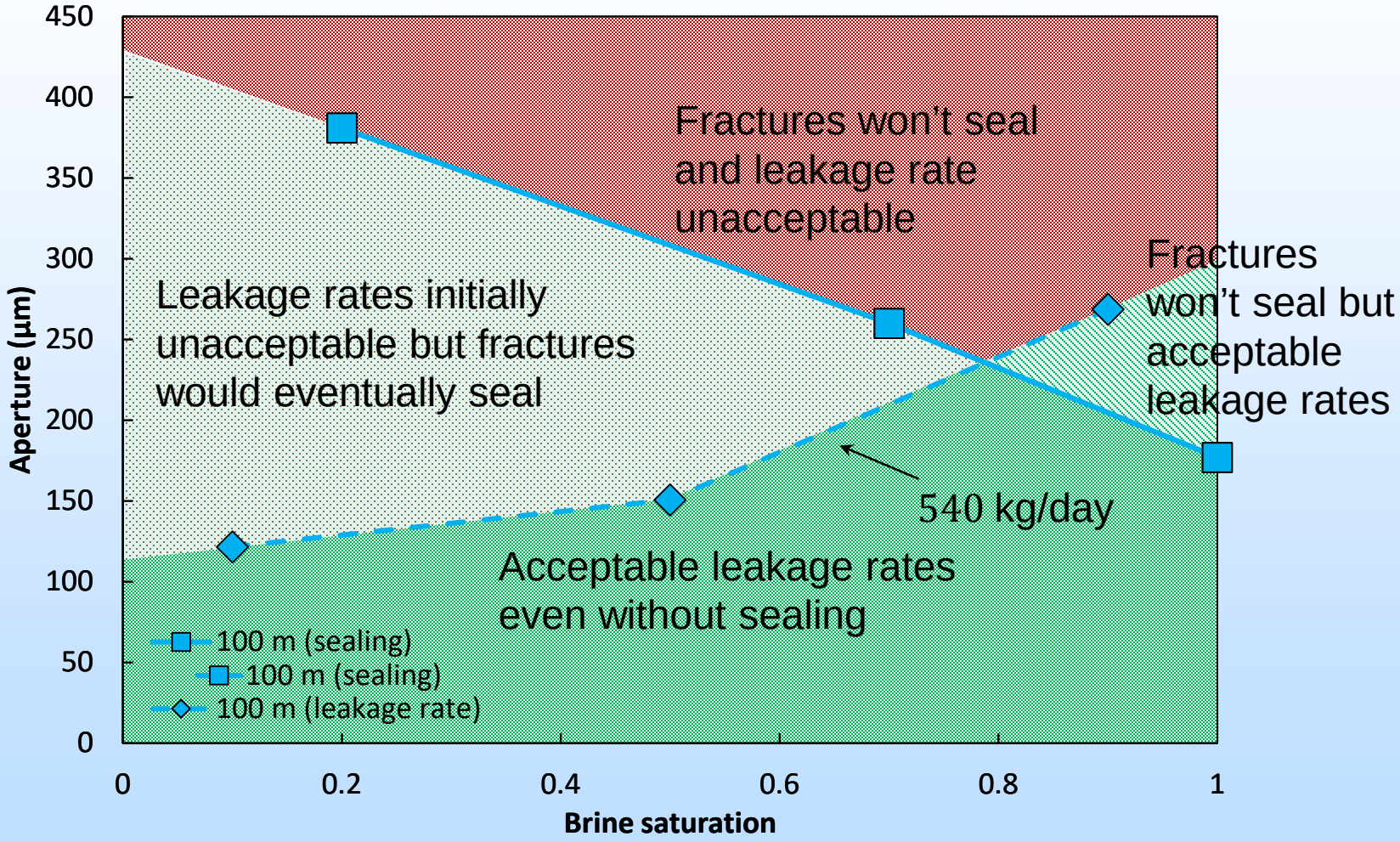


Iyer et al., 2017



J. Iyer, S. Walsh, X. Chen, Y. Hao, P. Roy, J. Morris, S. Carroll (LLNL)

Geochemical and geomechanical multiphase leakage model

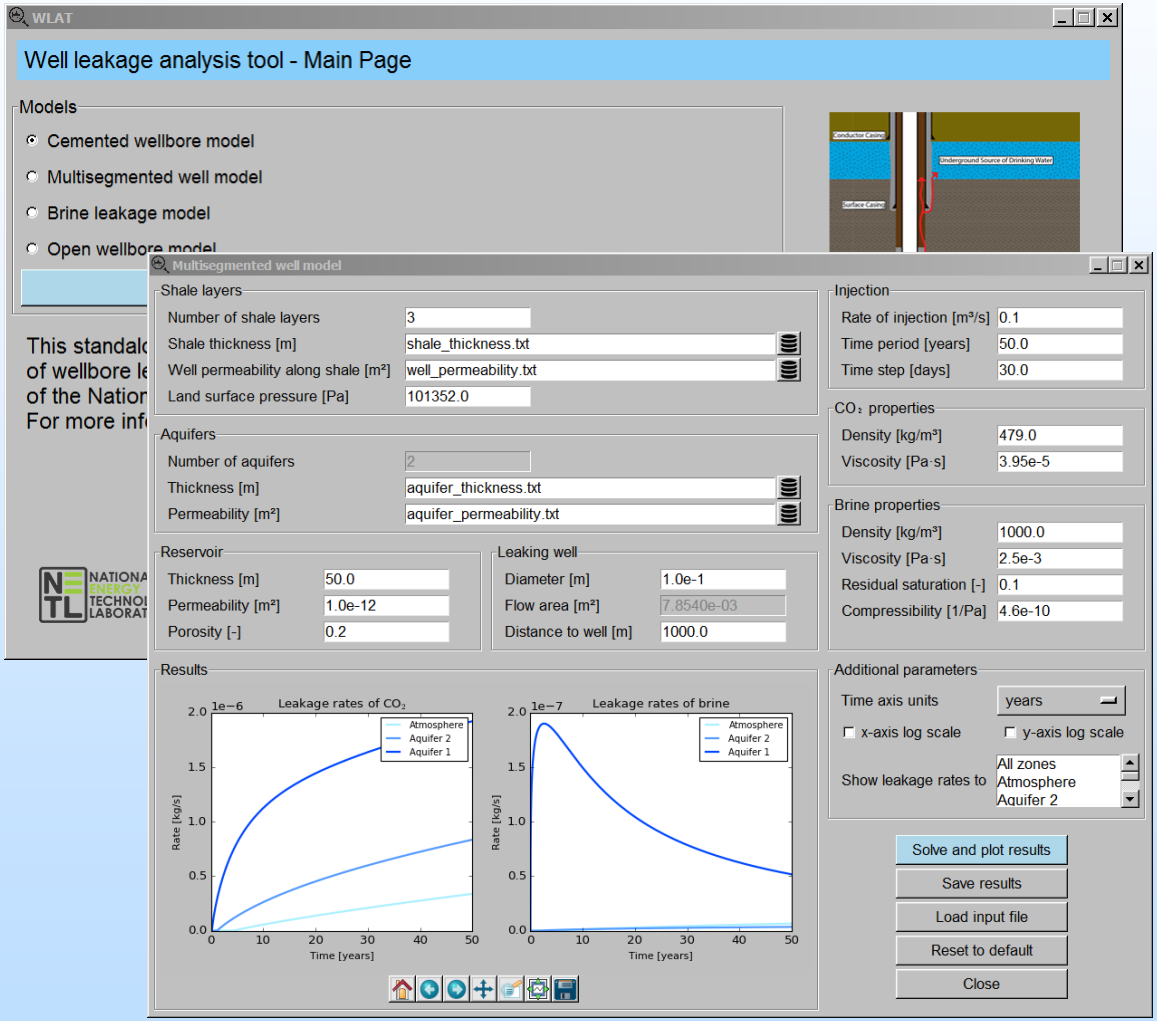


J. Iyer, S. Walsh, X. Chen, Y. Hao, P. Roy, J. Morris, S. Carroll (LLNL)

Reduced-complexity models

- **Current**
  - **Well leakage analysis tool**
  - **Uncertainty quantification approach (LLNL)**
  - **Multiphase moving front leakage ROM (NETL)**
  - **Determine when we need to consider coupling between the reservoir and well leak**
- **Future**
  - **Geochemical/geomechanical sealing ROM to couple with existing ROMs (LLNL/LANL/NETL)**
  - **Cross-flow ROM**
  - **ROM for monitoring / leakage detection**
  - **Develop test-bank of detailed simulations for future ROM QA/QC**

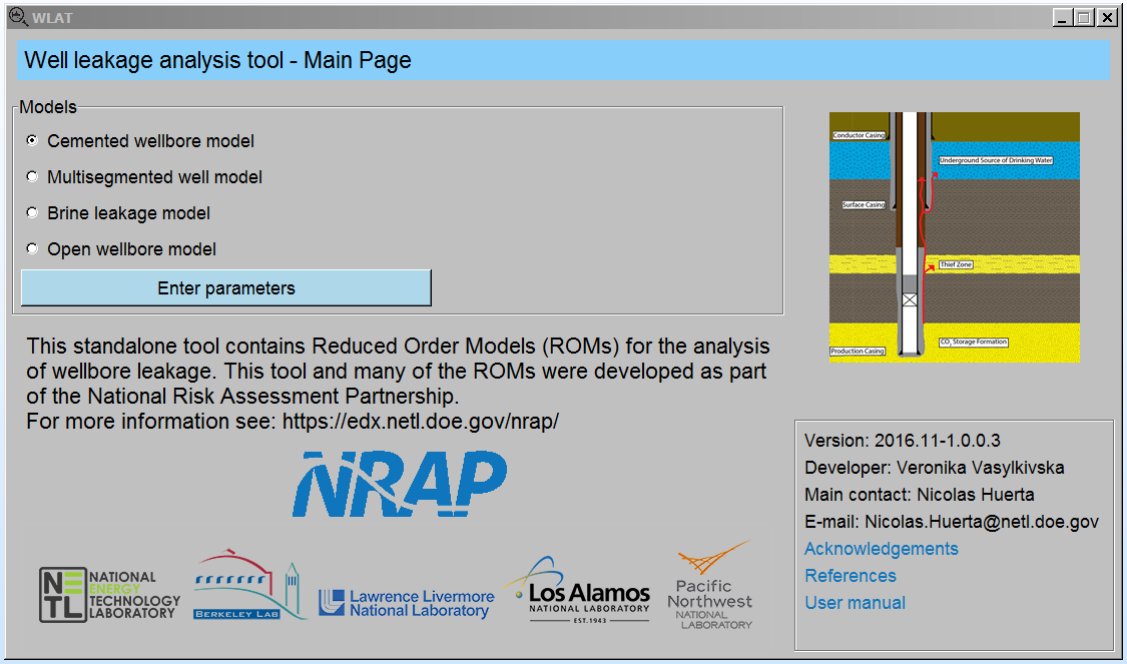
Well leakage analysis tool



- Models the migration of brine and/or CO_2 outside of storage reservoir
- Inputs are reservoir pressures and saturations
- Predicts flowrate into thief zone and groundwater aquifer
- Incorporates chemistry to identify flowrate changes as a function of time

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

Well leakage analysis tool, updates



Throughout Phase II we will be updating the tool

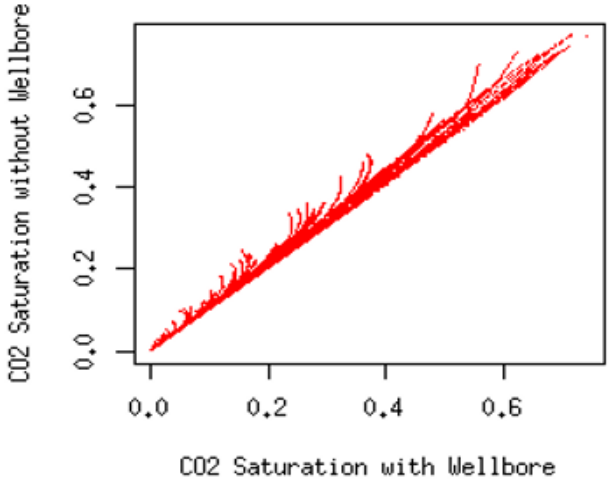
- Fixing bugs as they are found
- Adding capabilities based on user feedback
- Incorporating new ROMs as they are developed
- Develop a set of use cases
- Switch to web-based version control

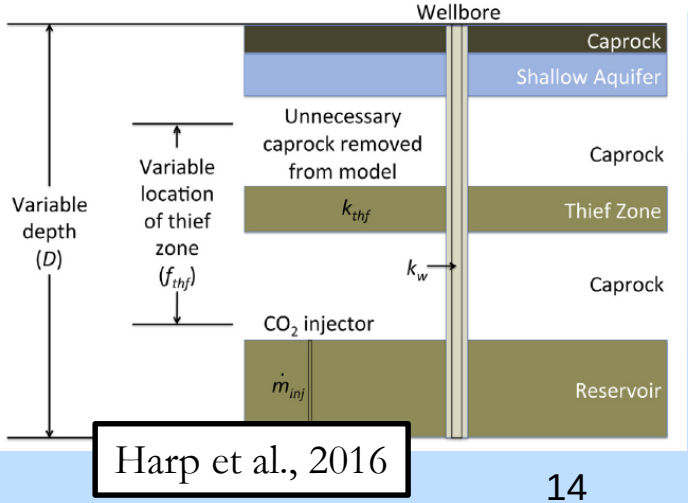
There will be an NRAP tool user's meeting after closing remarks today

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

When do we need to consider coupling between the reservoir and leaky well?

- Decoupling gives us considerable savings for Integrated Assessment Model implementation
- Previous NRAP work showed that decoupling has a minor effect for small leaks
  - Effect becomes more pronounced as well permeability approaches reservoir permeability
  - Pressure is unaffected but CO_2 saturation at the leak source is affected
- From a risk perspective decoupling gives a conservative estimate for leak rate
- But from a monitoring and leak detection perspective we may be over-estimating detection
- These relationships and their implications need to be better documented in our tools





Harp et al., 2016

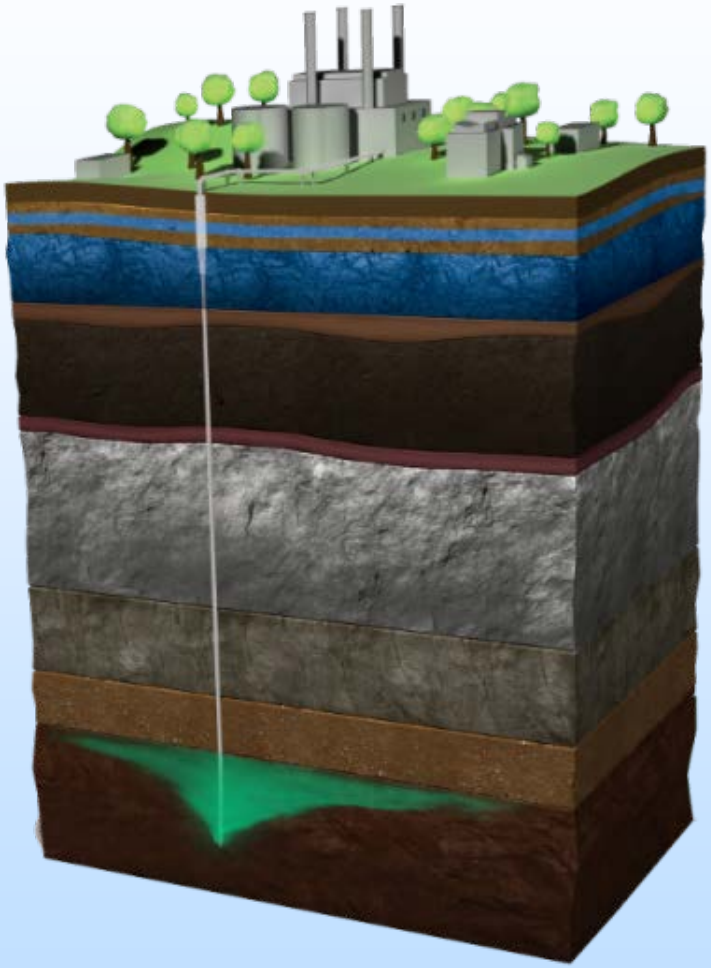
D. Martinez, R. Pawar, D. Harp (LANL)

Project Summary

- NRAP's well group is advancing our understanding how wells leak over time
  - Experimental observations
  - Detailed numerical simulations

- We are developing tools and methodologies that can be used at the field-scale to:
  - Assess leakage risk
  - Test monitoring and mitigation strategies

Questions?



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