NRAP Task 6 - Basin-Scale Risk Assessment for Geologic Carbon Storage

Evaluating the Geomechanical and Leakage Risks of Multiple CO_2 Injectors in the Same Basin

Julia Camargo, Ashton Kirol, Ryan Haagenson PNNL
Gabe Creason, Greg Lackey, Paige Morkner,
David Morgan, Jiaan Wang, NETL
Abdullah Cihan, Yingqi Chan, Quanlin Zhou, LBNL
Briana Schmidt, Jaisree Iyer LLNL
Bailian Chen, Qinjun Kang, Mohamed Mehana, Hichem Chellal, LANL

2024 Carbon Management Research Project Review Meeting
August 8, 2024

NRAP
National Risk Assessment Partnership

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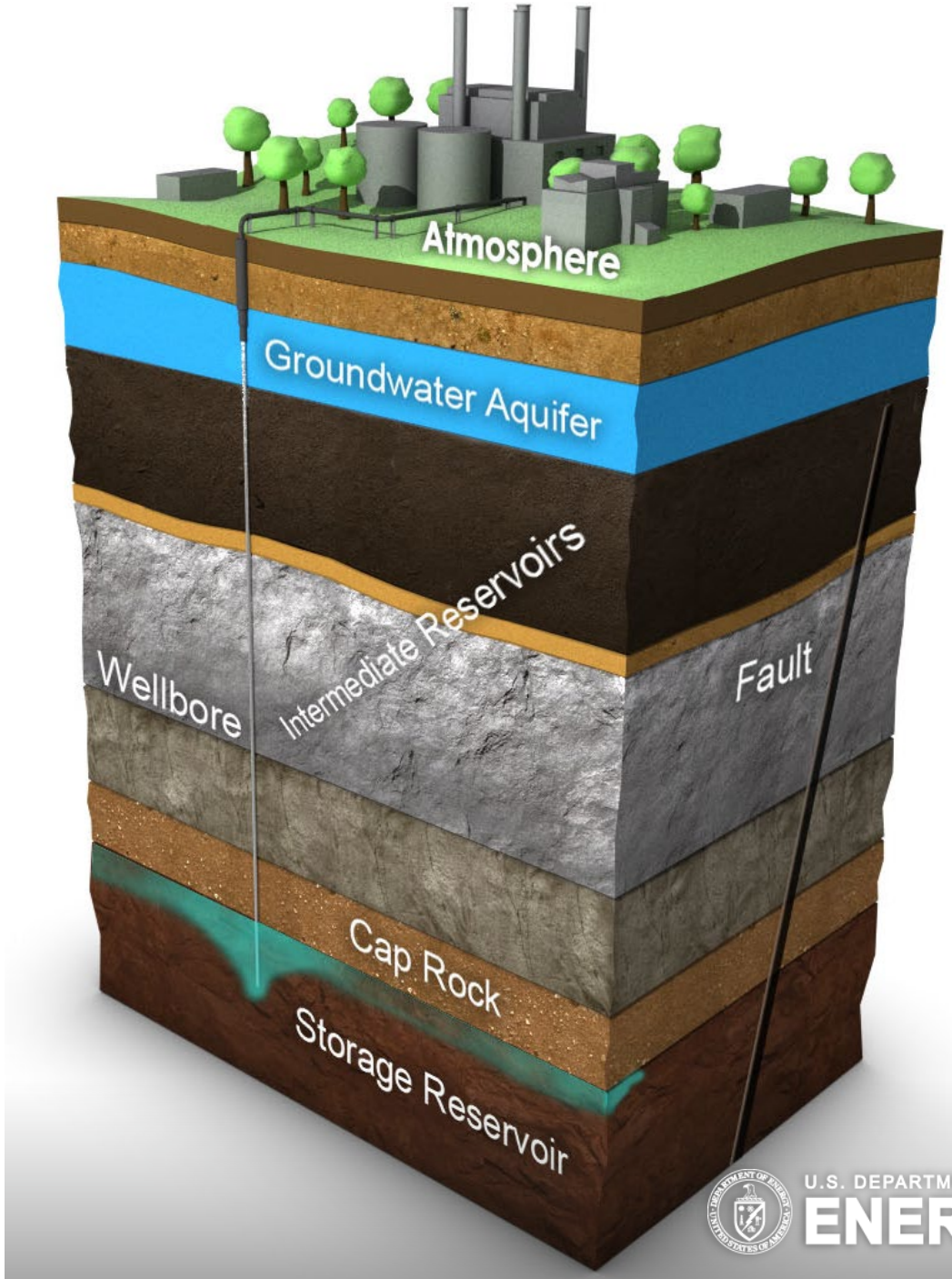
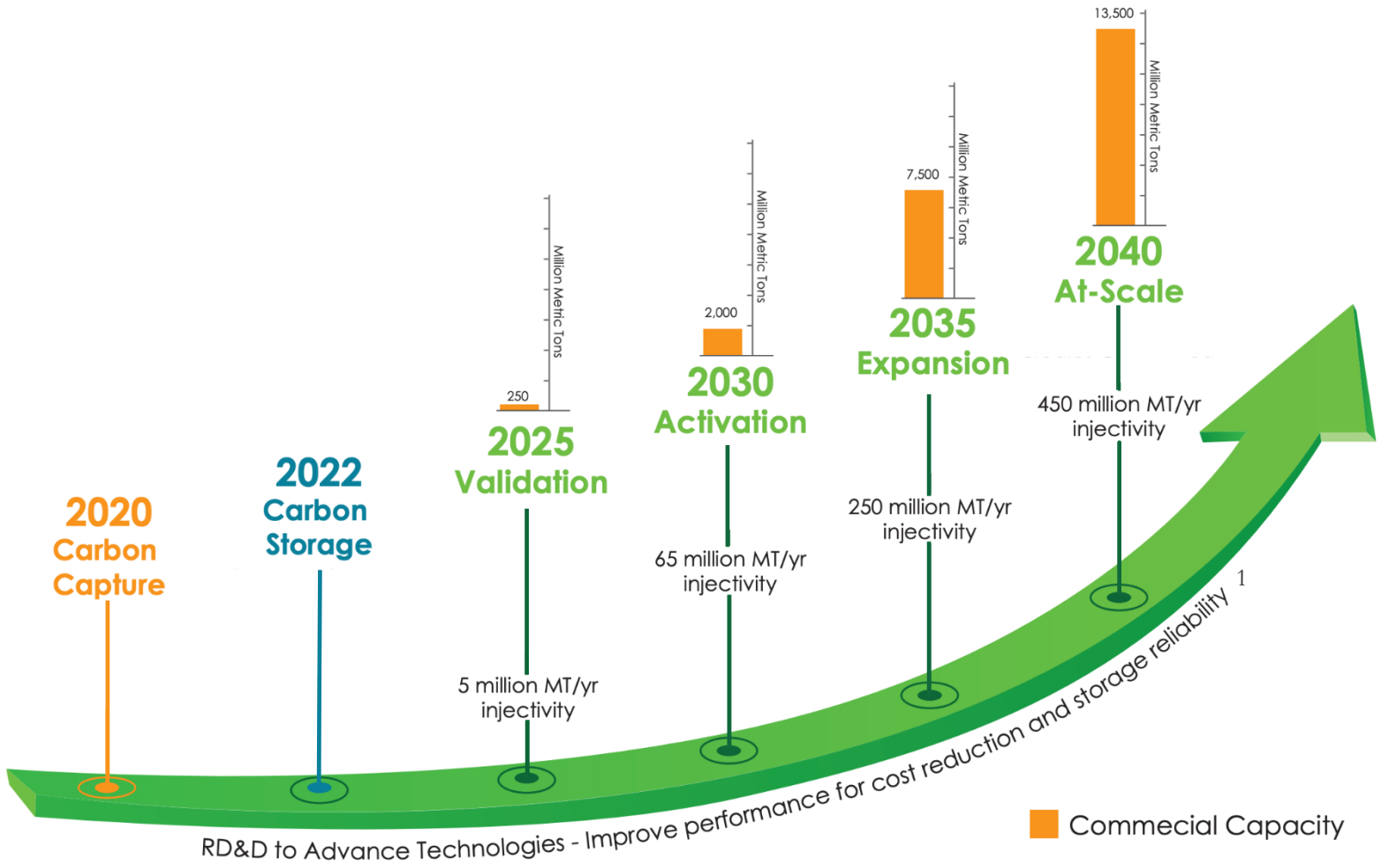
Los Alamos NATIONAL LABORATORY
Pacific Northwest NATIONAL LABORATORY



U.S. DEPARTMENT OF ENERGY

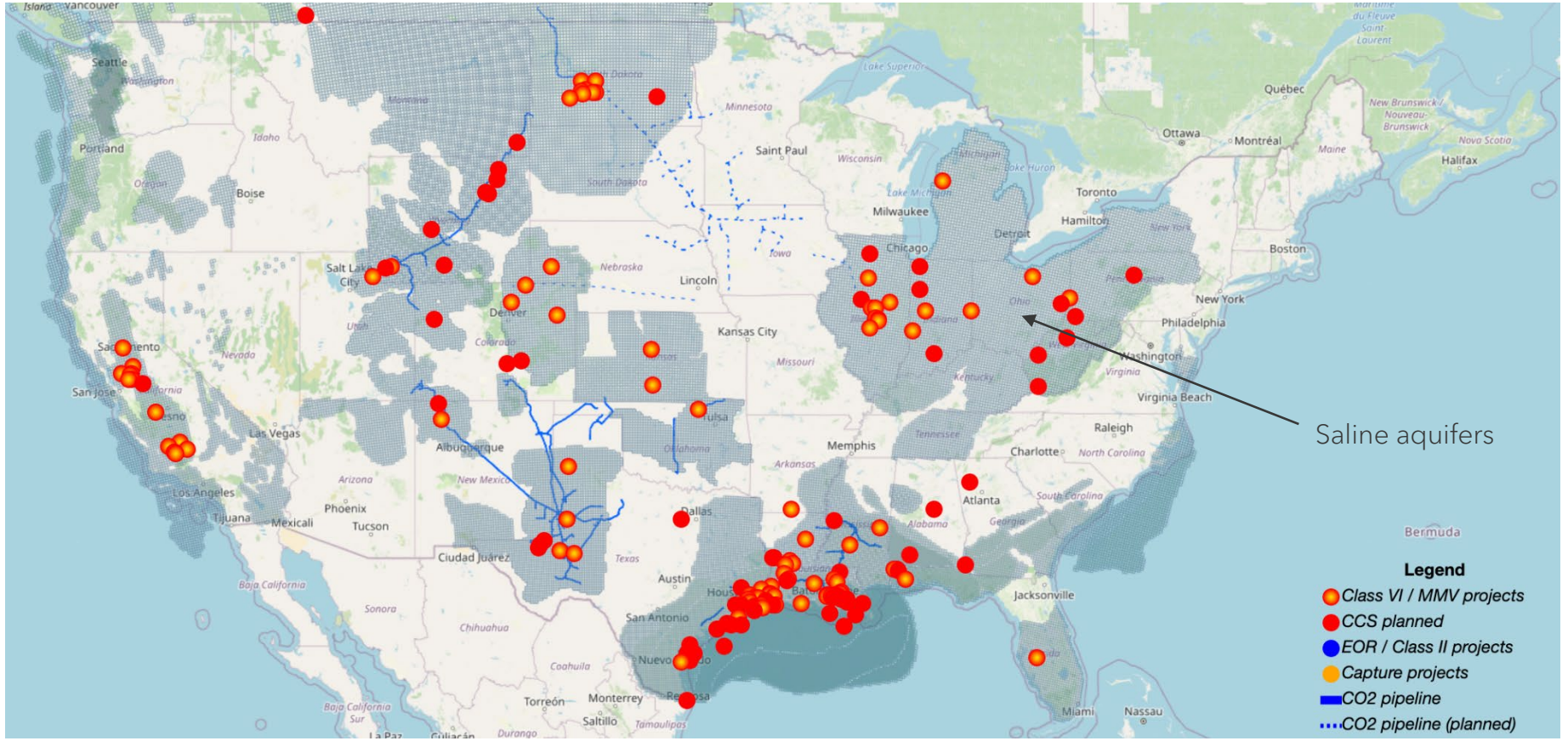
Pathway towards decarbonization



[1] "Strategic Vision – The Role of Fossil Energy and Carbon Management in Achieving Net-Zero-Greenhouse Gas Emissions", DOE Fossil Energy and Carbon Management, 2022. available at https://www.energy.gov/fecm/strategic-vision-role-fecm-achieving-net-zero-greenhouse-gas-emissions

Underground Injection Control Class VI Projects

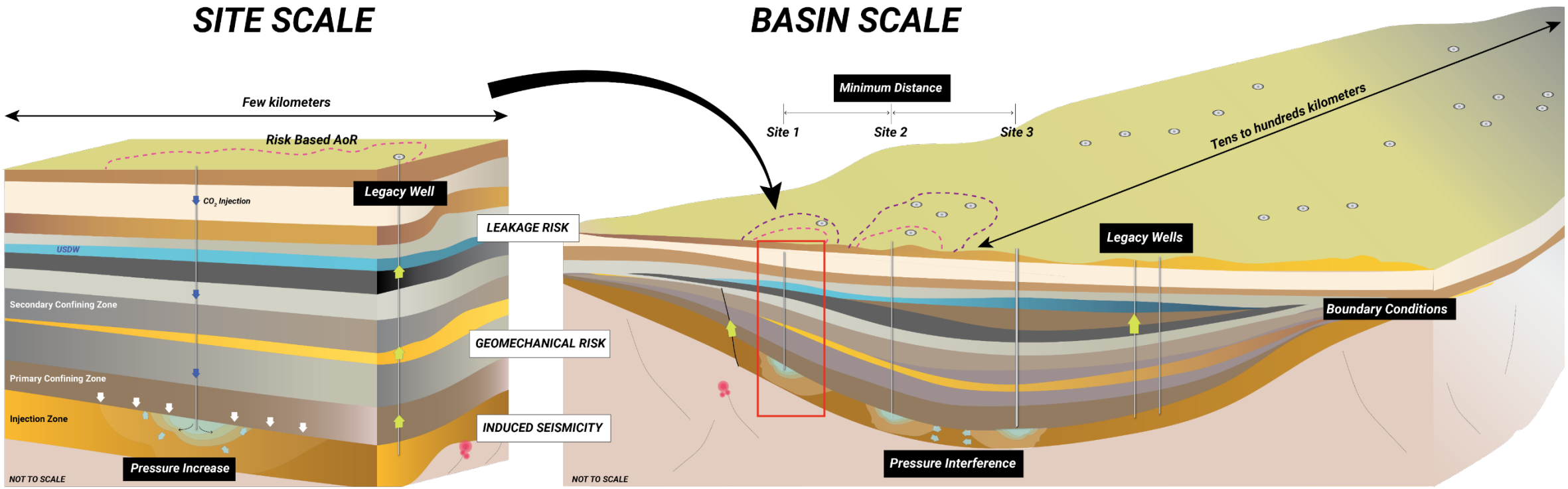
Source: CCUS map [1]



[1] ccusmap.com/markers/map/

Basin Scale Risk Assessment

Problem Definition



Task 6 Assessing and Managing Risks of Rapid, Basin-Scale GCS Deployment

Objective To develop and demonstrate a first-of-a-kind tool to assess and manage subsurface environmental basin-scale risks associated with rapid commercial-scale deployment of GCS.

MILESTONE
Prototype risk assessment for credible basin-scale deployment scenario

MILESTONE
Risk assessment for first sedimentary basin

MILESTONE
Risk assessment and risk mitigation scenario evaluation for second sedimentary basin

MILESTONE
Final risk assessment and risk mitigation scenario evaluations

OUTCOME: TOOL / WORKFLOWS TO ASSESS AND MANAGE RISKS OF BASIN-SCALE GCS DEPLOYMENT

Project Overview

Key Project participants

Delphine Appriou
Diana Bacon
Julia Camargo
Ryan Haagenson
Ashton Kirol

Gabe Creason
Greg Lackey
David Morgan
Paige Morkner
Jiaan Wang

Abdullah Chan
Yingqi Zhang
Quanlin Zhou

Jaisree Iyer
Briana Schmidt

Bailian Chen
Qinjun Kang
Mohamed Mehana
Hichem Chellal

Project Structure

Establish relevant basin-scale geologic storage commercial **deployment scenarios**

Update NRAP-Open-IAM to perform **basin-scale leakage** risk assessment

Update NRAP-Open-IAM to perform **basin-scale geologic hazard** assessment

Assess and manage **basin-scale risks**

Assess and manage **basin-scale pressure interference**

Illinois Basin Geomodel

Subtask 6.2: Develop a Geomodel to Support Basin-Scale Risk Modeling

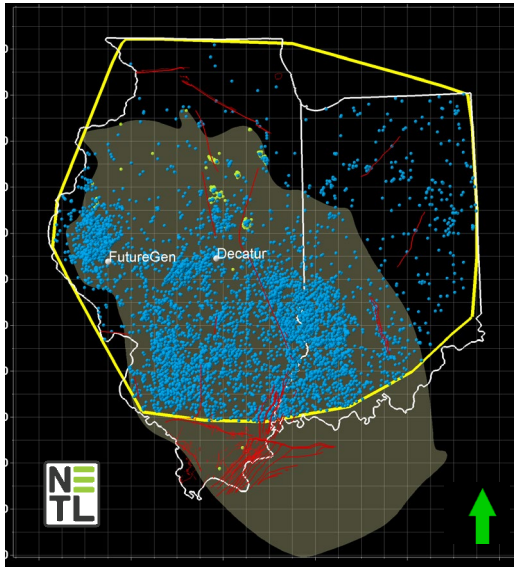
Gabe Creason, NETL

Data resources include:

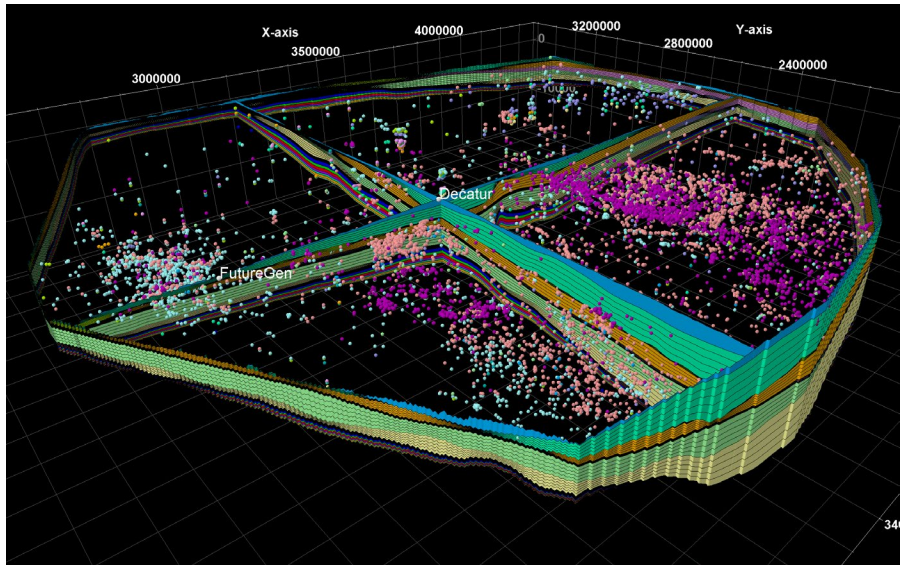
- ISGS public well data, IHS proprietary well data
  - Processed 800,000+ formation tops
- IBDP static geomodel
- Surface faults
- Petrophysical properties:
  - Porosity, permeability, salinity, temperature

Model development:

- 9 different geomodels:
  - 3 permeability/porosity configurations
  - 3 correlation length scales



- Model boundary is yellow line
- Well data locations shown as points: blue = commercial; green = public
- Major structures shown as red polylines
- Illinois Basin extent is brown shaded area



Model geometry (nI x nJ x nK):	560 x 507 x 73
Total number of grid cells:	20,726,160
Number of stratigraphic zones:	12 (18)
Number of geological layers:	73

Sacramento Basin Geomodel

Subtask 6.2: Develop a Geomodel to Support Basin-Scale Risk Modeling

Briana Schmidt, LLNL

Data resources include:

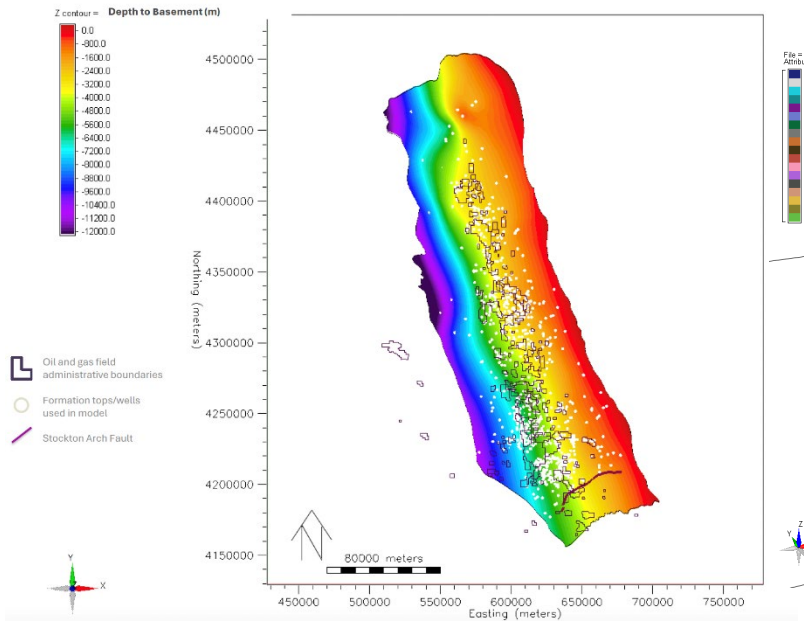
- Publicly available data California Department of Geologic Energy Management
  - Processed 6,400+ formation tops
- Petrophysical properties:
  - Porosity, permeability, salinity, temperature

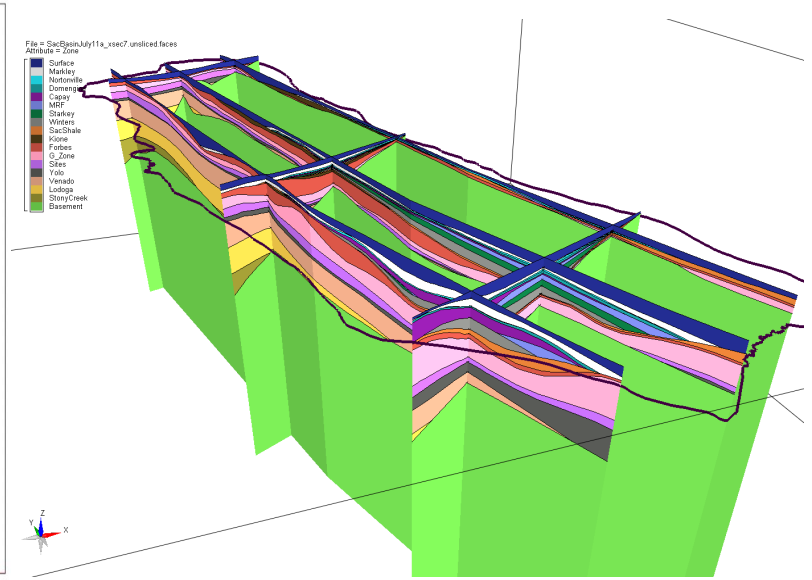
Dimensions:

- ~ 380 x 80 km

Future work:

- Refine structural model to include faults
- Incorporate facies to better distribute properties





Model geometry (nI x nJ x nK):	167 x 341 x 57
Total number of grid cells:	3,245,979
Number of stratigraphic zones:	10 (18)
Number of geological layers:	57

Basin Scale Reservoir Simulations

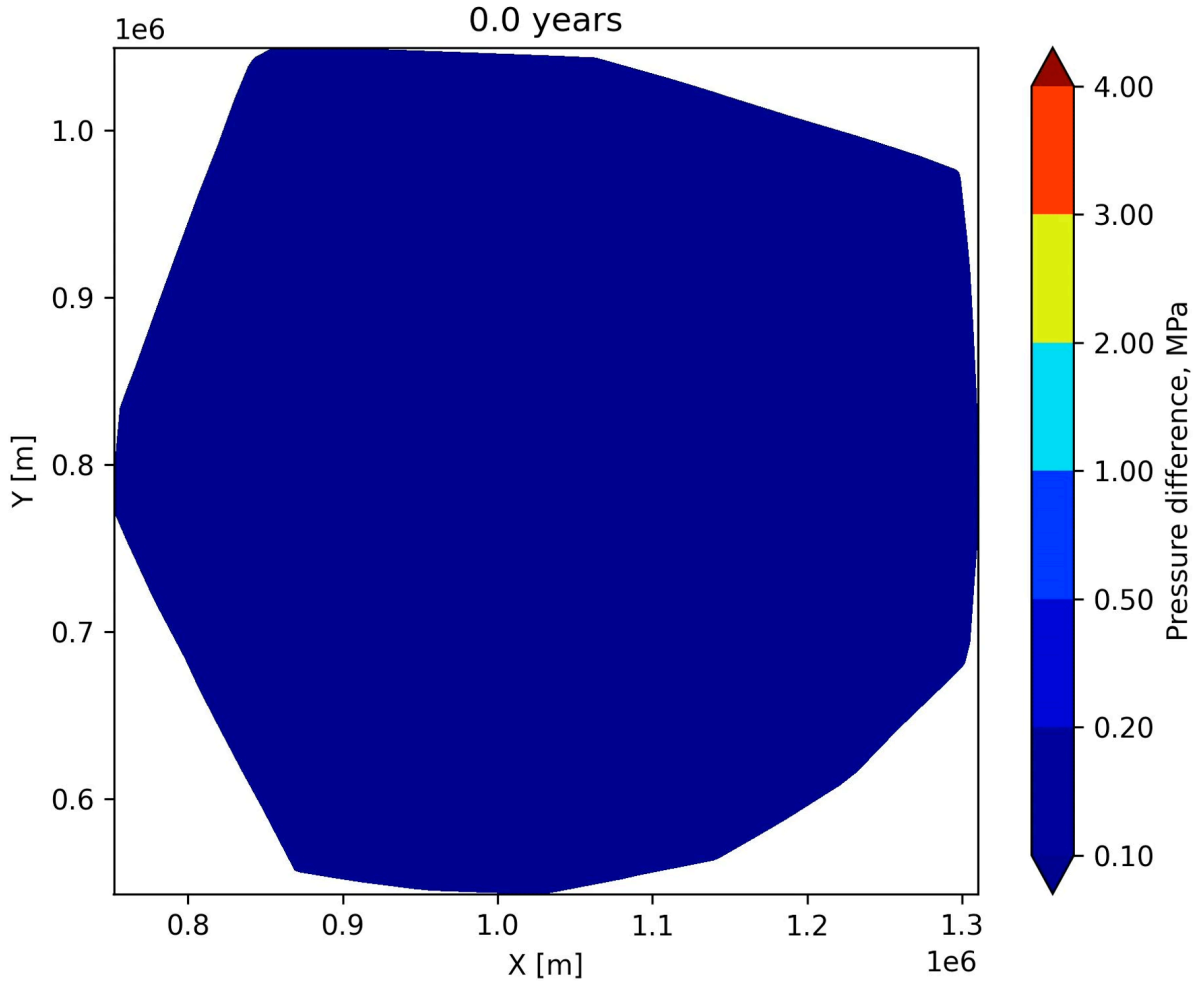
Subtask 6.2. Update NRAP-Open-IAM to Perform Basin-Scale Leakage Risk Assessment

Julia Camargo, Diana Bacon PNNL

- Developed a workflow to estimate leakage risk and geomechanical risk at the basin scale
- NRAP-Open-IAM **Theis reservoir component** with time-varying injection rates and multiple injectors/producers **completed**

Figure considers:

- 20 hypothetical injection sites in the Illinois Basin
- 5 Mt/year for each injection site for 50 years



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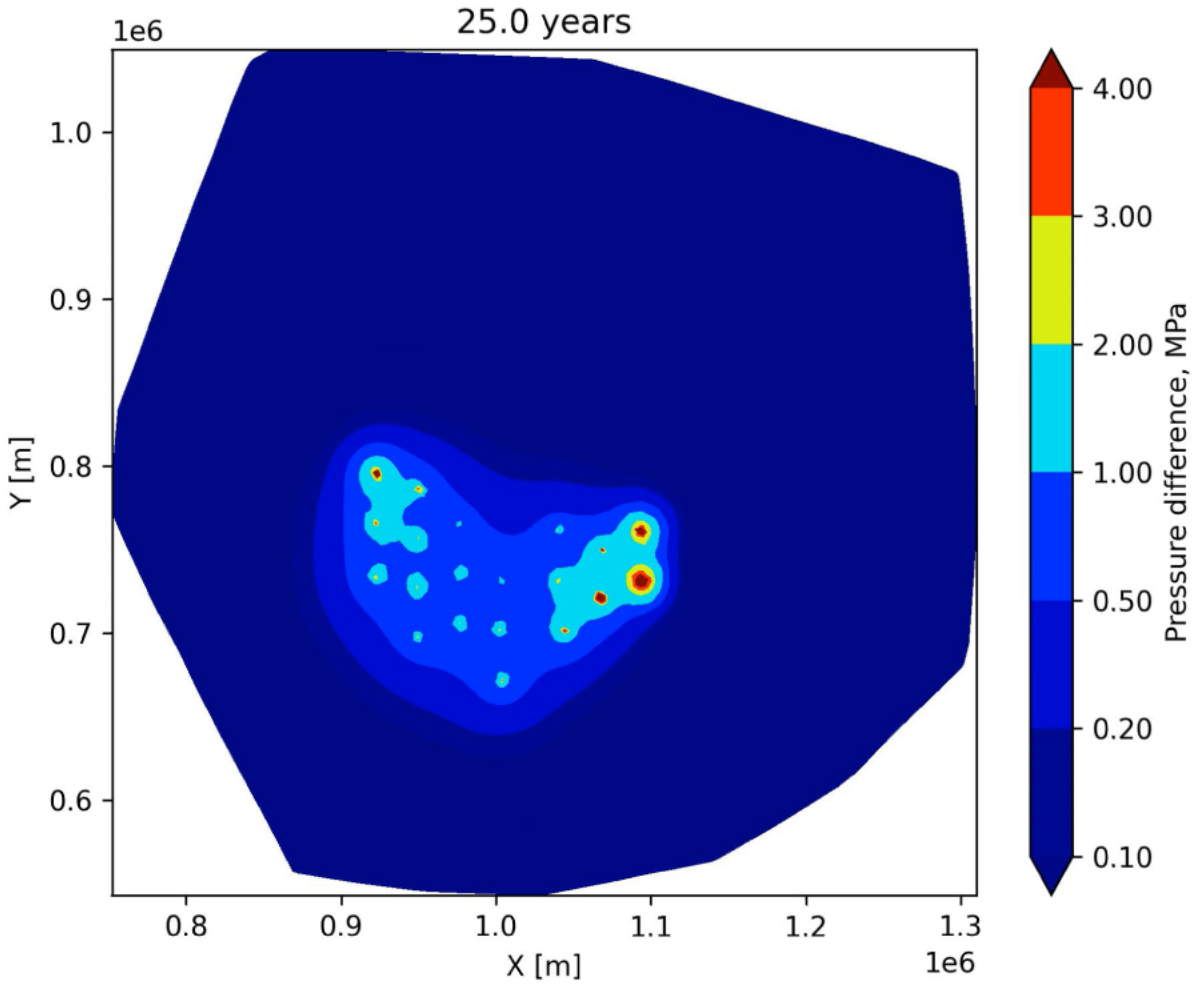

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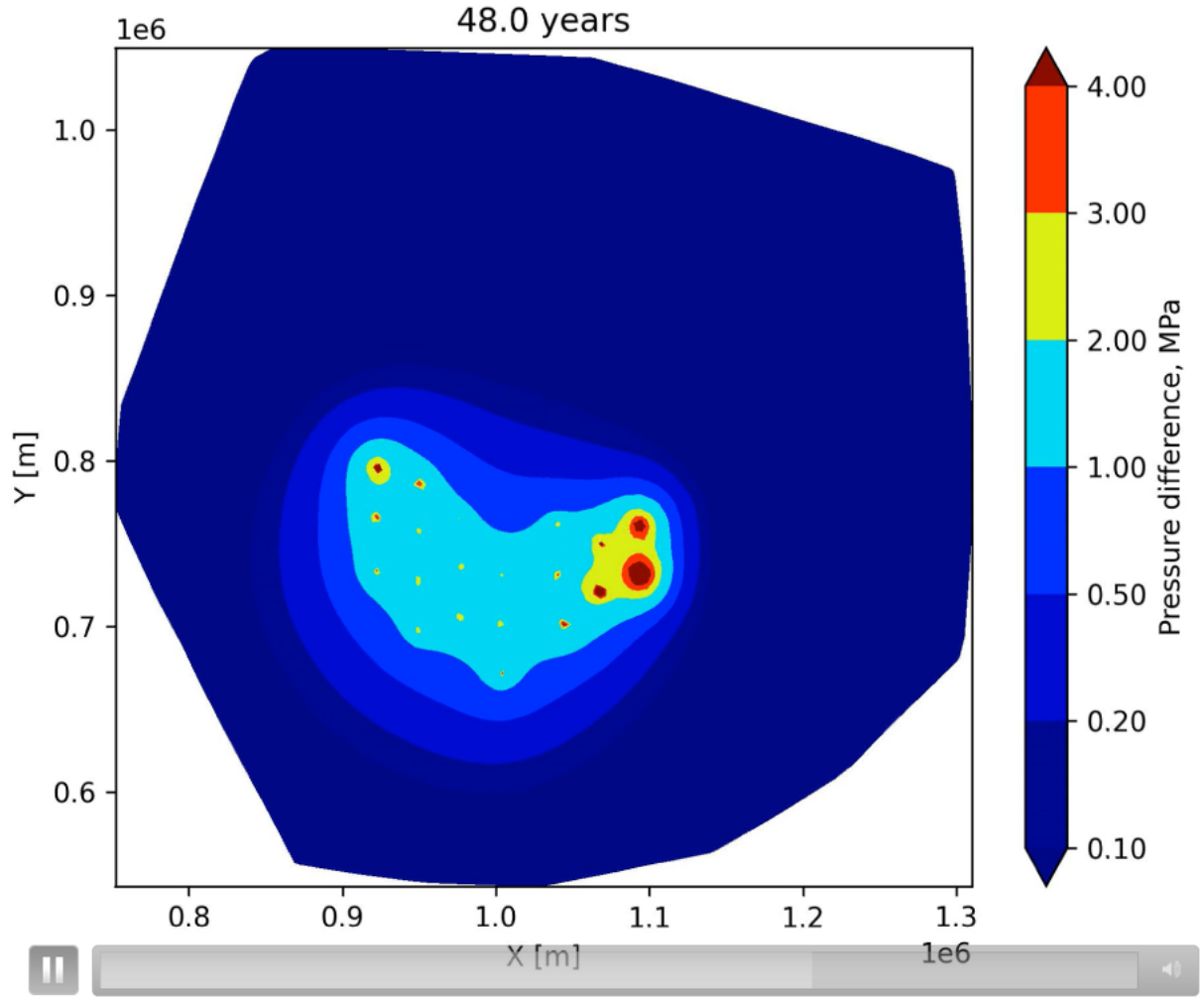
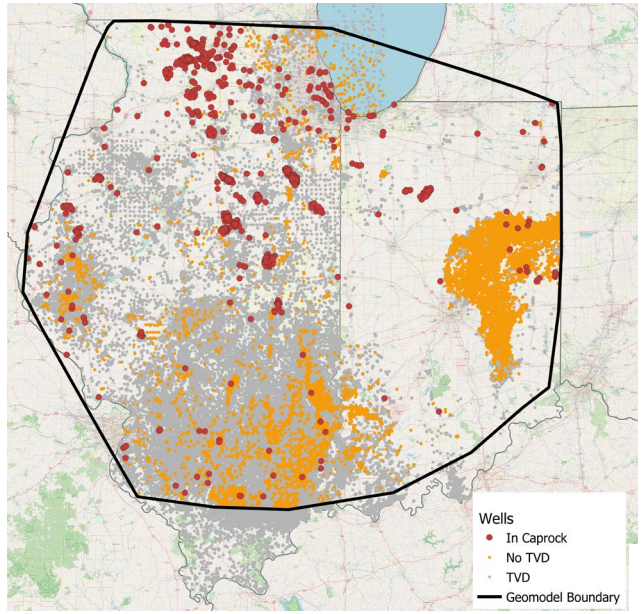
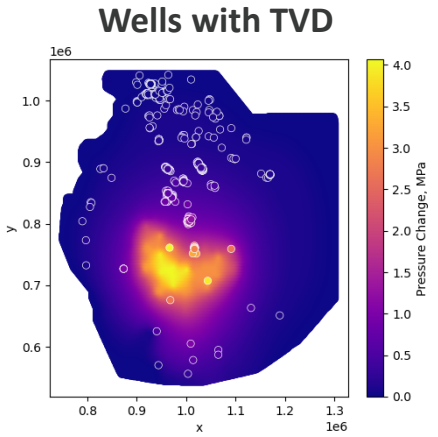


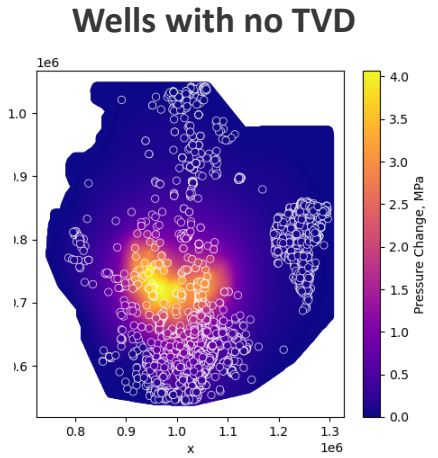
Wellbore Leakage Modeling

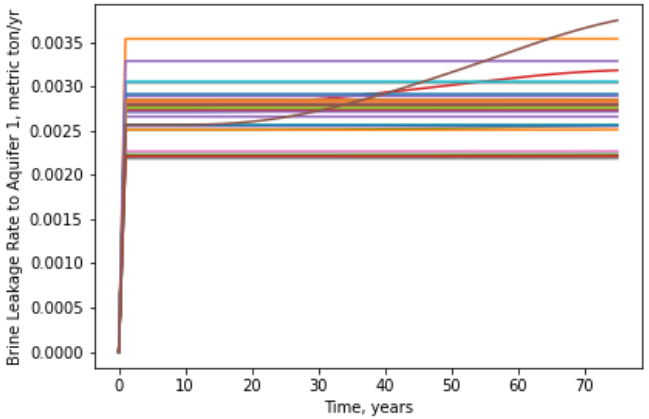
Subtask 6.4.1 Assessing and Managing Basin-Scale Risks
Greg Lackey, Jiaan Wang NETL

- **Developed basin-scale approach for screening legacy wells and simulating leakage risks**
  - Analyzed ~250k public well records from Illinois State Geological Survey and Indiana Geological Survey
  - Identified legacy wells in Mt. Simon that have known (1,652) and unknown (29,428) true vertical depths (TVD)
  - 1,652 wells penetrate the Eau Claire formation
  - Constructed NRAP-Open-IAM model for IL Basin







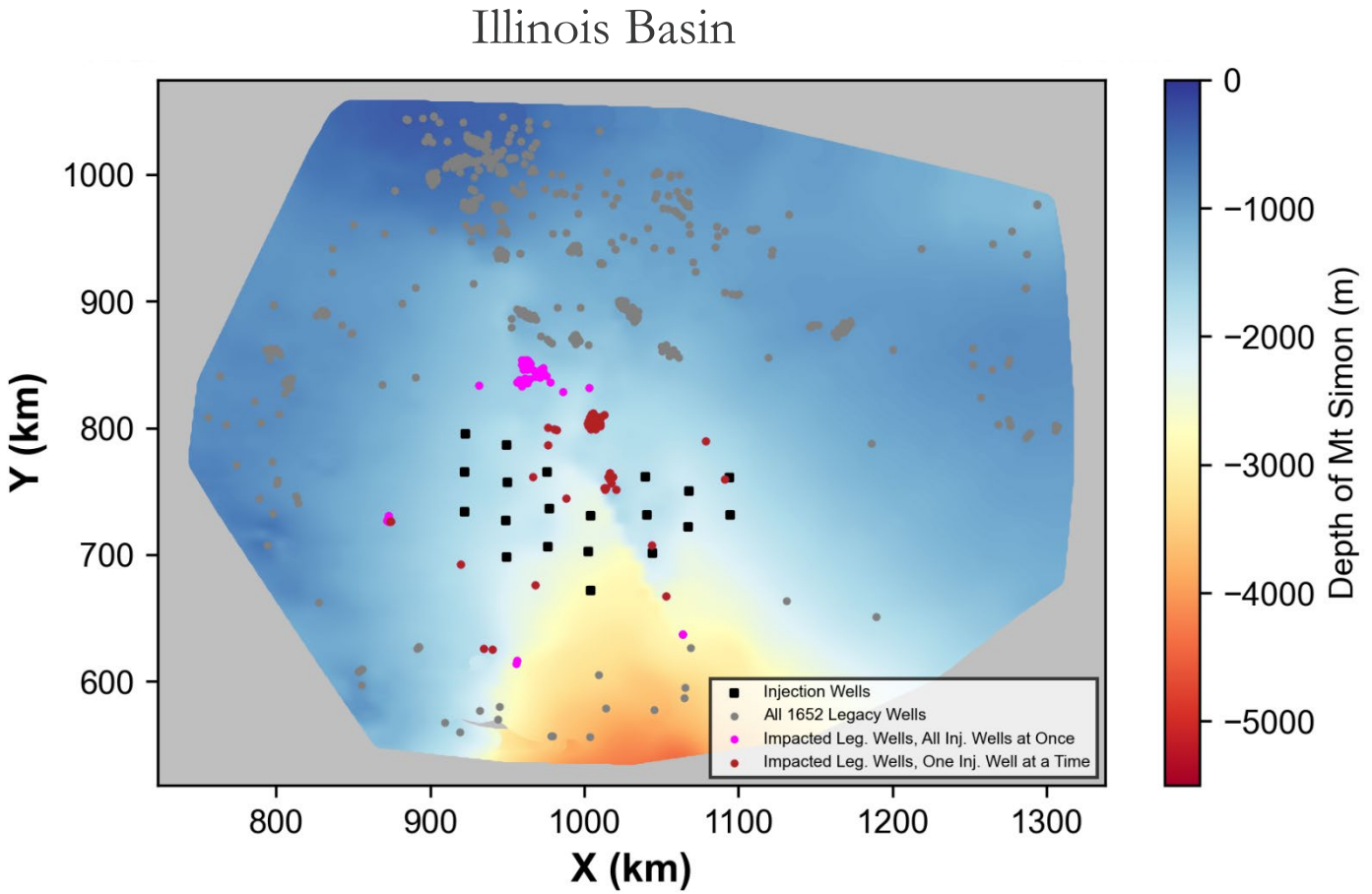


Legacy Well Leakage Risks

Subtask 6.4.1 Assessing and Managing Basin-Scale Risks

Greg Lackey, Jiaan Wang, Nate Mitchell, NETL

- **Quantifying increased leakage risks from basin-scale injections**
- **Calculating well leakage risks for two scenarios**
  1. One basin-scale simulation that considers all 20 injection sites
  2. Twenty separate simulations for each of the injection sites considered
- **Legacy wells that experienced a >0.1% pressure increase**
  1. Individual injections: 232
  2. Simultaneous injections: 414
- **182 more wells impacted by pressure increase when basin-scale injection considered**



Geomechanical Risk Assessment

Subtask 6.3 Update NRAP-Open-IAM to Perform Basin-Scale Geologic Hazard Assessment

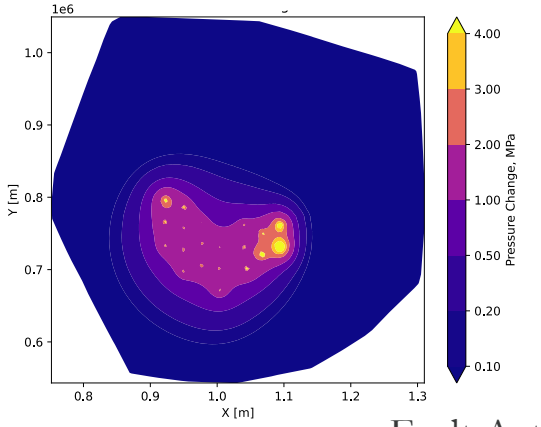
Ryan Haagenson, Julia Camargo PNNL

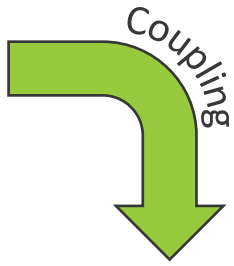
Coupling NRAP-Open-IAM with SOSAT

- Developed workflow to couple NRAP-Open-IAM pressure response with SOSAT risk analysis capabilities
- Estimated increase in probability of fault activation due to CO_2 injection for:
  - Critically oriented faults
  - Faults with user-prescribed orientations

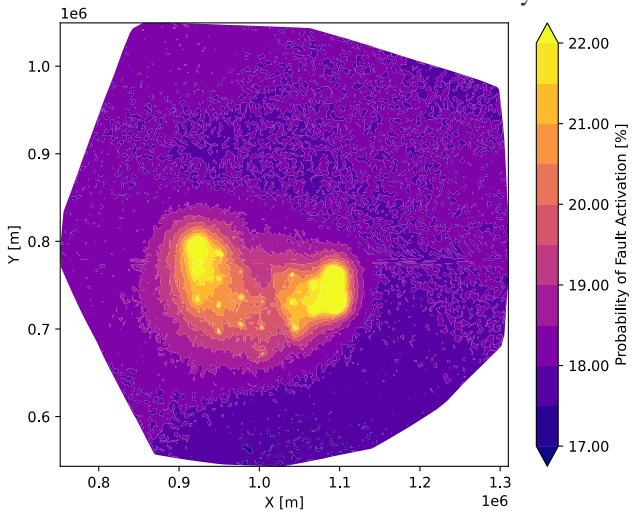
- 20 hypothetical injection sites
- 5 Mt/year for each injection site for 50 years
- Basin-wide pressure build up
- Pressure results are estimated with analytical Theis model

Pressure change (50 years)





Fault Activation Probability

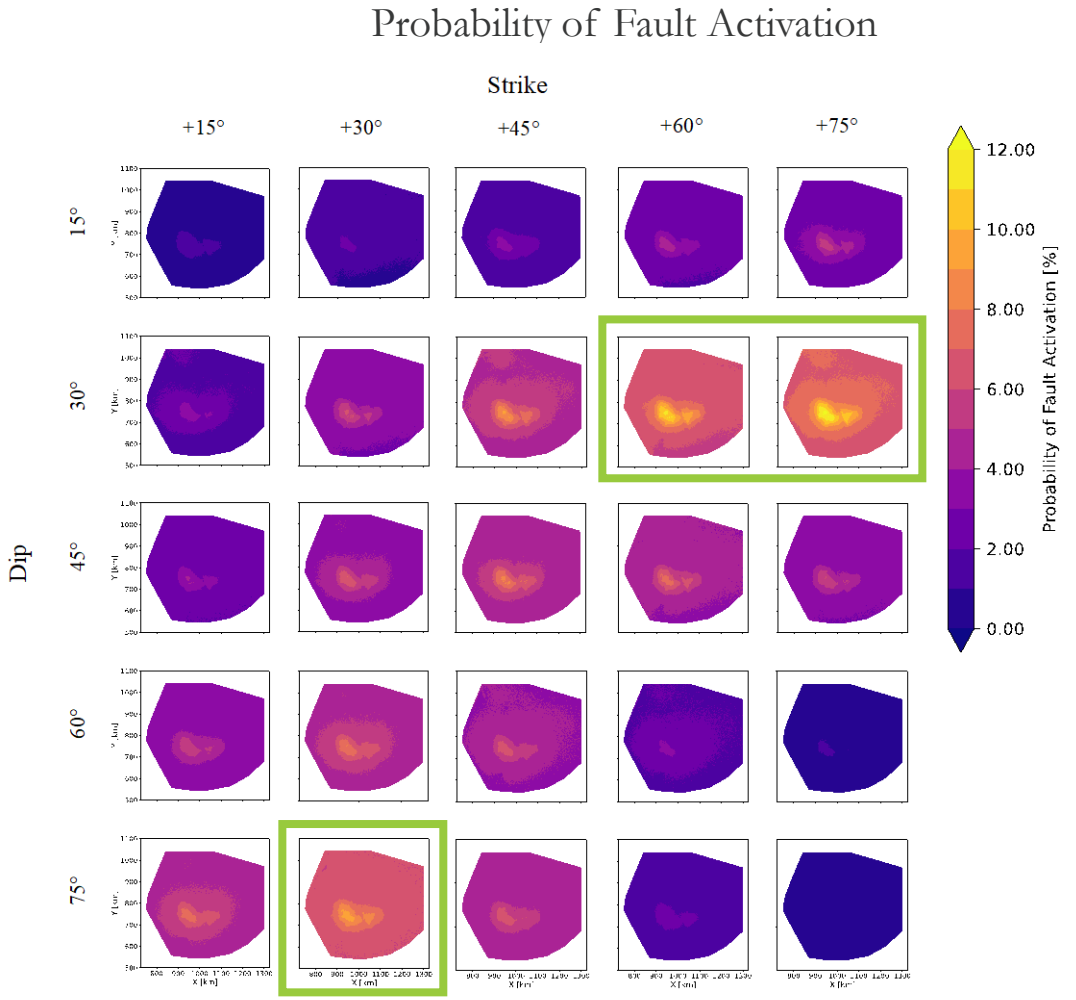


Geomechanical Risk

Subtask 6.3 Update NRAP-Open-IAM to Perform Basin-Scale Geologic Hazard Assessment
Ryan Haagenson PNNL

User-prescribed fault orientation

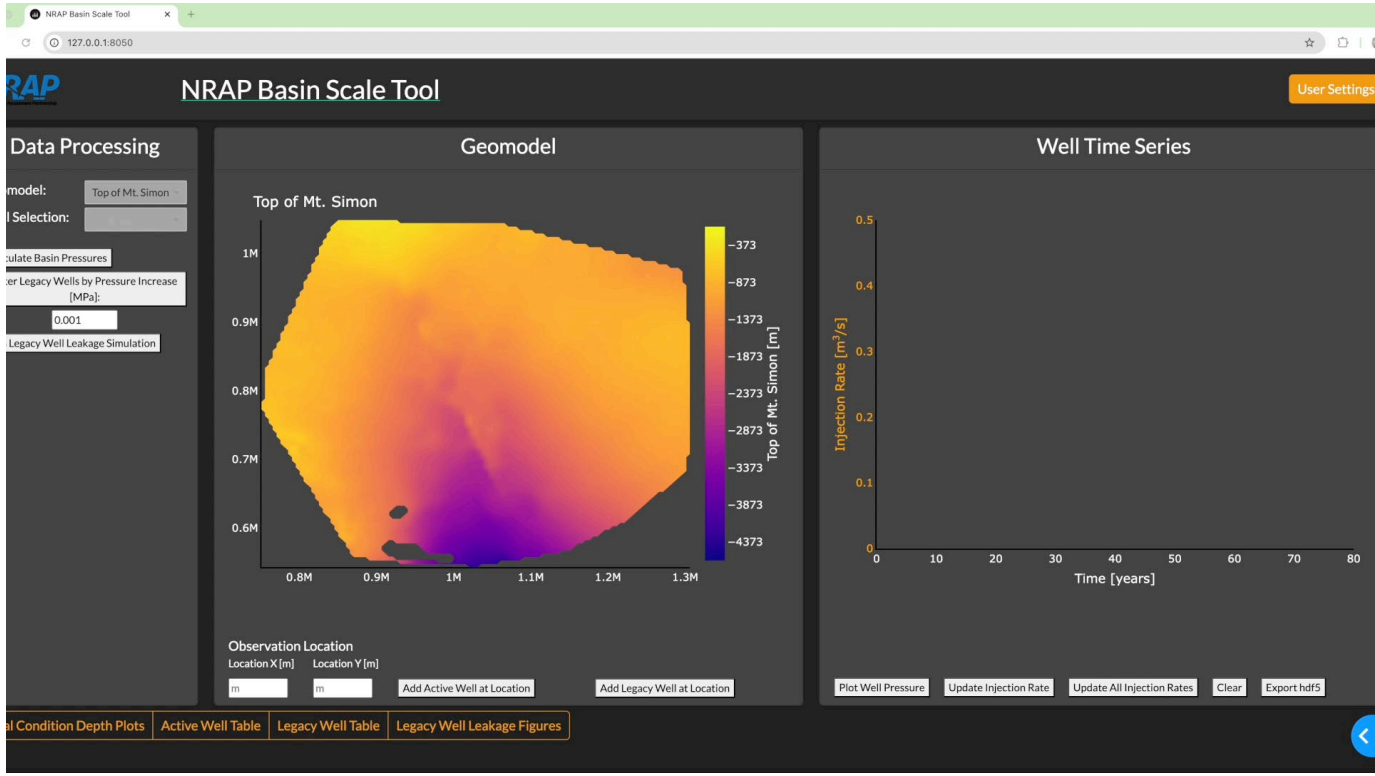
- Critically oriented faults are a conservative assumption; User-prescribed orientation is more realistic
- Performed sensitivity analysis with fault orientation – means to find risky orientations
- Evaluation of **geomechanical risk** (fault activation and hydraulic fracturing) in probabilistic approach for GCS projects on the basin-scale **completed.**



Basin-scale IAM Application

Subtask 6.4 Assessing and Managing Basin-Scale Risks
Ashton Kirol PNNL

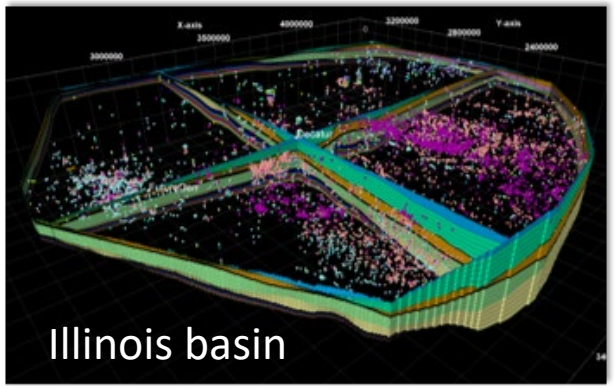
- Allows users to perform their own leakage risk assessment in the Illinois Basin.
- The risk assessment workflow for well leakage is captured in an application that can:
  - incorporate injection and legacy well as specified by user
  - calculate basin-scale pressure
  - filter out legacy wells that do not experience a pressure increase above a defined threshold
  - perform a legacy well leakage analysis
- Basin-scale application is available at https://gitlab.com/NRAP/basinscale
- Next steps:
  - Incorporate workflow for geomechanical risk analysis

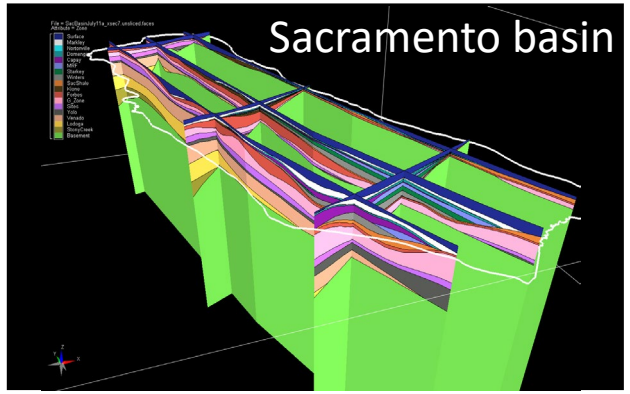


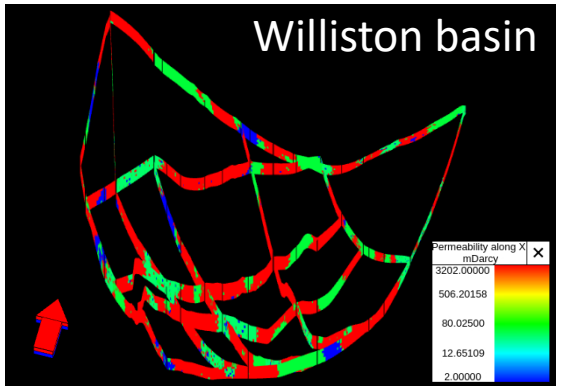
Basin Scale Pressure Interference

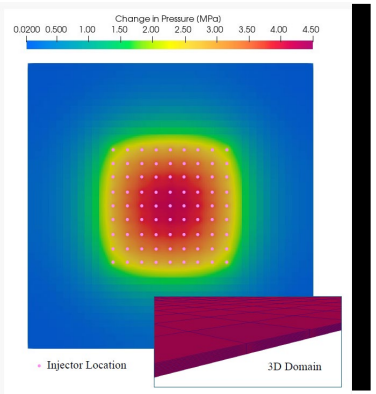
Understand pressure interference when many GCS projects operate in the same formation

Four geomodels to capture diverse geological settings

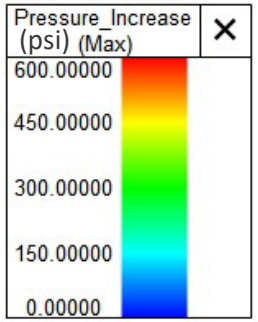


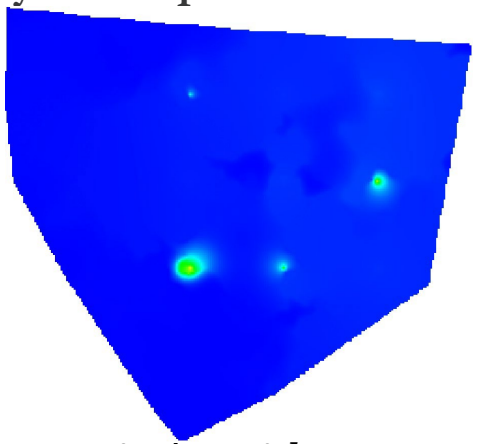




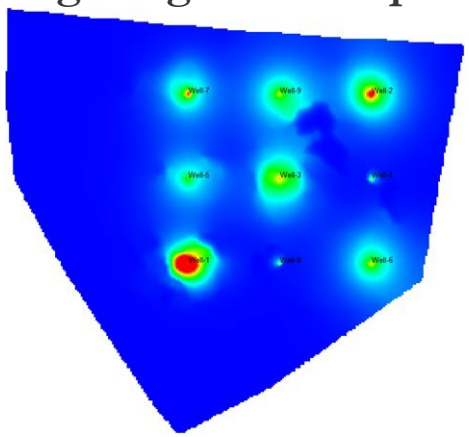


Quantify the impact of variation in geological and operational parameters on the basin pressure response

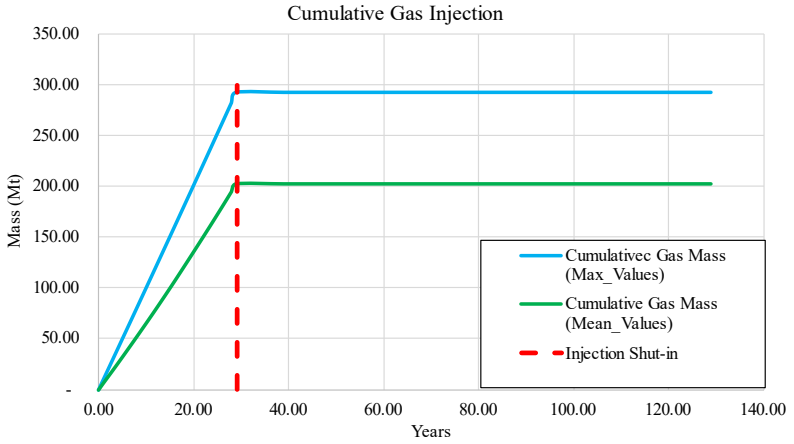




High ϕ and k



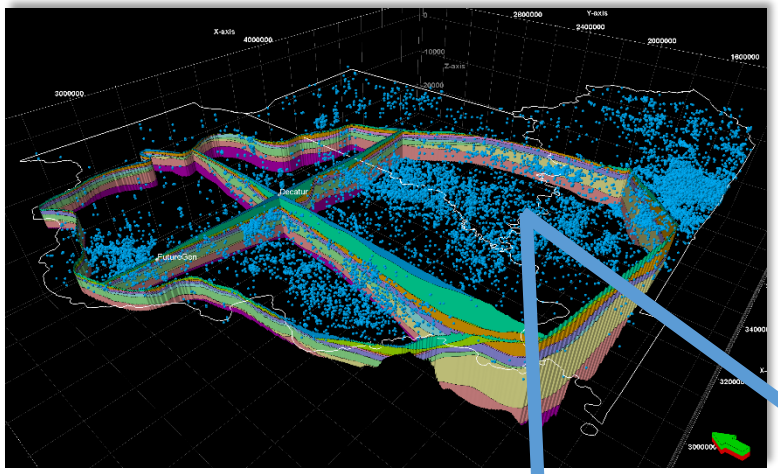
Medium ϕ and k



Basin Scale Risk Assessment

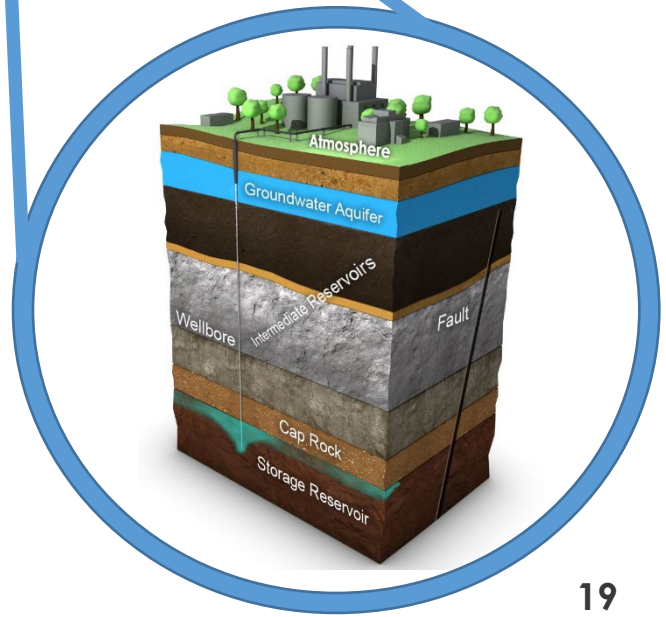
Contribution to commercial-scale GCS deployment

- Plan a new storage site
  - Estimate impact of preexisting storage sites on risk
  - Evaluate pressure management strategies
- Existing site can update risk assessment as new projects come online
- Evaluate potential to store CO_2 from all existing emitters
- Allow regulators to optimize storage across multiple permits



Basin Scale Risk Assessment

Site Scale Risk Assessment



Thank you!

Comments and Questions:

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