LA-UR-07-1635

Integration of CO_2-PENS and the Princeton Wellbore Release Model

Hari Viswanathan, Rajesh Pawar, Philip Stauffer, Seth Olsen, Tom McTighe and George Guthrie

Los Alamos National Laboratory

Dmitri Kavetski, Jan Nordbotten, and Mike Celia

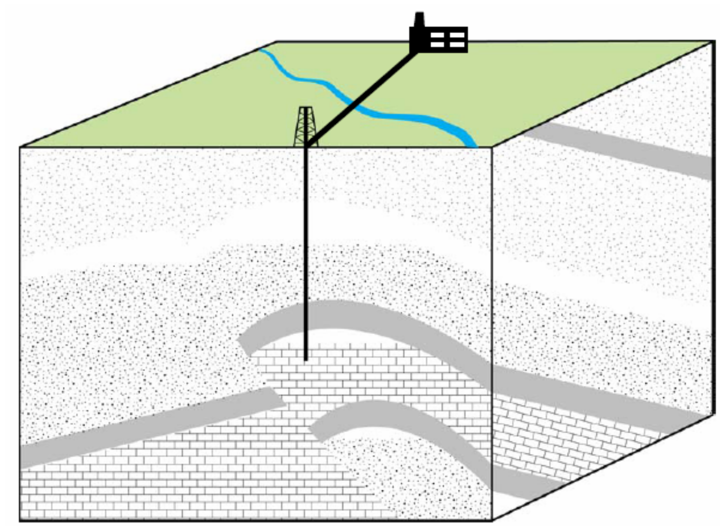
Princeton University

Los Alamos NATIONAL LABORATORY EST.1943

Outline

- CO2-PENS introduction
- Integrating the Princeton CMI Wellbore release model into CO2-PENS
- Example Impacts
  - Groundwater wells
  - Atmospheric CO2 concentrations
  - Other subsurface reservoirs

Quantitative Risk Assessment for Long-Term Storage of CO_2 in Engineered Geologic Systems

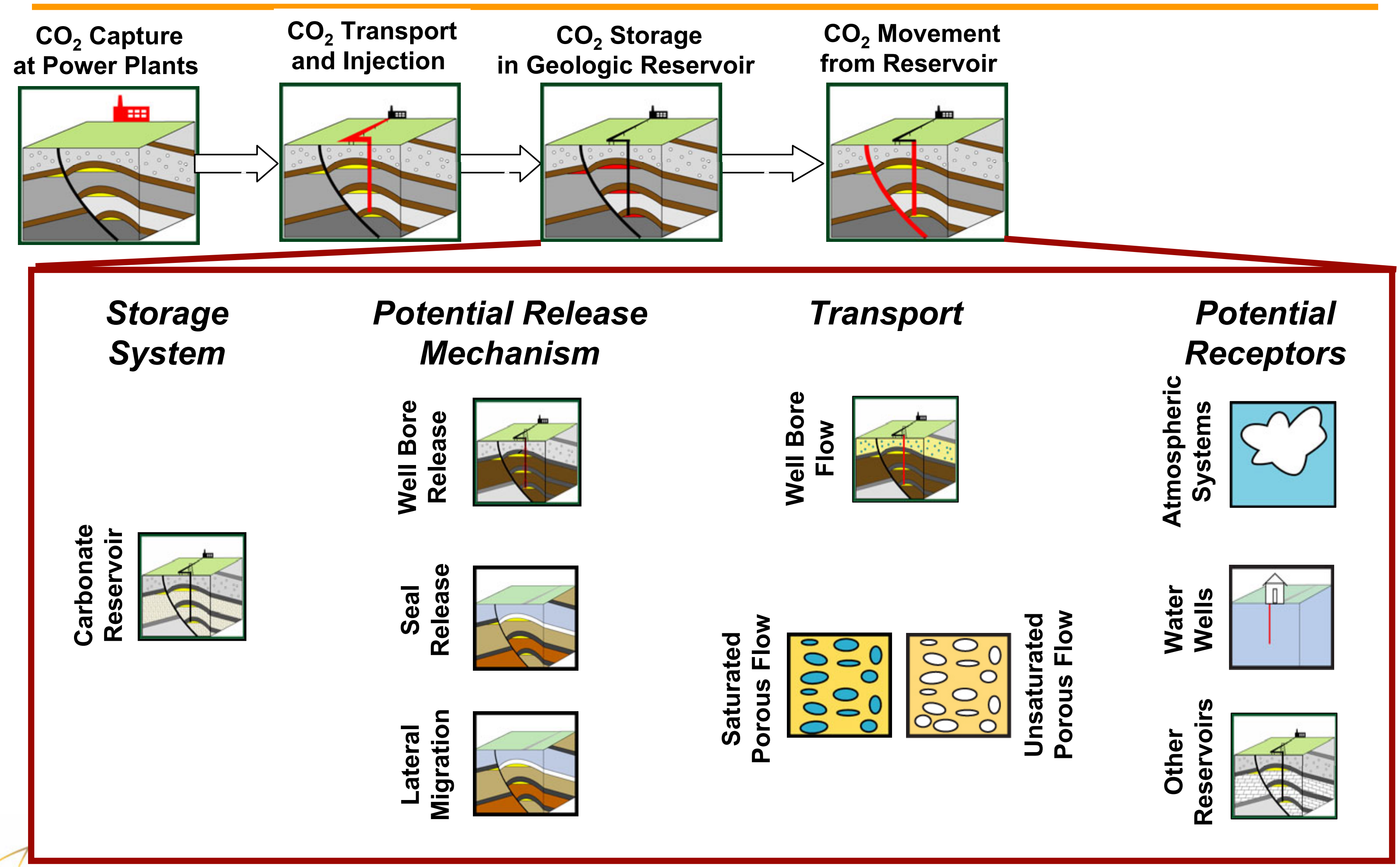


- **Risks to consider in CO_2 storage**
  - Economic-environmental-health
  - Short-term vs. long-term
- **Science based prediction for risk assessment**
  - Integration of field observations with theory-experiment-computation
  - Uncertainty and heterogeneity in natural systems
- **Integrity of cemented wellbores**
  - CO_2+brine is acidic, cement is basic
  - Long-term fate of cement
  - Migration of CO_2 through cement

Risk Assessment: Some Definitions

- Features/Events/Processes (FEPs) Analysis
- Performance Assessment (PA)
- Risk = Event Probability x Event Consequence
- Quantitative Risk Assessment (QRA)

Performance Assessment Framework



CO_2-PENS Performance Assessment Tool

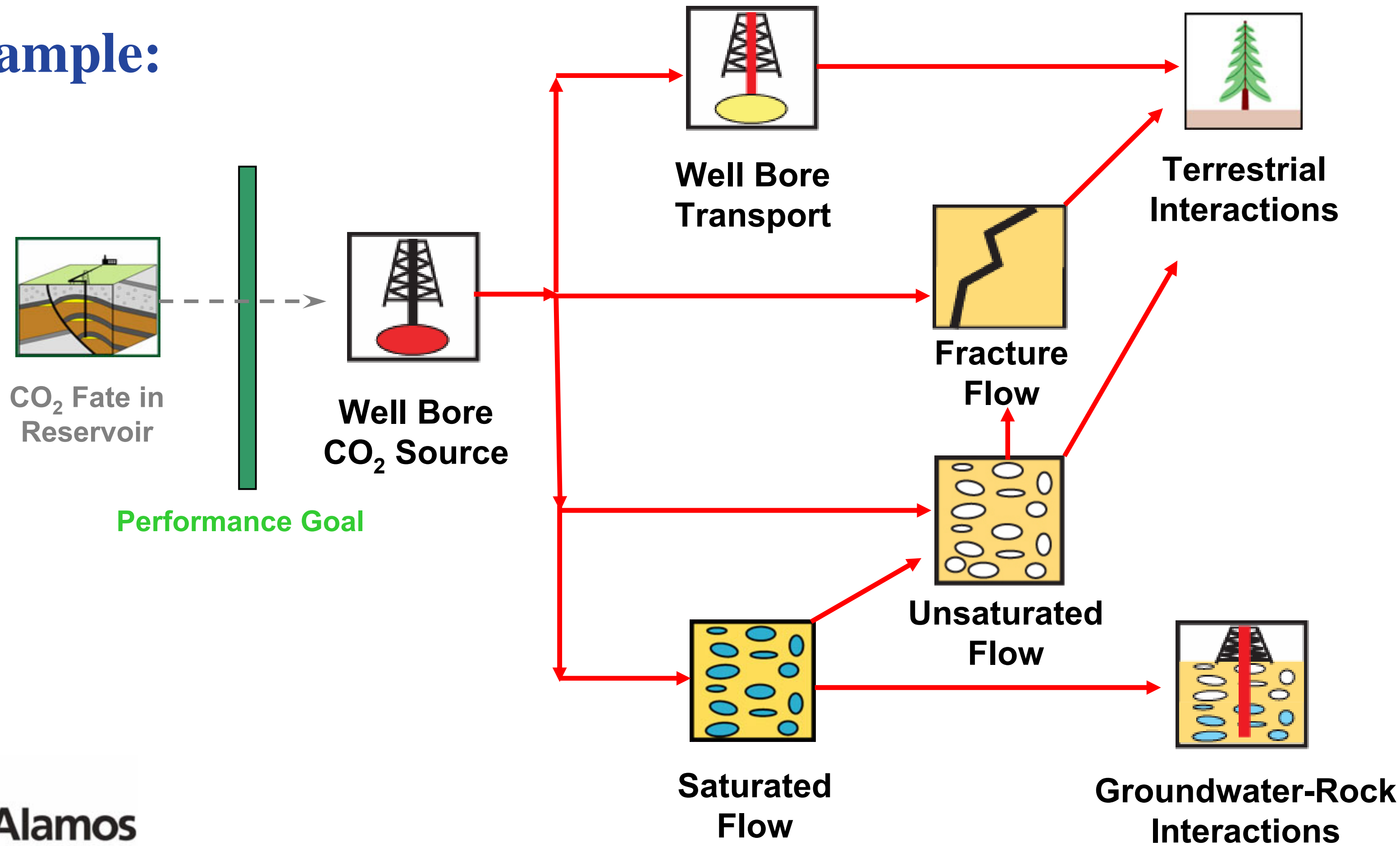
Modular, system level model to perform comprehensive analysis of CO_2 sequestration sites

- Simulate CO_2 transport & migration
- Integrates physics/chemistry based modules described by analytical/semi-analytical/detailed numerical models.
- Can be used to assess & certify specific storage sites.
- Can be used to tailor MMV & engineering options to specific sites.
- Supports a science based quantitative risk assessment.

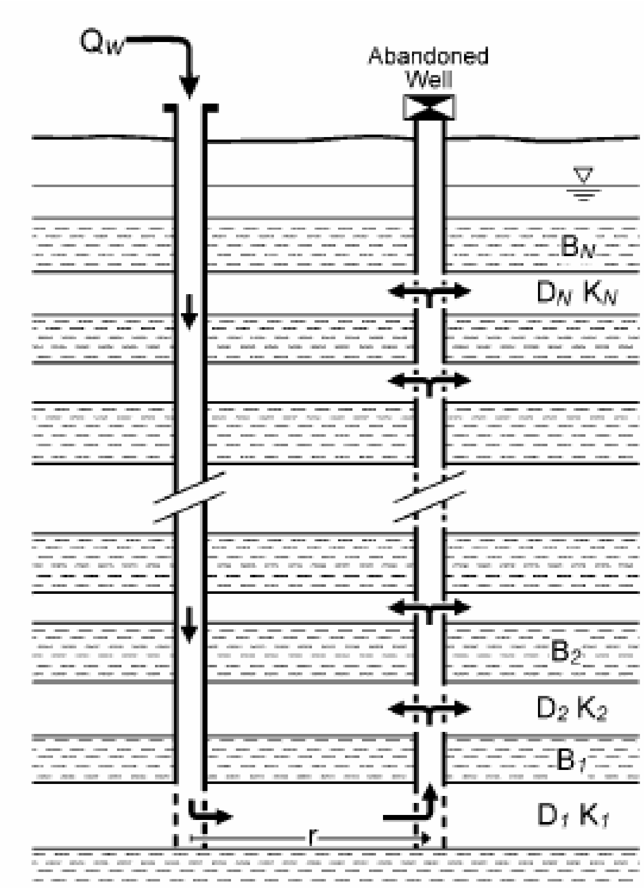
Motivation: understanding wellbore release pathways

Need to predict probability of wellbore failure and migration of CO_2 subsequent to release, to understand the impact of wellbore failure

Example:



Princeton CMI Model Underpinning CO2-PENS

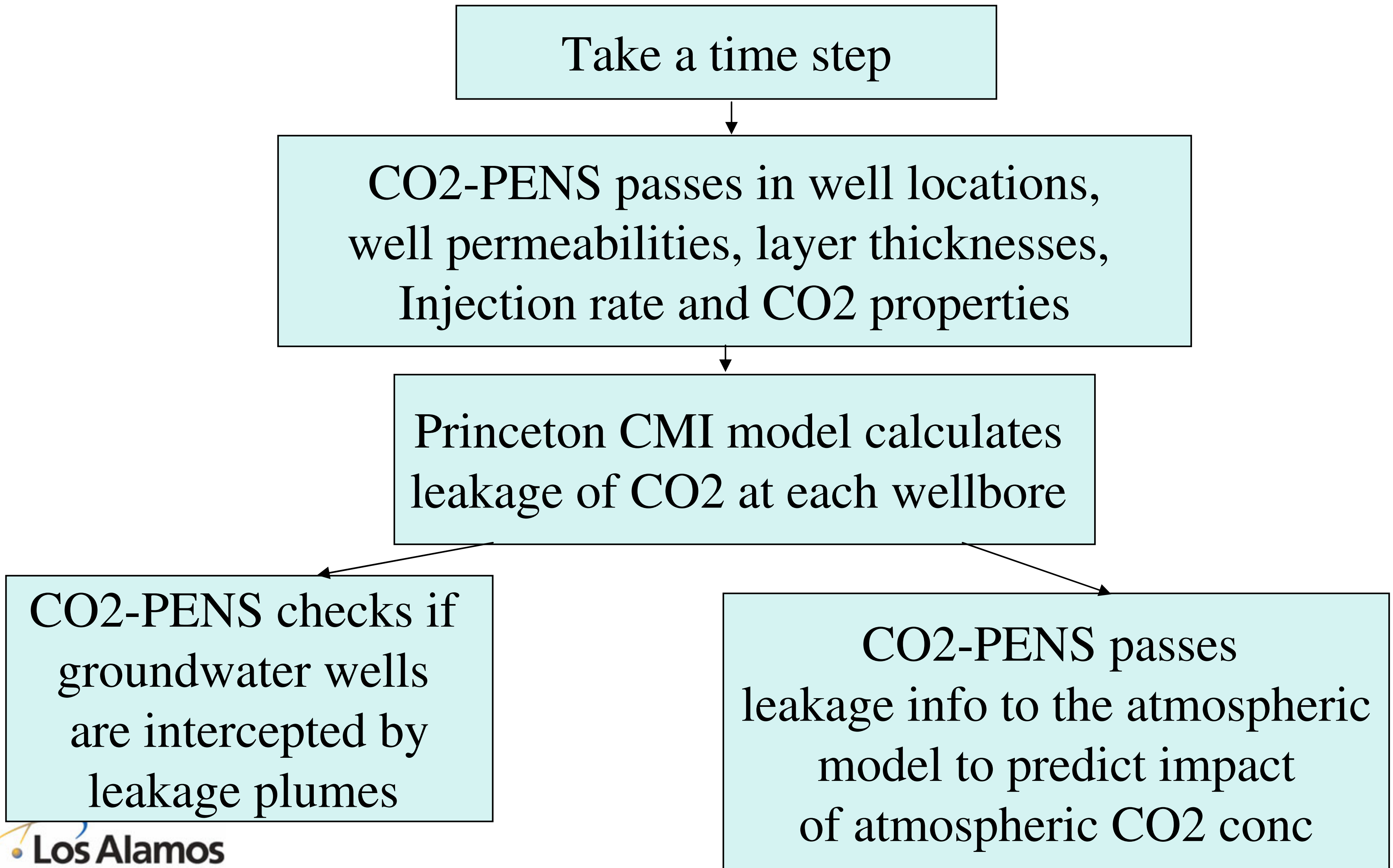


- Semi-analytical model describing wellbore release
- Stratified layers, one injection well, multiple existing wells
- Computationally efficient
- Multiphase physics

Modifying the PRINCETON CMI Release Model to create a CO2-PENS wellbore release module

- Assumptions
  - No post injection simulation (beta version exists)
  - No phase change
  - Top layer of the Princeton CMI model lies below the critical point
- Links to CO2-PENS
  - Amount injected depends on power plant capacity, capture efficiency, CO2 properties, etc.
  - Leakage plumes around existing wells used to detect if groundwater wells are affected by CO2
  - Leakage flux leaving the Princeton CMI model used to calculate impact on near surface concentrations
  - User chooses percentage of CO2 leaving top layer of Princeton CMI model

Schematic of Integrating Princeton CMI Model into CO2-PENS



Example

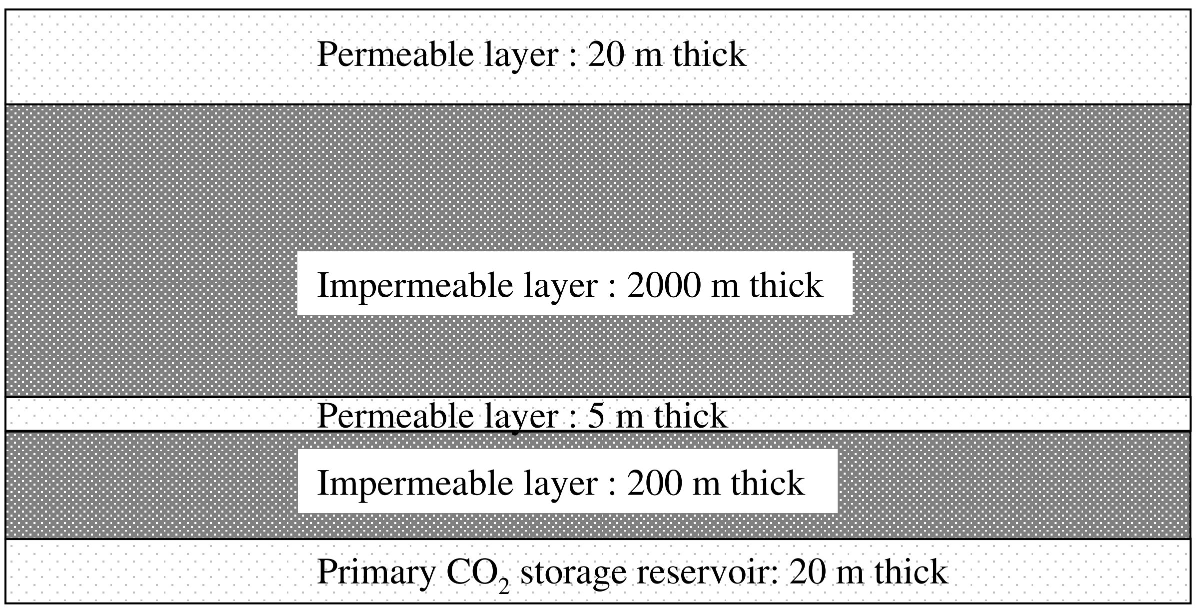
- A hypothetical reservoir
  - Constant reservoir thickness, area
  - Two cases: shallow (1 km) and deep reservoir (3 km)
  - Depth dependent pressure, temperature, fluid properties

- CO_2 output from a 1000 MW coal fired power plant

- 100 realizations, each simulating 50 year injection

Example Geometry

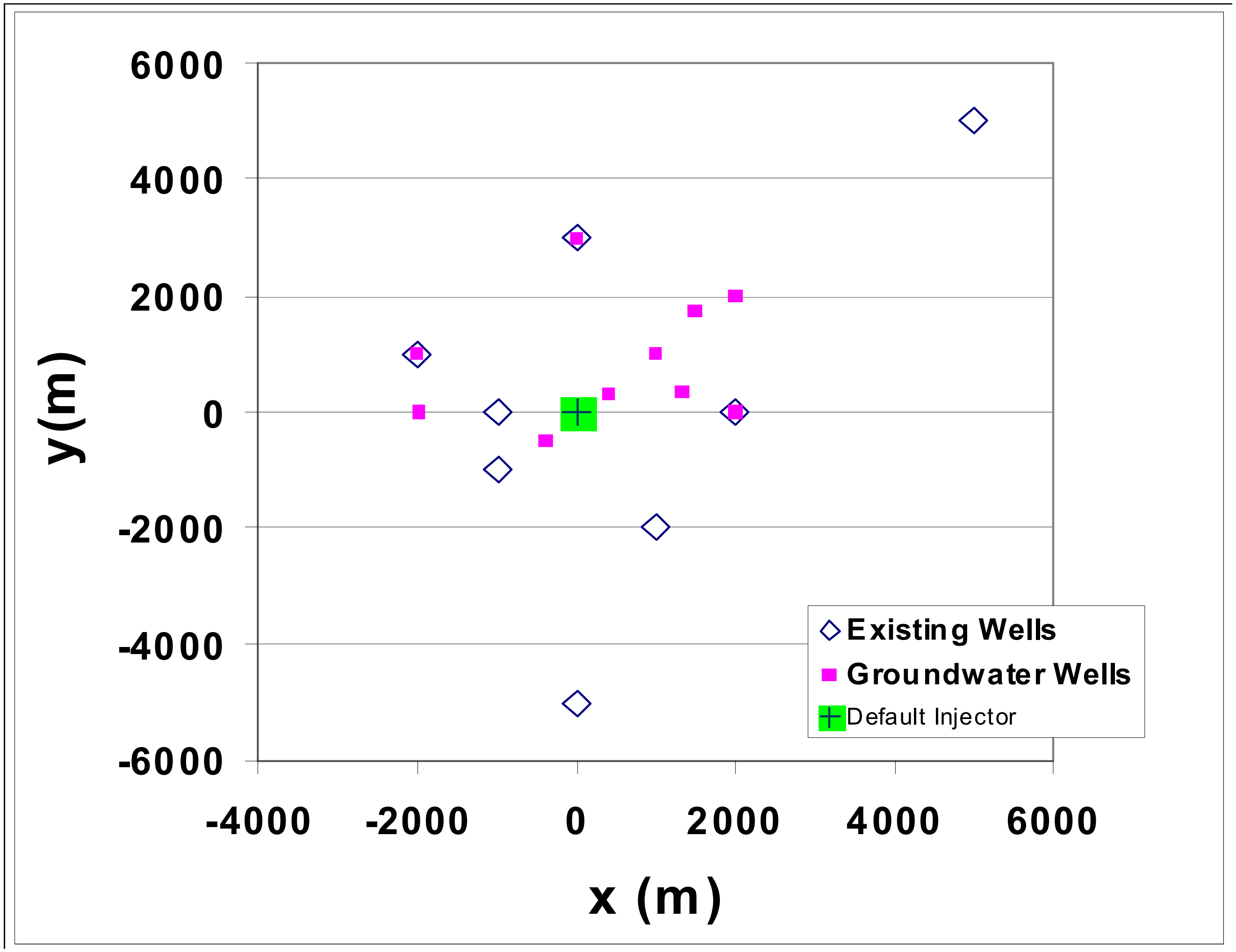
- Injection and wellbore release calculations performed using the Princeton CMI module in CO_2-PENS
  - CO_2-PENS provides input parameters to Princeton model DLL
  - Results from Princeton model are suppled to other CO_2-PENS modules.
- Hypothetical sequestration site:



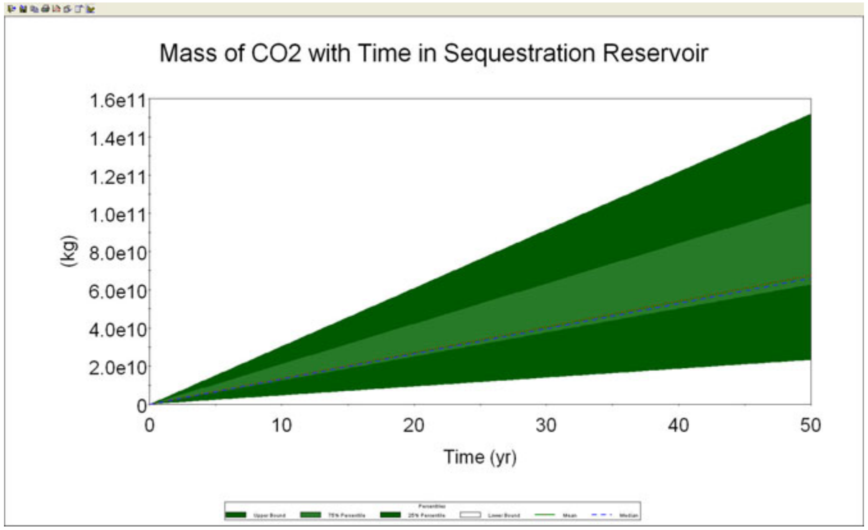
Example Parameters

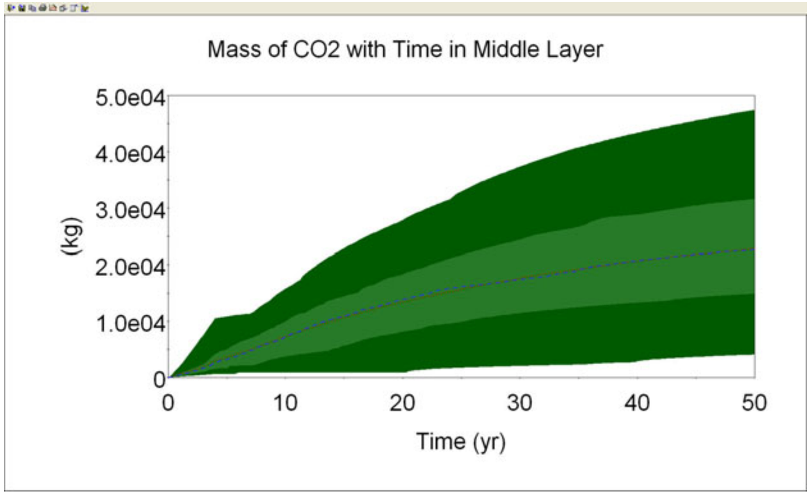
- 9 injection/production wells: 1 injection well, with 8 existing wells
- 10 groundwater wells
- 2 log-normal distributions used for wellbore cements:
  - Distribution 1: Mean $3x10^{-15}$ m^2, Std. Dev. $1x10^{-16}$ m^2
  - Distribution 2: Mean $1x^{-14}$ m^2, Std. Dev. $1x10^{-17}$ m^2
- Permeability & porosity of permeable layers sampled from distributions.
  - Distributions generated using GIS tools from well database
- Injection rate sampled from a distribution.
  - 50 years of injection
- Monte-Carlo simulations
  - Values of stochastic parameters for each realization provided to Princeton model

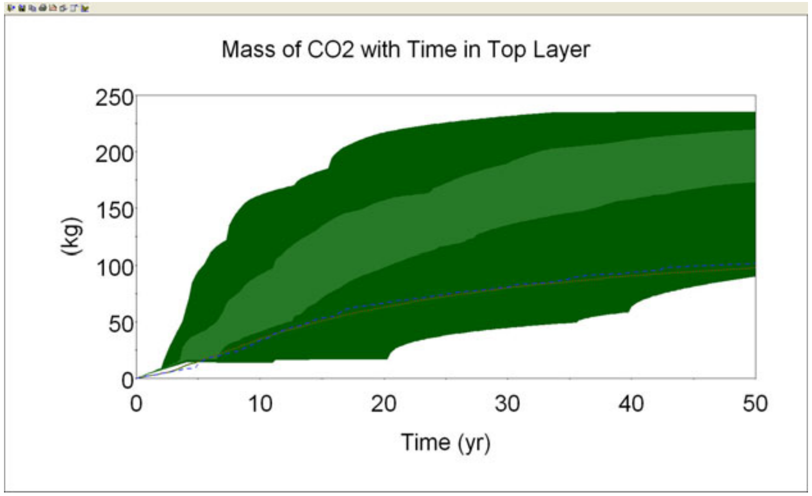
Well locations schematic



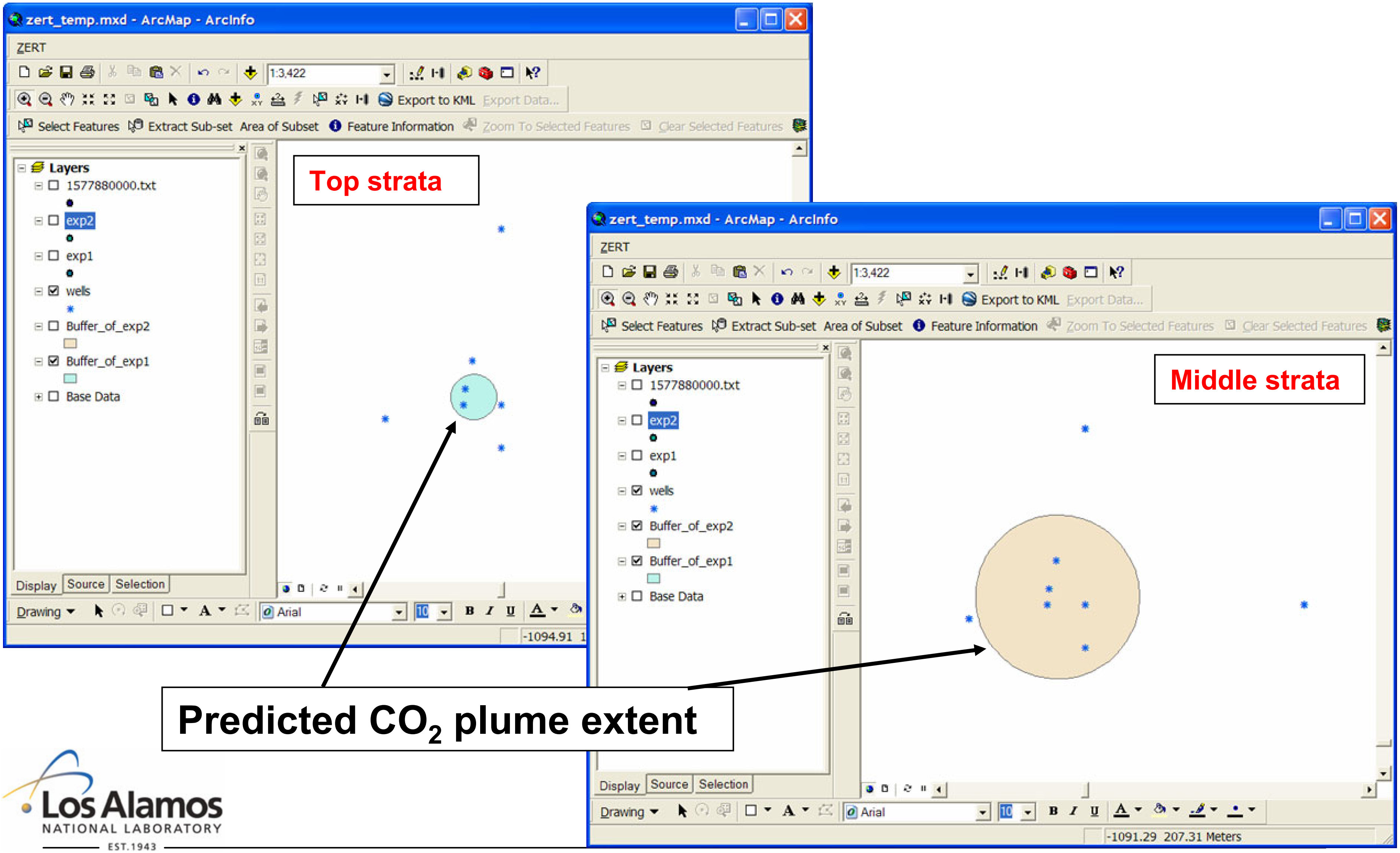
Prediction of CO_2 mass in three strata





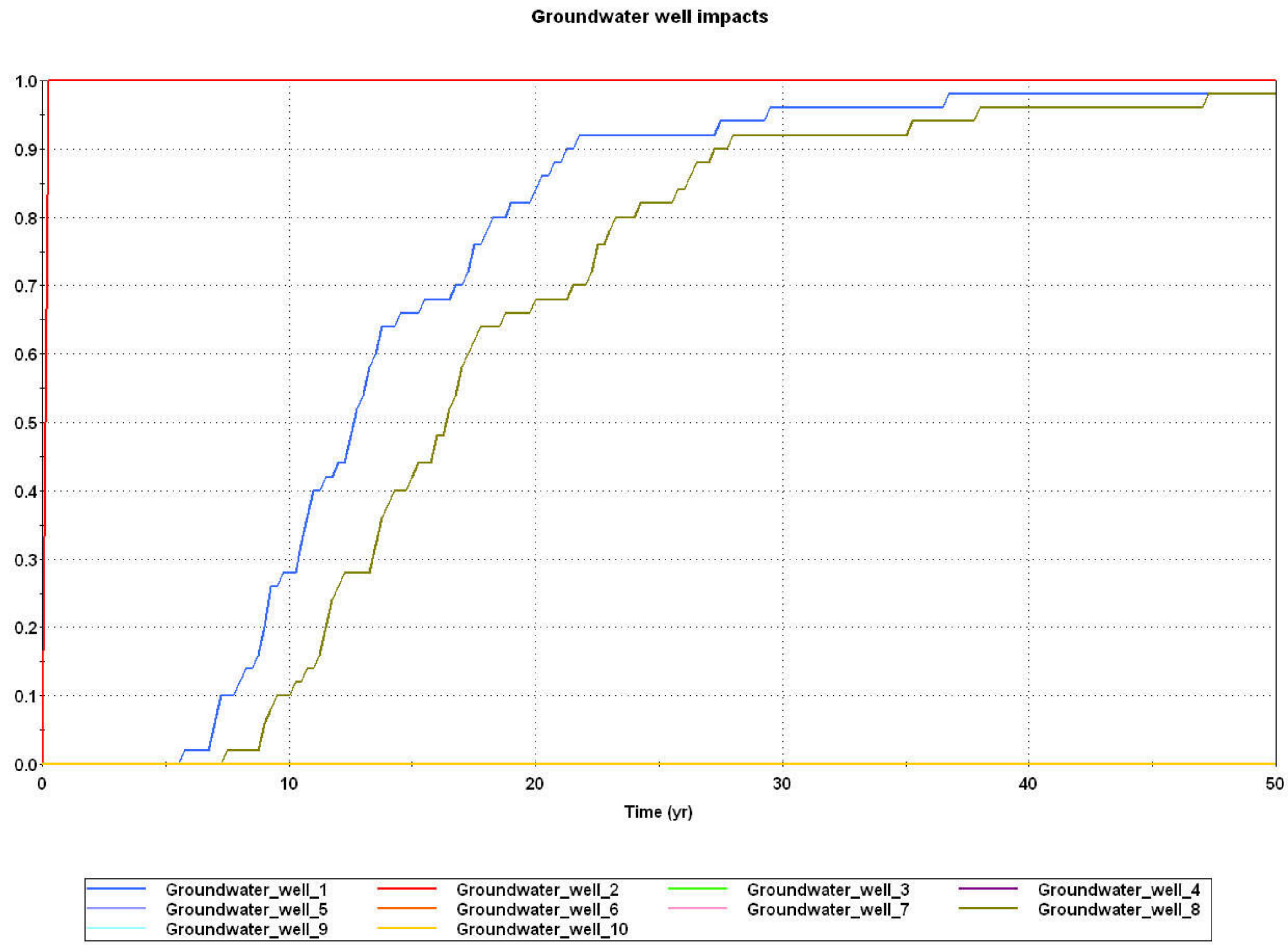


GIS tools used to show groundwater well impacts



Los Alamos NATIONAL LABORATORY EST.1943

Princeton CMI Module Determines which Groundwater Wells are Impacted and When



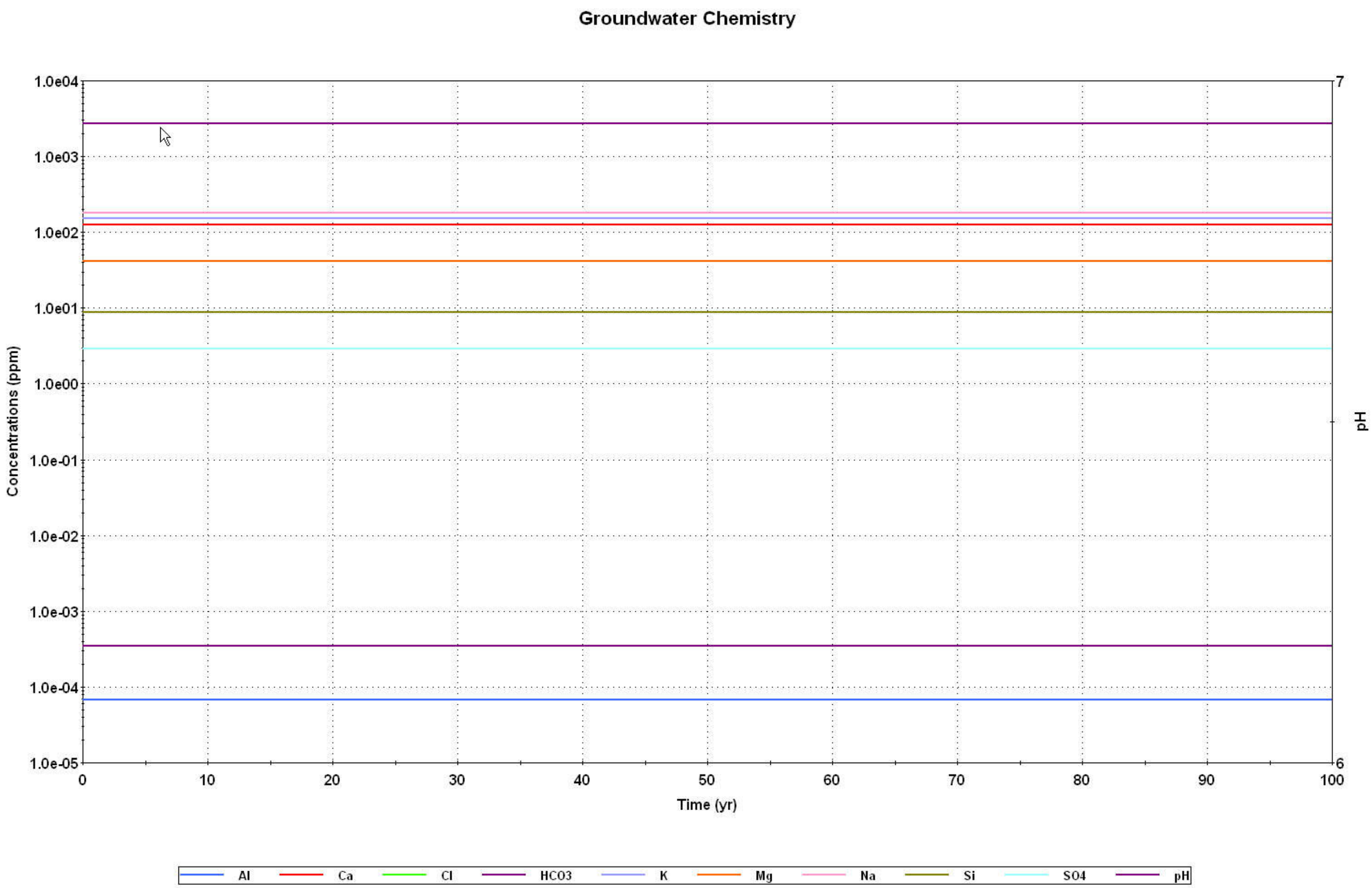
This graph goes to 1 when a well is impacted.

Los Ala
NATIONAL LABORATORY
EST. 1943

Groundwater Chemistry of Impacted Wells

- For impacted groundwater wells, we have linked CO_2-PENS to USGS code PHREEQC to calculate the change in groundwater chemistry due to CO_2
- Given the partial pressure of CO_2, the model calculates the equilibrium chemistry of the groundwater in contact with either carbonate or sandstone mineralogy

Groundwater Chemistry of Impacted Wells Using PHREEQC

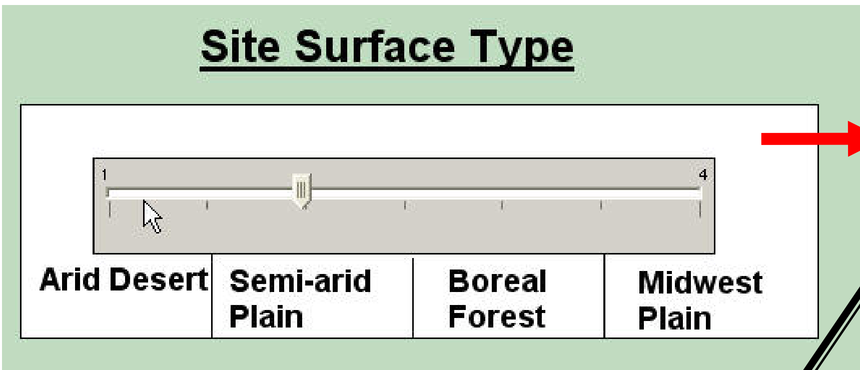


Los Alamos NATIONAL LABORATORY EST.1943

Atmospheric Model Details

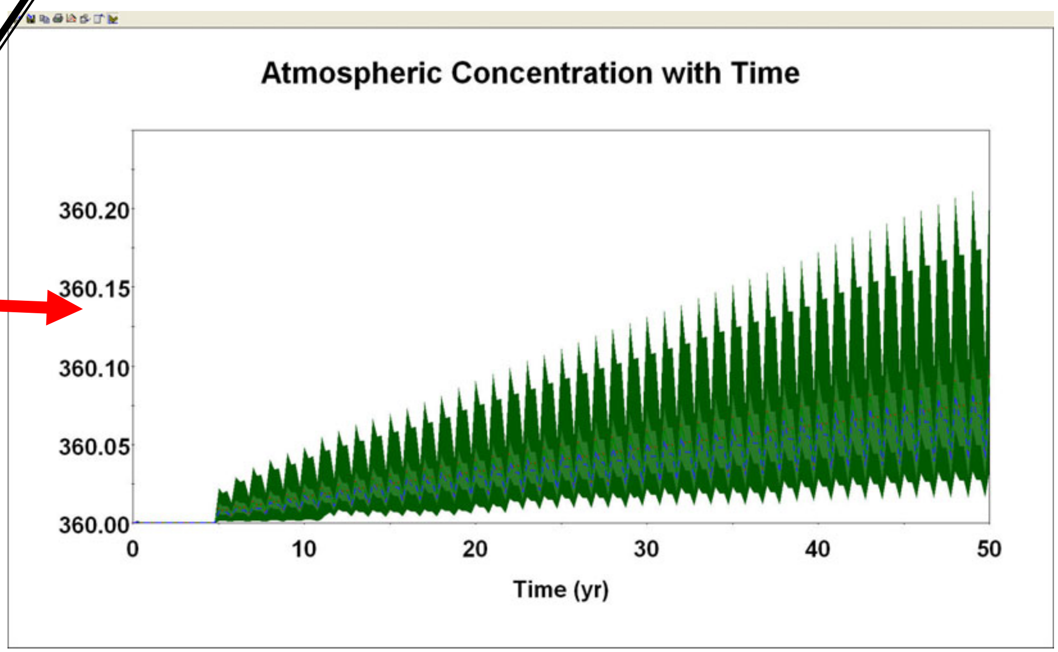
- Atmosphere split into two layers
  - Well mixed layer near the earth's surface
  - A free troposphere: surface conditions have little effect
  - CO_2 input from the ground surface
  - CO_2 leaving as the boundary layer mixes with the troposphere
  - Diffuse leak source

Princeton CMI Module linked to Atmospheric Module

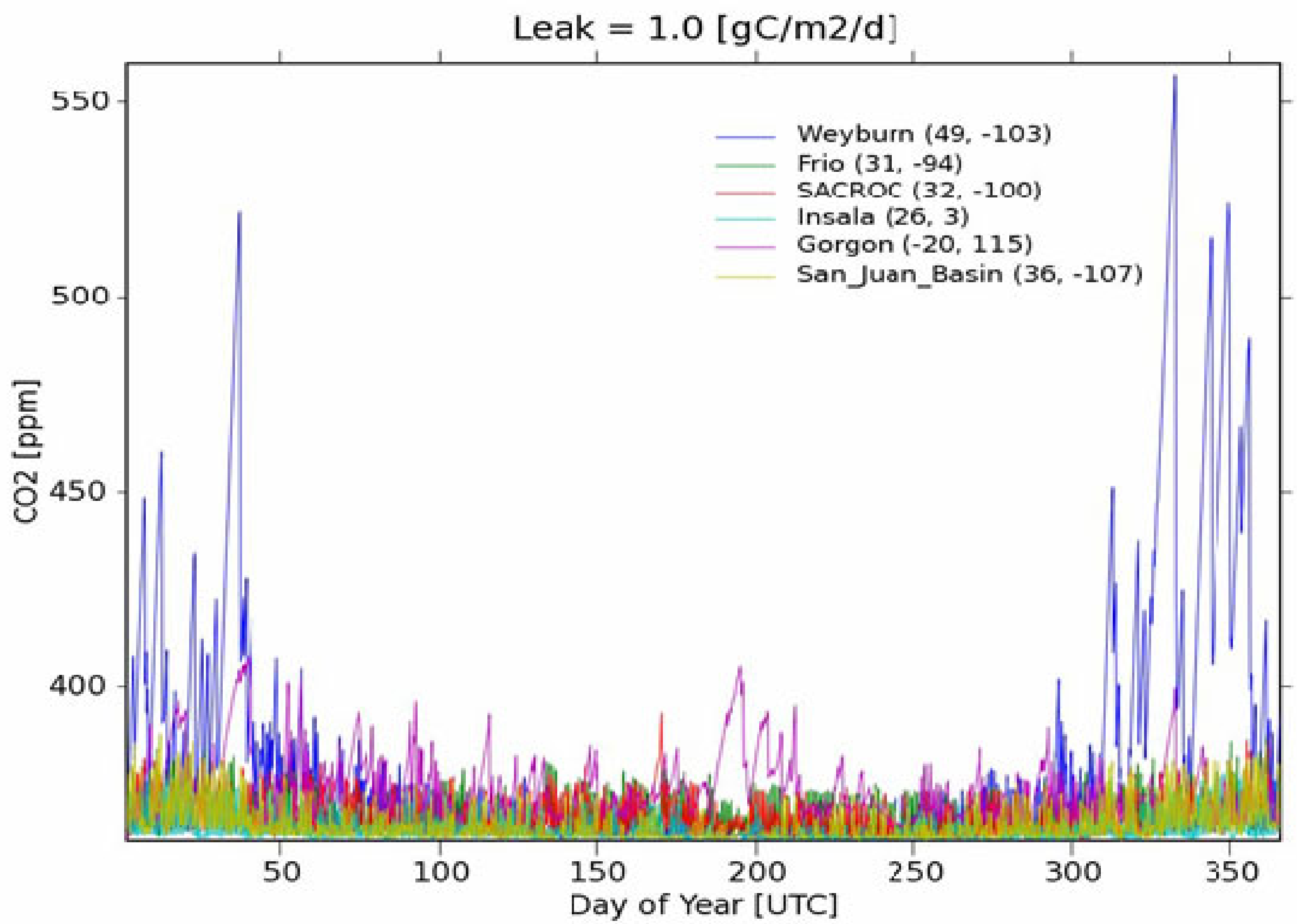


Input type of topography to access data on local atmospheric mixing conditions

Local atmospheric mixing conditions and predictions of CO_2 leak flux are used by the atmospheric module to calculate changes in local atmospheric CO_2 concentrations



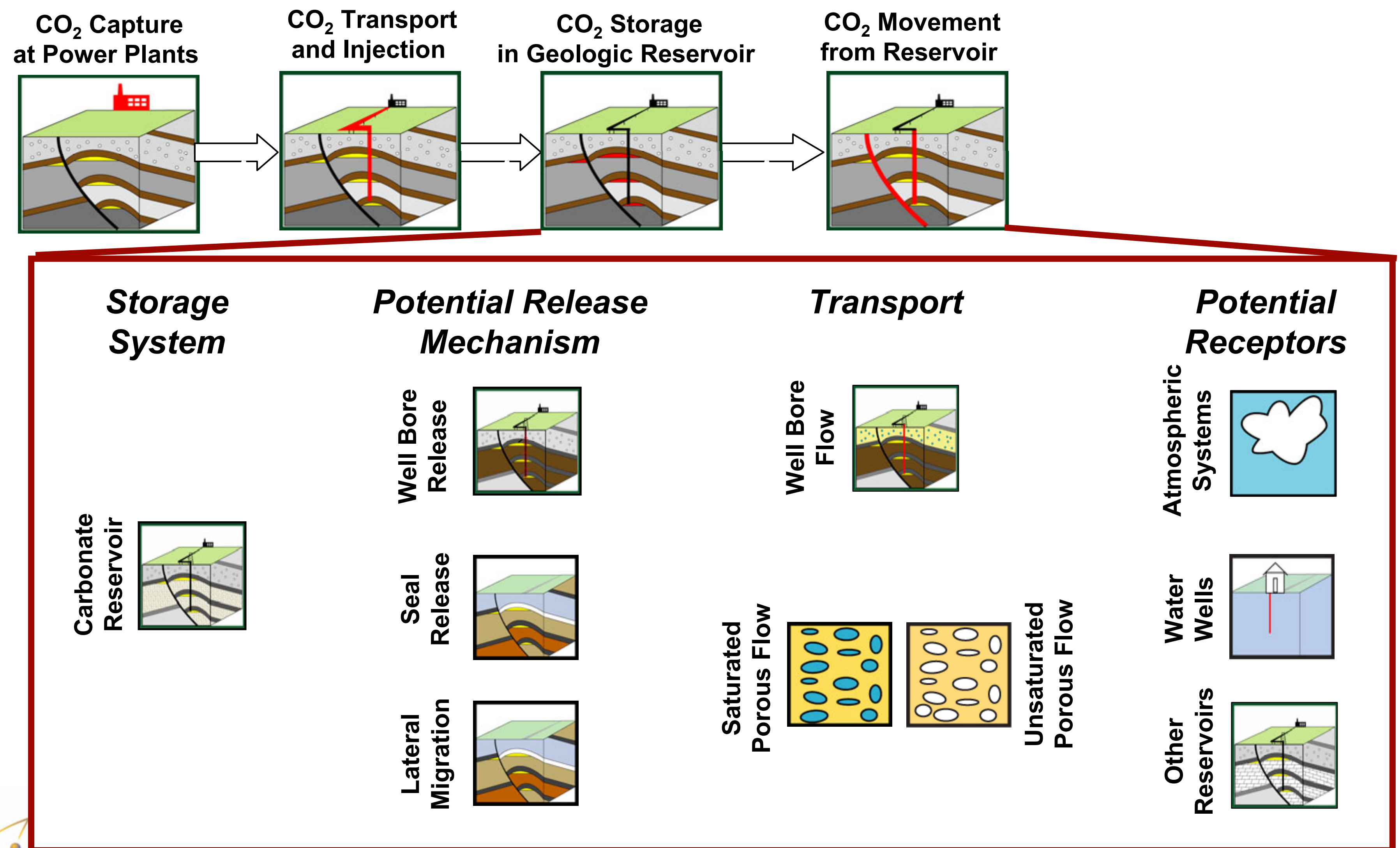
Example: prediction of daily changes in atmospheric CO_2 concentrations at global sequestration sites



Conclusions

- The Princeton CMI model was modified to create a new CO_2-PENS module for wellbore release.
- This module is coupled to the atmospheric and groundwater impact modules
- This demonstrates that the CO_2-PENS system level model is supported by strong scientific process modules.
- Large scale deployment of geologic CO_2 sequestration will require expanding this approach to include more modules

Risk Analysis Will Require Impact Analysis



LA-UR-07-1635

Contacts for further information on CO_2-PENS

Phil Stauffer, stauffer@lanl.gov

Hari Viswanathan, viswana@lanl.gov

Rajesh Pawar, rajesh@lanl.gov

George Guthrie, gguthrie@lanl.gov