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Regulatory/Oversight Programs

Certification Framework for Geologic CO_2 Storage

Curtis M. Oldenburg (LBNL)

Steven L. Bryant (UT, Austin)

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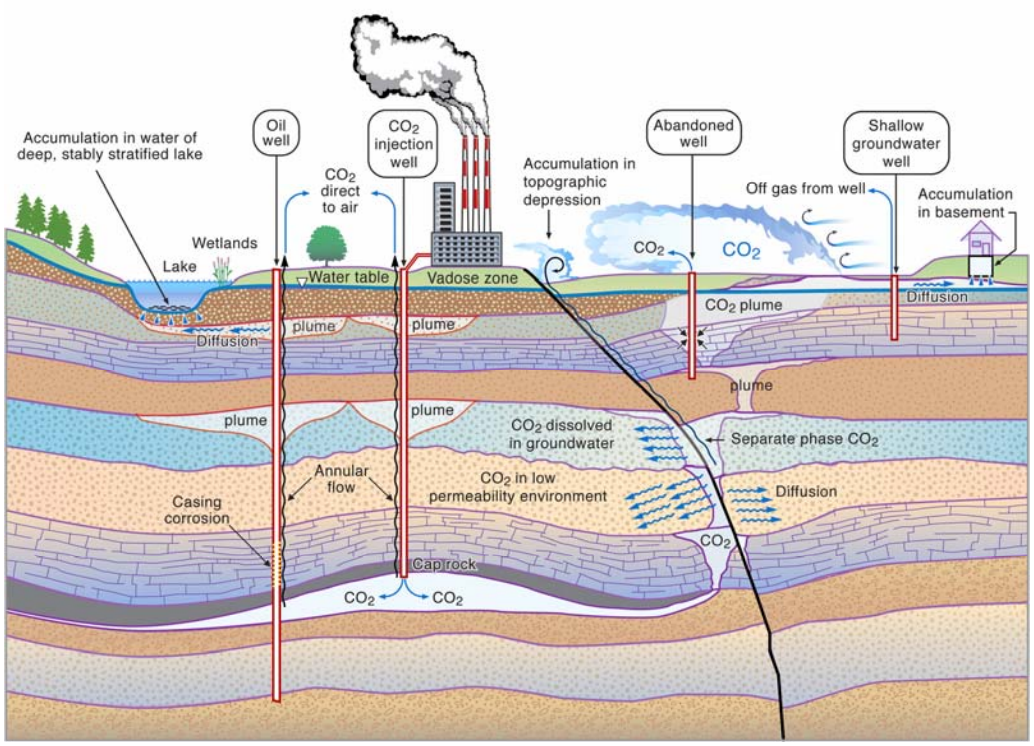
Outline

- Motivation for Certification Framework (CF)
- Overview of philosophy and approach
- Effective Trapping Requirement
- CO_2 Leakage Risk
- Methods of CO_2 Leakage Risk calculation
    - Compartments
    - Conduits
    - Impacts
    - Intersection of CO_2/conduits/compartments
- Elements of the CF project
- Summary

Motivation for CF



Critical to the large scale deployment of CCS is a simple, transparent, and accepted basis for regulators and stakeholders to certify that the risks of geologic CCS projects to HSE and resources are acceptable.

Certification Framework Overview

- Theory and Philosophy of Certification Framework
  - Effective Trapping requirement
  - CF is based on CO_2 Leakage Risk
  - Compartment concept
  - Broad classes of features
  - Catalog of model results
  - Model results are from sophisticated modeling of simplified systems
  - CF is probabilistic in existence of flow pathway, deterministic in flow along pathway
- Inputs are properties and definitions of the injection system
- Outputs are CO_2 Leakage Risk numbers for impacts to various compartments

Underground Injection Control (UIC)

- Class 1H are wells used to inject hazardous liquid waste.
- Requirement for certification is projection that no migration will occur from the injection zone while the waste remains hazardous (or for 10^4 years).
- USDW (Underground Source of Drinking Water) is primary concern.
- Class I well injection is deeper than (below) USDW.
- Injected fluids are nearly always denser than native fluids.

Under these conditions, the non-migration requirement is relatively easy to meet.

Main Differences Between Liquid Disposal and CO_2 Storage

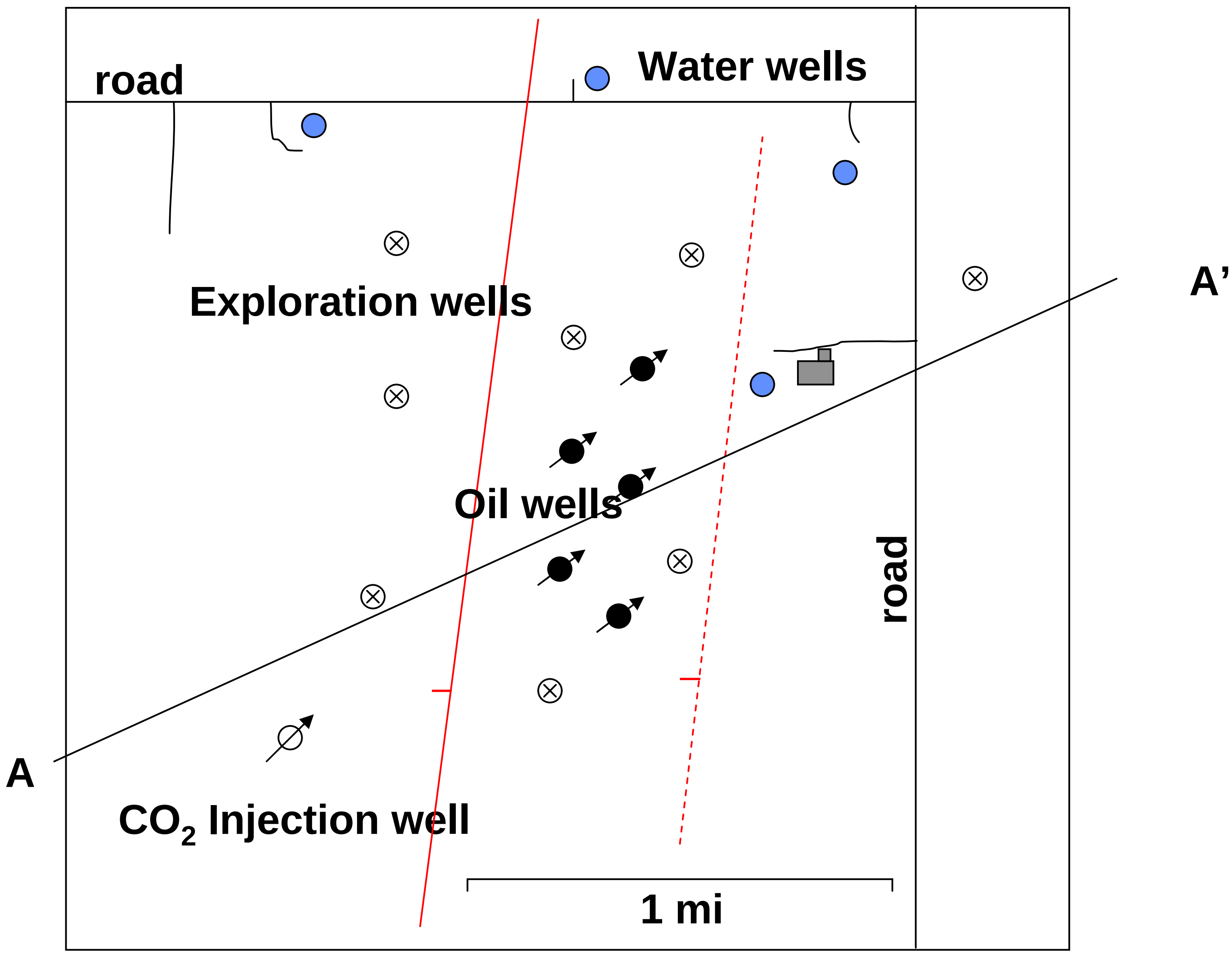
Liquid Disposal	CO_2 Storage
Liquid phase injectate	**Supercritical fluid, gas-like viscosity**
Density often greater than brine	**Density always less than brine**
Single-phase flow	**Multiphase flow**
Small volumes, low injection rates	**Large volumes, injection rates**

Implications for CO_2 Storage

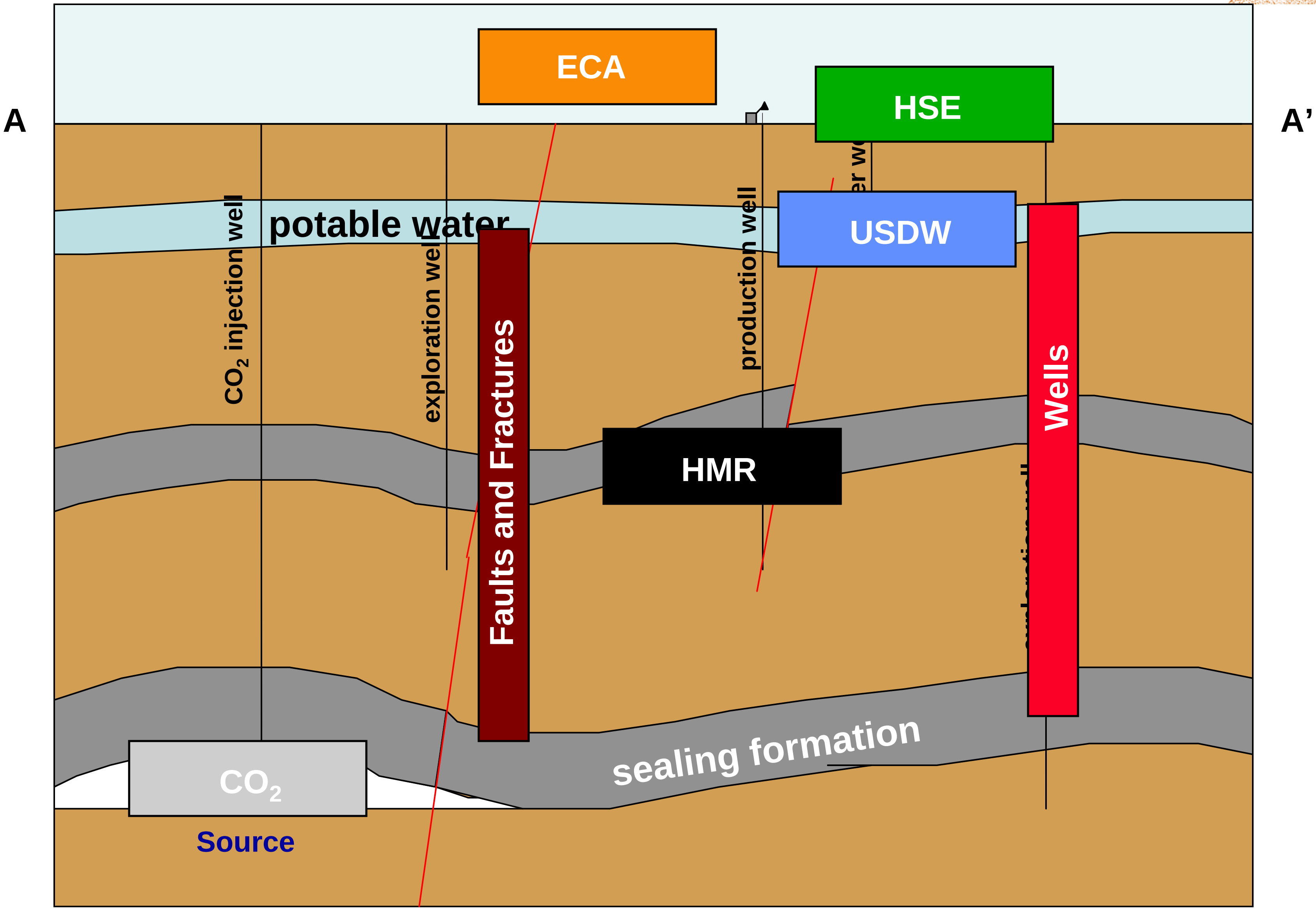
CO_2 immiscible with native fluids, highly mobile
CO_2 has tendency to migrate upwards
CO_2 may finger/bypass native fluids
CO_2 Area of Review may be very large

Key CF Definitions and Concepts

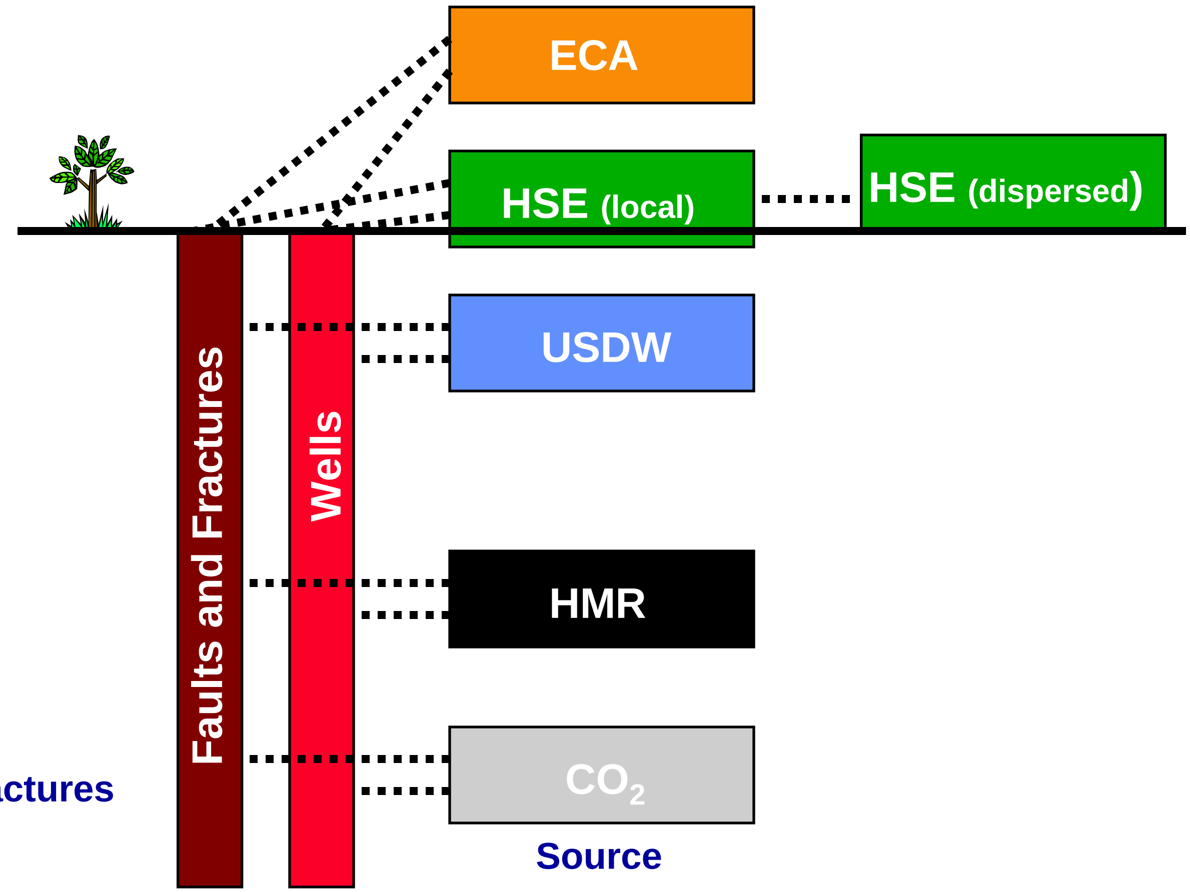
- **Effective Trapping** is the proposed overarching requirement for safety and effectiveness.
  - Effective Trapping implies that CO_2 Leakage Risk is below agreed-upon thresholds.
- **Storage Region** is the three-dimensional area of the subsurface intended to contain injected CO_2.
- **Leakage** is migration across the boundary of the Storage Region.
- **Compartment** is a region containing vulnerable entities (e.g., environment and resources).
- **Impact** is a consequence to a compartment, evaluated by proxy concentrations or fluxes.
- **Risk** is the product of probability and consequence (impact).
- **CO_2 Leakage Risk** is the probability that negative impacts will occur to compartments due to CO_2 migration.


road
Water wells
Exploration wells
A'
Oil wells
road
A
CO_2 Injection well
1 mi

Example Cross-Section



Compartments and Conduits



Two Conduits:

- **Wells**
- **Faults and Fractures**

Four Compartments:

- **ECA = Emission Credits and Atmosphere**
- **HSE = Health, Safety, and Environment**
- **USDW = Underground Sources of Drinking Water**
- **HMR = Hydrocarbon and Mineral Resources**

Factors in CLR (CO_2 Leakage Risk)

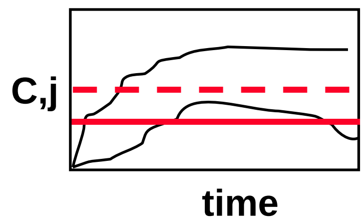
Impact X Probability

Receptors reside within compartments

(HSE, USDW, HMR, ECA)

Exposure to compartments leads to potential impact (CO_2 conc. (C) and flux (j) over time)

Limits are defined



Fault or well intersecting CO_2

Fault or well being conductive

Fault or well intersecting compartment

(Total probability is the product of the individual probabilities)

Exceeding limits = Impact [=] conc.-time, or flux-time

Impact X Total Probability = CLR

e.g., CLR [=] no. of conc.-time events/time

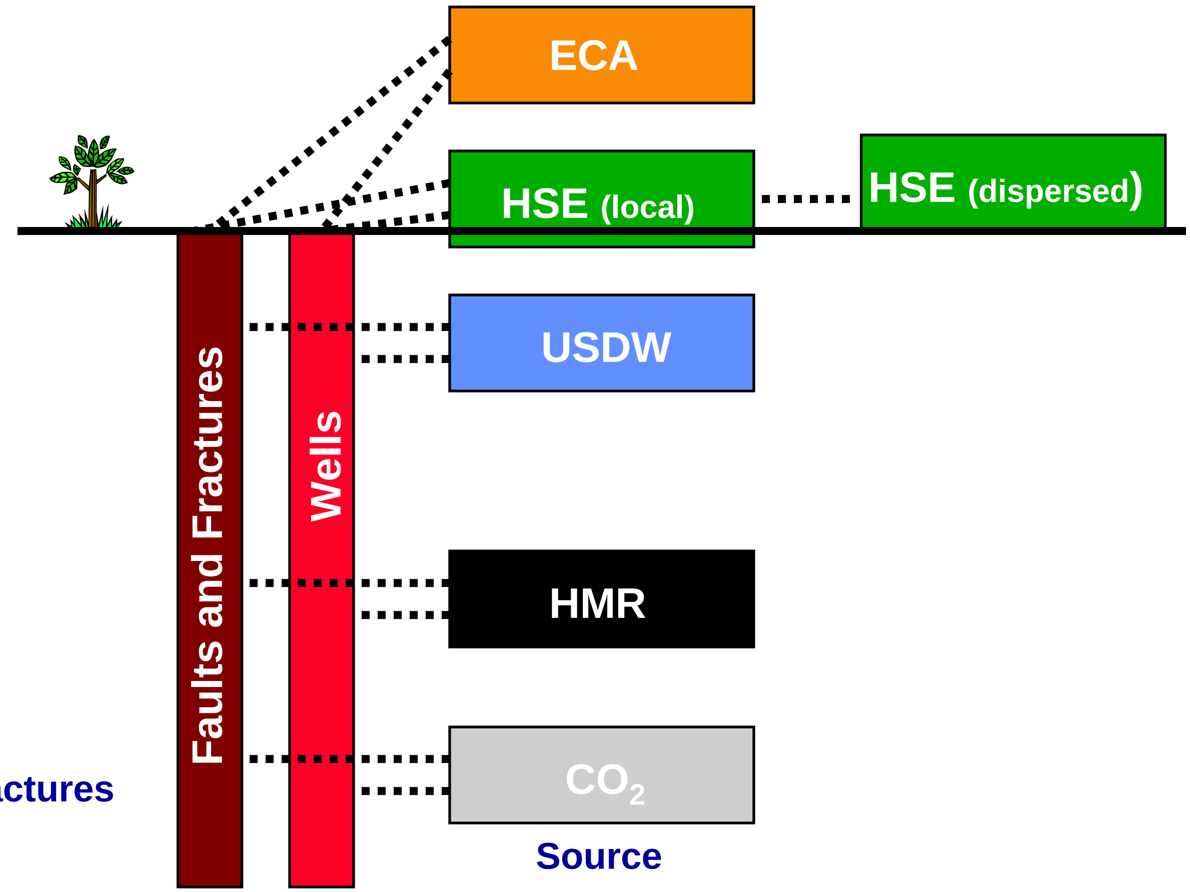
Examples of Impacts

- Exceeding concentration limit at a receptor
  - E.g., 0.4% CO_2 in air in an HSE compartment (indoors, local)
- Exceeding flux limit at a receptor
  - E.g., CO_2 flux greater than 100 times background to the USDW compartment.
- Exceeding time-integrated conc. or flux at a receptor
  - E.g., Concentration of CO_2 exceeds ten days of greater than 0.1% CO_2 in an HSE compartment (outdoors, local).

Limits and Thresholds

- (1) Limits of flux, concentration, and their time-averaged forms need to be set for the compartments
  - —Pertains to impacts that can occur due to exposure of compartments to CO_2.
- (2) Thresholds of CLR in compartments need to be set
  - —Pertains to probability of occurrence of exceeding limits of concentrations, fluxes, and durations in compartments.
- In short, certification of a site will be allowed only if the CLR is below thresholds established for the probability that a limit will be exceeded for concentrations or fluxes at all compartments.
- When the CLR is below all thresholds, the effective trapping requirement will be met.

Compartments and Conduits



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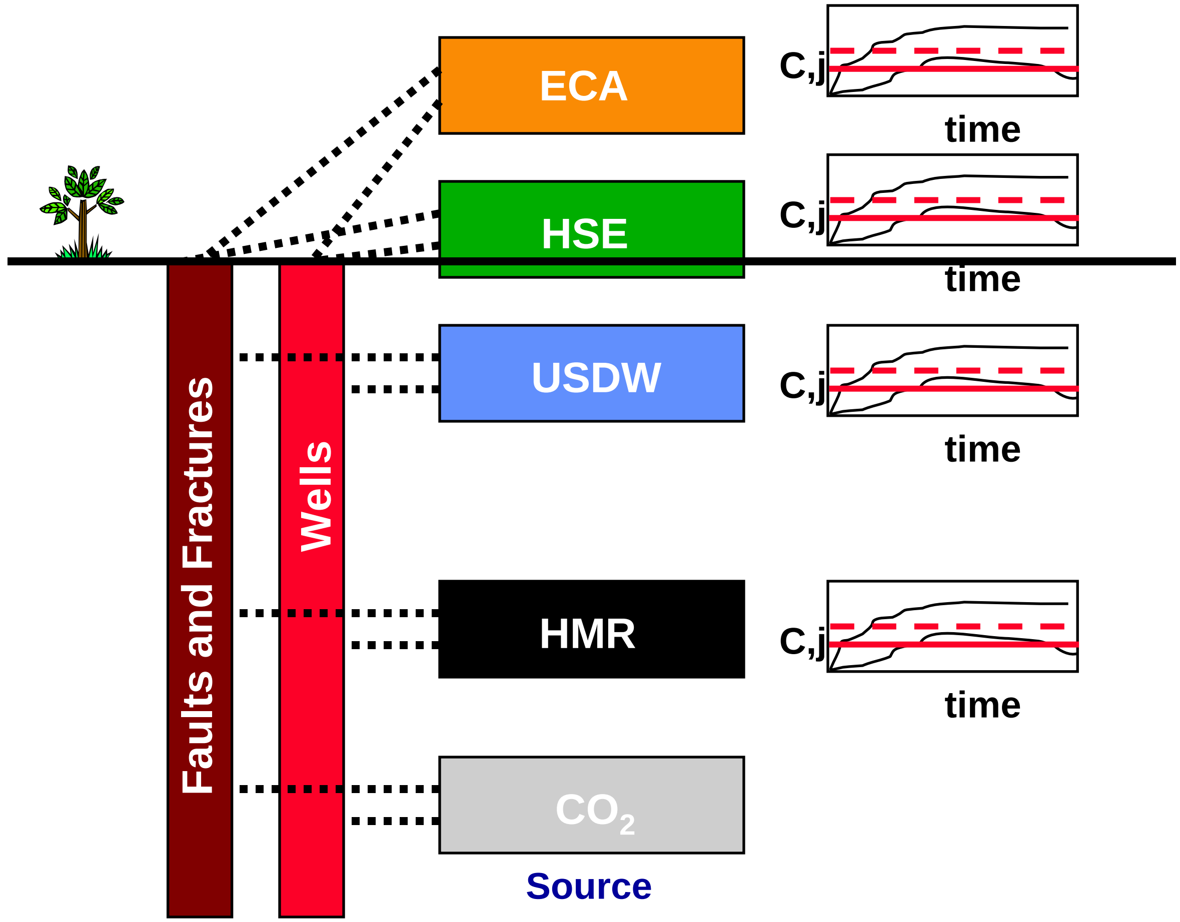
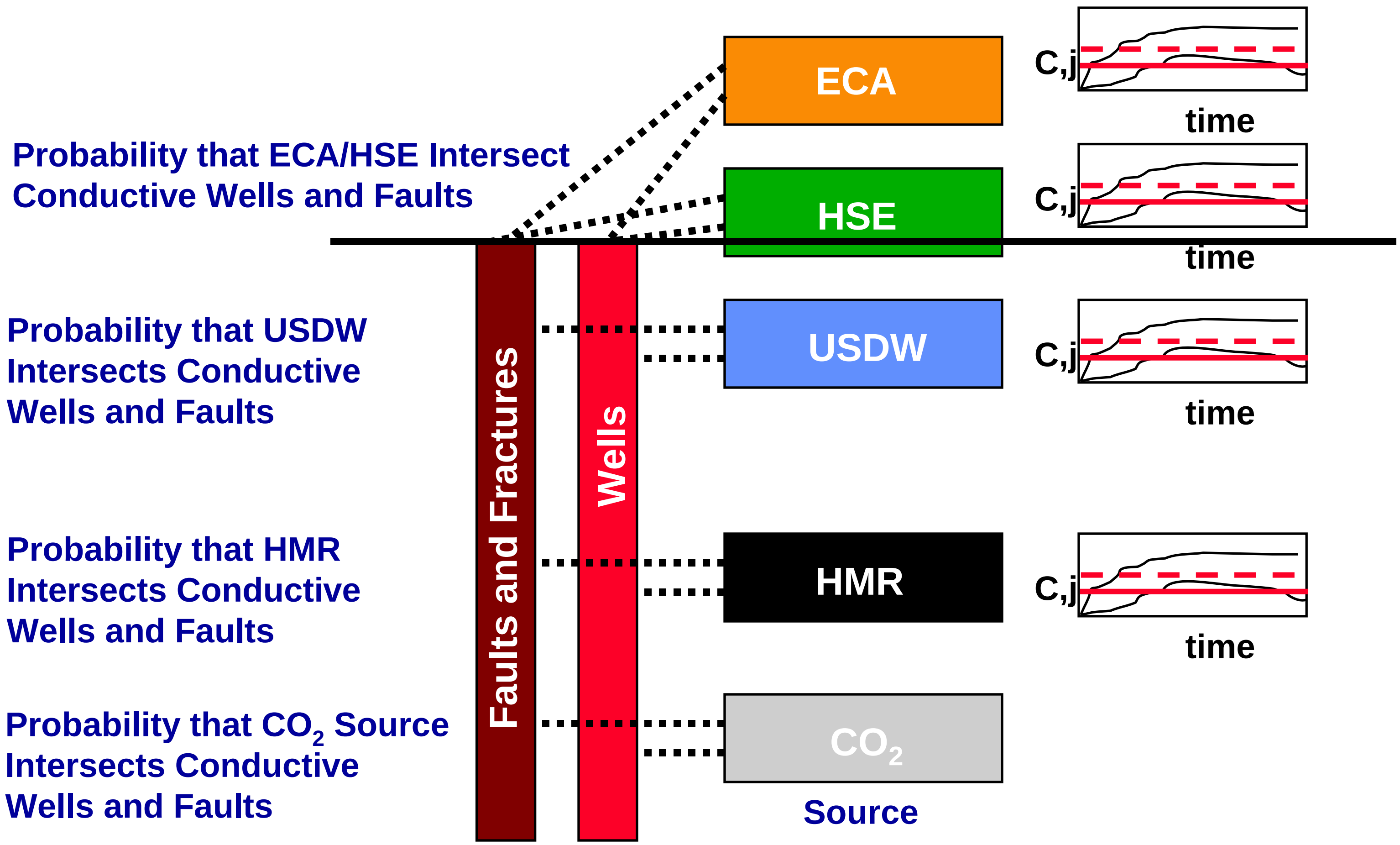
Impacts



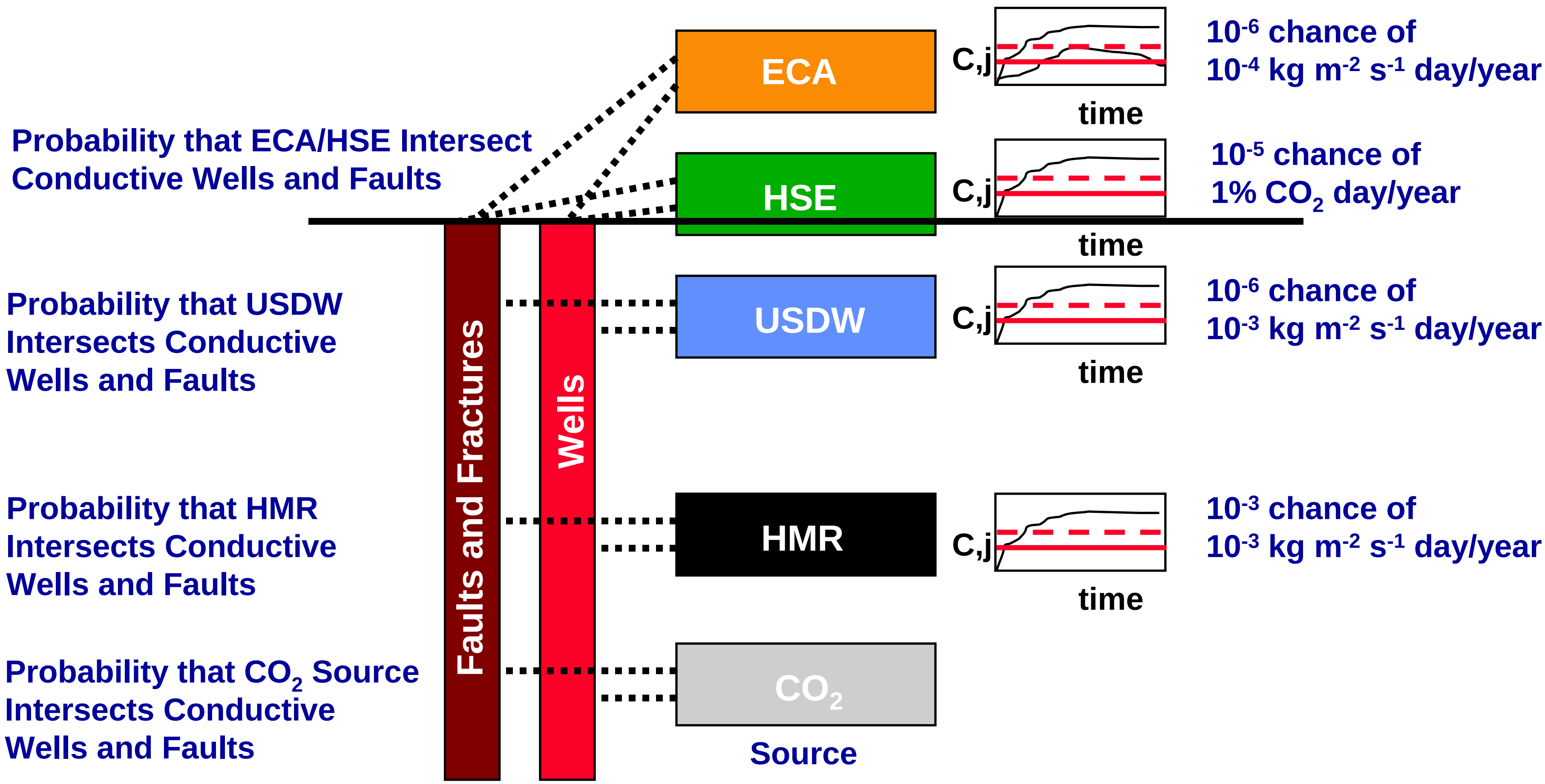
Impacts occur when the concentration or flux exceed limits agreed upon a priori by regulators and industry. Impacts are concentration-time or flux-time events (e.g., 1% CO_2 days, or 10^{-4} kg CO_2 m^{-2} s^{-1} days).

Probabilities



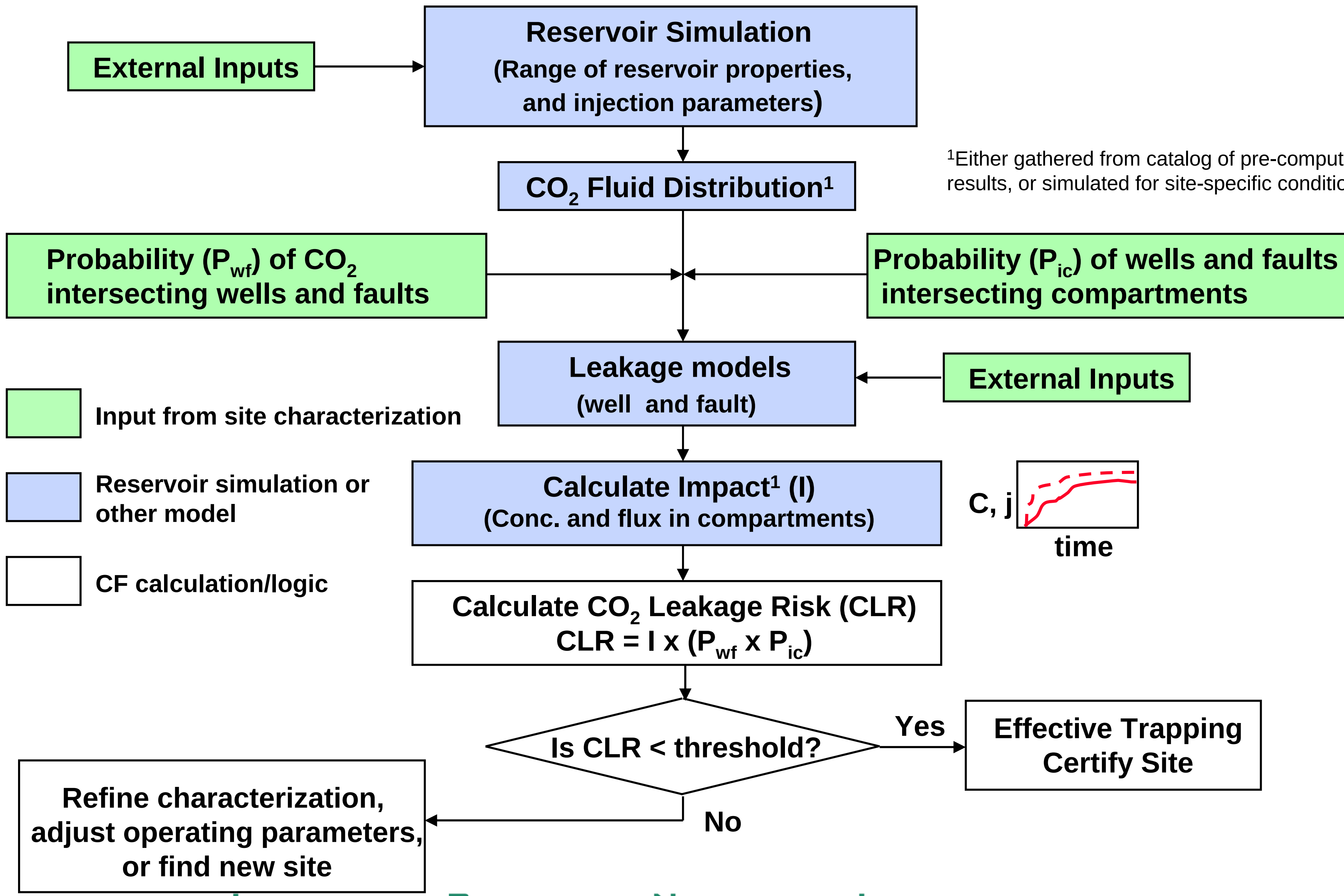
The probabilities considered by the CF are the probabilities of conduits intersecting the CO_2 source and the compartments.

CO_2 Leakage Risk



CLR to any compartment is the product of the probabilities that CO_2 will intersect source and compartment times the impact as calculated by concentration- or flux-time events. If CLRs are below thresholds, site can be certified.

CF Flow Chart



[1]Either gathered from catalog of pre-computed results, or simulated for site-specific conditions.

CF Work Presented in Pittsburgh

- **Minkoff, S.E., S.L. Bryant, J.-P. Nicot, and C.M. Oldenburg, Modeling leakage of CO_2 along a fault for risk assessment. *Oral Presentation Wed. 1:30 PM (Evaluation of Geol. Fms.)*.**

- **Kumar, N, and S.L. Bryant, Simulation studies for geological CO_2 storage certification framework, *poster presentation*.**

- **Huerta, N., S. L. Bryant, S.E. Minkoff and C. M. Oldenburg, Well Leakage Pathways and Their Importance to CO_2/Cement Reactions: Analysis of Long-Term Cement Competence as Part of a Certification Framework for CO_2 Sequestration Projects. *Oral Presentation Wed. 1:30 PM (Well Integrity).***

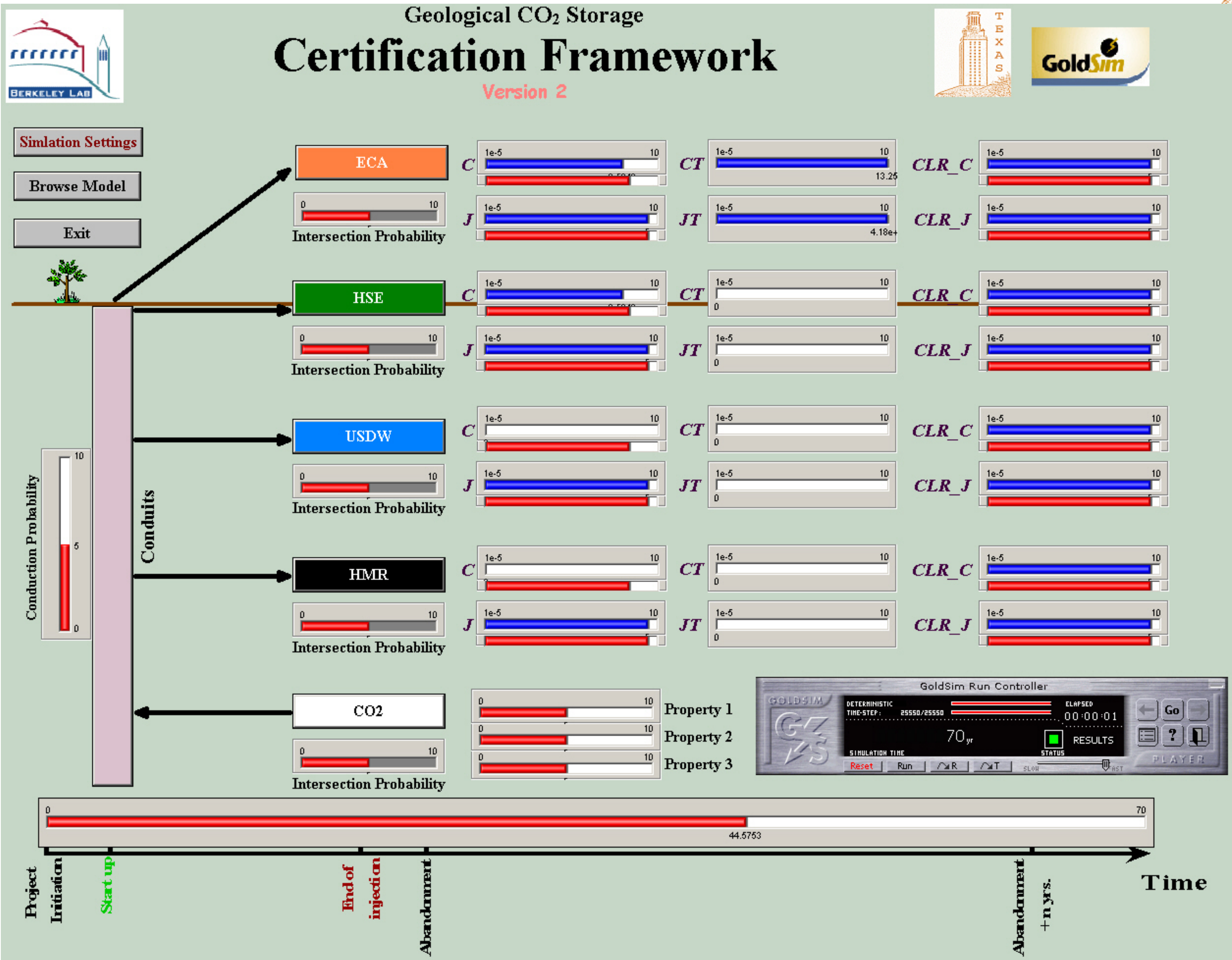
- **Chang, K.W. and S. L. Bryant. Dynamics of CO_2 Plumes Encountering a Fault in the Reservoir. *Oral Presentation Wed. 1:30 PM (Evaluation of Geol. Fms.).***

- **Saadatpoor, E., Effect of heterogeneity in capillary pressure on buoyancy driven flow of CO_2. *Oral presentation Wed. 1:30 PM (Evaluation of Geol. Fms.)*.**

Ongoing Efforts for CF

- **Fault intersection and characterization (Jordan (LBNL))**
- **Above-ground CO_2 migration (Chow, Granvold (UCB))**
- **Interaction with regulators, guidance on impact limits and risk thresholds (McKone, Sohn, Price (LBNL))**
- **Uncertainty by fuzzy membership models (Zhang (LBNL))**
- **Rapid prototype (Zhang (LBNL))**

Rapid Prototype in GoldSim



Certification Framework Summary

- CF project is developing a simple, transparent, and accepted approach to geologic storage site certification.

Simplification

  - Certification based on Effective Trapping Requirement
  - CO_2 Leakage Risk
  - Compartment concept
  - Broad classes of features
  - Catalog of model results--but site-specific can be used also
  - CF is probabilistic in existence of flow pathway, deterministic in flow along pathway
- Transparency
  - Sophisticated modeling of simplified systems
  - Process and I/O can be visualized in GoldSim application
- Acceptance
  - Effective Trapping Requirement analogous to UIC non-migration
  - Advisory board for feedback
  - Task to interact w/regulators

Acknowledgments

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CO_2 Capture Project