Probabilistic Performance Assessment Methodology for long term subsurface CO2 storage

PSAM 9, Hong Kong, May 19th, 2008

Claudia Vivalda & Laurent Jammes
Schlumberger Carbon Services

Outline

- Carbon Capture and Storage Site Description
- CO2 Storage Sites Peculiarities
- Probabilistic Performance Assessment Methodology with Examples
- Performance Analysis Outcomes

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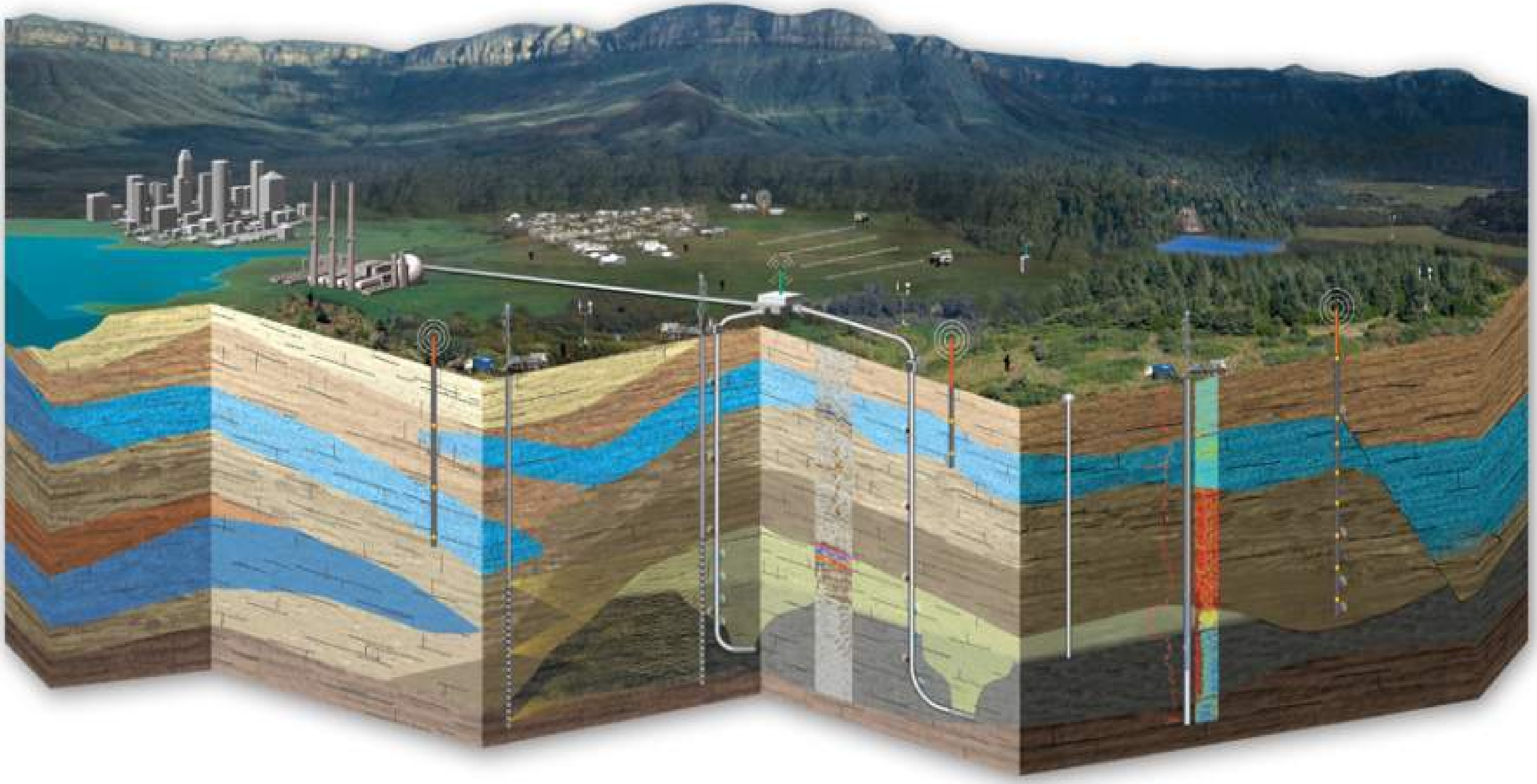
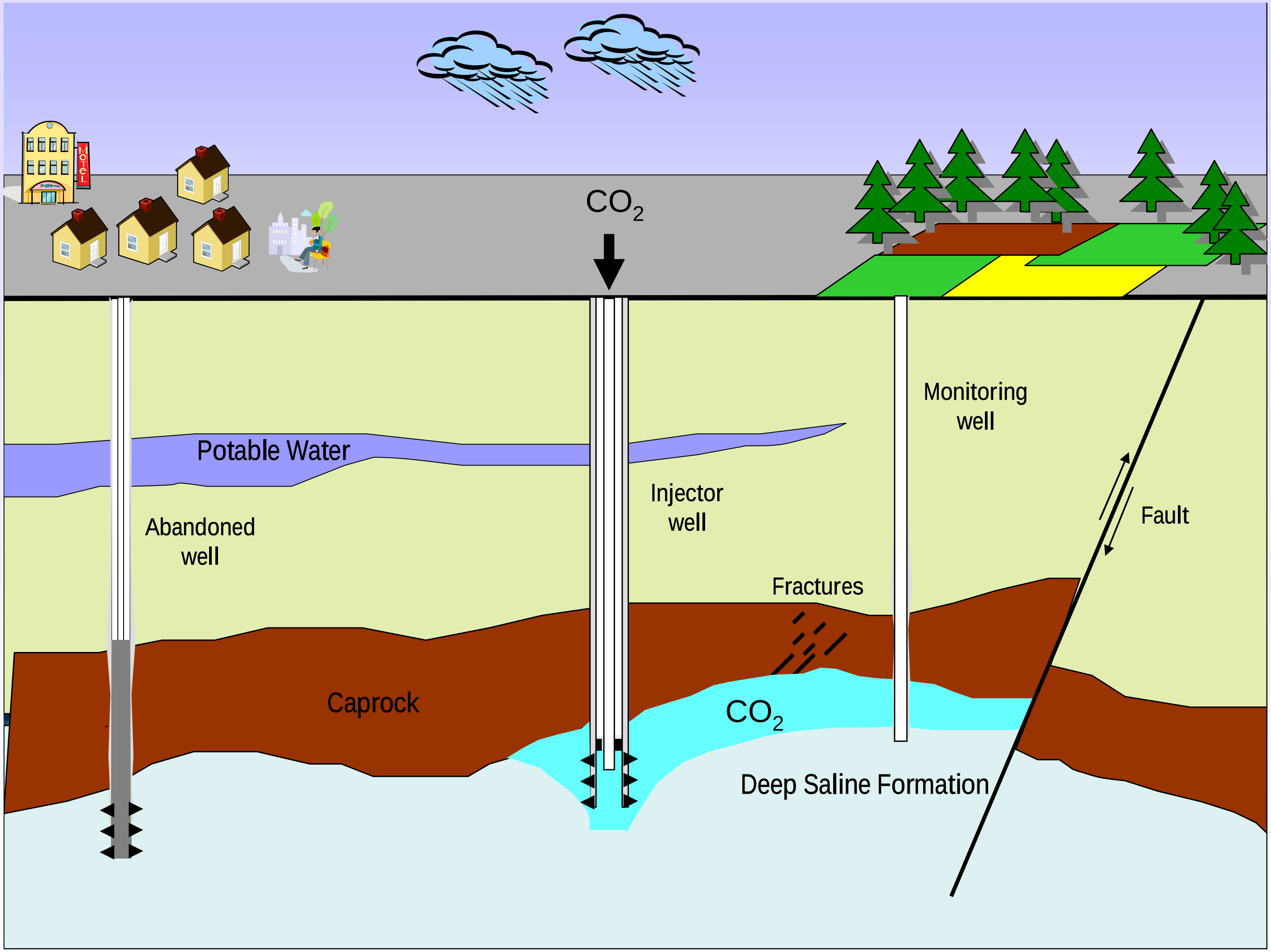
Example of Carbon Capture and Storage Site



Simplified Example of CO_2 Geological Storage System



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CO2 Storage Sites' Peculiarities

- The geological system and its constituting parts (subsystems and components) are **continuous media** with not fully known properties
- Each site is "**unique**" i.e. not reproducible
- The **dynamic** of the system in response to the injected CO_2 is only **governed by physical processes** - CO_2 induced physical, chemical and mechanical effects - there are **no active components** installed underground
- **Analogs**, i.e. natural analogs, natural gas storage, waste repositories, **do not** present characteristics fully corresponding to CO_2 storage

And … the application is **new** – mainly **research and demonstration projects**

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Performance Analysis Aim

- **Life cycle approach** aiming at <u>evaluating</u>, <u>controlling</u> and <u>maintaining</u> the expected **performance** of a CO2 storage site.
  - **Performance** is a measure of the injectivity, capacity and containment (effectiveness) of the CO2 storage site.
  - **Risk** is a loss of performance with and impact on Health & Safety, the environment, the costs, the image, …

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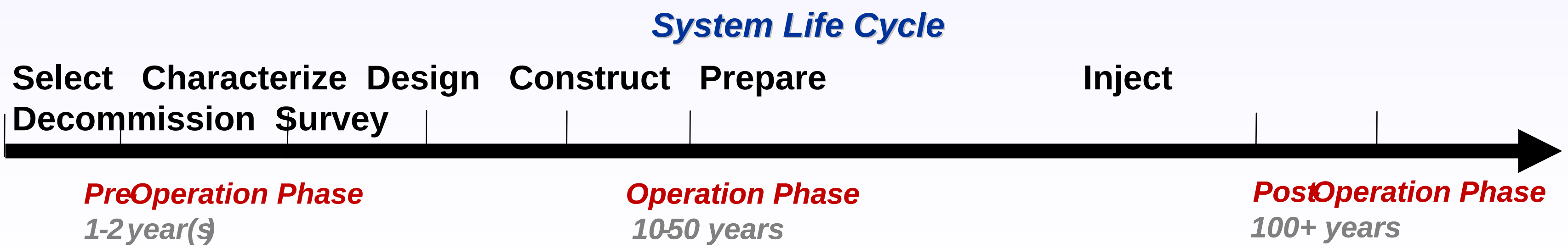

Performance Characteristics

- **Storage capacity** is the *amount of CO_2 that can be safely injected*;
- **Injectivity** is the *capability of injecting CO_2* at the designed *rate* during a defined *period of time*, with respect to the cumulative volume and emission rate of the CO_2 source associated with the storage site; and
- **Containment** is the *capability of keeping the injected CO_2* in the geologic formation targeted for storage during a *long period of time*, *without impairing* health, safety, the environment, the global cost ...

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Performance Analysis Methodology (I)

The **First step** addresses the

Initial Site Characterization

based on a Preliminary Performance Assessment that includes:

- *Collection* of all the *relevant data available*; interpretation and identification of the main **uncertainty areas.**
- *Initial site characterization* in terms of **injectivity**, **capacity**, and **containment** (effectiveness) based on the limited initial data set. **Initial risk pathways** identification and qualitative assessment.

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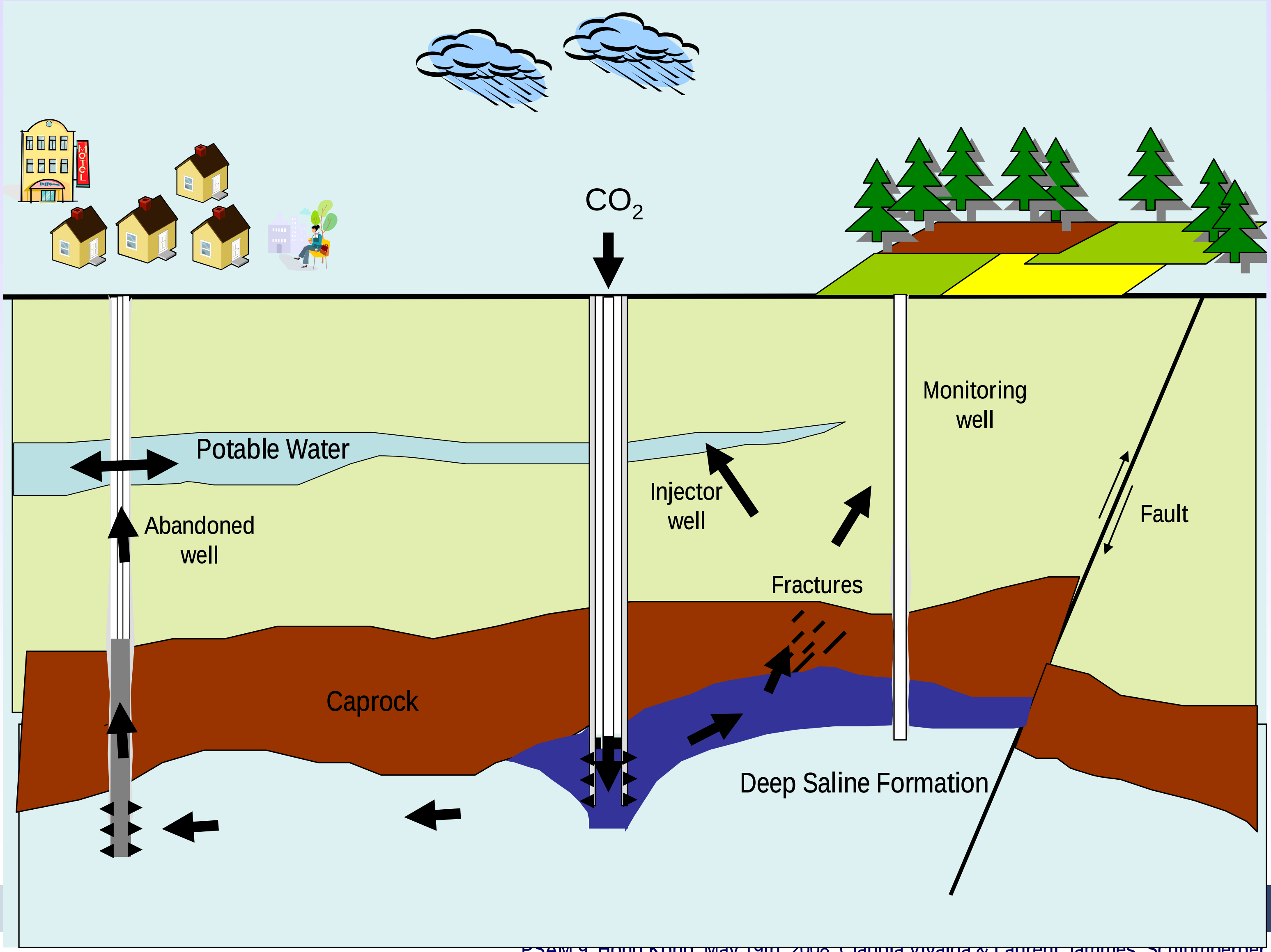
Example of Risk Pathways



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Performance Analysis Methodology (II)

The **Second step** addresses a

Detailed Site Characterization

in which the Performance Assessment and Management includes:

- **Acquisition of new data** to build *detailed subsurface models* (both static and dynamic) as recommended in the first step.
- *Identification* of the **possible mid/long-term evolution** of the system in the perspective of **loss of performance** (i.e. injectivity, capacity, containment/effectiveness) and its *description* in terms of reference **risk pathways** and **scenarios**.

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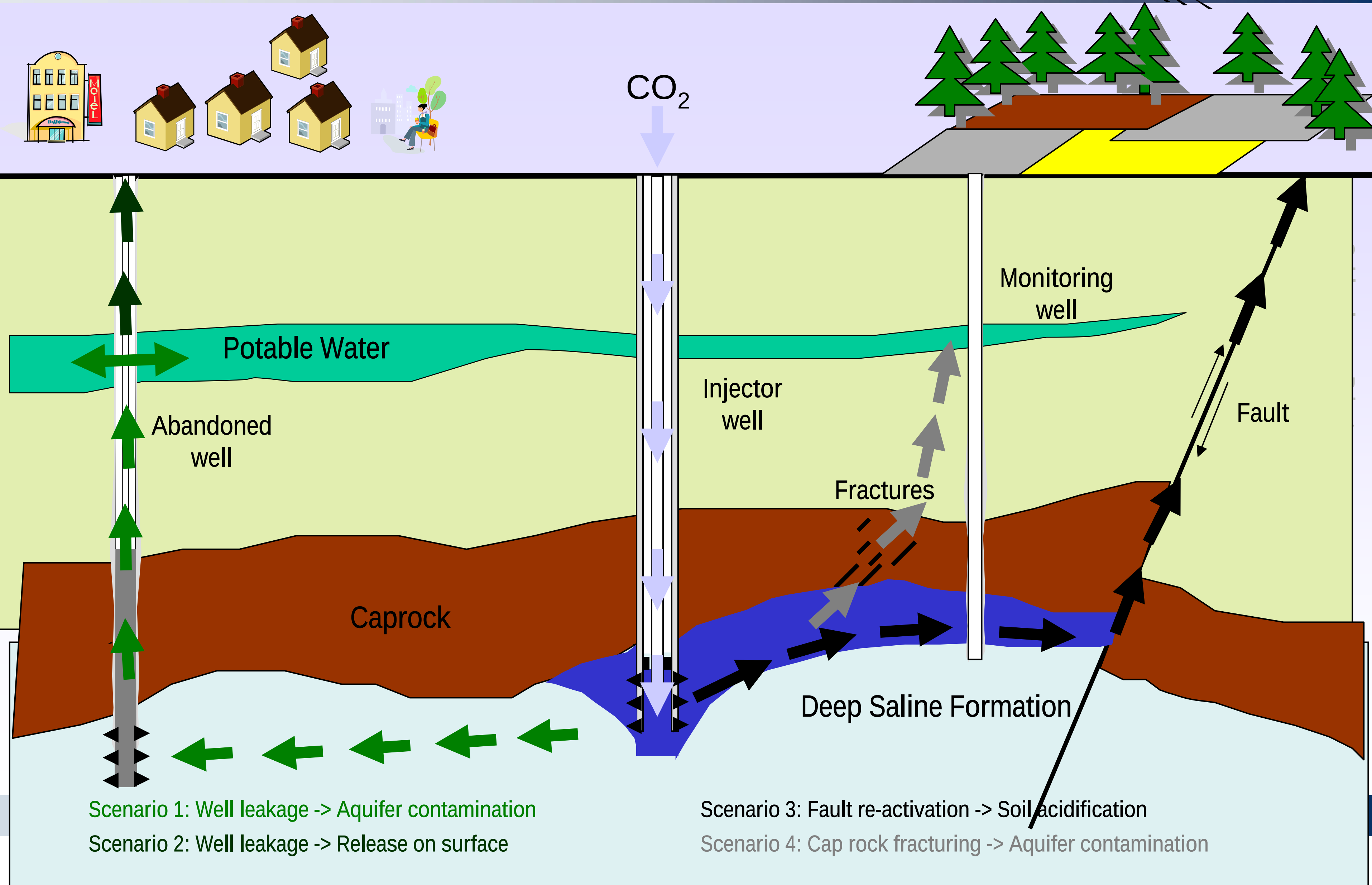
Containment – Potential Leakage Pathways



Performance Analysis Methodology (III)

- For *each risk pathway*, assessment of:
  - its probability of **occurrence** (using of the previous steps results, dedicated analysis/simulations, field data, expert judgment), and
  - the **severity** of its consequences (impact on costs, health, safety, environment, image, etc).
- **Dynamic analysis** of *few representative risk pathways* by simulation models, including the **propagation** of the associated **uncertainties** and **sensitivity analysis**.
- Risk pathways **ranking** according to their **criticality**

Current limitations: *the analyzed scenarios are not exhaustive of the overall risks and treated as independent => An overall risk figure cannot be inferred from this analysis*

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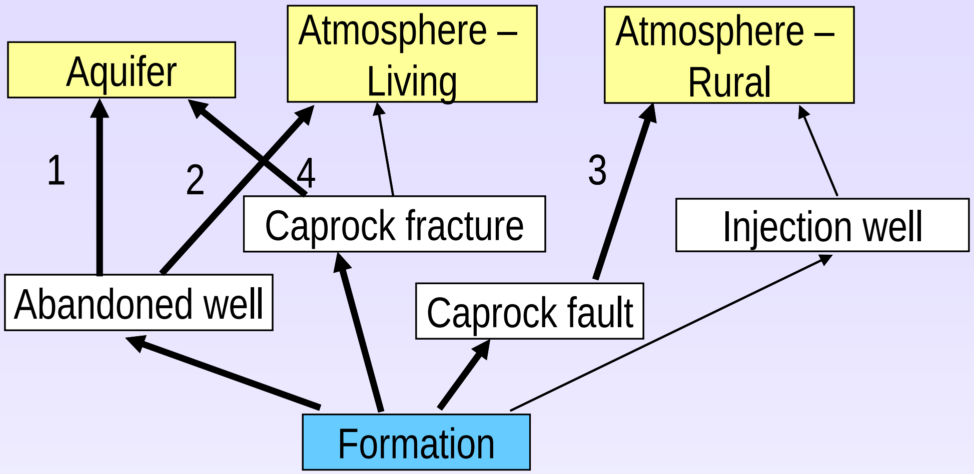
Risk Pathways Ranking



Scenario 1: Well leakage -> Aquifer contamination

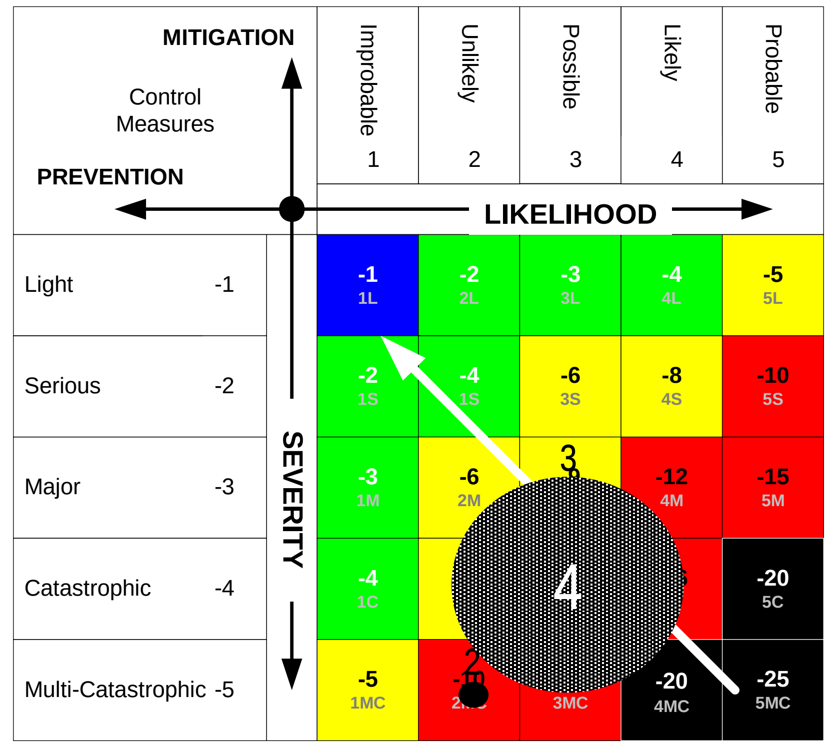
Scenario 2: Well leakage -> Release on surface

Scenario 3: Fault re-activation -> Soil acidification

Scenario 4: Cap rock fracturing -> Aquifer contamination

Effect of uncertainties
(e.g. cap rock fracture pressure)

-25 to -20	BLACK	NON-OPERABLE:	Evacuate the zone and or area/country
-16 to -10	RED	INTOLERABLE:	Do not take this risk
-9 to -5	YELLOW	UNDESIRABLE:	Demonstrate ALARP before proceeding
-4 to -2	GREEN	ACCEPTABLE:	Proceed carefully, with continuous improvement
-1	BLUE	NEGLIGIBLE:	Safe to proceed



White arrow indicates decreasing risk

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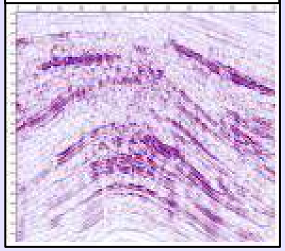
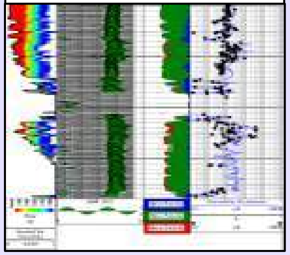
Building a Static Model – Structure & Properties

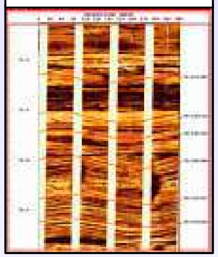
Geophysics



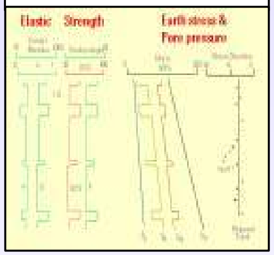
Flow / Transport



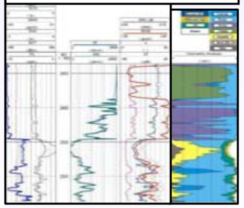
Geology

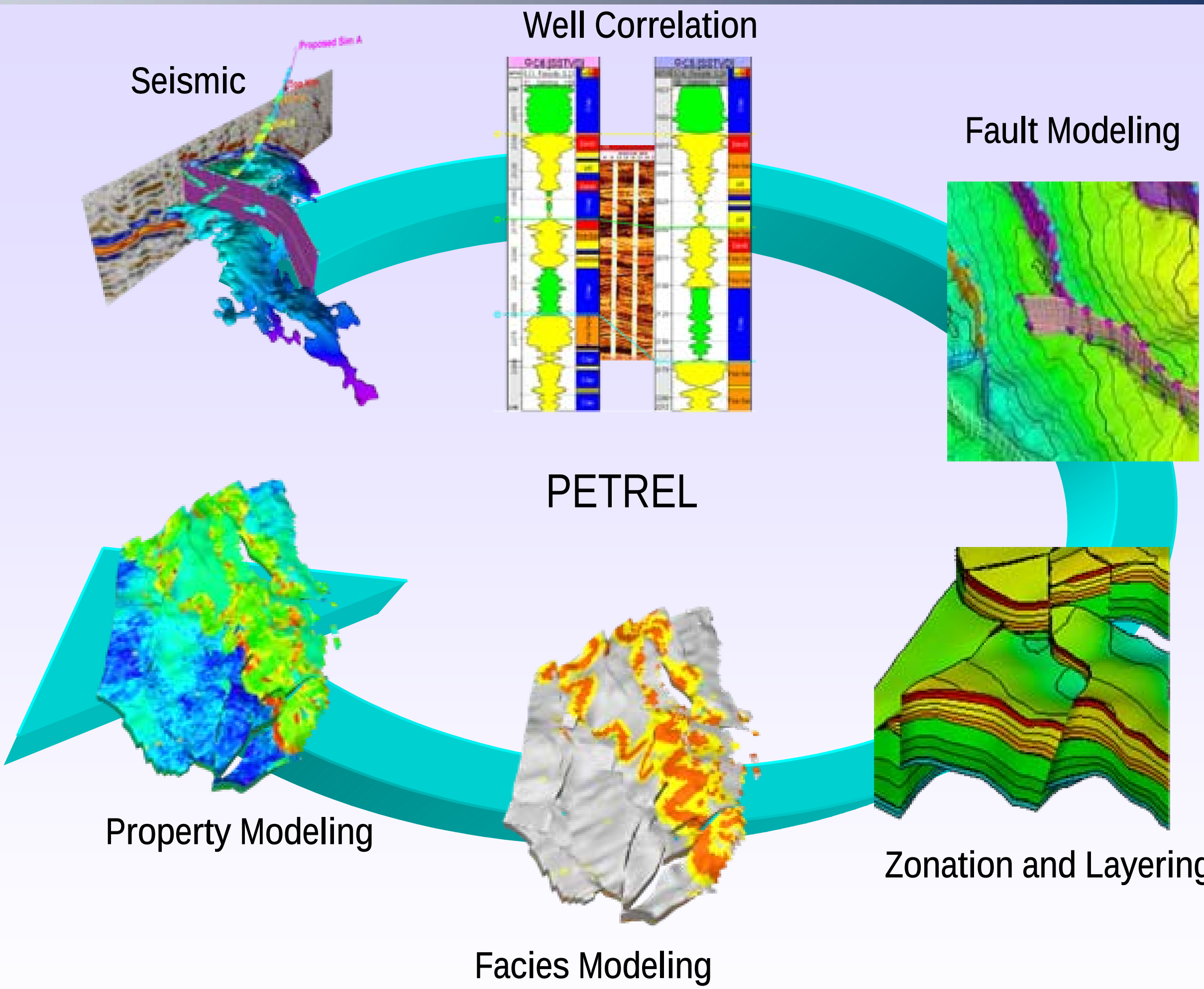


Geomechanics



Petrophysics
Mineralogy





Model should include overburden

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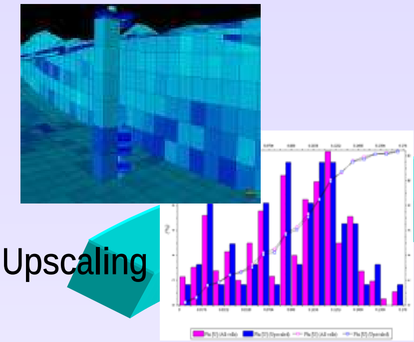
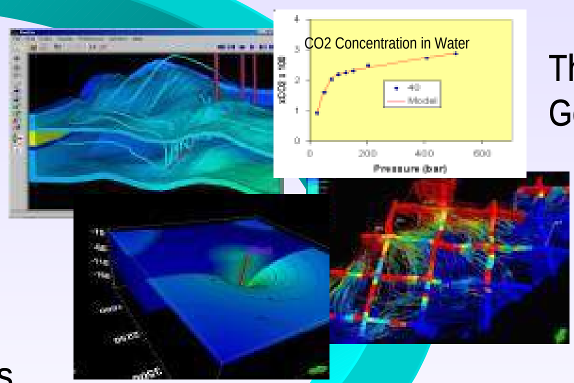
CO2 Injection Dynamic Modeling

Accurate description of fluid-fluid / fluid-rock interactions
- Thermodynamics
- Precipitation / dissolution reactions
- Coal swelling and shrinkage



Upscaling

ECLIPSE – E300



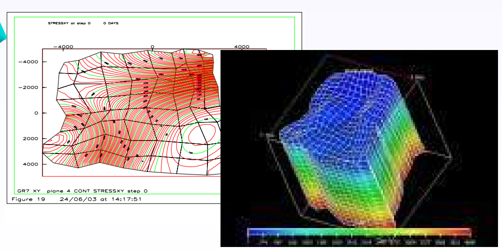
Thermodynamics
Geochemistry

Thermal Modeling

Calibration on monitoring measurements
(History match)

3D Full Compositional Flow Simulator

Geomechanics Simulator



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Performance Analysis Methodology (IV)

- Suggestion of **remediation actions** (prevention and/or mitigation) and assessment of their impact
- Design of an **implementation program** of the **selected remediation actions** in short, mid and long term (e.g. CO_2 resistant cement, type of monitoring, etc.).
- Regular **analysis update** to address changes in the system and to reduce uncertainties through new input data (e.g. monitoring, …)

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Main Remediation Action - Monitoring Program

Measurement, Monitoring and Verification (MMV) are the primary means through which the safe and effective storage of CO2 in geological formations can be established.

A main outcome of the performance assessment is:

- The **Design** of an **optimum monitoring program** capable of *controlling critical risk-specific parameters* which impact on the site performance and guaranteeing the expected safety level.

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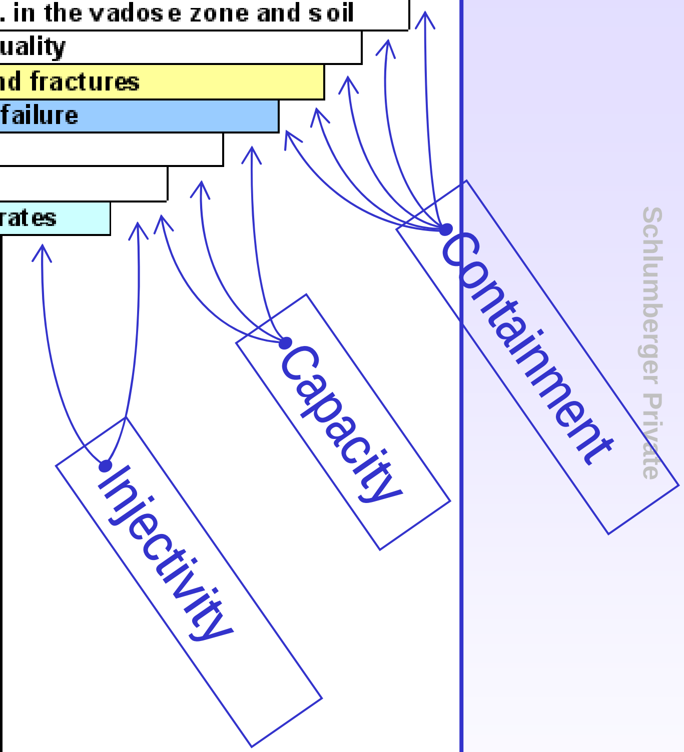
Monitoring Targets vs Methods

(IEA_GHG Monitoring Workshop 2007, presented by Ken Hnottavange-Telleen-SLB)

Monitoring Targets and Monitoring Methods

Monitoring Targets

Monitoring Methods	Injection-well condition, pressures, flow rates	Solubility and mineral trapping	CO2 plume location	Early warning of caprock failure	Leakage up faults and fractures	Groundwater quality	CO2 conc. in the vadose zone and soil	CO2 conc. and fluxes at ground level
Flow metering, Orifice or other differential	x							
Infrared CO2 detectors	x							x
Borehole logs (casing, cement, fluids)	x		x					
Pressure msmt: Well, reservoir, annulus, aquifer	x		x	x	x			
Gravity measurements			x	x				
EM (electrical, electromagnetic) surveys			x		x			
Seismic: 3-D time-lapse surveys			x	x	x			
Seismic: Microseismicity monitoring			x	x	x			
Seismic: VSP, walkaway, cross-well			x	x	x			
Tiltmeters			x	x	x			
Satellite and/or airborne data			x	x	x		x	
Samples: Fluid; optional tracers		x	x		x	x	x	
Vegetation changes observed on ground					x	x	x	x
Samples: Soil gas					x		x	x
Samples: Air, via eddy-flux towers or grab								x



x = Method applicable to target

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Performance Analysis Outcomes

- Identification of the **information needed for a complete analysis** and of the needs for further characterization of features or properties
- Potential **risk pathways**
- **Uncertainties** on the results and their importance
- Risk pathways **ranking**
- List of **remediation actions** and their efficacy
- Remediation **actions implementation** program
- Design of optimum **Monitoring Program**
- Directions for **Maintenance Plan** (preventive, on-condition, corrective)
- Directions for **Contingency Plan**

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