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## Managing a leaky abandoned well: detection and advanced mitigation options (hydraulic barrier)

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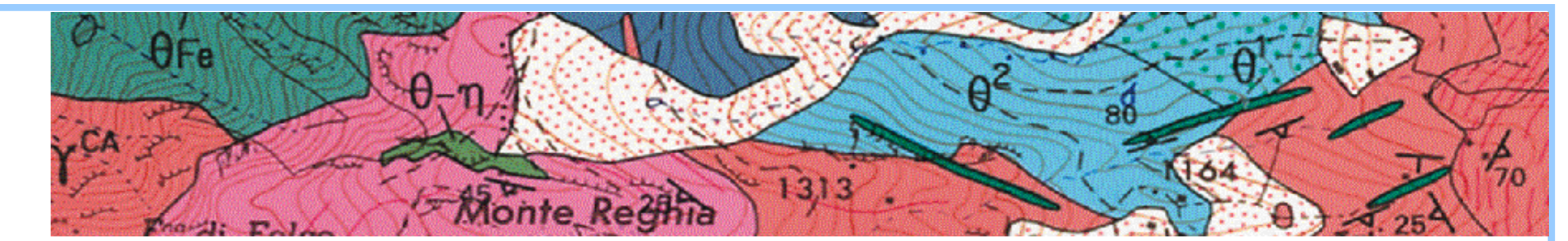
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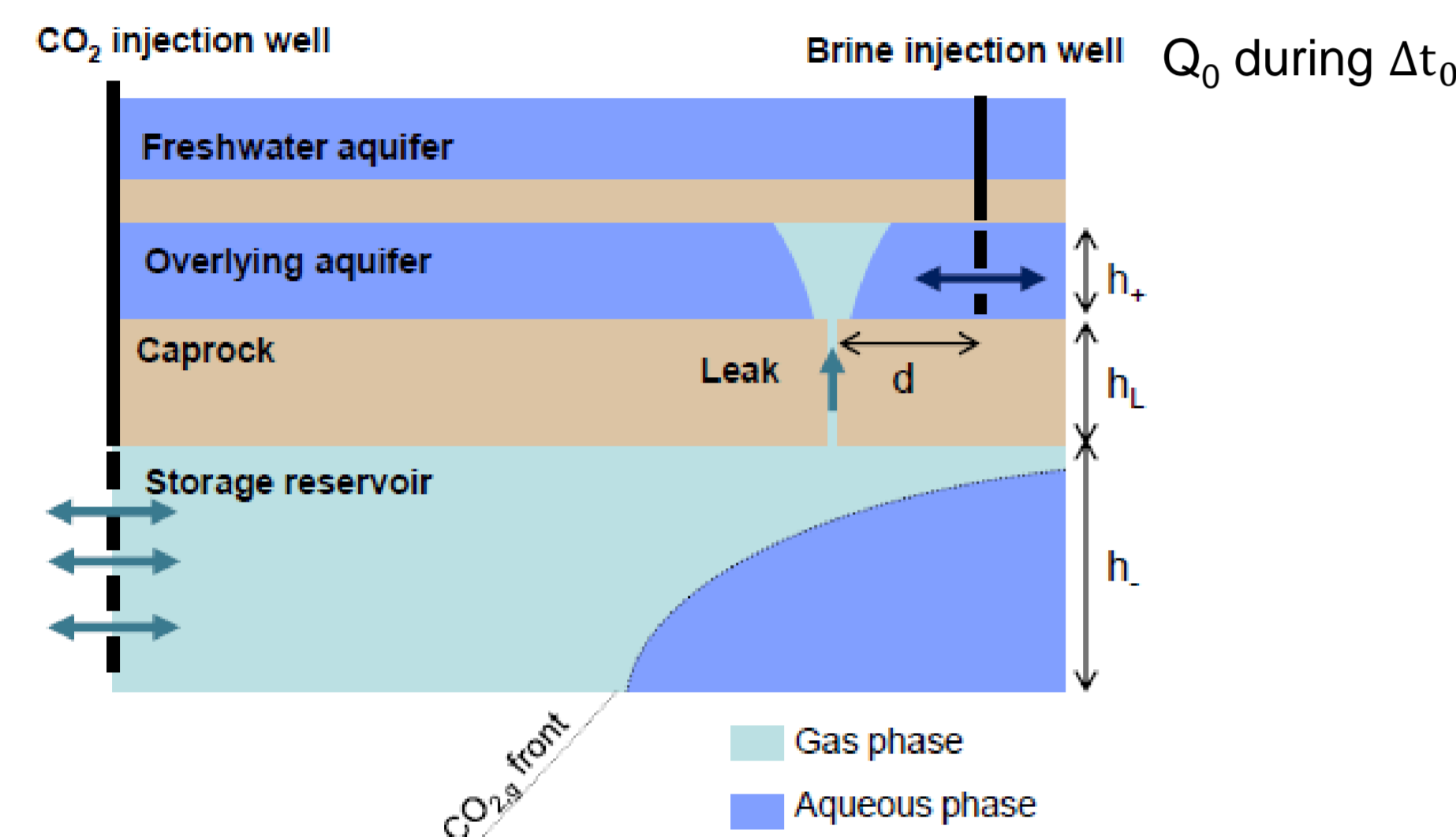
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# Hydraulic barrier design and applicability for managing the risk of CO<sub>2</sub> leakage from deep saline aquifers

## Objectives

- > In the case of leakage of CO<sub>2</sub> into an overlying aquifer through man-made (e.g. abandoned well) or natural (e.g. permeable fault) pathways, directly modifying the leak hydraulic properties may not be possible.
- > Used as a corrective measure, the “hydraulic barrier” relies on brine injection in the top aquifer in order to counter the driving forces of the migration (CO<sub>2</sub> buoyancy and injection-induced over-pressure)



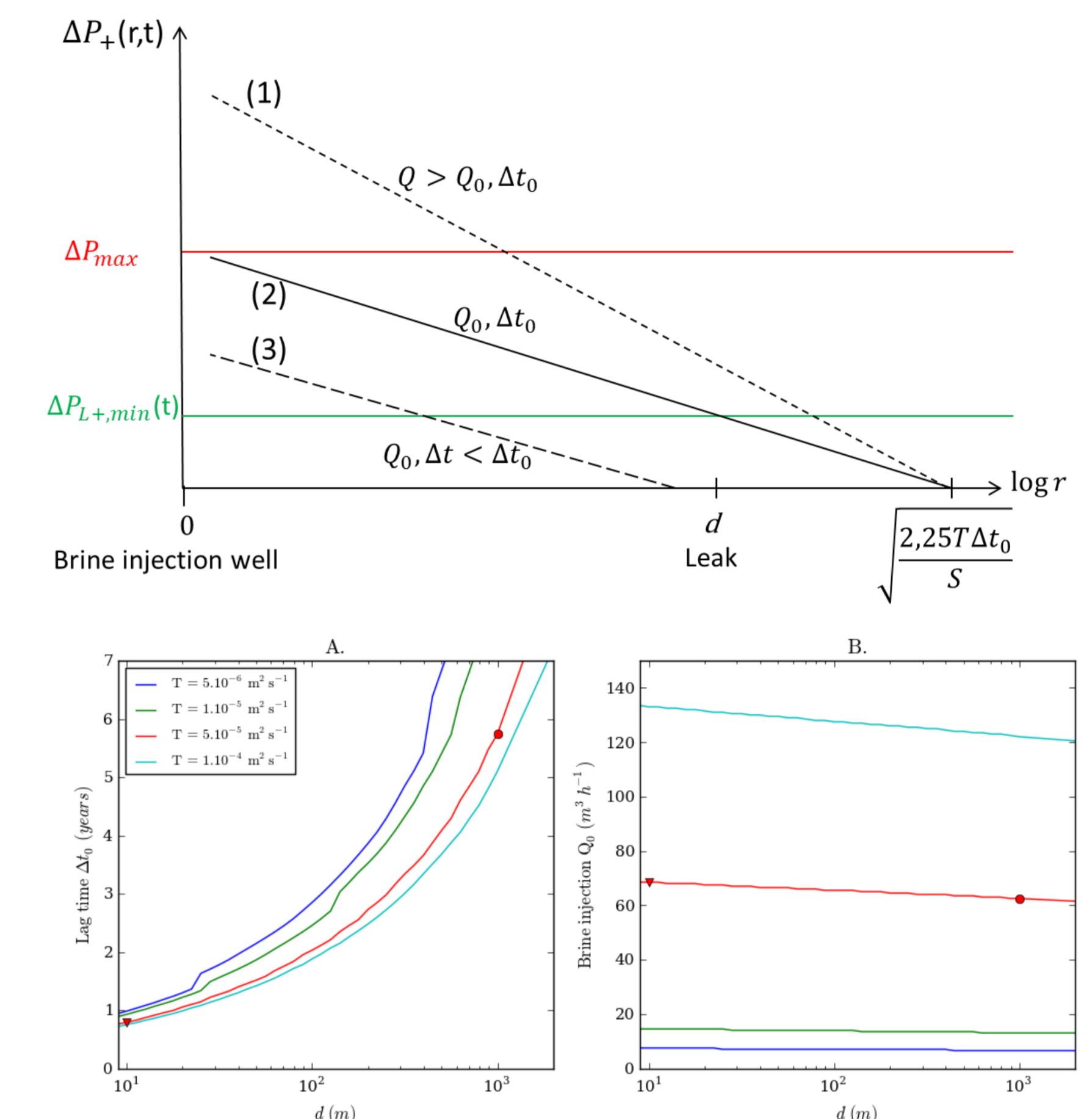
## Operational issues

- > Brine availability, surface piping and equipment
- > Possibility of re-using an existing well
- > Time delays of drilling a new well
- > Permitting and regulatory issues
- > Applicable once the secondary accumulation is detected (~ 1000/10000 tons of CO<sub>2</sub> at 1km depth) and characterized
- > Detection and characterization time

## Hydraulic barrier design: Q<sub>0</sub> & Δt<sub>0</sub> estimates

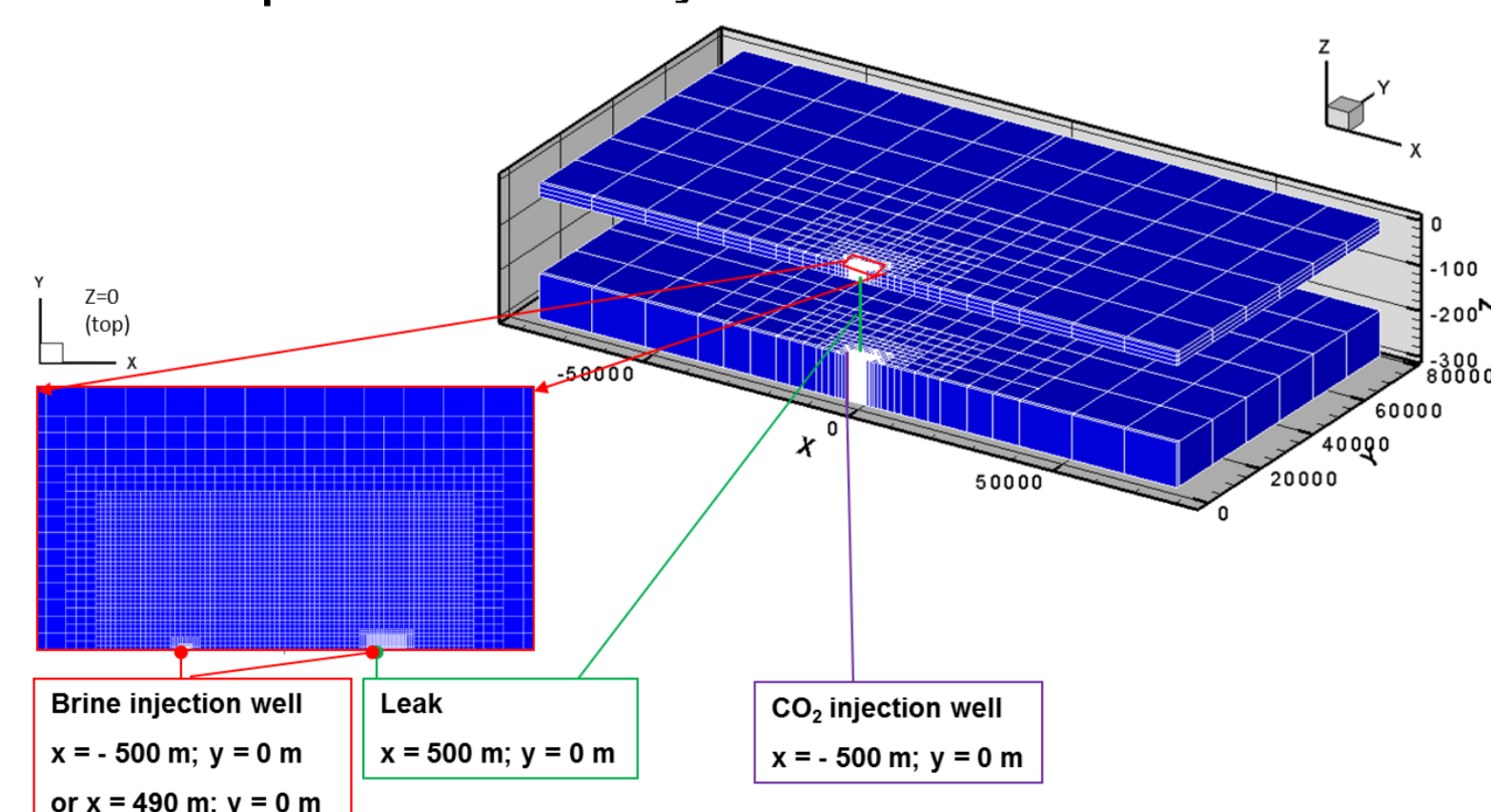
The brine injection rate Q<sub>0</sub> and duration Δt<sub>0</sub> are chosen in order to fulfill the following requirements :

- > **Rapidity:** The duration necessary for stopping the leak should be as short as possible.
- > **Integrity (mechanical):** Simple conservative analytical model of the tensile failure in the caprock in order to determine the maximum overpressure ΔP<sub>max</sub>
- > **Efficiency:** ΔP<sub>L+,min</sub>(t) ≤ ΔP<sub>L+</sub>(t), where ΔP<sub>L+,min</sub> is the pressure build-up over the leak necessary for preventing the leakage due to the pressurized storage aquifer and to the CO<sub>2</sub> buoyancy (determined for the considered leakage scenario). ΔP<sub>L+</sub> is the overpressure induced by the brine injection over the leak, estimated using the analytical Theis solution.



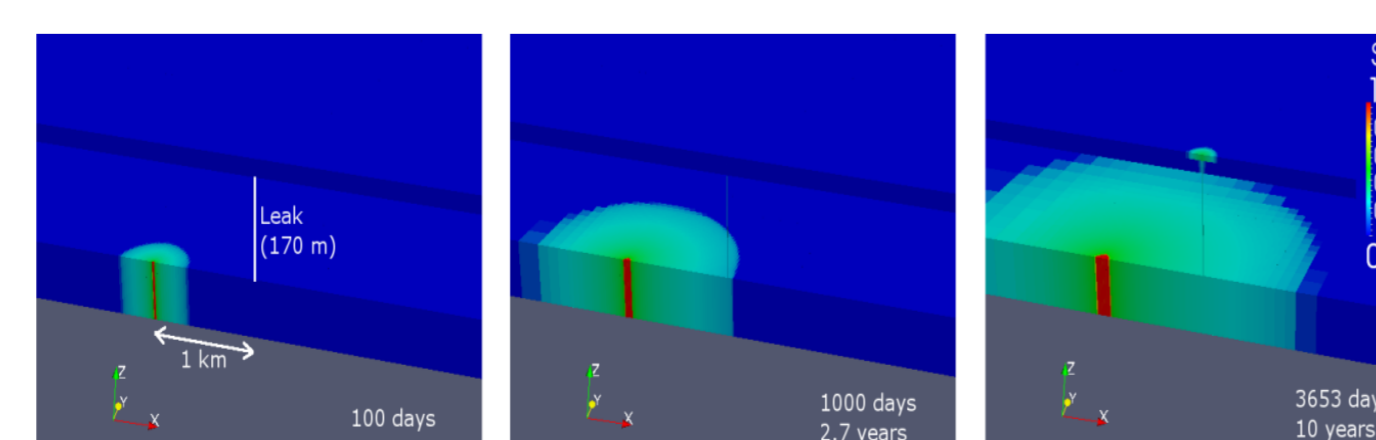
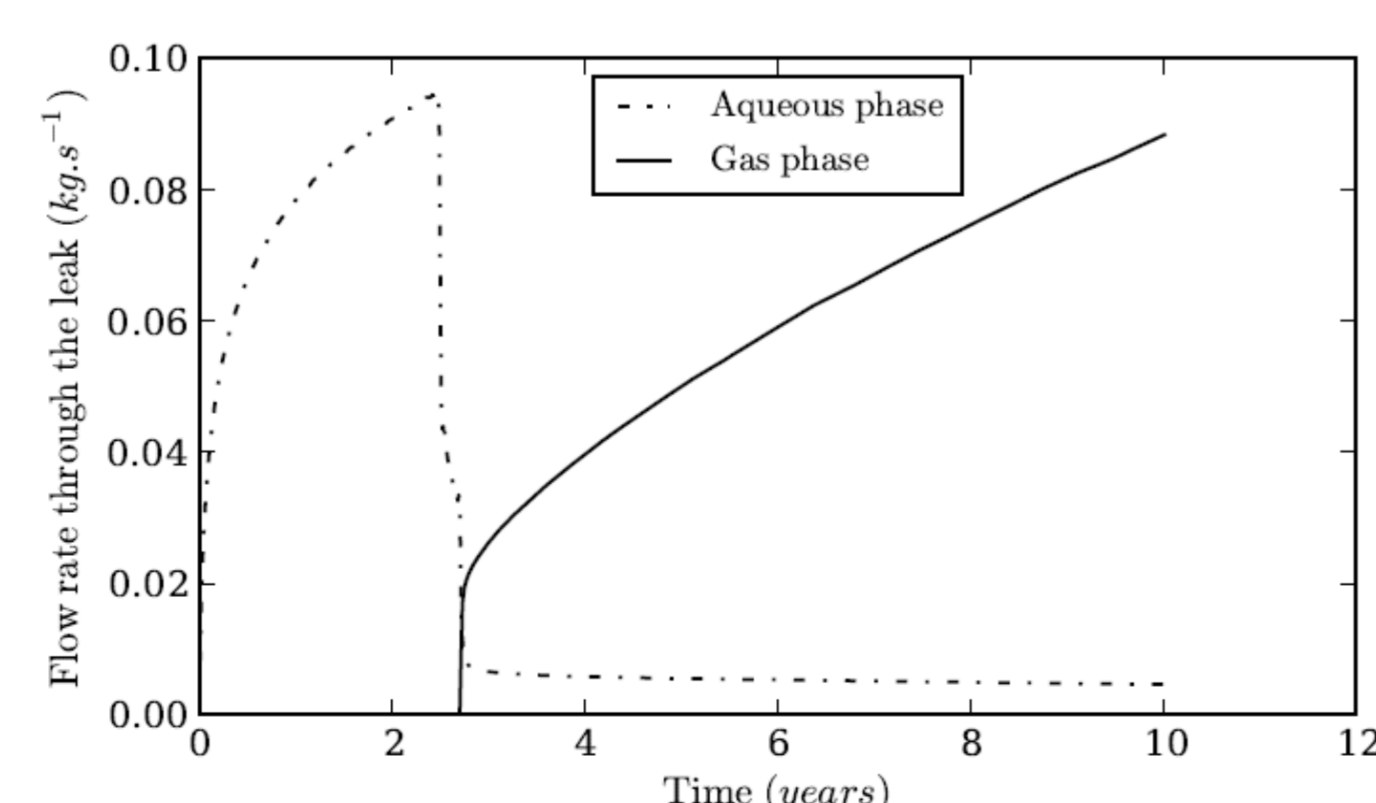
## Numerical model

- > Large scale multiphase flow transport simulation using TOUGH2 code
- > two horizontal and homogeneous 78 × 78 km aquifer layers are connected by a 170 m high vertical conduit
- > exponential grid refinements down to a 0,8m x 1,6 m grid block section for the leak
- > 100 thick storage layer (gravity neglected); 3x10m thick overlying aquifer
- > 3 Mt/y CO<sub>2</sub> injection
- > Homogeneous petrophysical properties typical of deep sedimentary basin.



## Leakage modeling

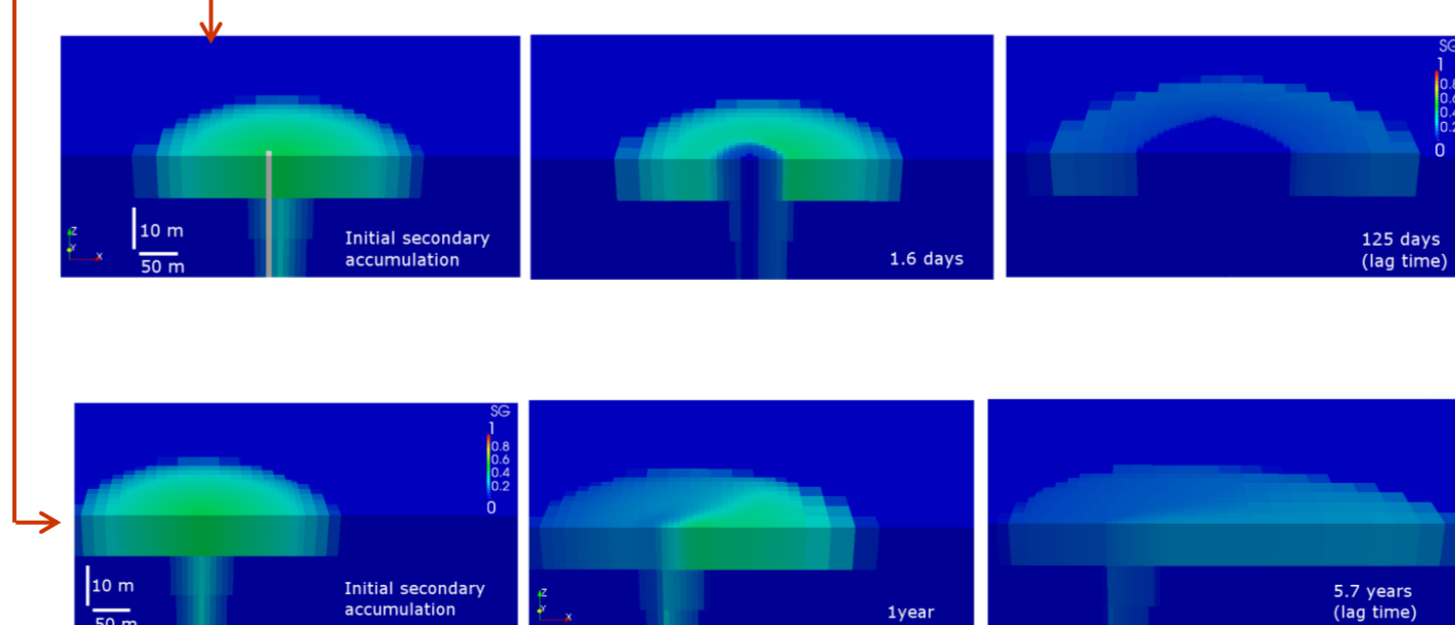
- > Leakage detection at 10 years
- > CO<sub>2</sub> injection is stopped
- > Secondary accumulation: 13.8 kt of CO<sub>2</sub> (detectable through seismic survey), 18% only is dissolved



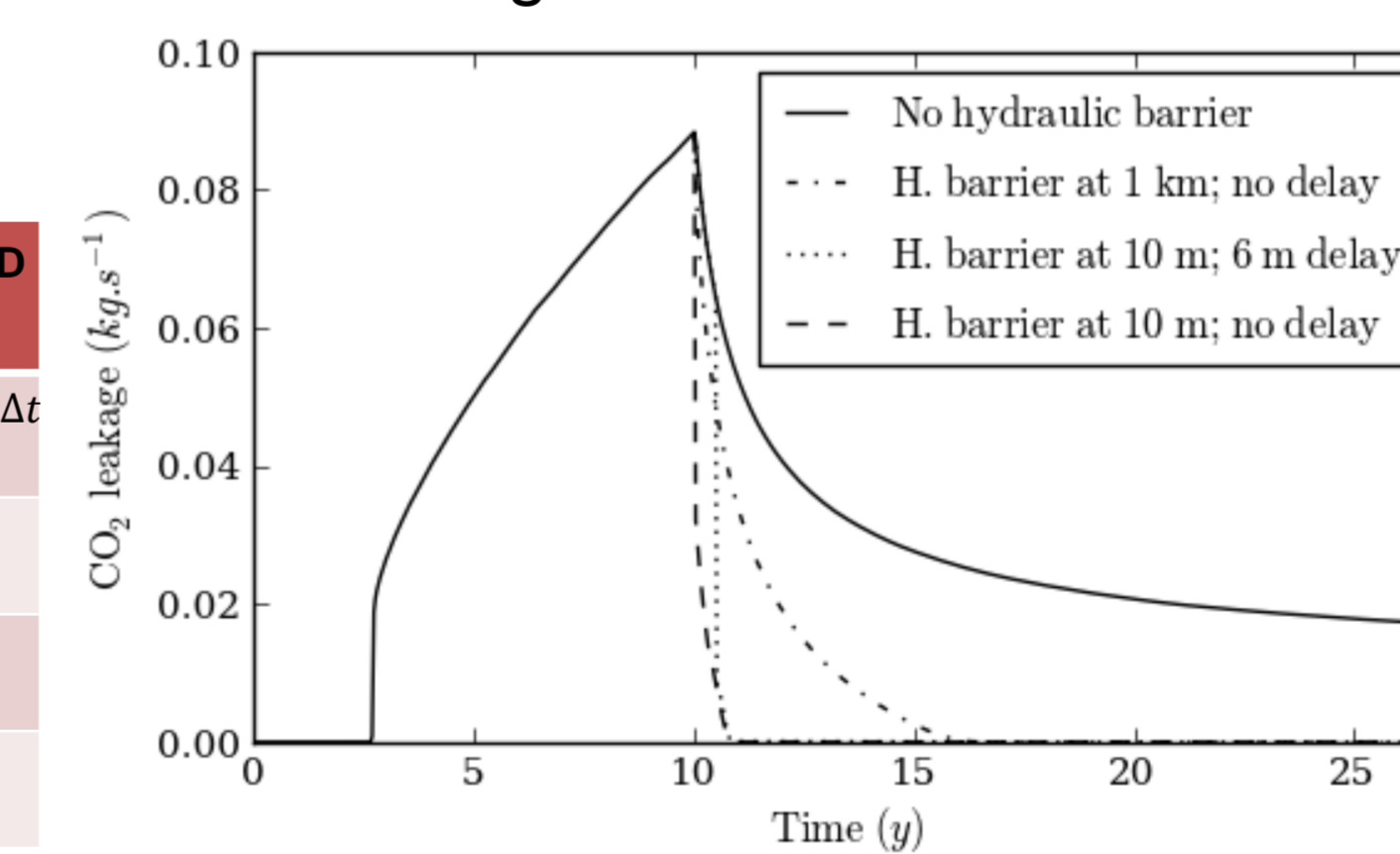
## Hydraulic barrier modeling and results

- > Simulated hydraulic barriers cases and comparison of the duration necessary for stopping the leakage

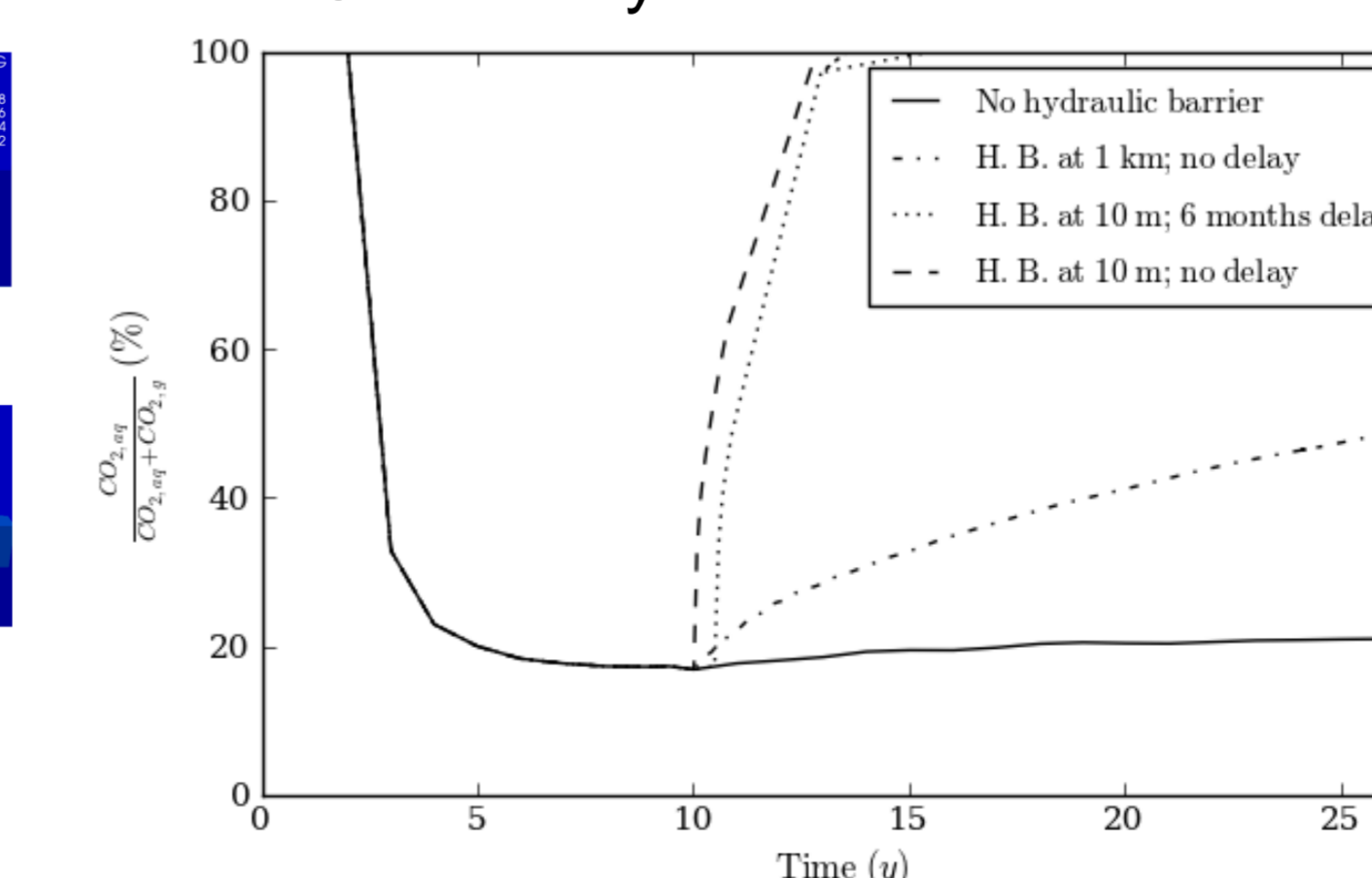
Case	Parameters set using the design methodology		Results from the 3D simulations	
	Q <sub>0</sub>	Δt <sub>0</sub>	Δt <sub>0</sub> <sup>3D sim.</sup>	(Δt <sub>0</sub> <sup>3D sim.</sup> - Δt <sub>0</sub> ) / Δt <sub>0</sub>
Well at 1 km, no delay	62.5 m <sup>3</sup> /h	5.7 years	5.6 years	-3 %
Well at 10 m, no delay	68.5 m <sup>3</sup> /h	289 days	287 days	-1 %
Well at 10 m, 6 months delay	71.5 m <sup>3</sup> /h	125 days	105 days	-16 %



- > Leakage over time



- > Secondary accumulation over time



## Conclusions

- > This methodology proposes some clear criteria for setting the main parameters of the hydraulic barrier. This remediation option can then be balanced with other possible strategies.
- > The time necessary for stopping the leakage are in good agreement with those obtained through 3D numerical simulation.
- > From the analytical results:
  - A leakage into a high transmissivity aquifer increases the necessary brine injection rate
  - Brine must be injected in the vicinity of the secondary accumulation