Sensitivity of Pressure Monitoring for Leak Detection

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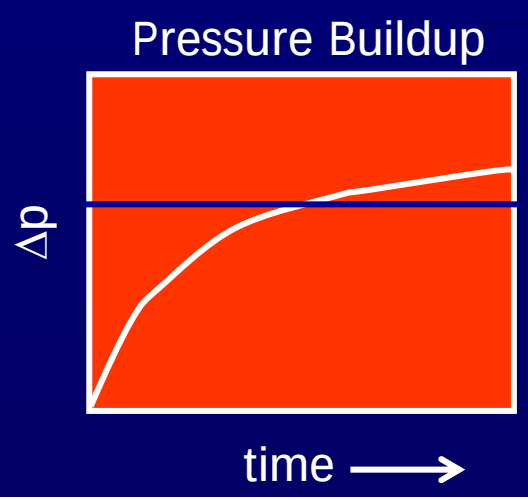
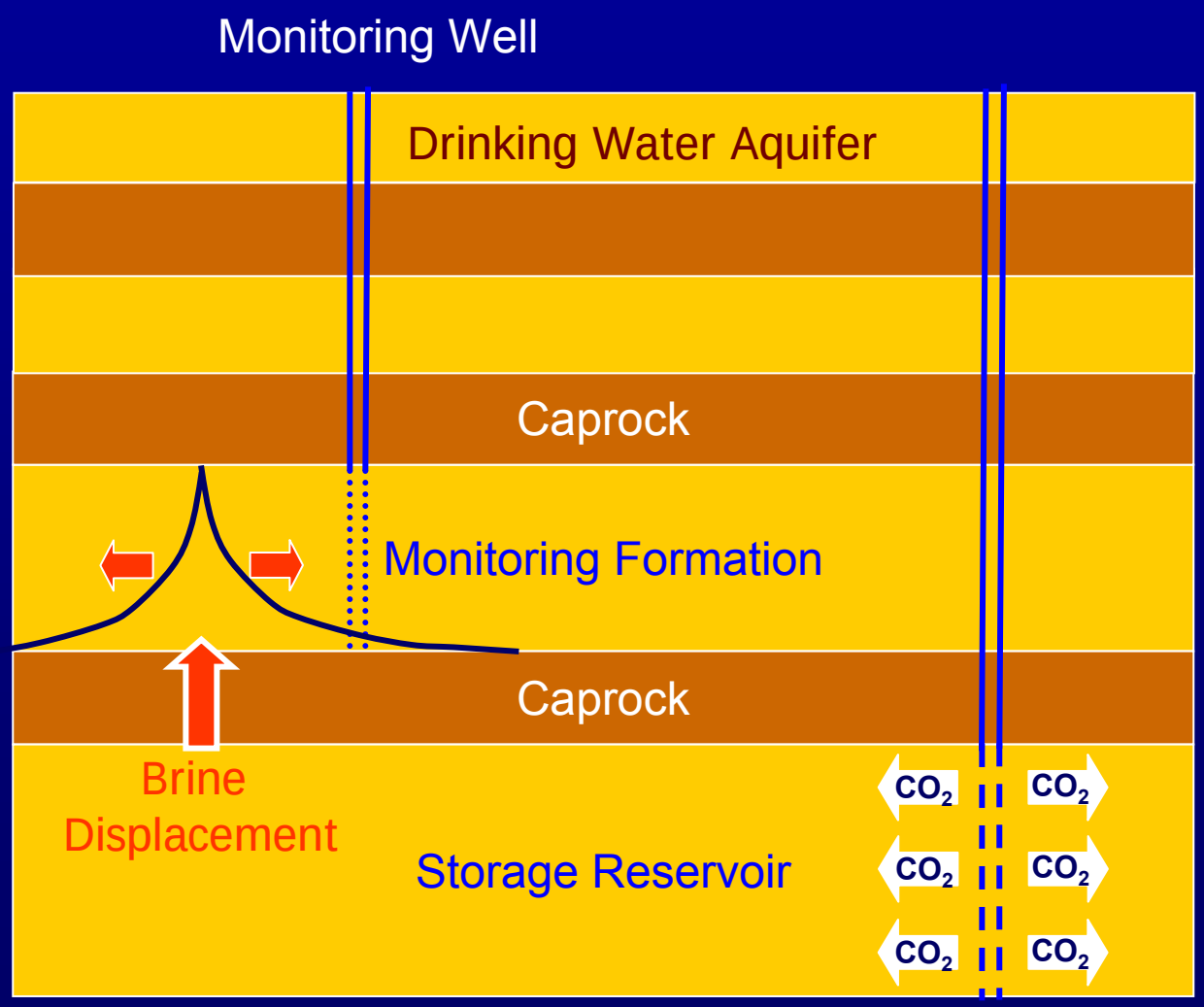
Basic Question Asked?

- Do pressure transient measurements have the sensitivity needed to detect significant leakage from the storage formation?
- What are the most promising and cost effective deployment approaches?

Basic Design of the Study (Part I)

- Leakage up a well
- Leakage though a localized region in the caprock
- Specified volumetric displacement in the monitoring formation
- Radial flow from a line source





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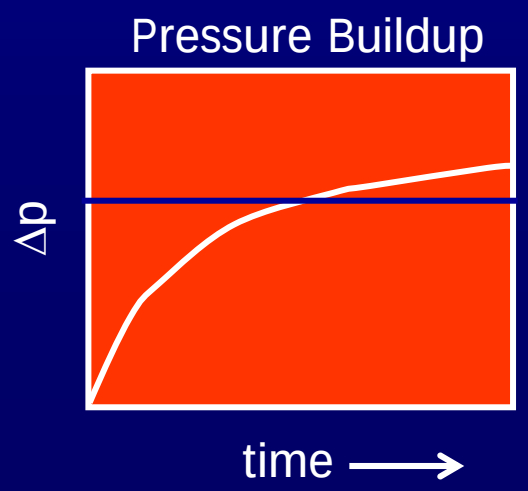
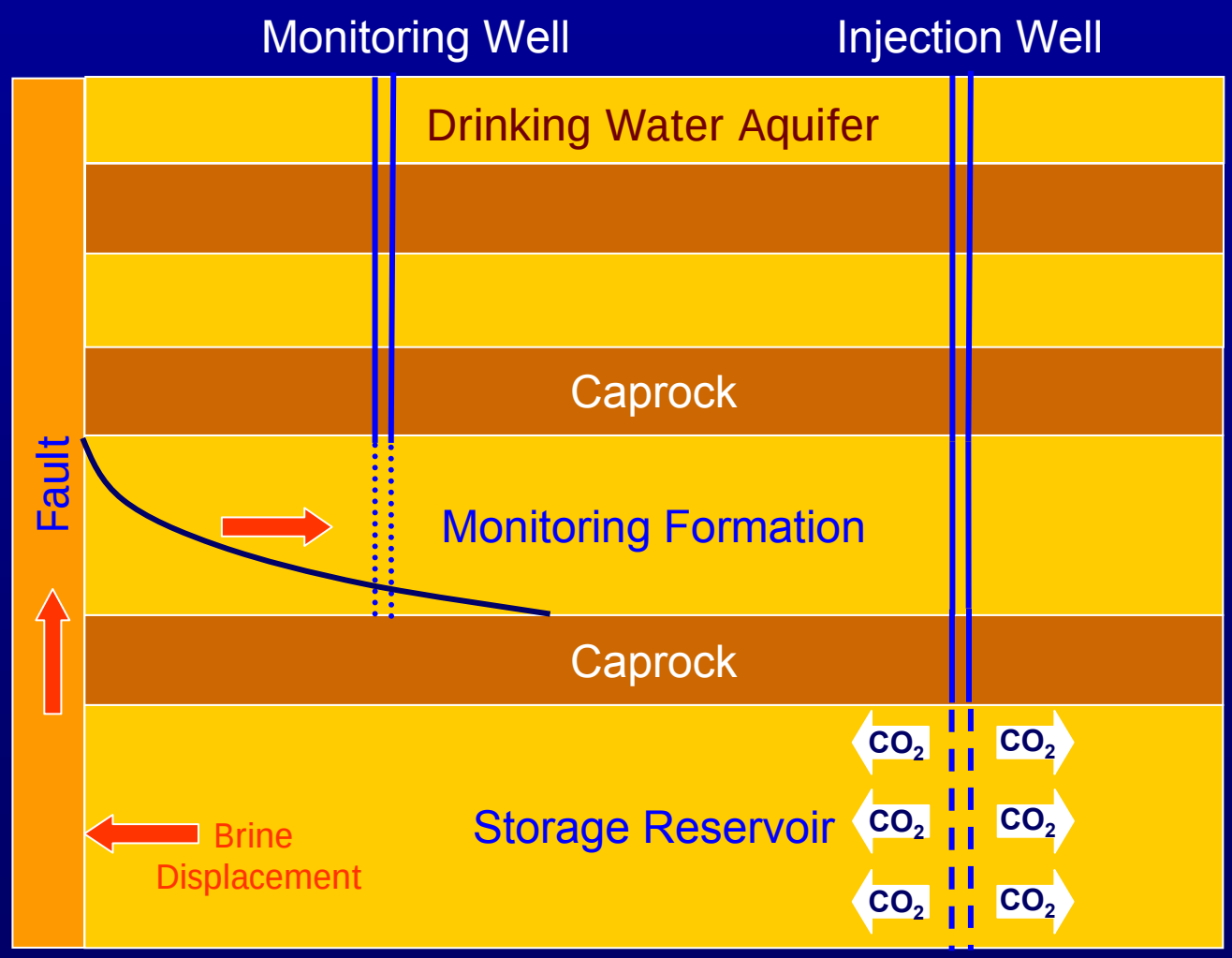
Basic Design of the Study (Part II)

- Leakage up a fault
- Specified volumetric injection rate in the storage formation





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Detection Limits for Pressure Changes

- Instrument resolution < 0.0007 bar (0.01 psi) at formation pressure
- Natural background fluctuations
  - Atmospheric pressure <~ 0.07 bar
  - Earth tides < ~0.005
  - Ocean tides (depends on location)
  - Precipitation
  - Effects of pumping or other uses

Can be filtered from the data.

- Instrument drift?

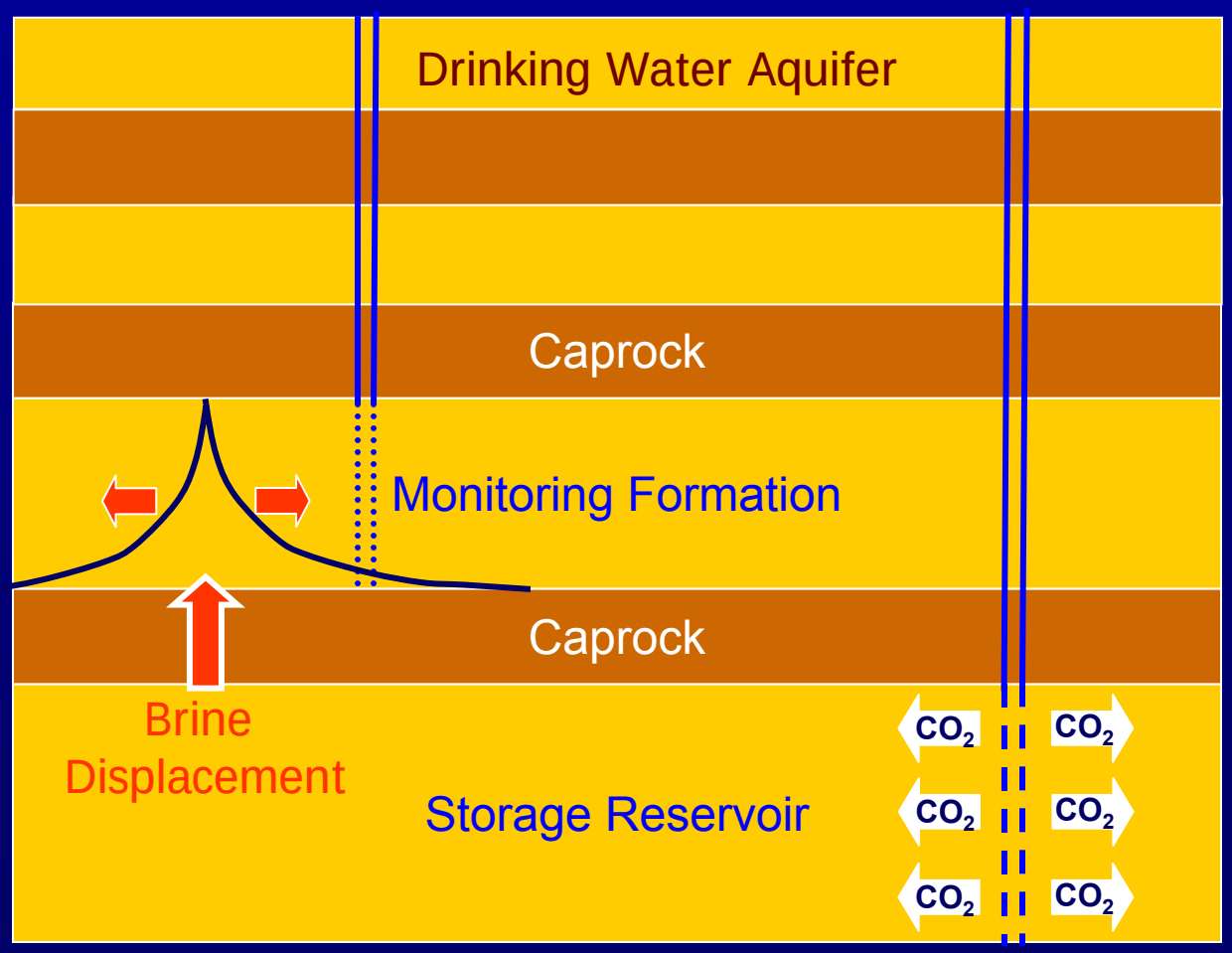
Assume: Pressure changes greater than 10x instrument resolution can be detected and are diagnostic of leakage ~ 0.007 bar (0.1 psi)

Sensitivity Studies (Part I)
Detection Sensitivity For Leakage Up a Well

$T = kh\rho g/\mu = 10^{-7}$ to 10^{-3} m^2/s
$S = 10^{-5}, 10^{-4}, 10^{-3}$
$r = 0.1, 0.5, 1, 10$ km

$Q = 0.1\%yr,$
$0.01\%yr,$
$0.001\%/yr$
$0.0001\%/yr$
$x\ CO_2$ mass in place

CO_2 mass in place:
5 Mt, 50 Mt



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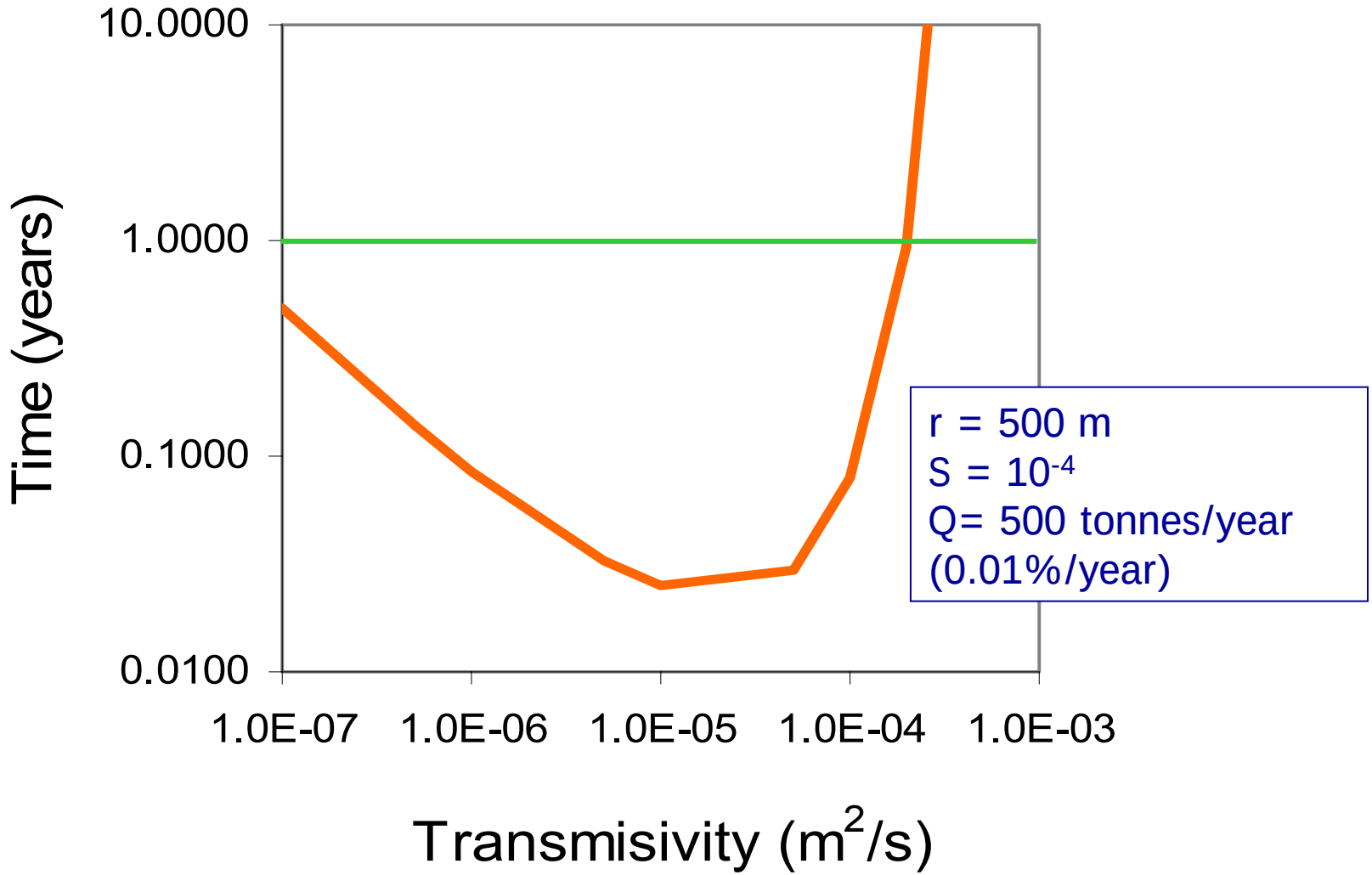
How long does it take to detect 0.007 bar (0.1 psi) pressure buildup?



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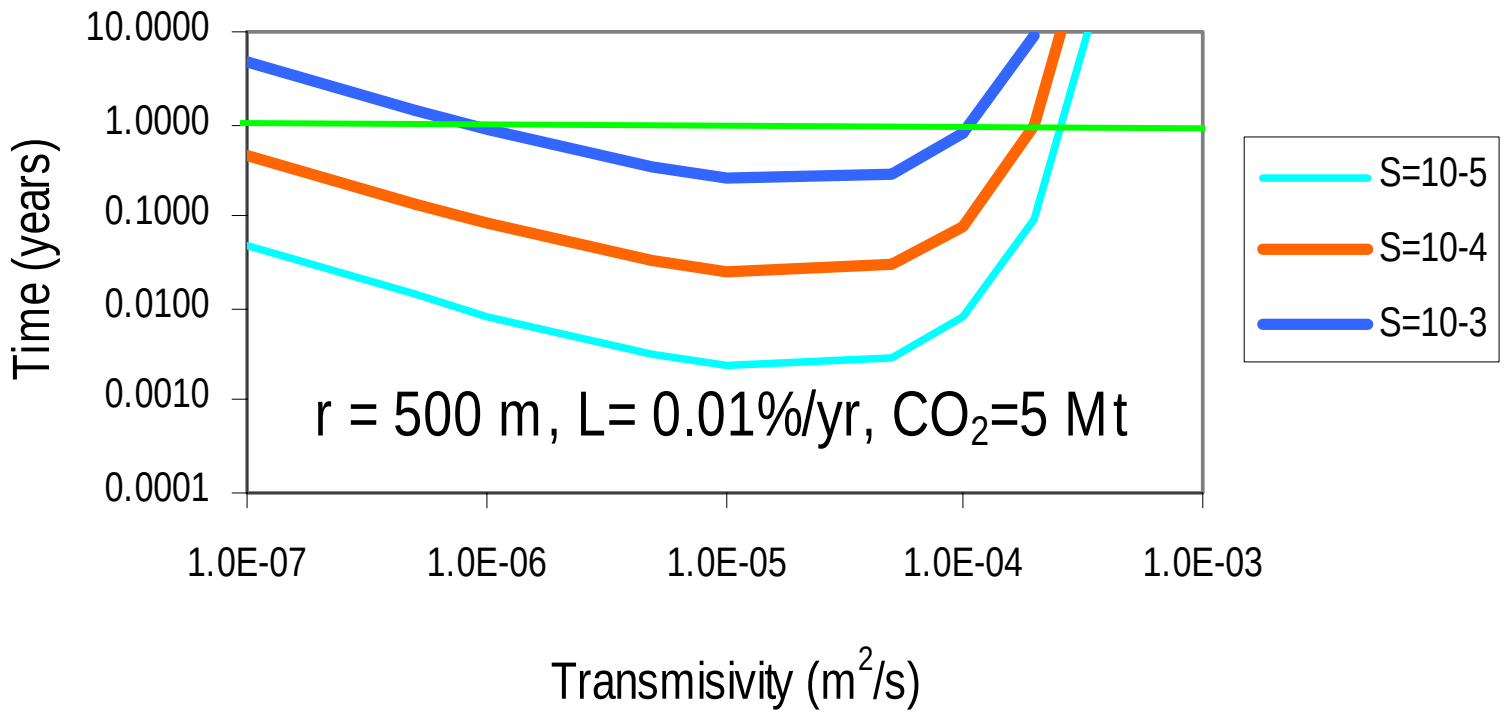
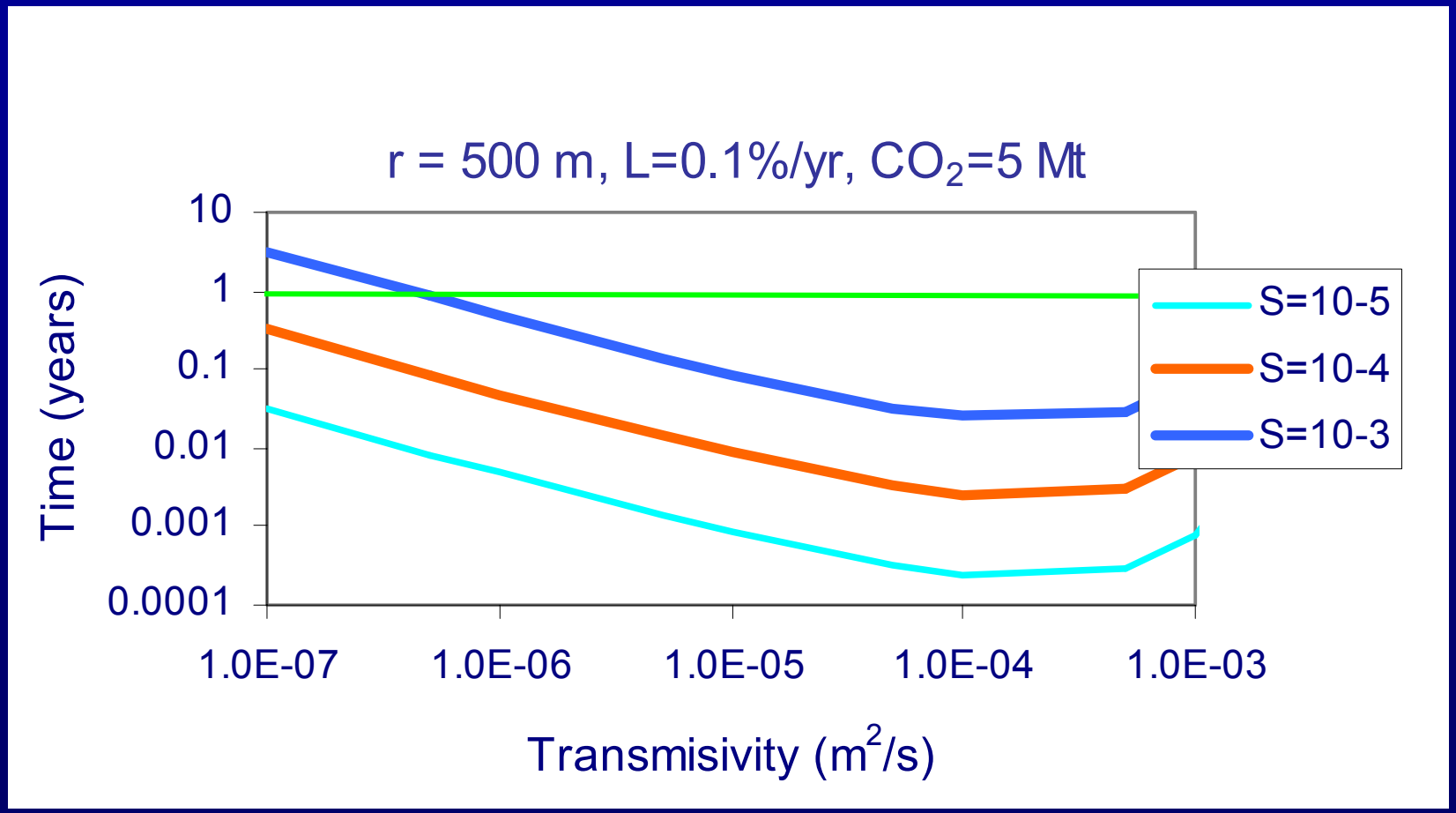


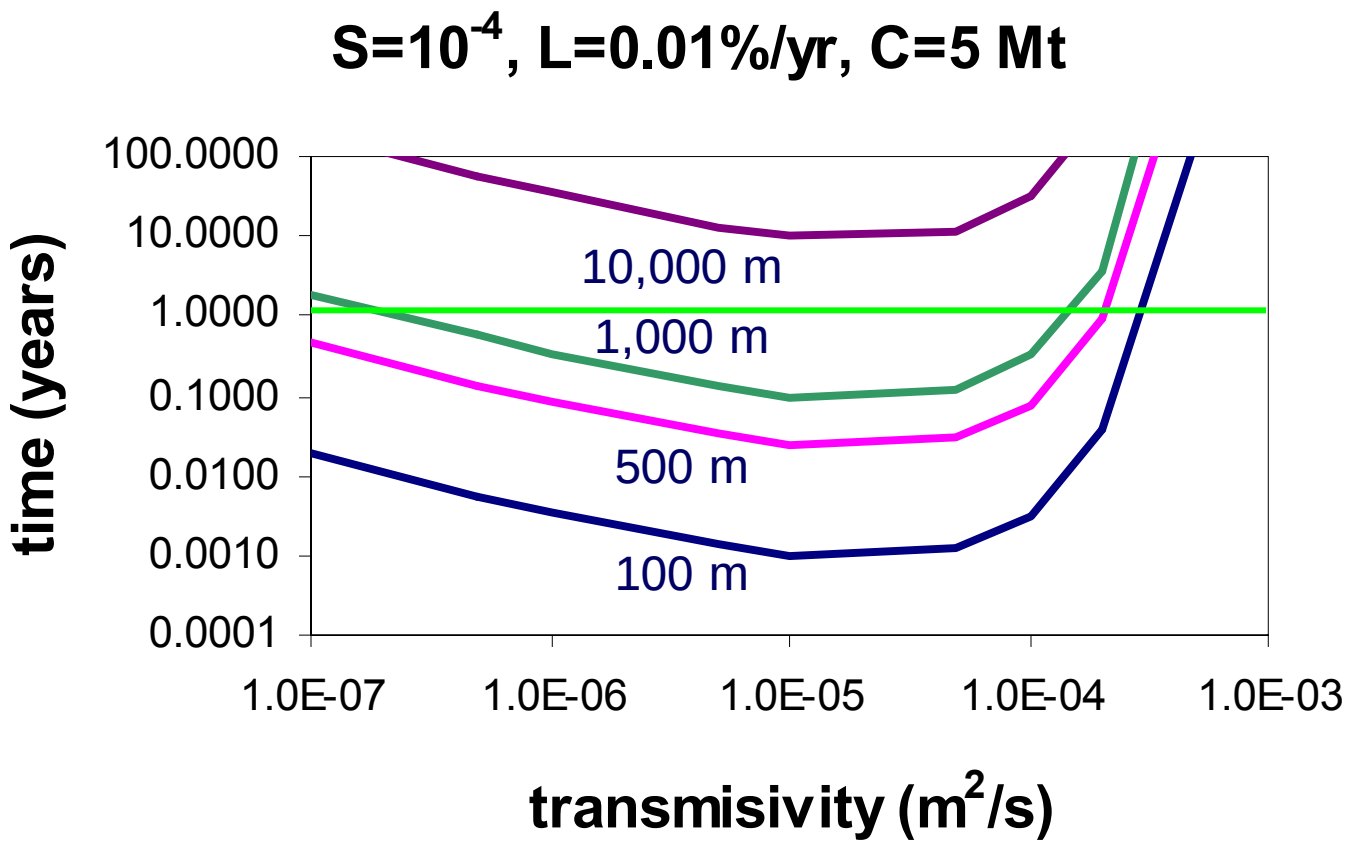
Leakage = 0.01%/yr * 5 Mt = 500 tonnes/year

At higher leakage rates...

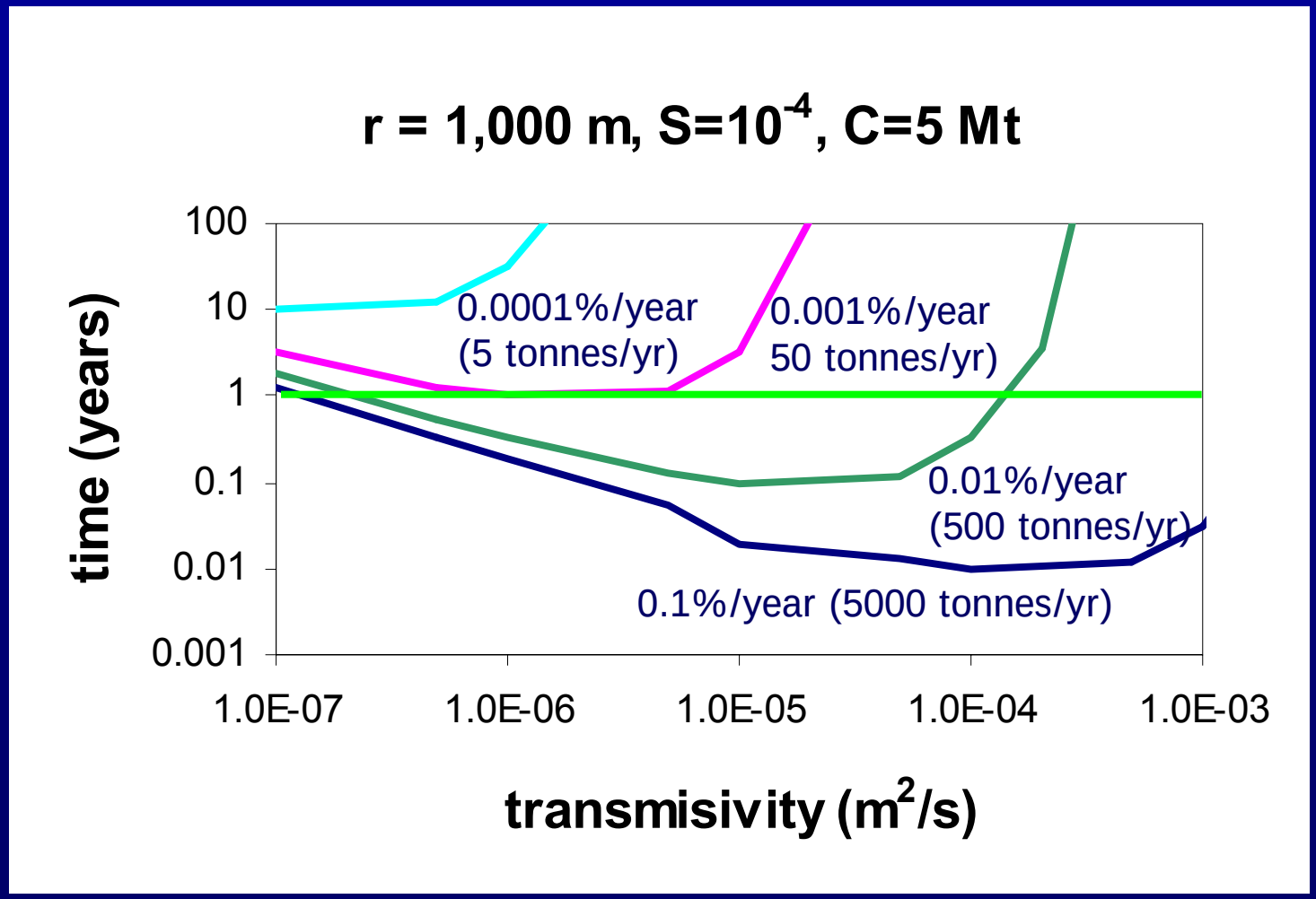


Leakage = 0.1%/yr * 5 Mt = 5000 tonnes/year

How close must the monitoring well be to the leak to detect leakage?



How small a leak can be detected?

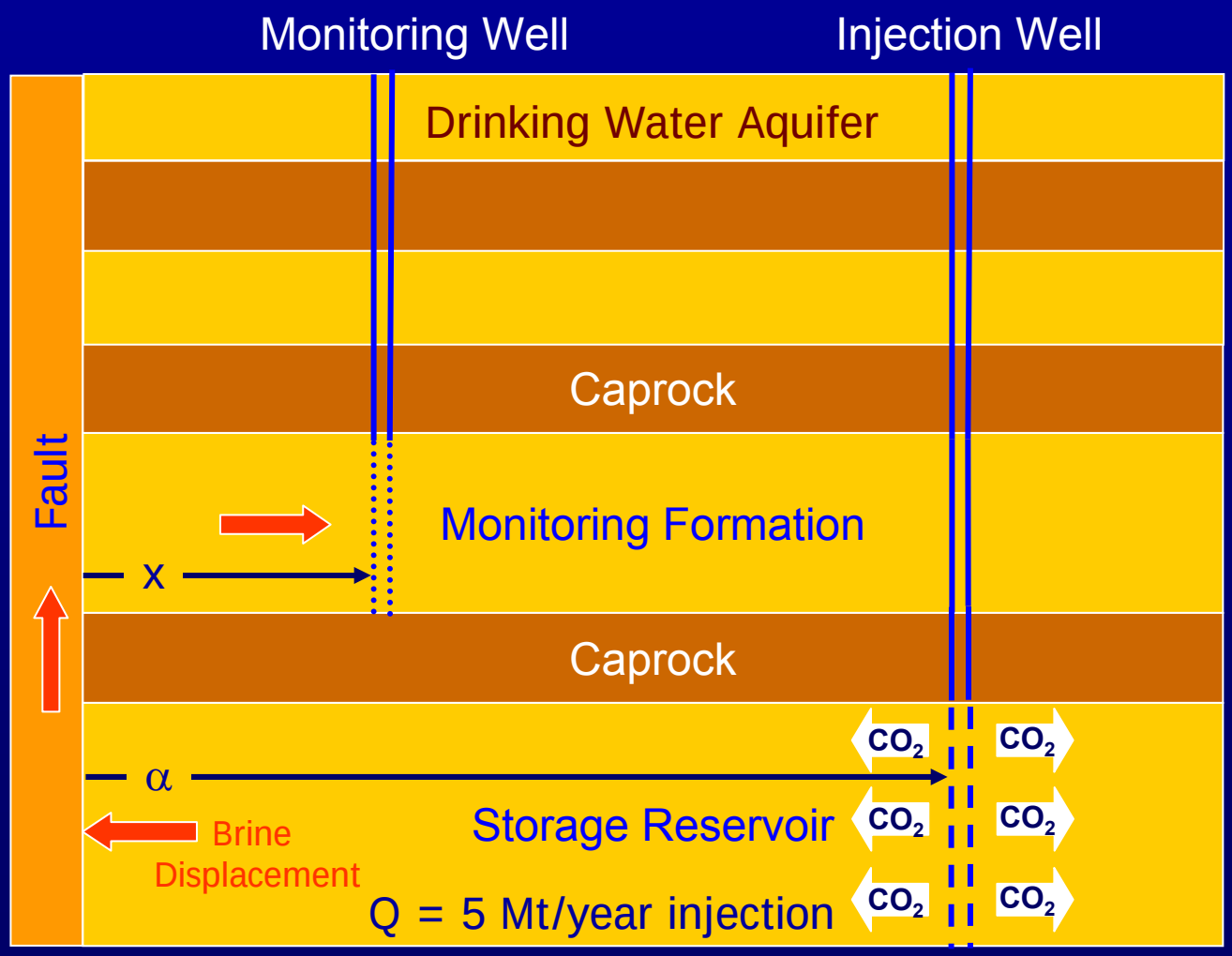


Maybe... it depends on the permeability and thickness of the monitoring horizon.

Sensitivity Studies (Part II)
Detection Sensitivity For Leakage Up a Fault

$T_S = 10^{-6}$ to 10^{-3} m^2/s
$T_m = 2x10^{-7}$ to $2x10^{-4}$ m^2/s
$S_s = 10^{-3}$
$S_m = 2x10^{-4}$
$T_f = 10^{-8}$ m^2/s
$L_f = 70$ m
$x = \alpha = 0.1, 0.5, 1, 5, 10$ km
$X = 10$ m, $\alpha = 2{,}000$ m

CO_2 injection rate: 5 Mt/year



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After Shan, C., I. Javandel, and P. A. Witherspoon, 1995.

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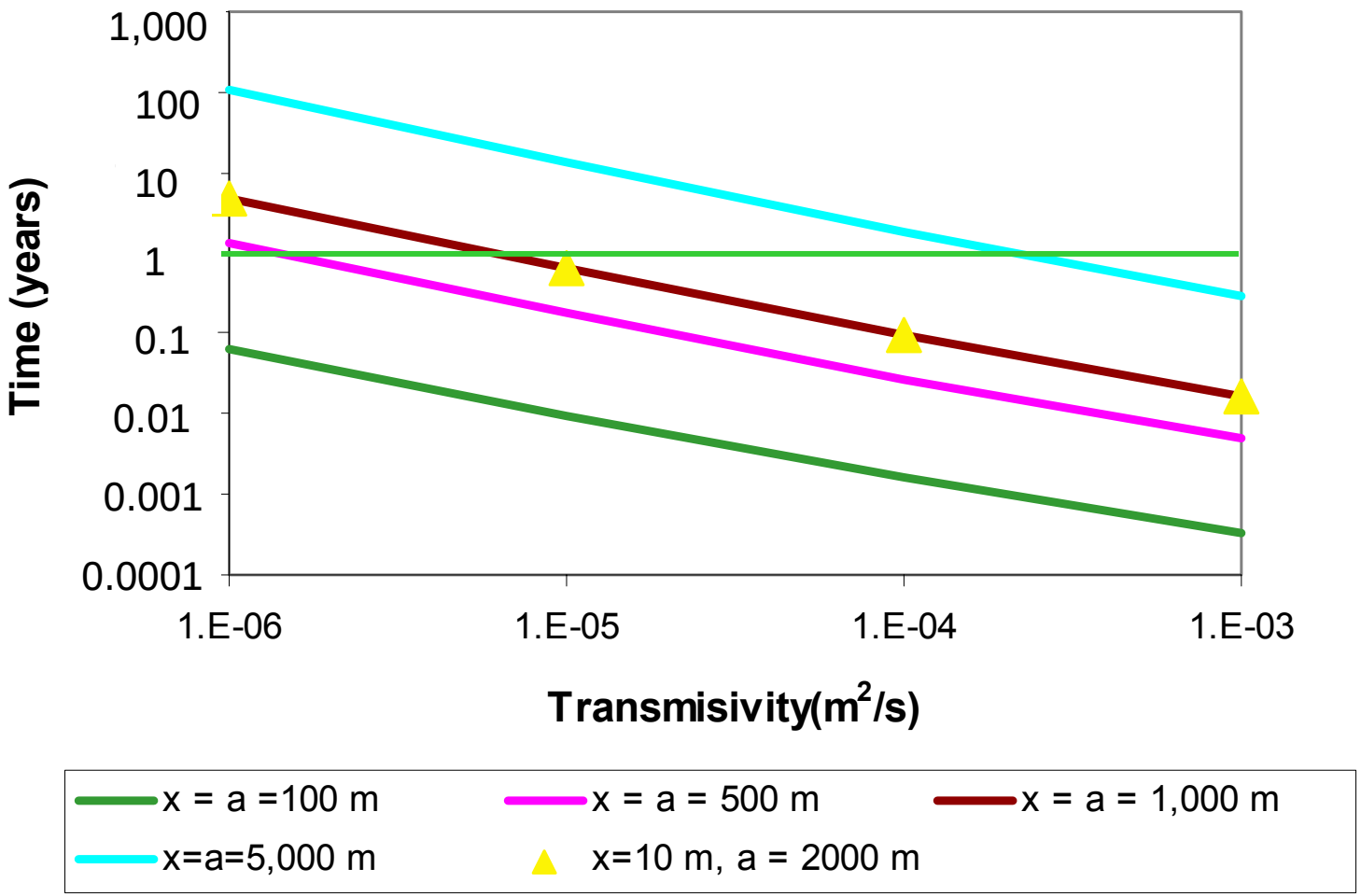
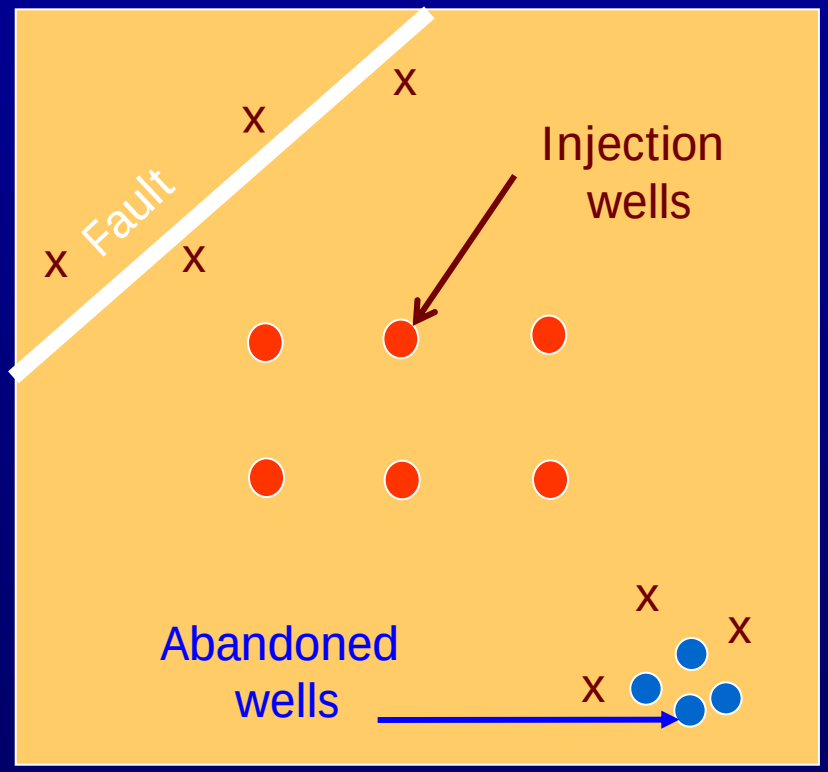
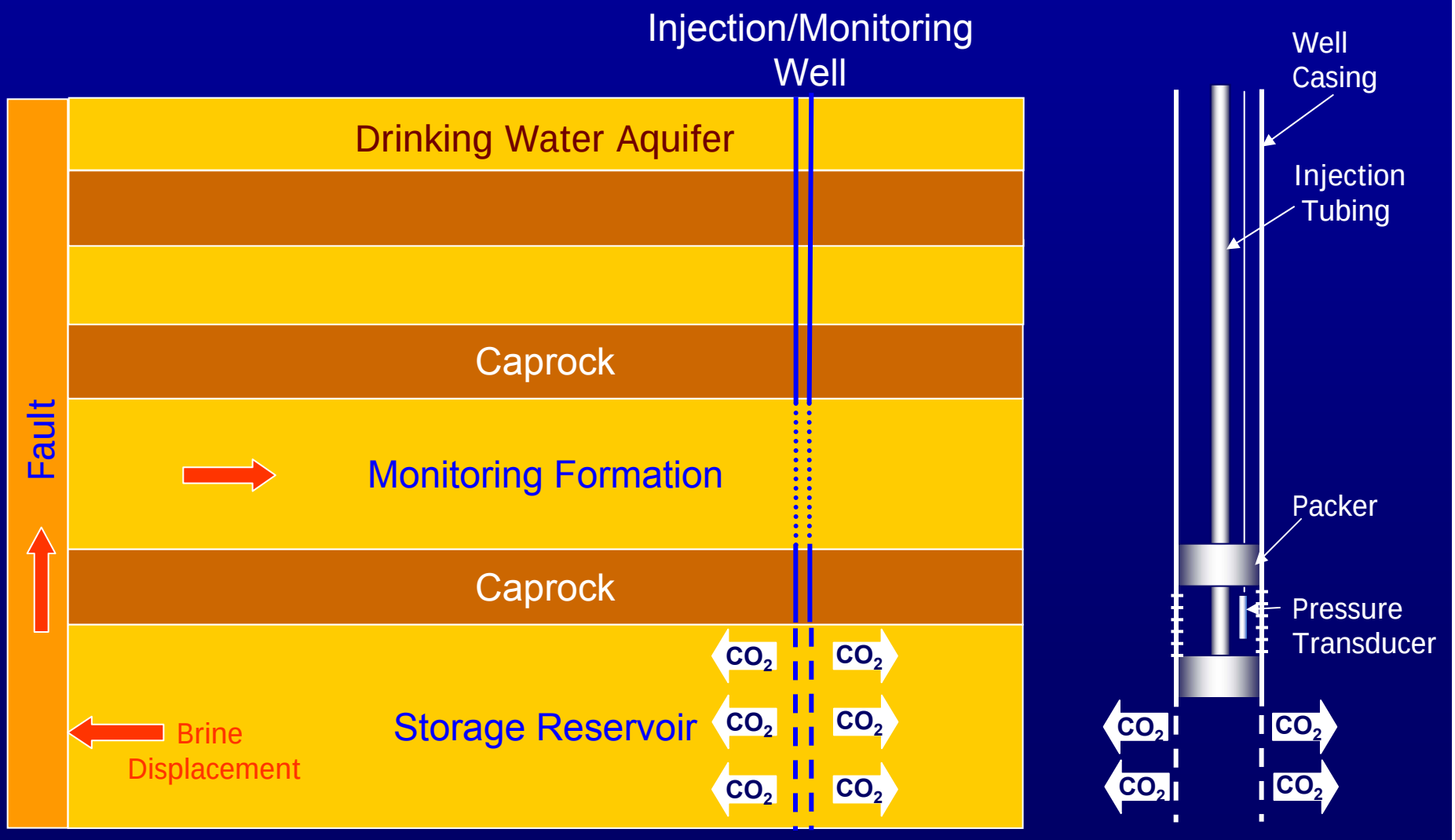


Strategy for Optimizing Detection Using Pressure Monitoring Wells

- Place monitoring wells near known vulnerabilities
  - Faults
  - Abandoned wells
- Use existing or abandoned wells for monitoring
- Modify injection wells for monitoring pressure above the injection zone
- Slimhole monitoring installation



Dual Purpose Injection and Monitoring Wells



Conclusions

- Under some circumstances pressure measurements could have the needed sensitivity to detect small leakage rates (0.01%/year, 500 tonnes/year)
  - Thin strata with moderate permeability is optimal
  - Site specific assessment needed
- Leak detection most probable for distance of 1 km or less from the leak
- Could be useful for providing early warning of large leaks (< 1 year after injection begins)
  - Brine displacement also can be detected
- Optimization needed to employ at reasonable cost
  - Placement of monitoring wells
  - Dual purpose injection and shallow monitoring wells
  - Slimhole drilling
- Unlikely to replace seismic monitoring, but may help to reduce the frequency or costs of seismic data acquisition
- Particularly useful for assessing known vulnerabilities