Issues Related to Multiple Wells Perforated in the Same Injection Zone

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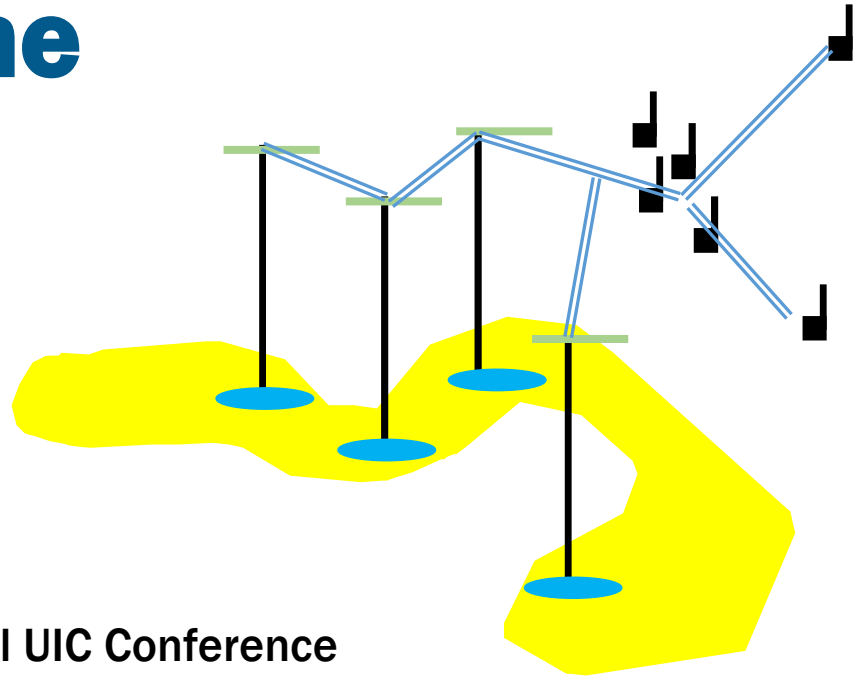

Presented to Groundwater Protection Council UIC Conference
Oklahoma City OK, Feb 27, 2024

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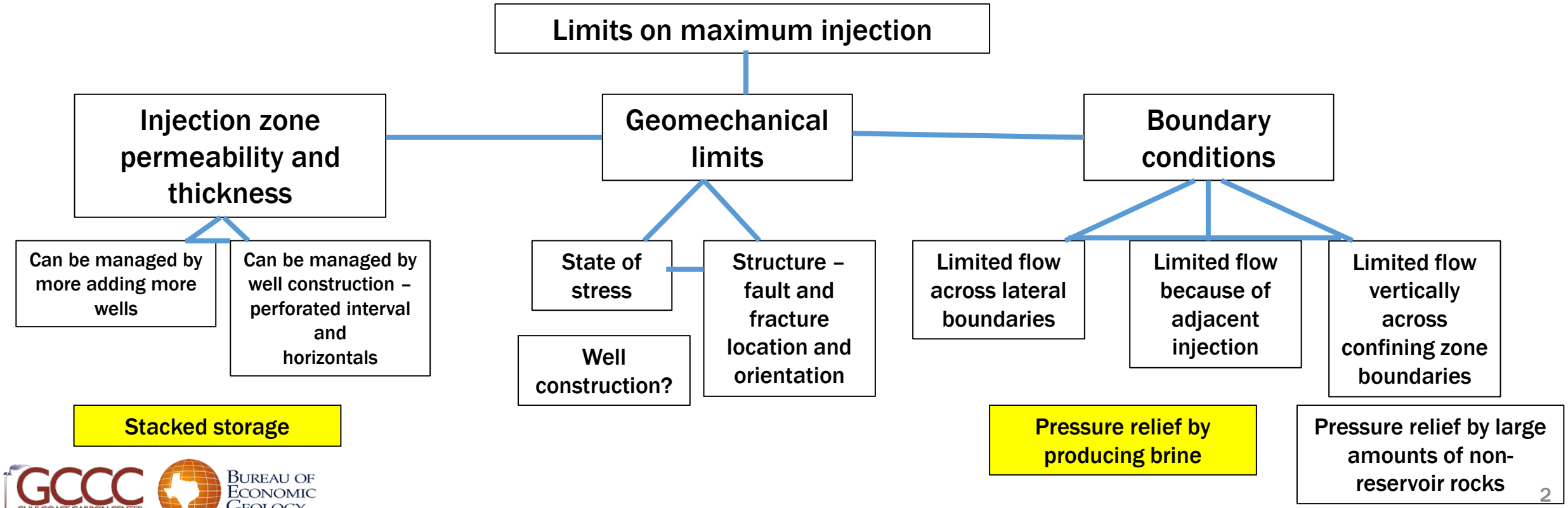
All space in the subsurface is limited

- Pushing to maximum scale at hubs will probe these limits
- This brings management questions how to manage interferences



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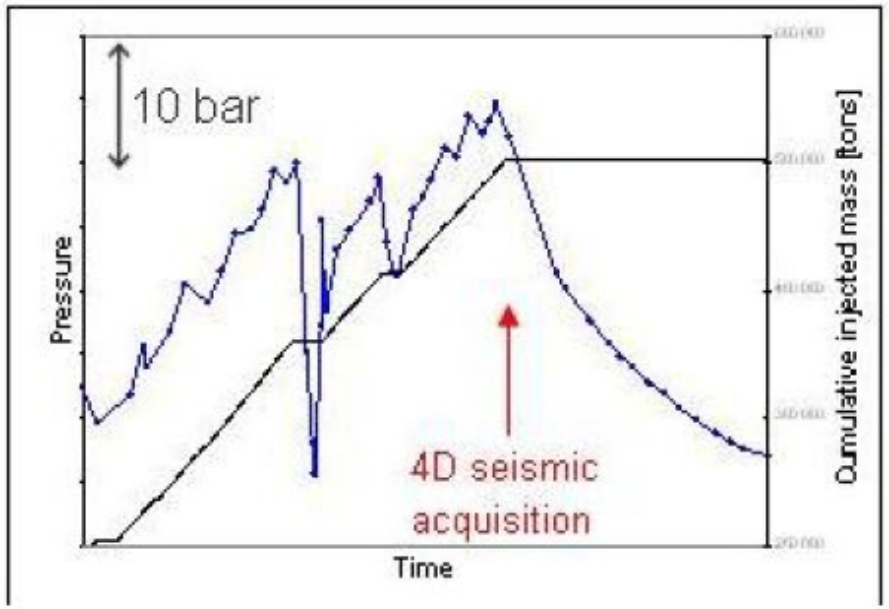
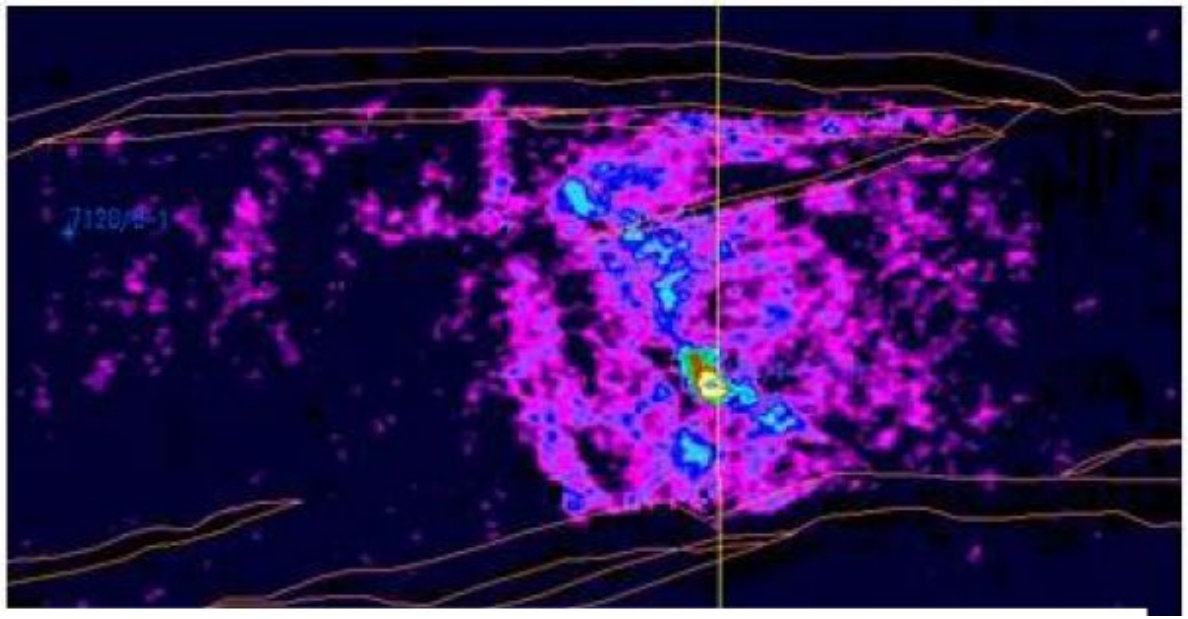
Not an academic exercise -- Issues have occurred with CO_2 injection (but been solved by management)

- Horizonal well to optimize injectivity exceeded geomechanical limits and fracturing seal - In Salah
- One well exceeding available pressure-space –Snøhvit Barents Sea

Change in bottom hole pressure



4-D seismic difference map

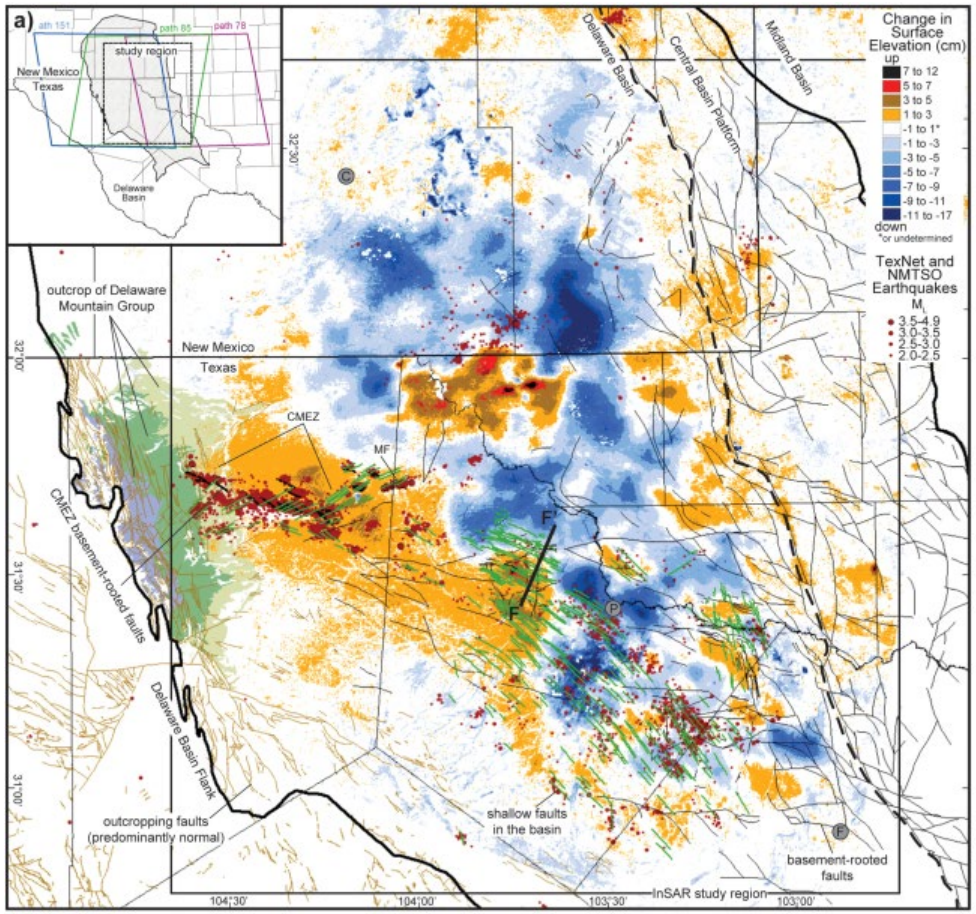


Eiken, Hermenrud, Nazarian, Torp, Høier, doi:10.1016/j.egypro.2011.02.541

Example of basin–scale pressure build up, Permian basin TX -NM

Class II water injection from many wells has aggregated and interferes with continued injection

A lesson for class VI



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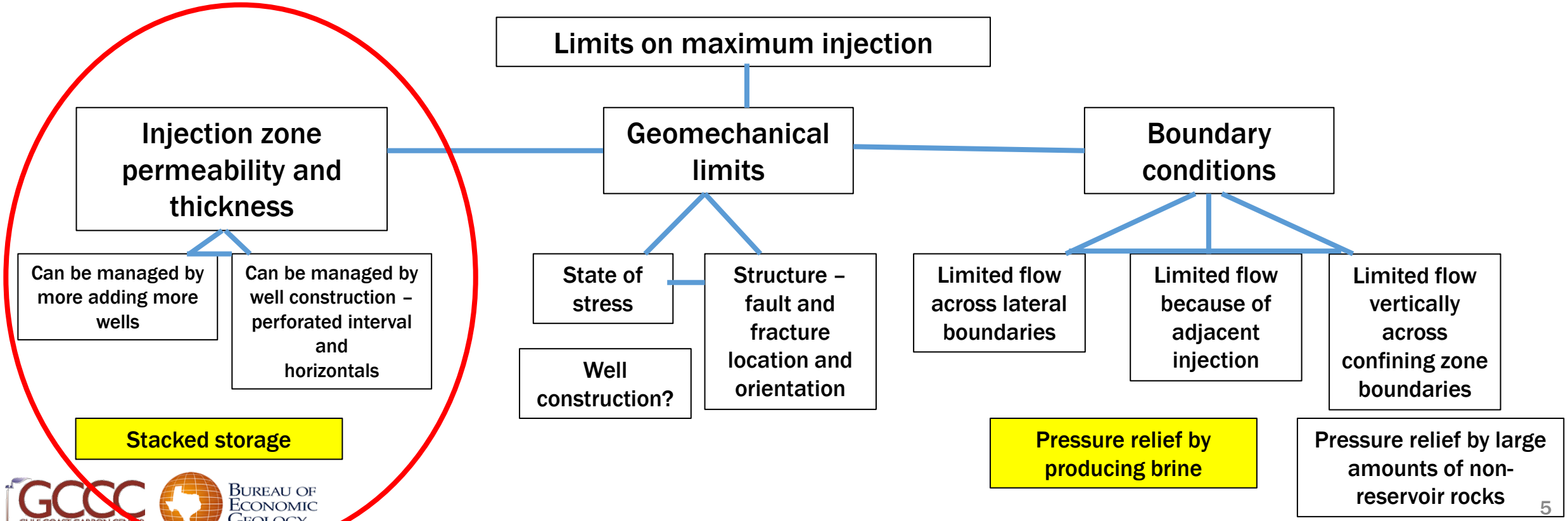
Hennings et al, 2023, https://doi.org/10.1016/j.scitotenv.2023.166367

All space in the subsurface is limited

- Pushing to maximum scale at CO2 and hydrogen hubs will probe these limits
- Already multiple uses of subsurface
- This brings questions how to manage interferences



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Using EASiTool to explore options for management of pressure-space

- Links full physics analytical models
- Free and online (contact Seyyed.hossieni@beg.utexas.edu)

Excel spreadsheet input of parameters

Reasonable defaults for difficult-to-find parameters

Few second runtime

Graphic and tabular output

However, have to move to other models to assess impact of reservoir architecture, heterogeneity, dip

We

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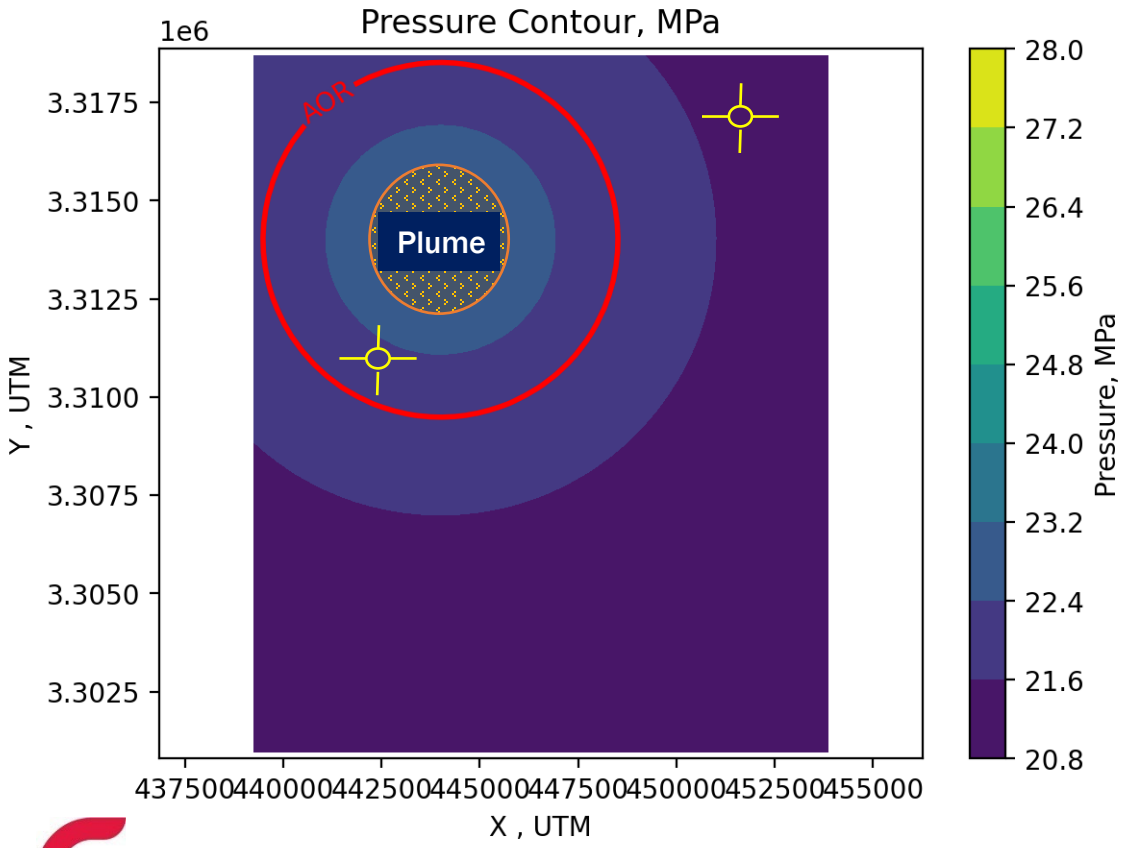
EASiTool output for one well



EASi-tool 5.0

P&A well

Input depth, thickness, porosity, permeability, critical pressure for AoR calculation. Add rock and fluid properties (if known).

Specify injected rate and duration

Map pressure increase in injection zone, estimate CO_2 plume area and Area of Review

Also run sensitivity on parameter uncertainty

Simple finance model also available in software

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Management by adding more wells

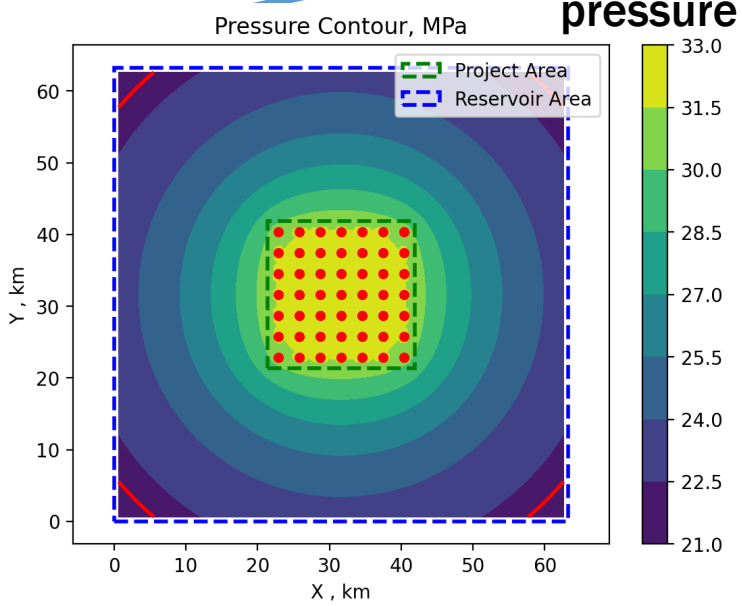
- Turning single wells into well fields or multiple projects

Limits on maximum pressure

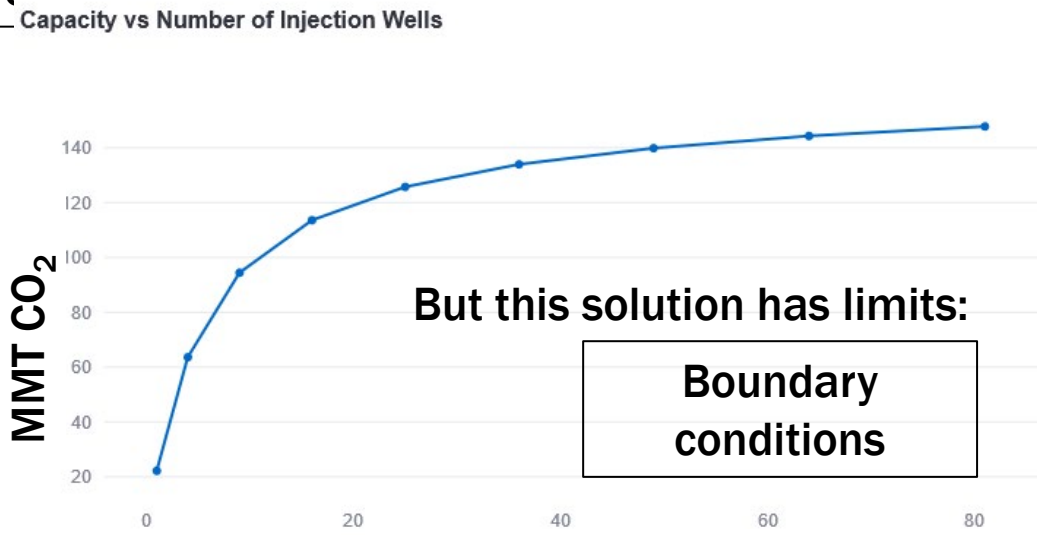
Injection zone permeability and thickness

Can be managed by more adding more wells

Can be managed by well construction – perforated interval and horizontals



pressure



But this solution has limits:

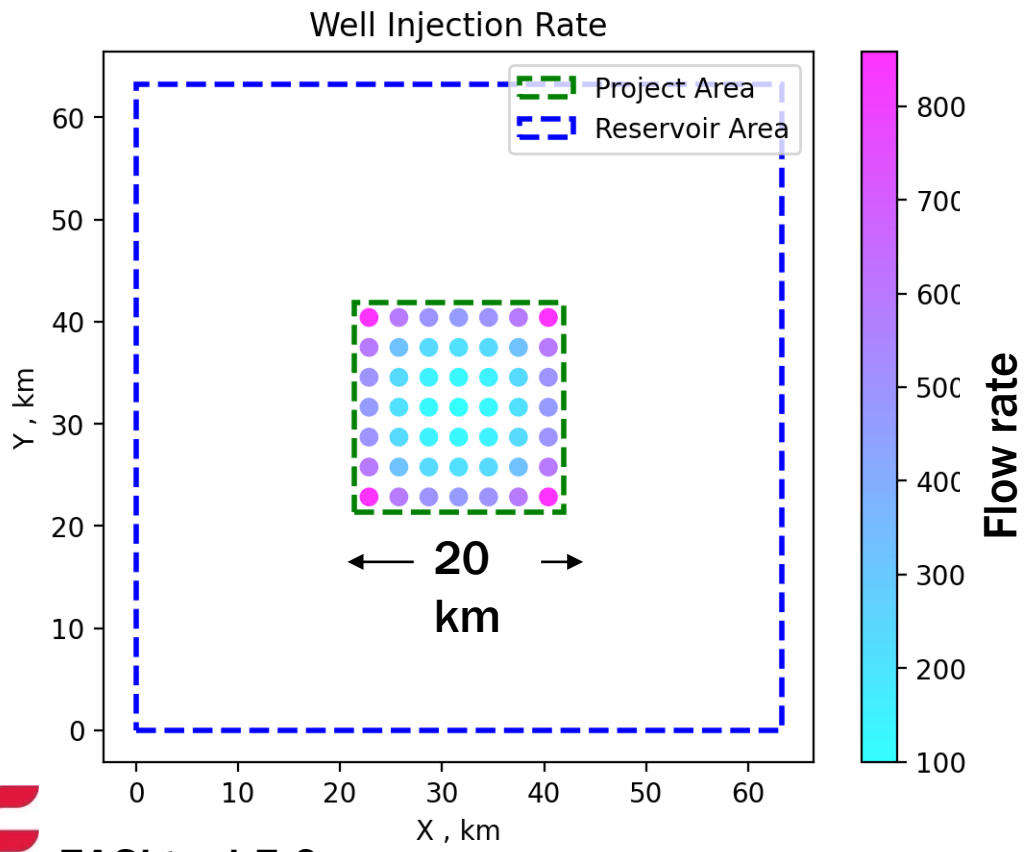
Boundary conditions

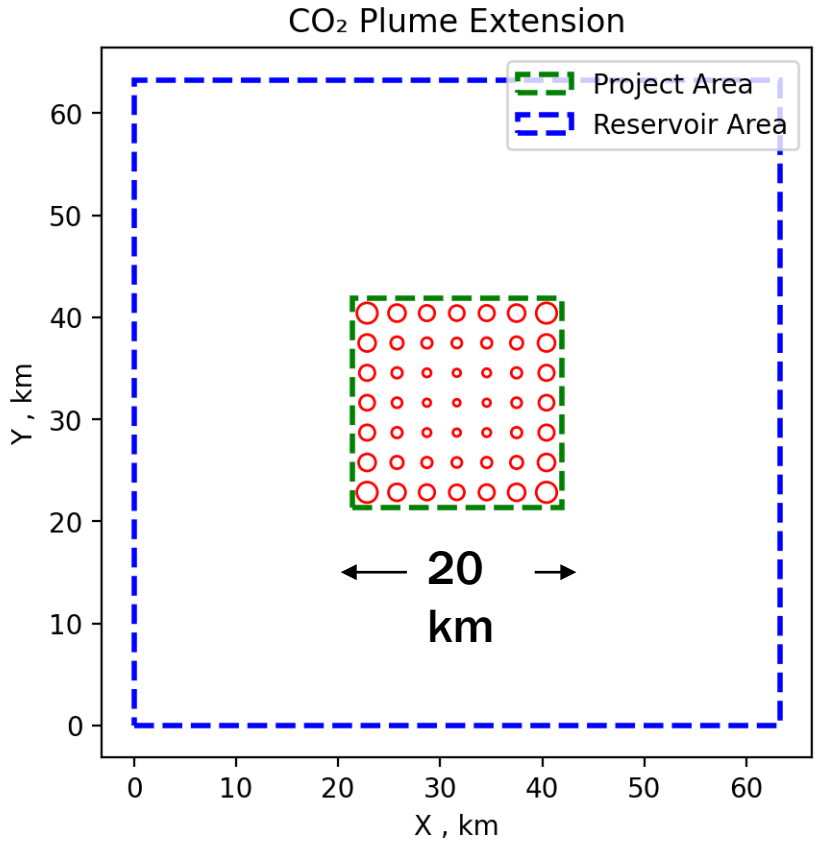
Number of injection wells

- CO_2 plume

EASitool 5.0

See the impact of adjacent wells in injection amounts





EASi-tool 5.0

Plume extent

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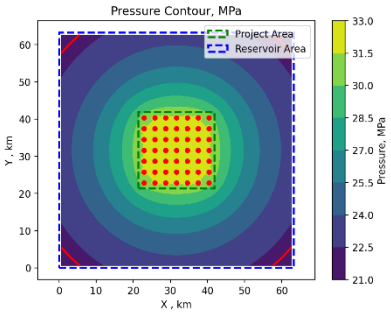
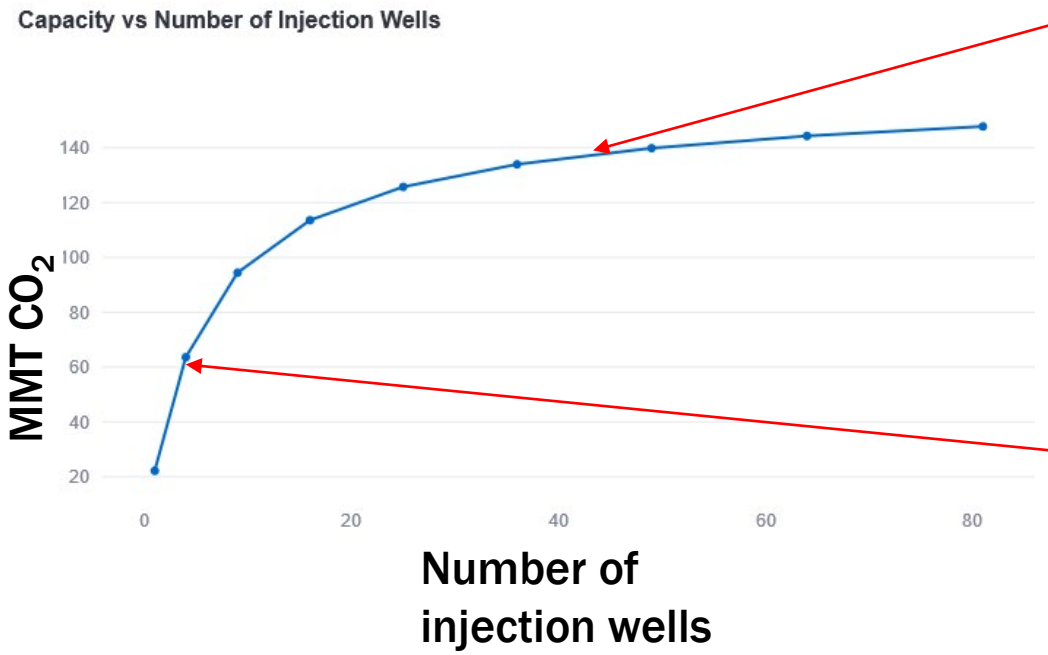
Note policy tradeoffs





- Maximum use of the pores space results from many wells competing
- This an advantage for property owner, may benefit a single operator
- Maximum net present value for first few operators is to stop permitting and allow no competition

"capacity" is not a single number but depends on how many wells

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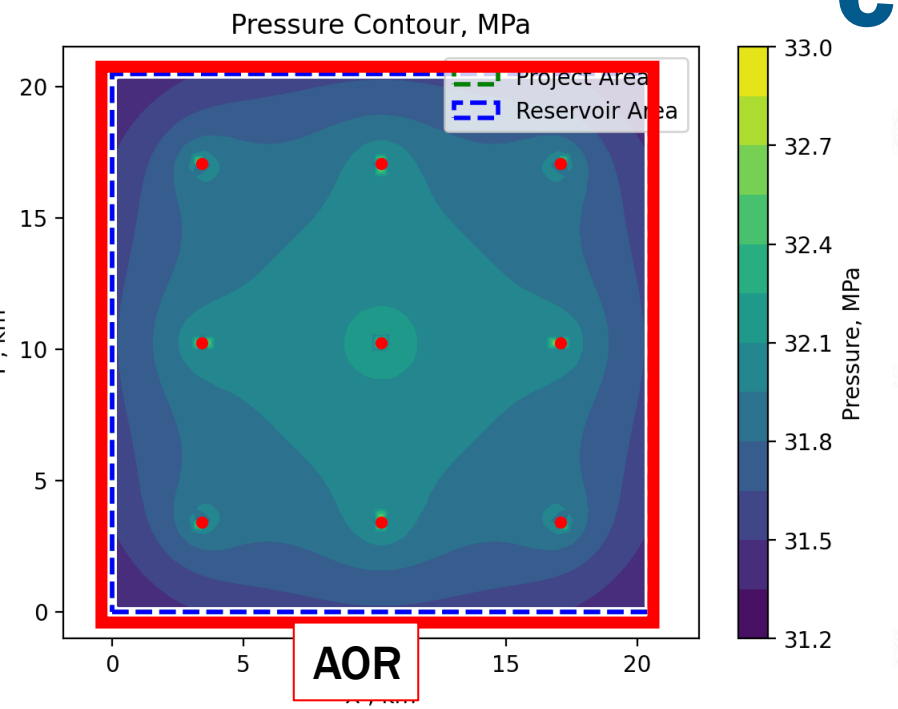
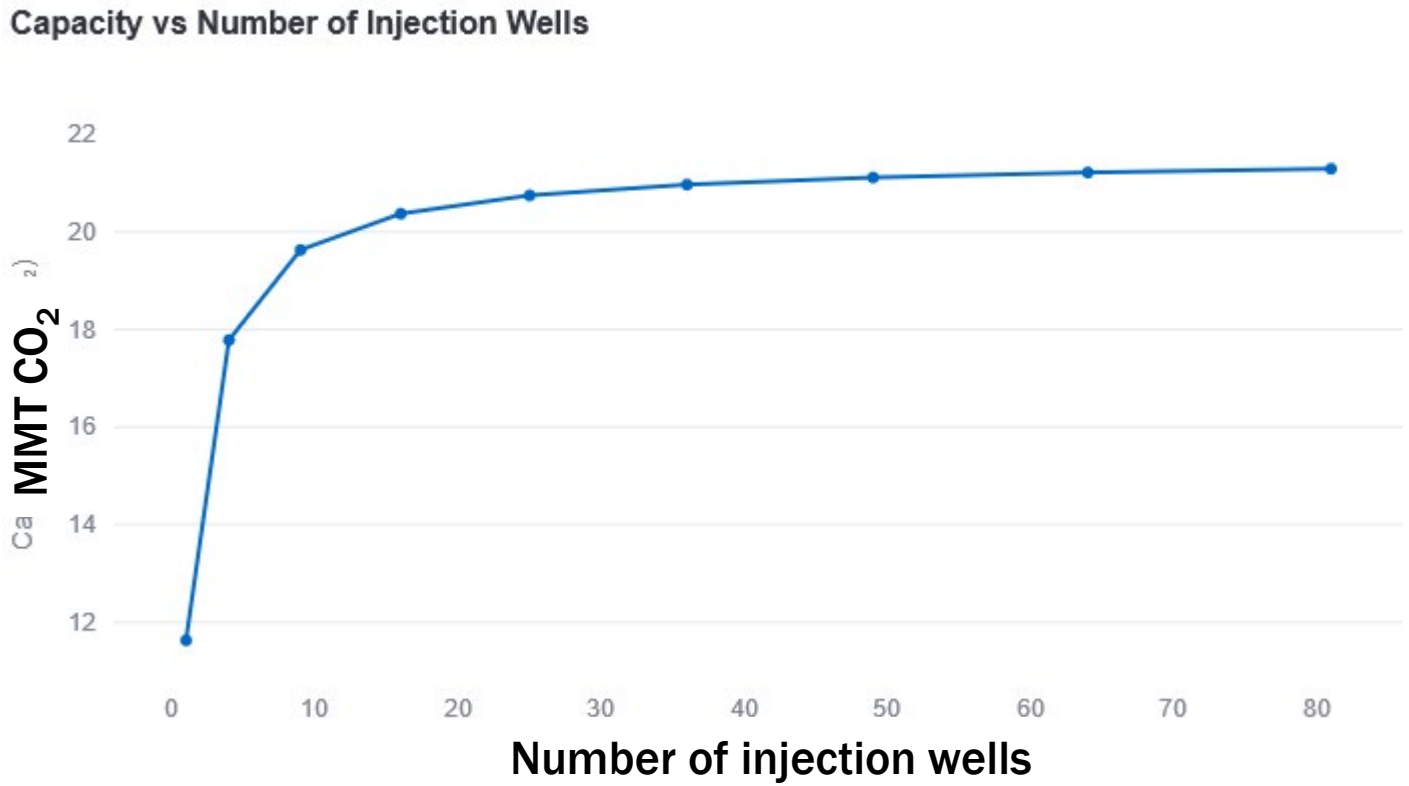
Impact of boundaries -- Same model, closed boundaries





20 km

EASitool 5.0

CO_2 plume

Closure can be faults or adjacent projects

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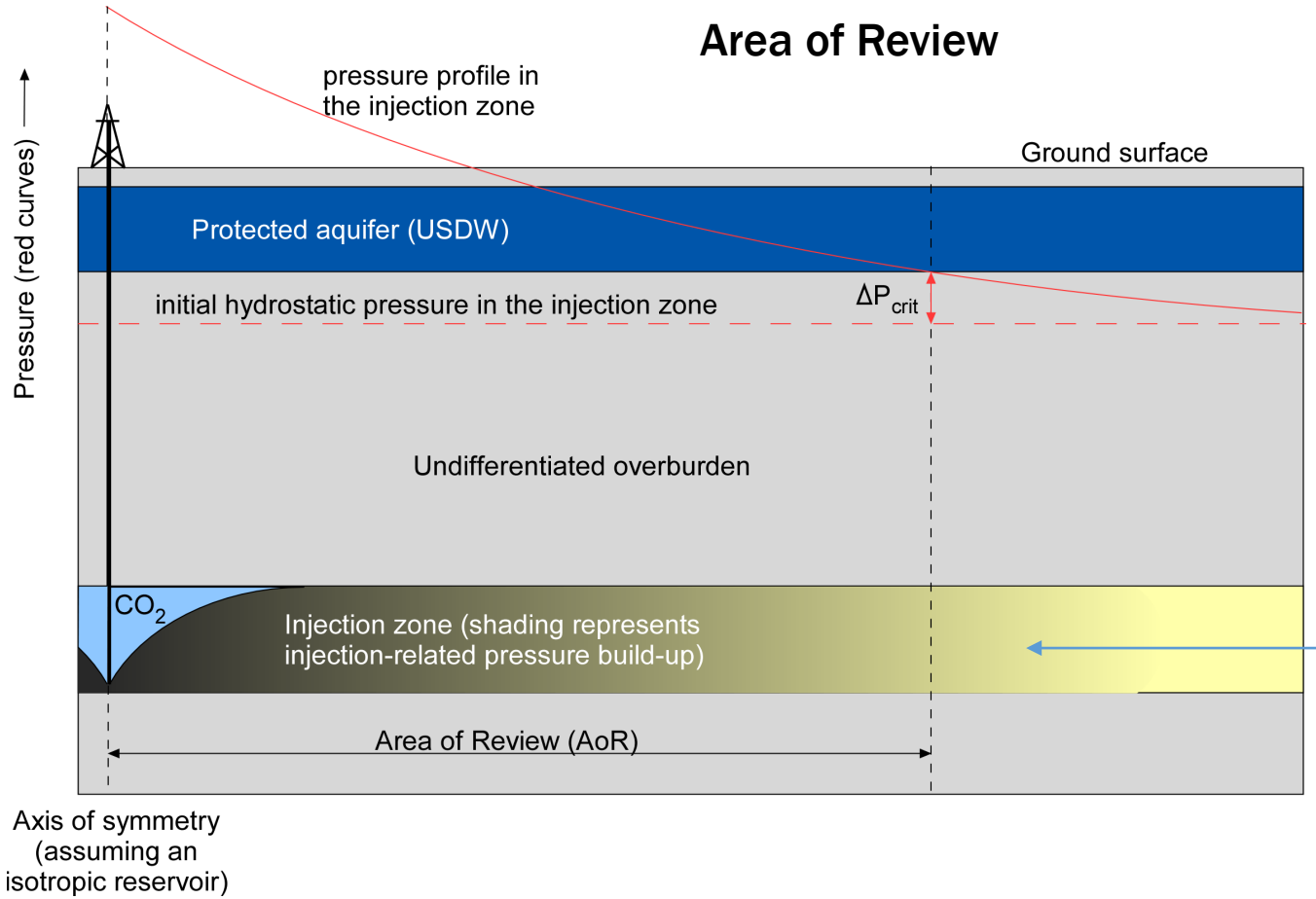
Project's Pressure Footprint



Detectable change in pressure

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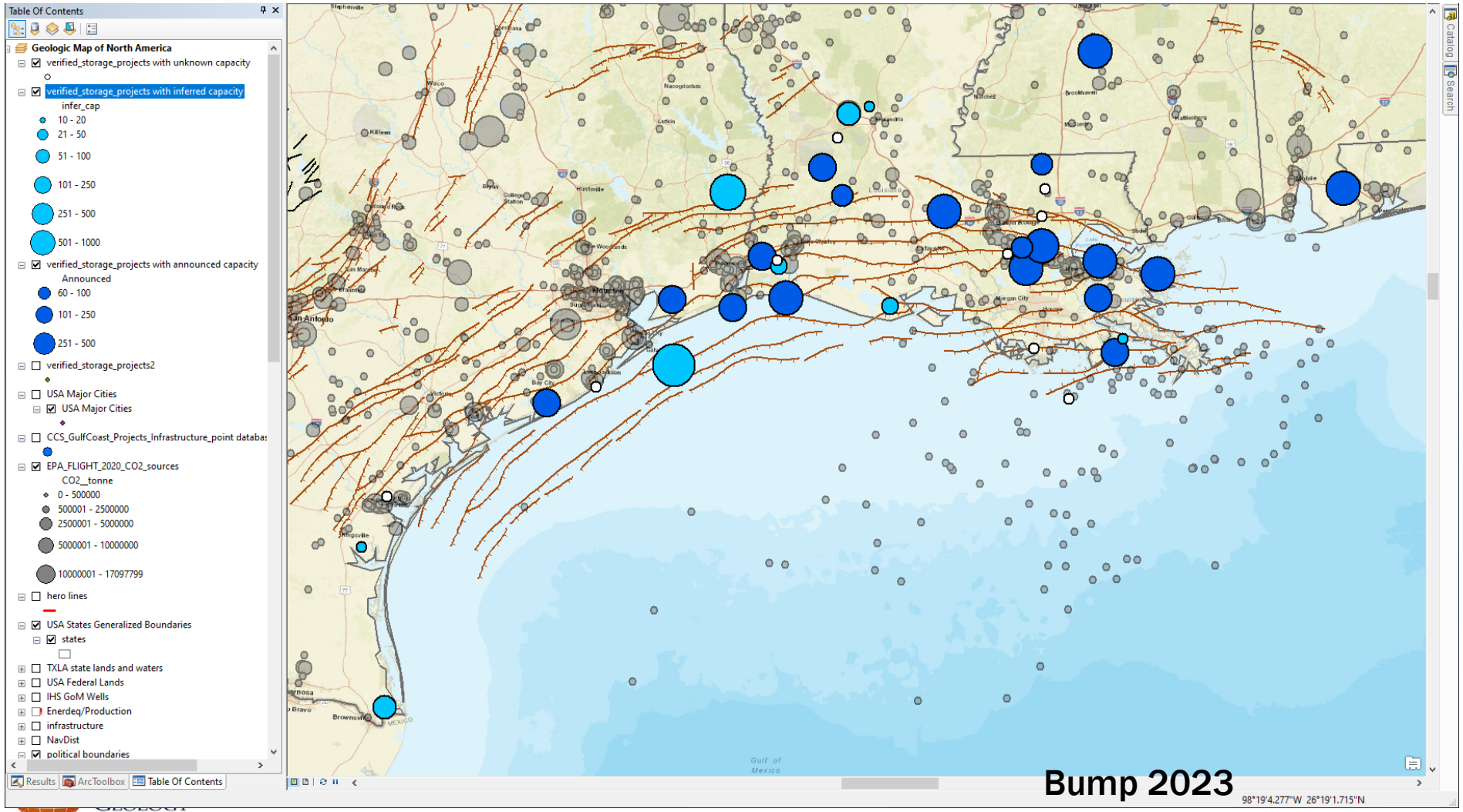
Volumes planned to be injected are large



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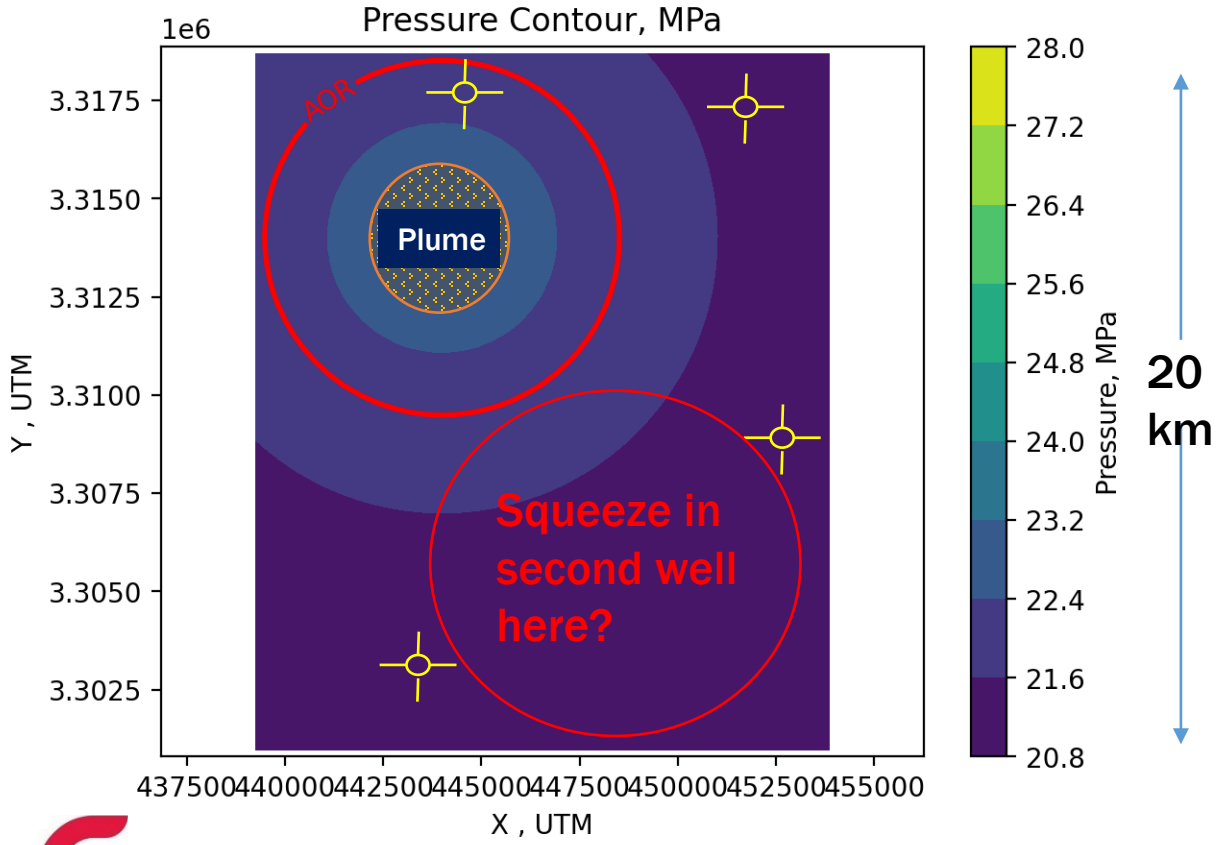
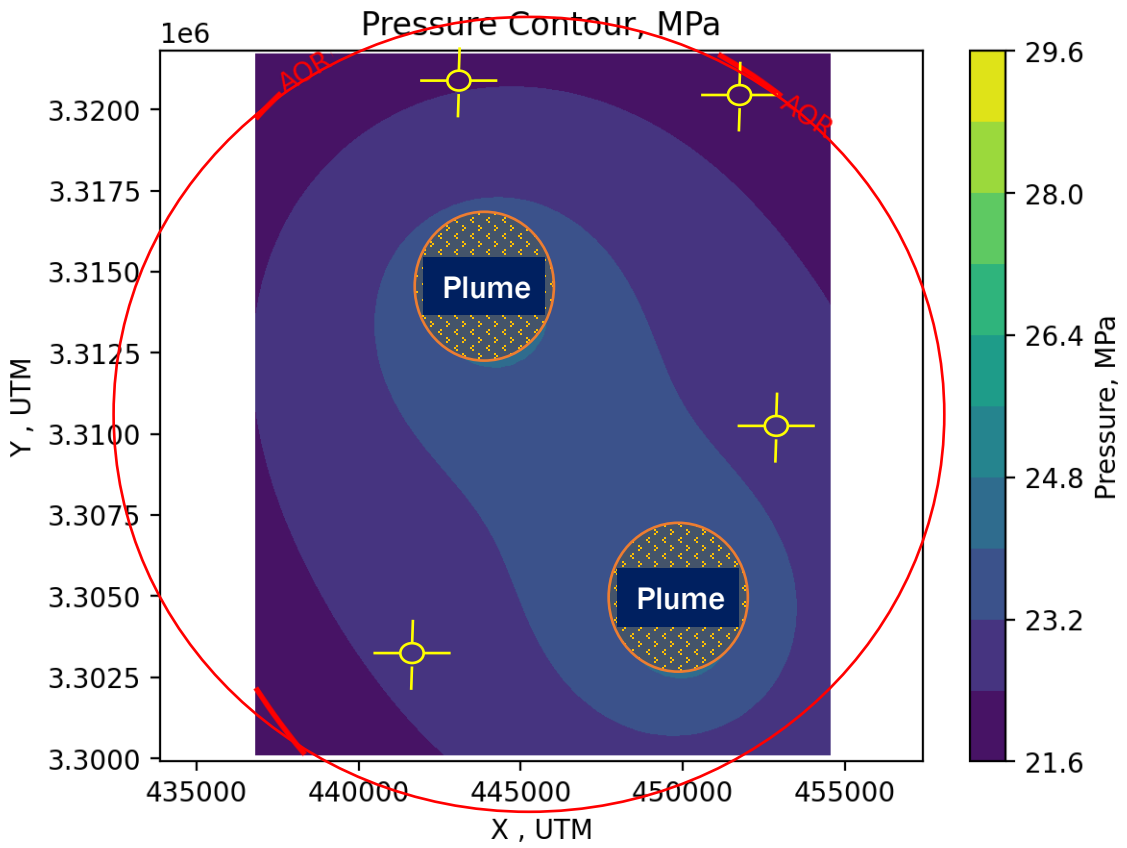
Impact of two wells on AOR



20 km

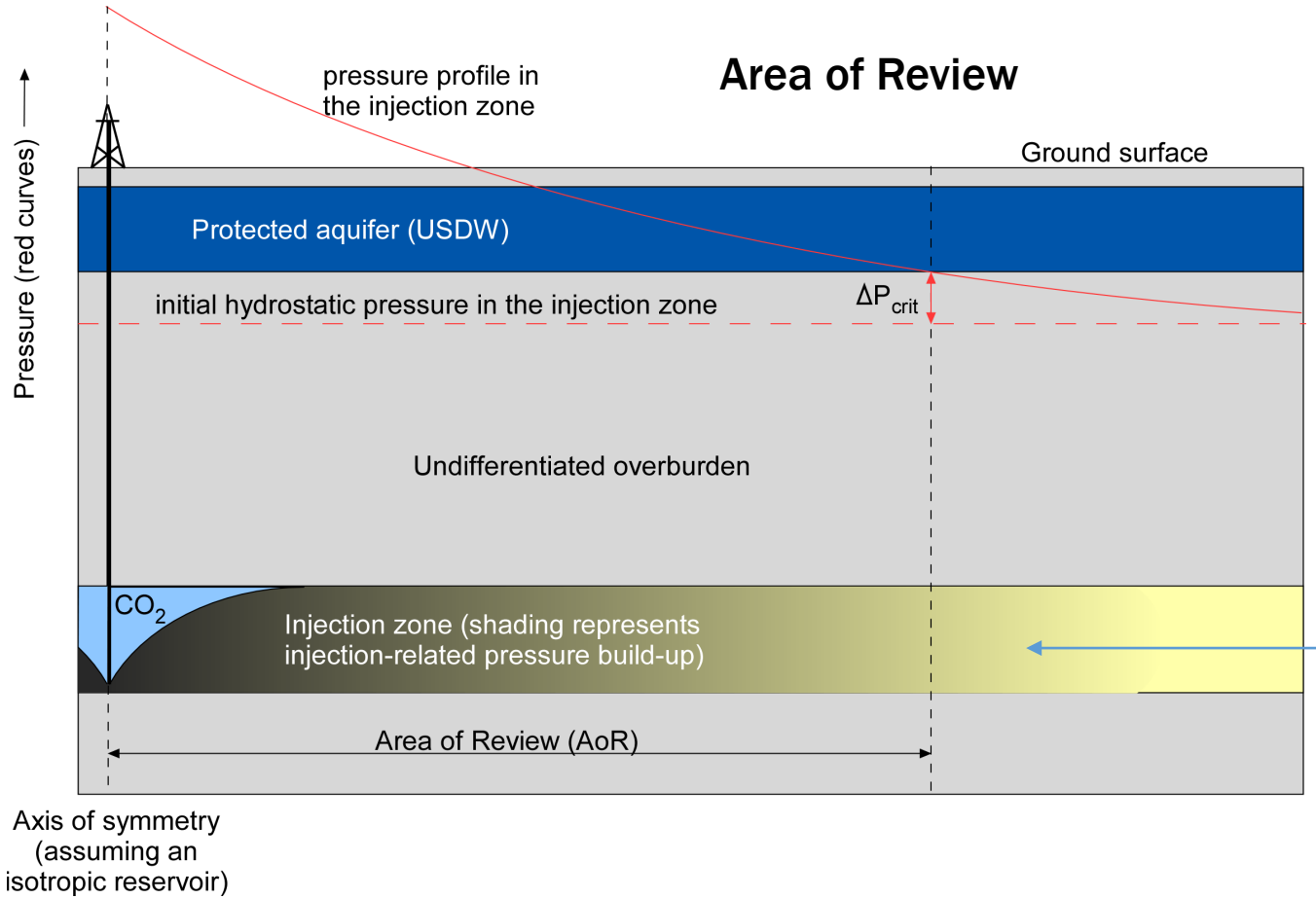


20 km

EASi-tool 5.0

P&A well

Single Project's Pressure Footprint



Detectable change in pressure

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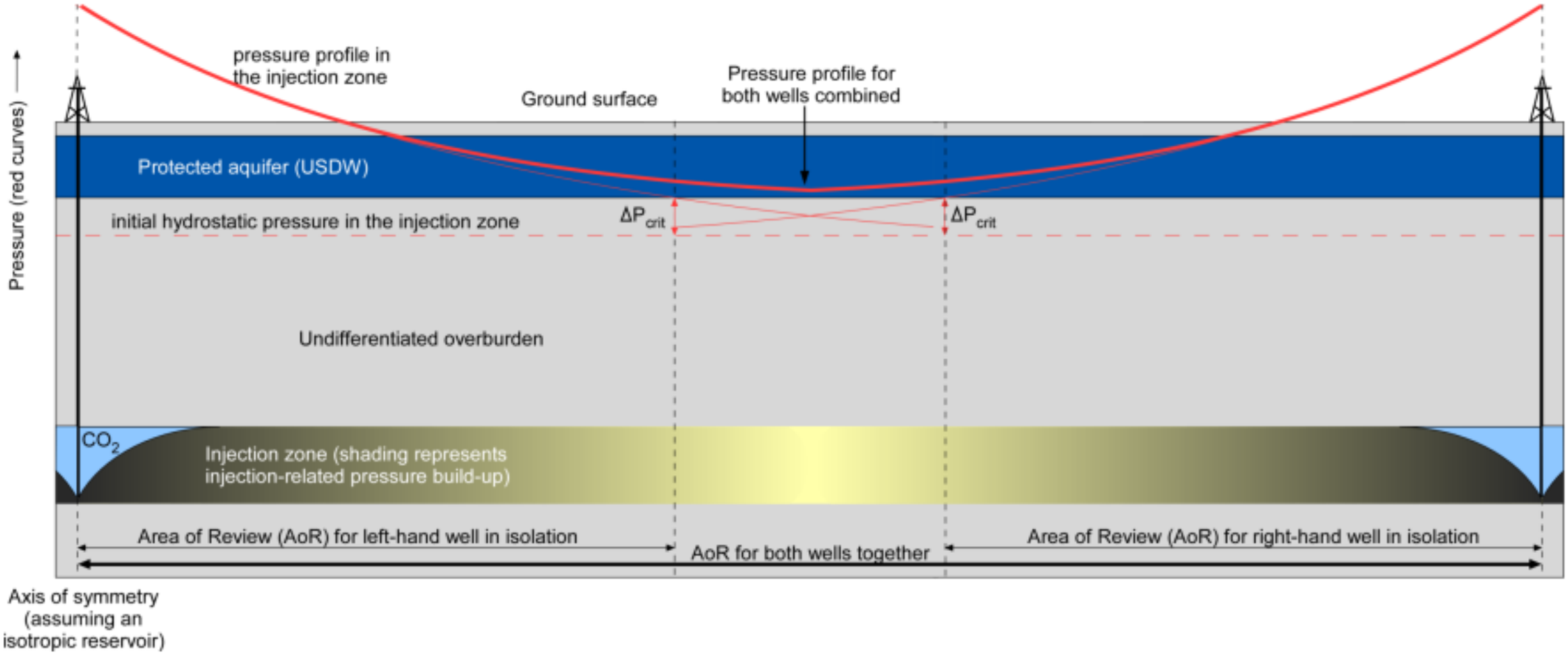
What happens to AoR when there are multiple wells



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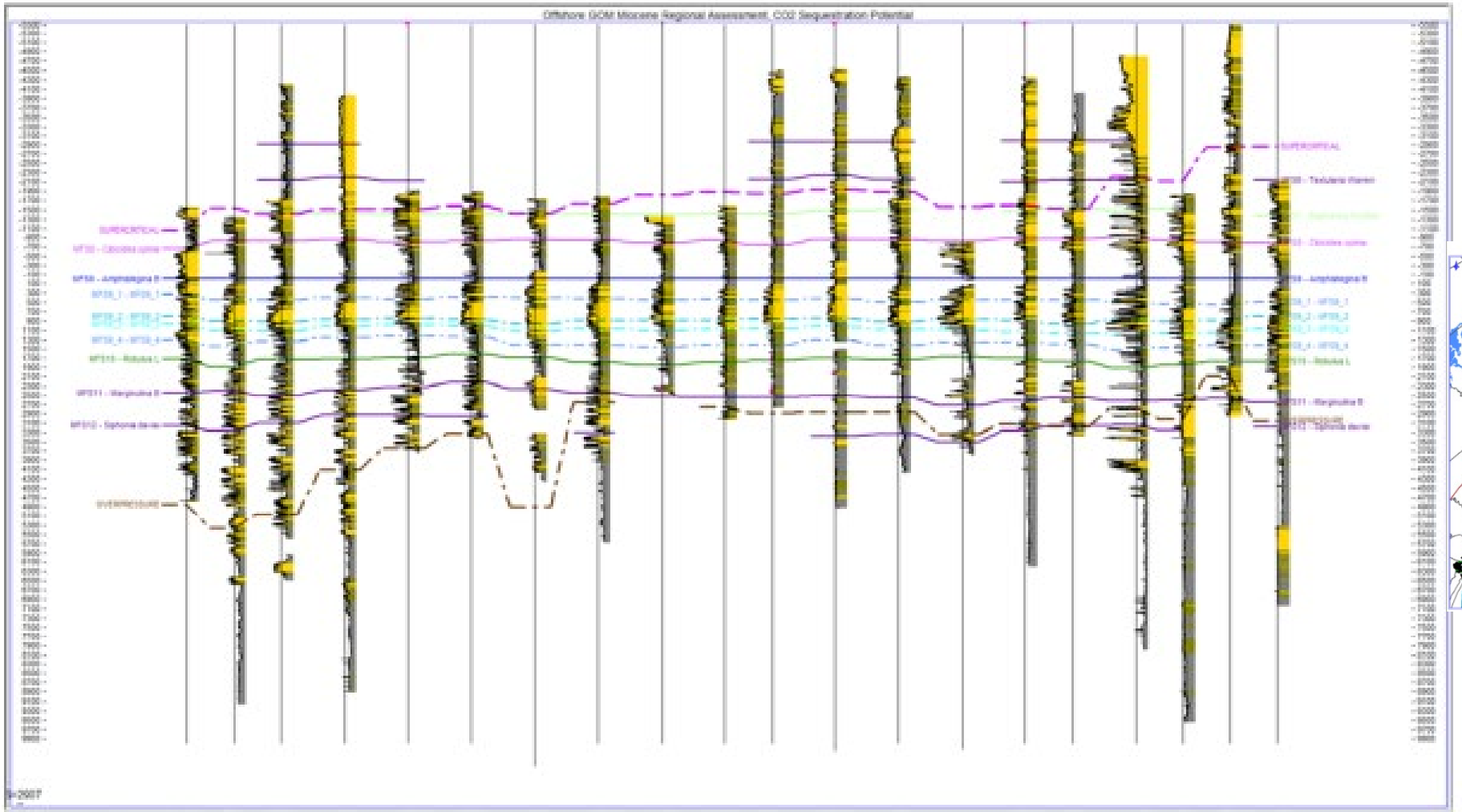
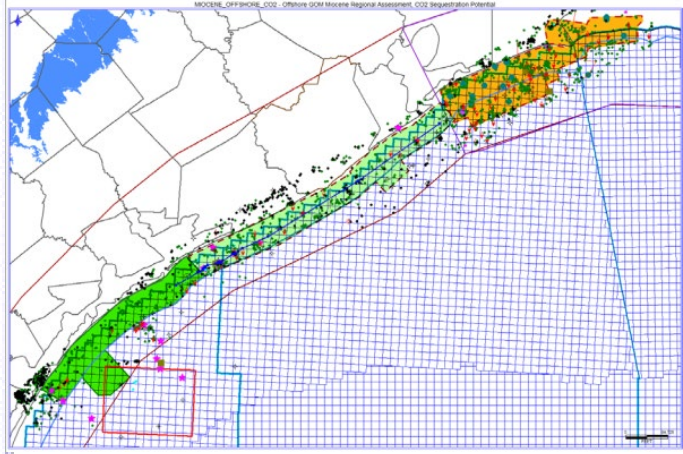
Subsurface environments have limited lateral continuity

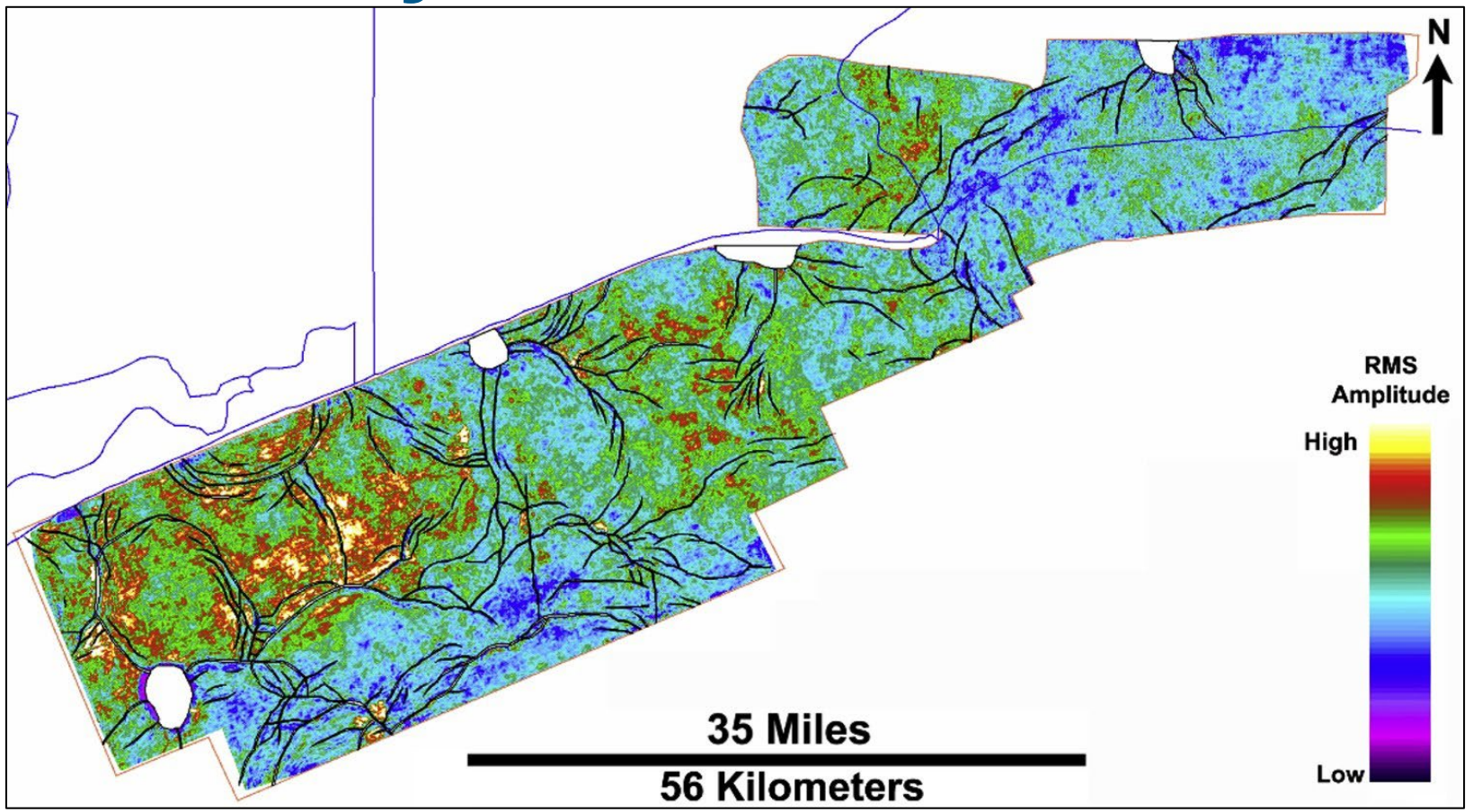
In terms of flow unit continuity





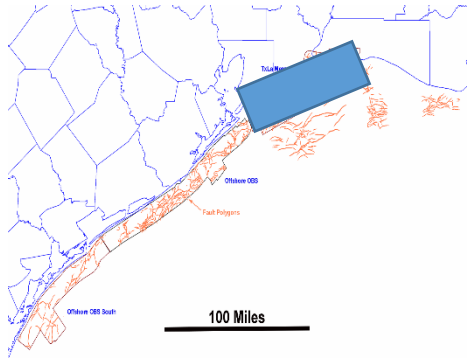
Olariu 2019 GCCC

Subsurface environments have limited lateral continuity



DeAngelo GCCC

In terms of structural discontinuities



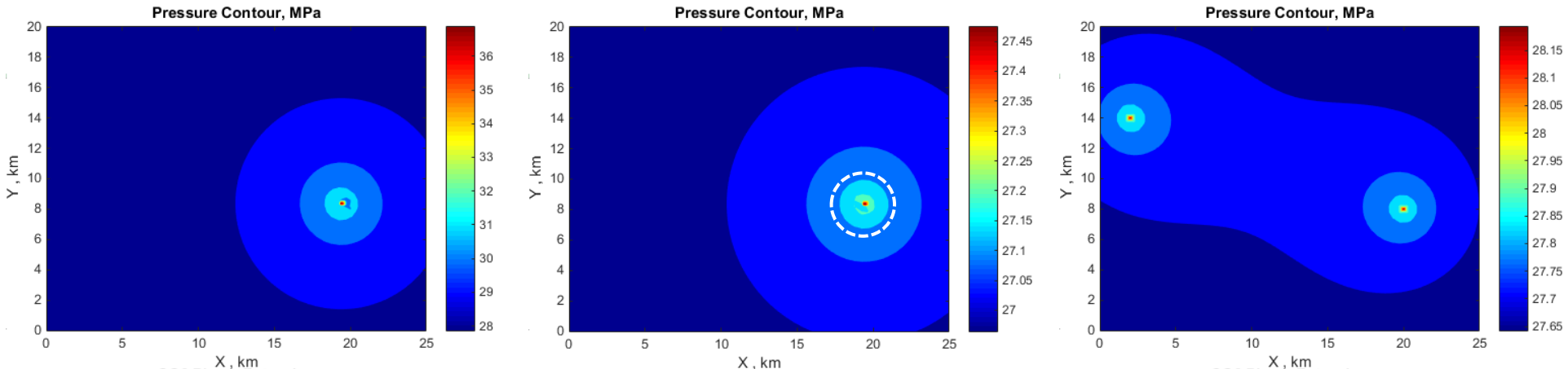
What if two projects are in Same Compartment?

A. 100m net reservoir

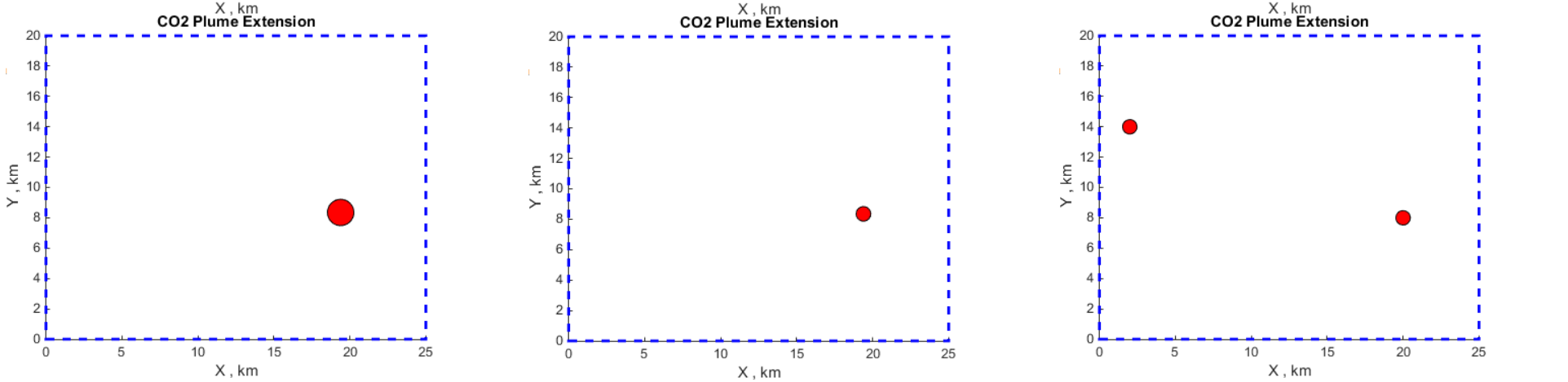
B. 400m net reservoir

C. 400m net reservoir, 2 wells

Pressure plume



CO_2 plume



All models: 400km^2, closed boundaries, 25% porosity, 100mD, injecting 1Mtpa for 20 years at 2.5km depth

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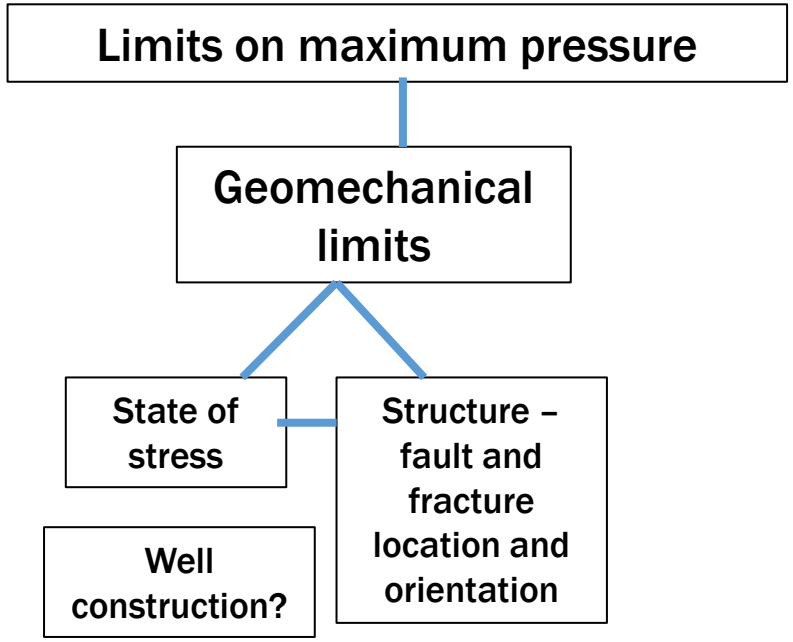
In some basins seismicity risk comes to the top of the limitations

Still difficult issues – limited data, limited experience, heterogeneous state of stress



Also this poorly constrained possible mitigation

Limited flow vertically across confining zone boundaries

Pressure relief by large amounts of non-reservoir rocks

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When is pressure space not important?

- What about producing water to “make room” for CO_2
  - Onshore water has to be reinjected.
    - Need “pressure space” for water
    - Class VI project water disposal permit type?
    - Offshore water may be “overboarded”

- Conclusion:
  - In injection of CO_2 pressure space is a key commodity.

Conclusion

- In injection of CO_2 pressure space is a key commodity.
- Free online EASiTool is available to assess multi-project impacts (contact Seyyed.hossieni@beg.utexas.edu)
- Some questions require policy input:
  - How should landowner and operator differences on preferred outcome be balanced? As much CO_2 as possible? Or best economics for first operators?
  - Merged AoR will happen – how to manage?
    - First vs last operator advantage?
    - Technical solution – this small amount over critical pressure at late stages for shorter durations with potential for moving small of brine into USDW – risk based endangerment standard can simplify?
- Coming next: Issues with vertically stacked storage – interference and comingled AoR