

The Impacts of Carbon Dioxide Storage in the Saline Arbuckle Aquifer on Water Quality in Freshwater Aquifers in Kansas

Tiraz Birdie, Lynn Watney, Paul Gerlach, Michael Killion, Jennifer Raney, Eugene Holubnyak, Tandis Bidjoli, Gene Williams, Minh Nguyen, and Brownie Wilson

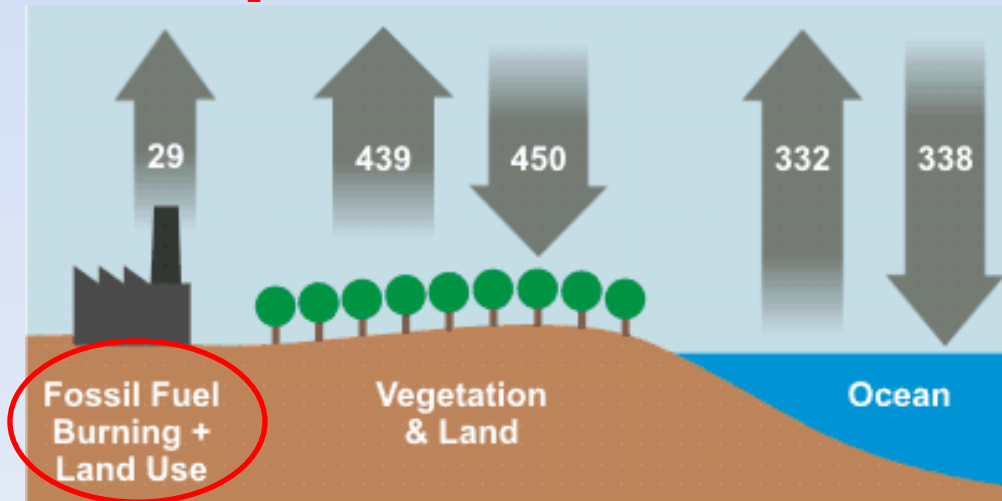
Midwest Groundwater Association Conference
Lawrence, KS

October 1st, 2014

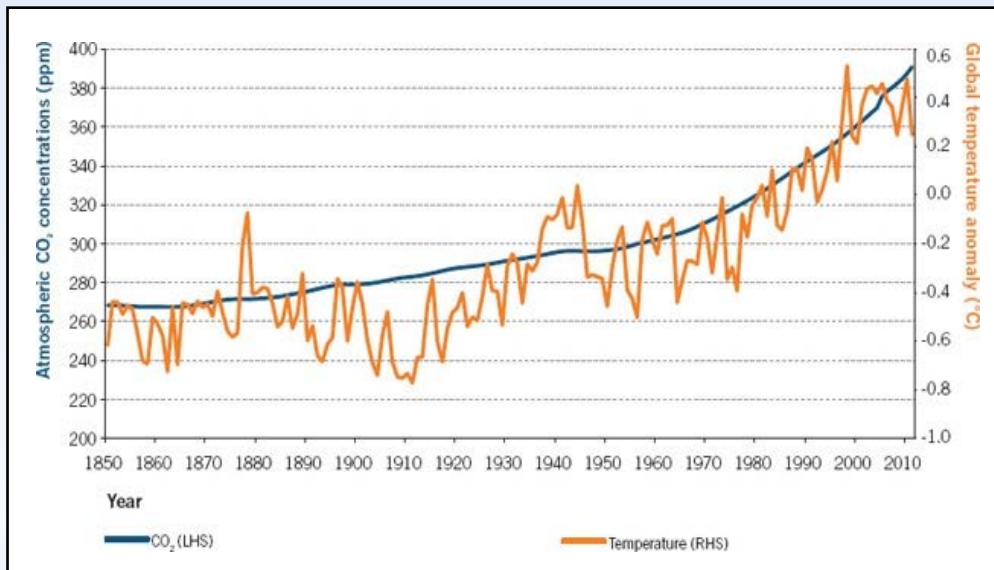
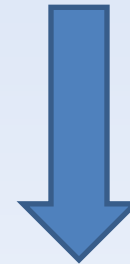


Global CO₂ Cycle

CO₂ Cycle (billion tons per year, BT)

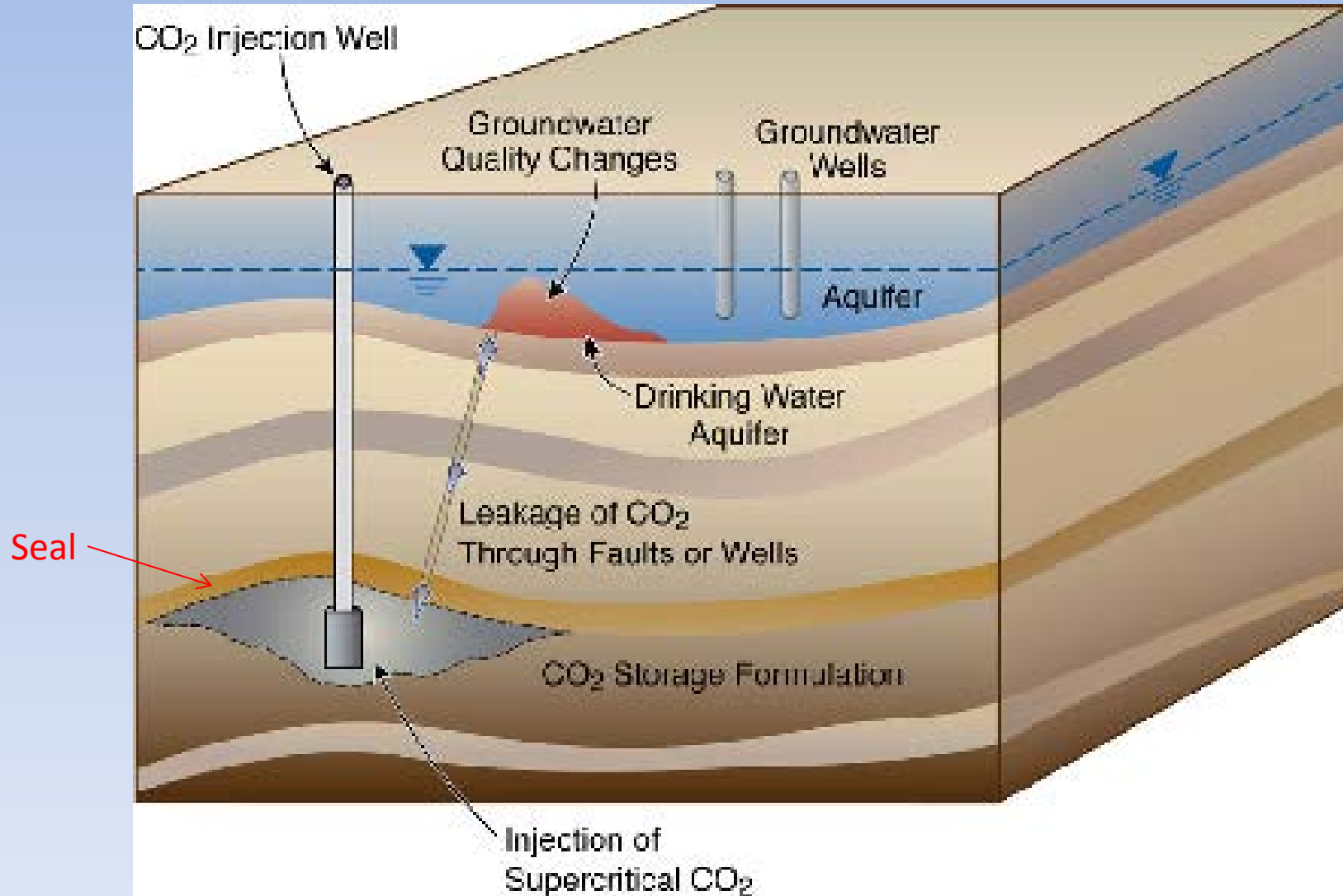


| | |
|-----------------------|--------|
| Emissions | 800 BT |
| Natural Sequestration | 788 BT |
| Balance | 12 BT |

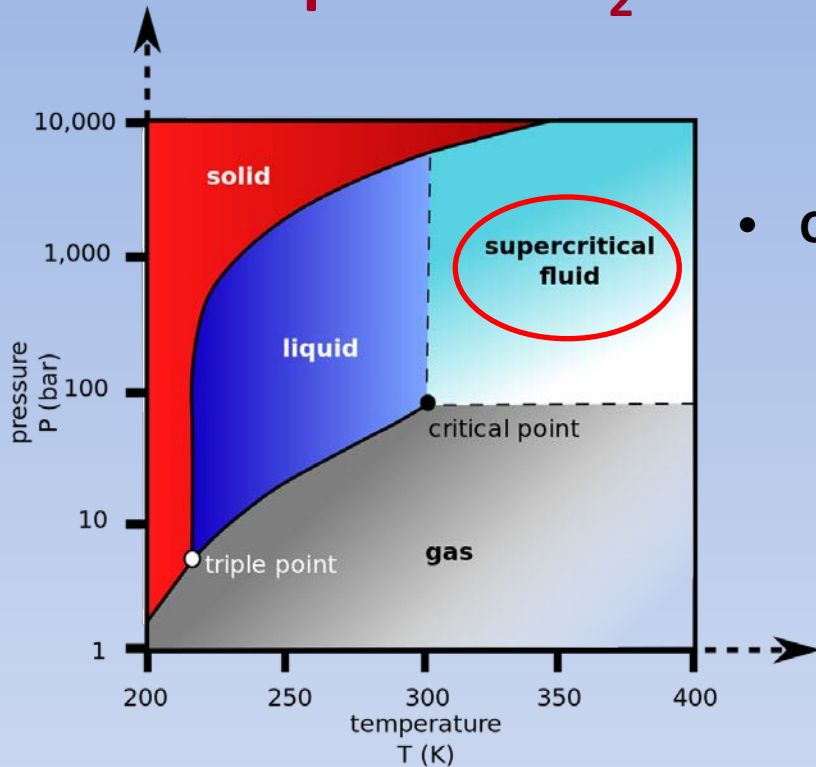


- Atmospheric CO₂ levels rising since start of industrial era.
- Present concentrations of 400 ppm CO₂ close to 2050 target of 450 ppm.

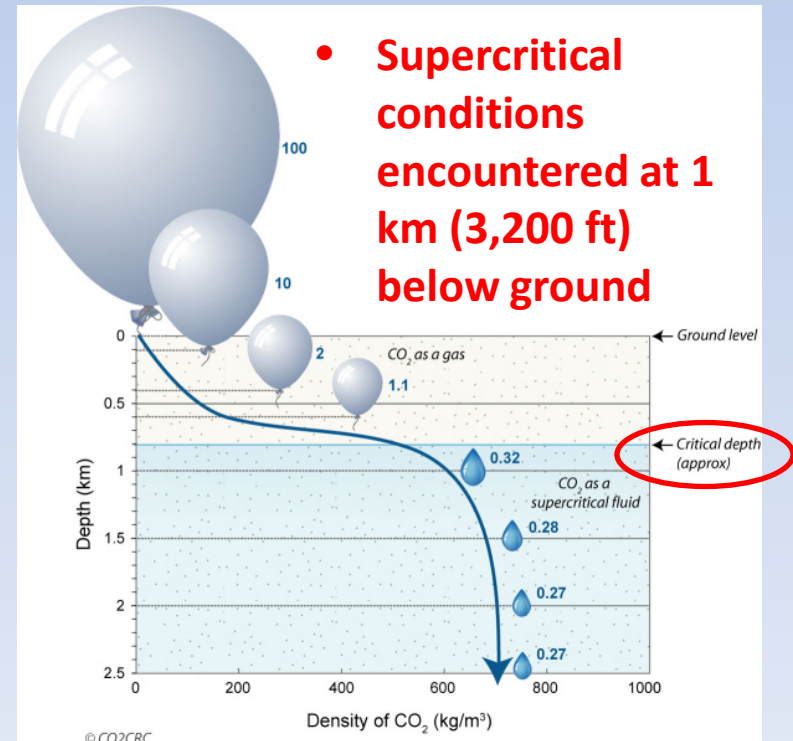
Geologic Sequestration of CO₂ a Viable Bridge Technology for Post Fossil-Fuel Economy



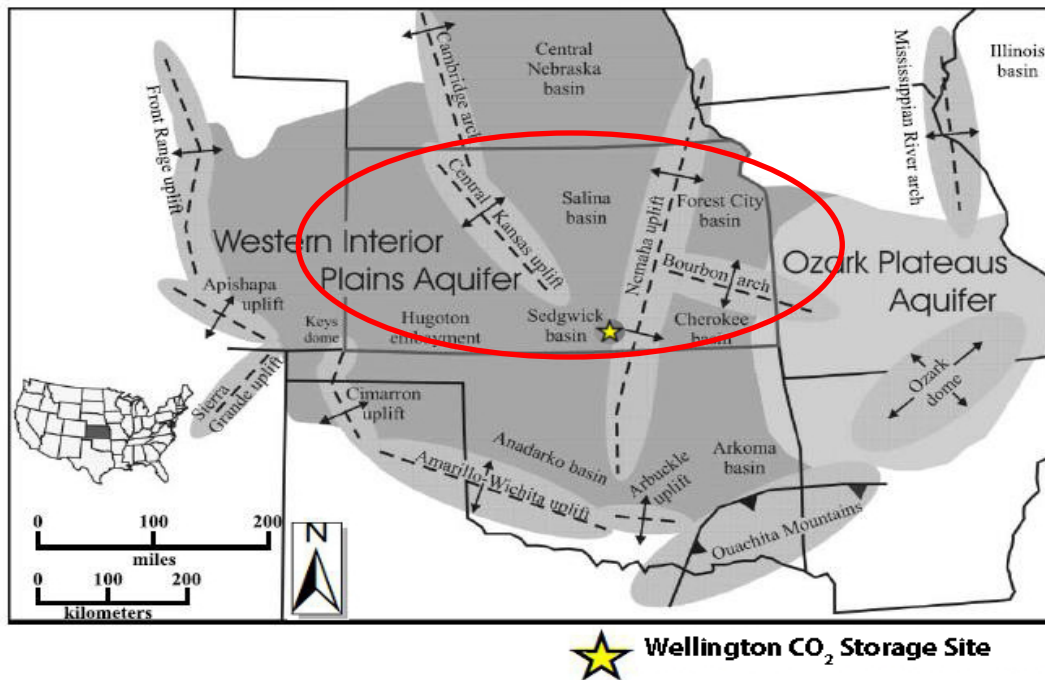
Optimal CO₂ Phase for Geologic Sequestration



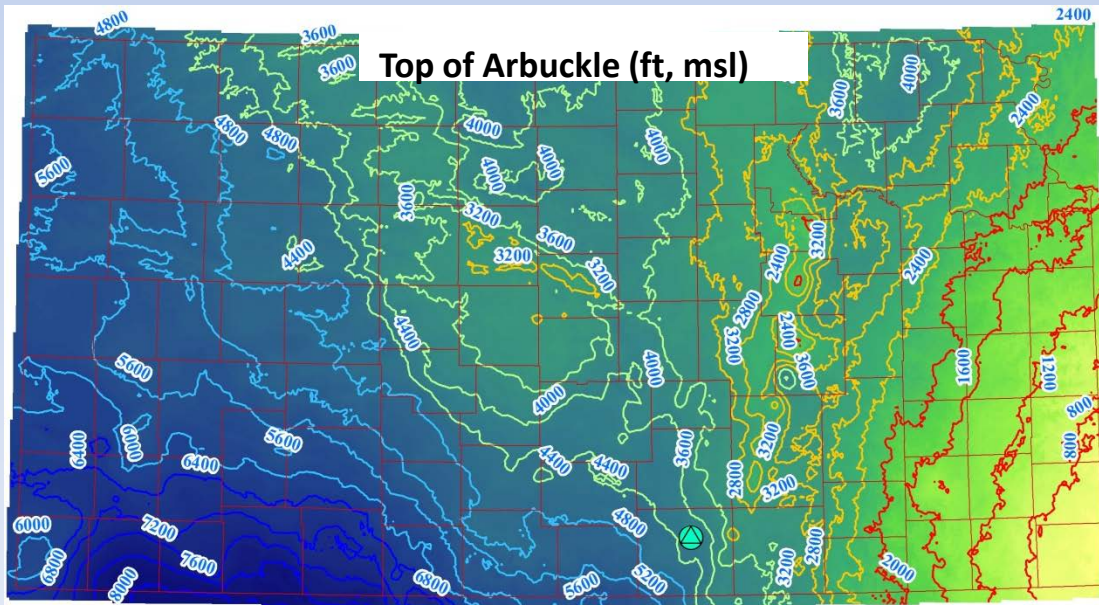
- CO₂ most dense in supercritical phase



Arbuckle Aquifer Targeted for Sequestration in Kansas

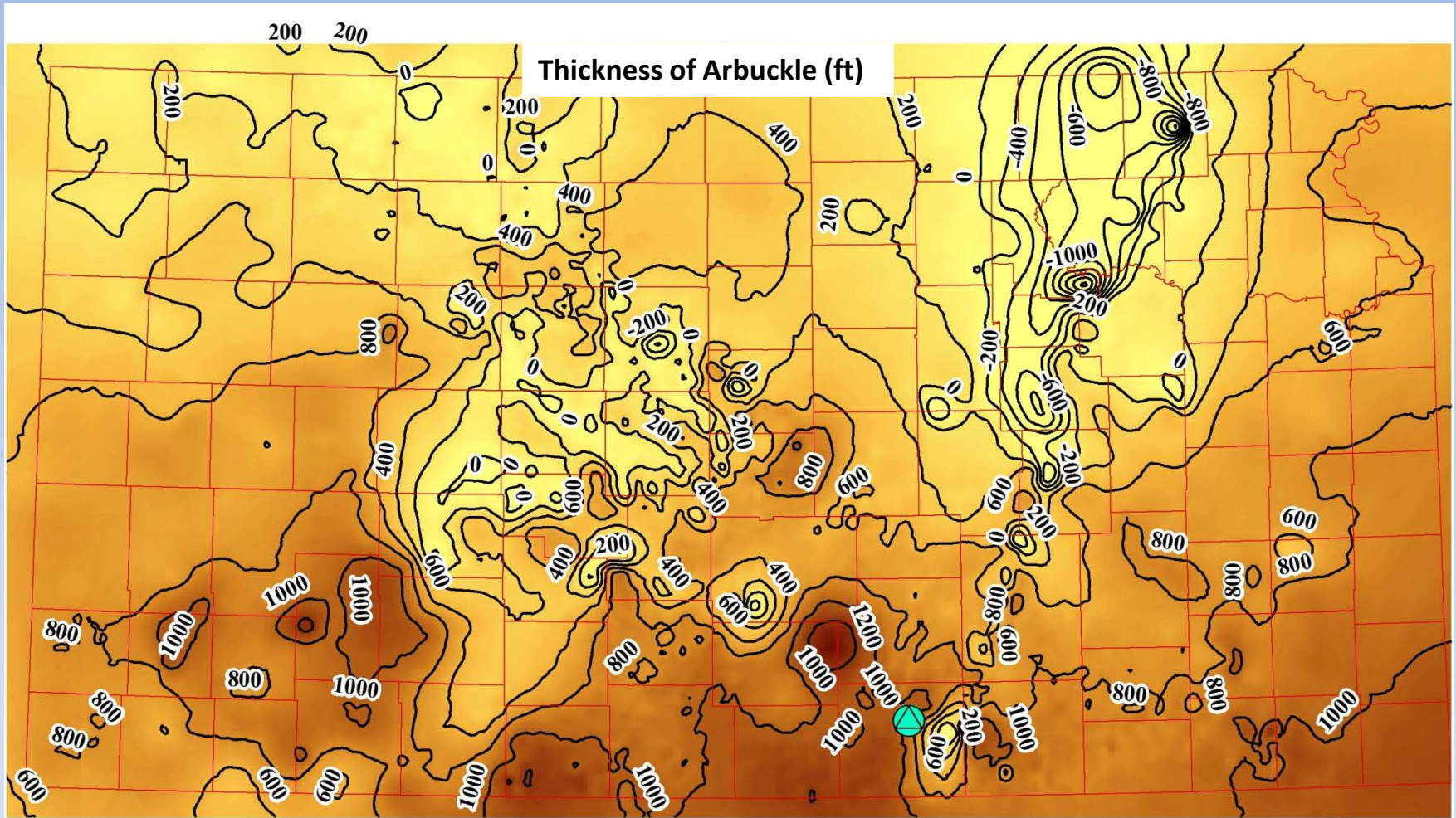


- Cambrian-Ordovician Arbuckle aquifer (Dolomitic)



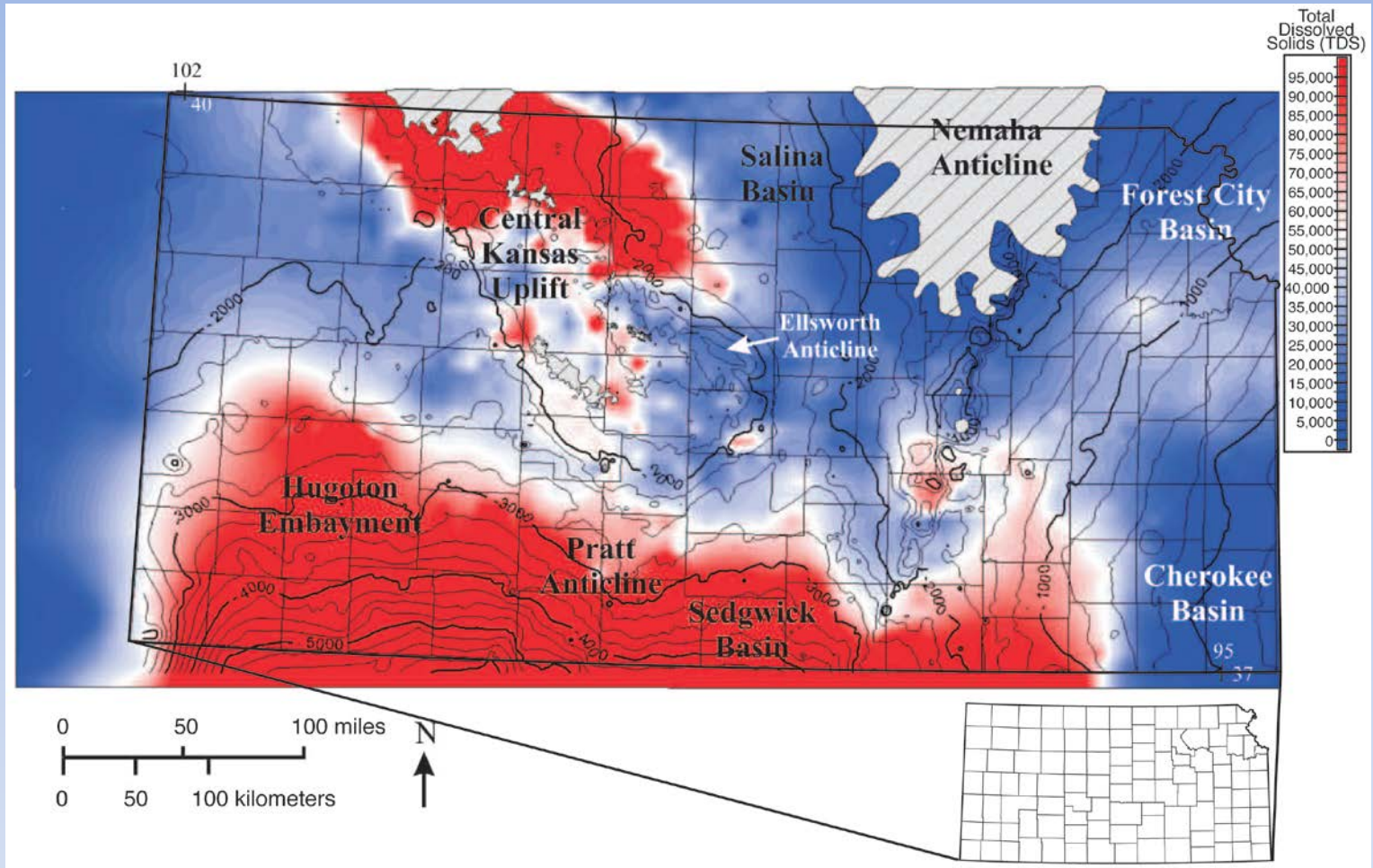
- Top of Arbuckle >3,000 feet below ground in SW Kansas

Thickness of Arbuckle Aquifer



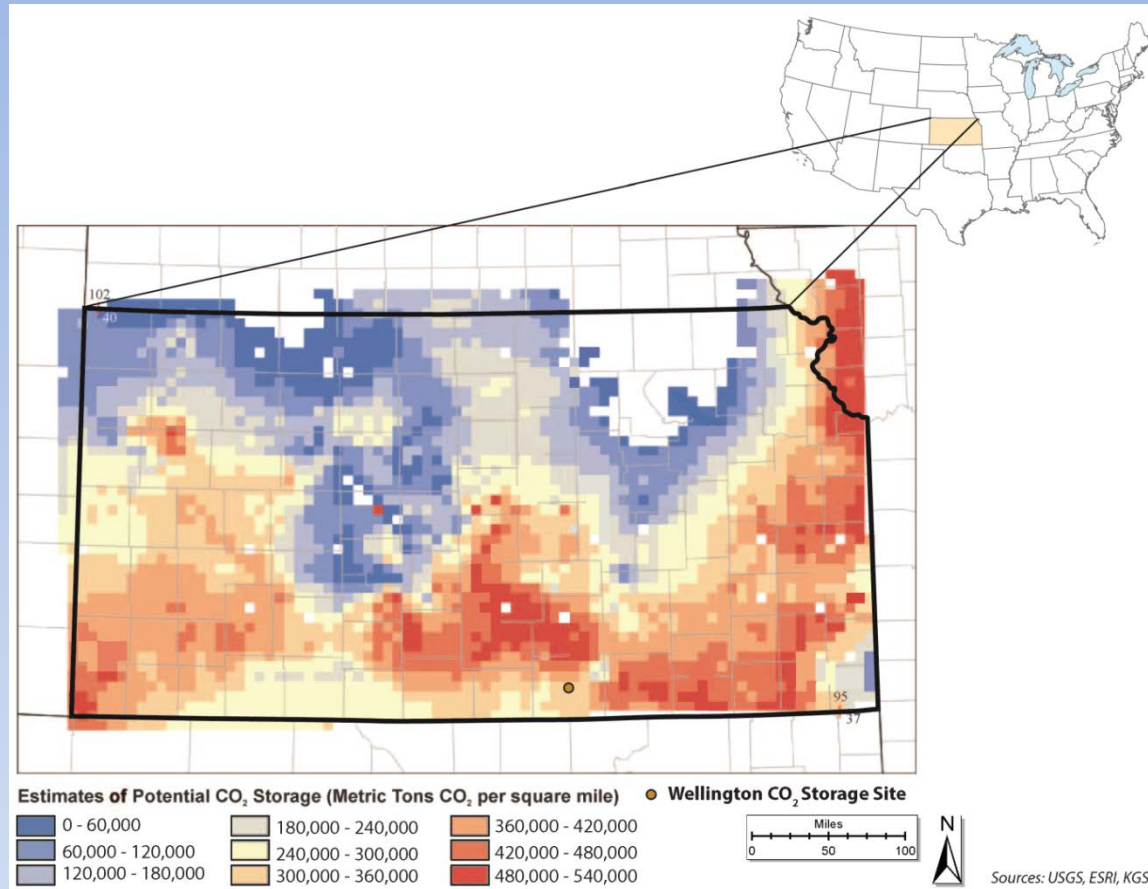
- Arbuckle ~ 1,000 ft thick in SW Kansas
- Porosity ~ 5%

Arbuckle Salinity



- Total Dissolved Solids > 100,000 ppm in SW Kansas

DOE Estimated Arbuckle CO2 Storage Capacity



Total Arbuckle CO2 capacity ~ 60 BT

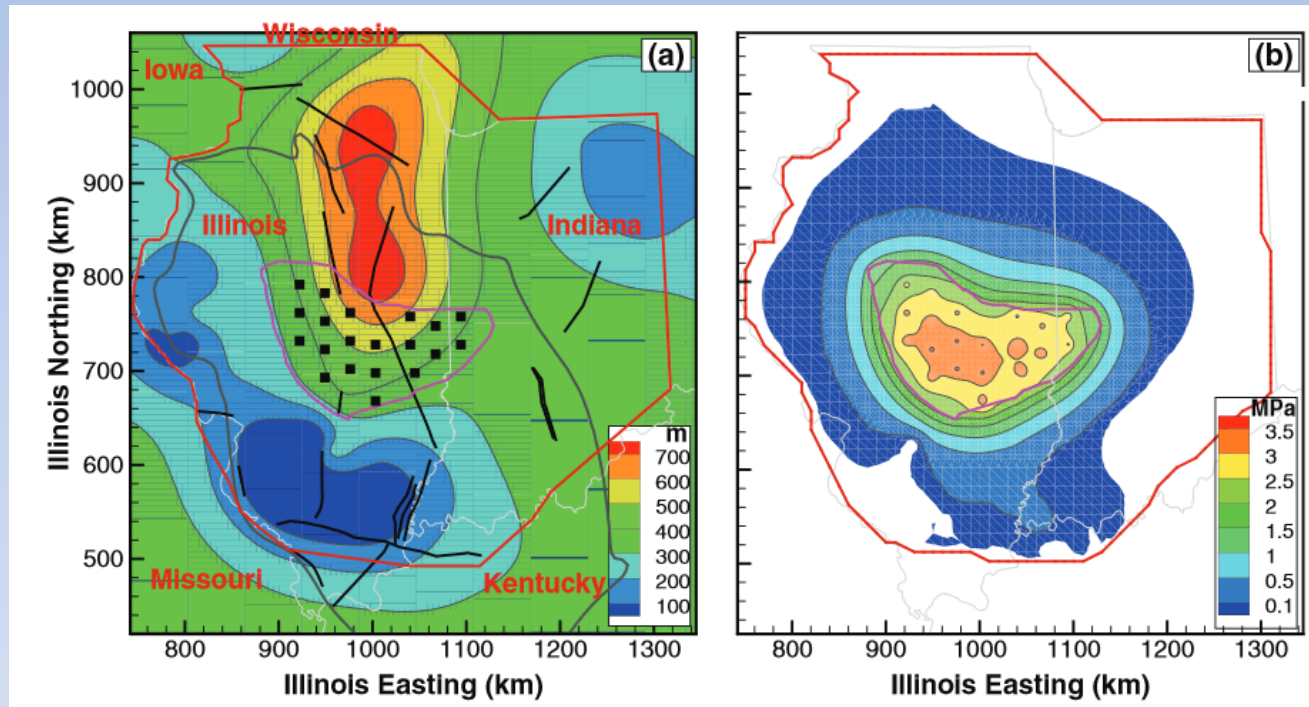
Total Annual US Emission ~ 5.4 BT

Total Annual KS Emission < .1 BT

Arbuckle can sequester over a century of Kansas emissions and several decades of US emissions

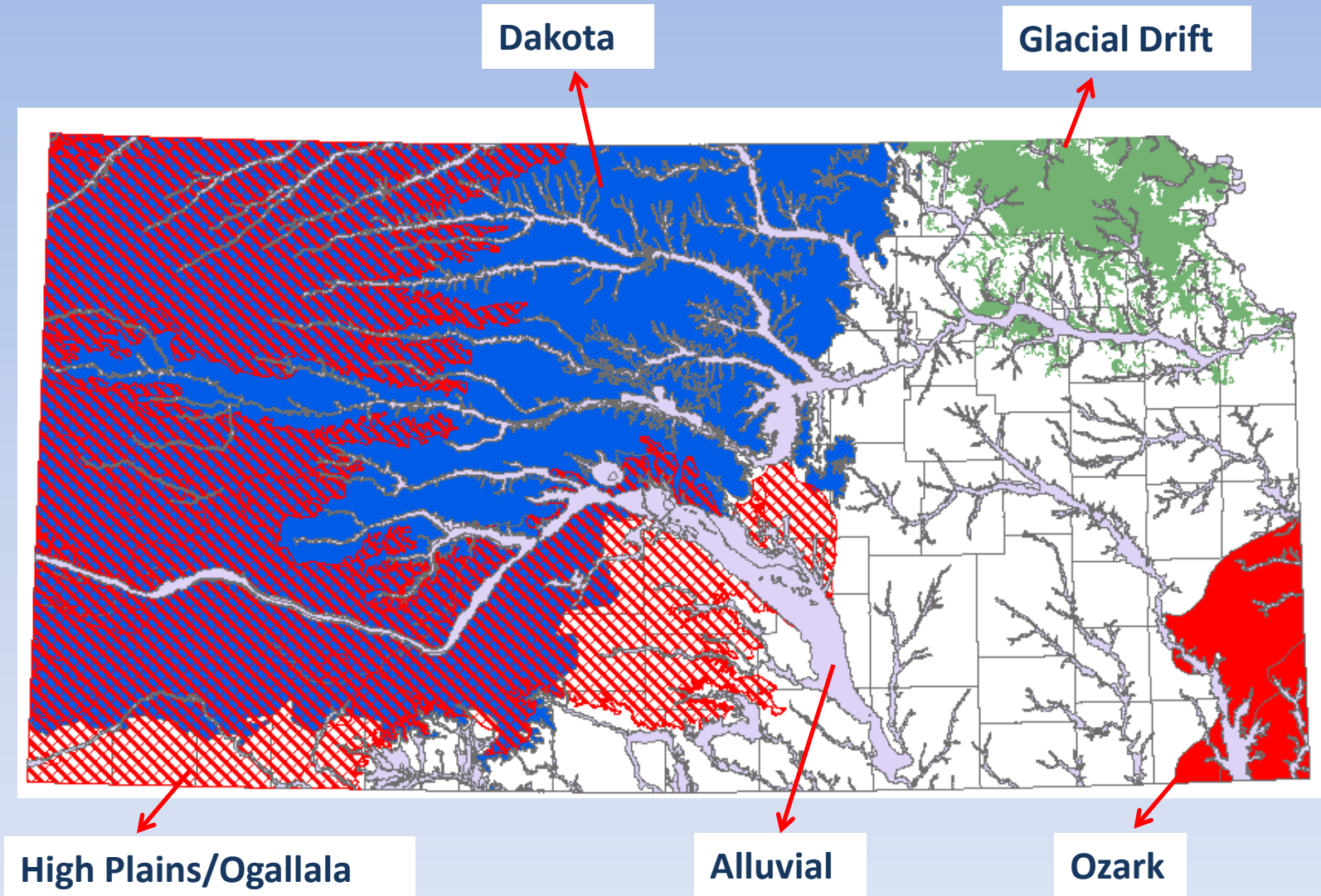
Wide Spread Increase in Pore Pressures Expected Due to CO₂ Injection

Multistate Scale Simulated Pressure Impacts Due to Injecting 100 MT/year for 50 years (1MPa =145 psi)

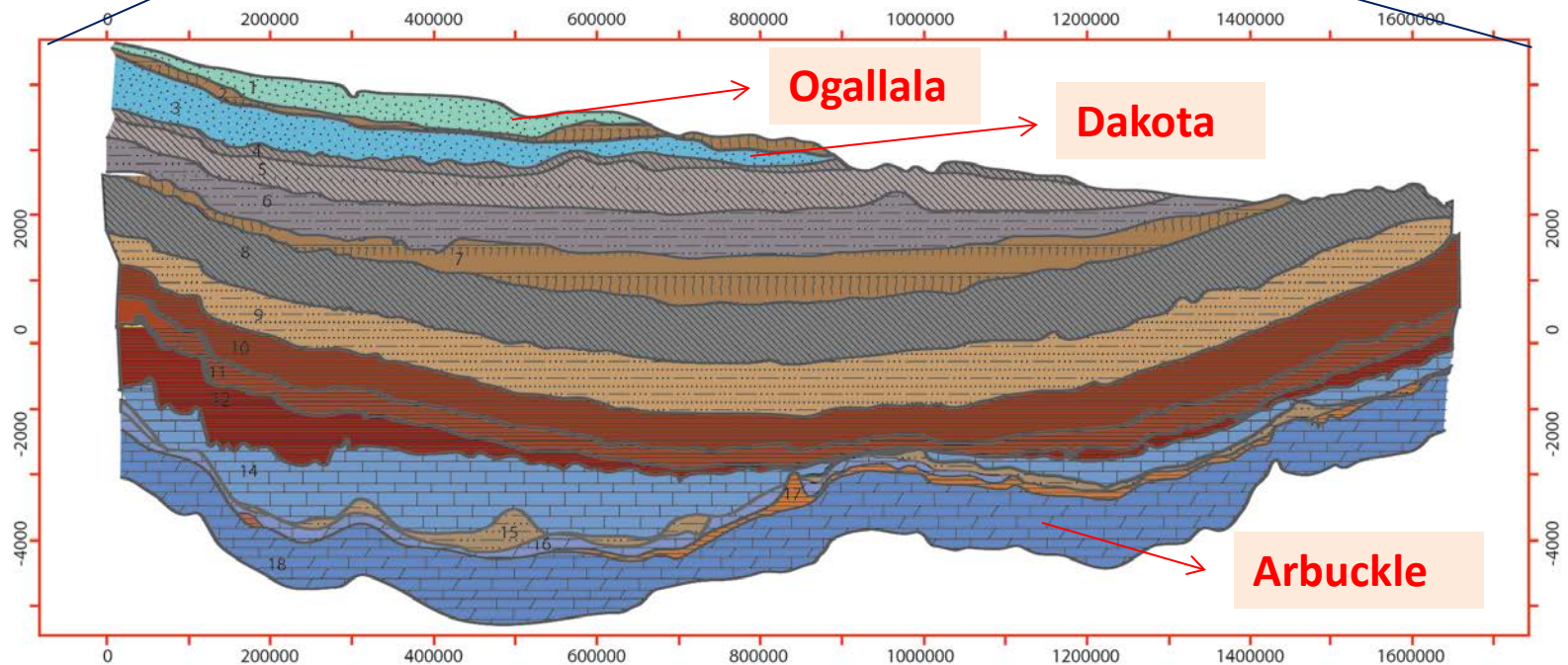
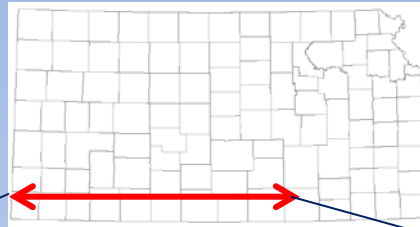


- Will induced pressures due to commercial scale CO₂ injection in Kansas cause brines to migrate into freshwater aquifers through abandoned wells and faults?

Freshwater Aquifers in Kansas



Large Degree of Hydraulic Confinement and Separation Between Arbuckle and Freshwater Aquifers

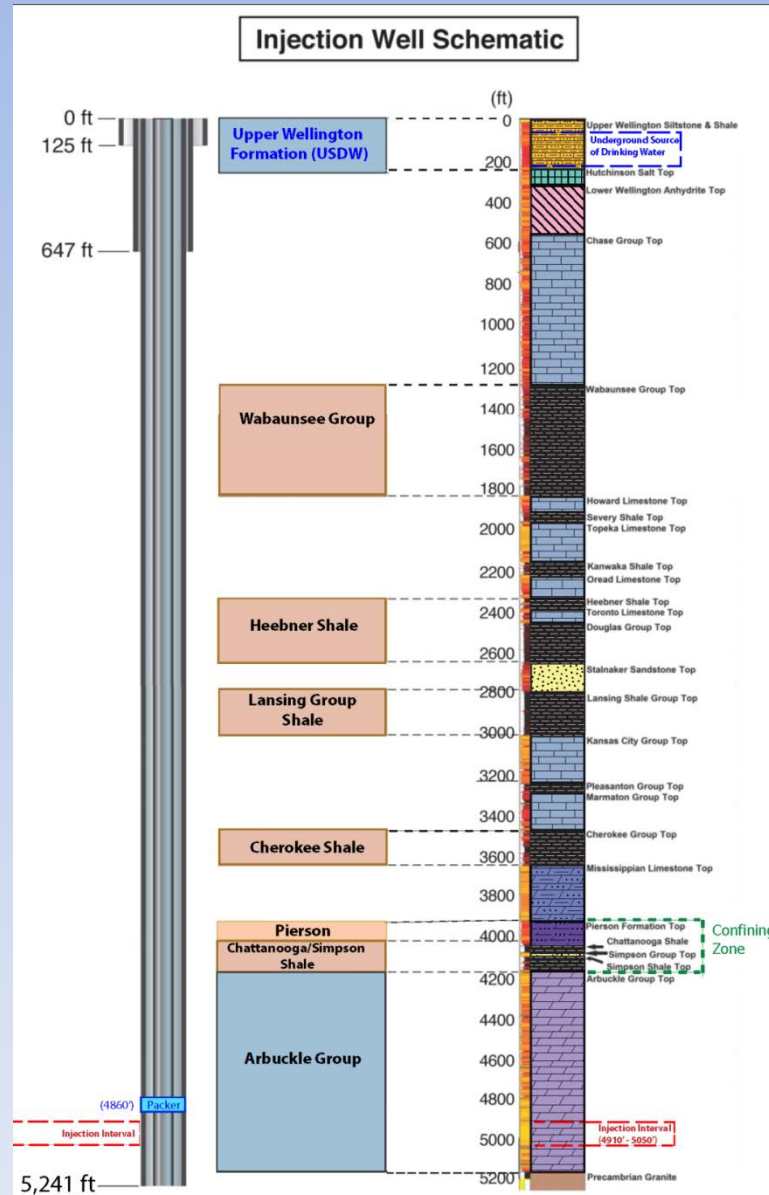


1. Present-day surface
2. High Plains base (Neogene)
3. Top Dakota (Cretaceous)
4. Base Dakota (Cretaceous)
5. Blaine Formation (Permian)
6. Cedar Hills Formations (Permian)

7. Top Stone Corral Formation (Permian)
8. Hutchinson Salt (Permian)
9. Top Chase Group (Permian)
10. Root Shale (Upper Pennsylvanian)
11. Heebner Shale (Upper Pennsylvanian)
12. Stark Shale (Upper Pennsylvanian)

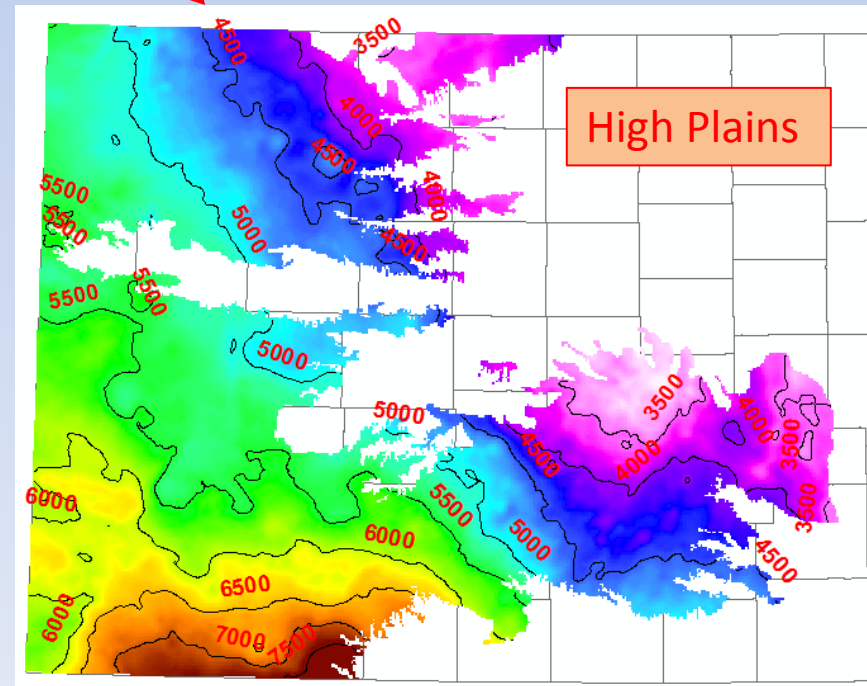
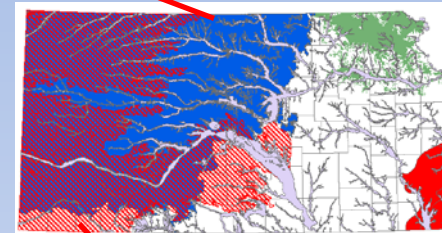
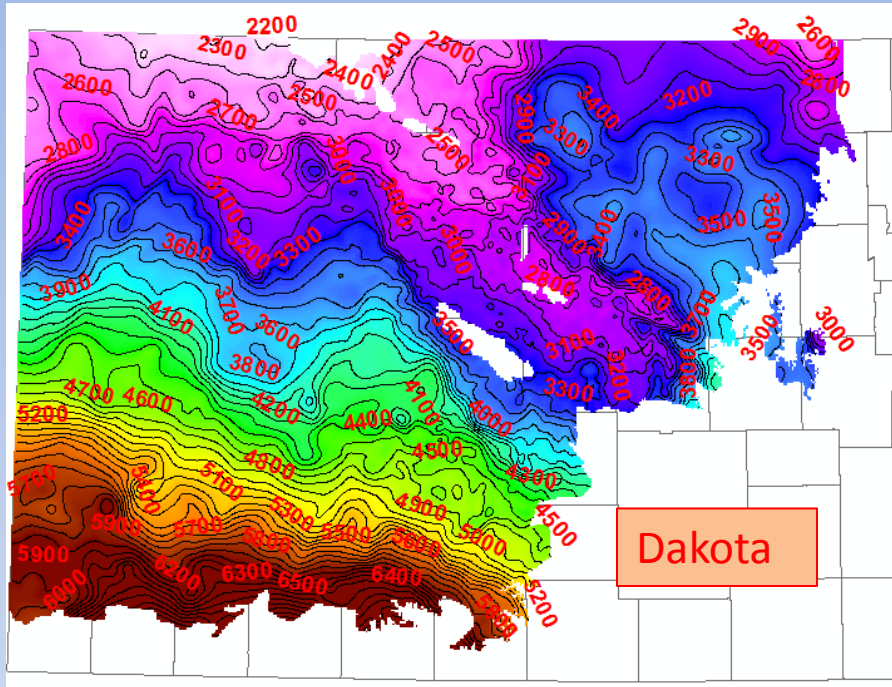
13. Top Cherokee Group (Middle Pennsylvanian)
14. Top Mississippian (Upper Mississippian)
15. Top Pierson Formation (Middle Mississippian)
16. Top Viola Limestone (Middle Ordovician)
17. Top Simpson Group (Middle Ordovician)
18. Top Arbuckle (Lower Ordovician)
19. Top Basement (Precambrian)

Large Degree of Hydraulic Confinement and Separation Between Arbuckle and Freshwater Aquifers



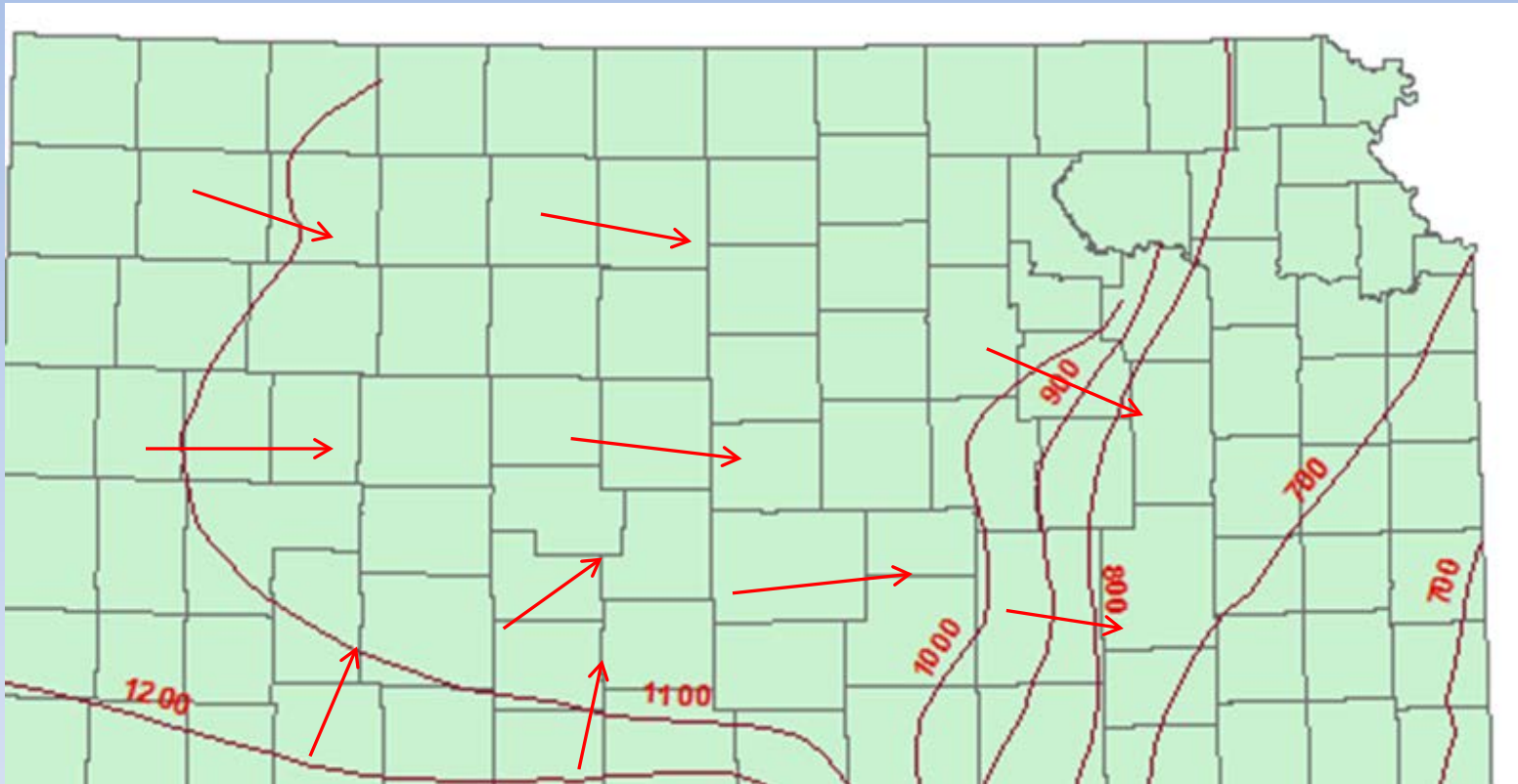
**CO₂ Injection Test
Site in Sumner
County, KS**

Vertical Separation (ft) between the Top of Arbuckle and Base of Freshwater Aquifers



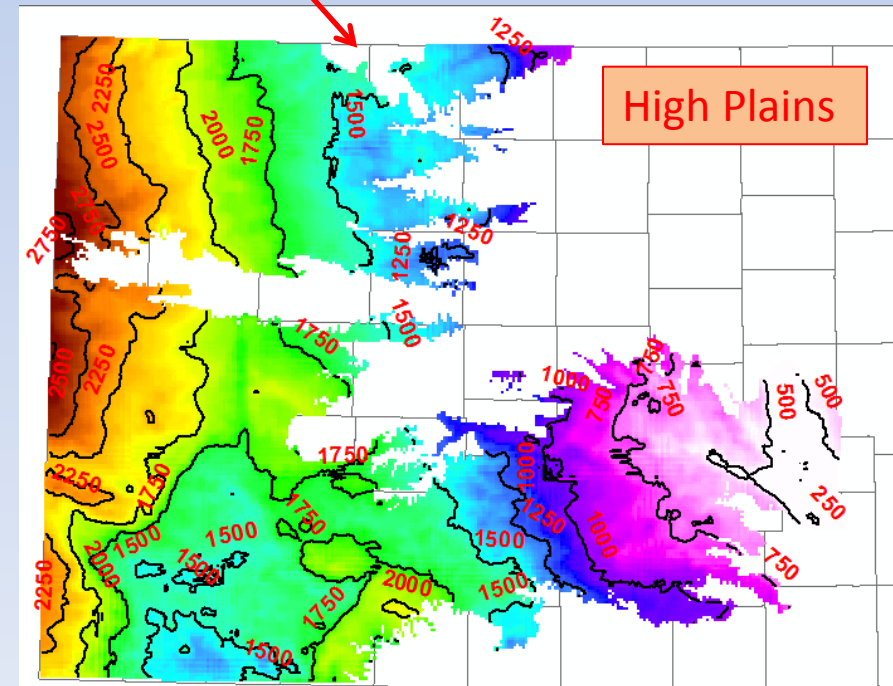
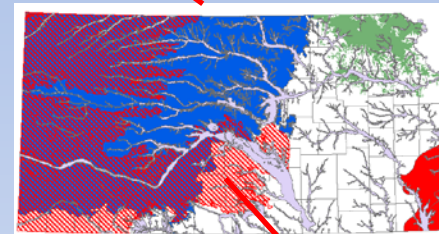
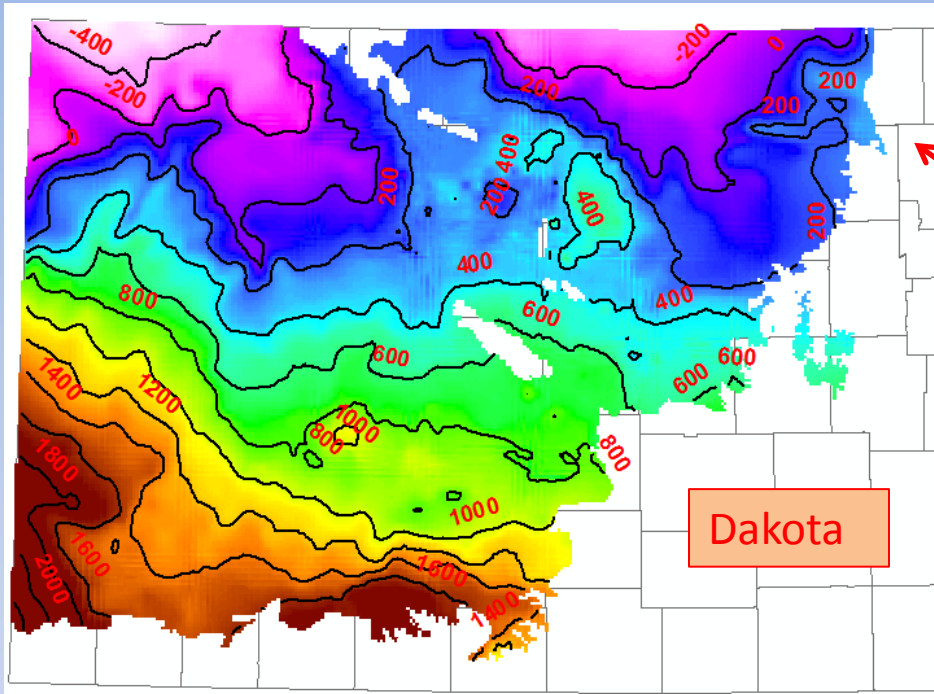
Potentiometric Surface of Arbuckle

Equivalent Freshwater Heads (ft, msl)



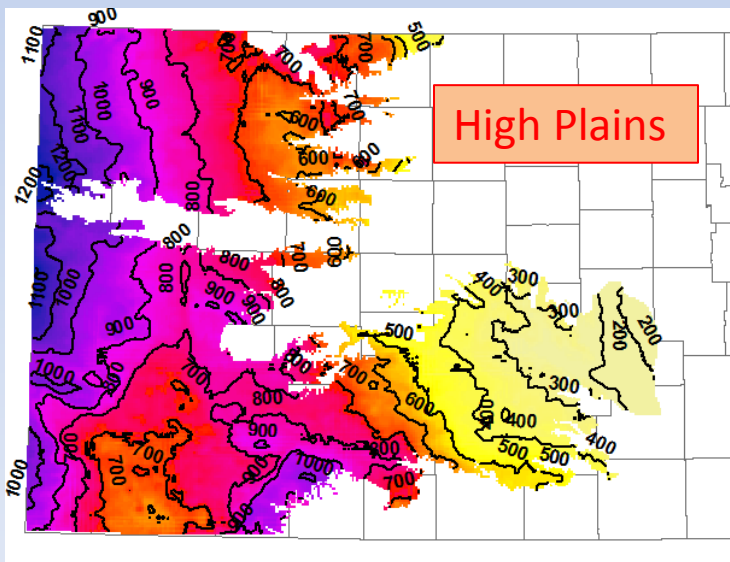
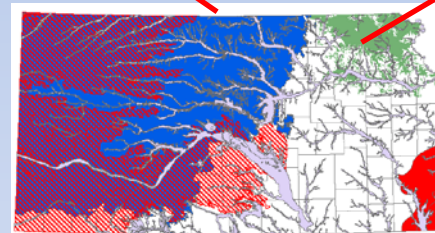
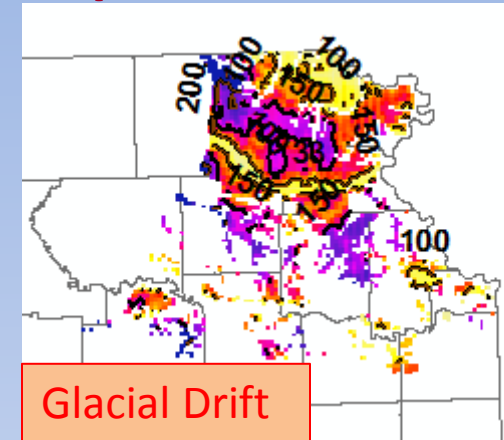
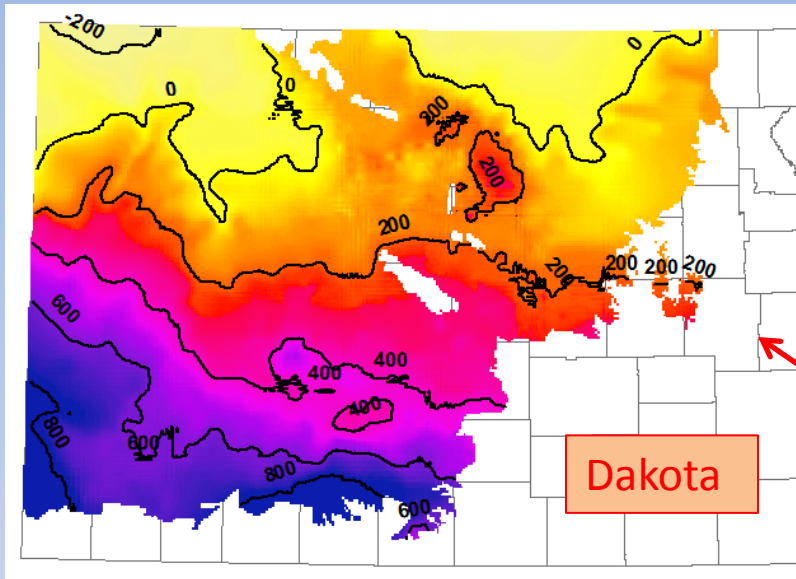
- Merging of two regional flow fields (Rocky Mountain & Anadarko Basin)
- Groundwater flow across state takes approximately $\frac{1}{4}$ to $\frac{1}{2}$ million years

Distance (ft) from Base of Freshwater Aquifers to In-situ Water Levels in the Arbuckle



- Hydraulic buffer exists to accommodate increased pressures due to CO₂ injection without causing brines to migrate into freshwater aquifers via improperly abandoned wells and open faults

Required Increase in Pore Pressure (psi) for Migration of Brines from Arbuckle into Freshwater Aquifers

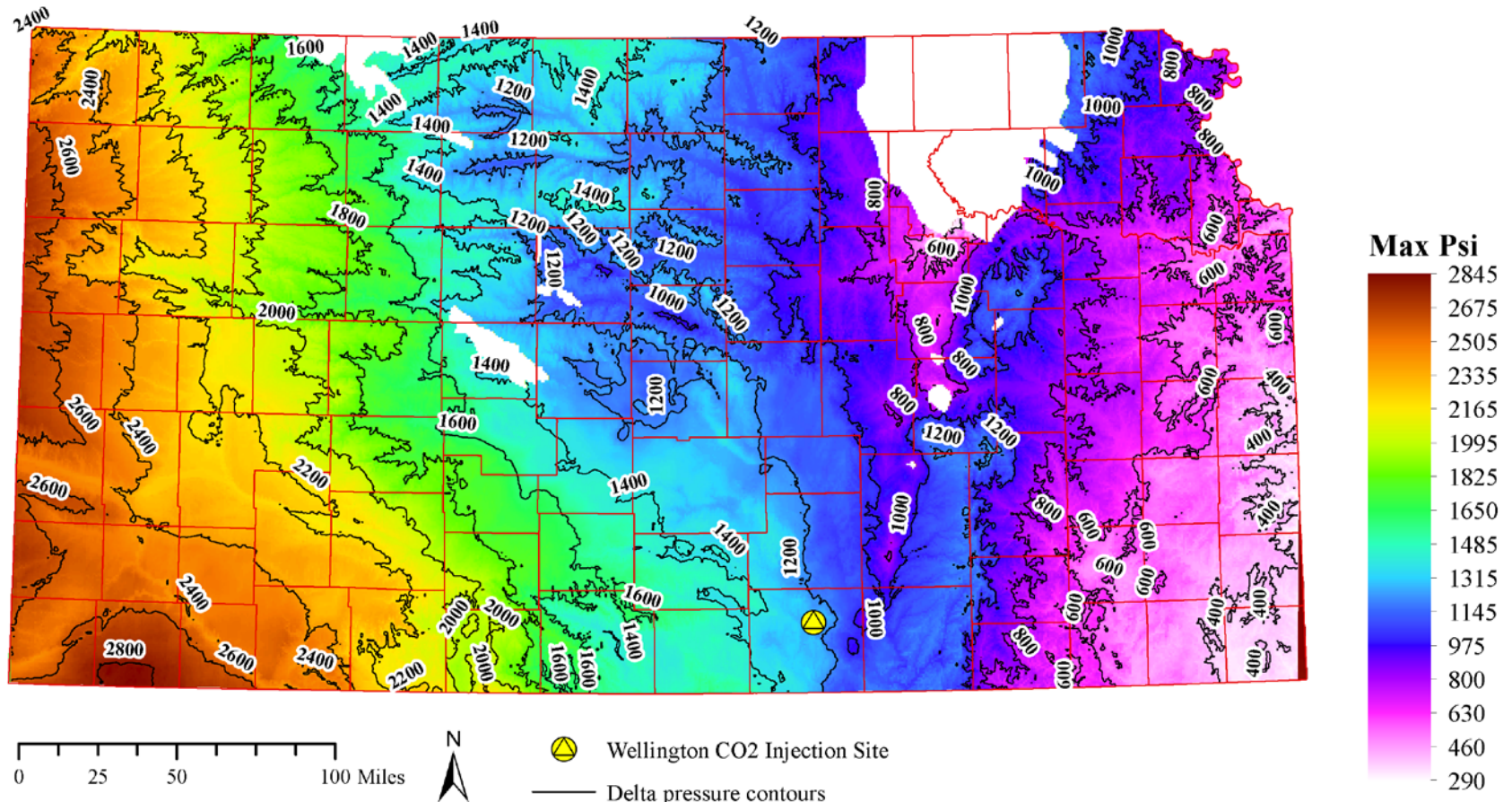


- Need to ensure these pressures are not exceeded if improperly abandoned wells or communicative faults are present within zone of influence

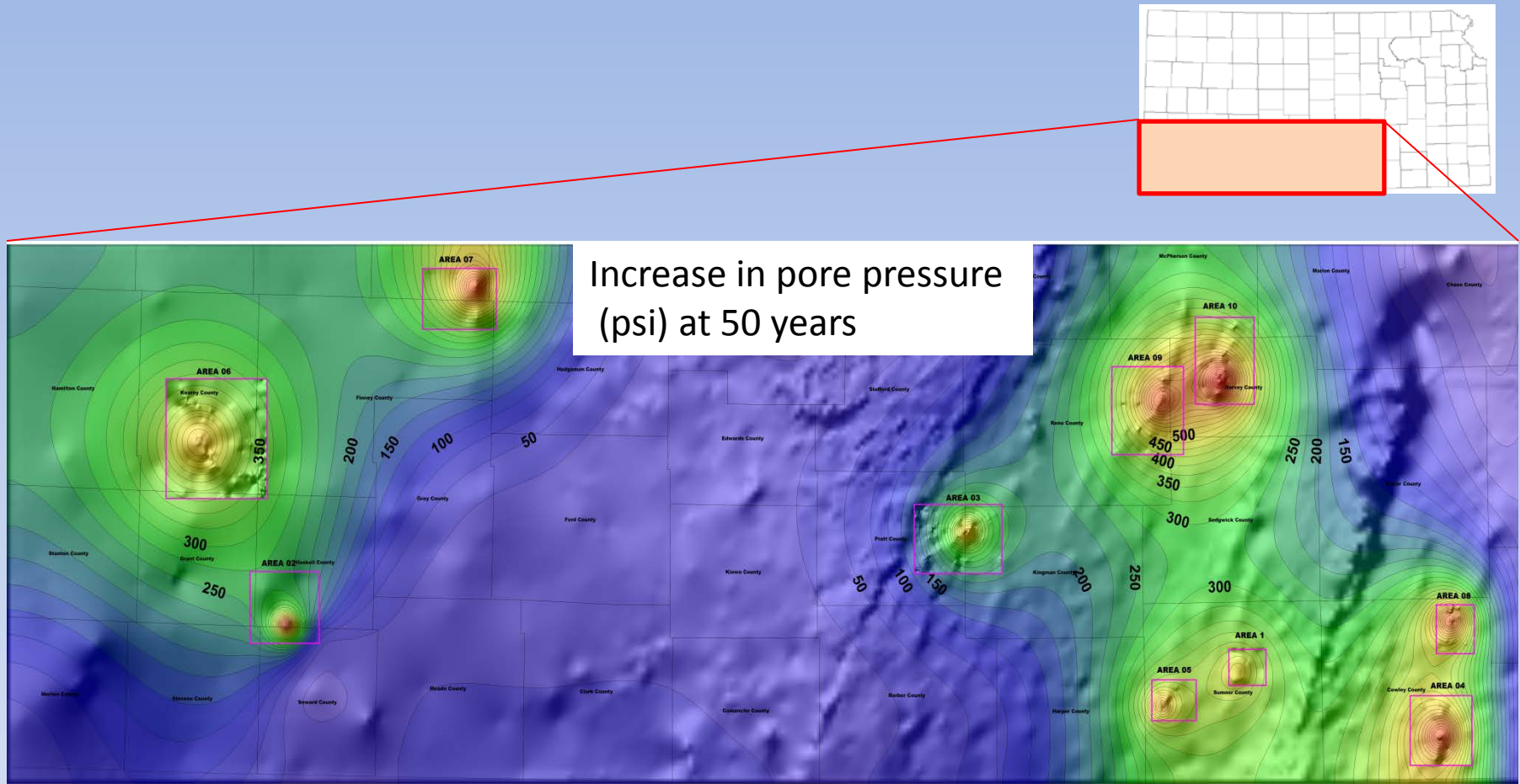
Maximum Allowable Fracture-Based Increase in Pore Pressure

- Induced pore pressures should not exceed 90% of the “Fracture Gradient” in Kansas of ~ 0.75 psi/ft [EPA Class VI injection well requirement]

Maximum Allowable Increase in Pore Pressure (psi) to Prevent Fractures



Simulated Increase in Pore Pressures

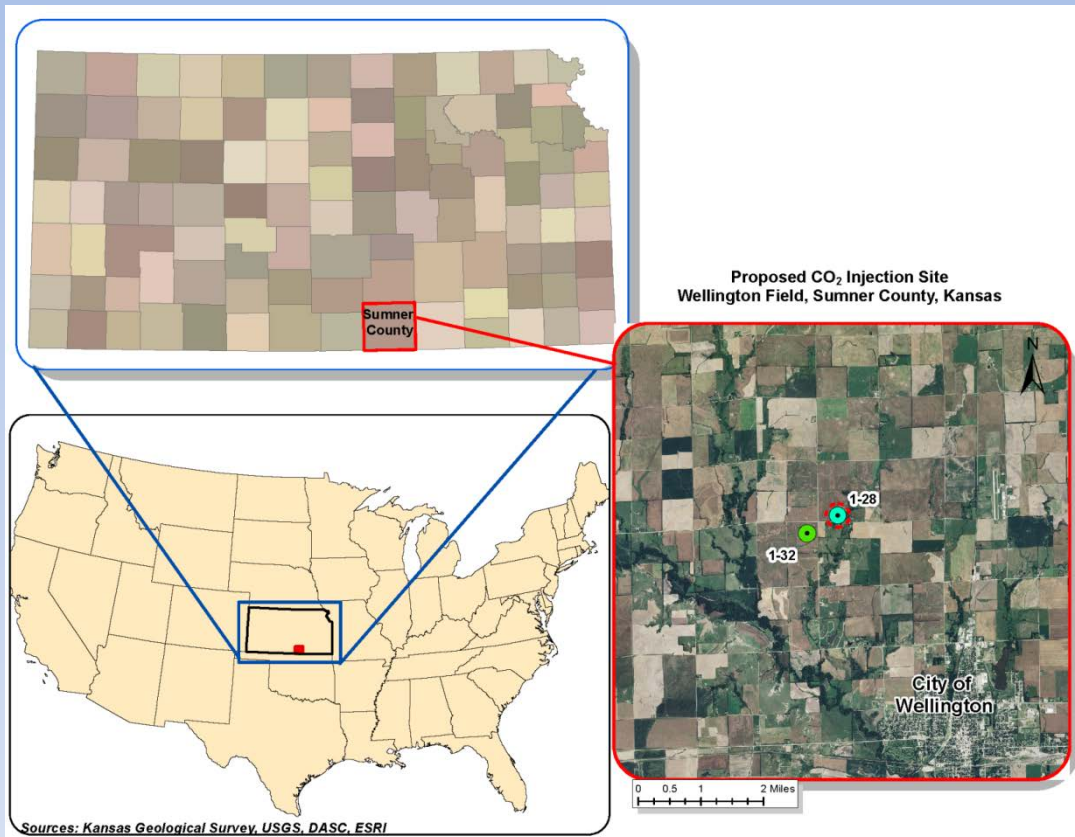


- Injection of 12 million tons/year of CO₂ over a 50 year period at 10 targeted sites in Kansas



- Large number of injection wells required to utilize all available pore space in Arbuckle due to injection pressure restrictions for preventing fracturing.
- Total sequestered volume over 50 year period ~ 0.65 BT (almost a decade of CO₂ emissions in Kansas).

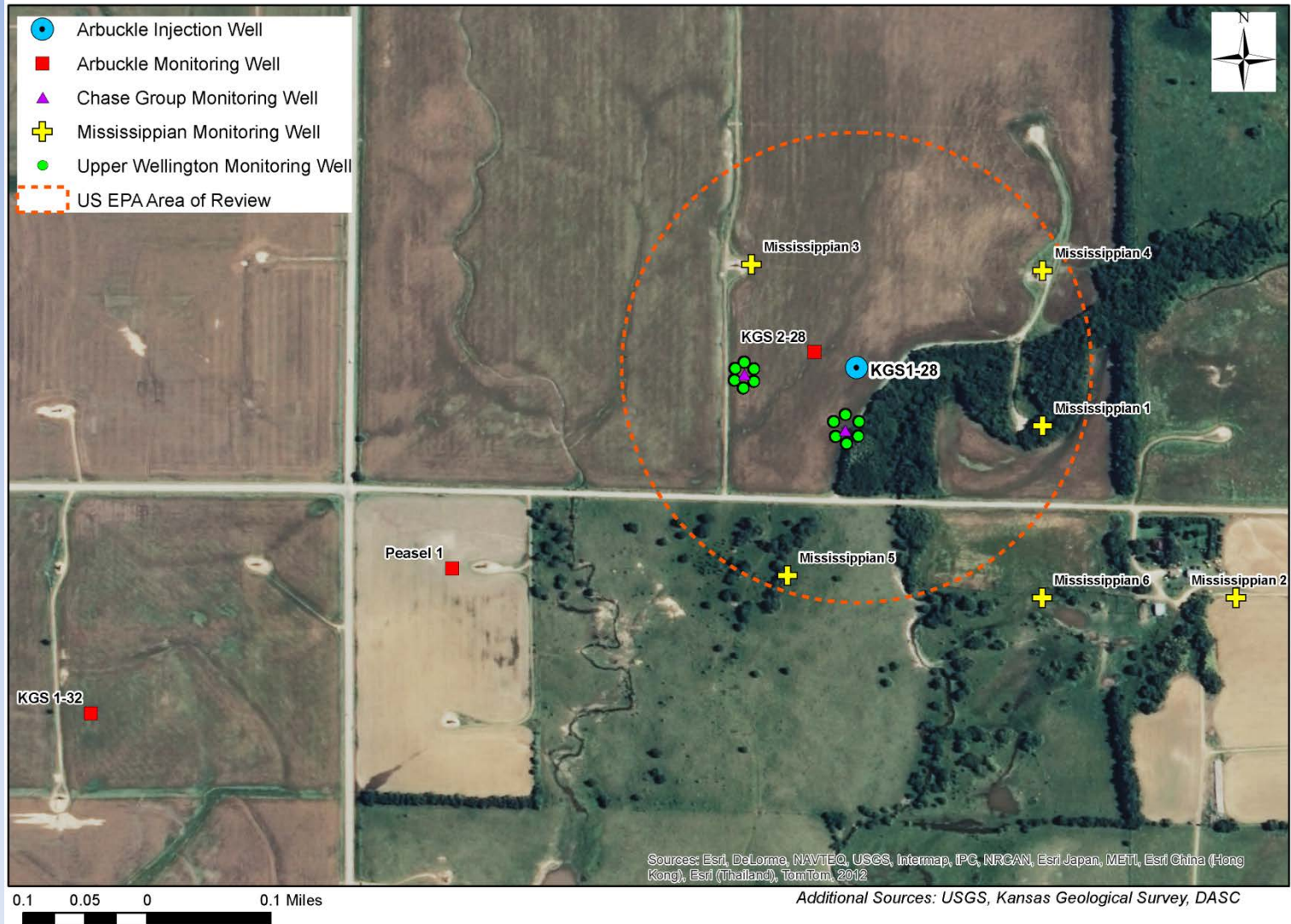
Ongoing Field-Scale Injection Study at Wellington, KS



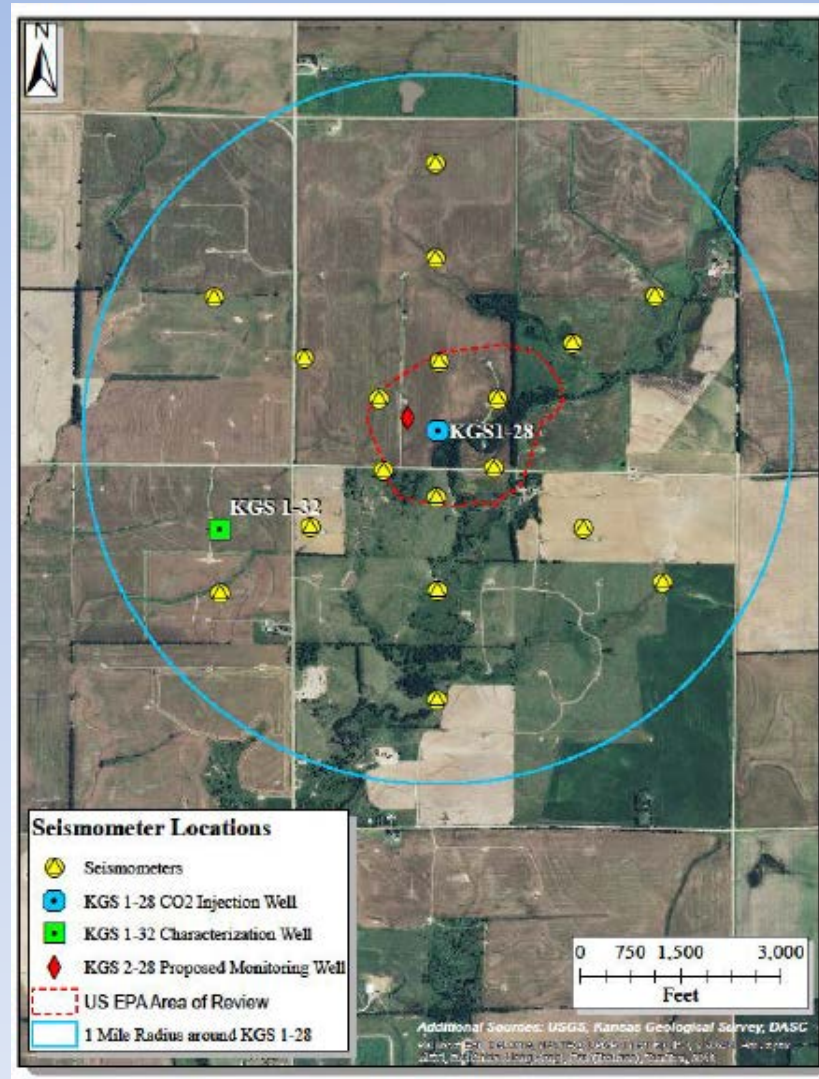
Goals:

- Demonstrate that CO₂ plume and pressures can be simulated, monitored, and verified.
- Carbon Capture and Storage is a viable climate-change mitigation technology.

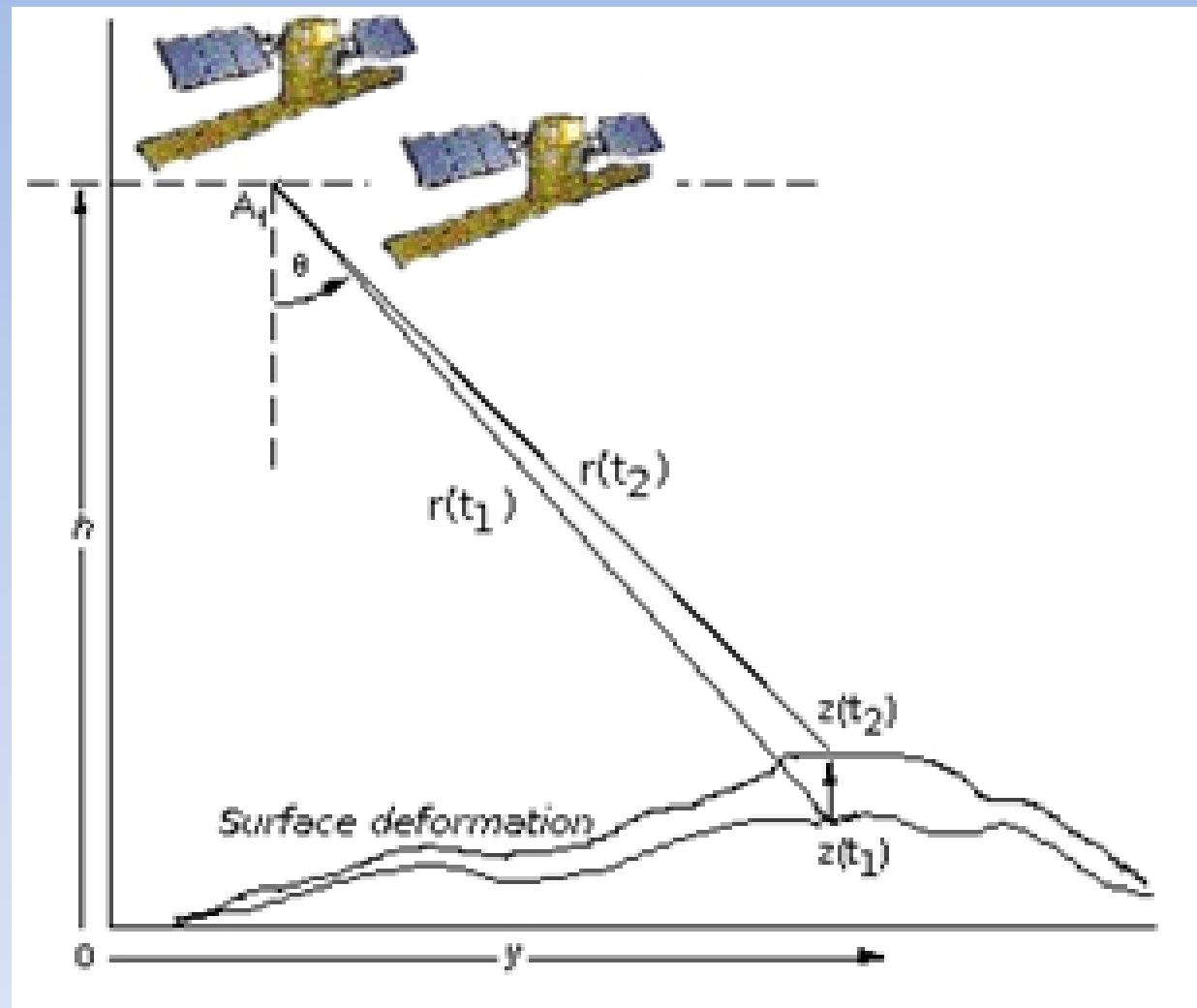
Extensive Monitoring and Visualization of CO₂ Plume and Pressures at Wellington CO₂ Test Site



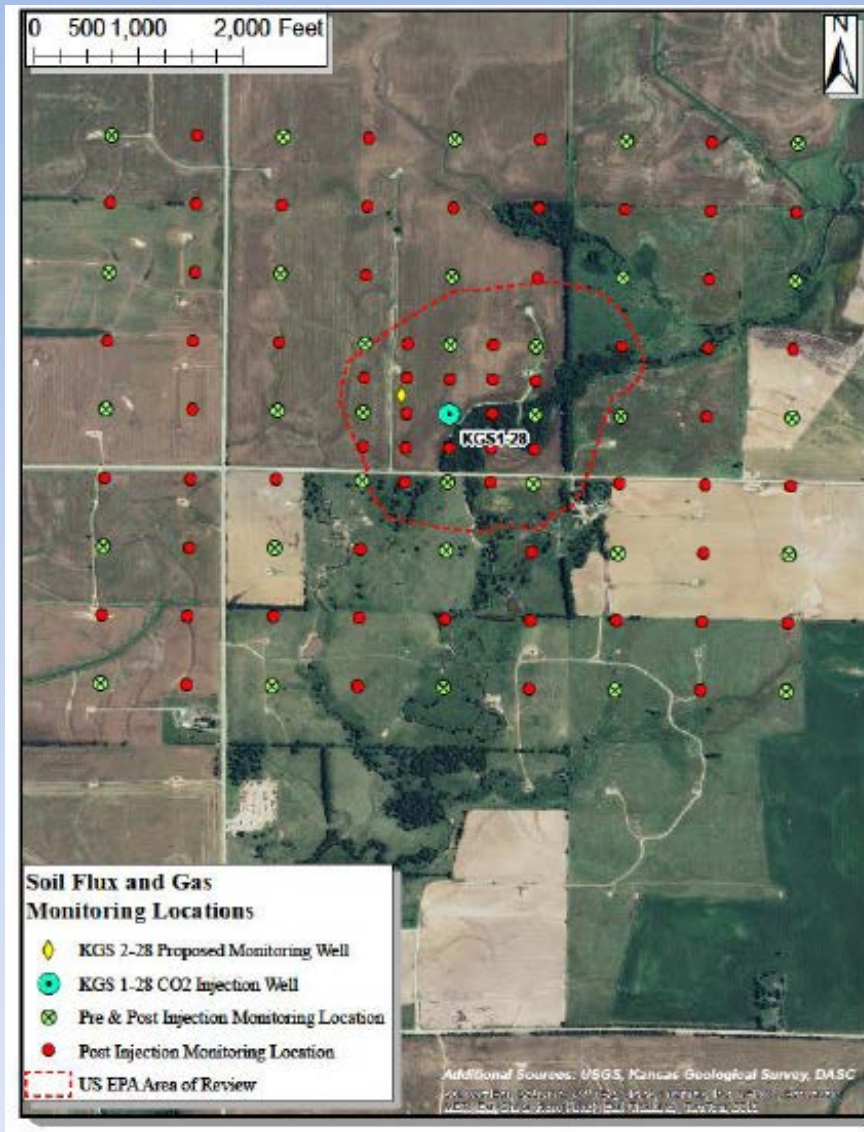
Pressure and Seismic Monitoring (Seismometer Network)



Pressure Monitoring (InSAR)



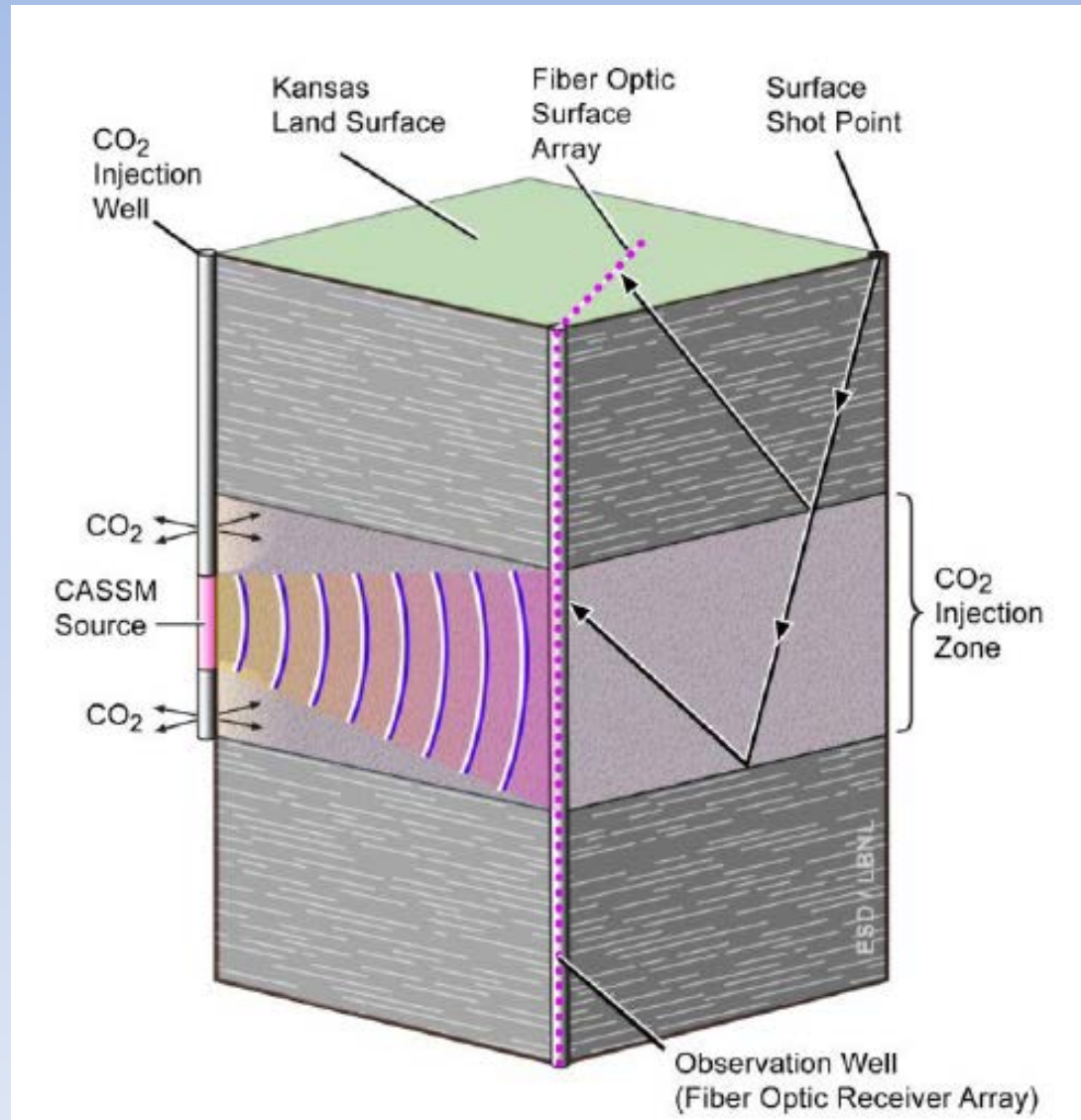
CO₂ Plume Monitoring (Soil Flux and Gas)



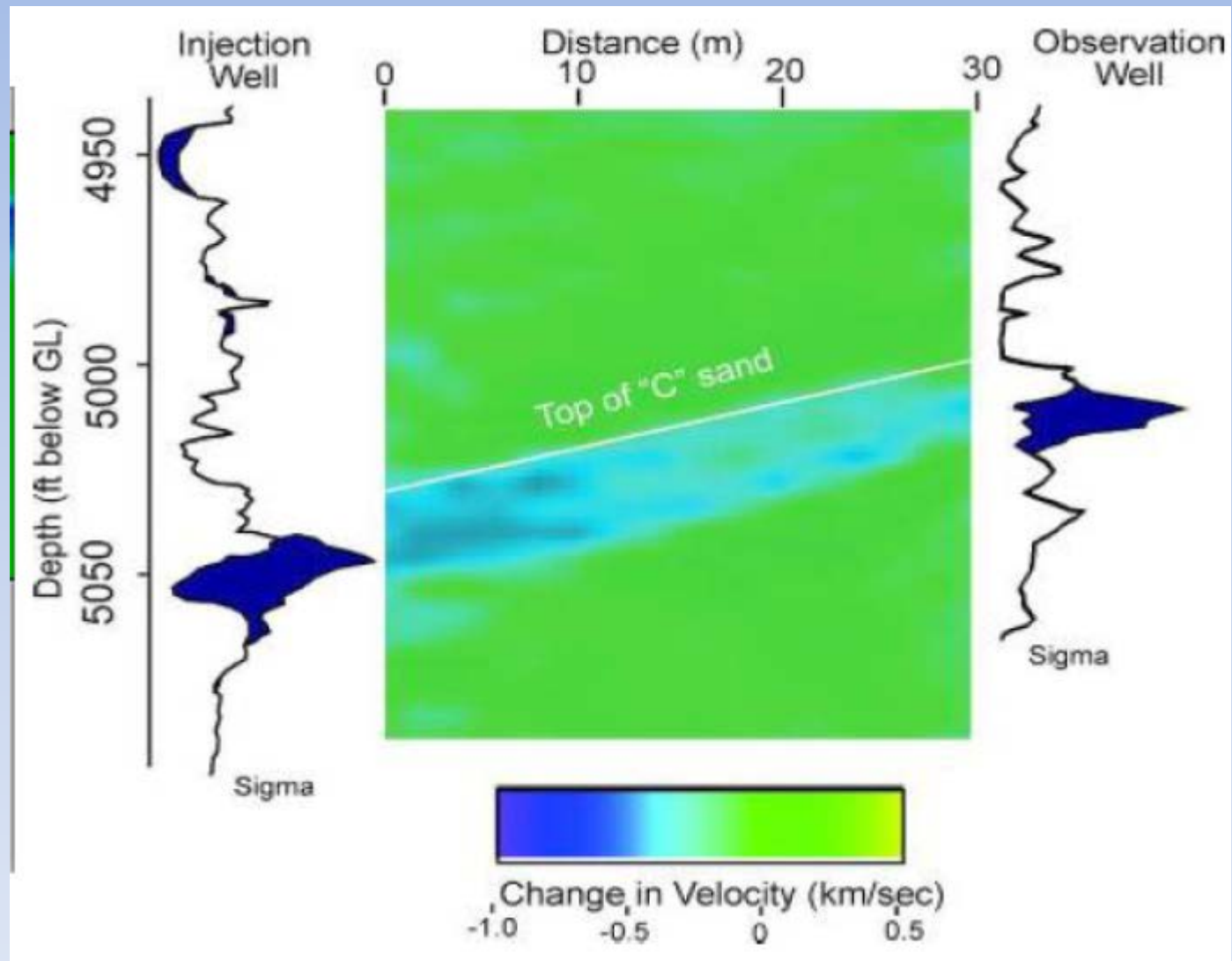
CO₂ Plume Monitoring (Borehole U-Tube)



CO₂ Plume Monitoring (Fiber Optic)



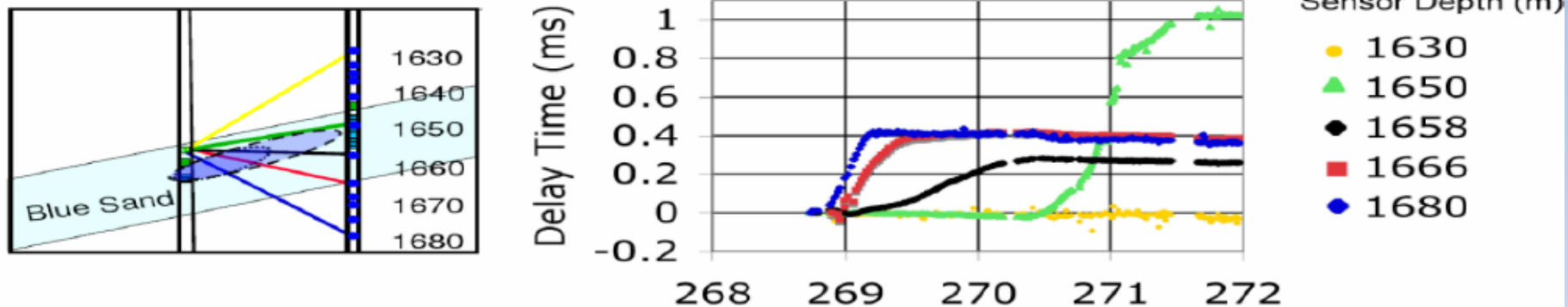
CO₂ Plume Monitoring (Cross-Hole Seismic)



CO₂ Plume Monitoring (Continuous Active Source Seismic, CASSM)

Traveltime Response to CO₂ Injection

Real time detection using continuous source cross-well seismic



Conclusions

- The saline Arbuckle aquifer has large capacity to store anthropogenic CO₂ emission from Kansas and surrounding states for many decades.
- Pressures due to injection will need to be managed to ensure that dissolved brine-CO₂ mixture as well as gaseous phase CO₂ does not migrate into freshwater aquifers or cause fractures to develop.
- Pressure constraint maps have been prepared to guide in developing an optimal state wide plan for commercial scale storage of anthropogenic CO₂ using computer simulation models.
- Pilot scale study at Wellington is ongoing to demonstrate the feasibility of injection and the viability of real-time CO₂ monitoring.

Acknowledgements & Disclaimer

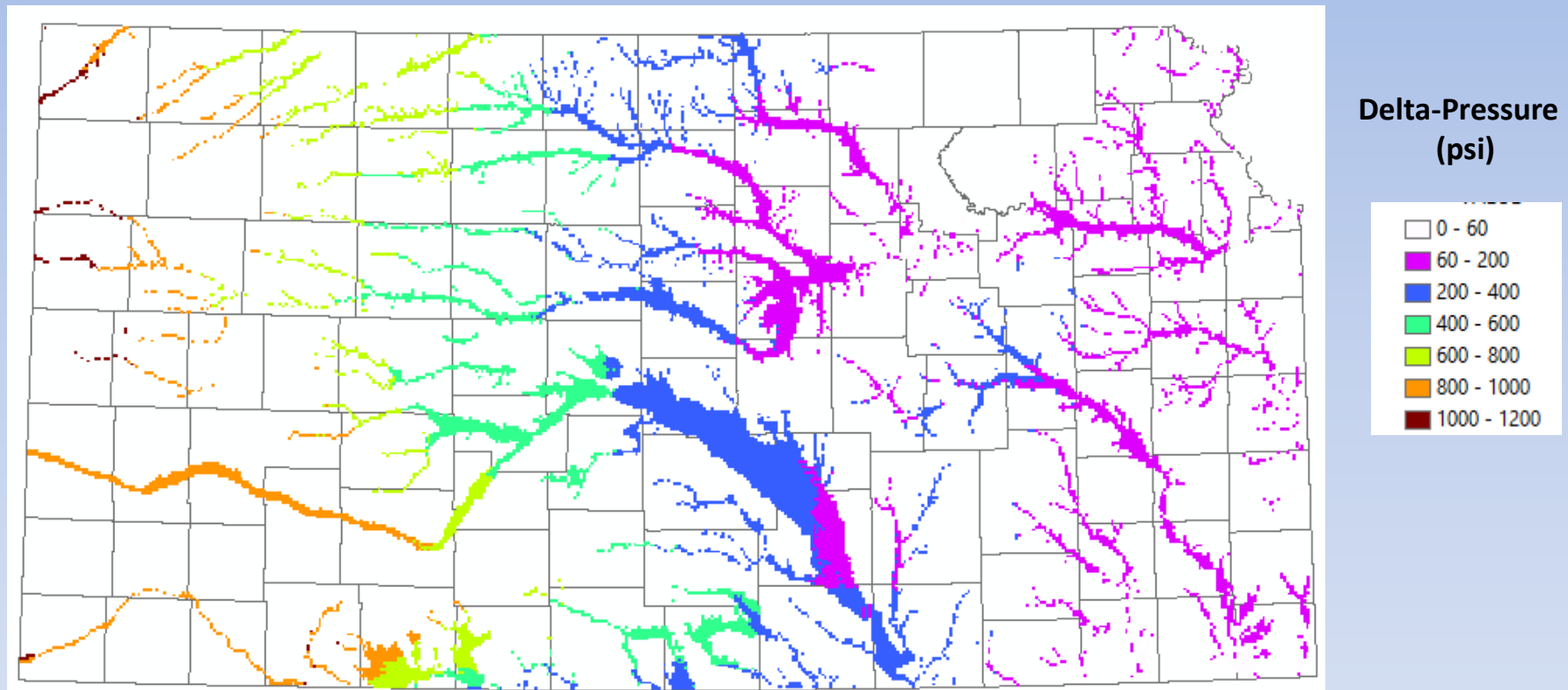
Acknowledgements

The work supported by the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) under Grant DE-FE0002056 and DE-FE0006821, W.L. Watney and Jason Rush, Joint PIs. Project is managed and administered by the Kansas Geological Survey/KUCR at the University of Kansas and funded by DOE/NETL and cost-sharing partners.

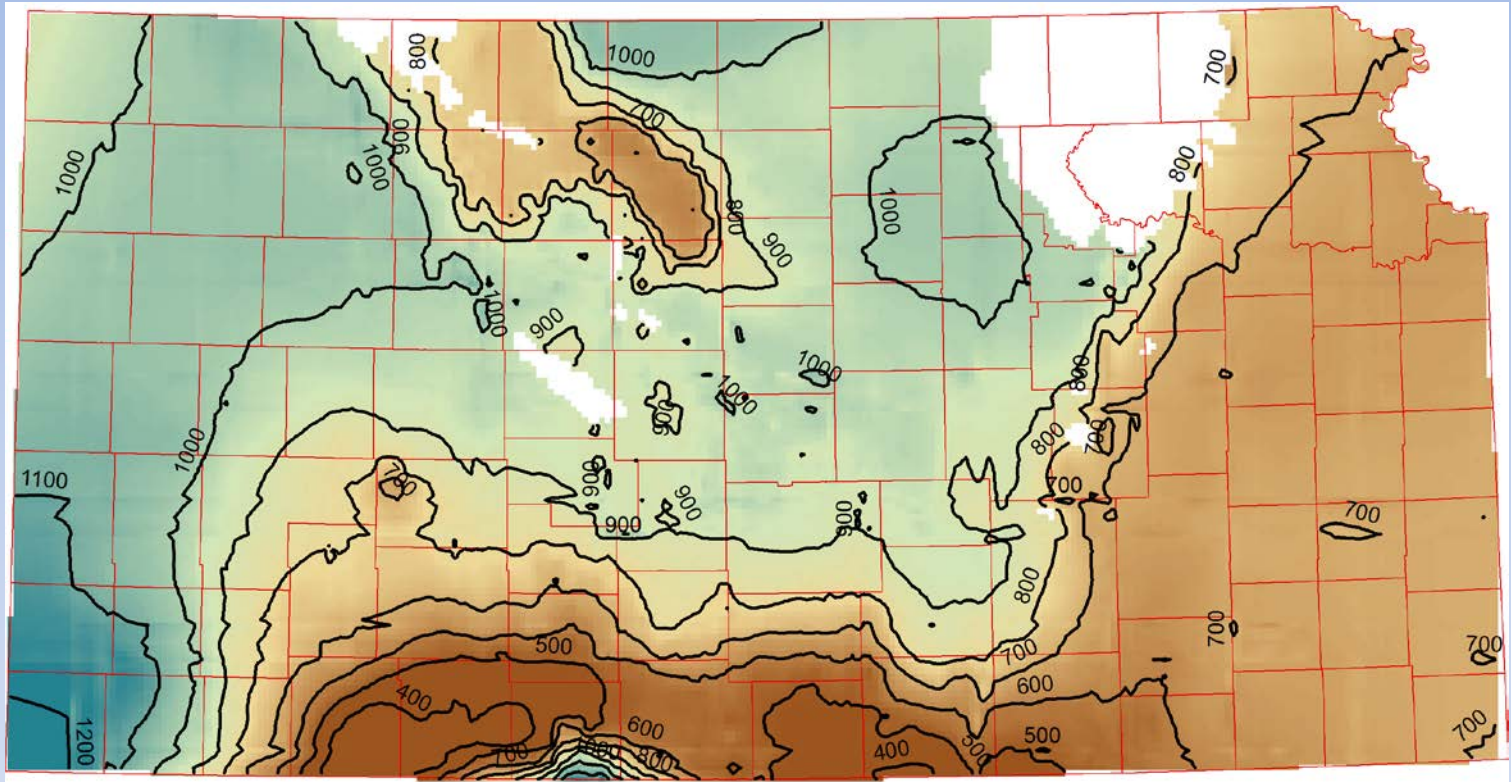
Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Required Increase in Pore Pressure for Migration of Brines from Arbuckle into Alluvial Aquifers



Insitu Groundwater Levels (ft, msl)



- In-situ water levels lower by about 600 ft in SW Kansas due to heavier brines in the Arbuckle