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

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Midwest Groundwater Association Conference

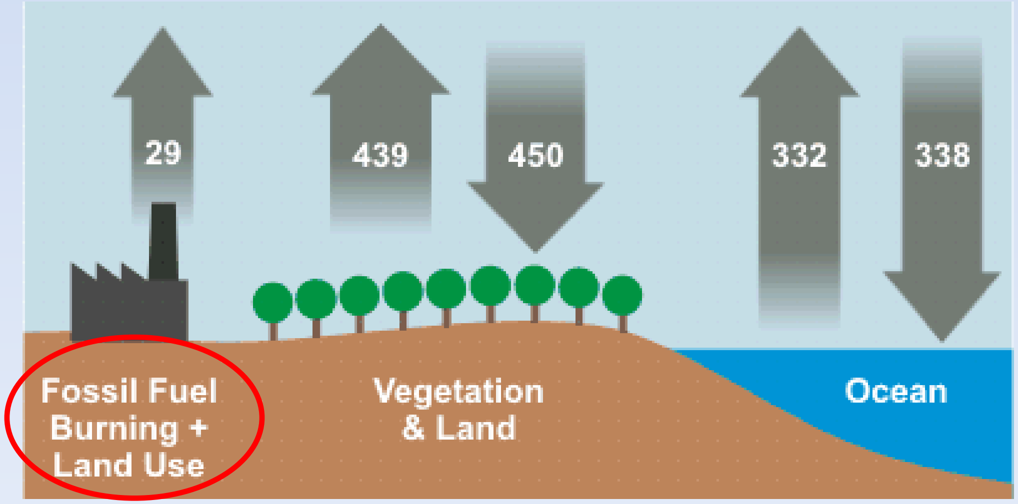
Lawrence, KS

October 1st, 2014

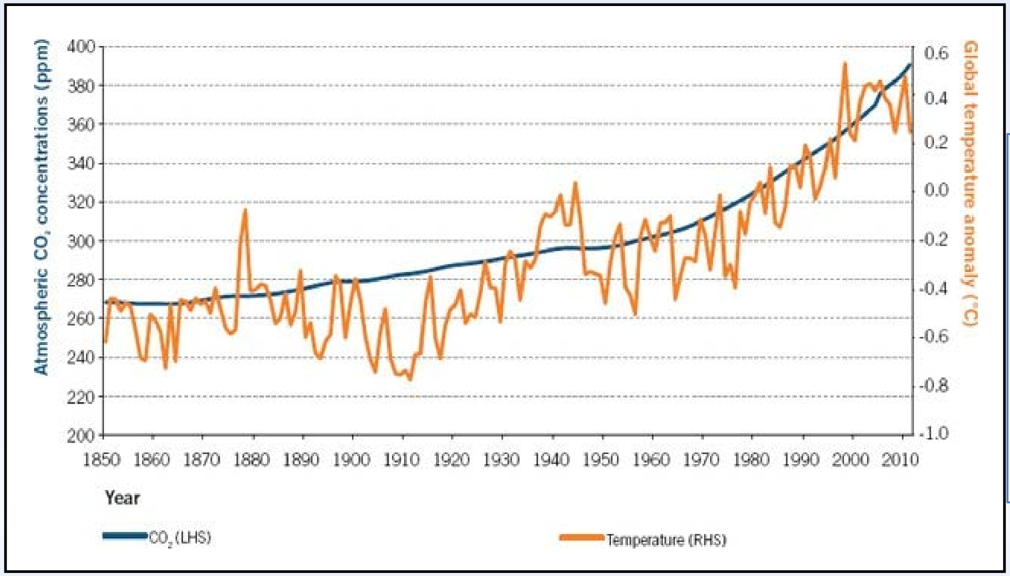
KANSAS GEOLOGICAL SURVEY
The University of Kansas

Global CO_2 Cycle

CO_2 Cycle (billion tons per year, BT)

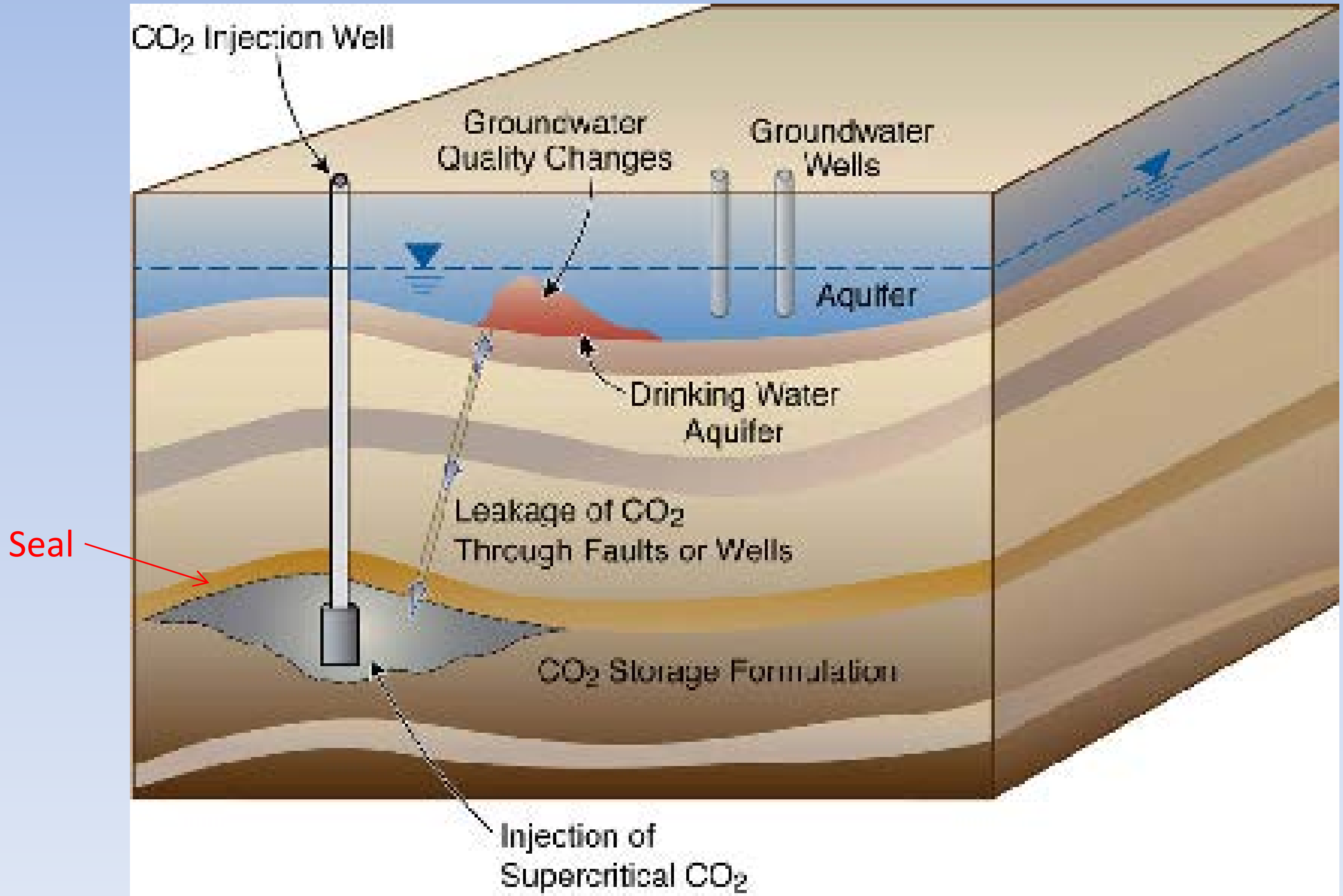


Emissions	800 BT
Natural Sequestration	788 BT
Balance	12 BT

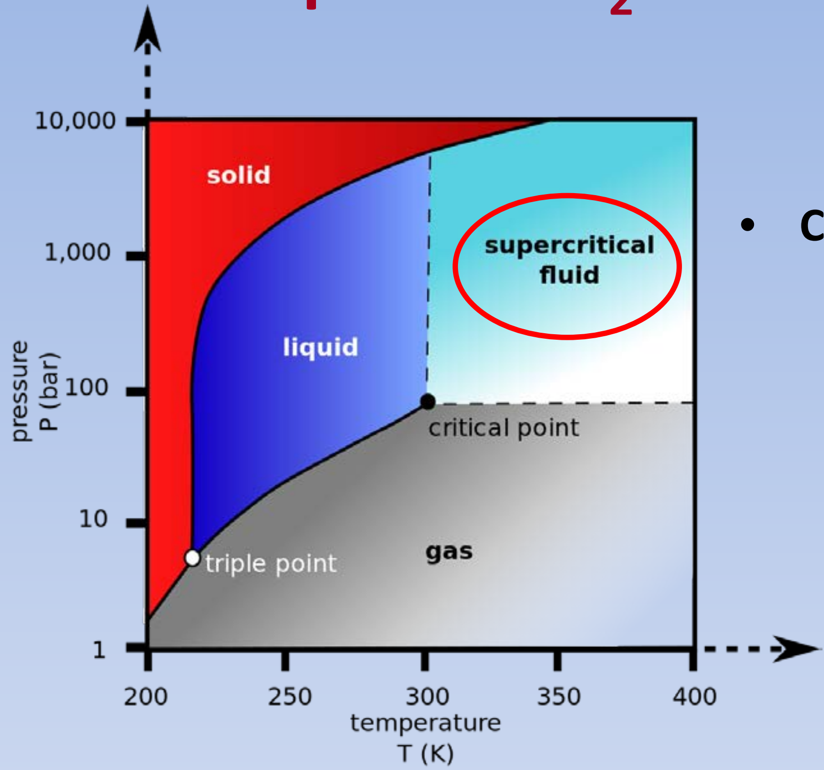


- Atmospheric CO_2 levels rising since start of industrial era.
- Present concentrations of 400 ppm CO_2 close to 2050 target of 450 ppm.

Geologic Sequestration of CO_2 a Viable Bridge Technology for Post Fossil-Fuel Economy

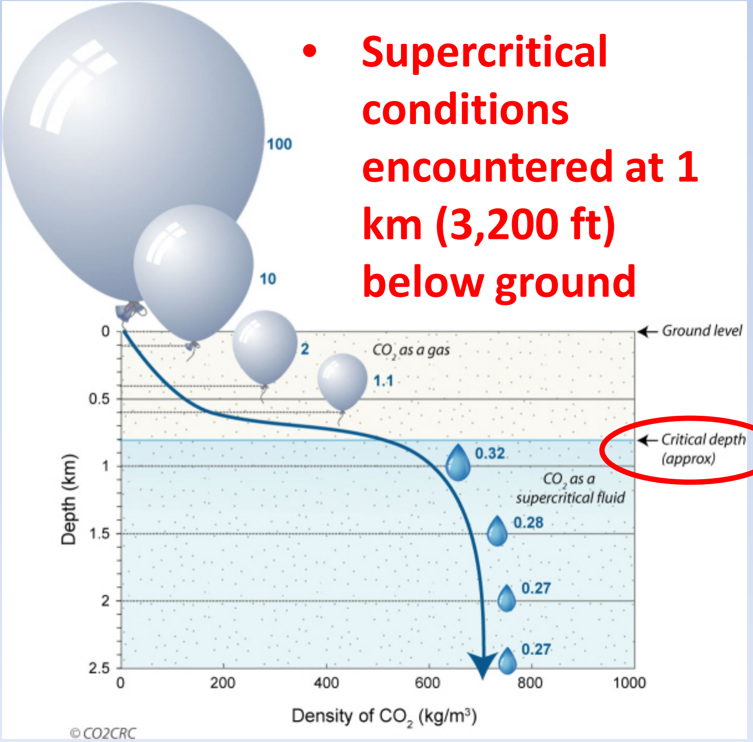


Optimal CO_2 Phase for Geologic Sequestration

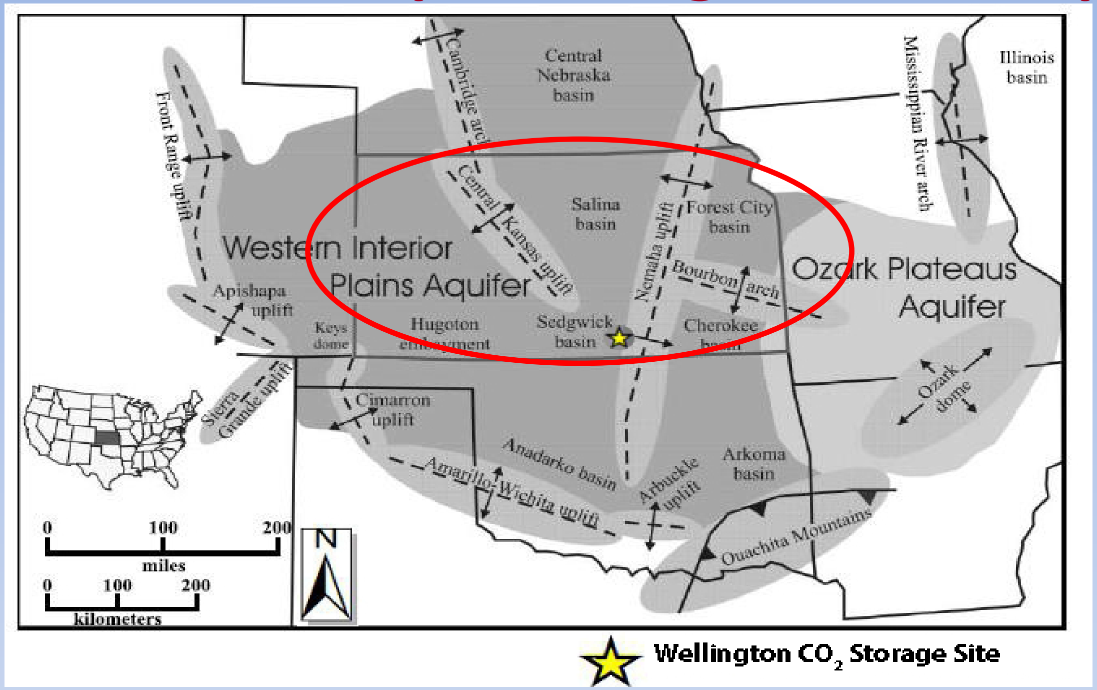


- CO_2 most dense in supercritical phase

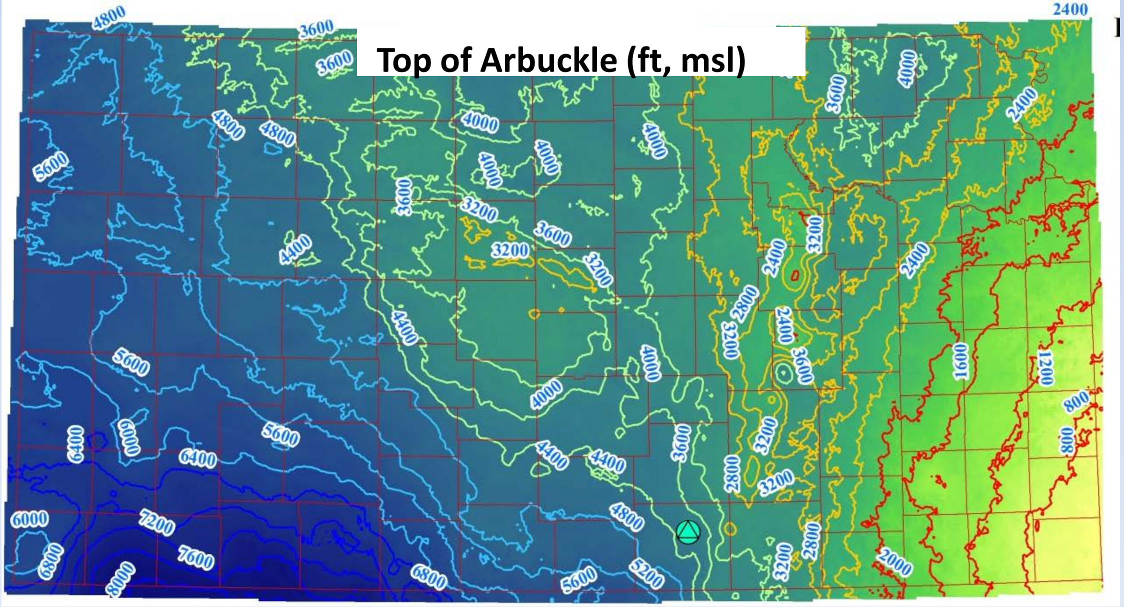
- Supercritical conditions encountered at 1 km (3,200 ft) below ground



Arbuckle Aquifer Targeted for Sequestration in Kansas

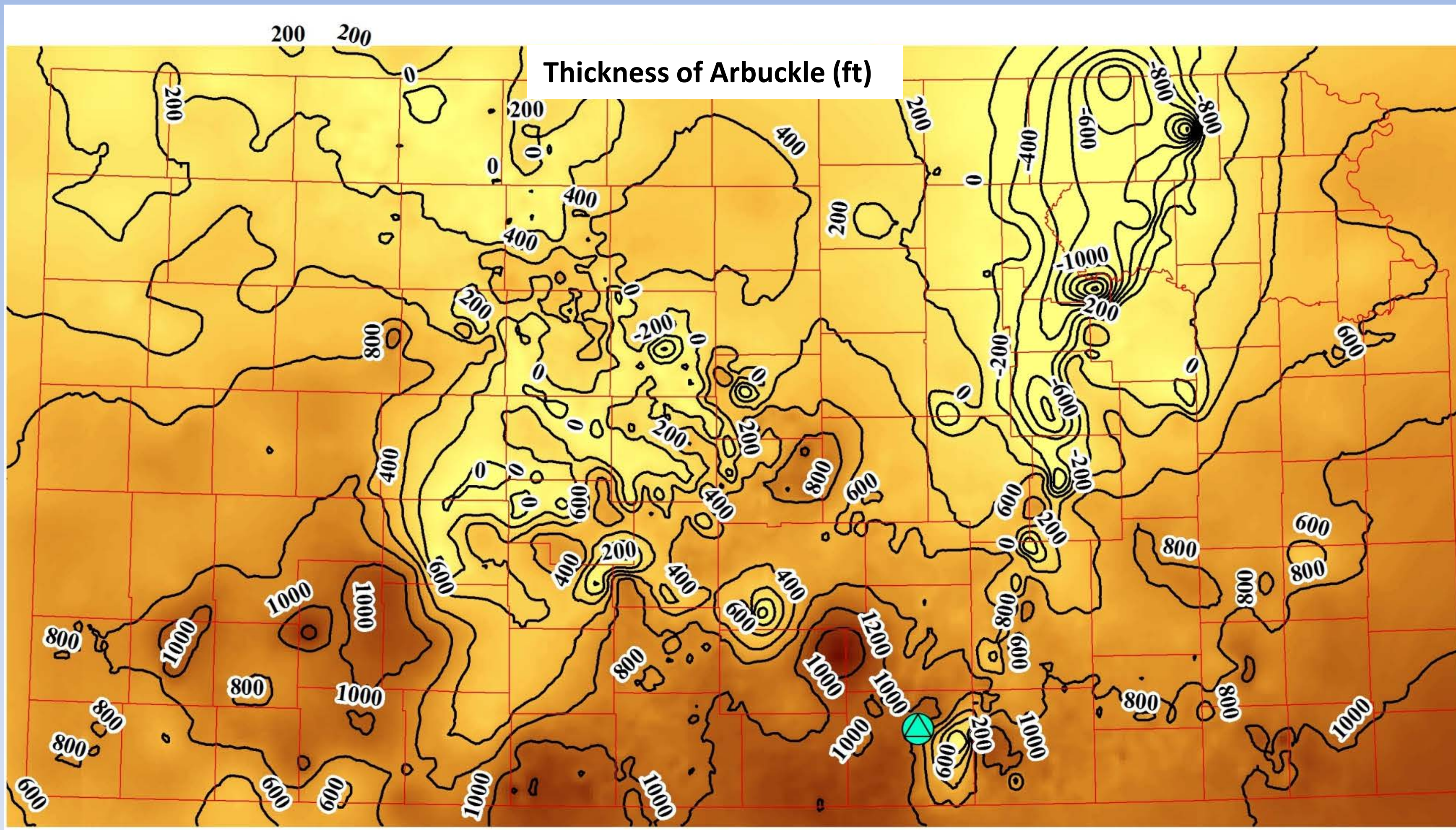


- **Cambrian-Ordivician Arbuckle aquifer (Dolomitic)**



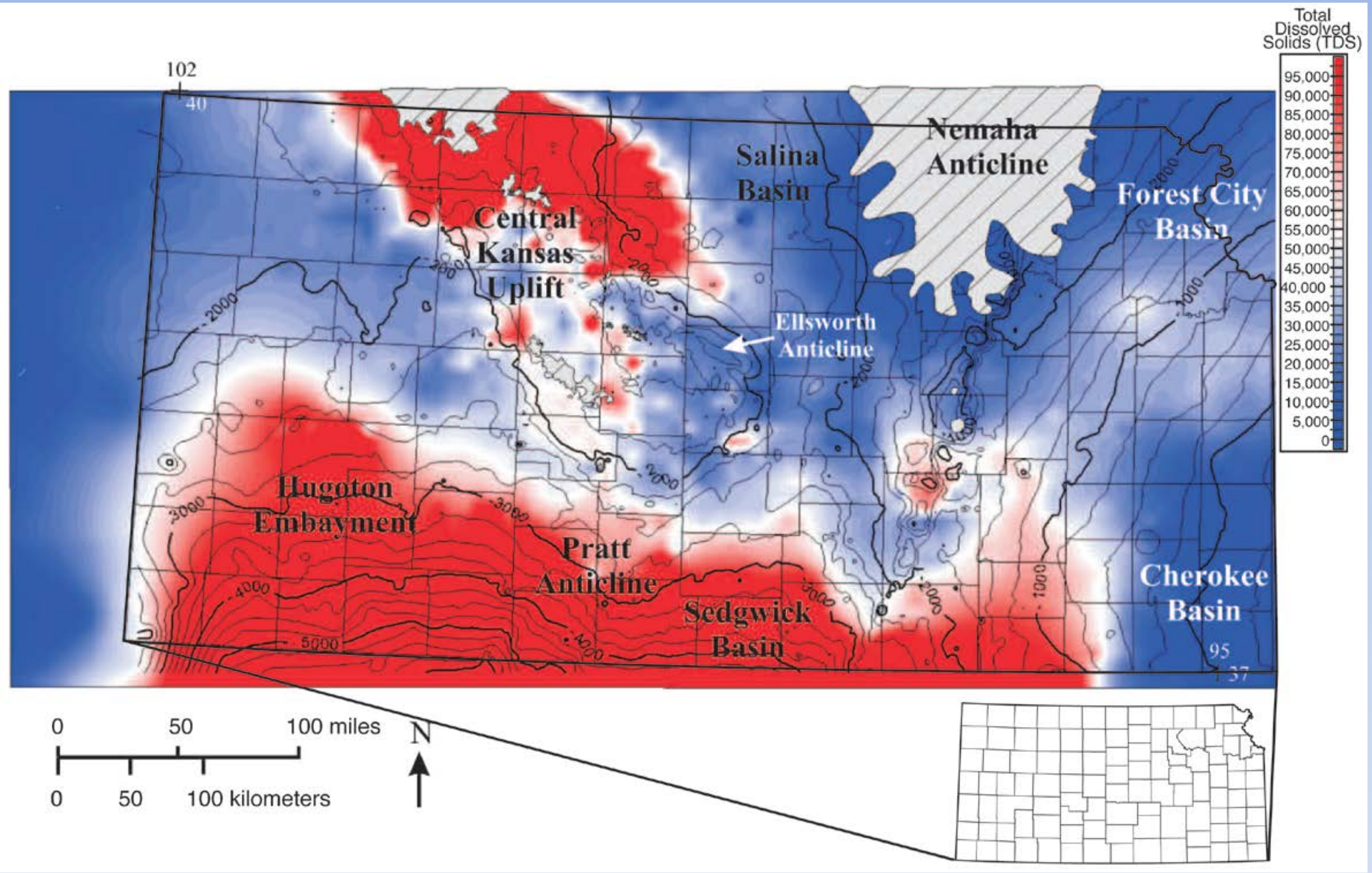
- **Top of Arbuckle >3,000 feet below ground in SW Kansas**

Thickness of Arbuckle Aquifer



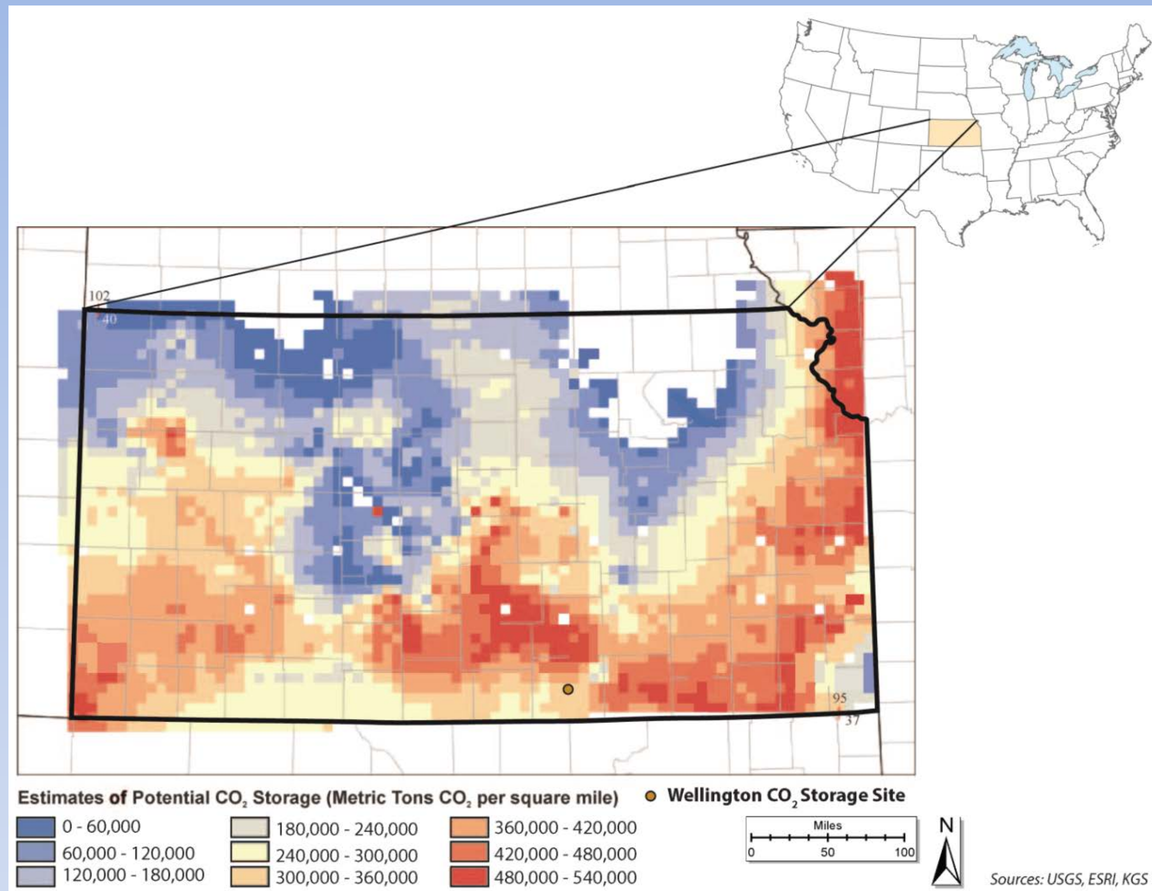
- **Arbuckle ~ 1,000 ft thick in SW Kansas**
- **Porosity ~ 5%**

Arbuckle Salinity



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

DOE Estimated Arbuckle CO2 Storage Capacity

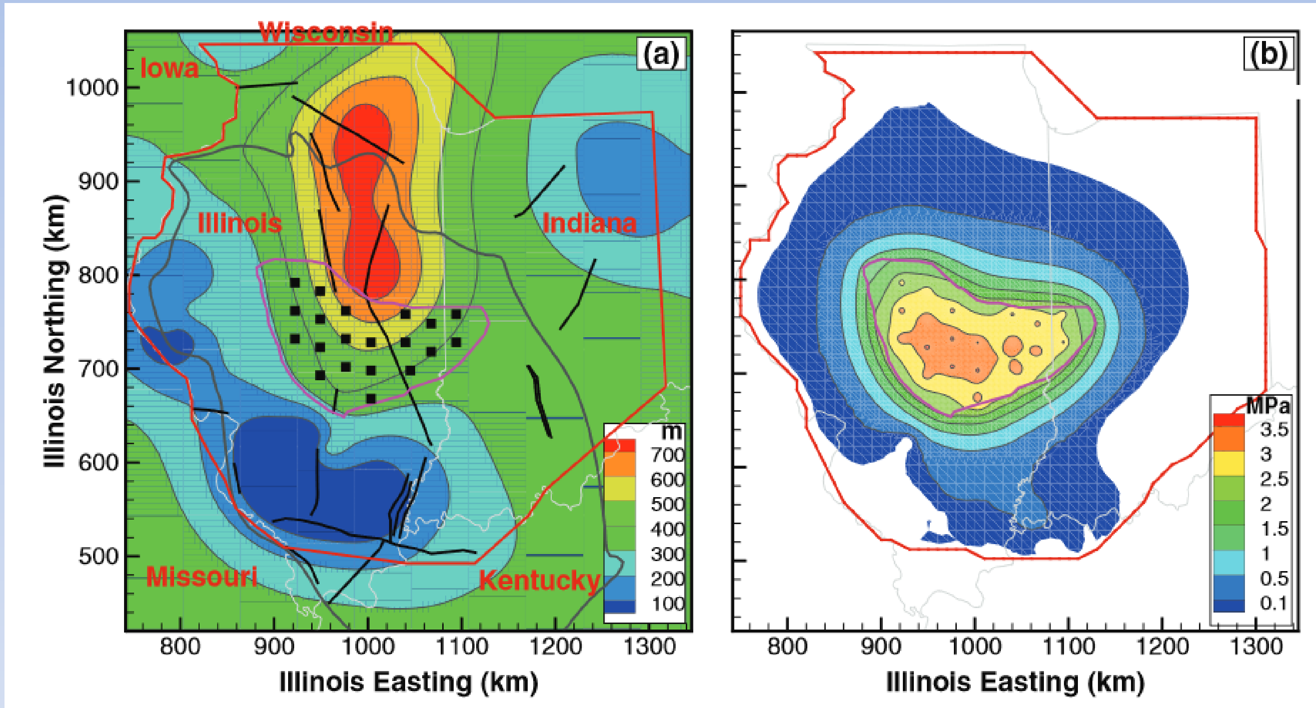


Total Arbuckle CO2 capacity ~ 60 BT
Total Annual US Emission ~ 5.4 BT
Total Annual KS Emission < .1 BT

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

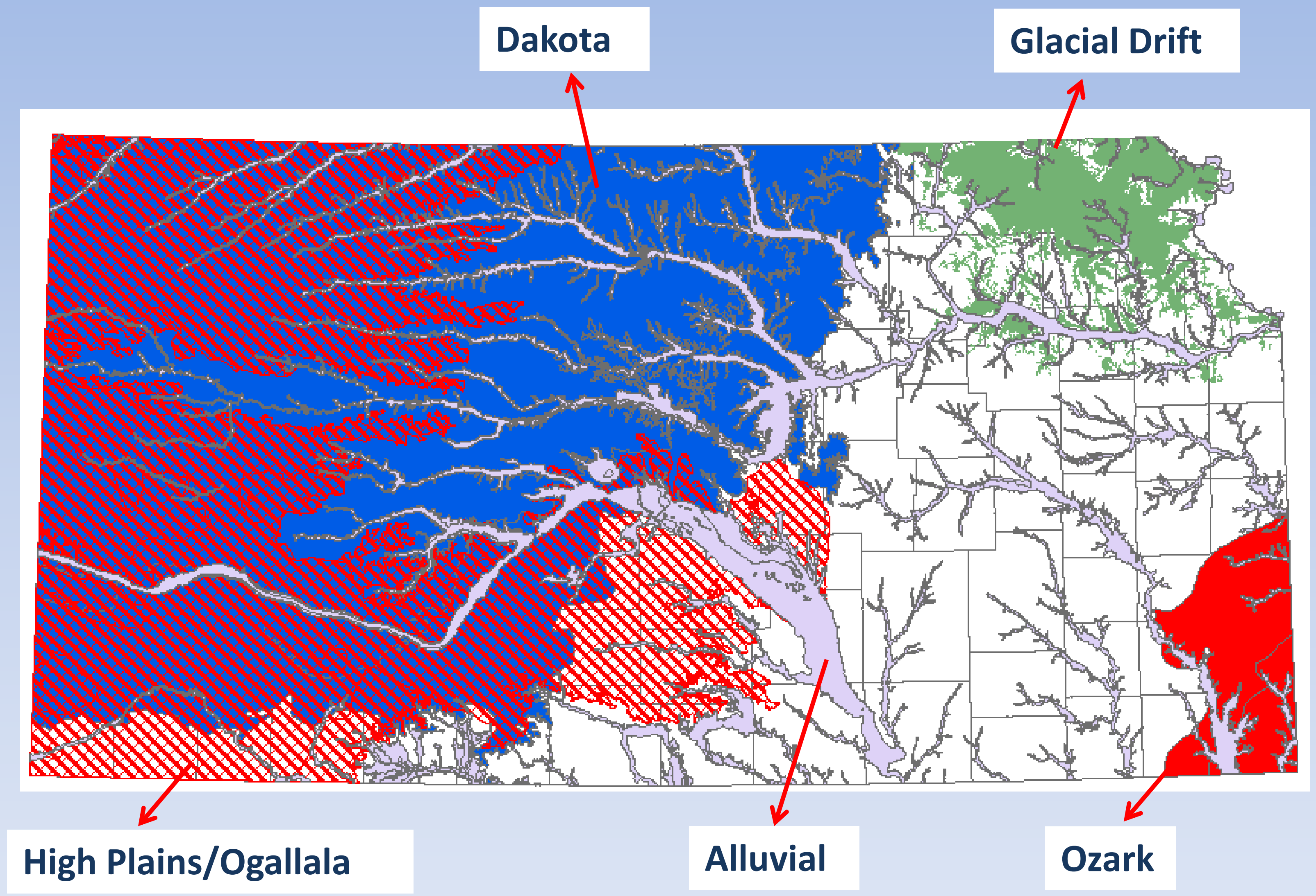
Wide Spread Increase in Pore Pressures Expected Due to CO2 Injection

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

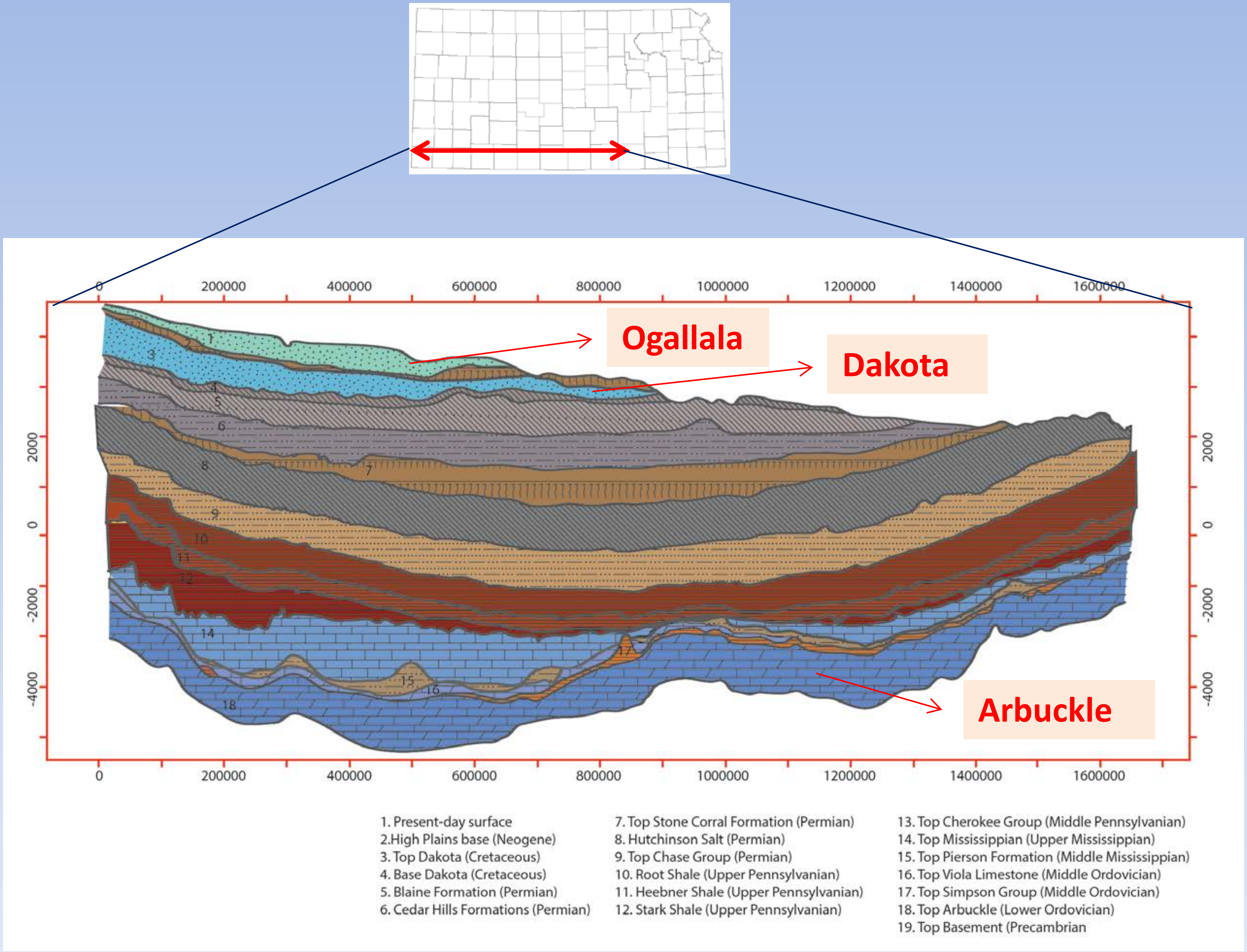


- **Will induced pressures due to commercial scale CO_2 injection in Kansas cause brines to migrate into freshwater aquifers through abandoned wells and faults?**

Freshwater Aquifers in Kansas



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



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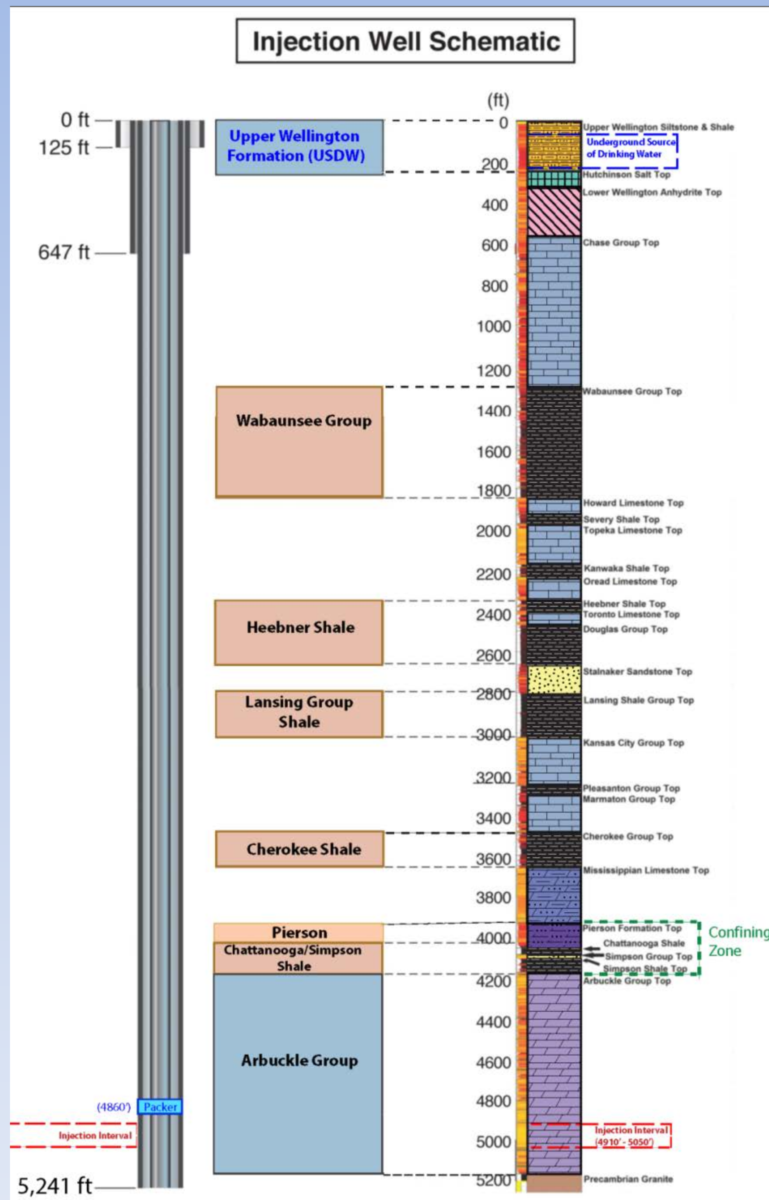
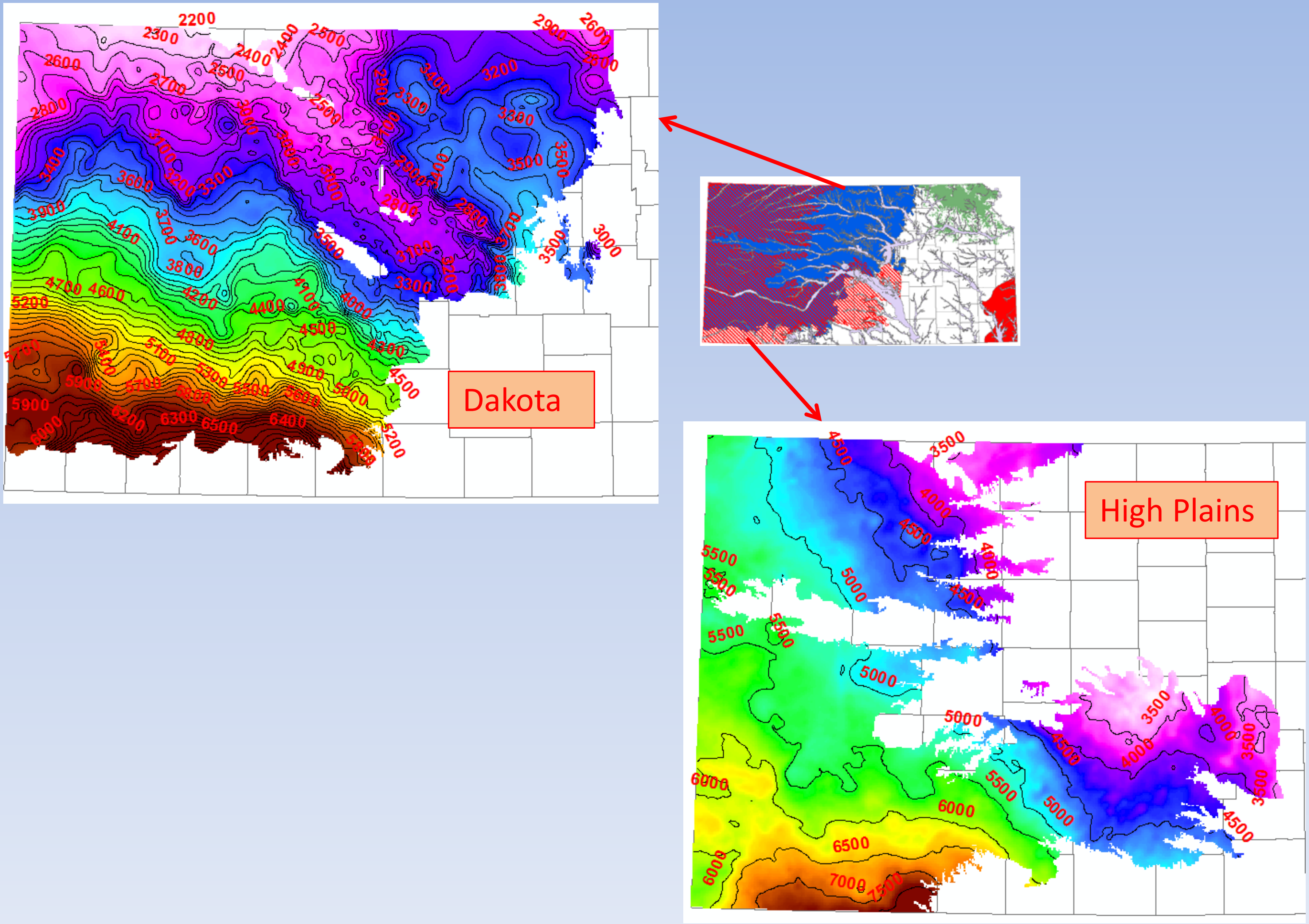


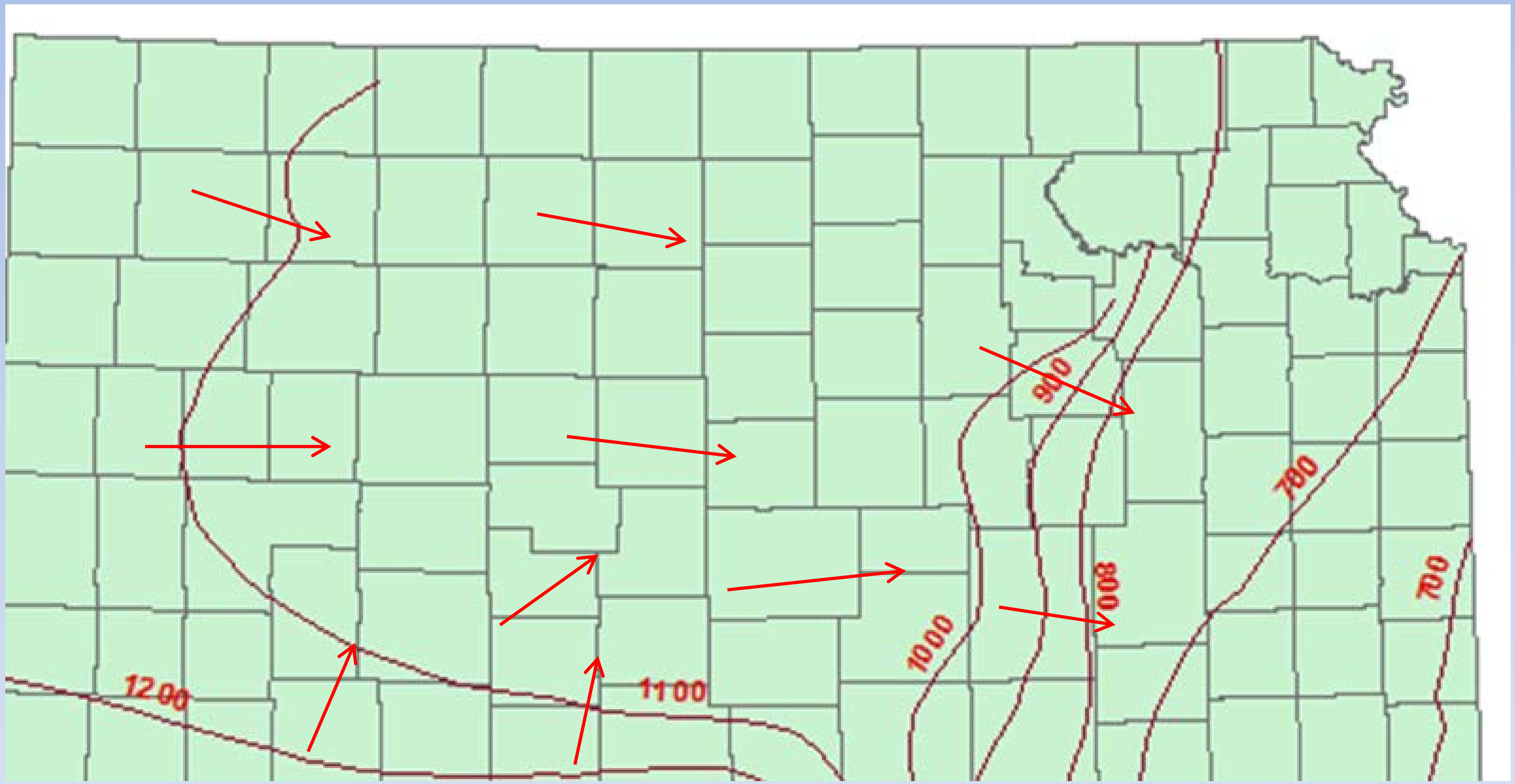
CO_2 Injection Test Site in Sumner County, KS

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



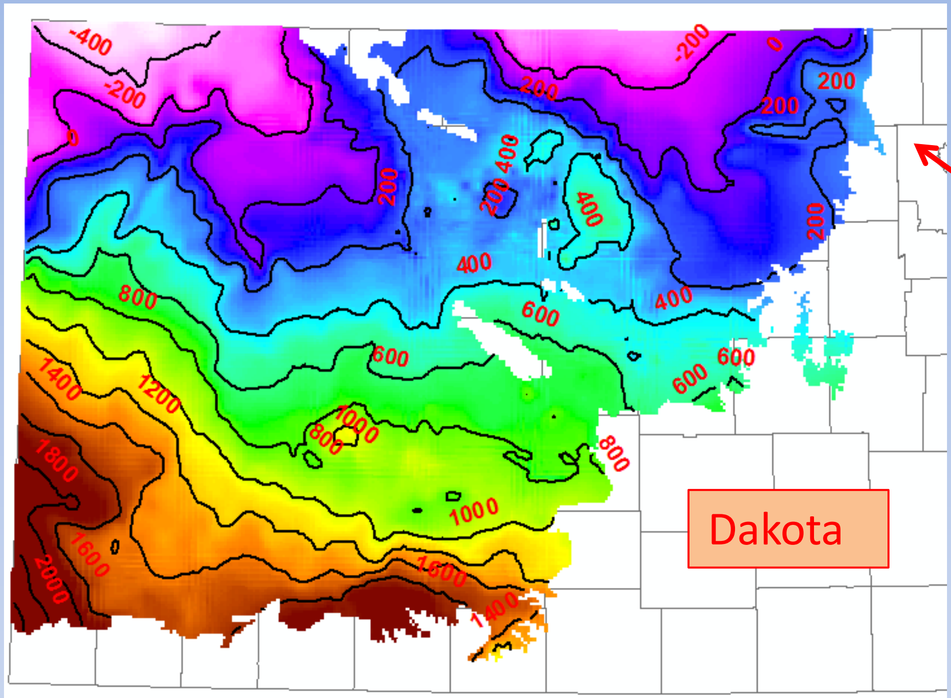
Potentiometric Surface of Arbuckle

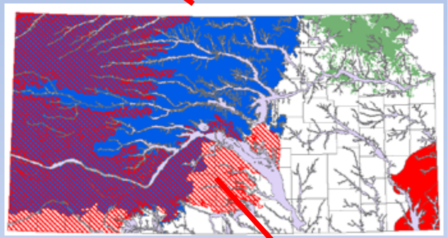
Equivalent Freshwater Heads (ft, msl)

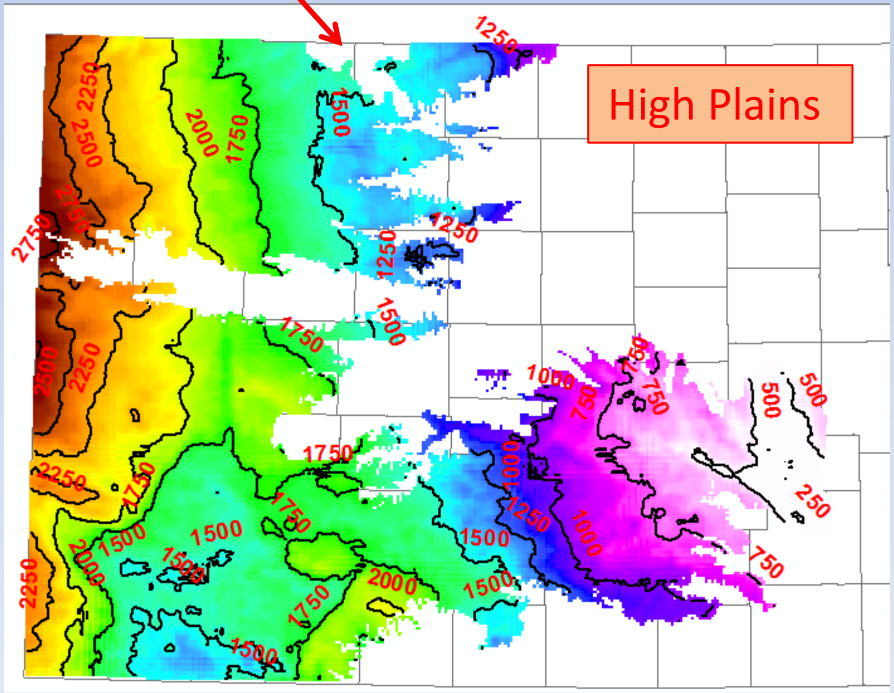


- **Merging of two regional flow fields (Rocky Mountain & Anadarko Basin)**
- **Groundwater flow across state takes approximately ¼ to ½ million years**

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

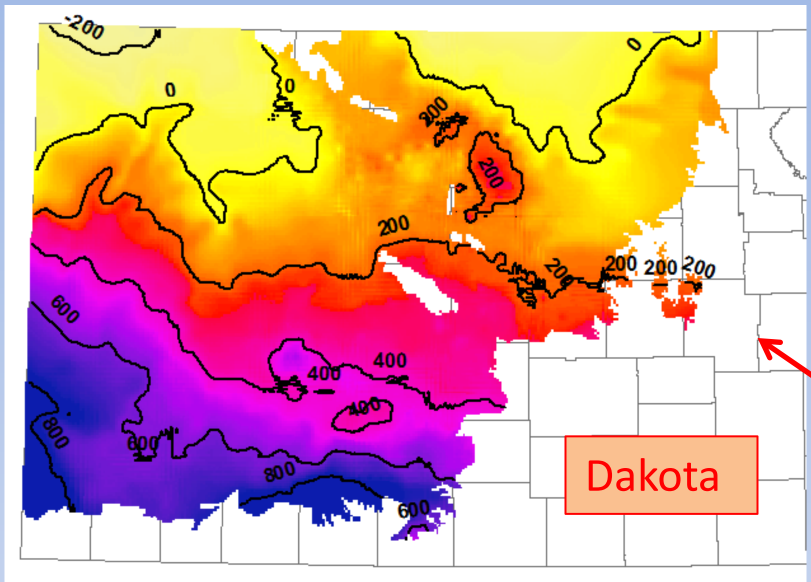


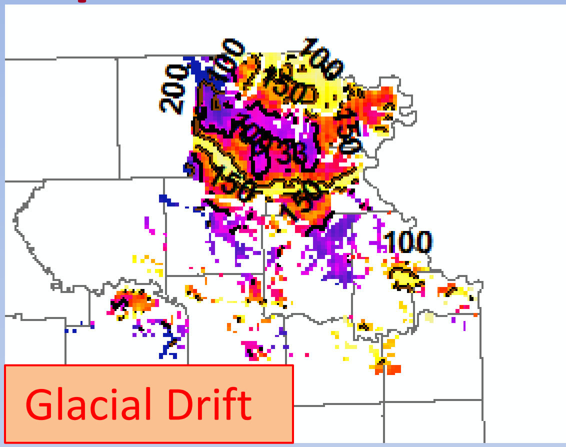


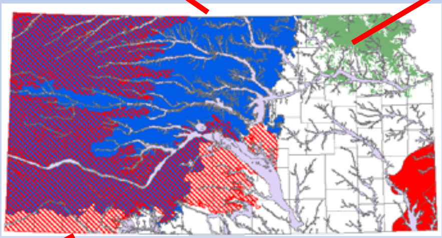


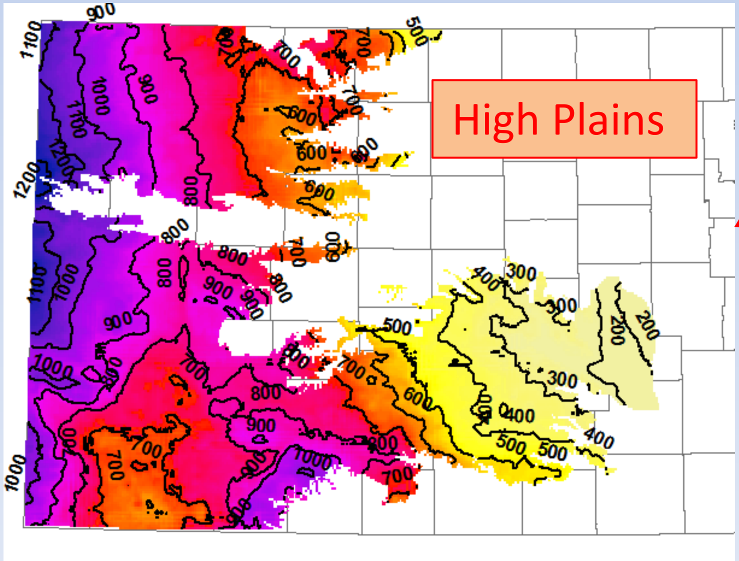
- **Hydraulic buffer exists to accommodate increased pressures due to CO_2 injection without causing brines to migrate into freshwater aquifers via improperly abandoned wells and open faults**

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





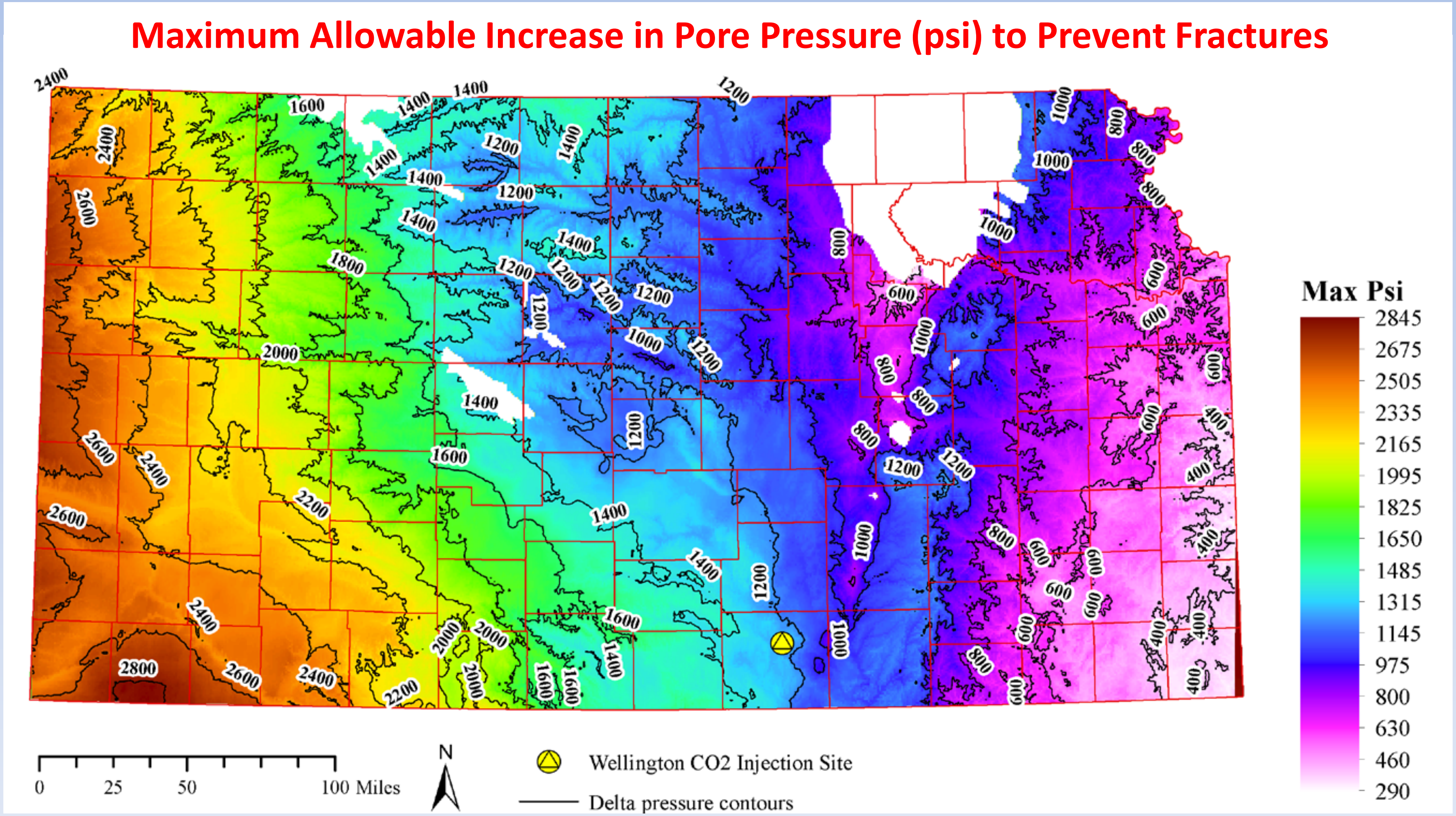




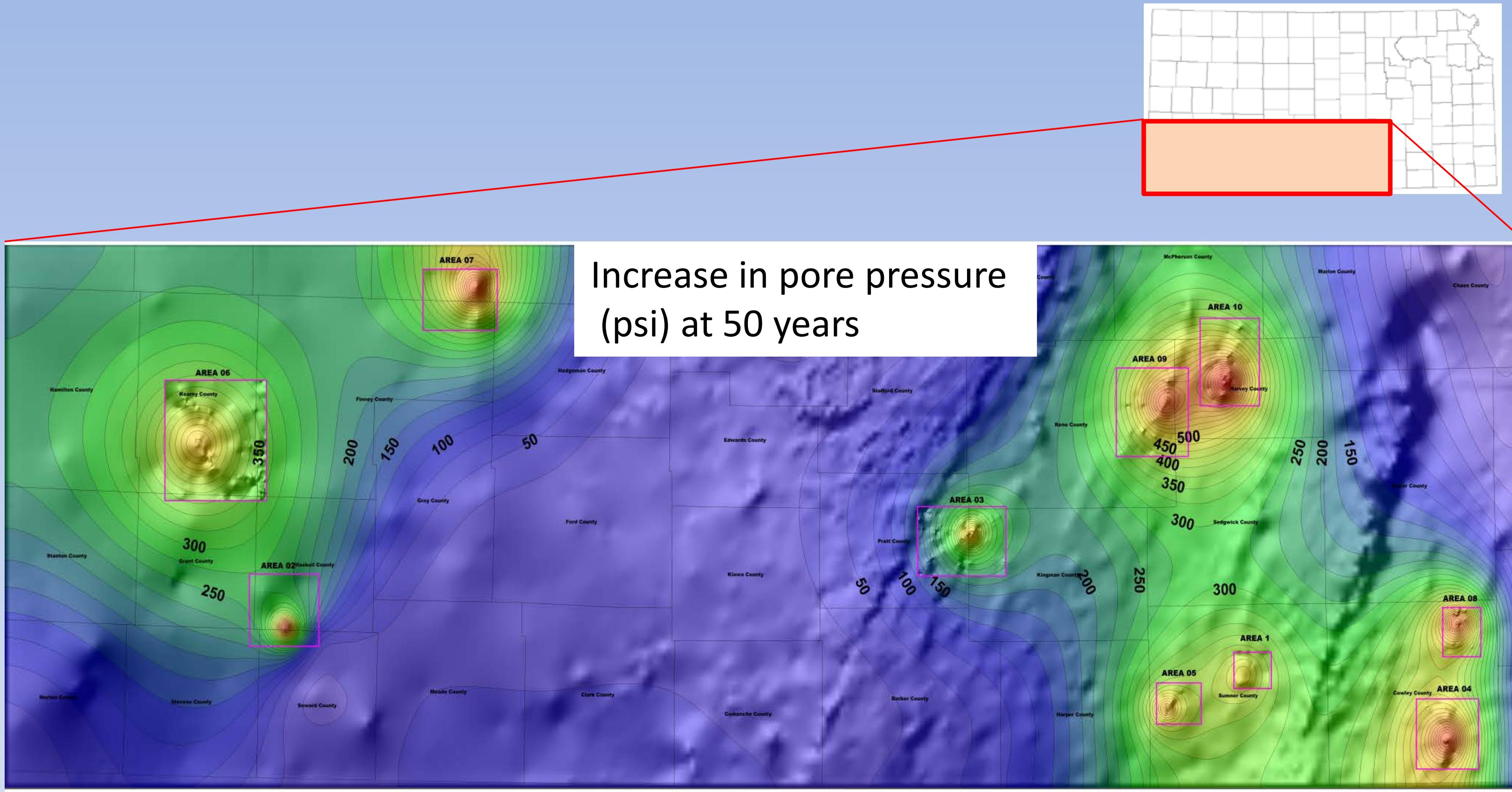
- Need to ensure these pressures are not exceeded if improperly abandoned wells or communicative faults are present within zone of influence

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]

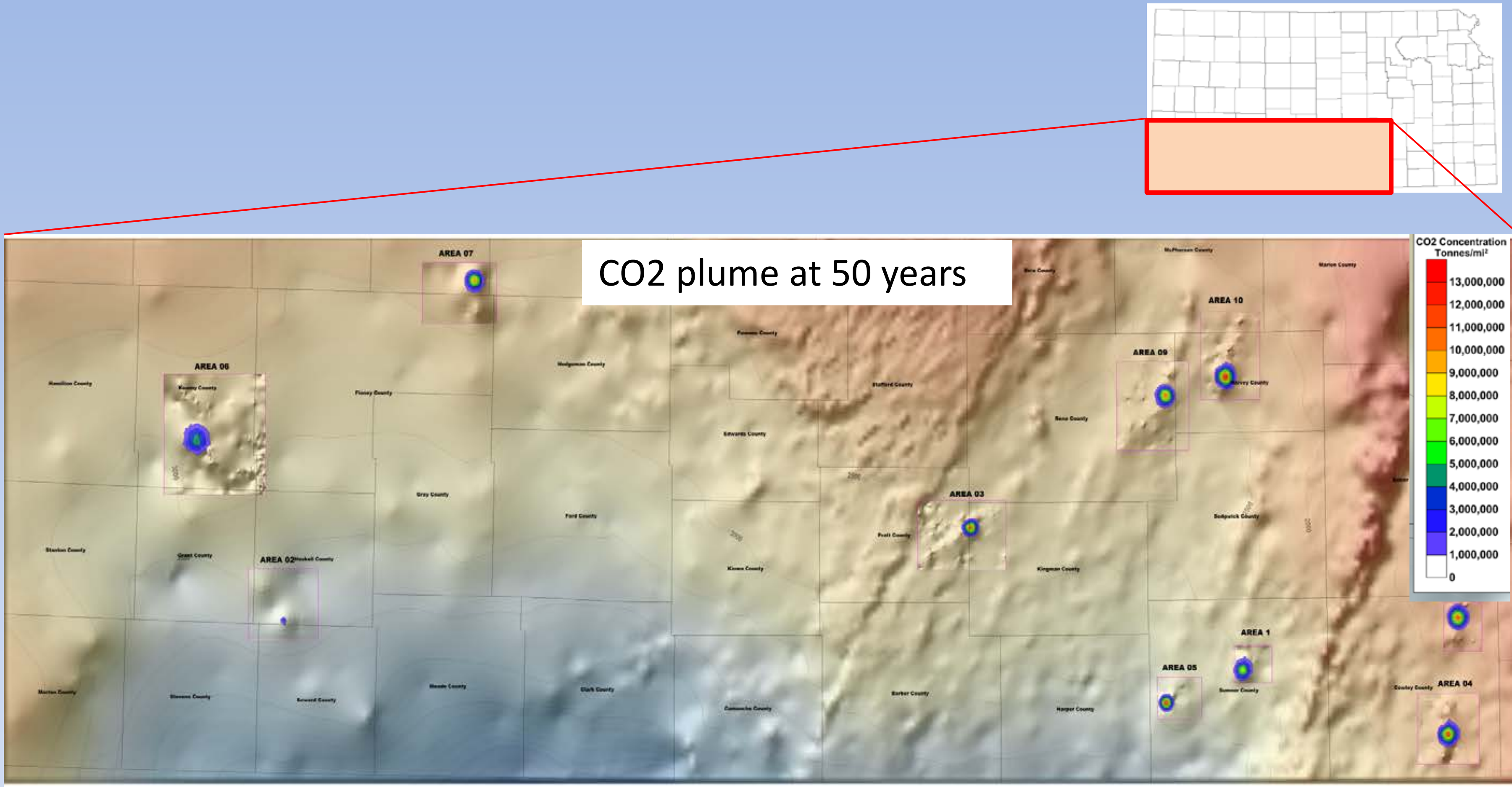


Simulated Increase in Pore Pressures



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

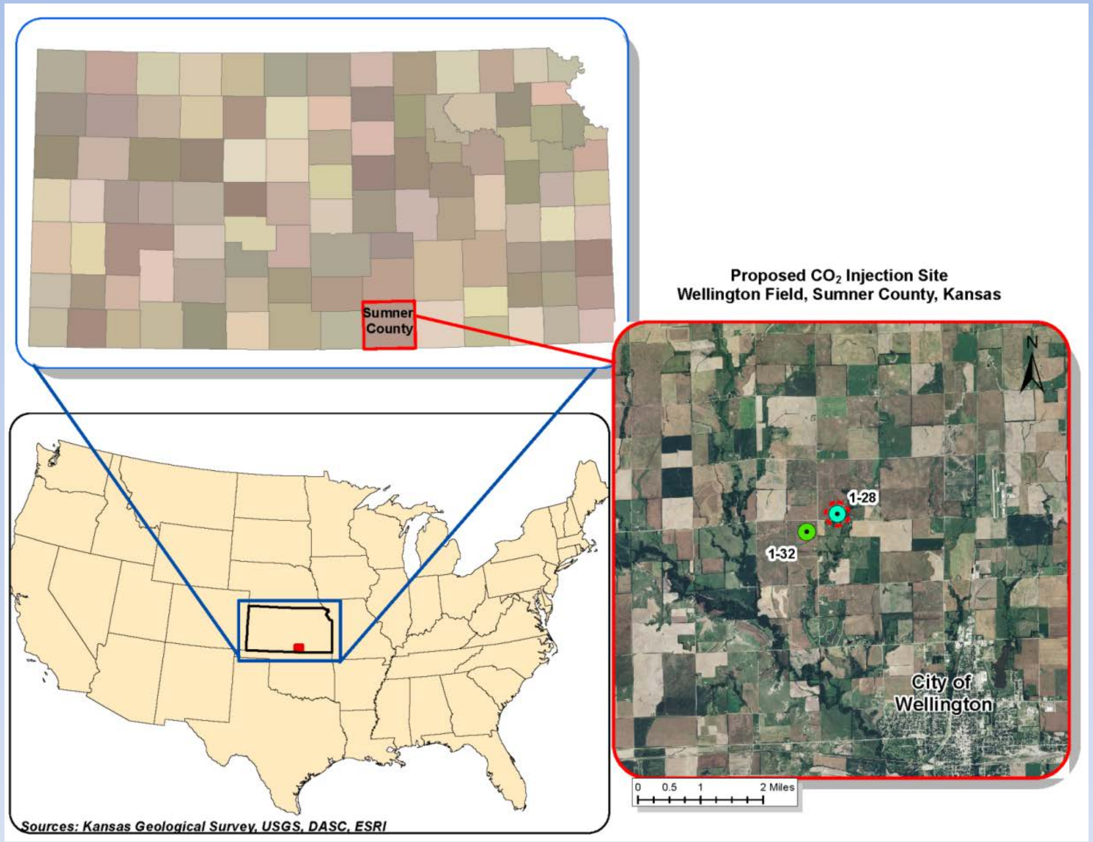
Simulated Sequestered Volumes of CO_2



- 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).

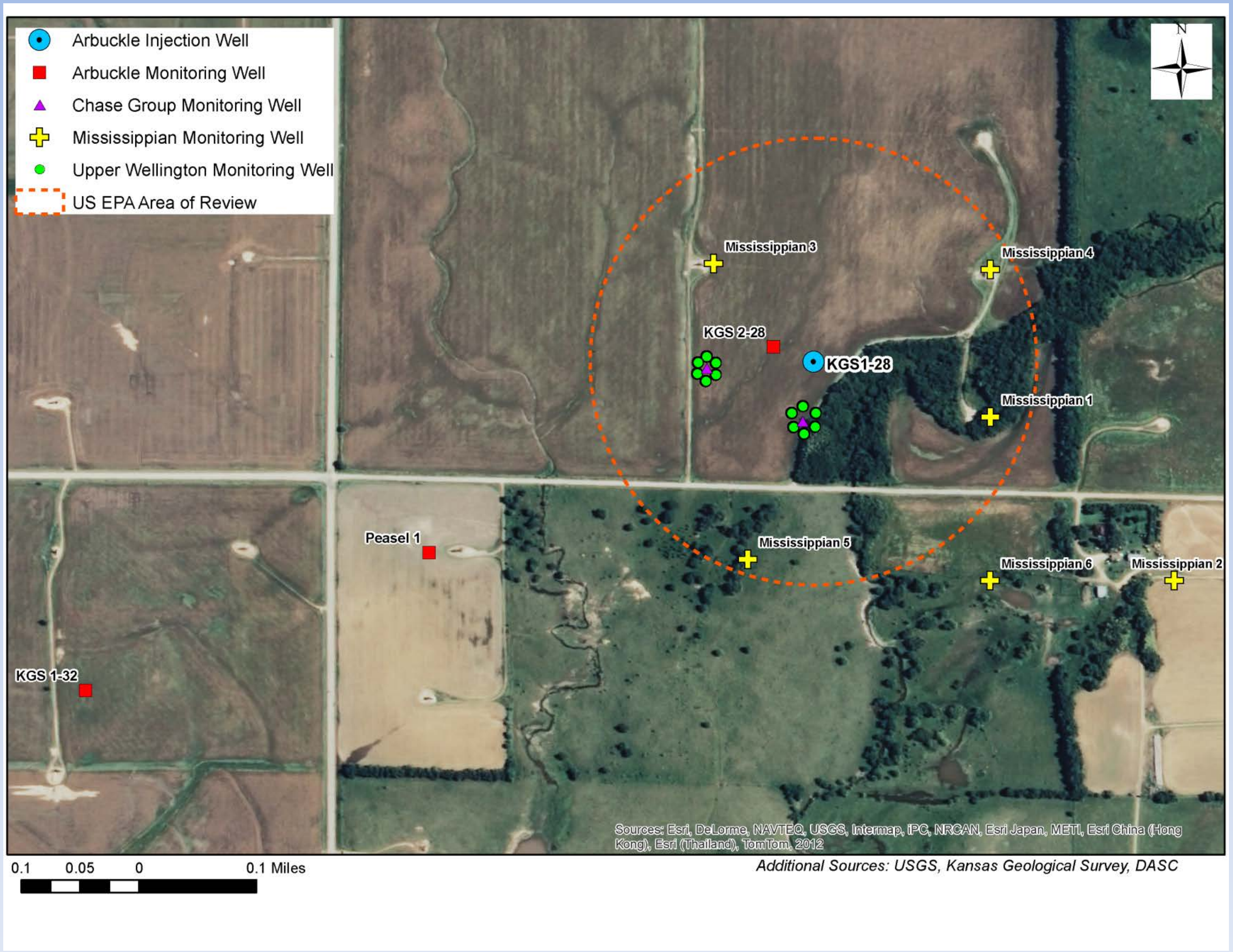
Ongoing Field-Scale Injection Study at Wellington, KS



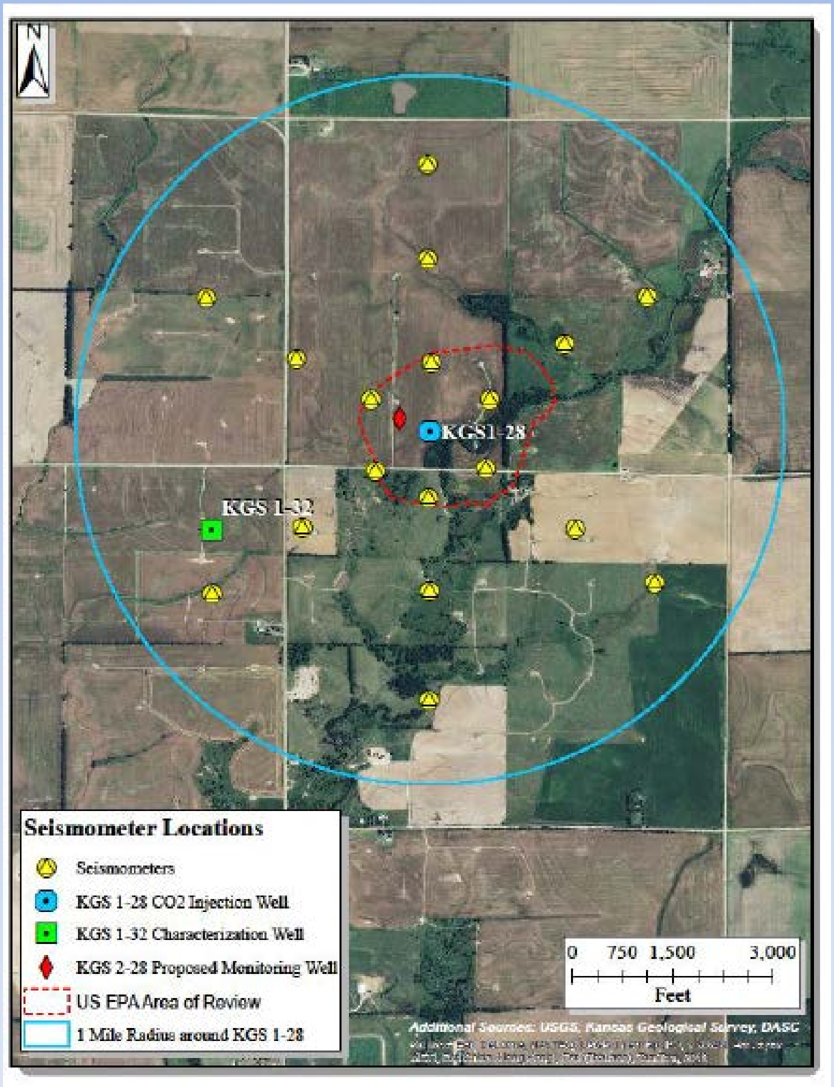
Goals:

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

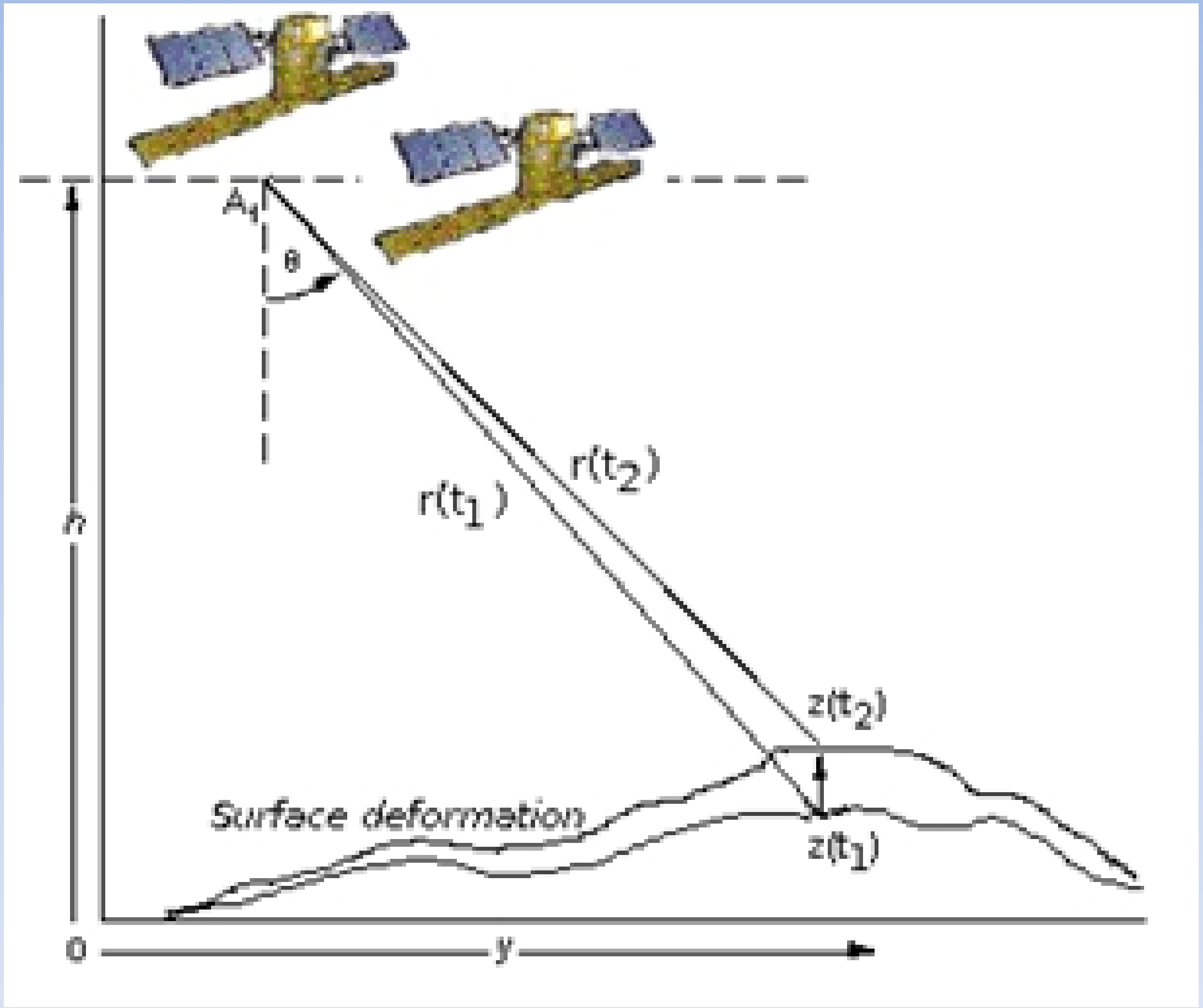
Extensive Monitoring and Visualization of CO_2 Plume and Pressures at Wellington CO_2 Test Site



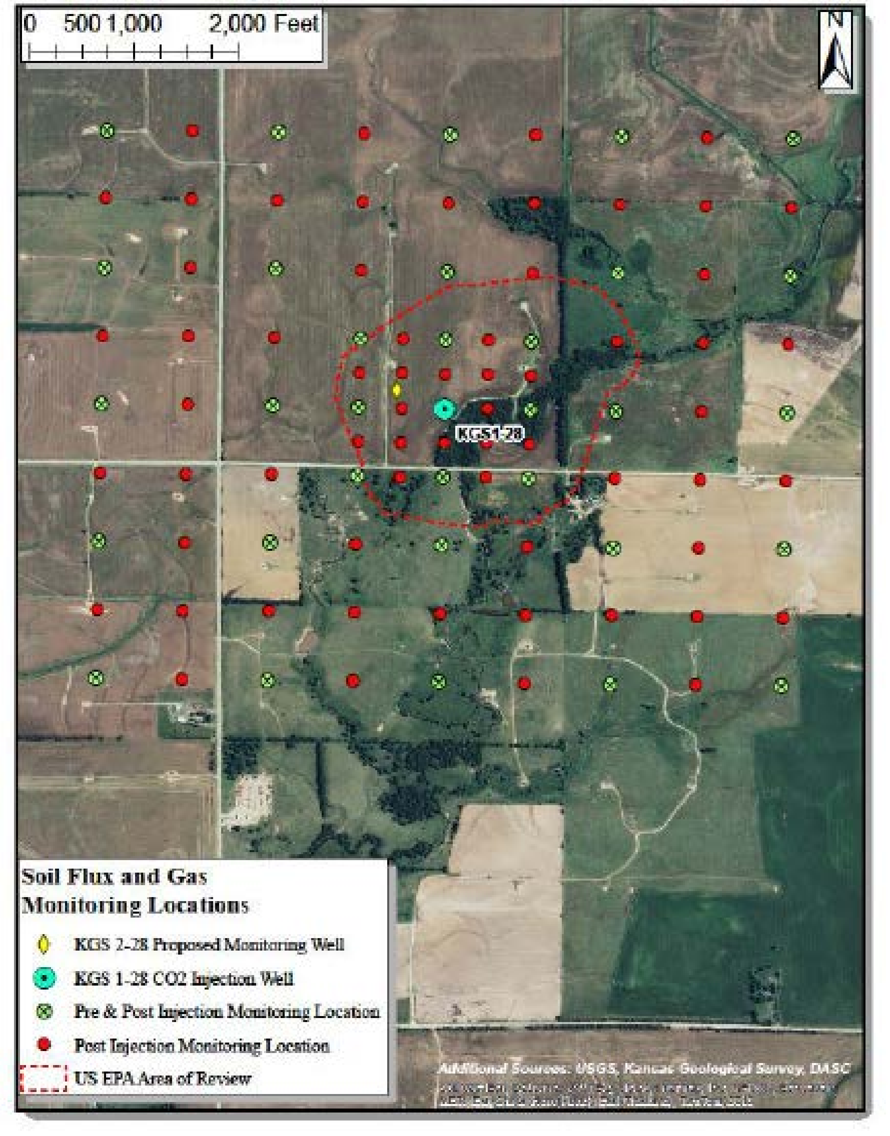
Pressure and Seismic Monitoring (Seismometer Network)



Pressure Monitoring (InSAR)

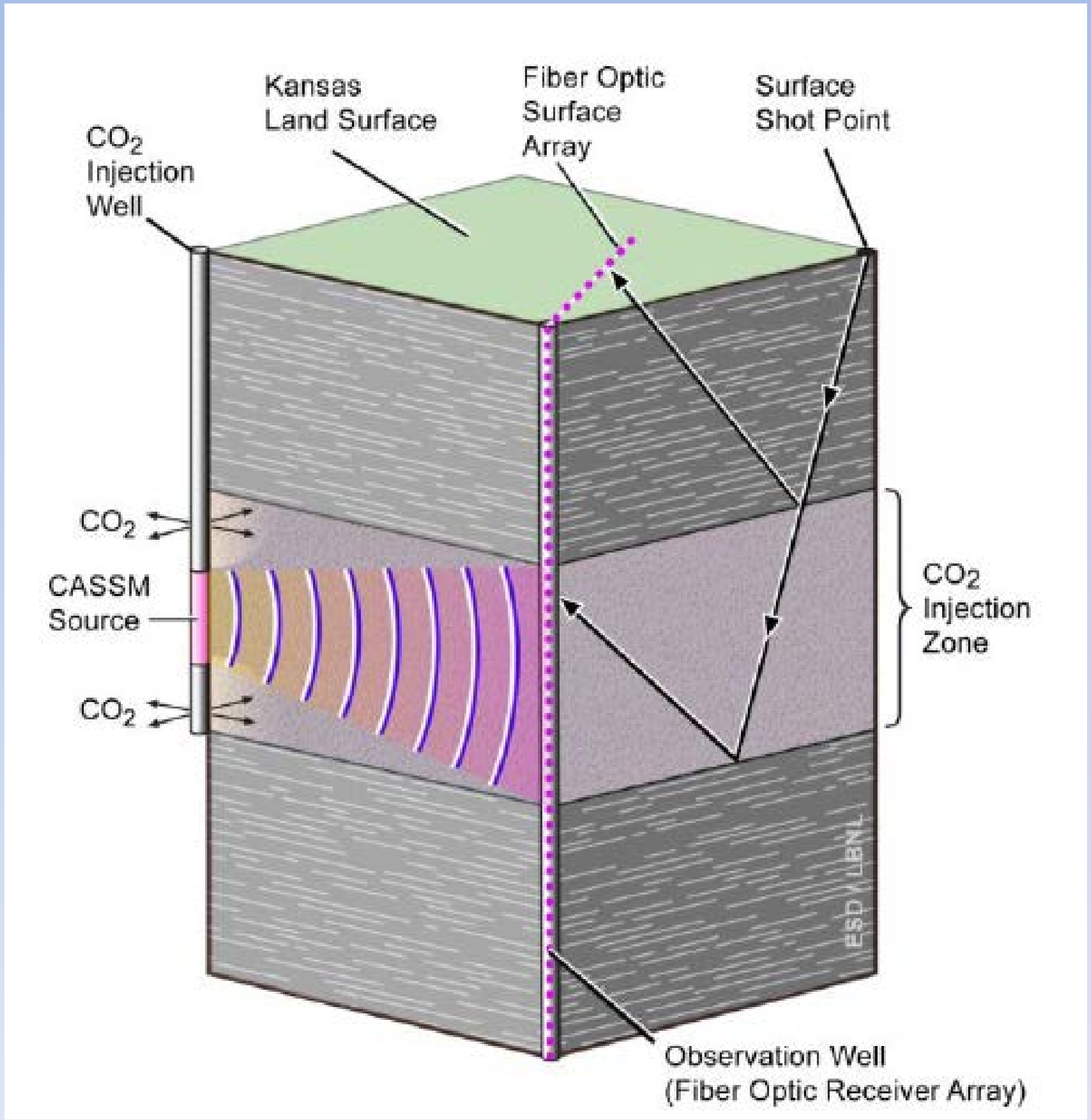


CO_2 Plume Monitoring (Soil Flux and Gas)

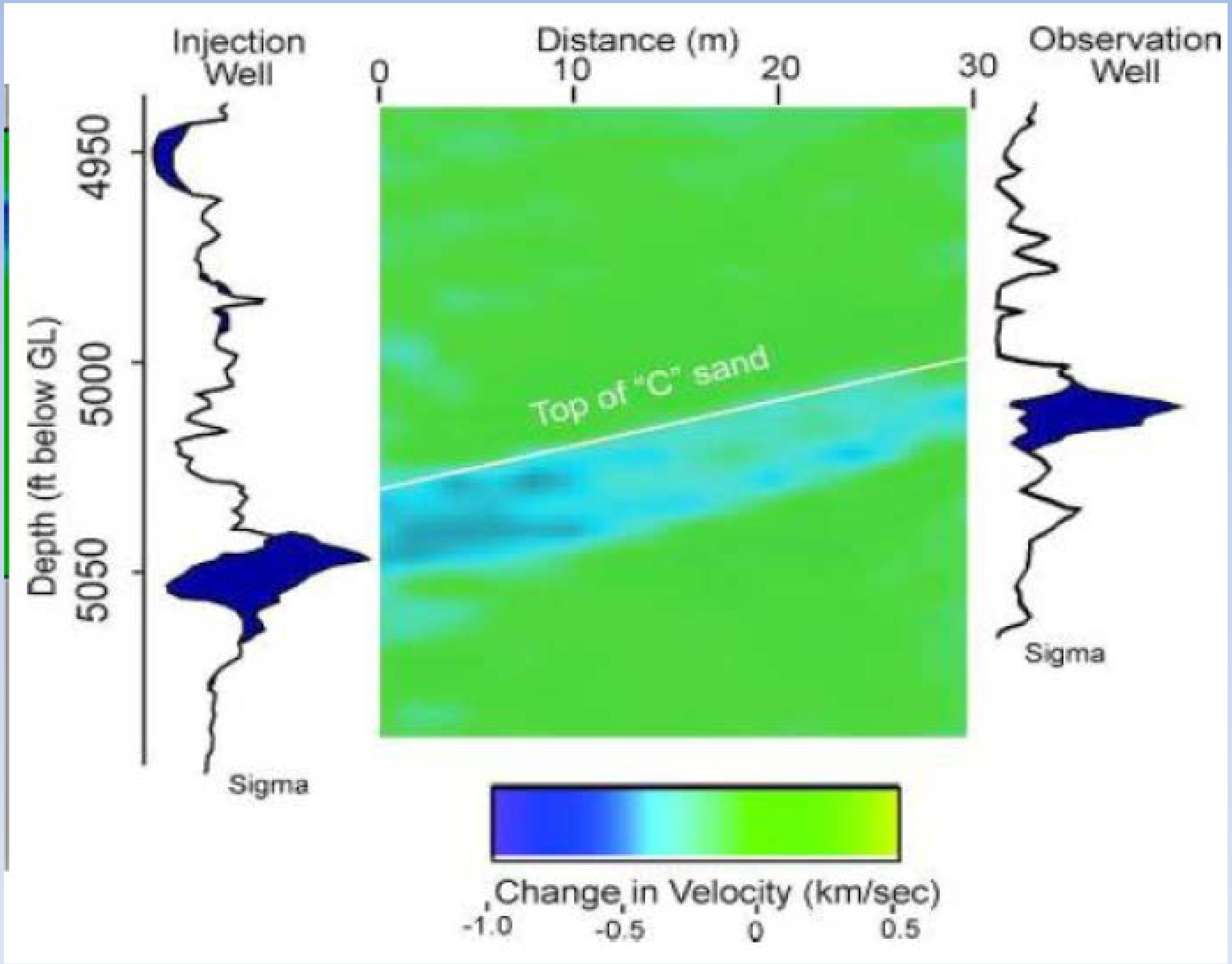


CO_2 Plume Monitoring (Borehole U-Tube)

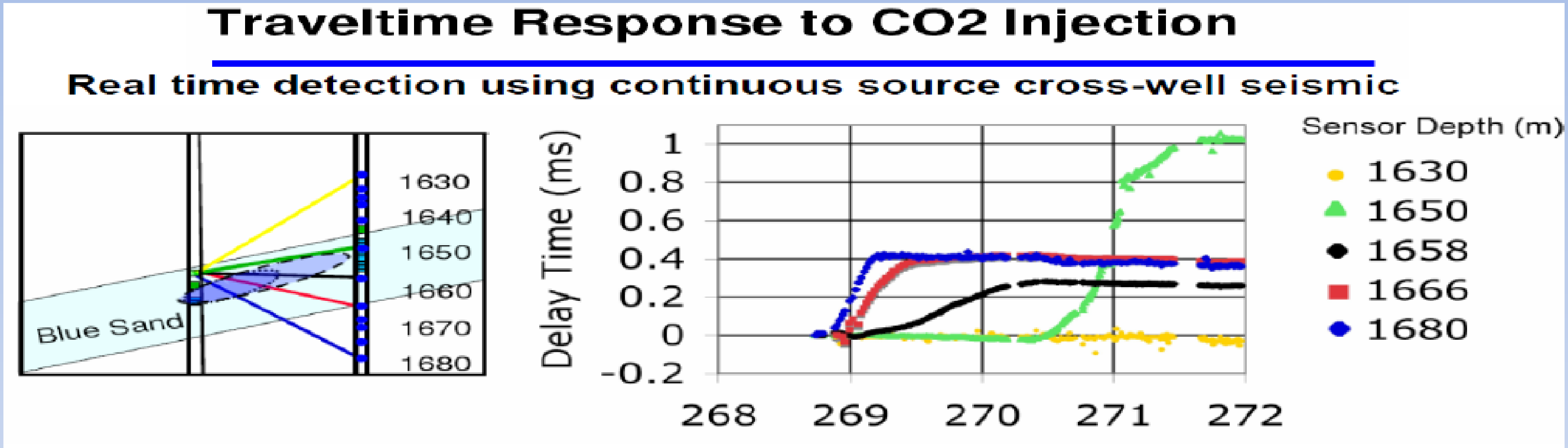
CO_2 Plume Monitoring (Fiber Optic)



CO_2 Plume Monitoring (Cross-Hole Seismic)



CO_2 Plume Monitoring (Continuous Active Source Seismic, CASSM)



Conclusions

- **The saline Arbuckle aquifer has large capacity to store anthropogenic CO_2 emission from Kansas and surrounding states for many decades.**

- **Pressures due to injection will need to be managed to ensure that dissolved brine-CO_2 mixture as well as gaseous phase CO_2 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 CO_2 using computer simulation models.**

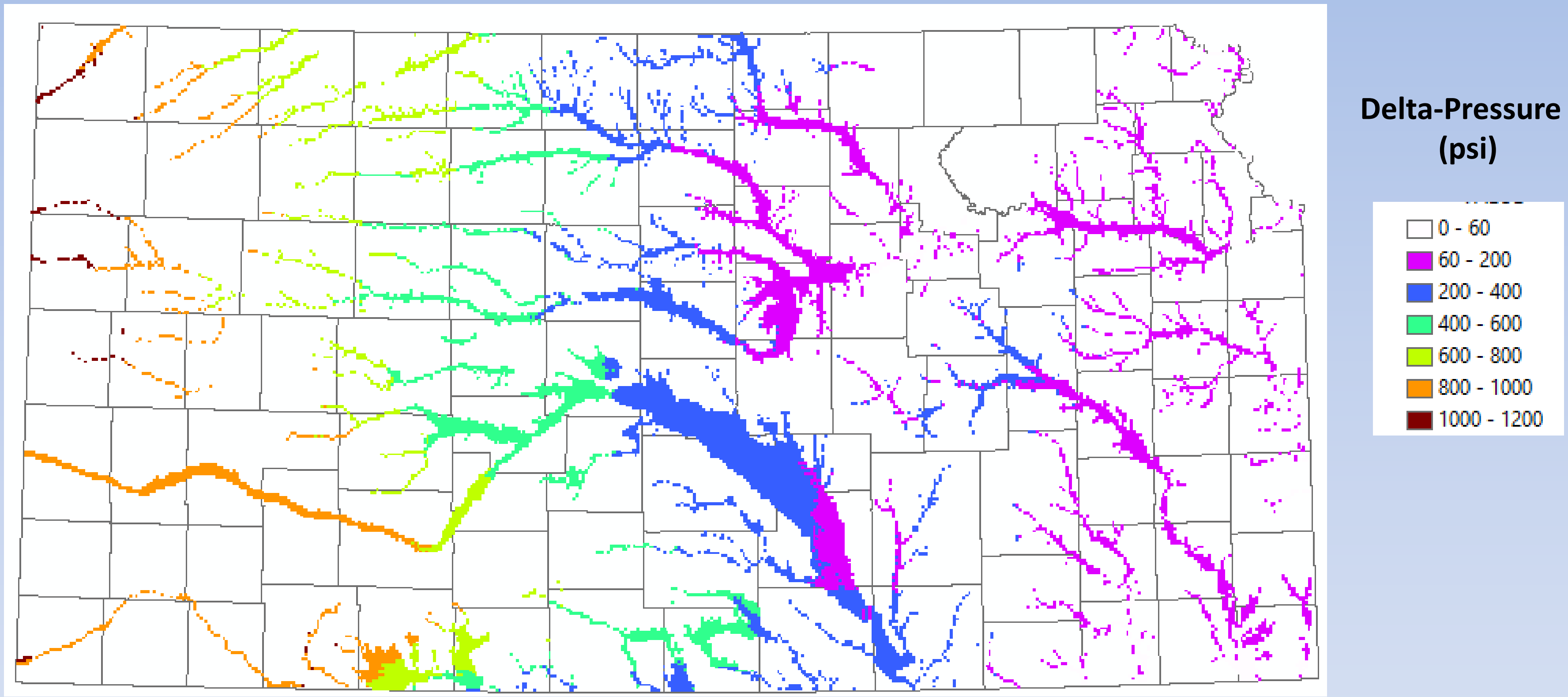
- **Pilot scale study at Wellington is ongoing to demonstrate the feasibility of injection and the viability of real-time CO_2 monitoring.**

Acknowledgements & Disclaimer

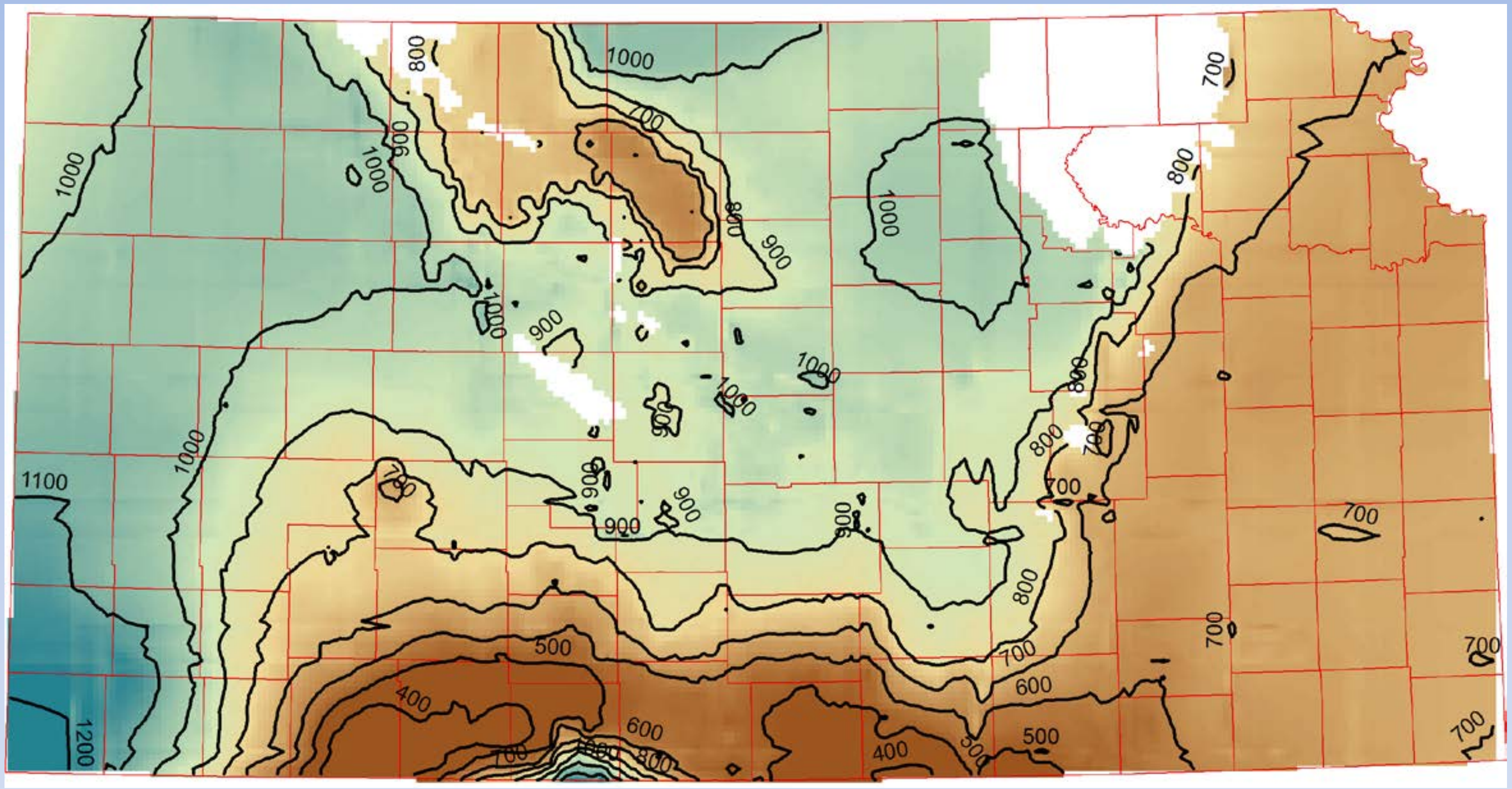
Acknowledgements

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.

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**