PS Dynamic Modeling of Pilot Scale CO_2 Injection in the Arbuckle Formation Saline Aquifer in Southern Kansas*

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Abstract

The Arbuckle Group saline aquifer is a thick (>800 ft) and deeply buried (>3,500 ft) siliceous dolomite with interbedded shales. This aquifer is identified as an excellent candidate for geological CO_2 storage due to its location and proximity to major CO_2 emission sources, high storage capacity potential, and multiple overlying sealing units, which can ensure safe CO_2 storage for the long term. A DOE sponsored pilot-scale project has been funded in which 40,000 metric tons of CO_2 will be injected in the lower part of the Arbuckle reservoir over a period of 9 months at Wellington Field in Sumner County, KS. The key objective of this work is to estimate the resulting rise in pore fluid pressure, the extent of CO_2 plume migration, and geochemical stability of the formation rock and any structural features that may be present in order to insure that the CO_2 injection will not compromise the underground sources of drinking water in the area. Another objective of this work is to estimate the potential storage CO_2 capacity at the Wellington Field and to suggest optimal injection strategy at this location. A detailed geocellular model of the Arbuckle reservoir was produced based on the existing well-logs, seismic data, drill stem tests, step rate test, and core analysis. The data from this model was upscaled to the CMG-based dual-permeability compositional model. The simulation results indicate that if the proposed injection scenario is implemented the injection pressure within the Arbuckle reservoir will not exceed the 300 psi threshold limit which can cause the Arbuckle brine to migrate into the overlying freshwater aquifers via improperly abandoned wells or faults. The CO_2 plume is projected to be primarily vertical; spreading less than 1200 feet laterally. For the commercial scale injection the 20 M metric tons of CO_2 were injected into the Arbuckle reservoir via single vertical, single horizontal, and multiple well schemes.

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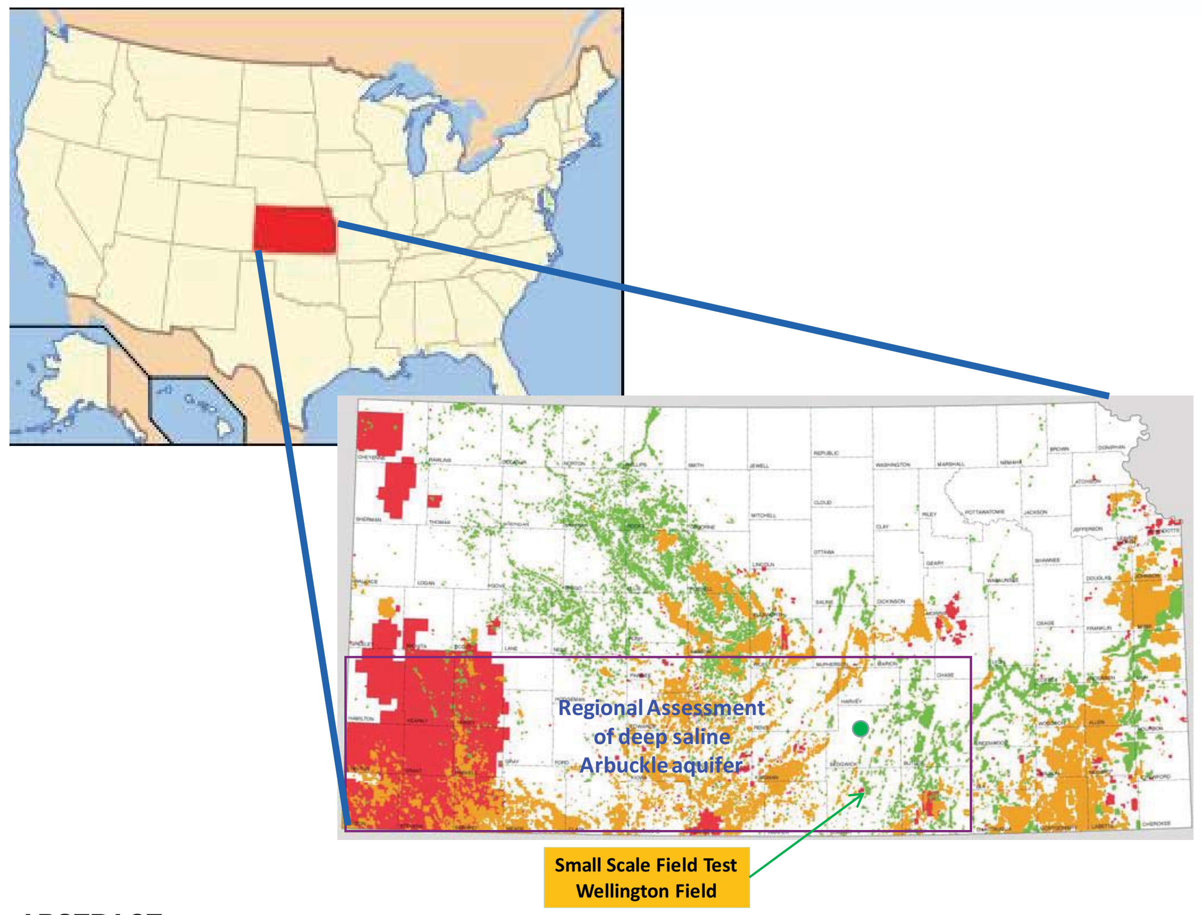


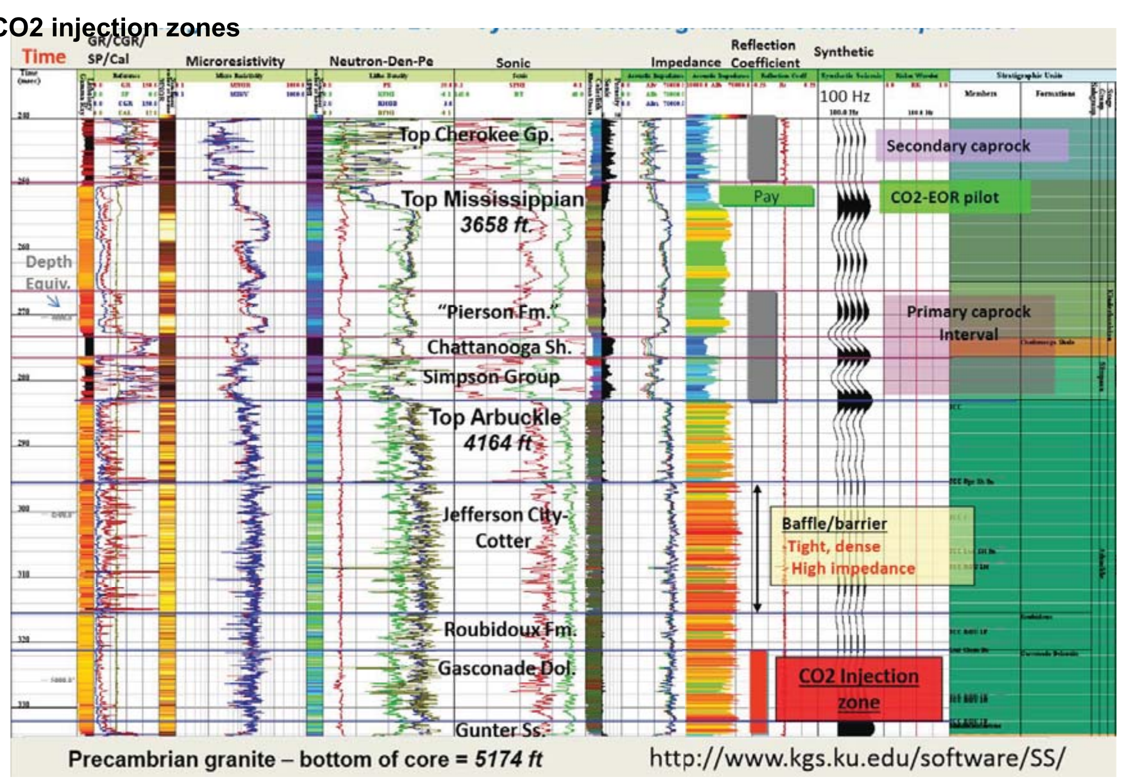
ABSTRACT

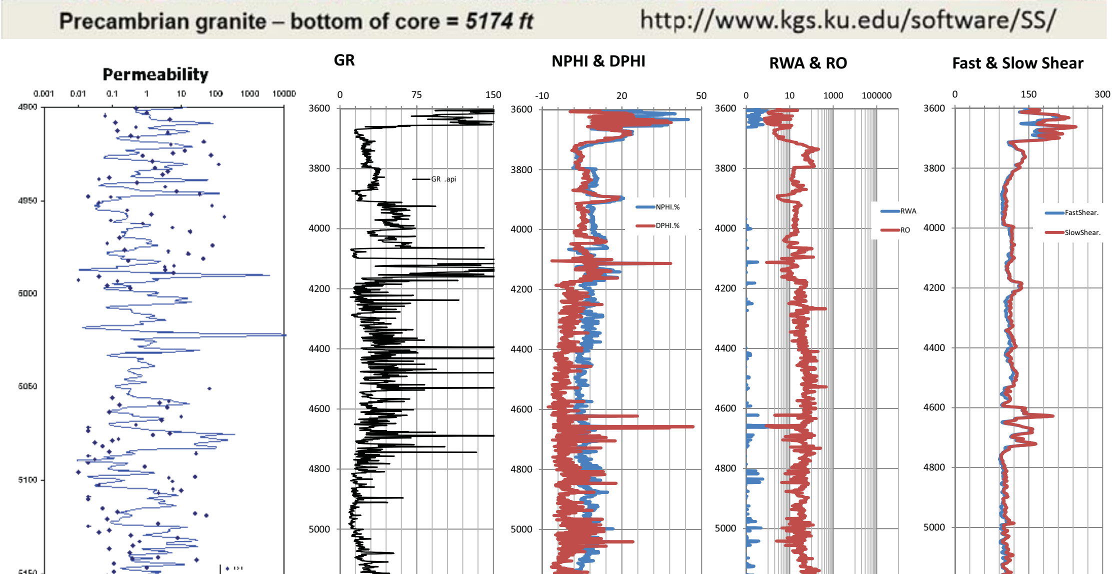
The Arbuckle Group saline aquifer is a thick (>800 ft) and deeply buried (>3,500 ft) siliceous dolomite with interbedded shales. This aquifer is part of the Paleozoic-age Ozark Plateau Aquifer System (OPAS) in southern Kansas. It is identi ed as an excellent candidate for geological CO_2 storage due to its location and proximity to major CO_2 emission sources, high storage capacity potential, and multiple overlying sealing units, which can ensure safe CO_2 storage for the long term. A DOE sponsored pilot-scale project has been funded in which 40,000 metric tons of CO_2 from a nearby biofuel plant will be injected in the lower part of the Arbuckle reservoir over a period of 9 months at Wellington eld in Sumner County, KS.

This work focuses on development of various dynamic simulation scenarios in order to assess potential risks in support of the EPA class VI (CO_2 sequestration) well permit application. The key objective is to estimate the resulting rise in pore uid pressure, the extent of CO_2 plume migration and geomechanical of the formation rock and any structural features that may be present. The over arching goal for the EPA is to ensure that the injected CO_2 does not negatively impact the underground sources of drinking water in the area.

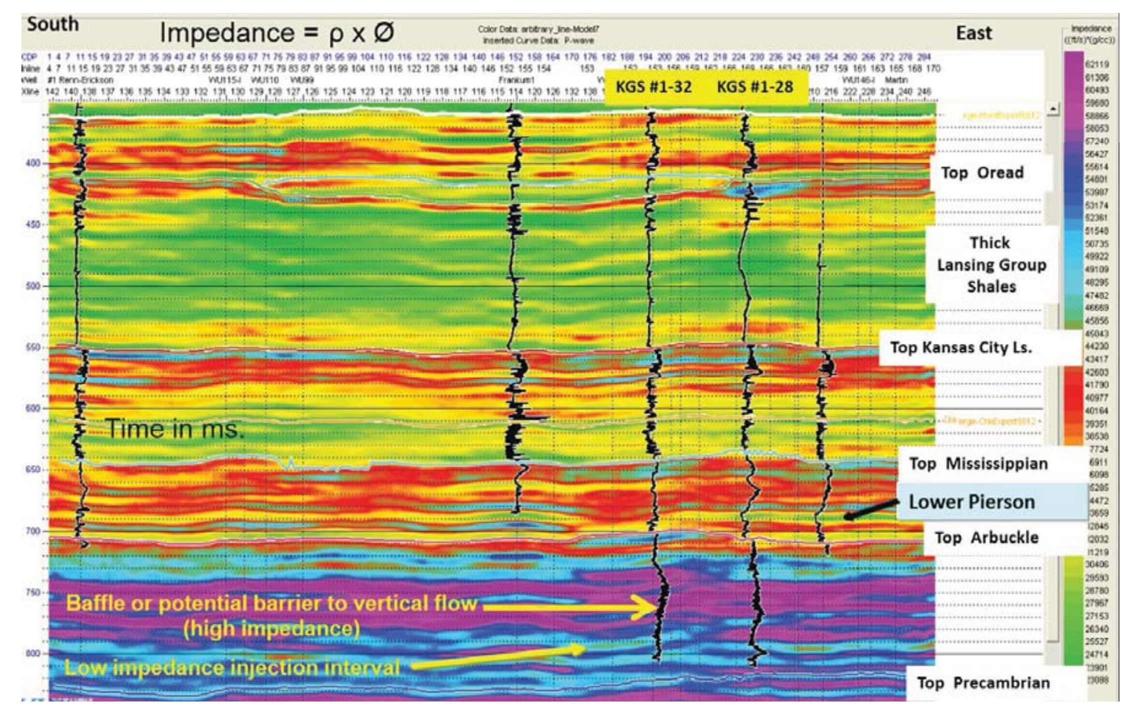
A detailed geocellular model of the Arbuckle reservoir was produced based on the existing well-logs, seismic data, drill stem tests, step rate test, core analysis, and geochemical evaluations. The data from this modeled was upscaled to the CMG-based dual-permeability compositional model. Base case and alternative dynamic model simulations were conducted by varying key reservoir properties of the formation uids, rock, and structural features. The simulation results indicate that the injection pressure within the Arbuckle will not exceed the 300 psi threshold limit which can cause the Arbuckle brine to migrate into the overlying freshwater aquifers via improperly abandoned wells or faults. The CO_2 plume is projected to be primarily vertical; spreading less than 3100 feet laterally. The low permeability units within the Arbuckle will e ectively contain the free phase CO_2, which eventually dissolves in the brine within a period of 30 years. The spatial distribution of mechanical stresses is also presented from which it is clear that the simulated reservoir pressures are not large enough to compromise sealing unit and wellbore integrity.

CO2 injection zones





ARBITRARY SEISMIC IMPEDANCE PROFILE



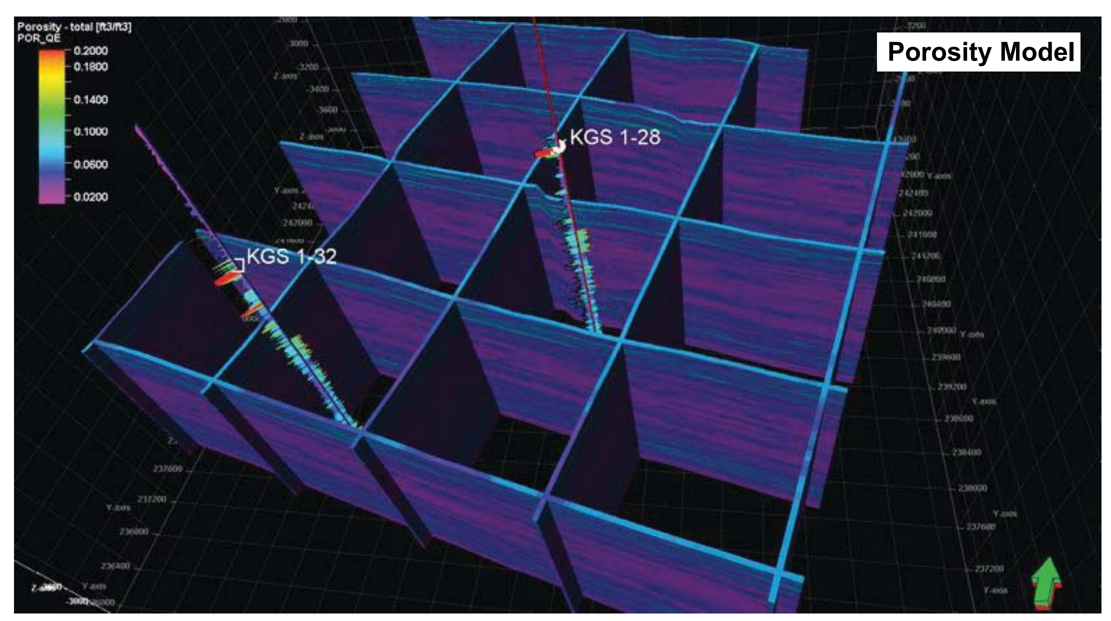
POROSITY MODELING

The porosity model was constructed using Sequential Guassian Simulation (SGS). The porosity logs were upscaled using arithmetic averaging. The raw upscaled porosity histogram was used during SGS. The nal porosity model was then smoothed. The following parameters were used as inputs:

I. Variogram (spherical; nugget: 0.001; anisotropy range and orientation; lateral range (isotropic): 5000 ft; and vertical range: 10-ft)

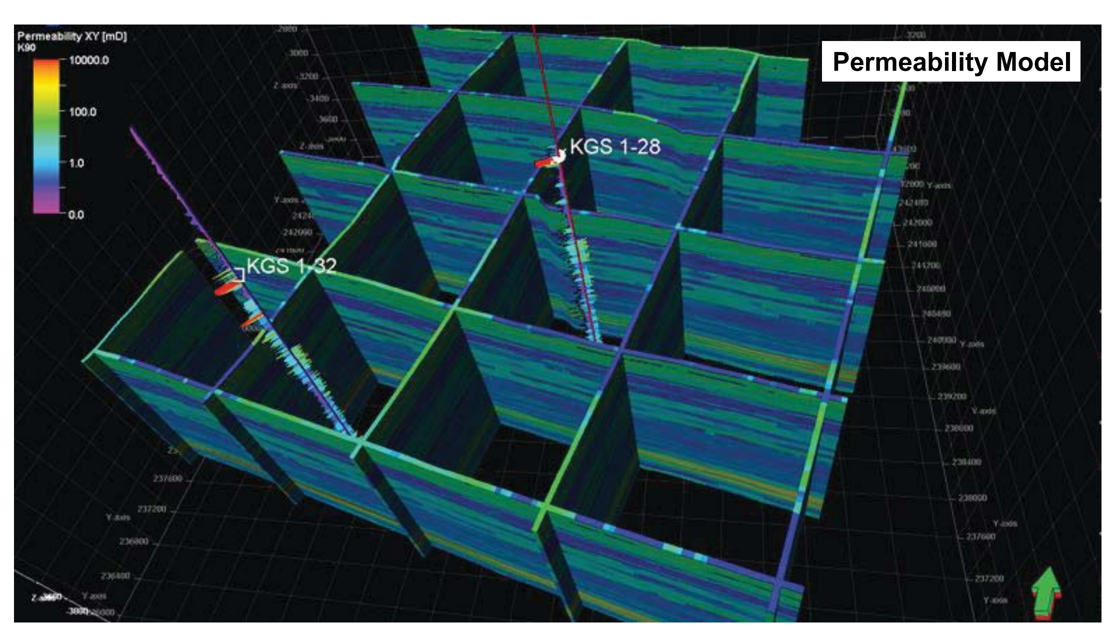
II. Distribution: actual histogram range (0.06–0.11) from upscaled logs

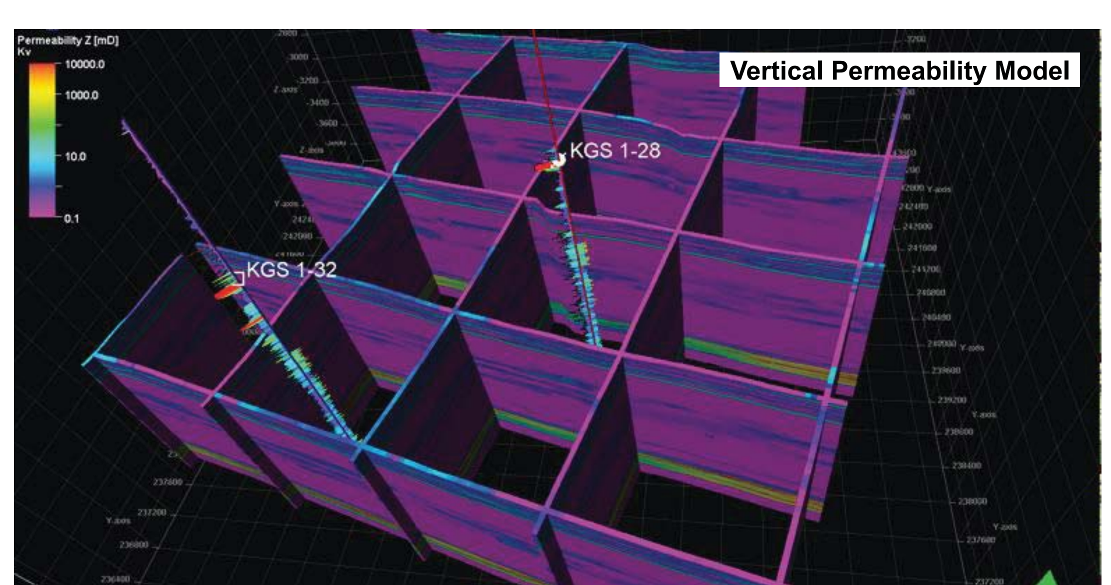
III. Co-Kriging (secondary 3-D variable: inverted porosity attribute grid and correlation coe cient: 0.75



PERMEABILITY MODELING

The upscaled permeability logs were created using the following controls: geometric averaging method; logs were treated as points; and method was set to simple. The permeability model was constructed using Sequential Guassian Simulation (SGS). Isotropic semi-variogram ranges were set to 3000-ft horizontally and 10-ft vertically. The standard permeability distribution from the upscaled logs (range: 0.13–242 mD) was used for the modeling. The permeability was collocated and co-Kriged to the porosity model using the calculated correlation coe cient (~0.70).

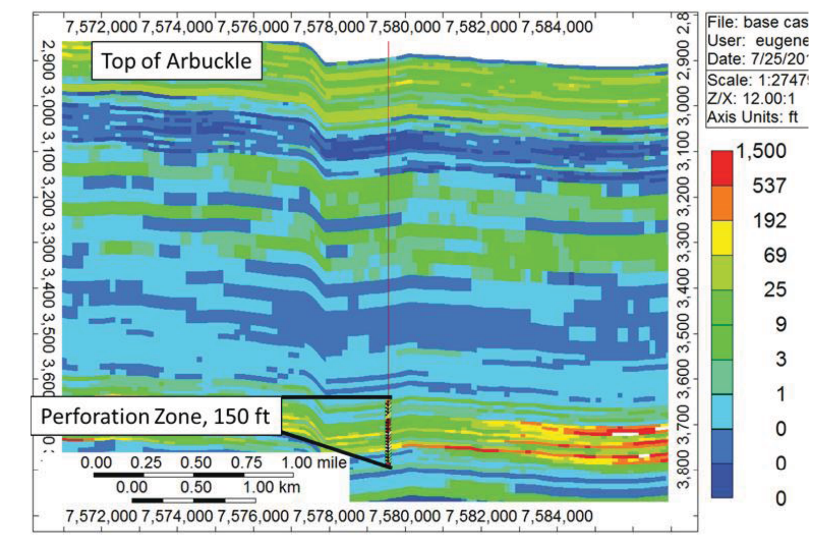




RESERVOIR MODEL

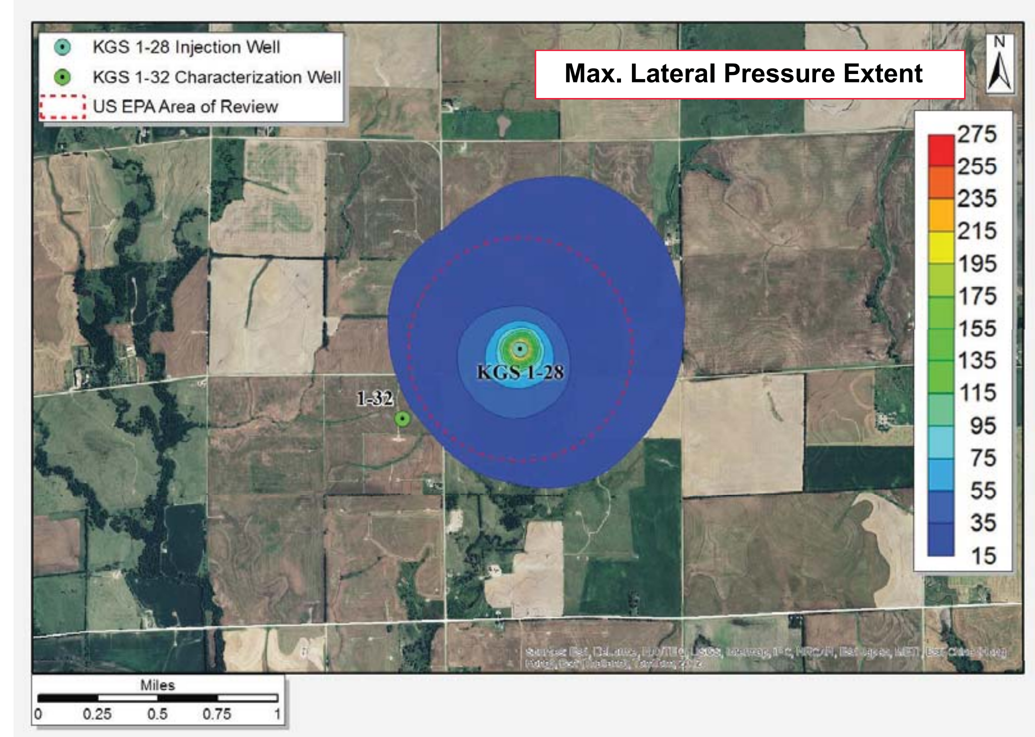
The Petrel based geomodel mesh discussed above consists of a 706 x 654 horizontal grid and 79 vertical layers for a total of 36,476,196 cells. The model domain encompasses a 17 miles2 area and the formations from the base of the Arbuckle Group to Chattanooga and Ft. Simpson Group Formations from depths of 4100 to 5175 feet BGL at Well 1-28. In order to reduce reservoir simulation time, this model was upscaled to a (157x145) horizontal mesh with 79 layers for a total of 1,798,435 cells to represent the same rock volume. The model was divided into 79 layers. The thickness of the layers varies from 5 to 20 ft, with an average of 13 feet.

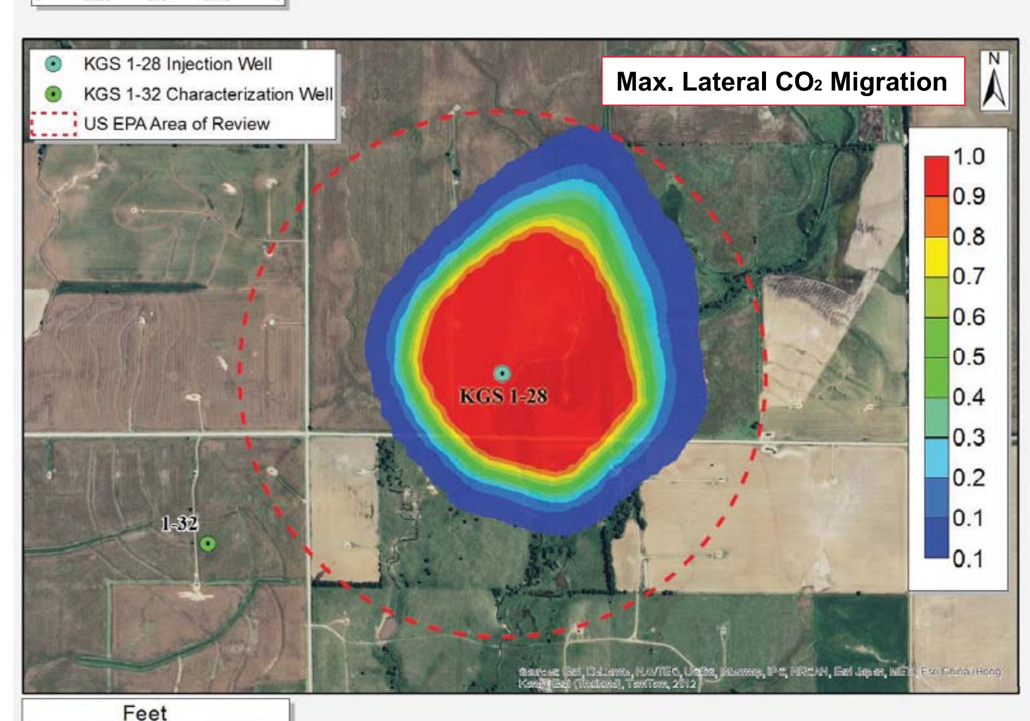
Temperature	60 °C
Temperature Gradient	0.008 °C/ft
Pressure @ 4,960' RKB	2093 psi
Perforation Zone	4910-5050 ft
Perforation Length	140 ft
Perforation Layers	54 to 73
Injection Period	9 months
Injection Rate	150 tons/day
Total CO2 injected	40,000 mt



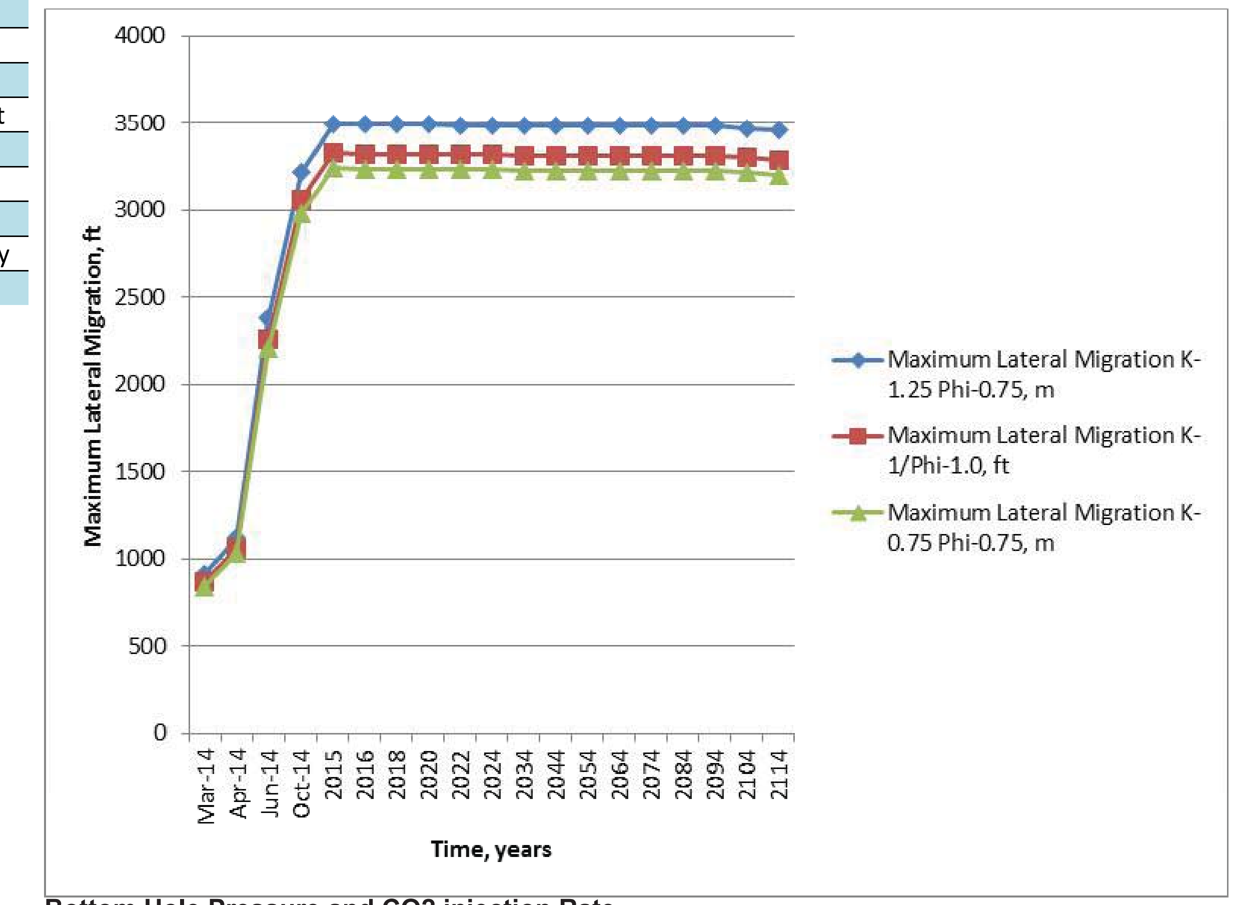
DYNAMIC SIMULATION RESULTS

Modeling Case	Case Identifier	CO2 Maximum Diameter of Aerial Extent	Maximum Bottom-Hole Pressure, psi (5050 ft)	Max Delta Bottom-Hole Pressure, psi
Low Permeability, Low Porosity	K-1/Phi-0.8	2989 ft., 911 m	2602	509
Medium Permeability, Low Porosity	K-5/Phi-0.8	2629 ft., 801 m	2462	369
High Permeability, Low Porosity	K-10/Phi-0.8	3334 ft., 1016 m	2418	325
Low Permeability, Medium Porosity	K-1/Phi-1.0	2218 ft., 676 m	2512	419
Medium Permeability, Medium Porosity	K-5/Phi-1.0	2433 ft., 741 m	2428	335
High Permeability, Medium Porosity	K-10/Phi-1.0	2803 ft.,8543 m	2415	322
Low Permeability, High Porosity	K-1/Phi-1.2	1952 ft., 595 m	2525	432
Medium Permeability, High Porosity	K-5/Phi-1.2	2517 ft., 767 m	2459	366
High Permeability, High Porosity	K-10/Phi-1.2	2802 ft., 854 m	2410	317

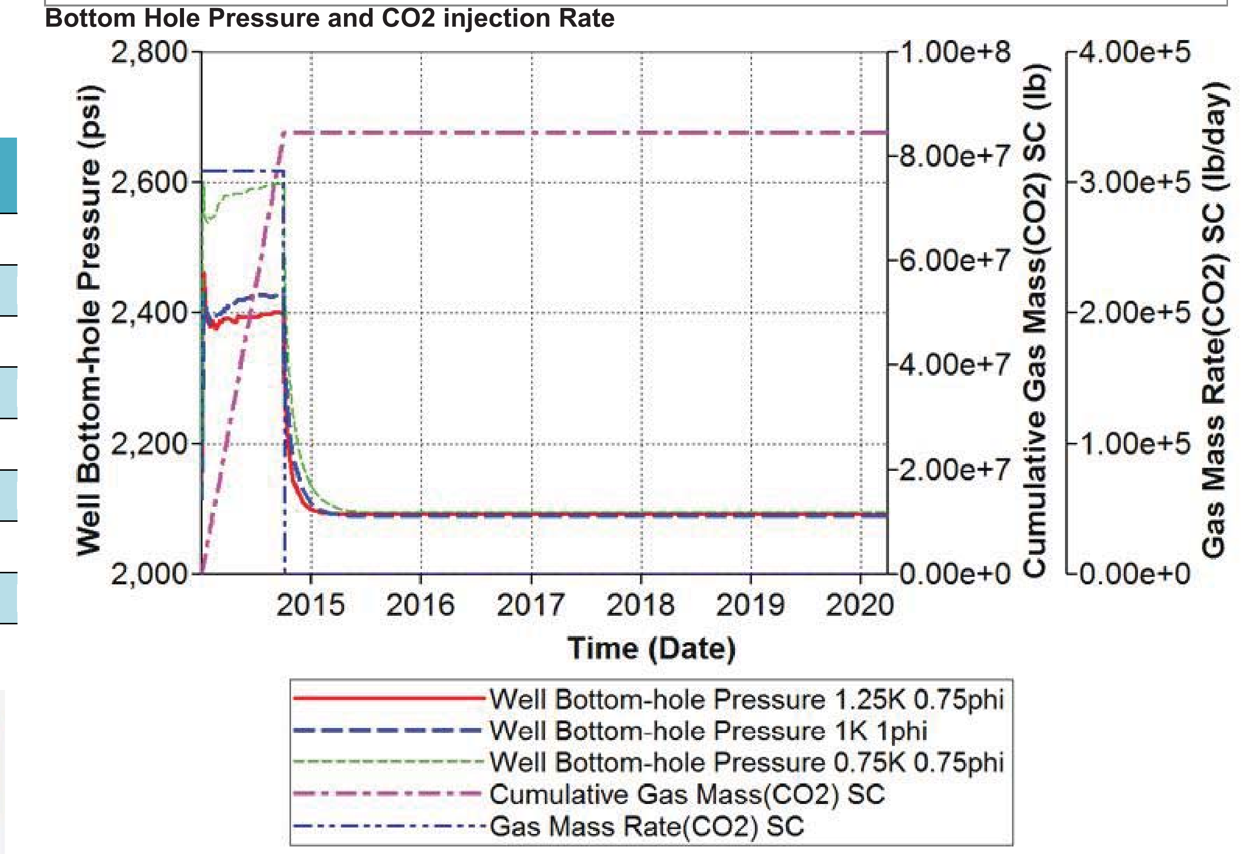




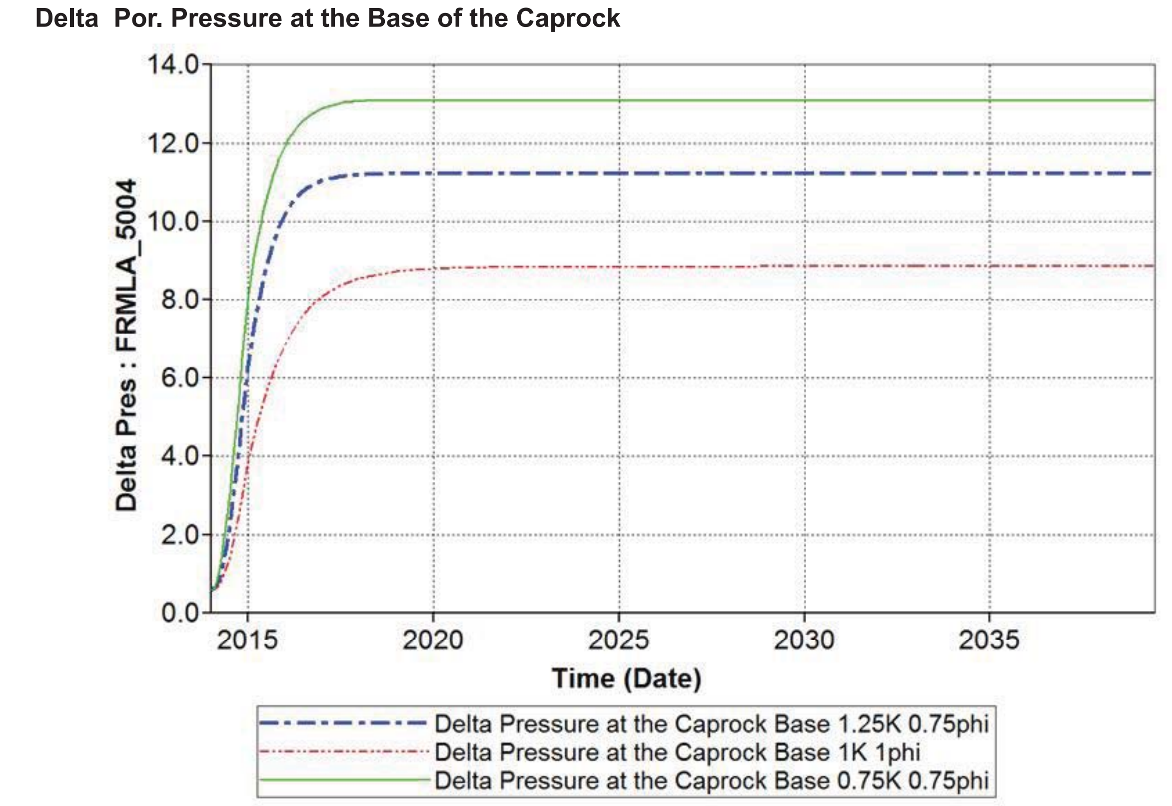
Maximum Lateral CO_2 Migration and Rate



Bottom Hole Pressure and CO2 injection Rate



Delta Por. Pressure at the Base of the Caprock



CAPROCK CO_2 ENTRY PRESSURE