Regional CO_2 Storage Capacity Estimations for Arbuckle Saline Aquifer in South-Central and Southwestern Kansas*

Yevhen Holubnyak[1], Eugene Williams[2], Mina FazelAlavi[1], Paul Gerlach[1], Tandis S. Bidgoli[1], and Lynn Watney[1]

Search and Discovery Article #80486 (2015)**
Posted October 26, 2015

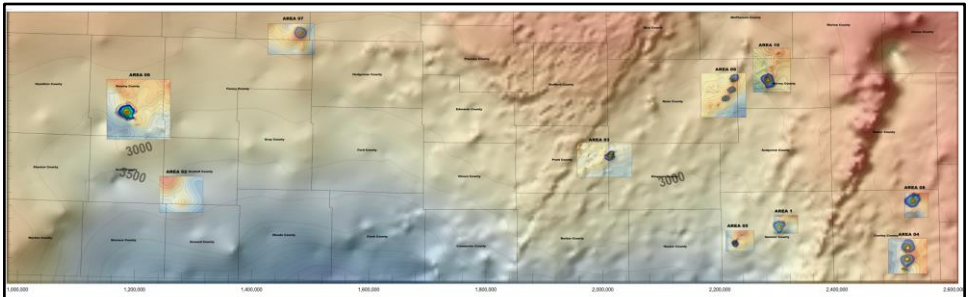
*Adapted from oral presentation given at AAPG Annual Convention & Exhibition, Denver, Colorado, May 31-June 3, 2015. Please see closely related article, "Dynamic Modeling of Pilot Scale CO_2 Injection in the Arbuckle Formation Saline Aquifer in Southern Kansas", Search and Discovery article #80344.

[1]Kansas Geological Survey, Lawrence, Kansas (eugene_gol@hotmail.com)
[2]Williams Petroleum Consulting, Houston, Texas

Abstract

The Arbuckle Group (Cambro-Ordovician) consists dominantly of shallow shelf carbonates overprinted by karstic features developed during repeated subaerial exposure. The Arbuckle saline aquifer in southwestern and south-central Kansas is an ideal candidate for CO_2 sequestration because of thickness (600-1000 ft), supercritical depth (>3500 ft), stratigraphic isolation from freshwater aquifers, and limited oil and gas production. In addition, this formation has an extensive history of waste and back flow water disposal in Kansas and Oklahoma. Moreover, the Arbuckle is noticeably underpressured which potentially allows for higher volumes of disposal fluids to be accepted without risk of overpressuring of the reservoir. Previously published estimates of CO_2 sequestration capacity in the Arbuckle Group in Kansas vary between 1.1 to 8.8 billion metric tons based on static CO_2 solubility in brine under in situ pressure and temperature. This work provides a more detailed and comprehensive approach to regional CO_2 storage capacity estimations.

A detailed geological characterization was performed where existing well log and core data was analyzed and new exploratory wells were drilled in central and western Kansas with extensive logging and coring programs. Based on this analysis, ten potential commercial-scale CO_2 injection sites were selected, characterized, and modeled. Accurate calculation of CO_2 storage capacity for south-central and southwestern Kansas was performed where researchers used several different approaches including volumetric calculations (proposed by Department of Energy and Carbon Sequestration Leadership Form Task Force of CO_2 Storage Capacity Estimation), extrapolation based on CO_2 storage capacity of selected ten modeled sites, detailed regional model numerical simulation, and using statistical approach. Modeling scenarios included maximum allowable pressure, which was estimated based on calculated fracture pressure gradient, various pressure maintenance scenarios, and boundary conditions. Depending on the proposed scenarios and assumptions for system conditions, estimates for CO_2 storage capacity for south-central and southwestern Kansas vary between 0.66 to 2 billion metric tons.



Regional CO_2 Storage Capacity Estimations for Arbuckle Saline Aquifer in South Central and Southwestern Kansas

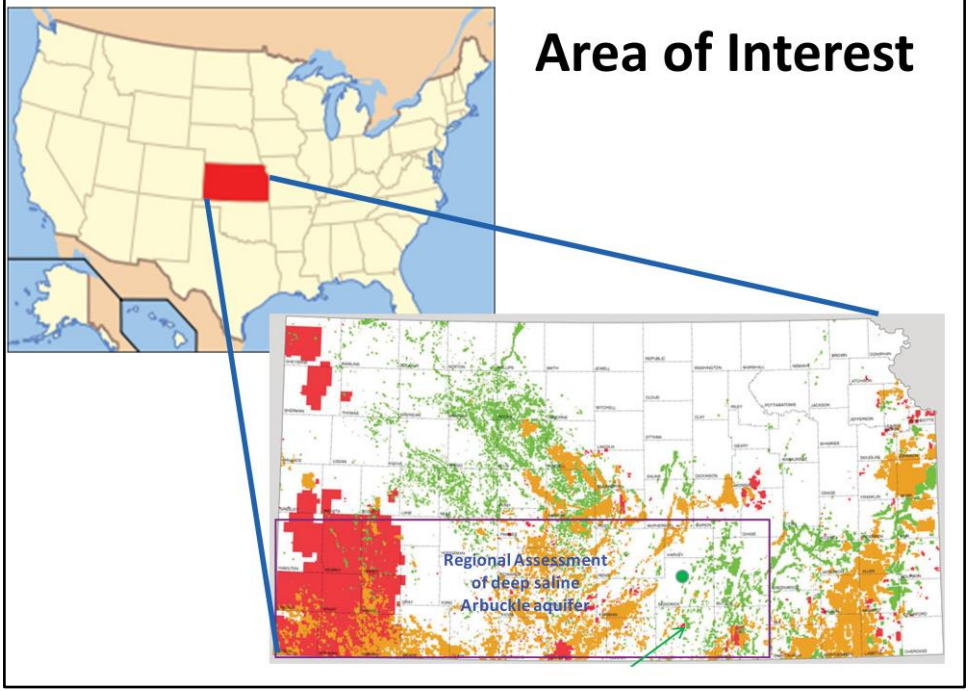
Yevhen Holubnyak, Eugene Williams, Mina FazelAlavi,
Paul Gerlach, Lynn Watney

2015 AAPG Annual Convention & Exhibition
Denver, CO

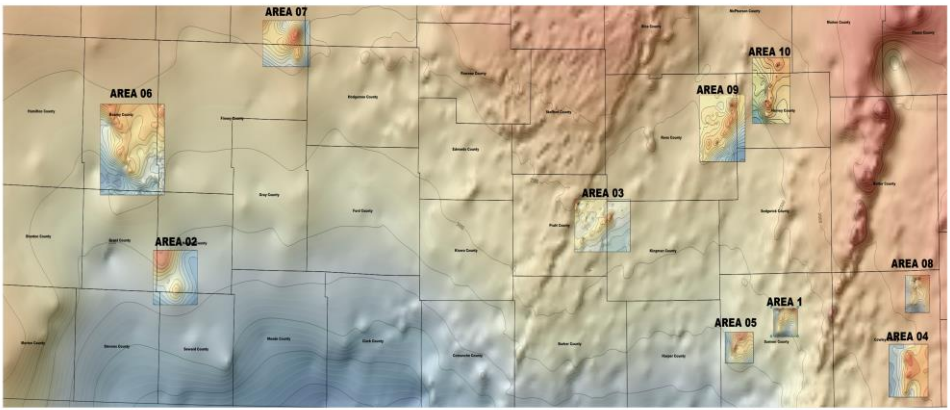
KU KANSAS GEOLOGICAL SURVEY
The University of Kansas

NETL

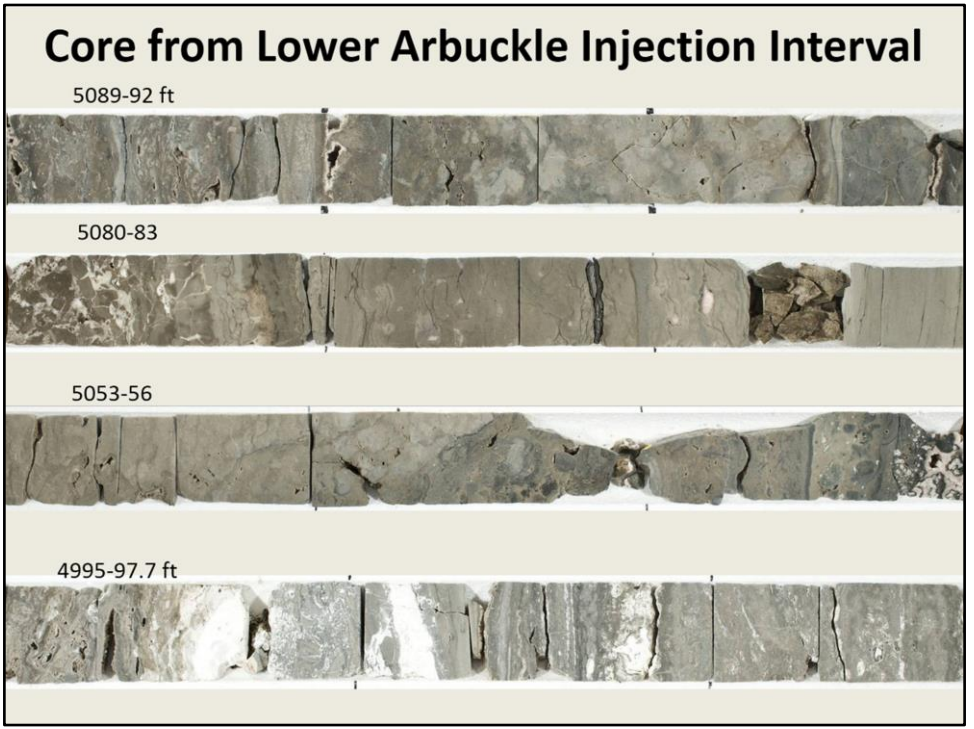
Area of Interest

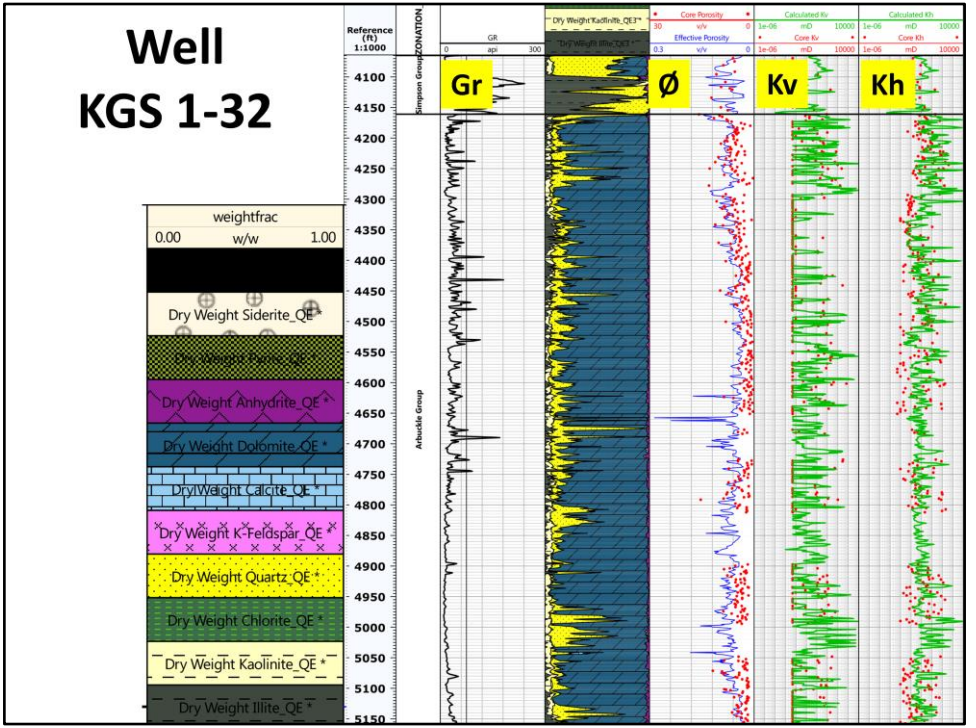


Top Arbuckle Structure Map showing Study areas

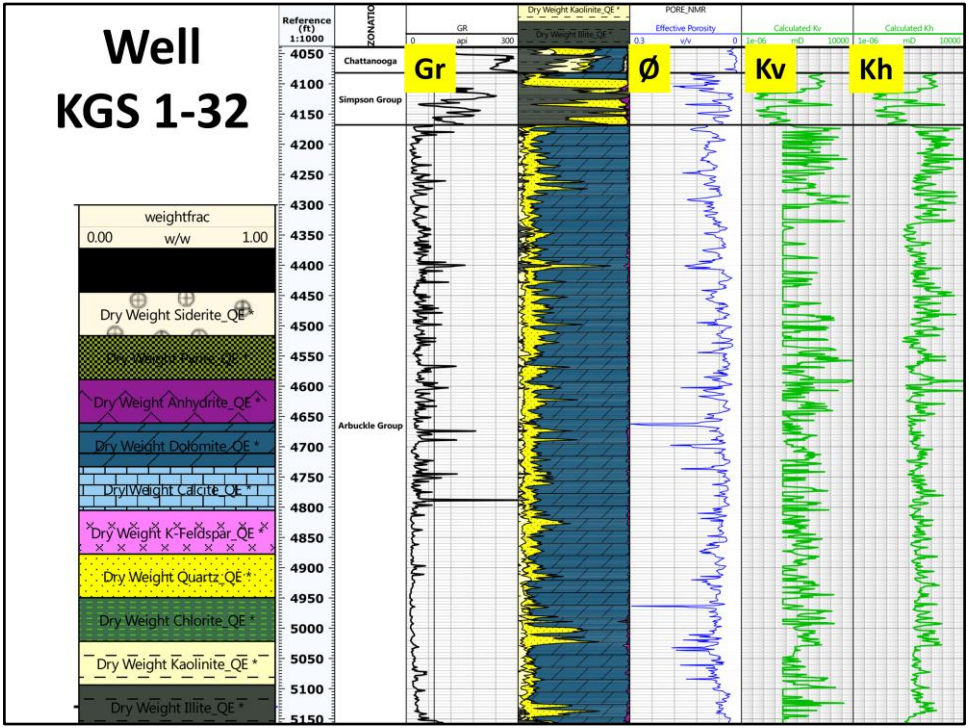


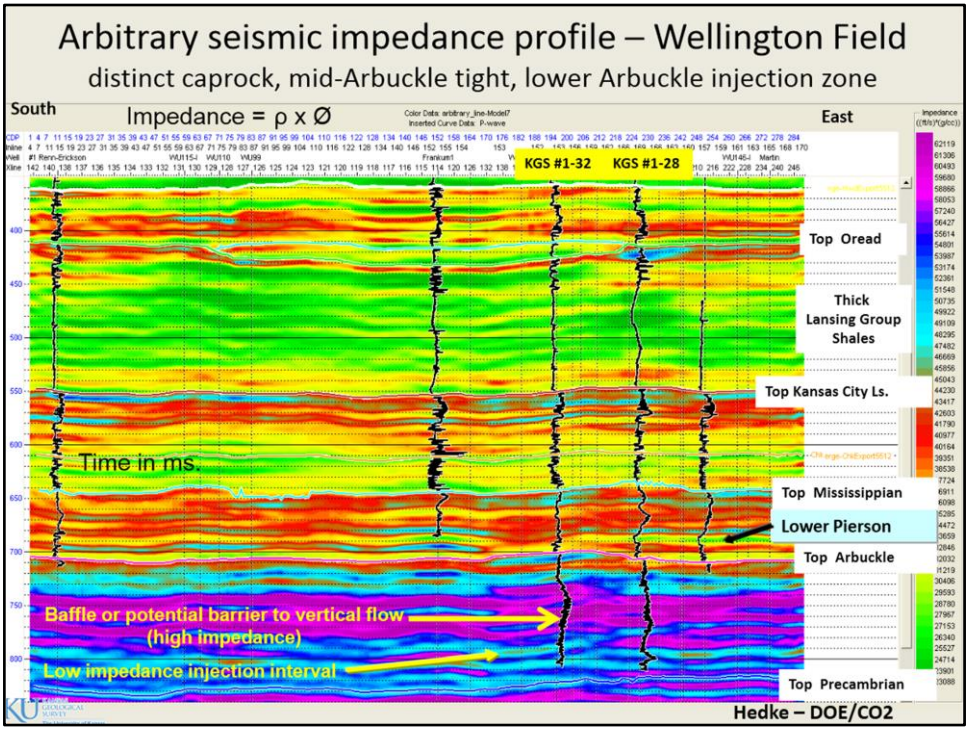
Core from Lower Arbuckle Injection Interval



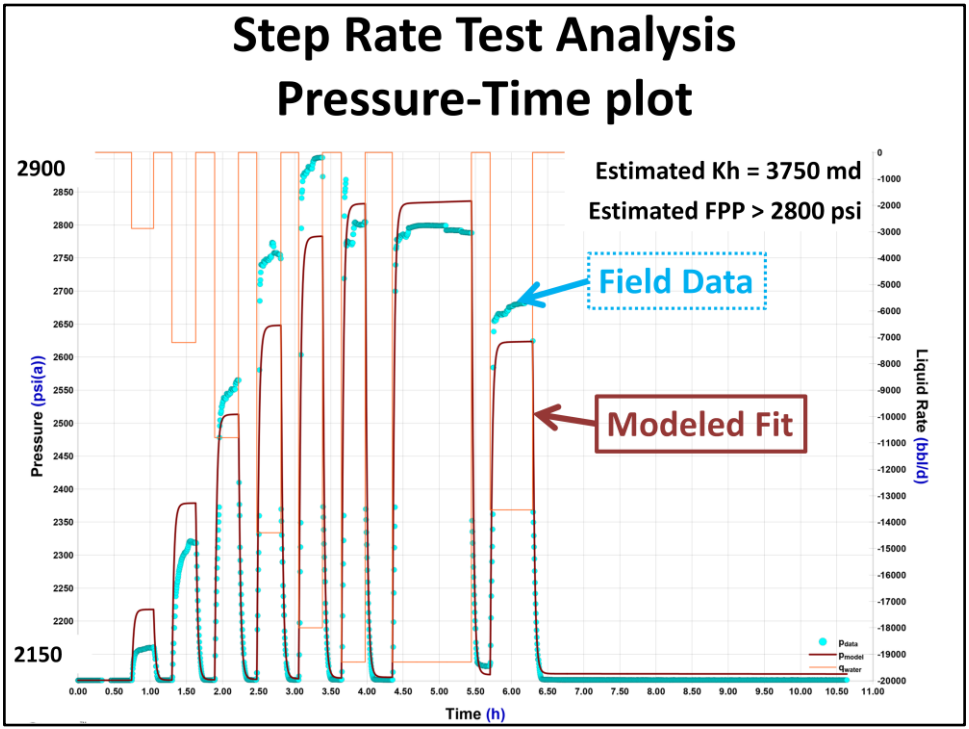


Presenter's notes:
Gr – Gamma Ray log
Lithology
Ø – porosity (red dots – core data, blue line – log analysis)
Kv – vertical permeability calculations (red dots – core data, green line – log analysis)
Kh – horizontal permeability calculations (red dots – core data, green line – log analysis)
Note baffle zone and low vertical permeability in certain areas of Mid. Arbuckle (areas around 4900 ft, 4750 ft, 4270-4450ft)
Calculated reservoir permeability from log analysis is ~ 500-5000 md


Well
KGS 1-32
weightfrac
0.00
w/w
1.00
Dry Weight Siderite_QE *
Dry Weight Anhydrite_QE *
Dry Weight Dolomite_QE *
DryWeight Calcite_QE *
Dry Weight K-Feldspar_QE *
Dry Weight Quartz_QE *
Dry Weight Chlorite_QE *
Dry Weight Kaolinite_QE *
Dry Weight Illite_QE *
Reference (ft) 1:1000
ZONATIO
Chattanooga
Simpson Group
Arbuckle Group
GR
0
api
300
Gr
Dry Weight Kaolinite_QE *
Dry Weight Illite_QE *
PORE_NMR
Effective Porosity
0.3
v/v
0
Ø
Calculated Kv
1e-06
mD
10000
Kv
Calculated Kh
1e-06
mD
10000
Kh
4050
4100
4150
4200
4250
4300
4350
4400
4450
4500
4550
4600
4650
4700
4750
4800
4850
4900
4950
5000
5050
5100
5150



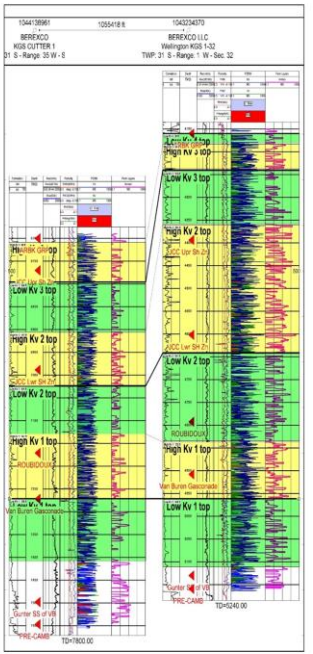
Presenter's notes: This is seismic data which was used for geologic model construction. This data also suggests that there are barriers for vertical flow in Mid. Arbuckle



Presenter's notes: This is the Step Rate Test (SRT) analysis. A series of constant-rate injections ("Steps") increasing from low to high, designed to determine the Formation Parting Pressure (FPP) and to estimate reservoir properties and injectivity. Based on SRT analysis, reservoir permeability is 3750 md which is in agreement with log analysis, but not the core data. Core data does not take into account fractures, only matrix.

Model Layering

- Type log shows the 7 principal flow units:
  - Low KV 4 — Model Layer 1
  - High KV 3 — Model Layer 2
  - Low KV 3 — Model Layer 3
  - High KV 2 — Model Layers 4-7
  - Low KV 2 — Model Layer 8
  - High KV 1 (Inj) — Model Layers 9-11
  - Low KV 1 — Model Layer 12

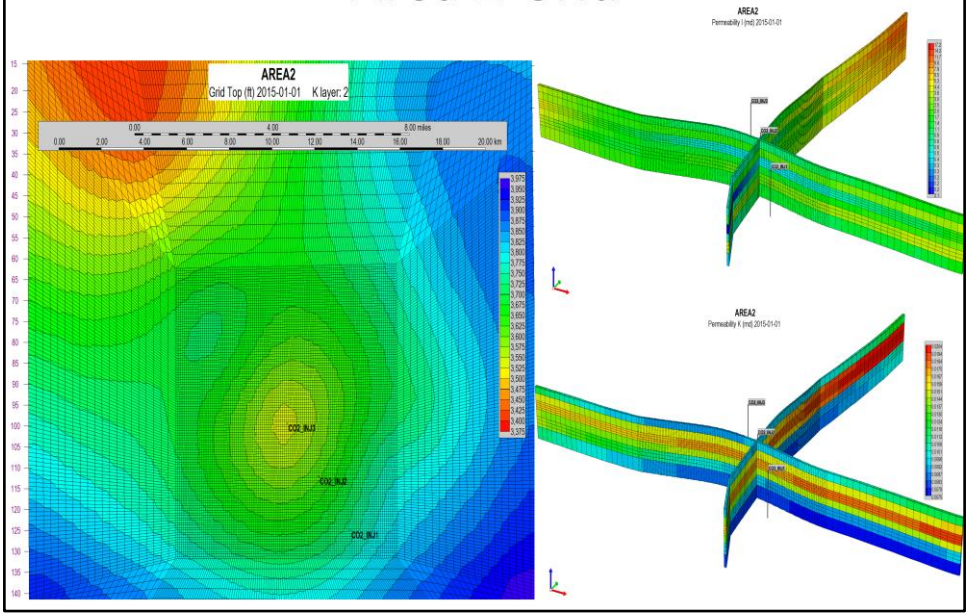


Summary of Simulation Model Areas

Area	Inum	Jnum	Knum	Multiple Pressure	Alternate Well	Multiple Well	HZ Well	Water Injectors	Aquifer	Flow Unit
1	155	119	12	✓	✓	✓			✓	✓
2	160	145	12	✓	✓		✓			
3	200	180	12	✓	✓					
4	200	200	12	✓	✓	✓				
5	190	160	12	✓	✓	✓				
6	250	300	12	✓	✓	✓	✓			
7	200	120	12	✓	✓	✓		✓		
8	240	200	12	✓	✓	✓				
9	200	180	12	✓	✓	✓			✓	
10	180	190	12	✓	✓	✓				

AREA 2 (CUTTER)

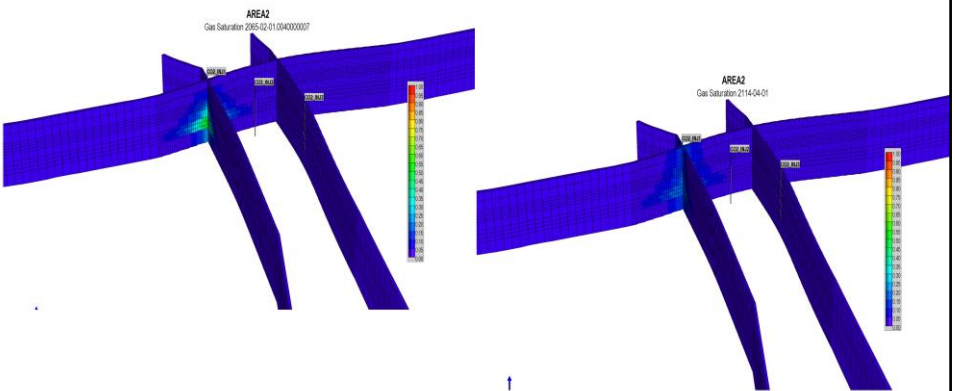
Area 2 Grid

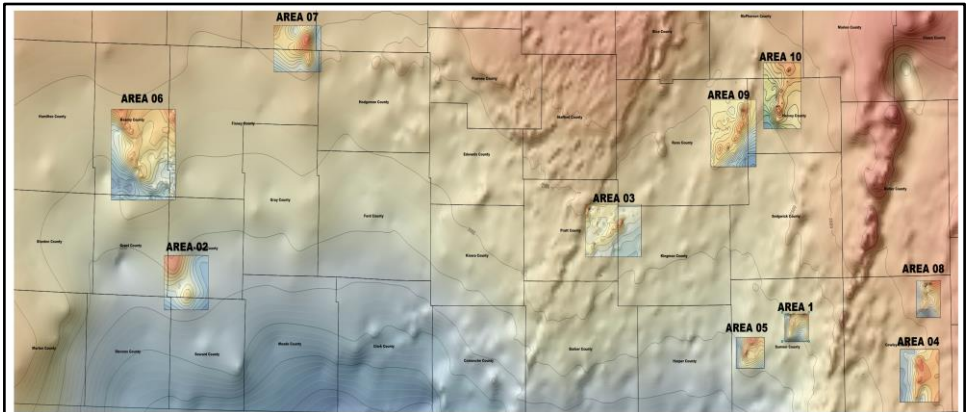

AREA2
Grid Top (ft) 2015-01-01 K layer: 2
AREA2
Permeability I (md) 2015-01-01
AREA2
Permeability K (md) 2015-01-01

Area 2 Simulation Cases

Simulation Model FileName	Area	Well Constraint Max Injection Rate [MMCFD	Max BHP [psi	# of Inj Wells	Well1	Well2	Well3	Well4	Field	Initial Reservoir Pressure [psi	Water Inj Rat	Aquifer PseudoWell Specified Prod Constraint [BBL/Day]	Cumulative Injection [ton	Simulation Max CO2 Inj Rate MMCFD/day
KGS_SalineAquifer_Jul10-2014_00001	AREA2	100	2500	1			18,614		18,614	2,333			1,085,960	1.149
KGS_SalineAquifer_Jul10-2014_00002	AREA2	100	3000	1	84,960				84,960	2,333			4,956,660	5.213
KGS_SalineAquifer_Jul10-2014_00003	AREA2	100	3000	1			66,621		66,621	2,333			3,886,760	3.979
KGS_SalineAquifer_Jul10-2014_00004	AREA2	100	2500	1	15,975				15,975	2,333			931,975	0.988
KGS_SalineAquifer_Jun09-2014_0_00026_Hz	AREA2	100	3000	1				311	311	2,709			18,128	0.021
KGS_SalineAquifer_Jun09-2014_0_00036	AREA2	100	3000	1			48		48	2,709			2,814	0.004
KGS_SalineAquifer_Jun30-2014_00001	AREA2	100	2500	1			26		26	2,333			1,493	0.002
KGS_SalineAquifer_Jun30-2014_00003	AREA2	100	3000	1			148		148	2,333			8,630	0.014
KGS_SalineAquifer_May11-2014_00008	AREA2	50	3500	1		128			128	2,709			7,492	0.011

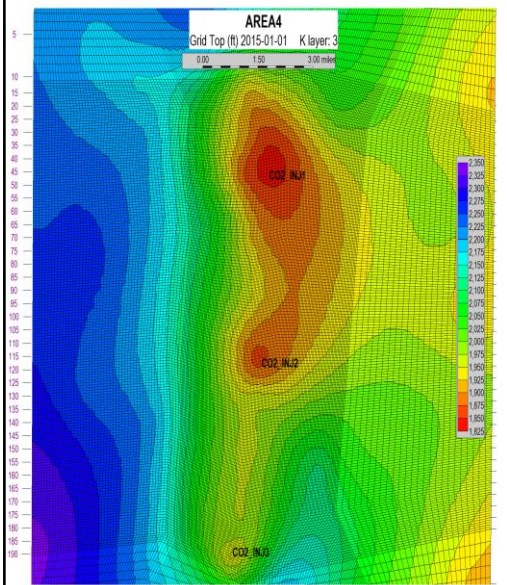
Area 2 CO_2 Spatial Distribution

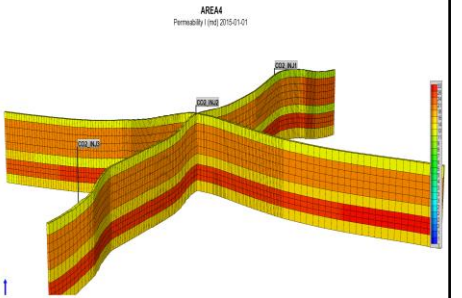


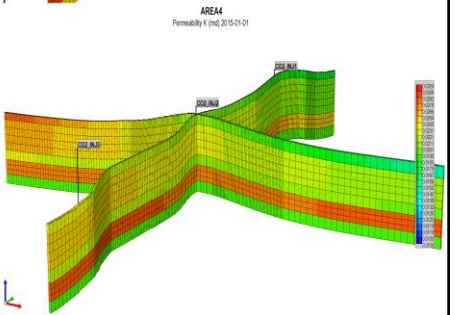

AREA 07
AREA 06
AREA 10
AREA 09
AREA 03
AREA 02
AREA 08
AREA 1
AREA 05
AREA 04

AREA 4

Area 4 Grid


AREA4
Grid Top (ft) 2015-01-01 K layer: 3
0.00 1.50 3.00 miles
CO2_INJ1
CO2_INJ2
CO2_INJ3

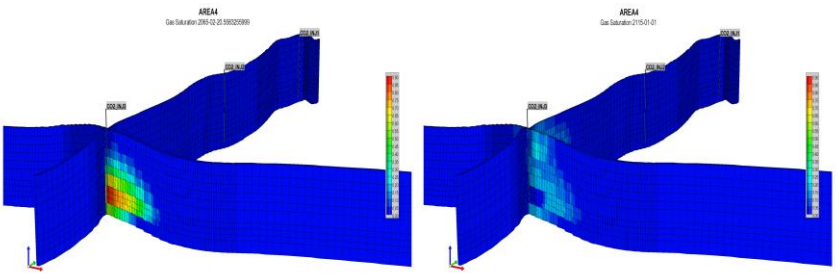

AREA4
Permeability I (md) 2015-01-01
CO2_INJ1
CO2_INJ2
CO2_INJ3


AREA4
Permeability K (md) 2015-01-01
CO2_INJ1
CO2_INJ2
CO2_INJ3

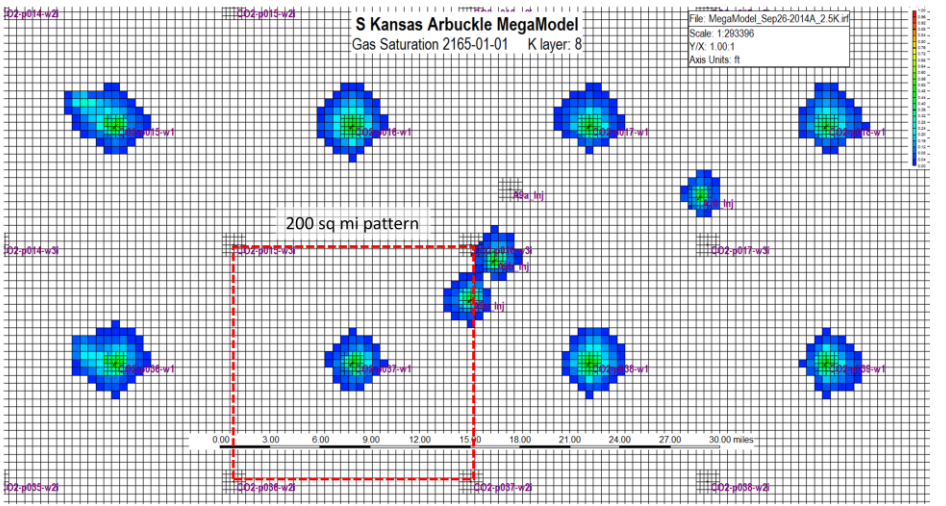
Area 4 Simulation Cases

Simulation Model FileName	Area	Well Constraint Max Injection Rate [MMCFD	Max BHP [psi	# of Inj Wells	Well1	Well2	Well3	Well4	Field	Initial Reservoir Pressure [psi	Water Inj Rat	Aquifer PseudoWell Specified Prod Constraint [BBL/Day]	Cumulative Injection [ton	Simulation Max CO2 Inj Rate MMCFD/day
KGS_SalineAquifer_Jun09-2014_0_00018	AREA4	100	2500	1			1,212,570		1,212,570	2,003			70,743,000	78.4833
KGS_SalineAquifer_Jun09-2014_0_00022	AREA4	100	2500	1	867,342				867,342	2,003			50,602,000	55.6712
KGS_SalineAquifer_Jun09-2014_0_00040	AREA4	100	3000	1	1,677,740				1,677,740	2,003			97,881,500	100
KGS_SalineAquifer_May11-2014_00001	AREA4	50	3500	1			3,396,440		3,396,440	2,003			198,152,500	223.188
KGS_SalineAquifer_May20-2014_00003	AREA4	100	3000	2	1,676,300		1,203,070		2,879,360	2,003			167,986,000	163.022
KGS_SalineAquifer_May20-2014_00014	AREA4	100	2500	2	863,721		1,207,480		2,071,200	2,003			120,836,500	115.68
KGS_SalineAquifer_May31-2014_00002	AREA4	100	3000	3	1,553,980	1,493,070	1,824,740		4,871,790	2,003			284,226,500	295.768
KGS_SalineAquifer_May31-2014_00007	AREA4	100	2500	3	775,914	732,307	1,191,010		2,699,230	2,003			157,477,000	154.092

Area 4 CO_2 Spatial Distribution



Injection into 10 study areas plus 1 injector per 200 Sq mile pattern across area



Southern Kansas CO_2 injection model
Gas saturation - 100 years after injection stops

~ 4 Billion tonnes injected

~ 300 psi average pore pressure increase