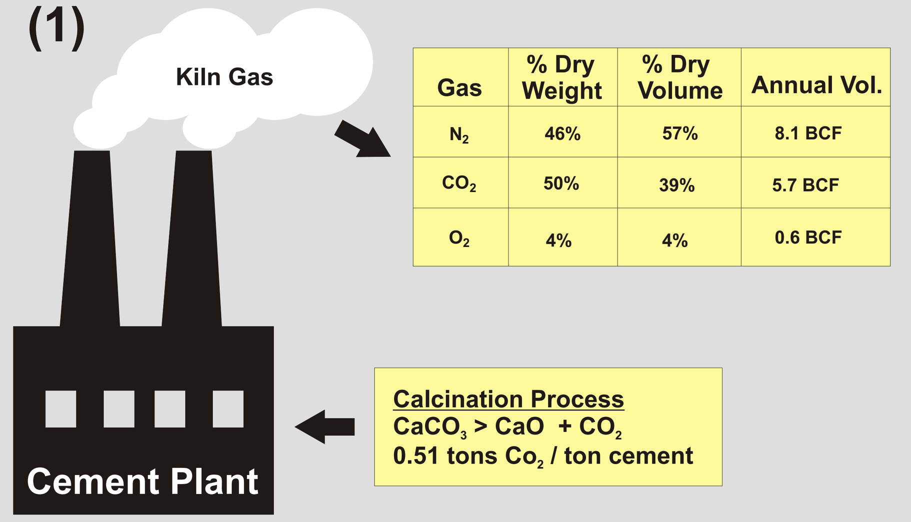
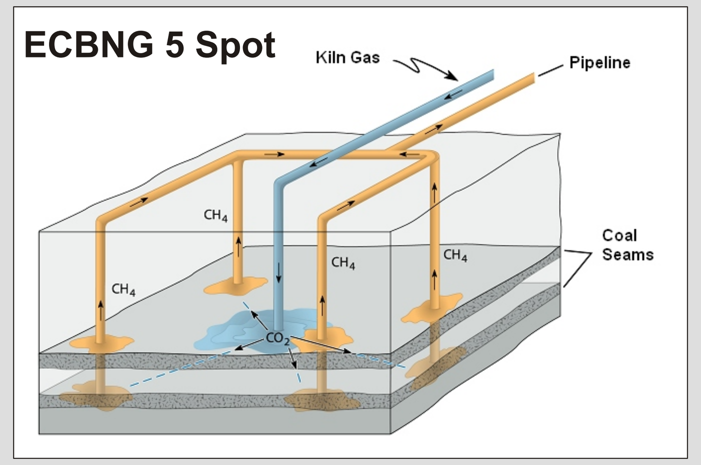
Enhanced Coalbed Natural Gas Technologies

(1)

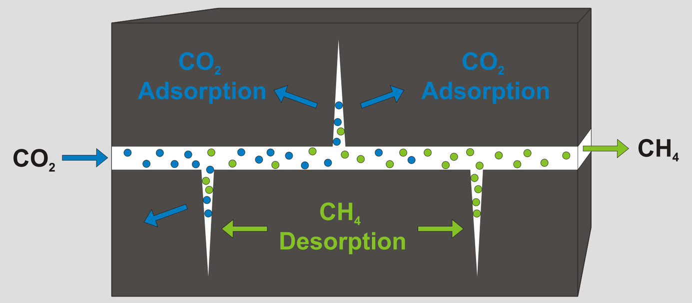


Gas	% Dry Weight	% Dry Volume	Annual Vol.
N_2	46%	57%	8.1 BCF
CO_2	50%	39%	5.7 BCF
O_2	4%	4%	0.6 BCF

(2)



(3)



Enhanced Coalbed Natural Gas (ECBNG) is a recovery technique in which CO_2 or gas mixture, such as kiln gas (1), is injected into subsurface coalbeds to enhance the recovery of CH_4 (2). The process is based on the assumption that CO_2 preferentially adsorbs to coal over CH_4. Injected CO_2 travels through the cleat system and into the coal matrix replacing the sorbed CH_4, freeing it to be produced (3). ECBNG is still evolving, with many aspects of it still not fully understood. Ideally, a successful ECBNG project will provide a positive result of increased CH_4 production, while helping to alleviate the problem of greenhouse gases.

List of Model Input Variables

The following list of variables were needed as input for running CMG's GEM Reservoir Simulator. The GEM Simulator is a multi-component, multi-phase reservoir simulator that utilizes Equations of State (EOS) formulations. The software has numerous built-in features to account for many complex interactions that take place in a CBNG reservoir and ECBNG recovery.

Basic Reservoir Model Variables

- Start Date
- Grid Geometry
- Gridtop
- Grid Thickness
- Porosity (Matrix, Fracture)
- Permeability I, J, K (Matrix)
- Permeability I, J, K (Fracture)
- Fracture Spacing (I, J, K)
- Rock Compressibility
- Reference Pressure
- Sw (matrix, fracture)
- Well Location
- Perforations
- Well Constraints

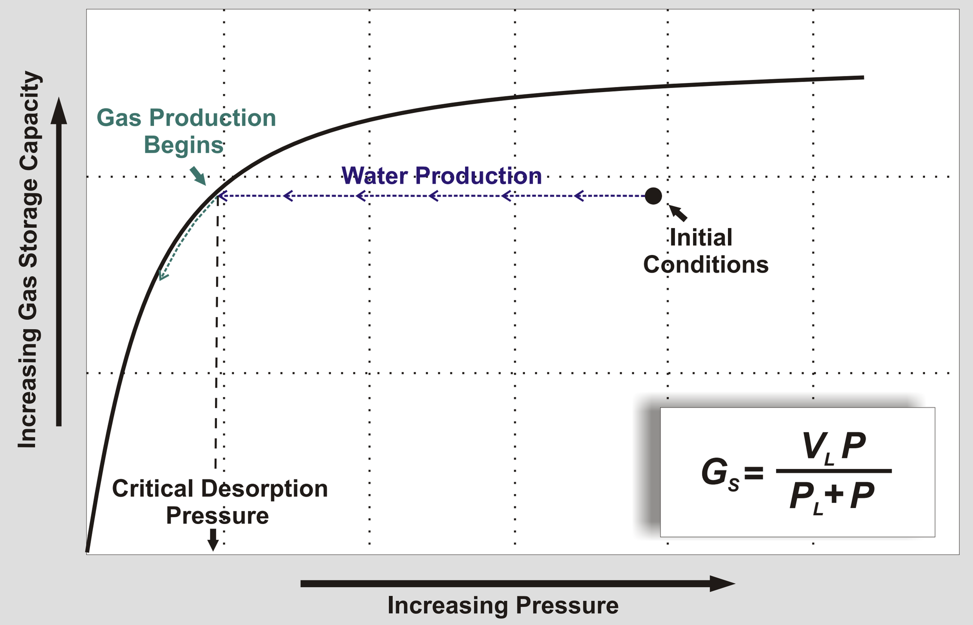
CBNG Model Variables

- Define Components
- Water Viscosity
- Reference Pressure for Water Density
- Initial Reservoir Pressure
- Reservoir Temperature
- Max Gas Content
- Langmuir Pressure
- Initial Gas Content
- Coal Desorption Time
- Coal Diffusion Coefficent
- Initial Gas Composition

Palmer and Mansoori Model Variables

- Young's Modulus
- Poisson's Ratio
- Strain at Infinite Pressure
- Palmer and Mansoori Exponent

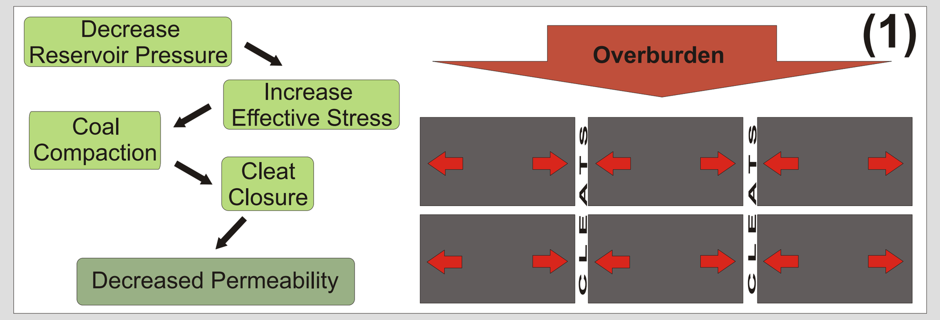
Langmuir Isotherm

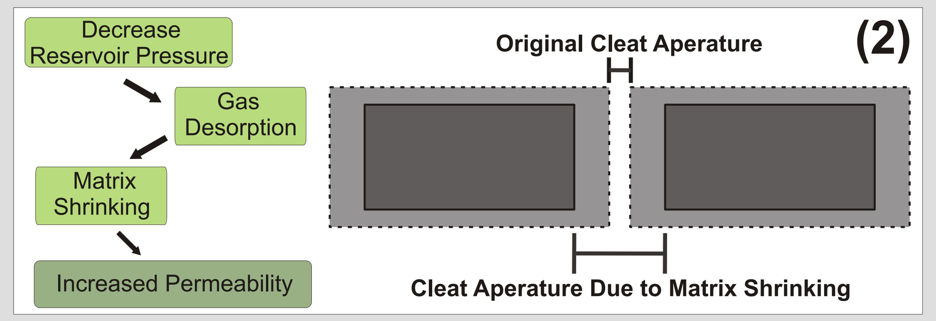


Gas storage capacity of a coal can be expressed by the above equation - a function of its Pressure (P), Langmuir volume constant (V_L), and Langmuir pressure constant (P_L). The maximum amount of sorbed gas in a coal is represented by the Langmuir volume constant. The Langmuir pressure constant is the pressure at which gas storage capacity equals half of the Langmuir volume constant. The (V_L) and (P_L) dictate the shape of the isotherm, which can be used to predict the amount of gas released as reservoir pressure is reduced.

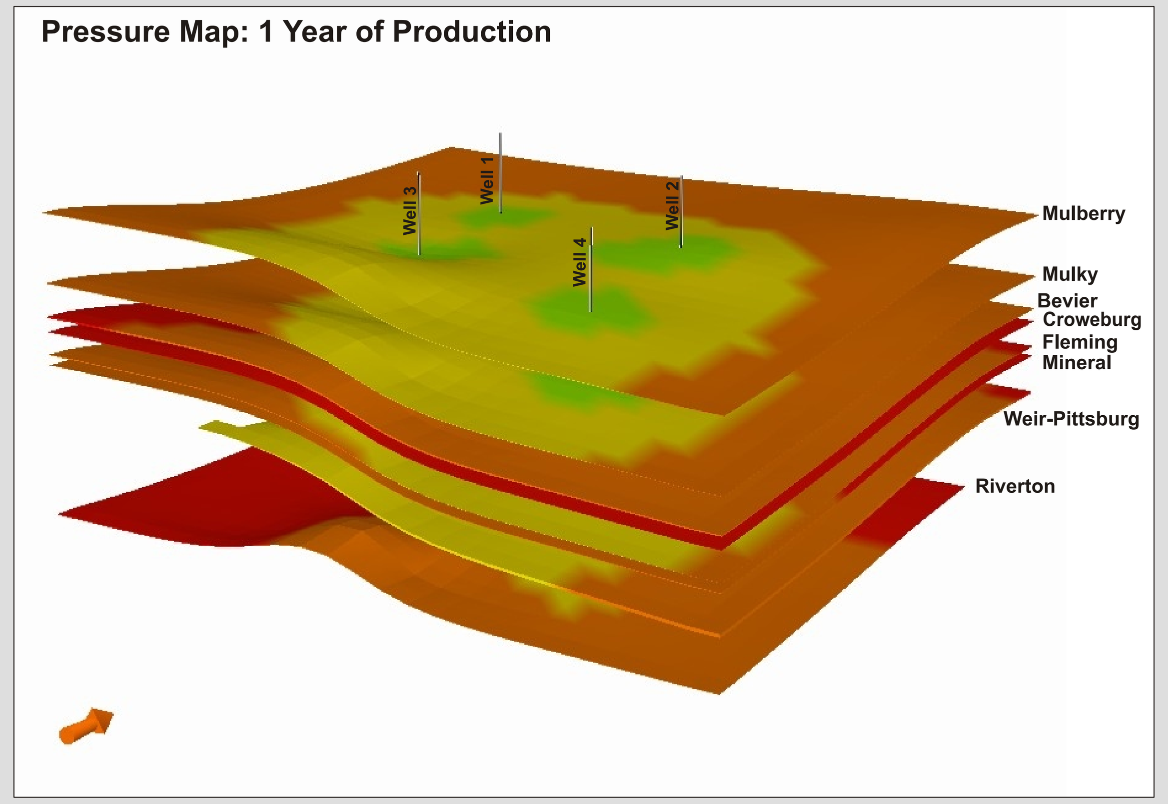
Coal Behavior During Production

Changing reservoir conditions during the production or injection of gases, from or into coalbeds can greatly affect permeability of the cleat system. At initial conditions the permeability of the cleat system is a function of the effective stress, a balance of overburden pressure, and reservoir pressure. Upon well completion and production, reservoir pressure of a coalbed the reservoir pressure is lowered. Lowering of pressure means an increase in effective stress, which leads to a compaction of the coalbed and closure of the cleat system, which reduces permeability (1). However, a lower reservoir pressure also leads to gas desorption, causing the coal matrix to shrink, thus opening the cleat system (2). In the case of gas injection the opposite process occurs. The processes of compaction and shrinkage counteract each other, and the relative effects of each are dependent on several variables including reservoir depth, pressure variation, and total gas production or injection. Reservoir simulators account for these processes, by using a model developed by Palmer and Mansoori (1998). The variables for the simulator will be listed later.





Modeling

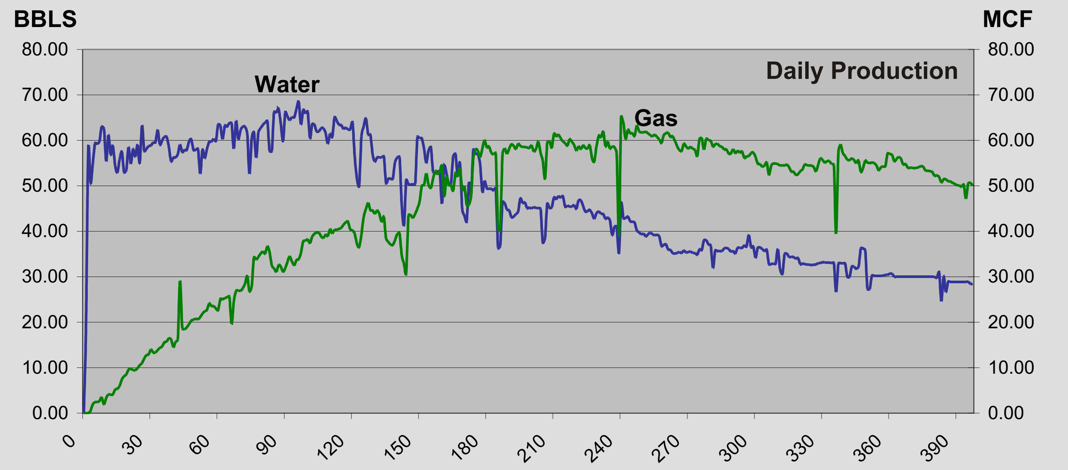


The use of a reservoir simulator designed to accommodate the complexities of a CBNG reservoir is a good means to obtain a reasonably accurate estimation of the effects of an ECBNG project. The information derived from the CBNG exploration model mentioned earlier provides the basic inputs for creating a reservoir model from which simulations are run.

The simulation area covers roughly a one-square-mile region within Wilson County that has producing CBNG wells, from which production data could be obtained. The model consists of a 26-by-26 grid of cells, each cell measuring 220 by 220 feet, and 15 layers of varying thickness. Layer thickness was derived from isopachs of 8 coals targeted for production, and 7 layers representing the thickness between these coals. These layers were hung from the structure of the uppermost coal (1), The volume created provided the base framework for the remaining reservoir properties to be applied. A complete list of the model input variables is provided below.

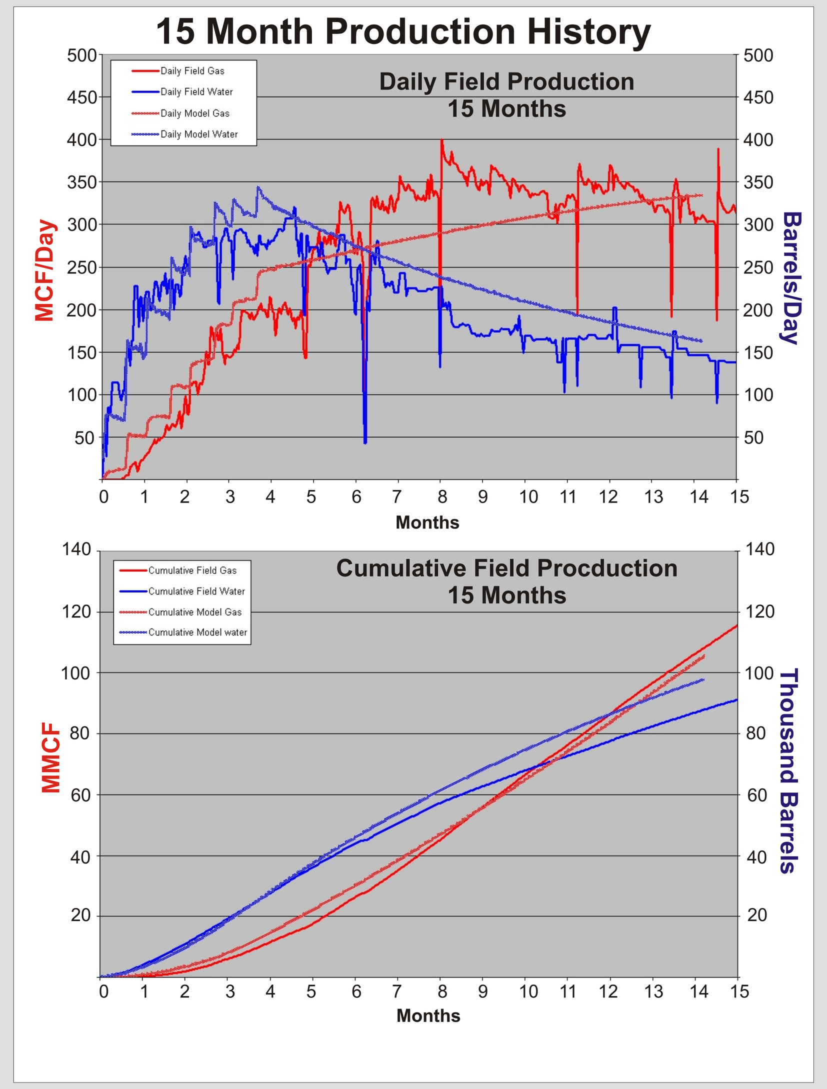
Setup and input of the model parameters is the first step towards the goal of simulating an ECBNG project. Before running a simulation of CO_2 injection, a history match was done to match the production of the wells in the area. This was accomplished by slightly adjusting the variables, while keeping them within a geologically acceptable range. After a history match was completed, the geologic constraints were kept constant for the remainder of the simulation work. The history-matching and ECBNG portion of the study went through numerous iterations, testing the effects of injection rates and timing, to attempt to distinguish the most positive method of CO_2 sequestration.

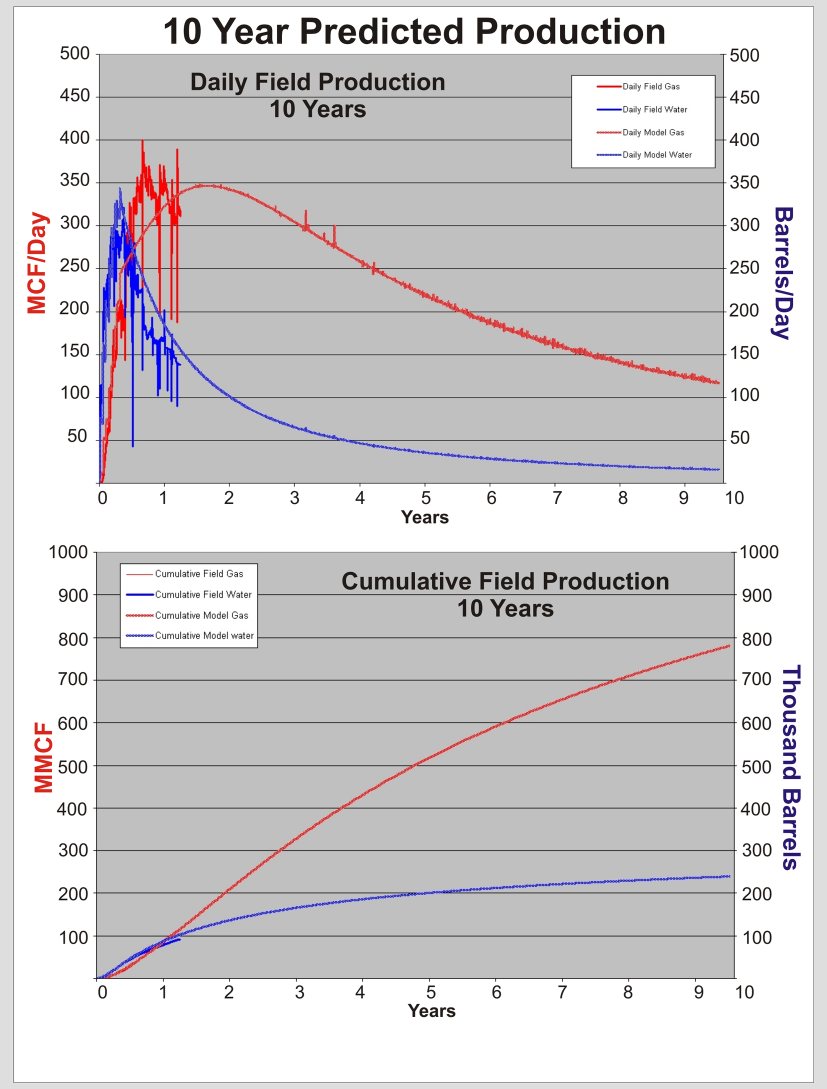
Typical Production Curves



A typical production curve of a CBNG well in Wilson County, Kansas, showing the daily rates of gas and water production. After the well is completed water is produced to reduce the reservoir pressure. The reduction of reservoir pressure leads to the desorption of gas. Unlike a typical gas well, gas rates in a CBNG well increase for a period before they begin to slowly decline.

History Matching





History Matching was performed on a field-wide scale. The field is comprised of four producing CBNG wells that had 15 months of gas and water production data reported on a daily basis. Fifteen months provided a sufficient amount of time for the wells to come on-line and begin to show production trends.

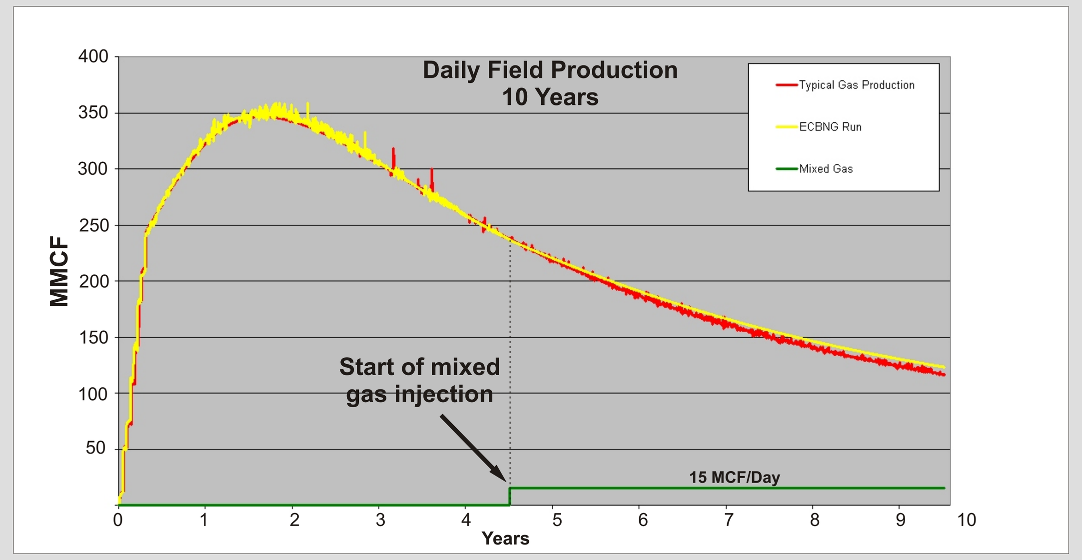
The model was modified by slightly changing variables until its behavior closely matched the performance of the actual reservoir. The simulation time was then lengthened to 10 years to analyze the predicted results. These results were compared to actual production trends from other wells in the region with at least 10 years of production history. It is important when history matching to not just match cumulative production values, but also the shape and trends of the production curves as well.

Calculating the volumetrics of the reservoir is another method for checking the accuracy of the model. The volumetric for the model are outlined below:

Volumetrics

	Gas				Water			
	OGIP = 1.64 BCF				OWIP = 490,000 Barrels			
	Produced		In-Place		Produced		In-Place	
15 Months	115 MMCF	7%	1.53 BCF	93%	98,000 Barrels	20%	392,000 Barrels	80%
10 Years	780 MMCF	48%	860 MMCF	52%	240,000 Barrels	49%	250,000 Barrels	51%

Preliminary ECBNG Simulation Results



Simulation work with respect to the injection of kiln gas for this study is still in the very preliminary stages. The initial ECBNG simulation work was performed under the assumption that adsorption of CO_2 over methane production in coal is 2-to-1. Further simulation work will be performed when isotherms for each component of the mixed gas (CH_4, CO_2, N_2) are determined.

Preliminary results from the simulation work indicate that enhanced production of significant quantities of methane is not likely with the injection of kiln gas. These results are highly dependent upon several factors including sorption capacities for each component of the mixed gas, placement of injection wells, timing of injection, and rate of injection. Further simulation work is needed to investigate the effects of these factors upon the sequestration potential for CO_2 and enhanced recovery of methane.

Conclusions

A CNBG exploration model provides an organized method for determining and understanding the key factors controling production.

An accurate geologic model can be constructed for the purpose of reservoir simulation.

History matching for the field has been successfully completed for the 15 months of available production data, as well as matching 10 year production trends from nearby wells.

Preliminary simulation results indicate that enhanced rates of recovery are minimal, but are highly dependent upon sorption capacities of mixed-gas components, as well as placement, timing, and rates of injection. Further simulation work is being performed to investigate the effect of these factors

References

Boyer, C.M.,II,1989, The Coabed Methane Resources and the Mechanisims of Gas Producibility: GRI Topical Report GRI-89-0266, p. 46.

Scott, A.R., 1999, Review of Key Hydrogeologic Factors Affecting Coalbed Methane Producibility and Resource Assesment; Oklahoma Geological Survey, Open-File Report 6-99, p. 12-36.

Palmer, I. and Mansoori, J., 1998, How Permeability Depends on Stress and Pore Pressure in Coalbeds: A New Model, SPE 52607, SPEREE, pp. 539-544.

Rice, Dudley D.,1993, Compositions and Origins of Coalbed Gas: Chapter 7 in SG 38: Hydrocarbons from Coal AAPG Special Publications, p. 159-184

Zeller, D.E., ed., 1968, The stratigraphic succession in Kansas: Kansas Geological Survey Bulletin 189, 81 p.

Acknowledgments

I would like to thank the Kansas Geological Survey for providing the funding for this project as part of my Masters research. I would like to specifically thank Tom O'Neill with Dart Oil and Gas for providing an exceptional data set, as well as Computer Modeling Group (CMG) for use of their GEM Simulator software. Many thanks to the staff of the Kansas Geological Survey for providing useful insight into many of the questions raised.