Western Kentucky Deep Saline Reservoir CO$_2$ Storage Test

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Electric power generating and industrial plants in western Kentucky discharge about 78 million metric tons of carbon dioxide to the atmosphere each year.

NETL, 2007, Carbon Sequestration Atlas of the United States and Canada
Project Goals

- Demonstrate CO$_2$ storage in deep saline reservoirs under the Western Kentucky Coal Field through the drilling and testing of an 8350 ft well in east-central Hancock County
- Demonstrate the integrity of reservoir sealing strata for long-term CO$_2$ storage in western Kentucky
- Demonstrate appropriate technologies for the evaluation of CO$_2$ storage in Kentucky deep saline reservoirs
- Publish the project results for use by government, industry, and the public in evaluating CO$_2$ storage in Kentucky
- Accomplish this project with consideration of the interests and concerns of the landowner, residents of Hancock County and western Kentucky, and the citizens of the Commonwealth
HB-1 mandates drilling a CO$_2$ storage demonstration well in the Western Kentucky Coal Field (blue).
The shallowest drill depth to reach the targeted reservoirs is in east-central Hancock County.
The completed CO₂ storage test well will be among the deepest wells drilled in western Kentucky.
Deep Rock Units in Western Kentucky

Regional saline reservoirs:

- Mt. Simon Sandstone
- Knox Group dolomites
- St. Peter Sandstone

Rock units:

- Maquoketa Gp
- Lexington Ls
- Black River Gp (High Bridge Gp)
- Joachim Dol
- St. Peter Ss
- Beekmantown Fm
- Copper Ridge Dol.
- Eau Claire Fm
- Mount Simon Ss
- Granite-Rhyolite Complex

Potential CO₂ sinks/reservoirs:

- Knox Gp.

Sealing interval:

Missing section:

Sink or seal:

(depending on location)

Metamorphic and igneous rocks (mostly seal)
Deep Rock Units in Western Kentucky

Just as important in an injection project are the sealing units:

- Eau Claire Formation
- Maquoketa Shale
- Ordovician carbonates
- Devonian Shales

Potential CO$_2$ sinks/reservoirs
Sealing interval
Missing section
Sink or seal (depends on location)
Metamorphic and igneous rocks (mostly seal)
At the proposed wellsite, Precambrian Basement will be at about -7500 ft subsea or ~8150 ft. drill depth.

Approximate limit of Mt. Simon Sandstone

Proposed Well
KGS #1
TD 8350 ft

Figure is by Jim Drahovzal. Interpreted from proprietary seismic data from western Kentucky and adjacent southern Indiana.
North-South Seismic Line 7, Hancock County, showing the projected location of the proposed CO\(_2\) storage test well.

Modified from Drahovzal, 1997, figure 2

Proposed Well
KGS #1
(Projected Location)

Top of Knox Group Dolomites

Mt Simon Sandstone pinches out to South

New Albany Shale

TD 8450 ft

North

0 1 mile

Modified from Drahovzal, 1997, figure 2
The Mt. Simon is used for waste injection in other states.

- Restricted to the area north of the Rough Creek Graben.
- Thins to the southeast in northern Kentucky.
- Not a primary reservoir target in the test well.

Map from MGCS data.
Mt Simon Sandstone Porosity Trend in the Illinois Basin

Data sources (828 samples):
- Metarko (1980; 89 samples)
- Shebl (1985; 9 samples)
- Makowitz (2004; 27 samples)
- Kunledare (2005; 690 samples)
- DuPont #1 WDW (13 samples)
Mount Simon Sandstone Reservoir

Exxon Jimmy Bell #1
- Drilled on the northern margin of the Rough Creek Graben, Webster County
- Encountered 750 ft of low porosity Mt Simon Sandstone at 13,490 ft above granitic basement
Mount Simon Sandstone Reservoir

Thin section of a cutting from Exxon well Jimmy Bell #1 at 14,220 ft shows little porosity due to quartz overgrowths (O) on quartz grains (Q) and microquartz (M) filling pore space.

Kersting, (1982, Fig. C-7)
Knox Group Reservoirs

The Knox Group is a widespread, thick unit of dominantly non-porous dolomite, but known to have several intervals of well-developed porosity.

Proposed Well
KGS #1
TD 8350 ft

Hickman et al., www.esri.com/mapmuseum/mapbook_gallery/volume19/environment3.html
The Knox Group dolomites in western Kentucky have many well-developed porosity zones (red). The test well will encounter intervals of intercrystalline, vuggy, and fracture porosity.
The DuPont WAD #1 found multiple thin, vuggy to cavernous and fracture-associated porosity zones in the Knox Group dolomites.
Porosity Development in Knox Group Dolomites, DuPont WAD #1

Mean porosity 5.5%

Intragranular Porosity

Vuggy Porosity

1718 ft
2521 ft
2815 ft
Vuggy porosity in the LG&E Wainscott #1 Oldham County, KY 1452-1453 ft

Wells Creek Formation

Beekmantown Dolomite with well-developed vuggy porosity

Ohio Stratigraphic Borehole Tuscarawas County, Ohio

Knox Group porosity: FMI and core.

Vuggy porosity in the LG&E Wainscott #1 Oldham County, KY 1452-1453 ft

From: Mullet and Riley, *Ohio’s Deep CO₂ Sequestration Test Well*
Rough Creek Graben

Regional Dip \( \sim \frac{1}{2} \degree \)

The Knox Group unconformity in western Kentucky shows a very shallow westerly dip
Generalized structure cross section of western Kentucky showing potential reservoir (+) and sealing (*) intervals. Primary reservoir targets are porous and permeable zones in the Beekmantown and Copper Ridge Dolomites of the Knox Group. Vertical x 22.
Generalized stratigraphic cross section of the Knox Group. Outside of the Rough Creek Graben porosity (red) is best developed in the B2-B4, B6, CR2, and lower CR 3 members.
Drilling Program

- Drill to 400 ft and cement casing to isolate groundwater and any shallow oil and gas zones.
- Drill to 3845 ft and cement casing to ensure against any possible leakage to the surface during testing.
- Drill to 8350 ft to gather geological, geophysical, and geochemical data to identify and aid the design and evaluation of the intervals to be tested.
KGS #1 Well

Drilling Program

- Drilling to 8350 ft is expected to take ~45 days including time coring
- >300 ft of whole cores will be cut
  - New Albany Shale (30 ft)
  - Maquoketa Shale (30-60 ft)
  - Trenton/Black River (30-60 ft)
  - St Peter Sandstone/Knox Dolomite (60-120 ft)
  - Knox Dolomite (180-360 ft)
- Rotary sidewall cores will be cut in intervals not whole cored
  - New Albany Shale
  - Mt Simon Sandstone
- Extensive electric log program
Testing Program

- Testing will proceed from the deepest interval to the shallowest below casing
- Test intervals will be isolated from deeper and shallower intervals
- All intervals will be first tested by injection of an artificial brine
- The most favorable interval will be tested by injection of a small volume of CO$_2$
- At the completion of testing the well will be plugged and abandoned to Kentucky and EPA standards
Project Status: Organization

- Project agreements are in final legal review for execution
  - 501(c)3 industry partners’ foundation
  - Memorandum of Agreement between KGS and the foundation
  - Right of Way and Injection Test Agreement with the landowners
  - Data Sharing Agreement with the oil and gas leaseholder
- Estimated project budget is ~$7 Million
- KGS has discussed the project in public meetings with Hancock County officials and residents
Project Management Structure

RELATIONSHIPS OF PARTNERS AND DIVISION OF RESPONSIBILITIES
(Dashed lines indicate oversight; solid lines indicate payment for services)
Project Status: Operations

• **Bids for services have been solicited, are under review, or have been awarded**
  – Title search (Paul L. Madden, Jr., Esq.)
  – Phase 1 environmental survey (GeoScience Consultants, Inc.)
  – Seismic acquisition (in review)
  – Project manager (Sandia Technologies, LLC)

• **Well design and testing program is under review by ConocoPhillips engineering and drilling staff in consultation with KGS and Sandia Technologies**

• **Wellsite construction evaluation is in progress by ConocoPhillips drilling staff**
Hancock County Seismic Program

Proposed Well KGS #1
TD 8350 ft
Western Kentucky Project Timeline

- Characterize the background surface conditions for follow-on environmental monitoring
  - Shallow seismic program at the wellsite to define karsting
  - Soil gas surveys of the area surrounding the wellsite
- Acquire ~26 mi of new seismic lines in east-central Hancock County to characterize the subsurface structure
- Permit the well for CO$_2$ injection with EPA Region IV
- Drill an 8350 ft well to Precambrian basement rocks
  - Collect subsurface reservoir characterization data for Knox Group dolomites and other reservoirs
  - Complete an extensive reservoir evaluation program of geologic and geochemical testing and petrophysical, geomechanical, and reservoir engineering modeling
- Conduct an extensive program of fluid injection and pressure testing including both brine and CO$_2$
- Conduct long-term surface environmental monitoring
Western Kentucky Project Timeline

- **2008**: Organization
- **2009**: Site Characterization
  - EPA Permitting
  - Drilling
  - Testing
- **2010**: Evaluation and Reporting
- **2011**: Monitoring
- **2012**: Abandonment
The western Kentucky CO\textsubscript{2} storage demonstration project has progressed quickly

- A consortium of KGS and energy industry partners has been organized
- The project funding vehicle has been established
- A drill site has been identified and lease terms negotiated with the landowner and oil and gas leaseholder
- Initial contractor service bids are under review
- Drillsite construction is being evaluated

- Estimated commencement of operations is during the 4\textsuperscript{th} Quarter of 2008 with well testing, reservoir evaluation, and final reports completed by yearend 2009

- Surface monitoring will continue through year-end 2012 until the abandonment of the well and dissolution of the consortium
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