Protecting Drinking Water by Reducing Uncertainties Associated with Geologic Carbon Sequestration in Deep Saline Aquifers

Presented by William R. Roy
University of Illinois at Urbana-Champaign

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # 488220

Project Introduction

EPA Project Officer: Barbara Klieforth

EPA Quality Assurance Officer: Lisa Doucet

Principal Investigator: William Roy

Project period: Nov. 16, 2009 to Nov. 15, 2012

The Research Team

Sally Benson
Stanford University, Stanford, California

Peter Berger, Ivan G. Krapac, Yu-Feng Lin, Edward Mehnert, and Samuel V. Panno
University of Illinois at Urbana-Champaign

Chittaranjan Ray
University of Hawai'i, Honolulu, Hawai'i

The Illinois Basin Decatur Project

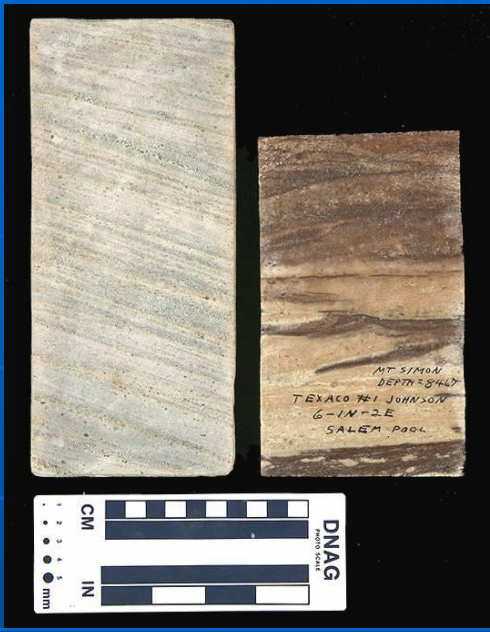
The new EPA project was designed to leverage the on-going US DOE Phase III deep saline reservoir demonstration—the Illinois Basin Decatur Project (IBDP).

Midwest Geological Sequestration Consortium (the Illinois State Geological Survey, Indiana Geological Survey

and the Kentucky Geological

Survey

The Illinois Basin Decatur Project



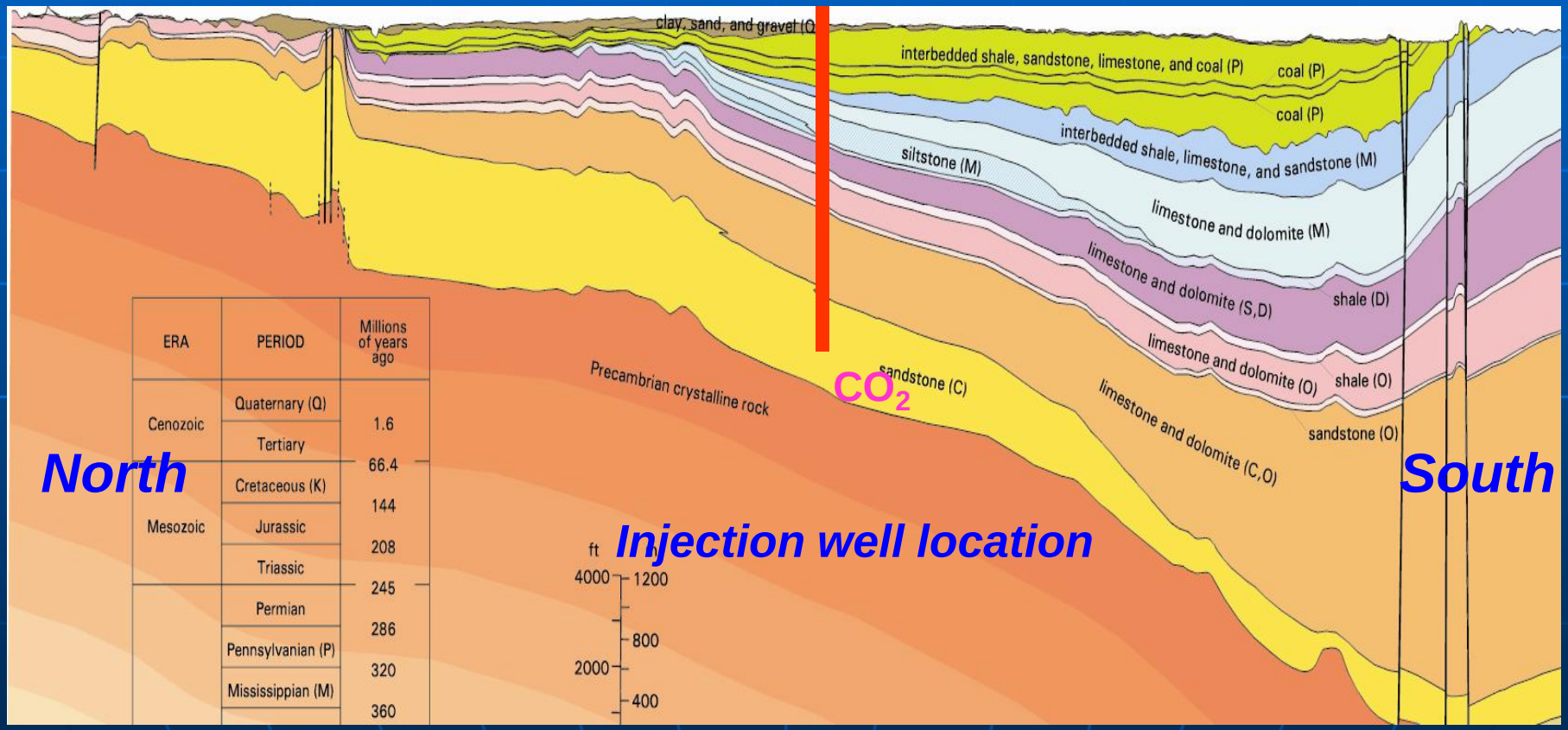
Injection formation: Mt. Simon Sandstone

Primary seal: Eau Claire shale

Mt. Simon Sandstone is used for natural gas storage in Champaign County, IL at depth of 4,000 to 4,200 ft. & 9 other locations in & around the Illinois Basin

Geologic Overview

Mt. Simon is Cambrian age, basal sandstone in Illinois Basin



Thickness of the Mt. Simon is 1,506 feet

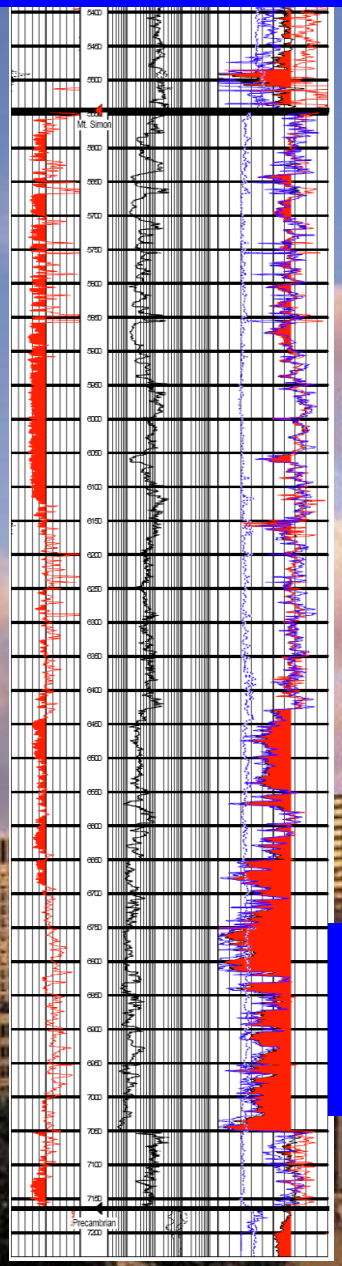
Height of Willis Tower (Sears Tower)

Roof is 1,451 feet

Antenna is 1,730 feet

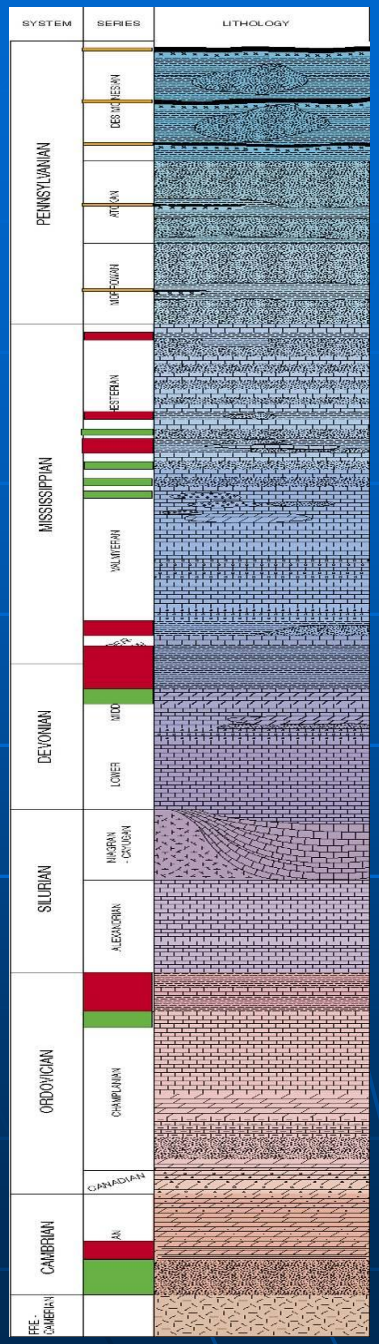
Washington Monument is 555 feet tall

Core and flag pole about 30 feet



Porous injection Zone is 400 feet thick)

Illinois Basin Stratigraphic Column



Pennsylvanian coal seams

Mississippian sandstone and carbonate oil reservoirs

New Albany Shale

Maquoketa Shale

St. Peter Sandstone

Eau Claire Shale

Mt. Simon Sandstone

The Illinois Basin Decatur Project

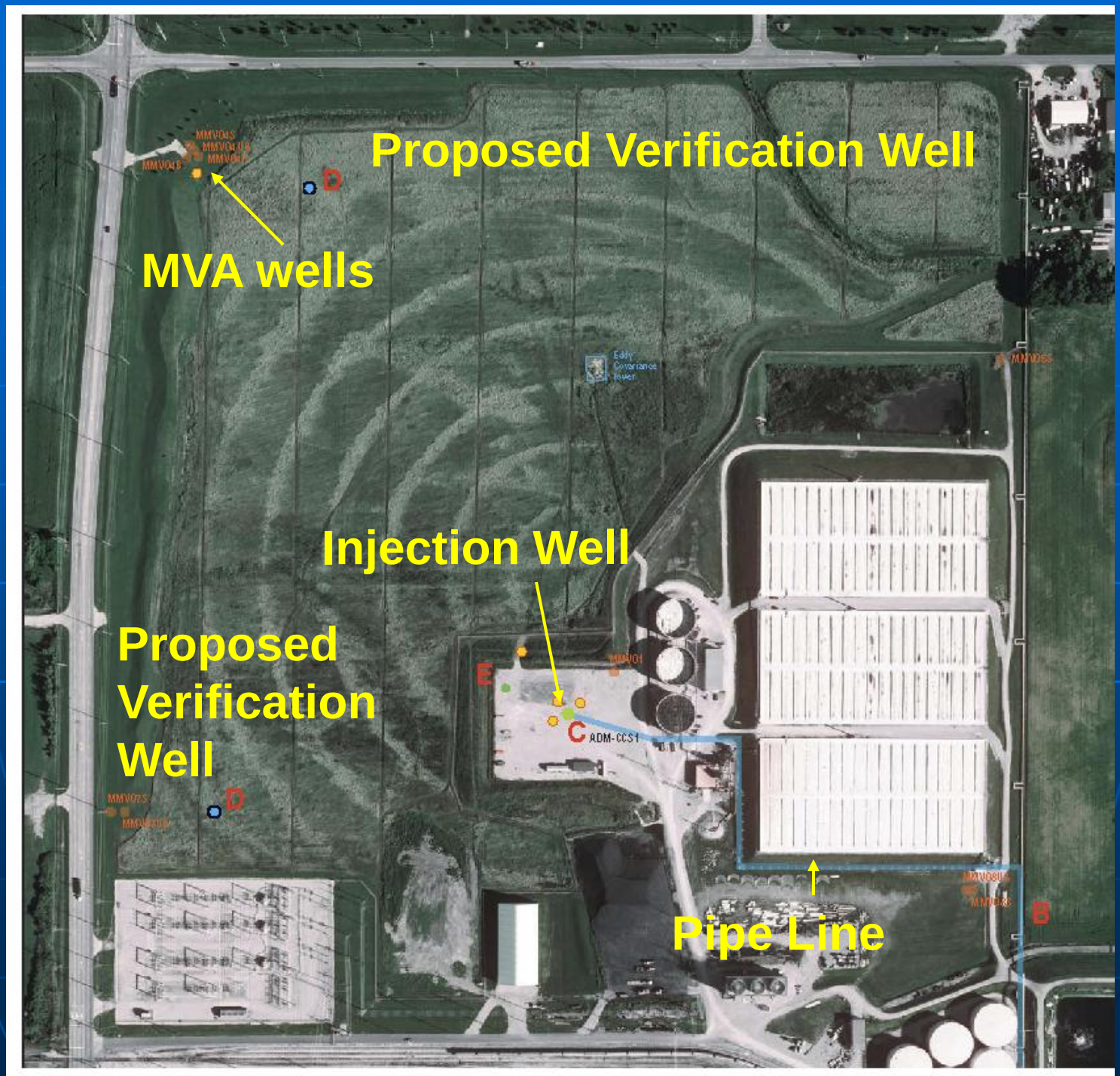
The Illinois Basin Decatur Project

We are working with Archer Daniels Midland (ADM) in Decatur.

ADM produces CO_2 as a by-product of ethanol production.

An CO_2 injection well was drilled on-site this year.

Background data will be collected for one year, then CO_2 will be injected continuously for three years.


Proposed Verification Well
MVA wells
Injection Well
Proposed Verification Well
Pipe Line
D
D
E
C
B
ADM-CCS1

This project: Protecting Drinking Water by Reducing Uncertainties

This 3-year study is organized into five research tasks:

Task 1. Data Mining & monitoring natural gas storage fields.

Task 2. Vertical pressure profiles and brine migration at the IBDP.

Task 3. Enhancement of regional groundwater models.

Task 4. Geochemical Investigations.

Task 5. Monitoring saline seeps.

Task 1 led by E. Mehnert

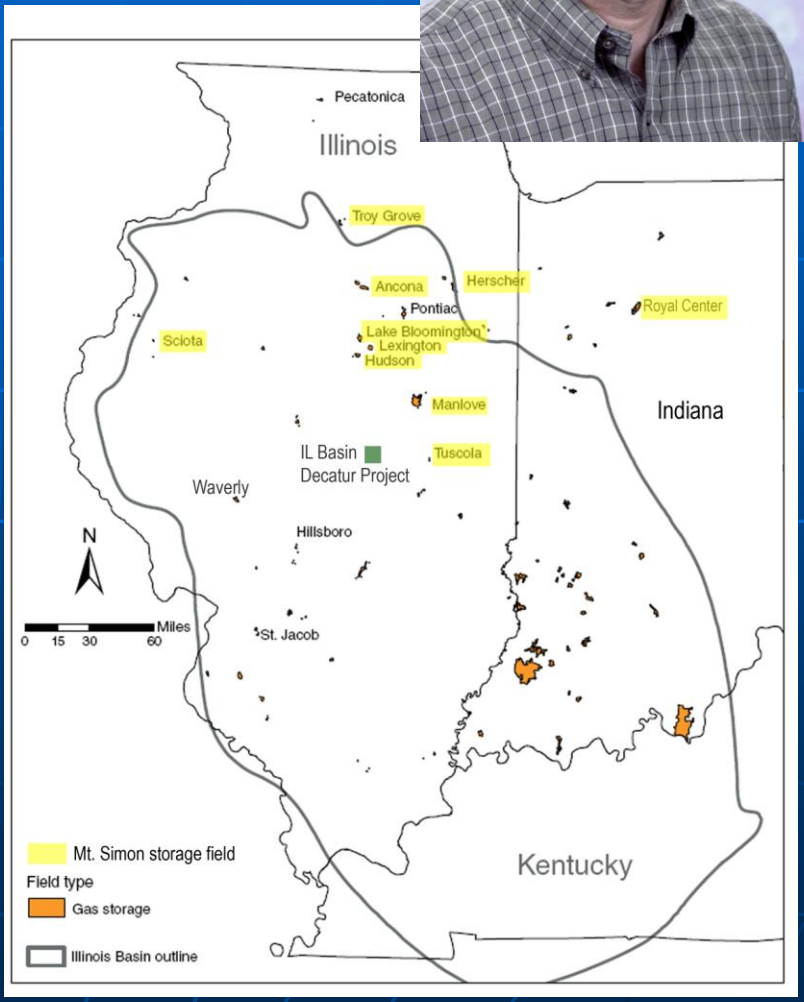
Data mining and monitoring pressures in 10 storage fields that are completed in the Mt. Simon Sandstone in the Illinois Basin.

*Compile available geologic and pressure data from commercial gas storage companies.

*Install pressure transducers at select sites

*Determine pressure-response trends.

Seek valuable input to basin-scale models of the Mt. Simon Sandstone during CO_2 injection.



Task 1. Data Mining …

Data mining efforts to date

*Developing an almanac of the gas storage fields

*Found pumping test data for Ancona

*Found water quality data for 8 Mt. Simon wells and 2 Ironton wells (overlying aquifer)

Date of last revision: 3/12/2010

Almanac of Mt. Simon Gas Storage Fields in the Illinois Basin

Dean Ekberg and Ed Mehnert
Illinois State Geological Survey

1. Ancona Project (Status: Active since 1963)

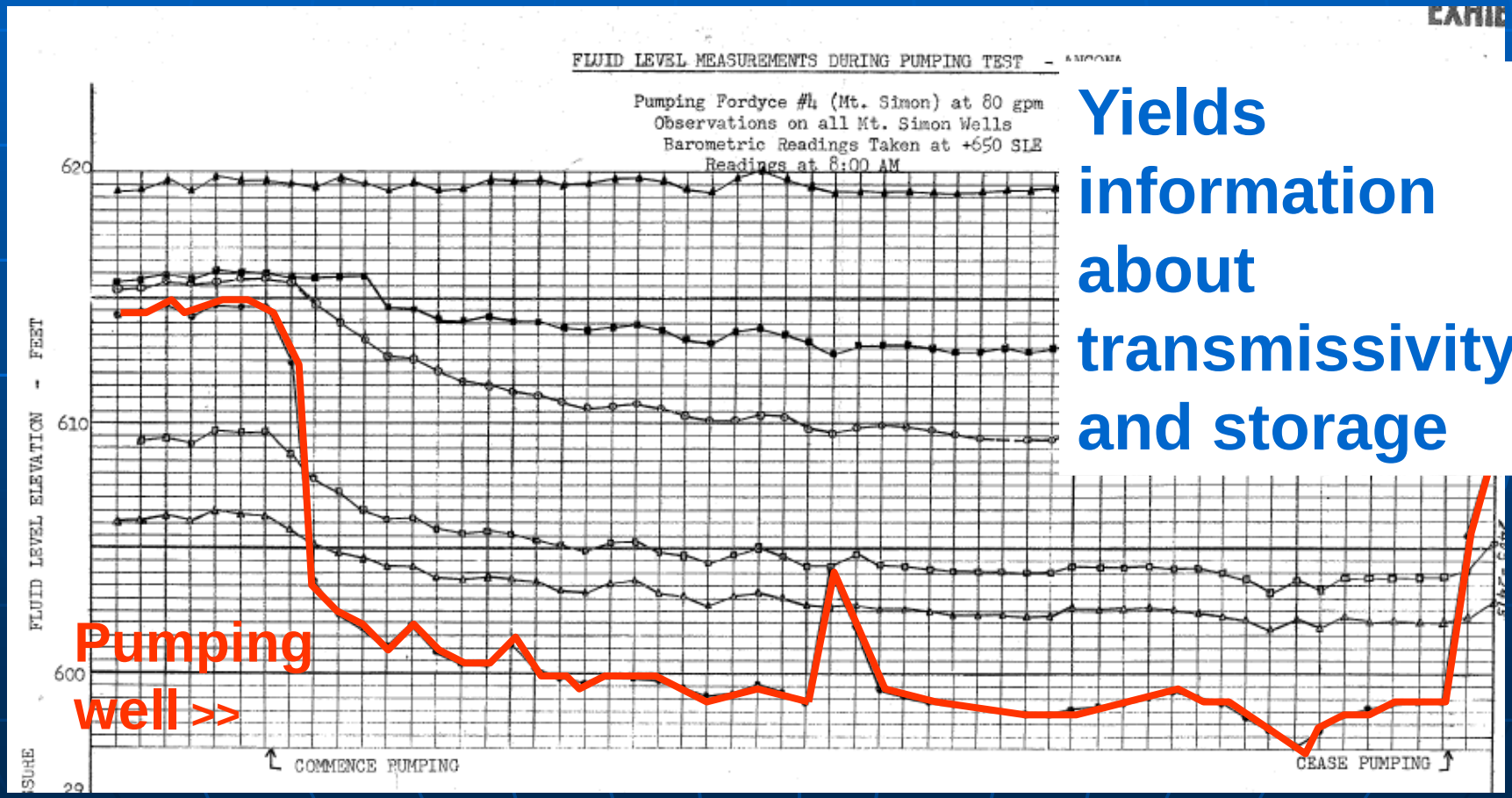
Location	Livingston and LaSalle Counties Near Ancona, 7 miles southwest of Streator T 29 & 30 N, R 2 & 3 E
Owner/Operator	Nicor (formerly Northern Illinois Gas Company)
Operational History	1958: Structural drilling began
	1963: Gas injection began
	1965: Storage project operational
Geology	Storage formation: Mt Simon Sandstone
	Structure: Double-domed Anticline
	Caprock: Eau Claire formation
Reservoir Characteristics	Storage Capacity: 102 Bcf
	Areal Extent: 12,840 acres
	Closure: 290 ft
	Depth: 2,154 ft
	Porosity: 12.3% (average)
	Permeability: 114 millidarcies (average)
	Active Wells: 85 injection/withdrawal wells & 26 observation wells
	Injection Pressure: 1,160 psig (average)
Other	Formerly known as Garfield Project
Company Contacts	Joe Deters, 630-388-2988, jdeters@nicor.com
	Office address:

Notes: Bcf= Billion cubic feet of natural gas

Task 1. Data Mining …

Data mining efforts to date

***Found 40-day pumping test data for Ancona– pumping well and 5 monitoring wells in Mt. Simon!**



Yields information about transmissivity and storage

Task 1. Data Mining …

Data mining efforts to date

- *Developing an almanac of the gas storage fields
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WATER ANALYSIS RESULTS

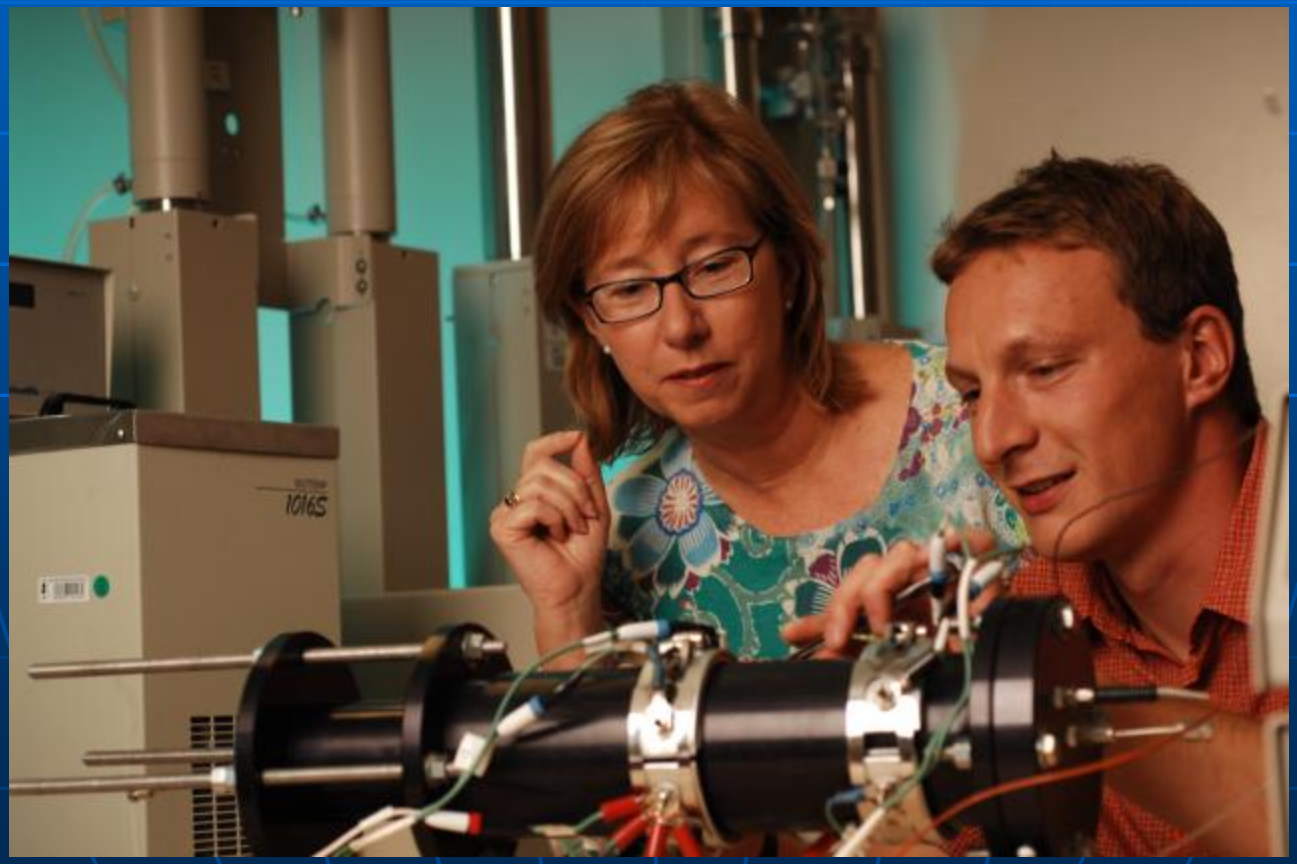
BRADFORD LABORATORIES — Division Of HAGAN CHEMICALS & CONTROLS, INC.

CLIENT: Northern Illinois Gas, Inc. Case No. 62E27

Sample No.		X1	X2	X3	X4
Date Sampled		6/20/62	7/6/62	7/12/62	7/12/62
Time Sampled		5:15 p.m.	2:00 p.m.	-	-
Date Received					
Location: ANCONA		Fordyce #1 Mt. Simon	Fordyce #3 Galesville	Clark #1 St. Peter	Clark #1 St. Peter
Appearance When Sampled		-	-	-	-
Appearance After Standing		Clear-brown sed.	Sl. Hazy brown sed.	Sl. Hazy brown sed.	-
Odor		-	-	-	-
Temperature	°F	n.d.	n.d.	n.d.	n.d.
pH		7.5	7.3	7.8	7.2
Carbon Dioxide	CO_2	15	19	8	35
Dissolved Oxygen	O_2	n.d.	n.d.	n.d.	n.d.
Residual Chlorine	Cl_2	n.d.	n.d.	n.d.	n.d.
Hydrogen Sulfide	H_2S	n.d.	n.d.	n.d.	n.d.
Turbidity	SiO_2	1.5	1.0	n.d.	n.d.
Carbonate Alkalinity	CO_3	0	0	0	0
Bicarbonate Alkalinity	HCO_3	240	238	274	304
Chlorides	Cl	10200	1800	473	467
Total Hardness	$CaCO_3$	2350	968	234	256
Calcium	Ca	676	254	45	50
Magnesium	Mg	150	80	30	31
Sulfates	SO_4	660	460	145	150
Meta Phosphate	$NaPO_3$	-	-	-	-
Manganese	Mn	-	-	-	-
Iron (Total)	Fe	14.0	4.5	2.5	2.5
Iron (Dissolved)	Fe	-	-	-	-
Total Solids	Dissolved (calculated)	17,901	3,785	1,243	1,166
Suspended Solids					
Specific Gravity (60°F)					

Task 2 led by Sally Benson

Measure fluid pressure changes within the Mt. Simon Sandstone at the IBDP site.



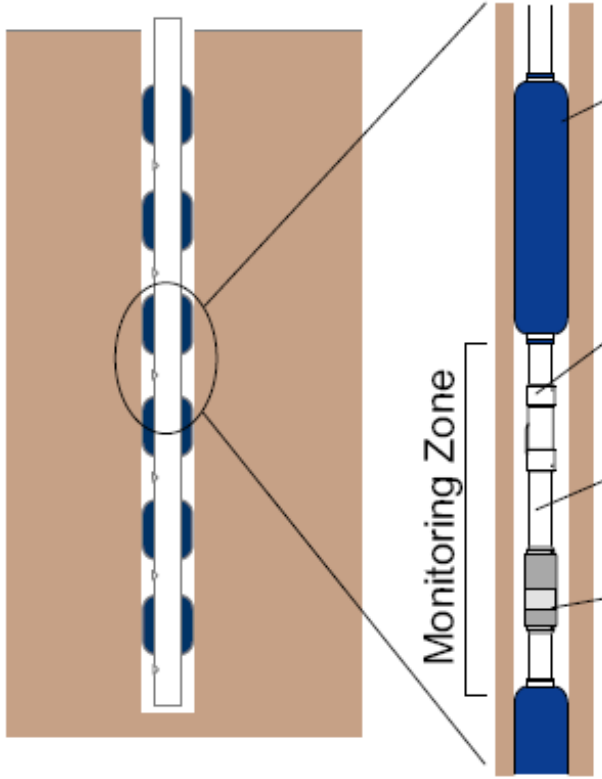
Task 2 (cont.)

Test the Westbay system which can collect discrete fluid samples in a vertical profile while measuring fluid pressures.

Apply a combination of analytical and numerical models to refine the Westbay application.

Develop a protocol for applying this system in commercial-scale CO_2 storage projects.

Westbay System



Packer
- independent hydraulic inflation

Measurement Port
- in-situ measurement, low-k testing, and for fluid sampling

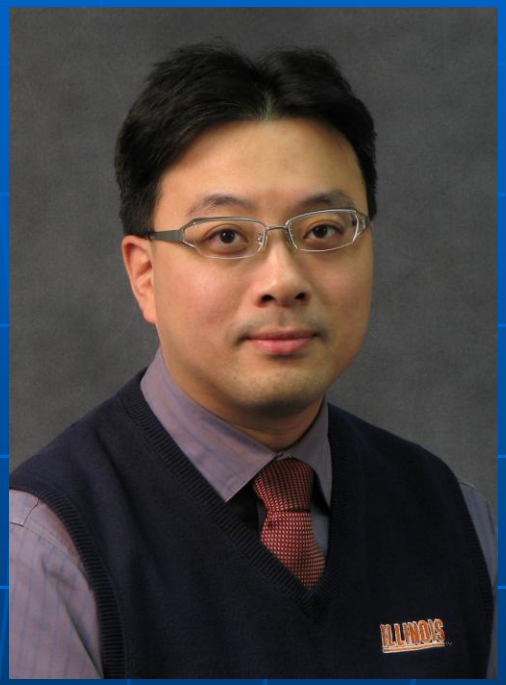
Casing
- variable lengths

Pumping Port
- for hydraulic conductivity testing and purging

Task 3 led by Yu-Feng Lin

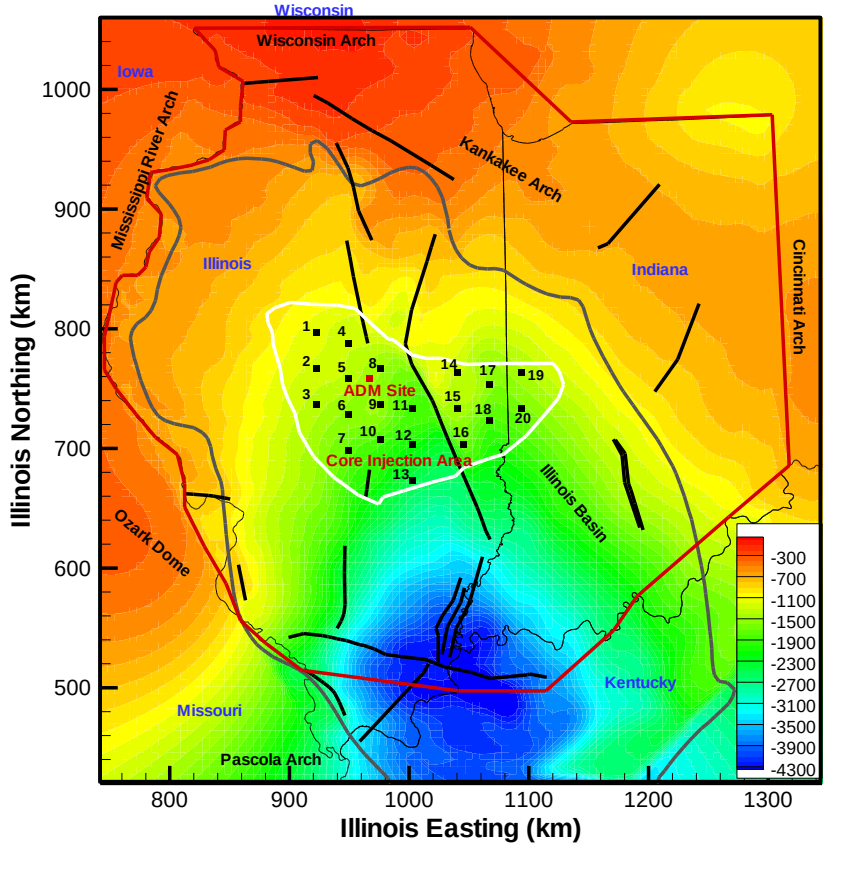
Link two 3D models to better understand the regional impacts of sequestration in the Illinois Basin

- **TOUGH2-MP model of carbon sequestration**
- **MODFLOW model of bedrock aquifers in NE Illinois (multi-layer, includes Mt. Simon)**



Task 3 (cont.)

- Contours show elevation of top of Mt. Simon Sandstone
- Structural features are shown in black
- TOUGH2-MP boundary is shown in red
- Hypothetical scenario for commercial scale GCS: 20 wells shown



Task 4 led by W. Roy

Conduct laboratory geochemical studies using core samples collected at the IBDP and brine samples collected with the Westbay system.

Using high-P, high-T reaction vessels, investigate reaction mechanisms, kinetics, and solid-phase products. Pressure: 3,000 psi, temperature: 40 to 50 ºC.

Use results as input to geochemical models such a Geochemist's Workbench and TOUGHREACT.

Mt. Simon Sandstone

Eau Claire shale

Mt. Simon
6414 – 6415 feet

Upper part of Eau Clair Shale

ACHTUNG !
WARNING !

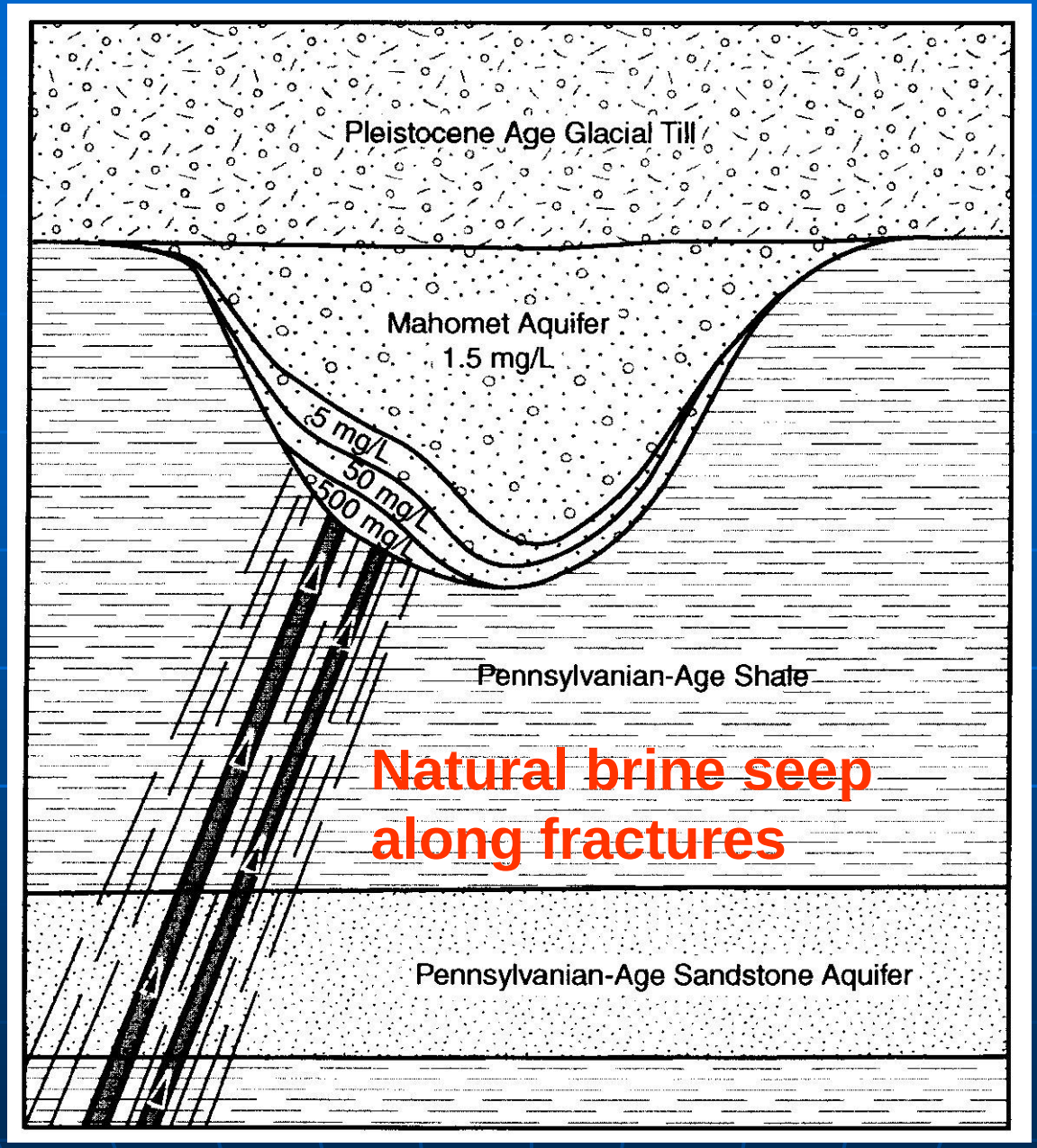
Task 5 led by S. Panno

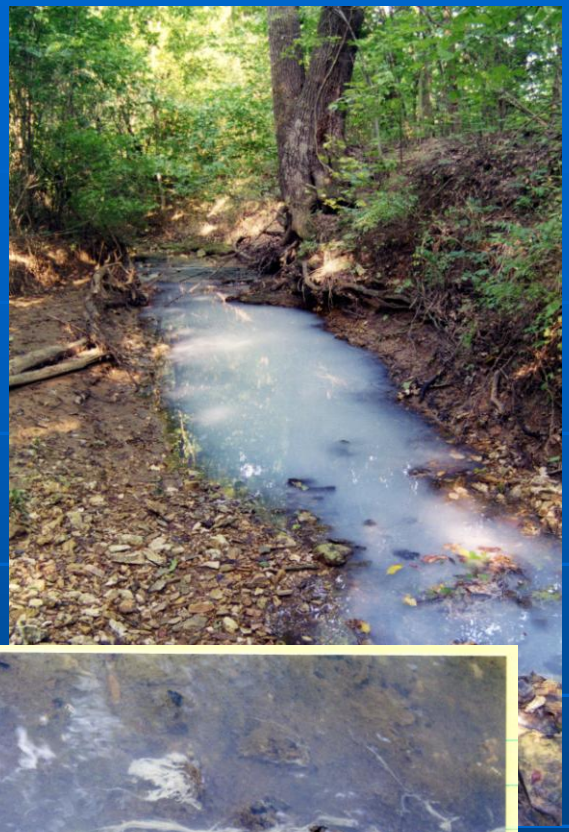
Synthesize baseline data for surface discharges of saline groundwater in the Illinois Basin (what is the background before sequestration?)

Estimate discharge volumes and identify geologic sources of the saline groundwater.

Prepare maps of high-Cl groundwater.

Use results for long-term comparisons during CO_2 sequestration. Displaced brines?


Pleistocene Age Glacial Till
Mahomet Aquifer
1.5 mg/L
5 mg/L
50 mg/L
500 mg/L
Pennsylvanian-Age Shale
Natural brine seep along fractures
Pennsylvanian-Age Sandstone Aquifer



Phase II. Enhanced oil recovery

Enhanced oil recovery: inject CO_2 in old oil fields, sequester the CO_2, and enhance the recovery of oil.

The first test site: Loudon Oil Field.

Designed to be a "Huff'n'Puff"

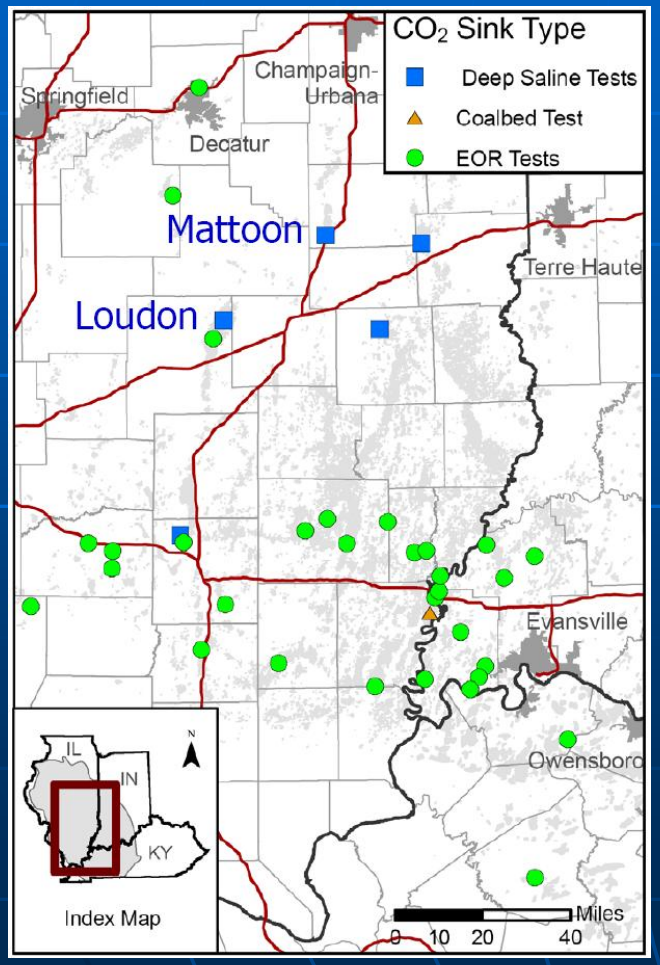
Initial injection of CO_2, (the huff, a soak-in period), and then opening the well, (the puff), which allows some of the CO_2 to escape before pumping resumes.

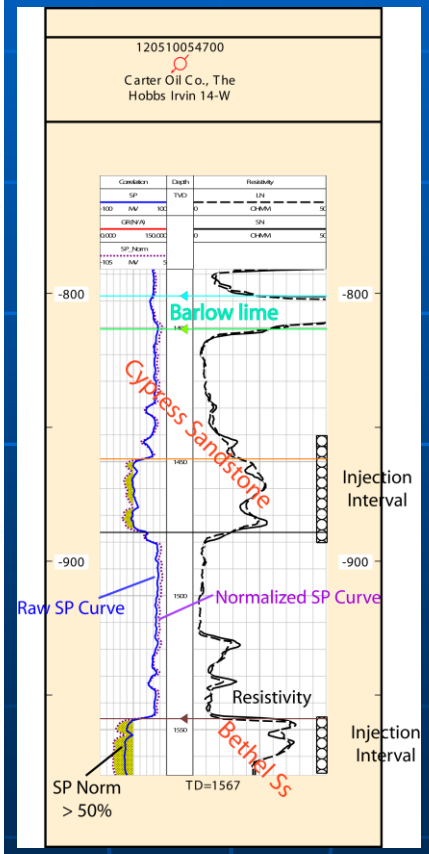
The soak-in period allows the CO_2 time to reduce the viscosity of the oil.

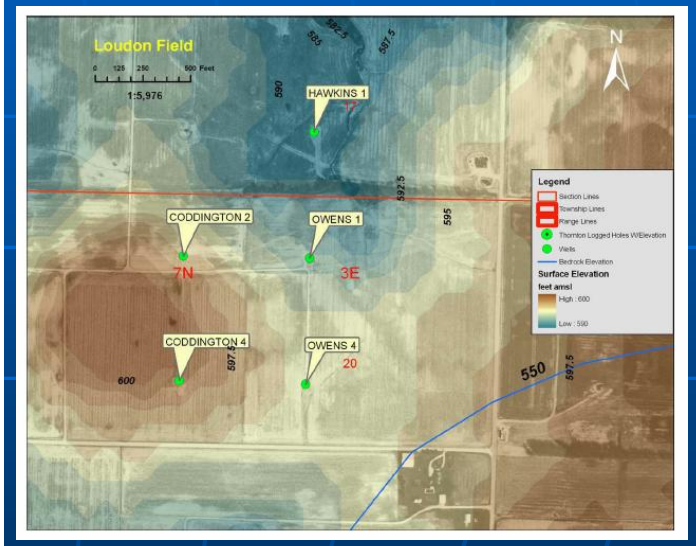
The Loudon Project

- We pumped 39 tons of CO_2 into the Cypress Sandstone formation for 5 days (March, 2007) , and the well was then shut in for eight days.
- Brine samples were collected before CO_2 injection and after injection for 732 days from wells Owens 1 (injection well), Owens 4, and Coddington 2W and 4.

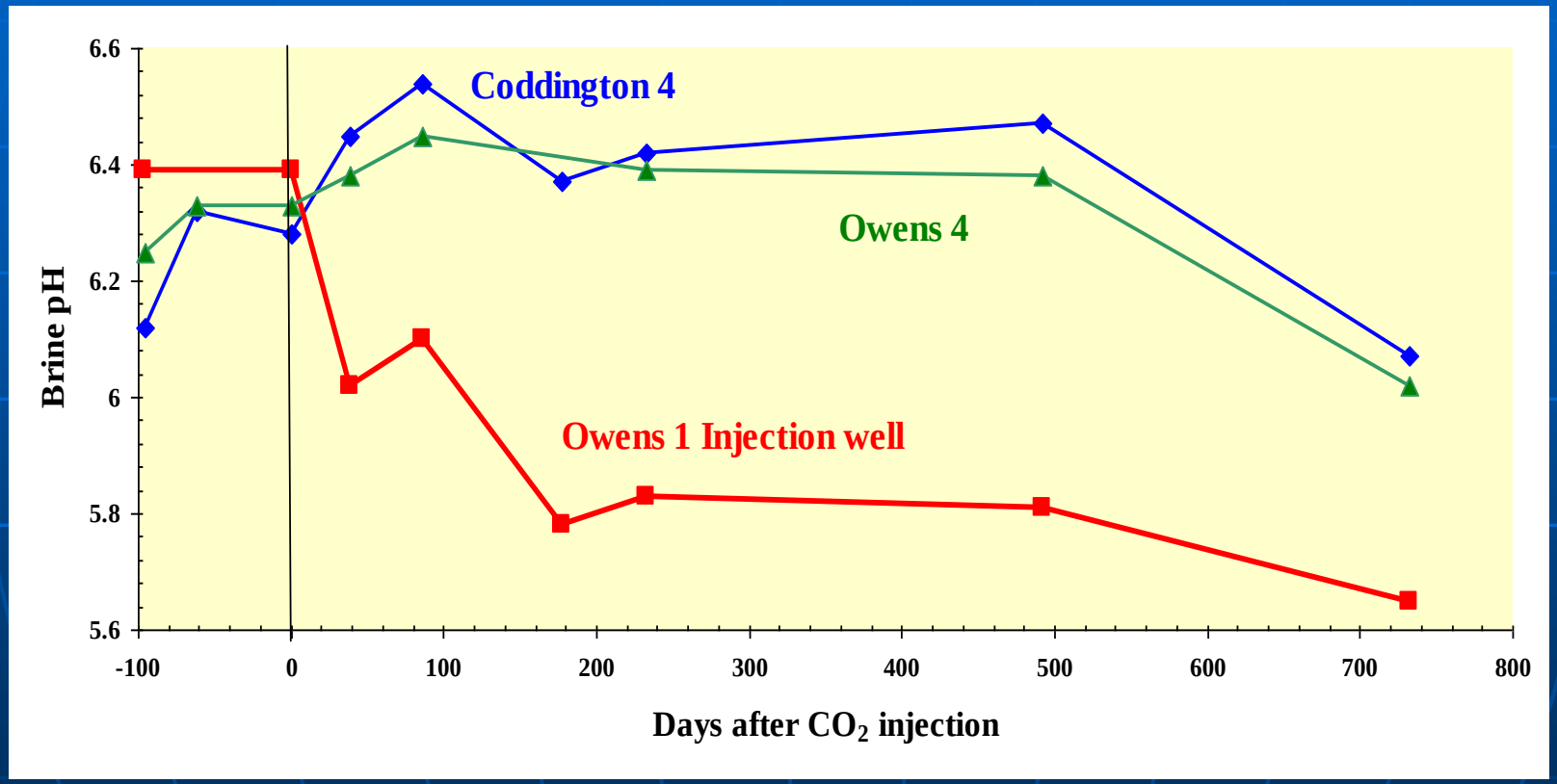
The Loudon enhanced oil recovery Project



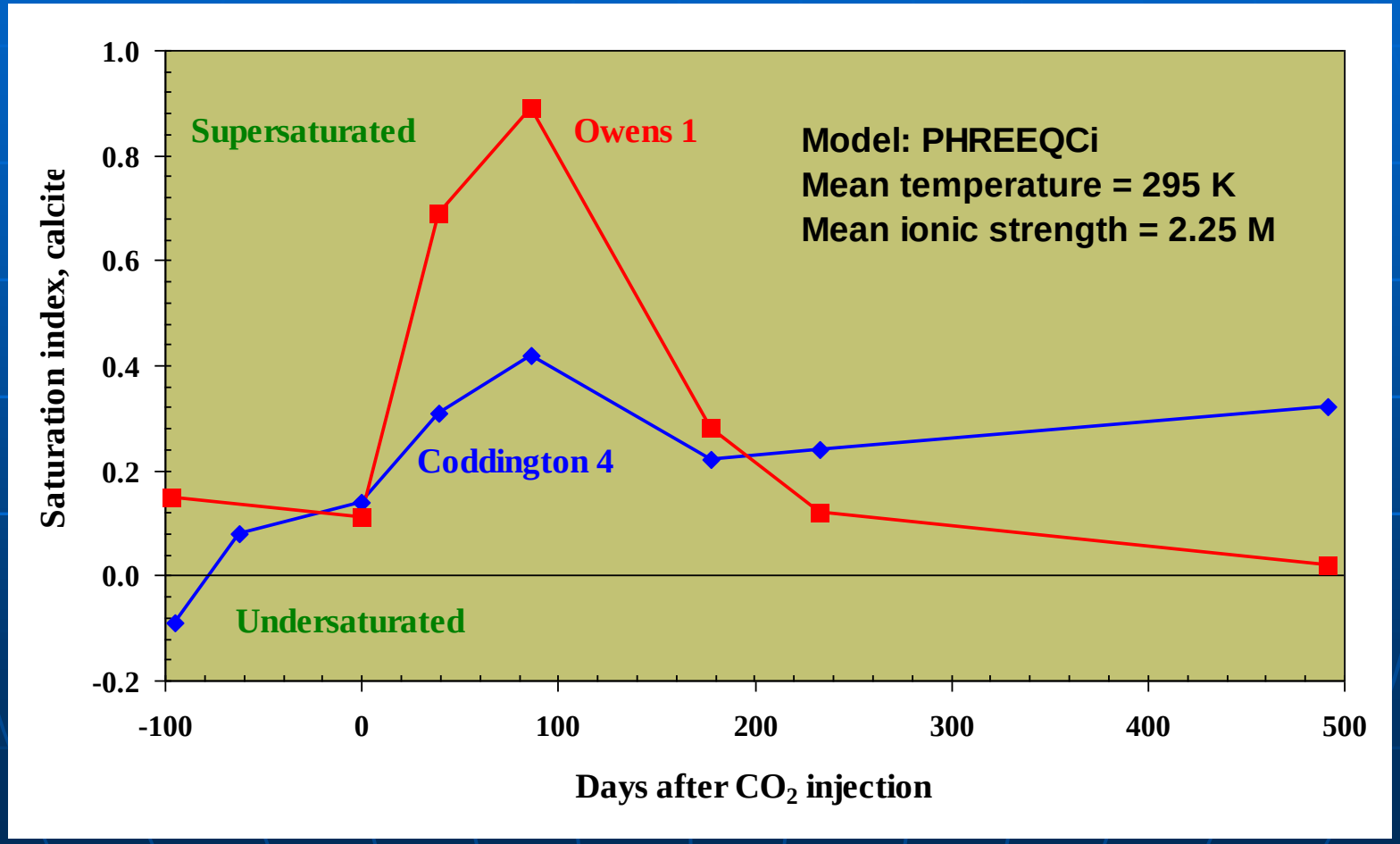




Brine pH


Coddington 4
Owens 4
Owens 1 Injection well
Brine pH
6.6
6.4
6.2
6
5.8
5.6
-100
0
100
200
300
400
500
600
700
800
Days after CO_2 injection

Calcite equilibria at the Loudon EOR



Enhanced oil recovery

Current study at Sugar Creek, KY

We are injecting 8,000 tons of CO_2 to a depth of 1,870 feet during a 6- to 8-month period.

Mumford Hills, IN

Will inject 8,000 tons of CO_2 to a depth of 1,900 feet during a 6- to 8-month period.

New DOE study

An Evaluation of the Carbon Sequestration Potential of the Cambro-Ordovician Strata of the Illinois and Michigan Basins

Principal Investigator: Hannes Leetaru

Co-Principal Investigator: W. R. Roy

Support: $4,803,000

- 3-year study
- University of Illinois (ISGS)
- Kentucky Geological Survey
- Indiana Geological Survey
- Western Michigan University
- Schlumberger Carbon Services

Geochemical Investigations

Purpose of the study is to explore other options if the Mt. Simon sandstone is too deep, too thin, or not available.

Task 9:

Conduct lab-scale batch-interaction studies with the Knox Dolomite (the injection formation) and the Maquoketa Shale (caprock)

Post Doctoral Research Associate
Illinois State Geological Survey
University of Illinois at Urbana-Champaign

We are seeking an individual to conduct laboratory geochemical investigations with geologic materials and carbon dioxide as related to scenarios involving the geologic sequestration of CO_2.

Qualifications: Ph.D. in geochemistry, soil chemistry, physical chemistry, or related discipline. Employment as a post doctoral research associate requires the completion of a Ph.D. no more than five years prior to the beginning of the employment start date.

Qualified candidates must submit a letter of application which details qualifications noted above, résumé, list of publications, working e-mail address, and the names, addresses, phone numbers, and e-mail addresses of three professional references to: **Lori Walston, Human Resources, Illinois State Geological Survey, 615 East Peabody Drive, Champaign, IL 61820**

217-244-2401 walston@isgs.illinois.edu

Thank you

Questions?

"Earth Care II "

"My anxiety was to gain real knowledge of the earth."
--Harry in "Journey to the Center of the Earth" by Jules Verne.