



**Prairie Research
Institute**

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

ILLINOIS STATE GEOLOGICAL SURVEY
ENERGY & MINERALS | SUBSURFACE ENERGY RESOURCES

A Play-Based Exploration of CO₂ Storage in the Illinois Basin

Nathan Webb

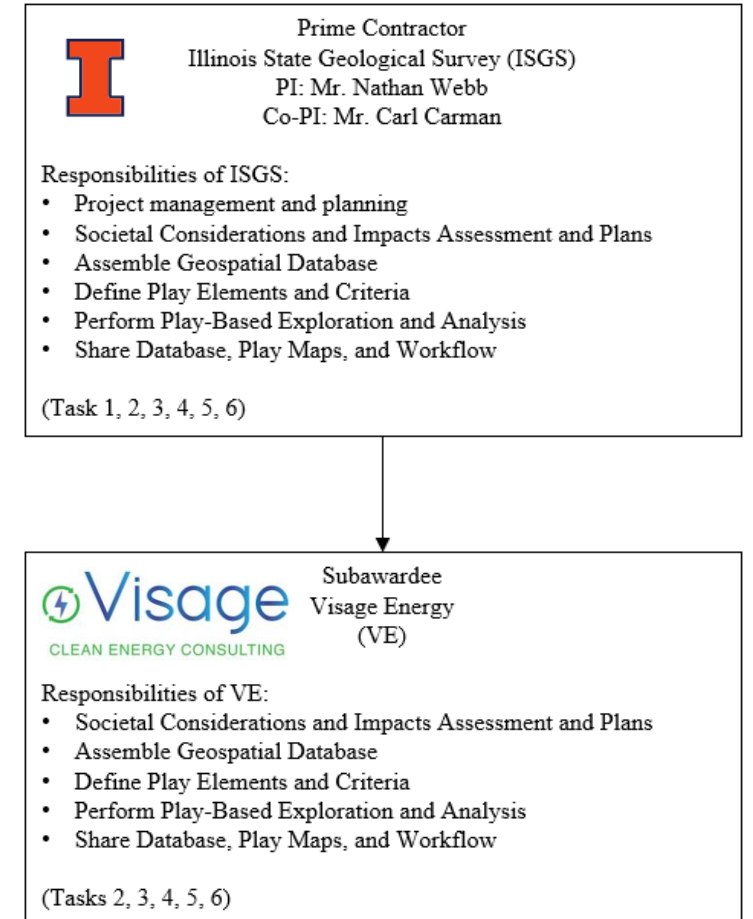
**Principal Research Scientist, Geologist
Head – Subsurface Energy Resources Section**

**2024 FECM / NETL Carbon Management Research Project Review Meeting
August 5, 2024**



Project Overview

- **Period of Performance:** 1/1/2024 to 12/31/2025
- **Funding:** \$999,984 Federal Share; \$251,992 Cost Share
- **Objective:** build a database using existing subsurface, surface, and societal data for entities screening areas of Illinois for commercial geologic CO₂ storage
 - Test the database using play-based exploration and analyses methods to create composite maps that clearly delineate areas in the state with the lowest risk for storage site development,
 - Share the database with DOE, the four existing RI projects, and the AOI 1 Recipients under this FOA, and
 - Provide the public with access to the database and resulting composite maps, specifically those screening Illinois for commercial storage sites or those potentially impacted by the development of such sites

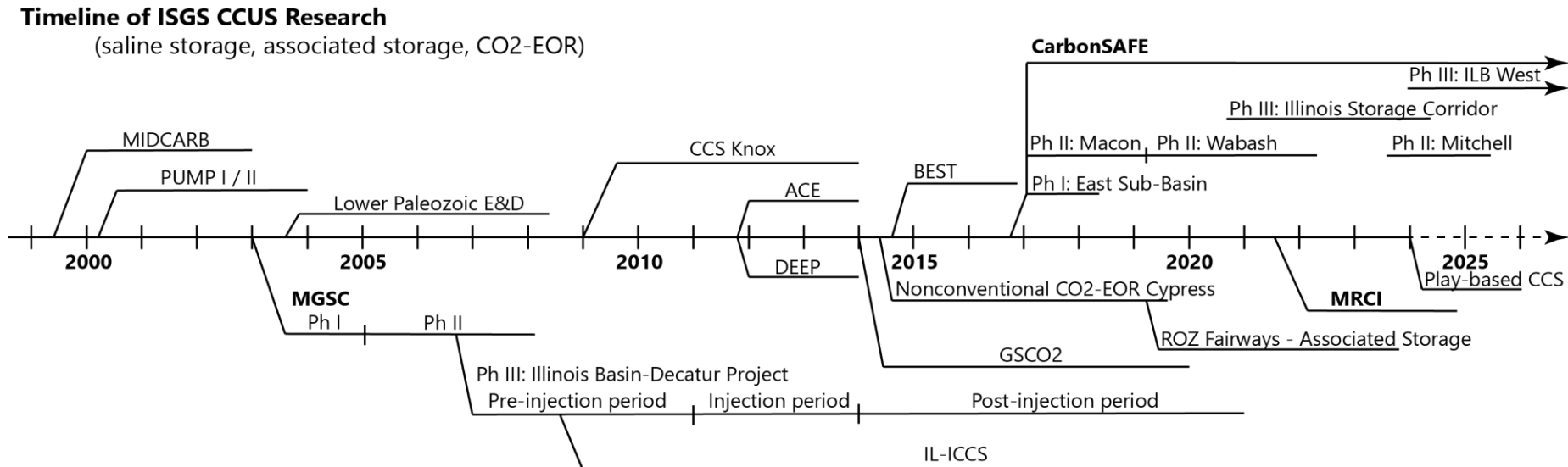




Project Background

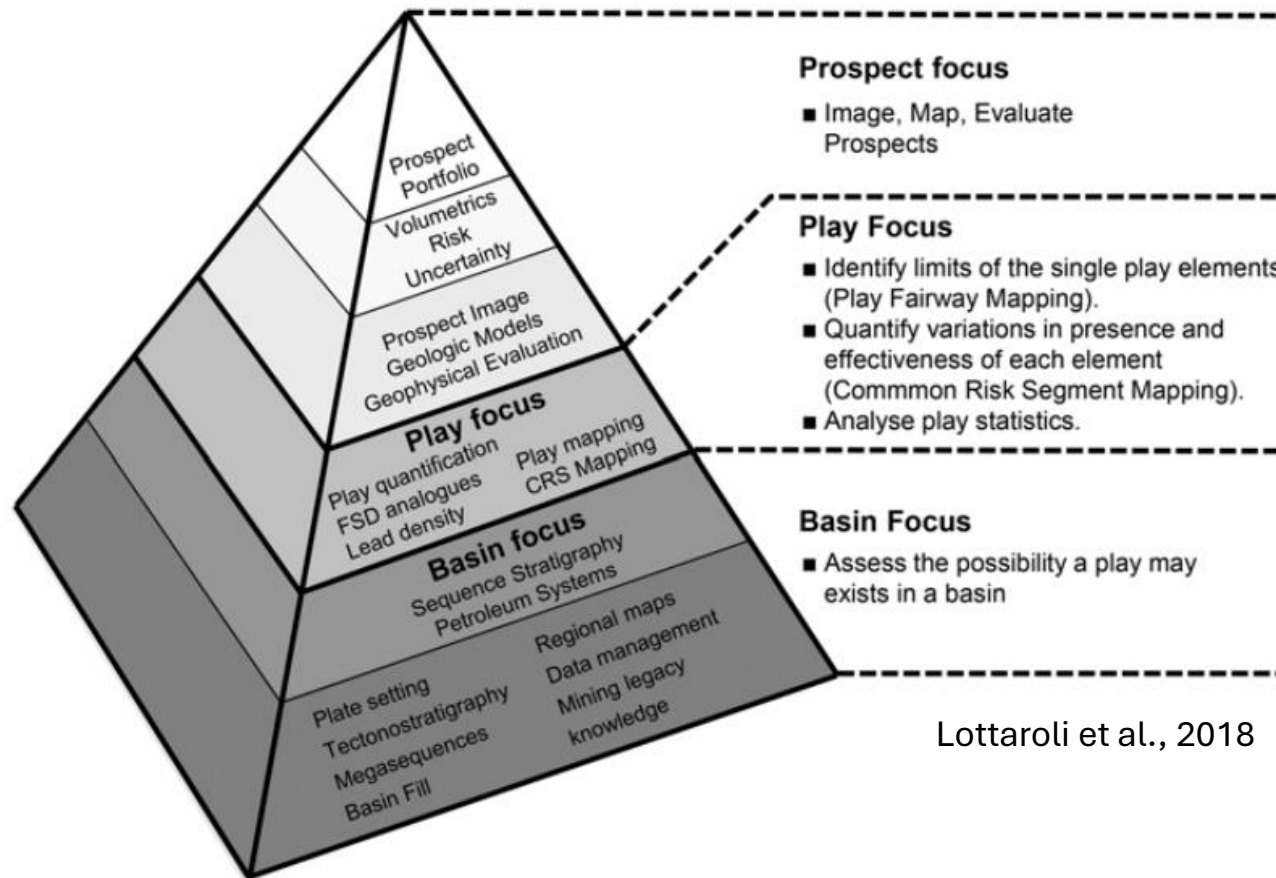
- ISGS has been conducting CCS research for over 20 years
 - Improving understanding of ILB geology
 - Reducing uncertainty in CCS development

- Regional studies (e.g., MGSC, MRCI)
 - Data synthesis
 - Resource assessment
- Site specific studies (e.g., Illinois Basin-Decatur Project, CarbonSAFE)
 - Detailed characterization





Play-based exploration: Concept



Lottaroli et al., 2018

Strengths:

- Screening regional opportunities
- Selecting new exploration areas
- Management of complex exploration portfolios

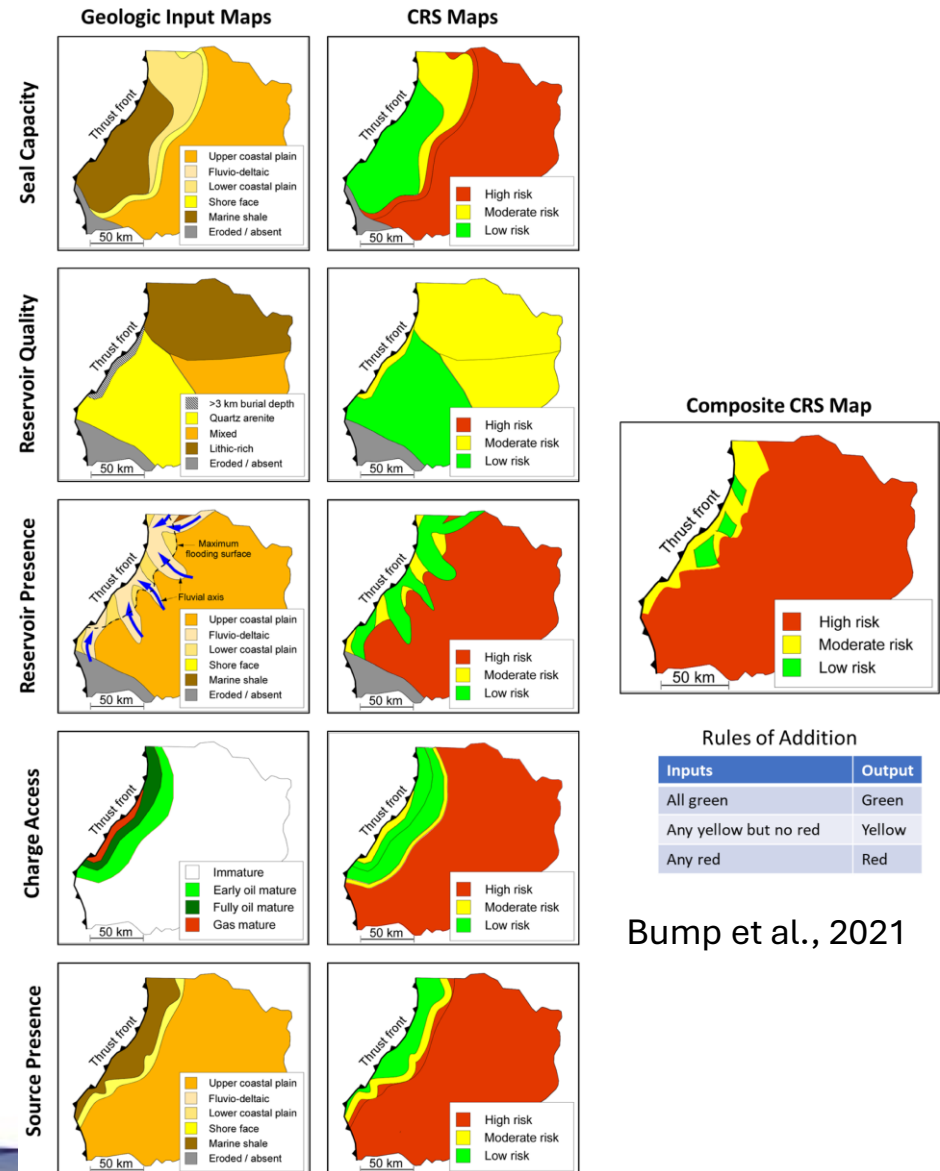
Re-focus technique on CCS

- Basin focus reveals carbon sequestration systems
- Play focus identifies areas of high and low potential within the basin
- Prospect focus allows CCS projects to be identified, classified, and analyzed in the context of the play



Play-based exploration workflow:

- Define Play elements and suitability criteria
- Develop Play element maps
- Apply suitability criteria to Play element maps to create CRS maps
- Convolve CRS maps into composite maps to identify “sweet spots”
 - Verify composite maps reflect conceptual geologic model of the Illinois Basin



Bump et al., 2021



Project Background

- Create CCS Play maps
 - Reduce exploration risk and expense
 - Create investment assurance
 - Focus future studies on the most promising sites
- Develop public website with annotated story maps
 - Facilitate communication of site selection rationale without the need for a keen understanding of CCS
- Build framework for future resource use
 - CRS maps can be redefined based on the preferred injectant (e.g., natural gas, hydrogen)
 - Play maps can be regenerated to show prospects for a range of energy storage scenarios that may compete for available pore space
 - Data synthesis is a step toward developing robust 3D models of the Illinois Basin



Major Project Tasks

- 1.0 - Project Management and Planning
- 2.0 - Community Benefits Plan
- 3.0 - Assemble Geospatial Database
- 4.0 - Define Play Elements and Criteria
- 5.0 - Perform Play-Based Exploration and Analysis
- 6.0 - Share Database, Play Maps, and Workflow

Table of Deliverables		
Task Number	Deliverable Title	Due Date
1 / 1.2	Updated Project Management Plan	January 31, 2024
3 / 3.4	Geospatial Database	December 31, 2024
5 / 5.0	Annotated and Contextualized Carbon Storage Play Maps for the State of Illinois	November 30, 2025
6 / 6.1	Project Website with Story Maps	December 31, 2025
6 / 6.2	Play Based Exploration and Analysis for CCS Topical Report	December 31, 2025



Gantt Chart with Team Responsibilities by Task. Letters refer to milestones.				Budget Period 1																								Organization				
#	Task Name	Start Month	End Month	01/24	02/24	03/24	04/24	05/24	06/24	07/24	08/24	09/24	10/24	11/24	12/24	01/25	02/25	03/25	04/25	05/25	06/25	07/25	08/25	09/25	10/25	11/25	12/25	ISGS	VE			
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24					
1.0 Project Management and Planning																																
1.1	Project activities, objectives, and milestones	1	24	A																									X			
1.2	Project management plan	1	2		B																								X			
1.3	Data management	1	24																										X			
2.0 Community Benefits Plan																																
2.1	Community and stakeholder engagement	1	24												C													C	X	X		
2.2	Investing in job quality and a skilled workforce	2	8																										X	X		
2.3	Diversity, equity, inclusion, and accessibility	1	24																										X	X		
2.4	Justice40	1	24																										X	X		
3.0 Assemble Geospatial Database																																
3.1	Subsurface dataset	1	9																											X		
3.2	Surface dataset	1	9																											X		
3.3	Social dataset	1	9																											X	X	
3.4	Geospatial database	8	12																											X		
4.0 Define Play Elements and Criteria																																
4.1	Play elements	1	6																											X		
4.2	Subsurface, surface, and social criteria	5	12												E															X	X	
5.0 Perform Play-Based Exploration and Analysis																																
5.1	Play element maps	11	16																											X		
5.2	Common risk segment maps	14	19																											X	X	
5.3	Composite play maps	17	22																											X		
5.4	Volumetric analysis	20	23																											X		
6.0 Share Database, Play Maps, and Workflow																																
6.1	Share	17	24																												X	
6.2	Document workflow	19	24																												X	X

Task	Milestone	Date
3	Complete Subsurface, Surface and Social Datasets	10/1/24
4	Define Subsurface, Surface and Social Criteria	1/1/25
5	Complete Play Element Maps	4/1/25
5	Complete Composite Play Maps	11/1/25



Task 2.0 - Community Benefits Plan

- Developed the Subsurface Energy Resources Summer Experience Program (SERSEP) to run concurrently with the ISGS Paul Edwin Potter Internship Program
 - Used “A Play-Based Exploration of Carbon Capture and Storage (CCS) of the Illinois Basin” as the foundation
 - Mentors:
 - Participated in NAGT mentorship workshop
 - Developed a curriculum that incorporated DEIA inclusive mentorship components as supported by the National Academy of Science
 - Provided skill development workshops for SERSEP participants:
 - Intro to CSS; CCS community engagement; Intro to GIS for CCS; Geospatial data collection, processing, analysis, and reporting; Intro to Story Maps in GIS; Common Risk Segment Mapping; CCS Risk Assessment; Scientific Writing Skills; and How to Compose a Literature Review



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Recently, the talented Paul Edwin Potter Interns at the Illinois State Geological Survey had the incredible opportunity to visit the National Sequestration Education Center with [ADM](#) at [Richland Community College](#)!

During the tour, the Potter interns learned about ADM's groundbreaking work, including their achievement as the first American company to be granted a Class VI [#CCS](#) well permit by the [US Environmental Protection Agency \(EPA\)](#). ADM's CCS wells in Decatur have been successfully operating for over a decade.

The Paul Edwin Potter Internship Program immerses students in projects that address geologic issues in [#Illinois](#). For 10 weeks during the summer, student interns work with and learn from professional geologists at ISGS.

[#summerinternship](#) [#geology](#) [#carboncapture](#)



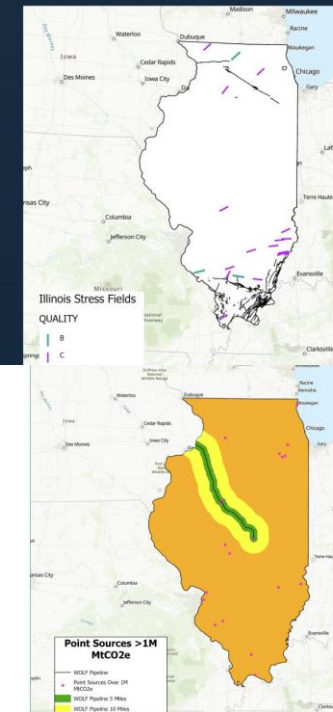


Task 2.0 - Community Benefits Plan

- Developed the Subsurface Energy Resources Summer Experience Program (SERSEP) to run concurrently with the ISGS Paul Edwin Potter Internship Program
 - Three participants undertook a 10-week project with each focused on a single Play element
 - Stepped through Play analysis workflow:
 - Reviewed literature
 - Compiled GIS data
 - Explored mapping of Play elements to develop appropriate suitability classifications
 - Worked towards a common RAM
 - Created story maps
 - Opportunity for ISGS staff to test the Play analysis workflow and GIS tools

Stress Orientations in Illinois

In addition to analyzing basic fault and earthquake data, looking into the orientation of a fault with respect to broader orientations of stress can help to understand the likelihood of fault slip. The map to the right shows data obtained from the World Stress Map (WSM) database of the stress orientations filtered in Illinois and the quality of them. The WSM is an open access database of quality ranked stress field information at a global scale. According to the WSM quality ranking scheme, "A quality means that the orientation of the maximum horizontal compressional stress SHmax is accurate to within ±15°, B quality to within ±20°, C quality to within ±25°, and D quality to within ±40°;" only qualities A-C are considered reliable stress indicators. A being the highest. The maximum horizontal stress is the most compressive stress that acts on faults and in Illinois it is generally oriented 68 degrees NE. A fault orientation within 30 degrees of the maximum



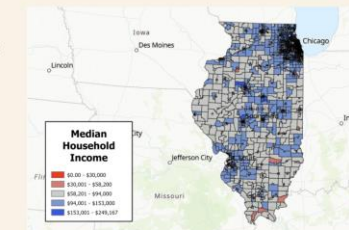
Conclusion

Pipeline suitability is a complicated study determined by measuring several different factors. After calculating a suitable reservoir for CCS, identifying suitable CO₂ emission facilities as point sources to then create a pipeline to a sequestration site is necessary. Suitability for pipelines is based on proximity of sources to each other and to the reservoirs, and emission amount. Along with that, it is influenced by geological and environmental factors, regulatory and permitting requirements, economic factors, paired with public perception and stakeholder considerations.

Financial Economic Resilience

Yahoo Finance reports that those with an income in the bottom 20 percentile are identified as lower class, followed by lower-middle class (up to 40th percentile), middle class (up to 60th percentile), upper-middle class (up to 80th percentile) with the remainder considered upper class using the data from the U.S Census Bureau.

Economic resilience plays a pivotal role in the successful deployment and operation of CCS projects. It ensures financial stability, mitigates risks, and can garner community support. One of the key factors contributing to economic resilience is the income level of the community. Higher income levels generally provide greater financial stability, more disposable income, and better access to resources that can help a community adapt and recover from economic disruptions.



Data from U.S Census Bureau. Classifications from Yahoo Finance. Classifications followed from the method of Yahoo Finance. The black lines indicate census tracts.



Task 3.0 Assemble Geospatial Database

Subsurface Data

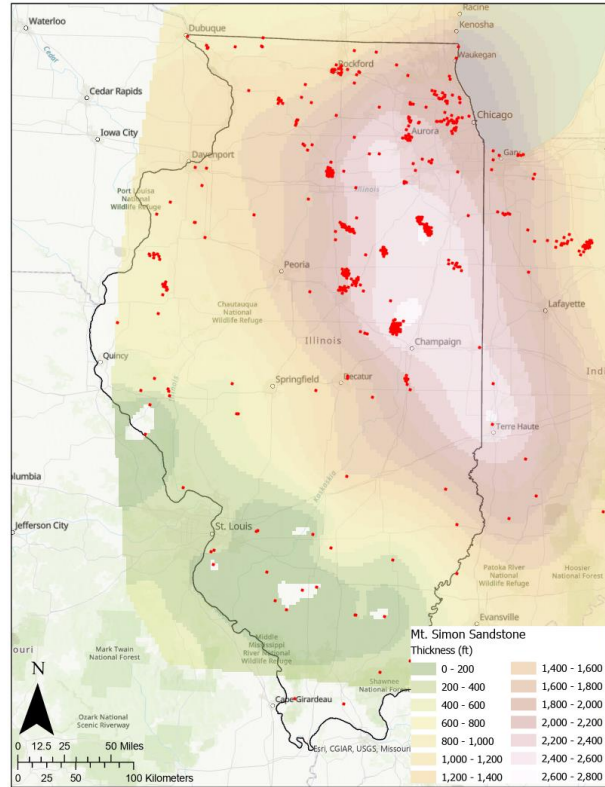
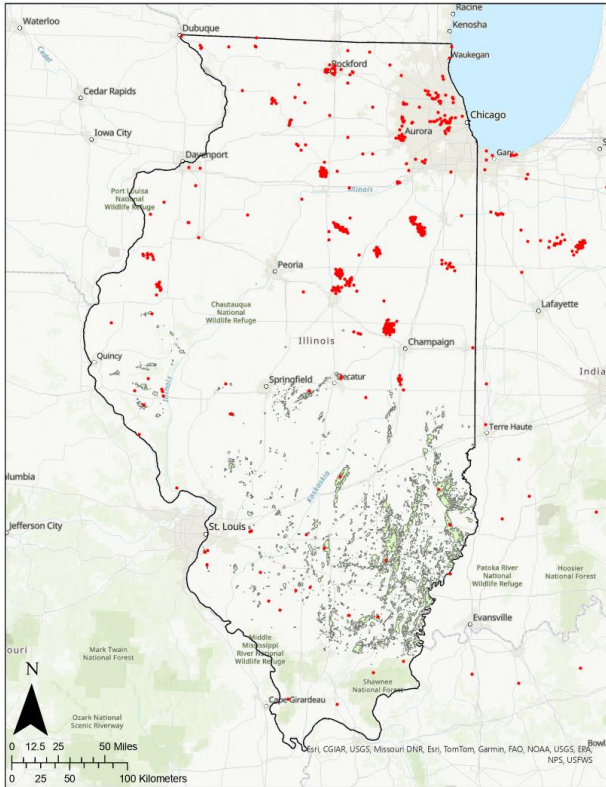
- Organized and classified 2D seismic survey data
- Worked with ISGS geoscientists to combine their stratigraphic formation tops from wells in Illinois that penetrate the Cambro-Ordovician Storage complex to build a database of control wells
- Collaborated with the DOE CATALOG team on the development and implementation of their Oil and Gas Regulatory Record digitizEr (OGRRE) tool to digitize well construction data from existing regulatory well records in Illinois

Surface and Societal Data

- Collected, reprojected, transformed and organized:
 - Surface infrastructure data, including railways and roads, and digitized proposed pipeline routes
 - EPA FLIGHT tabular data on point sources of CO₂
 - Social data, including CEJST and EJScreen
 - US Census tabular data for multiple social and economic Play elements



Subsurface Data Improvement – Legacy Wells



Red dots represent Mt. Simon SS legacy well penetrations

Oil fields (green polygons) approximate counties where ISGS has scanned well construction and other records

Mt. Simon Thickness approximates where there is significant interest in CCS development and where legacy well data is critical

OGRE
PROJECTS
RECORDS

Field	Value
Well_Name_and_No	Joseph Poiter Unit #1
Permit_No	1198
Date_Issued	1975-10-07
Location	330'S 330'E NWC SW
County	Perry
Section	28
Township	5S
Range	3W
Elevation_DF	
Elevation_KB	486.3
Elevation_Ground	467
Total_Depth	7057
PBTD	

ILLINOIS WELL COMPLETION REPORT

Released 10-7-76
DIVISION OF OIL AND GAS
COUNTY No. 235-31
SPRINGFIELD, ILLINOIS

INSTRUCTIONS: Within thirty (30) days after the completion of any well, the owner or operator shall transmit to the Oil and Gas Division the Original and one Copy of this form. Upon request, geological information will be kept confidential for one year from the date that permit is issued. A copy of an electric log (if run) and other pertinent information is to be sent to Illinois State Geological Survey, Natural Resources Building, Urbana, Illinois.

OTL _____
 Oil _____ Gas _____ Dry Hole _____ SWD _____ Water Input _____ Gas Input _____ Conv. _____ Str. Test _____

Operator: **Richard W. Beeson** Water Supply: Observation
 Well Name and No. **Joseph Poiter Unit #1**
 Permit No. **1198** Date Issued **10/7/75** Location **330'S 330'E NWC SW**
 County **Perry** Section **28** Township **5S** Range **3W**
 Elevation: DF _____ KB **486.3** Ground **467** Total Depth **7057** P.B.T.D. _____
 Date Drilling Began **10-26-75** Date Drilling Completed **12-16-75**
 Rotary Tools from **0** To **7057'** Cable Tools from _____ To _____
 Hole Size **8 3/4"** Electric or Other Logs Run: Yes No _____ Date **11-20-75** **12-17-75**

New Well Deepened _____ Drilled Out _____
 Was Well Cored: Yes _____ No Plugged Hole _____ Lease Sign Posted: Yes _____ No
 Drill Stem Test Run: Yes _____ No

TUBULAR RECORD

Surface	Size	Depth	Size Cement	Ceg. Pulled
Mine or Intermediate	13 3/8"	343 @ 360'	37# sk	none
Producing	9 5/8"	3021.80	400 sk	none 1000.73'

PRODUCTION INFORMATION

Name of Producing or Injection Formations: **None**
 Date of First Prod. _____ Date of Test _____ Length of Test _____
 Daily Production Bbls: Oil _____ Water _____ Gas (MCF) _____

WELL COMPLETION INFORMATION

Intervals _____
 Check Type Below: _____ List Amount Used or Other Details Below: _____
 Perforated _____ None _____ **RECEIVED**
 Shot _____ **DIVISION OF OIL & GAS**
 Acidized _____ No Test Core _____ **APR 14 1976**
 Fractured _____ **DEPARTMENT OF**
 Other _____ **MINES & MINERALS**

The information given herewith is a correct record of the well and all work done so far as can be determined from all available records.
Richard W. Beeson
 Evanville, Indiana Address 47708 4-12-76 Date

OGRE digitization is allowing significant improvements:

- Location
- Tubular record
- Completion intervals



Task 4.0 - Define Play Elements and Criteria

- Defined 35 play elements that will be included in the study
 - Developed a justification for each Play element based on the interpretation of possible impact on CCS suitability
- Each Play group was subdivided into subcategories (e.g., containment, storage, and groundwater for the subsurface group)
- Began developing an approach to classify suitability for CCS development using a CCS-specific RAM

				Likelihood of Impact on CCS Project				
Impact Categories			Severity of Impact on CCS Project	1-Highly Improbable	2-Improbable	3-Possible	4-Likely	5-Certain
\$	HSE	Σ						
Up to \$1k	No Injury; No Leakage	Delay of up to 2 weeks	1-Negligible	1	2	3	4	5
\$1k to \$10k	Injury: first aid; Leakage: no contamination of water supply or surface environment damage	Delay of 2 weeks to 6 months	2-Mild	2	4	6	8	10
\$10k - \$100k	Injury: medical procedure; Leakage: localized contamination of water supply or surface environment; additional monitoring required	Delay of 6 to 12 months	3-Moderate	3	6	9	12	15
\$100k - \$1,000k	Injury: permanent; Leakage: reversible contamination of water supply or surface environment, remediation required	Delay of 1 to 2 years	4-Severe	4	8	12	16	20
> \$1,000k	Injury: fatality; Leakage: irreversible contamination of water supply or surface environment	Delay of 2 or more years	5-Catastrophic	5	10	15	20	25



Task 4.0 - Define Play Elements and Criteria

Play Element: Subsurface Examples →

- Data from:
 - Wells (e.g., construction records, geophysical logs, core, brine composition)
 - 2D seismic surveys
 - Maps
 - Models

Containment	Seal Geometry	Structural position, thickness, and areal extent of caprocks
	Seal Integrity	Caprock geomechanical properties in the context of ambient stress fields that may be modified by CO2 injection.
	Saline springs	Natural geological formations where groundwater containing high concentrations of dissolved salts emerges at the Earth's surface.
	Legacy wells	Abandoned or inactive oil, gas, or water wells that were drilled in the past for resource extraction purposes but are no longer in use or have been improperly sealed or plugged.



Task 4.0 - Define Play Elements and Criteria

Play Element: Surface Examples →

- Data from:
 - PRI databases and publications
 - Public sources

Play Element: Societal Examples →

- Data from:
 - Public sources (national atlas, census, CEJST, EJ Screen)

Environmental	Wetlands	areas that are covered (often intermittently) with shallow water or have soil saturated with moisture.
	Karst terrain	Irregular limestone topography with sinkholes, underground streams, and caverns.
	Sole-source aquifer	An aquifer that supplies at least 50% of the drinking water for its service area and there are no reasonably available alternative drinking water sources should the aquifer become contaminated.
Societal Land Use	City limits	Defined boundary of a city.
	Parks	Areas of land set aside and managed for public recreation, conservation, and enjoyment.
	Historic places	Places of historical significance that are worthy of preservation.
	Federally owned land	Land that is owned and managed by the federal government.
	Tribal lands	Areas of land set aside for Native American tribes as part of agreements between the federal government and tribal nations.



Next Steps (Year 2)

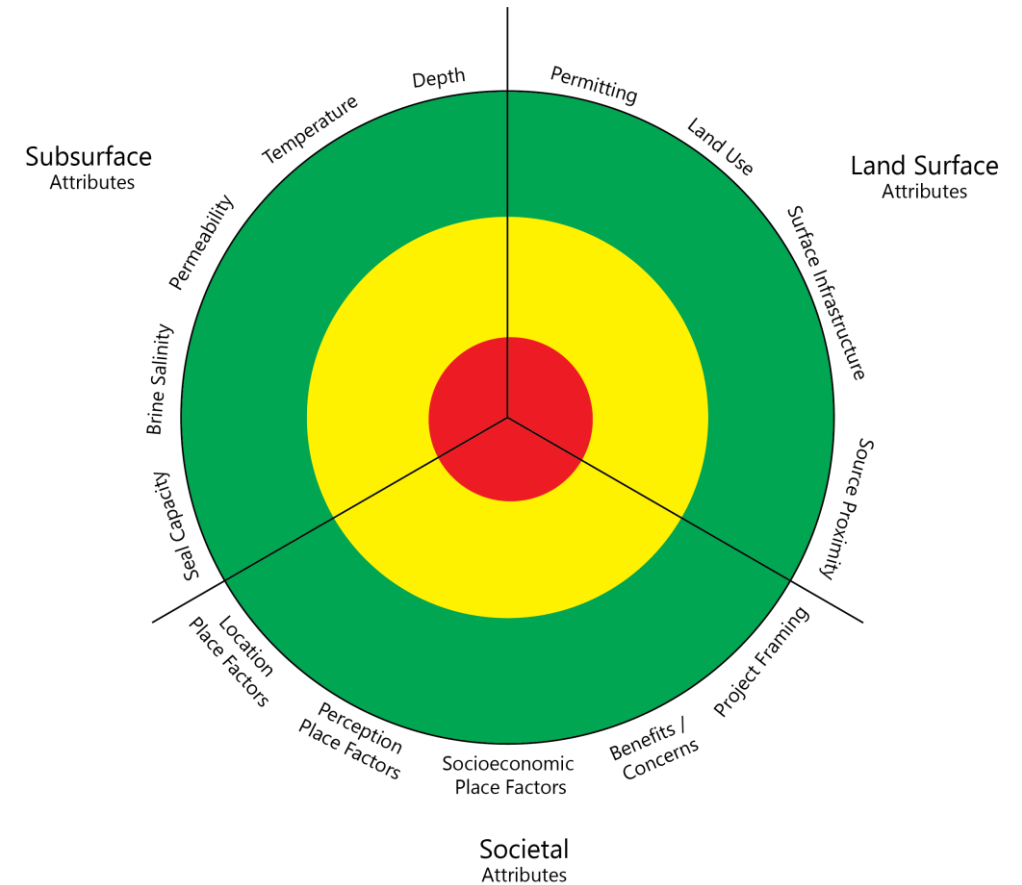
Task 5.0 - Play Element Convolution

- Create CRS maps and define suitability and classify as prospective (green), conditional (yellow), and critical (red)

Task 6.0 - Project Website & Story Mapping

- Develop Annotated and Contextualized Carbon Storage Play Maps for the State of Illinois
- Setting expectations: Suitability criteria will vary
 - ISGS will develop and apply suitability criteria as an exercise; *our criteria and maps will be interesting, not definitive*

Task 6.0 - Play Based Exploration and Analysis for CCS Topical Report





Acknowledgements

- Research herein supported by the US Department of Energy (Project number DE-FE0032366; FPM Jacob Smith)
- Through a university grant program, IHS Petra, Geovariences Isatis, and Landmark Software were used for the geologic, geocellular, and reservoir modeling, respectively
- Thanks to Greg Lackey and the DOE CATALOG team for collaboration on OGRRE well construction record digitization

References

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- von Rothkirch, J., and O. Ejderyan, 2021, Anticipating the social fit of CCS projects by looking at place factors: International Journal of Greenhouse Gas Control, v. 110, p. 103399