Data Gap Assessment
Subtask 4.1
Topical Report

March 1, 2017 through May 30, 2019

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Report Issued: October 30, 2018

Report Number:
U.S. DOE Cooperative Agreement Number: DOE-FE0029445-5
CARBONSAFE ILLINOIS EAST SUB-BASIN

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Executive Summary

Data sets were compiled and assessed for the Cambro-Ordovician Storage Complex across the CarbonSAFE Illinois East Sub-Basin study area to assess the data needs to support drilling a stratigraphic borehole at the East Sub-Basin case study site located at the Wabash Integrated Gasification Combined Cycle (IGCC) plant north of Terre Haute, Indiana. Available data for the Mt. Simon Sandstone, within a 50 mile range in the East Sub-Basin study area, was assembled and cataloged. A summary of regional data documenting seal penetrations in the Cambrian Eau Claire and Ordovician Maquoketa was compiled, but a lack of deep well control over the project area illustrates the need for test boring and data acquisition at the East Sub-Basin case study site.

Introduction

This report summarizes the state of regional data available to support drilling a stratigraphic test hole into the Mt. Simon Storage Complex at the CarbonSAFE Illinois East Sub-Basin case study site. The East Sub-Basin site is located at the Wabash Integrated Gasification Combined Cycle (IGCC) plant north of Terre Haute, Indiana. Available data from the Mt. Simon include, but are not limited to, the following: regional geologic maps, structural maps, water quality, surface geophysics, downhole geophysics, core analysis, petrophysical properties, and geomechanics. This summary of regional data documents the seal penetrations in the Cambrian Eau Claire and Ordovician Maquoketa formations.

Summary

The essential data parameters required to establish storage reservoir suitability include: overlying confining intervals, target formation injectivity, and storage capacity. Regional data in the East Sub-Basin were reviewed to distinguish between required and desired datasets (Table 1), and to identify which of these data are already available to the project.

Data needs		Country/state Scale	Basin Scale	Site Characterisation	Site Deployment
Maps	Regional geology	R	R	D	
	Detailed geology		D	R	R
	Structure		D	R	R
	Reservoir geometry		D	R	R
	Reservoir quality		D	R	R
	Fault	D	D	R	R
	Seismicity	D	D	R	R
	Water salinity	D	D	R	R
	Surface infrastructure	D	D	R	R
	Topography	D	D	R	R
Seismic	2D	D	R	R	R
	3D		D	R	R
Well logs	Gamma ray		D	R	R
	Porosity		D	R	R
	Sonic			R	R
	Density			R	R
	Image			R	R
Core analyses	Porosity	D	R	R	R
	Permeability	D	R	R	R
	Anisotropy			R	R
	Relative permeability			R	R
	Capillary pressure		D	R	R
	Mineralogy		D	R	R
	Rock strength		D	R	R
Hydraulic Tests	Repeat formation tests (RFT), drillstem tests (DST)		D	R	R
	Leak-off tests (LOT); formation integrity tests		D	R	R
Reservoir characterisation	Tectonic model	R	R	D	
	Sequence stratigraphy	D	D	R	R
	Biostratigraphy	D	D	R	R
	Regional stress regime	D	R	D	
	Analogues		D	R	R
	Fluid properties		D	R	R
	Production history		D	R	R
	Static model			R	R
	Dynamic model			R	R
Economics				R	R
Regulatory framework				R	R

D: desirable; R: required

Table 1: Summary of main data needs for reservoir characterization (modified from Kaldi and Gibson-Poole, 2008).

The CarbonSAFE Illinois East Sub-Basin project builds upon several regional or site-specific studies within the study area, including the US DOE FutureGen initiative, research of the DOE's Regional Carbon Sequestration Partnership program, and other DOE-funded projects such as the evaluation of the Cambrian-Ordovician strata and a study on residual oil in the Mississippian Cypress Sandstone.

The Mt. Simon Sandstone (Figure 1) has excellent properties for large-scale carbon storage: it is deeply buried throughout the East Sub-Basin study area, with pressures and temperatures which can maintain CO_2 as supercritical; contains non-potable, highly saline formation waters; has anticipated favorable storage capacity (US DOE, 2015); is overlain by numerous laterally extensive sealing formations (Figure 1); has suitable petrophysical characteristics for injection.

Data sets were compiled in the East Sub-Basin primary region of interest (Figure 2) to assess the state of data availability documenting penetration into or through the Ordovician system and the Cambrian Eau Claire Shale. Any available datasets for the Mt. Simon within 50 miles of the East Sub-Basin case study site, within the East Sub-Basin region of interest, were compiled and assessed to determine data deficiency.

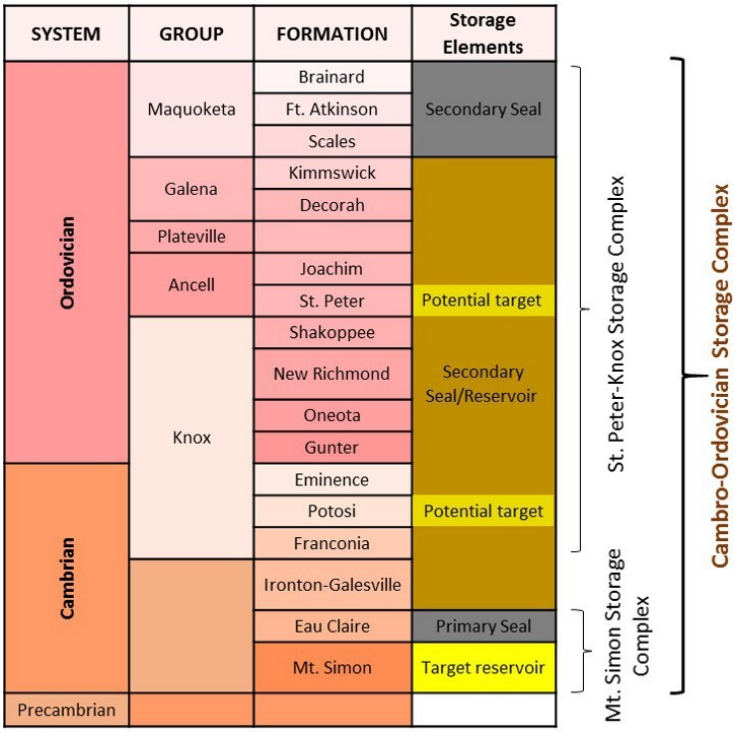

Figure 1. Storage complexes (reservoirs and seals) identified in stratigraphic column of the Cambrian and Ordovician Strata in the central Illinois Basin

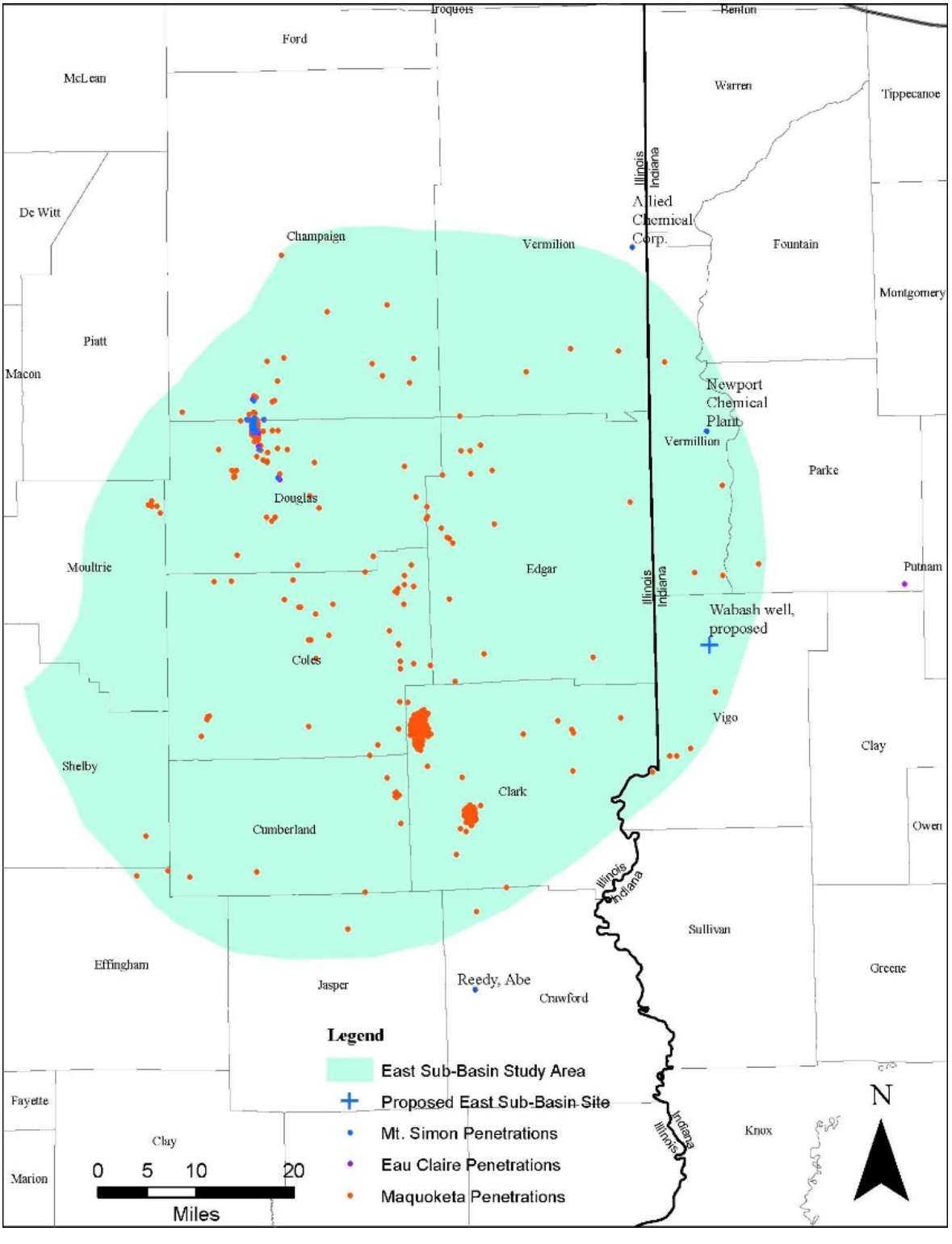

Figure 2. East Sub-Basin region of primary interest showing drilling penetrations into the Mt. Simon, Eau Claire, and Maquoketa formations.

In the Illinois Basin, hydrocarbon reservoirs have been one focus for potential carbon capture and sequestration (CCS) opportunities, due in large part to the significant supporting datasets from years of study and characterization.

Deep saline formations are very promising for large-scale CO_2 storage since the formations are often much more extensive than hydrocarbon reservoirs, resulting in greater potential storage capacity and higher likelihood for being present near CO_2 sources. Although these formations possess and have demonstrated a large potential for storage, the deep saline formations have far less data available for characterization compared to the relatively shallower hydrocarbon fields.

Deep saline formation data within the CarbonSAFE Illinois East Sub-Basin region of interest are scarce (Table 3). There are 15 Upper Mt. Simon penetrations in northern Douglas County: 14 wells were associated with the Tuscola Gas Storage Field while 1 location, east of Tuscola, was an oil exploration attempt. Tuscola Gas Storage Field records indicate 4 Mt. Simon core analysis reports, 169 brine analysis reports from 14 Mt. Simon wells, and geophysical log suites (Micro, Induction Electric, Neutron, and Sidewall Neutron Porosity) vintage 1970. Tuscola Gas Storage Field in northern Douglas County is immediately adjacent to Hayes Oil Field in southern Champaign County which focused oil production work in the Ordovician Trenton Formation. An additional 5 penetrations into the Mt. Simon were recorded in southern Champaign County.

The nearest well to the East Sub-Basin case study site penetrating the Upper Mt. Simon is the Newport Chemical Plant #WD-1, located approximately 22 miles north, which has fair reservoir quality, and was used as a disposal well for millions of gallons of wastewater. This well only penetrated the top 900 feet of the Mt. Simon so the Lower Mt. Simon remains unexplored in the local Wabash area. Data for Newport Chemical Plant #WD-1 include geophysical logs (Gamma, Neutron, SP, and Resistivity) collected in 1960, Mt. Simon core analysis, and a single brine sample analysis. Outside our study area, the Duke Edwardsport and Gibson wells, located 50 and 75 miles south of the proposed location also penetrated the Mt Simon and possessed fair quality reservoir characteristics.

Table 2. Deep well penetrations in the study area with distance from the Wabash site.

API/Well ID	Well Name	Well No.	Distance from Wabash site (miles)	Total Depth (feet)	State	County	Penetration	In Study Area?
121830184800	Allied Chemical Corporation	1	41.5	6684	IL	Vermilion	Lower Mt. Simon	N
120333567100	Abe Reedy	A1	42.5	8347	IL	Crawford	Upper Mt. Simon	N
125110	Newport Chemical Plant	WD-1	21.9	6160	IN	Vermillion	Upper Mt. Simon	Y
157501	Summers	24-15	20.9	4668	IN	Parke	Eau Claire	N
124214	Swan Street	0	4.7	2980	IN	Vigo	Maquoketa	Y

Table 3. Well penetrations of the Maquoketa, Eau Claire, and Mt. Simon formations in the East Sub-Basin primary region of interest

State	Maquoketa penetrations	Eau Claire penetrations	Mt. Simon penetrations
IN	10	1	1
IL	442	28	19

Allied Chemical Corporation is the nearest penetration into the Lower Mt. Simon is 1.65 miles outside the region of interest (see map) and 41.5 miles north of the East Sub-Basin site. Modern log suites and well documentation are available for that well, and also for the nearest other two Mt. Simon penetrations to the site, though they only penetrate the Upper Mt. Simon (Table 2). There are relatively few well penetrations into the Lower Mt Simon within the Illinois Basin. The Hinton #7 well, located in Manlove Gas Storage Field, Champaign Co., Illinois, 75 miles northwest of the Wabash site, has 215 feet of excellent quality reservoir.

Full well documentation is available for the nearest Eau Claire well penetration, in Parke Co., Indiana. The nearest Maquoketa well penetration is undocumented, but a significant amount of data is available across the over 400 Maquoketa penetrations within the region of interest.

There are no commercially-available 2D seismic data in the immediate vicinity of the CarbonSAFE Illinois East Sub-Basin case study site. The seismic data nearest the site are over 30 miles to the south and west, in Illinois. Data acquisition for the East Sub-Basin case study site should be planned to avoid or minimize the overlap of surface transect lines with abandoned underground coal mines (existing throughout Vigo County, Indiana), as the presence of coal mine voids may degrade the quality of deeper seismic reflection information.

Modeling and Risk Assessment

An assessment of the National Risk Assessment Partnership (NRAP) tool(s) used in the CarbonSAFE Illinois East Sub-basin prefeasibility study will be addressed in a separate report. However, for a potential feasibility study at the East Sub-Basin case study site, the NRAP tools could be employed to 1) evaluate the performance of the tools for the specific tasks and 2) improve the site risk assessment by quantifying the potential impact scenarios such as leakage of CO_2 or brine. The tools applied to an East Sub-Basin site would be the Integrated Assessment Model (IAM) and the Design for Risk Evaluation and Management (DREAM) modules. The tools typically require as input estimates of static properties at the site scale, including average permeability, porosity, salinity, temperature, elevation, and thickness. The tools also require output from separate reservoir simulation models of the distribution of CO_2 pressure and saturation from planned injection.

The properties needed (Table 4) would require assessment of the storage reservoir and overlying formations, including any Underground Source of Drinking Water (USDW) aquifers that could be impacted. Estimates exist for these values from regional studies, and other input, such as the intrinsic permeability of hypothetical leaking wells, is available in the literature and built-in data libraries of the tools themselves. The reservoir simulation output required for some modules, like the IAM tool, would be generated in the course of project tasks, and extracted as necessary. However, the DREAM tool requires a special simulation of three-dimensional advection and transport of brine or CO_2 leaking into an overlying aquifer. This data gap is anticipated and the required output would be generated during the project.

The majority of data required for the NRAP tools is assembled during the initial site review or generated as output from reservoir simulations. However, regional data estimates can only be further refined by acquiring additional subsurface data nearer the project site.

Table 4. Variables impacting storage reservoir and overlying aquifer used in the example NRAP IAM and DREAM tools.

Static data generated as part of the characterization	
Storage reservoir	Elevation
	Thickness
	Mean permeability & porosity
	Salinity
	Temperature

Reservoir simulation data generated as part of the characterization	
Storage reservoir	Pressure before, during and after injection
	CO_2 saturation before, during and after injection
Static data available on a regional basis	
Overlying aquifer	Elevation
	Thickness
	Mean permeability & porosity
	Salinity
	Temperature

Reservoir simulation data that will be conducted solely for NRAP	
Overlying aquifer	CO_2 saturation from hypothetical leakage
	Salinity/TDS change from hypothetical leakage
	Ph change from hypothetical leakage

Conclusions

Regional well data and geological trends support the existence of favorable Mt. Simon reservoir characteristics at the CarbonSAFE East Sub-Basin case study site. However, the lateral continuity of high quality Lower Mt. Simon reservoir remains uncertain due to limited well control. In order to determine the potential reservoir quality, heterogeneity, and capability for long-term and large-scale storage, a geological characterization borehole must be completed at the East Sub-Basin site. The acquisition and interpretation of downhole geophysical log suites, petrographic analysis of core samples, geochemical evaluation formational fluid samples, and 2D seismic survey data would provide much needed data control to underpin our geological characterization of the East Sub-Basin case study site and enhance our regional understanding of the Cambrian and Ordovician storage complexes in the Illinois Basin.

References:

Kaldi, J.G., Gibson-Poole, C.M. (Eds.), 2008. Storage Capacity Estimation, Site Selection and Characterisation for CO2 Storage Projects. Report No: RPT08-1001, CO2CRC, Canberra, ACT, AU.

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