Stacked Greenfield and Brownfield ROZ Fairways in the Illinois Basin Geo-Laboratory: Co-optimization of EOR and Associated CO_2 Storage

DOE Project Number DE-FE0031700

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ILLINOIS
Illinois State Geological Survey
PRAIRIE RESEARCH INSTITUTE

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National Energy Technology Laboratory
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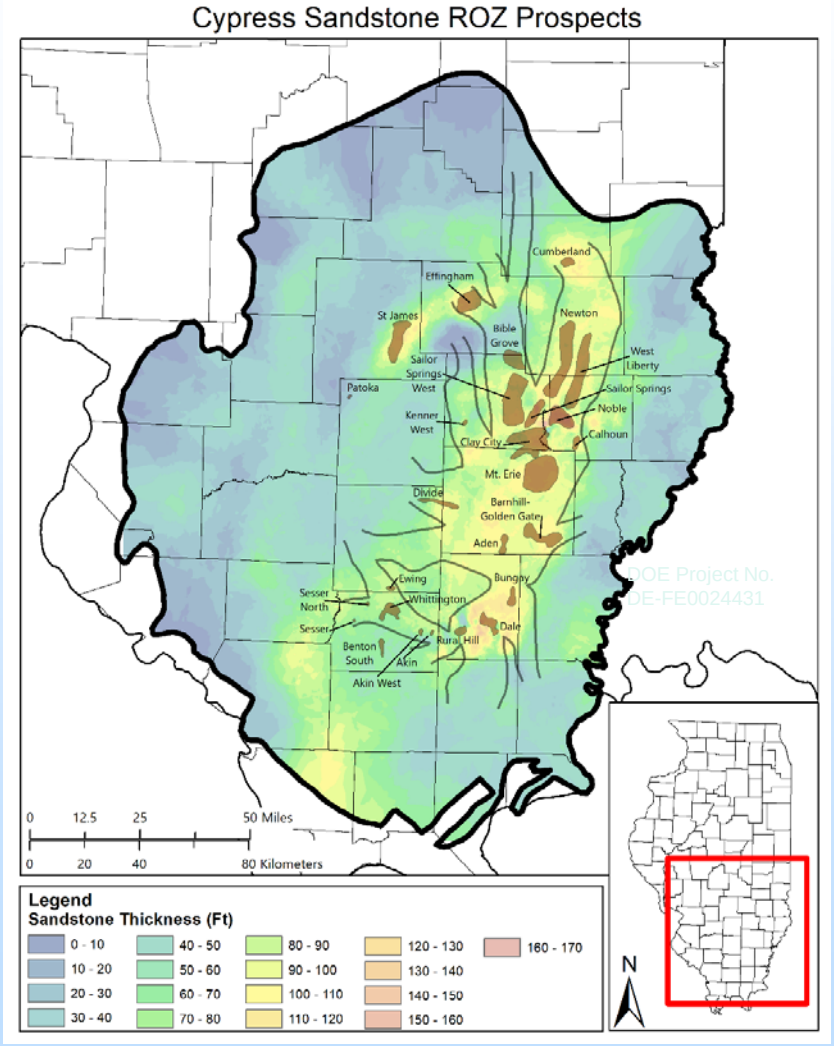
Presentation Outline

- Motivation
- Methodology
- Accomplishments
- Summary
- Future work
- Synergy opportunities
- Acknowledgements
- Appendices

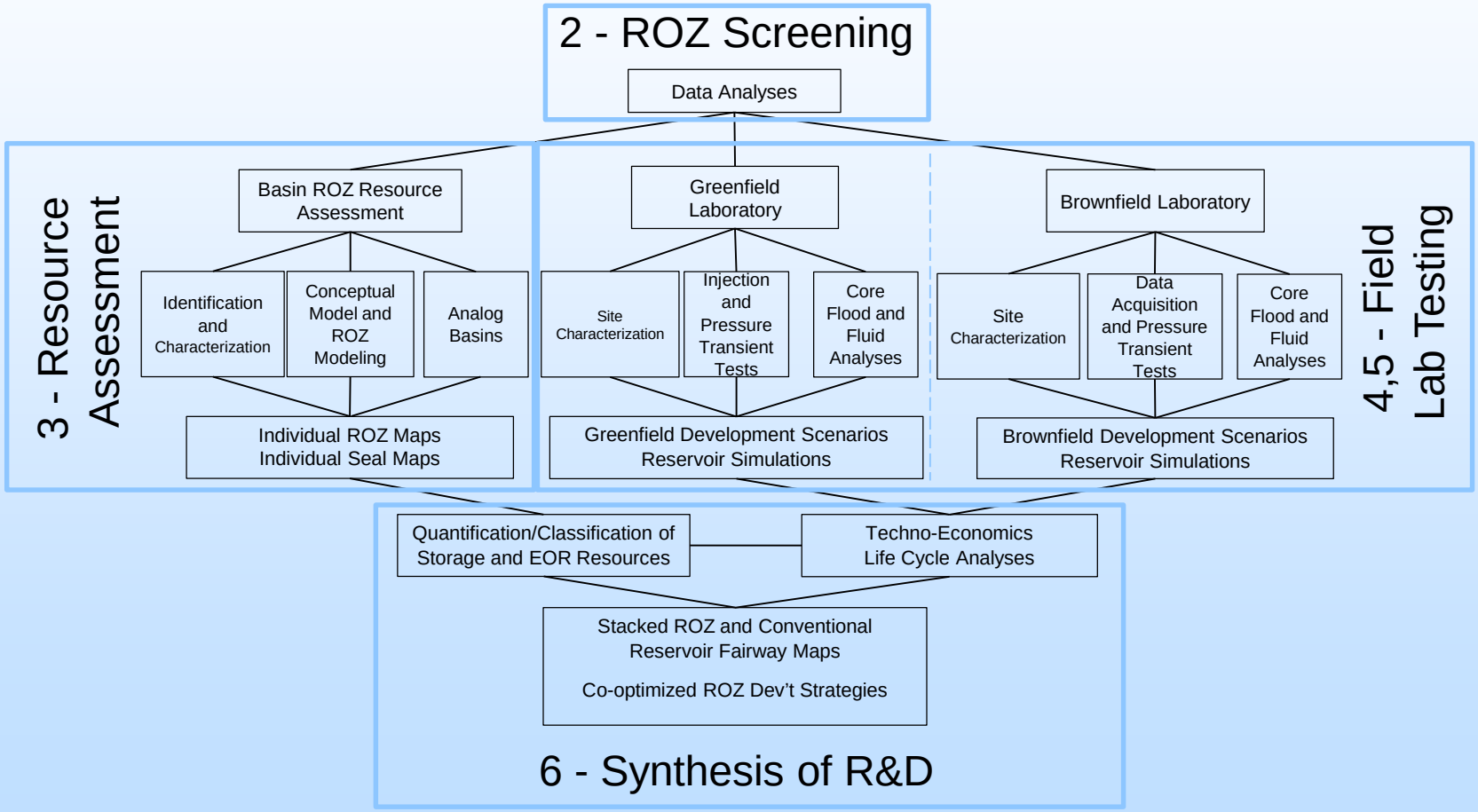
Illinois Basin ROZ research

- ROZ fairway in Cypress Sandstone
  - Found greenfields and brownfields
  - Developed methods to identify /characterize ROZ
    - Well log analysis; historical data; core
  - Investigated geologic controls on ROZ
  - Developed production strategies
- New Cypress CO_2-EOR and storage resource
  - ROZ fairway covers ~1.9 million acres
    - Contains ~1 million acre-ft of pore volume
  - Estimated resource in ROZ prospects:
    - 1.8 billion barrels of oil in place[1]
    - 196 million barrels recoverable[2]
    - 10.4 billion tonnes associated CO_2 storage[3]



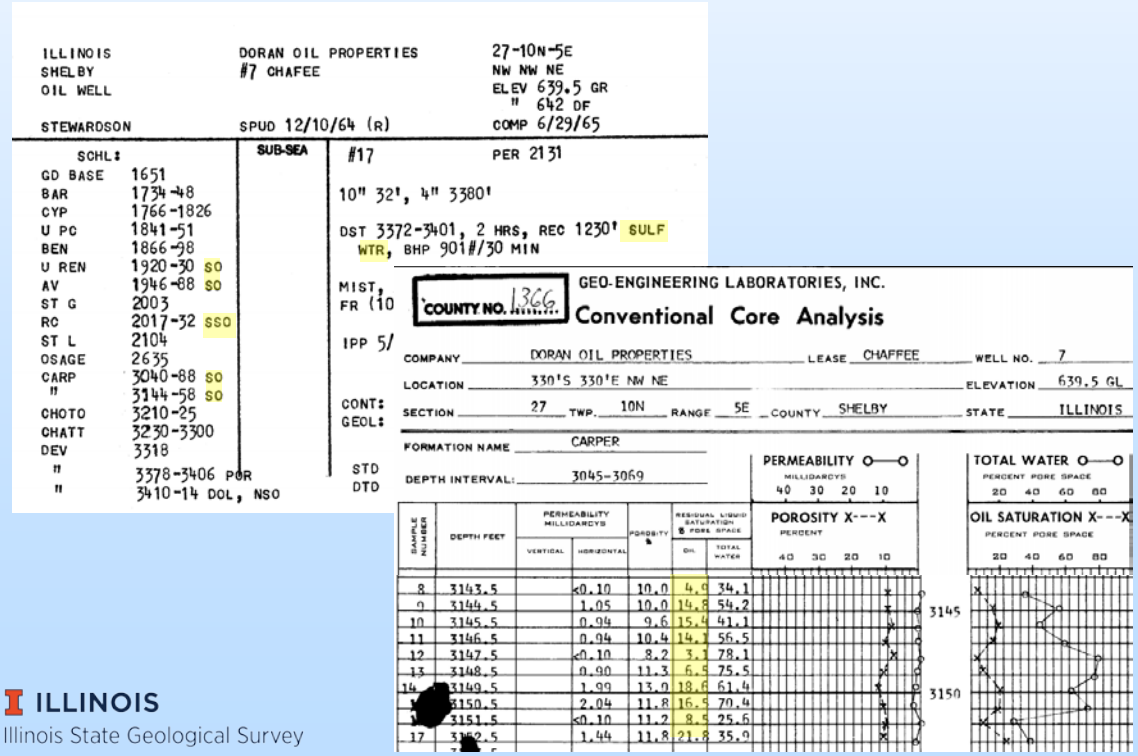
[1]23% median S_{OR}
[2]80-acre WAG flood EOR factor of 11.4% assuming miscible conditions
[3]Net utilization of 1,479 Mscf/stb

Project tasks



ROZ screening

- Screening seven formations
  - Five siliciclastics, two carbonates
- Working with oil field database
  - Analyzing, digitizing, and mapping data



ILLINOIS
SHELBY
OIL WELL

STEWARDSON

DORAN OIL PROPERTIES
#7 CHAFEE

SPUD 12/10/64 (R)

27-10N-5E
NW NW NE
ELEV 639.5 GR
" 642 DF
COMP 6/29/65

SCHL:

GD BASE	1651	
BAR	1734-48	
CYP	1766-1826	
U PC	1841-51	
BEN	1866-98	
U REN	1920-30	SO
AV	1946-88	SO
ST G	2003	
RC	2017-32	SSO
ST L	2104	
OSAGE	2635	
CARP	3040-88	SO
"	3144-58	SO
CHOTO	3210-25	
CHATT	3230-3300	
DEV	3318	
"	3378-3406	POR
"	3410-14	DOL, NSO

SUB-SEA

#17 PER 2131

10" 32', 4" 3380'

DST 3372-3401, 2 HRS, REC 1230' SULF WTR, BHP 901#/30 MIN

MIST, FR (10

IPP 5/

CONT:
GEOL:

STD
DTD

COUNTY NO. 1366

GEO-ENGINEERING LABORATORIES, INC.

Conventional Core Analysis

COMPANY DORAN OIL PROPERTIES LEASE CHAFFEE WELL NO. 7

LOCATION 330'S 330'E NW NE ELEVATION 639.5 GL

SECTION 27 TWP. 10N RANGE 5E COUNTY SHELBY STATE ILLINOIS

FORMATION NAME CARPER

DEPTH INTERVAL: 3045-3069

PERMEABILITY MILLIDARCYS 40 30 20 10

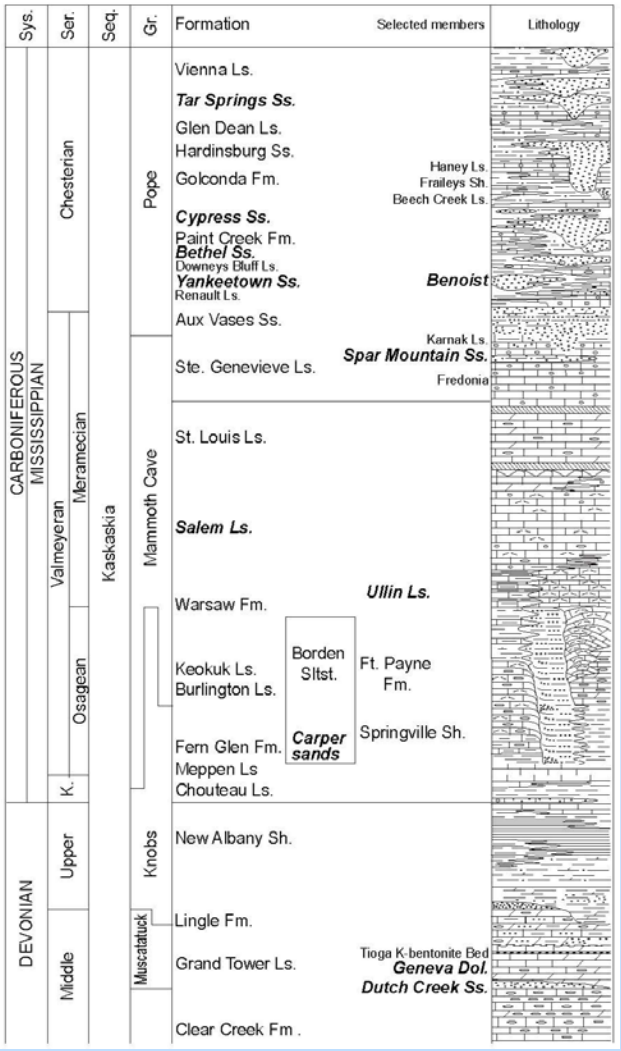
TOTAL WATER PERCENT PORE SPACE 20 40 60 80

POROSITY X---X PERCENT 40 30 20 10

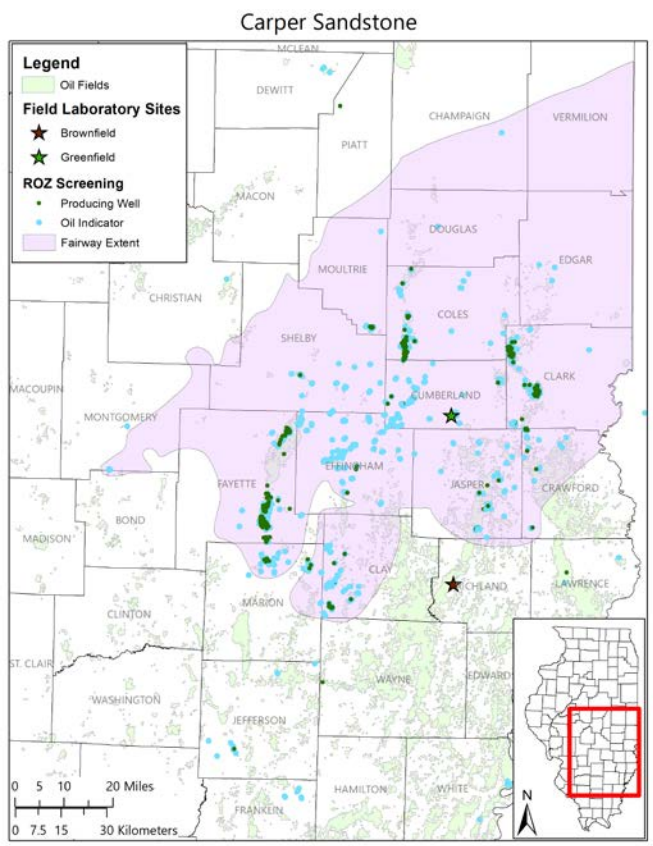
OIL SATURATION X---X PERCENT PORE SPACE 20 40 60 80

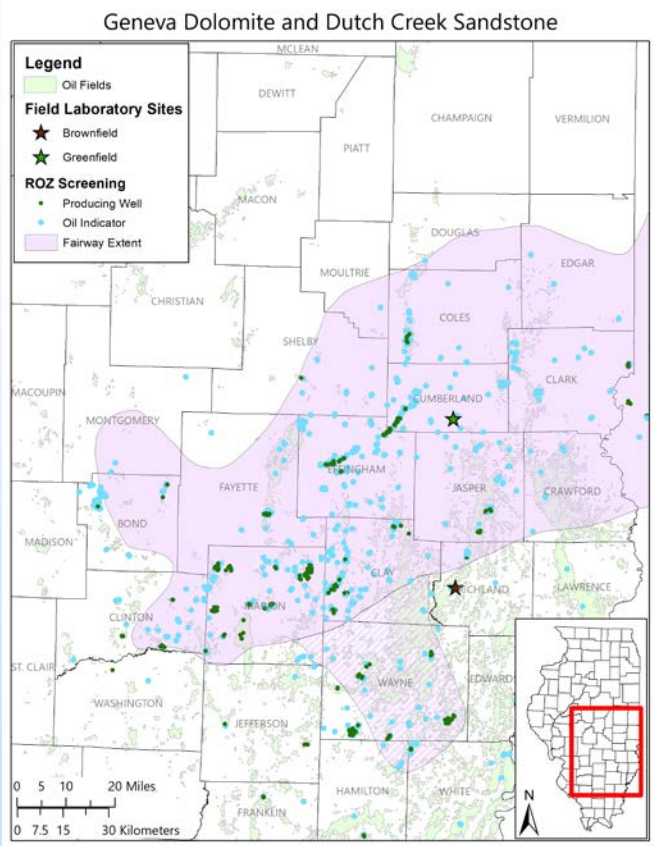
SAMPLE NUMBER	DEPTH FEET	PERMEABILITY MILLIDARCYS VERTICAL	PERMEABILITY MILLIDARCYS HORIZONTAL	POROSITY	RESIDUAL LIQUID SATURATION % PORE SPACE OIL	RESIDUAL LIQUID SATURATION % PORE SPACE TOTAL WATER
8	3143.5		<0.10	10.0	4.9	34.1
9	3144.5		1.05	10.0	14.8	54.2
10	3145.5		0.04	9.6	15.4	41.1
11	3146.5		0.04	10.4	14.1	56.5
12	3147.5		<0.10	8.2	3.1	78.1
13	3148.5		0.90	11.3	6.5	75.5
14	3149.5		1.99	13.0	18.6	61.4
15	3150.5		2.04	11.8	16.5	70.4
16	3151.5		<0.10	11.2	8.5	25.6
17	3152.5		1.44	11.8	21.8	35.9

3145
3150



ROZ screening





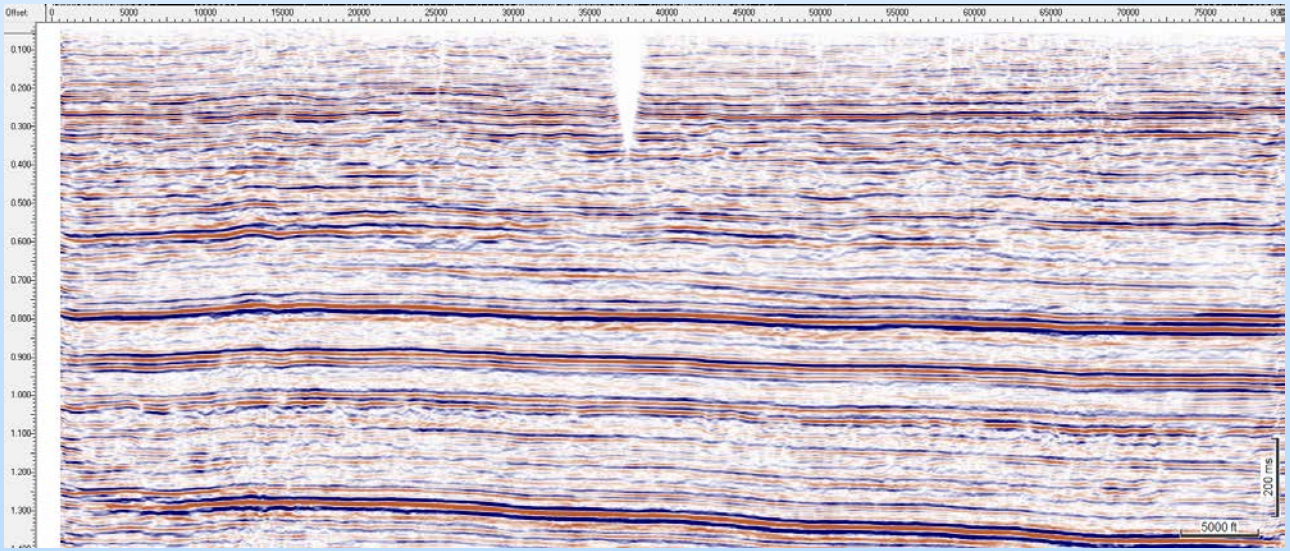
- Selecting three ROZs for regional characterization based on:
  - Geologic properties (porosity, permeability, fairway potential)
  - ROZ indicators (oil shows, core with S_o>0, DSTs with sulfur water – e.g. Trentham and Melzer 2013)
  - Data availability (well logs, core)

Data compilation and analyses

- Regional characterization of selected ROZs
  - Locating available core data
- Field lab sites
  - Brownfield site
    - Developing geological prognosis for research well
    - Acquired seismic as part of CarbonSafe (DE-FE0029445)
  - Greenfield site
    - Obtained operator data (core analysis, completion, stimulation, production)

Noble Field

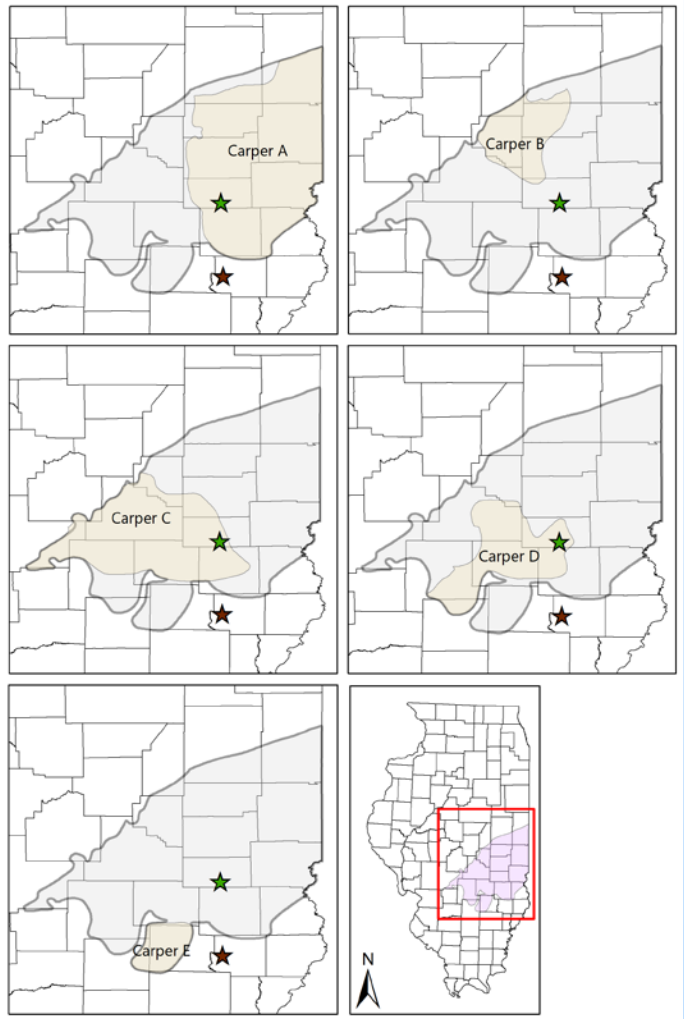
North



South

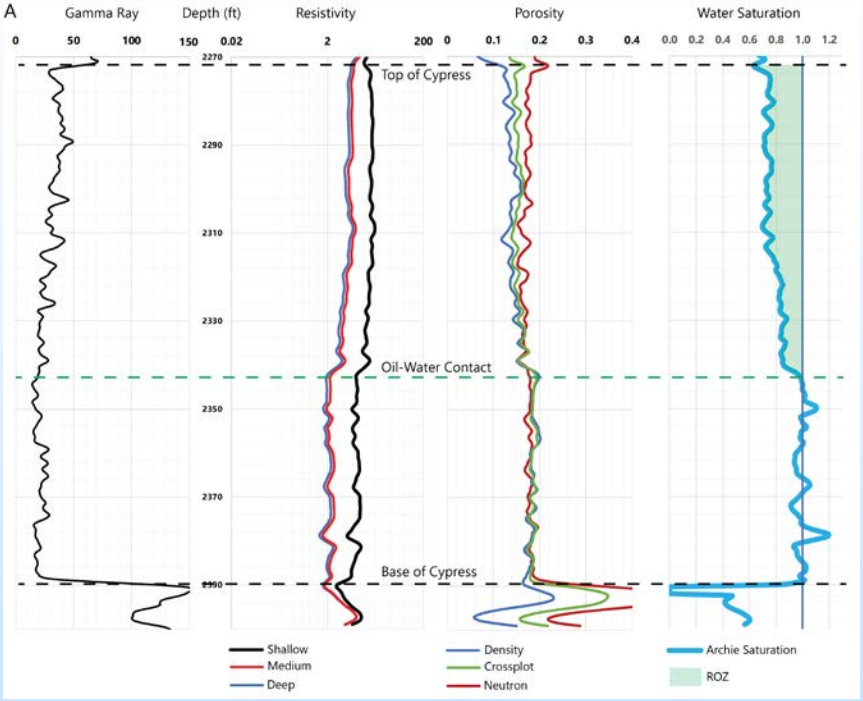
Characterization

- Developing geologic model for Carper Ss:
  - Mapping reservoir body geometry and architecture
  - Classifying facies
  - Characterizing petrophysical and mineralogical properties
  - Interpreting depositional environment and diagenetic histories
- Identifying samples to begin laboratory testing
  - Petrography, MICP, relative permeability, core flooding

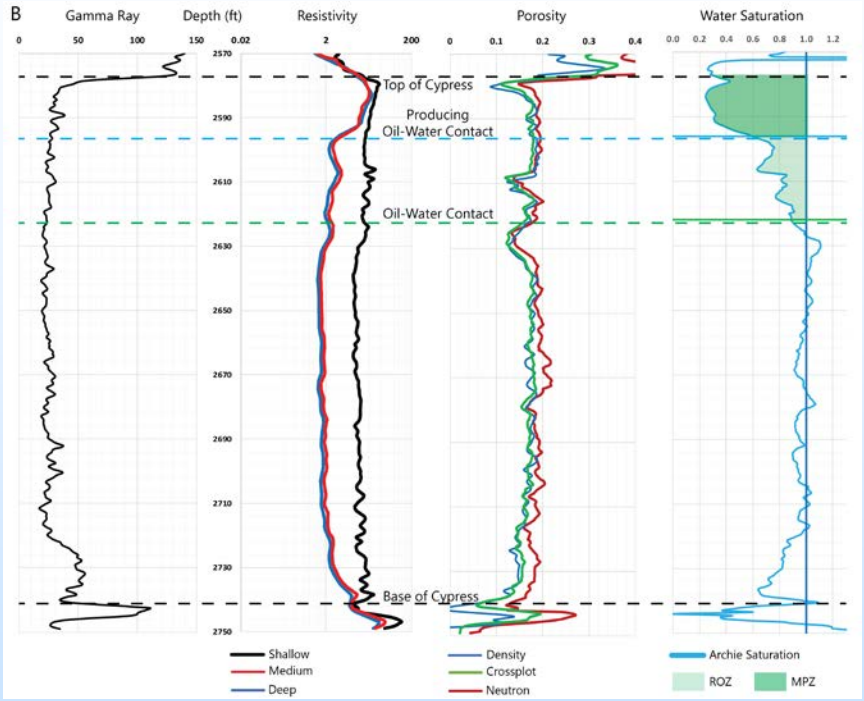


Well log analysis

Greenfield site



Brownfield site

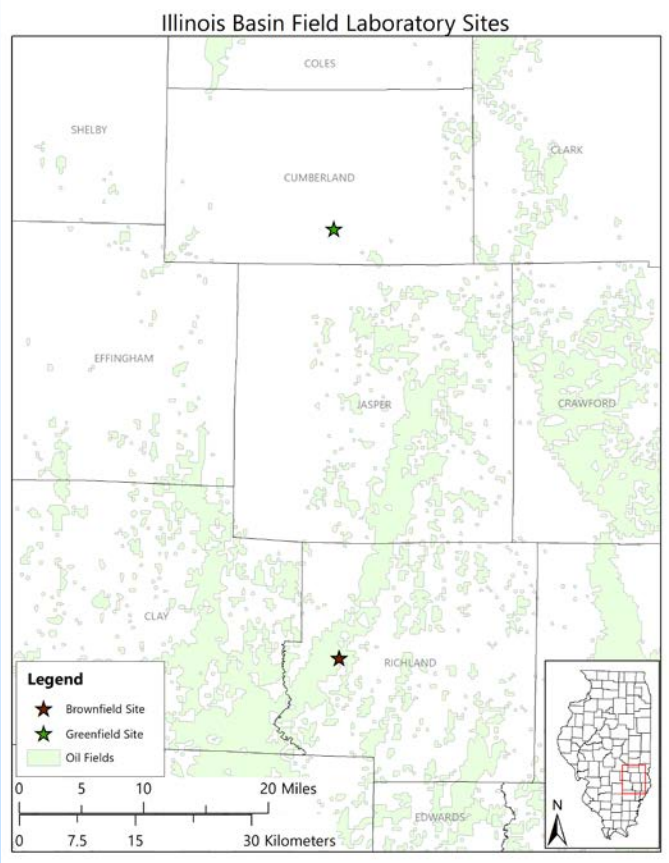


- Analysis techniques
  - Developed and calibrated for the Cypress Sandstone
  - Adjusting to deal with more heterogeneous rocks
    - Different lithology, mineralogy, texture, fluid properties, etc.

Field laboratory test preparation

Greenfield Site Plan

- Perform pressure transient tests in existing well
- Conduct short term CO_2 injection test (huff n' puff or single well chemical tracer test) to acquire oil rate change
  - Characterize ROZ
  - Demonstrate efficacy of CO_2-EOR in ROZ



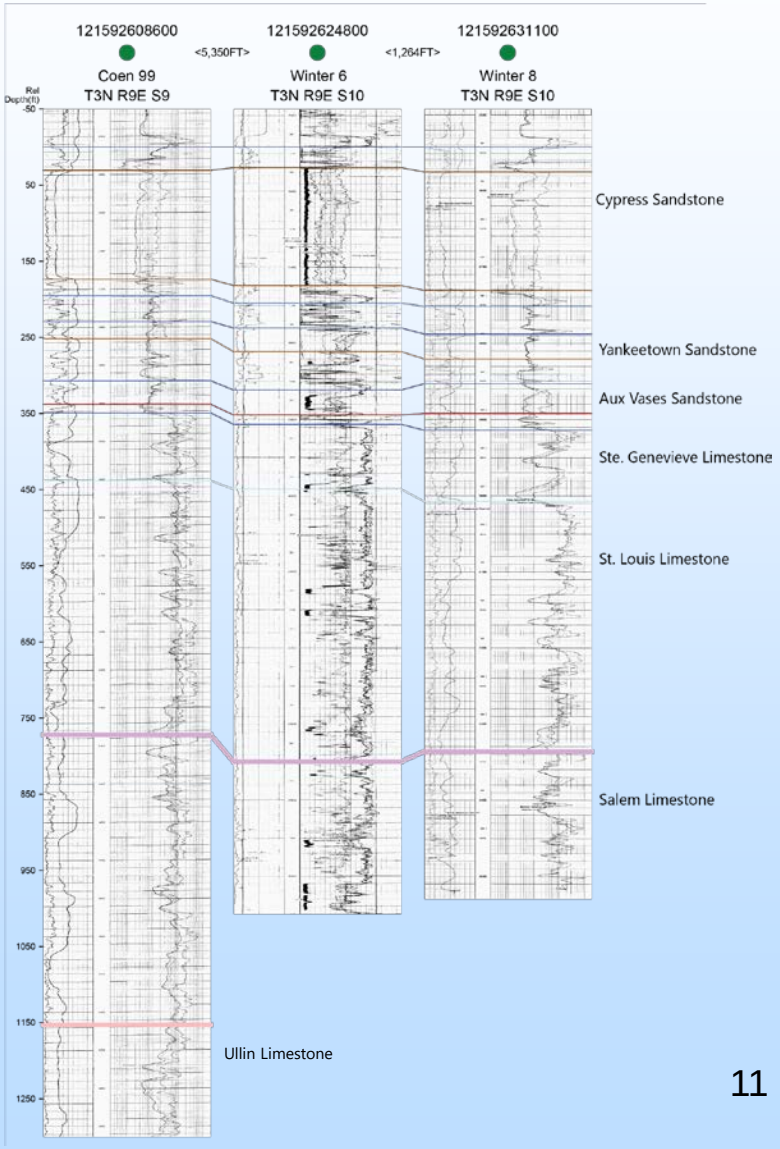
Brownfield Site Plan

- Drill new well for reservoir characterization
  - Collect core and logs to validate Cypress ROZ
    - Correlate with previous field laboratory RST logging
    - Investigate geologic controls on residual oil saturation
    - Refine geologic interpretation
  - Sample reservoir fluids
  - Perform pressure transient tests

- Use field laboratory test data to calibrate reservoir models

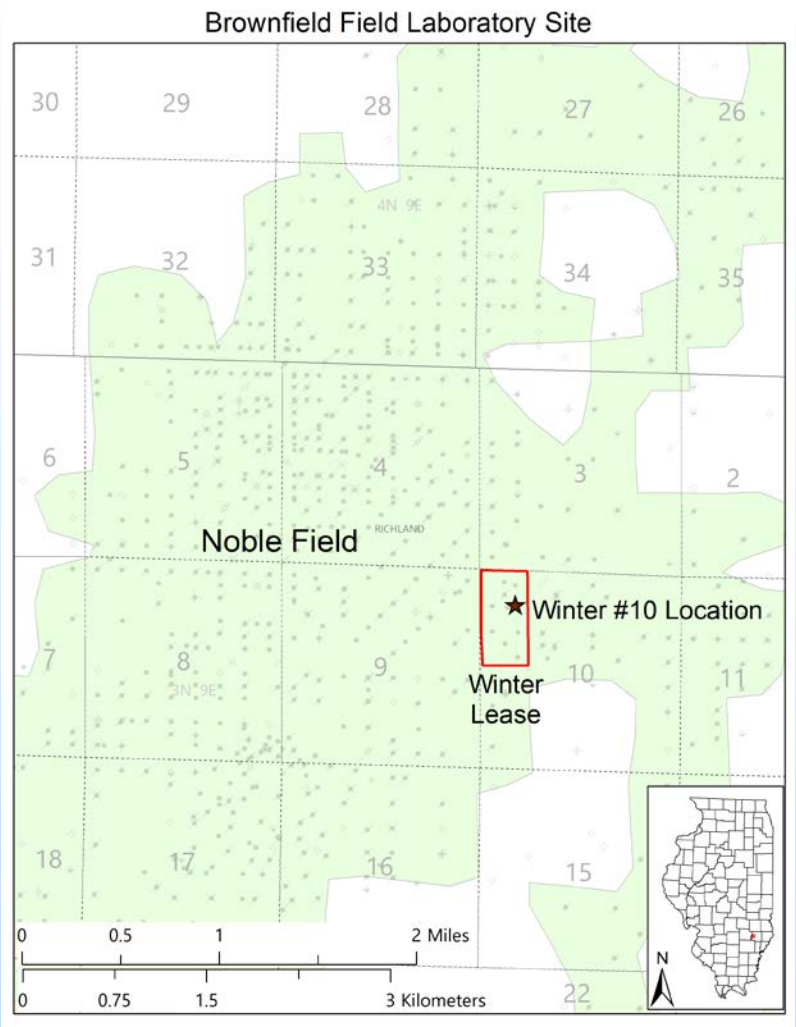
Brownfield site – characterization

- Identifying and correlating stacked ROZs and conventional reservoirs
  - Seven producing reservoirs; additional formations with oil indicators
- Developing maps to be used in models and reservoir simulations
- Identifying available core



Brownfield site – well planning

- Working with site operator (Podolsky Oil) to plan research well
  - Determined location and obtained permit
  - Discussing coring and logging program
- Examining data from adjacent wells to avoid redundant data collection

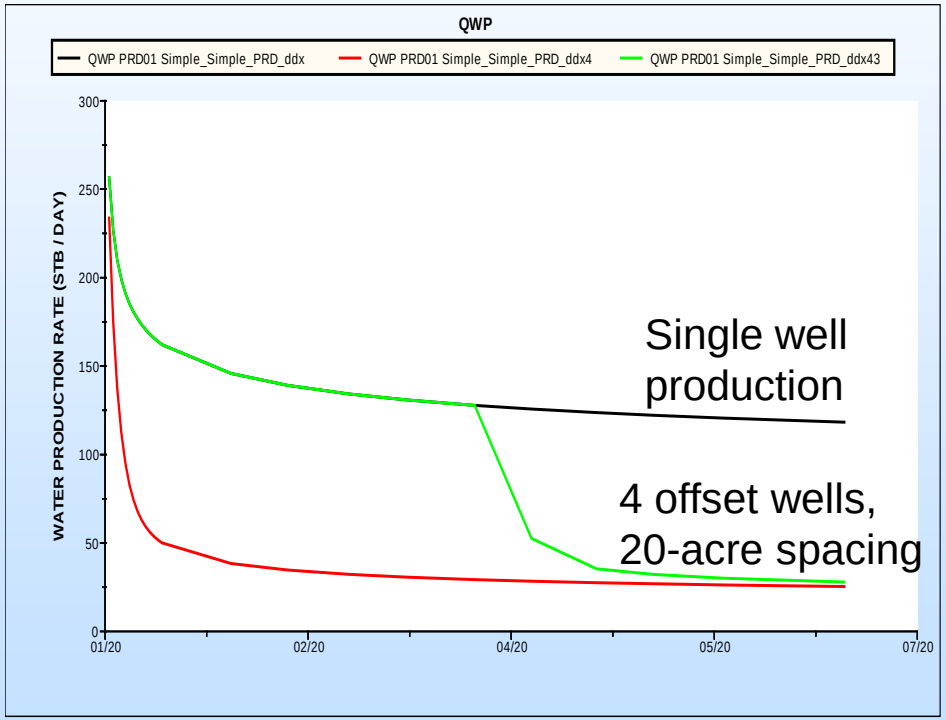


Greenfield site – data analysis

- Working with site operator (Bi-Petro Inc.) to analyze existing well data
  - Reconciling six months of production data with reservoir properties derived from core and logs to identify what additional analyses are needed
- Correlating reservoir with nearby wildcat wells and oil fields to determine its extent and continuity

Greenfield site – injection design

- Developed simple homogenous model with typical properties
- Matching historical water production
  - Mimicking hydraulic fracture stimulation by doubling wellbore radius and using negative skin
  - Exploring possible causes for later drop in water production
- Modeling CO_2 injection to evaluate achievable rate, duration
  - Planning for up to 1,000 tons



Lessons learned

- Projects that incorporate field laboratory research require extra attention to detail to:
  - Reconcile schedule (project vs. operator vs. weather)
  - Meet **all** stated objectives
  - Stay on budget

Project summary

- Many formations in the Illinois Basin have oil indicators outside of productive areas and potential for ROZs; selections being made for ROZs to characterize
- Characterization of Carper Sandstone underway
- Preliminary modeling and simulation efforts ongoing to design CO_2 injection test at greenfield site
- Geologic characterization underway at brownfield site to prepare for drilling and modeling

Future work

- Finalize selection of ROZs for characterization
- Begin characterization of selected ROZs
- Prepare for field laboratory research
  - Design injection test for greenfield site
  - Design coring and logging program for brownfield site

Synergy opportunities

- Methodologies for finding and characterizing ROZs in mature basins developed as part of this study are applicable in other basins
  - We look forward to comparing the results with findings from the Williston and Powder River Basins
- Siliciclastic ROZs in other basins are expected to have similar characteristics to Illinois Basin ROZs
  - Lessons learned from CO_2 flooding in siliciclastics in the Powder River Basin would be applicable to our ROZs

Acknowledgments

- Research herein was supported by US Department of Energy contract number DE-FE0031700
- Through a university grant program, IHS Petra, Geovariences Isatis, and Landmark Software were used for the geologic, geocellular, and reservoir modeling, respectively

- For project information, including reports and presentations, please visit:

http://www.isgs.illinois.edu/research/ERD/NCO2EOR

Appendix: Benefit to the program

- Goal: The Storage Infrastructure Technology Area research effort is carrying out regional characterization and small- and large-scale field projects to demonstrate that different storage types in various formation classes, distributed over different geographic regions, both onshore and offshore, have the capability to permanently store CO_2 and provide the basis for commercial-scale CO_2 projects. This, working together with the two other research areas, address significant technical challenges in order to meet program goals that support the scale-up and widespread deployment of CCS.
- Benefits Statement: This research will potentially demonstrate CO_2-EOR and associated storage as an economically feasible option for small-middle size operators in the Illinois Basin and drive demand for CO_2 and investment in infrastructure.

Appendix: Project Overview
Goals

DOE Program

- ROZs:- formation, characterization, and associated storage in conjunction with EOR
- Co-optimizing CO_2-EOR with associated storage in storage complexes that have stacked reservoirs

Stacked ROZ Fairways in ILB Geo-Laboratory

- Identify and characterize primarily siliciclastic ROZs and quantify the CO_2-EOR and associated storage resource using data collected and test results from greenfield and brownfield field laboratory sites
- Design economic development strategies to co-optimize CO_2-EOR and associated storage in stacked storage complexes using reservoir simulations calibrated to field laboratory test results

Appendix: Project overview
Objectives

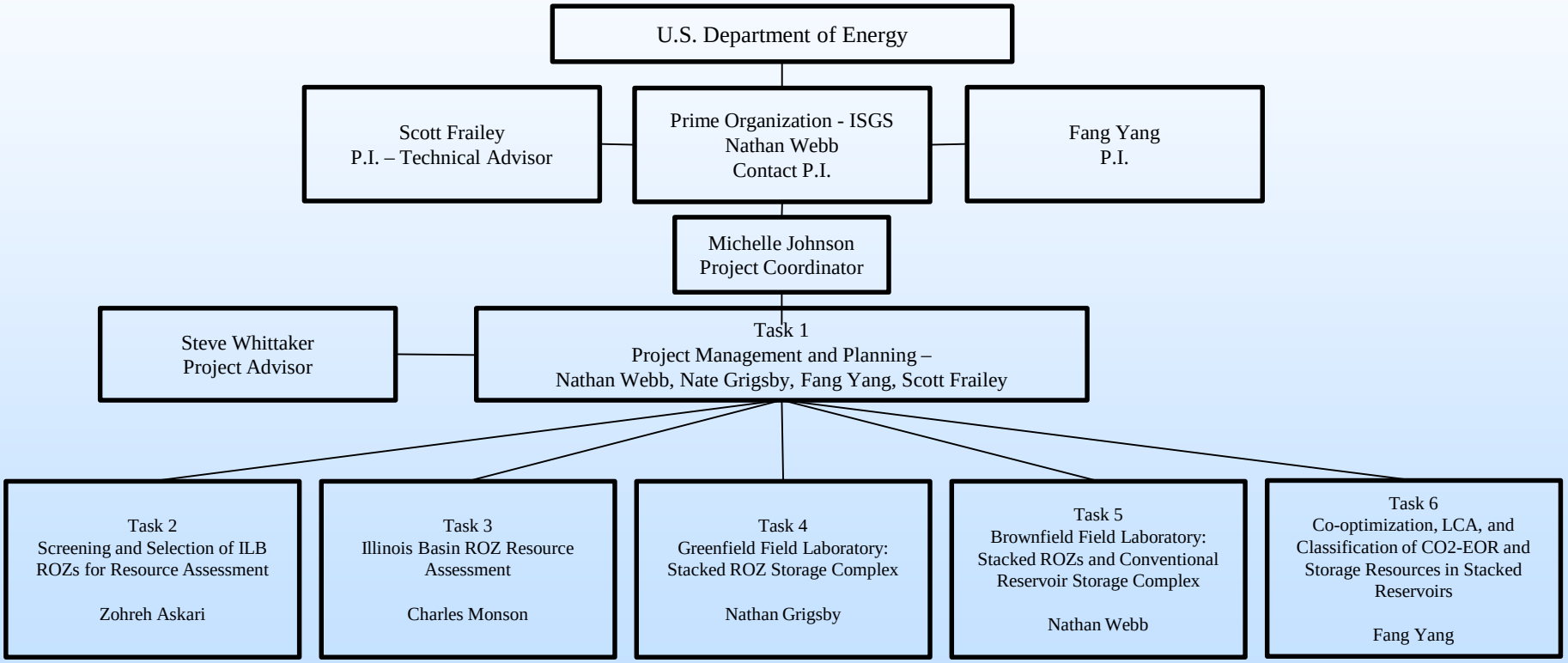
DOE Program

- Develop specific subsurface engineering approaches leveraging CO_2 injection field tests and applied research and development, that address research needs critical for advancing CCS to commercial scale

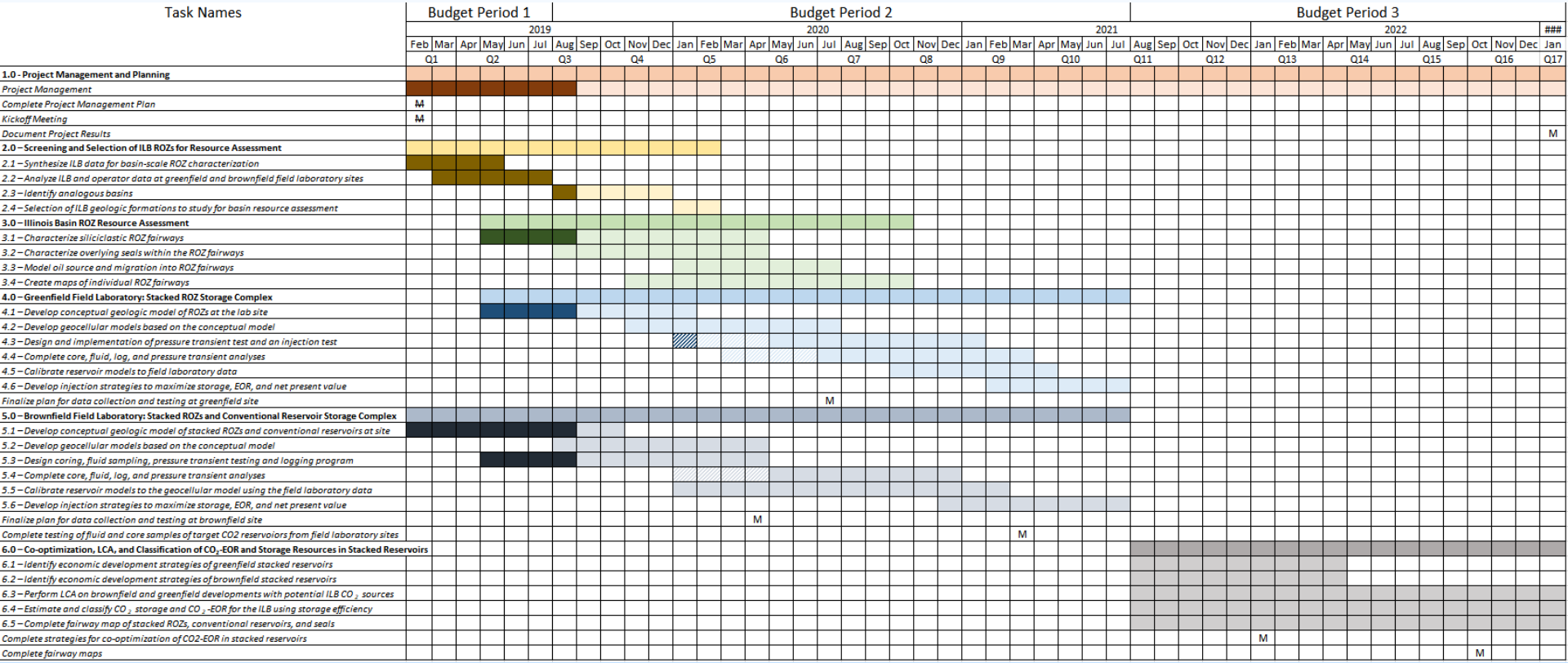
Stacked ROZ Fairways in ILB Geo-Laboratory

- Screen for ROZs using analysis of empirical data and basin evolution modeling
- Characterize stacked brownfield/greenfield siliciclastic ROZs at field laboratory sites
- Conduct injection tests and collect and analyze core and logs at field laboratory sites
- Employ calibrated simulation models and life-cycle analyses for identifying development strategies

Appendix: Organization chart



Appendix: Gantt chart



Appendix: Bibliography

- Nothing to report