Wabash CarbonSAFE

DE-FE0031626

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U.S. Department of Energy

National Energy Technology Laboratory

Final Project Review Meeting

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Presentation Outline

Technical Status, Project Background

Accomplishments

Project Review

- Mt. Simon-Eau Claire Storage Complex
- Potosi-Maquoketa Storage Complex
- Regional Characterization
- Other Assessments and Reporting

Project Summary: Key Findings, Next Steps

Technical Status

Project Background

Phase II: Assess the feasibility of developing a commercial-scale geological storage complex at Wabash Valley Resources (WVR) gasification facility near Terre Haute IN, that could store up to 50 million tonnes of industrially-sourced CO_2. (2/1/2019 – 3/31/2022)

- Task 1.0 – Project Management and Planning
- Task 2.0 – Risk Assessment and Monitoring
- Task 3.0 – National Risk Assessment Partnership (NRAP) Screening
- Task 4.0 – Stakeholder Engagement and Public Outreach
- Task 5.0 – Business and Economic Development Assessment
- Task 6.0 – Permitting and Compliance
- Task 7.0 – Subsurface Characterization
- Task 8.0 – Drilling and Well Testing
- Task 9.0 – Storage Complex Modeling
- Task 10.0 – Infrastructure Development
- Task 11.0 – Storage Complex Development Planning

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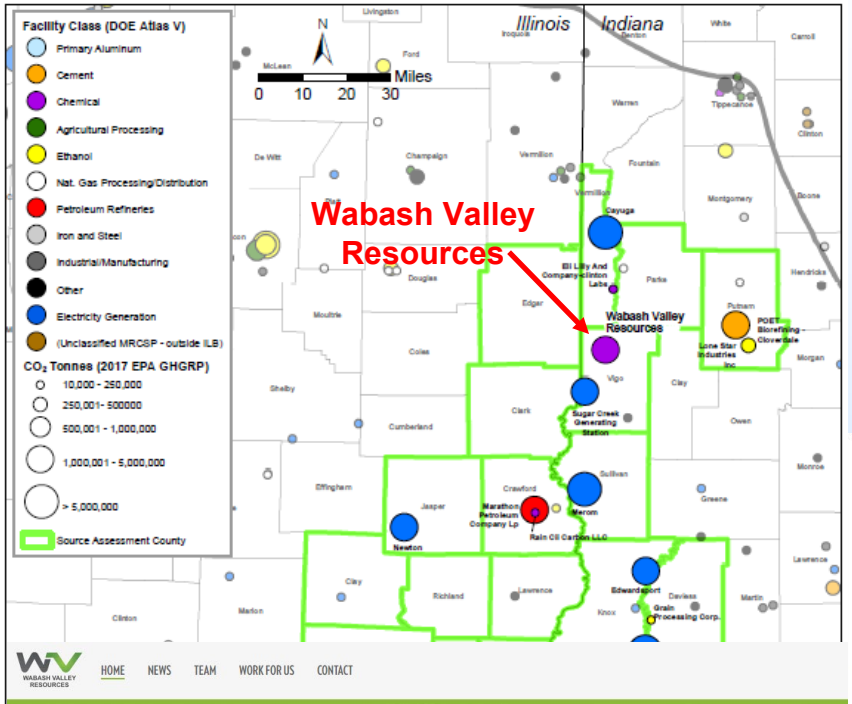
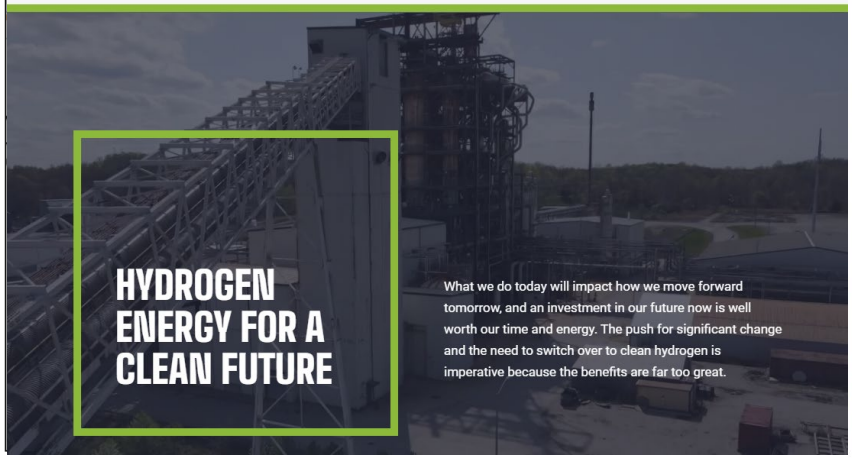
GEOSTOCK SANDIA
ENTREPOSE

U.S. DEPARTMENT OF ENERGY | NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

Project Background





- Site at Former WRGS: IGCC Unit 1A (DOE 1995-1999); Commercial operations 1999-2016.
- Modification planned to produce net-zero carbon intensity hydrogen for power generation, transportation fuels, chemical markets
- 1.65 million tons+; 99% pure CO_2 for capture
- Target 2024 commercial operations

Project Background

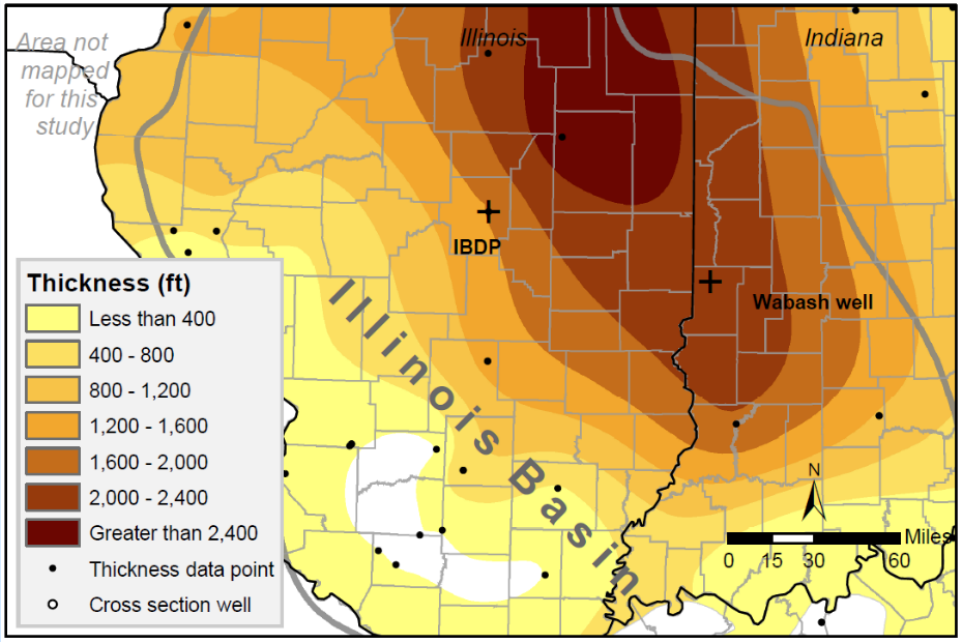
Mt. Simon Sandstone – target reservoir
Potosi Dolomite – secondary reservoir

SYSTEM	GROUP	FORMATION	Storage Elements
Ordovician	Maquoketa	Brainard	Secondary Seal
		Ft. Atkinson	
		Scales	
	Galena	Kimmswick	
		Decorah	
	Plateville		
	Ancell	Joachim	
		St. Peter	Potential target
	Knox	Shakoppee	Secondary Seal/Reservoir
		New Richmond	
		Oneota	
		Gunter	
		Eminence	
		Potosi	Potential target
		Franconia	
Cambrian		Ironton-Galesville	
		Eau Claire	Primary Seal
		Mt. Simon	Target reservoir
Precambrian			

St. Peter-Knox Storage Complex

Mt. Simon Storage Complex

Cambro-Ordovician Storage Complex



Few deep wells in ILB through Mt. Simon

- Data collection necessary, characterization
- Fill data gaps, expand storage resource

Accomplishments

Project Milestones

Task	ID	Milestone	Planned Completion	Completion	Verification Method
1.0/1.1	**A**	Project Kickoff Meeting	04/01/19	03/21/19	Attend Meeting, Presentation File
1.0/1.2	**B**	Revised Project Management Plan	03/29/19	03/27/19	File provided to DOE
1.0/1.4	**C**	Finalized Communication Plan	06/02/19	03/27/19	File provided to DOE
2.0/2.1	**D**	Risk Assessment Summary	2/28/22	03/21/22	Summary in quarterly reports
3.0/3.1	**E**	NRAP Assessment Report	9/30/21	08/13/21	File provided to DOE
5.0/5.1	**F**	Business Environment Study	9/30/21	09/30/21	File provided to DOE
6.0/6.2	**G**	Obtain Stratigraphic Well Drilling Permit	10/31/19	11/12/19	Summary in quarterly reports
7.0/7.1	**H**	Pre-Drilling Site Assessment	07/31/19	11/27/19	File provided to DOE
7.0/7.3	**I**	Regional 2D Seismic Survey	10/31/19	08/21/19	Summary in quarterly reports
7.0/7.4	**J**	Deliver Integrated Data for Modeling	12/31/21	12/31/21	Data provided
8.0/8.2	**K**	Stratigraphic Test Well Completed	5/31/20	02/07/20	Summary in quarterly reports
9.0/9.4	**L**	Report on Modeling	1/31/22	02/13/22	Summary in quarterly reports
10.0/10.1	**M**	CO_2 Source Assessment	11/30/21	11/30/21	File provided to DOE
11.0/11.1	**N**	Detailed Characterization Plan	06/29/22	04/26/22	File provided to DOE

Accomplishments

Technical Reports

1) **Pre-drilling Site Assessment** - Subtask 7.1, Topical Report: DOE-FE0031626-1. U.S. Department of Energy.

2) **Application of Policy Frameworks for Improved Carbon Capture and Storage Social Site Characterization & Stakeholder Engagement** - Subtask 4.1, Topical Report: DOE-FE0031626-2. U.S. Department of Energy. DOI: 10.2172/1820317.

3) **Application of the NRAP Tools to the Wabash CarbonSAFE Site for Risk Assessment Associated with Geologic Carbon Storage Activities -** Subtask 3.1, Technical Report: DOE-FE0031626-3. U.S. Department of Energy. DOI: 10.2172/1819307.

4) **Business Environment Study** - Subtask 5.1, Technical Report: DOE-FE0031626-4. U.S. Department of Energy. DOI: 10.2172/1820317.

5) **CO_2 Source Assessment** - Subtask 10.1, Technical Report: DOE-FE0031626-5. U.S. Department of Energy. DOI: 10.2172/1833016.

6) **Policy, Regulatory, Legal, and Permitting Evaluation** – Task 6.0, Technical Report: DOE-FE0031626-6. U.S Department of Energy. DOI: 10.2172/1843217.

7) **Roadmap for Network and Storage Deployment** – Subtask 10.3, Technical Report: DOE-FE0031626-7. U.S. Department of Energy. DOI: 10.2172/1859753.

8) **Static and Dynamic Modeling** – Task 9.0, Technical Report: DOE-FE0031626-8. U.S Department of Energy. DOI: 10.2172/1859755.

9) **The Geology of the Mt. Simon Sandstone Storage Complex at the Wabash #1 Well, Vigo Co., Indiana** – Subtask 7.2, Technical Report: DOE-FE0031626-9. U.S Department of Energy. DOI: 10.2172/1866412.

10) **Geologic Analysis of the Potosi Dolomite Reservoir Interval and Potential Confining Units at the Wabash #1 Well, Vigo Co., Indiana** – Subtask 7.2, Technical Report: DOE-FE0031626-10. U.S Department of Energy. DOI: 10.2172/1866416.

11) **Wabash CarbonSAFE Detailed Site Characterization Plan** – Task 11.0, Technical Report: DOE-FE0031626-11. U.S Department of Energy. DOI: 10.2172/1866419.

Project Review

Wabash #1 Stratigraphic Test Well

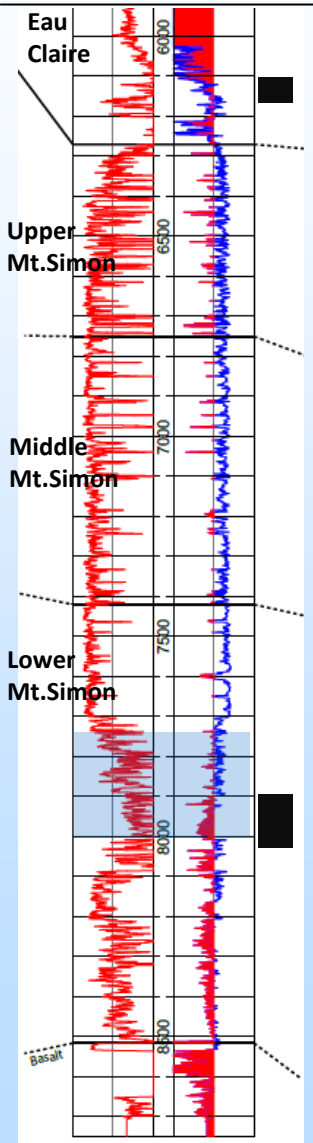
- Wabash #1 permit (6+ months IN-DNR); spud 11/29/19
- Wabash #1 TD 8,739 ft 02/07/2020; Plugged 7/31/2020
- Difficult drilling; did not reach crystalline basement
- Cored 245 ft (target reservoir + 2 seals) + RSWC
- Full suite of geophysical logs; limited in Potosi Dol.
- Two DSTs + Mt.Simon modeling prior to cased-hole well testing…

Photo: R. Chambers

Wabash #1 (IGWS-ID# 168045) Formation Tops	**MD (ft)**
Log reference: Kelly bushing (552 ft elev.)	0
Ground Level (537 ft surface elev.)	15
Pennsylvanian Bedrock, approximate	30
Sea Level (below KB)	552
Mississippian-Pennsylvanian Unconformity	748
St Louis Limestone	748
Salem	906
Harrodsburgh	957
Muldraugh	1,032
Borden	1,126
Chouteau/Rockford Limestone	1,638
New Albany Shale	1,642
Devonian Carbonates	1,742
Silurian	1,965
Maquoketa Group	2,386
Trenton Limestone	2,700
Black River/Platteville Group	2,863
Joachim Dolomite	3,168
Dutchtown	3,257
St. Peter Sandstone	3,326
Shakopee Dolomite	3,354
Oneota Dolomite	3,970
Potosi Dolomite	4,473
Davis	5,162
Eau Claire	5,322
Mount Simon Sandstone	6,277
Basalt (Cambrian)	8,515
Mount Simon Sandstone/Argenta	8,535
T.D.	8,739

Geological Characterization

Eau Claire Formation, Mt. Simon Sandstone



Seal: Eau Claire Fm

- 955 ft thick @ 5,322 ft MD
- 66 ft core, few RSWC

Rotary sidewall core plug from 6,187 ft MD. (Eau Claire Fm.)

Mt. Simon Sandstone

- 2,238 ft thick @ 6,277 ft MD
- Lower porosity than IBDP wells

Reservoir Target: Lower Mt. Simon – 'Arkosic zone'

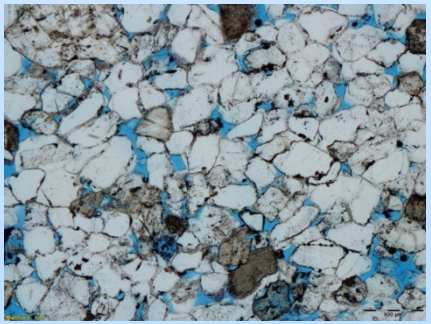
- ~260 ft thick, 119 ft cored @ 7,900-8,019' + RSWC
- Cored section: WC sample poros avg 7.6%
- Routine, CT scan, FMI, thin section, petrography

Primary porosity; minor secondary

- partial feldspar dissolution
- quartz cements, low connectivity

Zircons: some dates older than IBDP

- other sediment source/direction
- fine grain size, distal sediments

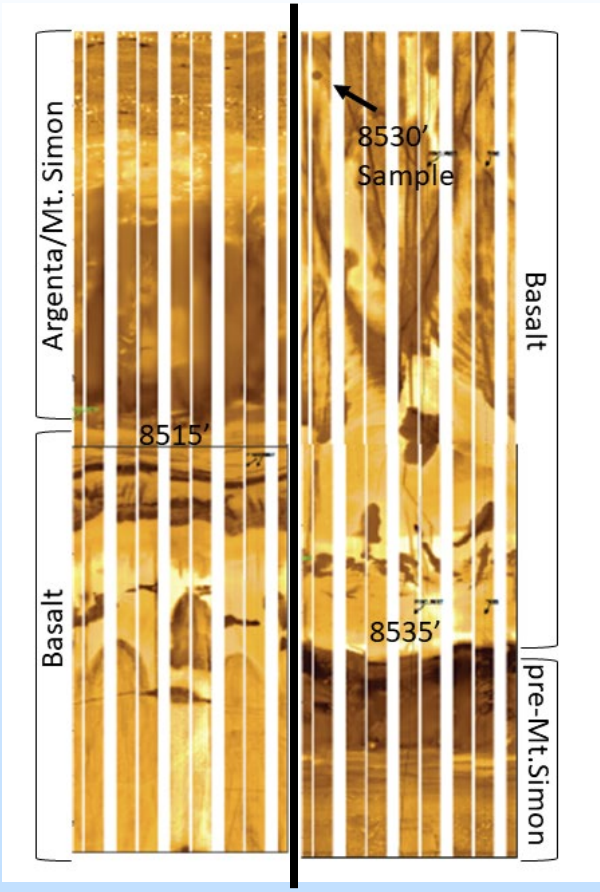


Thin Section. 7750 ft MD (Mt. Simon Sandstone).

F.D. core: 7,924-7,930 ft

Geological Characterization

Mt. Simon Sandstone / Argenta

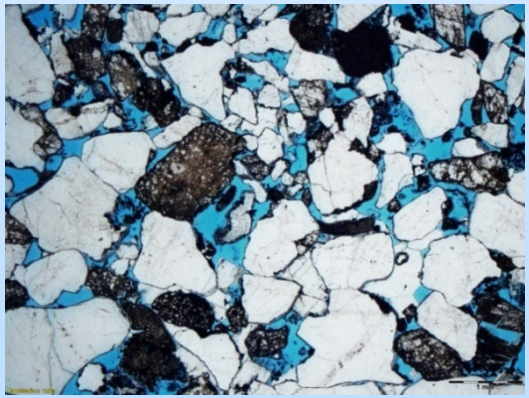


Fullbore formation micro-imager (FMI) log photos showing the top contact of the basalt with the Mt. Simon or Argenta sandstone at 8,515 ft and the basal contact with sediments at 8,535 ft.

- The basalt penetrated in the Wabash #1 well (8,515-8,535 ft) is interpreted as a flood overlying lacustrine deposits
- Early Cambrian in age

- Sediments below basalt: DZ proximal source, more like lower Mt. Simon
- 8,690 ft: best reservoir properties from sandstone samples*
- Secondary porosity via anhydrite cement partial dissolution
- Incomplete thickness 204 ft
- Potential reservoir rocks below well TD 8,739 ft (?)

Rotary sidewall core plug from 8690 ft MD, sandstone below basalt



Thin Section. 8690 ft MD

Geological Characterization

Mt. Simon Sandstone / Argenta

Whole core + RSWC confirm Arkose interval has **lower porosity and permeability than expected.**

Whole core (Arkose) porosity and permeability statistics.

	Count	Average	St. Dev	Median	Minimum	Maximum
Porosity (%)	37	7.61	3.77	8.19	0.97	12.95
Permeability (mD)		2.19	2.76	1.00	0.09	10.90

Rotary sidewall core porosity statistics.

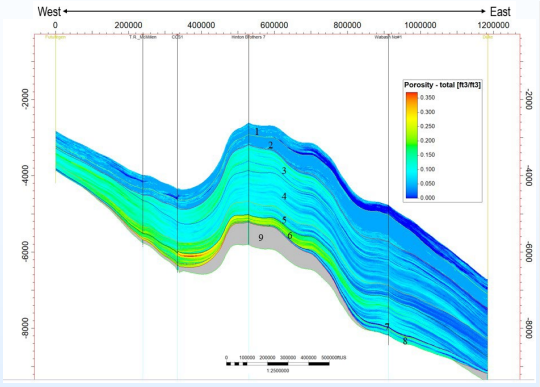
Unit	Porosity (%)				Permeability (mD)		
	Count	Average	Minimum	Maximum	Average	Minimum	Maximum
Eau Claire sh.	1	6.00	6.00	6.00	**0.09**	**0.09**	**0.09**
Upper	2	12.50	12.00	13.00	5.35	0.09	10.61
Middle	5	11.20	7.00	13.00	1.22	0.04	3.54
Lower	11	8.91	5.00	11.00	0.68	0.02	2.91
Arkose	9	9.67	4.00	12.00	6.57	0.02	27.93
Whole Mt. Simon	**27**	**9.85**	**4.00**	**13.00**	**3.09**	**0.02**	**27.93**
Argenta	10	14.20	11.00	20.00	1.34	0.10	7.02
Unidentified	4	17.25	8.00	30.00	27.95	0.09	109.08
All Data	**42**	**11.50**	**4.00**	**30.00**	**5.09**	**0.02**	**109.08**

Mt. Simon Storage Complex

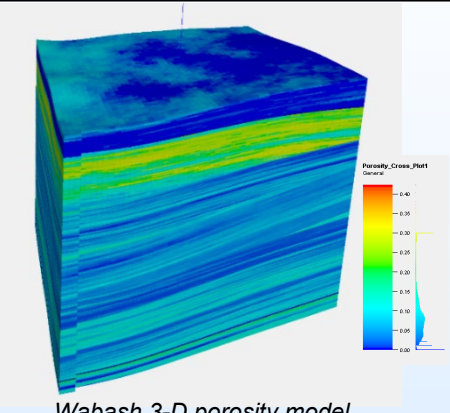
Static Model Development

Static model: 22 x 22 mi, clipped from regional
740 layers, >2.6 million grid cells
Top Precambrian – Eau Claire Fm

Data from: Core analyses, log suite, DSTs



West-East cross section, regional porosity model



Wabash 3-D porosity model

Two DSTs immediately after drilling to calibrate perm:

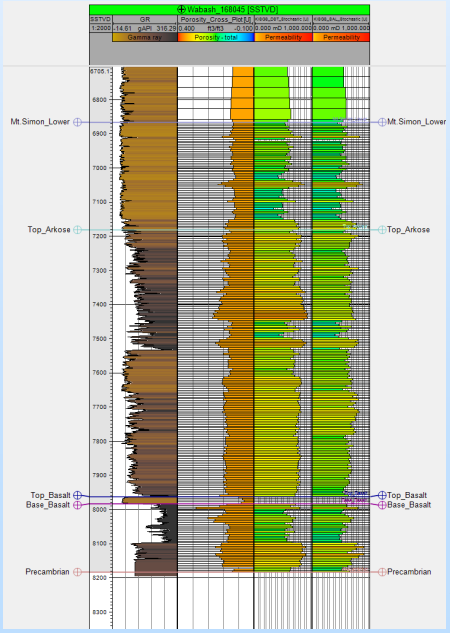
- 7,696-8,120 (424 ft; Arkose) and
  6,710-6,912 (202 ft; UMS/MMS)
- 2 to 5 millidarcy averages
- higher permeability in localized intervals

Mt.S Log porosity → transform function → perm. curves

Non-unique results:

Core-matching and **DST-matching** curves

Low/high perm endmembers for modeling cases, respectively



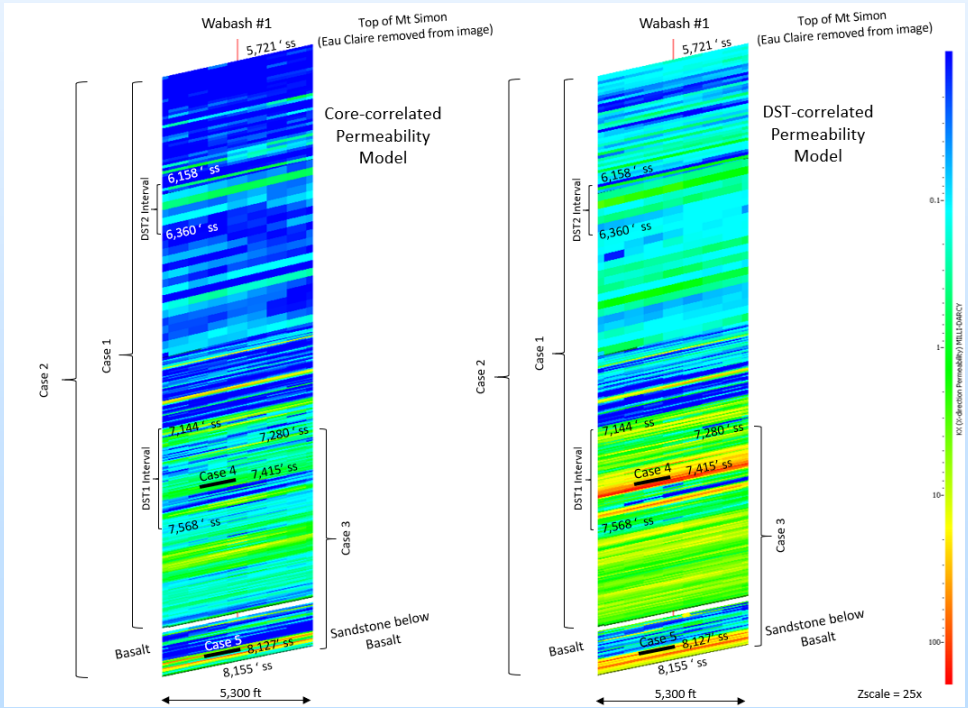
Permeability scale-up into static model

Mt. Simon Storage Complex

Dynamic Modeling

Mt. Simon Simulations:

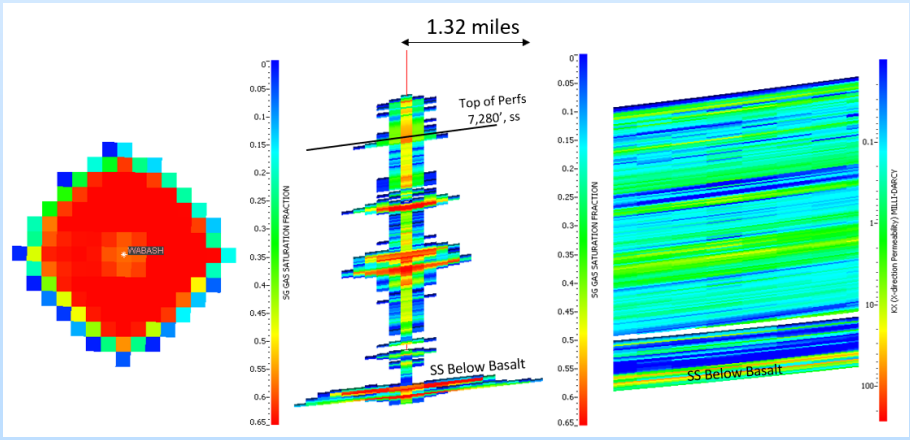
- Run numerous model scenarios (30 yrs): vary zones, vert & horiz well, by perm case
- Assess injection rates, plume dimension, max injection pressure
- Single well cannot inject 1.67 MMTA of CO_2 for 30 years:
  0.2 MMTA; multiple wells needed vs. 1.16 MMTA; two wells needed
- Initial simulations informed selection of zones for cased-hole well testing program



Partial cross section through Wabash #1 from both the Core-correlated and DST-correlated models showing horizontal permeability on a log scale, with well perforation and DST locations denoted.

Case	Interval	Perforation Length ft
1	Vertical well, All of Mt Simon (5,721' - 7,958')	2,237
2	Vertical well, All of Mt Simon + sandstone below Basalt (5,721' - 8,155')	2,434
3	Vertical well, Lower Mt Simon + sandstone below Basalt (7,280' - 8,155')	877
4	1,000 m Horizontal well, within DST1 interval (7,415')	3,281
5	1,000 m Horizontal well, in sandstone below basalt (8,127')	3,281

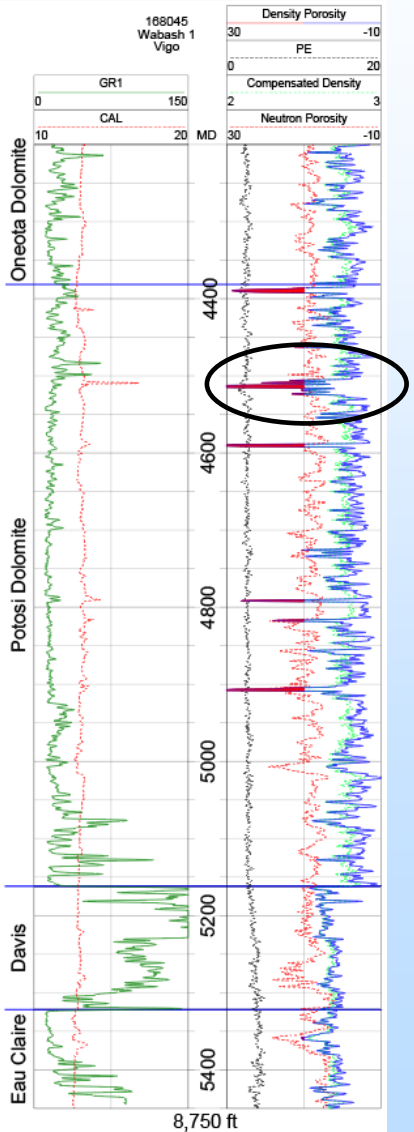
Mt. Simon single well simulation cases.



Case 3, Core-correlated permeability model results after 30 years of injection, showing plume radius (map view), plume cross section and permeability cross section.

Data Acquisition

Cased-Hole Well Testing



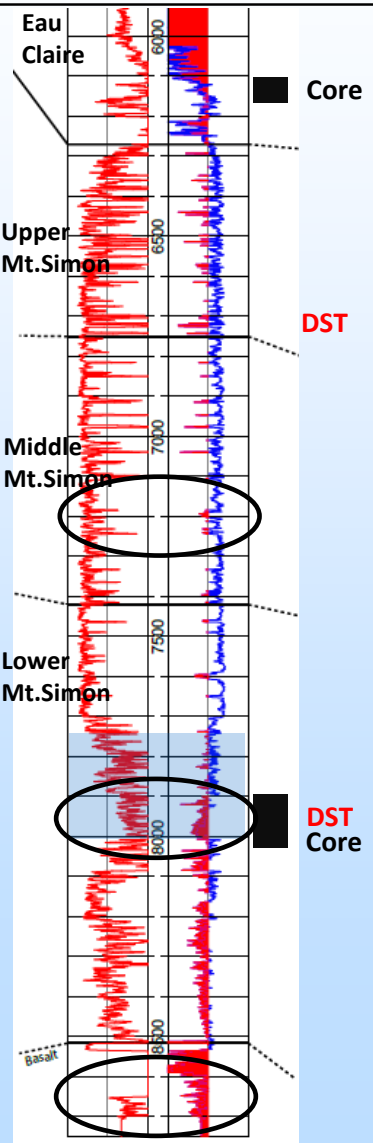
Pressure Fall-Off and Step Rate Testing:

- Potosi Dolomite, Knox Gp.
  - Vuggy porosity in several zones
  - Test interval 4,505-4,525 ft MD
  - 24,000 md-ft over 10ft; 2,400 md
  - (45,000+ md)

- Mt. Simon:
  - 7,192-7,202 ft
  - Test too short; no P response

- 7,976-7,996 ft
  - 85 md-ft over 20 ft (375 md-ft)
  - 4.25 md (18.75 md)

- Sandstone below basalt:
  - 8,661-8,671; 8,681-8,691*
  - 89 md-ft over 20 ft; 4.45 md



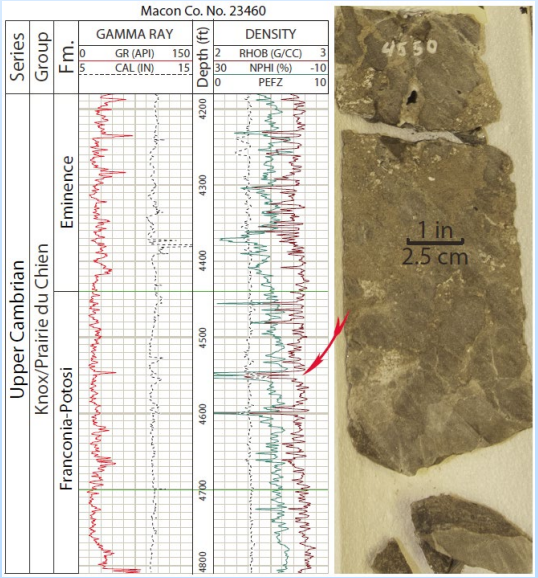
Potosi Dolomite (Knox Group)

Previous/Regional Knowledge

- Thick bedded, fine to coarsely crystalline dolomite unit
- Chert and partially/completely mineralized cavities common
- Vugular, brecciated, fractured and/or cavernous intervals

Vuggy porosity with the cavities lined with drusy quartz in the Potosi Dolomite; ADM Verification Well #1, Macon Co. IL.

- Regionally extensive, several zones with high porosity & permeability
- Trace in logs: Knox-St.Peter Project, IBDP, CarbonSAFE
- Lost circulation zone throughout Basin: IBDP (and Wabash)
- No Potosi core in Wabash #1, limited logs (e.g. no FMI)

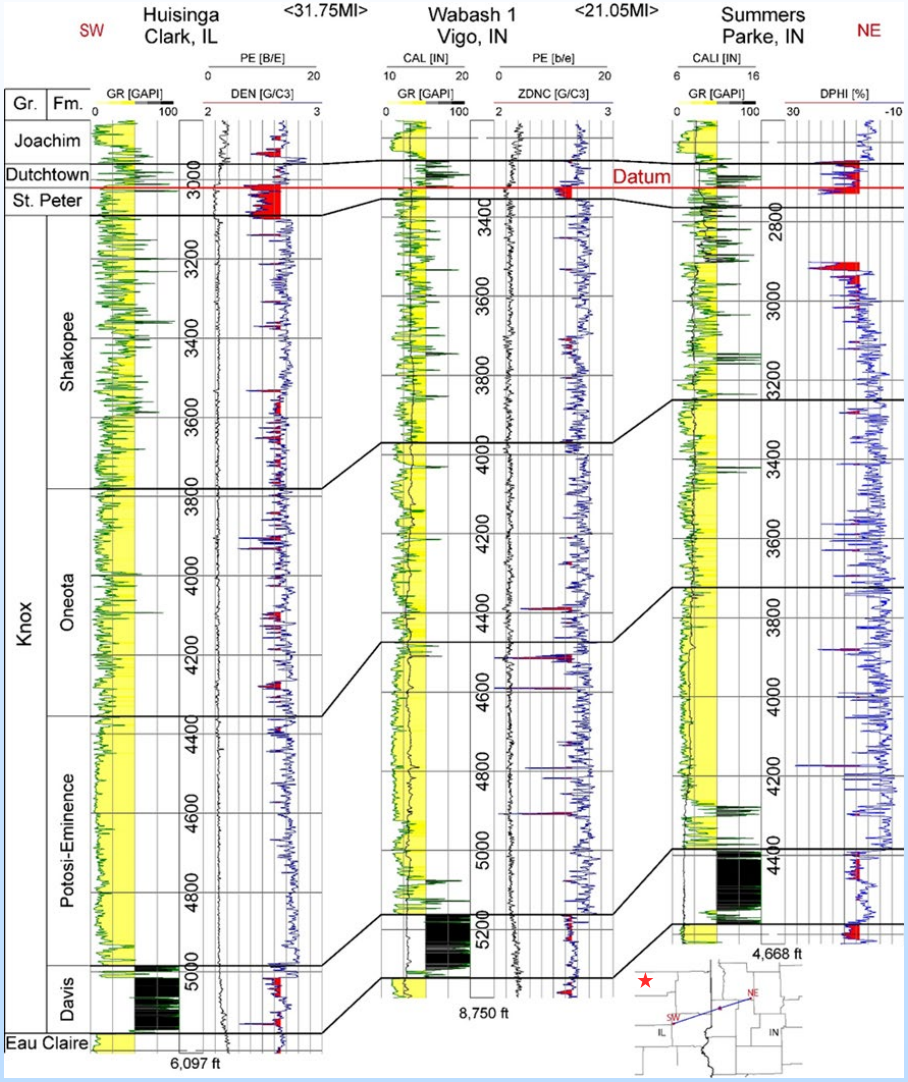


Potosi Dolomite

Previous/Regional Knowledge

Tuscola, IL chemical waste disposal wells (~50mi WNW):

- From an injectivity/ falloff test, the estimates of Potosi permeabilities were greater than 9,000 md
- Since 1970, injected 18 billion Gal of liquid into the Potosi through Cabot-Tuscola #2 well
- Equivalent to injecting more than 50 million metric tons of CO_2
- Still injecting equivalent to 60,000 tonnes per month of CO_2



Southwest-northeast correlation of the units in the Knox Group from east-central Illinois to west-central Indiana (Datum top of the St. Peter Sandstone). Note: The available Cabot #2 well log is incomplete for the Potosi Dolomite, but the approximate well location in Tuscola, IL is shown in the index map as a red star.

Potosi Dolomite

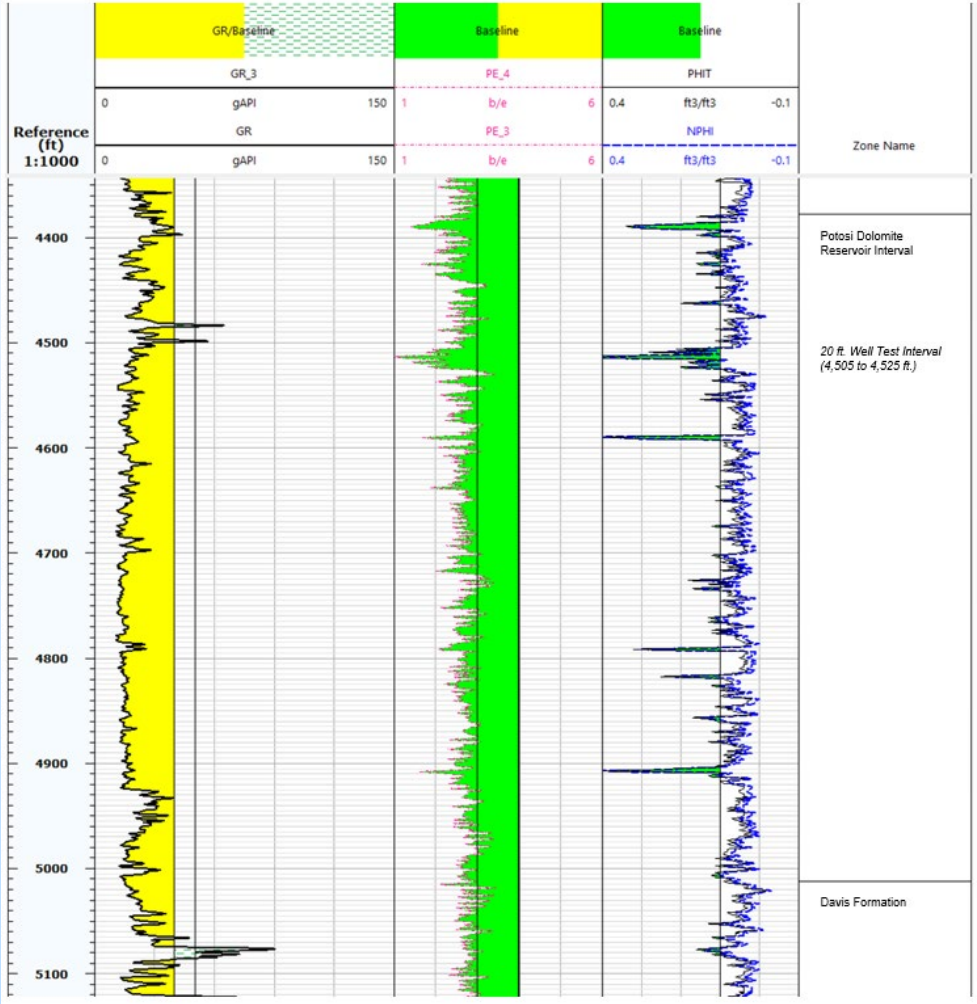
Wabash #1: Petrophysical Analysis

Wabash #1 well:

- Six significant porous & permeable intervals
- Range from less than 5 ft to ~20 ft in thickness
- Neutron-density porosity in the 20-ft test interval is estimated to be over 30%

Potosi Dolomite reservoir interval:

- 784 ft thick at 4,378 ft MD
- Total of 149.5 ft is greater than 10% porosity.



Geophysical log of the Potosi Dolomite reservoir interval in the Wabash #1 Well, Vigo County, Indiana. Note the top of the Potosi reservoir interval includes 95 ft of the lower Oneota Dolomite. The green highlighted areas on the right-most porosity column are zones with greater than 10% porosity.

Maquoketa Group

Wabash #1: Core Studies

Maquoketa Group in the Wabash #1 well (regional seal):

- Dominantly interbedded shale + argillaceous layers in upper zone
- Increasing limestone and argillaceous limestone in middle to lower
- 314 ft thick at 2,386 ft MD in Wabash #1
- Core 2,435-2495 ft: fairly consistent, thinly-laminated calcareous shale lithology

Sealing capacity/integrity to CO_2:

MICP data:

- Formation pressure: 1,080 psi; assume a CA range between 20° and 40°
- Data indicate the Maquoketa can hold a $scCO_2$ column height of 2,020 ft

Geological characterization and geomechanical testing:

- FMI log + core show little to no natural fractures within the Maquoketa Group interval
- Triaxial test results, Maquoketa:
  - has high Young's modulus (suggesting very stiff rock and not easily deformable)
  - has high cohesive and uniaxial compressive strength
    (suggesting it will require very high injection pressures [above the fracture gradient of the reservoir] to induce a failure in the formation)

The test results indicate the Maquoketa is an effective caprock to $scCO_2$ migration and exhibits geomechanical characteristics of a good seal.

Photo: R. Bauer

	Petrophysical properties	Static elastic properties			
Seal	ρ (g/cc)	υ	UCS (MPa)	C_0 (Mpa)	φ (°)
Maquoketa	2.61-2.71	0.23-0.3	180	51.8	30

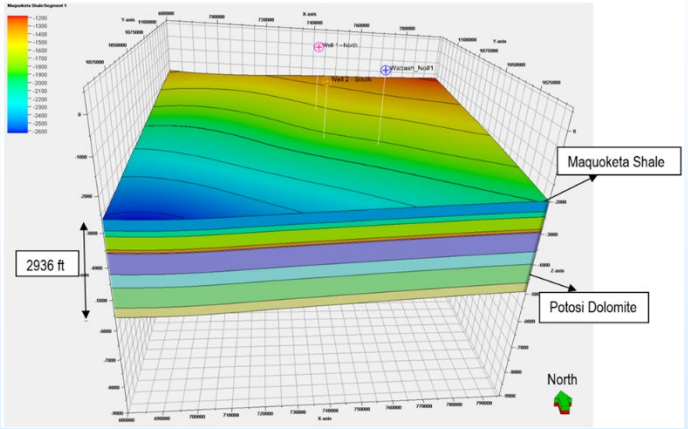
Static Model Development

Potosi Static model: 22 x 22 mi, 241 layers

7 confining units above Potosi and below Maquoketa:

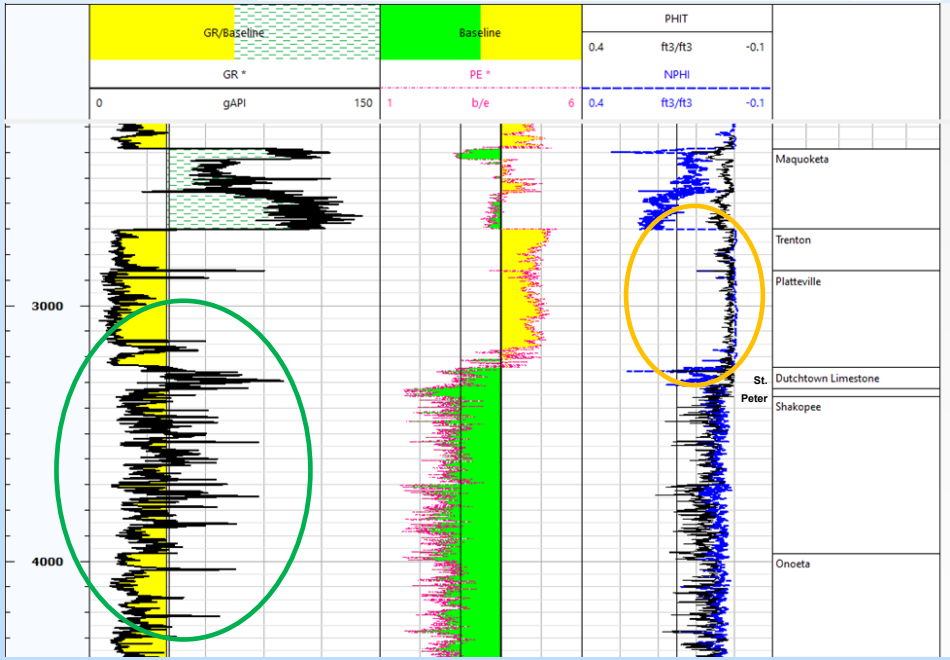
- Dense carbonates with interbedded shales
- 1,678 ft cumulative thickness between Potosi and Maquoketa

3-D structural framework



Confining Zone	Formation Thickness (feet)	Depth (feet)	Avg. Porosity (%)	Avg. Permeability (mD)	Shale Thickness (feet)
Maquoketa Group	314	2,386	3.0	0.0001-0.00001	312
Trenton Limestone	163	2,700	1.3	0.00000273	3.5
Platteville Group	379	2,863	1.2	0.00000475	16
Dutchtown Limestone	84	3,242	2.8	0.0000840	70.5
St. Peter Sandstone	28	3,326	4.0	0.0039	3.5
Shakopee Dolomite (upper)	346	3,354	2.8	0.022360406	101
Shakopee Dolomite (lower)	270	3,700	9.1	0.098032	71
Oneota Dolomite	408	3,970	7.1	2.585488	15

Data from: Well test data, geophysical well logs, and calculations (Lucia 1995; 2007) that link rock fabrics to petrophysical properties.

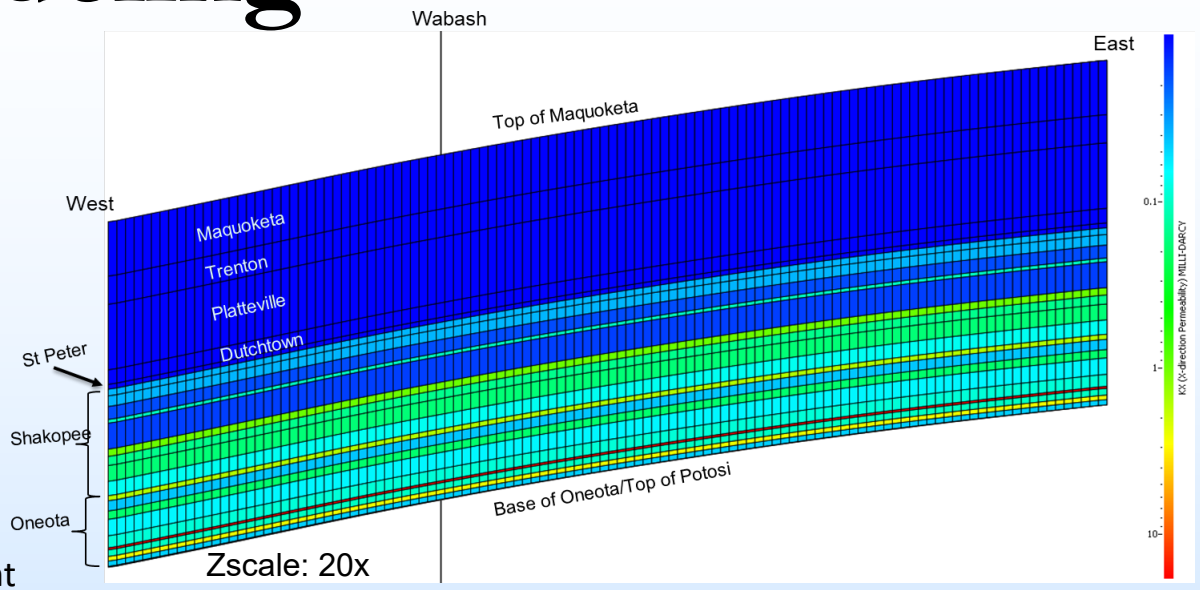


Partial geophysical log, Wabash #1 Well, Vigo County, Indiana.

Dynamic Modeling

Nexus Simulation model:

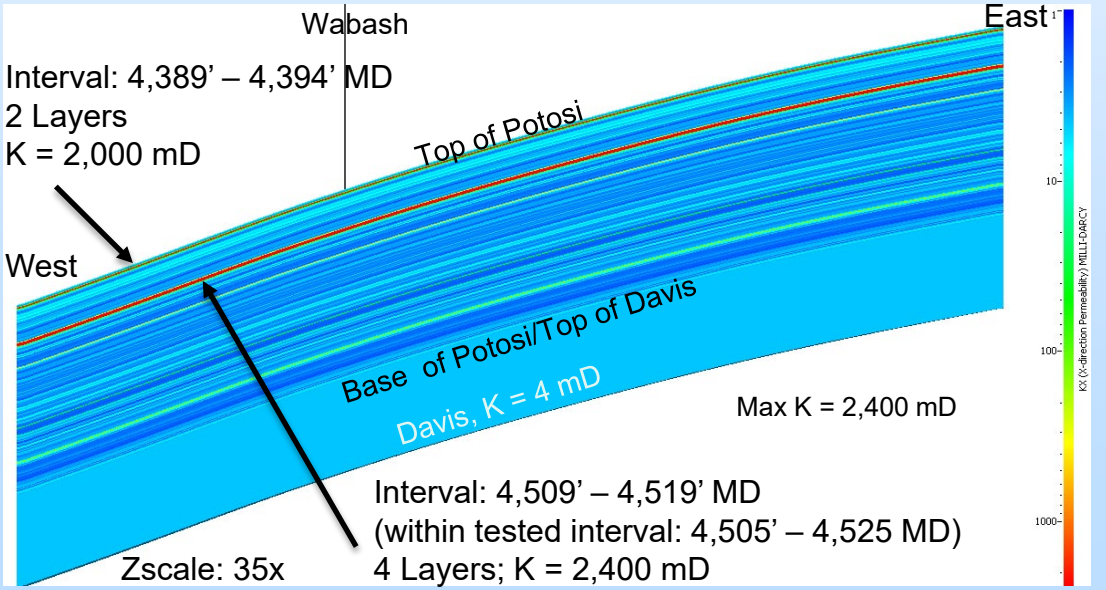
- 22 x 22 miles; based on geologic model
- Constant property within layers
  (vertical heterogeneity)
- Potosi contains vuggy intervals with high perm.



Model Size, Grid Cells:

- 1000’ x 1000’ / 333’ x 333’ local refinement
- 241 layers
  - 217 within the Potosi (~3 ft thick)
  - 23 in confining units; 1 below
- Total blocks: 7.6 million; infinite acting aquifer boundary

Parameter	Value
Initial Pressure	1,954 psia at 4,500' MD
Resevoir Temperature	108F at 4,500' MD
Salinity	34,250 ppm
Frac Gradient	0.71 psi/ft



Dynamic Modeling

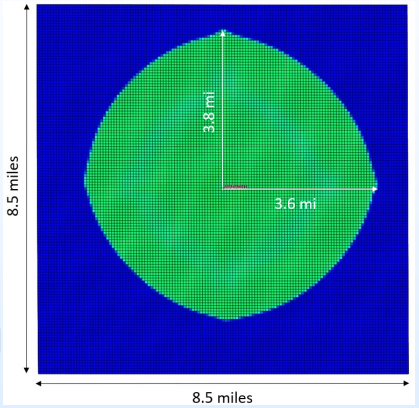
Wabash #1 Example

30-year injection period
- Entire Potosi perforated
- CO_2 injection rate of 1.67 Mta
- 50 mil. tonnes CO_2 injected
- Injection constraint
  - Pmax = 0.9 * 0.71 psi/ft
  - Applied at top of perf interval

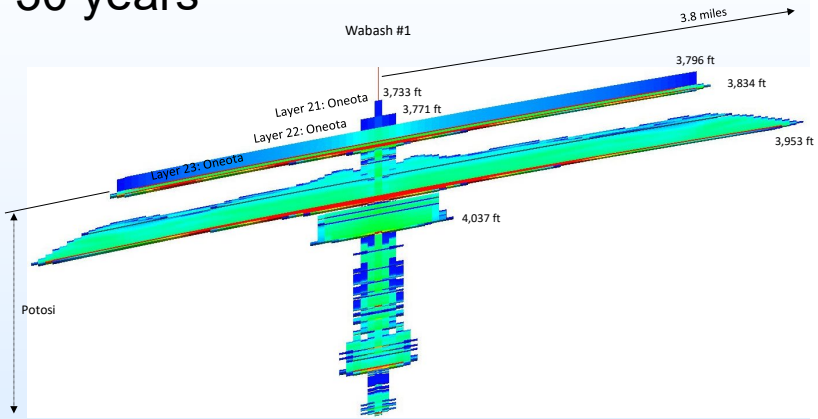
50-year post-injection period
Max CO_2 plume radius: 3.8 miles

Plume does not move in the lateral direction, after injection stops
- Plume moves vertically and saturation changes with time
- Vertical migration into Oneota Dolomite
- > 1,270 ft below base of Maquoketa seal

30 years

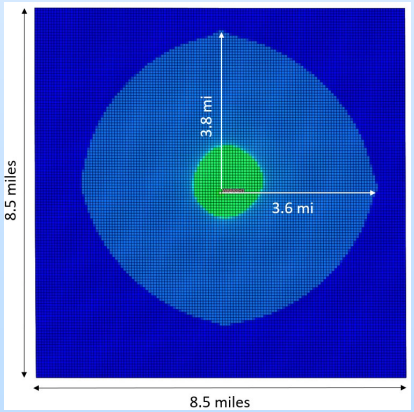


Layer 67 (Potosi, top of tested interval)



S-N cross-section through well
Cells with Sg ≥ 1%
Zscale = 20x

80 years



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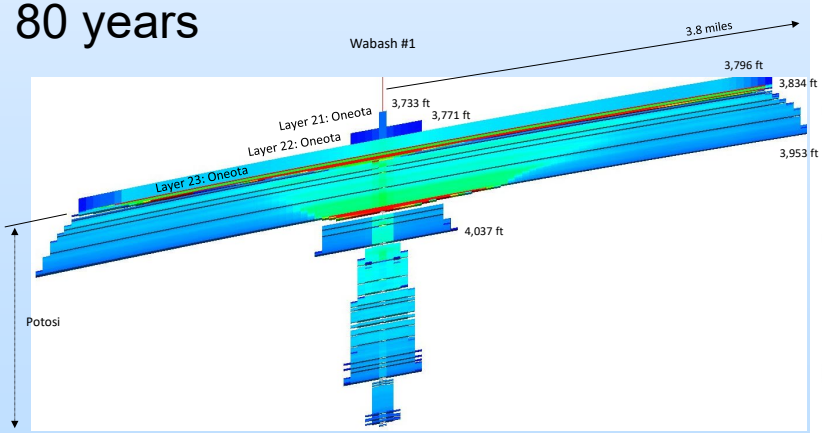
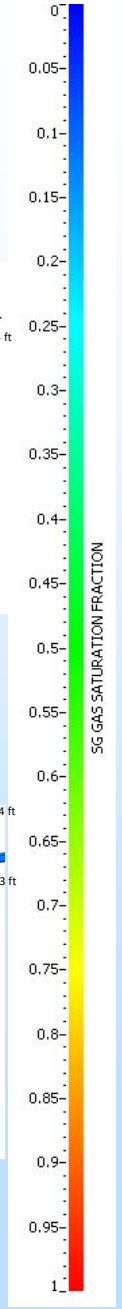


S-N cross-section through well
Cells with Sg ≥ 1%
Zscale = 20x



CO_2 Plume Radius vs. Time

Dynamic Modeling

Well pressures

- 30-year injection period (1.67 Mta)
- 50-year post-injection period

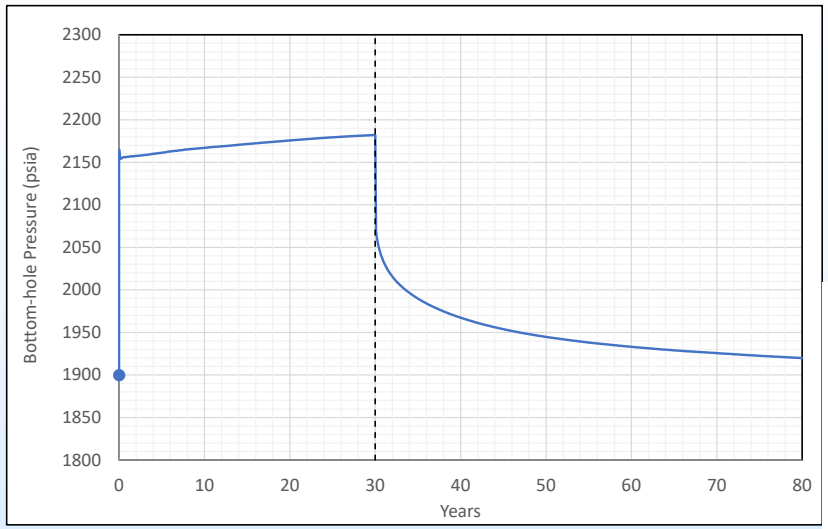
- Maximum BHP constraint:
  2,804 psia at 3,829 ft, ss

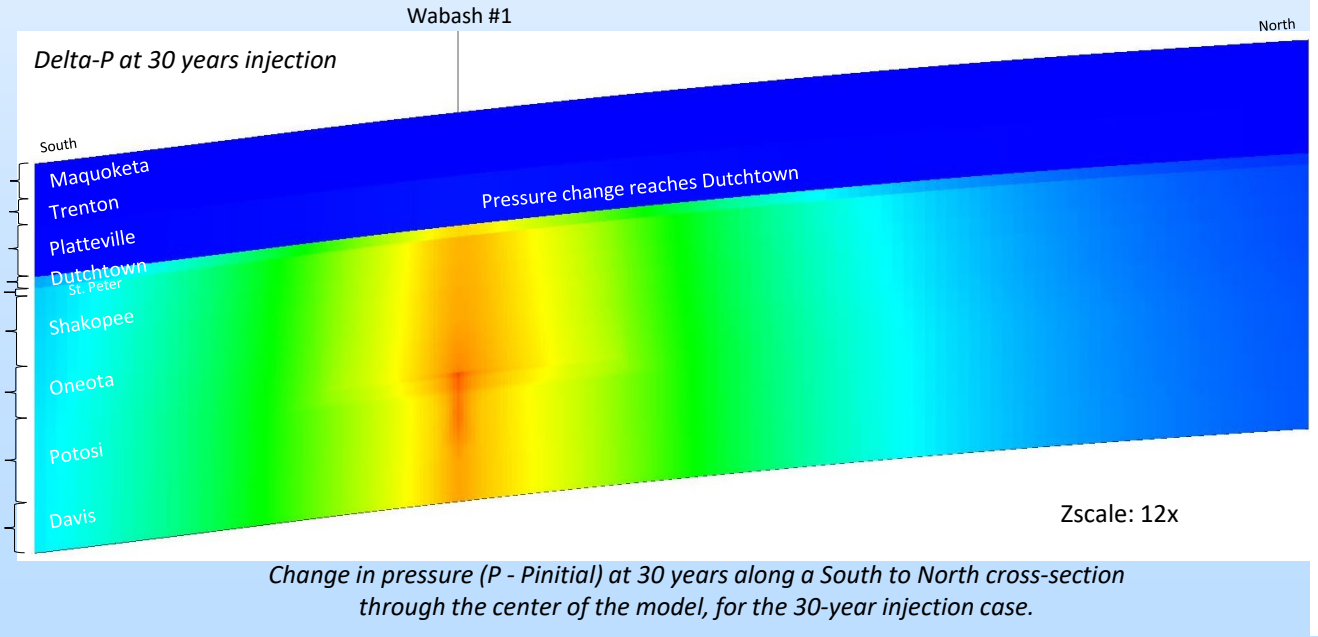
- BHP increases by 282 psi at 30 years
- Well BHP (2,182 psia) is significantly below maximum BHP constraint

Injection never reaches pressures high enough to fracture reservoir

Pressure change reaches Dutchtown Limestone

Bottom-hole Pressure (psia)





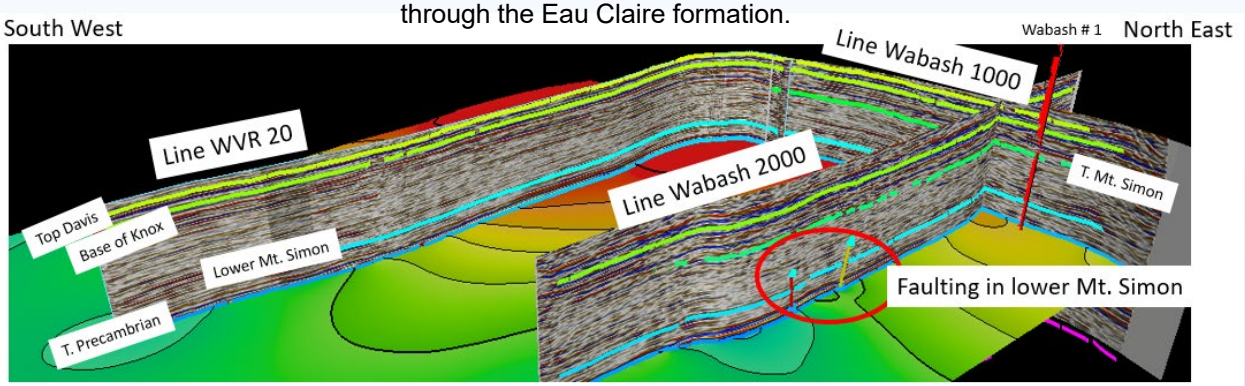
Change in pressure (P - Pinitial) at 30 years along a South to North cross-section through the center of the model, for the 30-year injection case.

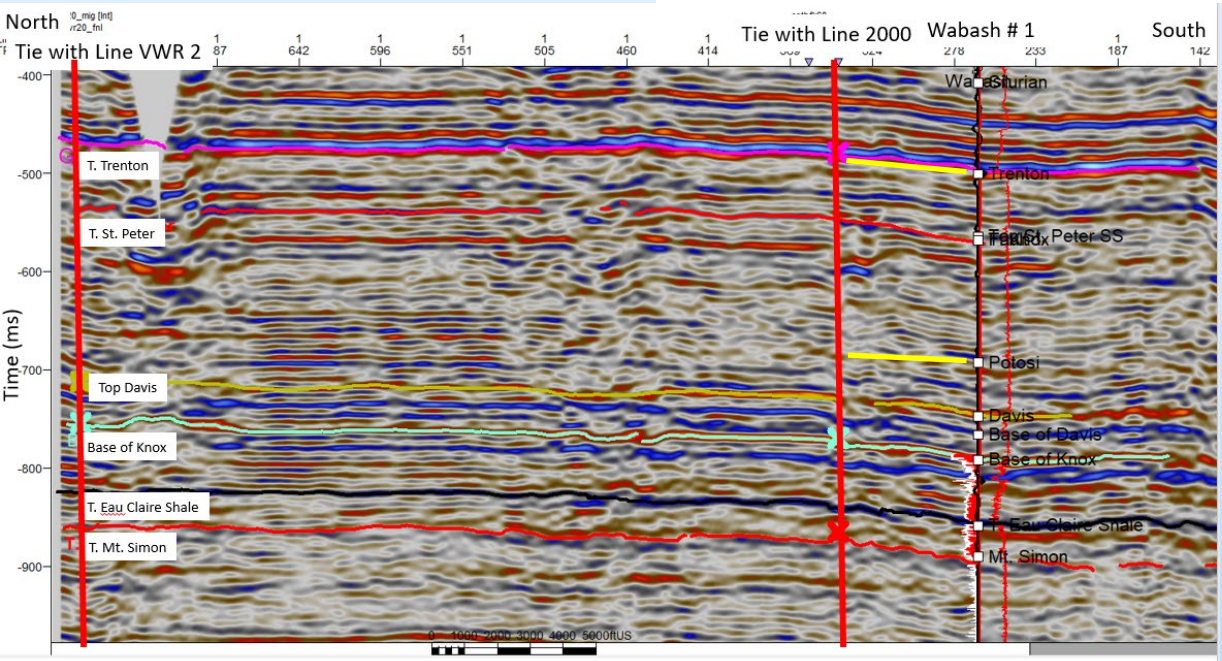
Geological Characterization

Seismic Interpretation – Site Specific

- 2 x 10 miles 2D seismic acquisition summer 2019 (+ 15 mi WVR)
- Some faulting in the Precambrian and lower Mt. Simon Sandstone
- Faults do not appear to be present in upper Mt. Simon and Eau Claire Fm.

Three-dimensional view of the Precambrian through the Eau Claire formation.





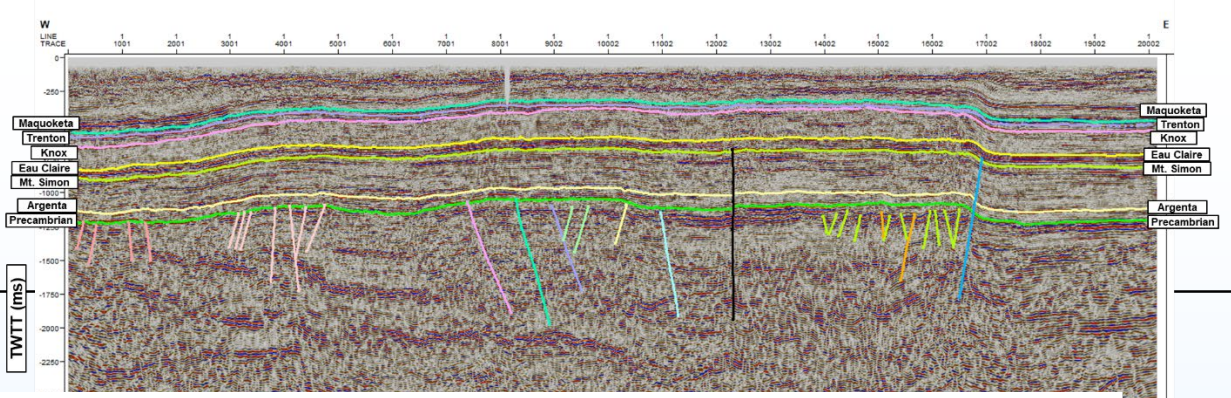
- No faulting observed through Potosi-Maquoketa interval

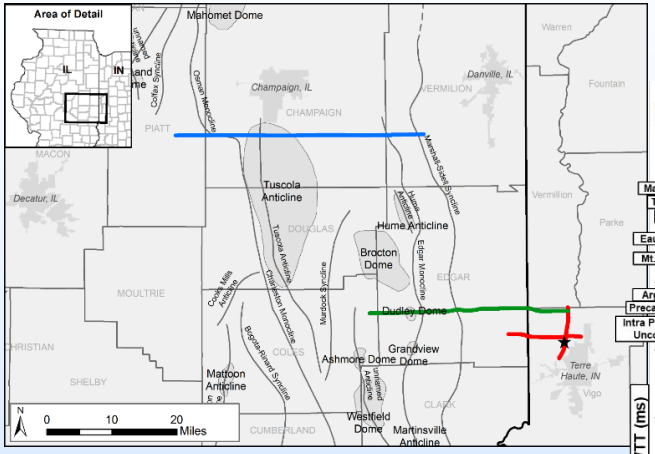
Line 1000 (N-S) showing correlation of the Wabash #1 with the seismic reflection data.

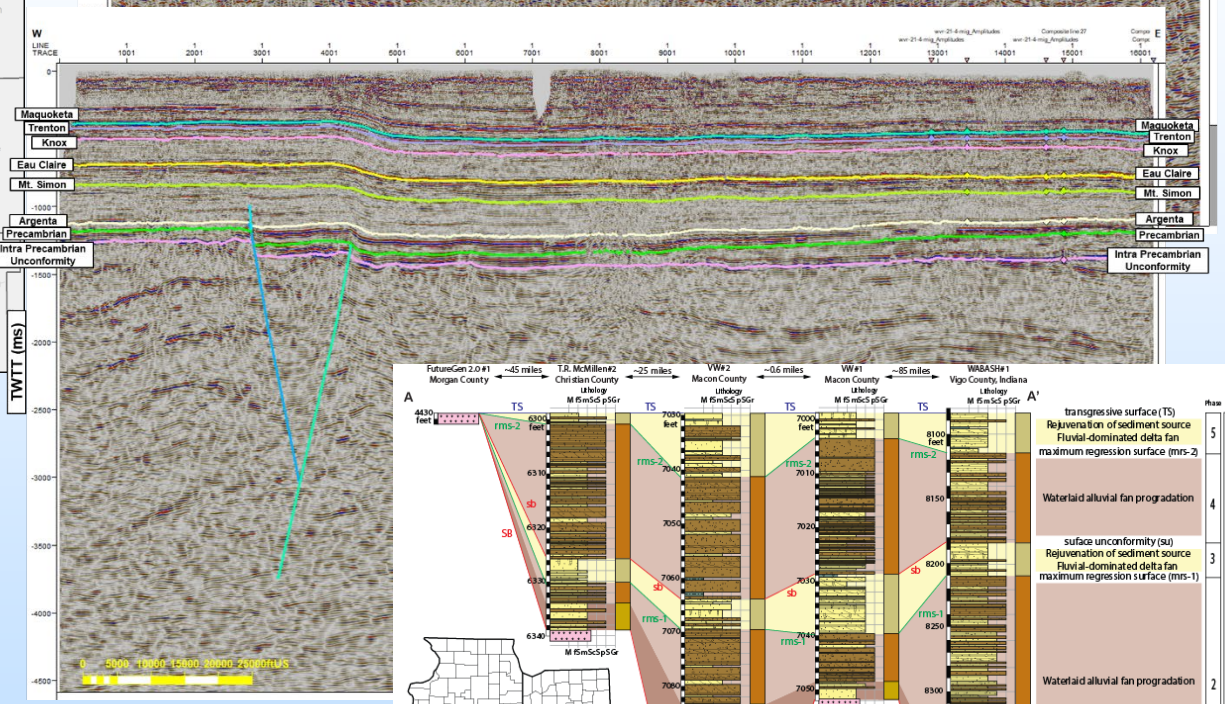
Regional Characterization

(ongoing)

(Blue on map) Champaign 2D

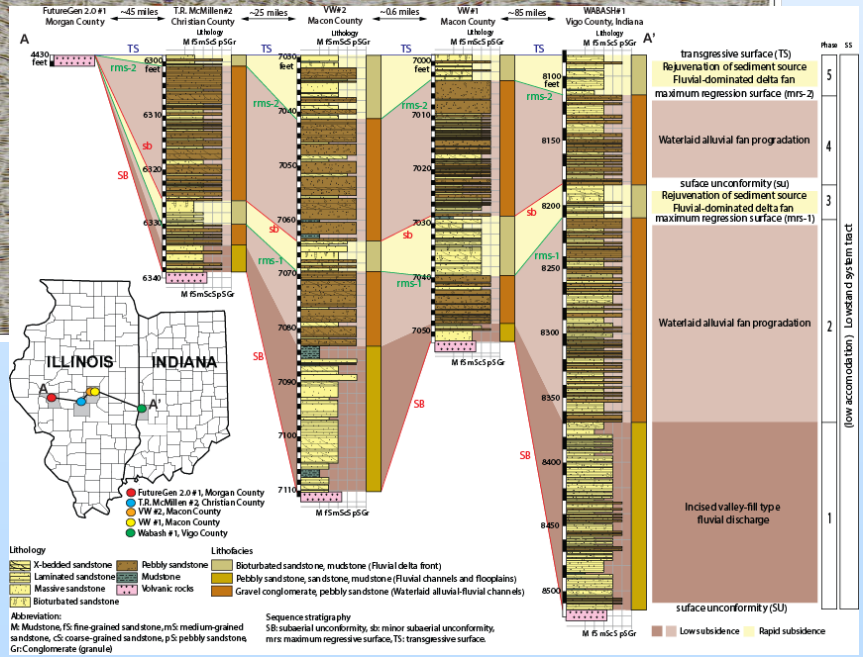






- 30 + 40 miles 2D acquired fall 2021
- Linkage with a region having known storage characteristics
- Examine reservoir/seal continuity across structures westward into IL
- Better evaluate and interpret Basin features & depositional sequences significant to storage
- Synergy with IL Storage Corridor

(Green on map) Paris-Wabash 2D seismic profile



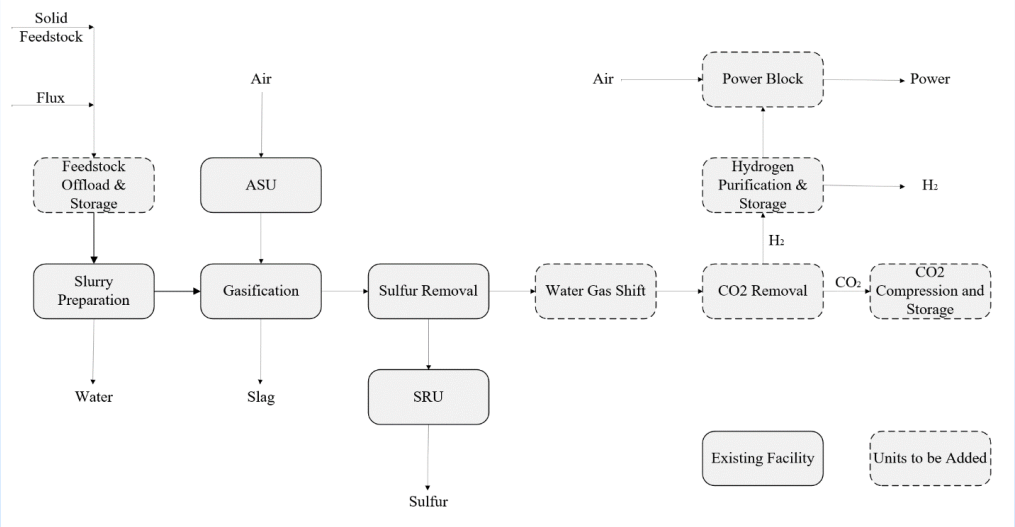
Tectono-stratigraphic Correlation between Wabash #1, IBDP VW #1 and 2, T.R. McMillen #1 and FutureGen #1 boreholes.

CO_2 Source Assessment

CO_2 Source + Business Environment

Technical Reports

- DOE-FE0031626-5: CO_2 Source Assessment
- DOE-FE0031626-4: Business Environment Assessment



WVR facility block flow diagram.

WVR IGCC Plant

- Clean hydrogen fuel + power with CCS
- Generate up to 300MW of electricity
- Retrofit existing gasification facility:
  - reduces the technical risk and capital costs
  - higher probability of implementation
  - more competitive product prices
- Dual Refrigeration CO_2 Fractionation Unit (DCRF):
  - will separate CO_2 from hydrogen as high purity liquid (sc) carbon dioxide stream
  - allows for use of pumps to elevate the pressure level for subsurface storage
  - avoids cost, complexity, and electrical usage penalty of a large compressor

Business Environment Study: Wabash Valley Resources

- Utilizing 45Q allows for a realized economic value in *pre-tax dollars*
- State of Indiana support
- Project's CCS capital expenditures funded by private equity investments and government loan guarantees
- Project appears to have commercial viability

Permitting & Regulatory

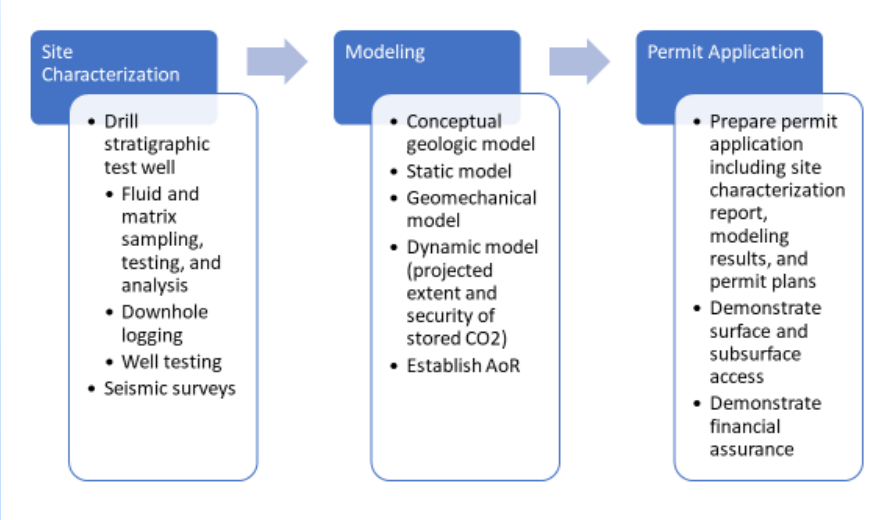
Technical Report
- DOE-FE0031626-6: Policy, Regulatory, Legal, and Permitting Evaluation

State of Indiana
- State of Indiana support for WVR
  IN Public Law 291 (May 2019) for pore space and pipeline access and acquisition
- Eminent Domain for Transportation of Carbon Dioxide by Pipeline (IC 14-39)
- IN Public Law 163 (HB 1209, Mar 2022): provides for the mechanism for underground storage of carbon dioxide in Indiana; enables future projects.

US Environmental Protection Agency (EPA) Class VI
Permitting for the Protection of Groundwater Resources

- Wabash CarbonSAFE Permitting Plan developed
- Catalog technical components of UIC Class VI permit application, Guidance Documents, etc.
- General 'timeline'/progression of steps

- Research expected lowermost USDW at host site
- Identify data gaps for detailed site characterization / next steps…



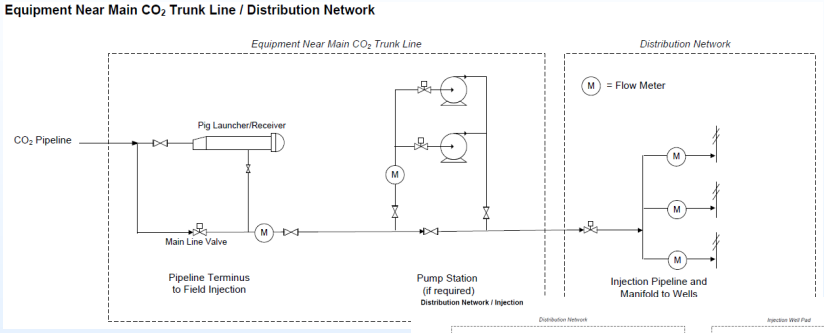
Site characterization and modeling needs in support of Class VI UIC permit application

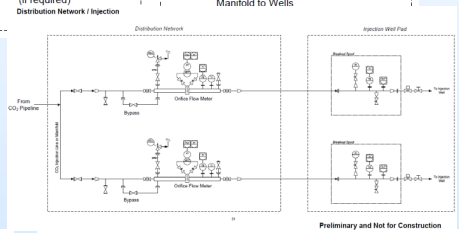
Infrastructure Development

Infra/Transport and Network Expansion Studies

Reports

- Trimeric: Wabash Conceptual CO_2 Source Expansion Evaluation
- DOE-FE0031626-7: Roadmap for Network and Storage Deployment





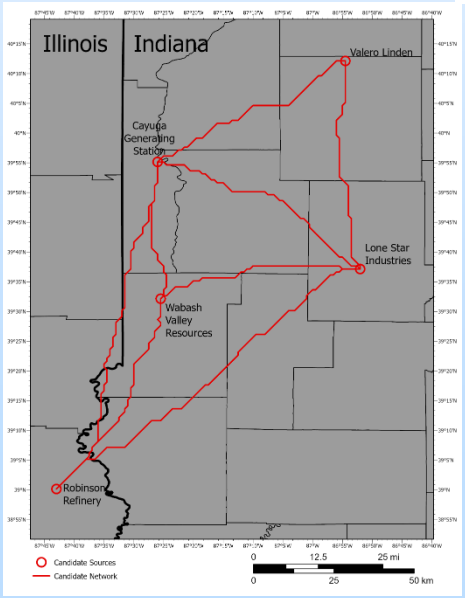
Potential Source Expansion/Transport

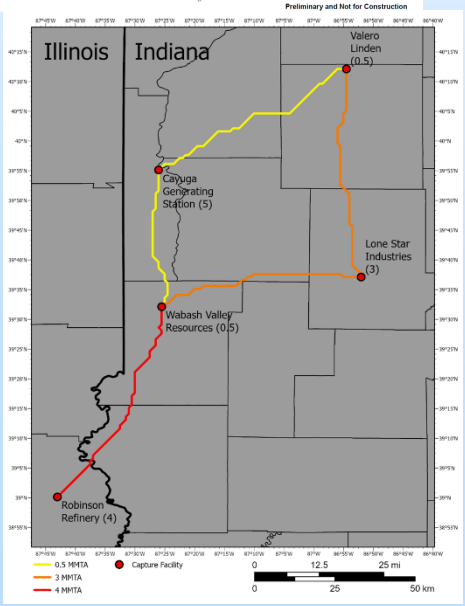
- Catalog of regional high purity sources
- 50mi or 150mi distance, hi/lo production scenarios
- Pipeline sizing/boosting and general costs
- Receiving equipment + routing at injection site from main trunk line

SimCCS/Network Roadmap

Simulate/optimize CCS at WVR site

- With 5 additional sources (various types)
- Conceptual pipeline network
- Capture amount and cost estimate scenarios
- Plants incorporated by cost, based on injection availability at storage site





Candidate sources, pipeline network, and example deployment scenario for SimCCS Gateway simulations. Cayuga Generating Station Units 1 and 2 coincide.

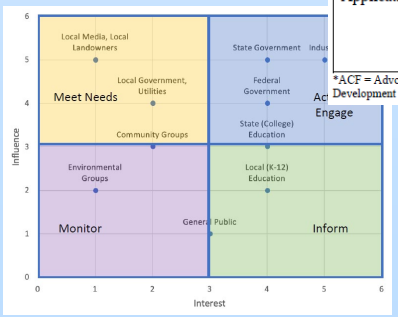
Stakeholder Engagement

Multi-Scale Approach

Products/Report

- Public Outreach Flyers: Wabash CarbonSAFE project characterization and seismic data collection efforts.
- DOE-FE0031626-2: Application of Policy Frameworks for Improved CCS Social Site Characterization & Stakeholder Engagement

- Outreach flyers (Project + 2D seismic)
- Assisted WVR meetings: explain geology, answer questions, talk to local stakeholders
- Academic study: assessment of stakeholder engagement policy frameworks re: CCS



Summary of Policy Frameworks Assessed

	ACF	NPF	CGF	PCF	IAD/SES
Scope of Analysis	Interaction at the coalition and subsystem levels.	Applications at the micro, meso, and macro levels.	Particularly valuable for coalition-level collaboration, but the scope can be interpreted broadly.	Conflict at the individual and group levels.	Broad, conceptual blueprint for examining institutional-level issues.
Key Questions	"What factors influence coalition formation, policy learning, and policy change (Sabatier& Weible, 2014)."	"Do narratives play an important role in the policy process (Sabatier& Weible, 2014)?"	How can collaborative learning, dispute resolution, and cross-coalition decision-making be applied to address complex issues (Emerson et al., 2012)?	"Under what settings do policy conflicts emerge, endure, and subside and which forms have what consequences (Heikkila & Weible, 2017)?"	"How do people devise institutional arrangements to solve collective action problems and provide shared benefits (Sabatier& Weible, 2014)?"
Methodology Clarity	Clearly stated assumptions. Many case studies use consistent ACF methods and generally include surveys used as appendices.	Clear methods and codebooks available for applying the framework in various contexts.	The framework is highly conceptual, so it must be paired with specific methodologies.	Methods are defined in existing literature, but there have been few applications of this framework thus far.	Clear guidelines for laying out policy issues, but very conceptual in nature.
Extent of Application	Extensive use in multiple countries, with particular use in environmental policy-related issues.	Some applications in the United States, but the NPF is still a relatively new framework.	Many case studies cite collaborative governance broadly, but the official CGF is a relatively new development.	Very recent application for oil and gas conflict issues. Due to the recent development of the PCF, only a few applications exist.	Many cases have used the IAD/SES throughout the world to conceptually address common-pool and stakeholder issues.

*ACF = Advocacy Coalition Framework, NPF = Narrative Policy Framework, CGF = Collaborative Governance Framework, PCF = Policy Conflict Framework, IAD/SES = Institutional Analysis and Development Framework/Social-Ecological System Framework.

- Understand stakeholders, needs, engagement types and priorities
- Need systematic way to implement social site characterization, monitor social media

Risk Assessments

Multi-Scale Approach

Reports

- DOE-FE0031626-3: Application of the NRAP Tools to the Wabash CarbonSAFE Site for Risk Assessment… Geologic Carbon Storage
- Projeo: Wabash CarbonSAFE Risk Assessment Report, with Risk Register and Response Plan

NRAP Toolkit Assessment:

Modeling:

- STOMP reservoir simulation for Potosi Dolomite

Well Risk: NRAP-Open-IAM ROM:

- Consider hypothetical uncemented wells or damaged cemented wells
- Overall risk profile for well leakage is low. For cemented well (annulus):
  - no significant brine leakage; negligible CO_2 leakage to aquifers and atmosphere (0.035 Mt).
  - impact plumes for pH and dissolved CO_2 the radii do not exceed 0.3 mi from the leak source.

Subsurface Stress: SOSAT ROM:

- Tested new version–including better constraint of horizontal stress magnitude.
- Estimates a low risk of shear failure resulting from CO_2 injection.

Risk Assessment Report: Risks associated with UIC Class IV permitting

- Wabash CarbonSAFE Risk Register and Response Plan prepared and evaluated:
  15 categories with ties to U.S. EPA permit application guidance or other source documents.
- Key gaps and recommendations for future work were identified.
- Applicable to other CCS projects

+ Risks managed during the project…

Risk Management

Multi-Scale Approach

+ Risks managed during the project…

Table from Wabash CarbonSAFE Proposal, 2018

Table 3: Project Risks and Mitigation Strategies			
Description of Risk	Probability	Impact	Mitigation and Response Strategies
Technical Risks:			
Unsuitable geology	Low	High	• Select secondary storage sites • Select multiple storage reservoirs
Lack of data	Med	Med	• Develop data acquisition strategy
Delays or difficulty when drilling well	Med	High	• Conduct Drill On Paper exercises • Monitor drilling activities daily
Non-technical Risks:			
Negative stakeholder response	Med	Med-High	• Develop comprehensive stakeholder engagement strategy
Lack of policy support	Med	Med-High	• Continue to interface with decision-makers
Resource Risks			
CO_2 source not available	Low	High	• Identify additional sources • Develop network of potential sources
Lack of team skills to populate CCS Team	Low	Med	• Continue to build team capacity • Grow team over time
Unable to achieve financial support to progress project	Med	High	• Continue to seek new funding sources • Seek additional partners to contribute support
Management risks			
Key personnel loss	Low	Med	• Maintain back-up and depth in team
Project cost over runs	Med	High	• Maintain proper project management practices • Drilling well represents largest risk, monitor costs and performance daily

Project Summary

Key Findings

Key Findings

- Wabash #1 and 2D Seismic data providing greater insight into regional distribution of Mt. Simon Ss
- Potosi Dolomite appears to have excellent storage reservoir potential
- Containment:
    - Maquoketa Group regional seal
    - Multiple confining units between reservoir and seal
    - No faulting or significant fracturing observed through Potosi-Maquoketa interval
- Modeling shows Potosi can accept required CO_2 amount; no adverse pressure buildup
- Potosi-Maquoketa storage complex has economic potential

Outcome

- CarbonSAFE goals: to accelerate commercial development of CCS
- Data from Wabash #1 has led WVR to develop Class VI permit material and continue with site characterization and development

Project Summary

Next Steps

WVR industrial project continuing under DOE Coal FIRST *(FE0031994)*:

Flexible fuel gasification-based carbon-negative power and carbon-free hydrogen co-production. FEED designs for CCS process & infrastructure and power generation.

Data Gaps for Future Characterization Activities: Need for additional data and verification

- Additional drilling; enhanced well logging, testing, and core analyses in Potosi and confining units
- Direct fluid sampling and verification of lowermost USDW (vs. swab sample and regional data)
- Additional seismic information (VSP + 3D seismic for additional control and resolution)
- Refinements to numerical modeling to reduce uncertainties:
  - Additional well data -> heterogenous model (vs. current "layer cake"); uncertain vuggy extent/interconnectedness
  - Lab measurements of permeability, relative permeability, and capillary pressure using cores from the Potosi are recommended; perm and capillary entry press for confining units (vs. correlations).

Research/Challenges Remaining

- How to model Potosi, continuity of porous and permeable zones, monitoring
- Cambrian sandstone at Wabash #1 TD: potential reservoir below these
- Deep IL Basin structural and depositional history, regional correlations with new data collections

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Thank You!

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