Carbon Storage Complex Feasibility for Commercial Development in Southeastern Michigan- CarbonSAFE Phase II
(DE-FE0032312)

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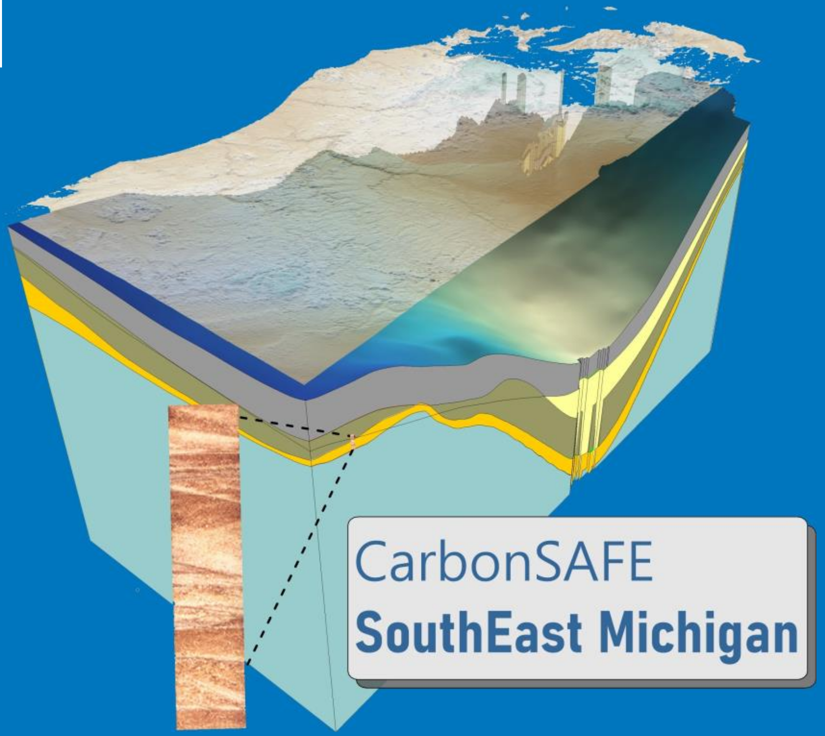
2024 U.S. DOE/NETL Carbon Management Research Project Review Meeting



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Project Overview

Funding: ($8.1M DOE, $2.0M Cost Share)

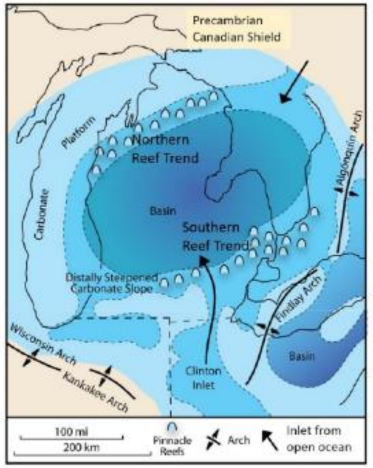
Performance Dates: 2 years
(October 2023 to September 2025)

DOE/NETL Project Manager: Nick Means

Project Team: *Battelle (*Research Institute in Columbus, Ohio)

*DTE Energy (**DTE**)* (Detroit-based diversified energy company serving 2.3 million electric & 1.3 million natural gas customers)

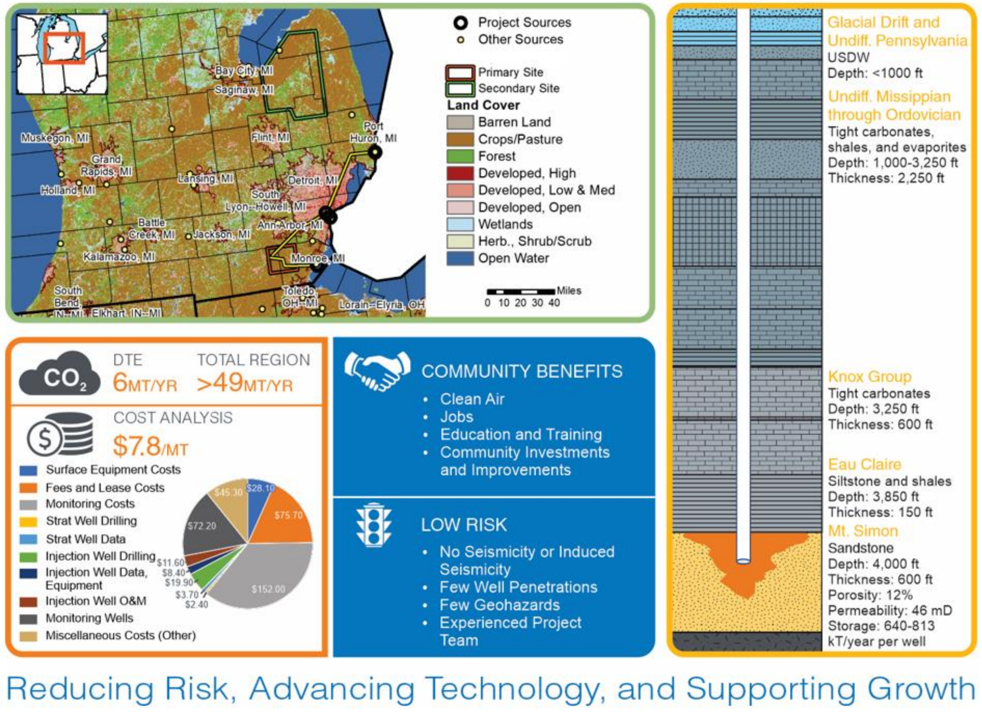
Objective: Develop an integrated commercial-scale storage complex capable of storing 63-million tonnes CO_2 in saline formations within 30-years in the Southeastern region of the Michigan Basin.

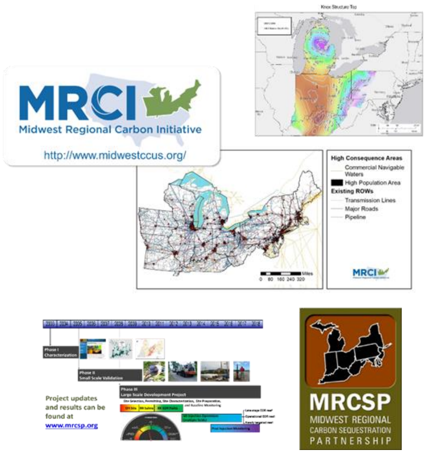


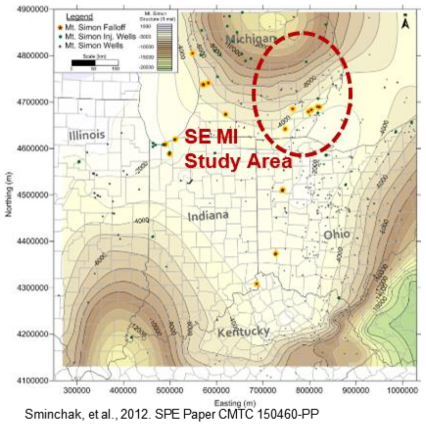
- ***Storage Hub** – Southeastern MI*
- ***Storage Site** – SE Michigan site, or alt. northern SE Michigan site*
- ***CO_2 Sources** – Blue Water Energy Complex (BWEC), St. Clair County, **3 MT/yr**, potential future CCGT w/CCS ~**3 MT/yr***
- ***Additional Sources** – numerous sources along I-75 corridor 5MT/yr*

Background

- Battelle and DTE are teaming to evaluate CO_2 storage hub feasibility for power generation and other emitters in SE Michigan.
- The project builds on collaborations between Battelle, Midwestern Regional Carbon Sequestration Partnership, Midwest Regional Carbon Initiative, & a previous CarbonSAFE Northern Michigan Basin Phase I project.
- A previous evaluation was also completed by Battelle Carbon Services for DTE to determine the feasibility of commercial-scale storage in Southeastern Michigan.







Sminchak, et al., 2012. SPE Paper CMTC 150460-PP

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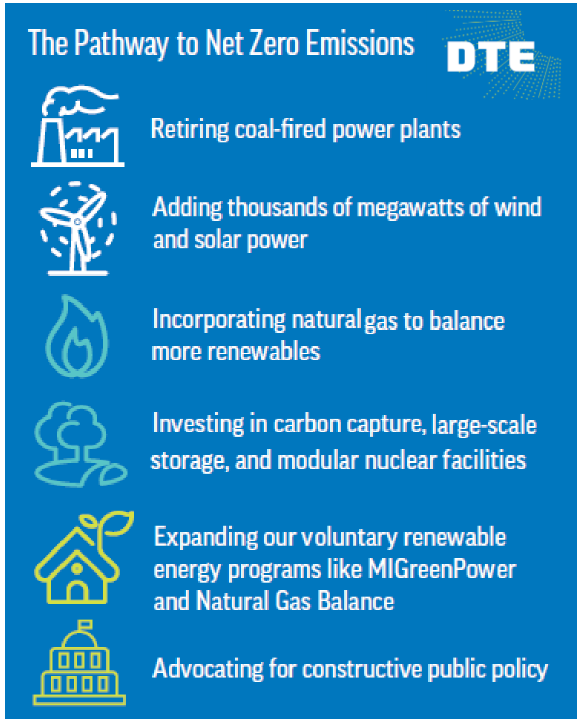
Project Benefit to DOE Program Goals

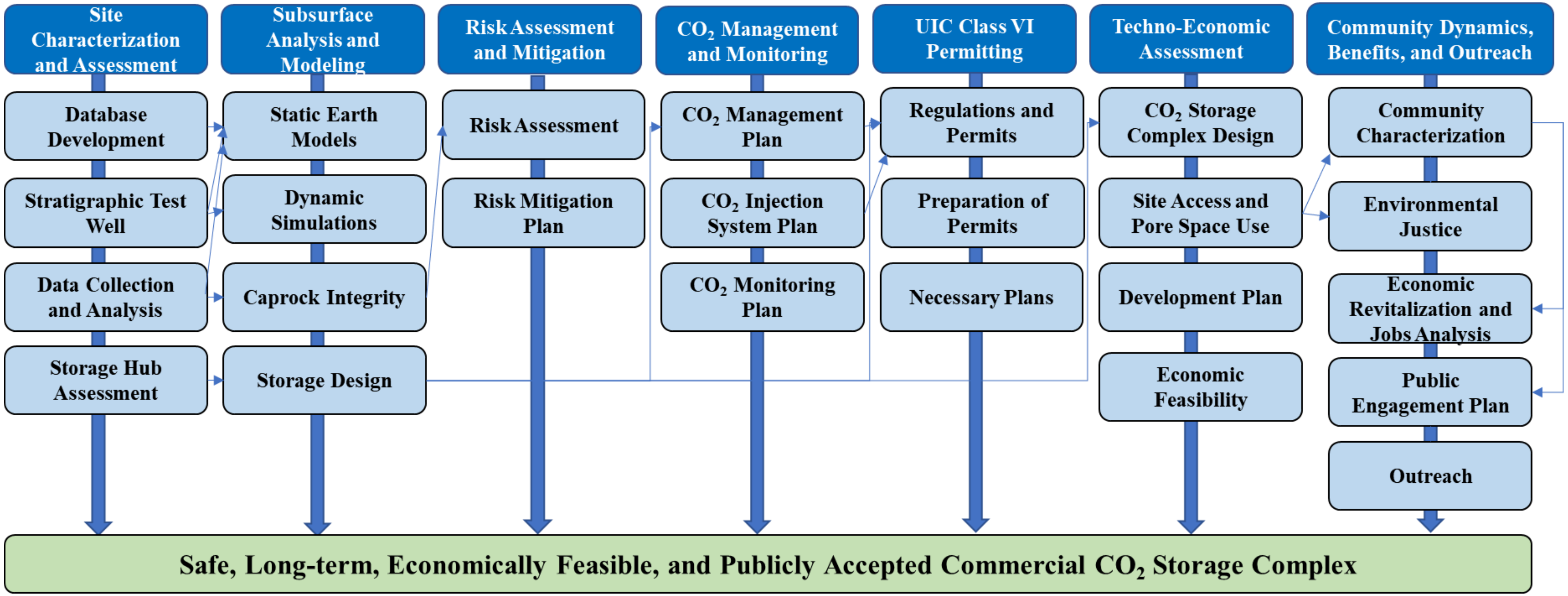
- **Supports** DOE FECM programmatic goals to develop industrial scale CarbonSAFE hubs to help reduce greenhouse gas emissions, develop skilled workforce, and support carbon capture implementation.
- **Provides** 63 million metric tons of secure carbon storage to a key industrial area along I-75 corridor by 2030 with power generation, refining, chemical facilities, steel plants, hydrogen.
- **Progresses** CO_2 storage from SRMS prospective storage volume to contingent storage resource with a 4,600 ft deep stratigraphic test well, analysis of ~200 miles of 2D seismic data, design of safe CO_2 storage system, and risk mitigation measure for a CO_2 storage hub.
- **Benefits** communities in areas with skilled workforce development needs, underserved communities, investments in energy transition.



Technical Approach

Technical Approach includes 7 tasks designed to ensure safe, long-term, economically feasible, and publicly accepted commercial CO_2 storage complex.

Technical Task Organization



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Community Benefits Plan

GOAL: Focus on areas with skilled workforce development needs, underserved communities, and needs for investments in energy transition.

Potentially impacted communities: Lenawee, St. Clair, Wayne, Washtenaw, Monroe Counties MI

- 10 of 11 counties in SE MI have DACs - cumulative impacts – poor economic, environmental, social, & health indicators
- Nearest DAC to proposed hub approx. 12 miles SW in Lenawee County
- Many DACs in SE MI highly dependent on fossil fuel industry for employment

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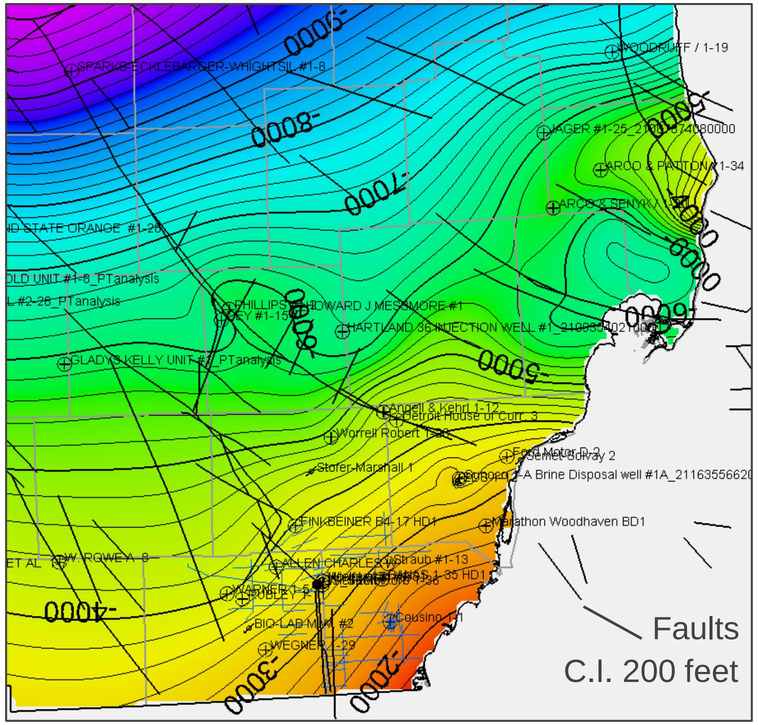
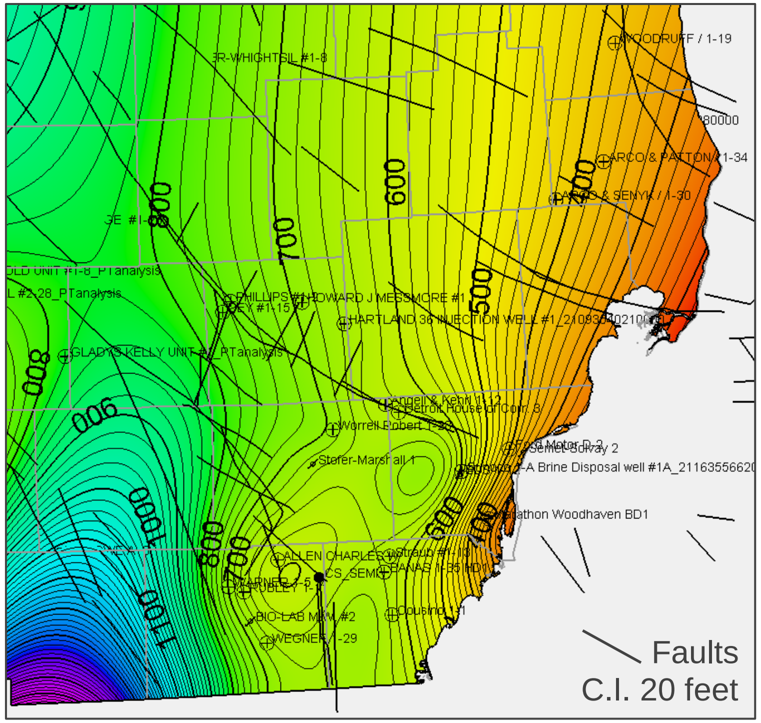
Regional Subsurface Characterization

- Geotechnical database created March 2024
- Subsurface maps provide a reasonable trend guide until seismic and faults are integrated into interpretation
  - Mt. Simon deepens to the Northwest
  - Mt. Simon thickens to the West
- Significant uncertainty until all subsurface data are integrated
- **<u>Geotechnical Database</u>**
  - Log data, driller data/interpretations
  - Available seismic line locations
  - Faults and lineaments
  - Core data
  - Injection well data
  - Battelle interpretations of cross sections
  - Purchased core data, Seismic data (non-public)

Mt. Simon Depth Structure (SSTVD, feet)

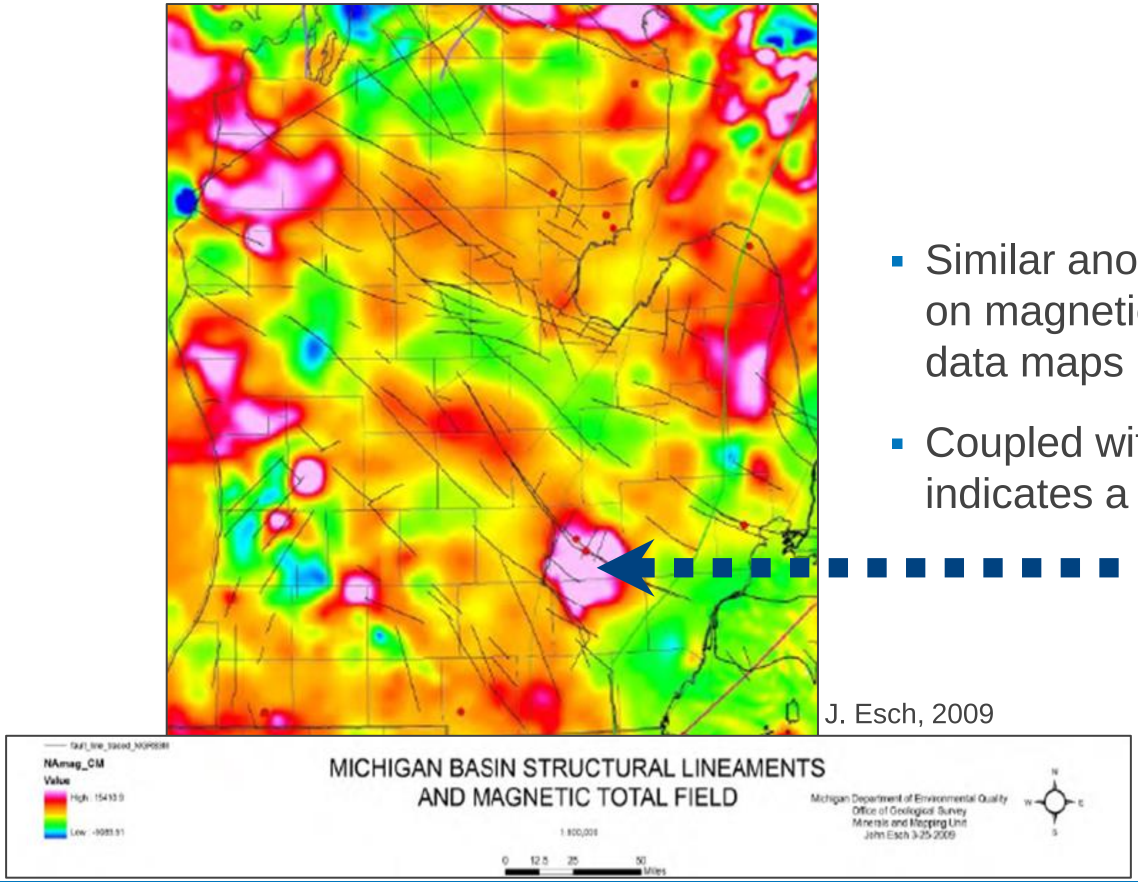


Mt. Simon Isopach (feet)

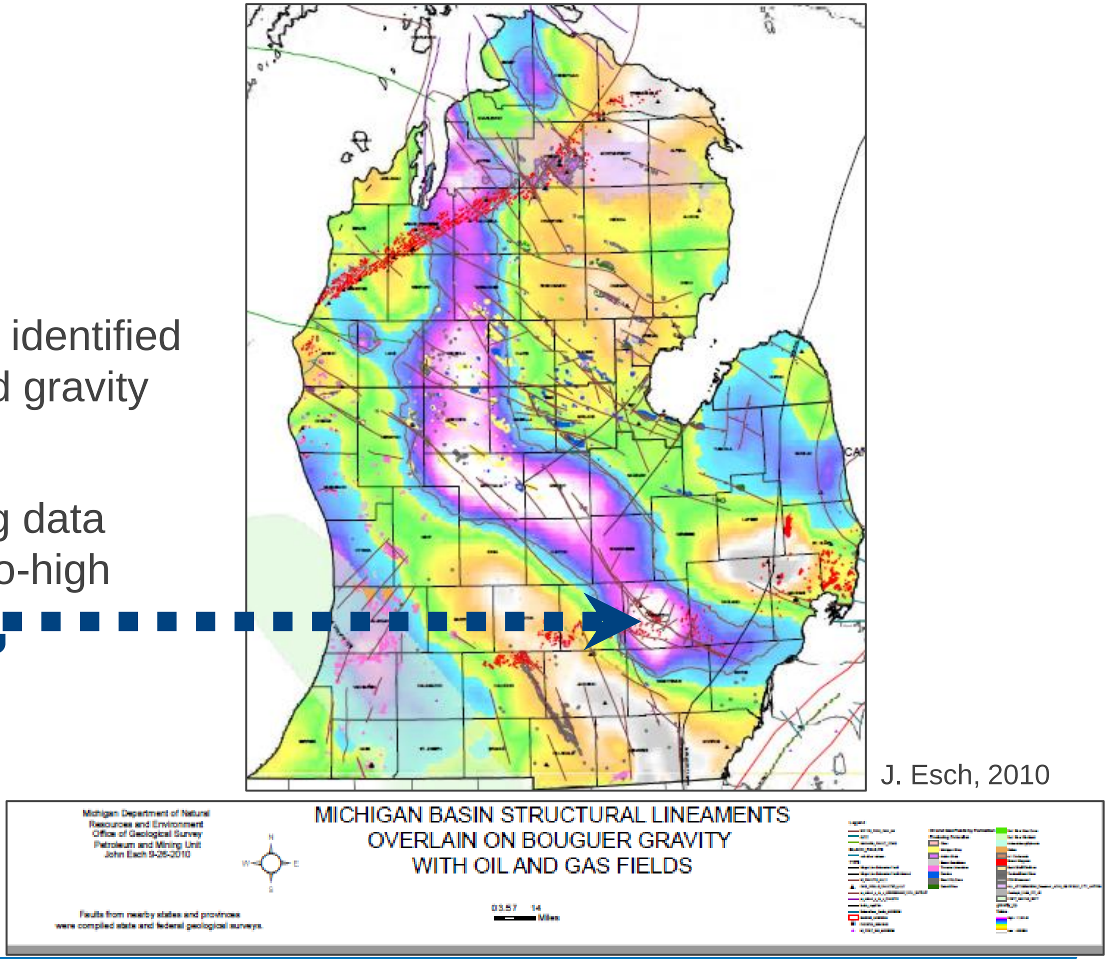


Integration of Gravity and Magnetic Maps

- Possible insights to help guide geologic interpretations and best STW location
  - Avoid Precambrian highs (Livingston County)
  - Similar anomaly identified on magnetic and gravity data maps
  - Coupled with log data indicates a paleo-high



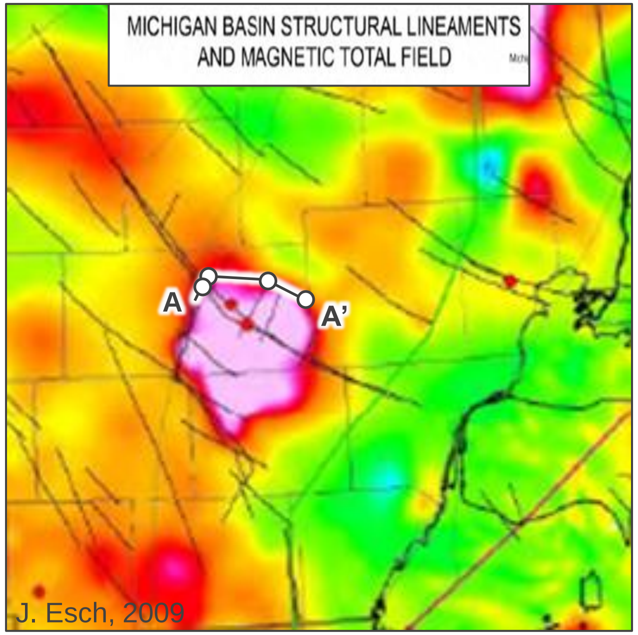
J. Esch, 2009

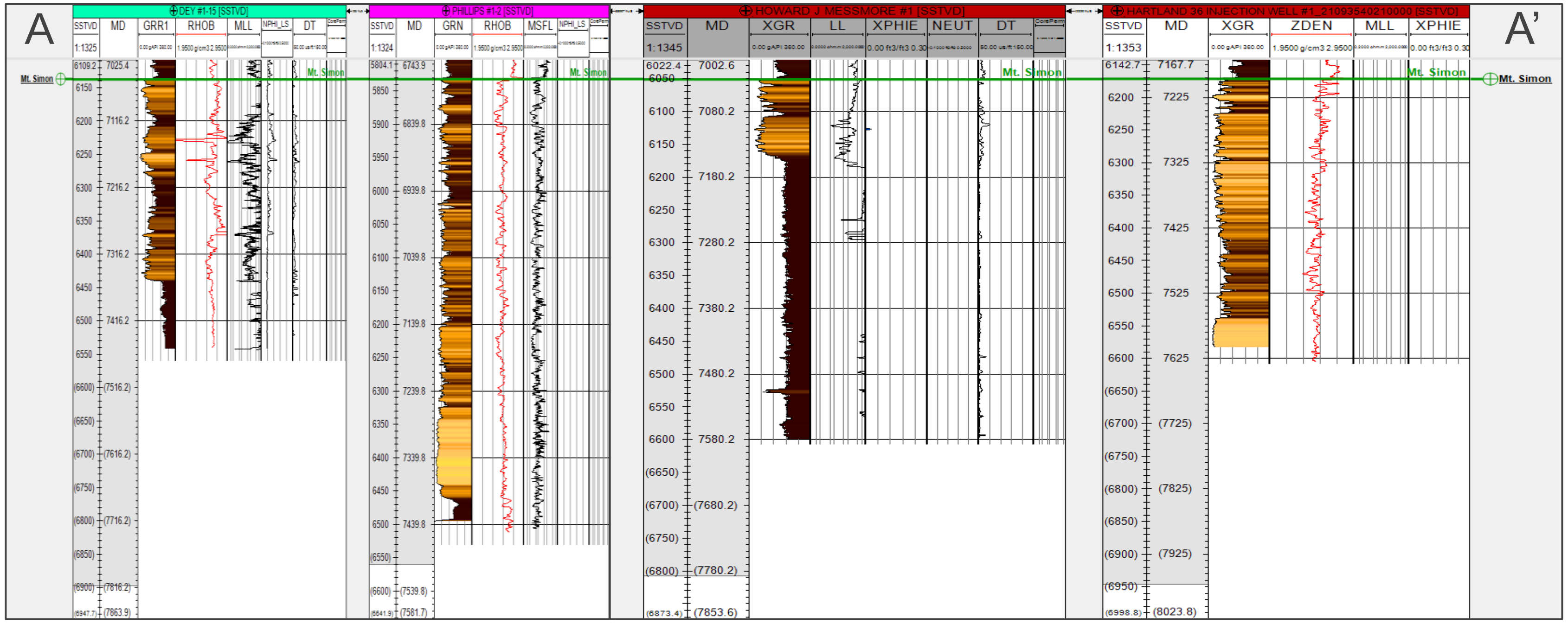


J. Esch, 2010

Paleo-highs & lows

- Paleo-highs and Paleo-lows are difficult to identify location or delineate shape
- Known paleo-high in Livingston County appears to correlate to magnetic data
- If correlation is valid, the shape and size can be estimated





Well logs courtesy of TGS, interpretation from Battelle

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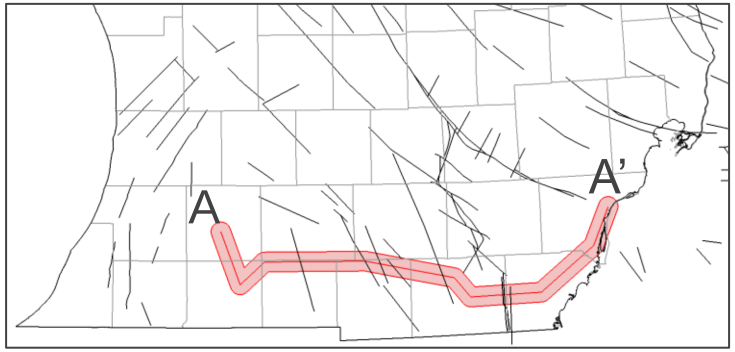
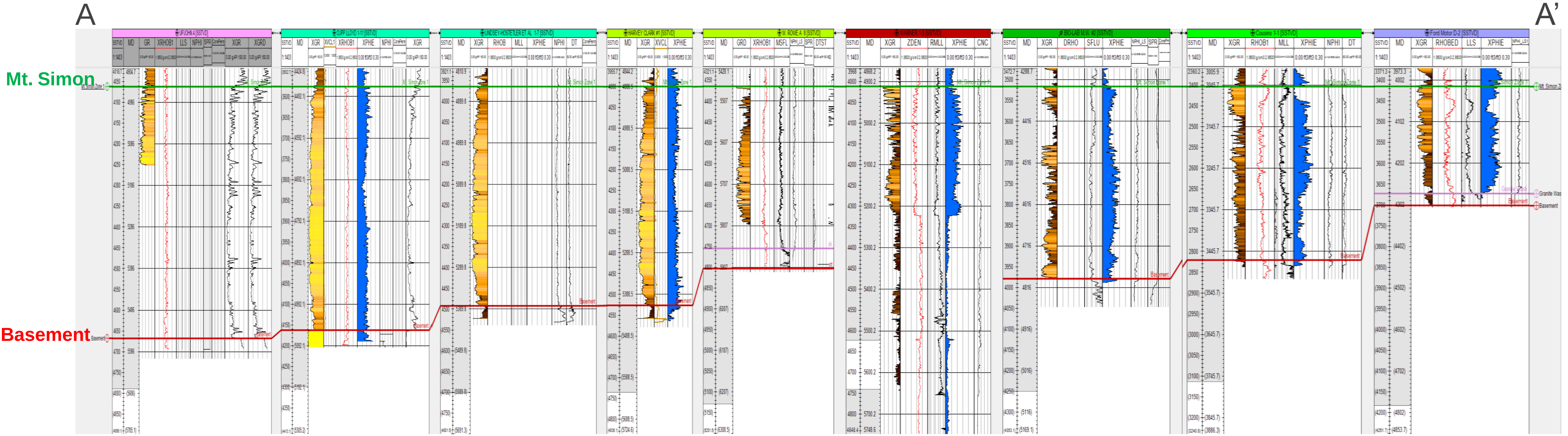
Mt. Simon Depositional Changes Across Michigan

- Continued scrutiny of data has not revealed the exact intersection of the different depositional systems
- Integration to seismic observations occurs at a local scale





Well logs courtesy of TGS, interpretation from Battelle

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Legacy vs Reprocessed Data

- Acquired by Shell in 1986; reprocessed by SEI in 2015
- Vibroseis source -60 fold
- High frequency results
- More detail in faulted areas
- Lateral amplitude variation & character

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2D Identification of faults

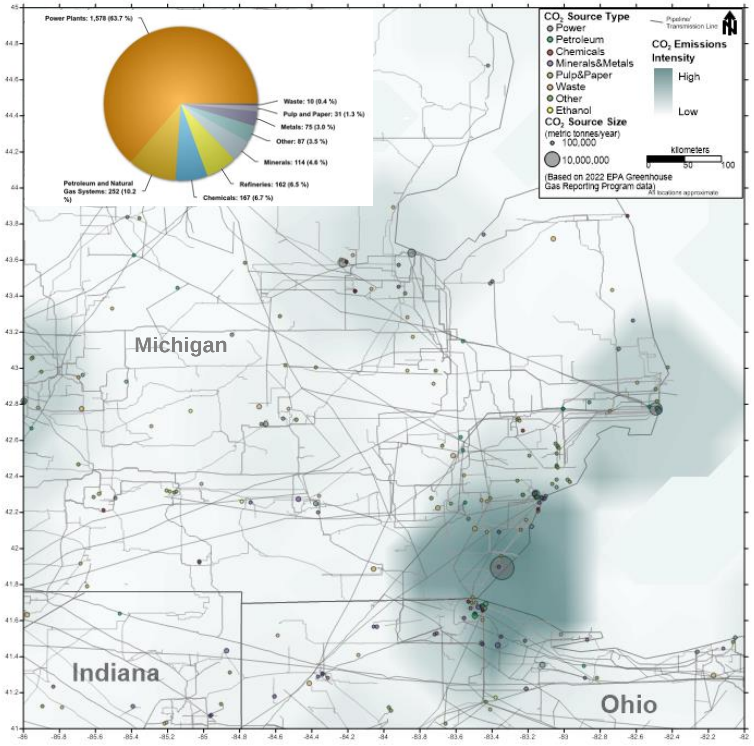
- More structurally complex than base map representation
- Some faulting extends into shallow sections
- STW location is pending ongoing seismic interpretation and integration with other subsurface data

Seismic data owned or controlled by Seismic Exchange, Inc.; interpretation is that of Battelle

Subsurface Modeling and Analysis: Source Assessment

- Hub assessment source assessment completed to delineate CO_2 source specifications, potential for capture retrofit, and options for connecting to CO_2 storage hubs in SE MI.

CO_2 Source Assessment



CO_2 Capture Techno-Economic Assessment

CO₂ Ranking	1	1.7 million tons CO2/yr
	2	Between 0.3-1.7 million tons CO2/yr
	3	0.3 million tons CO2/yr
Purity Ranking	1	75-100 CO2 mol %
	2	25-75 CO2 mol %
	3	0-25 CO2 mol %
Cost	1	$0-25 per tCO2
	2	$25-40 per tCO2
	3	$40+ per tCO2
Technology	1	Technology is in use
	2	Some technology development
* Uncertain development	3	Little technology development
Age	1	0-25 years
	2	25-50 years
	3	50+ years

Facility/Plant name	County	State	Industry Type/ Primary Fuel	Industry Sector	Total annual CO2 emission (tons)	Techn-ology Rank	Purity Rank	Cost Rank	CO2 Emission Rank	Age Rank	Overall Rank (without age)	Overall Rank (with age)	Additional notes
Air Products and Chemicals Inc./Detroit Hydrogen Facility Marathon Refinery	Wayne	MI	Hydrogen Production	Chemicals	444520	1	2	1	2	1 *(Air Products to Build Michigan Hydrogen Plant to Supply Marathon's Detroit Heavy Oil Upgrade Project, 2009)*	6	7	
CARBON GREEN BIOENERGY	Ionia	MI	Stationary Combustion, Industrial Wastewater Treatment	Other, Waste, Ethanol Production	83957	1*	1	1	3	1 *(Our History)*	6	7	
THE ANDERSONS MARATHON HOLDINGS LLC	Calhoun	MI	Stationary Combustion, Carbon Dioxide (CO2) Supply	Other, Suppliers of CO2, Ethanol Refinery	228679	1*	1	1	3	1 *(Ethanol)*	6	7	
Alpont LLC	Lucas	OH	Stationary combustion, petrochemicals	Chemicals	51162	3*	1	1	3	1 *(Andersons Albion Ethanol LLC; Chen A., 2020)*	8	9	

Hub Scale CO_2 Sources in SE MI

Facility Category	Number of Facilities	Total CO2 Emissions (million metric tons/yr)
Category 1	13	33.836
Category 2	46	50.238
Category 3	82	54.123

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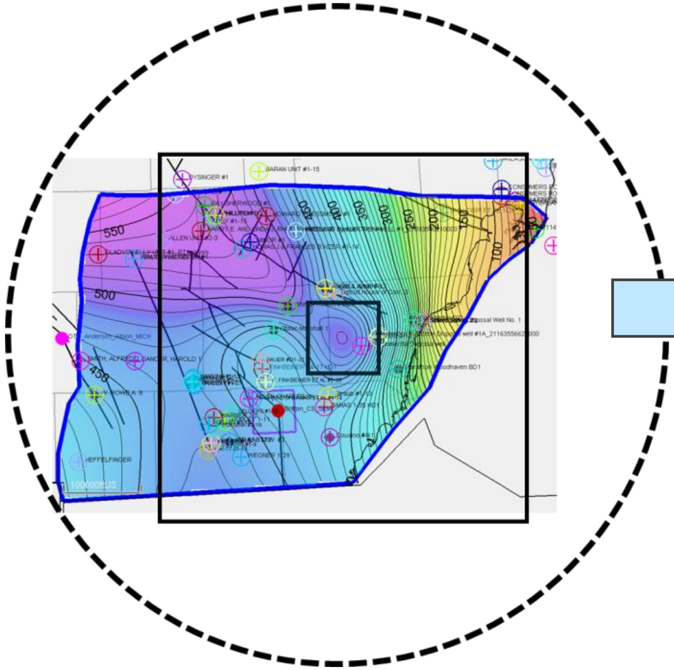
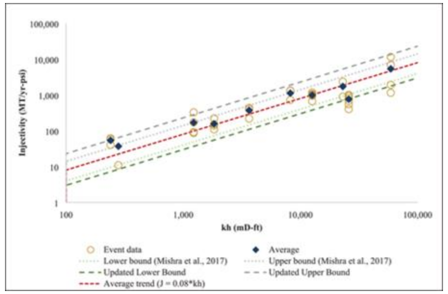
Subsurface Modeling and Analysis: Hub Design

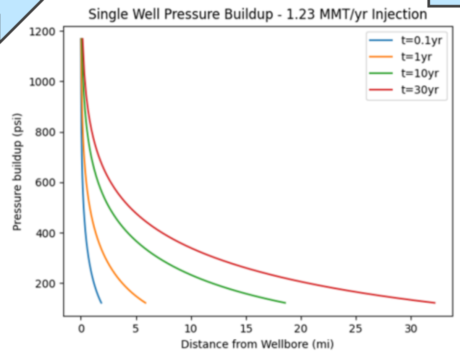
- Hub assessment in progress to evaluate linking CO_2 sources in SE Michigan to large scale CO_2 storage hub(s).

Regional Geologic Setting & Geotechnical Parameters

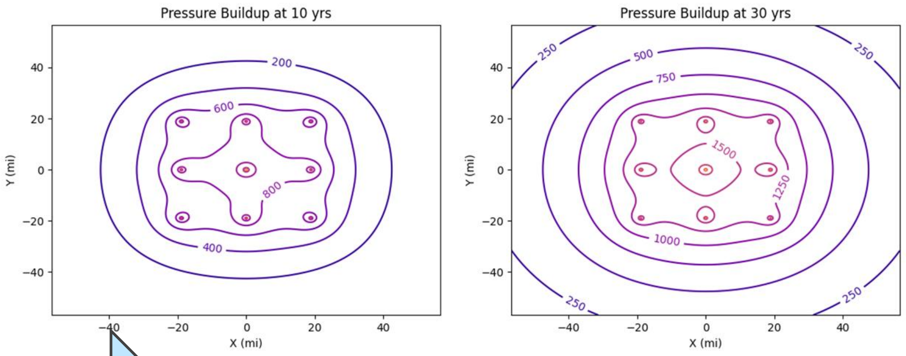


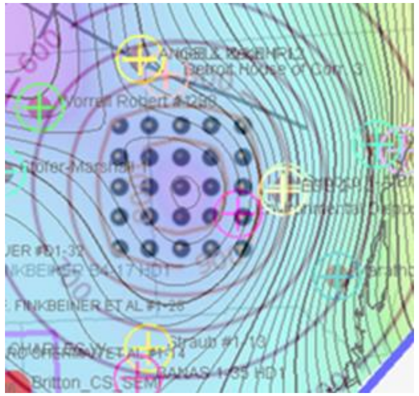
Injectivity Analysis





Hub Scale Injection Field Design





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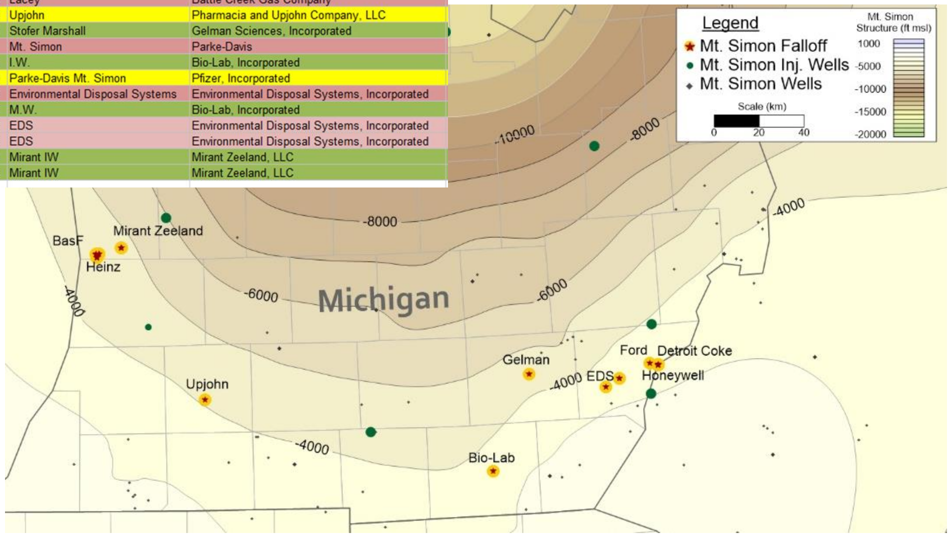
Subsurface Modeling and Analysis

- Injectivity analysis completed for 27 Class I UIC disposal wells. Operational data on injection rates & pressures used to estimate equivalent CO_2 injection rate sustainable in SE Michigan.

- Injectivity Index generally falls in range **200-400 tonnes/yr/psi**
  - Some as high as ~1000 tonnes/yr/psi for short periods

Class I UIC Wells in SE MI

	A	B	F	H
1	Permit.Index	WellAPINo	Permit.WellNAme	OWNER
2	**M0002**	21121000027000	Dupont Montague	E.I. DuPont de Nemours & Co., Incorporated
3	**M0051**	21139000517000	Heinz	Heinz North America
4	**M0052**	21139000527000	Heinz	Heinz North America
5	**M0053**	21139000537000	Heinz	Heinz North America
6	M0069	21163000697000	Disposal Well	Detroit Coke Corporation
7	M0070	21139000707000	Deep Well	Chemetron Corp.
8	M0071	21139000717000		BASF Chemetron
9	**M0129**	21139001297000	Mt Simon	Pfizer, Incorporated
10	**M0130**	21139001307000	Mt Simon	Pfizer, Incorporated
11	**M0137**	21077001377000	Upjohn	Pharmacia and Upjohn Company, LLC
12	**M0155**	21163001557000	Semet-Solvay	Honeywell International, Incorporated
13	M0184	21163001847000	Ford Motor	Ford Motor Company
14	M0217	21139002177000		BASF Chemetron
15	**M0226**	21163002267000	Semet Solvay	Honeywell International, Incorporated
16	M0321	21015003217000	Lacey	Battle Creek Gas Company
17	**M0327**	21077003277000	Upjohn	Pharmacia and Upjohn Company, LLC
18	M0328	21161003287000	Stofer Marshall	Gelman Sciences, Incorporated
19	M0336		Mt. Simon	Parke-Davis
20	**M0357**	21091003577000	I.W.	Bio-Lab, Incorporated
21	**M0373**	21139003737000	Parke-Davis Mt. Simon	Pfizer, Incorporated
22	**M0376**	21163003767000	Environmental Disposal Systems	Environmental Disposal Systems, Incorporated
23	**M0430**	21091004207000	M.W.	Bio-Lab, Incorporated
24	**M0462**	21163004527000	EDS	Environmental Disposal Systems, Incorporated
25	**M0463**	21163004537000	EDS	Environmental Disposal Systems, Incorporated
26	**M0509**	21139004707000	Mirant IW	Mirant Zeeland, LLC
27	**M0510**	21139004717000	Mirant IW	Mirant Zeeland, LLC



Pressure Fall Off and Injection Performance Analysis

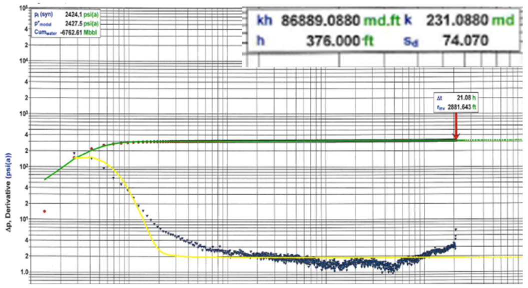
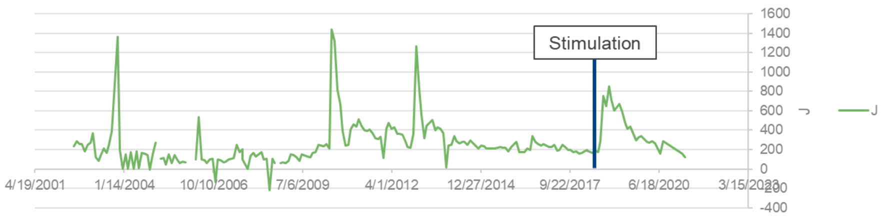


Table 4
Historical Ambient Reservoir Test Measurements

Well ID	Date	Depth (feet) BGL	kh (md-ft)	Skin	P* (psia)
IW1	08/2020	5,200	54,125	64.1	2,429
IW2	08/2019	5,200	86,501	73.9	2,423
IW1	08/2018	5,200	79,172	8.7	2,419
IW2	08/2017	5,200	44,035	60	2,448
IW1	08/2016	5,200	44,137	61	2,429
IW2	09/2015	5,200	49,466	82	2,441
IW1	09/2014	5,200 KB	35,248	35	2,416
IW2	09/2013	5,200	58,500	96	2,439
IW1	09/2012	5,187	39,881	46	2,427
IW2	09/2011	5,200	91,598	118	2,454
IW1	10/2010	5,200	32,279	9	2,379
IW2 int	10/2009	5,200	24,816	--	--
IW2	11/2008	5,200	24,938	33	2,520
IW1	11/2007	5,220	71,304	87	2,450
IW1	11/2006	5,052	55,390	96	2,394
IW2 static	09/2006	5,039	--	--	--
IW1	09/2005	5,220	34,726	50	2,436
IW2	09/2004	5,150	5,419	-1	2,527
IW2	09/2003	5,167	5,663	0	2,437
IW1	12/2002	5,280	31,866	17	2,472

Injectivity Index for CO2 – Mirant IW1



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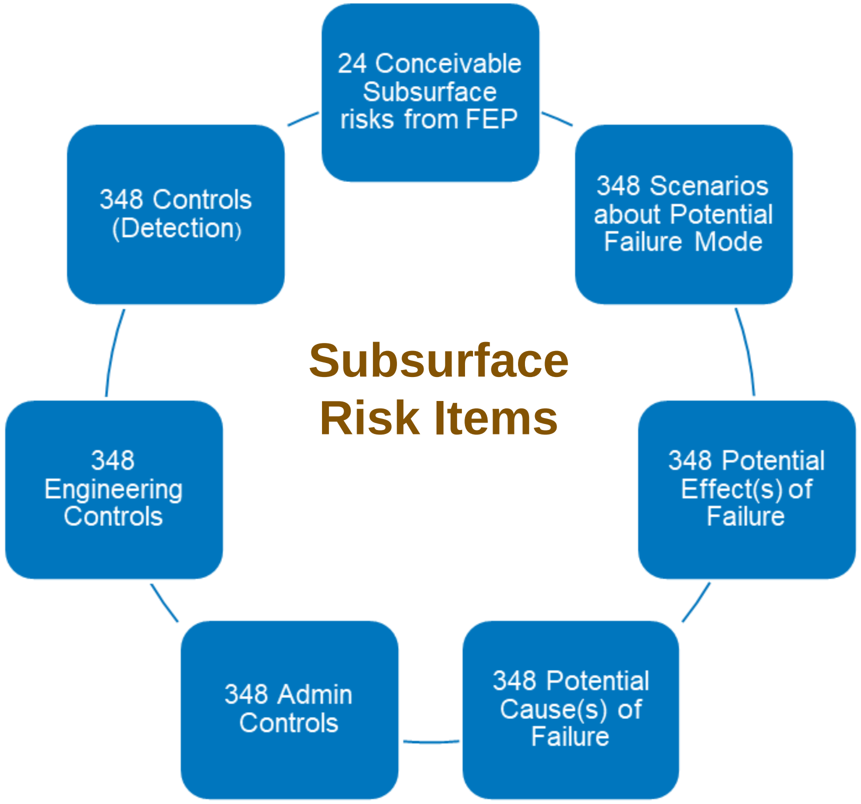
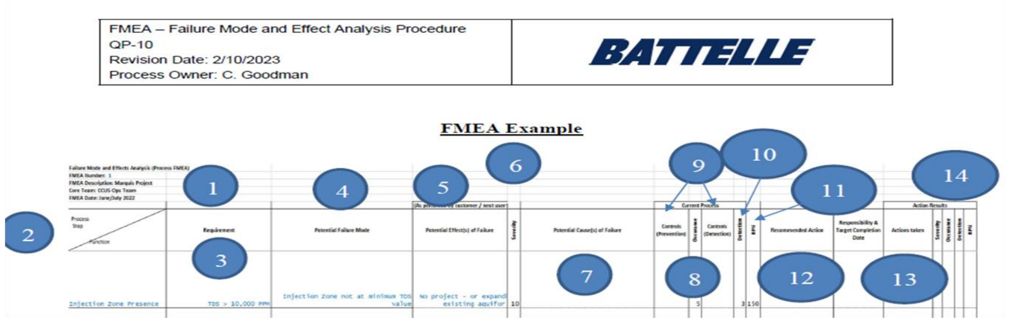
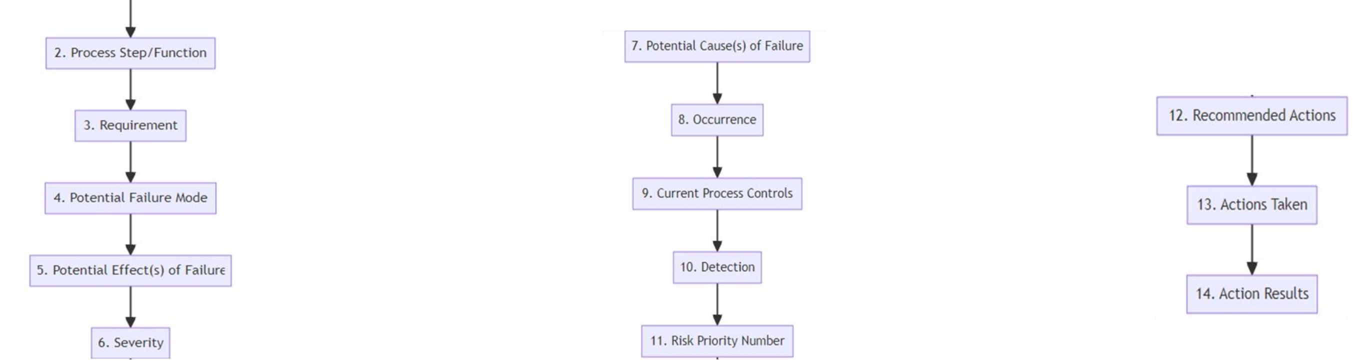
Risk Assessment and Mitigation

- Risk analysis completed to prioritize individual project risks for analysis or action by assessing their probability of occurrence & impact for **subsurface**, **non-technical**, **surface** items.
- Key benefit of this process is that it focuses efforts on high-priority risks throughout the project.



FMEA Example





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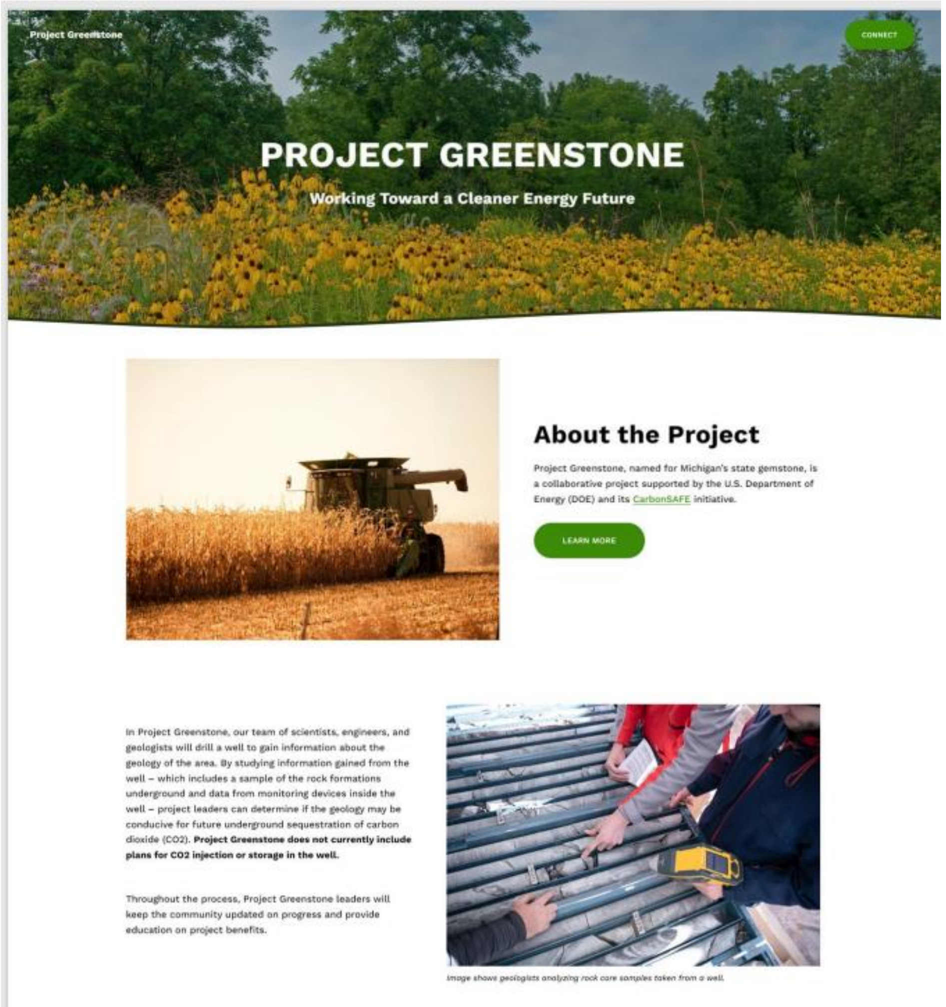
Stakeholder Outreach

To date, we have:

- Formed internal Engagement Team with DTE
- Designed and built project website (not live) with email address for two-way engagement
- Implemented engagement tracking
- Drafted a project fact sheet
- Participated in unique DEIA training session
- Drafted a Community Open House plan
- Scheduled "boots on the ground" visit to proposed site
- Conducted initial EJ Assessment
- Identified tentative "fenceline" neighbors



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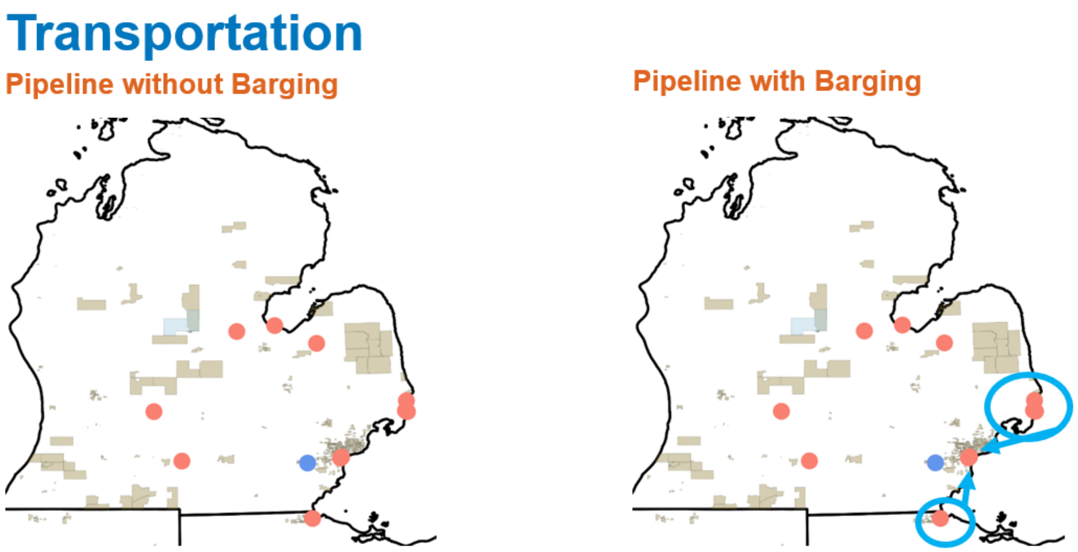
CO_2 Management, Monitoring, Class VI Permitting, Techno-economic assessment (scheduled later in project)

- Initial discussions with Michigan Environment, Great Lakes, and Energy for stratigraphic test well plan and Class VI permit process.
- Preliminary techno-economic analysis of CO_2 capture for sources in SE MI.

CO_2 Transportation Options



Techno-Economic Capture Assessment

Facility/Plant name	County	Industry Type/ Primary Fuel	Industry Sector	Total annual CO2 emission (tons)	Techn-ology Rank	Purity Rank	Cost Rank	CO2 Emission Rank	Age Rank	Overall Rank (without age)	Overall Rank (with age)
Air Products Detroit Hydrogen Facility Marathon Refinery	Wayne	Hydrogen Production	Chemicals	444,520	1	2	1	2	1	6	7
The Andersons Marathon	Calhoun	Ethanol	Ethanol Refinery	228,679	1*	1	1	3	1	6	7
Belle River	St Clair	Subbituminous coal	Power Plants	7,441,135	1	3	3	1	2	8	10
Blue Water Energy Center	St Clair	Natural gas	Power Plants	1,854,681	1	3	3	1	1	8	9
Dan E Karn	Bay	Subbituminous coal	Power Plants	3,646,483	1	3	3	1	3	8	11
Dearborn Industrial Generation	Wayne	Natural gas	Power Plants	1,814,546	1	3	3	1	1	8	9
Midland Cogeneration Venture	Midland	Natural gas	Power Plants	2,947,970	1	3	3	1	2	8	10
Monroe	Monroe	Subbituminous coal	Power Plants	16,290,016	1	3	3	1	3	8	11
Oregon Clean Energy Center	Lucas	Natural gas	Power Plants	2,301,852	1	3	3	1	1	8	9

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Technical Approach

Schedule/Milestones/Success Criteria

- 2-year project (October 2023-September 2025)
- Key success criteria: drill test well, identify site for hub, community/stakeholder engagement, verify design & techno-economics.

Task/ Subtask	Milestone & Description	Planned Completion Date	Verification Method
3.0	Well drilled and planned characterization activities complete	16 Months after project start	Well Completion Report
4.0	Static Earth Model and Dynamic Model completed	18 Months after project start	Geologic Modeling and Plume Extent Report
2.0/8.0	Techno-Economic Assessment and Jobs and Economic Revitalization Assessment show a viable, economically attractive project with benefits to affected communities	18 Months after project start	Techno Economic Assessment and Public Engagement Plan
7.0	Additional Characterization and Class VI permitting plans completed	30 Days before end of project	Additional Characterization and Permitting Plan
2.0	Community characterization to understand demographics, challenges, and history to guide outreach plan	12 Months after project start	Community characterization report
2.0/9.0	Public engagement/Community Benefits Plan to guide communications and engagement with communities, DEIAs, DACs, and EJ areas	Update 90 days after project start Final 30 days before project end	Community dynamics, benefits, and outreach report

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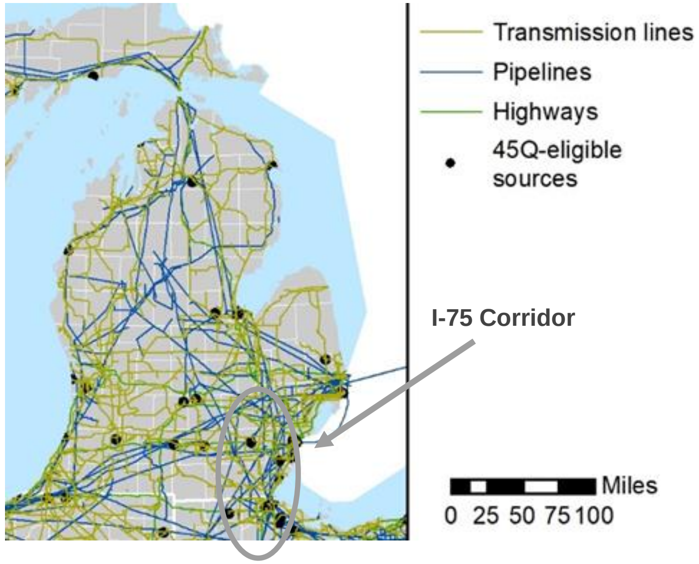
Plans for Future Commercialization

- **Future plans**: include linking sources and sinks for a variety of CO_2 sources in southern Michigan and northern Ohio (DTE Energy, Marathon, and other industrial emitters along the I-75 corridor).
- DTE is investing in upgrading its power generation portfolio and corresponding distribution grid to reduce outages.
- Implementing the SE MI CarbonSAFE project enables a reliable power supply through dispatchable resources that can accelerate decarbonization, helping mitigate climate change/resilience risks.



Storage certainty remains a key need in Michigan. Previous work has shown the potential for saline storage projects in the state; however, storage projects have not been researched to support commercial-scale implementation.
Path Forward: Support for integrated, targeted commercial-scale projects is needed to provide storage certainty. **5 of 6**

Infrastructure must be developed to transport CO_2. CO_2 pipelines will likely be needed to transport CO_2 from Michigan sinks to storage areas. In addition, storage hubs will require the drilling of injection and monitoring wells.
Path Forward: Michigan's existing pipeline, oil and gas, and brine disposal businesses provide a significant resource for CCUS project development. **3.5 of 6**

State-level funding, incentives, and policies are needed to attract interest to Michigan. MRCI has been receiving interest in CCUS from several industrial sources in Michigan, including electric power companies and chemical plants.
Path Forward: State-level incentives could propel these companies to implement CCUS in Michigan. State policy must be developed to provide project certainty. **2 of 6**

Public outreach, a crucial part of any project, must be completed for specific project sites. These efforts should focus on the benefits of projects while addressing the risks and project safeguards.
Path Forward: Public outreach can be accomplished through meetings, factsheets, and public meetings with stakeholders. **6 of 6**

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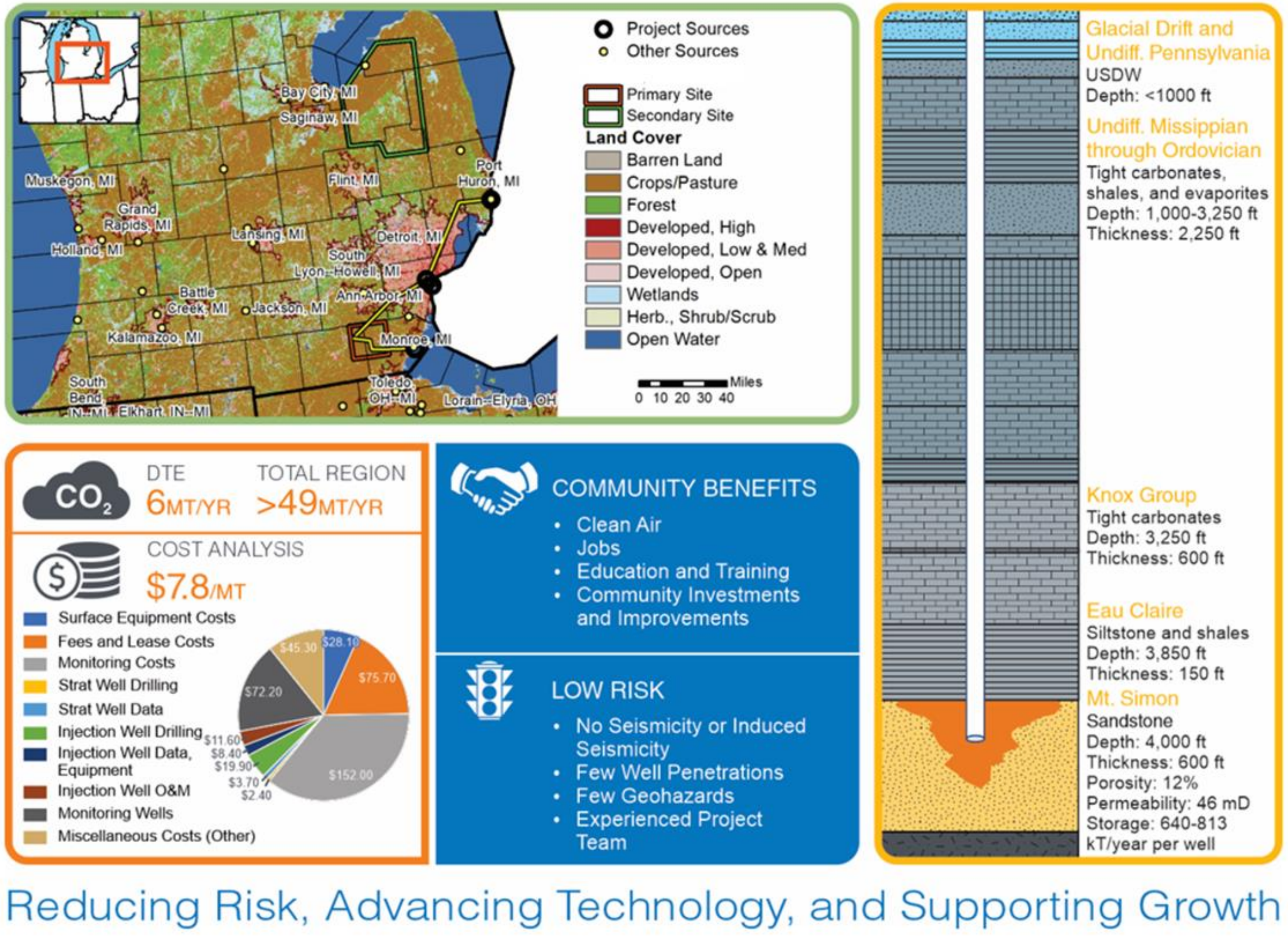
Summary

- Technical approach is designed to ensure a **safe**, long-term, economic, and publicly accepted commercial 63 Mt CO_2 storage complex in SE Michigan
- Progress to date:
  - Processing & interpretation of 290 miles of 2D seismic
  - Regional geological characterization
  - CO_2 storage hub design, risk analysis
  - Outreach & Community Benefits Plan refinement and specification
  - Finalizing stratigraphic test well location



Safe and secure CO_2 storage system is required with storage capacity, sufficient confining layers, monitoring, and safety protocols to ensure public acceptability.

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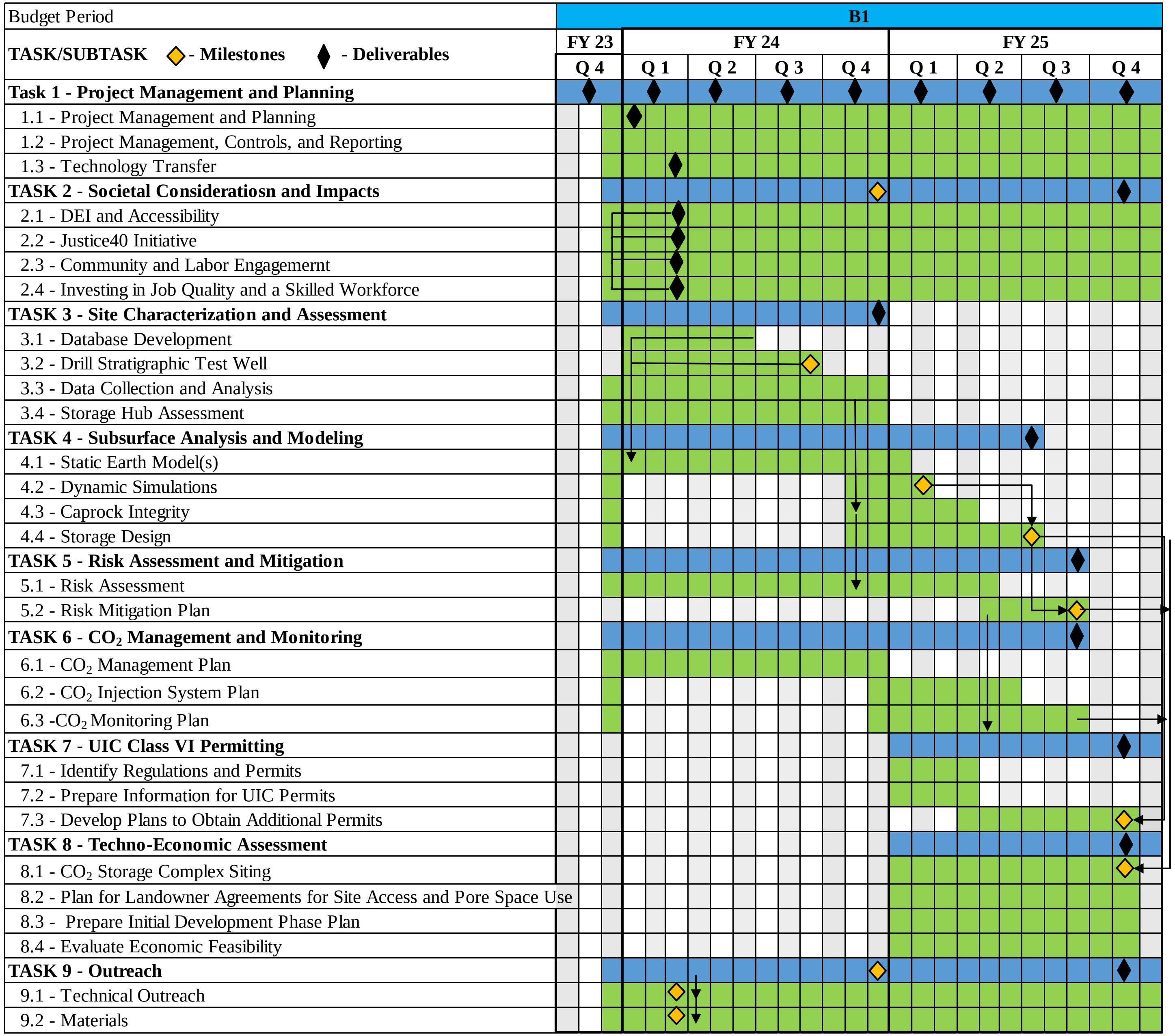
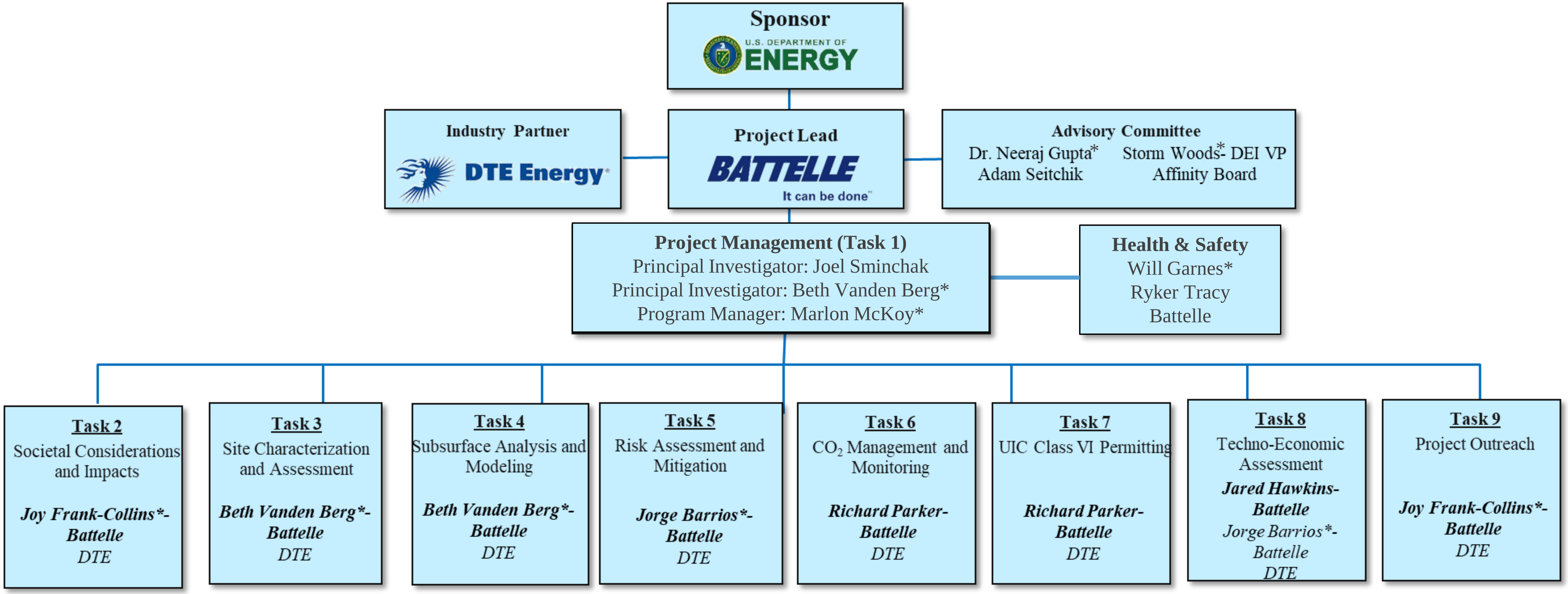
Project Execution Plan & Timeline



Technical Approach

Task leads assigned for technical tasks. DTE task leads in progress.



* *Underrepresented persons in STEM*

Project Success Criteria

Project milestones and scheduled dates

Task/ Subtask	Milestone & Description	Planned Completion Date	Corresponding Calendar Date
3.0	Well drilled and planned characterization activities complete	16 Months after project start	01/21/2025
4.0	Static Earth Model and Dynamic Model completed	18 Months after project start	03/21/2025
2.0/8.0	Techno-Economic Assessment and Jobs and Economic Revitalization Assessment show a viable, economically attractive project with benefits to affected communities	18 Months after project start	03/21/2025
7.0	Additional Characterization and Class VI permitting plans completed	30 Days before end of project	08/20/2025
2.0	Community characterization to understand demographics, challenges, and history to guide outreach plan	12 Months after project start	09/19/2024
2.0/9.0	Community Benefits plan to guide communications and engagement with communities, DEIAs, DACs, and EJ areas	Update 90 days after project start Final 30 days before project end	12/19/2023 & 08/20/2025

Project success criteria and scheduled dates

Task	Success criteria	Scheduled date	Corresponding Calendar Date
1.0	Datasets, files, metadata, software/ tools and articles developed as part of project	No more than 24 months after initial award	08/31/2025
3.0 and 4.0	Verification of commercial scale storage and injectivity	16 months after project start	01/21/2025
4.0	Development of feasible storage complex design	18 months after project start	03/21/2025
5.0 and 6.0	Reduce project risks and uncertainties	30 days before end of project	08/20/2025
8.0	Provide evidence that project is economically feasible	18 months after project start	03/21/2025
7.0	Draft UIC Class VI permit	30 days before end of project	08/20/2025
2.0	Evaluate public acceptance and community engagement	Updated plans 90 days after project start 30 days before end of project	12/19/2023 & 08/20/2025