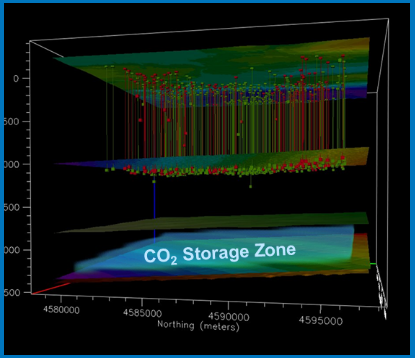
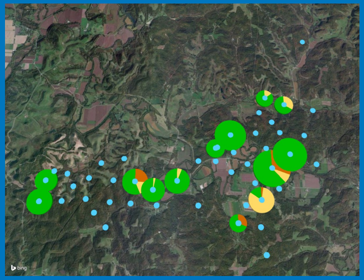
Systematic Assessment of Wellbore Integrity for Carbon Storage Projects Using Regulatory and Industry Information

DE-FE0009367





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U.S. DOE/NETL

U.S. Department of Energy
National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Transforming Technology through Integration and Collaboration
August 18-20, 2015

Ohio Development Services Agency

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Outline

1. Benefit to Program
2. Project Overview
3. Technical Status
4. Accomplishments to Date
5. Synergy Opportunities
6. Summary

- Appendix Material

Acknowledgements

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- Co-funding provided by Ohio Development Services Agency Agreement CDO-D-13-01.
- Thanks to project team Autumn Haagsma, Glenn Larsen, Jackie Gerst, Neeraj Gupta, Andrew Burchwell (Battelle), Nigel Jenvey, Brian Dotson, Walter Crow (BP Alternative Energy), Andrew Theodos, Jason Martin (Columbia Pipeline), many others.

U.S. DOE/NETL

Benefit to the Program

- Existing and plugged and abandoned wellbores are one of the greatest risks for CO_2 migration pathways
- This project was designed to provide a methodology to identify risks and recommend mitigation procedures
  - Area of Interest 1: Studies of Existing Wellbores Exposed to CO_2
  - Develop and validate technologies to ensure 99% storage permanence
  - Develop technologies to improve storage efficiency while ensuring containment effectiveness (goals)
- The project utilized available industry and regulatory data to evaluate well integrity and develop effective technology to account for wellbore issues from field evaluation to CO_2 storage field siting

Benefit to Program

- Areas in the Midwest have perceived risk for carbon capture utilization and storage (CCUS) due to long drilling history.
- However, many of the old wells may not present realistic risk for CCUS b/c they are shallow, depressurized, or properly plugged and abandoned.

Source: Drake Well Museum.

13. Cardington, Ohio, U. S. Route 42, looking east-southeast, c. February 1964. A companion to Photograph Number 10.

Source: Morrow County Oil Boom. 1994. Ohio Geological Society.

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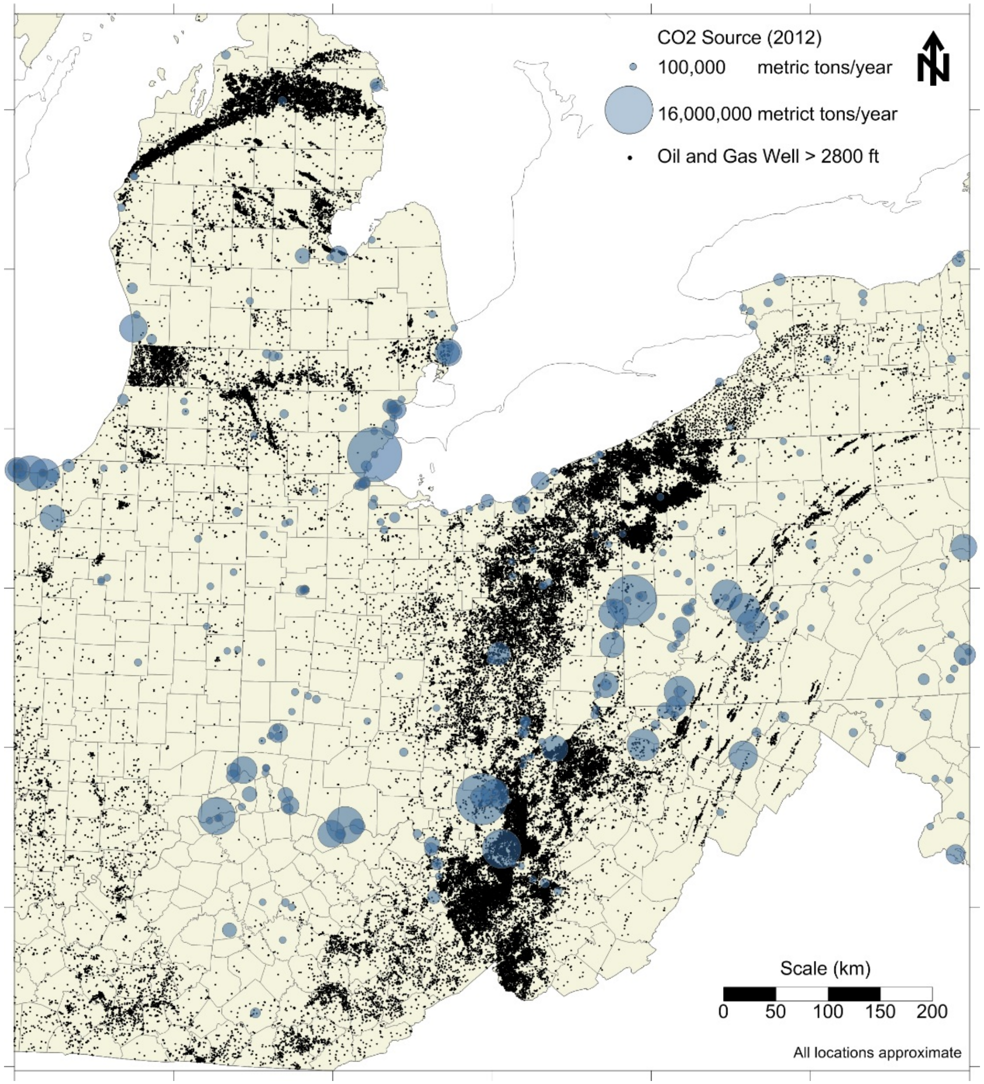
Benefit to Program

- Over 1 million oil & gas wells in Midwest U.S. dating back to 1859.
- What is the condition of these wells?
- How would they affect geologic CO_2 storage projects?
- What can we learn from evaluation of wellbore integrity for example test areas?



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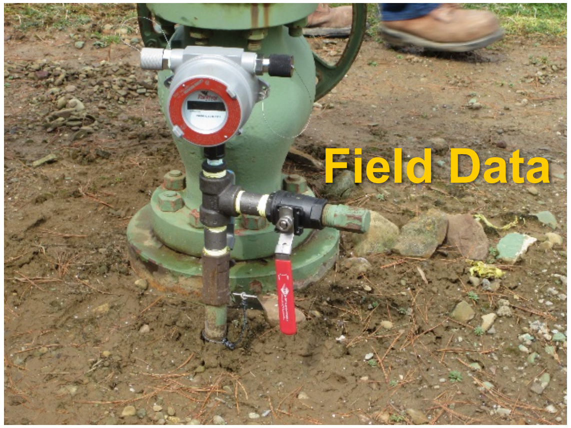
Project Overview: Wellbore Integrity

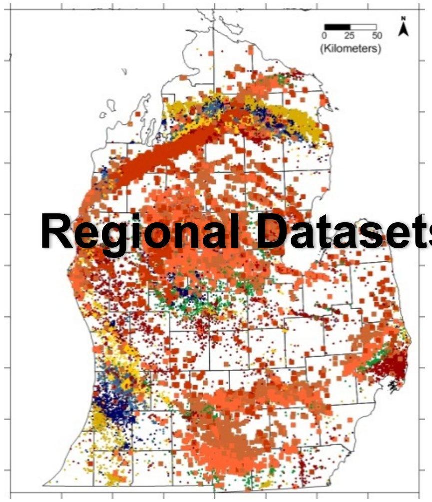
- Wells may exhibit <u>combined</u> effect of many types of well defects.

Well Integrity Item	Evaluation Factors
Cement degradation	Cement type, cement age, additives, hydrogeologic conditions
Cracks and Microannuli	Cement age, plug intervals, cement type
Acid-Gas Zones	Geologic logs, drilling logs, hydrogeologic zones
Channeling	Cementing procedures, cement age, cement mix
Casing Corrosion	Casing inspection logs, case studies

Project Overview: Objectives

- Overall: Complete a systematic assessment of wellbore integrity using regulatory and industry information.
- Determine the distribution of wellbores in a study area through collection and analysis of well records.
- Identify and develop methodologies that can indicate future wellbore integrity risks from available public data with high confidence.





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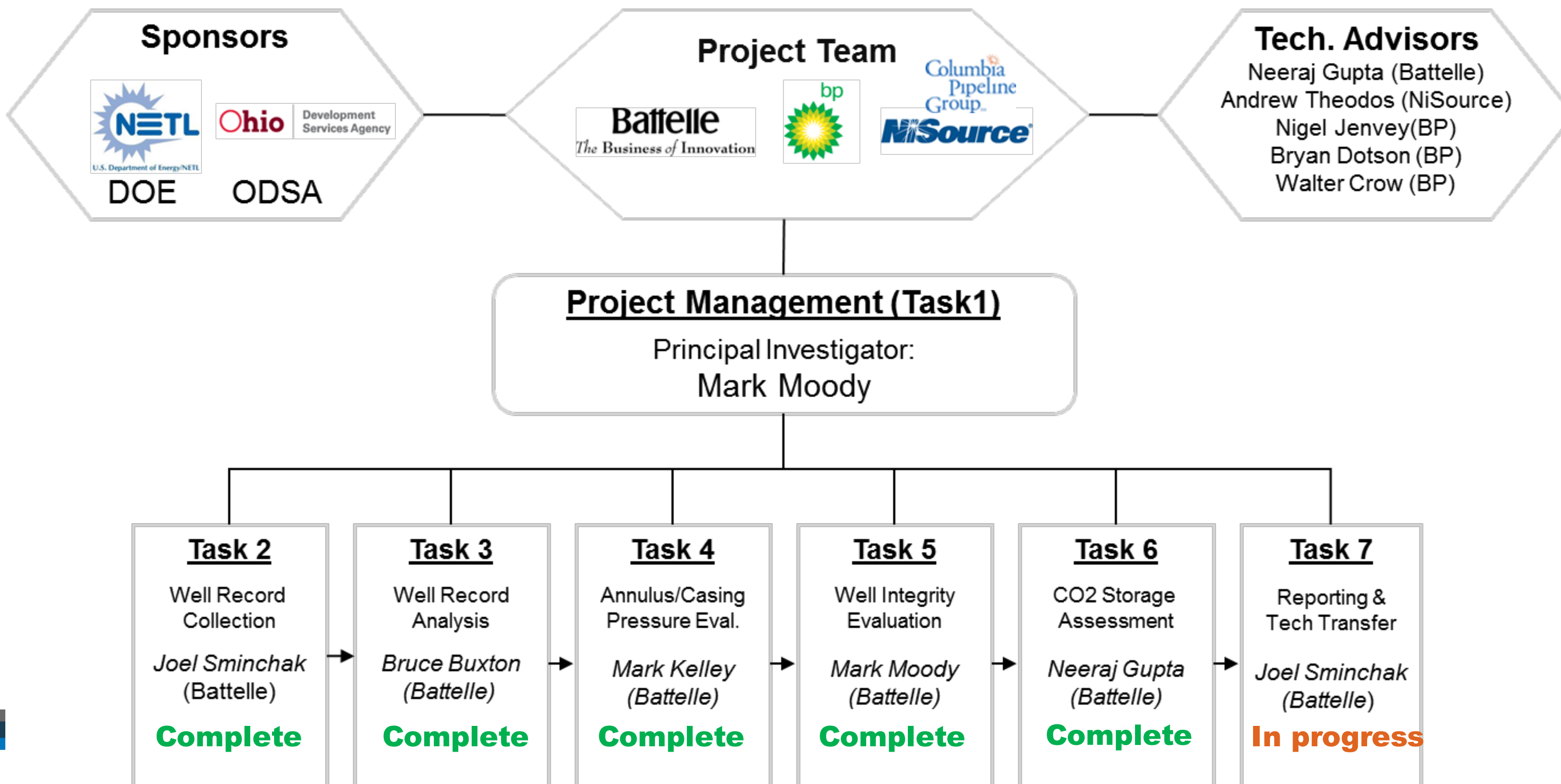
Technical Status

- Overall: three year project, on schedule for completion in September 2015.
- Main remaining task = Final Technical Report.



Accomplishments to Date

- The project consisted of seven tasks over a 3-year period (October 2012-September 2015):
  - Task 1 – Project Management
  - **Task 2 – Well Record Collection**
  - **Task 3 – Well Record Analysis**
  - **Task 4 – Sustained Casing Pressure Analysis**
  - **Task 5 – Well Integrity Analysis**
  - **Task 6 – CO_2 Storage Assessment**
  - **Task 7 – Final Report**
- Technical tasks are complete. Summary and major conclusions for each task follows:

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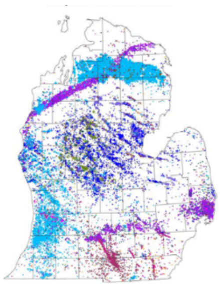
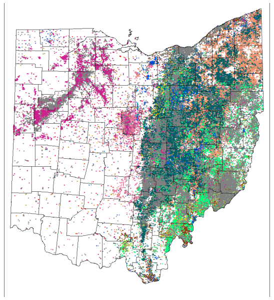
Task 2: Well Record Collection Review

- Database of over 4 million items for Michigan and Ohio study areas:



1. Well construction information,
2. Plugging and abandonment details, and
3. Cement bond logs.

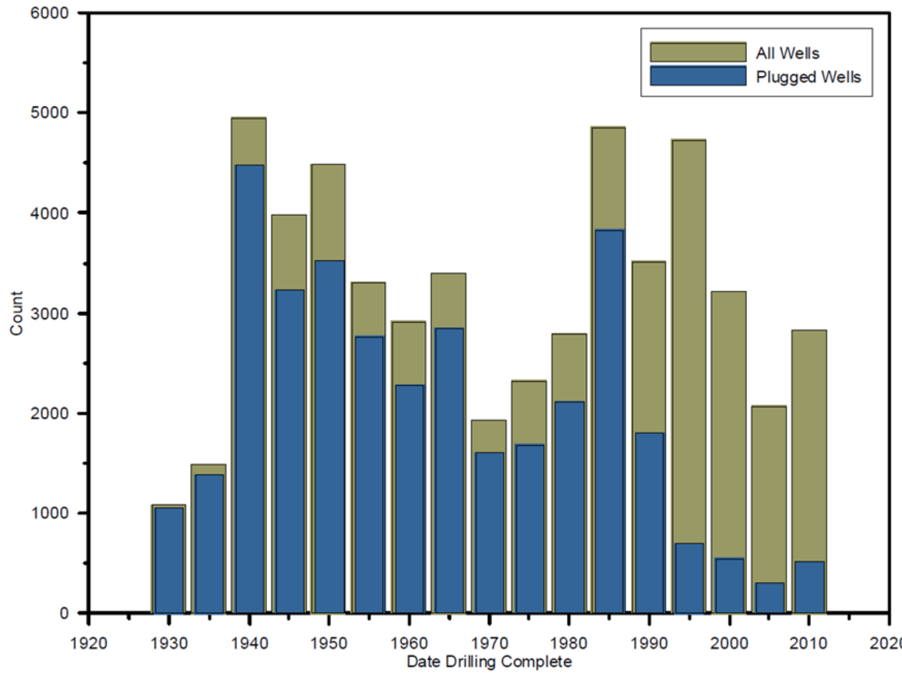


Well Construction/Status	Plugging & Abandonment	Cement Bond Logs
Location	Plug date	Bond interval
Age	# Plugs	Bond quality
Depth	Plug type	Cement issues
Formation	Plug thickness	
Type	Plug interval	
Status	Plug amount (sacks, tons)	
Date Plugged	Additives	

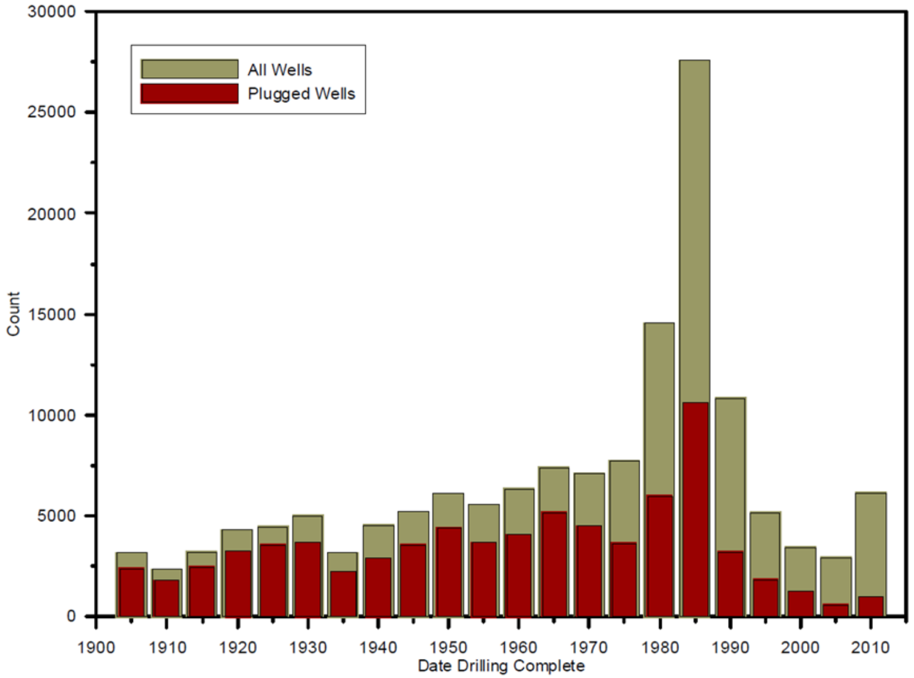
Task 3: Well Record Analysis

- Data suggest 102,246/207,892 (49%) of the wells in Ohio are listed as plugged.
- Data suggest 34,587/53,800 (65%) of the wells in Michigan are listed as plugged.

Michigan



Ohio



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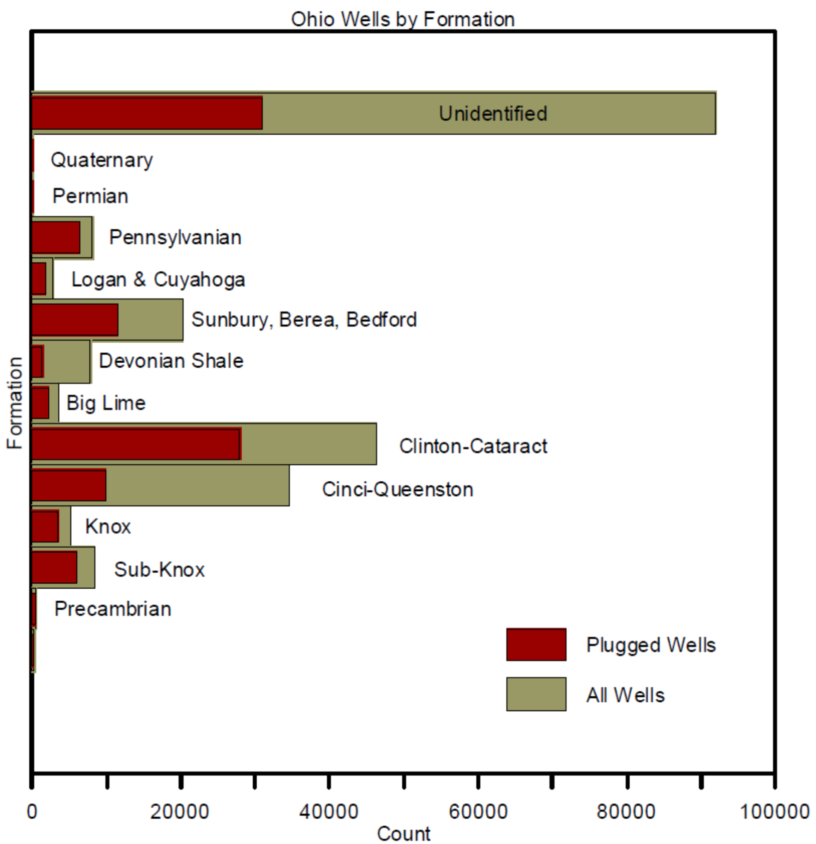
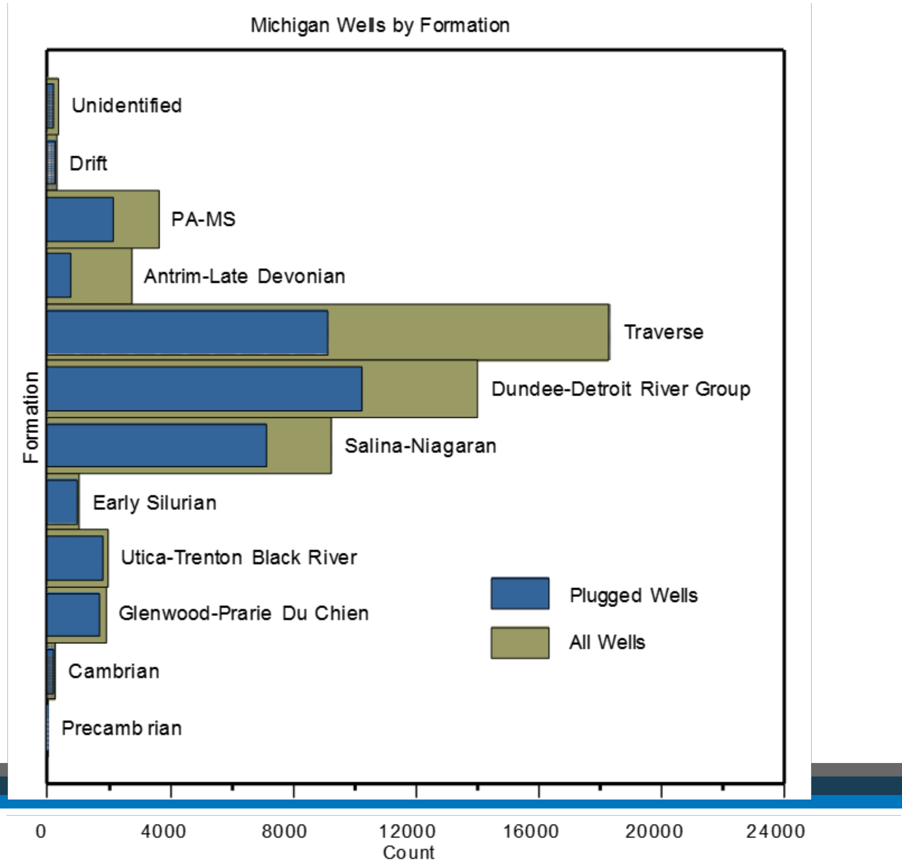
Task 3: Well Record Analysis

- Wells classified by formation helps understand relationship of CO_2 storage zones versus well fields.
- Many wells completed in hydrocarbon zones: 'Clinton' in Ohio. Antrim & Niagaran in Michigan.



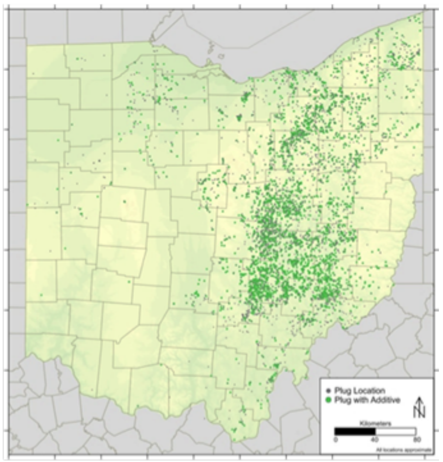


Task 3: Well Record Analysis

- A 5% subset on P&A records was tabulated for Ohio and Michigan to determine the method, arrangement, and materials used to plug wells in the region. Fields compiled: # plugs, plug thickness, amount, materials.

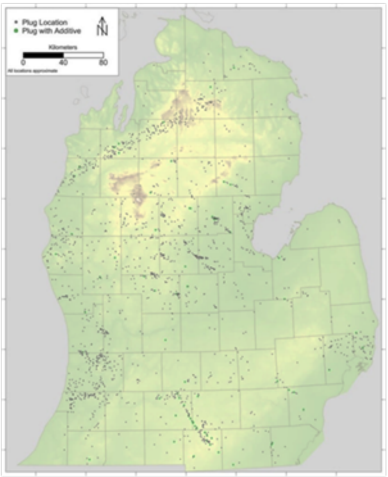
Ohio P&A Data

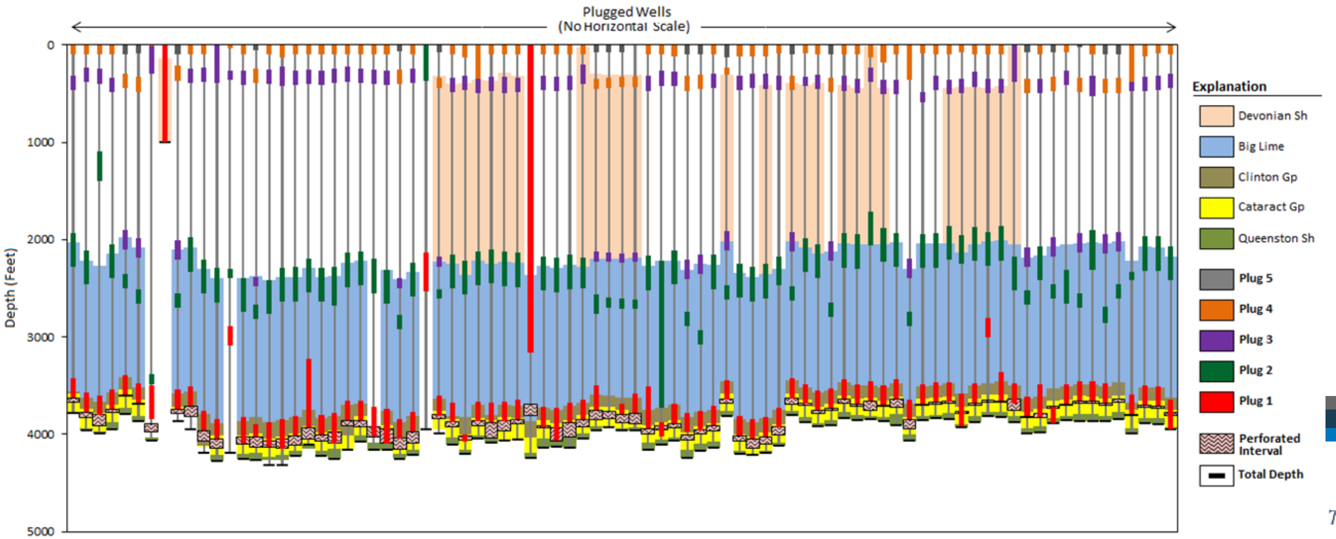
Parameter	Stat	Unit
Total Wells	6390	#
Total Plugs	20767	#
Cement Plugs	16205	#
Class A	15094	#
Clay Plugs	3665	#
Plugs with Additives	7561	#
Plugs with Gel	6006	#
Avg Gel%	2.7	%
Plugs with CaCl	773	#
Avg CaCl%	2.5	%
Plugs with Bent.	1010	#
Avg Bent%	3.4	%
Fire Clay	800	#
POZ mix	557	#
9 Sack Grout	502	#
Salt	357	#
Other	82	#



Michigan P&A Data

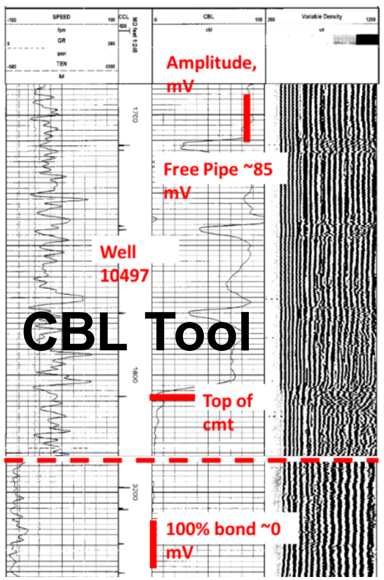
Parameter	Stat	Unit
Total Wells	1730	#
Total Plugs	5055	#
Cement Plugs	3178	#
Class A	124	#
Clay Plugs	182	#
Mud Plugs	1332	#
Plugs with Additives	69	#
Plugs with LCM	36	#
Plugs with CaCl	51	#
Avg CaCl%	2.6	%
POZ mix	10	#
Plugs with Gel	2	#

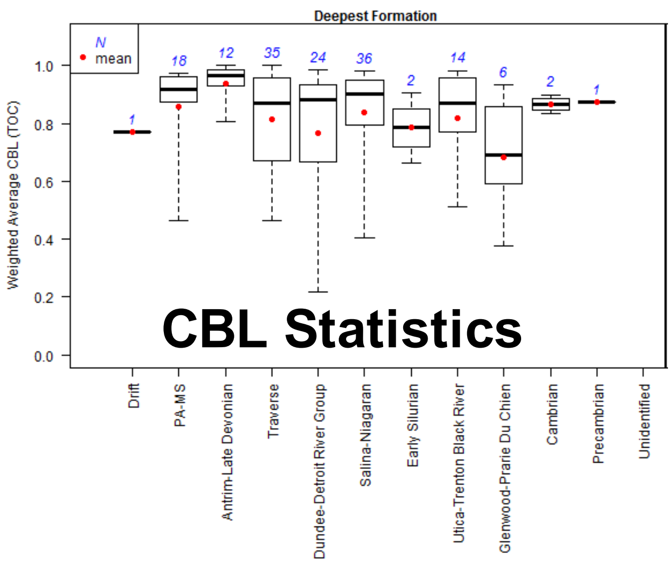


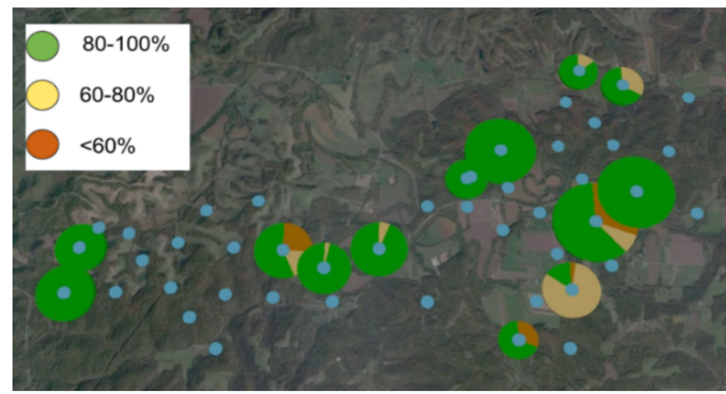


Task 3: Well Record Analysis

- A 10% subset of cement bond logs were evaluated with a systematic evaluation tool to evaluate cement condition around well casing for the Michigan and Ohio study areas.
- Results were analyzed with statistics to assess trends with cement bond versus geologic formation, depth, and age.



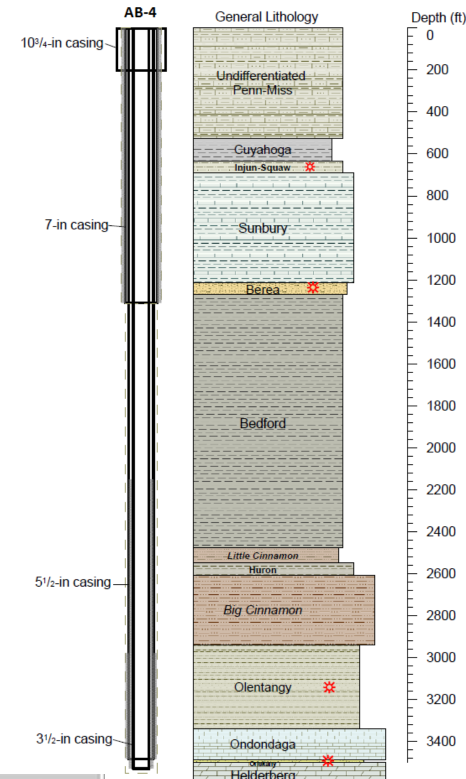




CBL Results Showing Cement Rating in Well Field

Task 4: Sustained Casing Pressure Analysis

- Sustained casing pressure field monitoring was completed for 13 wells.
- Results suggest cement still provide zonal isolation after 50+ years with typical well construction.
- Intermediate zones may transmit gas.
- Well testing and/or monitoring may be suitable to demonstrate integrity rather than requiring expensive corrective action (like replugging, overdrilling, etc).



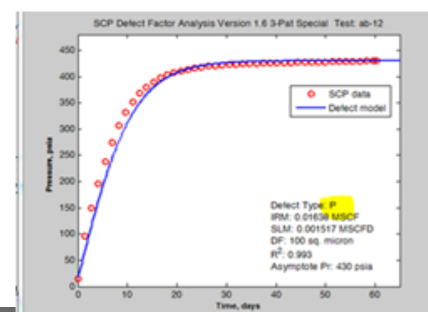
- **Instant Release Metric (IRM)**
  - Indicate potential volume of sudden gas release
  - Unit is MSCF

$$IRM \sim f(P_{asym}, V_g)$$

- **Sustained Leakage Metric (SLM)**
  - Maximum possible gas leakage rate
  - Unit is MSCFD

$$SLM \sim DF$$

- **Well Integrity Factor**
  - Predict well integrity for containment
  - Unit is μm^2



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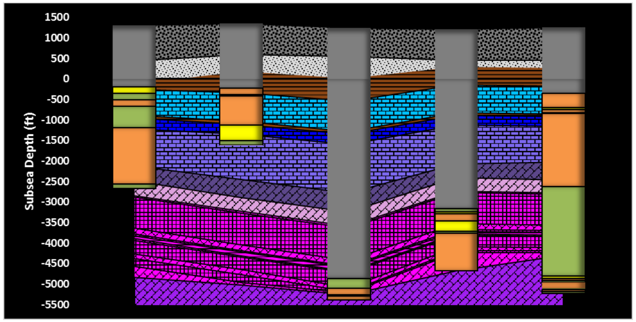
Task 5: Well Integrity Analysis

- Task 5 Lead will be Mark Moody of Battelle
- This task will focus on factors that effect wellbore integrity:
  - Drilling and completion practices
  - Well construction
  - Casing cement quality
  - Casing cement types and quantities
  - Construction materials
  - Operation and maintenance procedures
  - Plugging and Abandonment practices



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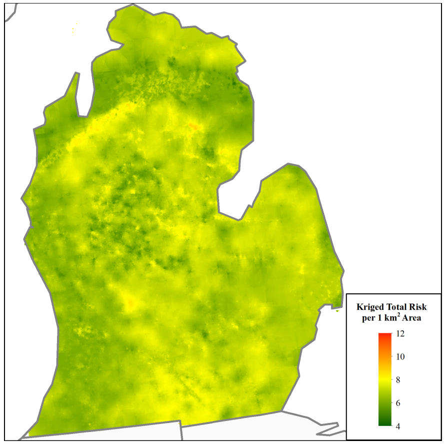
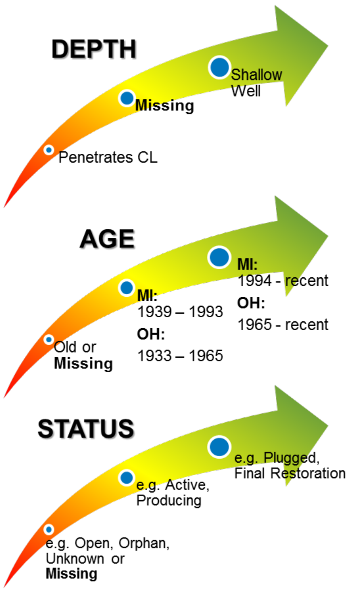
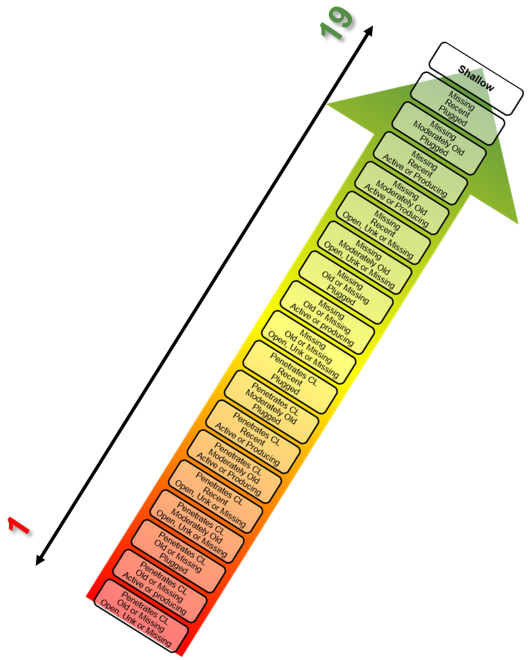
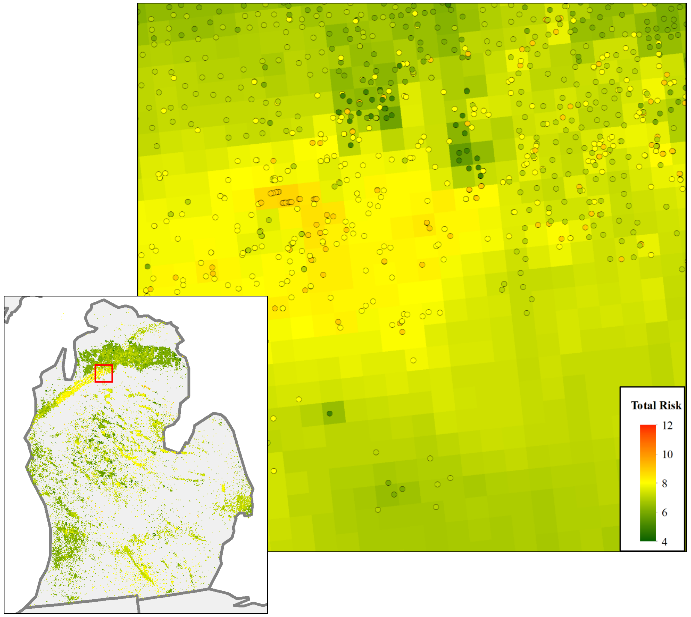
Task 5: Well Integrity Analysis

- Statistical analysis completed to portray well integrity indicator index based on wells depth, age, status.





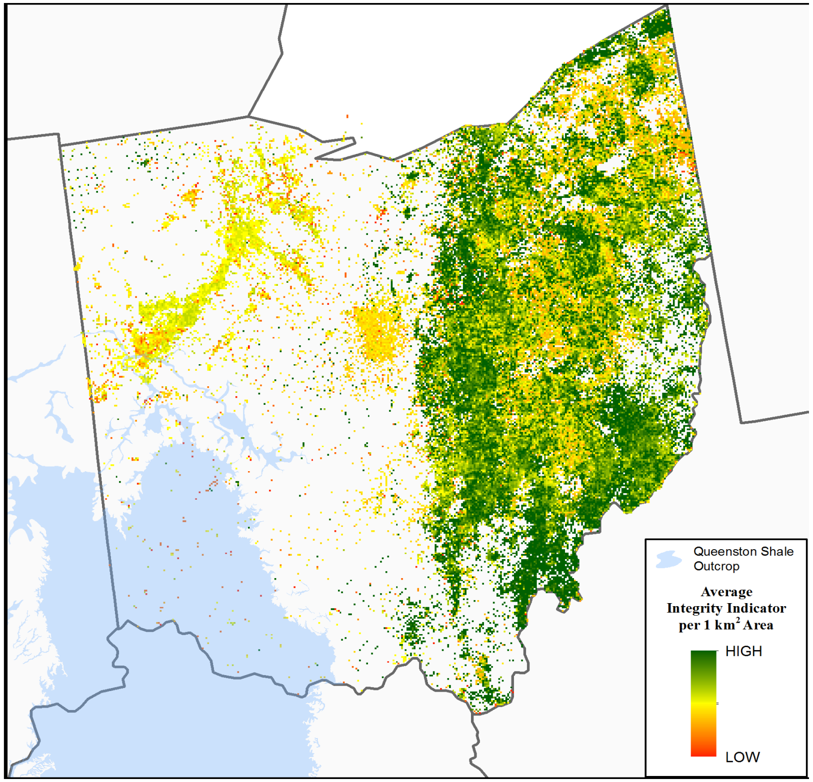


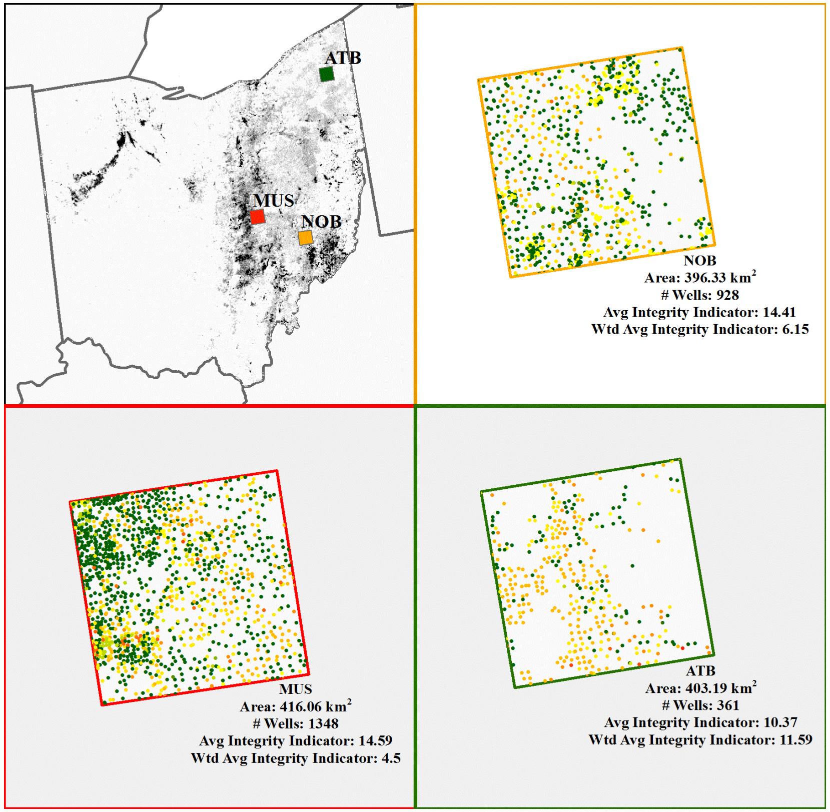


(Field Site: approx 25 km x 25 km)

Task 5: Well Integrity Analysis

- Results provide a regional estimate of well integrity.
- Site specific evaluation tool also developed.





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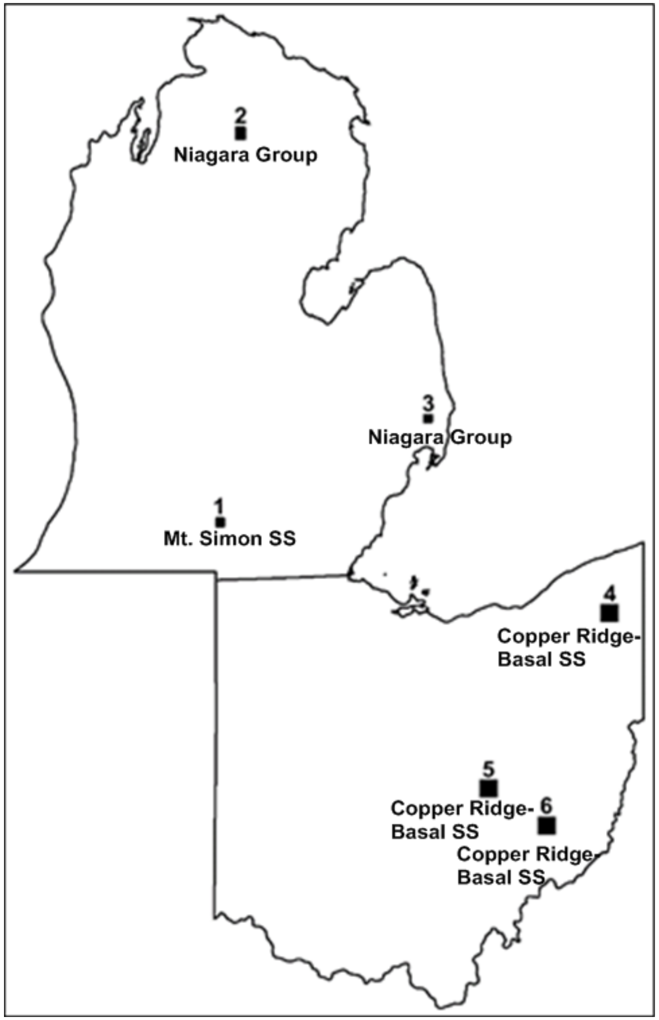
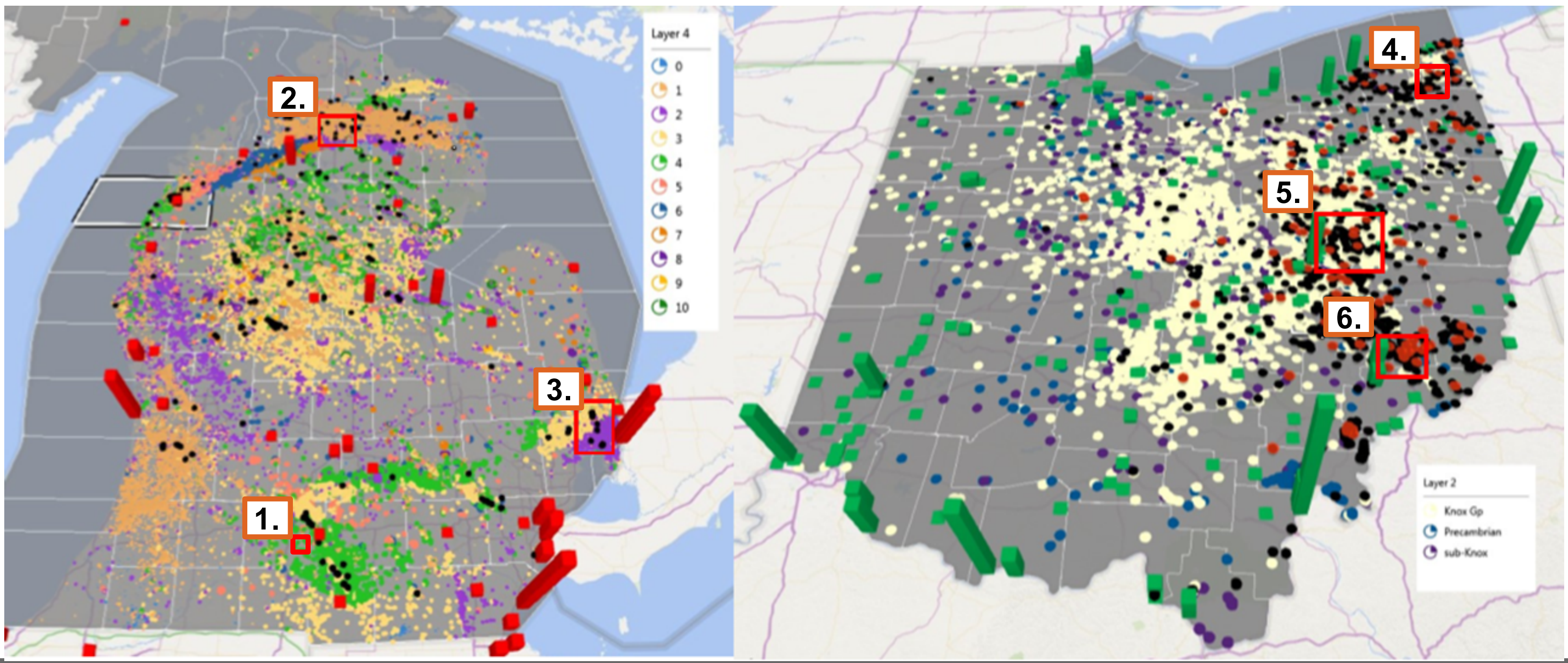
Task 6: CO_2 Storage Assessment

- Approach: examine 6 hypothetical CO_2 storage test study areas based on industrial scale CO_2 storage application.
- Study area was defined as Michigan and Ohio to facilitate overall project.



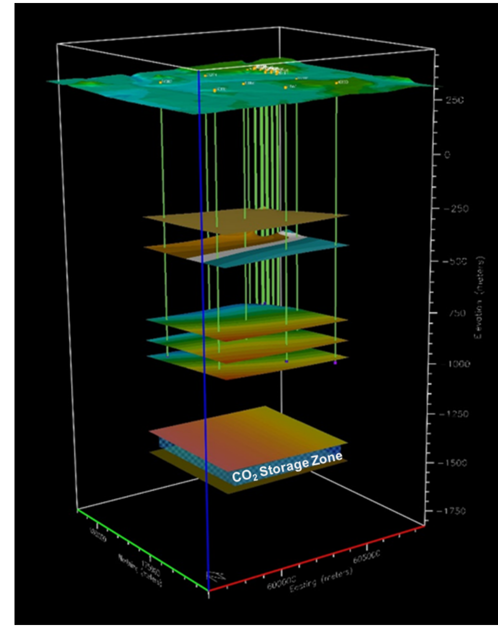
Task 6: CO_2 Storage Assessment

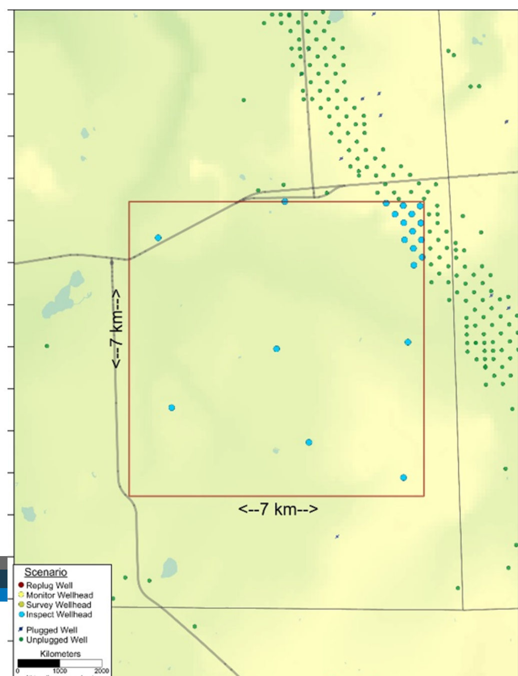
- Hypothetical test study areas selected based on:
  - # of wells
  - CO_2 storage zones present
  - Proximity to CO_2 emitting facilities

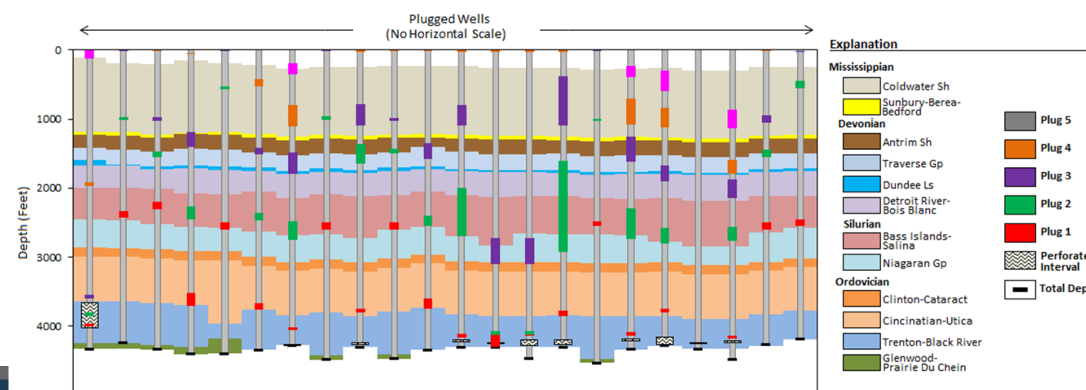


Task 6: CO_2 Storage Assessment

- **Example: Test Study Area 1-** Calhoun County, MI. Mount Simon storage zone.
- 7x7 km area adjacent to Albion-Scipio
  - 22 total wells (0 active/22 plugged)
  - (12 dry hole/10 oil)
  - No wells penetrate storage zone (Mt. Simon SS or overlying confining layer).







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Task 6: CO_2 Storage Assessment

- Based on well status and conditions, wells in the six test areas were classified into corrective action categories.
- Ratings were used to determine level of effort and costs necessary to prepare sites for CO_2 storage application.

Corrective Action	Well Status
Inspect Wellhead	Producing wells, P&A wells
Test Well	P&A w/ no records
Monitor Wellhead	Domestic well w/ no records, Historical producer, active well in storage zone
Add Plugs to Well	Unplugged well
Re-enter and Plug	Unplugged well or well that demonstrates leakage during CO_2 storage period

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Task 6: CO_2 Storage Assessment

- Varying levels of corrective action for 6 sites, but most sites have reasonable level of work.
- Most effort seems related to locating/inspecting wells.
- Sites have up to 1,221 wells, so there may be perception issue related to shallow oil & gas wells.

Corrective Action	1 *S-Central Michigan*	2 *N-Central Michigan*	3 *SE Michigan*	4 *NE Ohio*	5 *E-Central Ohio*	6 *E. Ohio*
Total # of Wells	22	446	156	357	1221	868
Zero Corrective Action	22	313	9	357	919	629
Inspect Well Head	0	123	127	0	293	193
Test Well	0	0	1	0	0	26
Monitor Wellhead	0	0	0	0	9	4
Add Plugs to Well	0	10	18	0	0	0
Re-enter & Plug	0	0	0	0	0	16

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Task 6: CO_2 Storage Assessment

- The six study areas demonstrated a range of scenarios, from sites that required zero corrective action to sites that required overdrilling and replugging.
- Corrective action analysis for each study area and ties in the cost analysis to give overall cost estimates to prepare a site for CO_2 storage in the region.

Corrective Action	Cost Per Well	Michigan			Ohio		
		Calhoun	*Otsego*	*Saint Clair*	*Trumbull*	*Musk/Cosh*	*Noble*
Total # of Wells		*22*	*446*	*155*	*357*	*1221*	*868*
Zero Corrective Action	$0	$0	$0	$0	$0	$0	$0
Inspect Well Head	$400	$0	$49,200	$50,800	$0	$117,200	$77,200
Test Well	$25,000	$0	$0	$25,000	$0	$0	$650,000
Monitor Wellhead	$20,000	$0	$0	$0	$0	$180,000	$80,000
Add Plugs to Well	$75,000	$0	$750,000	$1,350,000	$0	$0	$0
Re-enter & Plug	$145,000	$0	$0	$0	$0	$0	$2,320,000
Test Study Area Cost Estimate		$0	~$800,000	~$1,425,000	$0	~$300,000	~$3,100,000

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Synergy Opportunities

- Project has significant synergies with other ongoing work on carbon storage technologies, shale gas developments, other CO_2 storage research.
- Activities included:
  - Risk assessment for MRCSP MI Basin field site.
  - Work with BP Alternative Energy on well integrity in Alaska.
  - Data uploaded to DOE-NETL EDX website.
  - SPE/CSGM Workshop on *Sustained Casing Pressure Diagnosis Using the Wellhead Model* given by Mark Moody, and Matthew Place, SPE/CSGM Gas Migration Challenges – Identification and Treatment Workshop, May 13-14, 2015 Banff, Alberta, Canada.
  - Eight presentations at technical meetings.

Synergy Opportunities

- Special wellbore integrity issue of *Greenhouse Gases: Science & Technology* in progress:
  - *Systematic Wellbore Integrity Evaluation of CO_2 Storage Sites in the Michigan Niagaran Reefs*, ***Autumn Haagsma*** *(Battelle)*
  - *Wellbore Integrity Factors for CO2 Storage in Oil and Gas Producing Areas in the Midwest United States*, **Joel Sminchak and Mark Moody** (Battelle)
  - *Sustained Casing Pressure Diagnosis with Extended Data Collection to Support CO_2 Storage Projects*, **Matthew Place and Brian Dotson** (Battelle/BP Alternative Energy)
  - (In addition)
    - *Establishing well isolation in legacy wells for CCS projects*, **Andrew Duguid** (Battelle/Schlumberger)
    - *Well integrity and annulus size estimation in a 68 year old well exposed to CO2*, **Andrew Duguid** (Battelle/Schlumberger)
    - *Wellbore cement degradation by CO2 reaction and its effect on wellbore integrity*, **Wooyong, Um** (Pacific Northwest National Lab)

Conclusions

- The impact of wellbore integrity issues on site suitability for geologic CO_2 storage in the Midwest U.S. was completed based regional and site specific analysis.
- Several practical products were developed under this project to support CO_2 storage in the region:
  - Sustained casing pressure testing methods,
  - Systematic cement bond log analysis procedure, and
  - Regional database on well integrity indicators for MI and OH,
  - Statistical analysis of well integrity indicators,
  - Assessment of practical methods and costs necessary to repair/remediate typical wells in the region based on assessment of 6 test study areas.

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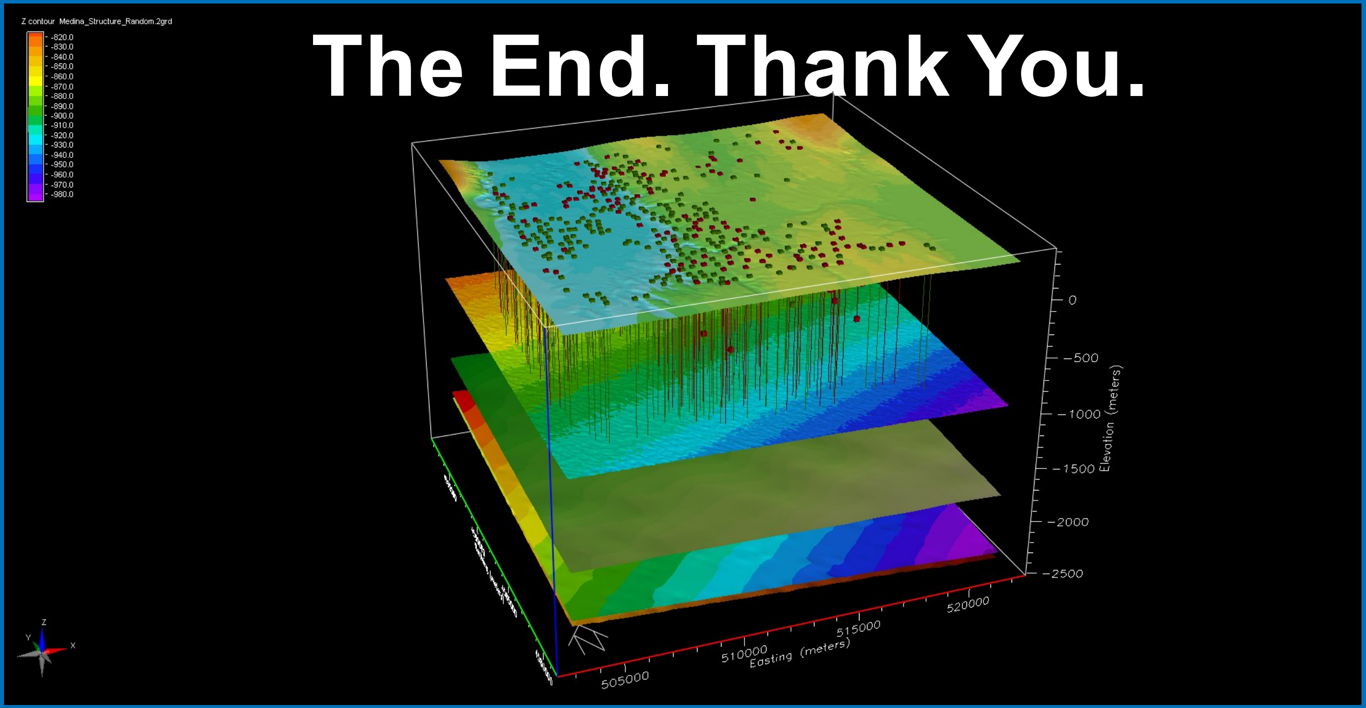
Conclusions

- Well status, condition, cement bond logs, and plugging records were used to estimate corrective actions necessary to prepare the test areas for CO_2 storage.
- Test areas had 22 to 1,221 oil & gas wells in various stages of activity, plugging & abandonment, and records.
- Most of the wells in the test areas did not penetrate deeper caprock or storage intervals, so corrective action may be technically feasible and have reasonable cost.
- Well testing, surface monitoring, and inspection may be options for wells with uncertain wellbore integrity.
- Presence of many older oil & gas wells may present a perception issue requiring some level of corr. action.

The End. Thank You.



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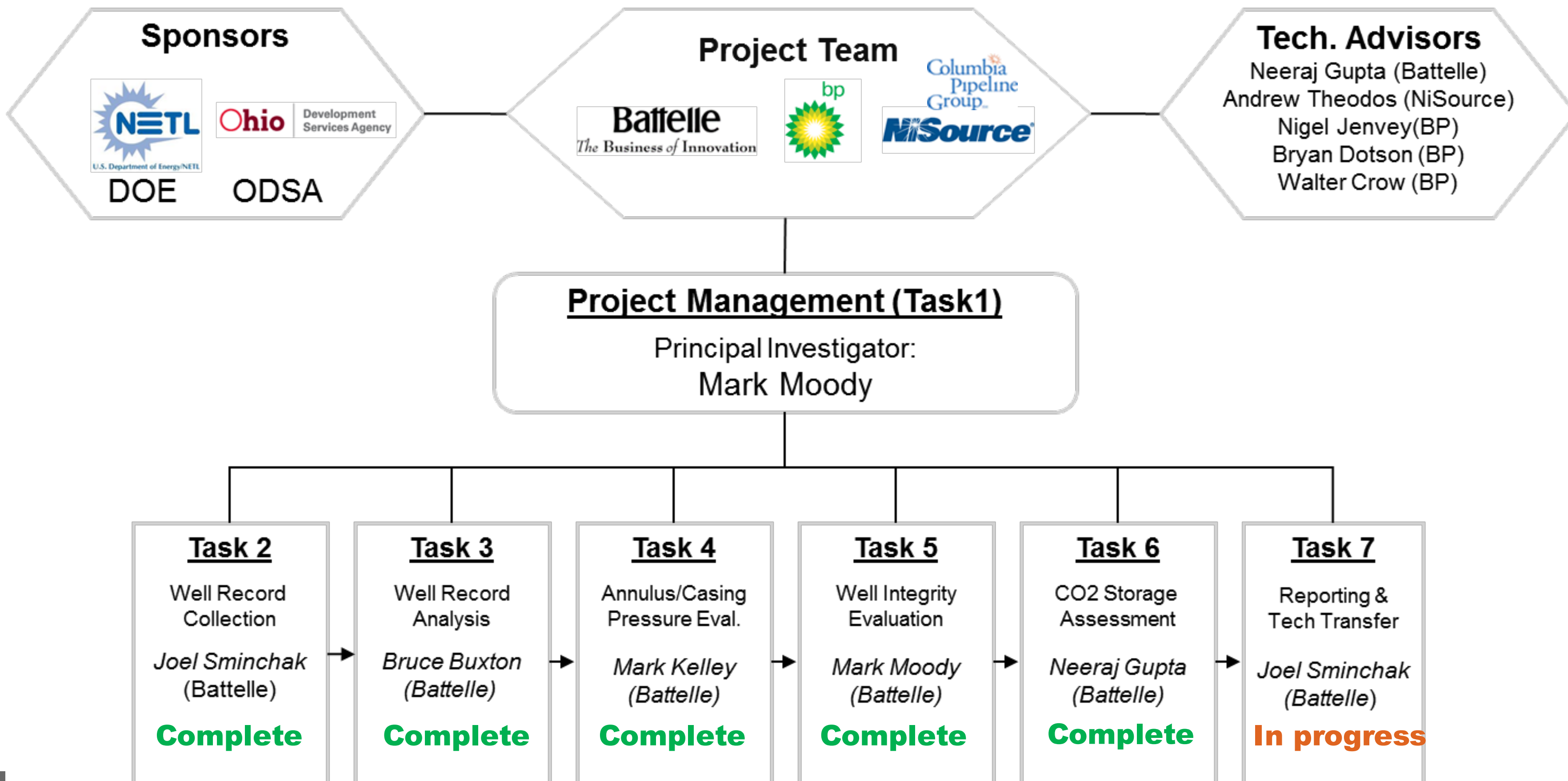
Additional Project Information

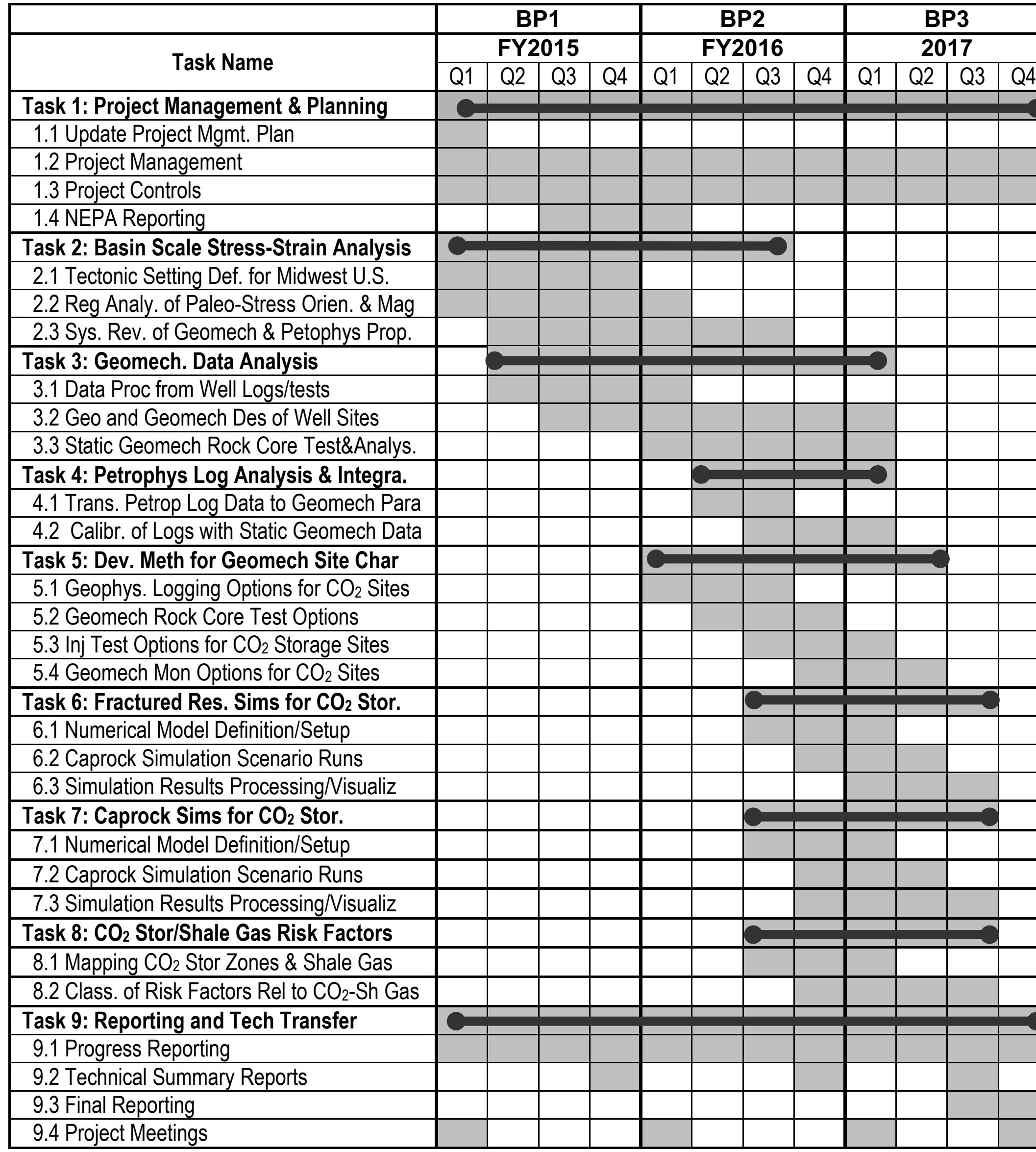
Project Organization Chart

- Project organized into 7 main technical tasks.



Task/Subtask Breakdown

- Project included a sequential series of tasks over 3 years.



Deliverables/Milestones

Milestones

Budget Period	Milestone Description	Planned Due Date	Verification Method
1	Submit Updated Project Management Plan to DOE	30 days after initial award	Project Management Plan
1	Collect and Analyze Geotechncial Data for Basin Scale Paleo-Stress/Strain Analysis	September 2015	Topical Report
2	Acquire and Process 3-4 Advanced Geophysical Logs from Key Wells in the Region	September 2016	Annual Report, Upload data to EDX
2	Complete Testing of 10 Rock Cores for Geomechanical Parameters	September 2016	Annual Report, Upload data to EDX
3	Complete Development of a Methodology for Geomechanical Site Characterization for CO_2 Storage Sites	March 2017	Summary Technical report
3	Complete Reservoir Simulations for fractured reservoirs and caprocks	June 2017	Topical Report with Simulation Results
3	Develop maps and identify risk factors for CO_2 Storage/Shale Gas Zones in the Region	June 2017	Summary Technical Report
3	Preparation of final technical report detailing all test data, analysis, and project results	90 days after end of the project	Final Technical Report

Deliverables/Milestones

Deliverable List

Deliverable	Task	Description	Deliverable Due Date
Project Management Plan	1	Updated Project Management Plan	30 days after initial award
Annual Renewal Application	1	Annual report with technical progress, key findings, and request for continued funding	30 days before end of Budget Period 1 and Budget Period 2
Project Fact Sheet	1	Updated fact sheet for project	30 days after initial award
Basin Scale Paleo-Stress/strain Analysis	2	Basin scale paleo-stress strain setting analysis (Topical report)	September 2015
EDX Upload of Data	3-4	Submit relevant geophysical and core test geomechanical data (upload to EDX, summarize in annual report)	June 2017
Methodology for Geomechanical Site Characterization	5	Summary Methodology for Geomechanical Site Characterization (summary technical report)	March 2017
Reservoir Simulations	6-7	Analysis of Simulation Results (Topical report)	June 2017
CO_2 Storage/Shale Gas Risk Factor Analysis	8	Summary of CO_2 Storage/Shale gas risk factors (summary technical report)	June 2017
Final Technical Report	9+	Technical report detailing all methods, simulations, analyses, and findings	90 days after end of the project

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- *Sustained Casing Pressure Diagnosis with Extended Data Collection*, **Matt Place**, Glenn Larsen, Bryan Dotson, Nigel Jenvey, and Mark Moody, SPE Eastern Regional Meeting, 13-15 October 2015, Morgantown, WV.
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- *Sustained Casing Pressure Diagnosis Using the Wellhead Model*, Bryan Dotson, **Mark Moody**, and Matthew Place, SPE/CSGM Gas Migration Challenges – Identification and Treatment Workshop, May 13-14, 2015 Banff, Alberta, Canada.
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