Midwest Regional Carbon Sequestration Partnership

DOE/NETL cooperative agreement # DE-FC26-05NT42589

Neeraj Gupta

Battelle Memorial Institute

MRCSP
MIDWEST REGIONAL
CARBON SEQUESTRATION
PARTNERSHIP

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

U.S. Department of Energy

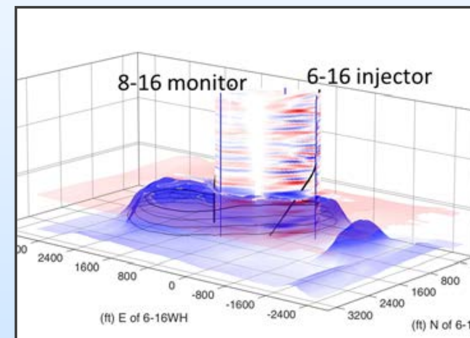
National Energy Technology Laboratory

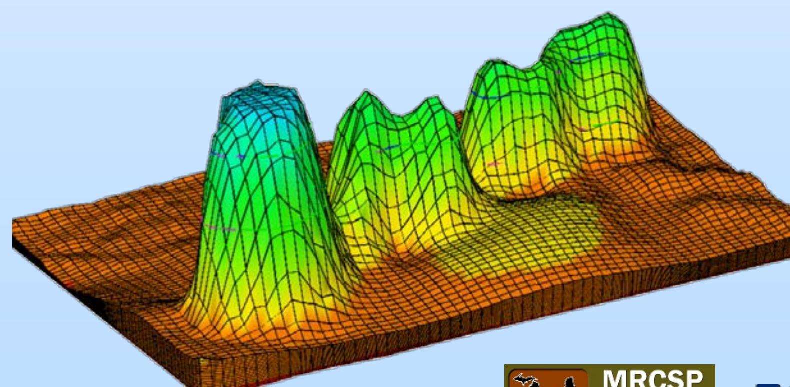
Addressing the Nation's Energy Needs Through Technology Innovation – 2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting

August 26-30, 2019

Presentation Outline

- Introduction
- Technical Status
  - – Monitoring/Modeling
  - – Accounting/LCA
  - – Regional Impact
- Summary
  - – Accomplishments
  - – Lessons learned
  - – Synergy Opportunities





Acknowledgements

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Ohio Development Services Agency's **Ohio Coal Development Office**

MRCSP's technical **partners, sponsors, and host sites since 2003**

The MRCSP Region's State **Geology Survey and University team members**

Partners over 16 years have helped make MRCSP successful

AEP
AMP Ohio
ArcelorMittal
BATTELLE It can be done
B&W the babcock & wilcox company
bp
Paulsson, Inc. Advanced Sensor Technologies
Constellation Energy Group
Consumers Energy Count on Us
CORE ENERGY, LLC
CONSOL ENERGY
Dominion It all starts here
DTE Energy
Duke Energy
FirstEnergy
Indiana Geological Survey Indiana University
OUCC Indiana Office of Utility Consumer Counselor
Kentucky Geological Survey University of Kentucky
The Keystone Center
Department of Natural Resources Maryland Geological Survey
Michigan Basin Core Research Laboratory Western Michigan University
National Rural Electric Cooperative Association
NYSERDA New York State Energy Research and Development Authority
New York State Museum
NiSource
Making Ohio Coal the Clean Choice
ODNR Geological Survey
Ohio Development Services Agency
Ohio Environmental Council
The Ohio State University
Pacific Northwest National Laboratory Operated by Battelle for the U.S. Department of Energy
Pennsylvania Geological Survey
PRAXAIR
Rutgers The State University of New Jersey
RWE
University of Maryland
WADE
財團法人中興工程顧問社
WVGES West Virginia Geological and Economic Survey
West Virginia University Where Greatness is Learned
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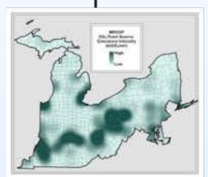
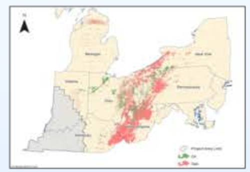
Historical Snapshot of MRCSP – 16 Years of CCUS Innovation

- DOE-funded regional partnerships to develop infrastructure for wide-scale CO_2 sequestration deployment

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018

Phase I
Characterization



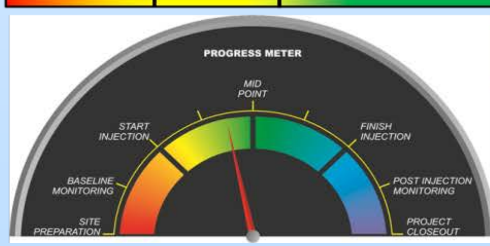


Phase II
Small Scale Validation

Phase III
Large Scale Development Project

Site Selection, Permitting, Site Characterization, Site Preparation, and Baseline Monitoring

OH Site | MI Saline | MI EOR Fields



MI Injection Operations (multiple fields)
- Late-stage EOR reef
- Operational EOR reef
- Newly targeted reef

Post Injection Monitoring

Project updates and results can be found at www.mrcsp.org

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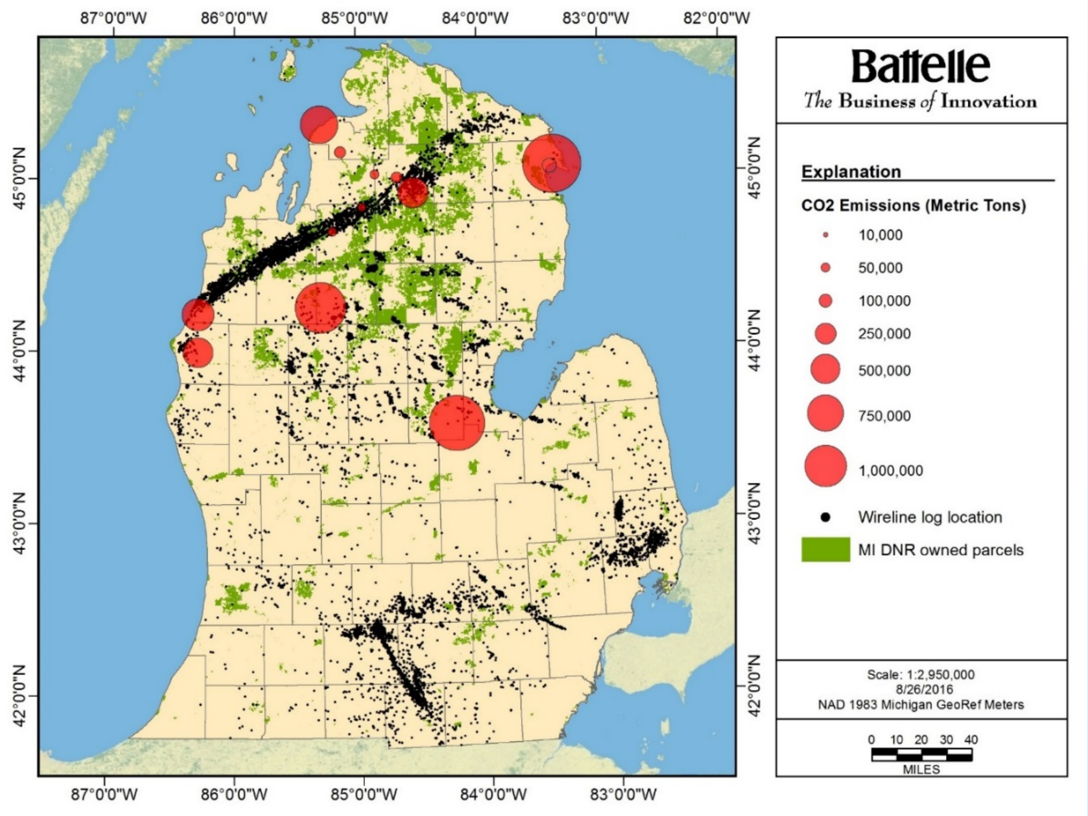
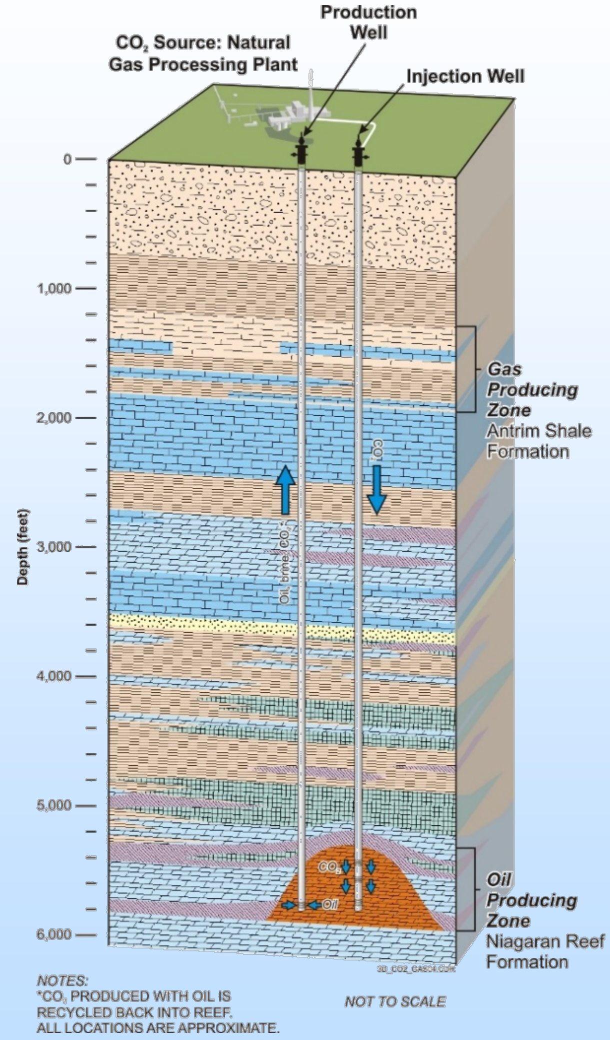
MRCSP Basin Large-Scale Injection

- Objective – Inject/monitor +1 million metric tons of CO_2 in collaboration with EOR operations.
- Evaluate CO_2 injectivity, migration, containment
- Evaluate regional storage resources
- Outreach and knowledge sharet





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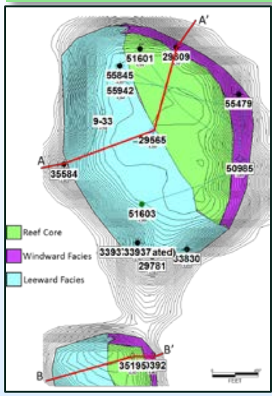
Large-scale Injection Test

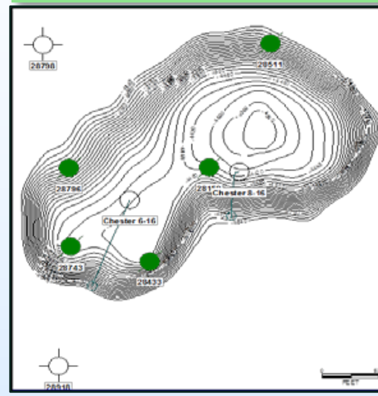
Key Reefs Vary in Setting and Operational History

Late-Stage Reef: Dover 33



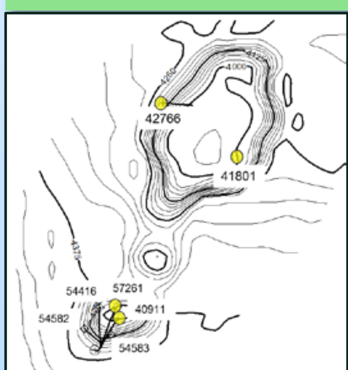
1 Lobe
Operational since 1974
Primary + CO_2-EOR
MRCSP Injection since 2013
- 1 CO_2 Injection Wells
- 2(+1) Mon./ Prod. Wells

Chester 16



2 Lobes
Operational since 1971
Primary + Water Inj.
MRCSP Injection since 2017
- 1 CO_2 Injection Well
- 1 Monitoring Well

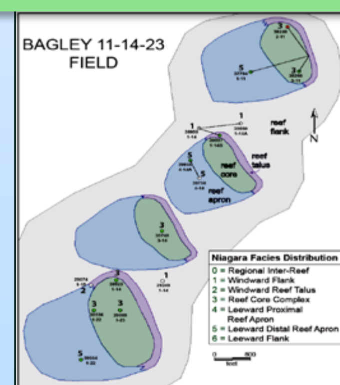
Charlton 19



2 Lobes
Operational since 1988
Primary Production
MRCSP Injection 2015-2017
- 1 CO_2 Injection Wells
- 2 Monitoring Wells

Currently in CO_2-EOR

Bagley



4 Lobes
Operational since 1973
Primary Production only
MRCSP Injection since 2015
- 3 CO_2 Injection Wells
- 4 Monitoring Wells

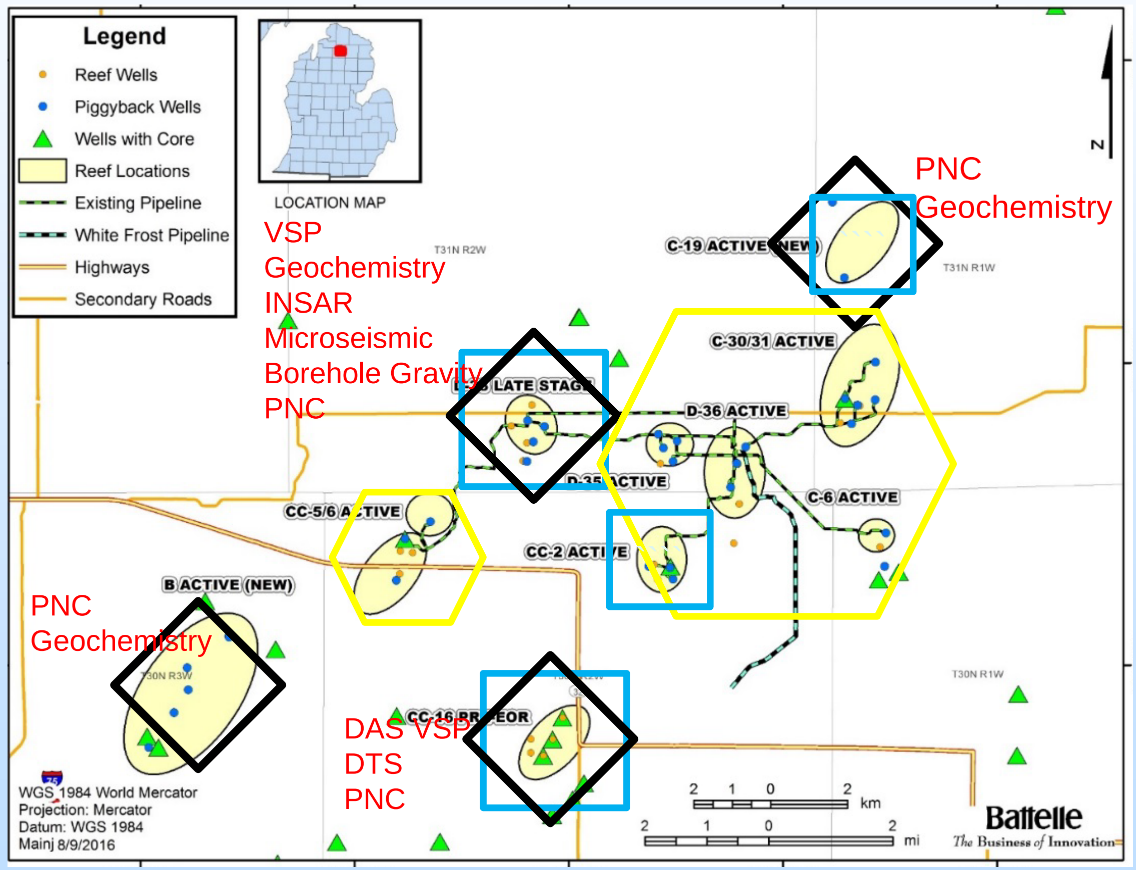
MRCSP Monitoring Program

- 10 reefs in various stages of EOR
- All Reefs - CO_2 accounting and reservoir pressure
- Advanced monitoring on selected reefs

Well characterization

Advanced monitoring

Basic monitoring



Objective-Based Monitoring Portfolio

Monitoring Technology	Injection Accounting	Leak Detection/ well integrity	CO_2 plume tracking	Induced seismicity /uplift
CO_2 injection rate	X		X	
Reservoir Pressure		X	X	
Temperature (DTS)		X	X	
PNC logging		X	X	
Borehole gravity			X	
Reservoir Geochemistry			X	
Vertical seismic profile (VSP)		X	X	
Microseismic				X
InSAR (Satellite radar)				X

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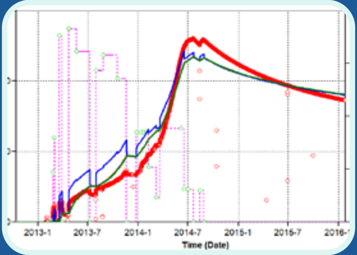
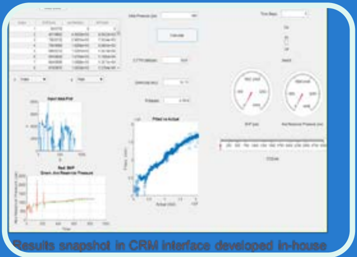
Modeling and Analyses

Reservoir properties and performance from CO_2 injection data



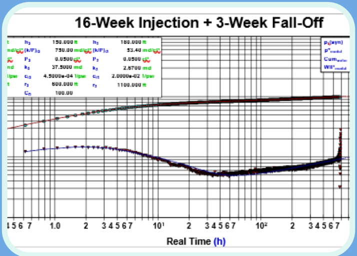
Static and dynamic modeling

- Integrate G&G data; constrain reservoir properties; evaluate reservoir performance for future scenarios
- Dover-33; Chester-16; Bagley; Charlton-19



Capacitance-resistance modeling

- Simplified estimation of reservoir capacity and injectivity; simplified analysis of future scenarios
- Charlton-19; Bagley



Transient pressure and rate analysis

- Estimate reservoir properties; synthesize results from multiple types of analysis; validate dynamic model
- Dover-33; Bagley; Chester-16; Charlton-19

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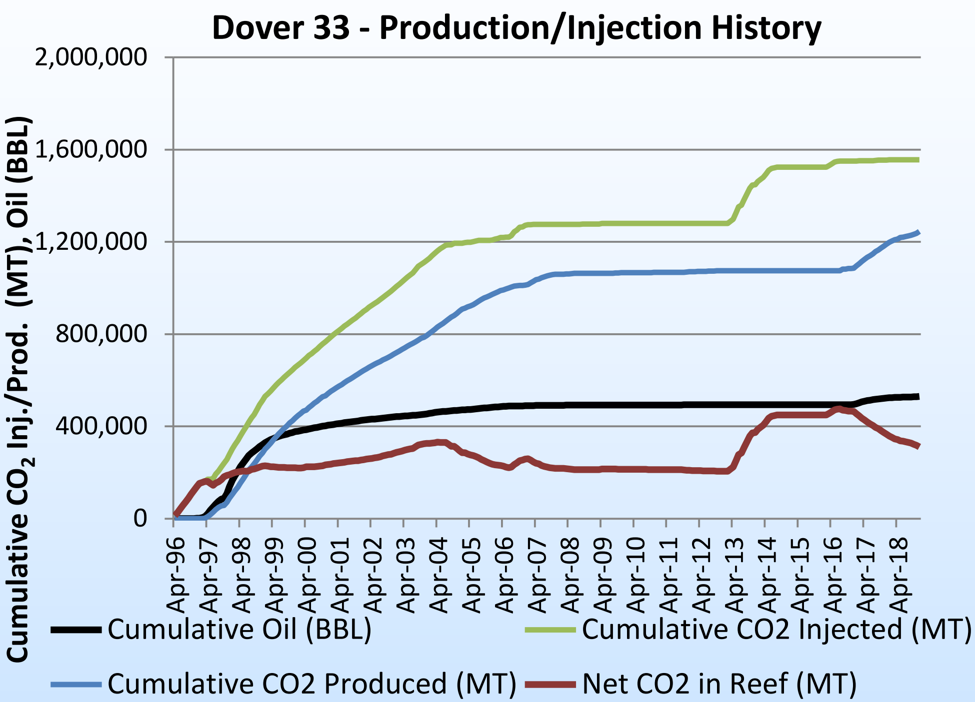
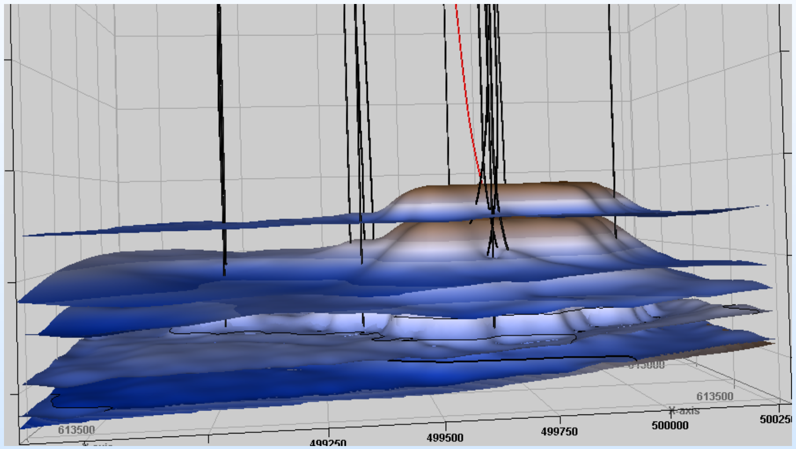
The Late State Reef Offered a Unique Opportunity to Collect and Analyze data at Various Stages in the Lifecycle





1974
Primary production

1996
CO_2 injection and EOR begins

2003
MRCSP Phase III

2012
InSAR began
Baseline Geochem, PNC

Level I&II Models

2013
Baseline microseismic, VSP, borehole gravity, PNC

2014
Geochem ended

2015
InSAR ended

2016
Repeat VSP.
Borehole gravity, microseismic, PNC

2016
New Well Characterization

2018
Repeat PNC, borehole gravity

2019
>275K tons of CO_2 stored

Level III Model

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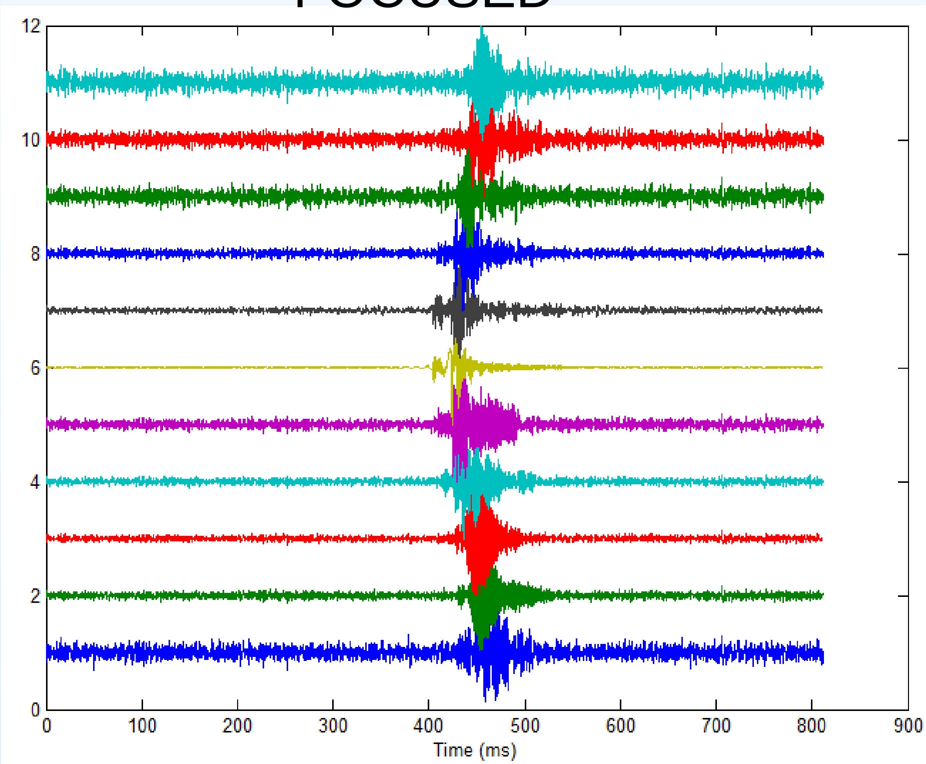
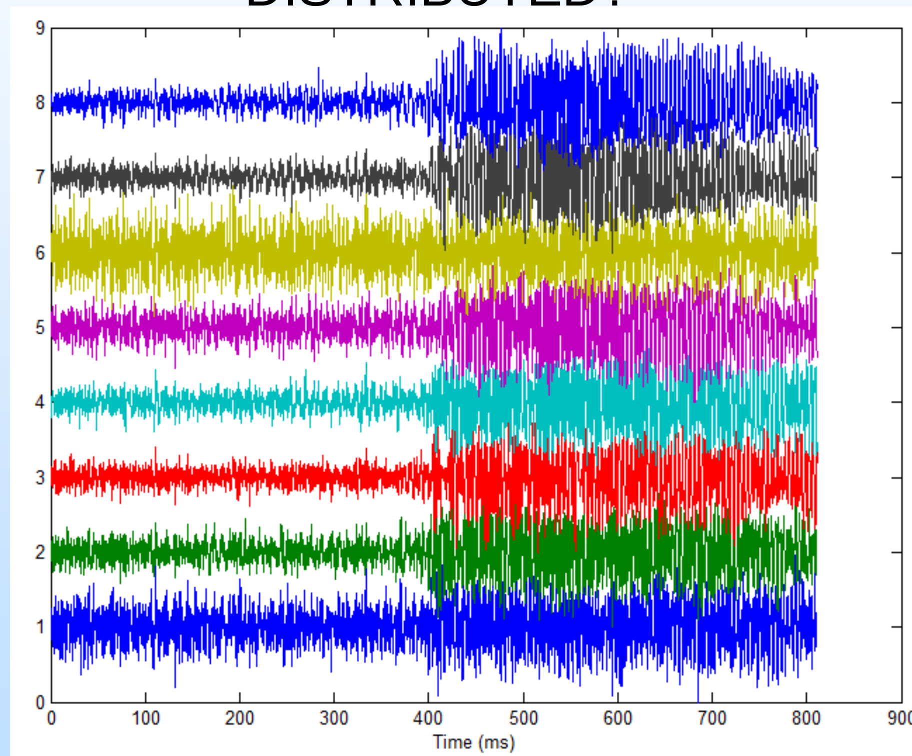
Dover 33 Microseismic Deeper Dive
Two Types of Events Detected

"FOCUSED"



"DISTRIBUTED?"



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Dover 33 Microseismic Study Deeper Dive

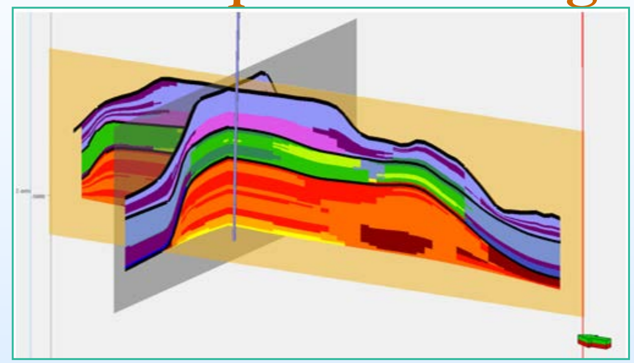
- Worked with NORSAR to reprocess data from 21-day repeat event
- unsupervised learning/ clustering used to classify ~200,000 events into three types
- Despite large number of events, no evidence for real microseismic events caused by CO_2 injection even though reservoir pressure was at discovery pressure.
- Type 1 (77%) related to surface activities/noise.
- Type 2 are small signals, with high frequency and lack of low frequencies and with unusually long duration – likely noise caused by resonance issues of the sensors.
- Type 3 have frequency content in the range from 20 to 200 Hz however atypical waveform characteristics do not point to real microseismicity

Evolution of the Modeling Approach for Improved Geologic Representation (Dover-33)

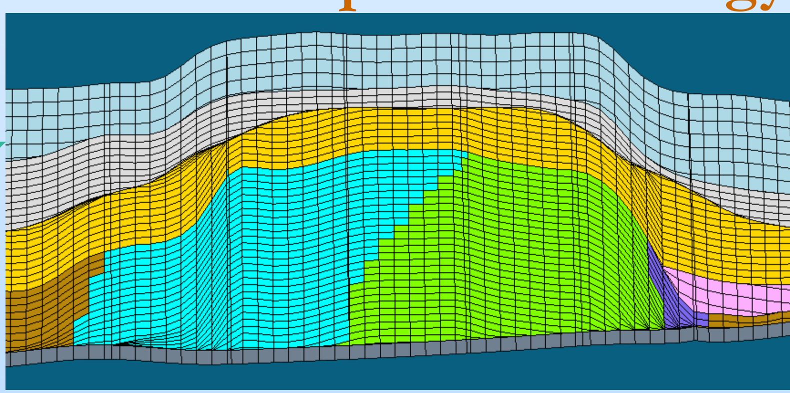
Increasing Data

Level 1-Lithostratigraphic

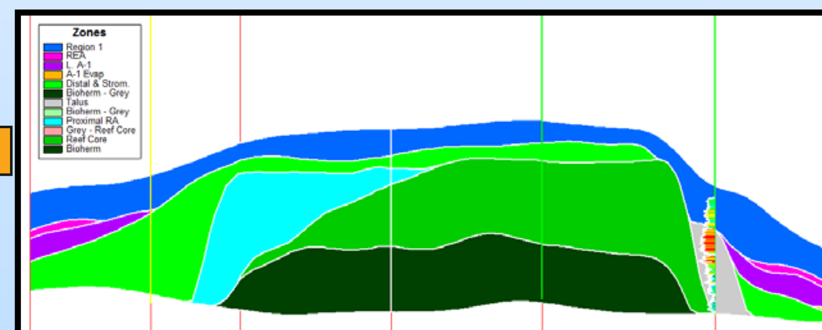
Level 2-Sequence Stratigraphy



Level 3- Simplified Lithology

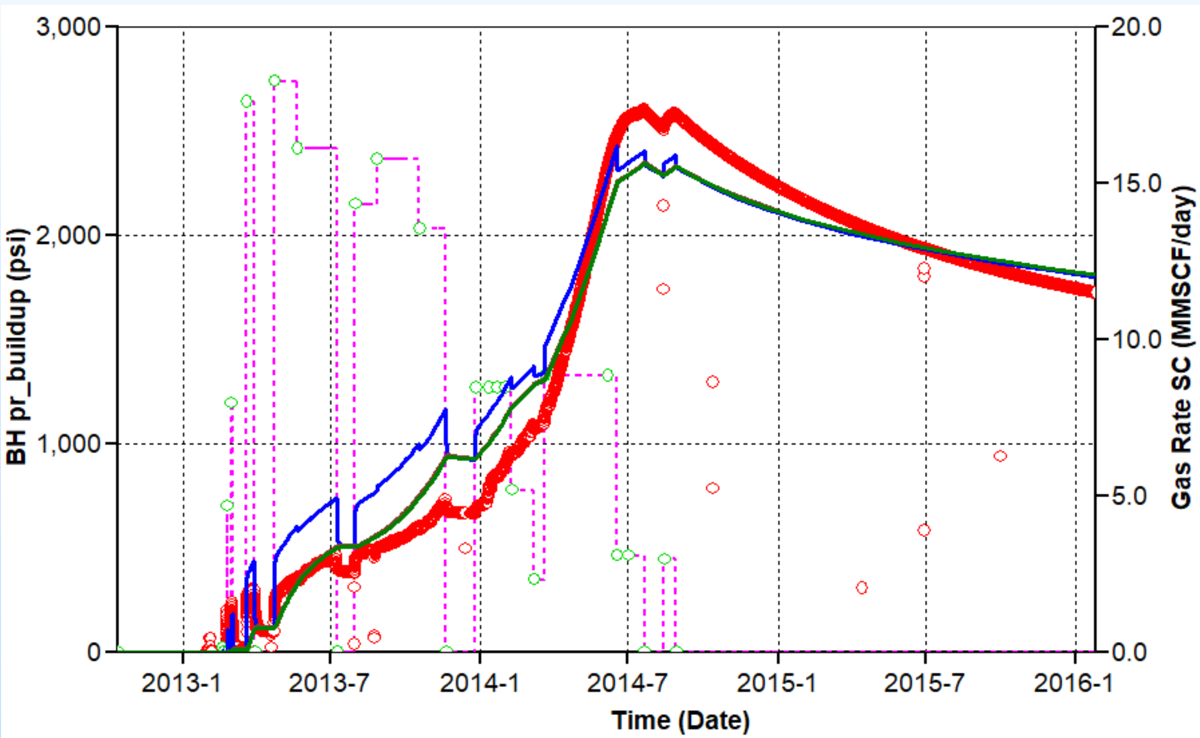


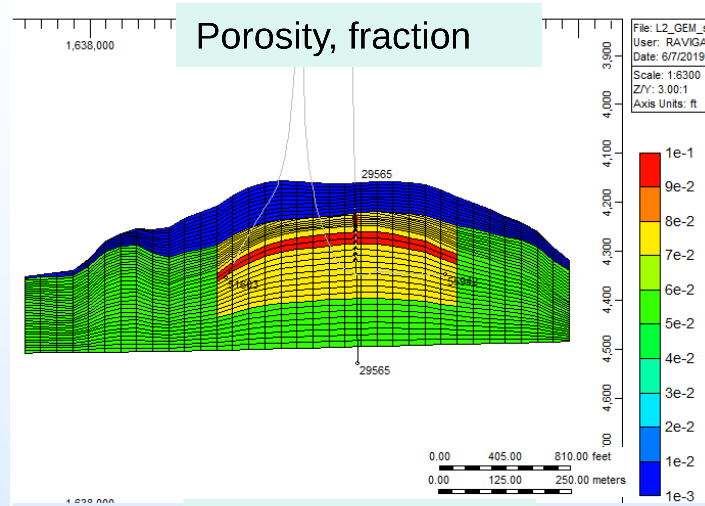
WMU- Depositional

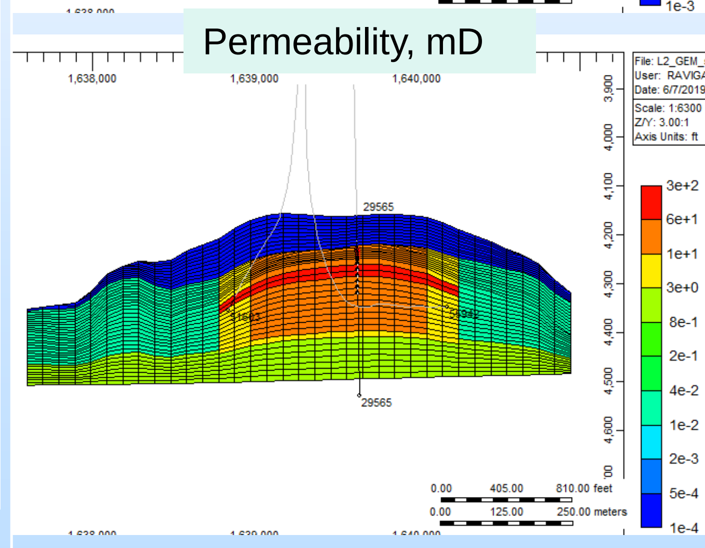


Late Stage Reef (Dover-33) - History Match to CO_2 Injection Data

High-permeability core area
low-permeability flank region







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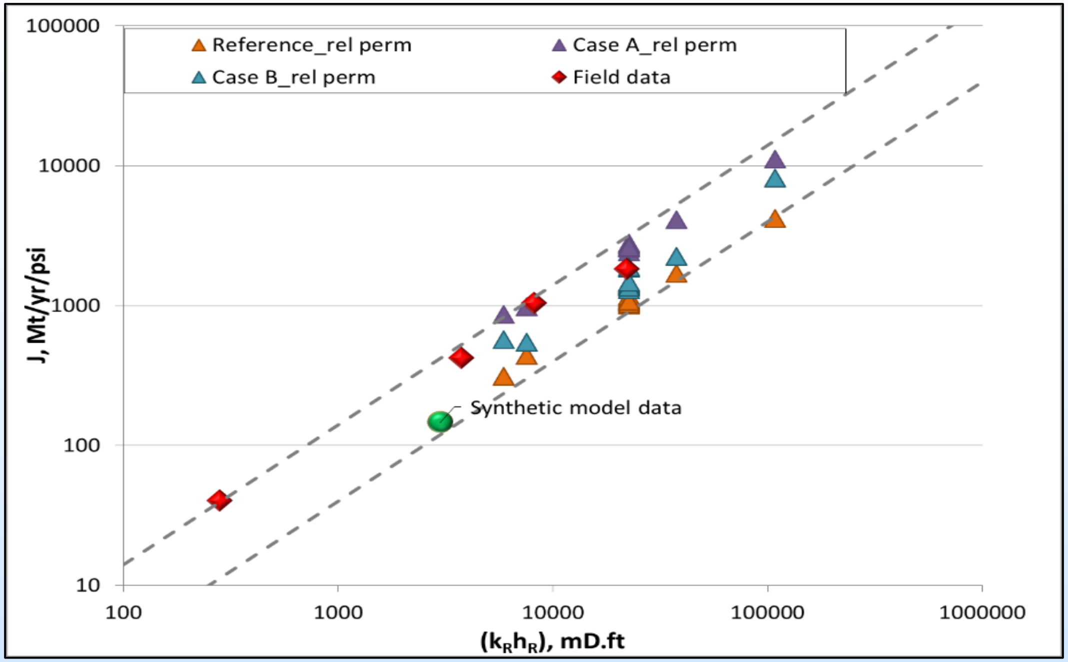
Transient Pressure and Rate Analyses for Permeability Estimation (Dover-33)

- **Injection-falloff analysis** (using IHS WELLTEST)
- **Injectivity (1-33) + productivity (9-33) analysis** (flowing material balance)

  $J = q/\Delta p \sim kh$

- **Synthesis of permeability estimates**



Welltest = k~2-15 mD

J_{inj} = k~9-18 mD

J_{prod} = k~5-11 mD

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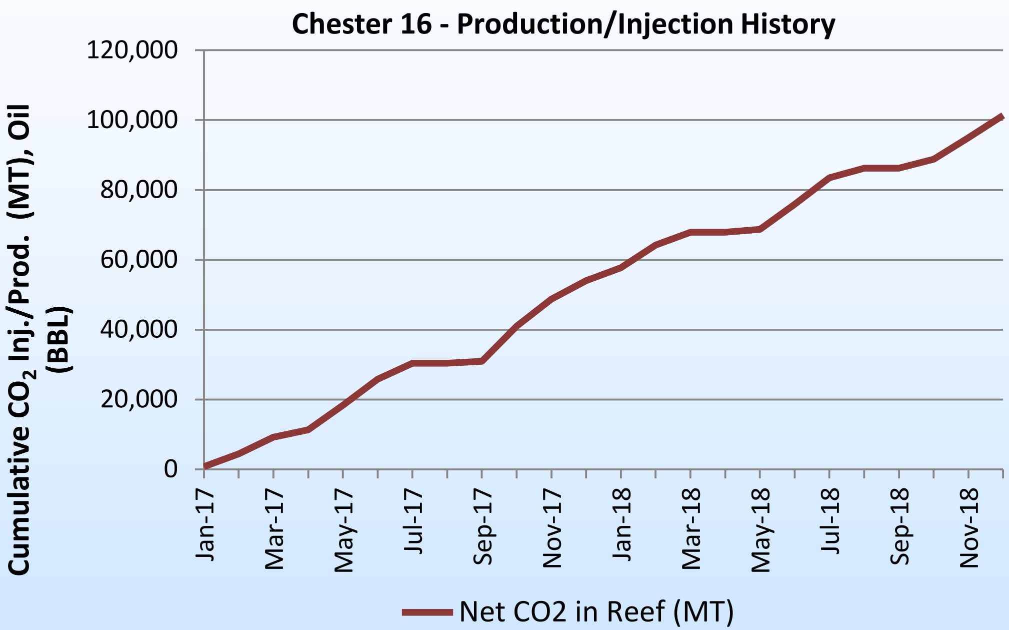
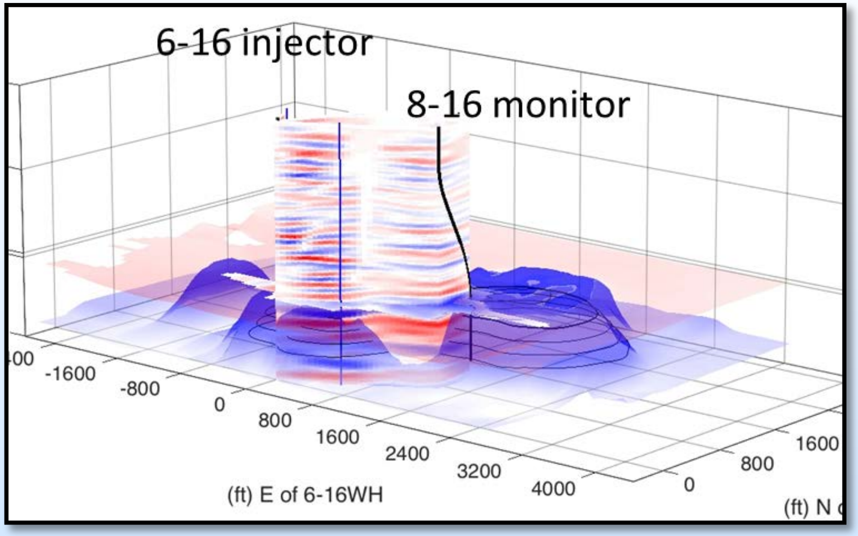
Chester 16 Reef used to Test New Technology and Methods





1971
Primary production

1983
Water Injection Began

1990
Water Injection Ended

2016
Injection well drilled
Fiber optics installed
Fluid sampling baseline
PNC baseline

2017
Monitoring well drilled
Fiber optics installed
PNC, DAS VSP baseline

Geomechanical Tests

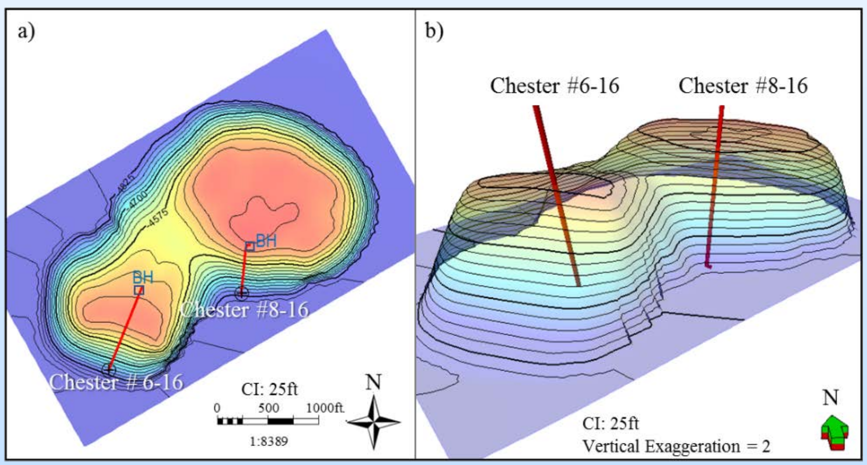
2018
DAS VSP repeat
Cross well seismic
Seismic attribute analysis

Model Development

2019
>100K tons of CO_2 stored

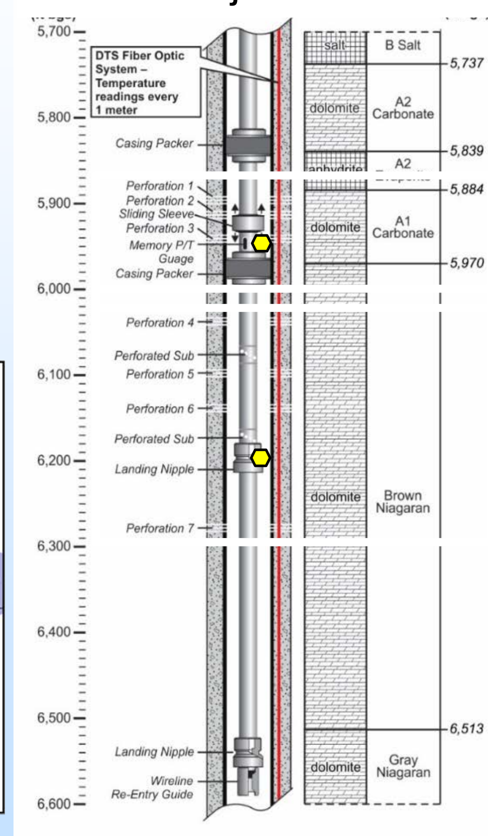
Temperature Monitoring Methods

- DTS – Real-time, fiber-optic data
- Five Behind-casing Temperature (and pressure) sensors (gauges)
- Memory gauges inside injection tubing at reservoir depth



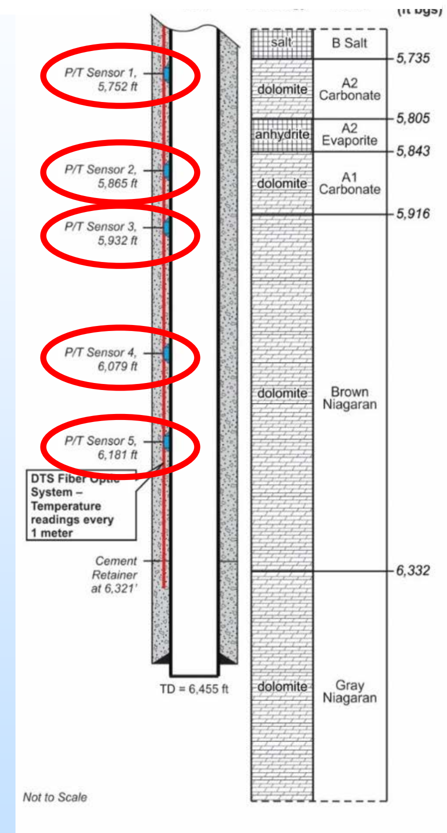
Chester 16 Reef

6-16
Injection Well



- DTS
- 2 Memory gauges inside injection tubing

8-16
Monitoring
Well



- DTS
- 5 permanent discrete depth gauges

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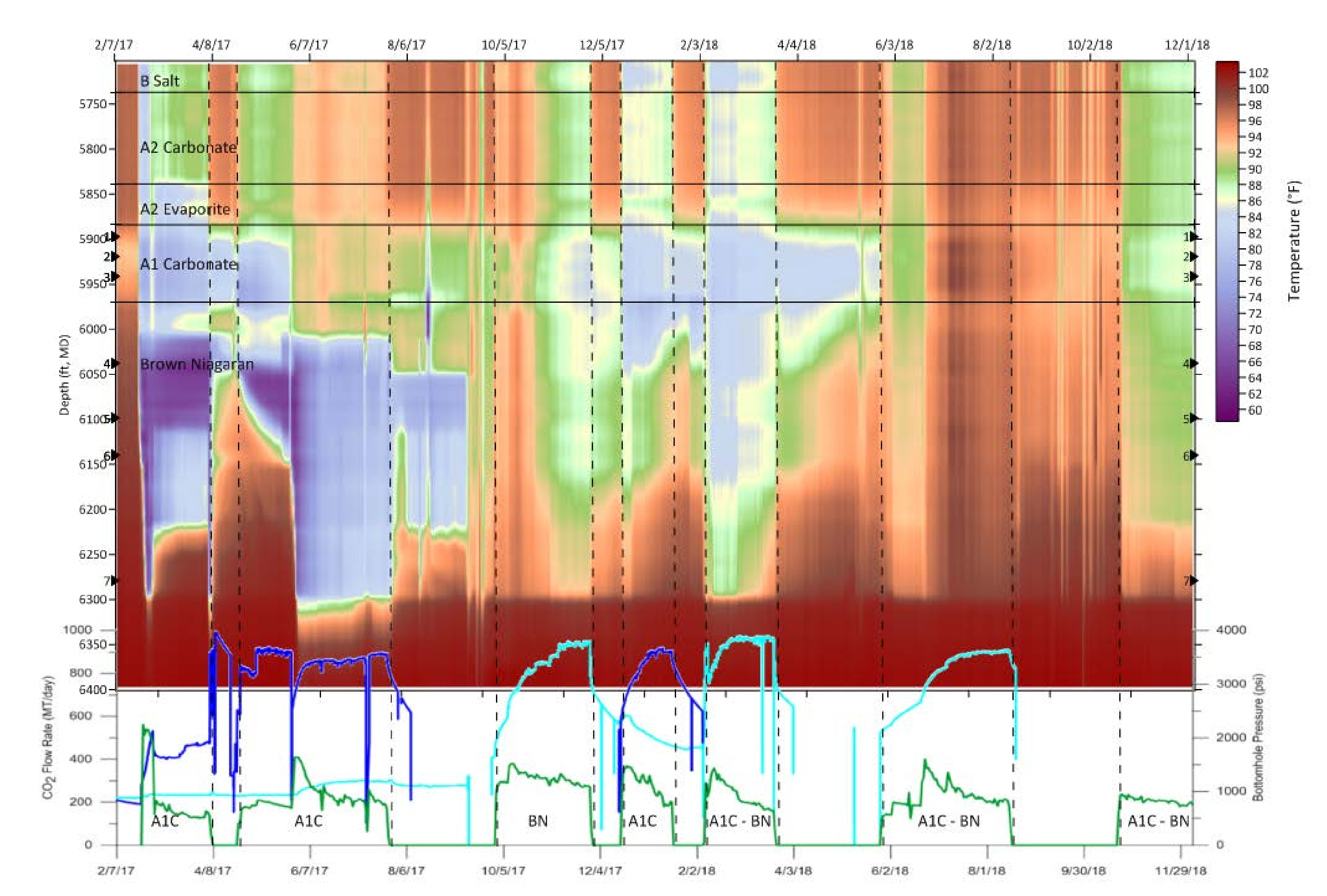
Discerning CO_2 Flow Zones with DTS

Warm-back Maps for CO_2 Intake Zones

Chester 6-16 Master Waterfall Plot



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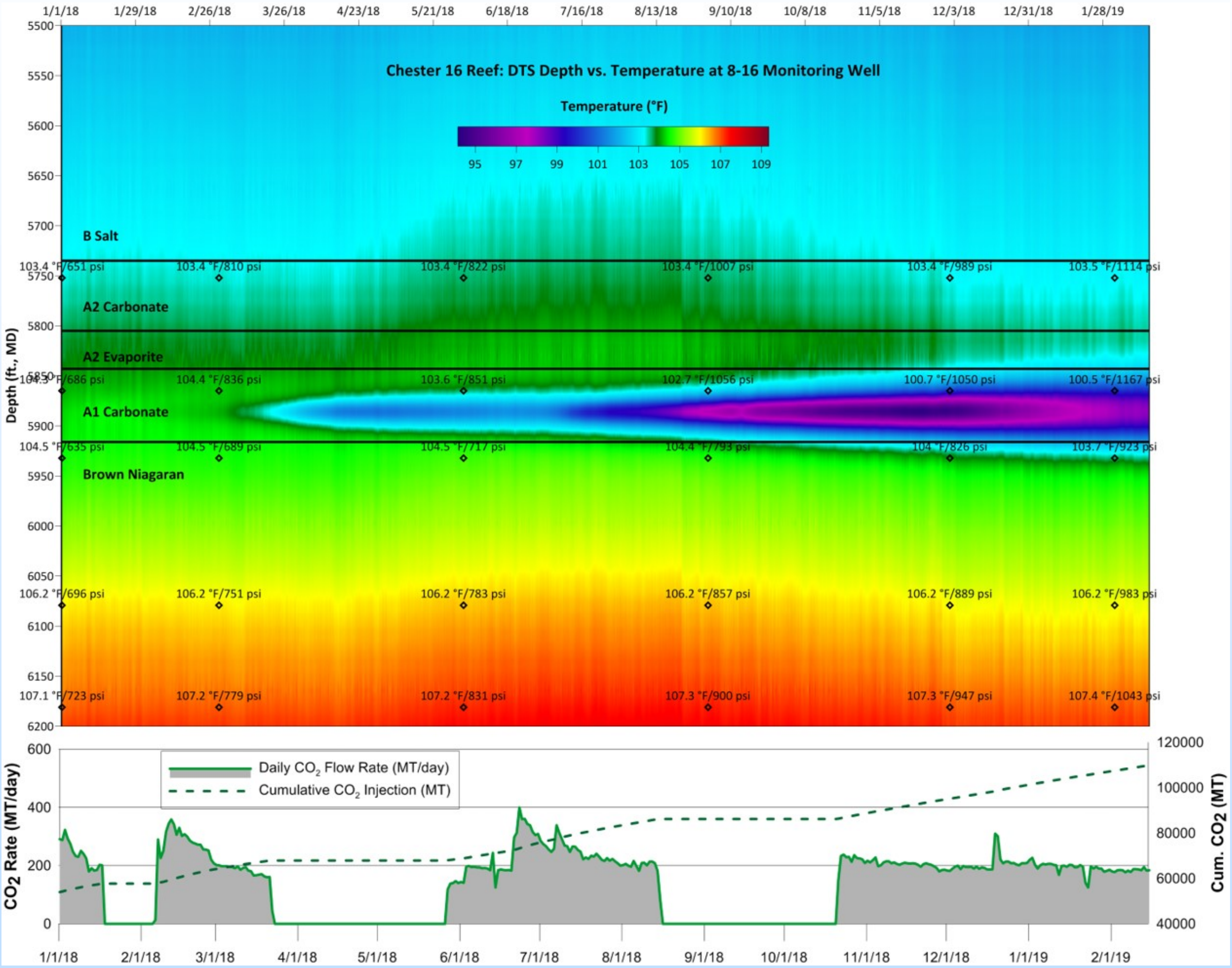
Discerning CO_2 Migration with DTS

CO_2 Moves to the top of reef in Obs. Well

Chester 8-16 Waterfall Plot



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Chester 16 Borehole Seismic Monitoring

DAS VSP

- Glacial till, carbonate rocks, lack of cement pose significant challenges
- Dynamite data too noisy to combine with vibroseis – limited areal coverage
- Extensive processing and modeling performed
- Results show partial CO_2 “plume” consistent with other monitoring

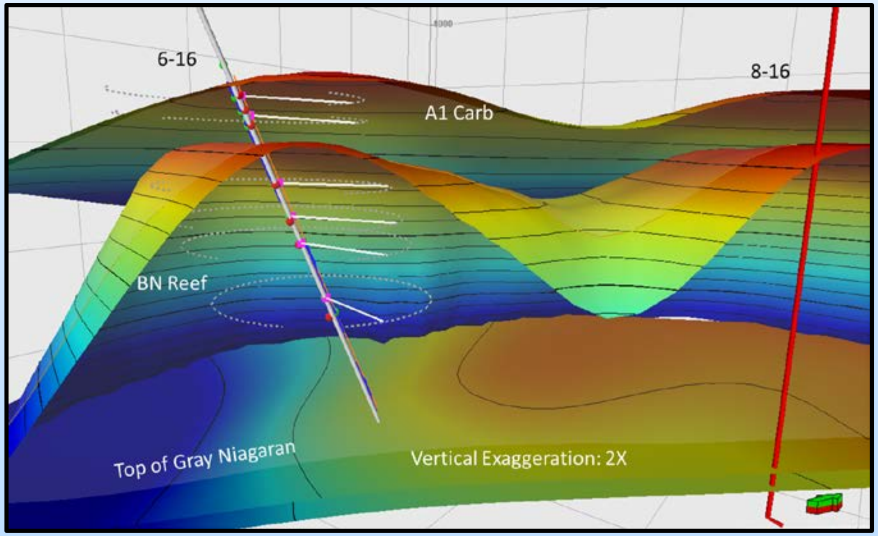
Cross-well Seismic

- Novel processing workflow to compensate for lack of baseline
- Full waveform inversion used for velocity tomograms – first time for Schlumberger
- Results are plausible but not without some ambiguity.

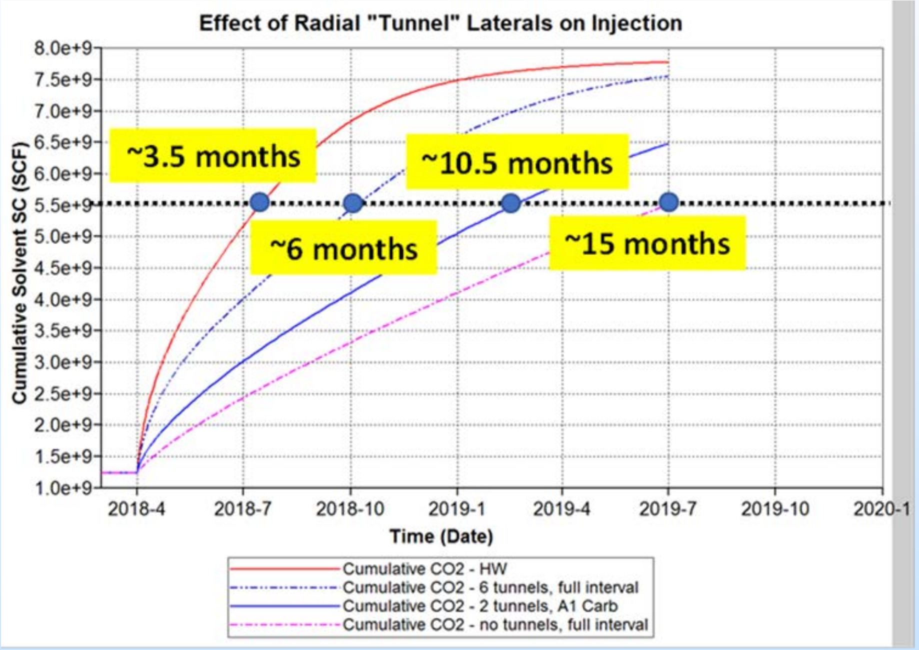
Evaluating Configurations to Improve CO_2 Injectivity

- Increasing the number of perforations provides only marginal improvement
- Drilling radial “tunnels” is more effective; performs similar to a horizontal well

Radial Tunnels are small open boreholes drilled laterally from existing well

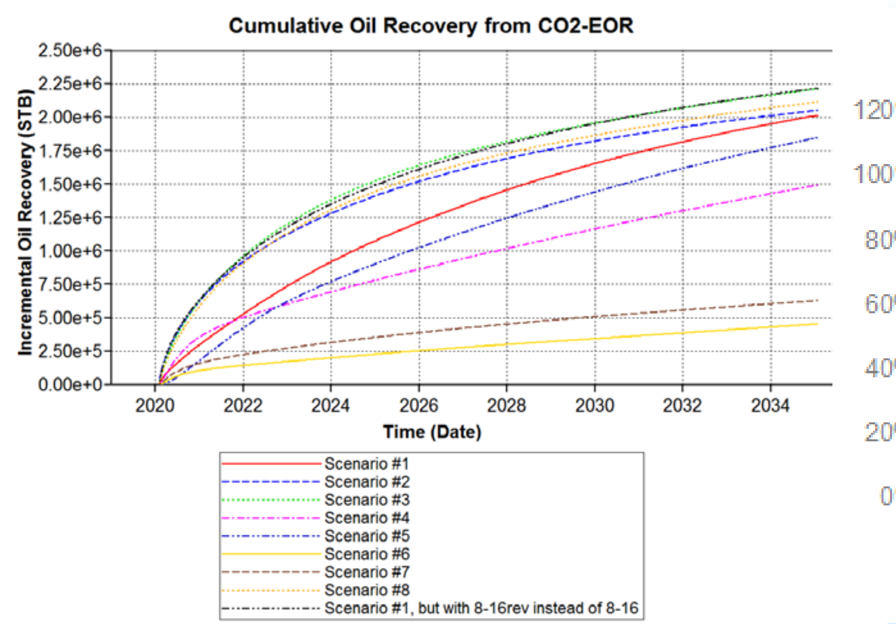


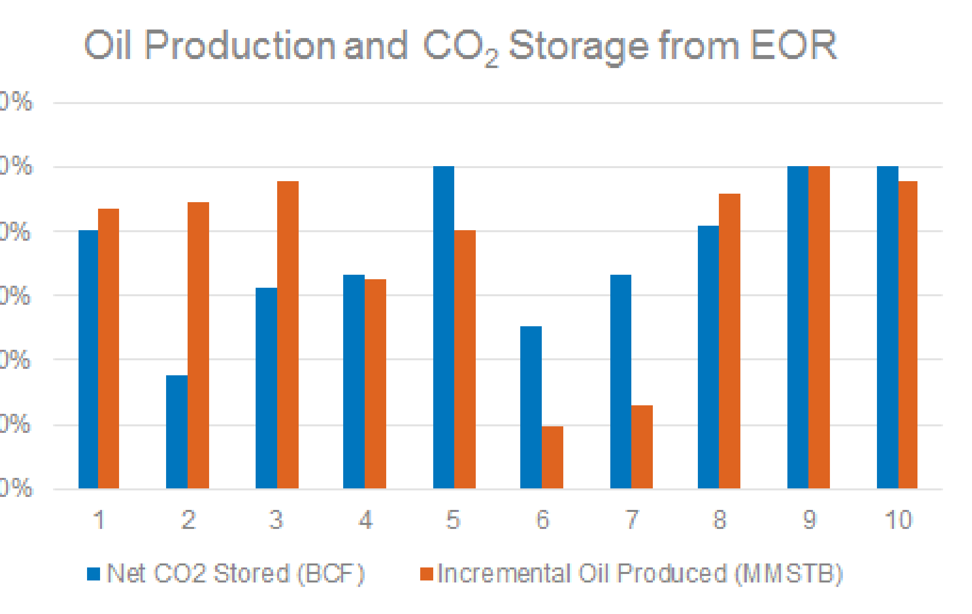
Injectivity with Radial Tunnels



However, radial tunnels drilling was not successful in the field

Co-optimizing oil recovery and CO_2 storage





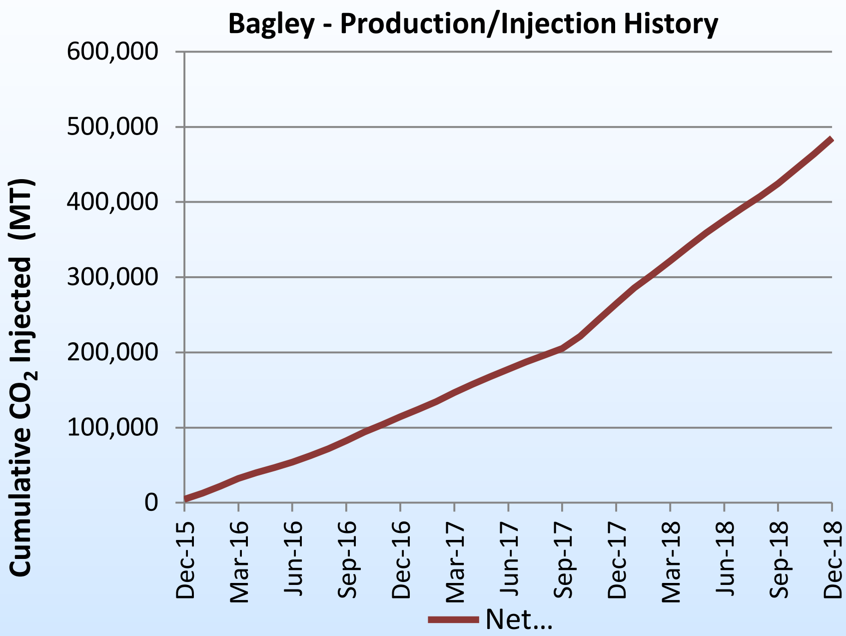
Simulating 10 Configurations to Optimize Production and CO_2 Storage.

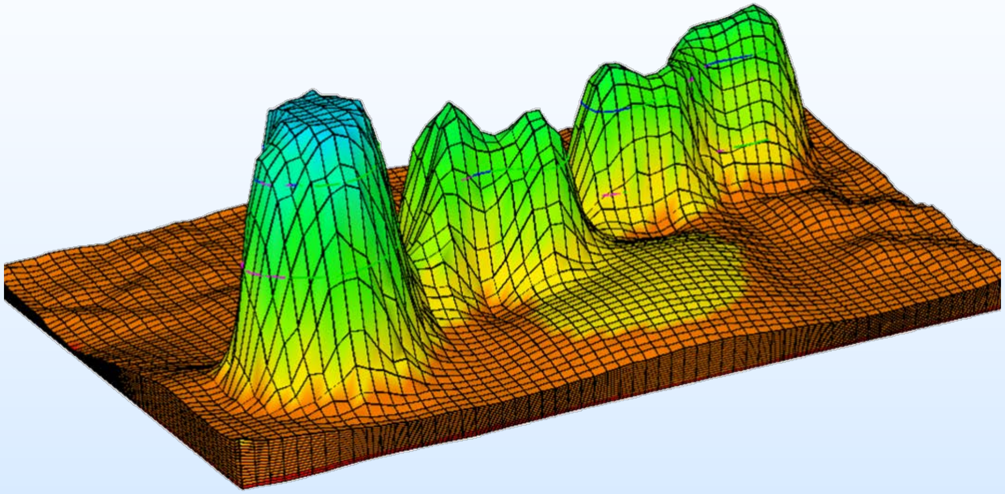
Strategy #9 maximizes both CO_2 Stored and Oil Recovery

Scenario 3 (Convert monitoring well to Injection) implemented

Perforating in fiber-optic wells a key challenge

New EOR Reef (Bagley) – Monitoring in a Complex Reef





1973
Primary production

2015
CO_2 Injection began
Baseline PNC

2016
Baseline PNC

2017
Repeat PNC

2018
Repeat PNC
Model Development

2019
>485K tons of CO_2 stored

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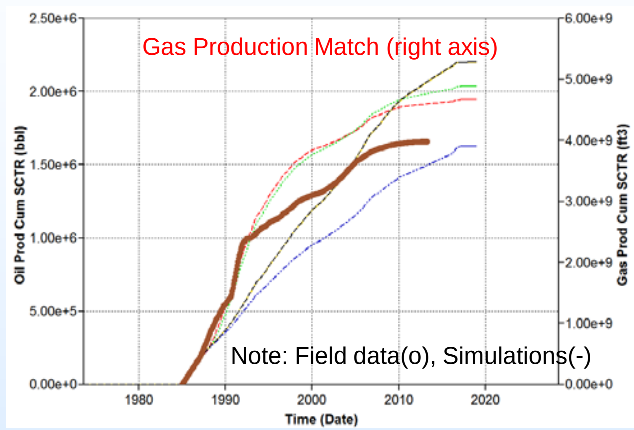
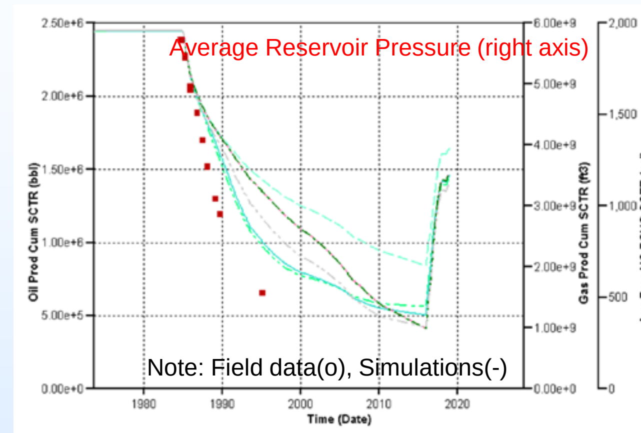
New Reef (Bagley) - History Match to Primary Production and CO_2 Injection Data

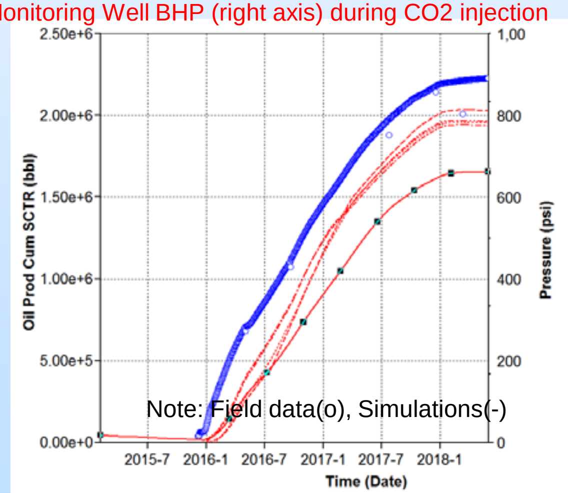
Primary production



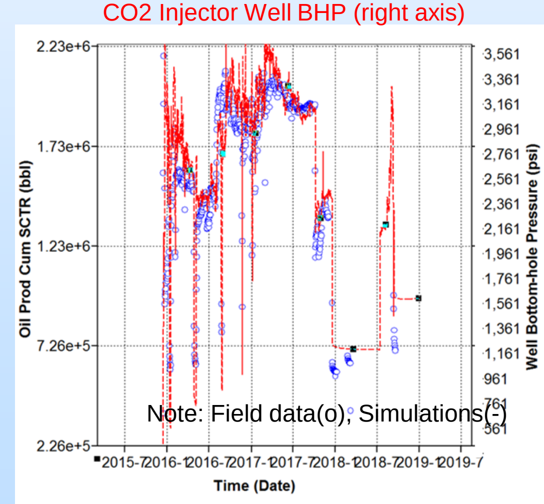


CO_2 injection

Monitoring Well BHP (right axis) during CO2 injection



CO2 Injector Well BHP (right axis)



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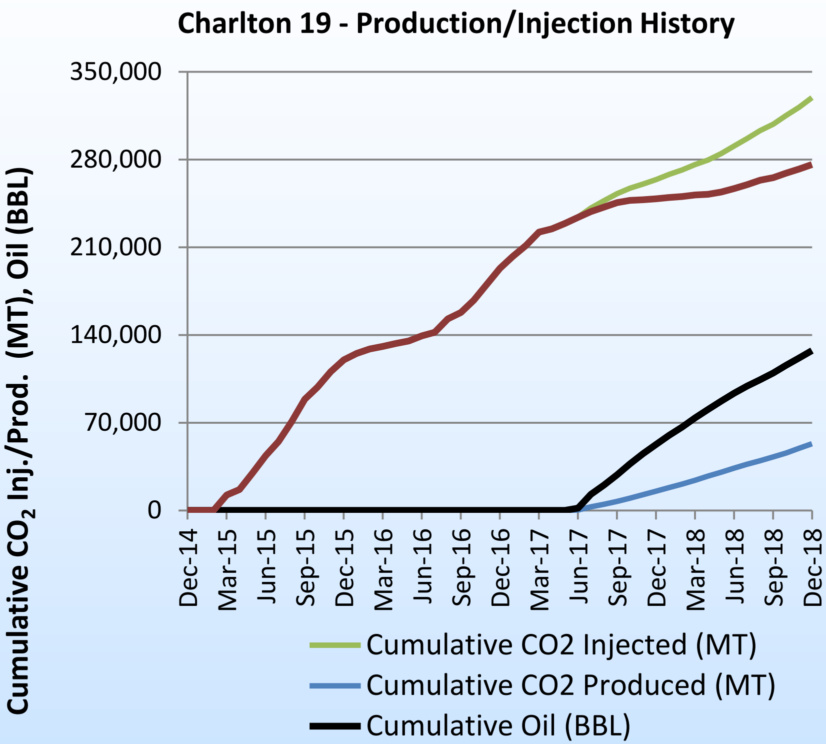
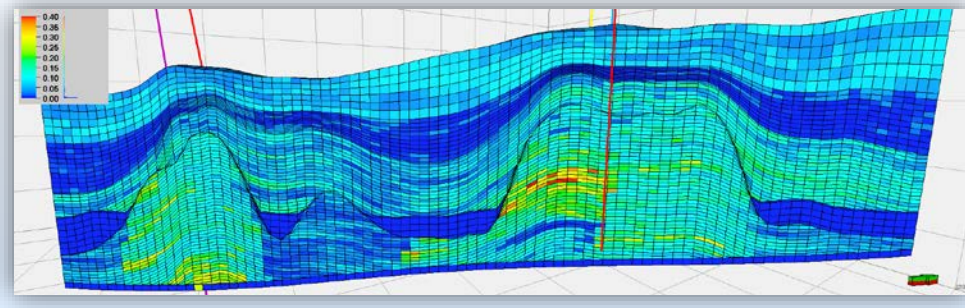
New EOR (Charlton 19) – Testing Simplified Modeling





1988
Primary production

2014
CO_2 Injection began

2015
Baseline PNC

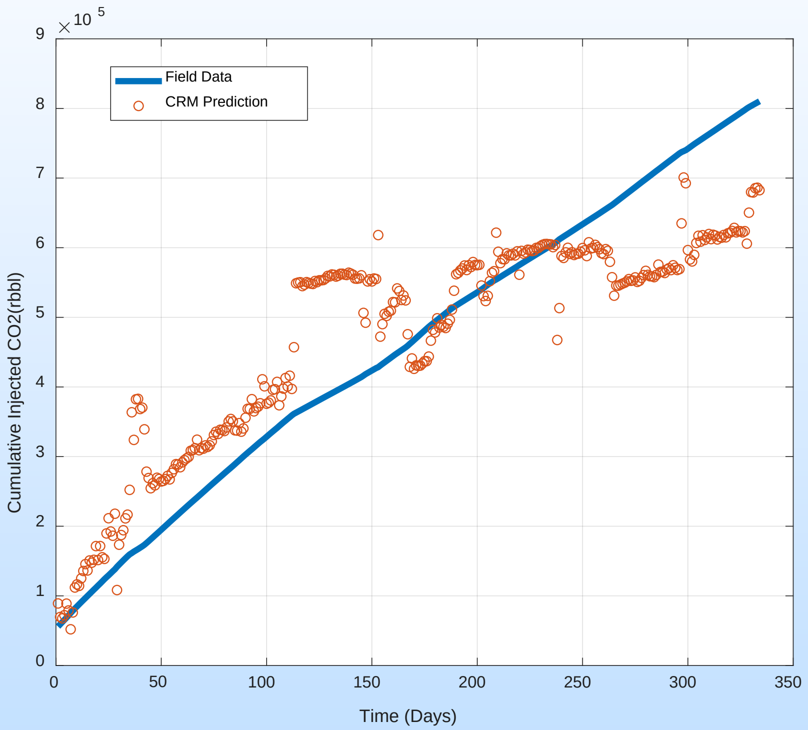
2017
EOR Production
Repeat PNC

2018
Repeat PNC
Model Development

2019
>276K tons of CO_2 stored

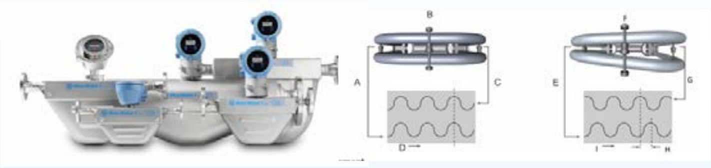
Application of Capacitance Resistance Model (CRM) to Estimate Reservoir Capacity and Injectivity (Charlton-19)

- Simplified (tank) model with two parameters
  - Total compressibility * Pore volume, C_t.PV
  - Injectivity index, $J = q/\Delta p$
- Applied to many waterflooding project
- Here, first application for history matching to CO_2 injection data
- Allows rapid prediction of pressure buildup for given injection rate (& vice versa)



Mass Balance Accounting Methods

- Bulk of injection, production and recycling flows measured by Coriolis flow meters – mass basis
- Low-pressure separators use vortex meters – volume basis
- Vented gas measured by orifice plate meters – volume basis
- Aggregate meters at Chester 10 Facility and at combined recycle gas after compression
- Plant Human-Machine Interfaces (HMIs) computer system



*Emerson Coriolis Mass Flow Meters

$$Net\ Stored\ CO_{2\ Reef} = Injected\ CO_{2\ Reef} - Produced\ CO_{2\ Reef}$$

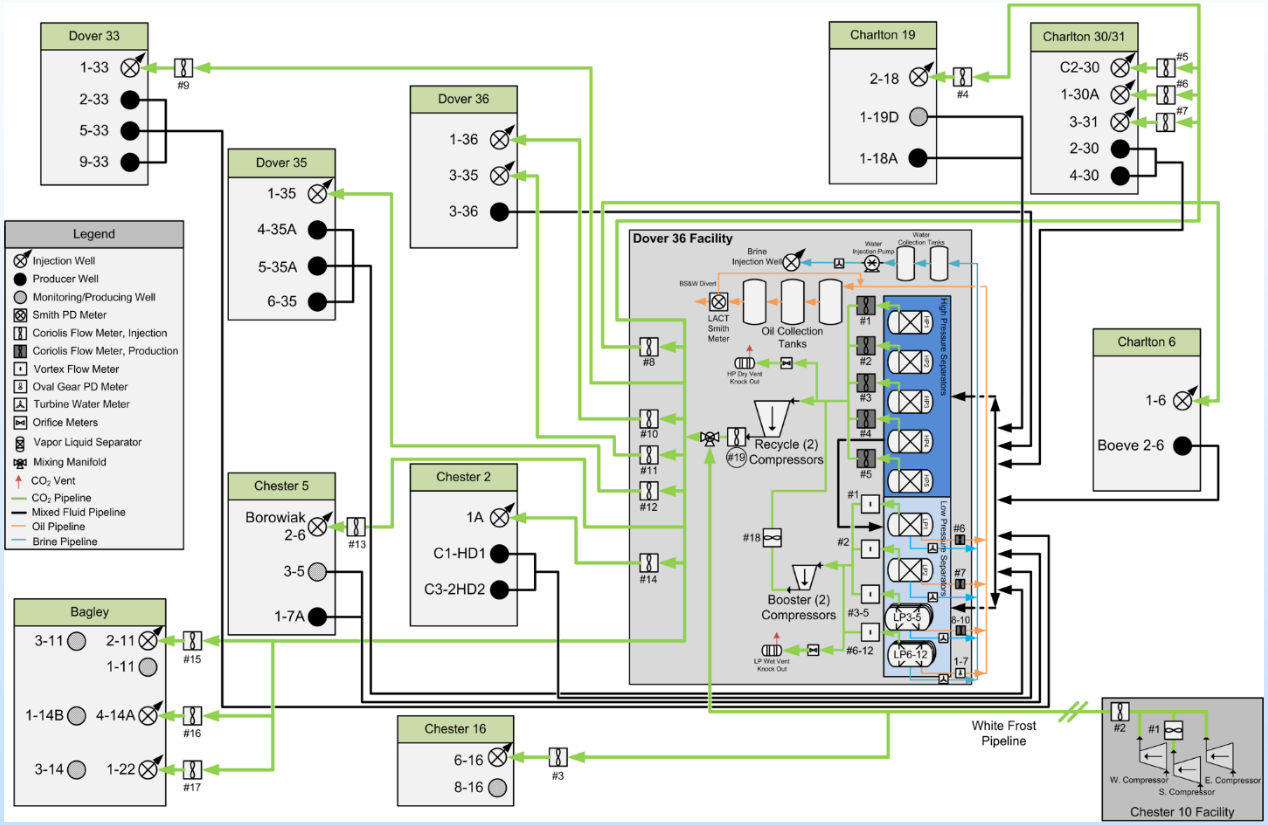
$$Net\ Stored\ CO_{2\ EOR\ Complex} = \sum_{\mathrm{Reef}=1}^{10} Net\ Stored\ CO_{2,Reef}$$

$$CO_2 = CO_{2I} - CO_{2P} - CO_{2E} - CO_{2FI} - CO_{2FP}$$

Equation RR-11 for EPA GHG Reporting

CO_2-EOR Complex & Central Production Facility

- Chester 10 facility provides pure CO_2
- ~80 miles of pipeline network
- 9 reefs interconnected at Dover 36 Facility
- 5 high and 12 low pressure separators
- Recycle/booster compressors
- Coriolis mass flow metering at all critical locations



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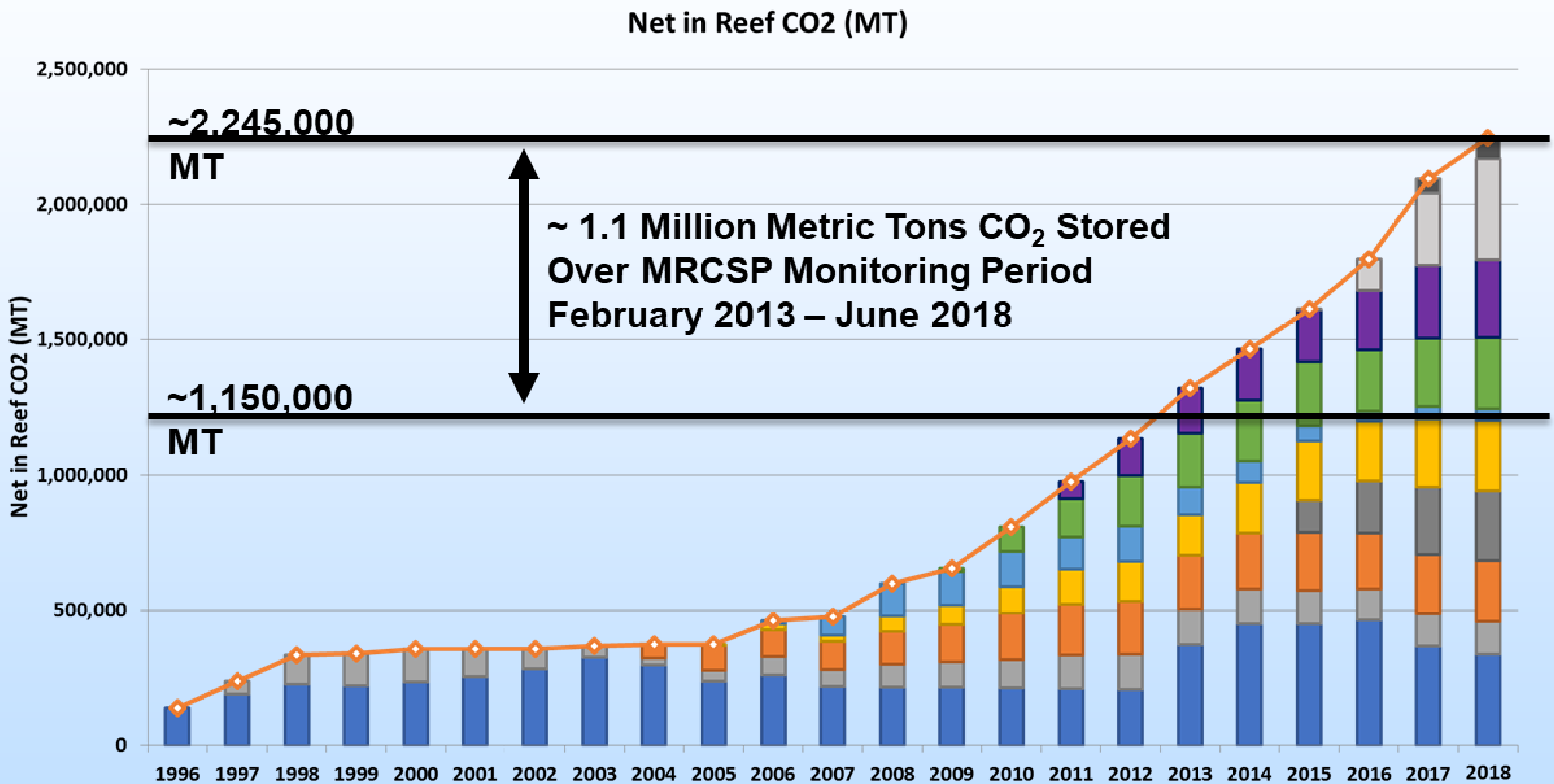
Net CO_2 Stored over MRCSP Monitoring >1.45Million MT Storage till June 2019



*Net-in-reef CO_2 stored represents difference between CO_2 injected and CO_2 recycled at 10 active EOR reefs.

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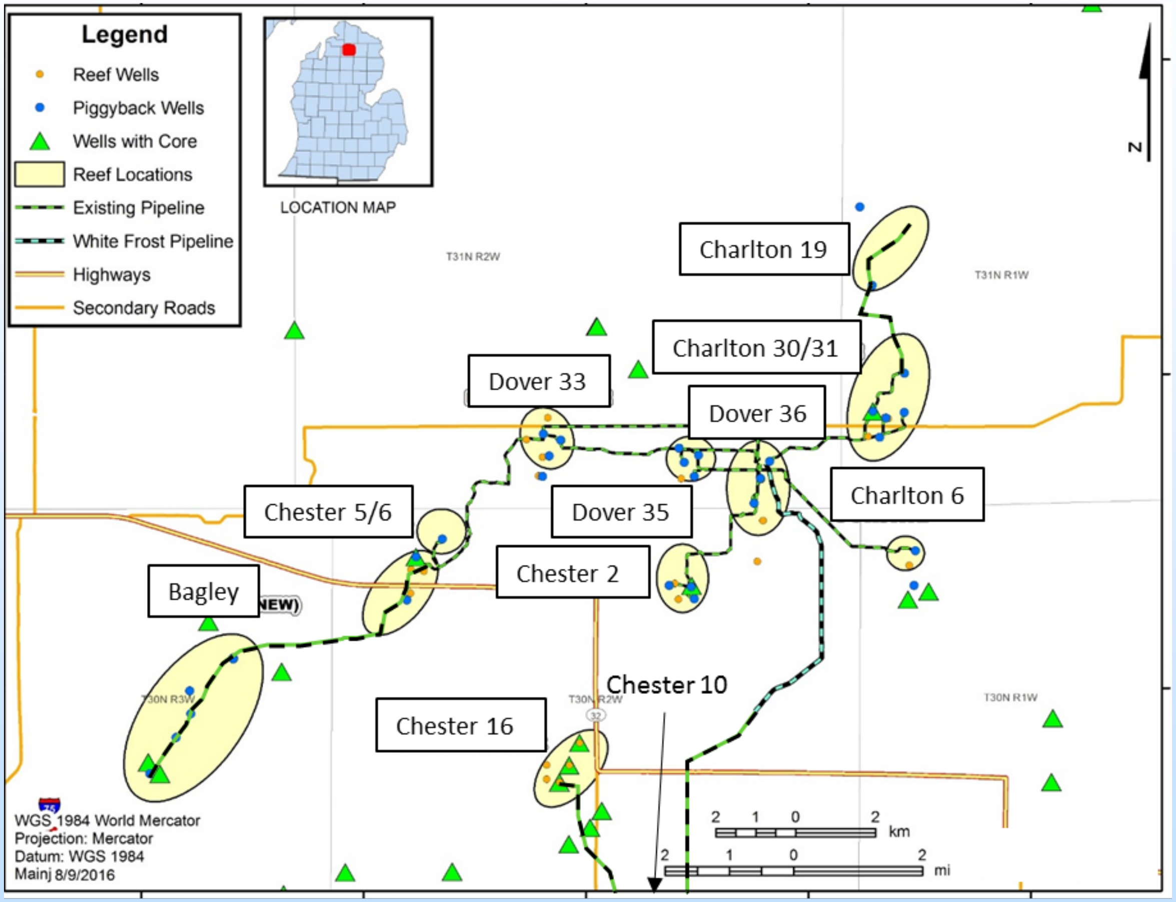
Monitoring, Reporting & Verification (MRV) Plan Approved by EPA

Reef	Date Initiated
Dover 33	1996
Dover 36	1996
Dover 35	2004
Charlton 30/31	2006
Charlton 6	2008
Chester 2	2009
Chester 5	2011
Charlton 19	2015
Bagley 11-14-23	2015
Chester 16	2017



MRV Plan (Subpart RR, EPA):

- Project Description
- Delineation of Active & Maximum Monitoring Area
- Evaluation of Leakage Pathways
- Monitoring Baselines
- EPA Mass Balance Equations

CCUS.LP 45Q Tax Equity Partnership Formed by Core

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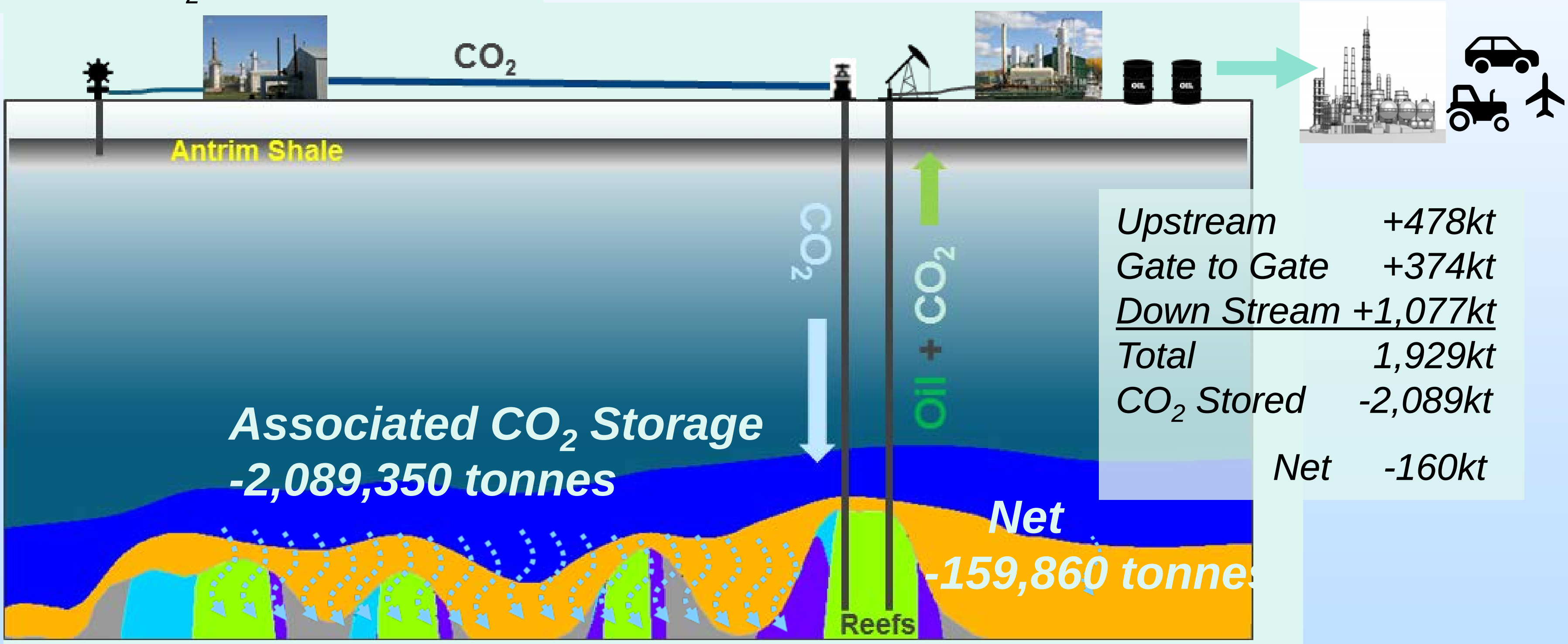
Results- Total LCA results 1996-2017

Upstream
CO_2 Capture Plant Operations
478,476 tonnes
CO_2e Generated

Gate to Gate
(compression, EOR, & gas processing)
374,147 tonnes
CO_2e Generated

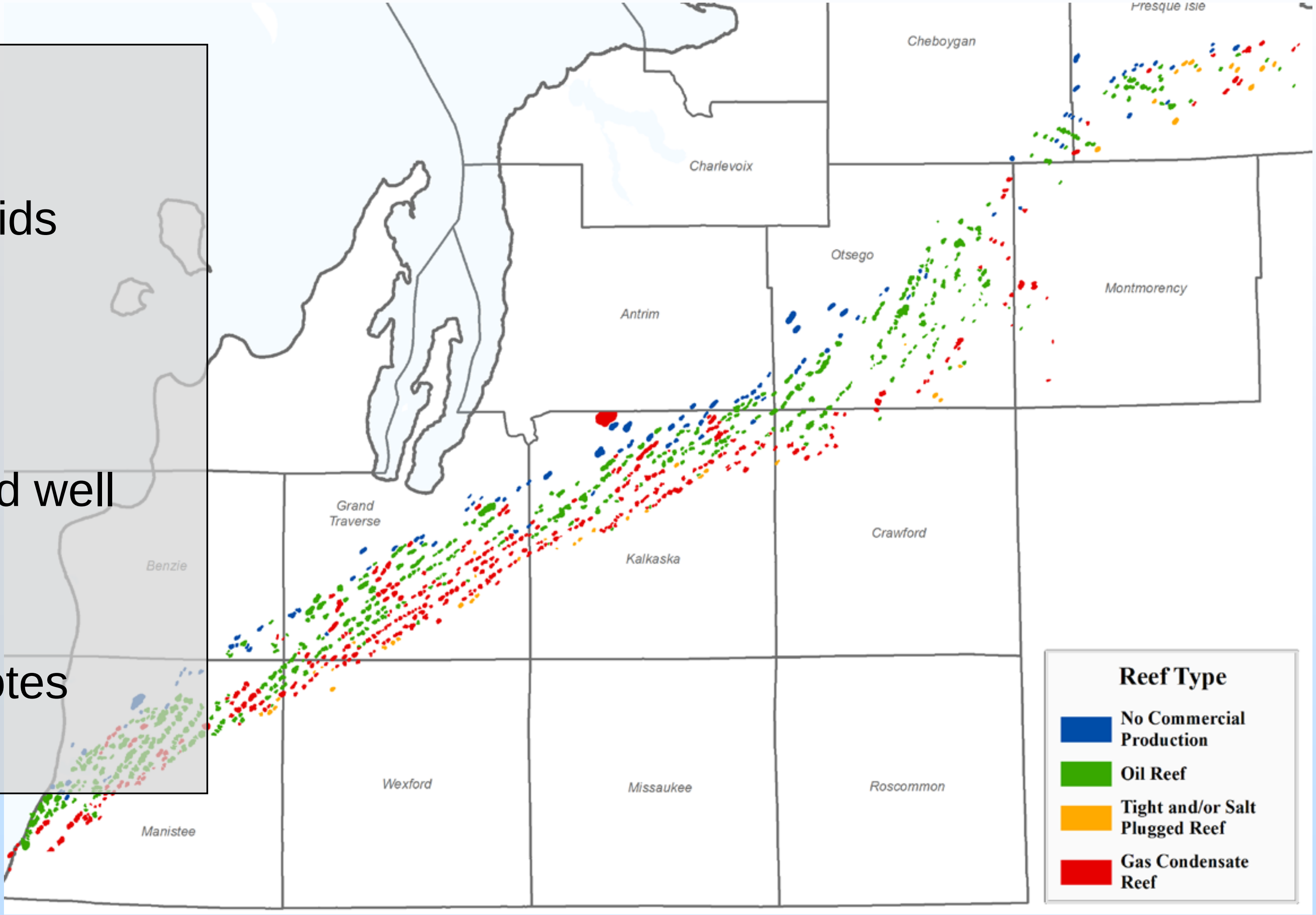
Downstream
1,076,867
tonnes CO_2e
Generated



Upstream	+478kt
Gate to Gate	+374kt
Down Stream	+1,077kt
Total	1,929kt
CO_2 Stored	-2,089kt
Net	-160kt

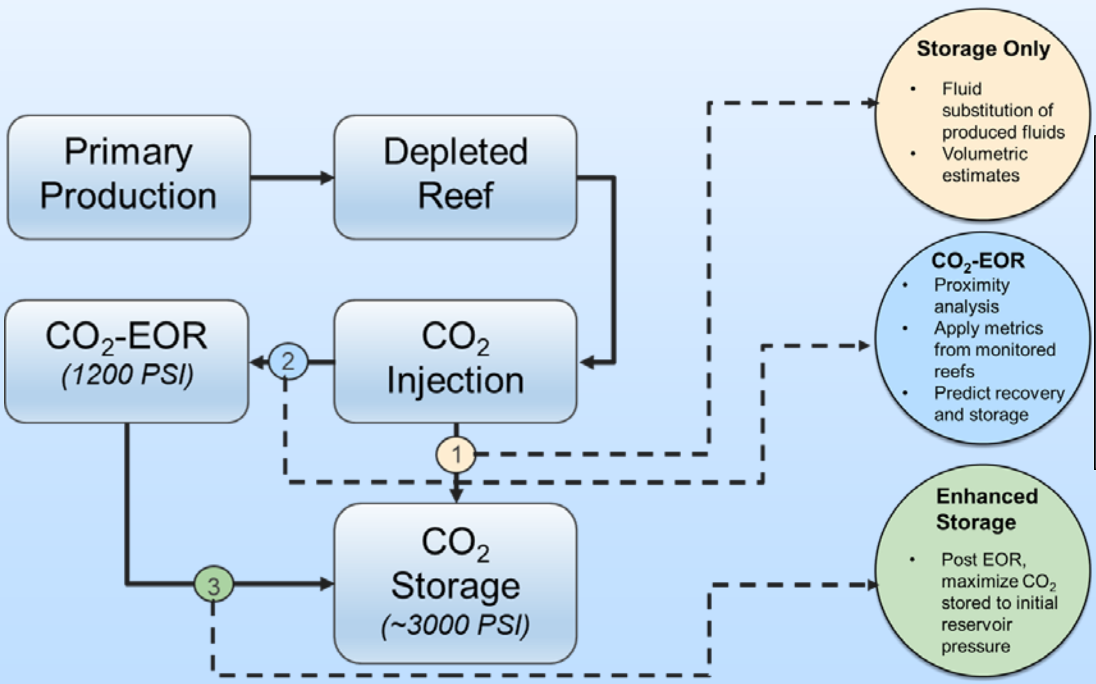
Development of a Reef Atlas

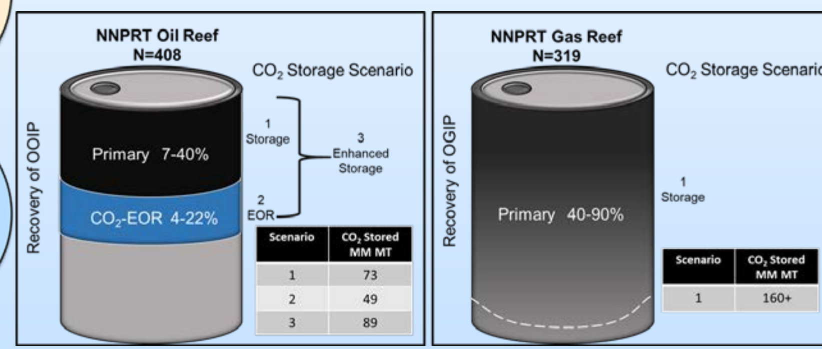
- Type
- Status
- Produced fluids
- Pressure
- OWC
- Reef height
- # of wells and well IDs
- Operators
- Additional notes



Regional Scale up to Entire NNPRT

- Regional reef atlas used to estimate CO_2 resources and EOR potential
- > 250 million metric tons of storage possible
- >100 million STB oil recoverable via CO_2-EOR





Scenario	CO_2 Stored MM MT
1	73
2	49
3	89

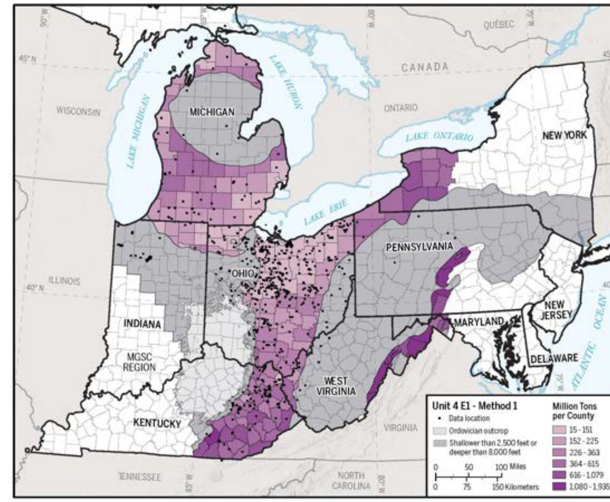
Scenario	CO_2 Stored MM MT
1	160+

Regional Characterization– Demonstrate Geological Storage Potential

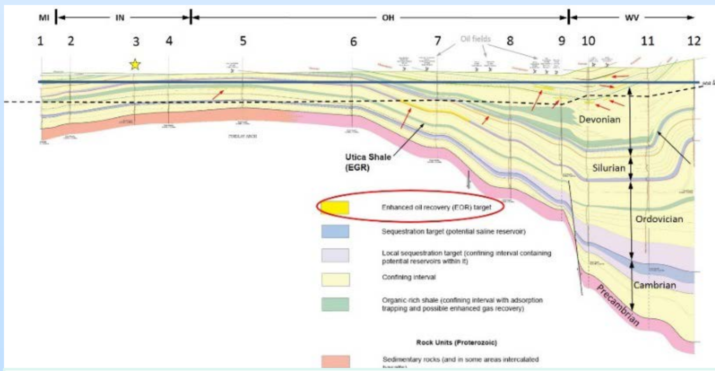
Establish fundamentals for CO_2 storage within the ten-state region and to qualify what volumes, how and where

- Assess the potential reservoirs and seals in the region, including offshore
- Determine the type of storage (saline, EOR or EGR reservoirs)
- Quantify the potential storage resources
- Generate products essential for siting, performance modeling, MVA

Series of reports under preparation



Storage resource estimate map



Regional cross section

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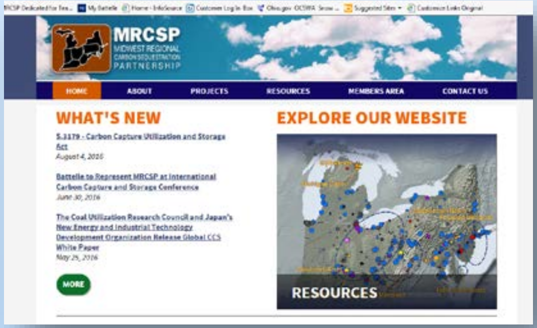
MRCSP Outreach

Sharing Lessons Learned to Foster CCUS Development

Stakeholder Meetings



www.mrcsp.org

Factsheets and BPMs

Conferences and Papers

Message Mapping

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MRCSP Outreach

FY2019 Highlights

- Highly attended MRCSP Annual Meeting in Annapolis, MD
- Participated in major conferences and workshops
  - GHGT-14
  - AAPG ACE and AAPG ES
  - CMTC
  - AGU
  - AICHE
  - IEAGHG
- Provided input into Permitting and Standards
  - DOE/EPA UIC meeting about permitting under MRCSP and related projects.
  - International Standards Organization (ISO) meetings
  - SPE SRMS System and Guidance Document
- Major emphasis on Peer-Reviewed papers in the final year
- Multiple volumes of reports under preparation for release in 2020

MRCSP Outreach – Final Meeting

2019 MRCSP ANNUAL MEETING

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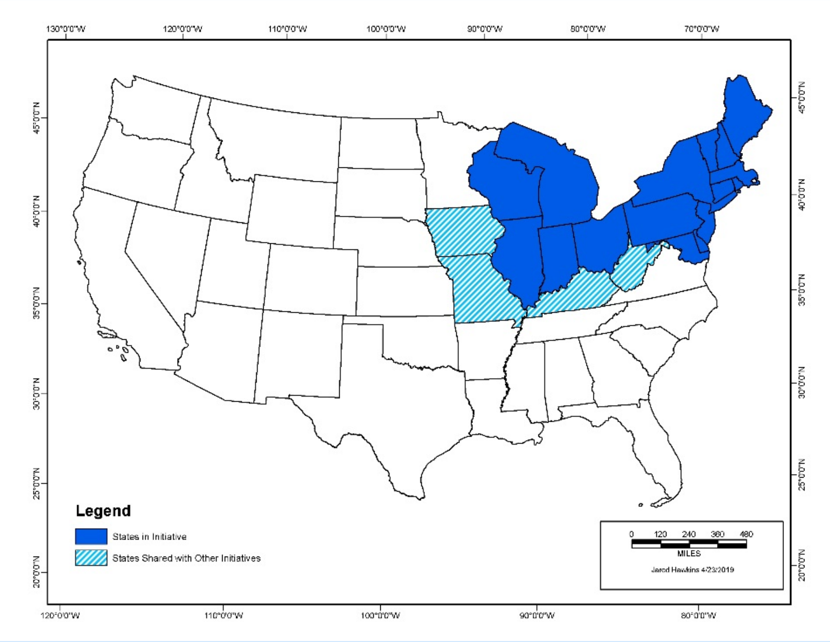
A Glimpse of the Future – Regional Initiatives! *Naming Rights still available!*



Joint Proposal with Illinois State Geological Survey / MGSC

Source Type	2017 Emission (MMt)	% of Total
Power Plant	694	73%
Metals	72.5	8%
Minerals	44.4	5%
Chemicals	38.3	4%
Petroleum, Natural Gas, and Refineries	28.4	3%
Other	28.0	3%
Ethanol	16.9	2%
Pulp and Paper	10.7	1%
Waste	7.9	1%
Manufacturing	3.5	<1%
TOTAL	945	-

- Decarbonization Initiative for the Midwest and Eastern Region (DIMER)
- Industrial CARbon Utilization and Storage (ICARUS) Initiative☺
- Carbon Initiative of the Northeast and Midwest and Atlantic (CINEMA)☺
- Laurentia Industrial Carbon Initiative!

Synergy Opportunities

- Growing commercial CCUS Practice under 45Q/LCFS Regime
- Southern Michigan Advanced CO_2-EOR (FOA1988)
- Geomechanical Stress Assessment (FOA1829)
- CarbonSafe Phase I (Ohio, Michigan, Nebraska) and Phase II (Nebraska, Kansas) projects
- Mid-Atlantic Offshore storage assessment
- Well integrity and risk management
- Brine disposal and induced seismicity research
- Knowledge share with RCSPs on monitoring and modeling
- Testing NRAP models and CO_2 Screen tools
- International projects - South Africa, China, Mexico, Indonesia, Spain
- IEAGHG monitoring/Modeling Networks
- DOE Best Practices Manuals

MRCSP Related Work - Building Block for CCUS Deployment

MRCSP Large-Scale EOR Public-Private Partnership

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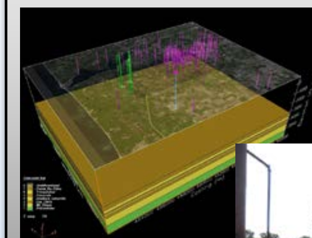
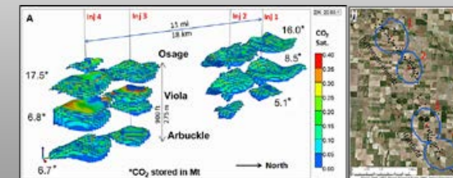
CARBON SEQUESTRATION
PARTNERSHIP

Carbon Storage/EOR 45Q Screening/Feasibility

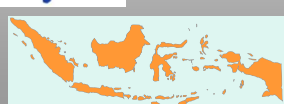


CarbonSAFE

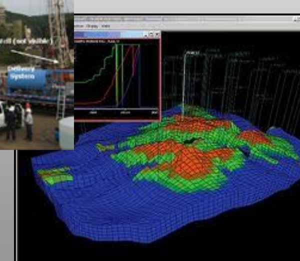


Integrated Mid-Continent Stacked Carbon Storage Hub (Nebraska & Kansas)

International CCUS Development

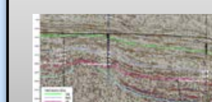


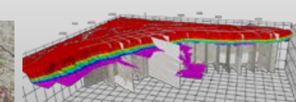
CO_2-EOR and Storage Exploration

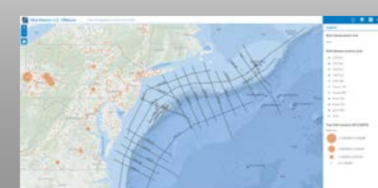


Offshore Carbon Storage

MID-ATLANTIC U.S. OFFSHORE
CARBON STORAGE RESOURCE
ASSESSMENT PROJECT







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Accomplishments to Date

- ~1.5M MT net stored under MRCSP monitoring, >2.6M MT stored since start of EOR in 1996
- Completed monitoring at main test bed in late-stage reef
  - Micro-seismic, Post-injection PNC, microgravity, and VSP completed, Post-injection test well drilled and characterized
  - Returned to normal EOR operations, with selected monitoring continued
- Added new EOR reefs with complex geology to monitoring
  - – Distributed temperature and Acoustic Monitoring
- Advancements in static and numeric modeling processes
- *MRV Plan and Life-Cycle Analysis completed*
- *Commercialization with 45Q CCUS Partnership by Core Energy, LLC*

Project Summary

- MRCSP Large-Scale Test >90% completed with diverse EOR field setting and variety of monitoring options
- Multiple monitoring options are being tested
- Both monitoring and modeling are essential for understanding performance – imperative to be able to do much with limited data
- Regional characterization helping identify new storage zones and estimate storage resources – setting stage for commercial scale CCS
- Results will contribute to developing standards and best practices, NRAP tools, CO_2 capacity estimation tools

Lessons Learned

- CO_2 **measurement/accounting** performed with high level of confidence in a multi-field EOR complex
- **Storage potential** in closed reservoirs evaluated, after active EOR ends – EOR to storage transition
- **Geologic complexity** within and across reefs affects CO_2 injection, migration, and storage
- **Pressure monitoring** remains the mainstay for managing injection operations and monitoring reservoir response
- Advanced monitoring technologies still require testing/validation for confident assessment of plume development
- Characterization-monitoring-modeling loop requires more research for cross-validation over the life-cycle
- A well-developed CO_2-EOR regulatory/policy framework with financial incentives essential for enhanced associated storage

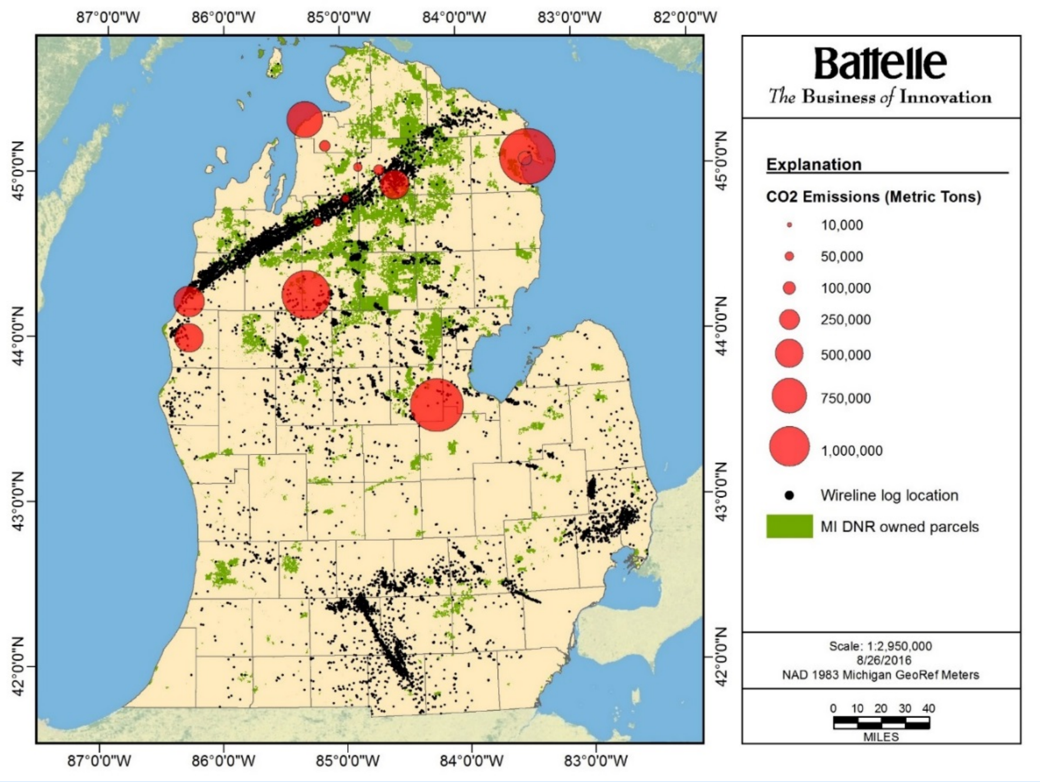
Appendix

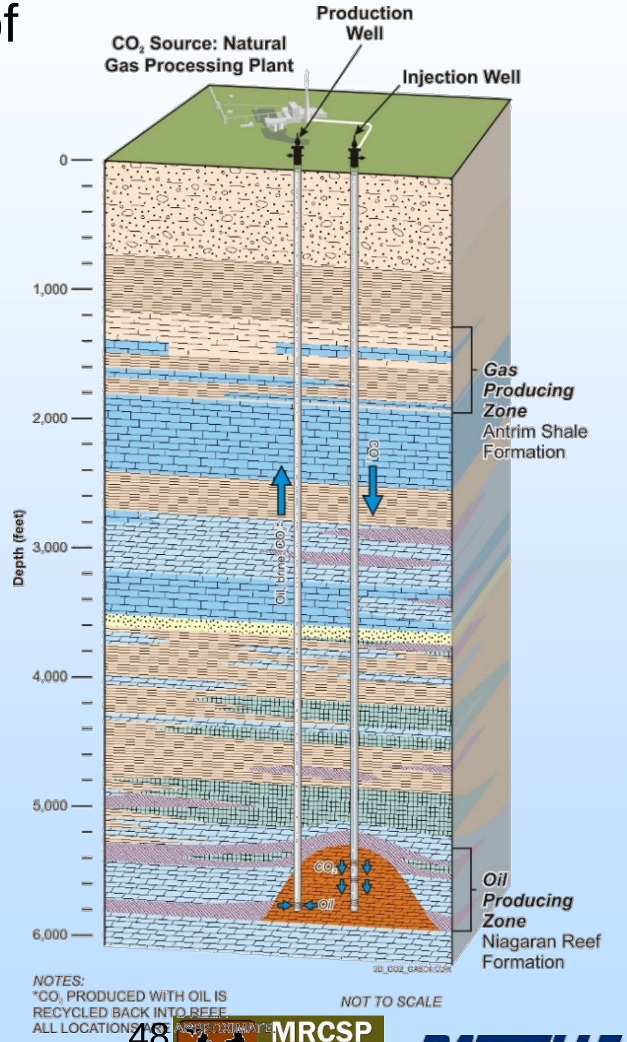
Benefit to the Program

MRCSP Approach/Benefit	DOE Program Goal
Geologic characterization, reservoir assessment and models correlated with field monitoring combined with MRCSP regional mapping.	Predict CO_2 storage capacity in geologic formations to within ±30%
Operational accounting for CO_2 during EOR Monitoring options to track and image plume, and monitor CO_2 storage and retention	Demonstrate that 99% of CO_2 remains in the injection zones
Test in EOR fields in various stages of their life cycle and examine effective strategies for utilizing the pore space created by the oil production	Improve reservoir storage efficiency while ensuring containment effectiveness
Contribute to BPMs through large-scale test and regional analysis across MRCSP	Development of Best Practices Manuals (BPMs)

MRCSP Basin Large-Scale Injection

- Objective – Inject/monitor 1 million metric tons of CO_2 in collaboration with EOR operations.
- Evaluate CO_2 injectivity, migration, containment





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Project Overview

Goals and Objectives

RCSP Goal	MRCSP Success Criteria
Goal 1 – *Prove Adequate Injectivity and Available Capacity*	• Success measured by injecting 1 million tonnes of CO_2 in CO_2-EOR fields within permitted pressures • Pressure analysis and modeling used to evaluate and validate capacity
Goal 2 – *Prove Storage Permanence*	• Seismic and well data used to evaluate storage and containment zones • Monitoring wells used to measure containment over time within the reef and immediate caprock • Reservoir modeling to evaluate storage mechanism
Goal 3 – *Determine Aerial Extent of Plume and Potential Leakage Pathways*	• Monitoring portfolio employed to image and track the lateral and vertical plume migration. Success measured by using monitoring data to compare to and validate plume models

Project Overview

Goals and Objectives

RCSP Goal	MRCSP Success Criteria
Goal 4 – *Develop Risk Assessment Strategies*	• Risk assessment for events, pathways, and mitigation planning • Success will be measured by comparing predicted to actual field experience for all stages of the project
Goal 5 – *Develop Best Practices*	• Phase III builds on Phase II best practices in siting, risk management, modeling, monitoring, etc. • Key emphasis is on operation and monitoring and scale-up to commercial-scale
Goal 6 – *Engage in Public Outreach and Education*	• Extensive outreach efforts for both Phase II and Phase III sites as well as technology transfer and sharing • Phase III lessons learned contribute directly to the RSCP Best Practice Manual updates

Organization Chart

DOE/NETL
Andrea McNemar
MRCSP Program Manager

Battelle
The Business of Innovation

Prime Contractor
Neeraj Gupta, PI/PM
M. Kelley, Characterization/Monitoring
A. Haagsma, Outreach & Regional Geology
A. Haagsma and A. Conner, Geology
S. Mishra, P. Ravi Ganesh, and A. Pasumarti Modeling
R. Wessinger (PM), A. Burchwell, (Dep. PM)
A. Conner Fieldwork

Pacific Northwest National Laboratory
Charlotte Sullivan
Alain Bonneville
Characterization Monitoring Support

Kentucky Geological Survey, University of Kentucky
Michigan Basin Core Research Laboratory
WVGES
New York State Museum
Rutgers

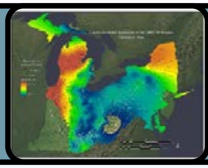
Kris Carter, PA Geo Survey
Regional Characterization Task Coordinators

WADE
Sarah Wade
Outreach Working Group Coordinator

The Ohio State University
David Cole
Geochemical Monitoring
LLNL

CORE ENERGY, LLC
Robert Mannes
Rick Pardini
Large-Scale Test Host

MRCSP Scope of Work Structured Around Six Tasks



Task 1

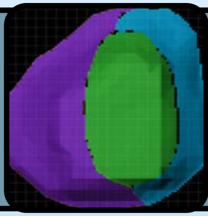
Regional Characterization: *Develop a detailed actionable picture of the region's geologic CO_2 storage resource base*

Task 2

Outreach: *Raise awareness of regional CO_2 storage opportunities and provide stakeholders with information about CO_2 storage*

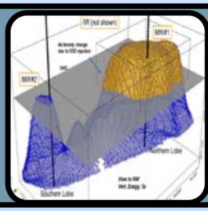
Task 3

Field Laboratory Using Late-Stage EOR Field: *Pressurize a depleted oil field with CO_2 injection to test monitoring technologies and demonstrate storage potential*



Task 4

CO_2 Storage Potential in Active EOR Fields: *Monitor CO_2 Injection and recycling in active EOR operations with different scenarios*



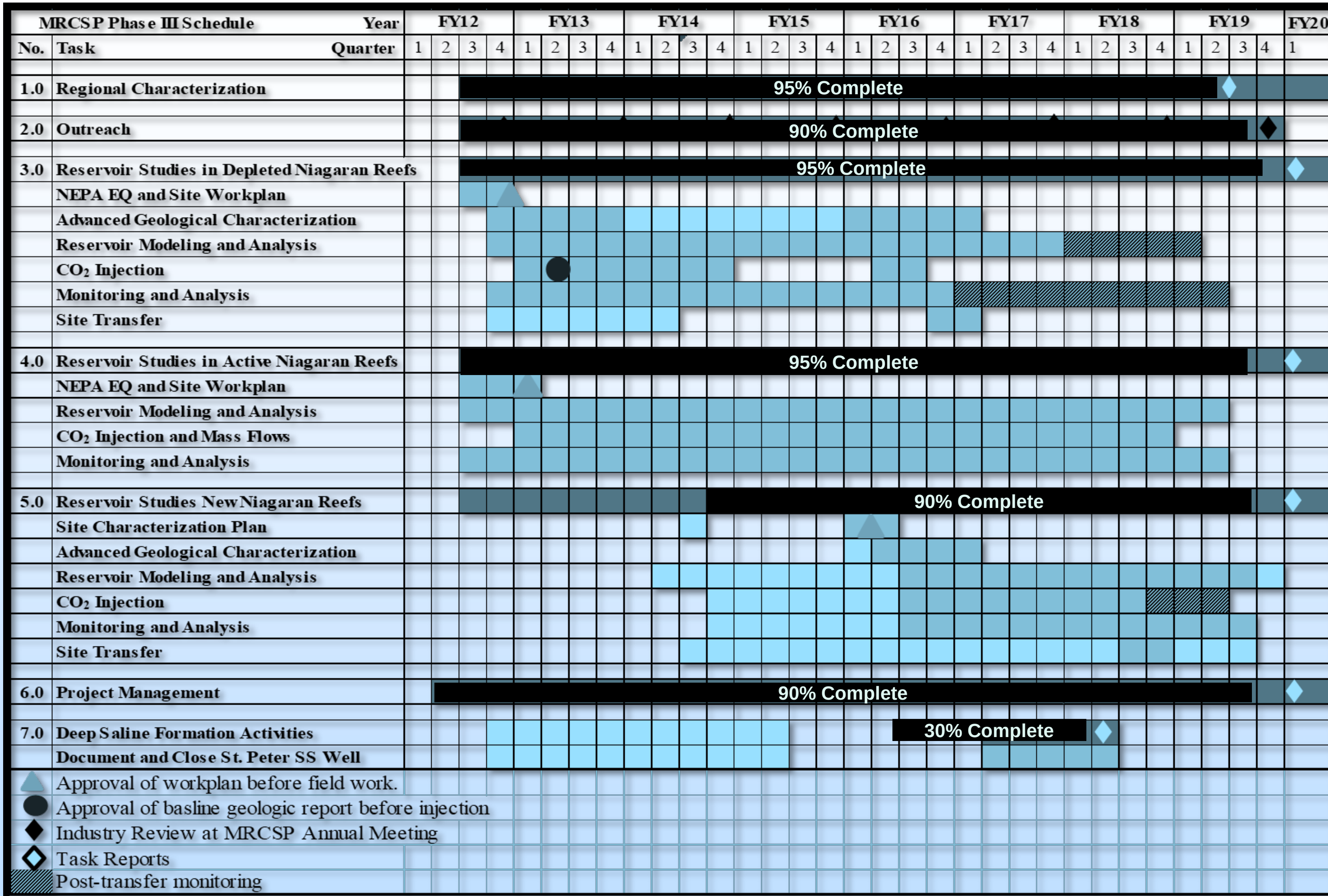
Task 5

CO_2 Injection in New EOR Field(s): *Monitor CO_2 injection into an oil field that has not undergone any CO_2 EOR to test monitoring technologies and demonstrate storage potential*

Task 6

Program Management

Gantt Chart



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- Welch S.A., Sheets J.M., Place, M.C., Saltzman M.R., Edwards C.T., Gupta, N., Cole D.R., 2019, Assessing Geochemical Reactions during CO_2 Injection into an Oil-Bearing Reef in the Northern Michigan Basin, Applied Geochemistry, 100, 380-392.

Papers in review

- Mishra, s., Haagsma, A., Valluri M., and Gupta, N. In Review. Assessment of CO_2 Enhanced Oil Recovery and Associated Geologic Storage Potential in the Michigan Northern Pinnacle Reef Trend. Energies.
- Haagsma, A., Main, J., Pasumarti, A., Valluri, M., Scharenberg, M., Larsen, G., Goodman, W., Conner, A., Cotter, Z., Keister, L., Harrison, W., Mishra, S., Pardini, R., and Gupta, N. In Review. A Comparison of CO_2 Storage Resource Estimate Methodologies for a Regional Assessment of the Northern Niagaran Pinnacle Reef Trend in the Michigan Basin. Environmental Geosciences