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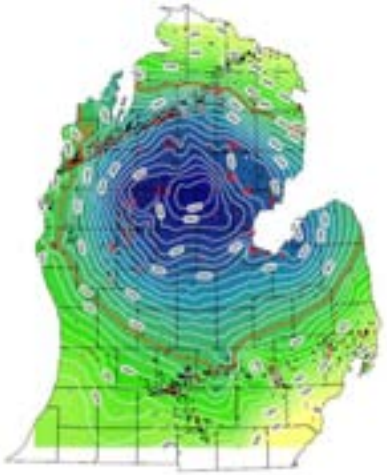
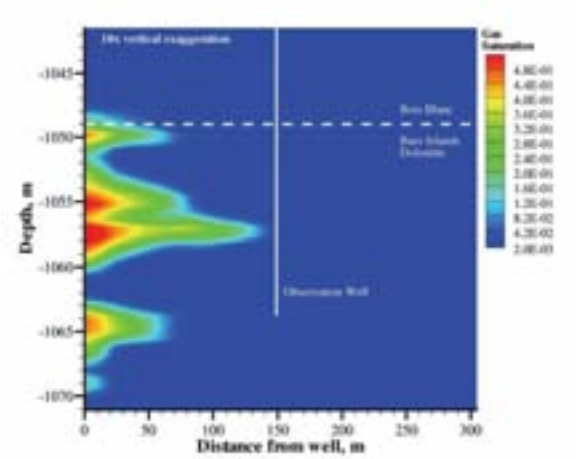




MRCSP Michigan Basin Test Site

Jacqueline Gerst, Battelle

Regional Carbon Sequestration Partnerships Annual Review

November 16-19, 2009

MRCSP
MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

Acknowledgements- Project Team

Abed Houssari, Steve Rawlings and Becky Cook

Dave Barnes, Bill Harrison, Sue Grammer

Dave Ball, Neeraj Gupta, Joel Sminchak, Judith Bradbury, Lydia Cumming, Ioan Feier, Diana Bacon, Danielle Meggyesy, Erica Howat, James Holley, Matt Place, Ryan Stowe, Evan Zeller

Traci Rodosta

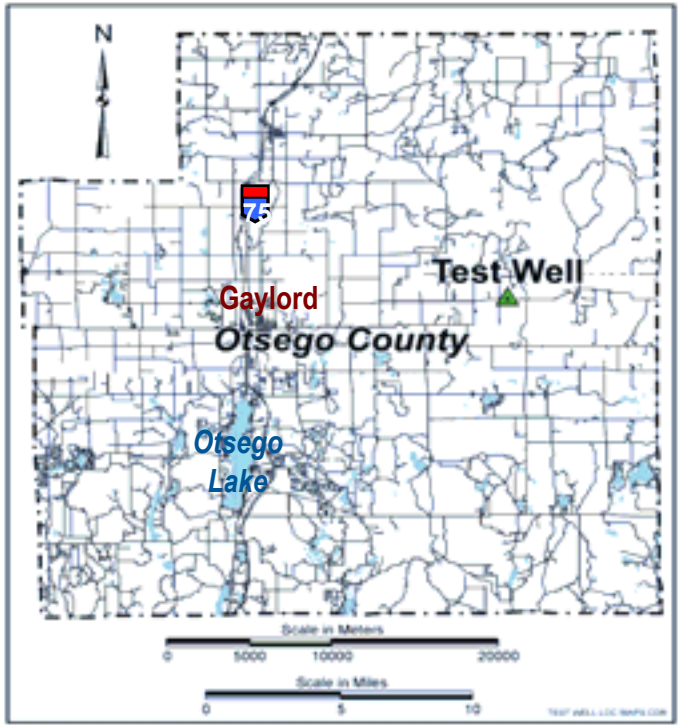
Robert Mannes, Rick Pardini, Bob Tipsword, Jane Davison

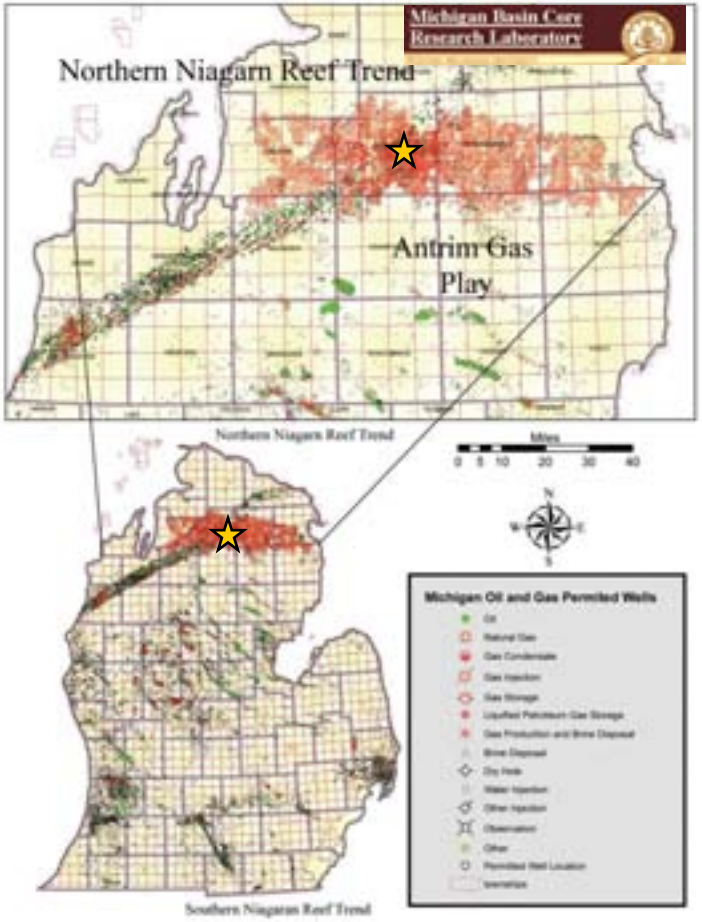
Additional Contributions by Numerous Other MRCSP Team Members

Michigan Basin-
Otsego County Test Site

- The location is at an existing gas field in the vicinity of a DTE gas processing plant outside of Gaylord, Michigan.

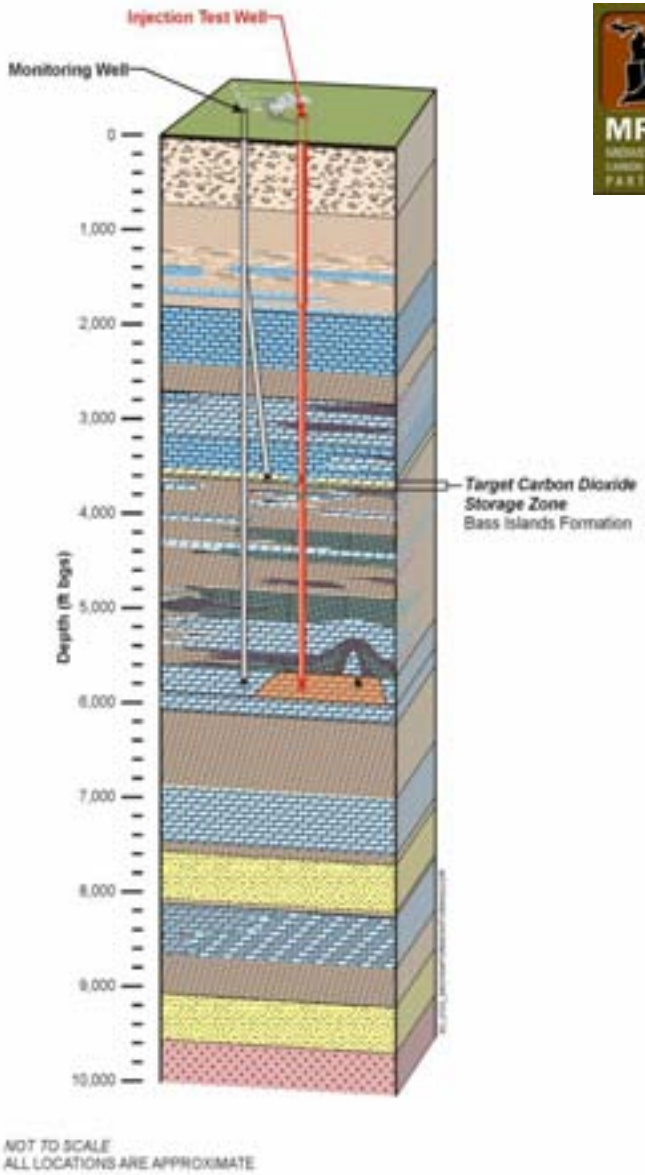
Site Location



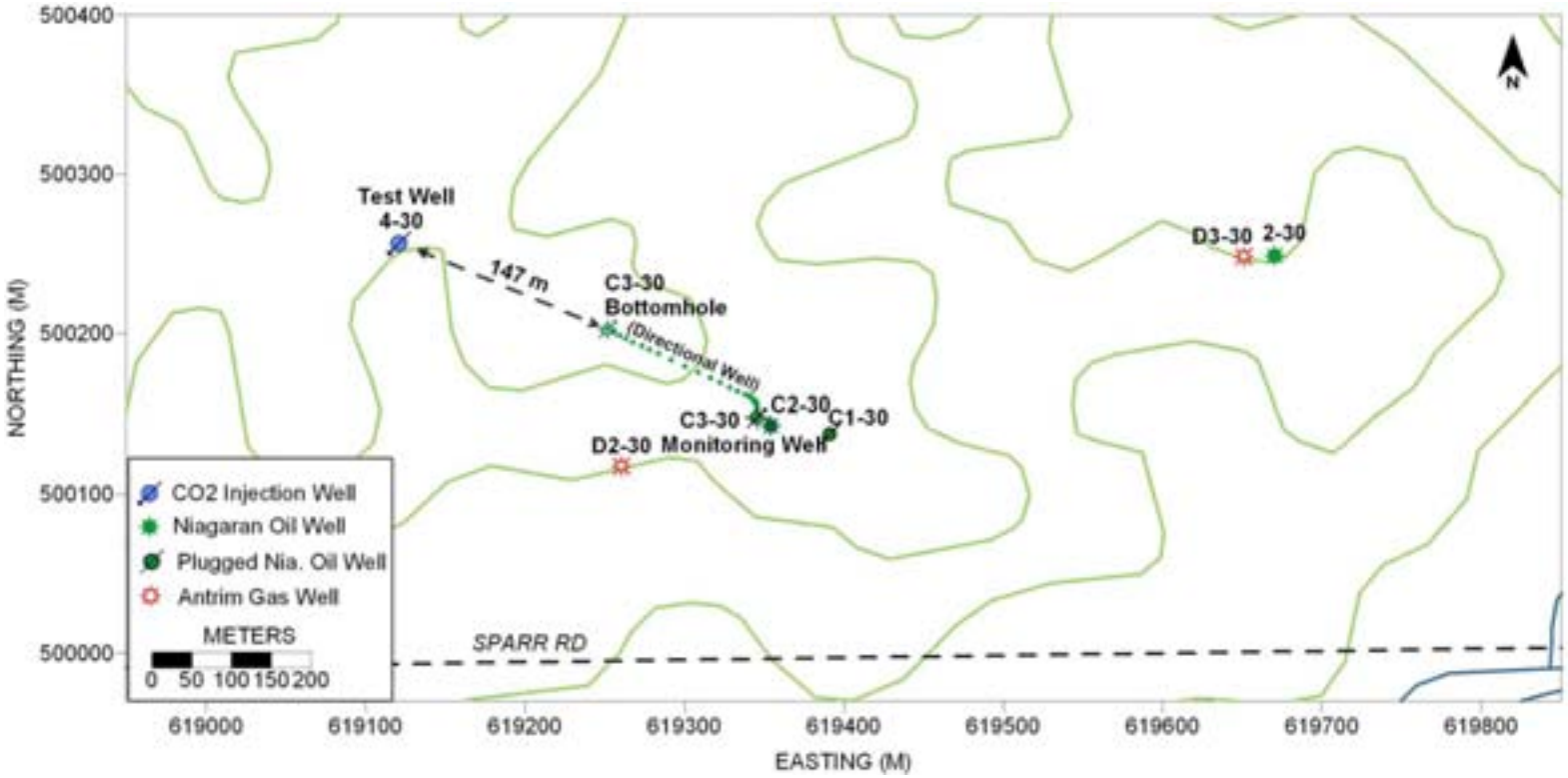


Injection System

- New well (State-Charlton 4-30) drilled for injection.
- Nearby well 3-30 used for monitoring.
- Variety of other monitoring methods used at the site.



Monitoring Wells



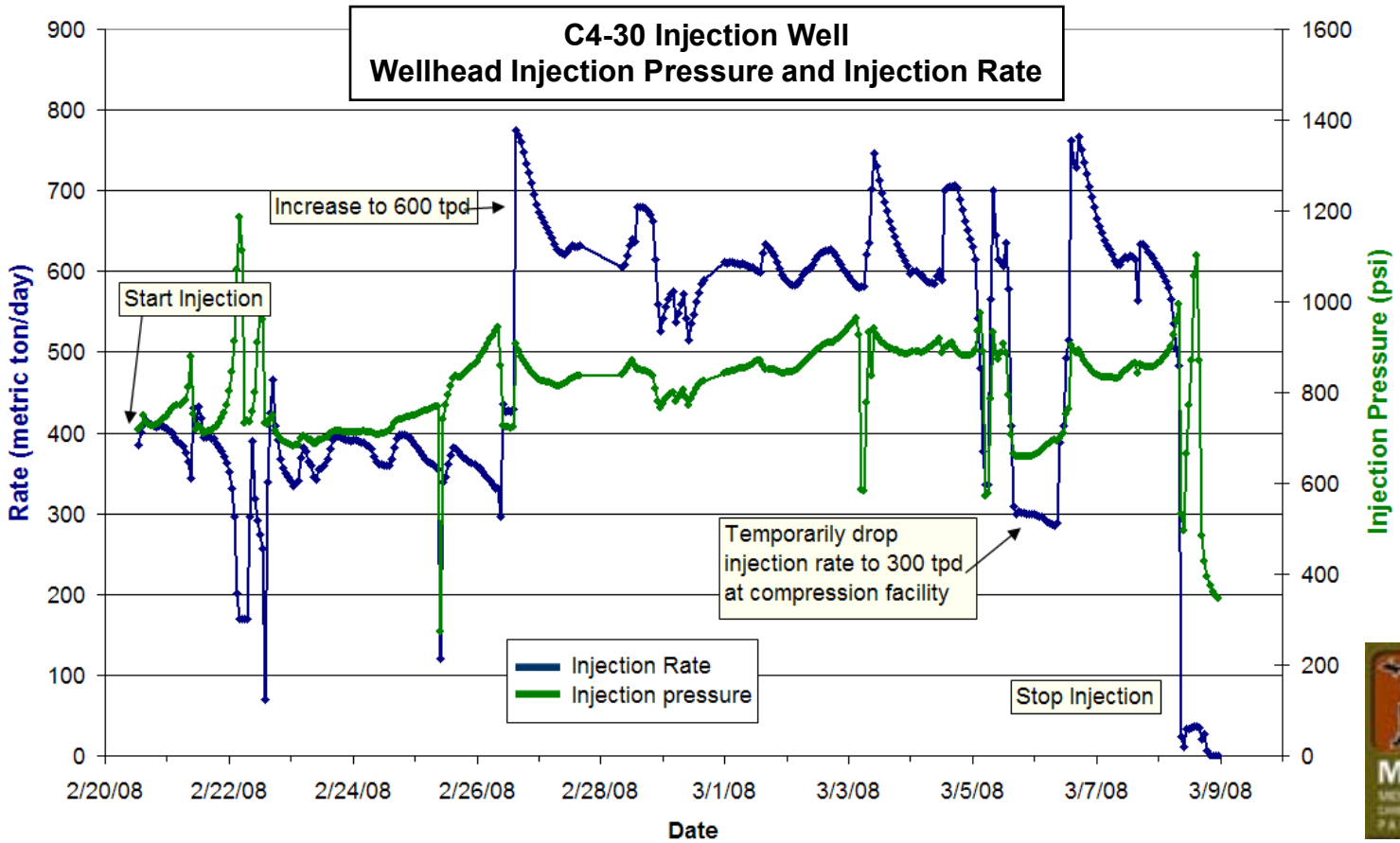
- C3-30A used as a monitoring well for a microseismic array, crosswell seismic and fluid sampling
- 2-30 used as a monitoring well for a microseismic array

Project Timeline

Year	Mo.	Task	Category
2005	Oct	Site Screening and Planning	Site selection and Screening
	Nov		
	Dec		
2006	Jan	Preliminary Site Review	
	Feb		
	Mar	Site Plan	
	Apr		
	May		
	Jun	Preliminary Geologic Assessment	Site Characterization
	Jul		
	Aug		
	Sep		
	Oct	Test Well Drilling	
	Nov		
	Dec		
2007	Jan	Analysis and Testing	Permitting
	Feb		
	Mar	UIC Permit Application	
	Apr		
	May	EPA Review and Response	
	Jun		
	Jul	Draft UIC Permit and Outreach Meeting	
	Aug		
	Sep	UIC Appeal to EPA EAB	
	Oct		
	Nov	MMv and Injection Plan	
	Dec	Permit Granted, Appeal denied by EAB	
2008	Jan	Final MMV Report, Baseline MMV	Injection Testing and Monitoring
	Feb	Field Injection Testing	
	Mar	Injection and post-injection MMV	
	Apr	Post-injection MMV	
	May		
	Jun		Post-injection Analysis and Reporting
	Jul	Post-injection Cement Bond Logging	
	Aug	Model Calibration and Validation	
	Sep	Data Analysis	
	Oct		
	Nov	Site Report	
	Dec		
2009	Jan	Additional MMV, Repermitting	Extension Injection Testing and Monitoring
	Feb	Field Injection Testing	
	Mar		
	Apr		
	May		
	Jun		
	Jul	Post-Injection MMV	
	Aug	Data Analysis	
	Sep	Site Report	

Initial CO_2 Injection Testing

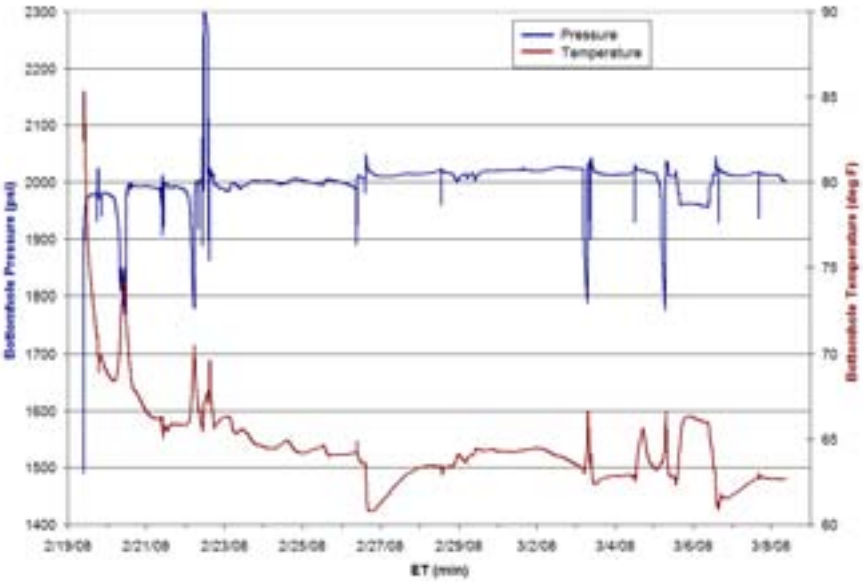
- 10,241 metric tons CO_2 was injected from February 18-March 8, 2008 (including initial mechanical integrity test volume).
- Injection Rate increased from 400 to 600 metric tons/day after 1 week (some fluctuations in injection rate due to compression facility).



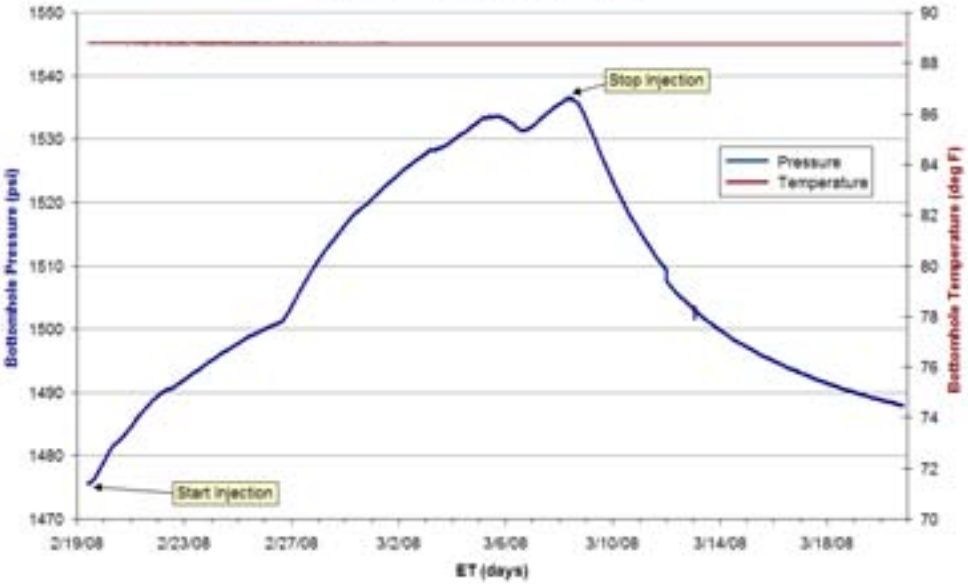
Initial CO_2 Injection Testing

- Bottomhole pressures were 2,000-2,020 psi during injection and generally stable throughout the 18 days of injection.
- Overall, testing indicates rates of 600 metric tons/day or higher may be sustained in the Bass Islands Dolomite.
- Pressure response in C3-30 monitoring well showed ~60 psi increase within the Bass Islands Dolomite formation. No temperature change. No direct indication of CO_2 breakthrough was detected at the monitoring well.

C4-30 Injection Well
Bottomhole Pressure and Temperature

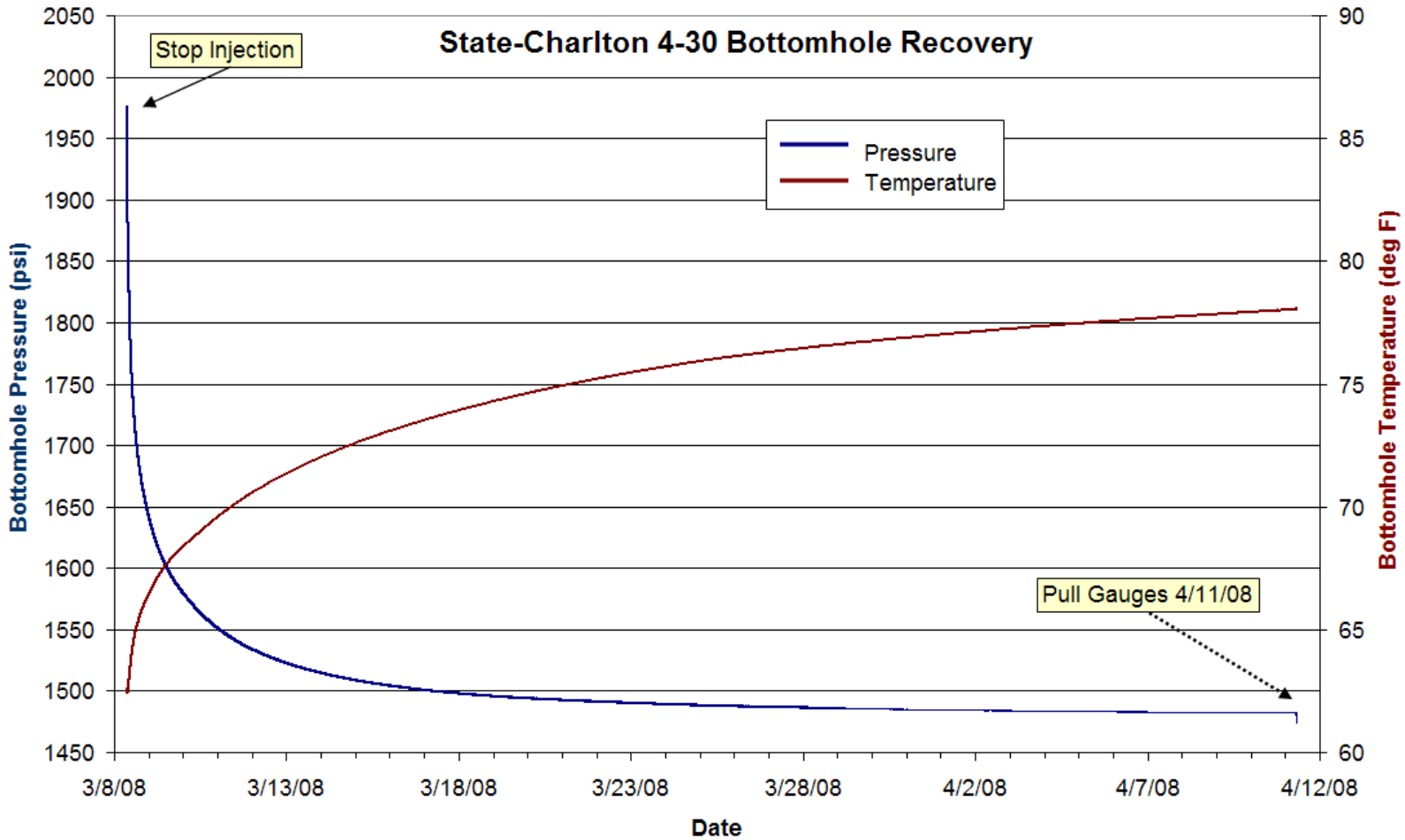


C3-30 Monitoring Well
Bottomhole Pressure and Temperature



Post-Injection P-T Response

- Pressures in the injection wells returned to normal in about 1 week.
- No significant pressure/temperature events detected



MVA Program – Initial Injection

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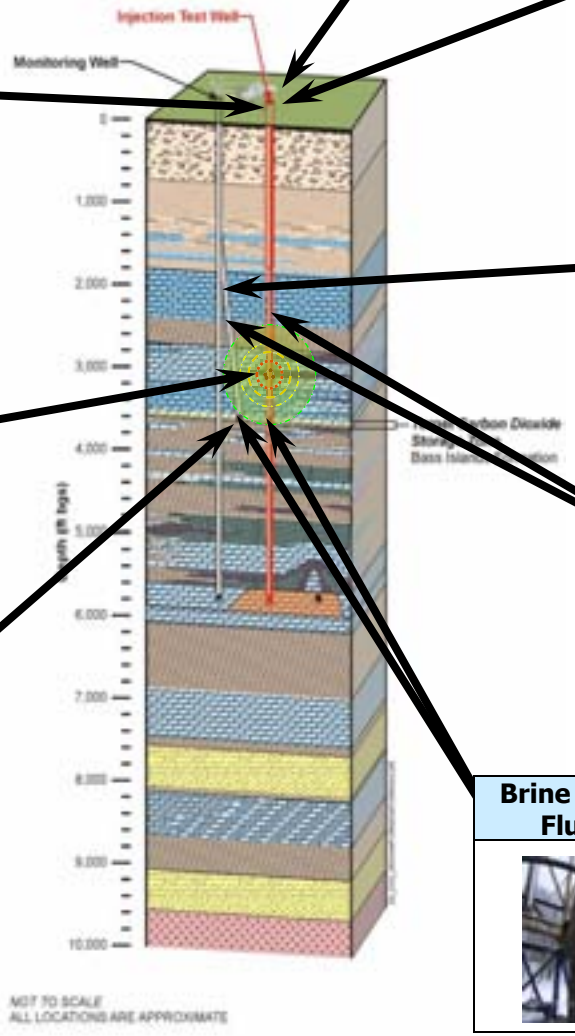
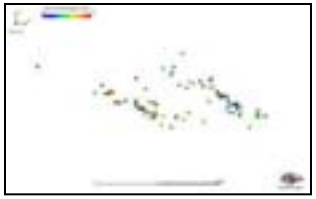
PFT Tracer Survey

Surface Gas Meters

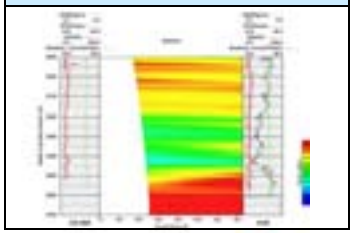
System Monitoring



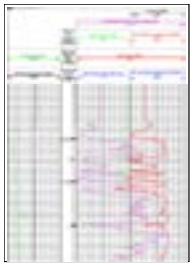
Acoustic Emissions



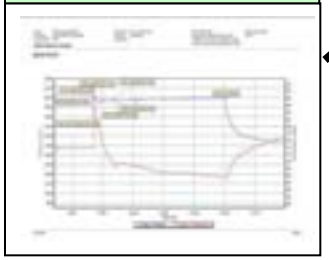
Cross-Well Seismic



Wireline Monitoring



Downhole Pressure



Brine Chemistry and Fluid Sampling

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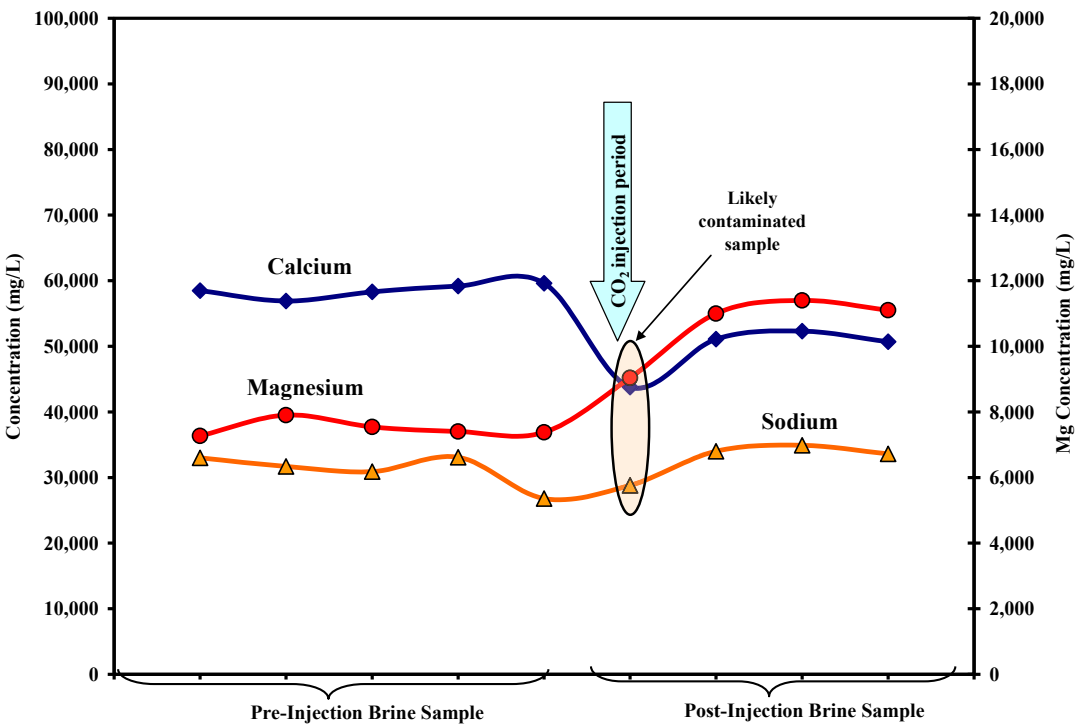
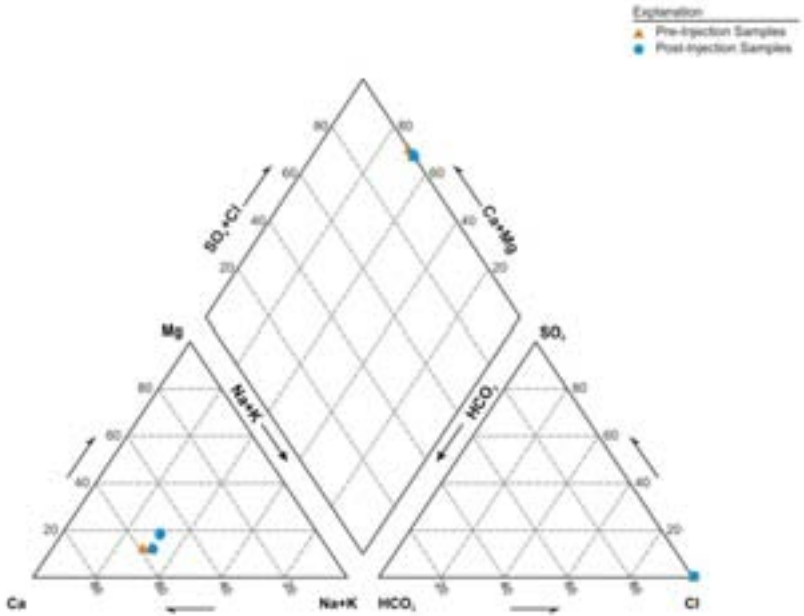
Michigan Brine Sampling Analysis (pre and post injection)

- Calcium levels decreased and Magnesium increased, possibly due to dissolution of dolomite and precipitation of anhydrite.
- These are very subtle indications of CO_2. More, sequential sampling needed.



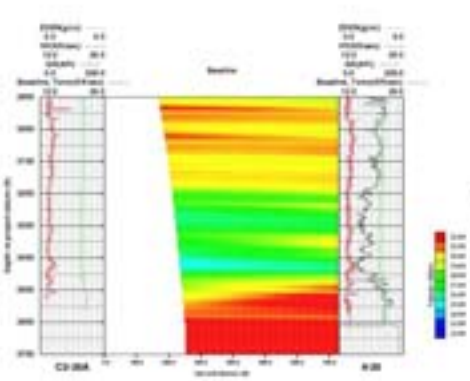
Piper Diagram



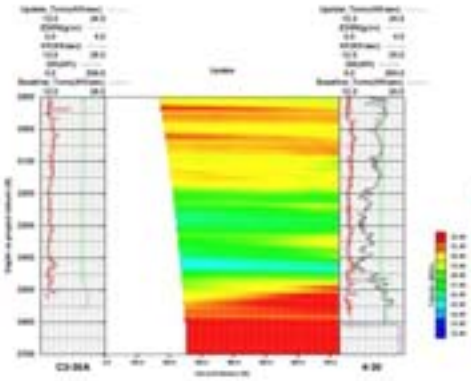
Crosswell Seismic Post Injection Survey

- Baseline cross-well survey run between 4-30 and C3-30A in October, 2007. Repeat, post-injection survey completed in May, 2008
- Excellent signal to noise ratio and high energy source yield resolution of only a few meters
- The difference between the two surveys shows a velocity decrease in the Amherstburg formation, approximately 300 ft above the perforated injection interval, with no apparent connection with the velocity change area at the injection interval.

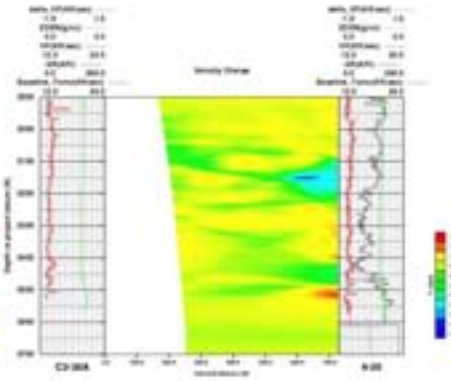
Baseline Survey



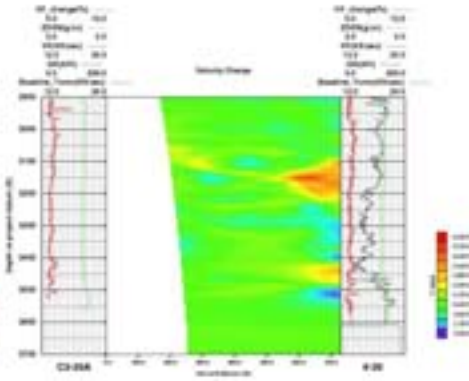
Repeat Survey



Straight Difference

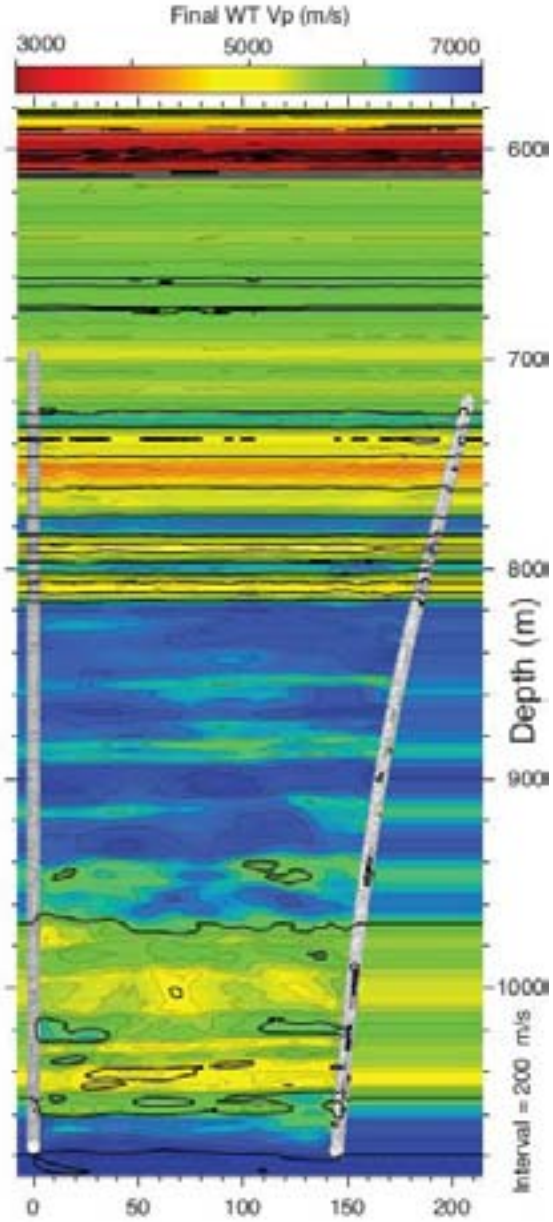


% change from baseline to repeat. Reds-yellows indicate decreases in velocity



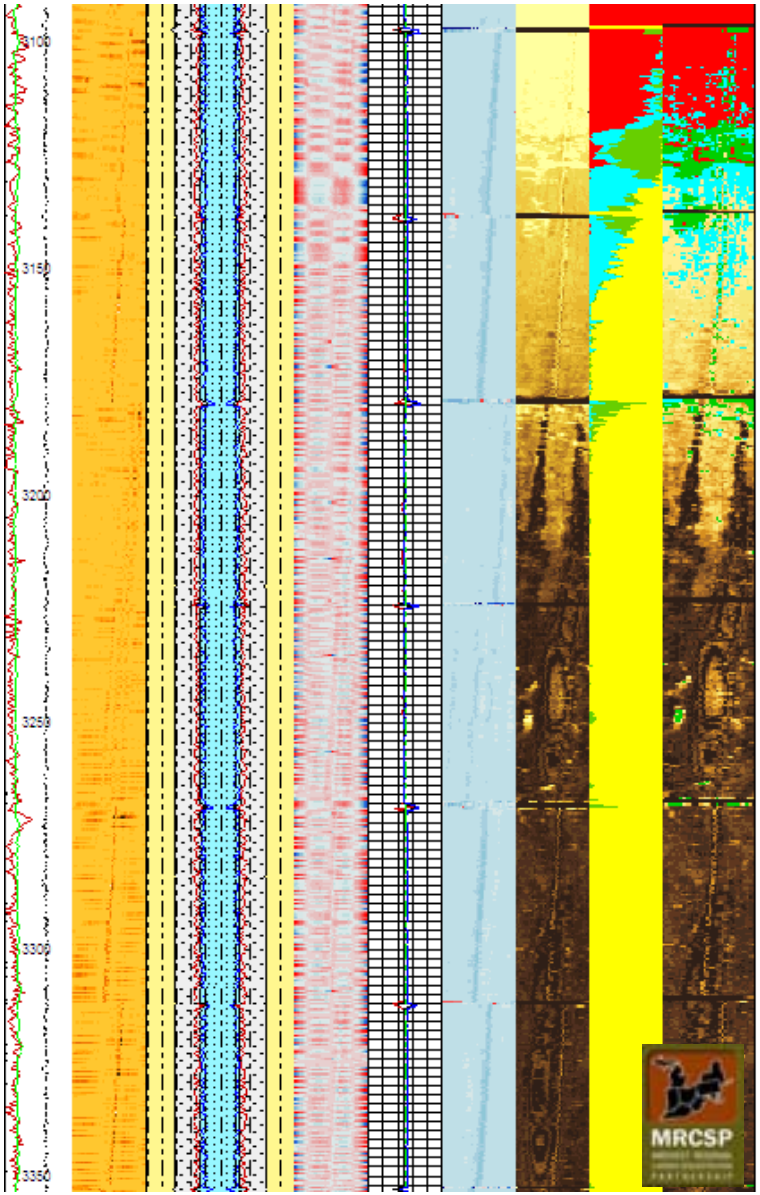
Additional Crosswell Processing

- Full waveform tomography can yield much more detailed information on the formations
  - Takes advantage of the additional information in the waveforms, beyond the first arrival time differences
- Figure shows reprocessed baseline survey.



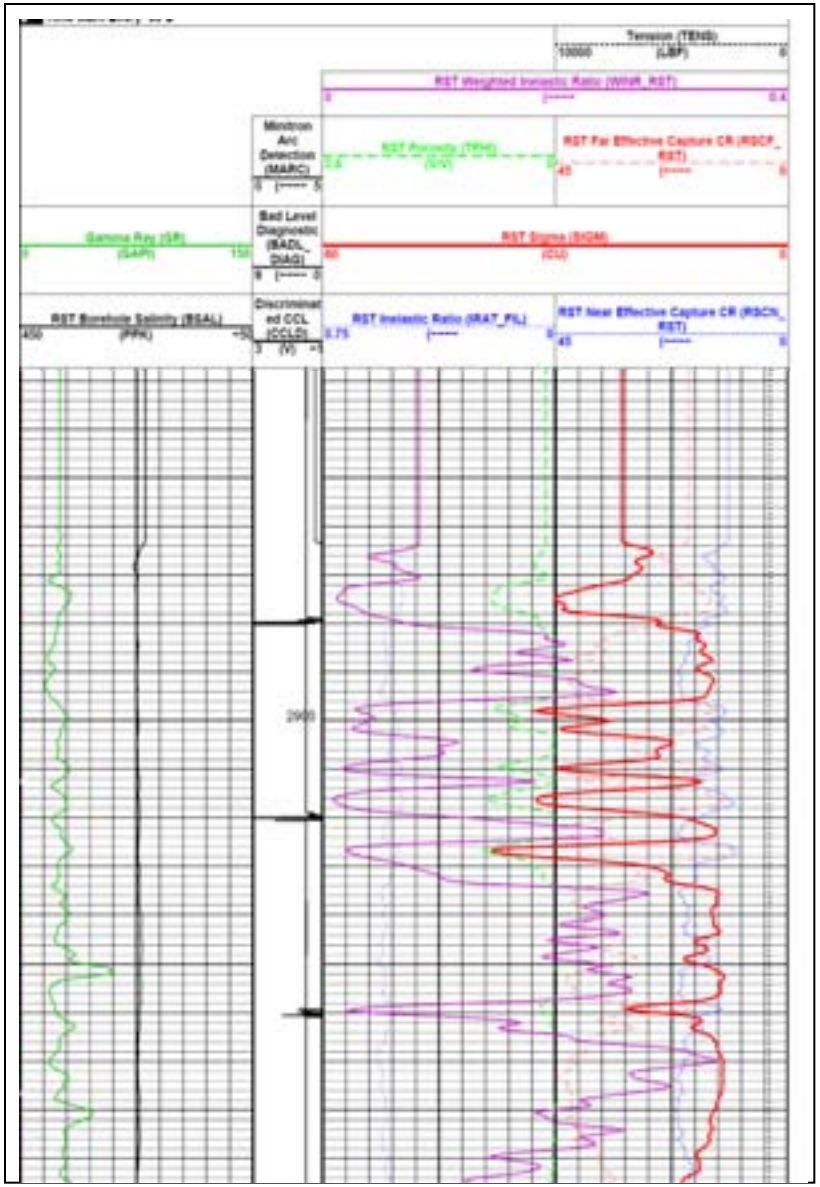
Evaluating Migration Pathways

- Potential causes for seismic velocity change were evaluated
  - A more detailed cement bond log (Isolation Scanner) was run to examine the cement quality
  - No obvious migration pathways were found between the injection depth and the velocity anomaly
  - Gas appears to be potentially present behind the casing at the location of the anomaly, based on wireline data
  - It is unclear if this is CO_2 or methane (there was a gas show during drilling). The available methods do not distinguish between CO_2 and CH_4
  - ***So far there is not conclusive evidence that the velocity change is due to CO_2.***



Pulsed Neutron Capture

- Baseline and two repeat surveys performed in the C3-30A monitoring well
- No definitive indication of CO_2 at the monitoring well
- This matches the modeling results



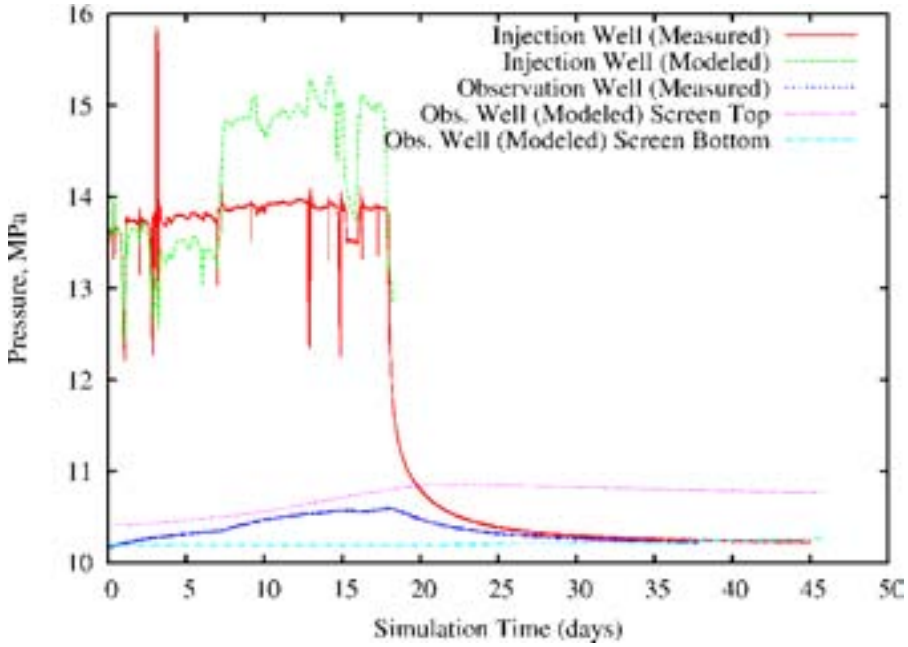
PFT Tracers

- 255 ml of PFT tracer (perfluoromethylcyclohexane) was added over 12 hours into injection stream.
- Soil gas and atmospheric sampling array monitored over several months in 1 pre-injection and 4 post-injection surveys. The detection limit of tracer is nearly one part-per-quadrillion.
- No evidence of leakage or migration was discernable in this study.

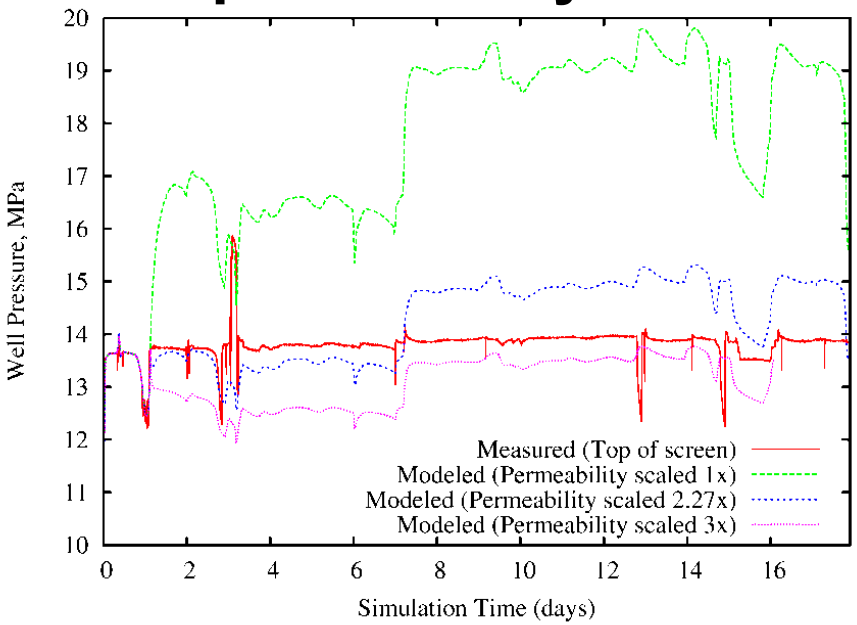
STOMPCO$_2$ Model Calibration

- Model was calibrated using actual injection rates and downhole pressures.
- Results suggest somewhat higher reservoir permeability than initially input.
- Very good calibration to post injection fall-off in the injection well.
- Pressures declined faster than simulation in the monitoring well.

Pressure comparison – inj. and obs. wells



Sensitivity of model to permeability



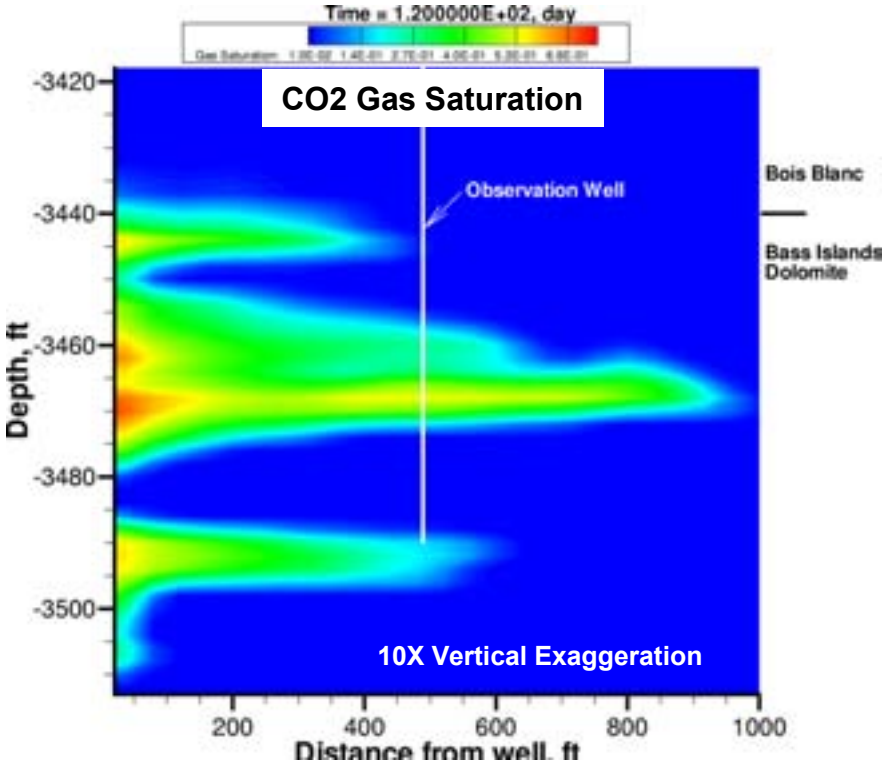
Michigan Basin Extended Injection

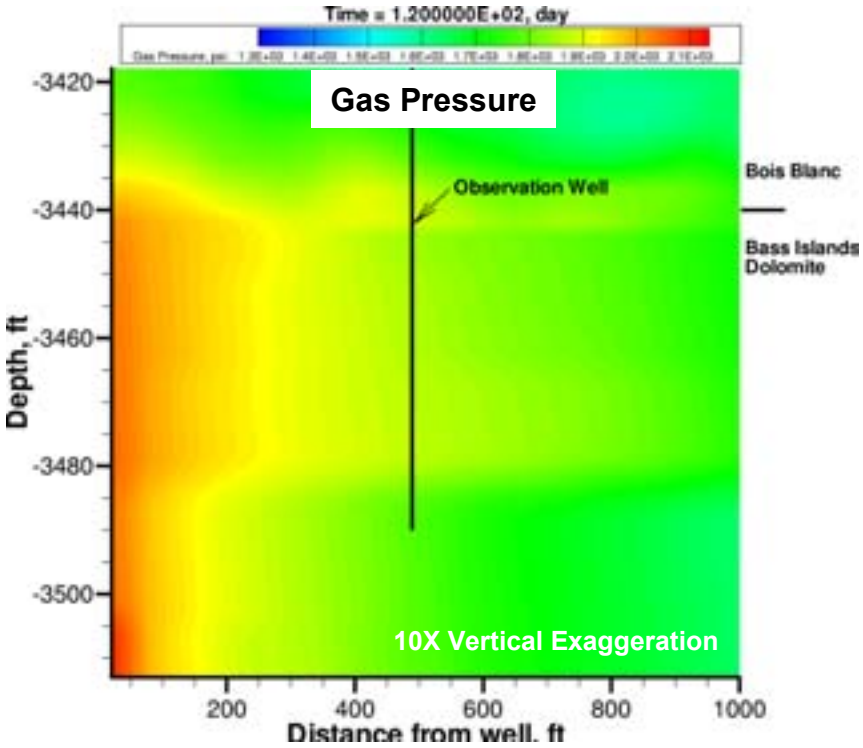
- Extended injection to further evaluate CO_2 storage behavior.
- Injection permit extended and AOR reviewed by EPA
- Total injection target of approximately 50,000 metric tons CO_2.
- Completed in July, 2009
- Rate = 0-600 metric tons CO_2/day.
- Target = Bass Islands Dolomite (same injection setup)
- Several monitoring techniques included to address some questions that arose in the initial test:
  - Breakthrough in monitoring well.
  - Geochemical
  - Cross well seismic
  - Injectivity

Extended Injection: STOMPCO2 Results

- Reservoir simulations of extended injection completed to support UIC permitting, test design, and monitoring plans.
- Results suggest that the majority of CO_2 will remain within 500 ft of injection well. A small portion of the CO_2 migrates along high permeability layer approximately 1000 ft from injection well.

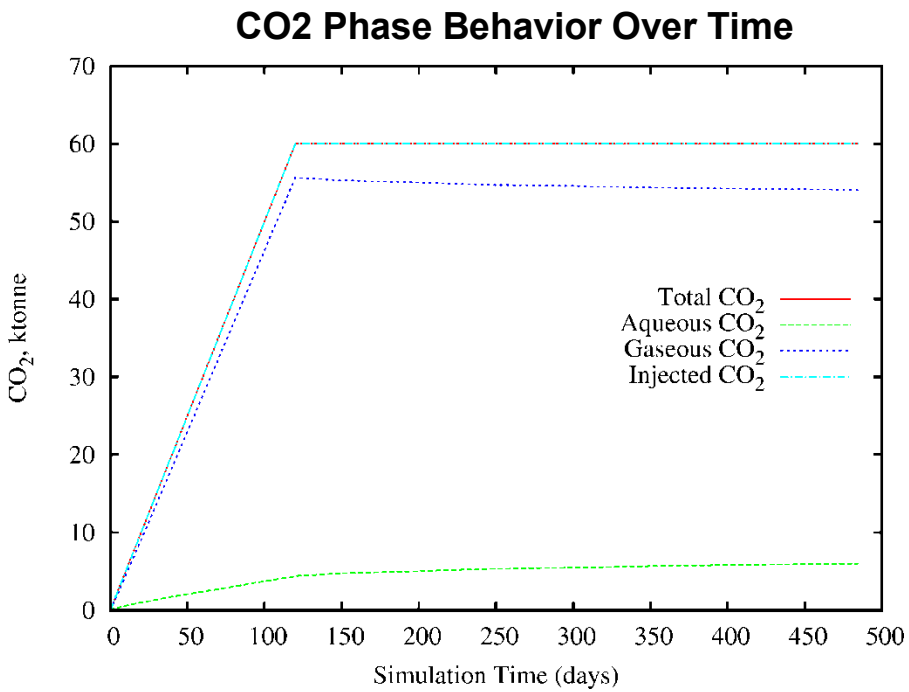
Simulation Time = 120 days
Total Injection = 50,000 metric tons CO2

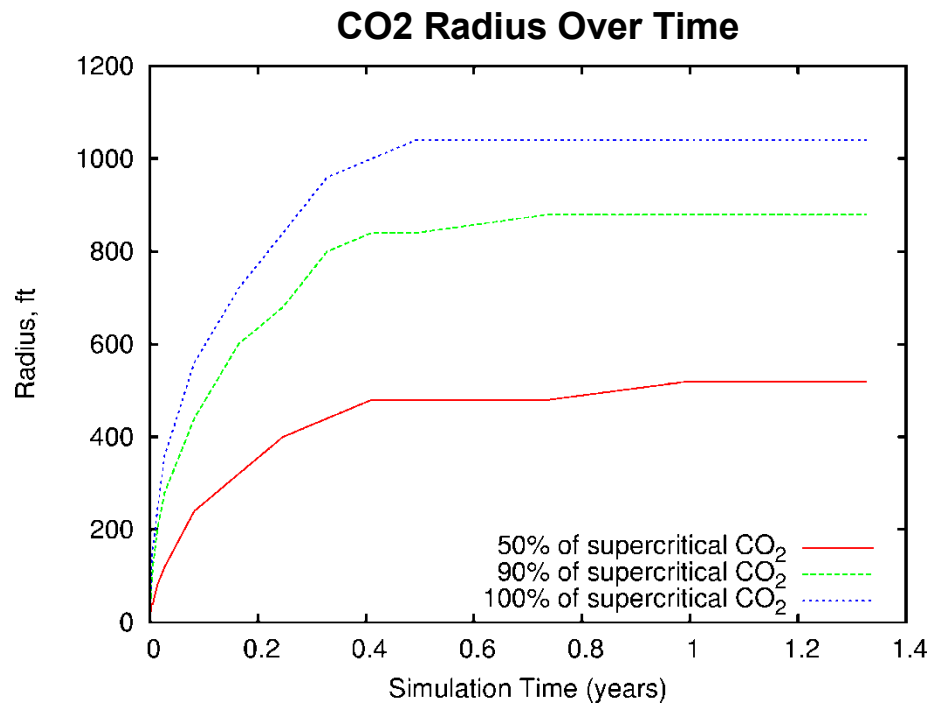




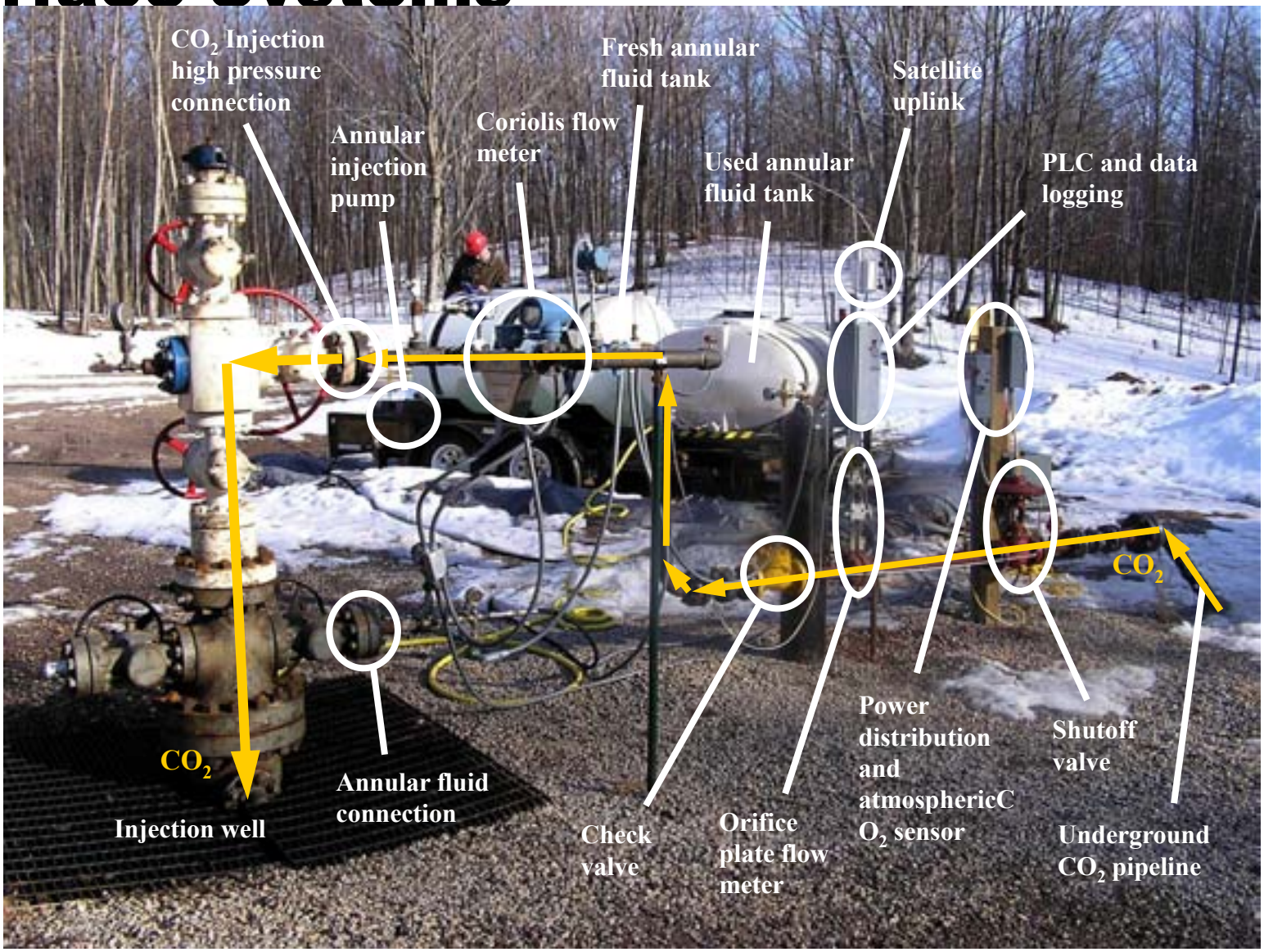
Extended Injection: STOMPCO2 Results

- Long term phase behavior of CO_2 in subsurface was investigated with the model.
- Modeling shows 5-7% of CO_2 will dissolve in formation brine, with slow additional dissolution over time.
- Little to no additional lateral migration after injection stops.



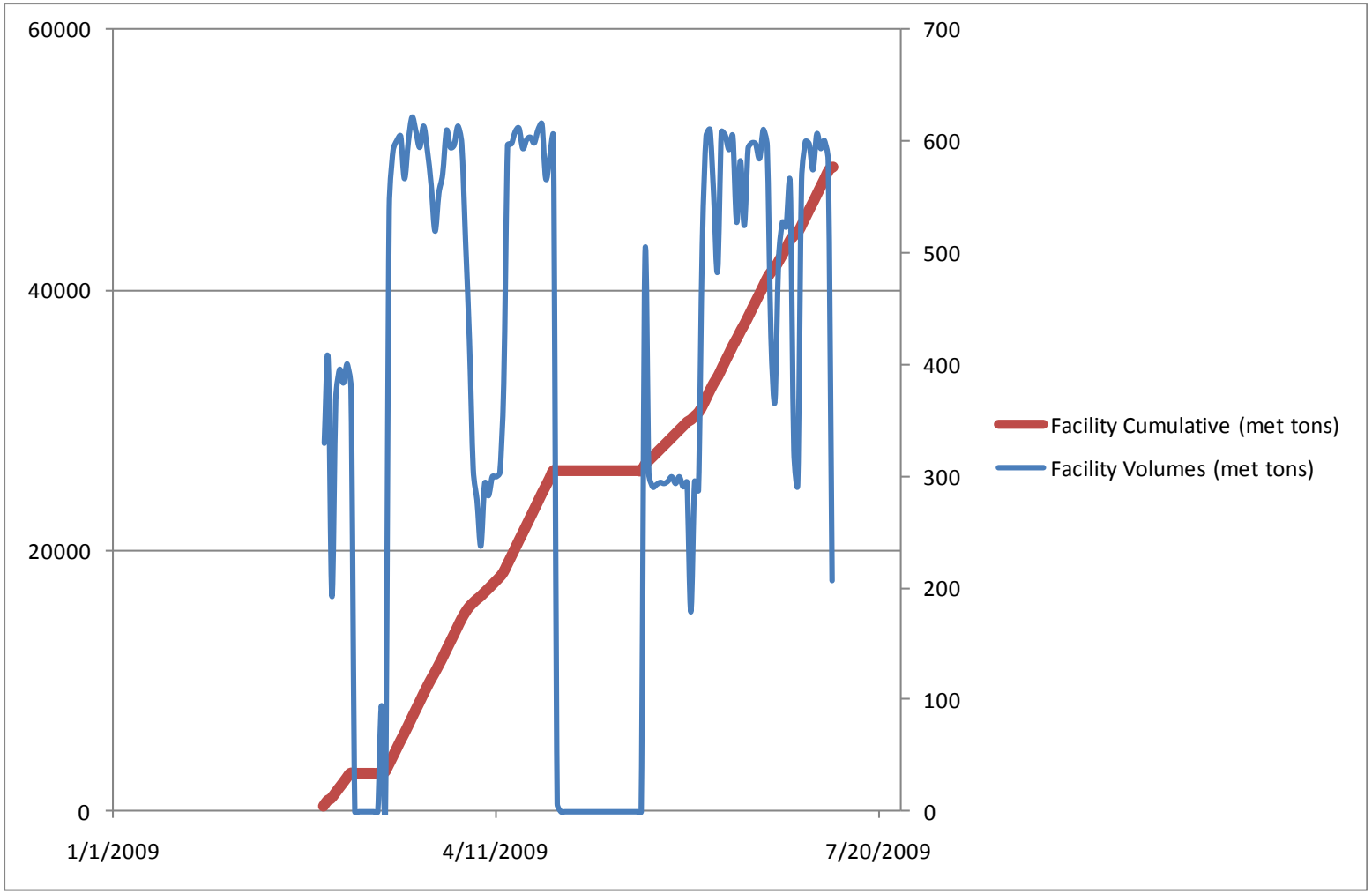


Extended Injection: Injection Well Surface Systems



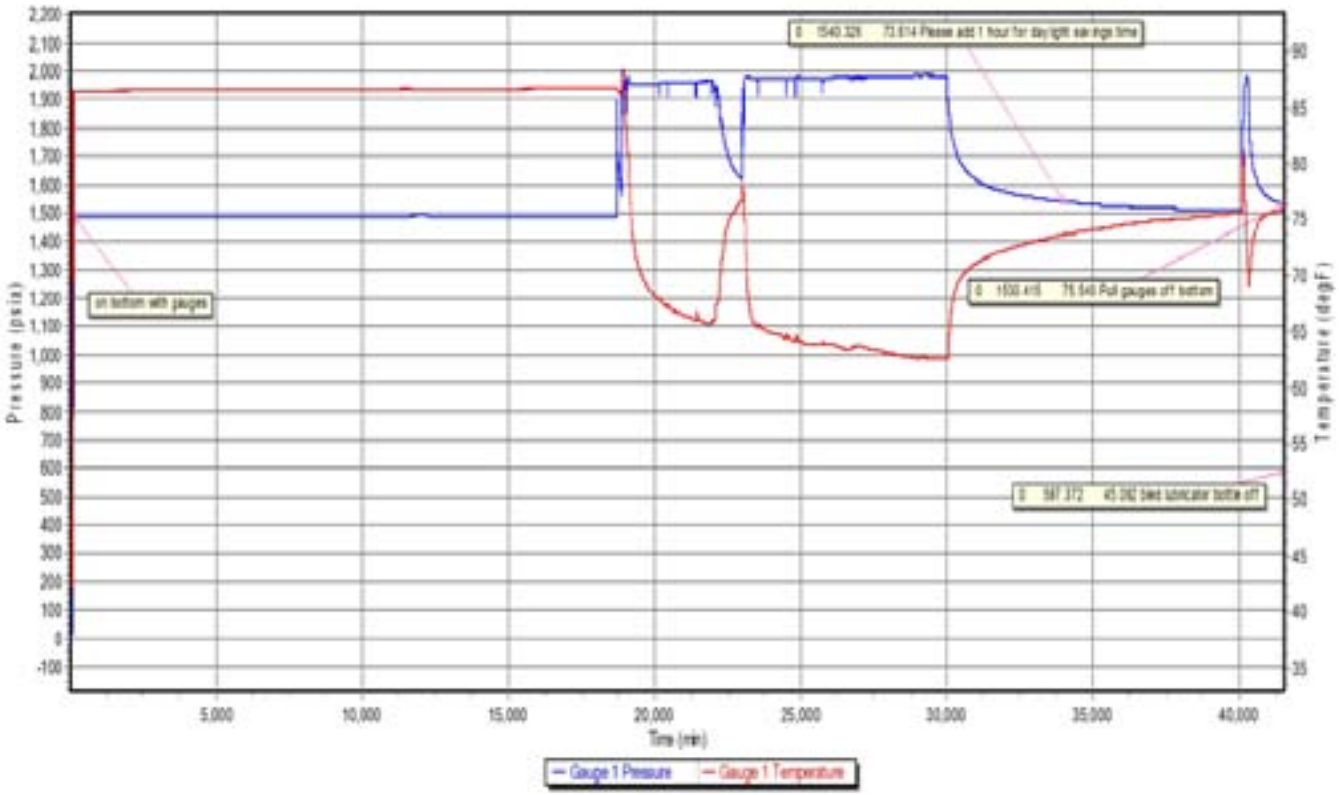
Extended Injection Operations

- Injection began on February 25, 2009 and finished on July 9, 2009. Approximately 50,000 tonnes of CO2 were injected.



Extended Injection Operations

- Bottomhole injection pressures and temperatures during the first half of injection showed fall-off towards ambient conditions

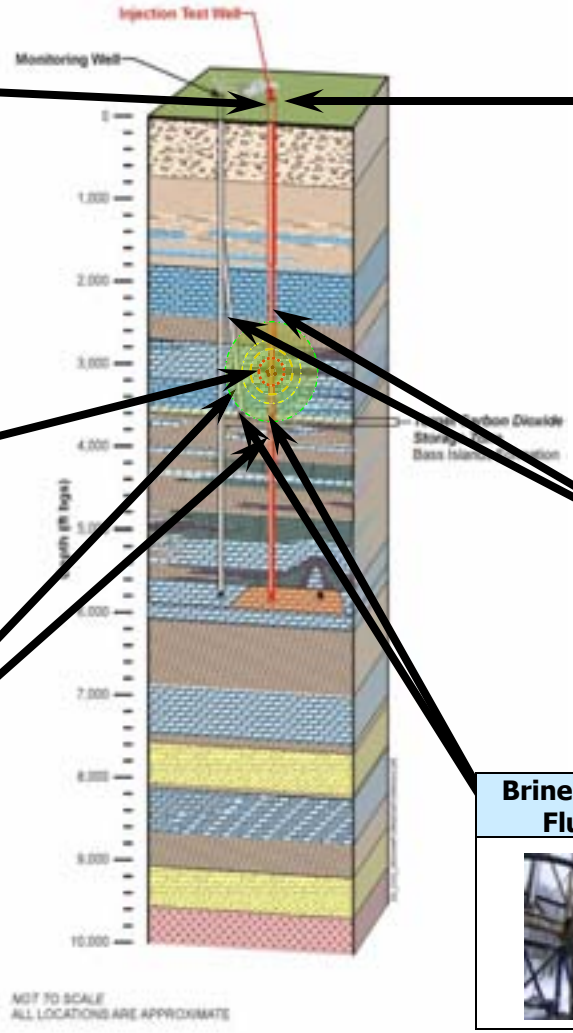


Extended Injection- Monitoring Program

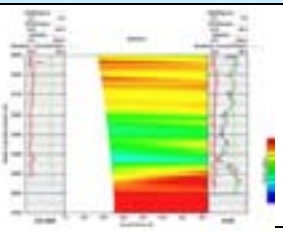
- Monitoring program designed to address uncertainties uncovered in the initial CO_2 sequestration tests.

System Monitoring

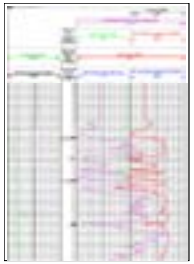
Surface Gas Meters



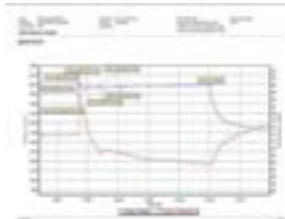
Cross-Well Seismic



Wireline Monitoring



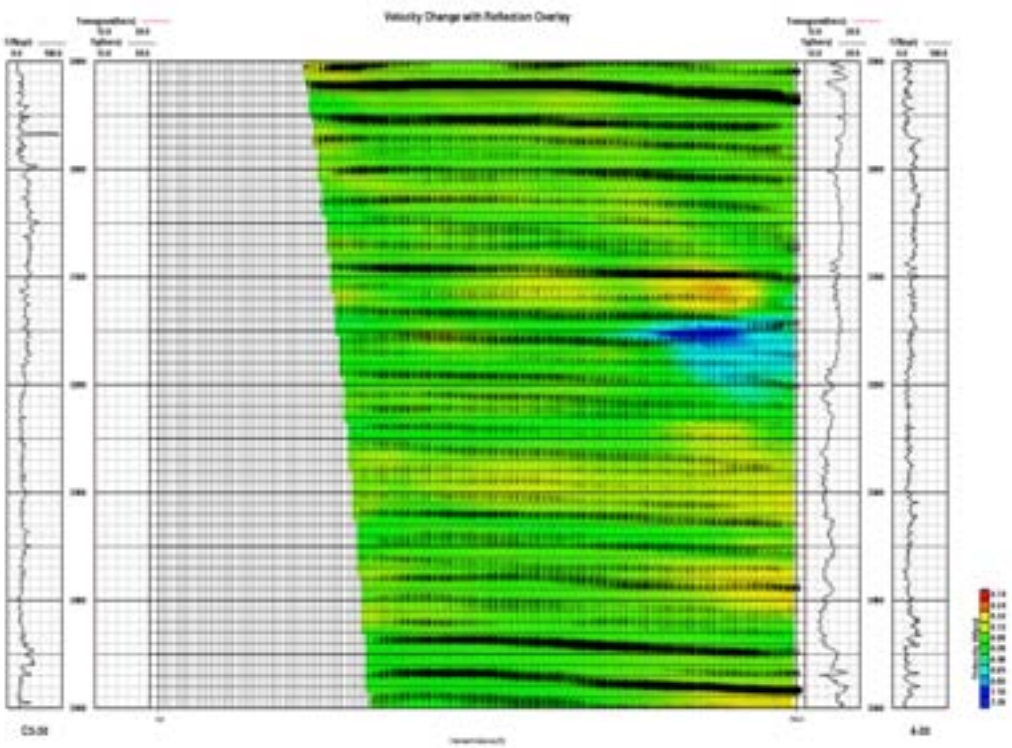
Downhole Pressure



Brine Chemistry and Fluid Sampling

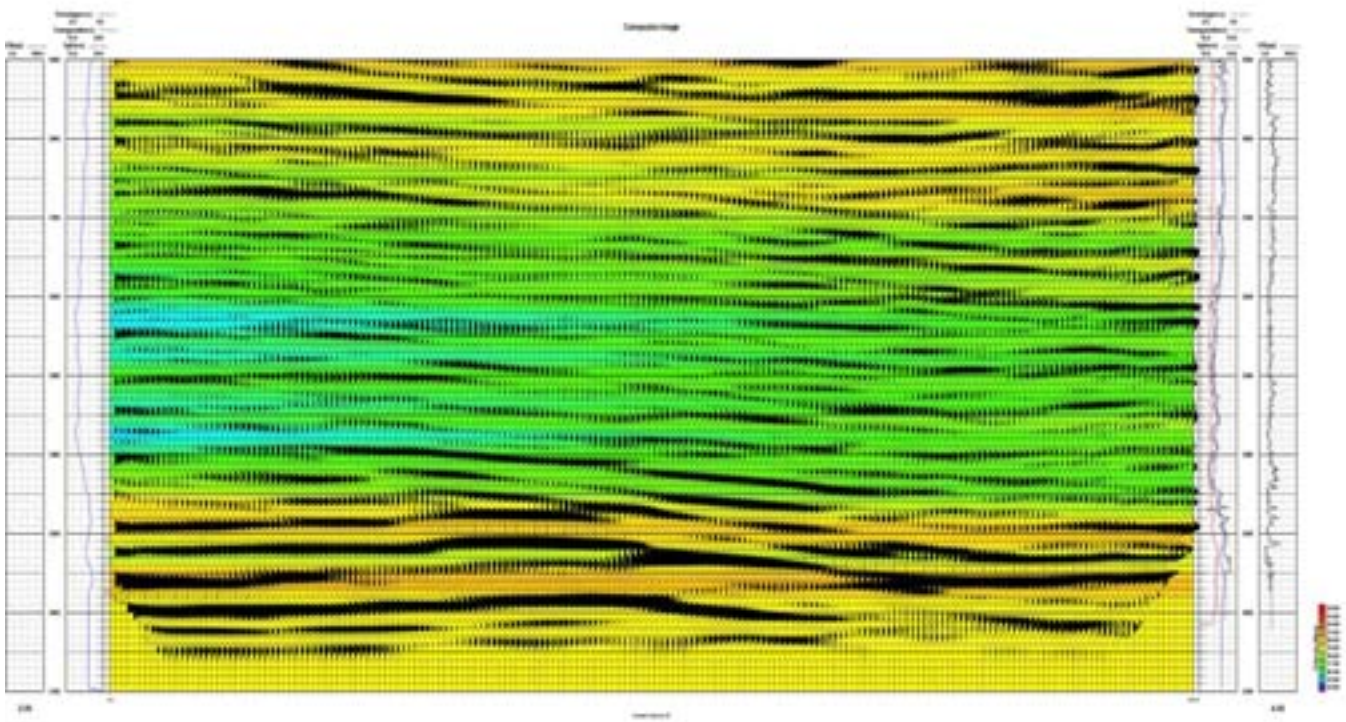
Pre Extended Injection Crosswell (Jan 2009)

- The difference between the baseline survey and the second repeat continues to show a velocity decrease (blue) in the upper section. The decrease across the perforations has disappeared.



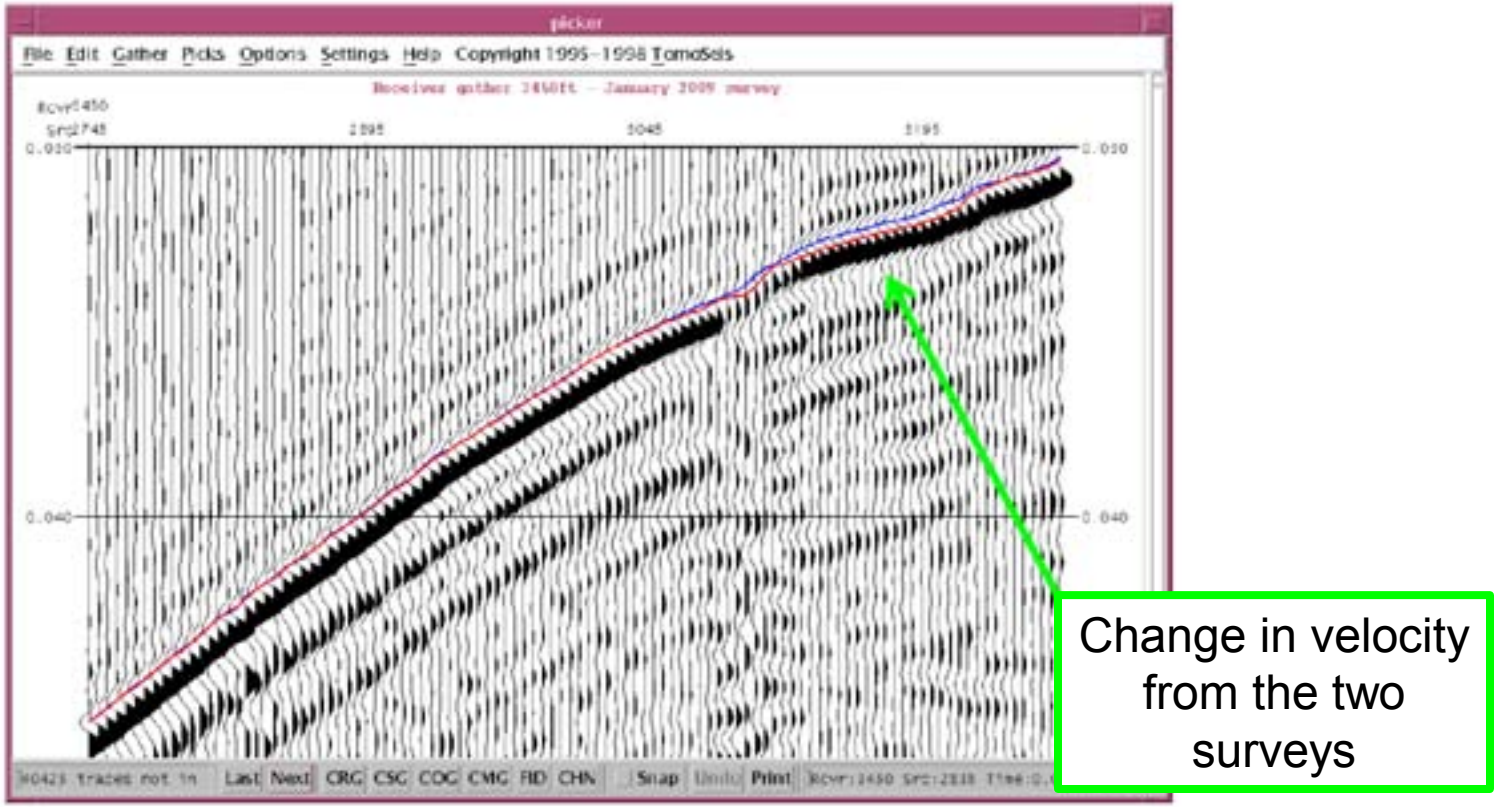
Pre Extended Injection Crosswell Survey between 4-30 and 2-30

- An additional cross section was collected and will be repeated post injection to help determine the nature of the velocity anomaly.



Extended Injection Final Crosswell

- Final surveys were collected in July, 2009
- Field data shows a potential velocity difference, indicating changes should be detectable
  - Blue is January survey and Red is July survey



Extended Injection Fluid Samples

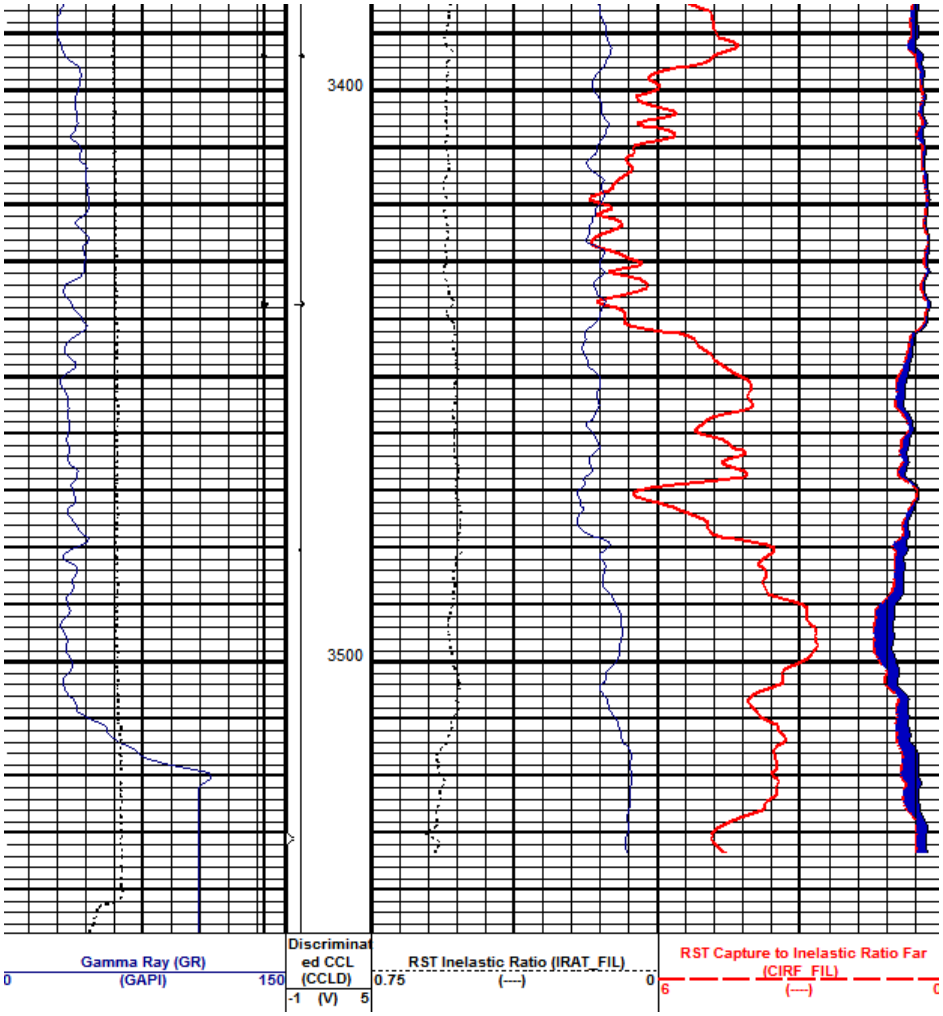
- Samples were taken from the monitoring well in March and July, 2009 and are being analyzed for major cations and anions.

Extended Injection Gas and Cement Sampling

- Sample of the fluid behind the casing (3090 ft) taken to be analyzed for CO2 and methane and other major cations and anions.
- Core samples of the casing and cement to test for changes in the cement (3150 and 3330 ft)

Extended Injection Repeat Wireline

- Repeat PNC logging in both the injection well and monitoring well completed.
- Repeat Isolation Scanner run in the injection well to monitor for changes to the cement.



Preliminary

Conclusions

- Bass Islands Dolomite in northern Michigan Basin has suitable injectivity for CO_2 sequestration at an industrial scale, on the order of several hundred thousand metric tons per year in one well.
- Injection test analysis was used to define the hydraulic behavior of the reservoir system in terms of flow behavior and leakage.
- Reservoir simulations provide fairly accurate predictions of hydraulic response to injection.
- It is not clear what the cross-well seismic based velocity anomaly ~300 ft above perforated interval is shows. Analysis of the samples taken will hopefully answer the question.
- Additional injection of CO_2 was successfully completed and analysis of post-injection MMV data is currently being done.

THANK YOU!