



EERC

Critical Challenges.

Practical Solutions.



DEMONSTRATION OF SECURE CO₂ GEOLOGICAL STORAGE ASSOCIATED WITH ENHANCED OIL RECOVERY IN THE PCOR PARTNERSHIP REGION

Carbon Management Technology Conference 2017
(CMTC 2017)

Houston, Texas

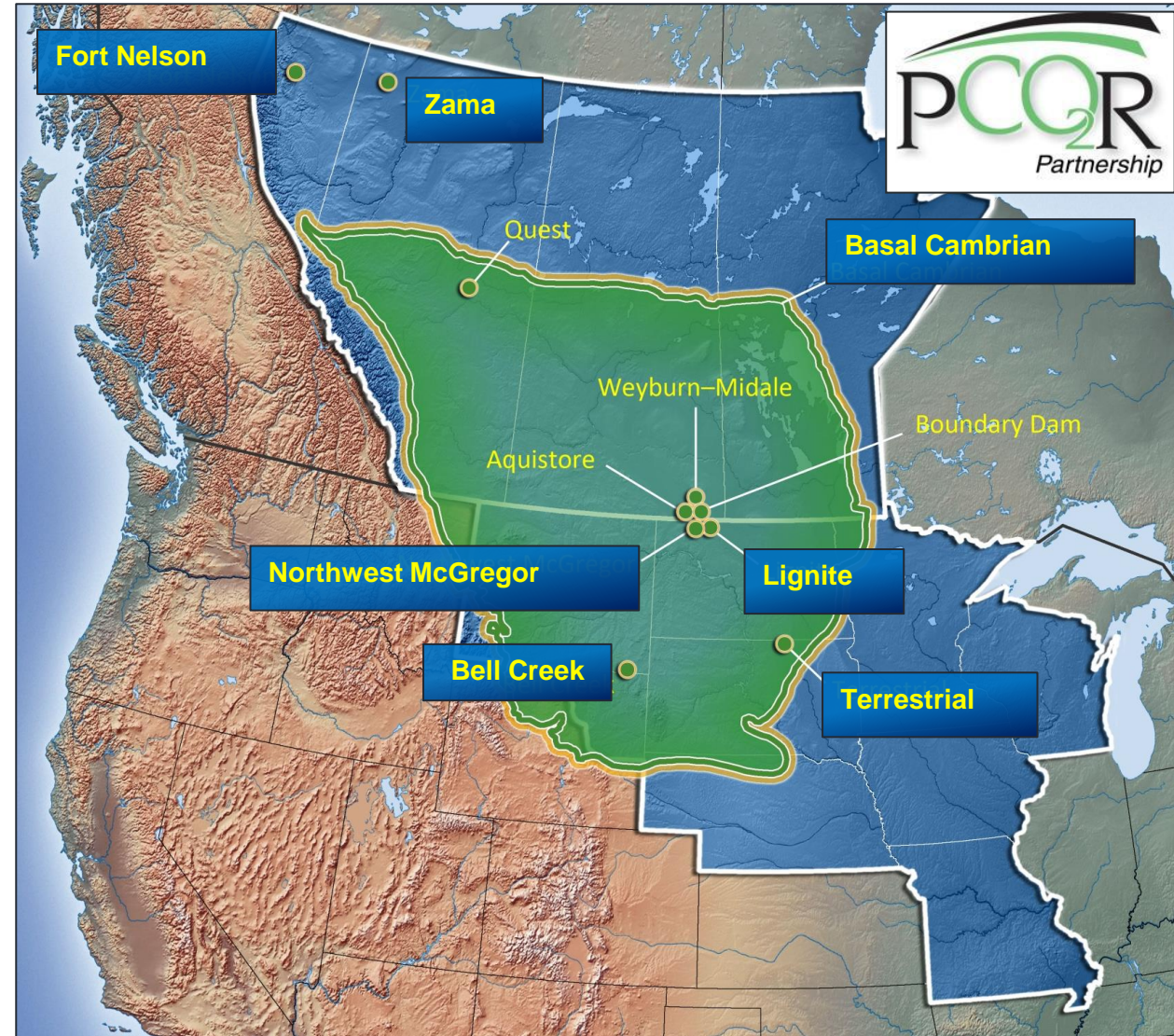
July 17–20, 2017

Wes Peck
Principal Geologist

Critical Challenges. **Practical Solutions.**

PLAINS CO₂ REDUCTION (PCOR) PARTNERSHIP

- Region includes:
 - Nine states.
 - Four Canadian provinces.
 - Over 3.6 million km².
- Several completed field projects.
- Over 3 million tons of CO₂ stored and monitored in association with CO₂ enhanced oil recovery (EOR).
- More than 120 partners.



PCOR PARTNERSHIP

PCOR PARTNERSHIP OBJECTIVES

- Safely and permanently achieve CO₂ storage on a commercial scale.
- Establish a relationship between the CO₂ EOR process and long-term storage of CO₂.
- Establish monitoring, verification, and accounting (MVA) methods to effectively monitor CO₂ storage.
- Use commercial oil/gas practices as the backbone of MVA strategies, and augment with additional cost-effective techniques.
- Share lessons learned for the benefit of similar projects across the region.

CO₂ EOR

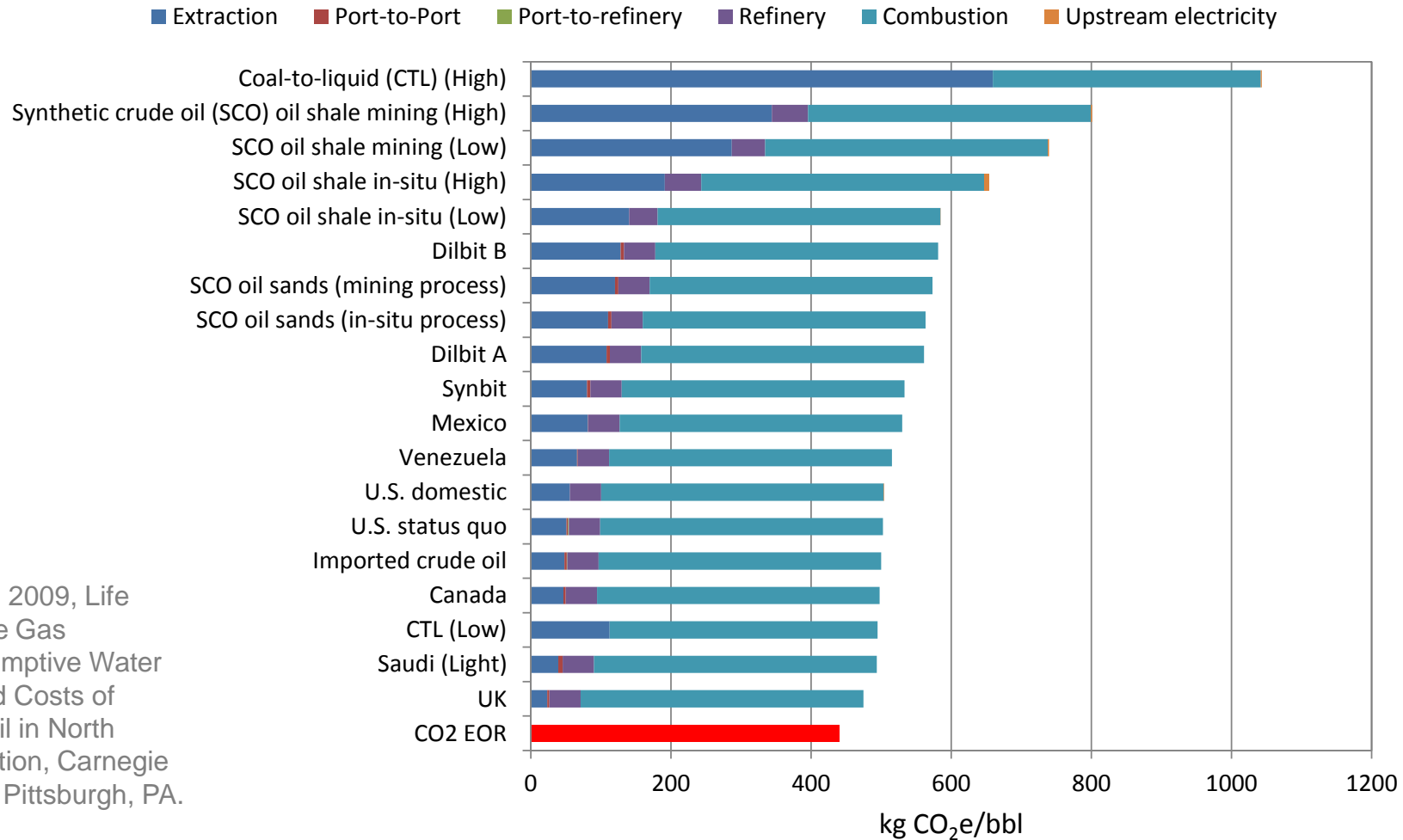
- **A great near-term storage option:**
- Over 40 years of handling and injecting large volumes of CO₂.
- Much of the infrastructure already in place.
- Storage cost can be offset by income from EOR.

“Greener” than conventionally produced oil:

- Existing EOR operations are already storing CO₂.
- Nearly every tonne of CO₂ purchased is eventually stored.



COMPARING CO₂ EOR TO “REGULAR” OIL



Adapted from:
Mangmeechai, A., 2009, Life Cycle Greenhouse Gas Emissions, Consumptive Water Use and Levelized Costs of Unconventional Oil in North America: Dissertation, Carnegie Mellon University, Pittsburgh, PA.

JOURNAL ARTICLE

International Journal of Greenhouse Gas Control 51 (2016) 369–379



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journal homepage: www.elsevier.com/locate/ijggc



How green is my oil? A detailed look at greenhouse gas accounting for CO₂-enhanced oil recovery (CO₂-EOR) sites



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<http://www.sciencedirect.com/science/article/pii/S1750583616302985>

The spreadsheet CO₂ EOR life cycle analysis model is available on the PCOR Partnership public Web site!



Plains CO₂ Reduction (PCOR) Partnership
Practical, Environmentally Sound CO₂ Sequestration

PARTNERS ONLY

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About the Partnership

Climate, CO₂, Sequestration

Regional Storage Potential

CO₂ Sequestration Projects

Technical Publications

Technical Reports

Technical Posters

CO₂ EOR LCA Model

PDM Video

Resources

Documentaries

Video Clip Library

FAQs

Links

Household Energy

CO₂ EOR LCA Model

The PCOR Partnership performed a life cycle analysis (LCA) to estimate the greenhouse gas emissions associated with oil produced via CO₂ EOR, including comparing the results to conventional oil. The results were published in the *International Journal of Greenhouse Gas Control*.

A spreadsheet-based model developed through this work allows users to input their own site-specific values for conducting the analysis.

Download the model

Article Title: *How Green Is My Oil? A Detailed Look at Greenhouse Gas Accounting for CO₂ Enhanced Oil Recovery (CO₂ EOR) Sites*

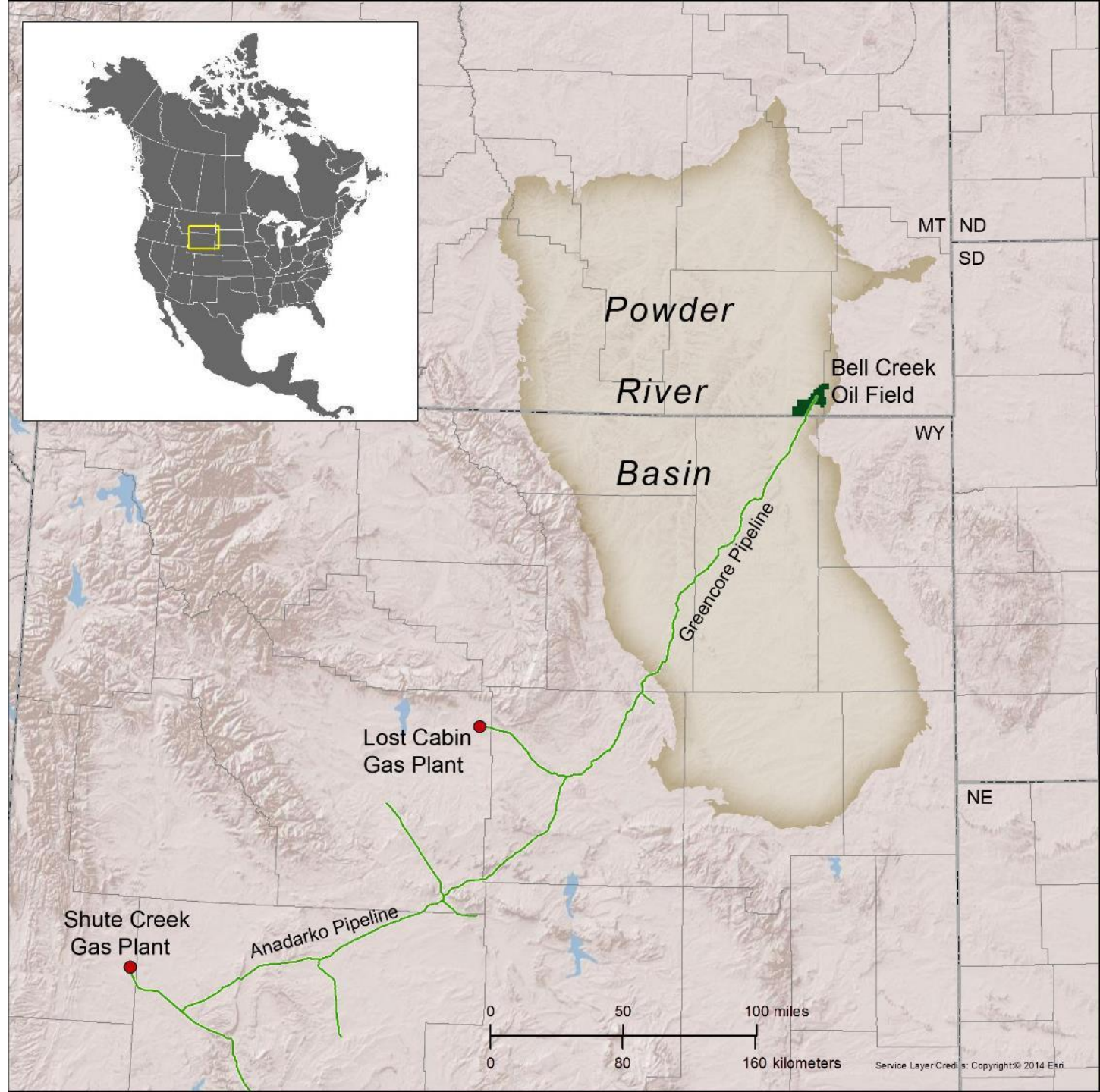
Abstract: This study presents the results of a detailed life cycle analysis of greenhouse gas (GHG) emissions associated with carbon dioxide enhanced oil recovery (CO₂ EOR) where the CO₂ is sourced from a coal-fired power plant. This work builds upon previous investigations and integrates new information to provide more plausible ranges for CO₂ storage in the reservoir during CO₂ EOR. The system model includes three segments: upstream, gate-to-gate, and downstream processes. Our base case model using Ryan-Holmes gas separation technology for the CO₂ EOR site determined the emissions from upstream, gate-to-gate, and downstream processes to be 117, 98, and 470 kg CO₂e/bbl (CO₂ equivalents per barrel of incremental oil produced), respectively, for total emissions of 685 kg CO₂e/bbl. However, these emissions are offset by CO₂ storage in the reservoir and the resulting displacement credit of U.S. grid electricity, which results in a net life cycle emission factor of 438 kg CO₂e/bbl. Therefore, CO₂ EOR produces oil with a lower emission factor than conventional oil (~500 kg CO₂e/bbl). Optimization scenarios are presented that define a performance envelope based on the CO₂ capture rate and net CO₂ utilization and suggest that lower emission factors below 300 kg CO₂e/bbl are achievable. Based on these results, CO₂ EOR where the CO₂ is sourced from a coal-fired power plant provides one potential means for addressing the energy demand–climate change conundrum, by simultaneously producing electricity and oil to meet growing energy demand and reducing GHG emissions to abate global warming.

View the journal article [here](#).

<http://www.undeerc.org/pcor/technicalpublications/CO2-EOR-Life-Cycle-Analysis.aspx>

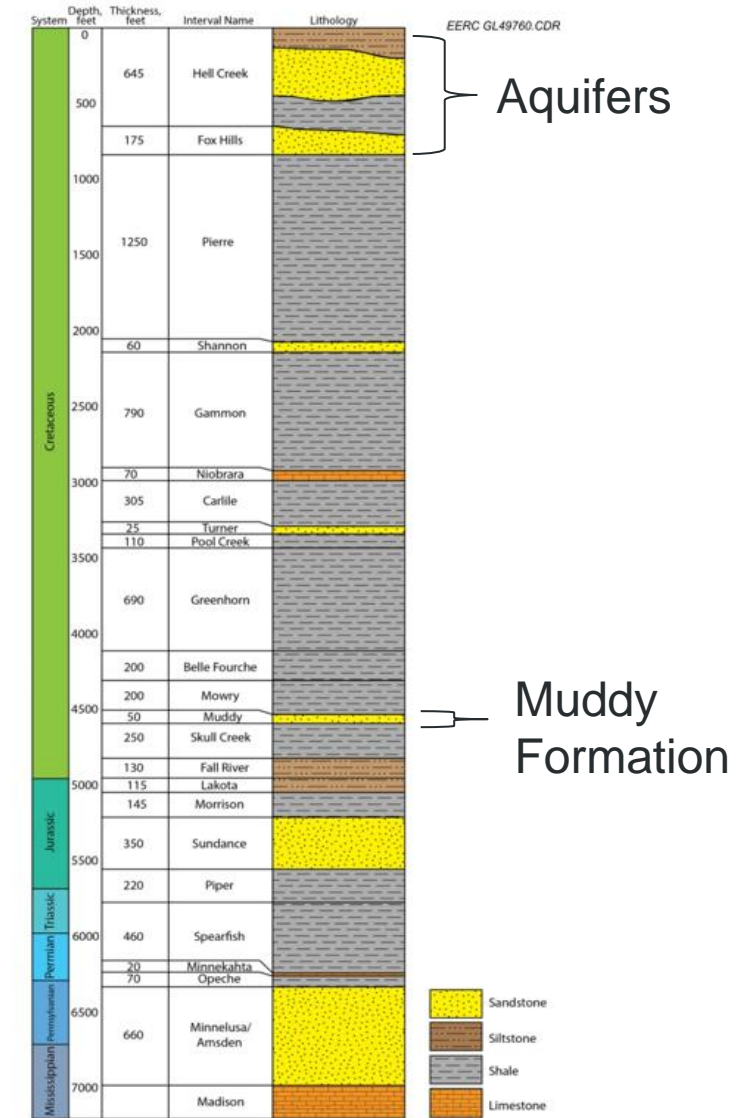
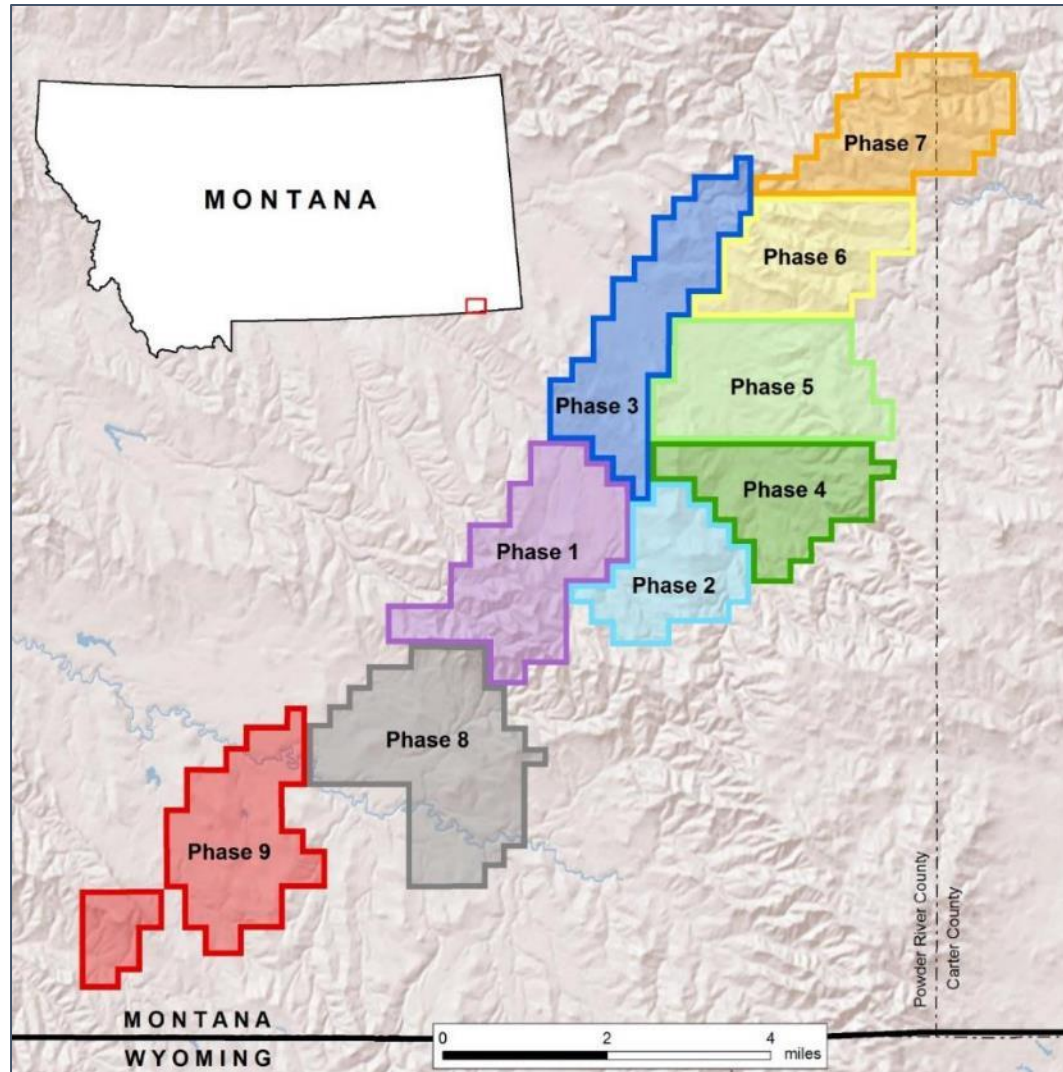
BELL CREEK

- The Bell Creek oil field is operated by Denbury Onshore LLC.
- CO₂ is sourced from ConocoPhillips' Lost Cabin and ExxonMobil's Shute Creek gas-processing plants.
- The Energy & Environmental Research Center is studying CO₂ storage associated with commercial CO₂ EOR.



FIELD DEVELOPMENT

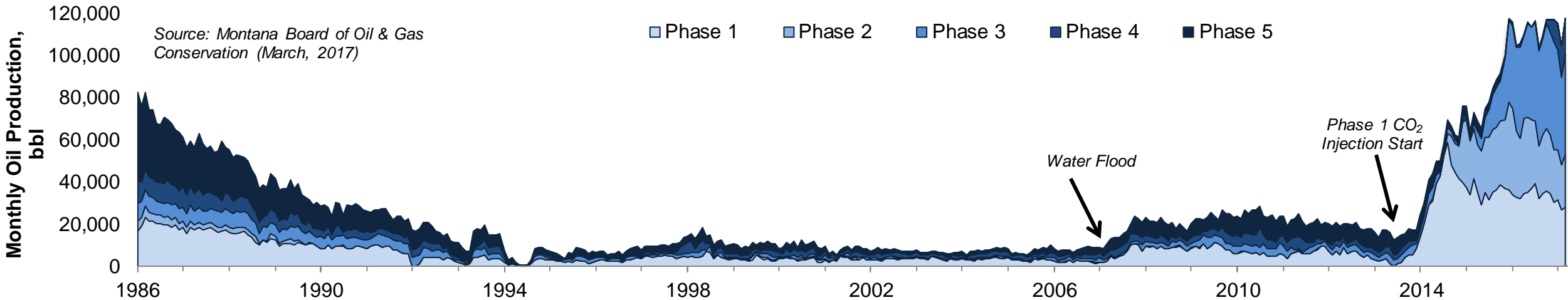
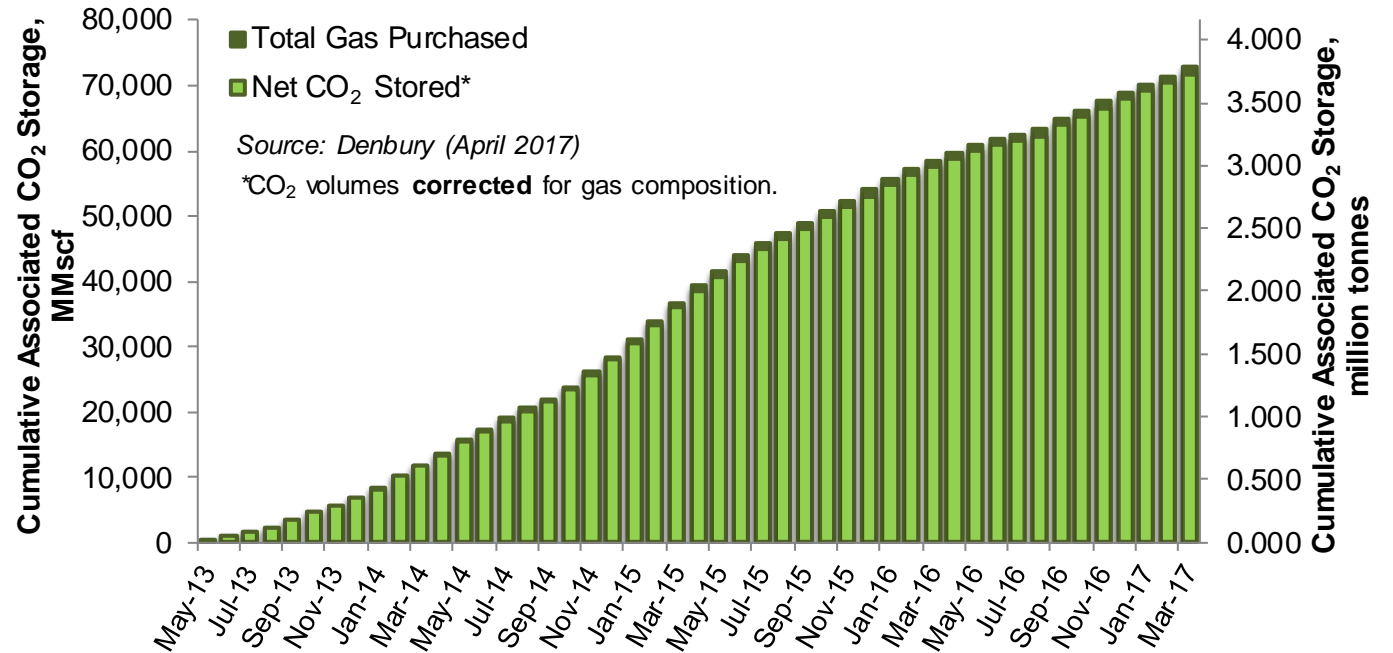
- Primary production and waterflooding produced ~37.5% original oil in place (OOIP).
- Estimated 40–50 million incremental bbl of oil.
- Estimated 12.7 million tonnes of CO₂ stored.



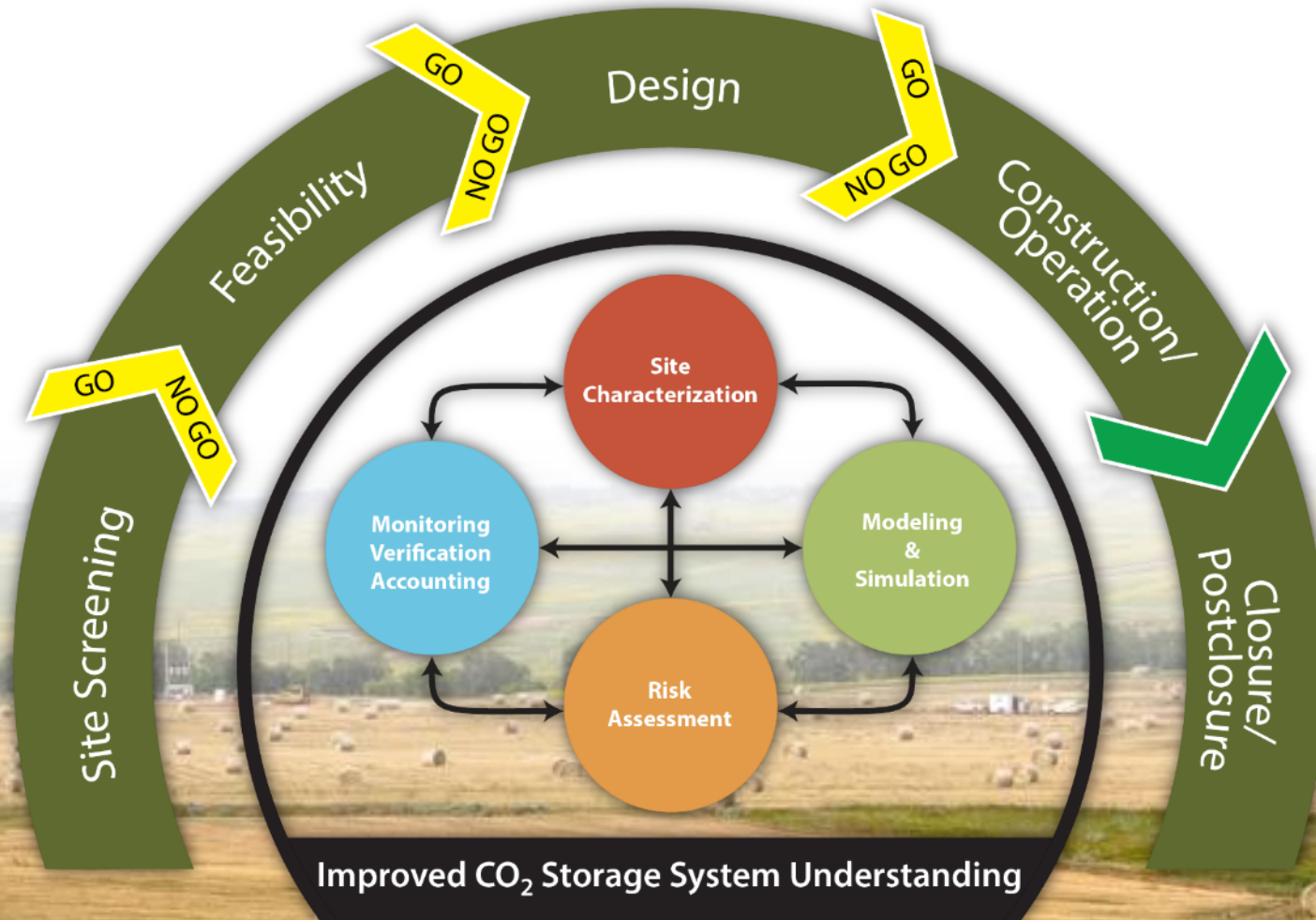
CO₂ INJECTION

As of March 2017

- Oil Produced: ~3.7 million barrels
(source: Montana Board of Oil & Gas [MBOG] database)
- CO₂ Stored: ~3.7 million tonnes
(source: Denbury)



ADAPTIVE MANAGEMENT APPROACH

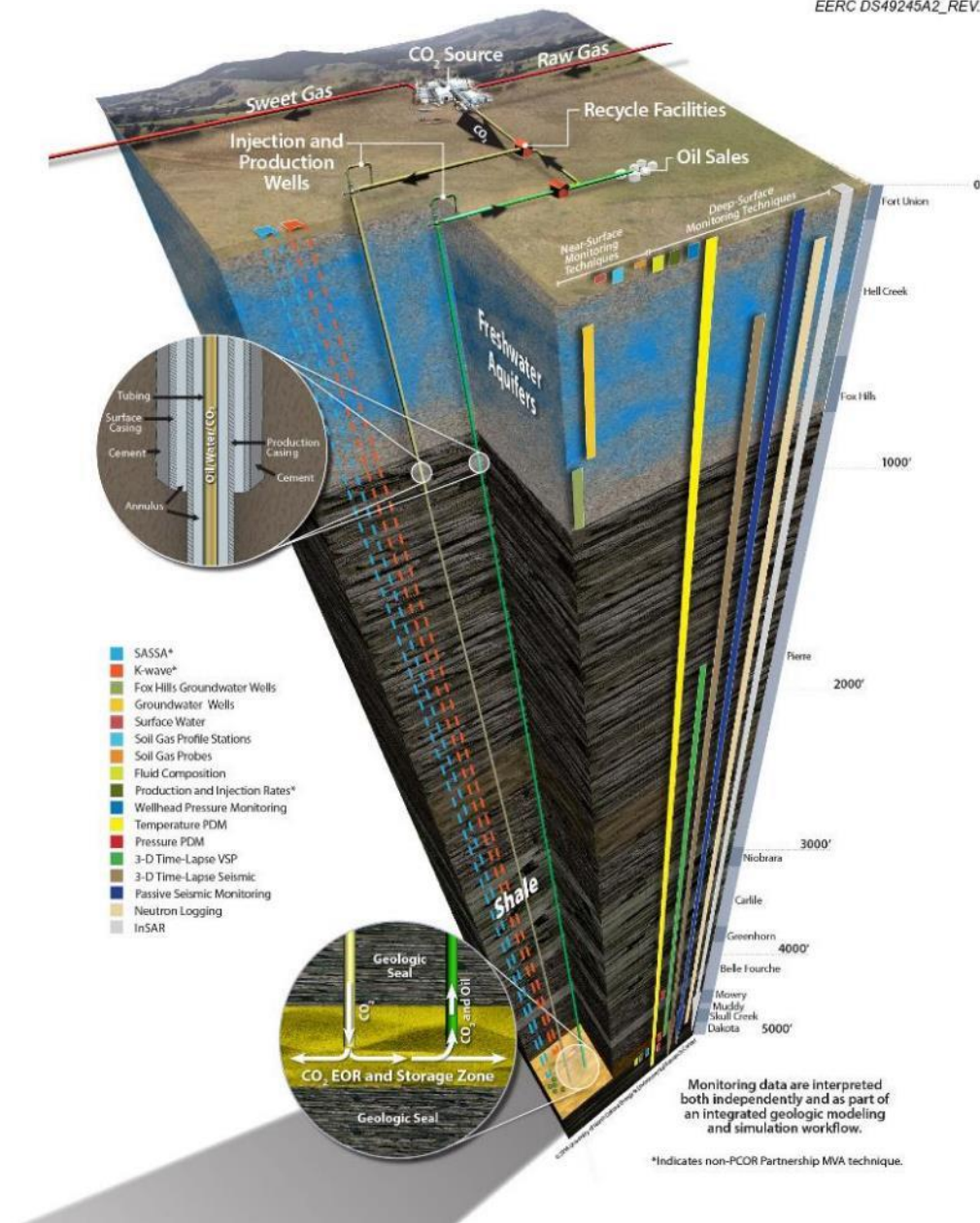


MVA

- 16 techniques
- 1.5 years of preinjection monitoring
- 3+ years of operational monitoring

Demonstrate and validate monitoring techniques and their associated economics to inform viable MVA strategies for commercial-scale carbon capture and storage (CCS).

Building off of the backbone of commercial operations data.

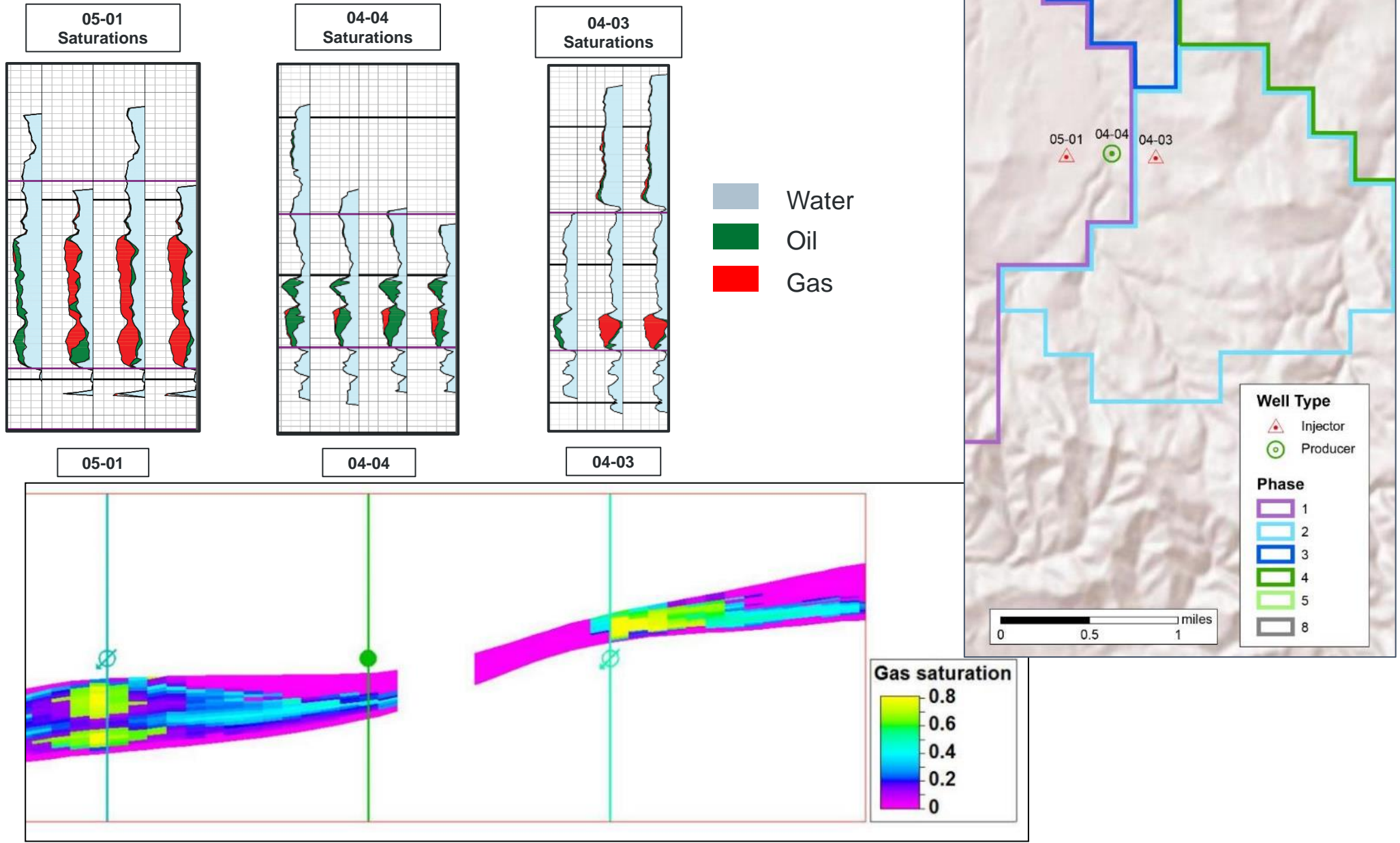


PULSED-NEUTRON LOG (PNL) CAMPAIGN

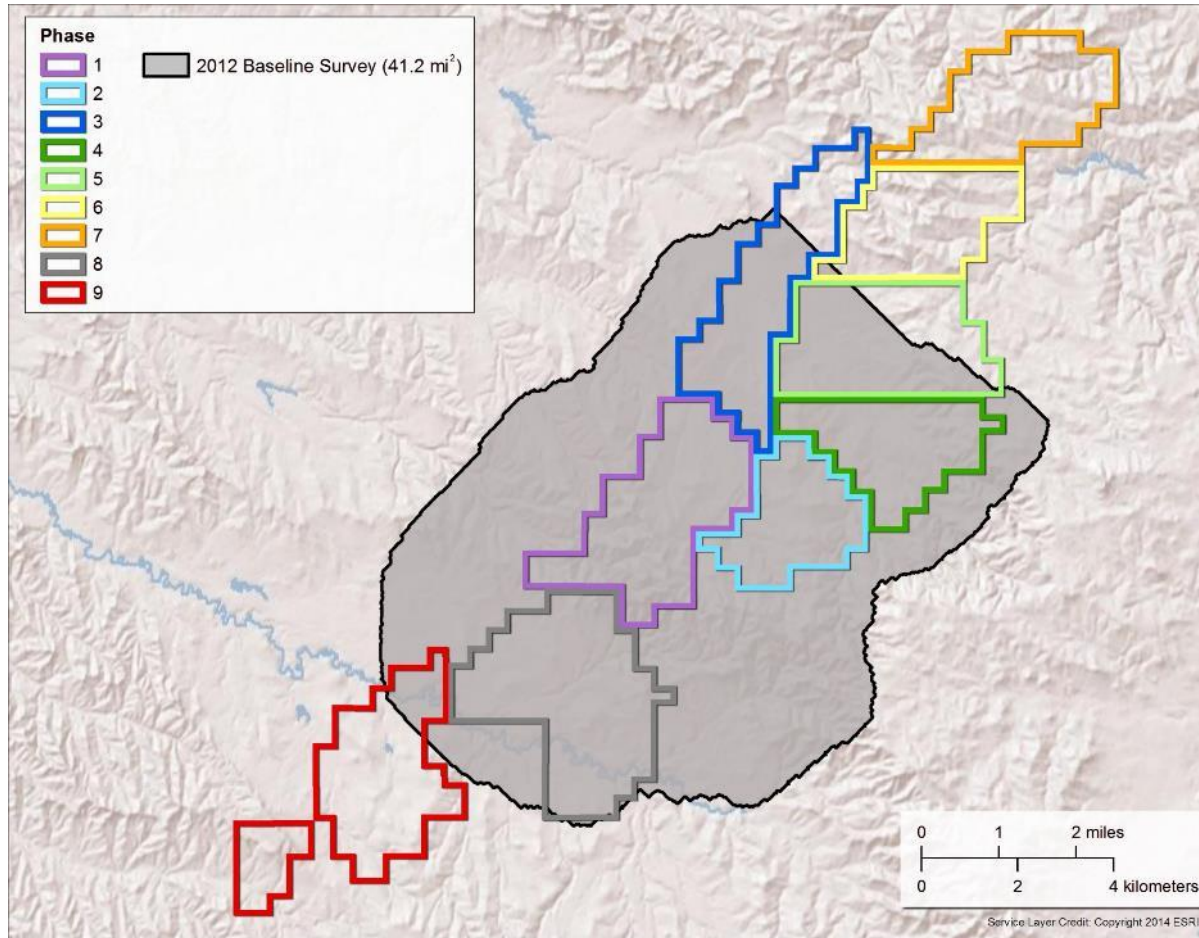
- **Seven PNL campaigns:**
 - **45 wells (92 total logs) logged to date:**
 - ◆ **45 baseline**
 - ◆ **47 repeat**



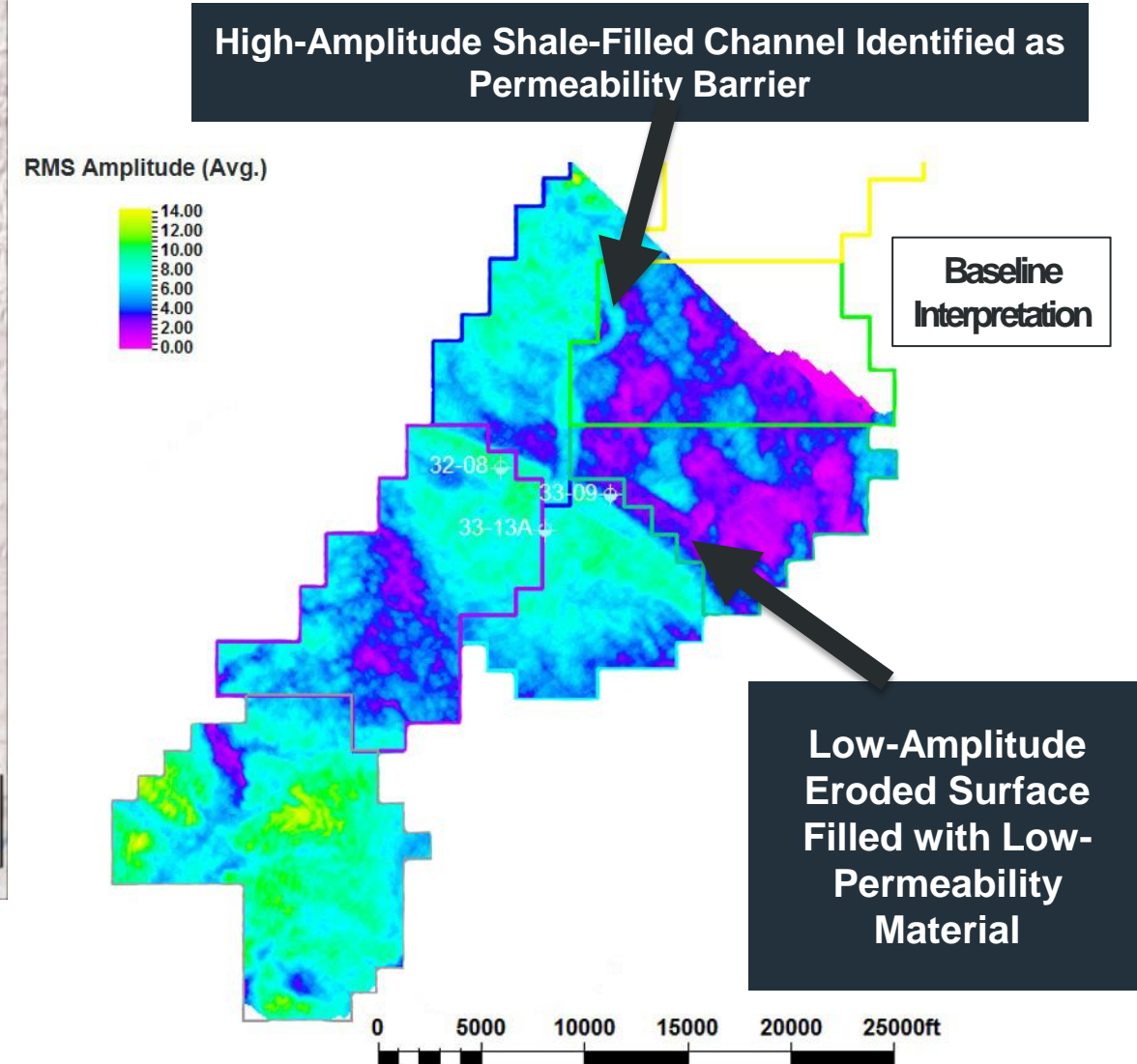
MVA FOR MODEL VALIDATION – PULSED-NEUTRON LOGGING



BASELINE 3-D SEISMIC SURVEY



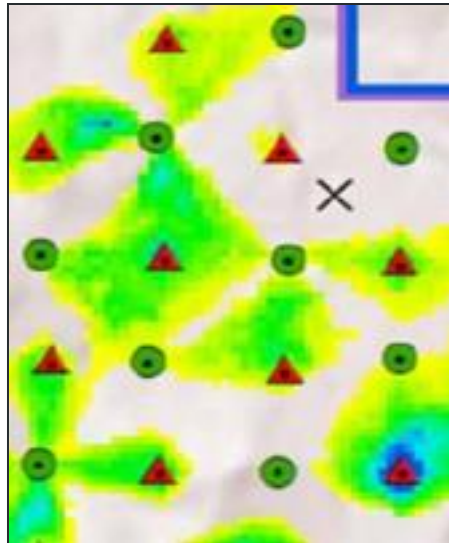
- 104-km Baseline Survey (August 2012)



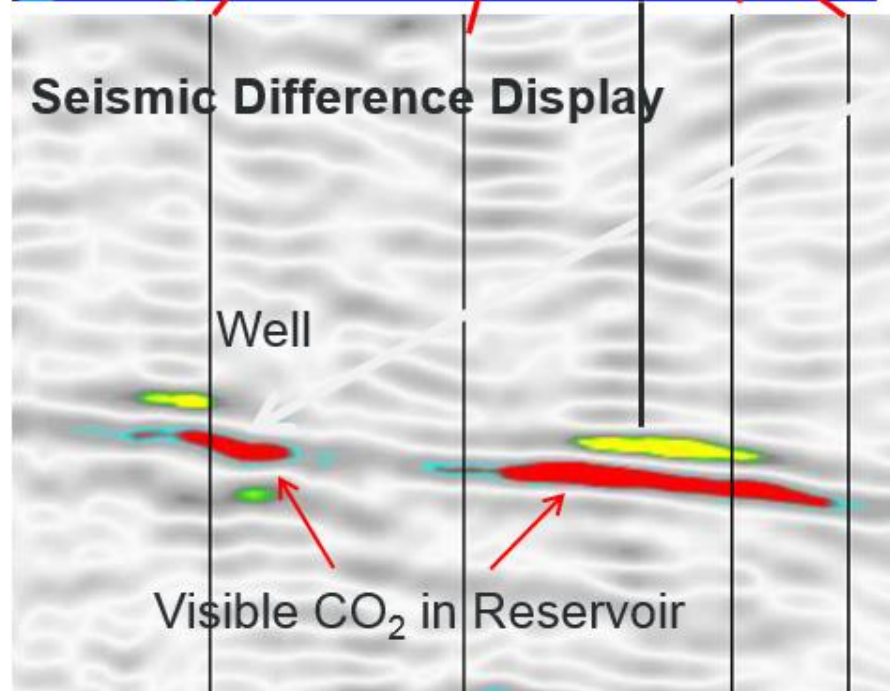
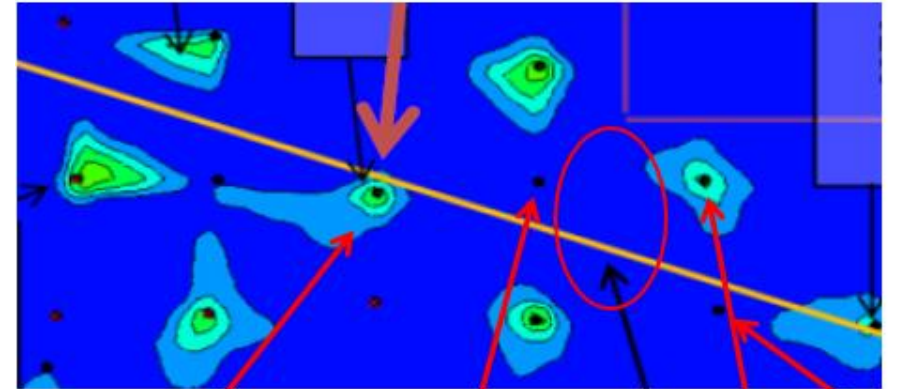
SIMULATION-GUIDED MVA

- Simulation was used to predict location and saturation of CO₂.
- 2-D seismic line used to confirm ability of seismic to detect CO₂ in the reservoir.
- Results supported decision to conduct large 3-D survey.

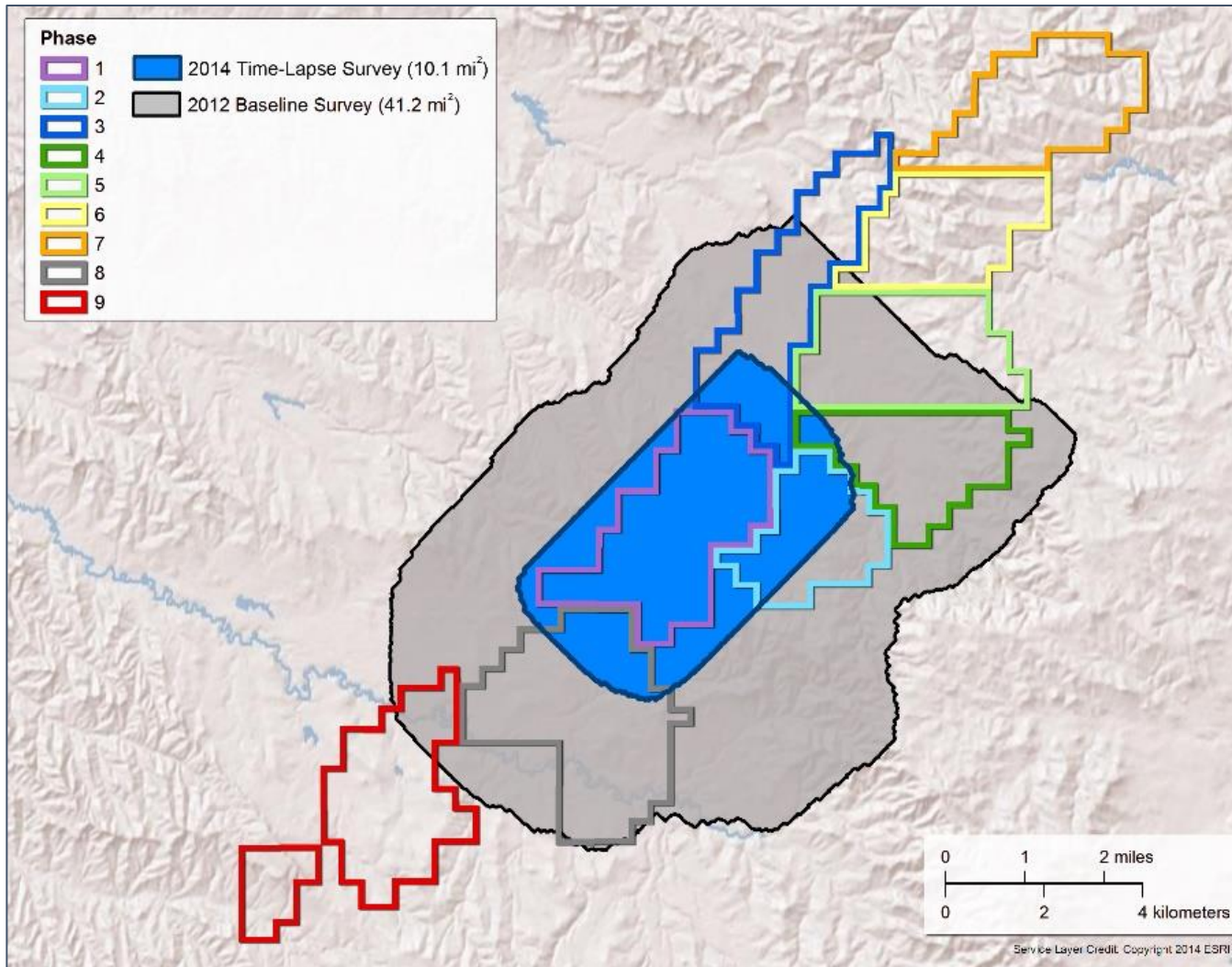
Predictive Simulation Results (CO₂ plumes)



Seismic Line Overlaying Simulation



FIRST REPEAT 3-D SURVEY

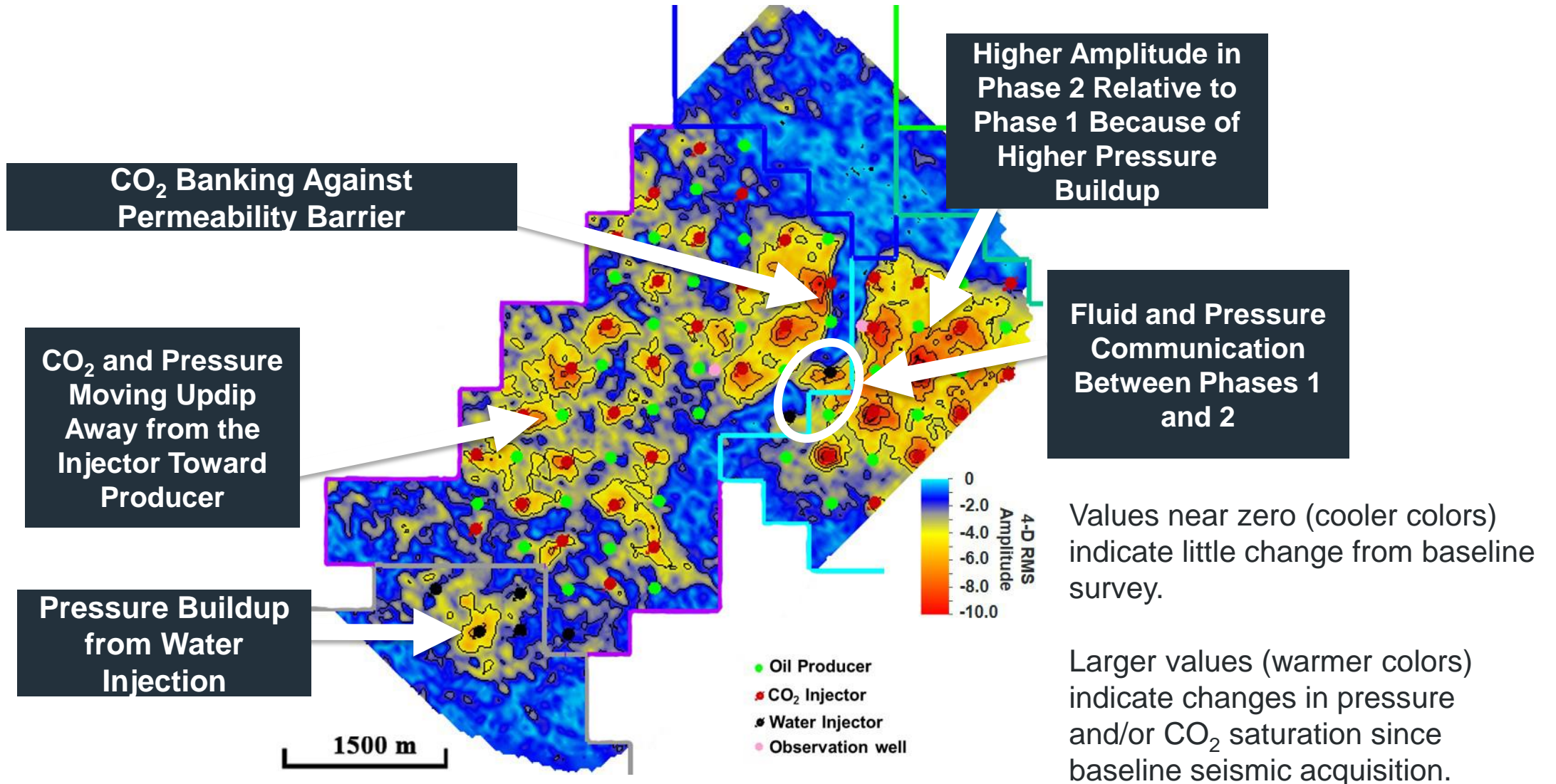


Phase	Start of CO ₂ Injection	Estimated Associated CO ₂ Storage (Oct 2014), Mt
1	May 2013	1.04
2	Dec 2013	.166

Calculated using MBOG data.

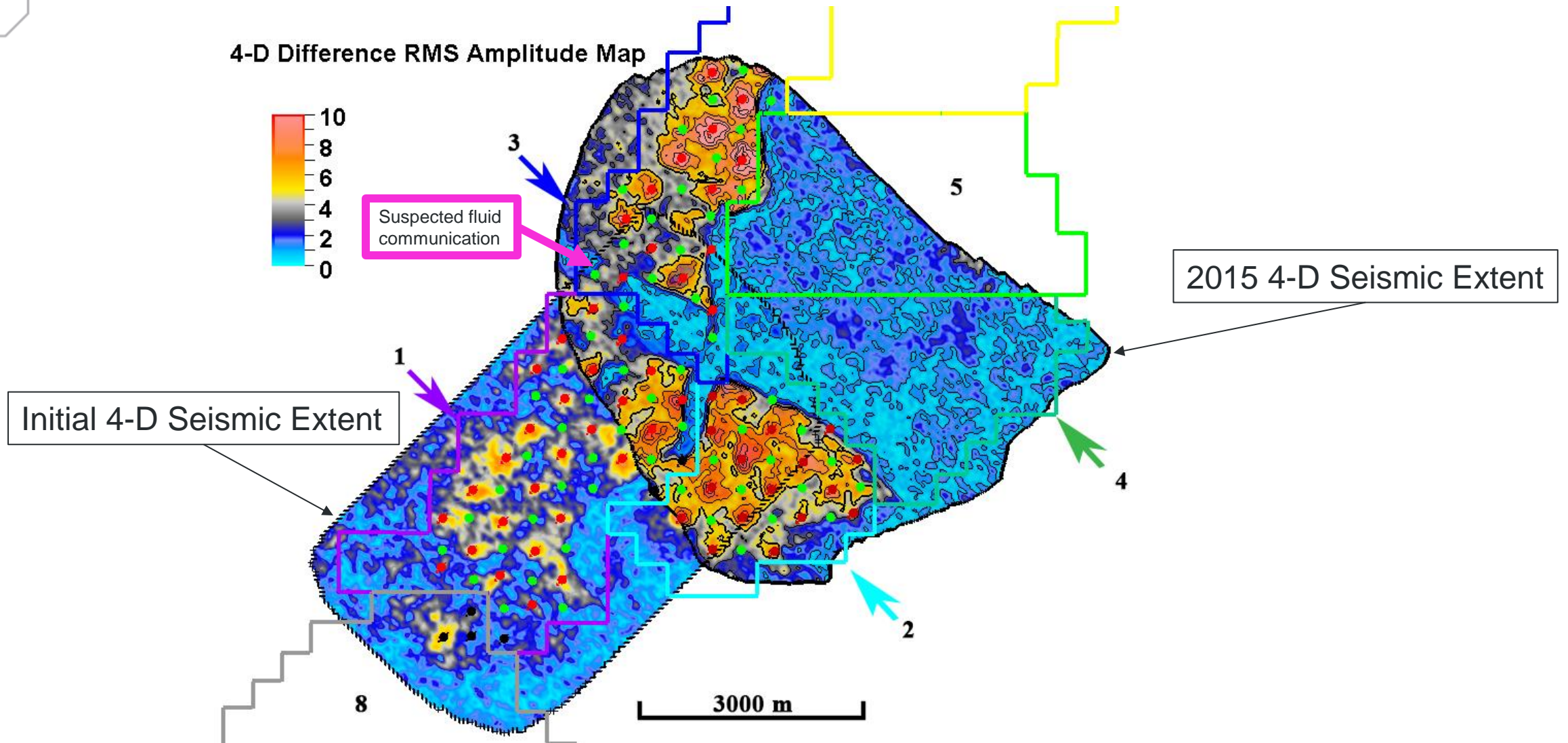
- 26-km² repeat (October 2014).
- ~1.2 Mt CO₂ stored in monitored area at the time of survey.

FIRST REPEAT 4-D DIFFERENCE INTERPRETATION (2012–2014)



ADDITIONAL OBSERVATIONS

An additional 4-D seismic analysis (survey acquired in 2015) shows suspected fluid communication between the Phase 1 and 3 areas...



IMPORTANT LEARNINGS FROM THE 4-D SEISMIC INVESTIGATION

- Permeability barriers (preventing fluid communication and pressure dissipation) have been illuminated where they were masked previously in the baseline seismic.
- Cross-phase fluid communication has been identified.
- CO₂ accumulating updip along the western edge of the N–S permeability barrier is visible.
- CO₂ and pressure plumes associated with injection wells are clearly shown.
- Improved insight into the reservoir's interwell heterogeneity.
 - Yielded important details necessary to adapt static models, enable better history matching, and increase accuracy in predictive simulations.
- Provided actionable information for the engineers operating the field while demonstrating associated CO₂ storage incidental to EOR.

CONTACT INFORMATION

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THANK YOU!



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