Critical Challenges. Practical Solutions.

Energy & Environmental Research Center (EERC)

WILLISTON BASIN ASSOCIATED CO_2 STORAGE FIELD LABORATORY DE-FE0031694

U.S. Department of Energy National Energy Technology Laboratory

2021 Carbon Management and Oil and Gas Research Project Review Meeting

August 5, 2021

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PRESENTATION OUTLINE

- Technical Status
- Accomplishments to Date
- Lessons Learned
- Project Summary
- Appendix

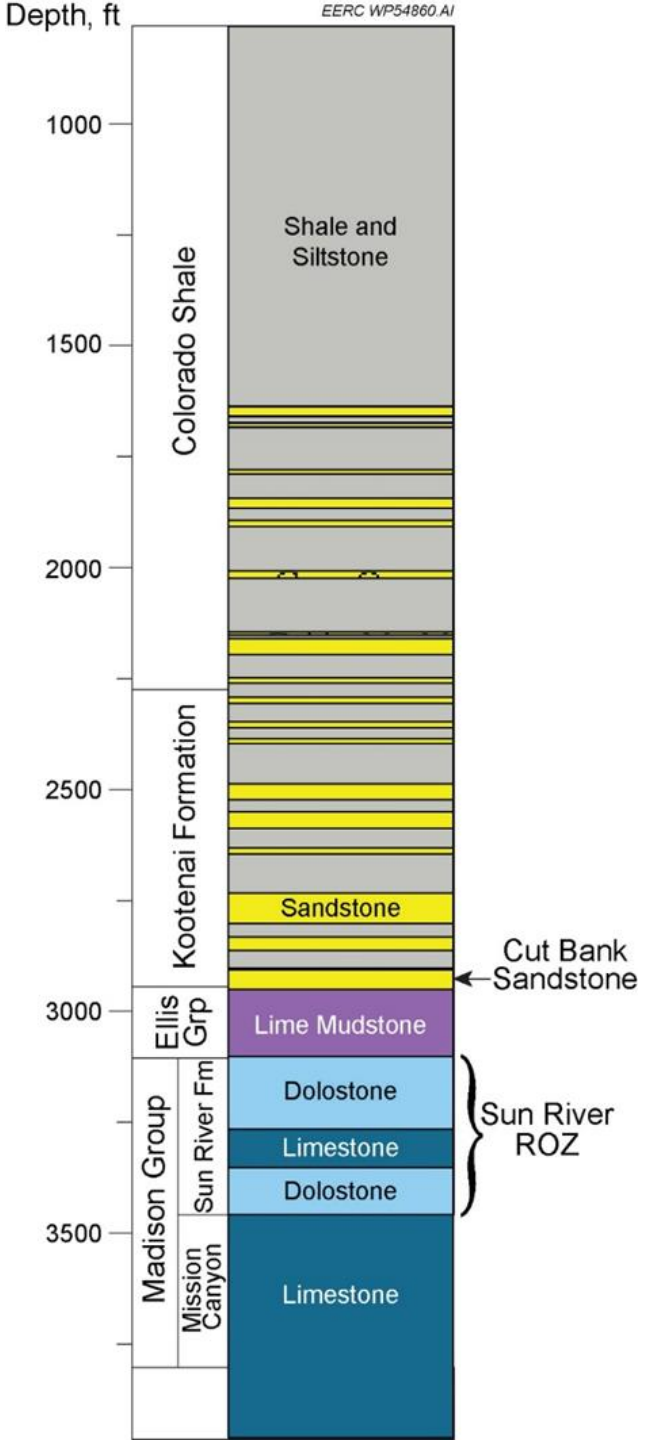
SOG Resources

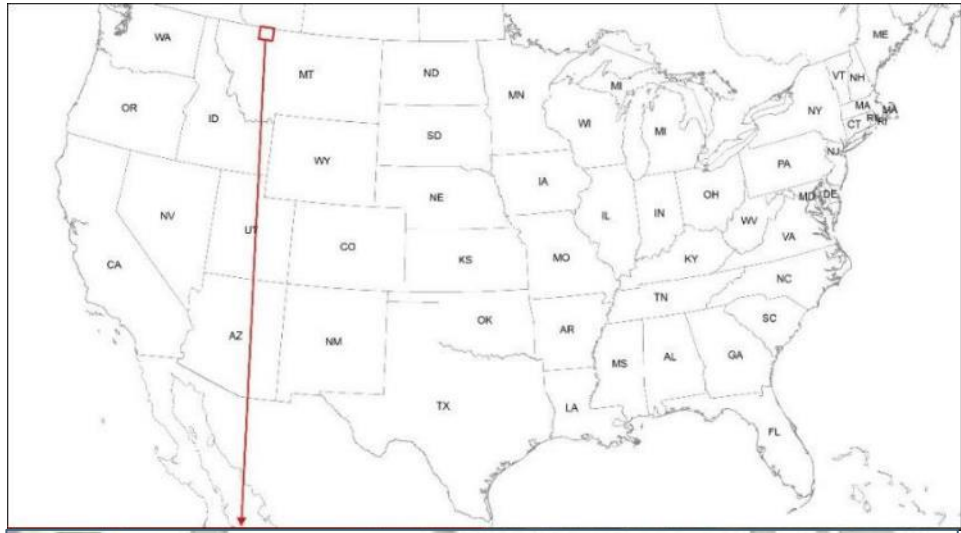
AREA OF INVESTIGATION

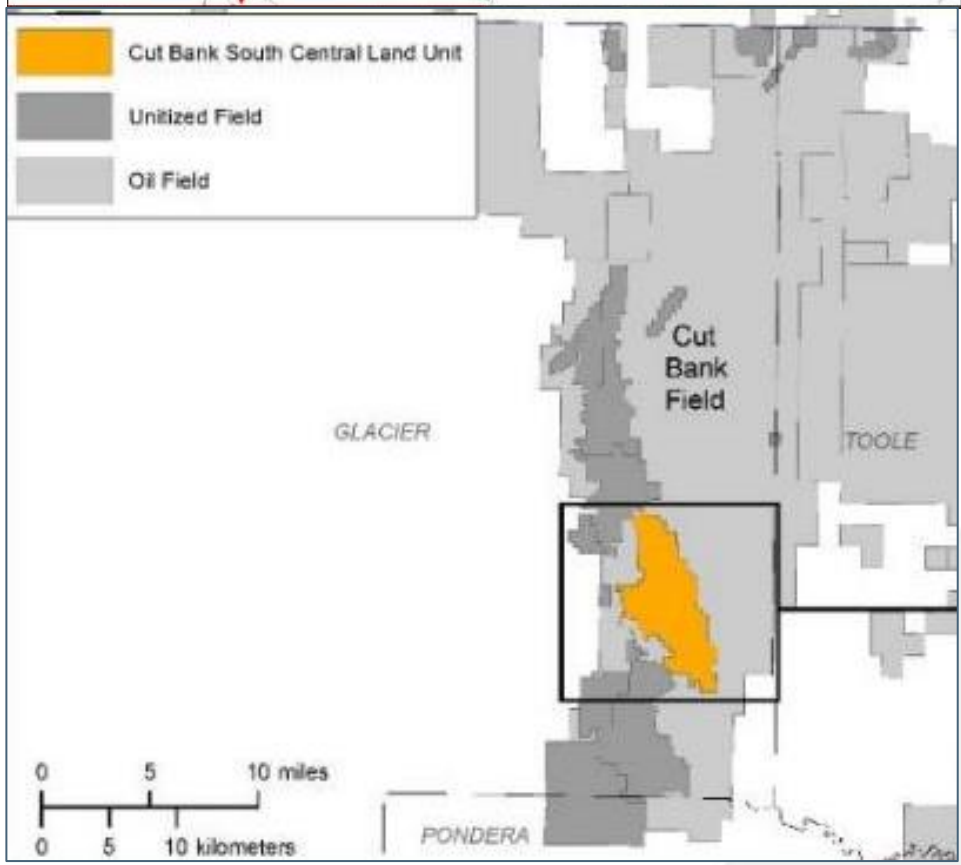
- Area of investigation: South Central Cut Bank Unit (SCCBU), Cut Bank, Montana.

- Two formations of interest:
  - Lower Cut Bank Formation
    - Main pay
    - Sandstone
  - Sun River Formation
    - Residual oil zone (ROZ)
    - Dolomite

- CO_2 is sourced from the Kevin Dome ~25 miles to the east.







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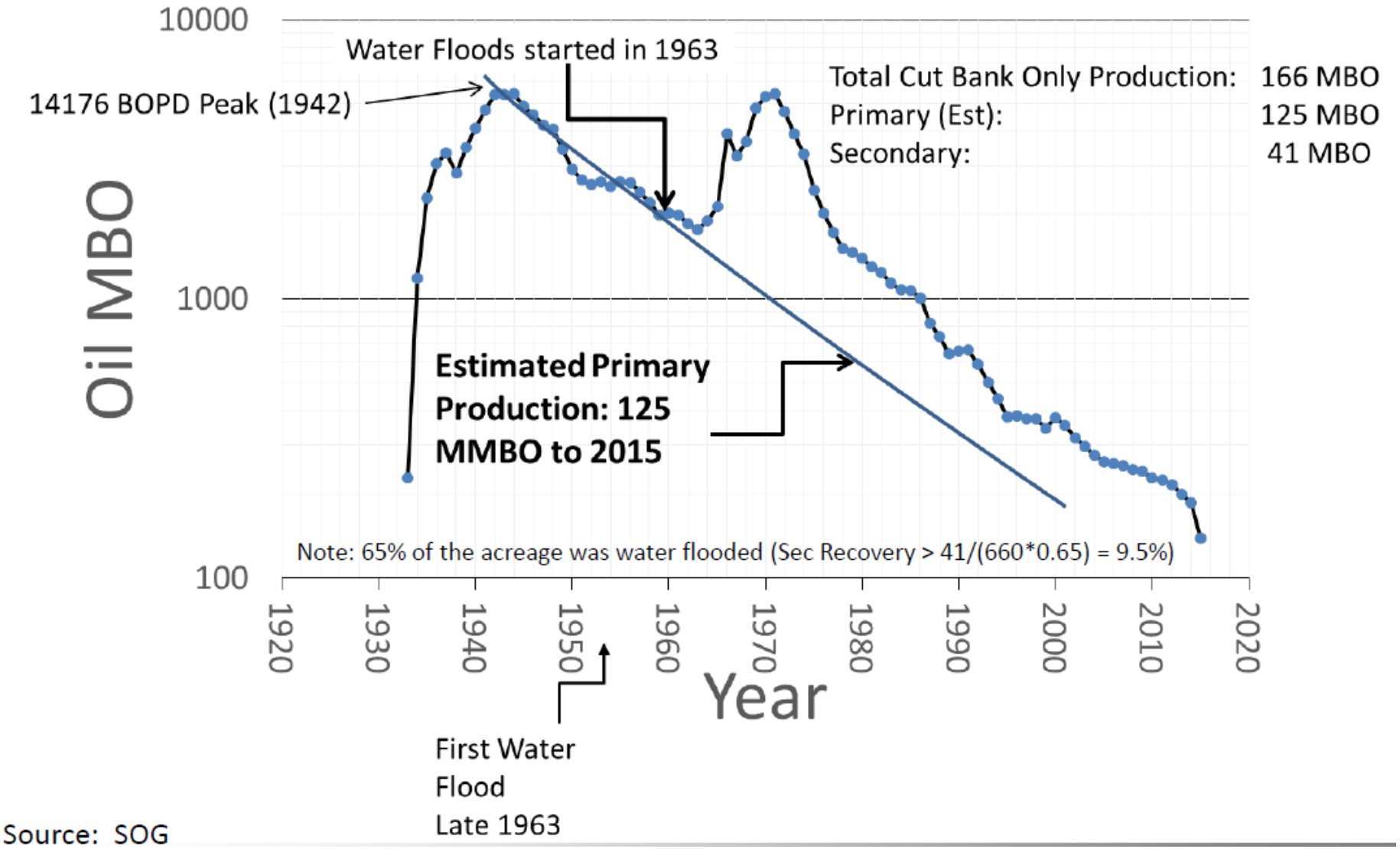
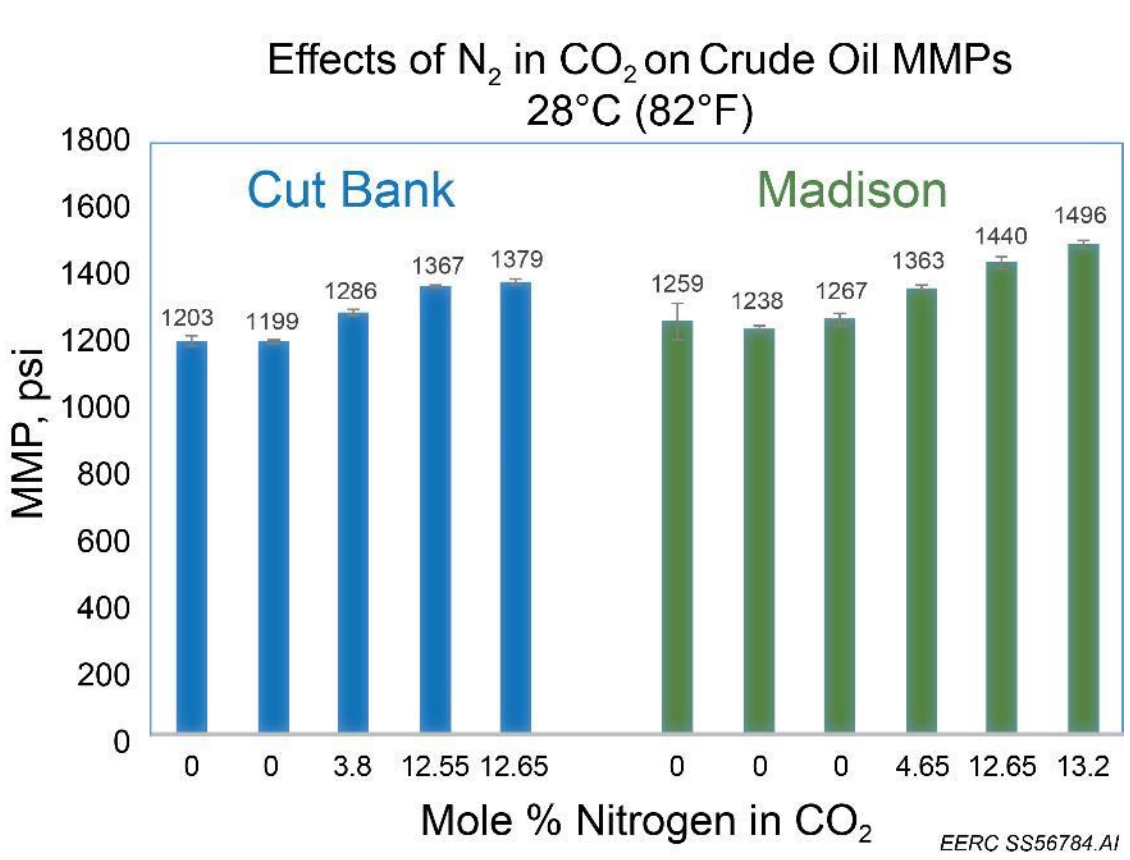
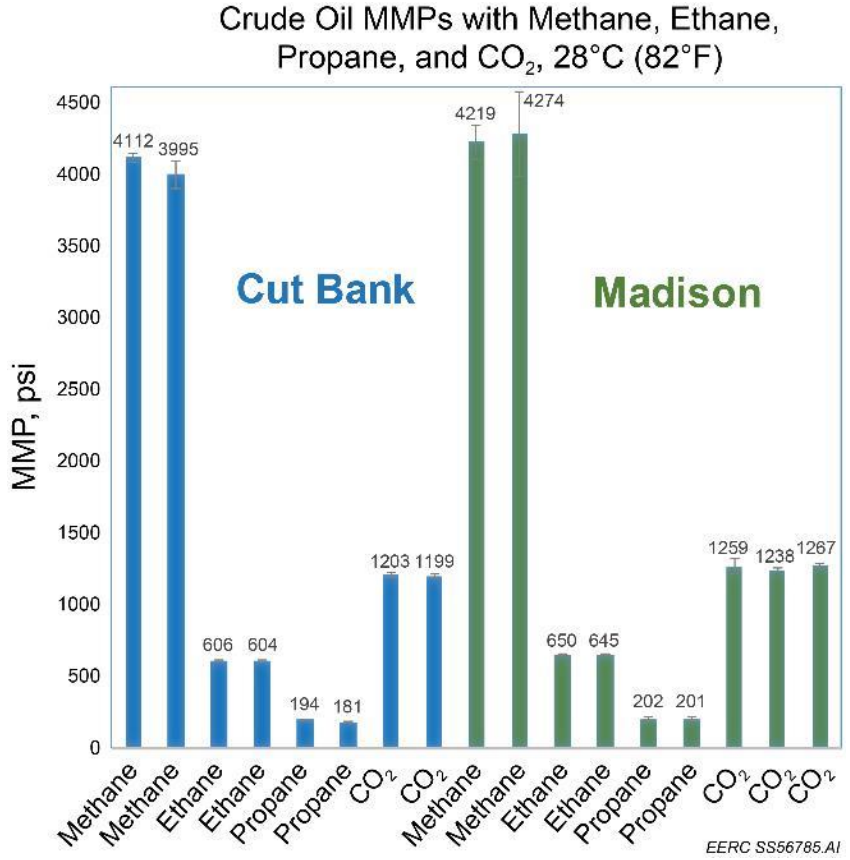
SCCBU BACKGROUND



Source: SOG

ACCOMPLISHMENTS TO DATE
Fluid Behavior Studies





ACCOMPLISHMENTS TO DATE

Core Analysis

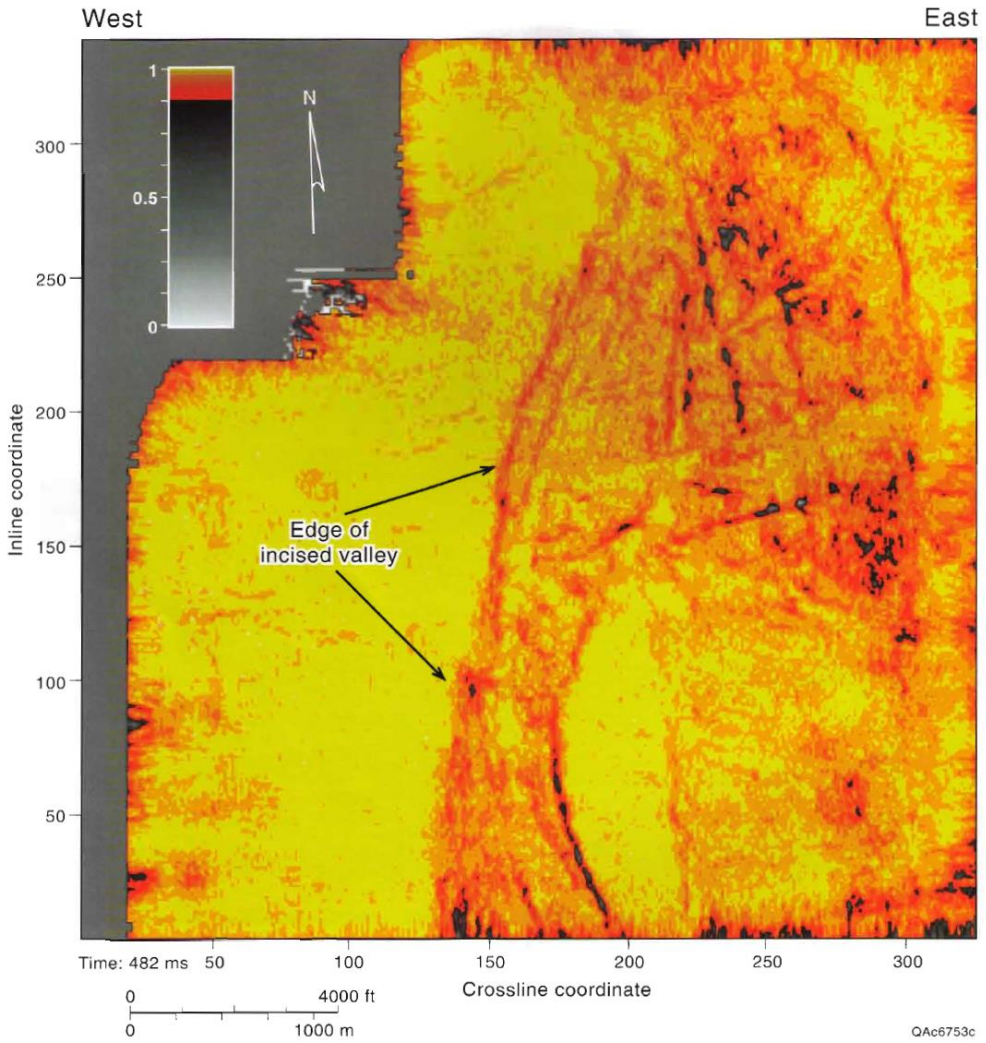
- Viewed Cut Bank Formation core collected near study area.

- Plugged and sampled rock from seal and reservoir. Analyses of samples include:
  - X-ray diffraction (XRD) and x-ray fluorescence (XRF).
  - Mercury injection capillary pressure (MICP).
  - Thin section.
  - Porosimetry.
  - Permeability.

ACCOMPLISHMENTS TO DATE

Site Characterization

- Historical characterization data
  - Geophysical data
    - ♦ 3D seismic
    - ♦ Check shots
  - Well logs
  - Core measurements
  - Fluid production
- Newly generated data during project
  - Core analysis
  - Pulsed-neutron logs (PNLs)
  - Seismoelectric survey



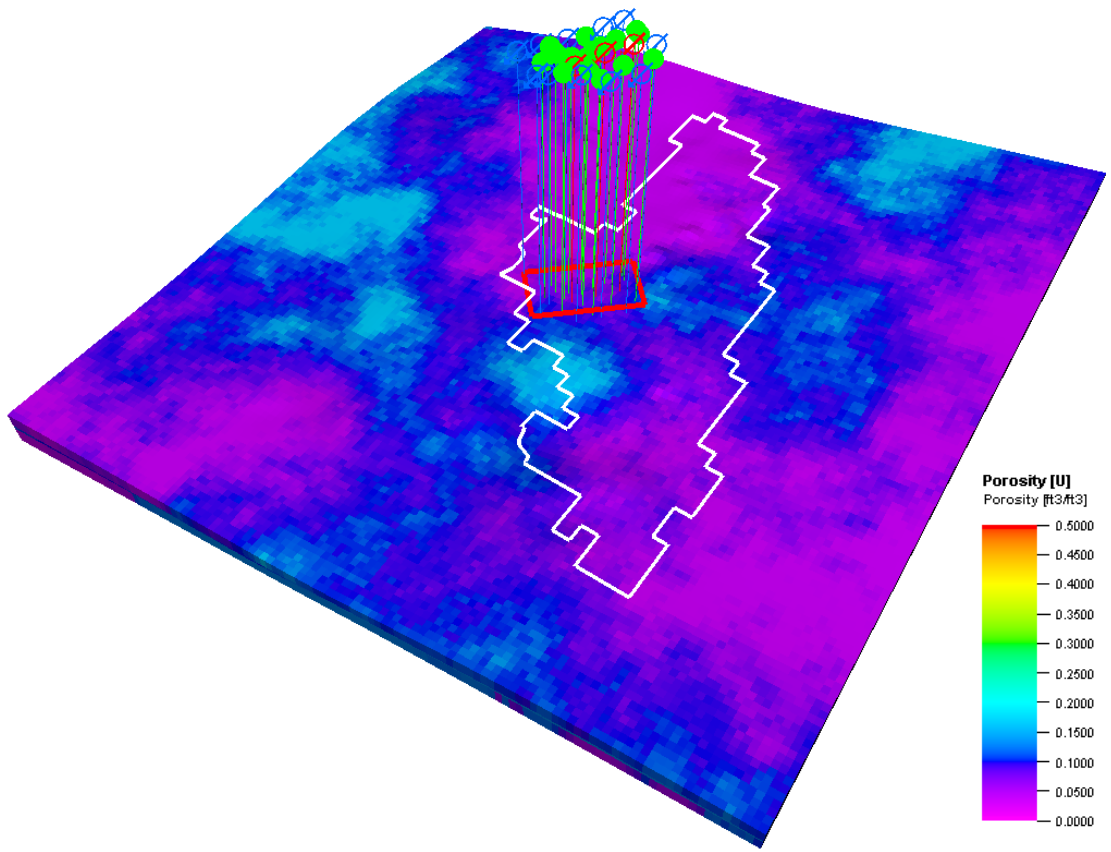
Time slice across coherence volume, illustrating potential incised valley (from DeAngelo and Hardage, 2001).

ACCOMPLISHMENTS TO DATE

Initial Geologic Model

- The EERC completed construction of the initial geologic model including the following:
  - Created 3D volumetric model which includes both the main pay zone and ROZ intervals.
  - Distributed lithofacies and petrophysical properties using available core data as control points.

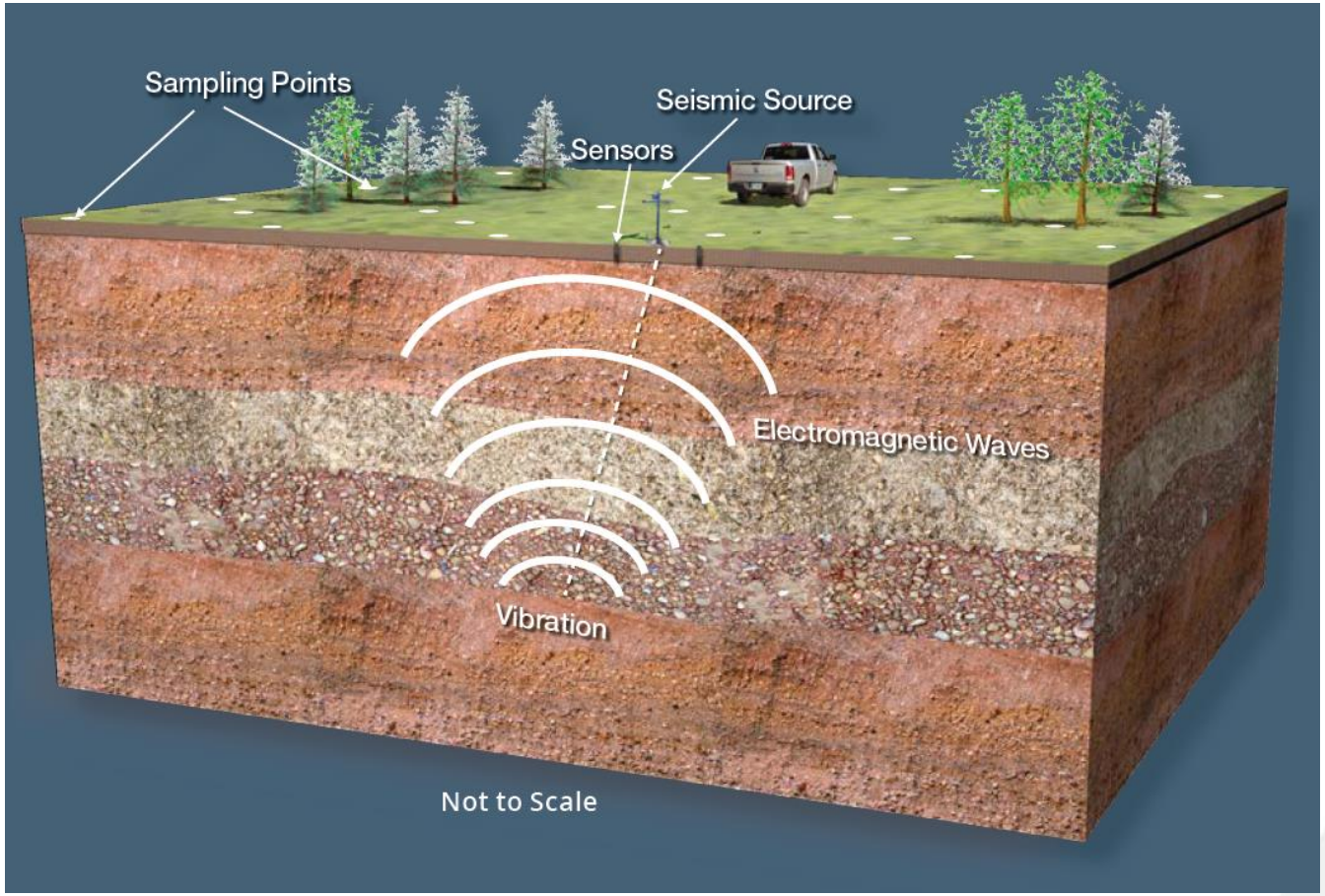
- *Next step*: complete history matching and initial dynamic modeling.



ACCOMPLISHMENTS TO DATE

Demonstration of Active Seismoelectric (ASE) Technology

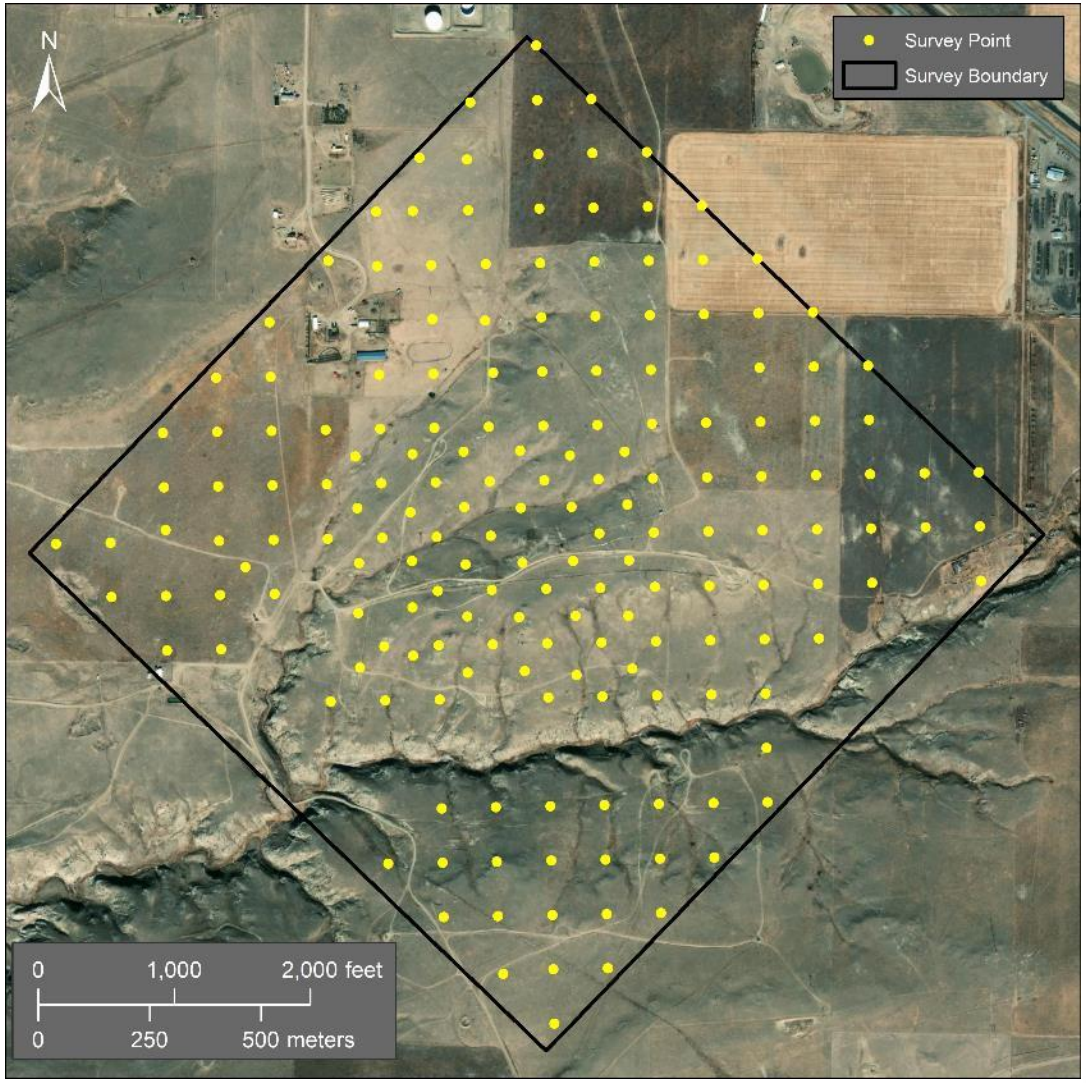
Sensor: dipole rods.
Source: buffalo gun seismic source.
Recorded Signal: electromagnetic wave generated by displacement of pore space dipole layers caused by seismic waves.
Results: depth displays directly below the sensor where the amplitude of the recorded signal is related to fluid properties.
Application: direct hydrocarbon indication, potential CO_2 monitoring.
Benefit: cost-effective, low-impact method.



ACCOMPLISHMENTS TO DATE

Baseline ASE Survey

- Conducted June 8–11, 2020
- 1-square-mile survey
- 180 shot points



ACCOMPLISHMENTS TO DATE

Baseline ASE Survey Processing

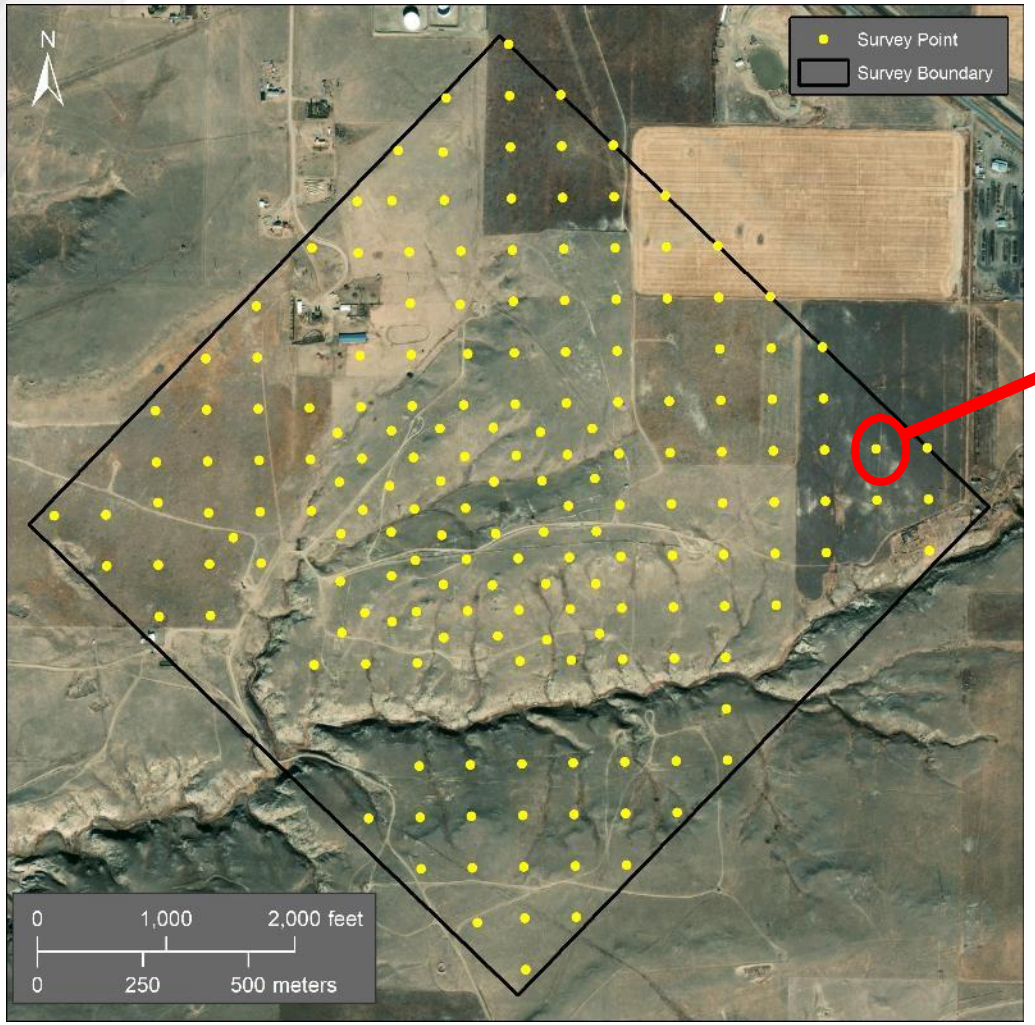
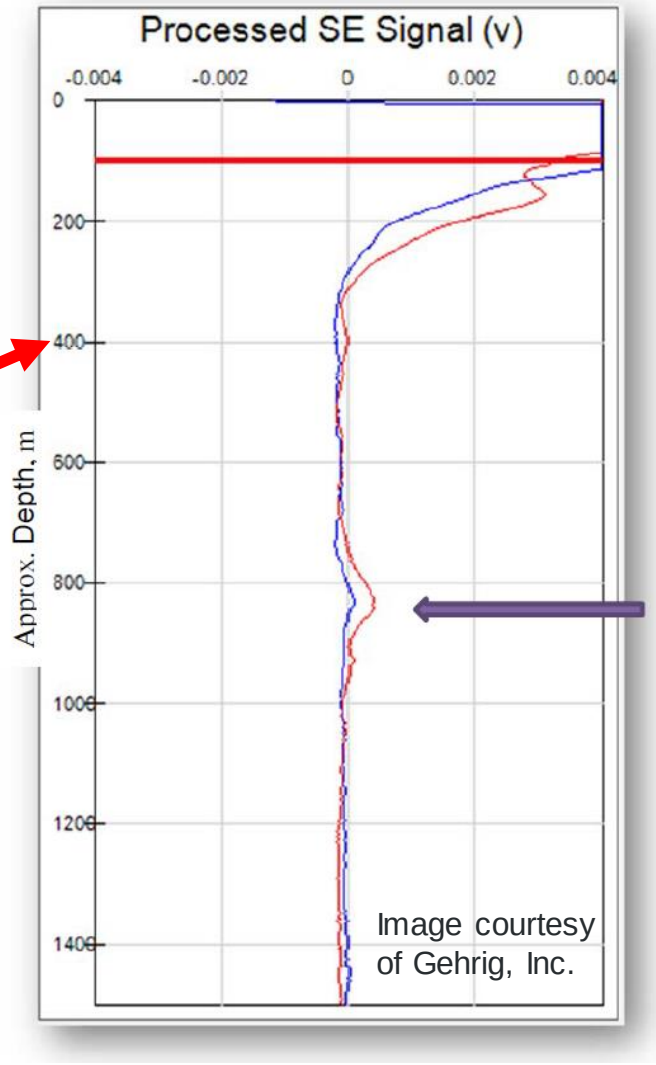


Diagram 3. ASE Sounding at Station 89



Seismoelectric response observed at the reservoir level at some locations. Advanced processing and modeling are being conducted to enhance data and understand the observed response.

LESSONS LEARNED/EXPECTED OUTCOMES

- Improved ROZ understanding with respect to oil recovery and associated storage.
- Provided quantitative lab and field results to initiate new projects in the Williston Basin based on advanced understanding of ROZs.
- Expanded CO_2 storage resources and future enhanced oil recovery (EOR) potential in the Williston Basin through minimum miscibility pressure (MMP) reduction using mixtures of CO_2 and hydrocarbon gases.
- Built a geologic and dynamic model to improve stacked storage and subsurface pressure understanding and related optimization strategies to improve sweep efficiency in stacked reservoirs.
- Matured a novel ASE technology for cost-effective monitoring of CO_2.
- Demonstrated the techno-economic feasibility of a commercial stacked storage project.

LESSONS LEARNED/UNANTICIPATED DIFFICULTIES

- Because of unforeseen circumstances created largely by the COVID-19 pandemic, macroeconomic conditions, and decline in oil markets, the following have been impacted for the Cut Bank EOR project:
  - DP1 for establishing the field test site has not been met.
  - Delays have been experienced in conducting field-related project activity in 2020 and 2021.
  - Tying the existing CO_2 source well into an existing pipeline for delivery to site injection well has not been achieved by SOG.
  - A baseline PNL and deepening of candidate wells have not been achieved to date in BP1.

Although project delays have been experienced in BP1, SOG continues to be committed to the CO_2 flood at Cut Bank and project activities with the EERC. During summer 2021, SOG is evaluating capital needs to repair existing pipeline from Kevin Dome to Cut Bank Field. A 9-month BP1 extension request has been submitted to DOE to allow fulfillment of BP1 goals/objectives.

PROJECT SUMMARY

- Project success criteria have been established in the active budget period.
- Establishing the associated storage field site is ongoing with SOG.
- Key characterization data have been collected to indicate ROZ and main pay zone.
- Future plans include deepening candidate wells, installing pressure gauges, and collecting a baseline PNL from a candidate well within the study area.

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THANK YOU

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APPENDIX

BENEFITS TO THE PROGRAM

- DOE Goals 1 and 2 will be addressed by introducing and developing lower-cost technologies that improve reservoir storage efficiency, ensure containment effectiveness, and/or ensure storage permanence through cross-validation of existing technology (Cut Bank and Sun River Formations).
- Goal 3, the ability to predict CO_2 storage capacity in geologic formations to within ±30%, will be addressed by integrating characterization data derived from the project into geocellular and dynamic reservoir models.
- Goal 4 will be addressed by producing information that will be useful for the development of DOE's series of commercial-scale best practices manuals when investigating the use of ROZs.

PROJECT BENEFITS FOR DOE

- DOE Carbon Storage Office
  - Generate lab- and field-based data for associated CO_2 storage in stacked reservoirs during EOR operations.
  - Characterize a ROZ for associated storage.
  - Evaluate a monitoring, verification, and accounting (MVA) technique for its applicability to associated storage in stacked complexes.
  - The results derived from implementation of the project will provide a significant contribution to DOE's Carbon Storage Program goals.

PROJECT BENEFITS FOR OUR PARTNERS

- SOG
  - Provide better reservoir understanding through the characterization of the main pay zone (MPZ) and ROZ for the pilot area in the SCCBU and technical feasibility.
  - Provide suggestions for future development in the field.
  - Understand EOR commercial feasibility at the SCCBU for both the MPZ and ROZ.
  - Collaborate on future data collection scenarios within the unit for further characterization.
  - Provide optimization suggestions to enhance NPV.
- Schlumberger
  - Showcase how leading industry software solves challenging problems.
  - Understand software limitations for further development.

FUNDING PROFILE

Funding Profile (February 1, 2019 – January 31, 2022)

	BP*1 (Feb 2019 – Apr 2021)		BP2 (May 2021 – Jan 2022)		Total	
	DOE Funds	Cost Share	DOE Funds	Cost Share	DOE Funds	Cost Share
EERC–Prime	$2,384,367	$596,092	$1,111,221	$277,805	**$3,495,588**	**$873,897**
Total Cost Share %	80	20	80	20	**80**	**20**

*Budget period.

9-month no-cost extension request for BP1 submitted to DOE in June 2021.

OVERALL PROJECT OBJECTIVES

- **Goal**: Understand and exploit residual oil zones (ROZs) for associated storage and develop technologies for monitoring injection into stacked reservoirs.

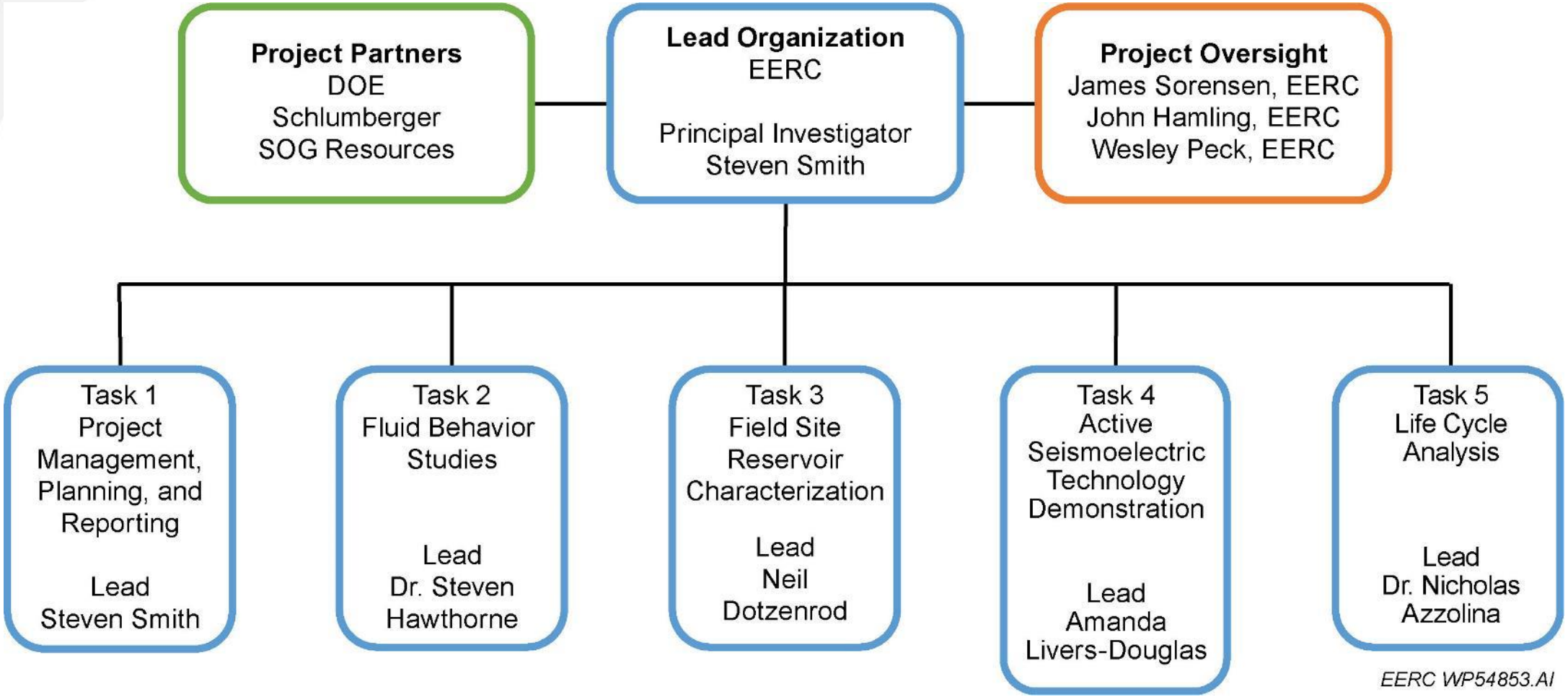
- **Objectives**:
  - Use the South Central Cut Bank Unit (SCCBU) as an associated CO_2 storage lab through the analysis of stacked enhanced oil recovery (EOR) in the main pay and a ROZ.
  - Test an innovative geophysical technique to monitor CO_2 in stacked complexes.
  - Characterize the reservoirs and perform modeling and simulation.
  - Perform a life cycle analysis (LCA) at the site and on a hypothetical stacked storage project.

SUCCESS CRITERIA

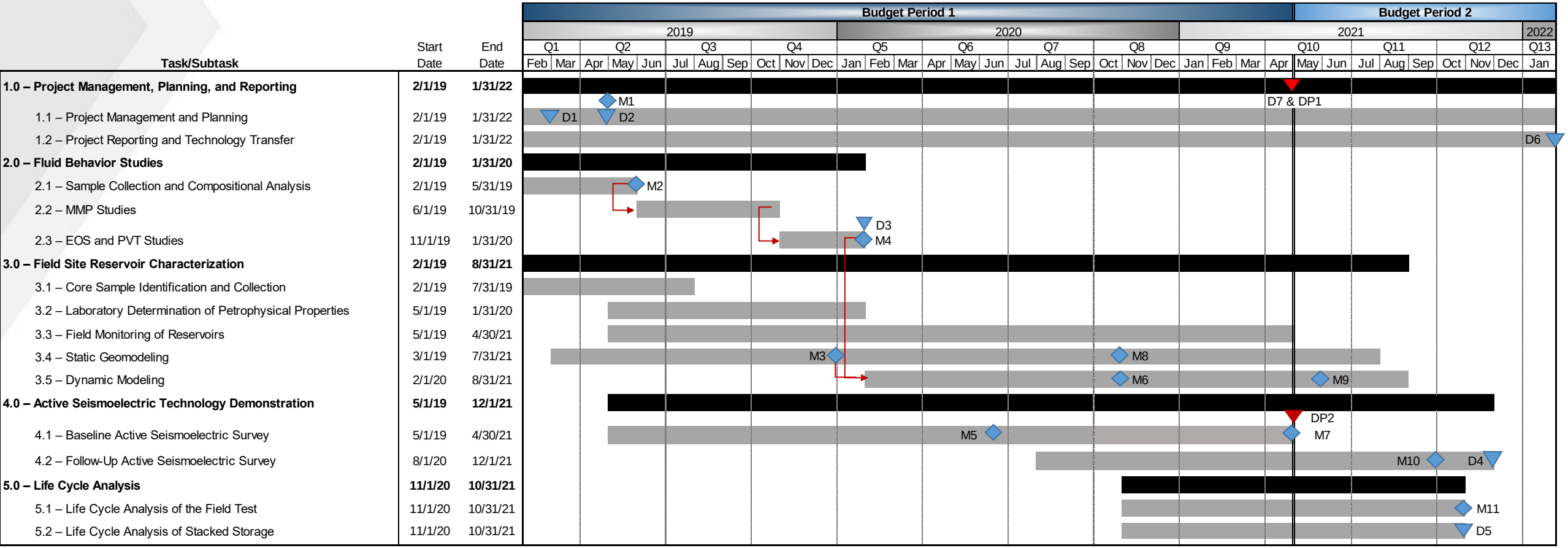
Project Success Criteria

- Generate field-based data on CO_2 EOR associated storage in stacked reservoirs.
- Characterize a ROZ for associated storage.
- Evaluate an MVA technique for its applicability to associated storage in stacked complexes.

ORGANIZATION CHART



EERC WP54853.AI



Task/Subtask	Start Date	End Date
1.0 – Project Management, Planning, and Reporting	**2/1/19**	**1/31/22**
1.1 – Project Management and Planning	2/1/19	1/31/22
1.2 – Project Reporting and Technology Transfer	2/1/19	1/31/22
2.0 – Fluid Behavior Studies	**2/1/19**	**1/31/20**
2.1 – Sample Collection and Compositional Analysis	2/1/19	5/31/19
2.2 – MMP Studies	6/1/19	10/31/19
2.3 – EOS and PVT Studies	11/1/19	1/31/20
3.0 – Field Site Reservoir Characterization	**2/1/19**	**8/31/21**
3.1 – Core Sample Identification and Collection	2/1/19	7/31/19
3.2 – Laboratory Determination of Petrophysical Properties	5/1/19	1/31/20
3.3 – Field Monitoring of Reservoirs	5/1/19	4/30/21
3.4 – Static Geomodeling	3/1/19	7/31/21
3.5 – Dynamic Modeling	2/1/20	8/31/21
4.0 – Active Seismoelectric Technology Demonstration	**5/1/19**	**12/1/21**
4.1 – Baseline Active Seismoelectric Survey	5/1/19	4/30/21
4.2 – Follow-Up Active Seismoelectric Survey	8/1/20	12/1/21
5.0 – Life Cycle Analysis	**11/1/20**	**10/31/21**
5.1 – Life Cycle Analysis of the Field Test	11/1/20	10/31/21
5.2 – Life Cycle Analysis of Stacked Storage	11/1/20	10/31/21

Task Duration
Subtask Duration
Critical Path

Deliverables (D)
D1 – Project Management Plan
D2 – Technology Maturation Plan
D3 – Fluid Behavior Studies Summary Report
D4 – Demonstration of Active Seismoelectric Technology for MVA
D5 – LCA and Technoeconomic Assessment of a Hypothetical Stacked Storage Project in the Williston Basin
D6 – Data Submitted to NETL EDX
D7 – Development of the Associated Storage Field Site
Go/No-Go Decision Point (DP)
DP1 – Field Test Site Established
DP2 – Verified ASE Technology

Milestones (M)
M1 – Project Kickoff Meeting Held
M2 – Sample Collection Completed
M3 – Initial Static Geomodel Completed
M4 – Fluid Behavior Studies Completed
M5 – Baseline Active Seismoelectric Survey Completed
M6 – Initial Dynamic Modeling Completed
M7 – Baseline Active Seismoelectric Data Processing Completed
M8 – Updated Static Geomodel Initiated
M9 – Updated Dynamic Modeling Initiated
M10 – Repeat Active Seismoelectric Survey Completed
M11 – Life Cycle Assessment of Dual-Pilot Project Completed

8.26.20 nsk

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9-month no-cost extension request for BP1 submitted to DOE in June 2021.

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BIBLIOGRAPHY

- List peer reviewed publications generated from the project per the format of the examples below.

- Journal, one author:
  - Gaus, I., 2010, Role and impact of CO2-rock interactions during CO2 storage in sedimentary rocks: International Journal of Greenhouse Gas Control, v. 4, p. 73-89, available at: XXXXXXX.com.
- Journal, multiple authors:
  - MacQuarrie, K., and Mayer, K.U., 2005, Reactive transport modeling in fractured rock: A state-of-the-science review. Earth Science Reviews, v. 72, p. 189-227, available at: XXXXXXX.com.
- Publication:
  - Bethke, C.M., 1996, Geochemical reaction modeling, concepts and applications: New York, Oxford University Press, 397 p.

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