Energy & Environmental Research Center
15 North 23rd Street, Stop 9018 • Grand Forks, ND 58202-9018 • P. 701.777.5000 • F. 701.777.5181
www.undeerc.org

June 1, 2023

Mr. Reice Haase
Deputy Executive Director
North Dakota Industrial Commission
ATTN: Oil and Gas Research Program
State Capitol – 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Mr. Haase:

Subject: EERC Proposal No. 2023-0150 Entitled "Bakken Production Optimization Program 4.0" in Response to the North Dakota Industrial Commission Oil and Gas Research Program Solicitation

The Energy & Environmental Research Center (EERC) is pleased to propose a continuation of a well-established research program that encourages and promotes the use of new technologies that have a positive economic and environmental impact on oil and gas exploration and production in North Dakota.

The $100 application fee for this proposal is provided through ACH Transaction No. 255028. The EERC, a research organization within the University of North Dakota, an institution of higher education within the state of North Dakota, is not a taxable entity; therefore, it has no tax liability.

This transmittal letter represents a binding commitment by the EERC to complete the project described in this proposal. If you have any questions, please contact me by telephone at (701) 777-5287 or by email at jsorensen@undeerc.org.

Sincerely,

DocuSigned by:
James Sorensen
James A. Sorensen
Director of Subsurface Research and Development

Approved by:

DocuSigned by:
Thomas Alfred Erickson
38EA2766DDAC46C...
for
Charles D. Gorecki, CEO
Energy & Environmental Research Center

JAS/bjr

Attachments

c/att: Brent Brannan, OGRP

Oil and Gas Research Program

North Dakota
Industrial Commission

Application

Program Title: Bakken Production Optimization Program 4.0

Applicant: Energy & Environmental Research Center

Principal Investigator: James A. Sorensen

Date of Application: June 1, 2023

Amount of Request: $6,000,000

Total Amt. of Proposed Project: $12,000,000

Duration of Project: 3 years

Point of Contact (POC): James A. Sorensen

POC Telephone: (701) 777-5287

POC Email Address: jsorensen@undeerc.org

POC Address:

15 North 23rd Street, Stop 9018

Grand Forks, ND 58202-9018

TABLE OF CONTENTS

ABSTRACT

The Energy & Environmental Research Center (EERC) proposes a 3-year extension of the existing and highly successful Bakken Production Optimization Program (BPOP). The first 9 years of BPOP were sponsored by the North Dakota Industrial Commission (NDIC) Oil and Gas Research Program (OGRP) and many of the Williston Basin's premier operating companies. **Objective:** To provide technical solutions and tools that optimize oil production, reduce carbon intensity, and lead to the broad deployment of technologies, including enhanced oil recovery (EOR), that enable continued sustainable development of North Dakota's vast Bakken resources. **Expected Results:** Increased productivity and decreased carbon intensity of Bakken resources. **Duration:** 3 years (September 1, 2023 – August 31, 2026). **Total Program Cost:** The total value of the project is $12,000,000. This proposal requests $2,000,000 annually for 3 years ($6,000,000 total) from OGRP. The U.S. Department of Energy (DOE) will provide $1,000,000 of cash cost share toward field testing of a new flare reduction technology. Devon Energy Corporation (Devon) will provide in-kind contributions (valued at $3,000,000) in the form of unique data sets, core, and fluid samples that will be used to support the design and execution of a CO_2 injection test in a Bakken well. Liberty Resources, LLC (Liberty) will provide in-kind contributions (valued at $363,639) in the form of an EOR pilot test using rich gas and produced water. Consistent with the first 9 years of BPOP, the EERC anticipates sustained industry engagement in the form of annual partnership fees. Those contributions, reported to NDIC as received, will increase the total value of the program. Based on past levels of participation, the attendant budget includes $1,636,361 from annual partnership fees. The full value of these fees is anticipated to exceed $2,000,000 over the 3 years. **Participants:** In addition to DOE, the EERC anticipates ongoing support of at least eight companies, including Chord Energy, ConocoPhillips, Devon, XTO Energy (a subsidiary of ExxonMobil), Hess Corporation, Liberty Resources LLC, Marathon Oil Company, and Petro-Hunt, L.L.C., which have supported previous BPOP phases. Additional partners are anticipated to join as the program continues.

PROJECT DESCRIPTION

The Energy & Environmental Research Center (EERC) proposes to extend the scope of the existing and highly successful North Dakota Industrial Commission (NDIC) Oil and Gas Research Program (OGRP)-sponsored Bakken Production Optimization Program (BPOP). The EERC proposes a 3-year continuation of this program that optimizes petroleum production in North Dakota. The proposed program is a continuation of the collaborative effort between the state of North Dakota, the petroleum industry, and the U.S. Department of Energy (DOE) to develop solutions to challenges in the Bakken. Accomplishments over the past 9 years of BPOP are provided in Appendix A.

Industry and state stakeholders have expressed a desire to maximize productivity of wells and drilling spacing units (DSUs), increase the ultimate recovery of oil, and reduce the carbon intensity of Bakken operations. Stakeholders are interested in optimizing primary production throughout the Bakken play, including Tier 2 and 3 acreages, determining how to best implement commercial-scale enhanced oil recovery (EOR) using rich gas and/or CO_2, reducing flaring and fugitive methane emissions, mitigating well souring, and improving operational efficiencies. Technical advances that result from the proposed activities will not only serve to support the long-term productivity and economic vitality of Bakken assets but will also demonstrably reduce the carbon intensity of Bakken oil, thereby enhancing the environmental, social, and governance (ESG) standing of operators.

The success of BPOP to date suggests a high likelihood of a significant return on investment by the state and its industry partners. Throughout the first 9 years of the program, the EERC has demonstrated that the strength of BPOP rests in its ability to address a broad range of ever-changing technical priorities. Key topics that will be addressed during the next 3 years of BPOP include:

- Moving Bakken EOR from pilot testing to commercial-scale deployment:
  - Building on the success of Liberty's East Nesson EOR pilot, which used a novel approach to rich gas and water injection to yield over >5000 bbl of incremental oil.
  - Working with Devon Energy Corporation (Devon) to perform a robust laboratory, modeling, and field-based examination of the potential to use CO_2 for Bakken EOR, which would not only

leverage the state's nascent but growing CO_2 capture, utilization, and storage (CCUS) industry to improve ultimate recovery of Bakken oil resources but would yield low-carbon-intensity oil.

  - Performing techno-economic modeling exercises focused on evaluating holistic strategies for broadly deploying EOR across the basin that account for key reservoir, operational, and infrastructure factors, as well as working fluid options.

- Economically assessing, monitoring, and mitigating fugitive methane emissions:
  - Developing approaches and tools for assessing emissions from operations.
  - Evaluating technologies for monitoring and mitigating fugitive methane emissions.
- Developing and deploying a new flare reduction technology:
  - Field testing of the "Polar Bear℠" technology at BPOP partner locations.
- Pursuing research activities identified as being of high priority based on partner feedback:
  - Mitigation of hydrogen sulfide (H_2S) generation in Bakken wells.
  - Basinwide characterization of produced oil, gas, and water.
  - Basinwide statistical analyses of drilling, completion, refracturing, and production operations using machine learning (ML) and artificial intelligence (AI) techniques.
  - Reservoir characterization using advanced petrophysics and sequence stratigraphy methods to support Tier 2 and Tier 3 acreage development and EOR scheme designs.
  - Evaluation of the potential for an emerging wellhead-based real-time data collection and analysis technology to optimize gas lift and improve production economics.

Goals and Objectives: The primary goals of the proposed BPOP efforts are to 1) provide the state and industry with science-based insight to maintain the economic and environmental sustainability of the Bakken play in North Dakota, with an emphasis on reducing carbon intensity through commercialization of EOR using rich gas and/or CO_2, new flare reduction technologies, and methane emission management and 2) provide stakeholders with the knowledge needed to plan and implement innovative development strategies that will add value to Bakken Tier 1, 2, and 3 acreages.

Methodology: BPOP will be organized along multiple technical topic areas as state and industry priorities dictate. The flexibility of the stakeholder-driven program will provide the ability to address emerging issues as needed. Through BPOP, the EERC will continue to serve existing and new North Dakota Petroleum Council (NDPC) task force groups established to address challenges such as flaring, vapor pressure compliance, and emissions. The primary research topic areas are described below.

Enhanced Oil Recovery: Three activities will be conducted to develop knowledge and operational best practices that will support broad commercial implementation of EOR across the Bakken play.

Optimization of Rich Gas/Water EOR at East Nesson with Liberty Resources: As part of BPOP 3.0, Liberty Resources, LLC (Liberty) conducted an EOR pilot at its East Nesson location that included coinjecting rich gas and a fresh water/surfactant blend. The East Nesson pilot was successful at building reservoir pressure, containing the injected gas in the reservoir and estimated to ultimately yield >5000 bbl of incremental oil. A second injection cycle of water alternating gas (WAG) using rich gas and produced water to optimize the economics of operations is currently being planned for summer/fall 2023. Specific BPOP activities to support the Liberty pilot will include modeling and simulation to evaluate the reservoir response and performance of the second injection cycle. The data generated throughout the project will be processed and interpreted by EERC in close coordination with Liberty to assess the pilot performance.

Examination of CO_2 EOR in the Bakken with Devon: The EERC will work closely with Devon to conduct activities designed to ultimately culminate in the commercial deployment of an EOR project in the Bakken that uses CO_2 from an industrial source in North Dakota. The effort will include assessment and development of a business case that features CCUS, whereby incremental oil production is combined with 45Q tax incentives derived from CO_2 storage associated with EOR. Activities under BPOP 4.0 will include reservoir characterization, EOR pilot test design, pilot test site selection, procurement of the CO_2 necessary to conduct a pilot test, and execution of a CO_2 injection test. Reservoir characterization will include laboratory-, modeling-, and field-based efforts that will ultimately lead to design and execution of a pilot-scale test in a Bakken reservoir owned and operated by Devon. Field-based efforts conducted by

Devon could include, but are not necessarily limited to, collection of core, fluids, and/or baseline reservoir pressure and temperature data from reservoirs being considered as candidate locations for a pilot-scale CO_2 EOR test. Reservoir core and fluid samples will be used in laboratory experiments to evaluate the interactions between CO_2 and reservoir rocks and fluids under relevant reservoir conditions Testing may include minimum miscibility pressure (MMP); pressure, volume, temperature (PVT); CO_2-based oil extraction from rocks; and/or other tests to determine the EOR and CO_2 storage potential of the Bakken. Activities will include reservoir modeling simulation exercises to evaluate different CO_2 EOR operational scenarios in support of designing a CO_2-based EOR pilot test.

Basinwide Assessment of the Bakken EOR Potential: The lessons learned from the EOR pilot projects performed through BPOP and also those performed by other operators in the Bakken and other tight oil plays will be compiled and used to perform a wider assessment of Bakken EOR potential. Modeling and simulation scenarios will be performed to evaluate the EOR potential of different geologic regimes (i.e., Tier 1, 2, and 3 acreage). Both rich gas and CO_2 will be evaluated for EOR, and different operational scenarios (gas injection only, WAG injection, surfactant addition, etc.) will be assessed. The results of the modeling and simulation work will be extrapolated to inform development strategies and estimate the potential resource recovery and associated economic value for the entire Bakken play.

Methane Emission Mitigation and Flare Reduction: Cost-effectively mitigating methane emissions and reducing flaring have long been priorities of the state and industry and is an important element of reducing the carbon intensity of Bakken oil. The EERC will develop approaches and web-based tools for assessing methane emissions from operations. Technologies for monitoring and mitigating methane emissions will be evaluated. Data from NDIC indicate that approximately 66% of flaring is sourced from medium to small facilities where traditional gas capture techniques are uneconomical. However, a patented technology recently developed by the EERC, called Polar Bear^{SM}, is able to achieve near-zero flaring and capture storage tank vapors from these locations. Polar Bear^{SM} overcomes economic challenges by providing fit-for-purpose compression and vastly reducing the maintenance associated with

traditional compression. Tank vapors are particularly difficult to recover because of "tank breathing" which imparts air/oxygen into the tank headspace, often exceeding the allowable concentration for pipeline transport. Polar Bear[SM] provides a means to recover the storage tank vapors eliminating the need to flare. Through BPOP 4.0, and with cofunding from DOE and BPOP partner support, this effort will test a prototype in a relevant environment to advance the technology readiness for field implementation. The objectives of the effort are to 1) develop and validate a novel technology to capture vapors from storage tanks to achieve zero or near-zero methane emissions; 2) complete engineering-scale testing of a prototype design functioning with anticipated gas components and at dynamic conditions to validate process controls, design parameters, and safety; and 3) advance the technology for field implementation.

Completion and Production Data Analytics: The EERC will assess the impacts of different completion techniques and operational parameters on well and DSU performance with the goal of identifying factors to optimize production. This activity will include the evaluation of geology and completion parameters such as DSU well count; lateral length; well spacing; treatment size; and completion type on oil, gas, and water production from hydraulically fractured and refractured wells. The analyses will leverage previous EERC work on refractured wells, completion optimization, lateral length, well spacing, and parent–child well interactions and utilize ML to identify and quantify trends at the DSU-, field-, and basin-scale. These learnings will provide data-driven foundations for quantifying optimal infill well completion designs and parent well management strategies to optimize Bakken development. In addition, the EERC will evaluate time-series trends in well completion practices and fluids production to better understand reservoir performance and predict future gas and water production volumes.

Fluids Characterization: The optimization of oil production in North Dakota requires accurate understanding of the fluids being produced. Oil, associated gas, and produced water are complex mixtures, and their chemical and physical properties can vary geographically and over the life of a well. Bakken fluids data collected by BPOP over 9 years has been used to identify and follow evolving trends in key basinwide performance indicators such as gas-oil ratio, oil-water ratio, and produced fluid

compositions. Detailed fluids data generated under this task will be used in the Completion and Production Data Analytics task.

Geological and Petrophysical Evaluations: To support the optimization of well completions and EOR, the quality of reservoir and source rock within the Bakken petroleum system will be assessed through use of sequence stratigraphy techniques and advanced petrophysical analyses. Leveraging previously gathered core analyses and logs, wells will be evaluated for lithology, water saturation, kerogen volumes, permeability, and reservoir quality. The EERC will apply learnings from high-tier data sets (e.g., spectroscopy and nuclear magnetic resonance logs) to wells with a more common data suite to build a reliable database for reservoir characterization through ML algorithms. The EERC will also work with at least one graduate student in the UND Harold Hamm School of Geology & Geological Engineering to develop a Bakken depositional framework, which, in turn, may guide future Bakken development strategies.

Understanding and Mitigating H_2S in Bakken Production Streams: H_2S is an undesired by-product of oil and gas production in both conventional and unconventional plays. Previous H_2S characterization activities under BPOP, including the analysis of H_2S isotope signatures, suggested at least two potential mechanisms of H_2S occurrence in Bakken wells, both of which are likely linked to well stimulation. In BPOP 4.0, the EERC will continue analysis of sulfur isotopes and focus on mechanisms to manage and/or mitigate H_2S generation, including the evaluation of completion practices to reduce the risk of souring.

Production Technology Optimization Assessment: This activity will focus on advancing concepts and technology to improve the efficiency of production facilities. Irregular flow behavior inherent in horizontal wellbores due to the undulating borehole trajectory has been modeled and studied within BPOP. Based on fundamental knowledge, the EERC will evaluate advanced concepts that can improve flow behavior and increase the efficiency of artificial lift. The EERC intends to work with BPOP partners and NeoTek Energy to evaluate a technology, developed by NeoTek Energy, that couples an advanced

wellhead analyzer with AI to guide real-time optimization of a gas lift system, with a goal of ultimately demonstrating the use of the technology in the field.

Facilities, Resources, and Techniques to Be Used: The EERC employs a multidisciplinary staff of about 300 and has 254,000 square feet of state-of-the-art offices, laboratories, and technology demonstration facilities, which enable staff to address a wide variety of research topics. The EERC houses eight analytical laboratories, including water resource characterization, petroleum resource characterization, and environmental chemistry. These laboratories have decades of experience and have been instrumental in previous Bakken research. The EERC has extensive geologic modeling, reservoir simulation, and data analytics experience and capabilities, including high-end workstation computers and a dedicated high-performance parallel computing cluster.

Environmental and Economic Impacts While Program Is Underway: The breadth of the program means the environmental and economic impacts will be wide-ranging and difficult to predict. However, the first 9 years of the program are evidence of the positive impact the program has had on North Dakota environmental concerns and economics related to Bakken development. Previous BPOP impacts are outlined in Appendix A, and maps are included in Appendix B.

Ultimate Technological and Economic Impacts: Ultimately, BPOP will provide broad technical and economic impacts. Each research task will have the potential to bolster oil and gas industry operations by improving resource recovery, decreasing costs, reducing environmental impacts, and increasing revenue. With original oil in place (OOIP) estimates for the Bakken Petroleum system ranging from 300 to 900 billion barrels, the impact of successful EOR operations alone could extend the lifetime of the play by decades, yielding billions of barrels of low-carbon-intensity incremental oil and billions of dollars of economic impact to North Dakota. In addition, flaring and methane emissions continue to be a major focus area for the state, industry, and federal government. The demonstration and implementation of a technology to economically capture gas from smaller volume well locations would provide a significant economic and environmental benefit to the state and industry.

Why the Project Is Needed: The past 9 years of this program resulted in unprecedented cooperation among state and industry partners in addressing headline issues. Multiple program partners have openly stated that the type of cooperation facilitated by this program exists nowhere else in the petroleum industry. BPOP efforts to date are summarized in Appendix A. It is anticipated that similar progress can be made on critical topics such as EOR, flaring and fugitive emissions management, future resource development strategies, H_2S mitigation, and other topics over the next 3 years.

STANDARDS OF SUCCESS

Success will be measured in the program's ability to address the oil and gas industry's critical issues as identified by OGRP and BPOP partners, ultimately resulting in more efficient resource development and cost savings. Developing options to help ensure the success of the oil and gas industry in North Dakota while conserving the state's resources leads to a strong state economy and the creation of jobs to support all aspects of oil and gas development. Annual meetings with OGRP and BPOP partners will be held, as a measure of success, to discuss project status and receive feedback and guidance. Success will also be measured by delivery of high-impact products to state and industrial stakeholders.

The current OGRP-approved process of reporting will be employed to deliver results. BPOP provides partners premium access to reporting of results from activities for a period of 15 months following review by select partners prior to release to the public on the BPOP website. Products will be prepared on specific topics to be determined based on partner guidance. Select products, as determined by BPOP partners, may be released after shorter review periods if early release is deemed to be of greater advantage to the partners. High-level progress updates will be provided in quarterly reports, in an executive summary format, to OGRP for inclusion on the OGRP website for immediate access by the public. An annual briefing to OGRP will highlight the successes of BPOP and next steps. A final report summarizing BPOP program achievements and challenges will be prepared. Presentations at technical conferences and public outreach events will cover pertinent topic areas.

BACKGROUND/QUALIFICATIONS

The EERC is a nonprofit branch of the University of North Dakota. Resumes of key personnel are provided in Appendix C. James Sorensen, Director of Subsurface R&D, will serve as Program Manager. Dr. John Harju, Vice President for Strategic Partnerships, will serve as Senior Program Advisor. Other key EERC personnel will include Bethany Kurz, Director for Analytical Solutions; Darren Schmidt, Assistant Director for Energy, Oil and Gas; Dr. Nick Azzolina, Assistant Director for Applied Data Analytics; Dr. Chantsalmaa Dalkhaa, Principal Reservoir Engineer; Matthew Belobraydic, Assistant Director for Geoscience; Marc Kurz, Principal Geologist; and Dr. Alexander Chakhmakhchev, Principal Scientist.

MANAGEMENT

The EERC manages over 200 contracts a year, with a total of over 1300 clients in 53 countries. Systems are in place to ensure that projects are managed within budget, schedule, and scope. Mr. Sorensen will oversee the entire program, with assistance in management of program activities and tasks by Ms. Kurz, Mr. Schmidt, and Dr. Azzolina. This will involve integration of tasks, program reporting, collaboration with industry and the Oil and Gas Research Council, recruiting of new partners, and strategic studies. The EERC will be responsible for coordination and execution of tasks, with assistance provided by program partners, and will disseminate results. Quarterly reports will be submitted to NDIC and partners 30 days after the end of each calendar quarter to provide highlights of ongoing research and anticipated future activities. A program kickoff meeting will be scheduled for fall 2023 to prioritize research areas with input from state and industry. At minimum, annual meetings will be scheduled to provide updates on research activities and discuss the direction of future activities. In addition, webinars will be held throughout the period of performance related to subjects within the scope of work.

TIMETABLE

This effort is proposed as a 3-year program (September 1, 2023 – August 31, 2026). Figure 1 summarizes the preliminary program timetable. Additional timetable detail will be developed as the program evolves.

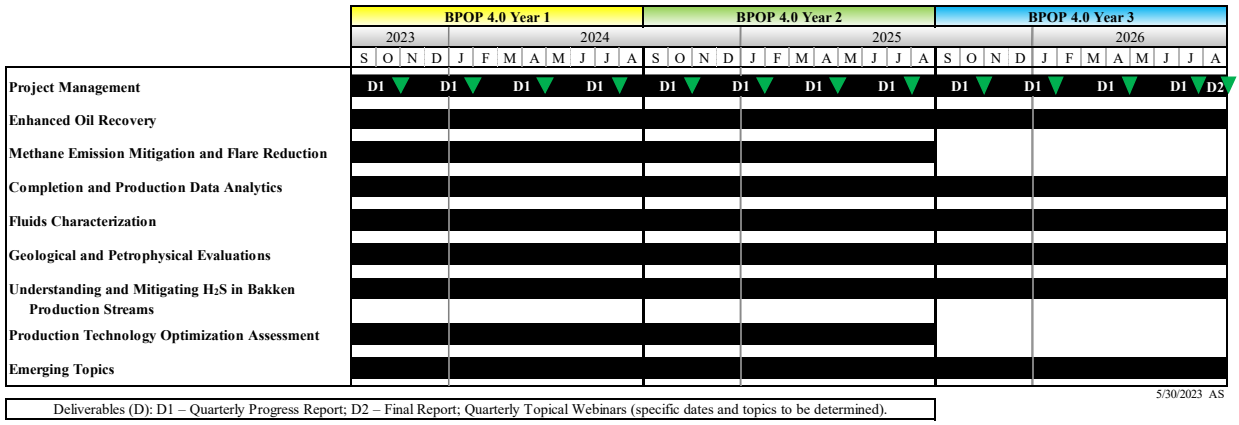


Figure 1. Preliminary program timetable.

BUDGET

The total estimated cost for the proposed effort is $12,000,000. $6,000,000 is requested from OGRP ($2,000,000/year). Cost share will include $1,000,000 cash from DOE (under contract negotiations, DOE Award No. DE-FE0032290). It is estimated that industry partners will provide a minimum of $1,636,361 in cash cost share. Support from at least eight companies is anticipated, including Chord Energy, ConocoPhillips, Devon, XTO Energy, Hess, Liberty, Marathon Oil Company, and Petro-Hunt, which all supported BPOP 3.0. This group includes six of the top top-oil producers in North Dakota, and their operations cover most of the Bakken play area (Appendix B). Liberty will provide in-kind cost share at a value of $363,639 based on costs associated with pilot operations. Devon is anticipated to provide in-kind cost share at a value of $3,000,000. Letters of commitment can be found in Appendix D as well as the letter from DOE notifying the EERC that is has been selected for award for the Polar Bear^{SM} project. The budget shown in Table 1 is based on previous EERC experience with BPOP. Budget notes can be found in Appendix E.

Table 1. Budget Breakdown

Project Associated Expense	NDIC Share (Cash)	DOE Share (Cash)	Industry Share (Cash & In-Kind)	Total Project
Labor	$3,303,682	$411,168	$1,009,994	$4,724,844
Travel	$167,314	$28,819	$0	$196,133
Equipment > $5000	$0	$209,871	$0	$209,871
Supplies	$72,800	$3,500	$0	$76,300
Subcontractor - Liberty Resources	$306,000	$0	$0	$306,000
Communications	$150	$170	$0	$320
Printing & Duplicating	$1,032	$664	$291	$1,987
Food	$9,957	$0	$0	$9,957
Professional Development	$1,800	$0	$0	$1,800
Freight	$0	$2,000	$0	$2,000
Laboratory Fees & Services				
EERC Analytical Research Lab	$49,485	$0	$0	$49,485
EERC Process Chemistry & Development Lab	$0	$12,600	$0	$12,600
EERC Document Production Services	$33,866	$28,707	$0	$62,573
EERC Shop & Operations	$0	$10,270	$0	$10,270
EERC Software Solution Services	$64,103	$0	$0	$64,103
EERC Technical Software Fee	$0	$9,450	$0	$9,450
EERC Engineering Services Fee	$3,721	$5,362	$0	$9,083
EERC Field Safety Fee	$0	$10,553	$0	$10,553
EERC Geoscience Services Fee	$42,792	$0	$12,440	$55,232
Outside Lab	$25,000	$0	$0	$25,000
Total Direct Costs	$4,081,702	$733,134	$1,022,725	$5,837,561
Facilities & Administration	$1,918,298	$266,866	$613,636	$2,798,800
Total Cash Requested	**$6,000,000**	**$1,000,000**	**$1,636,361**	**$8,636,361**
In-Kind Cost Share				
Liberty	$0	$0	$363,639	$363,639
Devon	$0	$0	$3,000,000	$3,000,000
Total In-Kind Cost Share	**$0**	**$0**	**$3,363,639**	**$3,363,639**
Total Project Costs	**$6,000,000**	**$1,000,000**	**$5,000,000**	**$12,000,000**

CONFIDENTIAL INFORMATION AND PATENTS/RIGHTS TO TECHNICAL DATA

This proposal has no confidential information. No patentable technologies are expected to be created.

STATUS OF ONGOING PROJECTS

The EERC is currently engaged in nine OGRP-funded projects. These ongoing projects, listed in Appendix F, are current on all deliverables.

APPENDIX A

BAKKEN PRODUCTION OPTIMIZATION PROGRAM
KEY ACCOMPLISHMENTS TO DATE

Energy & Environmental Research Center (EERC)

BAKKEN PRODUCTION OPTIMIZATION PROGRAM (BPOP) KEY ACCOMPLISHMENTS TO DATE

CURRENT BPOP PARTNERS

ConocoPhillips

devon

HESS

LIBERTY RESOURCES

Marathon Oil

OASIS PETROLEUM

PETRO - HUNT L.L.C.

XTO ENERGY

North Dakota oil & gas research program

U.S. DEPARTMENT OF ENERGY

NATIONAL ENERGY TECHNOLOGY LABORATORY

NORTH DAKOTA OIL AND GAS DIVISION

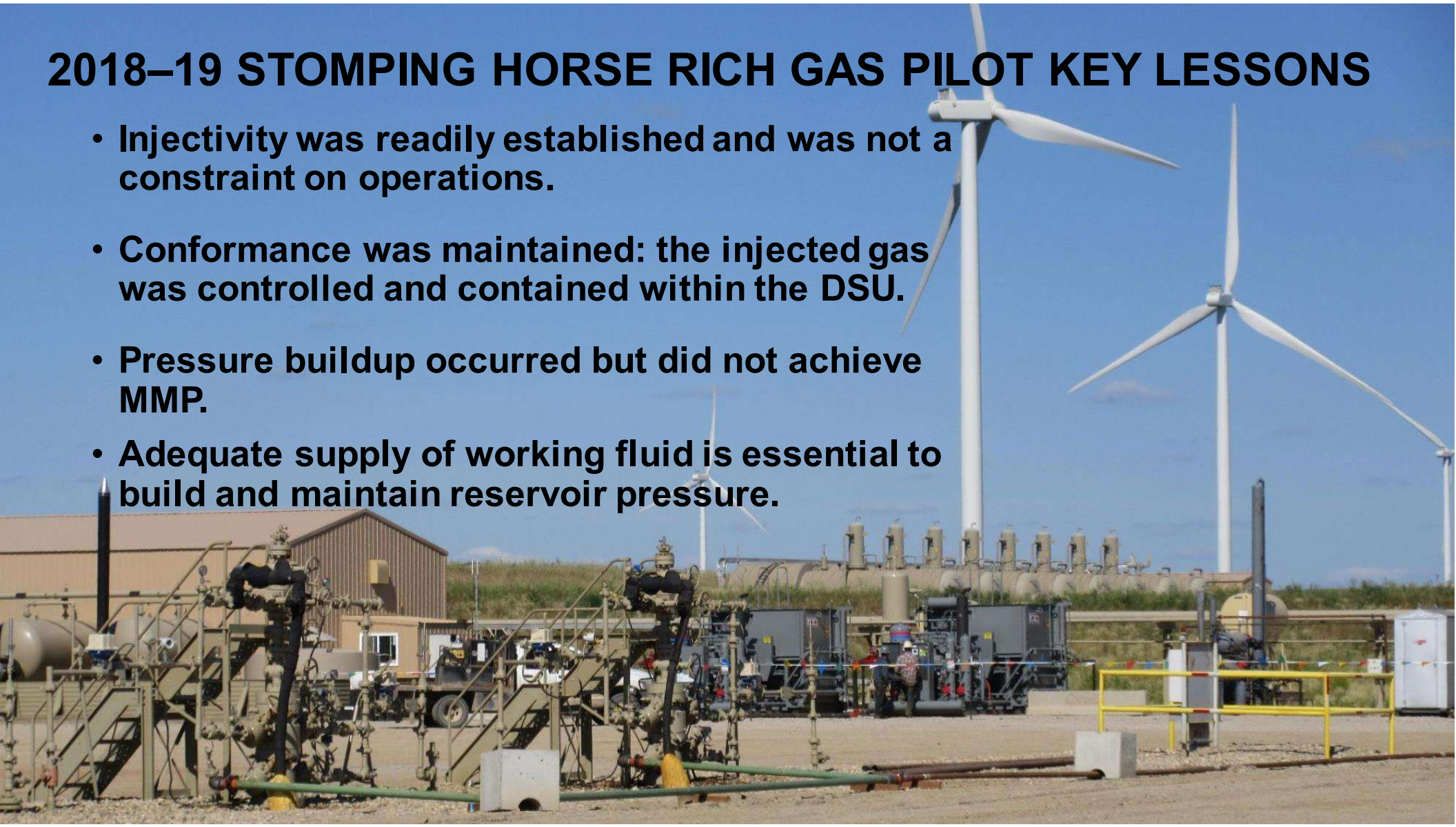
NORTH DAKOTA PETROLEUM COUNCIL

ENHANCED OIL RECOVERY (EOR) PILOT PROJECTS

- Two rich-gas EOR pilot projects supported through BPOP
  - Both conducted in conjunction with Liberty Resources
- Stomping Horse Field Demonstration
  - Supported by BPOP 2.0
  - Implemented in 2018 and 2019
- East Nesson Field Demonstration
  - Supported by BPOP 3.0
  - Implemented from 2021 to present
  - Included collaboration with EOR ETC on the demonstration of a novel gas injection technology

2018–19 STOMPING HORSE RICH GAS PILOT KEY LESSONS

- Injectivity was readily established and was not a constraint on operations.
- Conformance was maintained: the injected gas was controlled and contained within the DSU.
- Pressure buildup occurred but did not achieve MMP.
- Adequate supply of working fluid is essential to build and maintain reservoir pressure.



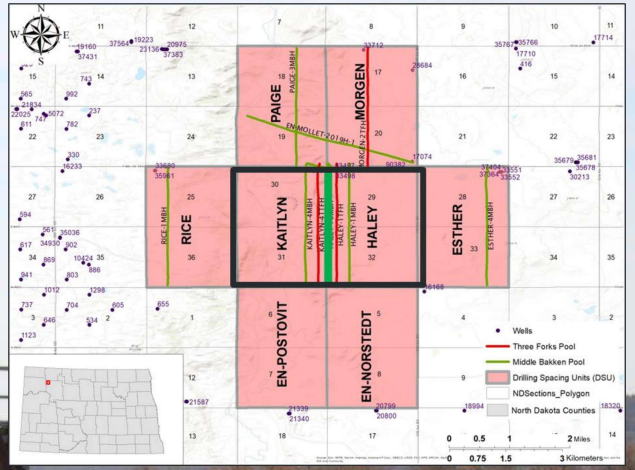
2021–22 EAST NESSON PROJECT HYPOTHESIS AND GOALS

- **Hypotheses:**
  - Coinjection of gas and water can increase pressure beyond MMP and help improve conformance and containment in the Bakken.
  - Coinjection process can lower injection pressure needed and associated cost.
- **The main goal and objective**:
  - To demonstrate the economic viability of enhanced oil recovery from the Bakken petroleum system by using produced rich gas in combination with water and surfactants.

EERC | UND UNIVERSITY OF NORTH DAKOTA

EAST NESSON EOR PILOT IMPLEMENTATION

Pilot Injection Start Date	September 10, 2021
Pilot Injection End Date	October 11, 2021
Number of Cycles	1
Pilot Production Start Date	October 12, 2021
Rich Gas Injected Volume	46MMscf (avg. ~1.5 MMscfd)
Water Injected Volume	40M bbl (avg. ~1.3 Mbwpd)
Surfactant Injected	~2400 gallons
EOR Technology Deployed	A novel EOR injection technology developed by EOR ETC



46 MMscf GAS

40M bbl WATER

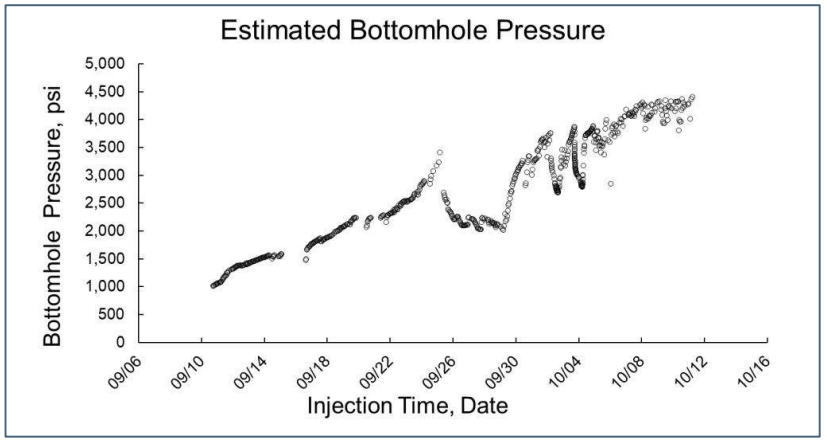
2400 gal SURFACTANT

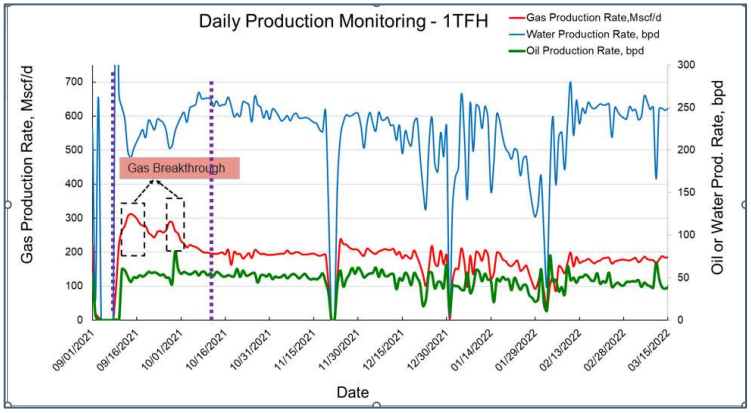
EAST NESSON EOR PILOT OPERATIONAL PRESSURES

Initial Bottomhole Pressure	~1000 psi
Est. Minimum Miscibility Pressure (MMP)	~2430 psi
Max. Wellhead Pressure (measured)	~1300 psi
Max. Bottomhole Pressure (calculated)	~4450 psi

KEY OBSERVATIONS FROM EAST NESSON 1st CYCLE

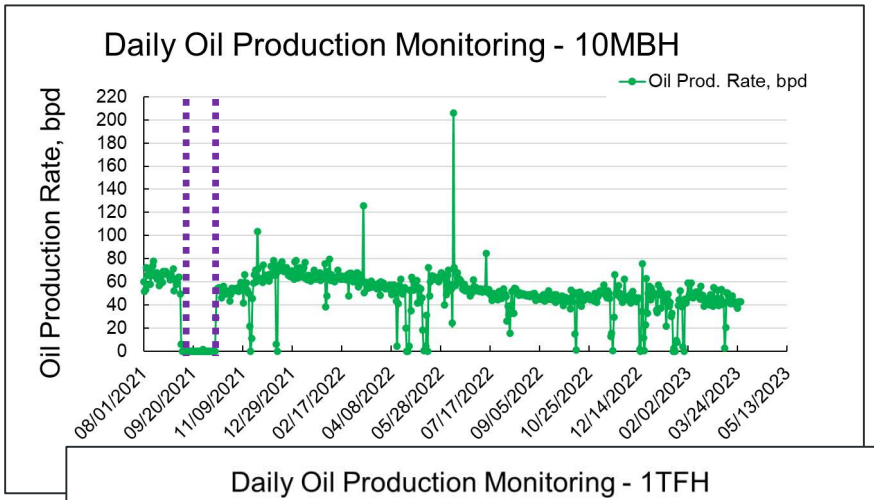
- Injectivity was readily established.
- Significant pressure buildup occurred (from 1000 to 4450 psi) and was maintained with coinjection, far beyond MMP.
- The lower wellhead injection pressure under 1300 psi was maintained by coinjection.
- A minor gas breakthrough at one of the adjacent wells was observed, but it was controlled and contained by increasing the water slug ratios to the well.

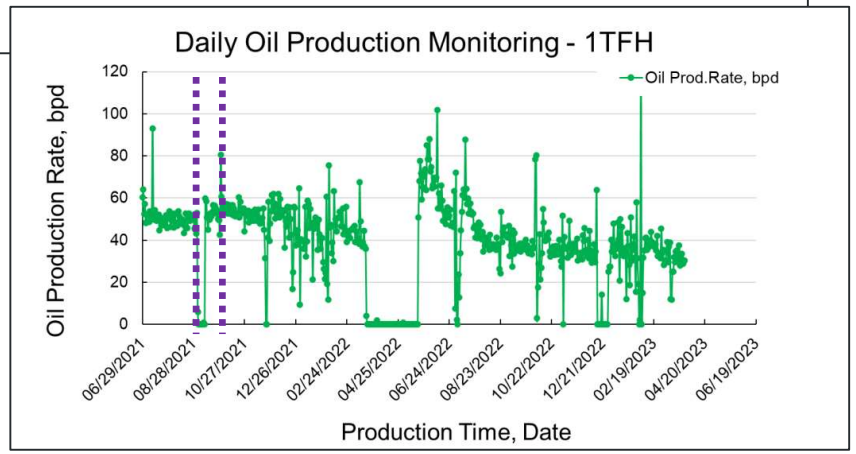




PILOT PRODUCTION RESPONSE

- Reservoir surveillance >19 months
- The estimated average oil rate uplift was 13.3 bpd (24%) for 10MBH (the EOR well).
- The estimated average oil rate uplift was 4.6 bpd (10%) for an offset well (1TFH) .

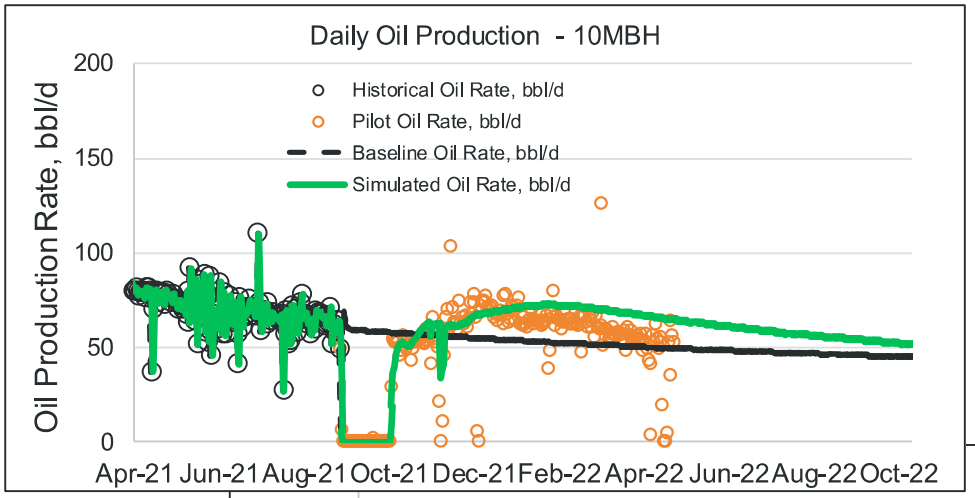


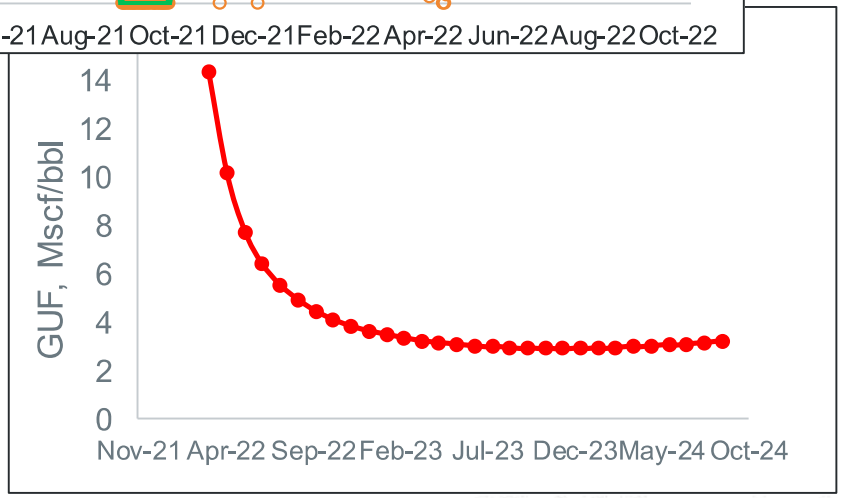


* Purple dashed lines show the injection period

PILOT INCREMENTAL OIL PRODUCTION

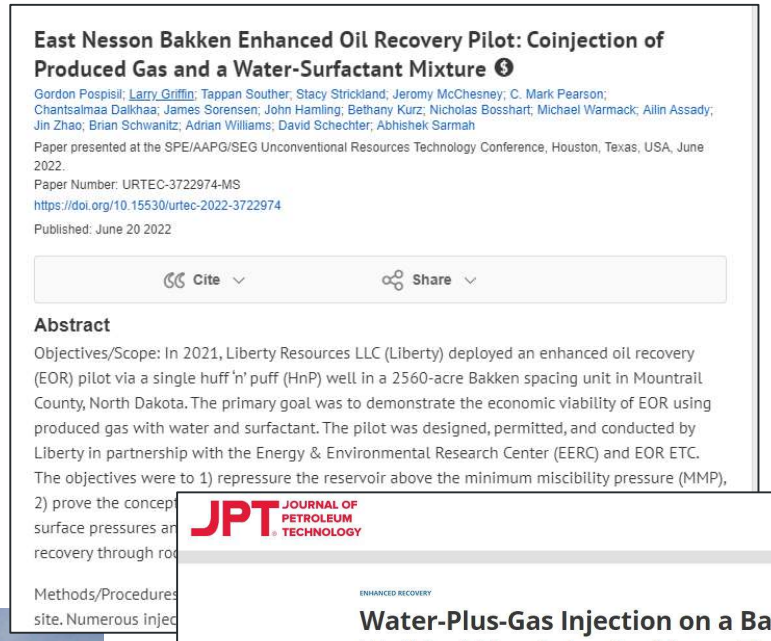
- The predicted incremental oil production from the pilot DSU is >5000 bbl over a 3-year period.
- A net GUF of ~5 Mcf per incremental oil barrel was estimated for the pilot project.
- Hoffman and Reichhardt (2020) report that this range (below 10) suggests an effective EOR process for unconventional reservoirs.





EAST NESSON EOR PILOT

- 1st cycle was a SUCCESS.
- 2nd cycle is being planned for summer/fall 2023.



East Nesson Bakken Enhanced Oil Recovery Pilot: Coinjection of Produced Gas and a Water-Surfactant Mixture

Gordon Pospisil; Larry Griffin; Tappan Souther; Stacy Strickland; Jeromy McChesney; C. Mark Pearson; Chantsalmaa Dalkhaa; James Sorensen; John Hamling; Bethany Kurz; Nicholas Bosshart; Michael Warmack; Ailin Assady; Jin Zhao; Brian Schwanitz; Adrian Williams; David Schechter; Abhishek Sarmah

Paper presented at the SPE/AAPG/SEG Unconventional Resources Technology Conference, Houston, Texas, USA, June 2022.
Paper Number: URTEC-3722974-MS
https://doi.org/10.15530/urtec-2022-3722974
Published: June 20 2022

Cite Share

Abstract

Objectives/Scope: In 2021, Liberty Resources LLC (Liberty) deployed an enhanced oil recovery (EOR) pilot via a single huff 'n' puff (HnP) well in a 2560-acre Bakken spacing unit in Mountrail County, North Dakota. The primary goal was to demonstrate the economic viability of EOR using produced gas with water and surfactant. The pilot was designed, permitted, and conducted by Liberty in partnership with the Energy & Environmental Research Center (EERC) and EOR ETC. The objectives were to 1) repressure the reservoir above the minimum miscibility pressure (MMP), 2) prove the concept
surface pressures ar
recovery through ro

Methods/Procedures
site. Numerous injec

JPT JOURNAL OF PETROLEUM TECHNOLOGY

Topics

ENHANCED RECOVERY

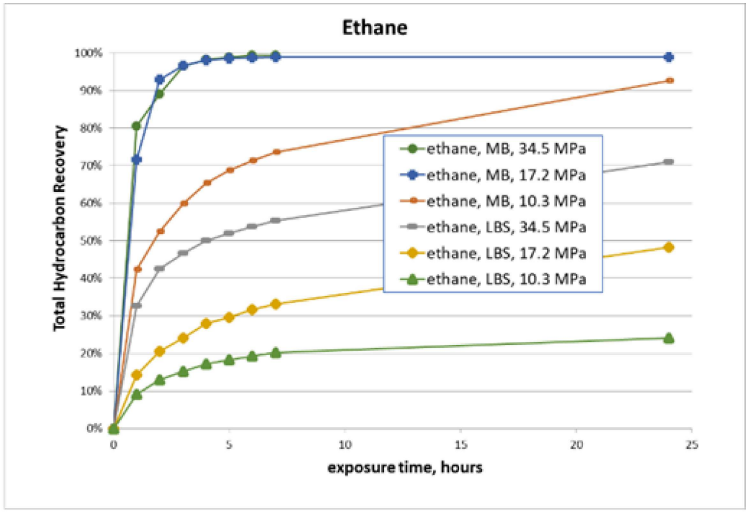
Water-Plus-Gas Injection on a Bakken Well Pad May Solve Problems That Stymied Shale EOR

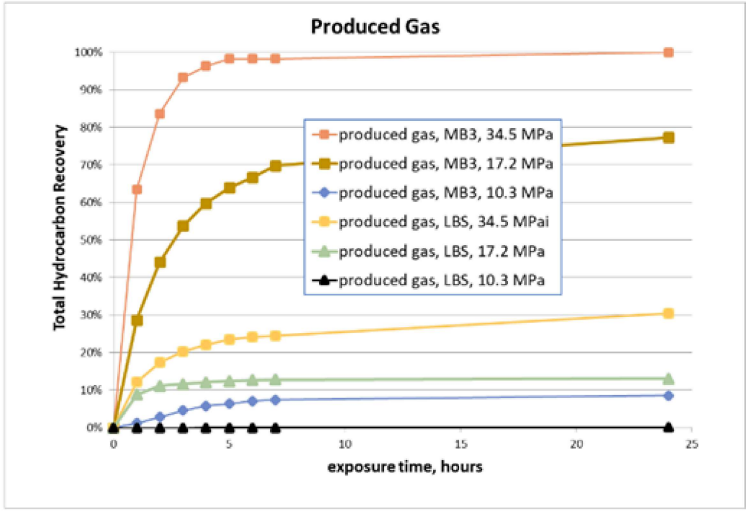
Injecting gas plus water proved more effective and less costly than gas-only injection in the Bakken.

October 1, 2022 By Stephen Rassenfoss
Journal of Petroleum Technology

EOR SUPPORT ACTIVITIES

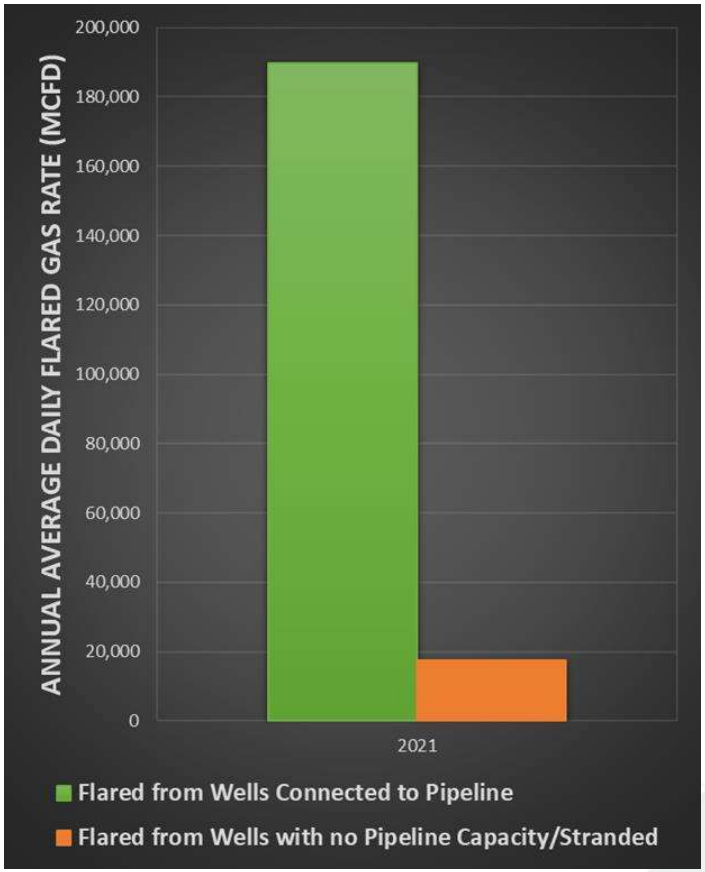
- BPOP has supported laboratory-based testing of Bakken crude oil and rock samples to better understand the potential for CO_2 and rich gas EOR in the Bakken petroleum system (BPS). BPOP activities in this space have included the following:
  - Minimum miscibility pressure (MMP) requirements of CO_2, methane, ethane, propane, and blends of gas to solubilize Bakken crude and maximize oil recovery.
  - Evaluation of the ability of various Bakken produced gases and gas blends to permeate various BPS rock types and effectively extract oil.





FLARING AND FUGITIVE EMISSION MITIGATION

- Early BPOP efforts (2013–2104) focused on participation in the North Dakota Petroleum Council's Flaring Task Force to formulate a multistage plan to decrease flaring rates:
  - BPOP provided flaring statistic analysis that served as the foundation for these plans. The BPOP team presented the resulting plan to the governor in January 2014, which is now integral to regulations enforced by ND DMR.
- More recent efforts have focused on development and implementation of a technology (Polar Bear^{SM}) that will economically eliminate flaring from wellsites where existing technologies for gas capture are uneconomical.



Polar Bear℠ provides cost-efficient recovery of flared gas that is not economical with conventional technology.

- Increase the environmental competitiveness of North Dakota oil
- Attract investment and jobs
- Generate revenue
- Patented
- Manufactured in North Dakota

Polar Bear℠

- Robust
- Adaptive
- Environmentally sensitive

POLAR BEAR℠ TECHNOLOGY PROGRESS

- BPOP has helped to advance the Polar Bear℠ technology through laboratory testing and support to develop a prototype.
- BPOP partners have closely monitored development of the technology, and as a result, the EERC acquired a license and three new patents.
- BPOP will support the first field trials of the concept in 2023.

Flaring is geographically distributed.

Many locations flare small volumes that, in aggregate, contribute to most of the remaining flared gas.

Solution is needed to capture gas for low flow rates at many locations and at higher rates for bulk and test facilities.

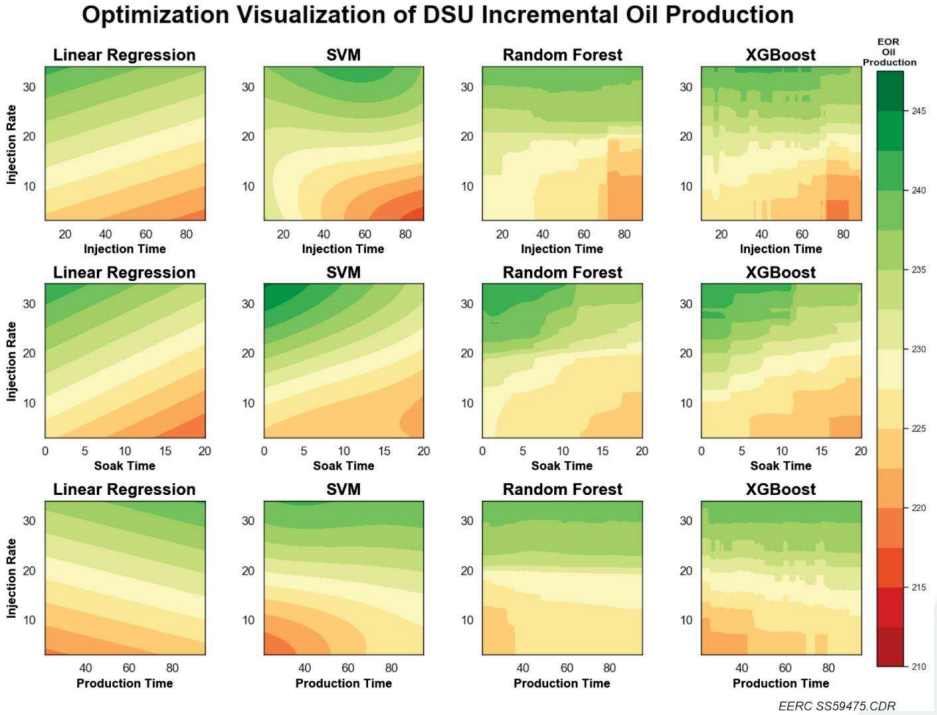
AI AND ML FOR EOR IN THE BAKKEN – 2021 HIGHLIGHTS

Artificial Intelligence & Machine Learning for Unconventional EOR Strategies – *Created algorithms informing reservoir performance predictions based on injection rate versus soak, production, and injection time.*

- *Created a tool for real-time visualization and forecasting to support real-time decision-making during production operations.*

Modeling Conformance Treatments and EOR Strategies – Explored advanced modeling and simulation techniques to determine mechanisms for improving conformance control in the Bakken, investigate alternative EOR strategies, and improve simulation run times.

- Embedded Discrete Fracture Modeling (EDFM) was shown to improve simulation run times and demonstrated excellent results matching fluid injection and production data.
- ***Modeling and simulation studies showed conformance could be gained through water injection or surfactant injection and demonstrated improvements in oil recovery.***



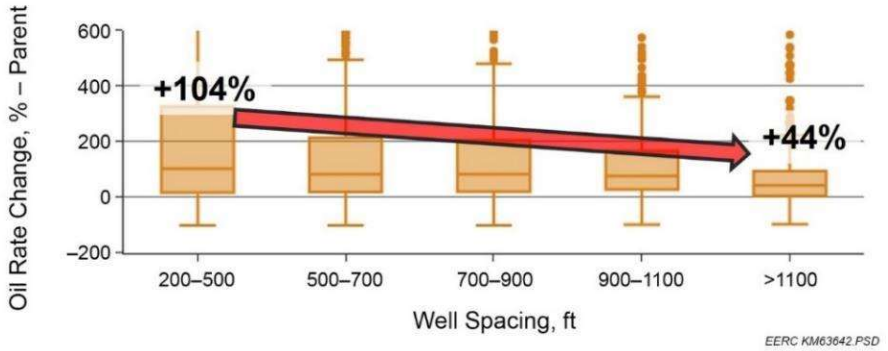
DATA ANALYTICS WORK PRODUCTS

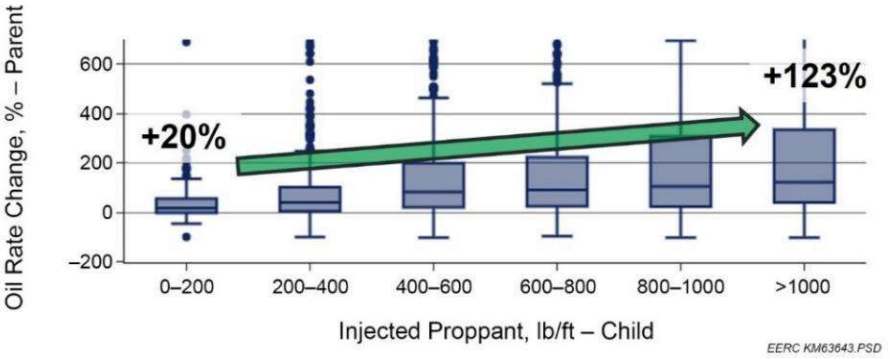
- Well completion and production: 7
- Refractured wells: 3
- H_2S in Bakken production: 1
- Online tools: 2

- We apply state-of-the-art statistics and ML tools to broad data sets of well completion and production to draw inferences about Bakken production and optimization.

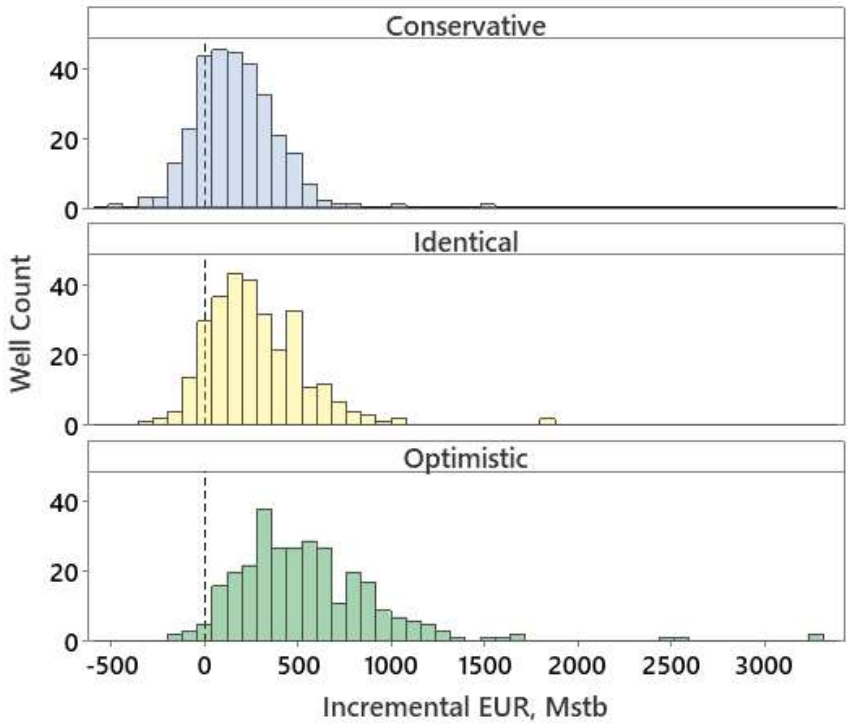
COMPLETION AND PRODUCTION DATA ANALYTICS

- The BPOP team applies state-of-the-art statistics and ML tools to identify key factors affecting oil, gas, and water production. Key topics include:
  - Quantify relationships between completion type/size and well production.
  - Evaluate completion optimization.
  - Assess parent–child well interactions and optimal DSU development.
  - Estimate core area expansion and future Bakken development potential.





REFRACTURED WELLS



- We continue to evaluate the performance of refractured wells to understand better the key factors that improve post-refrac well performance.
- This work has been continually updated as additional insight and data related to Bakken well refracs become available.
  - Three assessments have been conducted to date (2018, 2020, and 2023).
- The results suggest that 340 wells still exist in the Bakken that would be promising candidates for refracturing (single-stage completions, older completion dates, and barefoot completions).
- Refracturing these wells was estimated to produce a discounted net oil revenue of approximately $1.5 billion, which reflects the median outcome after deducting the refrac cost, taxes, and royalties.

H_2S GENERATION IN BAKKEN PRODUCTION

Goal

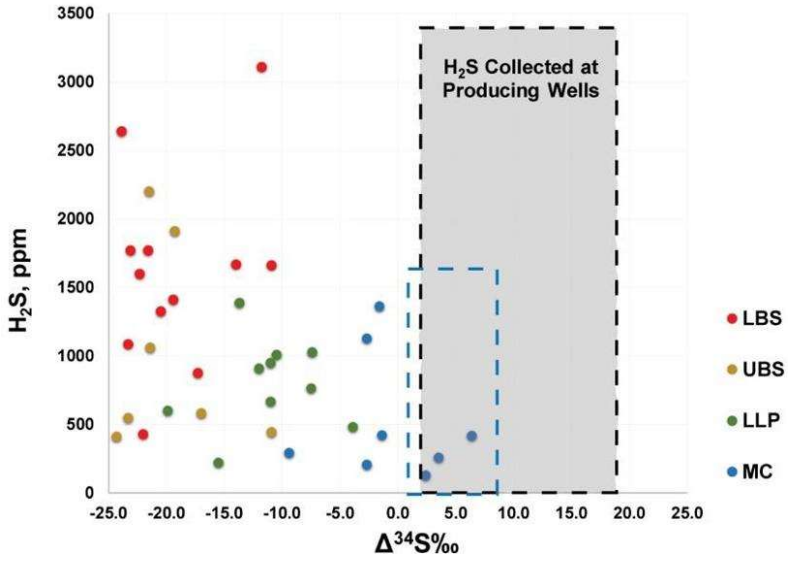
Understand mechanisms of the souring of Bakken production to develop a mitigation strategy

- Geochemical characterization of the source rocks and sulfur speciation work
- Laboratory simulation experiments including rocks and fluids
- Acquisition of H_2S concentration data provided by BPOP partners
- Collection of H_2S and fluid samples across the Bakken play
- Isotope characterization of S in H_2S, brine, and anhydrite
- Screening technologies to reduce the risk of souring

Results

- Possible mechanisms of souring were identified.
- Lab experiments and S isotopes confirmed the mechanism of souring via out-of-zone completion.
- The next phase of BPOP will focus on evaluating technologies to reduce the risk of souring.

Values $\delta^{34}S$ of Source Rock Pyrolysis and Producing Well H_2S

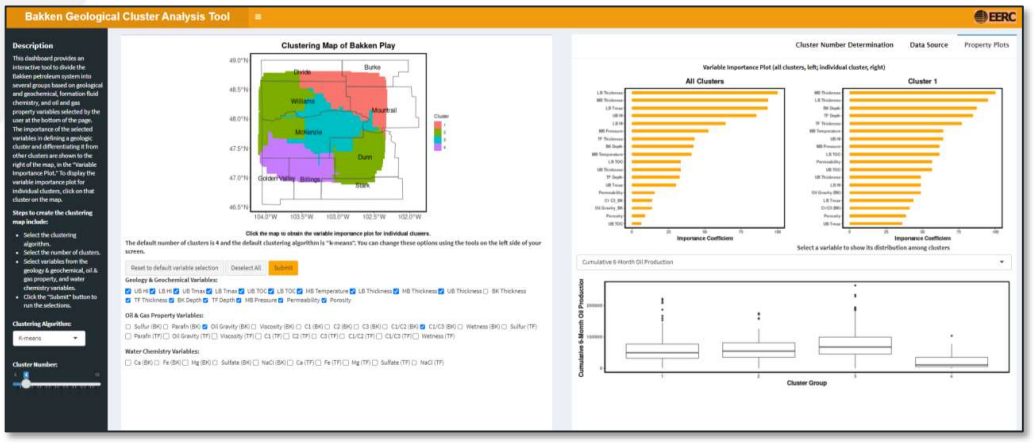


The blue rectangle outlines the range where Mission Canyon $\delta^{34}S$ matches $\delta^{34}S$ of well-produced H_2S.

EERC | UND UNIVERSITY OF NORTH DAKOTA

Critical Challenges. Practical Solutions.

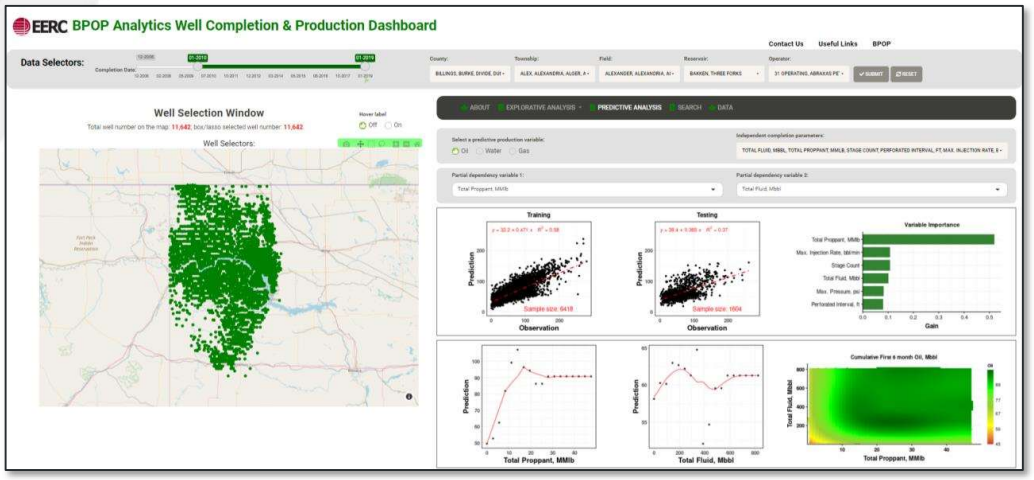
GEOLOGICAL CLUSTER ANALYSIS TOOL



- An interactive tool that subsets BPS into groups based on geological and geochemical, formation fluid chemistry, and oil and gas property variables selected by the user at the bottom of the page.
- The importance of the selected variables in defining and differentiating a geologic cluster from other clusters is shown to the right of the map in the "Variable Importance Plot." The user can click on that cluster on the map to display the variable importance plot for individual clusters.
- The tool provides value to our BPOP partners by providing an interactive resource for exploring the Bakken, investigating the relative importance of different features within specific geographic areas, and rapidly screening large amounts of information before moving forward with more detailed, site-specific analyses.

The Bakken Geological Cluster Analysis Tool can be found on the Partners-Only Website!

WELL COMPLETION & PRODUCTION DASHBOARD



- An interactive tool that allows the user to select a set of wells from BPS; explore relationships between oil, gas, and water production and several well completion parameters; and fit ML models.
- The predictive modeling uses Extreme Gradient Boosting (XGBoost) as the algorithm to construct predictive models for selected wells to predict well oil, gas, or water production (the response or target variable) from a set of user-defined completion parameters (the independent variables of features).
- The tool provides value to our BPOP partners by providing an interactive resource for exploring the Bakken and investigating which completion parameters drive oil, gas, and water production within subsets of the Bakken and rapidly screening large amounts of information before moving forward with more detailed, site-specific analyses.

The Analytics Well Completion & Production Dashboard can be found on the Partners-Only Website!

CARBON INTENSITY TOOL

Carbon Intensity Tool

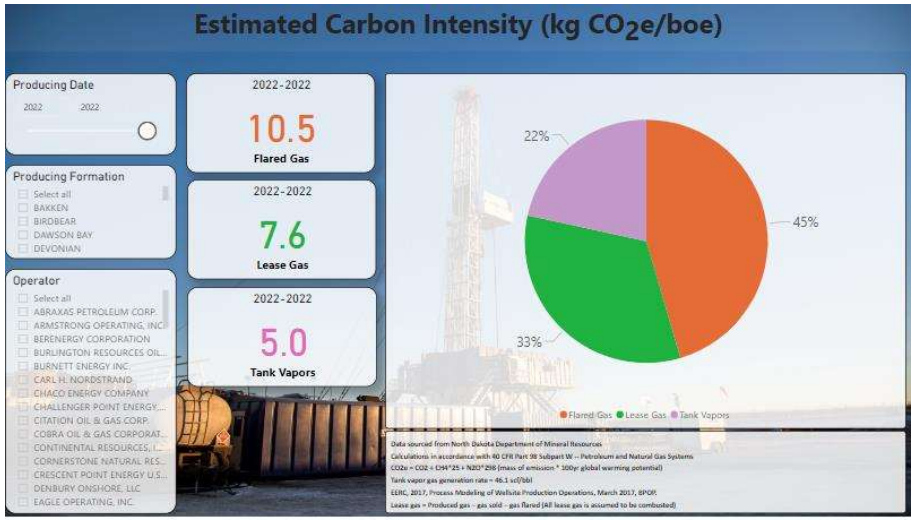
Premium

Date Published: 9/26/2022

'This dashboard provides an interactive tool to assess North Dakota oil & gas production related carbon intensity (kg CO_2e/boe). Produced Gas, Flared Gas, Lease Gas, and estimated Tank Vapors data is presented over time, shown geographically, and grouped by Central Tank Battery (CTB) f...'

Provides BPOP partners a means to examine temporal data pertaining to carbon intensity:

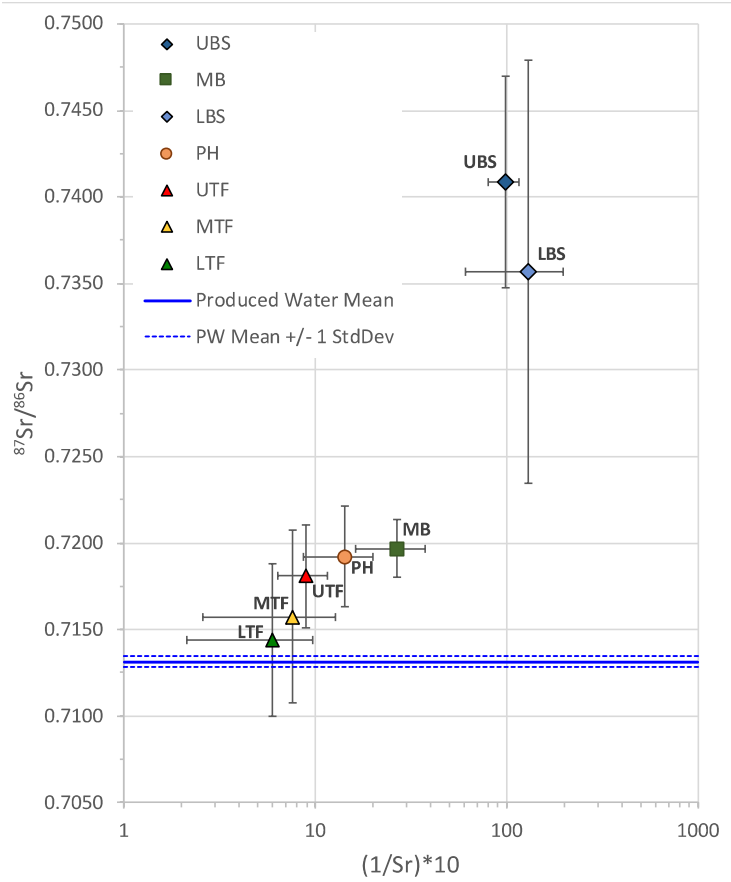
- Flaring
- Tank vapors
- Production plots
- Flaring profiles
- Geospatial tools and mapping



PRODUCED WATER AND OIL FINGERPRINTING

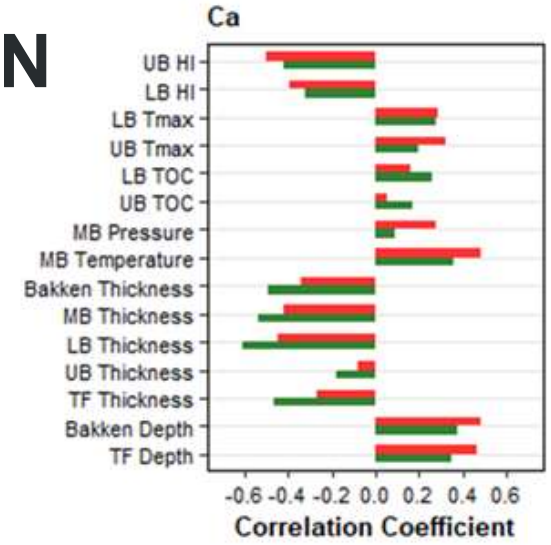
The BPOP team has been developing and testing fingerprinting techniques for produced fluids (water and oil) and rock extracts to:

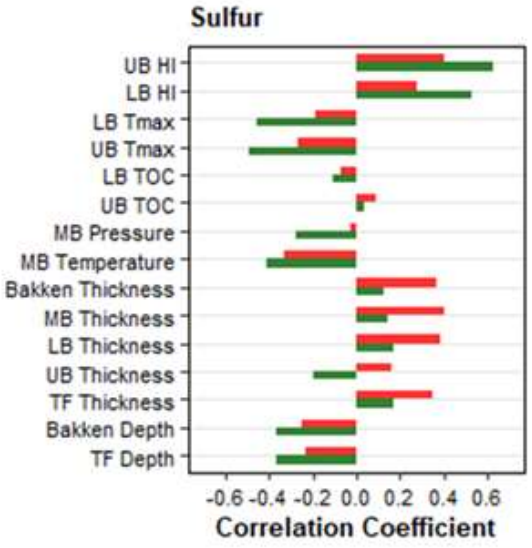
- Evaluate reservoir continuity.
- Understand reservoir drainage volume.
- Evaluate reservoir communication and mixing.
- Monitor production and compositional changes in produced fluids.
- Understand hydrocarbon charge from source rocks.



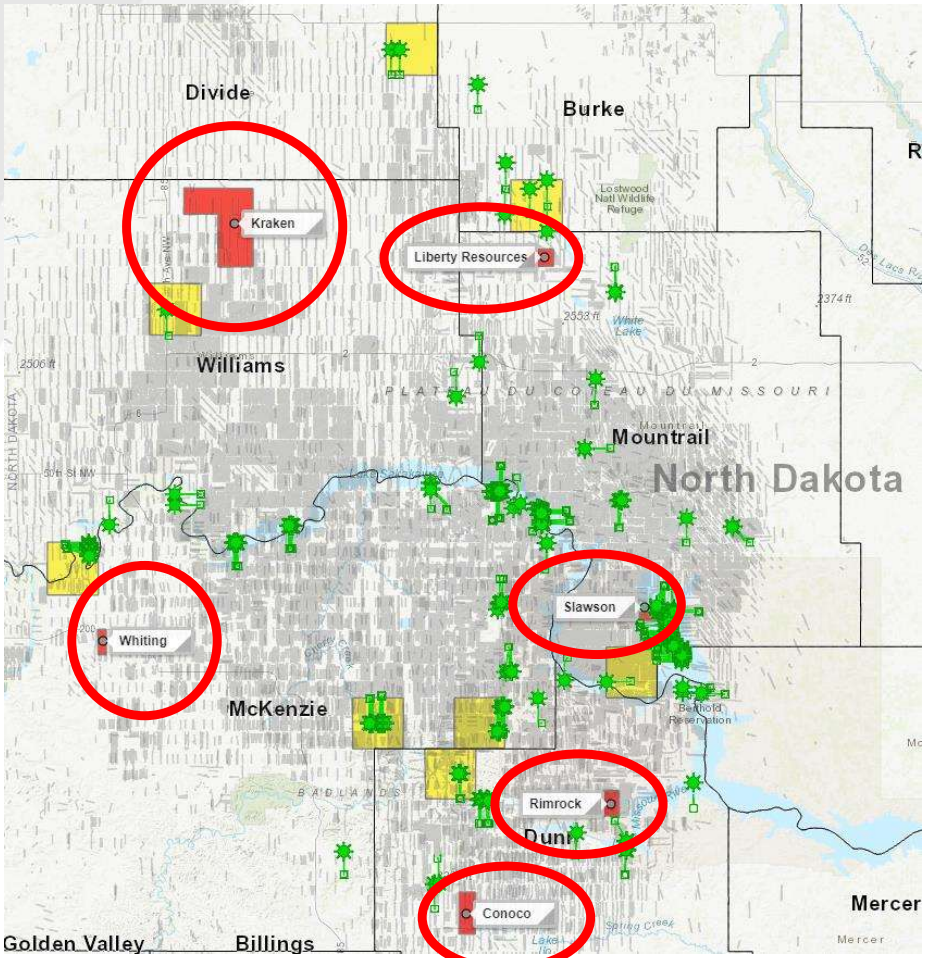
PRODUCED FLUIDS CHARACTERIZATION

- Through BPOP, the EERC has developed and continues to expand a data set of produced fluids compositions (brine and oil) to monitor changes in chemistry over time and to evaluate chemical differences in the different geologic units of BPS.
- The data collected through BPOP, coupled with the fluids fingerprinting techniques developed by the team, are being used to better understand the contribution of fluids from different zones (within and overlying/ underlying BPS) within produced oil and brine.





EVALUATION OF 3-MILE LATERALS



The red circles indicate new 3-mile horizontal well developments.

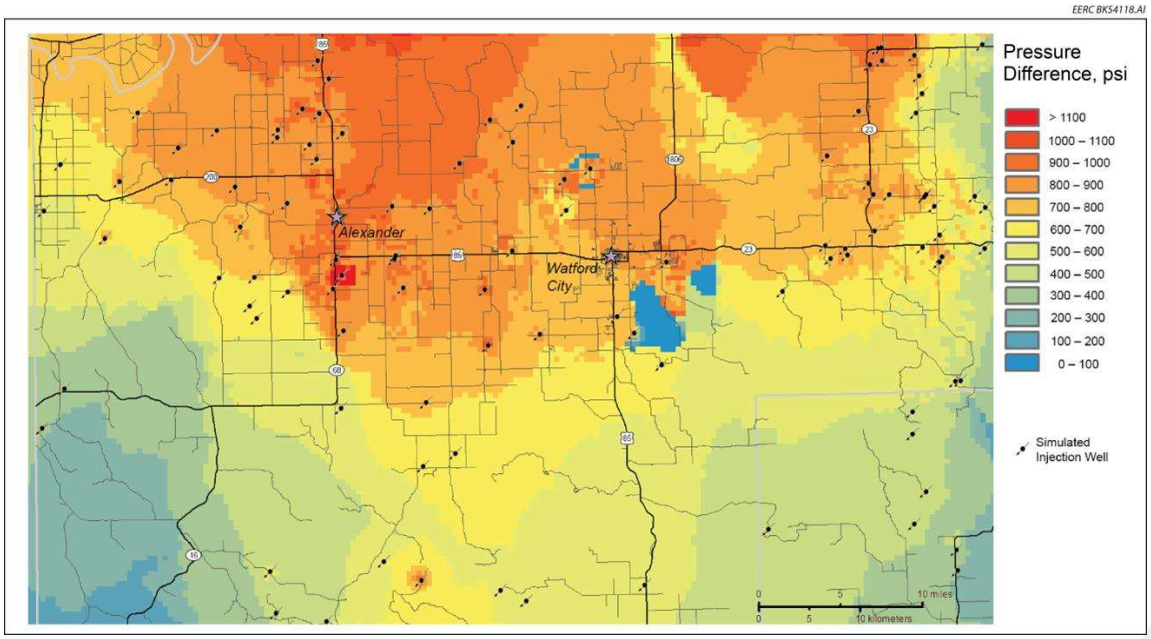
- As operators look for new ways to develop acreage outside of the core, BPOP investigated the history and prospect for 3-mile lateral wells.
- Extensive analysis was completed to compare **similar acreage** between 2- vs. 3-mile horizontal well performance.
- Data set: 235 wells dating back to 2011.
- Results provide insights to anticipated well performance targeting 50% additional EUR per well.
- Operators are pushing forward with 3-mile lateral plans. Development is no longer driven by geography and occurring in core and noncore areas.
- 70% of operators appear to be realizing anticipated additional production.

DSU SETBACK RULES

- BPOP facilitated a science-based process to determine if a change in rules regarding state drilling spacing unit (DSU) setbacks was prudent.
- To evaluate the impact of potential reductions in the setback distance from DSU boundaries, BPOP refereed several teams that performed independent modeling and numerical simulation based on criteria established by BPOP and the participants of the evaluation.
- The results of the effort were presented to the NDIC by the EERC and its partners in 2016, resulting in a reduction in DSU setbacks that allowed operators and the state of North Dakota to maximize the extraction of recoverable resources without undue risk to correlative rights.
- The estimated increase in tax revenue as a result of the changes was estimated at $1.27 billion.

SALTWATER DISPOSAL POTENTIAL OF THE INYAN KARA

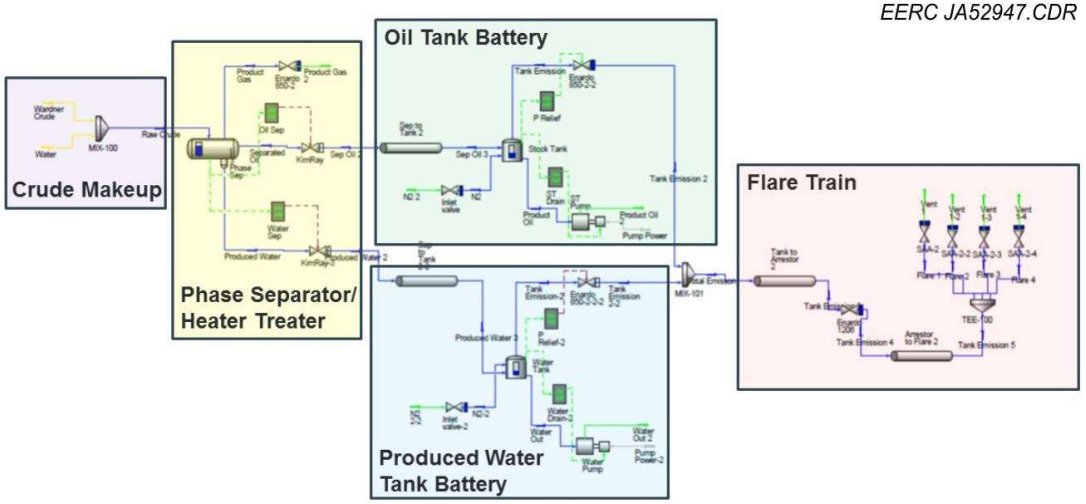
- Because of industry's reliance on the Inyan Kara Formation as a saltwater disposal (SWD) target, the BPOP team performed modeling and simulation to estimate local and regional pressure effects that have occurred as a result of historic SWD.
- Areas that may be suitable or problematic for disposal were evaluated through reservoir simulation of hypothetical future injection scenarios.



FACILITY PROCESS OPTIMIZATION

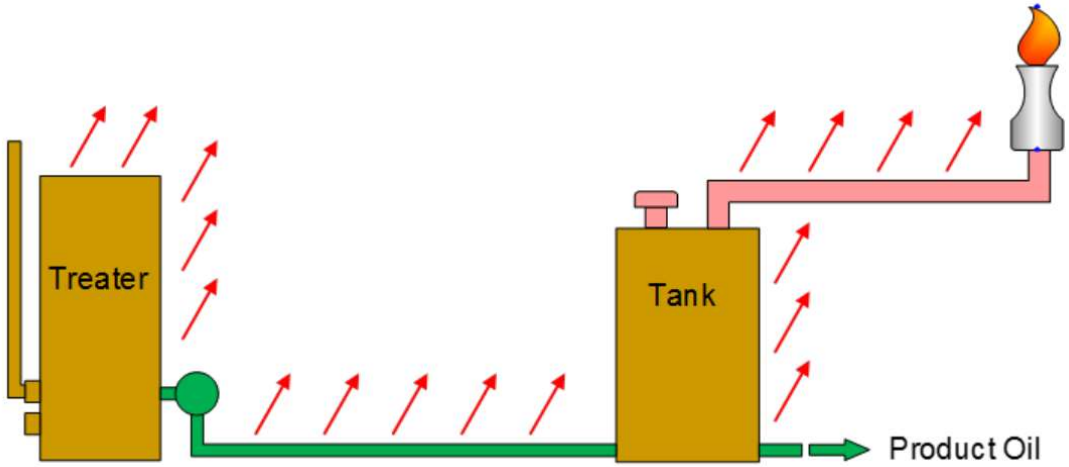
- Surface facilities are a key link in the overall Bakken production chain. Through BPOP, models were created with partner input to examine, in detail, parameters that affect fugitive emissions and crude oil properties.
- The modeling results were used to derive actionable suggestions for partner producers to consider in their facility operations as well as new, novel methods of operation.

EERC JA52947.CDR



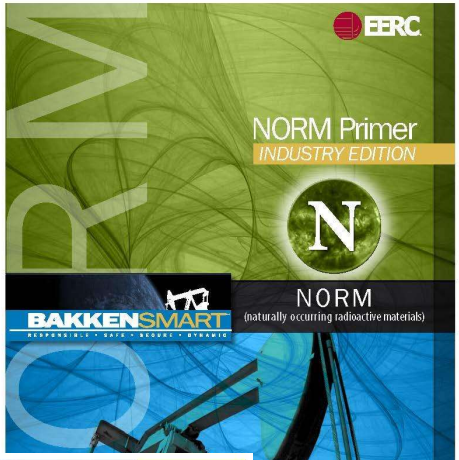
CRUDE OIL VAPOR PRESSURE MANAGEMENT

- Through BPOP, the EERC worked closely with industry operators to gather data, develop computer models, and validate them with field data to determine the optimal conditions for efficient operation of heater treaters.
- The results help operators comply with the state and midstream operators in cold weather and minimize hydrocarbon losses to gas stream in hot weather.



NORM-RELATED SUPPORT

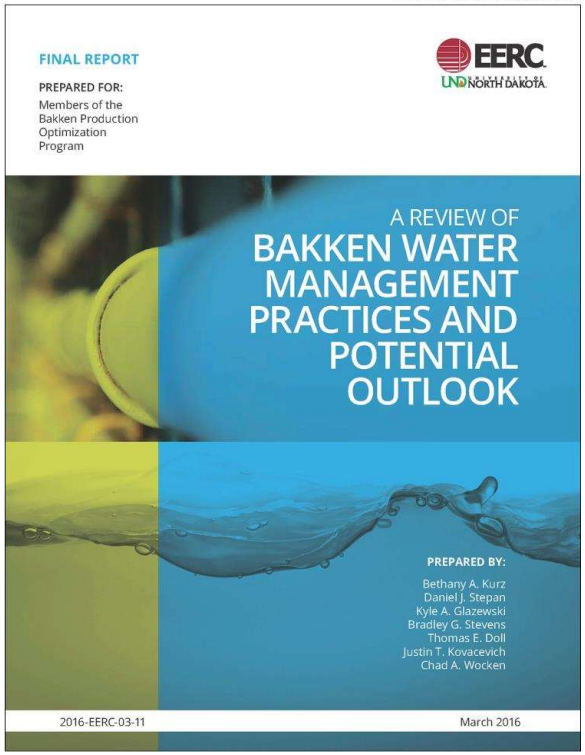
- BPOP representatives served as subject matter experts and advisors to NDPC's Naturally Occurring Radioactive Materials (NORM) Task Force.
- BPOP produced a series of NORM-related fact sheets and a primer to educate the general public on NORM and how NORM is regulated in North Dakota.
- The EERC coordinated a NORM sampling effort among several oil producers to further evaluate levels of NORM in drill cuttings, produced water, and fracturing fluid flowback. The results were interpreted by the EERC and used to help inform the state and the NORM Task Force.



ADDITIONAL ACCOMPLISHMENTS

- **Bakken Water Opportunities Assessment**
  - Performed two evaluations of key water use and handling issues in the Bakken, including estimation of future water supply and brine disposal needs, evaluation of brine treatment technologies and their applicability for Bakken produced water, and considerations for brine recycling and reuse.
- **Technical Forums for Industry**
  - BPOP provided a regular forum for peer-to-peer technical discussions on issues affecting all partners. Partners commented that this function is available nowhere else.

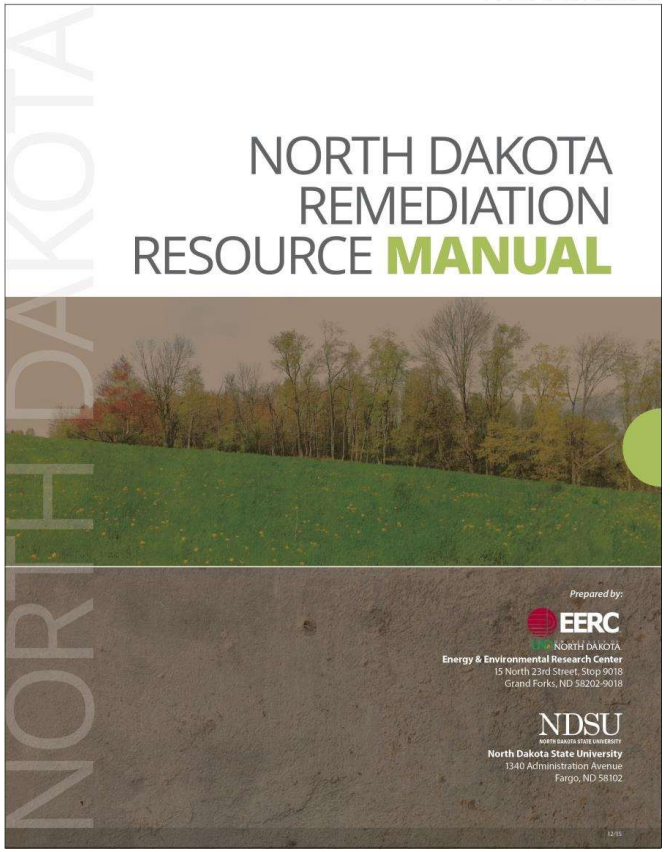
EERC JA52952.CDR



ADDITIONAL ACCOMPLISHMENTS

- **Remediation of Brine Spills**
  - BPOP coordinated discussion with state regulators and industry groups on the topic of best practices for remediation of brine spills associated with oil development. Based on the data and feedback received from these discussions, as well as from current research and literature, the EERC completed a best practices remediation manual that was shared with the state and industry.

EERC JA52956.CDR



APPENDIX B

OIL PRODUCTIVITY AND GEOGRAPHIC EXTENT OF BPOP PARTNER OPERATIONS

OIL PRODUCTIVITY AND GEOGRAPHIC EXTENT OF BPOP PARTNER OPERATIONS

The bar graph in Figure B-1 shows the top 20 operators in North Dakota in terms of daily oil production. BPOP 3.0 partner companies included four of the top five producers, six of the top ten producers, and eight of the top 20. The maps in Figures B-2 and B-3 show the geographic distribution of the BPOP 3.0 partners well locations, illustrating the fact that BPOP partnership spans a vast majority of the Bakken play in North Dakota. The eight BPOP partners also represent a diversity of company sizes, ranging from globally operating supermajors to companies for which the Bakken is the primary asset. This diversity within the partnership ensures that the views and needs of a wide variety of operators are served, fostering innovation, knowledge sharing, and broad applicability of results. It is anticipated that the eight BPOP 3.0 partners companies will continue their participation in BPOP 4.0. The EERC will actively recruit new partners and seek to grow the value of the program.

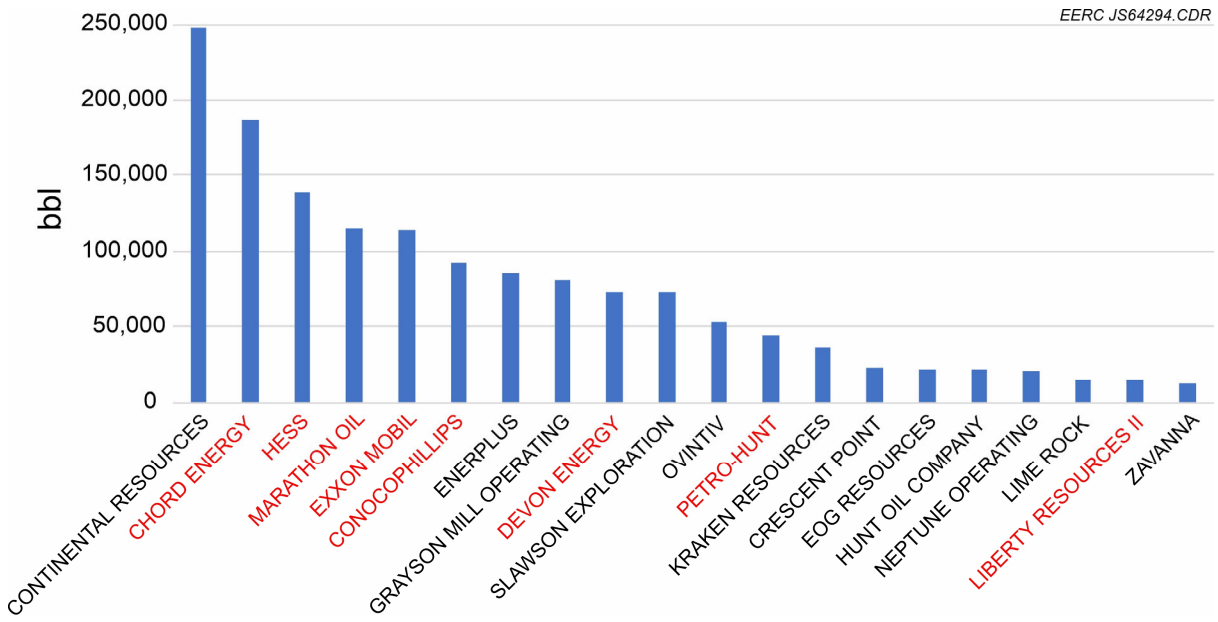


Figure B-1. Top 20 operators in North Dakota. BPOP partners are highlighted in red.

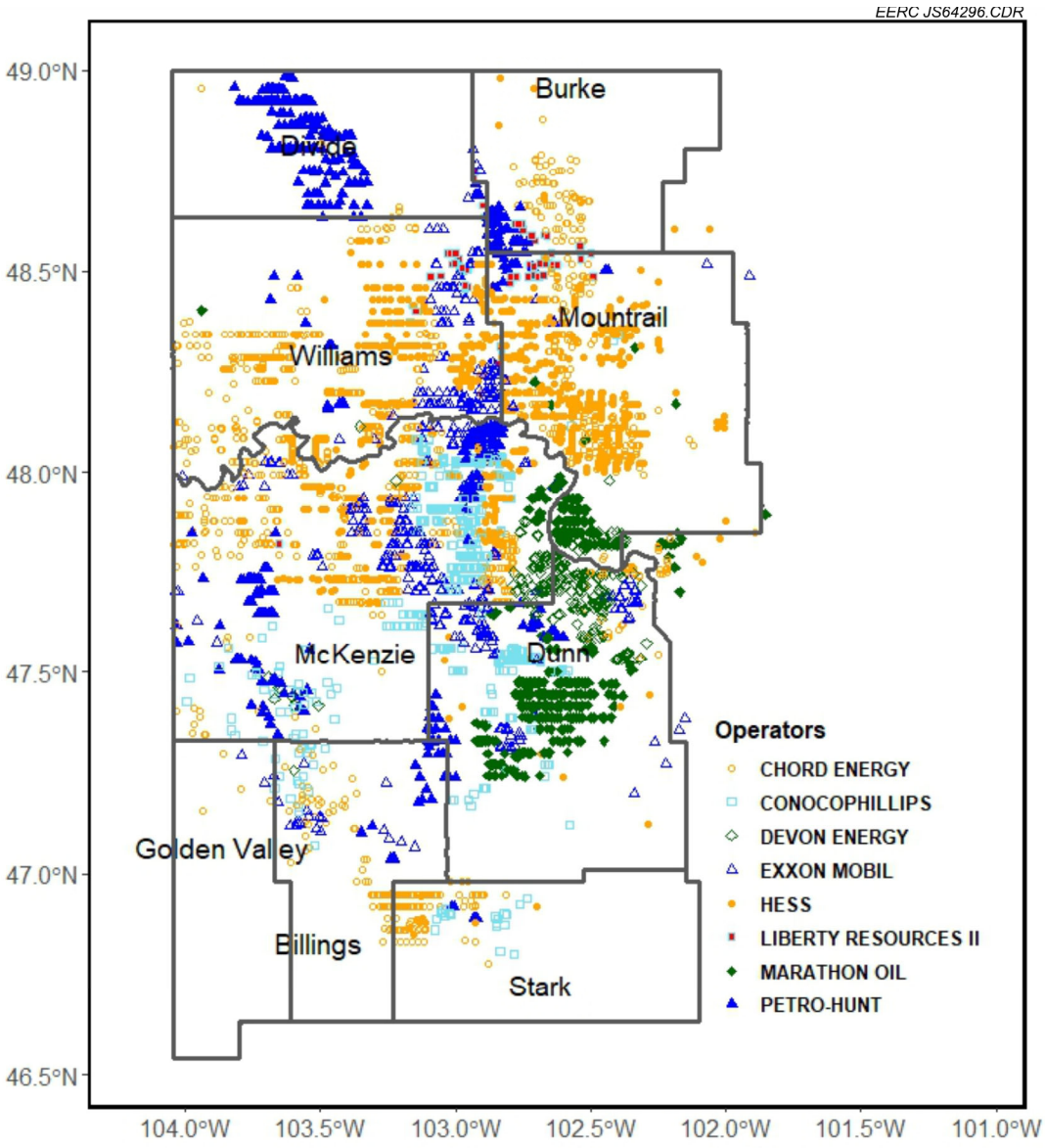


Figure B-2. Map showing geographic distribution of BPOP partner well locations.

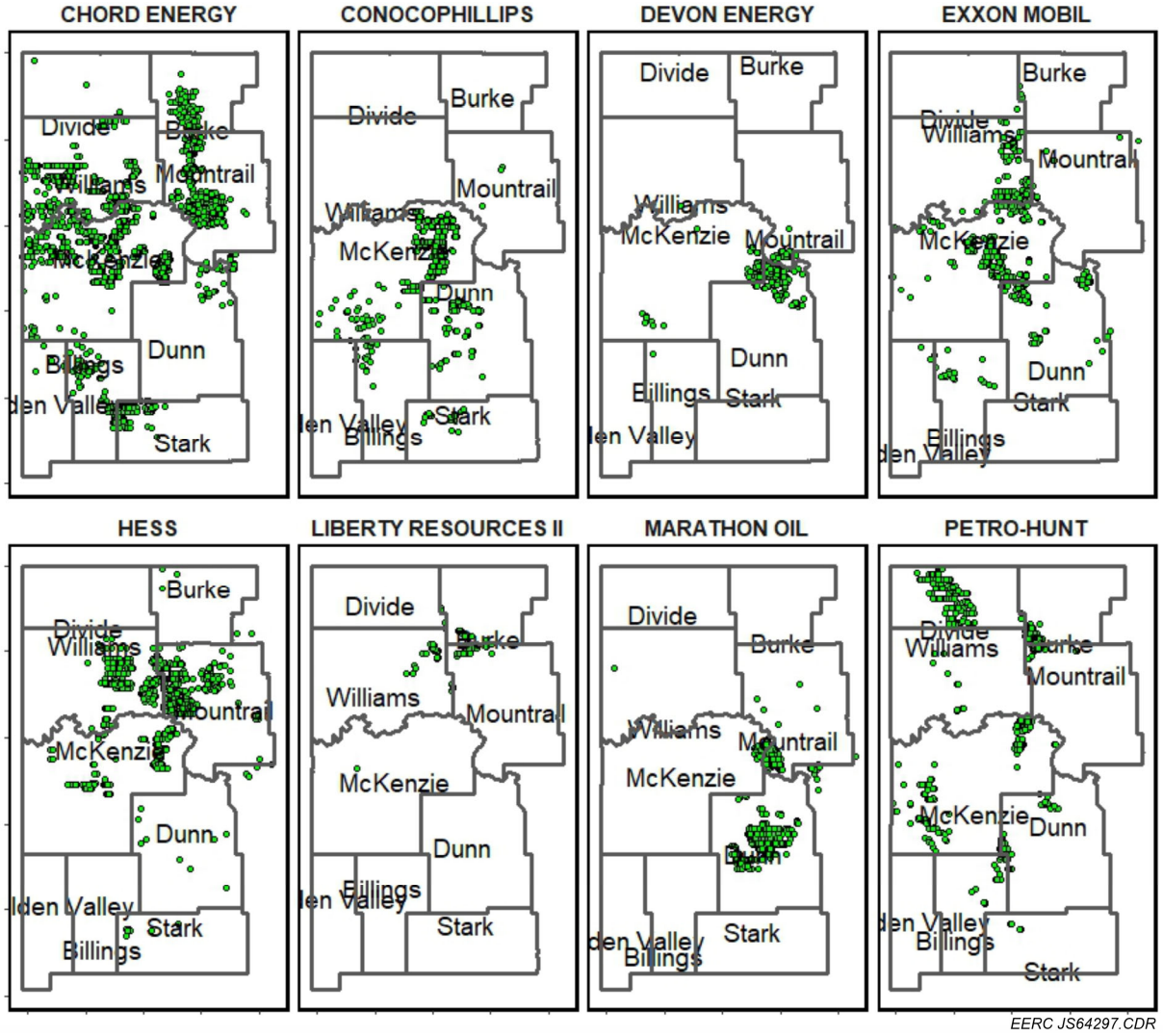


Figure B-3. Maps of well locations for each of the BPOP partners.

APPENDIX C

RESUMES OF KEY PERSONNEL

JAMES A. SORENSEN
Director of Subsurface Research and Development
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5287, jsorensen@undeerc.org

Principal Areas of Expertise
Mr. Sorensen's primary areas of interest and expertise are enhanced oil recovery (EOR) in unconventional tight oil formations, CO_2 utilization and storage in geologic formations, and tight oil resource assessment and development.

Education and Training
M.Eng., Petroleum Engineering, University of North Dakota, 2020.
B.S., Geology, University of North Dakota, 1991.

Research and Professional Experience
October 2019–Present: Director of Subsurface Research and Development, EERC, UND. Mr. Sorensen is responsible for developing and managing programs and projects focused on conventional, unconventional, and enhanced oil and gas production; the geological storage of CO_2; geothermal; and other energy and environmental research.

July 2018–September 2019: Assistant Director for Subsurface Strategies, EERC, UND. Mr. Sorensen developed business opportunities, provided technical support and guidance regarding emerging areas of research, and served as a principal investigator and task manager for projects related to the sequestration of CO_2 in geologic media and the sustainable development of tight oil resources.

1999–July 2018: Principal Geologist, EERC, UND. Mr. Sorensen served as manager and co-principal investigator for programs to develop strategies for CO_2 utilization and storage. He also led research focused on enhanced oil recovery (EOR) in the Bakken.

1997–1999: Program Manager, EERC, UND. Mr. Sorensen managed projects focused on produced water management and environmental fate of natural gas-processing chemicals.

1993–1997: Geologist, EERC, UND. Mr. Sorensen conducted field-based hydrogeologic investigations focused on natural gas production sites.

1991–1993: Research Specialist, EERC, UND. Mr. Sorensen assembled and maintained comprehensive databases related to oil and gas drilling, production, and waste management.

Professional Activities
Member, Society of Petroleum Engineers

Publications
Mr. Sorensen has coauthored nearly 200 publications.

BETHANY A. KURZ
Director of Analytical Solutions
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5050, bkurz@undeerc.org

Principal Areas of Expertise

Ms. Kurz's principal areas of interest and technical expertise include carbon capture, utilization, and storage (CCUS); produced natural gas storage; enhanced oil recovery (EOR) in conventional and unconventional oil and gas reservoirs; application of machine learning and data analytics to CCUS and oil and gas development; produced water and drilling waste management; assessment of critical materials in coal and produced brine; and resource management related to energy development.

Education and Training

M.S., Hydrogeology, University of North Dakota, Grand Forks, ND, 1998.
B.S., Geochemistry, Bridgewater State University, Bridgewater, MA, 1995.

Research and Professional Experience

May 2021–Present: Director of Analytical Solutions, EERC, UND. Ms. Kurz is responsible for developing business and research opportunities to address challenges in all areas of energy and natural resources development and management. She leads programs and projects related to CCUS; application of machine learning and artificial intelligence to CCUS and conventional and unconventional oil and gas development; EOR; produced water and drilling waste management; and critical materials resource assessments. Ms. Kurz also leads the EERC's research laboratories and a multidisciplinary team of scientists and engineers focused on addressing the needs of our partners and clients in areas related to energy development and management and environmental stewardship.

July 2018–April 2021: Assistant Director of Integrated Analytical Solutions, EERC, UND. Ms. Kurz was responsible for assisting the EERC's leadership team with developing business opportunities and successfully executing research projects related to oil and gas; natural resource management; and carbon capture, utilization, and storage. She oversaw a multidisciplinary team of scientists and engineers who work in the EERC's applied research laboratories. In that role, she was responsible for ensuring the quality assurance/quality control of data and results generated by the EERC's laboratories and integrating those results into the applied research efforts conducted by the Subsurface R&D team.

2011–July 2018: Principal Hydrogeologist, Laboratory Analysis Group Lead, EERC, UND. Ms. Kurz oversaw a multidisciplinary team of scientists and engineers and several of the EERC's analytical research laboratories that focus on classical and advanced wet-chemistry analyses; petrochemical, geochemical and geomechanical evaluation of rocks and soils; and advanced characterization of various materials, including metals, alloys, catalysts, and corrosion and scale products. Her primary areas of interest included the evaluation of water supply sources for the oil and gas industry, produced water management, characterization of geologic media for carbon storage and development and testing of proppants for use in hydraulic fracturing.

2002–2011: Senior Research Manager, Water Management and Flood Mitigation Strategies, EERC, UND. Ms. Kurz's responsibilities included project management, technical report and proposal writing,

public outreach, and the development of new research focus areas. Research activities included the evaluation of nontraditional water supply sources for municipal and industrial use, flood and drought mitigation, watershed-scale water quality assessments using hydrologic models, and public education and outreach on various water and energy issues.

1998–2002: Research Scientist, Subsurface Remediation Research, EERC, UND. Ms. Kurz's responsibilities included managing and conducting research involving remediation technologies for contaminated groundwater and soils, groundwater sampling and analysis, technical report writing, and proposal research and preparation.

Publications

Ms. Kurz has coauthored numerous professional publications.

DR. JOHN A. HARJU
Vice President for Strategic Partnerships
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5157, jharju@undeerc.org

Principal Areas of Expertise
Dr. Harju's principal areas of interest and expertise include carbon sequestration, enhanced oil recovery, unconventional oil and gas development, waste management, geochemistry, technology development, hydrology, and analytical chemistry, especially as applied to the upstream oil and gas industry.

Education and Training
Ph.D., Petroleum Engineering, University of North Dakota, 2022.
M.Eng., Petroleum Engineering, University of North Dakota, 2020.
B.S., Geology, University of North Dakota, 1986.

Research and Professional Experience
2002–Present: EERC, UND.
July 2015–Present: Vice President for Strategic Partnerships. Dr. Harju leads efforts to build and grow dynamic working relationships with industry, government, and research entities globally in support of the EERC's mission to provide practical, pioneering solutions to the world's energy and environmental challenges. He represents the EERC regionally, nationally, and internationally in advancing its core research priorities: coal utilization and emissions, carbon management, oil and gas, alternative fuels and renewable energy, and energy–water.

2003–June 2015: Associate Director for Research. Dr. Harju led a team of scientists and engineers building industry–government–academic partnerships to carry out research, development, demonstration, and commercialization of energy and environmental technologies.

2002–2003: Senior Research Advisor. Dr. Harju developed, marketed, managed, and disseminated research programs focused on the environmental and health effects of power and natural resource production, contaminant cleanup, water management, and analytical techniques.

2017–Present: Adjunct Lecturer, Department of Petroleum Engineering, UND.

1999–2002: Vice President, Crystal Solutions, LLC, Laramie, WY. Dr. Harju's firm was involved in commercial E&P produced water management, regulatory permitting and compliance, and environmental impact monitoring and analysis.

1997–2002: Gas Research Institute (GRI) (now Gas Technology Institute [GTI]), Chicago, IL.

2000–2002: Principal Scientist, Produced Water Management. Dr. Harju developed and deployed produced water management technologies and methodologies for cost-effective and environmentally responsible management of oil and gas produced water.

1998–2000: Program Team Leader, Soil, Water, and Waste. Dr. Harju managed projects and programs related to the development of environmental technologies and informational products related to the North American oil and gas industry; formulated RFPs, reviewed proposals, and formulated contracts; performed technology transfer activities; and supervised staff and contractors. He served as Manager of the Environmentally Acceptable Endpoints project, a multiyear program focused on rigorous determination of appropriate cleanup levels for hydrocarbons and other energy-derived contaminants in soils. He led GRI/GTI involvement with industry environmental consortia and organizations, such as PERF, SPE, AGA, IPEC, and API.

1997–1998: Principal Technology Manager (1997–1998) and Associate Technology Manager (1997), Soil and Water Quality.

1988–1996: EERC, UND.
1994–1996: Senior Research Manager, Oil and Gas Group. Dr. Harju served as:
- Program Manager for assessment of the environmental transport and fate of oil- and gas-derived contaminants, focused on mercury and sweetening and dehydration processes.
- Project Manager for field demonstration of innovative produced water treatment technology using freeze crystallization and evaporation at oil and gas industry site.
- Program Manager for environmental transport and fate assessment of MEA and its degradation compounds at Canadian sour gas-processing site.
- Program Manager for demonstration of unique design for oil and gas surface impoundments.
- Director of the National Mine Land Reclamation Center for the Western Region.
- Co-PI on project exploring feasibility of underground coal gasification in southern Thailand.
- Consultant to an International Atomic Energy Agency program entitled “Solid Wastes and Disposal Methods Associated with Electricity Generation Fuel Chains.”

1988–1994: Research Manager (1994), Hydrogeologist (1990–1994), Research Specialist (1989–1990), and Laboratory Technician (1988–1989).

Professional Activities
Member, National Coal Council (appointed 2018)
Member, National Petroleum Council (appointed 2010)
Member, Mainstream Investors, LLC, Board of Governors (2014–present)
Member, DOE Unconventional Resources Technology Advisory Committee (2012–2014)
Member, Interstate Oil and Gas Compact Commission (appointed 2010)
Member, Rocky Mountain Association of Geologists

Publications
Dr. Harju has authored or coauthored more than 100 professional publications and nearly 300 technical presentations.

DARREN D. SCHMIDT
Assistant Director for Energy, Oil, and Gas
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5201, dschmidt@undeerc.org

Principal Areas of Expertise
Mr. Schmidt's principal areas of interest and expertise include oil and gas facilities, production, injection, well stimulation, enhanced recovery, power generation, and renewable technologies.

Education and Training
B.S., Mechanical Engineering, West Virginia University, 1994.
Registered Professional Engineer (Mechanical and Petroleum).

Research and Professional Experience
February 2021–Present: Assistant Director for Energy, Oil, and Gas, EERC, UND. Mr. Schmidt leads a team focused on research, development, and commercialization related to efficient and clean fossil fuel production, utilization, carbon management, and alternative fuels and renewable energy.

2016–January 2021: Principal Engineer, Research and Technology, Equinor, Williston, North Dakota. Mr. Schmidt provided leadership for Equinor's research portfolio in the Bakken/ Williston Basin, with a focus on low carbon. He developed a project focused on reducing flaring in which a patent application was filed. Earlier work included leading a team to develop CO_2 used in well stimulations. Through Equinor's involvement with the North Dakota Oil and Gas Research Program, research was completed to address requirements surrounding crude oil vapor pressure. Mr. Schmidt worked closely with Equinor's Williston office regional manager to support operations including serving as the regulatory liaison for the emergency response team.

2013–2016: Completions Engineer, Statoil Completions, Williston, North Dakota. Mr. Schmidt served as a completions engineer for Williams County, with a strong focus on safe operations. He led a successful program in 2015 to use 10% produced water in Statoil hydraulic fracturing operations. He was responsible for hydraulic fracture designs, quality of operations, implementing new procedures, enforcing standard operating procedures, and approving field work. He mentored interns and completions related research projects to improve performance.

2012–2013: Technical Advisor, Weatherford Fracturing Technologies, Williston, North Dakota. Mr. Schmidt provided leadership to the Williston district to ensure job quality, safety, personnel management, education, and training. He supported revenue; provided intelligence; conducted marketing; provided urgent response to customers, field services, and client-based technical assistance; and ensured quality reporting. He also provided technical guidance to the district stimulation fluids laboratory.

2008–2012: Senior Research Advisor, EERC, UND. Mr. Schmidt was responsible for procurement and execution of research projects related to the Bakken Formation in the Williston Basin. Projects included utilization of associated gas in drilling operations, laboratory investigation of conductivity associated with proppants, fracturing fluids, and rock formations, enhanced production from coal bed methane, geologic storage of CO_2, and oil-field drilling, production, and workover operations. Additionally, Mr. Schmidt

was an advisor to distributed biomass gasification development and contributed to the organization's revenue through research proposals, publications, and intellectual property.

1998–2008: Research Manager, EERC, UND. Mr. Schmidt's responsibilities included securing research contracts, managing projects, and performing engineering tasks in the areas of cofiring and biomass power systems, including combustion, fluidized-bed, gasification, microturbine, and internal combustion engine generators; energy efficiency; ground-source heat pumps; hydrogen production from biomass; and researching the behavior of biomass in combustion systems relative to ash fouling and trace elements.

1994–1998: Mechanical Engineer, Research Triangle Institute (RTI), Research Triangle Park, North Carolina. Mr. Schmidt's responsibilities included serving as project leader for a $3M Cooperative Agreement with the U.S. Environmental Protection Agency (EPA) to demonstrate electricity production using a 1-MW wood gasification technology. Significant experience included permit, design, installation, operations, and reporting. Other activities at RTI included support of marketing activities and coauthoring publications.

Summer 1993: Internship, EERC, UND, Grand Forks, ND. Mr. Schmidt supported combustion and coal ash studies.

Summer 1992: Internship, Foster Wheeler Development Corporation, Livingston, New Jersey. Mr. Schmidt supported gasification research and development.

Professional Activities

Appointed Member, North Dakota Oil and Gas Research Council
Cochair, North Dakota Petroleum Council Technology Solutions Group
Section Chair, Williston Basin Society of Petroleum Engineers

Publications

Mr. Schmidt has authored or coauthored over 80 peer-reviewed and other professional publications.

Patents

Method and Apparatus for Supply of Low-Btu Gas to an Engine Generator. U.S. Patent 8,460,413, June 11, 2013.
Application of Microturbines to Control Emissions from Associated Gas. U.S. Patent 8,418,457, April 16, 2013.
Hydrocarbon Gas Recovery Methods. U.K. Application No. 2009516.2, filed June 22, 2020.

DR. NICHOLAS A. AZZOLINA
Assistant Director for Applied Data Analytics
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5120, nazzolina@undeerc.org

Principal Areas of Expertise
Dr. Azzolina is a hydrogeologist and statistician with over 25 years of industrial and consulting experience, specializing in the analysis and modeling of large, complex environmental data sets.

Education and Training
Ph.D., Environmental Management and Science, Carnegie Mellon University, 2015.
M.S., Hydrogeology, Syracuse University, 2005.
B.A., Geological and Geophysical Sciences, Princeton University, 1997.

Research and Professional Experience
March 2023–Present: Assistant Director for Applied Data Analytics, EERC, UND.

September 2021–March 2023: Assistant Director for Applied Artificial Intelligence, EERC, UND. Dr. Azzolina manages technical staff and supports projects across the EERC's Subsurface Group that require expertise with machine learning, statistics, or data analytics. Example research areas and projects include (i) carbon dioxide (CO_2) management through carbon capture, utilization, and storage (CCUS); (ii) oil and gas production from conventional and unconventional reservoirs; (iii) water resource options for the energy industry, (iv) risk assessments for CCUS and other subsurface projects, and (v) life cycle analyses (LCAs) for CCUS and other subsurface projects.

December 2016–September 2021: Principal Hydrogeologist and Statistician, EERC, UND. Dr. Azzolina supported a broad array of projects related to CO_2 enhanced oil recovery (EOR), CCUS, unconventional oil and gas production, and chemical contamination of environmental media (soil, groundwater, and sediment). He also conducted LCAs and risk assessments for CCUS and other subsurface projects.

2010–2017: Independent Consultant, The CETER Group, Inc.

2008–2010: Scientist/Project Manager, Foth, Green Bay, Wisconsin.

2005–2008: Scientist/Project Manager, The RETEC Group, Inc., Ithaca, New York.

2004–2005: Scientist, O'Brien and Gere Engineers, Inc., Syracuse, New York.

2003–2005: Research Assistant/Head Teaching Assistant, Syracuse University, Department of Earth Science, Syracuse, New York.

2000–2003: Supervisor, McMaster-Carr Supply Co., Dayton, New Jersey.

1997–2000: Senior Field Engineer, Schlumberger Oilfield Services, Edinburg, Texas.

Publications
Dr. Azzolina has authored and coauthored numerous peer-reviewed and other professional publications.

DR. CHANTSALMAA DALKHAA
Principal Reservoir Engineer, Reservoir Engineering Team
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5448, dalkhaa@undeerc.org

Principal Areas of Expertise

Dr. Dalkhaa's principal areas of interest and expertise include numerical modeling and simulation of various enhanced oil recovery (EOR) techniques, including solvent and thermal methods and cold heavy oil production with sand (CHOPS); CO_2 sequestration and monitoring; and production evaluation and estimation of ultimate recovery of unconventional shale oil plays.

Education and Training

Ph.D., Petroleum and Natural Gas Engineering, Middle East Technical University (METU), Ankara, Turkey, 2010.
M.S., Petroleum and Natural Gas Engineering, METU, Ankara, Turkey, 2005.
B.S., Petroleum and Natural Gas Engineering, METU, Ankara, Turkey, 2003.
Proficient in the use of Petrel (geologic modeling), Eclipse (fluid flow reservoir simulation), CMG IMEX/STARS/GEM/CMOST, TOUGH2/TOUGHREACT, ArcGIS/Arcmap, and IHS Harmony/DeclinePLUS/RTA/Petra.

Research and Professional Experience

February 2020–Present: Principal Reservoir Engineer, Reservoir Engineering Team, EERC, UND. Dr. Dalkhaa coleads the Reservoir Engineering Team, supervises reservoir engineers and geoscientists, manages and oversees projects, contributes to research proposal writing and preparation, and conducts technical and research work.

June 2019–January 2020: Senior Reservoir Engineer, Reservoir Engineering Team, EERC, UND. Dr. Dalkhaa supervised junior reservoir engineers and student research assistants and worked with reservoir engineers, geologists, and geophysicists to develop and calibrate geologic models of the subsurface and run dynamic simulations to evaluate CO_2 EOR performance of oil fields and the long-term fate of CO_2 sequestration into saline aquifers, evaluate production performance of unconventional oil and gas reservoirs, and assess refracturing potential in the Bakken petroleum system.

2016–May 2019: Reservoir Engineer, Reservoir Modeling and Simulation, EERC, UND. Dr. Dalkhaa worked with teams of reservoir engineers, geologists, and geophysicists to develop and calibrate geologic models of the subsurface and run dynamic simulations to evaluate CO_2 EOR performance of oil fields and the long-term fate of CO_2 sequestration into saline aquifers, estimate ultimate oil recovery, and evaluate production performance of unconventional oil reservoirs.

2014–2015: Postdoctoral Fellow, Department of Chemical and Petroleum Engineering, University of Calgary, Calgary, Alberta, Canada. Dr. Dalkhaa's activities included the following:

- Construction of a geologic model of heavy Canadian oil fields using Petrel.
- Simulation of a wormhole formation and growth in CHOPS reservoir and history matching of reservoir fluid and sand productions.

- Assessment of reservoir performance of thermal, solvent, and hybrid EOR methods using CMG STARS.

2011–2014: Postdoctoral Fellow, Department of Geoscience, University of Calgary, Calgary, Alberta, Canada. Dr. Dalkhaa's activities included the following:

- Stimulation of microbial activities in a CHOPS reservoir in the Lloydminster area, Canada, to enhance oil recovery for a project funded by Natural Sciences and Engineering Research Council of Canada and Husky Oil Operation Ltd.
- Reactive transport simulation of CO_2 injection into a reservoir and CO_2 leakage to shallower formations for the Quest Project, funded by Shell Canada.
- Application of stable isotopic techniques in monitoring of injected CO_2 for the Quest Project and Swan Hills and PennWest CO_2 pilot projects.
- Simulation of CO_2 injection into a H_2S-containing aquifer located in central Alberta for a project funded by Carbon Management Canada.
- Oilfield fluid sampling and analysis at various fields (Pembina Cardium CO_2 EOR pilot, Swan Hills CO_2 EOR fields in the Western Canadian Sedimentary Basin).
- Laboratory work on CO_2 reactivity and microbial EOR in CHOPS reservoirs.

2006–2011: Research and Teaching Assistant, Department of Petroleum & Natural Gas Engineering, METU, Ankara, Turkey. Dr. Dalkhaa's activities included the following:

- Reservoir simulation of immiscible CO_2 and water alternating gas injection into a heavy oil field in Europe in southeastern Turkey using Eclipse/Petrel (2007–2009).
- Mentorship and guidance of senior year students for graduation projects and coordination of courses (2007–2011).
- Evaluation of coalbed methane production capacity from the Soma coal bed in Turkey (2011).

Professional Activities

Member, Association of Professional Engineers and Geoscientists of Alberta – Engineer in Training (2011–present)
Member, Society of Petroleum Engineers (2003–present)
Member, European Association of Geoscientists and Engineers (2010)
Member, The Geochemical Society (2012)
Technical Reviewer, *Journal of CO_2 Utilization* (since 2019), *International Journal of Greenhouse Gas Control* (since 2017), and *Greenhouse Gases: Science and Technology* (since 2017)
Postdoctoral Representative, Faculty of Science, University of Calgary (2012–2013)
General volunteer, MentorUp Calgary (2014)
General volunteer, APEGA (2014)
Member, EERC Social Cause Committee (since 2016)

Publications

Dr. Dalkhaa has coauthored several professional publications.

MATTHEW L. BELOBRAYDIC
Assistant Director for Geoscience
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5030, mbelobraydic@undeerc.org

Principal Areas of Expertise

Mr. Belobraydic's principal areas of interest and expertise include stratigraphic and structural interpretations, geologic characterization, data science, process automation, geostatistical analysis, geomodeling, and uncertainty analysis.

Education and Training

M.S., Geology, Ball State University, 2006. Thesis: "Drainage Basin Analysis and Fluvial Geomorphic Reconstruction Plan for the Killbuck–Mud Creek Subwatershed, Delaware County, Indiana."

B.S., Geology, University of Idaho, 2003. Senior Project: "Drainage Analysis for Colfax South, Diamond, Dusty, Thera, Thornton Quadrangles and an Experimental Quadrangle of Eastern Washington."

Research and Professional Experience

2022–Present: Assistant Director for Geoscience, EERC, UND. Mr. Belobraydic collaborates with EERC subject matter experts, principal investigators, and leadership to prepare proposals and pursue new business opportunities and leads and manages projects in the areas of enhanced oil recovery (EOR) in conventional and unconventional formations, CO_2 and produced gas storage, natural resource management, critical materials resource characterization and recovery, geologic and synthetic materials characterization, produced water management, and the environmental aspects of energy development.

- Manages a team of petrophysicists and subsurface data management professionals.
- Coaches and mentors more than ten geoscientists in geology, stratigraphy, geostatistical, geologic modeling, and uncertainty methods.
- Develops strategic plans for petrophysical products and data-handling procedures for subsurface teams.
- Assists the Director of Analytical Solutions by providing business directions for technical reports and technical expertise.
- Creates project proposals and maintains client relationships.

December 2020–2022: Principal Geoscientist, Geoscience and Engineering Group, EERC, UND. Mr. Belobraydic collaborated with EERC subject matter experts and principal investigators to create geological interpretations and prepared proposals in the areas of EOR in conventional and unconventional formations, CO_2 and produced gas storage, natural resource management, geologic materials characterization, produced water management, and environmental aspects of energy development.

- Mentored geoscientists as subject matter expert in geology and geological modeling for more than ten federal, state, and private contracts.
- Coached modeling team members through team-building and workflow improvement exercises.
- Characterized reservoirs and depositional environments for projects to maximize subsurface understanding and minimize development risk.
- Managed resources, budgets, and timelines on projects to successfully complete within deadlines and scope.

October 2020–December 2020: Geoscientist, EERC, UND. Mr. Belobraydic produced geology and geological modeling results for CO_2 storage projects as part of an integrated team of EERC subject matter experts. Specific activities included the following:

- Produced 3D geologic models for CO_2 storage for select clastic formation within the Williston Basin.
- Coached three geoscientists through geostatistical and geomodeling methods as on-the-job training.

September 2008–April 2020: Senior III Reservoir Geologist, Schlumberger, Denver, Colorado. Mr. Belobraydic produced data-driven client solutions as part of a multidisciplinary consulting team, improving internal technical processes and workflows to increase efficiency and maximize profits. Specific activities included the following:

- Managed team of petrophysicist, geophysicist, geologist, and reservoir engineers from proposal to project close as technical lead for more than ten client projects.
- Introduced Agile and Scrum project management to local consulting team, changing work processes, shortening turnaround times by 66% and increasing bottom line.
- Reviewed green energy workflows and processes for internal geothermal and carbon capture and storage teams as subject matter expert to mitigate risk and uncertainty.
- Initialized and maintained backlog for basin interpretation cloud subscription service as Scrum product owner to capture previously inaccessible market share.
- Adapted working style and deliverables to become trusted technical advisor for more than 20 client organizations, each with unique business priorities.
- Coordinated stakeholders and potential clients for four cloud subscription service offerings to maximize value, drive communication, and quantify feedback of results.
- Created harmonious and integrated team environments for technical staff from both Schlumberger and client organizations for project collaborations.
- Characterized petroleum systems and depositional environments for client acreage to maximize reservoir understanding and minimize development risk.
- Interpreted structure and stratigraphy for full 3D models, combining seismic data for conventional and unconventional plays in more than ten basins and 30 fields globally.
- Analyzed raw and interpreted data to generate geostastically accurate static reservoir models in Petrel on more than five projects per year for worldwide clients.
- Published and automated uncertainty optimization technique, reducing dynamic simulation iterations by 80% and generating a positive feedback loop to initial inputs.
- Built custom Python, SQL, and Petrel workflows, increasing productivity by up to 900%.
- Coached and mentored more than 30 individuals through organized team-building activities and formal career development.
- Created advanced modeling curriculum and training programs in Petrel for more than 25 junior geoscientists.
- Published results and methodologies for select client work as posters and papers to technical conferences and professional societies.
- Requested presenter to professional societies for geology, data science, and machine learning.
- Prepared and reviewed proposals, reports, and project documentation, effectively communicating technical results and methodology to clients and working teams.

September 2006–August 2008: CO_2 Enhanced Oil Recovery Research Assistant, UND. Mr. Belobraydic researched CO_2 enhanced oil recovery and sequestration potential for the Williston Basin alongside the EERC. Specific activities included the following:

- Generated systematic approach for assessing enhanced oil recovery and carbon dioxide sequestration for fields of interest.

- Produced 3D reservoir models to simulate enhanced oil recovery and carbon dioxide sequestration potential.

May 2005–May 2006: National Science Foundation GK–12 Fellow, Ball State University, Muncie, Indiana. Mr. Belobraydic provided in classroom support to Indianapolis Public Schools (IPS) teachers through inquiry-based lessons and assisted in professional development for K–8 science standards. Specific activities included the following:

- Developed middle school Earth science curriculum and lessons for IPS.
- Provided aid in the professional development of IPS teachers as a knowledge resource.

Professional Activities

Member, American Association of Petroleum Geologists
Member, Rocky Mountain Association of Geologists

Publications

Mr. Belobraydic has authored or coauthored numerous professional publications.

MARC D. KURZ
Principal Geologist, Process Chemistry and Development Team Lead
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5278, mkurz@undeerc.org

Principal Areas of Expertise

Mr. Kurz's principal areas of interest and expertise include design, operation, and maintenance of laboratory- and pilot-scale reactor systems for biofuel development; biofuel chemistry and analysis; design and implementation of subsurface and groundwater remediation technologies; and geophysical characterization testing.

Education and Training

B.S., Environmental Geology and Technology, University of North Dakota, 1993.
Postgraduate coursework in soil sciences, groundwater remediation, global change issues, satellite image processing, and geographic information systems (GIS), 2001–2007.
40-hour OSHA Training for Hazardous Waste Site Personnel, 1997 (refresher course, 2002).

Research and Professional Experience

May 2021–Present: Principal Geologist, Process Chemistry and Development Team Lead, EERC, UND. Mr. Kurz coordinates and conducts the analysis of various laboratory- and pilot-scale reactor product and by-product effluents to provide data for the calculation of material balances, conversions, and product qualities in support of EERC projects. He provides a variety of general and specialized analytical testing, including wet-chemical testing, thermogravimetric analysis (TGA)/differential calorimetry scanning (DSC), gas chromatography/mass spectrometry, flash point and cold-flow properties of fuels, and refinery gas analysis (RGA) of combustion gases.

2010–April 2021: Senior Geologist, Process Chemistry and Development Team Lead, EERC, UND. Mr. Kurz coordinated and conducted the analysis of various laboratory- and pilot-scale reactor product and by-product effluents to provide data for the calculation of material balances, conversions, and product qualities in support of EERC projects.

2007–2010: Research Scientist, Renewable Energy and Biofuel Technology, EERC, UND. Mr. Kurz served as a research scientist on projects related to alternative energy technologies. His primary responsibilities included conducting laboratory- and pilot-scale research experiments related to biofuel technology and operating various laboratory analytical instruments.

2000–2007: Research Scientist, Subsurface Treatment and Remediation Research, EERC, UND. Mr. Kurz served as a manager and co-principal investigator on a variety of research projects related to groundwater remediation and oil and gas industry-related issues. His responsibilities included supervision of graduate research assistants and fieldwork personnel, proposal writing, budget management, and presentation of project research at a variety of technical conferences.

1996–2000: Geologist/Research Scientist, Groundwater Remediation Program, EERC, UND. Mr. Kurz's responsibilities included researching and report writing on various remediation technologies for contaminated groundwater and soils, conducting extensive fieldwork activities, and performing

analytical laboratory testing. In addition, he was involved in research related to the exploration, production, and environmental aspects of coalbed methane exploitation.

1994–1996: Research Assistant, Water and Wastewater Treatment, EERC, UND. Mr. Kurz's primary responsibilities included various field- and laboratory-based research on a variety of water and wastewater remediation projects.

Publications
Mr. Kurz has coauthored several technical publications.

DR. ALEXANDER CHAKHMAKHCHEV
Principal Scientist
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5393, achakhmakhchev@undeerc.org

Principal Areas of Expertise

Dr. Chakhmakhchev is a geoscientist with over 25 years of experience in the international petroleum industry. He has significant industry and academic expertise in geoscience and applying the results to petroleum exploration efforts, field development, production optimization, and problem solving in various geologic settings. In his career, he has focused on the geochemistry of oils and source rocks and applying the results to petroleum systems analysis and reservoir/production management. In his work, he has utilized a wide range of hydrocarbon indicators: gas and gasoline range hydrocarbons, n-alkanes, biomarkers, sulfur aromatics, diamondoids, and isotope composition of C, S, and metal distributions. He has developed new technologies for oil/oil/organic matter (OM) correlations, maturity evaluation, and phase type prediction of hydrocarbons lacking biomarkers (condensates and light oils). He has developed and conducted lab experiments simulating subsurface fluid behavior, including the vertical migration process in PVT (pressure, volume, temperature) cells. He has extensively used distributions of n-alkanes, biomarkers, and sulfur aromatic compounds for fingerprinting of fluids and indicators of depositional environments, type of source rock, lithologies, age, and biodegradation. He has identified and characterized OM of source rocks using techniques such as total organic carbon (TOC), Ro, Rock-Eval, infrared (IR) spectroscopy, biomarker distributions, gas logging, and carbon isotope composition. He has unitized various statistical technics in data interpretation, including cluster analysis, principal components, multiple regression, and gradient boosting. He has developed database structure and surface geochemistry information and data and performed basin-modeling studies using PetroMod and BasiMod and focusing on a new prospect risking, including time of oil generation, hydrocarbon charge volumetric assessment, and fluid-quality prediction.

Education and Training

Special Postdoctorate Program for Foreign Students, Shimane University, Japan, 1992–1994.
Ph.D., Petroleum Geochemistry, All-Russia Research Institute for Geological, Geochemical, and Geophysical Information Systems, Moscow, CIS, 1988–1992; dissertation: “Geochemical Methods of Oil and Gas Prospecting Using Multivariate Statistical Analysis.”
M.S., Petroleum Geology, Moscow State University, Moscow, Russia, 1982–1987.

Research and Professional Experience

2019–Present: Principal Scientist, EERC, UND. Dr. Chakhmakhchev leads projects and research work in the areas of enhanced oil recovery, production optimization, geochemical solutions, and environmental protection.

2017–2018: Senior Data Scientist, Applied Chem Data (ACDGL.com). Dr. Chakhmakhchev provided consulting services in completion optimization and monitoring and performance analysis of electric submersible pumps.

2014–2017: Principal Geochemist, Geochemistry Services, SGS Oil, Gas, and Chemical Services, The Woodlands, Texas. Dr. Chakhmakhchev’s activities included the following:

- Led global geochemical services in the areas of geochemical characterization of petroleum system, reservoir compartmentalization, production allocation, prediction of hydrocarbon type and quality of oil, migration and biodegradation processes, and monitoring enhanced recovery processes.
- Provided consulting work and interpretation for data generated by SGS laboratories and applied in petroleum exploration in frontier basins and unconventional resources.
- Completed standardization project for global SGS labs, aligning output formats with the best industry standards, including biomarker analyses (gas chromatography (GC])–mass spectroscopy (MS), whole oil GC, IR MS, Rock-Eval, and visual kerogen characterization.
- Helped operator in Colombia optimize an exploration program based on geochemical characterization of heavy biodegraded oil discovered.
- Advised oil and gas operator on the potential (liquids vs. gas) of unexplored zones in the Berkine Basin of Algeria Basin based on regional geochemical characterizations of gas condensates, light oils, source rock, gas-logging data, and basin modeling.
- Geochemically characterized oils and condensates produced in a shale play to understand the source and maturity level of fluids (Woodford, Eagle Ford).
- Created reservoir geochemistry workflows, and completed a pilot project for reservoir compartmentalization, production allocation, and production monitoring.
- Informed operator of the source of produced condensate samples and tested the fluids for possible contamination from oil base drilling mud.
- Using carbon and hydrogen isotope data and chemical composition of gas, explained the source (biogenic vs. thermogenic) of the gas discovered in Malaysia.
- Developed and conducted lab experiments simulating subsurface fluid behavior, including the vertical migration process in a PVT cell.
- Created tool/workflow-based sulfur isotope data to predict H_2S contamination in production streams in various locations of Kuwait.
- Investigated the composition of return fluids sampled during pressure testing and explained their nature and source using whole oil GC, biomarkers, oil-based mud (OBM) data, and published geochemical information on oils in India.
- Diagnosed tubing leaking in West Africa offshore wells using fluids composition data. Set up a fully capable geochemistry lab in Texas and Malaysia for petroleum characterization in source rock, oil, and ocean floor sediments using GS–MS–MS instrumentation and GC (high-resolution whole oil GC, HTGC).
- Built retention time database for various biomarkers based on global oil samples.
- Trained and coached chemists and junior geochemists in the organization.

2001–2014: Geoscience Data Advisor, IHS Energy, Global Support Organization, Houston, Texas; Director, Big Data and Analytics, IHS. Dr. Chakhmakhchev's activities focused on the following:

- Created solutions and new decision-making products focused on deep water, unconventional resources and based on various subsurface data integration, predictive analytics, and big data technologies.
- Predicted unconventional well performance in Niobrara play performance using log, geochemical, and mineralogy data and applying multivariate statistical analysis.
- Created algorithms for well log interpretation to correlate log patterns and shale oil production. Performed completion optimization modeling in the Eagle Ford shale play using U.S. well and production data-mining method, gradient boosting.
- Completed a significant number of consulting jobs covering the remaining exploration potential of basins, understanding risks and reserve estimates and analyzing country/regional/basin trends. In these assignments, integrated various data and information, including petroleum system characterization, basin geological history, depositional environment, OM maturity, timing of generation, migration and accumulation, and play/trap type information.

- Led a team of geoscience data advisors whose role was to provide training, consulting services, and support to IHS clients, including ExxonMobil, Marathon, Chevron, Shell, Anadarko, Noble, BHP, and others.

1996–2001: Project Manager, New Ventures, YUKOS Oil Company, Moscow. Dr. Chakhmakhchev managed integrated geologic studies internationally to identify prospective drilling targets and estimate potential reserve volumes.

1994–1996: Project Researcher–Geochemist, Japan National Oil Company, Chiba, Japan. Dr. Chakhmakhchev's activities included the following:

- Investigated lithology, source, and maturity effects on sulfur aromatic compounds and biomarker distributions in oil and OM of source rocks in Niigata and Akita Basins of Japan.
- Developed a new maturity parameter based on dibenzothiophene distributions successfully applied in overmature petroleum.
- Performed a comparison study of oils derived from siliceous sources of Japan, the United States, and Russia.
- Applied instrumentation including GC, GC–MS, and Rock-Eval.
- Analyzed petroleum systems in different worldwide basins: West Siberian Basin; Okhotsk Basin, Sakhalin; Timan–Pechora Basin; Akita and Niigata Basins (Japan); North Caspian Basin; Santa Barbara–Ventura, Santa Maria (USA).
- Performed 1-D basin modeling (BasinMod) in basins of Japan focusing on new prospect risking, including time of oil generation, hydrocarbon charge volumetric assessment, pressure, and fluid-quality prediction.

1992–1994: Postdoctoral Researcher, Shimane University, Japan North of Western Siberia. Dr. Chakhmakhchev's activities included the following:

- Identified effective source rocks and their depositional environment based on oil/source rock correlation and using biomarkers, gasoline hydrocarbons, and isotope composition.
- Revealed maturity trend(s) and the effects of biodegradation.
- Predicted HC type in unexplored territories.
- In basins of Russia, Kazakhstan, and Japan, investigated lithology effects (siliceous, carbonate, and argillaceous) on biomarker and aromatic sulfur compounds in oils.
- In Volgo-Ural Province (Buzuluk Depression), proposed new maturity indicators based on distribution of aromatic sulfur compounds for overmature petroleum lacking sufficient biomarkers.

1986–1992: Researcher–Geochemist, VNIIGeosystem, Moscow. Dr. Chakhmakhchev's activities included the following:

- Performed extensive geochemical data processing and interpretation using multivariate statistical methods (factor analysis, discriminant analysis).
- Focused on distributions of gasoline range hydrocarbons C5–C7 in oils and condensates derived from different OM sources and characterized by wide ranges of maturity level.
- Developed a technique to recognize overmature condensates derived from different types of OM (Types I–II and III).
- Created a database for surface geochemistry information.

Professional Activities

Member, European Association of Organic Geochemists
Member, American Association of Petroleum Geologists (AAPG)
Member, Society of Petroleum Engineers (SPE)
Member, Japanese Association for Petroleum Technology
Reviewer for AAPG and *Organic Geochemistry*

Publications

Dr. Chakhmakhchev has published over 20 research papers and four technical reports in leading international journals and participated in tradeshows and conventions, including the World Petroleum Congress, AAPG, SPE, IHS Regional Roundtables, and NAPE.

APPENDIX D

LETTERS OF COMMITMENT

devon

June 1, 2023

Mr. John Harju
Vice President for Strategic Partnerships
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Dear Mr. Harju:

Subject: Devon Energy Corp. – Letter of Support for the Project Entitled "Bakken Production Optimization Program (BPOP) 4.0"

Devon Energy (Devon) is interested in partnering with the Energy & Environmental Research Center (EERC) in the subject proposed project to investigate the feasibility of implementing large-scale enhanced oil recovery (EOR) in the Bakken petroleum system using carbon dioxide (CO_2) captured from industrial sources in North Dakota.

Devon supports the EERC's proposal to conduct a series of research activities as part of the proposed Bakken Production Optimization Program (BPOP) 4.0 efforts. Devon is willing to consider providing significant in-kind cost-share to the proposed BPOP 4.0 program. In-kind contributions may include, but are not necessarily limited to, access to unique core and fluid samples, reservoir diagnostics data, and any other qualifying costs that may be generated as part of future CO_2 EOR-related efforts being considered by Devon. It is estimated that the value of those contributions may be as high as $3,000,000. Should EERC be awarded funding for the proposed BPOP 4.0 efforts, it is anticipated that Devon will make a final decision regarding the specific nature and extent of its participation in the BPOP 4.0 EOR-focused activities.

We look forward to working with EERC in this exciting project to advance the science of CO_2-based EOR in tight reservoirs, reservoir conformance, fluid-fluid and fluid-rock interactions (including the potential for Bakken and Three Forks rocks to store CO_2), reservoir surveillance, and the understanding of tight complex reservoirs.

Should you have any questions, please do not hesitate to contact me by phone at (918) 237-2139 or by e-mail at William.Westler@dvn.com.

Sincerely,

William M. Westler Jr.
William Westler
BU Vice President - Rockies

March 13, 2023

SENT VIA ELECTRONIC MAIL

Sheryl Eicholtz-Landis, Business Point of Contact
University of North Dakoka
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018
slandis@undeerc.org

SUBJECT: Selection of Application for Negotiation Under Funding Opportunity Announcement Number DE-FOA-0002616, "Innovative Methane Measurement, Monitoring, and Mitigation Technologies (iM4 Technologies)"

Dear Ms. Eicholtz-Landis:

We are pleased to provide this update on your application. The Office of Fossil Energy and Carbon Management within the Department of Energy (DOE) has completed its evaluation of your application submitted in response to the subject Funding Opportunity Announcement (FOA). The application below has been recommended by the Office of Fossil Energy and Carbon Management for negotiation of a financial award (Note: This notification does not guarantee Federal Government funding, as funding will only be obligated upon completion of successful negotiations):

Application: "Polar Bear Ð Innovative Capture of Storage Tank Vapors", Principal Investigator Darren D. Schmidt, Application Control Number 13740484

Receipt of this letter does not authorize you to commence with performance of the project. DOE makes no commitment to issue an award and assumes no financial obligation with the issuance of this letter. Applicants do not receive an award until award negotiations are complete and the Contracting Officer executes the funding agreement. Only an award document signed by the Contracting Officer obligates DOE to support a project.

The award negotiation process may take up to 90 days. You must be responsive during award negotiations (i.e., provide requested documentation) and meet the stated negotiation deadlines. Failure to submit the requested information and forms by the stated due date, or any failure to conduct award negotiations in a timely and responsive manner, may cause DOE to cancel award negotiations and rescind this selection. DOE reserves the right to terminate award negotiations at any time for any reason.

Please complete the following items and submit to DOE no later than March 24, 2023:

- Pre-Award Information Sheet (available at https://www.netl.doe.gov/business/business-forms/financial-assistance)

If your organization or any subrecipient anticipates utilizing foreign nationals (FNs) in the performance of the award, your organization is required to provide a list of all FNs planned to participate on the award along with basic information about each. You must download and complete the "Foreign National Participation Document" located at https://www.netl.doe.gov/business/business-forms/financial-assistance under Post Selection Forms/Information and submit the completed document to basicinfo@netl.doe.gov with a courtesy copy to the assigned Project Manager (PM) and Grants Management Specialist.

Upon receipt of the completed "Foreign National Participation Document," we will create a secured file sharing drop box folder(s) for **ALL** FNs proposed to participate on the award. The purpose of the secured file folder is for your organization or any subrecipient to submit additional information.

As part of the requirement to submit additional information for all FNs, your organization must ensure completion of the "Foreign National Participation **Data** Document" also located at https://www.netl.doe.gov/business/business-forms/financial-assistance. The document and all required attachments must be uploaded to the secured file sharing drop box folder(s) provided by DOE's FN Request Coordinator. The assigned PM will contact the appropriate FN Data Entry POC in the event there are issues with the submission.

Please note that all FNs identified within the "Foreign National Participation Document" are **not** permitted to participate on the award until written authorization is received from the Contracting Officer.

The Contracting Officer will notify your organization of DOE's decision regarding the FNs participation on the award**.** The DOE reserves the right to request additional information or deny participation of any FN at any time.

Please provide the requested documents to the attention of Kate Hubbs, who is the Grants Management Specialist from the Finance and Acquisition Center handling the administrative portion of your application. Ms. Hubbs can be reached at Anna.Hubbs@netl.doe.gov. Robert Noll is the DOE Project Manager from the Project Management Division handling the technical portion of your application and can be reached at Robert.Noll@netl.doe.gov.

Sincerely,

Janet S. Laukaitis

Janet S. Laukaitis
Contracting Officer
Finance and Acquisition Center

cc: FOA File
Basicinfo@netl.doe.gov
Darren D. Schmidt, Principal Investigator, dschmidt@undeerc.org
Robert Noll, Project Manager, Robert.Noll@netl.doe.gov
Kate Hubbs, Grants Management Specialist, Anna.Hubbs@netl.doe.gov

APPENDIX E

BUDGET NOTES

BUDGET NOTES

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

BACKGROUND

The EERC is an independently organized multidisciplinary research center within the University of North Dakota (UND). The EERC is funded through federal and nonfederal grants, contracts, and other agreements. Although the EERC is not affiliated with any one academic department, university faculty may participate in a project, depending on the scope of work and expertise required to perform the project.

INTELLECTUAL PROPERTY

The applicable federal intellectual property (IP) regulations will govern any resulting research agreement(s). In the event that IP with the potential to generate revenue to which the EERC is entitled is developed under this project, such IP, including rights, title, interest, and obligations, may be transferred to the EERC Foundation‡ , a separate legal entity.

BUDGET INFORMATION

The proposed work will be done on a cost-reimbursable basis. The distribution of costs between budget categories (labor, travel, supplies, equipment, etc.) and among funding sources of the same scope of work is for planning purposes only. The project manager may incur and allocate allowable project costs among the funding sources for this scope of work in accordance with Office of Management and Budget (OMB) Uniform Guidance 2 CFR 200.

Escalation of labor and EERC recharge center rates is incorporated into the budget when a project's duration extends beyond the university's current fiscal year (July 1 – June 30). Escalation is calculated by prorating an average annual increase over the anticipated life of the project.

The cost of this project is based on a specific start date indicated at the top of the EERC budget. Any delay in the start of this project may result in a budget increase. Budget category descriptions presented below are for informational purposes; some categories may not appear in the budget.

Salaries: Salary estimates are based on the scope of work and prior experience on projects of similar scope. The labor rate used for specifically identified personnel is the current hourly rate for that individual. The labor category rate is the average rate of a personnel group with similar job descriptions. Salary costs incurred are based on direct hourly effort on the project. Faculty who work on this project may be paid an amount over the normal base salary, creating an overload which is subject to limitation in accordance with university policy. As noted in the UND EERC Cost Accounting Standards Board Disclosure Statement, administrative salary and support costs that can be specifically identified to the project are direct-charged and not charged as facilities and administrative (F&A) costs. Costs for general support services such as contracts and IP, accounting, human resources, procurement, and clerical support of these functions are charged as F&A costs.

Fringe Benefits: EERC fringe benefits consist of two components that are budgeted as a percentage of direct labor. The first component (26%) is a fixed percentage approved annually by the UND cognizant audit agency, the Department of Health and Human Services. This portion of the rate covers vacation, holiday, and sick leave (VSL) and is applied to direct labor for permanent staff eligible for VSL benefits.

The approved rate will be charged to the project. The second component (30%) is estimated on the basis of historical data and is charged as actual expenses for items such as health, life, and unemployment insurance; social security; worker's compensation; and UND retirement contributions. These benefits will be charged based on expenses actually incurred and will vary by individual.

Travel: Travel may include site visits, fieldwork, meetings, and conferences. Travel costs are estimated and paid in accordance with OMB Uniform Guidance 2 CFR 200, Section 474, and UND travel policies, which can be found at http://und.edu/finance-operations (Policies & Procedures, A–Z Policy Index, Travel). Daily meal rates are based on U.S. General Services Administration (GSA) rates unless further limited by UND travel policies; other estimates such as airfare, lodging, ground transportation, and miscellaneous costs are based on a combination of historical costs and current market prices. Miscellaneous travel costs may include parking fees, Internet charges, long-distance phone, copies, faxes, shipping, and postage.

Equipment: Equipment is budgeted as part of the DOE related work for the Polar Bear effort and will be paid for with DOE funds. A gas supply system will be fabricated to demonstrate the performance to capture tank vapors, and a flow meter will be purchased to test the capture of the tank vapors in the manufactured model.

Supplies: Supplies include items and materials that are necessary for the research project and can be directly identified to the project. Supply and material estimates are based on prior experience with similar projects. Examples of supply items are chemicals, gases, glassware, nuts, bolts, piping, data storage, paper, memory, software, toner cartridges, maps, sample containers, minor equipment (value less than $5000), signage, safety items, subscriptions, books, and reference materials. General purpose office supplies (pencils, pens, paper clips, staples, Post-it notes, etc.) are included in the F&A cost.

Subcontractor – Liberty Resources, LLC: Liberty Resources, LLC, will conduct a second injection cycle at its EOR pilot at its East Nesson location. Expenses will include regulatory and contract supervision, preparation and operation of the injection cycle, water and gas supplies, well work, and surveillance.

Professional Fees: Not applicable.

Communications: Telephone, cell phone, and fax line charges are included in the F&A cost; however, direct project costs may include line charges at remote locations, long-distance telephone charges, postage, and other data or document transportation costs that can be directly identified to a project. Estimated costs are based on prior experience with similar projects.

Printing and Duplicating: Page rates are established annually by the university's duplicating center. Printing and duplicating costs are allocated to the appropriate funding source. Estimated costs are based on prior experience with similar projects.

Food: Expenditures for project partner meetings where the primary purpose is dissemination of technical information may include the cost of food. EERC employees in attendance will not receive per diem reimbursement for meals that are paid by project funds. The estimated cost is based on the number and location of project partner meetings.

Professional Development: Fees are for memberships in technical areas directly related to work on this project. Technical journals and newsletters received as a result of a membership are used throughout the development and execution of the project by the research team.

Operating Fees: Operating fees generally include EERC recharge centers, outside laboratories, and freight.

EERC recharge center rates are established annually and approved by the university.

Laboratory and analytical recharge fees are charged on a per sample, hourly, or daily rate. Additionally, laboratory analyses may be performed outside of the university when necessary. The estimated cost is based on the test protocol required for the scope of work.

Document Production Services recharge fees are based on an hourly rate for production of such items as report figures, posters, and/or images for presentations, maps, schematics, website design, brochures, and photographs. The estimated cost is based on prior experience with similar projects.

Shop and Operations recharge fees cover specific expenses related to the pilot plant and the required expertise of individuals who perform related activities. Fees may be incurred in the pilot plant, at remote locations, or in EERC laboratories whenever these particular skills are required. The rate includes such items as specialized safety training, personal safety items, fall protection harnesses, respirators, CPR certification, annual physicals, protective clothing/eyewear, research by-product disposal, equipment repairs, equipment safety inspections, and labor to direct these activities. The estimated cost is based on the number of hours budgeted for this group of individuals.

Engineering Services recharge fees cover specific expenses related to retaining qualified and certified design and engineering personnel. The rate includes training to enhance skill sets and maintain certifications using Webinars and workshops. The rate also includes specialized safety training and related physicals. The estimated cost is based on the number of hours budgeted for this group of individuals.

Geoscience Services recharge fees are discipline fees for costs associated with training, certifications, continuing education, and maintaining required software and databases. The estimated cost is based on the number of hours budgeted for this group of individuals.

Software Solutions Services recharge fees are for development of customized websites and interfaces, software applications development, data and financial management systems for comprehensive reporting and predictive analysis tools, and custom integration with existing systems. The estimated cost is based on prior experience with similar projects.

Technical software fees are user fees for ASPEN modeling software.

Field safety fees cover safety training and certifications, providing necessary PPE and annual physicals. The estimated cost is based on the number of days individuals are budgeted to work in the field.

Freight expenditures generally occur for outgoing items and field sample shipments.

Outside labs are budgeted for isotope analyses of water samples.

Facilities and Administrative Cost: The F&A rate proposed herein is approved by the U.S. Department of Health and Human Services and is applied to modified total direct costs (MTDC). MTDC is defined as total direct costs less individual capital expenditures, such as equipment or software costing $5000 or more with a useful life of greater than 1 year, as well as subawards in excess of the first $25,000 for each award.

Cost Share: Cash cost share is being provided in the form of annual partnership payments from BPOP partners. A total of $1,636,361 is expected in cash from partners. In-kind cost share will also be provided by Liberty Resources, LLC and Devon in the amounts of $363,639 and $3,000,000 respectively. Cost share will include $1,000,000 cash from DOE (under contract negotiations, DOE Award No. DE-FE0032290).

APPENDIX F

STATUS OF ONGOING PROJECTS LIST

STATUS-OF-ONGOING PROJECTS LIST

Project Title	Contract Award No.
Bakken Production Optimization Program 3.0	G-051-98
Field Study to Determine the Feasibility of Developing Salt Caverns for Hydrocarbon Storage in Western North Dakota	G-054-104
Hydrogen Energy Development for North Dakota	G-054-105
Improving EOR Performance Through Data Analytics and Next-Generation Controllable Completions	G-050-97
iPIPE 2.0: The Intelligent Pipeline Integrity Program	G-055-108
iPIPE: The Intelligent Pipeline Integrity Program	G-046-88
PCOR Initiative to Accelerate CCUS Deployment	G-050-96
Underground Storage of Produced Natural Gas – Conceptual Evaluation and Pilot Project(s)	G-049-092
Unitized Legacy Oil Fields: Prototypes for Revitalizing Conventional Oil Fields in North Dakota	G-045-086