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

October 28, 2020

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
600 East Boulevard Avenue, Department 405
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: Quarterly Progress Report for the Period of July 1 – September 30, 2020, "Bakken Production Optimization Program 3.0"; Contract No. G-051-98; EERC Fund 24568

Attached please find the Energy & Environmental Research Center (EERC) Quarterly Progress Report for the subject project. If you have any questions, please contact me by phone at (701) 777-5287 or by e-mail at jsorensen@undeerc.org.

Sincerely,

DocuSigned by:
James Sorensen
0671D00C8437443...

James A Sorensen
Director for Subsurface R&D

JAS/rlo

Attachment

c/att: Brent Brannan, North Dakota Industrial Commission

BAKKEN PRODUCTION OPTIMIZATION PROGRAM

Quarterly Progress Report

(for the period July 1 – September 30, 2020)

Prepared for:

North Dakota Industrial Commission

Partners of the Bakken Production Optimization Program (BPOP) Consortium
- ConocoPhillips
- Equinor
- Hess Corporation
- Liberty Resources LLC
- Marathon Oil Company
- Oasis Petroleum
- Petro-Hunt, LLC
- WPX Energy
- XTO Energy, Inc.

Prepared by:

James A. Sorensen
Bethany A. Kurz
Chad A. Wocken
John A. Hamling
Charles D. Gorecki
John A. Harju
Steven B. Hawthorne
Loreal V. Heebink
Chantsalmaa Dalkhaa
Alexander V. Chakhmakhchev
Nicholas A. Azzolina
Marc D. Kurz
Lucia Romuld

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

October 30, 2020

EERC DISCLAIMER

LEGAL NOTICE This research report was prepared by the Energy & Environmental Research Center (EERC), an agency of the University of North Dakota, as an account of work sponsored by the North Dakota Industrial Commission (NDIC). Because of the research nature of the work performed, neither the EERC nor any of its employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement or recommendation by the EERC.

NDIC DISCLAIMER

This report was prepared by the EERC pursuant to an agreement partially funded by the Industrial Commission of North Dakota, and neither the EERC nor any of its subcontractors nor the North Dakota Industrial Commission nor any person acting on behalf of either:

(A) Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

(B) Assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the North Dakota Industrial Commission. The views and opinions of authors expressed herein do not necessarily state or reflect those of the North Dakota Industrial Commission.

TABLE OF CONTENTS

LIST OF TABLES

EXECUTIVE SUMMARY

The Bakken Production Optimization Program (BPOP) was established to facilitate Bakken petroleum system oil recovery while simultaneously reducing the environmental footprint of oil and gas development. This program is administered by the Energy & Environmental Research Center (EERC), with funding from the North Dakota Industrial Commission (NDIC) Oil and Gas Research Program (OGRP) and the North Dakota petroleum industry. Through BPOP, the EERC is working closely with a consortium of industry partners and the state to address emerging opportunities and challenges related to Bakken development. This progress report presents an overview of BPOP activities from July 1 through September 30, 2020.

The final BPOP 2.0 highlights and a look at the next 3 years in BPOP 3.0 were presented to OGRP on August 4, 2020. The EERC continued to engage the BPOP partners on discussion of results from prior studies and discussion of their needs and priorities for the upcoming months. Four webinars were held to share findings from project activities. Fluid fingerprinting method development continued. Knowledge gained with the methods will be used to select the most informative hydrocarbon indicators for the Bakken crude oil fingerprinting. Strontium isotope fingerprinting applications appear promising in Bakken formation fluids. Well completion optimization data analysis continued with the creation of an interactive cluster calculator to divide the Bakken play into several subareas or clusters. History-matching a dynamic simulation model of the East Nesson area being considered by Liberty Resources for an enhanced oil recovery (EOR) pilot was completed. An experimental design plan for laboratory-based testing of rocks and fluids to support design of an EOR pilot being considered by Oasis Petroleum Inc. was developed.

The EERC holds an unwavering commitment to the health and well-being of its employees, partners and clients, and the global community. As such, precautionary measures have been implemented in response to COVID-19. Staff continue to carry out project-related activities remotely, and personnel supporting essential on-site laboratory and testing activities are proceeding under firm safety guidelines. Travel has been minimized, and protective measures are being undertaken for those who are required to travel. At this time, work conducted by EERC employees is anticipated to progress with minimal disruption. Challenges posed by economic variability will be met with open discussion between the EERC, the NDIC Project Manager, and BPOP partners to identify solutions. The EERC is monitoring developments across the nation and abroad to minimize risks, achieve project goals, and ensure the success of our partners and clients.

BAKKEN PRODUCTION OPTIMIZATION PROGRAM

INTRODUCTION

The Bakken Production Optimization Program (BPOP) was established to facilitate Bakken petroleum system (BPS) oil recovery while simultaneously reducing the environmental footprint of oil and gas development. This program is administered by the Energy & Environmental Research Center (EERC), with funding from the North Dakota Industrial Commission (NDIC) Oil and Gas Research Program (OGRP) and the North Dakota petroleum industry. Through BPOP, the EERC is working closely with a consortium of industry partners and the state to address emerging opportunities and challenges related to Bakken development.

The goals of BPOP are to:

- Provide the state and industry with science-based insight to maintain the economic and environmental sustainability of the Bakken play in North Dakota.
- Provide stakeholders with the knowledge needed to plan and implement innovative development strategies that will take the Bakken into the next decade and help achieve the Governor's goal of 2 million barrels per day of North Dakota oil production.

The anticipated ongoing outputs of BPOP are 1) increased well productivity and economic output of North Dakota's oil and gas resources; 2) decreased environmental impacts of wellsite operations; and 3) guidance to stakeholders regarding optimal, prudent development of North Dakota's Bakken petroleum resources.

ACCOMPLISHMENTS DURING REPORTING PERIOD

Several activities performed under BPOP 2.0 had continued interest from partners. Efforts continued this quarter to advance the research activities.

A journal article entitled "Comparison of CO_2 and Produced Gas Hydrocarbons to Dissolve and Mobilize Bakken Crude Oil at 10.3, 20.7, and 34.5 MPa and 110°C" was published by *Energy & Fuels* on August 25, 2020. The material is based upon work performed under BPOP and the matching effort under the U.S. Department of Energy (DOE). A link to the article is available on the BPOP website.

Process Optimization

Processing produced fluids from the well to market, although simple when described in a basic flow diagram, is complicated by dynamic and variable production rates and fluids composition, extreme climate, complex business and financial models, and evolving regulations. By working with BPOP partners, the EERC can systematically analyze trends by assimilating

data and information from multiple operators, assist in defining the challenges to improved process efficiency, and identify technological and operational solutions through process modeling and system design. 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.

Over the past several months, the EERC has engaged BPOP partners to discuss results from prior studies and to discuss their needs and priorities for the upcoming months. Recognizing the evolving challenges to oil and gas production in the Bakken, the EERC is actively seeking input from our stakeholders to ensure our work supports their efforts to improve the efficiency and reduce the environmental impact of oil and gas production.

Based on input from partners received to date, the EERC has begun a systems-level assessment of wellsite emissions resulting from both combustion sources and hydrocarbon vapor management. The goal is to develop a data-based prioritization of emission sources, characterization of those emissions, and systems-level analysis of mitigation strategies. These may include improved technologies such as high-destruction efficiency flares, or vapor handling equipment, and alternate processing strategies that reduce hydrocarbon vapor loss or reduce the quantity of vapor requiring flare-based destruction. During this reporting period, the EERC began gathering information on well-site hydrocarbon gas characterization (quantity and quality) and developed process models that will be used to assess vapor behavior across the production facility. With this information, the EERC will be able to identify optimization strategies for subsequent field validation and trials.

During this reporting period, the EERC held two webinars to share findings from these recently completed investigations. A presentation summarizing the use of mobile data centers for flare gas mitigation entitled “Exploration of a Novel Avenue Toward Wellsite Gas Capture – Power Generation for Mobile Data Centers” was given July 7, 2020. A presentation summarizing the opportunities and challenges of large, centralized facilities for processing produced fluids entitled “Analysis of Central Production Facilities” was given July 23, 2020.

Fluids Characterization

The optimization of crude oil production in North Dakota requires accurate understanding of the fluids being produced. Crude oil, associated gas, and produced water are complex mixtures, and their chemical and physical properties can vary geographically over the life of a well. Over the first 6 years of BPOP, a large amount of fluids data has been acquired, and a database of fluids information has been created. The EERC will continue to maintain and expand this valuable database and coordinate data gathering and sampling and analysis activities to support all the program tasks.

To better understand drainage mechanisms and crude oil volumes in the different lithofacies of the BPS, oil fingerprinting methods were further improved. Several sample preparation methods were adapted in the laboratory, including 1) extraction of oil/bitumen from rock using sonication and Soxhlet extractors and 2) fractional separation using an open column. To improve the results of gas chromatography–mass spectrometry (GC–MS) analysis, a fraction

separation method using an open column was tuned and modified for Bakken crude oil. Aromatic and saturate fractions were analyzed separately, and relative abundances of various groups of compounds were evaluated. This knowledge will be used to select the most informative hydrocarbon indicators for the oil fingerprinting purpose.

A literature review on various approaches to fingerprint water samples and their application in operational problem solving was completed. An initial assessment was completed to compare the chemistry of Bakken formation fluids with data from adjacent formations. The bulk chemistry of the reservoir fluid was combined with strontium (Sr) isotope composition data, and fluids representing various formations were discriminated using two-dimensional plots. The promising results of the Sr isotope fingerprinting applications in the Bakken have resulted in the EERC developing a method for in-house Sr isotope analysis.

Well Completion Optimization

Based on review of existing literature and results from initial work, EERC staff decided that completion optimization calculations can be improved if geologic and reservoir information is integrated into the statistical model. Available in-house and mappable geologic and reservoir data sets were enriched with fluid compositional data, and this information package was finalized for further cluster analysis. An interactive cluster calculator was created to divide the Bakken play into several subareas or clusters.

After several trials, Microsoft Power BI was selected for competitor analysis visualization. The list of graphs and charts demonstrating operators' changing strategy in 2019/2020 was finalized, and a few examples of the operational analyses were completed. The master data set, including well production and completion information, has been updated and cleaned and is in the process of being finalized.

Two webinars were held this reporting period to share findings from this work. On August 27, 2020, a presentation entitled "Quantifying the Effect of Completion Parameters on Well and DSU [drill spacing unit] Production Using Multilevel Regression" focused on two specific aspects of the May 2020 BPOP report. The presentation reviewed the Bakken completion and production data set, described the statistical methods used, and summarized the results and interpretation. On September 30, 2020, a presentation entitled "Predicting Oil Production Using Machine Learning" focused on experiential data mining approaches to better understand data behavior and to select algorithms for predicting oil production. The presentation reviewed the machine learning workflow, data treatment, selecting machine learning algorithms, model tuning, and sensitivity analysis, demonstrating the impact of completion design parameters on well performance. The presentations are provided in Appendix A.

Enhanced Oil Recovery

Two BPOP member companies (Liberty Resources and Oasis Petroleum Inc. [Oasis]) continue to develop plans for future enhanced oil recovery (EOR) pilot tests, and EERC personnel conducted activities to support those planning efforts. Specific activities include the completion of history-matching a dynamic simulation model of the East Nesson area being

considered by Liberty Resources for an EOR pilot and the development of an experimental design plan for laboratory-based testing of rocks and fluids to support design of an EOR pilot being considered by Oasis.

Biweekly meetings were held with Liberty to discuss progress and next steps on the East Nesson area model. Specific progress includes the following:

- A layer-cake model was adapted from the East Nesson geologic model for dynamic simulation. A fracture network including both induced hydraulic and natural fracture systems, built using the embedded discrete fracture model approach (EDFM), was incorporated into the dynamic simulation model.

- History-matching was conducted and completed to calibrate the dynamic simulation model based on the available production data of the East Nesson area to be used in prediction of performance of EOR methods.

- A simulation matrix case was developed to evaluate EOR performance of several hypothetical EOR scenarios with consideration for operational parameters likely to be encountered by Bakken operations. The matrix includes single phase, gas injection, and coinjection of gas and water for huff ‘n’ puff operations.

- Rock exposure laboratory experiments to better understand the parameters controlling oil hydrocarbon recoveries were designed. Middle Bakken rock samples from two BPOP member wells were obtained from the North Dakota core library and cut to produce the required sample geometries (11-mm rods, 7-mm rods, and ca. 2-mm-thick “coins”).

The EERC held several discussions with producers and technology providers to discuss applicability and performance of hybrid surfactant systems for application to unconventional EOR scenarios.

Program Management and Development

The final BPOP 2.0 highlights and a look at the next 3 years in BPOP 3.0 were presented to the Oil and Gas Research Council on August 4, 2020. The presentation entitled “Bakken Production Optimization Program (BPOP) 2.0 Final Presentation” is provided in Appendix A.

The EERC is operational and open for business. Personnel who are not essential for on-site operations have transitioned to working from home. Essential project, laboratory, and field-based activities are proceeding with the incorporation of Centers for Disease Control and Prevention (CDC), the state of North Dakota, and University of North Dakota guidelines associated with COVID-19, and mitigation measures have been implemented.

In collaboration with project partners, the EERC is continually assessing potential impacts to project activities resulting from COVID-19 and/or the U.S. economic situation.

In the event that any potential impacts to reporting, scope of work, schedule, or cost are identified, they will be discussed and addressed in cooperation with NDIC.

PARTNERSHIP AND FINANCIAL INFORMATION

The original budget as proposed to NDIC OGRP is $12,000,000, as shown in Table 1. Expenses to date are also listed in Table 1.

Table 1. BPOP – Budget and Expenses to Date

Sponsors	Budget	Actual Expenses as of 9/30/2020	Balance
NDIC Share – Cash	$6,000,000	$483,804	$5,516,196
Industry Share – Cash	$500,000	$41,109	$458,891
Liberty – In-Kind	$4,000,000	$0	$4,000,000
DOE – Cash	$1,500,000	$134,547	$1,365,453
Total	**$12,000,000**	**$659,460**	**$11,340,540**

FUTURE ACTIVITIES

Process Optimization

Activities next quarter will include continued fluid/vapor characterization work to better understand the nature of hydrocarbon vapors present across the production facility, process model simulations, and data collection from participating partners. The EERC will continue to engage BPOP partners to solicit input on ways the EERC staff and BPOP resources can be applied to meet their needs.

Fluids Characterization

Upcoming activities include continued engagement with industry partners to understand their needs related to Bakken production issues and practices and to expand the geographical extent of the sampling and analysis effort. Data collection and sample acquisition are expected to occur in October 2020, with results supporting the ongoing compositional evaluations of each fluid, supporting temporal evaluations, and enhancing the size and usefulness of the database to the various BPOP research efforts. This task will also support new and developing field-based EOR and gas storage projects to be conducted by the EERC and specific BPOP partners.

During the next quarter, work will focus on standardization of the GC and GC–MS methods and creation of convenient output formats for further data interpretation. The research team will continue their efforts to understand vertical and lateral variations in organic facies using dozens of source rock samples representing the Upper and Lower Bakken Shales and crude oil produced from the Middle Bakken. It is planned that newly generated geochemical data on a molecular level will be integrated with available in-house information on organic petrology and bulk characteristics of the source rocks. Fingerprinting efforts will focus on identification of

reliable indicators or hydrocarbon ratios for the oil/rock correlations and tools for the reservoir communication evaluation in the BPS. Obtained data and knowledge will be used to build reliable tools to determine reservoir connectivity, understand drainage volume, possibly determine the source of high concentration of H_2S in Bakken production streams, diagnose out-of-zone completions, and monitor subsurface fluid flow.

Well Completion Optimization

The well completion optimization work will build upon the existing machine learning analyses previously conducted on the BPOP analytics database. Additional data about geology and fluids (oil, gas, and water) for a subset of the wells will be incorporated into a revised database. These additional features will be used to subdivide the BPS into several clusters or subareas using one or more clustering algorithms (e.g., k-means clustering). The reservoir properties may be more similar within each cluster, which will reduce the within-group variance and thereby reduce potential confounding factors in the analysis. Further optimization calculations will be performed either by individual cluster/subarea or for the entire BPS with the cluster information included in the predictive model.

Optimization calculations will be performed on both individual wells and DSUs. The current algorithm for assigning individual wells to a unique DSU will be updated and improved. Competitor analyses of the top ten operators will focus on both 2019 growth and 2020 optimization strategies.

Three additional webinars are planned in the coming quarter. A webinar entitled “Completion Design Optimization in Three Subareas of the Bakken Using Gradient Boosting” is scheduled for October 22, 2020. A webinar is scheduled for November 19, 2020, to present an overview of some of the historical Bakken production trends (oil, gas, and water production and metrics derived from these values) and completion trends (information about well drilling, completion, and stimulation, such as lateral length, stage count, stage spacing, frac fluid volume, proppant volume, etc.). A webinar is scheduled for December 17, 2020, to present an overview of recent and planned Bakken production data analytics work being performed as part of BPOP 3.0. BPOP partners will also be asked to provide feedback and input on our planned Bakken production data analytics research activities to ensure that we include the key questions and research priorities of our members in these efforts.

Enhanced Oil Recovery

Simulations will be conducted to evaluate the performance of single- and dual-phase injection scenarios described in the simulation case matrix using the history-matched East Nesson model. A report on the modeling and simulation work will be drafted to be provided to BPOP partners following review.

Laboratory work will continue. Test gas (ca. 67%/20%/13% methane/ethane/propane) that mimics Bakken produced gas will be prepared for use in hydrocarbon recovery laboratory tests. Laboratory tests to determine hydrocarbon recovery performance under various scenarios analogous to continuous gas injection and huff ‘n’ puff scenarios will be conducted.

Program Management and Development

Additional research activity ideas for the current project year will be discussed with project partners.

APPENDIX A

BAKKEN PRODUCTION OPTIMIZATION PROGRAM (BPOP) 2.0 FINAL PRESENTATION

Energy & Environmental Research Center (EERC)

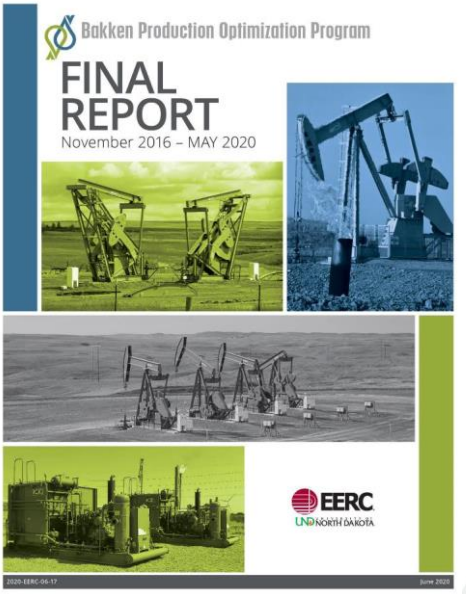
BAKKEN PRODUCTION OPTIMIZATION PROGRAM (BPOP) 2.0 FINAL PRESENTATION

Presented to Oil & Gas Research Council
Bismarck, North Dakota
August 4, 2020

Charlie Gorecki, CEO
John Harju, Vice President for Strategic Partnerships
Jim Sorensen, Director of Subsurface R&D

AGENDA

- BPOP 2.0 Highlights
  - Partners
  - Budget Evolution
  - Rich Gas Enhanced Oil Recovery (EOR) Pilot
  - Surface Facilities & Infrastructure
  - Subsurface Topics
  - Website
- BPOP 3.0 – The Next Three Years



PARTNERS

BPOP 2.0 BUDGET EVOLUTION

Sponsors	Original Budget	Final Budget	Actual Expenses	Balance
NDIC Share – Cash	$6,000,000	$6,000,000	$5,999,645	$355
Industry Partners – Cash	TBD	$2,050,000	$1,949,581	$100,419
Marathon – In-Kind	$7,280,000	$12,615,401	$12,615,401	$0
Liberty – In-Kind		$3,255,937	$3,255,937	$0
DOE – Cash		$2,000,000	$1,999,849	$151
Total	$13,280,000	$25,921,338	$25,820,413	$100,925

- Program resources were nearly doubled from those originally proposed, resulting in leverage of NDIC resources > 3:1.
- A member contribution received late spring 2020 was rolled into BPOP 3.0's resources.

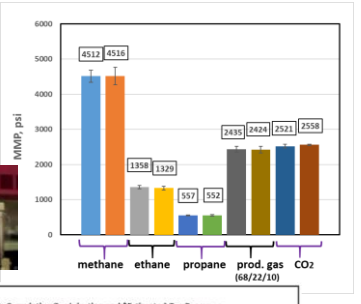
RICH GAS EOR – ACTIVITIES

- Lab studies of rich gas interactions with fluids and rocks
- Iterative modeling of surface and subsurface components
- Pilot performance assessment

RICH GAS EOR – HIGHLIGHTS

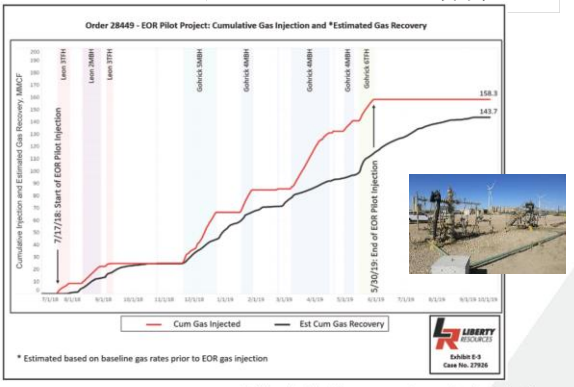
From the Lab:

- The richer the gas, the lower the MMP!!!
- Wellhead produced gas and CO_2 have similar MMP.



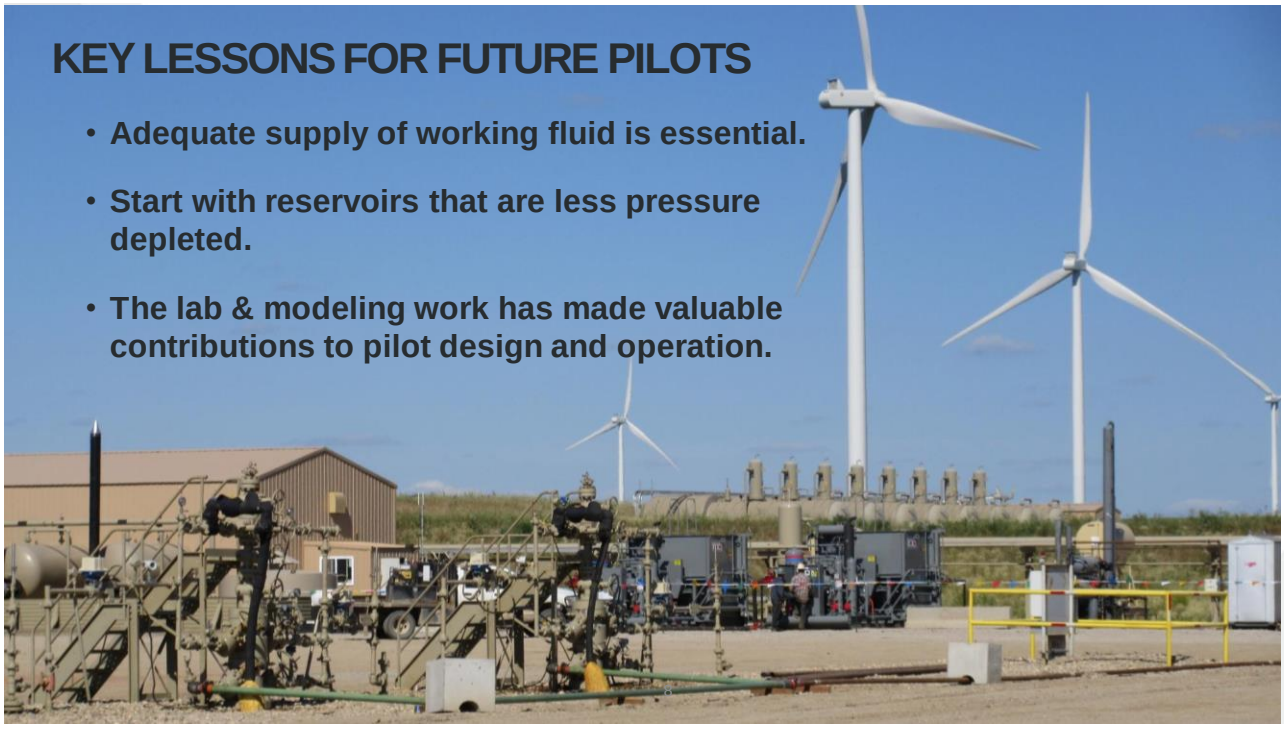
From the Field:

- ~160 MMscf gas injected in five wells during six different periods.
- Injected gas was controlled and contained within the DSU.
- Pressure buildup was achieved.

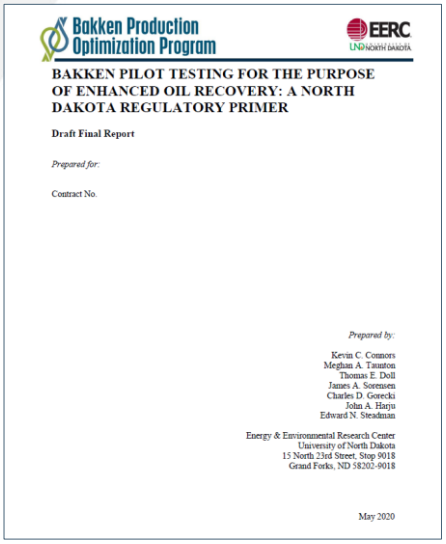


KEY LESSONS FOR FUTURE PILOTS

- Adequate supply of working fluid is essential.
- Start with reservoirs that are less pressure depleted.
- The lab & modeling work has made valuable contributions to pilot design and operation.



PRIMER FOR PERMITTING AN EOR PILOT



Bakken Production Optimization Program

EERC UND NORTH DAKOTA

BAKKEN PILOT TESTING FOR THE PURPOSE OF ENHANCED OIL RECOVERY: A NORTH DAKOTA REGULATORY PRIMER

Draft Final Report

Prepared for:

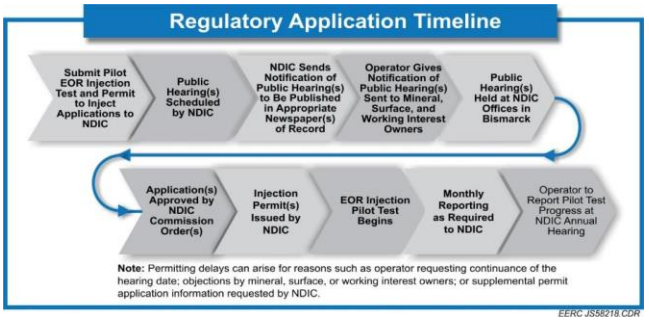
Contract No.

Prepared by:

Kevin C. Connors
Meghan A. Taunton
Thomas E. Doll
James A. Sorensen
Charles D. Gorecki
John A. Harju
Edward N. Steadman

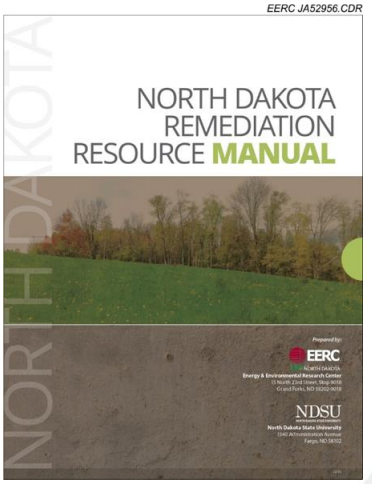
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

May 2020



SURFACE HIGHLIGHTS
A Platform for Technical Industry Forums

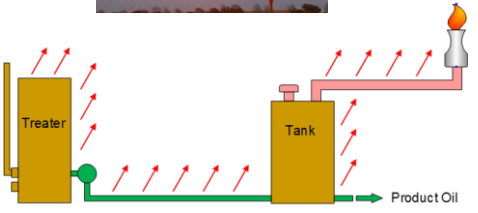
- Technical support to the NDPC Hydrocarbon Remediation Task Force.
  - Co-authored the North Dakota Remediation Resource Manual.
    - ♦ Updated to include brine and hydrocarbon remediation, released March 2019.
- Supported gas capture efforts.
- Co-chaired the NDPC Technical Solutions Group, providing a forum to hear from oil field technology providers and share process optimization lessons learned.



SURFACE HIGHLIGHTS – FACILITY OPTIMIZATION

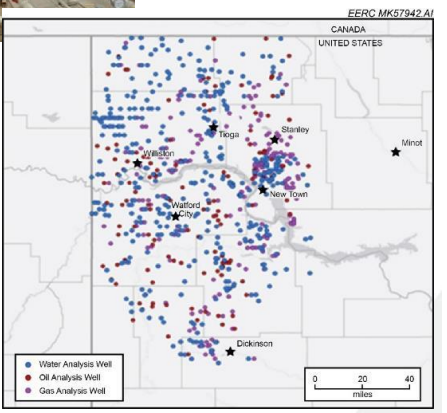
Member participation, computational modeling, and field studies addressed:

- **Emissions**
  - Impacts of production rate and tank design on tank emissions.
- **Gas Capture**
  - Technoeconomic analysis of mobile data centers as a flare mitigation strategy.
- **Crude Oil Vapor Pressure**
  - Design and operational strategies to improve vapor pressure compliance in cold weather.
- **Tank Vapor Management**
  - Identified operational conditions necessary to avoid flammable atmosphere in tank batteries.
- **Central Facilities**
  - Technoeconomic analysis of a central facility and identified advantages and challenges relative to a DSU-based facility.



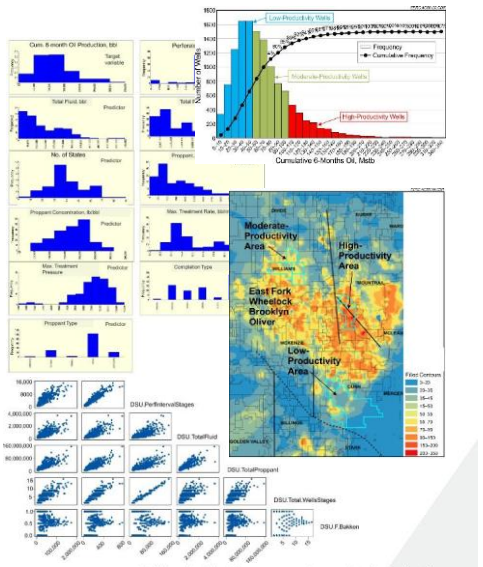
SURFACE HIGHLIGHTS – FLUIDS CHARACTERIZATION

- Bakken/Three Forks produced fluids database:
  - 1000 produced water & gas samples
  - 500 crude oil samples
  - Maps were created and used to identify trends and correlations between fluid characteristics, geology, and well design & operational parameters.
- Produced gas composition observed to change over the first few years of production, with an increase in methane and a decrease in rich components.
- These findings were similar to, and used to validate, a separate basin wide gas composition forecasting effort.



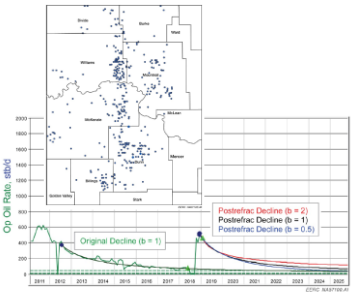
SUBSURFACE HIGHLIGHTS – WELL DATA ANALYSIS

- ML algorithms and data analytics used to determine the top factors that affect oil production.
- Example findings:
  - ♦ The top completion-related parameters that affected 6-month oil production were total proppant mass, total fracturing fluid volumes, number of wells within a DSU.
  - ♦ Sensitivity analyses showed that oil production generally increases with more intense completion practices.
  - ♦ All other inputs being equal, a well completed in the Three Forks has an 8% lower cumulative oil production in the first 6 months (on average) than an equivalent Bakken well.

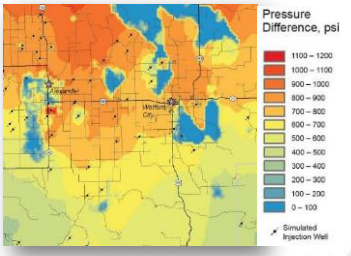


SUBSURFACE HIGHLIGHTS – REFRACS AND SWD

- **Evaluation of well refrac opportunities in the Bakken**
  - Identified ~ 400 wells that would be promising candidates for refracturing.
  - Based on 2019 economics, refracturing these wells estimated to yield a discounted net oil revenue of approximately $2 billion, reflecting the median outcome after deducting the refrac cost, taxes, and royalties.



- **Modeling and simulation of SWD in the Inyan Kara Formation (Dakota Sandstone)**
  - Localized areas of pressurization have occurred.
  - Predictive model simulations suggest that the areas of elevated pressure could expand in size and magnitude with continued long-term injection, especially in the northern portion of McKenzie County.



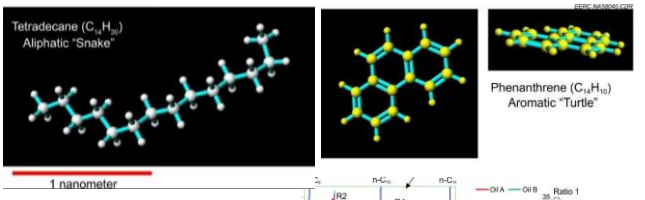
SUBSURFACE HIGHLIGHTS – OIL FINGERPRINTING

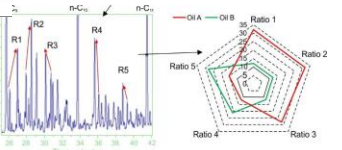
- **Oil fingerprinting using aromatic/aliphatic (AA) ratios**

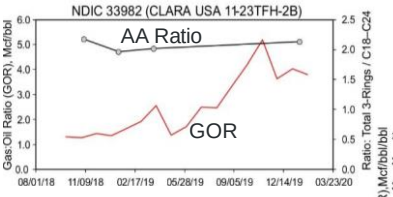
  Statistically significant differences in the AA ratio of oil from the shales vs nonshale reservoirs were identified from 105 rock samples.

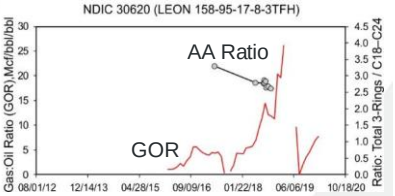
  Temporal AA ratios for oil from 12 Marathon & Liberty wells:

  - 10 wells had no statistically significant changes in AA, suggesting no changes in the source of oil.
  - 2 wells showed decreasing AA ratio, suggesting less contribution of oil from shales over time.









PRODUCTS CAN BE ACCESSED ON THE WEBSITE

Bakken Production Optimization Program

EERC UND NORTH DAKOTA

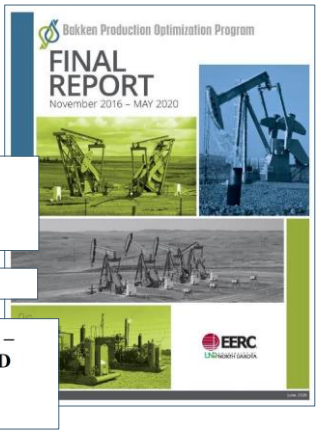
REFRACTURING IN THE BAKKEN – AN ANALYSIS OF DATA FROM ACROSS NORTH DAKOTA

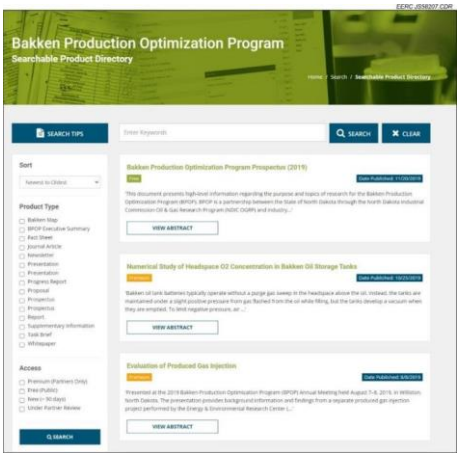
OVERVIEW SUMMARY OF ADVANCED ANALYSIS OF BAKKEN DATA TO OPTIMIZE FUTURE PRODUCTION STRATEGIES

PRODUCED FLUID CHARACTERIZATION

ENHANCED OIL RECOVERY IN THE BAKKEN – KEY OBSERVATIONS AND LESSONS LEARNED FROM LABORATORY STUDIES, MODELING, AND FIELD TESTING

TURTLES AND SNAKES: USING MOLECULAR SHAPE TO UNDERSTAND OIL MIGRATION AND PRODUCTION IN THE BAKKEN PETROLEUM SYSTEM





BAKKEN PILOT TESTING FOR THE PURPOSE OF ENHANCED OIL RECOVERY: A NORTH DAKOTA REGULATORY PRIMER

EXAMINATION OF PREFERENTIAL SORPTION OF RICH GAS COMPONENTS IN BAKKEN SHALE

EERC | UND UNIVERSITY OF NORTH DAKOTA

Critical Challenges. Practical Solutions.

16

ROAD AHEAD FOR THE BAKKEN…

- Operators face challenges beyond current price environment.
  - Flaring
  - Produced water
  - Fugitive emissions
  - Takeaway capacity

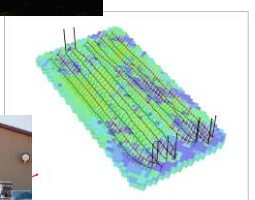
17

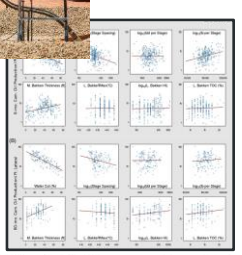
17

BPOP 3.0 MAY 2020 – APRIL 2023

Key questions to be addressed during the next 3 years could include:

- How do we go about a “Smart Restart” for Bakken wells & infrastructure?
- How do we apply lessons to next-generation pilots and build momentum to commercial EOR?
- What is the best development strategy for Bakken and Three Forks resources over the next decade?
- How do we manage long-term, large-volume water and rich gas coproduction?
- How can recent advances in BDA and ML be applied to oil and gas resource development in North Dakota?





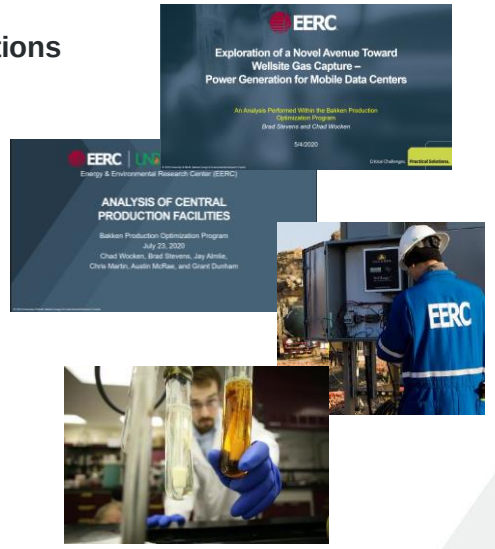
EERC | UND UNIVERSITY OF NORTH DAKOTA

Critical Challenges. Practical Solutions.

BPOP 3.0 CURRENT ACTIVITIES

- **Surface operations and infrastructure investigations**
  - Knowledge transfer through webinars
  - Planning for next round of field data collection
  - Beginning to look at impact of shut-ins on infrastructure

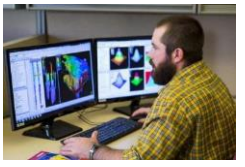
- **Subsurface investigations**
  - Knowledge transfer through webinars
  - Planning for next round of field data collection
  - Advanced analysis of well completions and fluids production data
  - Continuing to improve oil fingerprinting methods



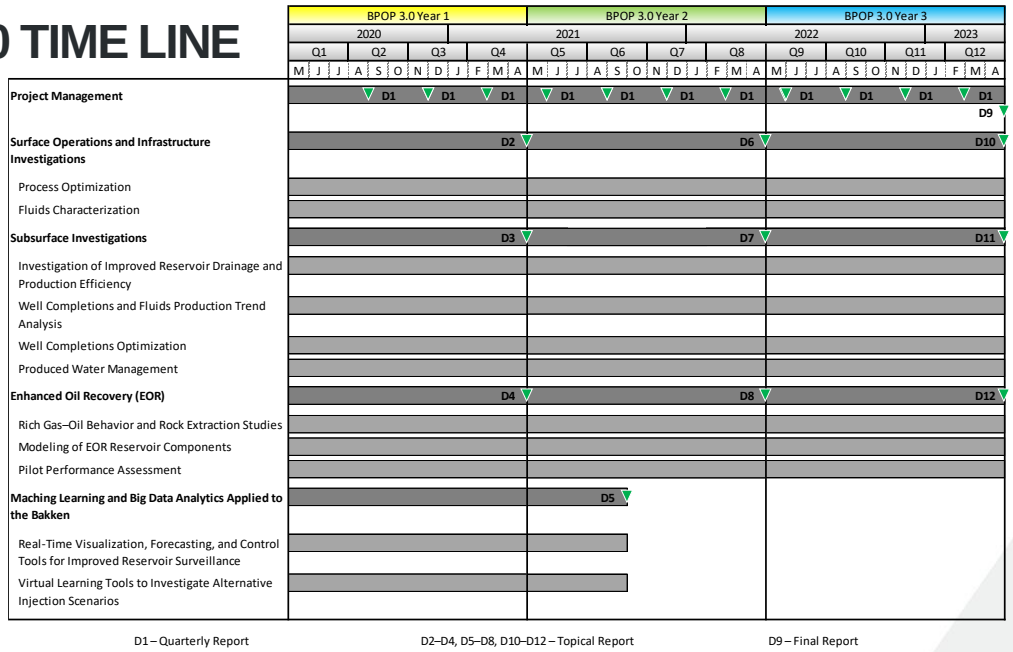
BPOP 3.0 CURRENT ACTIVITIES

- **Enhanced oil recovery**
  - Rich gas–oil fluid behavior and rock extraction studies in conjunction with Oasis
  - Reservoir modeling and simulation in support of new Liberty Resources pilot concept

- **Machine learning and big data analytics applied to the Bakken**
  - U.S. Department of Energy match
  - Real-time visualization, forecasting, and control tools for improved reservoir surveillance
  - Virtual learning tools to investigate alternative injection scenarios



BPOP 3.0 TIME LINE



D1 – Quarterly Report

D2–D4, D5–D8, D10–D12 – Topical Report

D9 – Final Report

BPOP 3.0 PROPOSED BUDGET

	NDIC Share	Industry Share	Federal Share	Total Project
Total Cash Requested	$6,000,000	$500,000	$1,500,000	$8,000,000
Total In-Kind Cost Share		$4,000,000		$4,000,000
Total Project Costs	$6,000,000	$4,500,000	$1,500,000	$12,000,000

QUESTIONS?

Charlie Gorecki
CEO
cgorecki@undeerc.org
701.777.5355 (phone)

John Harju
Vice President for Strategic Partnerships
jharju@undeerc.org
701.777.5157 (phone)

Jim Sorensen
Director of Subsurface R&D
jsorensen@undeerc.org
701.777.5287 (phone)

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

www.undeerc.org
701.777.5000 (phone)
701.777.5181 (fax)