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January 28, 2021

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 October 1 – December 31, 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:
6AD3DF00E40048F...
James A. Sorensen
Director for Subsurface R&D

JAS/kal

Attachment

c/att: Brent Brannan, North Dakota Industrial Commission

BAKKEN PRODUCTION OPTIMIZATION PROGRAM

Quarterly Progress Report

(for the period October 1 – December 31, 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.

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January 28, 2021

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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 October 1 through December 31, 2020.

The EERC requested and received permission from NDIC OGRP to subcontract with Liberty Resources (Liberty) and EOR ETC, LLC (EOR ETC) to support an East Nesson Bakken enhanced oil recovery (EOR) field pilot in 2021. Subcontracting is proceeding with Liberty and EOR ETC to demonstrate a new technology to facilitate produced gas injection for EOR and/or subsurface geologic storage at Liberty's East Nesson Field. Liberty and EOR ETC will provide in-kind contributions to the pilot test.

Oasis Petroleum Inc. agreed to contribute in-kind cost-share funding in the form of core and PVT (pressure, volume, and temperature) analyses data. This information will be used to support evaluation of rich-gas EOR opportunities in the Bakken.

Four webinars were held to share findings from the well completion optimization work. These provided discussion opportunities between the research team and BPOP partners.

A systems-level assessment of wellsite emissions resulting from both combustion sources and hydrocarbon vapor management is being established with input from partners to develop a data-based prioritization of emission sources, characterization of those emissions, and systems-level analysis of mitigation strategies.

Several improvements to conventional fingerprinting and geochemical characterization methods were performed by expanding on the use of complex indicator compounds such as diamondoids and various polyaromatics. Complementary to hydrocarbon fingerprinting efforts, in-house instrumentation and analytical methods were modified for the purpose of conducting produced water fingerprinting techniques using strontium isotope analysis.

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 progressing 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.

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.

With input from partners, 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. During this reporting period, the EERC reviewed wellsite hydrocarbon gas characterization data (quantity and quality), gathered data on gas/oil ratio and tank gas/oil ratio, and continued the development and refinement of process models to assess vapor behavior across the production facility. Additionally, air emission regulations were reviewed to determine how production rate and key operational factors impact emissions.

Fluids Characterization

The optimization of crude oil production in North Dakota requires an 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 and also over the life of a single well. Over the first 6 years of BPOP, extensive fluids data have 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.

The EERC research team has improved on oil fingerprinting analytical techniques that are utilized by the oil and gas and analytical laboratory industry to better understand drainage mechanisms. This information will be utilized in an associated task effort to facilitate activities to enhance targeted oil recovery. Various groups of compounds have been identified using gas chromatography–mass spectrometry (GC–MS), and a retention time database for all individual hydrocarbons present in Bakken oil has been created. To expand EERC geochemical/analytical fingerprinting capabilities, additional in-house instrumentation was modified and calibrated for the purpose of the study. Several improvements to conventional fingerprinting and geochemical characterization methods were performed by expanding on the use of complex indicator compounds such as diamondoids and various polyaromatics.

Complementary to hydrocarbon fingerprinting efforts, in-house inductively coupled plasma (ICP)–MS instrumentation and analytical methods were modified for the purpose of conducting produced water fingerprinting techniques using strontium (Sr) isotope analysis. Several different techniques and modifications were evaluated to improve isotope measurement accuracy. Historical water chemistry data and information generated by the EERC laboratory are being compiled and will be used to identify compositional differences in water samples produced from various reservoirs.

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.

An internal master data set, including well production and completion information, was updated to reflect recent changes in the NDIC data source. Errors were investigated, and the data set was cleaned up and organized for further analysis. Microsoft Power BI was tested to create an analysis of oil and gas operator strategies in 2019–2020 and to demonstrate current completion and production trends.

Four webinars were held this reporting period to share findings from this work. These provided discussion opportunities between the research team and BPOP partners. Details of the webinars are as follows:

- On October 22, 2020, a presentation entitled "Completion Design Optimization in Three Subareas of the Bakken Using Gradient Boosting" included the results of completion optimization calculations under BPOP. The presentation reviewed the application of gradient boosting in three locations and provided recommendations for operational optimization in the Bakken play.

- On November 19, 2020, a presentation entitled "Historical Production and Completion Trends" provided 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, fracture fluid volume, proppant volume, etc.). The presentation covered figures from Section 2 of the May 2020 BPOP report and additional trend analyses using the BPOP January 2020 trend database.

- Some of the BPOP partners had expressed interest in the method that the EERC used to assign wells to a unique drill spacing unit (DSU) as part of the efforts to evaluate Bakken well development, completion techniques, and oil production on a DSU basis. As such, on December 2, 2020, a presentation entitled "Assigning Wells to Drill Spacing Units for Bakken Production Analysis" provided partners the opportunity to learn more about the EERC's approach of extracting, standardizing, and cleaning existing well file data, followed by GIS (geographic information system) analysis to assign Bakken and Three Forks wells to specific DSUs.

- On December 17, 2020, a presentation entitled "Overview of Current Data Analytics Research Efforts and Discussion" provided an overview of recent and planned Bakken production data analytics work being performed as part of BPOP 3.0. The initial results of the most recent work were presented, including an evaluation of the well completion strategies for the top ten producers in the Bakken and an analysis of the top 5%–10% producing wells, including the impacts of well location, operator, completion strategy, and service company on well performance. BPOP partners were asked to provide feedback and input on the planned Bakken production data analytics research activities to ensure that the key questions and research priorities of the BPOP partners are included in these efforts.

Enhanced Oil Recovery

Two BPOP member companies (Liberty Resources [Liberty] 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 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.

The EERC requested and received permission from NDIC OGRP to subcontract with Liberty and EOR ETC, LLC (EOR ETC) to support an East Nesson Bakken EOR field pilot in 2021. Subcontracting is proceeding with Liberty and EOR ETC to demonstrate a new technology to facilitate produced gas injection for EOR and/or subsurface geologic storage at Liberty's East Nesson Field. Liberty and EOR ETC will provide in-kind contributions to the pilot test.

Oasis agreed to contribute in-kind cost-share funding in the form of core and PVT (pressure, volume, and temperature) analyses data. This information will be used to support evaluation of rich-gas EOR opportunities in the Bakken. The analysis generated by the EERC will be shared with NDIC and BPOP 3.0 partners, who will have an obligation to keep such analysis (and any other data and/or other information such partners are rightfully entitled to receive in connection with BPOP 3.0) confidential. Any derivative products developed by the EERC will be provided to the BPOP partners for a period of 24 months following Oasis's approval, after which the derivative products will be provided to NDIC.

Biweekly, and when required, weekly meetings were held with Liberty to discuss progress and next steps on the East Nesson project. The simulation model was updated with site-specific fracture data received from Liberty. A single fracture stage simulation model of the East Nesson site was generated to integrate increased fracture density to produce a computationally efficient approximation of performance for a segment of a DSU. History-matching was reconducted for each simulation model developed, following the update on the fracture modeling. This approach allows multiple EOR scenarios to be efficiently evaluated and performance scaled to the DSU to validate the model and inform/optimize pilot design parameters. The simulation matrix developed in the previous quarter was revised to reflect operational parameters established by Liberty. The modeled performance of EOR scenarios for huff 'n' puff injection including single gas injection and two-phase coinjection of gas and water were evaluated.

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 project team continued to engage partners to guide the activities to meet their needs.

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.

Table 1. BPOP – Original Budget

Sponsors	Budget
NDIC Share – Cash	$6,000,000
Industry Share – Cash	$500,000
Liberty – In-Kind	$4,000,000
DOE – Cash	$1,500,000
Total	**$12,000,000**

Table 2 presents a revised expected budget based on the allocation of cost share secured by the EERC. Expenses to date are also listed in Table 2.

Table 2. BPOP – Expected Budget and Expenses to Date

Sponsors	Expected Budget	Actual Expenses as of 12/31/2020	Balance
NDIC Share – Cash	$6,000,000	$953,320	$5,046,680
Industry Share – Cash	$300,000	$74,841	$225,159
Oasis – In-Kind	$1,577,000	$0	$1,577,000
DOE – Cash	$1,500,000	$295,089	$1,204,911
Liberty – In-Kind	$810,000	$0	$810,000
EOR ETC – In-Kind	$80,000	$0	$80,000
Industry – TBD	$1,733,000	$0	$1,733,000
Total	**$12,000,000**	**$1,323,250**	**$10,676,750**

FUTURE ACTIVITIES

Process Optimization

Activities next quarter will include continued computational simulations to evaluate operating conditions and system designs capable of reducing emissions without negatively impacting safety, crude oil properties, or gas sales. The EERC will continue to engage BPOP partners to solicit input on ways 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 spring 2021, 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.

Efforts will continue to apply the oil fingerprinting analytical techniques and expand the applications to benefit current and future Bakken system research efforts.

Historical water chemistry data and information generated by the EERC laboratory will continue to be compiled and will be used to identify compositional differences in water samples produced from various reservoirs. Analytical efforts to evaluate both hydrocarbon and produced water phases of Bakken production will continue to be performed.

Well Completion Optimization

The well completion optimization work will build on 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.

Enhanced Oil Recovery

Sensitivity studies for multiple hypothetical EOR scenarios for the East Nesson site will be conducted to inform/optimize pilot design and operational parameters. A summary of modeling and simulation work and findings will be prepared.

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.