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April 13, 2017

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission (NDIC)
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 January 1 – March 31, 2017, Entitled "Bakken Production Optimization Program 2.0"; Contract No. G-040-080 EERC Fund 22010

Enclosed 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) 777-5276 or by e-mail at bkalk@undeerc.org.

Sincerely,

Brian P. Kalk
Director of Energy Systems Development

BPK/rlo

Enclosure

E-Mailed Report Only: Brent Brannan, NDIC Oil and Gas Research Council
Lynn Helms, NDIC Department of Mineral Resources, Oil and Gas Division
Ron Ness, North Dakota Petroleum Council

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April 13, 2017

Mr. Jeffrey Parker
Marathon Oil Company
5555 San Felipe
Houston, TX 77056

Dear Mr. Parker:

Subject: Quarterly Progress Report for the Period of January 1 – March 31, 2017, Entitled "Bakken Production Optimization Program 2.0"

Enclosed 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) 777-5276 or by e-mail at bkalk@undeerc.org.

Sincerely,

Brian P. Kalk
Director of Energy Systems Developement

BPK/rlo

Enclosure

E-Mailed Report Only: Faisal Rasdi, Marathon Oil Company
Erin Roehrig, Marathon Oil Company
Jake Stroupe, Marathon Oil Company
Paul Williams, Marathon Oil Company

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April 13, 2017

Mr. Gordon Pospisil
Vice President of Business Development
Liberty Resources LLC
1200 17th Street, Suite 2200
Denver, CO 80202-5854

Dear Mr. Pospisil:

Subject: Quarterly Progress Report for the Period of January 1 – March 31, 2017, Entitled "Bakken Production Optimization Program 2.0"

Enclosed 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) 777-5276 or by e-mail at bkalk@undeerc.org.

Sincerely,

Brian P. Kalk
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April 13, 2017

Mr. Jason Swaren
Vice President of Operations
Oasis Petroleum
1001 Fannin, Suite 1500
Houston, TX 77002

Dear Mr. Swaren:

Subject: Quarterly Progress Report for the Period of January 1 – March 31, 2017, Entitled "Bakken Production Optimization Program 2.0"

Enclosed 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) 777-5276 or by e-mail at bkalk@undeerc.org.

Sincerely,

Brian P. Kalk
Director of Energy Systems Development

BPK/rlo

Enclosure

E-Mailed Report Only: Jim Jolly, Oasis Petroleum
Jay Knaebel, Oasis Petroleum

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April 13, 2017

Ms. Stephanie Erickson
Supervisor, Reservoir Characterization/Base Reservoir Engineering
Williston Asset
Rockies Business Unit
ConocoPhillips
600 North Dairy Ashford
EC3-13-13W086
Houston, TX 77079

Dear Ms. Erickson:

Subject: Quarterly Progress Report for the Period of January 1 – March 31, 2017, Entitled "Bakken Production Optimization Program 2.0"

Enclosed 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) 777-5276 or by e-mail at bkalk@undeerc.org.

Sincerely,

Brian P. Kalk
Director of Energy Systems Development

BPK/rlo

Enclosure

E-Mailed Report Only: Kyree Johansen, ConocoPhillips

BAKKEN PRODUCTION OPTIMIZATION PROGRAM 2.0

QUARTERLY PROGRESS REPORT
January – March 2017

BACKGROUND

The Energy & Environmental Research Center (EERC) was awarded an extension to the existing and highly successful North Dakota Industrial Commission Oil and Gas Research Council (NDIC OGRC)-sponsored Bakken Production Optimization Program (BPOP). The purpose of this extension is to facilitate a 3-year continuation of this program to address emerging threats and issues to petroleum production in North Dakota. The extension is a continuation of the collaborative effort between the state of North Dakota and the North Dakota petroleum industry to apply North Dakota resources to provide North Dakota solutions to North Dakota challenges.

The goals of BPOP 2.0 are to:

- Employ a "system of systems" approach to enhance overall production efficiency, recognizing that improved coordination among various design factors (reservoir management, well design, surface processing, gas management, waste management) can lead to significant improvements in resource recovery efficiency.

- Conduct applied research in topic areas that positively impact the efficiency of production and reduce the environmental footprint of operations.

- Advise industry and state entities on scientific aspects of exploration and production activities, especially as they pertain to economic and environmental impacts.

- Facilitate collaboration on issues that may not otherwise receive collaborative attention from industry and/or the state of North Dakota.

The anticipated outcomes of BPOP 2.0 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) reduced demand for infrastructure construction and maintenance. Specific results will include improved resource recovery efficiency, reduced land use impacts, increased royalties and tax revenue from harnessed associated gas and natural gas liquid streams, and increased revenue from added product streams captured earlier in the well life cycle.

The following quarterly report summarizes the program activities from January through March 2017.

ACCOMPLISHMENTS DURING REPORTING PERIOD

Enhanced Oil Recovery Task

- Obtained rock samples from the Lower and Upper Shales and the Middle Bakken laminated zones from three wells located in thermally immature, moderate maturity, and mature areas. These rock cores were extracted with both CO_2 and ethane at 5000 psi for 24 hours. The EERC then analyzed the extracts to determine the relative abilities of CO_2 and ethane to recovery both light and heavy hydrocarbons from the Shales and Middle Bakken core samples.

- Began experiments to compare the quantity of crude oil and the ability to mobilize both light and heavy hydrocarbons using ethane vs. CO_2 in the "miscible" phase formed at reservoir conditions.

- Completed preliminary modeling activities to evaluate compression requirements to utilize wellhead gas as the stimulation fluid for the Liberty Resources enhanced oil recovery (EOR) demonstration. The EERC is now evaluating gas temperature, pressure, and composition to achieve a range of desired well bottomhole pressures.

- Liberty Resources provided the EERC with extensive data sets related to reservoir characterization, reservoir production, surface operations, and site infrastructure.

- Liberty Resources–EERC meetings to collaborate on the rich gas EOR pilot:

  - March 23 at the Stomping Horse facility. Toured the facility and developed an intimate understanding of the site's operational and infrastructure components.

  - March 21 in Bismarck with personnel from the North Dakota Department of Mineral Resources (Oil & Gas Division). Discussed the processes for injection well permitting and unitization as they relate to the planned rich gas EOR pilot.

  - March 20–21 in Denver. Met with Liberty's geoscience team to obtain relevant site characterization data in support of developing a static geomodel of the Stomping Horse area.

  - March 16 at the Stomping Horse facility. Collected baseline oil and water samples to support planned laboratory studies in support of the rich gas EOR pilot testing.

  - February 27–28 in Grand Forks. Discussed potential rich gas EOR pilot testing at the Stomping Horse location in Williams County.

Refracturing Optimization Task

- No progress reported during this reporting period.

Produced Fluid Characterization Task

- Coordinated with EERC's BPOP 2.0 program leads to identify key information and data needs to support ongoing and planned research efforts.

- Created GIS-based maps using publicly available data to identify and evaluate trends in chemical and physical characteristics occurring within the Williston Basin Bakken Formation. This information was used to identify existing data gaps and prioritize data needs and sample collection activities to help create a robust database of pertinent information to support industry and BPOP program research efforts.

- Created a fact sheet on BPOP 2.0 Bakken fluids characterization activities and data/sample collection needs. This fact sheet will be utilized to solicit cooperative efforts with industry partners. The fact sheet will also be useful in outreach efforts to disseminate information collected by BPOP 2.0 to industry and to the public.

- Developed partnerships with key industry partners to obtain access to confidential characterization data and for fluids sample collection access and support.

- Coordinated data collection and sample acquisitions among various program partners, then initiated analysis of collected fluids.

- EERC staff met with Liberty Resources staff to collect fluid samples from several Stomping Horse unit wells. The samples will be analyzed at the EERC to better understand the composition and origin of the fluids produced from Liberty's Stomping Horse development unit.

Reservoir Performance Modeling Task

- Reviewed published literature on the subject of optimal completion techniques for the Bakken.

- Completed a significant expansion of the reservoir performance database developed during the BPOP 1.0 preliminary study. The database has been expanded to 400 wells, compared to the 200 wells used in the preliminary study. The enlarged well number allows for better definition of areas of interest such as a specific field or geologically defined area. Additional geologic and well information as well as completion operations have been added. Cumulative production indicators at specific times are also added for comparison.

- Completed a decline curve analysis for the wells. Production forecast updates made for the wells that were used in the preliminary study showed good agreement with the original forecasts.

Water Injection Reservoir Assessment Task

- Improved the current reservoir model for the Inyan Kara Formation with an updated geologic model with modified reservoir permeability and porosity values.
  - A total of 103 saltwater disposal (SWD) wells were considered in the study region and built into the reservoir model.
  - Simulated a period spanning the years 1961 to 2020 (with history data to January 2016). 23 SWD wells were used in constructing the geologic model.
  - The first simulation case was performed after importing the field history injection rate data of all of the SWD wells.
  - As would be expected, the history of wellhead pressure for the 23 modeled wells was better matched than that of the other 80 SWD wells.
- Compared the simulated and field history wellhead pressure data to improve the history match of the reservoir model on a broad scale. Where necessary, adjustments were made to the reservoir permeability surrounding wells located in a particular area. This work is ongoing. Upon completing the necessary adjustments, additional simulations will be performed, and history matching will focus on refining the permeability values around each wellbore until an acceptable history match is achieved.

Facility Process Optimization Task

- EERC staff traveled to Houston on January 24–27, 2017, to attend a training session hosted by Virtual Materials Group. The training focused on dynamic simulations using our recently acquired VMGSim™ modeling software being used to assess non-steady-state operations on fugitive emissions, gas injection for EOR, and crude oil quality.
- Installed dynamic modeling software purchased in December. EERC staff then developed a facilities model and wellbore model for use in subsequent simulation tasks.
- Conducted process modeling for wellsite production operations typical of those found in the Bakken to analyze the impact of various operating parameters on fugitive emissions from storage tanks. A paper on the modeling exercise and its results was posted to the EERC's Web site at www.undeerc.org/Bakken/pdfs/CLM-BPOP%20Process%20ModBrief%20R4-Mar17.pdf.

Aromatic/Aliphatic Study Task

- Obtained crude oil samples from the Three Forks and Middle Bakken Formations from an operator in northeast Williams County. The operator also agreed to collect crude oil samples for aromatic/aliphatic analyses from the beginning of crude oil production into the decline curve for two wells being brought online in the next few months. These samples will be used

in an attempt to determine the relative contribution of the Upper and Lower Shales to crude production.

- Completed and tested a quantitative analytical method to accurately measure aromatic/aliphatic concentrations in both rock and crude oil samples. Also began analyses of approximately 40 rock extract samples.

Environmental Support Task

- Attended a quarterly Environmental Peer Group meeting on February 15, 2017, in Watford City in support of a vast array of environmental focal points being pursued by BPOP 1.0 member companies.

- Provided content for an education day focused on activities of the North Dakota Petroleum Council's Hydrocarbon Task Force. The content will inform on North Dakota crude oil quality issues and how hydrocarbon spills are remediated.

Program Management and Development

- Obtained verbal commitments for BPOP 2.0 membership from Oasis and ConocoPhillips, joining Liberty Resources and Marathon Oil as program partners.

- Continuing membership dialogue with Continental Resources, XTO Energy, Hess Corporation, Statoil, PetroHunt, Newfield Exploration, WPX Energy, and Whiting Oil & Gas. Additionally, membership opportunities will be sought in the coming quarter from strategically important service companies.

- Soliciting potential kickoff dates for May in Houston, and soliciting potential hosting by a member company.

- Provided testimony to the North Dakota House Energy and Natural Resources Committee on HB1257 (relating to approval requirements for unitization plans) in Bismarck, North Dakota, on February 3, 2017. HB1257 was passed by the ND Legislature and signed into law by Governor Burgum. This bill lowers the threshold for unitization approval to 55%.

- Attended the SPE Canada Unconventional Resources Conference in Calgary, Alberta, on February 14–16, 2017. Participated in a full-day workshop entitled "Introduction to Re-Fracturing Fundamentals."

- Met with Rice University leaders regarding a newly developed memorandum of understanding (MOU). While there, EERC and Rice staff discussed potential collaboration on advanced reservoir characterization technologies (nuclear magnetic resonance), produced water treatment, and nanotechnology applications.

MEMBERSHIP AND FINANCIAL INFORMATION

BPOP is sponsored by the NDIC Oil and Gas Research Council, Continental, and a consortium of Bakken producers and service companies. Table 1 presents the current budget for this program. Marathon Oil's expected in-kind contribution over the project duration is $7,280,000. The EERC is soliciting additional cash cost-share contributions from additional program members.

Expenses to date by funding source are listed in Table 2.

Table 1. BPOP – Expected Budget

Sponsors	Y1	Y2	Y3	Total
NDIC Share – Cash	$2,000,000	$2,000,000	$2,000,000	**$6,000,000**
Industry Share – Cash (confirmed participation)	$ TBD*	$ TBD	$ TBD	**$ TBD**
Industry Share – In-Kind	$2,500,000	$3,500,000	$1,280,000	**$7,280,000**
Total	**$4,500,000**	**$5,500,000**	**$3,280,000**	**$13,280,000**

* To be determined.

Table 2. BPOP – Expenses to Date

	Funding Source		
	NDIC	Industry	Total
EERC	$575,695	$0	$575,695
Industry – In-Kind		$0	$0
Total	**$575,695**	**$0**	**$575,695**

FUTURE ACTIVITIES

The planned activities for the next quarter are detailed below.

Enhanced Oil Recovery Task

- Data analysis on the ethane and CO_2 recoveries of crude oil hydrocarbons from the Upper and Lower Shales and the Middle Bakken rock core will be completed, and additional extractions will be performed as indicated by these initial results.

- Experiments to determine the relative abilities of CO_2 and ethane to mobilize both light and heavy hydrocarbons into the "miscible" phase will continue.

- A facilities model of Liberty Resources' production facilities will be developed to enable simulations of several EOR scenarios. The model will help define different injection and

production strategies and help ensure existing facilities can effectively process fluids generated during EOR operations.

- Gas handling and compression strategies will be evaluated to determine the quantity and quality of wellhead gas to be used for injection. Work will include modeling gas handling and compression processes and developing technical requirements for gas compression.

- Reservoir, facility, and gas compression modeling activities will be coordinated to ensure the development of an integrated EOR strategy.

- The EERC expects to submit a proposal to the U.S. Department of Energy for funding to support a rich gas EOR pilot project that will be conducted in close collaboration with Liberty Resources.

- Studies of minimum miscibility pressure (MMP) and hydrocarbon extraction experiments on representative rock samples from the Stomping Horse area will be initiated.

- Reservoir modeling activities will be continued.

Refracturing Optimization Task

- No progress is anticipated on this task during the next reporting period.

Produced Fluid Characterization Task

- Evaluation of data and information pertaining to the recent sample collection and analysis efforts will continue.

- Refinement and enhancement of the fluids characterization database will continue with newly acquired data and information. Emerging findings will be communicated to program staff.

- Data collection, sampling, and analysis on available fluids will continue as needed to support BPOP program goals.

- The EERC will continue to develop relationships and partnerships with industry to further understand their specific needs related to Bakken production issues and practices and to expand the geographical extent of the sampling and analysis effort.

Reservoir Performance Modeling Task

- Advanced statistical analysis will be performed with the database in an attempt to extract critical performance indicators across the developed area.

Water Injection Reservoir Assessment Task

- Tuning of the reservoir model will continue. After calibration of the model, several simulations will be performed to estimate the effects of long-term SWD on the formation pressure of the Inyan Kara and resulting impacts on the injectivity of individual SWD wells.

Facility Process Optimization Task

- The EERC will host a meeting of North Dakota operators to discuss the various design and operational factors influencing crude oil volatility. The goal of this meeting will be to evaluate options and assess the need for a comprehensive process modeling and field validation effort geared toward improving Basin-wide compliance with crude oil volatility specifications.

Aromatic/Aliphatic Study Task

- Analyses of approximately 40 rock extracts from all Bakken and Three Forks facies available from nine wells will be completed, and the data reduction will begin. The EERC will also begin collecting and preparing additional rock sample from a broader geographic distribution of the Bakken Formation.

- Initial work on determining the ability of the method to use drill cuttings will begin, if suitable samples can be obtained.

Environmental Support Task

- An education day focused on crude oil characterization and hydrocarbon remediation will be scheduled by the North Dakota Petroleum Council Hydrocarbon Taskforce. EERC staff will present as designated subject matter experts.

Program Management and Development

- EERC personnel will present on various BPOP 2.0 topics at the Williston Basin Petroleum Conference in Regina, Saskatchewan, Canada on May 2–4:
  - EOR in unconventionals
  - Bakken subsurface statistics and related geology and engineering to historic production
  - Surface facilities modeling