EERC
Energy & Environmental Research Center
UNIVERSITY OF NORTH DAKOTA
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Web Site: www.undeerc.org

ABBREVIATED LIST OF LIKELY BPOP 2.0 ACTIVITIES

This list is provided as an addendum to EERC Proposal No. 2016-0105 provided to the North Dakota Oil and Gas Research Program on June 1, 2016. Work to be performed covers a wide range of topics spanning all aspects of exploration, production, and handling of produced fluids. The EERC views all of these activities as interrelated since many decisions and actions have impacts up and down the value chain. In turn, a "system of systems" approach will be employed that maximizes benefit to member companies and the state of North Dakota. Member engagement in these areas will dictate priority and schedule. Members benefit from early access, while timely subsequent publication benefits the state and industry broadly.

- **Rich-Gas EOR** – Develop broader understanding of reservoir interactions with reinjected rich gas as a means of reducing flaring, reducing emissions, and improving ultimate recovery.
- **Refrac Optimization** – Facilitate broad industry engagement regarding candidate selection criteria, refrac execution, and postexecution evaluation.
- **Produced Fluid Characterization** – Collect and analyze data on crude oil, associated gas, and produced water to gain a better understanding of the resource and support facilities process modeling and reservoir modeling.
- **Fugitive Emissions** – Inform industry and state on the evolving emission regulatory picture, available emission measurement technologies, and available emission control technology.
- **Hydrocarbon Sampling** – Systematically investigate evolution of HC composition over time for surface equipment design, efficient reservoir recovery operations, and EOR planning.
- **Reservoir Performance Modeling** – Identify key reservoir and well performance metrics to enable better planning of surface facility development.
- **Water Injection Reservoir Assessments** – Identify key reservoir and well performance metrics to enable better planning of surface facility development.
- **Facility Process Modeling** – Develop a foundational tool for holistic examination of the coupled effects of several operations variables (produced fluid composition, climate, processing equipment, operating conditions, equipment suite designs, etc.) on fugitive emissions, crude oil properties, and equipment performance.
- **Aromatic/Aliphatic Study** – Evaluate oil composition as a tool to identify the source of produced oil and improve the understanding of oil recovery.
- **Site Equipment Survey** – Develop an empirical inventory of typical operational wellsite processing equipment and their performance parameters.
- **Regulatory Review** – Create tools to facilitate better understanding of regulations driving actions in the oil field, then use these tools to inform other BPOP 2.0 activities.

BPOP Phase I Membership

Continental Resources · Marathon Oil · Whiting · North Dakota oil & gas research program · ConocoPhillips · Nuverra Environmental Solutions · Hitachi Data Systems · Hess · Oasis Petroleum · SM Energy · XTO Energy

EERC
Energy & Environmental Research Center®
Putting Research into Practice

University of North Dakota
15 North 23rd Street, Stop 9018 • Grand Forks, ND 58202-9018 • P. 701.777.5000 • F. 701.777.5181
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June 1, 2016

Ms. Karlene Fine
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 Ms. Fine:

Subject: EERC Proposal No. 2016-0105 Entitled "Bakken Production Optimization Program – 2.0" 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.

Enclosed please find an original and one copy of the subject proposal along with a check for $100. 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) 777-5157, by fax at (701) 777-5181, or by e-mail at jharju@undeerc.org.

Sincerely,

John A. Harju
Vice President for Strategic Partnerships

Thomas A. Erickson, CEO (for)
Energy & Environmental Research Center

JAH/kal

Enclosures

c/enc: Brent Brannan, OGRC

Oil and Gas Research Program

North Dakota

Industrial Commission

Application

Program Title: Bakken Production Optimization Program – 2.0

Applicant: Energy & Environmental Research Center

Principal Investigator: John A. Harju

Date of Application: June 1, 2016

Amount of Request: $6,000,000

Total Amt. of Proposed Project: $13,280,000

Duration of Project: 3 years

Point of Contact (POC): John A. Harju

POC Telephone: (701) 777-5157

POC E-Mail Address: jharju@undeerc.org

POC Address:

15 North 23rd Street, Stop 9018

Grand Forks, ND 58202-9018

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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 3 years of BPOP were sponsored by the North Dakota Industrial Commission Oil and Gas Research Program (OGRP) and many of the Williston Basin's premier operating companies.

Objective: To continue addressing emerging threats and issues to petroleum production in North Dakota. Collaborative efforts between the state of North Dakota and the petroleum industry will continue to apply North Dakota resources to provide North Dakota solutions to North Dakota challenges.

Expected Results: Increased well productivity and economic output of North Dakota's oil and gas resources, decreased environmental impacts of wellsite operations, and 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.

Duration: Three years (July 1, 2016, to June 30, 2019).

Total Program Cost: The estimated cost of the program extension is $13,280,000. This proposal requests $2,000,000 annually for 3 years ($6,000,000 total) from OGRP. Marathon Oil will provide $7,280,000 of in-kind contributions. Consistent with the first 3 years of this program, the EERC anticipates sustained industry membership and stakeholder engagement. Those attendant contributions will be enumerated and reported to NDIC as received, increasing the total value of the program.

Participants: Marathon has committed to provide initial cost share. Several existing member companies have indicated strong interest in continuing this program.

PROJECT DESCRIPTION

The Energy & Environmental Research Center (EERC) proposes to extend the scope of the existing and highly successful North Dakota Industrial Commission Oil and Gas Research Council (NDIC OGRC)-sponsored Bakken Production Optimization Program (BPOP), managed by the EERC. The purpose of this proposed extension is to facilitate a 3-year continuation of this program that addresses emerging threats and challenges to petroleum production in North Dakota. As the original 3-year program winds down in 2016, additional threats, issues, and opportunities have arisen, while oil prices struggle to recover from recent lows, and additional regulatory pressures arrive from the federal government. The proposed extension is a continuation of the collaborative effort between the state of North Dakota and North Dakota's petroleum industry to apply North Dakota resources to provide North Dakota solutions to North Dakota challenges. The EERC anticipates the ongoing support of those companies that engaged in cofinancing the first phase of this program, namely, Continental Resources, Marathon Oil, ConocoPhillips, Whiting Petroleum, XTO Energy, SM Energy, Oasis Petroleum, Hess Corporation, Nuverra, and Hitachi.

Over the 3-year duration of Phase I of the program, we have seen relatively high crude oil prices and attendant production activity in the state. Consistent with the historically cyclical nature of oil production, we now observe depressed crude oil prices and an associated drop in drilling and completion activities. During the boom and the current slowdown, the program has provided a useful mechanism to address challenges common to all of the North Dakota operators. An "Executive Summary of Programmatic Achievements to Date" is provided in Appendix A. Industry and state attentions are growing more focused on efficient operations, including those that maximize productivity of individual wells and drill spacing units (DSUs) and those that minimize the environmental impact of today's and future operations. Industry recognizes that minimizing these impacts also results in decreased costs associated with unknown future liabilities. Industry and the state are collectively interested in avoiding

costs associated with fugitive emissions, stormwater discharges, TENORM (technologically enhanced naturally occurring radioactive material) disposal, flared gas, and spill remediation. Simultaneously, industry and the state are intensely interested in maximizing the efficiency of extraction of oil from the productive formations in the Williston Basin. BPOP has a proven history of quantitatively assisting both industry and the state with challenges in these areas.

The EERC views this proposal as an opportunity for North Dakota to continue its investment in the future of the state. The success of BPOP to date suggests a high likelihood of significant return on investment. Throughout the first 3 years of the program, it was demonstrated that the strength of the program rested in its ability to rapidly address ever-changing technical priorities. Prioritization was accomplished in a continuous fashion to tackle emerging topics that demanded investigation and solutions. It is envisioned that there will be an ongoing need for capacity to adapt and meet those challenges, both anticipated and unanticipated.

Goals and Objectives: The goals of the proposed expansion (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 would otherwise not receive collaborative attention from industry and/or the state of North Dakota.

Methodology: BPOP 2.0 will continue to be organized along multiple technical topic areas added as state and industry priorities dictate and one program support area. The following topic areas, offered as near-term examples of expected priorities, will benefit from program attention during early and middle portions of the proposed program extension.

►Hydrocarbon Utilization and Management Task

Support for Flaring Task Force. BPOP 2.0 has provided support to the North Dakota Petroleum Council (NDPC) Flaring Task Force since program inception. The EERC has provided critical technical guidance to industry and the state on this issue. Stakeholders also requested that the EERC create and maintain a database of information on flaring mitigation technologies and technology providers. Support for the Flaring Task Force and for the flaring database will be continued.

Fugitive Emissions. A new level of U.S. Environmental Protection Agency (EPA) focus on fugitive methane and VOC emissions in the oil field has resulted in significant questions about quantitative measurement of these emissions and exploration of viable technology to mitigate these emissions. The program will apply extensive EERC experience and expertise in emission measurement and emission control. Specific tasks include development of educational and outreach material on the topic of fugitive emission measurement and control, analysis of the effects of compliance on production and vice versa, modeling to assess potential improvements to fugitive emissions using a more integrated approach to wellsite design (system of systems approach), and a broad assessment of available fugitive emission measurement technologies.

Investigation of Improved Reservoir Drainage and Production Efficiency. Improving the efficiency of reservoir drainage and subsequent production operations is critical to improving ultimate recovery from Bakken and Three Forks wells. BPOP 2.0 will investigate the impact and interactions of phase behavior, well spacing, changing GOR (gas-to-oil ratio), allocation of produced oil to its source interval, and associated gas reinjection on resource recovery and system performance. The project team will also

engage in activities to further understand the geologic and fluid flow elements affecting the drainage of oil from Bakken reservoirs. Knowledge gained from these activities may serve as the basis for modified well-spacing criteria, provide technical guidance for future development of DSUs, support production facility design and operation, and eventually serve as a basis for the potential unitization of Bakken Fields for enhanced oil recovery (EOR) operations. BPOP 2.0 will employ additional laboratory activities to provide key fundamental knowledge necessary to support systems analysis and modeling.

►Waste Management

Support for NORM Task Force. The program has provided support to the NDPC NORM Task Force since program inception and will continue support of TENORM science and emerging state/industry needs resulting from implementation of new Department of Health rules governing disposal.

►Water Management

Saltwater Disposal Capacity Modeling. BPOP 2.0 will complete a previously initiated evaluation of the disposal capacity of the Inyan Kara Formation to predict locations where additional disposal wells may be optimal or problematic based on formation geology and proximity to existing saltwater disposal (SWD) wells. This continued effort will focus on expanding the detailed geologic model and reservoir simulations to encompass the additional Inyan Kara mapping project results provided by the DMR's North Dakota Geological Survey.

Assessment of Stormwater Management Practices. Current stormwater management practices on drilling sites will be surveyed to better define ways in which to improve and/or streamline current stormwater management practices while minimizing impacts to adjacent lands. Researchers will also work closely with DMR personnel to develop improved stormwater sampling and analysis protocols.

High-Value Minerals in Produced Fluids. A preliminary assessment of potential high-value minerals (HVM) within produced fluids will be conducted to evaluate opportunities to concentrate and extract valuable resources from these fluids. This effort will focus on the application of sample pretreatment

techniques to concentrate analytes of interest and overcome challenges associated with accurately quantifying low HVM concentrations within high-salinity fluids.

►Spill Remediation

BPOP 2.0 will continue support of the NDPC Saltwater Spills Task Force. A significant quantity of educational material has been produced for industry and the general public to facilitate a common understanding of best practices for brine and oil spill remediation procedures, processes, and technology.

►Bakken Data Analysis, Use, and Management

A large amount of data documenting many aspects of oil and gas production, performance, and regulation is currently maintained by the state in various databases. BPOP 2.0 will compile, process, and manage the various data sets generated in such a manner that they can be easily integrated with relevant state databases. “Big Data” analytics will provide valuable insights into production activities and support program members’ ability to increase production efficiency in North Dakota.

►Emerging Issues

A significant factor in the success of this program has been its ability to address emerging issues as the landscape changes. Several of the efforts receiving high acclaim within the existing program were not planned when the program was initially funded. Flexibility within the program has allowed resources to be quickly applied to headline-making topics. A portion of the overall budget will be set aside to accommodate future topics not foreseen as prominent issues today.

►Program Management

This will involve integration of intertopic tasks, public outreach to communities and local stakeholders, program reporting, collaboration with industry and OGRC, recruiting of new members, and strategic studies. The EERC will be responsible for coordination and execution of tasks with assistance provided by program members, will disseminate results, and periodically brief NDIC OGRC. A significant effort within the program will focus on looking for integration opportunities between individual tasks.

Anticipated Results: BPOP 2.0 will continue to provide the state and its oil and gas industry with a valuable tool to address key issues related to production optimization. The results of the proposed work will likely increase well productivity and economic output, decrease environmental impacts of wellsite operations, optimize infrastructure construction and maintenance, and improve the ability of the state to anticipate development trends and plan accordingly. The overall outcomes of this program will include the following:

- Environmental
  - Decreased incidence of spills, decreased wastewater production, reduced demand for freshwater supplies, decreased flaring and fugitive emissions, decreased truck traffic, decreased road damage and subsequent maintenance, and decreased road dust.
- Economic
  - Lower cost of production, increased royalties and tax base from harnessed associated gas and NGL (natural gas liquid) streams, increased profits from added product streams engaged earlier in the well life cycle, and decreased costs for water and wastewater hauling and disposal.

Facilities, Resources, and Techniques to Be Used: The EERC possesses a number of laboratory facilities that can be employed at will by individual tasks within this program. The Applied Geology Laboratory conducts geomechanical, petrographic, geochemical, and customized core sample-related experiments designed to solve targeted problems in the oil and gas industry. The Natural Materials Analytical Research Laboratory includes x-ray diffraction, x-ray fluorescence, and scanning electron microscopy systems. The Analytical Research Laboratory conducts wet-chemistry and advanced trace elemental analyses. Mobile chemistry laboratories owned by the EERC may be employed to conduct quick-turnaround analyses on the wellsite when wellsite logistics permit. The EERC's experienced staff encompasses the geology, chemistry, physics, and engineering disciplines. These laboratories have decades of experience and have been instrumental in previous Bakken research. The EERC also

possesses a rich-gas test facility capable of simulating Bakken-like associated gas mixtures to specification.

Environmental and Economic Impacts While Program Is under Way: Because BPOP 2.0 will involve an extensive assortment of research activities, the environmental and economic impacts will also be wide-ranging. It is difficult to predict specific environmental impacts evident while the program is under way. The first three years of the program are evidence of the positive impact the program has had on North Dakota environmental concerns related to Bakken development. Environmental and economic impacts will necessarily be managed and mitigated within each task scope.

Ultimate Technological and Economic Impacts: Ultimately, BPOP 2.0 will provide broad and far-reaching technical and economic impacts. Each research task will have the potential to bolster oil and gas industry operations by improving operational logistics, improving resource recovery, decreasing costs, reducing environmental impacts, and increasing revenue.

Why the Project Is Needed: The last three years of this program resulted in unprecedented cooperation among state and industry members in addressing headline issues. Multiple program members 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 now-emerging topics such as DSU setbacks, fugitive emission measurement and control, stormwater management, and many more topics that will surface during 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, ultimately resulting in more efficient resource development and cost savings. Results will be readily accessible through reports provided to OGRP for inclusion on its Web site. Technical publications will be approved by and targeted for the state and industry. Success will also be measured by timely delivery of high impact products to state and industrial stake holders that meet the goals of the program.

Deliverables: Deliverables will include fact sheets and quarterly reports highlighting results of ongoing research, topical reports summarizing completed tasks, a final report summarizing program achievements and challenges, and publications and presentations at technical conferences. Included as Appendix A is an executive summary of the program's efforts and deliverables to date.

BACKGROUND/QUALIFICATIONS

The EERC is a high-tech, nonprofit branch of the University of North Dakota, exclusively conducting contract research for a multinational client base. The EERC's oil and gas experience is highlighted within the Center for Oil and Gas, a specialized technical group focusing on design and implementation of new approaches to the exploration, development, and production of oil and gas. Related projects conducted in the past include studies focused on the Williston, Powder River, Denver–Julesburg, and Alberta Basins. Within the Center for Oil and Gas, the EERC has also completed studies on enhanced utilization of ungathered associated gas, drill rigs powered with associated gas, BPOP Phase I, and legislature-mandated liquid-gathering pipeline studies to assess potential for reduction of leaks.

Resumes of key personnel are provided in Appendix B. John Harju, EERC Vice President for Strategic Partnerships, will serve as Program Manager. Jay Almlie, Principal Engineer, and Chad Wocken, Principal Engineer, will serve as co-Principal Investigators and will guide technical aspects and integration of the program. Other key EERC personnel will include Beth Kurz, Principal Hydrogeologist (water management); Jim Sorensen, Principal Geologist (senior exploration and production leader); Brad Stevens, P.E., Senior Research Engineer (civil engineering); and Larry Pekot, Principal Engineer (reservoir engineering).

MANAGEMENT

The EERC manages over 200 contracts a year, with a total of more than 1330 clients in 52 countries. Systems are in place to ensure that projects are managed within budget, schedule, and scope. John Harju, EERC Vice President for Strategic Partnerships, will oversee the entire program. He will be responsible for program coordination, guidance, and supervision to ensure consistent progress and

adherence to budget and schedule constraints, maintaining the integrity of the program, and understanding economic and environmental implications of the activities being performed. Quarterly reports will be submitted to sponsors 2 weeks after the end of each calendar quarter to provide timely highlights of ongoing research and anticipated future activities. A program kickoff meeting will be scheduled late summer or early fall 2016 to prioritize research areas with input from state and industry. At a minimum, annual meetings will be scheduled to provide updates on the research activities and discuss the direction of future activities.

TIMETABLE

This effort is proposed as a 3-year program (July 1, 2016 – June 30, 2019). Figure 1 summarizes the preliminary program timetable. Additional timetable detail will be developed as the program evolves.

BUDGET

The estimated cost for the proposed effort is $13,280,000. This proposal requests $6,000,000 from the OGRP ($2,000,000/year). In-kind contribution valued at $7,280,000 will be provided by Marathon Oil. A letter of commitment can be found in Appendix C.

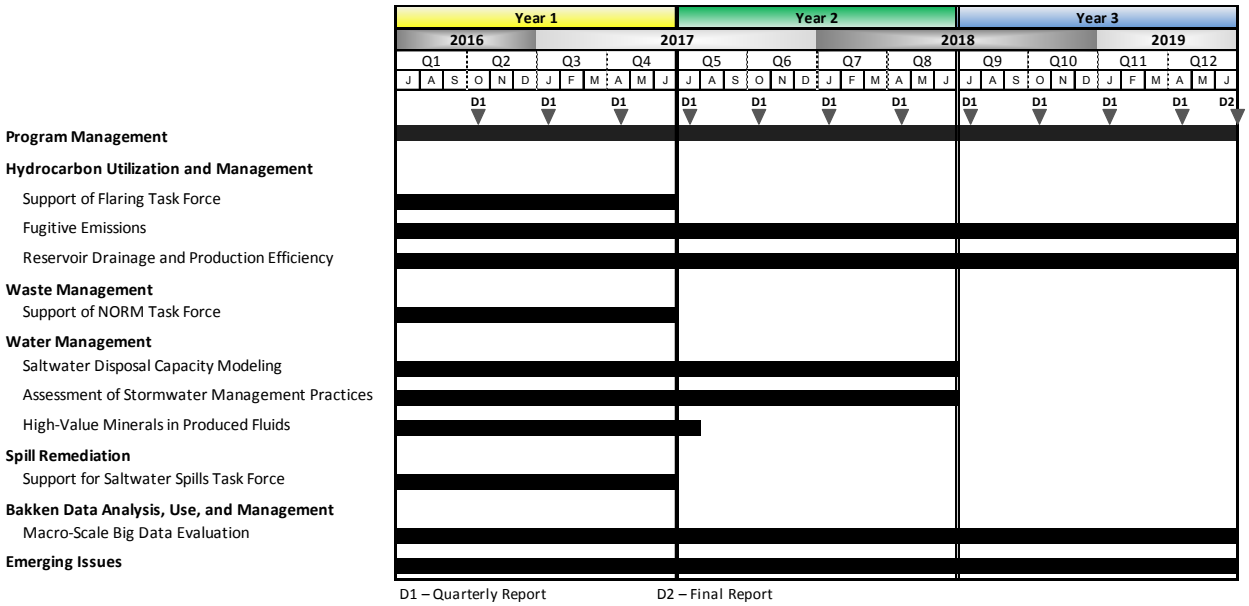


Figure 1. Preliminary program timetable.

Marathon's share includes costs to locate, drill, complete, and collect core samples and live oil samples from a new well to be drilled during the program's period of performance. The well will be used by the project technical team for the application of unique integrated field and laboratory characterization approaches toward reservoir characterization and resource assessment. Marathon's cost share will directly benefit activities related to the investigation of reservoir drainage and production efficiency. Several other tasks will benefit indirectly.

Existing member companies have expressed a desire to continue participation in the program and are working with the EERC to enumerate their contributions.

The budget shown in Table 1 is based on previous EERC experience with large programs such as the proposed. Detailed budgets for approved tasks will be developed as new tasks are identified. Budget

Table 1. Budget Breakdown

Project Associated Expenses	NDIC Share	Industry Share (cash/in-kind)	Total Program
Labor	$ 4,974,420	$ -	$ 4,974,420
Travel	$ 120,993	$ -	$ 120,993
Supplies	$ 9,680	$ -	$ 9,680
Subcontractor – Economic Study	$ 87,625	$ -	$ 87,625
Fees – Software Simulation	$ 135,450	$ -	$ 135,450
Other	$ 16,552	$ -	$ 16,552
Laboratory Fees and Services			
Analytical Research Lab	$ 26,739	$ -	$ 26,739
Particulate Analysis Lab	$ 52,043	$ -	$ 52,043
GC/MS Lab	$ 366,374	$ -	$ 366,374
Graphics Service	$ 43,851	$ -	$ 43,851
Shops and Operations	$ 3,439	$ -	$ 3,439
Research Information Service	$ 5,635	$ -	$ 5,635
Technical Software Fee	$ 157,199	$ -	$ 157,199
In-Kind Cost Share – Marathon	$ -	$ 7,280,000	$ 7,280,000
Cash/In-Kind Cost Share*		TBD	TBD
Total Program	**$ 6,000,000**	**$ 7,280,000 ***	**$ 13,280,000**

* Additional cash and/or in-kind contributions from industry are anticipated, and will be reported to NDIC as received.

justification can be found in Appendix D. If less OGRP funding is available, adjustments to scope and/or participating company contributions may be needed.

CONFIDENTIAL INFORMATION

There is no confidential information included in this proposal.

PATENTS/RIGHTS TO TECHNICAL DATA

No patentable technologies are expected to be created during this work.

STATUS OF ONGOING PROJECTS

G-015-030 – "Plains CO_2 Reduction (PCOR) Partnership Program – Phase III"; The EERC is developing and demonstrating technologies to reduce CO_2 emissions from large-scale sources.

G-036-072 – "Improved Characterization and Modeling of Tight Oil Formation for CO_2 EOR"; EERC is conducting research to evaluate the characteristics of the rocks and physical/chemical mechanisms affecting CO_2 permeation and oil extraction in tight, organic-rich, oil-wet, and mixed-wet systems.

G-Produced Water Pipeline 02 – "Produced Fluids Gathering Pipeline Study"; This legislatively mandated project regards construction standards and monitoring systems for gathering lines, which will guide NDIC's consideration of new administrative rules.

G-Sandia 01 – "NDIC Resource Characterization"; This U.S. DOE-funded study focuses on characterizing tight oil properties relative to safe storage and transport (NDIC funding to provide visibility into study).

G-000-003 – "Pilot Project to Remediate Soil Surrounding Legacy Brine Pits"; This project will demonstrate feasible remediation approaches for decades-old "legacy" brine evaporation pit sites.

G-030-060 – "Program to Determine the Uniqueness of Three Forks Bench Reserves, Determine Optimal Well Density in the Bakken Pool, and Optimize Bakken Production (a.k.a. Bakken Production Optimization Program); This Program will increase the understanding of potential petroleum reserves in the Bakken–Three Forks system and decrease recovery costs in an environmentally sound manner.

APPENDIX A

EXECUTIVE SUMMARY OF PROGRAMMATIC ACHIEVEMENTS TO DATE

Bakken Production Optimization Program

EXECUTIVE SUMMARY

A premier public–private partnership harnessing the best minds in North Dakota and in industry to **maximize productivity of the Bakken oil play** while simultaneously reducing its environmental footprint.

This summary of Bakken Production Optimization Program (BPOP) achievements at the end of calendar year 2015 was produced at the request of the **North Dakota Industrial Commission (NDIC)** and the associated **Oil and Gas Research Program,** which funded a portion of the work performed in this program. This summary is intended for public distribution and is intended to relay the ongoing successes of this **premier public–private partnership** in advancing North Dakota's economic and environmental interests directly related to exploration and production of oil from the Bakken and Three Forks Formations.

BAKKEN PRODUCTION OPTIMIZATION PROGRAM

BAKKEN PRODUCTION OPTIMIZATION PROGRAM

In June 2013, a consortium comprising the Energy & Environmental Research Center (EERC), Continental Resources, Inc., and several of the largest oil producers in the state was awarded North Dakota Oil and Gas Research Program funding to complete a 3-year, $117 million project with the **goal of improving Bakken system oil recovery** while simultaneously reducing its environmental footprint. The program was designed to accomplish the following:

- Maximize oil production from Bakken and Three Forks wells by employing an "all of the above" approach
  - Perform reservoir characterization
    - Develop data sets to determine whether the oil of the second and third benches in the Three Forks Formation should be considered separate and unique from those of the first bench
    - Predict future reservoir sweet spot areas
  - Improve drilling/stimulation/completion/production techniques and sequences
    - Determine optimal well spacing for development in the Middle Bakken and first, second, and third benches of the Three Forks
- Optimize wellsite surface operations
  - Reduce operating costs
  - Reduce development and operations impacts to surrounding landowners
  - Reduce demands on surrounding infrastructure and water resources

THE HAWKINSON PROJECT

$112M

- Drilling 11 New Wells
- Completions
- Reservoir Engineering
- Expansion Applications via 3-D Seismic

Pilot hole logs, core data, other data gathering from multiple wells to create a 3-D picture of what happens during and after the hydraulic fracture treatments in a multistage horizontal well. Continental analyzed this data set to:

- Assess total resource available in the second and third benches of the Three Forks Formation.
- Confirm whether these benches are distinct and independent of the existing Middle Bakken.
- Predict areas of future sweet spots.

EERC

$4.5M

- Optimization of Wellsite Operations

Site logistics, waste management, on-site hydrocarbon utilization, water management, process optimization, and systems failure analysis with an eye on decreased environmental impact.

> *The Bakken Production Optimization Program is a remarkable example of how state and industry can and do work together to better define the North Dakota petroleum resource and to maximize productivity of the E&P work in the state.*
>
> –Jessica Unruh, North Dakota Senate District 33

ANTICIPATED OUTCOMES

ECONOMIC

- Increased well productivity and economic output of North Dakota's oil and gas resources.
- Increased revenue for the state, royalty owners, and operators from added product streams captured earlier in the well's life cycle.
- Reduced demand for infrastructure construction and maintenance.
- Reduced road maintenance costs, wastewater production, waste disposal costs, and freshwater use.
- Significant increases to estimates of recoverable hydrocarbons.

ENVIRONMENTAL

- Decreased environmental impacts of wellsite operations.
- Less truck traffic, resulting in decreased diesel emissions, road dust, and spills.
- Reduced land use impacts.
- Reduced gas flaring.
- Evaluation of technologies to recycle wastewater and decrease freshwater demand.
- Improved TENORM (technologically enhanced naturally occuring radioactive material) waste disposal operations.

EDUCATIONAL

- Greatly increased understanding of Bakken–Three Forks reservoirs.
- Public education and outreach.

Serving on Energy and Natural Resources has allowed some insight and perspective useful for judging our oil and gas play. BPOP is helping greatly to bring efficiency, innovation, and coordination as we had hoped it would when creating this public–private entity.

–Phil Murphy, North Dakota Senate District 20

A PREMIER PARTNERSHIP

This program has been cited as an exemplary model by others nationwide. It has demonstrated that state lawmakers, state regulators, and industry can work together for positive results for shareholders and taxpayers alike.

PUBLIC–PRIVATE

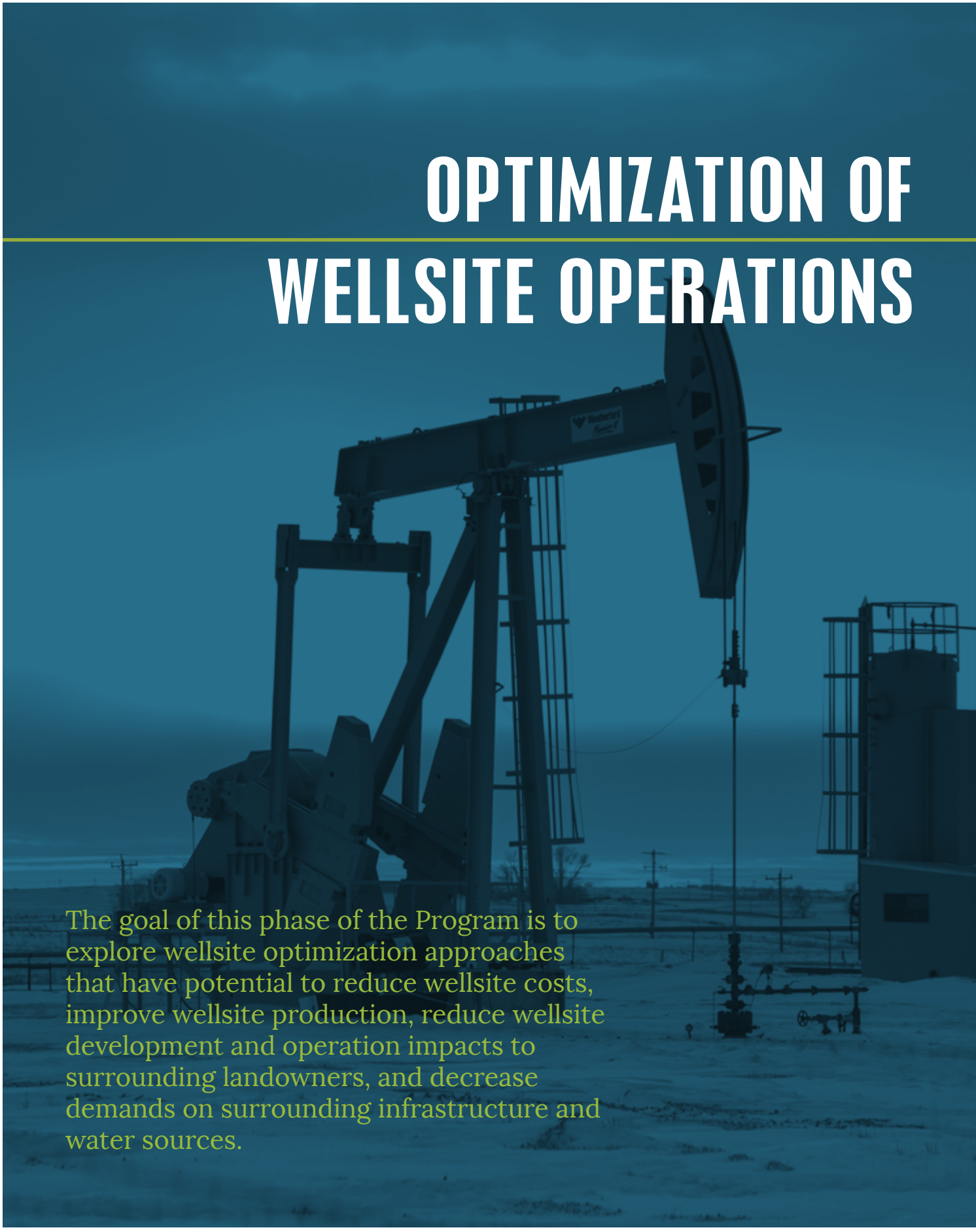
BPOP has demonstrated how effective a public–private partnership can be. Significant achievements directly attributable to this program have made measurable, positive impacts to how the business of oil and gas exploration and production is accomplished in North Dakota. This program has been cited as **an exemplary model** by others nationwide. It has demonstrated that state lawmakers, state regulators, and industry can work together for positive results for shareholders and taxpayers alike.

This document contains a **high-level summary** of the significant work performed by a public–private team, with each member pulling in the same direction. The work of this program has yielded **scientific results that will increase economic benefit** to the state of North Dakota, its landowners, its mineral rights holders, and the industry driving the shale revolution while simultaneously decreasing the impacts of this industrial activity on the environment of North Dakota and the region.

PROGRAM MEMBERS

- Continental Resources, Inc.
- Marathon Oil Corporation
- Whiting Petroleum Corporation
- North Dakota Oil and Gas Research Program
- ConocoPhillips Company
- Nuverra Environmental Solutions
- Hitachi
- Hess Corporation
- Oasis Petroleum, Inc.
- SM Energy
- XTO Energy, Inc.

OPTIMIZATION OF WELLSITE OPERATIONS



The goal of this phase of the Program is to explore wellsite optimization approaches that have potential to reduce wellsite costs, improve wellsite production, reduce wellsite development and operation impacts to surrounding landowners, and decrease demands on surrounding infrastructure and water sources.

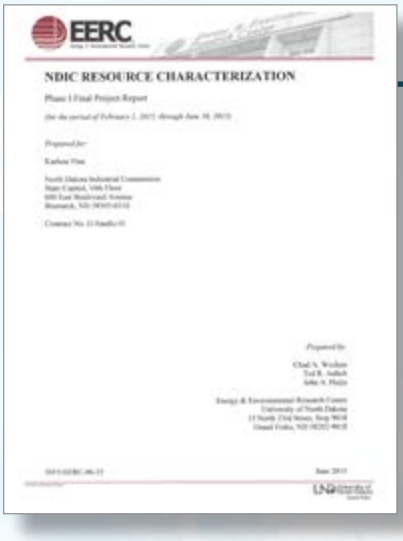
The EERC is conducting activities for Optimization of Wellsite Operations. These activities were driven by the common needs of all Program members. In general, the Program is addressing the headline issues of 2013–2016. Flaring reduction, TENORM disposal, and saltwater spills all became focus areas of the Program. Opportunities for improved water use and handling were also addressed within Program activities. The Program also collaborated with the EERC's ongoing activities with the U.S. Department of Energy (DOE) on the topic of improvements to methodologies of crude oil characterization for purposes of rail transport safety.

The goal of this phase of the Program is to **explore wellsite optimization approaches** that have potential to reduce wellsite costs, improve wellsite production, reduce wellsite development and operation impacts to surrounding landowners, and decrease demands on surrounding infrastructure and water sources.

Following is a summary of major activities in which the Program was engaged during the 2013–2015 period of performance.

> *Hess has been very pleased to participate in the Oil and Gas Research Program. This effort has brought the state's collective intellect and experience together on a significant challenge: improving the overall oil recovery from the Bakken and Three Forks reservoirs.*
>
> –Stephen McNally, General Manager – North Dakota, Hess Corporation

FLARING REDUCTION



Flaring Task Force

The EERC supported the North Dakota Petroleum Council's (NDPC's) Flaring Task Force at the direction of BPOP membership. As the Flaring Task Force formulated a multistage plan to decrease flaring rates, BPOP provided flaring statistics analysis that served as the foundation for these plans. The BPOP team presented the resulting plan to the Governor in January 2014. This plan was eventually endorsed by the Governor and is now integral to regulations enforced by the North Dakota Department of Mineral Resources.

Flaring Database

The EERC supported Program membership in their efforts to implement technologies and practices to utilize stranded wellhead gas and reduce gas-flaring volumes by creating a database containing 65+ technologies that claim to utilize wellhead gas economically for beneficial purposes. This database continues to add technologies and is used by industry to screen potential solutions to stranded gas challenges. The database can be examined at www.undeerc.org/Flaring_Solutions/Search.aspx.

Flaring Fact Sheet

A series of fact sheets was created to educate and inform the general public on key Bakken headline issues from 2013 to 2015. The flaring fact sheet explains what associated gas is, why flaring occurs, how flaring is regulated, and what North Dakota is doing to reduce flaring.

Crude Oil Characterization

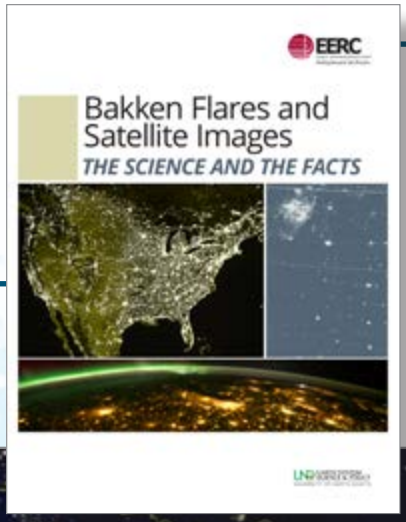
Rail accidents that occurred between 2013 and 2015 involving unconventional crude oil raised questions about the safety of rail transport of crude oil. In an effort to address these questions, DOE commissioned a study to investigate the properties of crude oil as they relate to its safe handling and transport. DOE contracted Sandia National Laboratories to conduct the study, and the EERC was contracted to provide technical support in execution of the project. In parallel, NDIC established a contract with the EERC to enable greater participation in the project and fund progress reporting to NDIC.

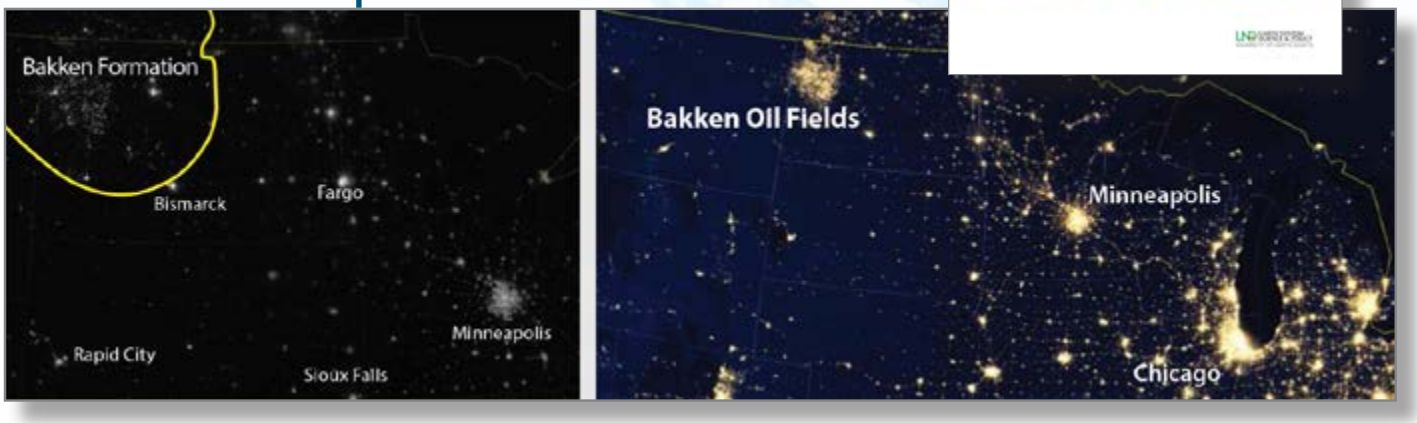
The key objectives of the crude oil characterization research project are to characterize and define tight crude oils based on their chemical and physical properties and to identify properties that could contribute to an increased potential for accidental combustion. The project scope of work consists of two primary tasks:

1. A literature survey of public sources of information on crude oil properties.
2. A conceptual crude oil characterization plan that describes the necessary sampling and the analytical and experimental activities needed to provide a comprehensive characterization of crude oil properties.

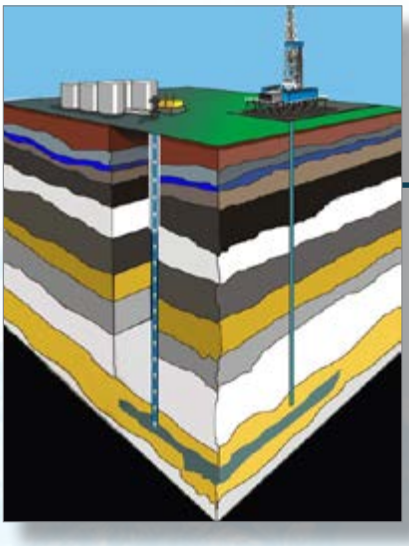
These Phase I tasks have been completed. The Phase I report, summarizing publicly available information on crude oil properties, was released in June 2015, and is available at http://energy.sandia.gov/tight-oil-study/. Additionally, work has begun on preparation of a crude oil characterization plan that will outline the tasks needed to collect the information necessary to evaluate crude oil properties and their relevance to the likelihood and severity of a combustion incident resulting from transport. A document describing the crude oil characterization plan is expected to be completed in 2016.

FLARING REDUCTION CONTINUED





WATER OPPORTUNITIES ASSESSMENT



Bakken Flares and Satellite Images Fact Sheet

Researchers from the EERC and the University of North Dakota's (UND's) Department of Earth System Science and Policy joined forces to better understand these bright satellite images. With images available through the National Oceanic and Atmospheric Administration (NOAA), improved methodologies were developed for identifying, characterizing, and processing flare images for several locations in western North Dakota.

In summary, this study produced images which, when including only light attributable to combustion sources (flared associated gas), would look more like the image at far left. This image shows faint, yet discernible, patches of light on a nighttime map of North Dakota, distinctly different from the various night sky images in newspaper and trade magazines (at left) that compare the Bakken region to New York City, Boston, and Chicago.

Bakken Water Opportunities Update

This report provides a summary of water use and handling trends in the Bakken, estimation of future water supply demand and disposal needs, an overview of potential treatment technologies, considerations for recycling and reuse, a summary of the implications of the report findings for our partners, and recommendations for future work.

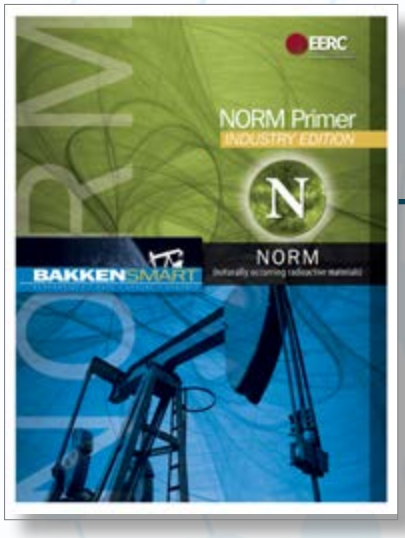
Water Fact Sheet

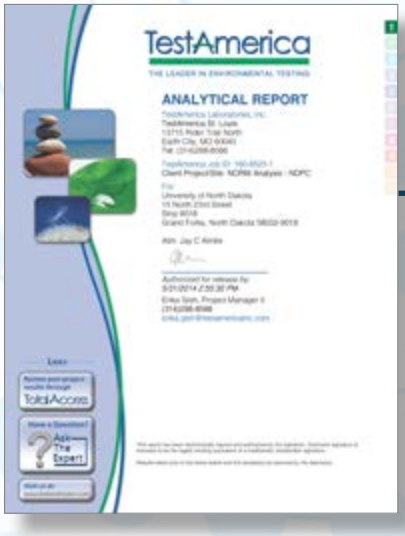
A series of fact sheets was created to educate and inform the general public on key Bakken headline issues from 2013 to 2015. The water fact sheet explains how water is used in oil and gas production, where producers obtain freshwater for operations, options available for water treatment and reuse, and water-handling costs.

Dakota Sandstone Capacity Modeling

Ongoing efforts through the optimization program are focused on evaluating the capacity of various formations in the Williston Basin as saltwater injection targets. This work will help us to better understand the volumes of brine that can be disposed of in these formations and where that additional storage capacity exists.

TENORM WASTE DISPOSAL





NORM Task Force

BPOP representatives served as subject matter experts and advisors to NDPC's NORM Task Force and to state interests throughout 2013–2015. During that period, the topic of TENORM was in the headlines regularly. Illegal dumping of filter socks from oilfield operations was casting a negative light on the state and the industry. BPOP was able to provide expert analysis on draft TENORM disposal regulations proposed by North Dakota's Department of Health (NDDH) in 2014. BPOP personnel provided public testimony before the North Dakota Legislature's Energy Development and Transmission Committee and during three public hearings held by NDDH to solicit public comments on the proposed TENORM in-state disposal rules.

NORM Fact Sheet

A series of fact sheets was created to educate and inform the general public on key Bakken headline issues from 2013 to 2015. The NORM fact sheet explains what NORM is, a layman's description of radiation, what levels of radioactivity are hazardous, how NORM is regulated in North Dakota, and how NORM waste is disposed of safely.

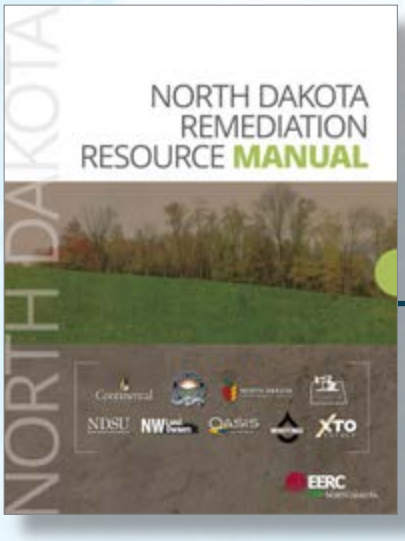
NORM Primer

The NORM Primer was produced to provide the reader with a brief, highly readable summary of the breadth of radiation science behind NORM regulations. Because radiation is one of the most complex topics in physics and because biological damage due to radiation is an inexact science, it is impossible to reduce the volume of knowledge in radiation physics to a single booklet. Therefore, this booklet was meant to provide the reader with enough information to begin asking good questions. It served as a mechanism to ensure that industry and state interests were speaking with commonality on facts.

Minisurvey of TENORM in Drill Cuttings, Produced Water, and Flowback Water

The EERC coordinated a TENORM sampling effort among several oil producers of the NDPC NORM Task Force. Fifty samples of drill cuttings, produced water, and flowback water were analyzed for radium content. The results of this survey were shared with industry and with NDDH. The EERC also supported the NORM Task Force in interpretation of the results. This work supported comments written by industry in response to NDDH's release of a draft of its new rules for in-state TENORM disposal.

SPILLS REMEDIATION



Saltwater Spills Task Force

BPOP provided subject matter expertise to NDPC's Saltwater Spills Task Force during 2014 and 2015. BPOP also enlisted the assistance of North Dakota State University's (NDSU's) Range Science, Soil Science, and Agricultural Extension Programs to ensure that all remediation and reclamation efforts for industry and the state were grounded in solid science. It is through this partnership with the EERC, NDSU, the Saltwater Spills Task Force, and industry at large that the Spills Primer and the Remediation Resource Manual were created.

Spills Fact Sheet

A series of fact sheets was created to educate and inform the general public on key Bakken headline issues from 2013 to 2015. The spills fact sheet explains the types of spills associated with oil and gas production, what happens when a spill occurs, and how spills are cleaned up and provided an objective perspective on spill statistics.

Reclamation Fact Sheet

A series of fact sheets was created to educate and inform the general public on key Bakken headline issues from 2013 to 2015. The reclamation fact sheet explains the reclamation process, who is typically involved in a reclamation project, how disturbed areas are reclaimed, and how spill sites are reclaimed.

Spills Cleanup Primer

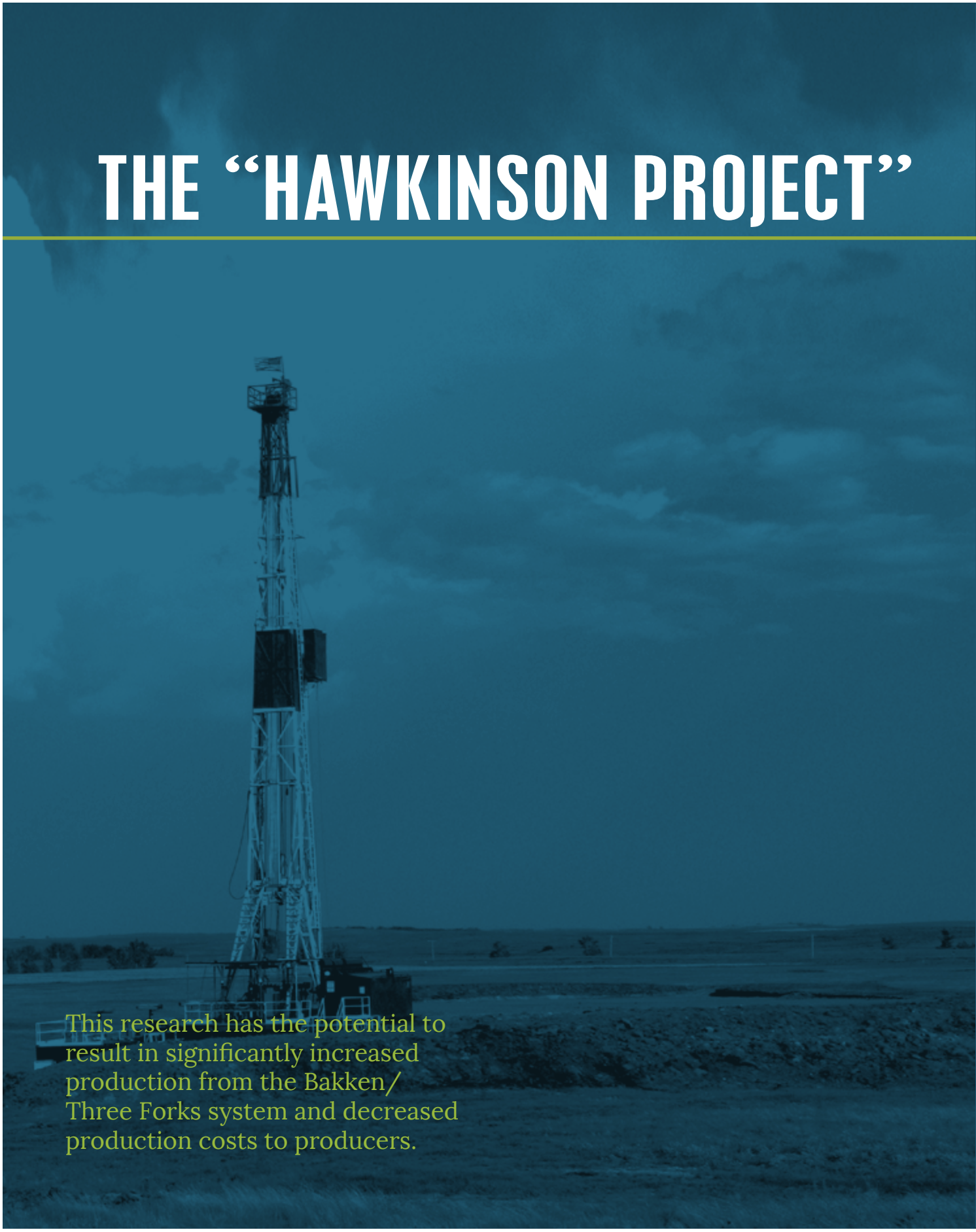
The Spills Cleanup Primer is intended to provide the reader with a fundamental understanding of hydrocarbon and brine spills from oil and gas production and the related remediation and reclamation of these spills. As oil and gas production in the Williston Basin has increased, the number and volume of spills have also increased; however, when normalized by actual volumes produced, spill rates have actually decreased. The primer is designed to inform the reader on spills, how spills are regulated, what measures are taken to minimize their impacts, and how spills are cleaned up. Material presented in this document regarding techniques, processes, and technologies to address spills is intended to be informational only; actual performance of spill-related activities will vary.

North Dakota Remediation Resource Manual

BPOP and the Saltwater Spills Task Force collaborated to create a field guide to aid those involved in the remediation and reclamation of sites impacted by oil field-related spills. Remediation information included in this document is for spills limited to soil impacts and does not address remediation related to groundwater impacts. In addition, the information is specific to the execution of these activities in North Dakota and may not be wholly applicable to other areas of the country.

This document is organized as an instruction manual with distinct sections for different topics such as soil types, spill evaluation, and determining when no further actions are necessary. This manual is based on practical, reproducible, and field-friendly procedures. Users can reference individual sections specific to their needs without having to read the entire document.

THE "HAWKINSON PROJECT"



This research has the potential to result in significantly increased production from the Bakken/ Three Forks system and decreased production costs to producers.

The Hawkinson Project, executed by Continental, was a research project aimed at **significantly increasing total production** and production rates from North Dakota oil wells where oil reserves of the second and third benches of the Three Forks Formation, located just below the Bakken oil formation, are being explored. This research has the potential to result in **significantly increased production** from the Bakken/Three Forks system and decreased production costs to producers.

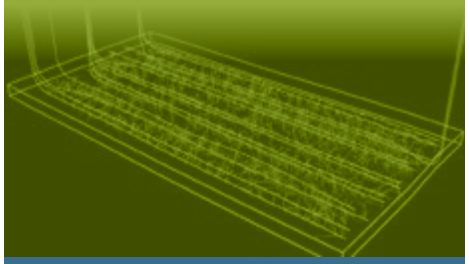
The Hawkinson Project was conducted in four phases.

PHASE I

Drilled 11 consecutive wells within a single unit and collected log and core data.

PHASE II

Completed 11 wells and collected microseismic and vertical seismic profile data.



PHASE III

Performed reservoir engineering analyses. Analyzed the data from Phases I and II. Integrated these data and analysis results into cohesive stimulation modeling and numerical reservoir simulations.

PHASE IV

Performed field acquisition, processing, and analysis of 3-D seismic survey.

A project to explore unit spacing and reservoir characteristics specific to North Dakota's Bakken/ Three Forks system.

Location of the Hawkinson Project in North Dakota.

Aerial view of surface operations associated with the Hawkinson Project.

NEED FOR THE PROJECT

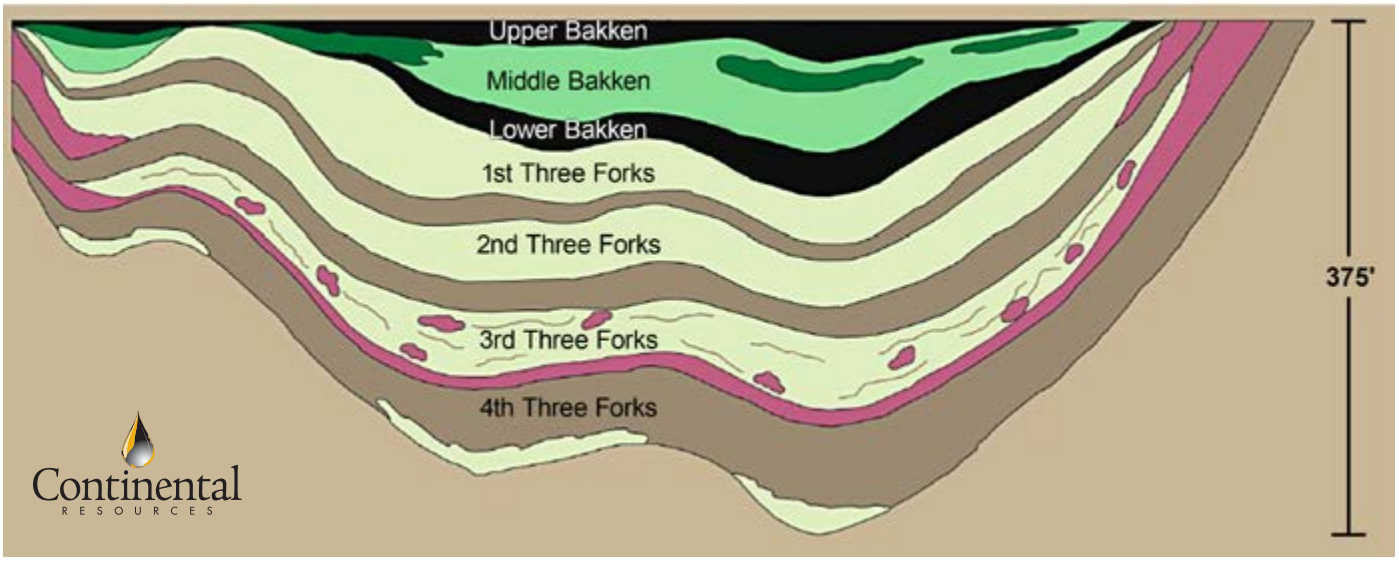
The Hawkinson Project area has already proved productive for the Middle Bakken and first, second, and third benches of the Three Forks zones. The Bakken Formation immediately overlies the Three Forks Formation. This stratigraphic relationship combined with geochemical similarities of the respective formation fluids has led many in the Williston Basin to theorize that the Three Forks zone is in communication with the oil-producing middle member of the Bakken. As a result, **petroleum resource estimations have typically summed the two together**. However, Continental had previously proved in its evaluation of the Middle Bakken and first bench of the Three Forks with the Mathistad Project that **these formations are indeed separate.**

The upper three benches of the Three Forks Formation have recently **shown great promise** as potentially prolific oil-producing zones in North Dakota. The second bench of the Three Forks zone had an initial production rate of 1140 barrels of oil equivalent a day in the Continental-operated Charlotte 2-22H well. The Charlotte 3-22H had an initial production rate of 953 barrels of oil equivalent a day from the third bench of the Three Forks.

Before the completion of this project, the stratigraphic interval used by the North Dakota Oil and Gas Division to define the Bakken Pool included the Sanish zone in most North Dakota oil fields. The result of this approach was that production information specific to the Sanish was limited, making a definitive determination of the uniqueness of the different benches of the Three Forks–Sanish play difficult. Acquiring new data focused on demonstrating that the different benches in the Three Forks are separate from the Bakken has now provided the state of North Dakota and the oil industry in the state with **new insight** that can be used to:

1. Develop realistic assessments and estimates of the first three benches of the Three Forks oil reserves.
2. Design and implement effective and efficient E&P (exploration and production) strategies for defining and developing an emerging second and third bench Three Forks play in North Dakota.

The upper three benches of the Three Forks Formation have recently shown great promise as potentially prolific oil-producing zones in North Dakota.



General layering of the Bakken and Three Forks pay zones.

INDUSTRY FIRSTS

DRILLING

- Drilled sequentially 11 long laterals in four formations within a single unit
- Four cemented liners, seven openhole packers

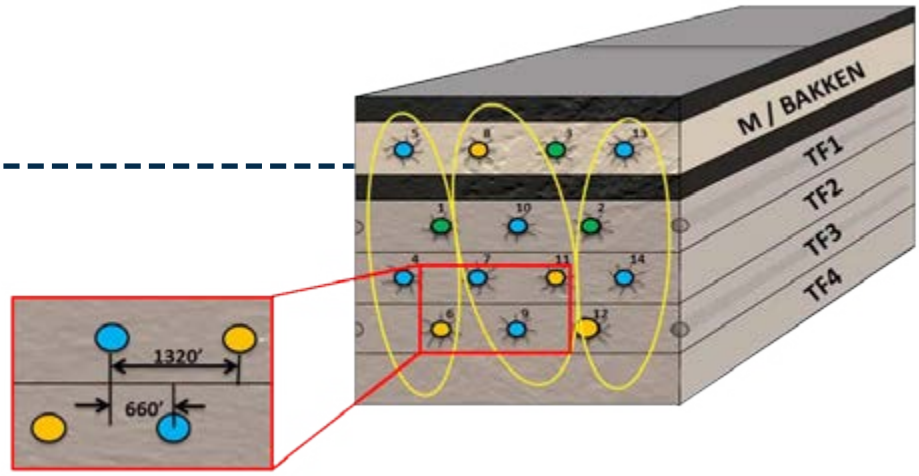
COMPLETIONS

- Completed 11 wells sequentially
- Tractored longest lateral USIT (ultrasonic imaging tool) runs (>21,000' MD)
- 63 days' continuous, 24/7, microseismic recording field operations

MICROSEISMIC

HISTORICALLY LARGEST TO DATE IN THE INDUSTRY

- Ten treatment wells sequentially monitored
- 283 stimulated stages recorded
- 171 tool monitoring days
- Longest laterals with three monitoring wells (>21,000' MD)
- Most footage of tractored tools in a single project (microseismic >270,000'; USIT >40,000')
- Longest lateral footage pulling ten geophone shuttles (>21,000' MD)
- Highest BHT (bottomhole temperature) project designed with three monitor wells (266°F)
- ~1,200,000 microseismic event picks generated
- 3-D full elastic modeling to design microseismic data collection
- Measured, via VSP (vertical seismic profiling), and applied "Q" to the microseismic data


M / BAKKEN
TF1
TF2
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TF4
1320'
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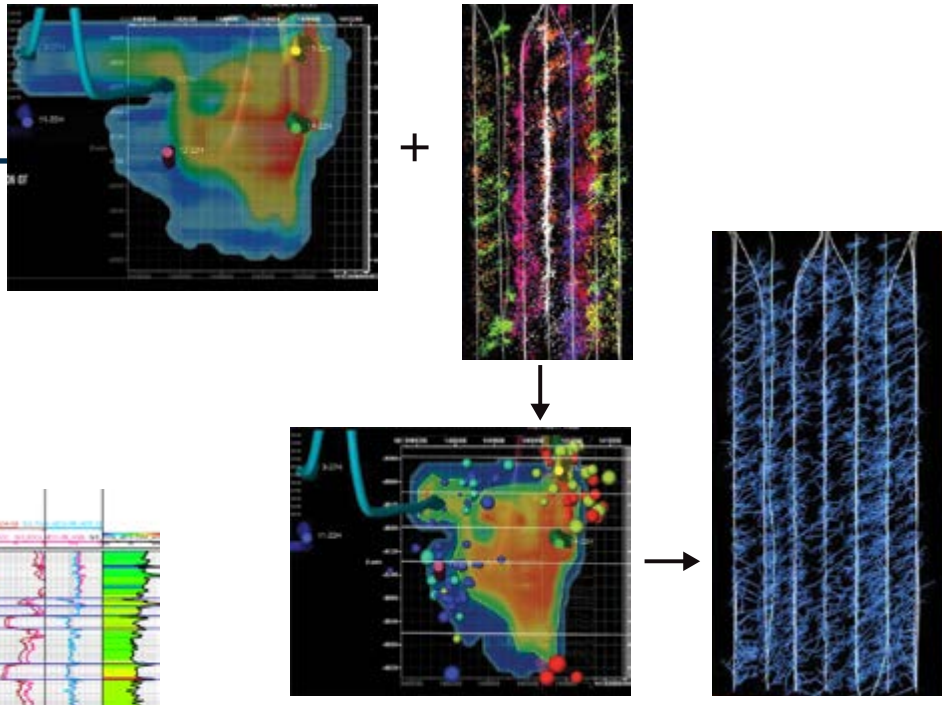
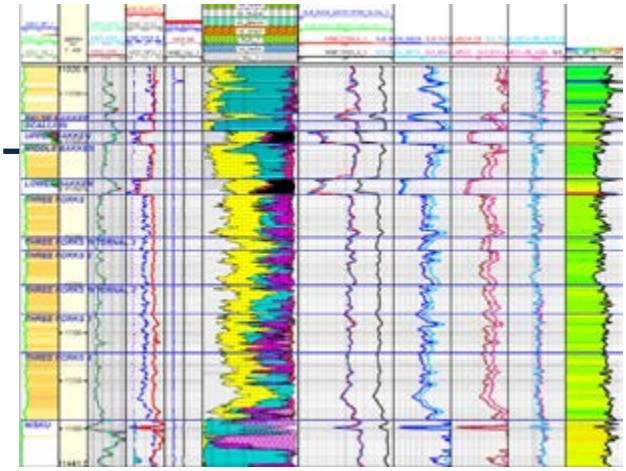




RESULTS AND DISCUSSION

The compressed development schedule provided the opportunity to collect a data set unique in its scope and quality. During the stimulations, Continental collected bottomhole pressure (BHP) data in three existing "parent" wells and microseismic data. Stimulation fluids were tagged with chemical tracers. Produced fluids were sampled, and the concentration of these chemical tracers was recorded. Subsequently, pulse tests were conducted.

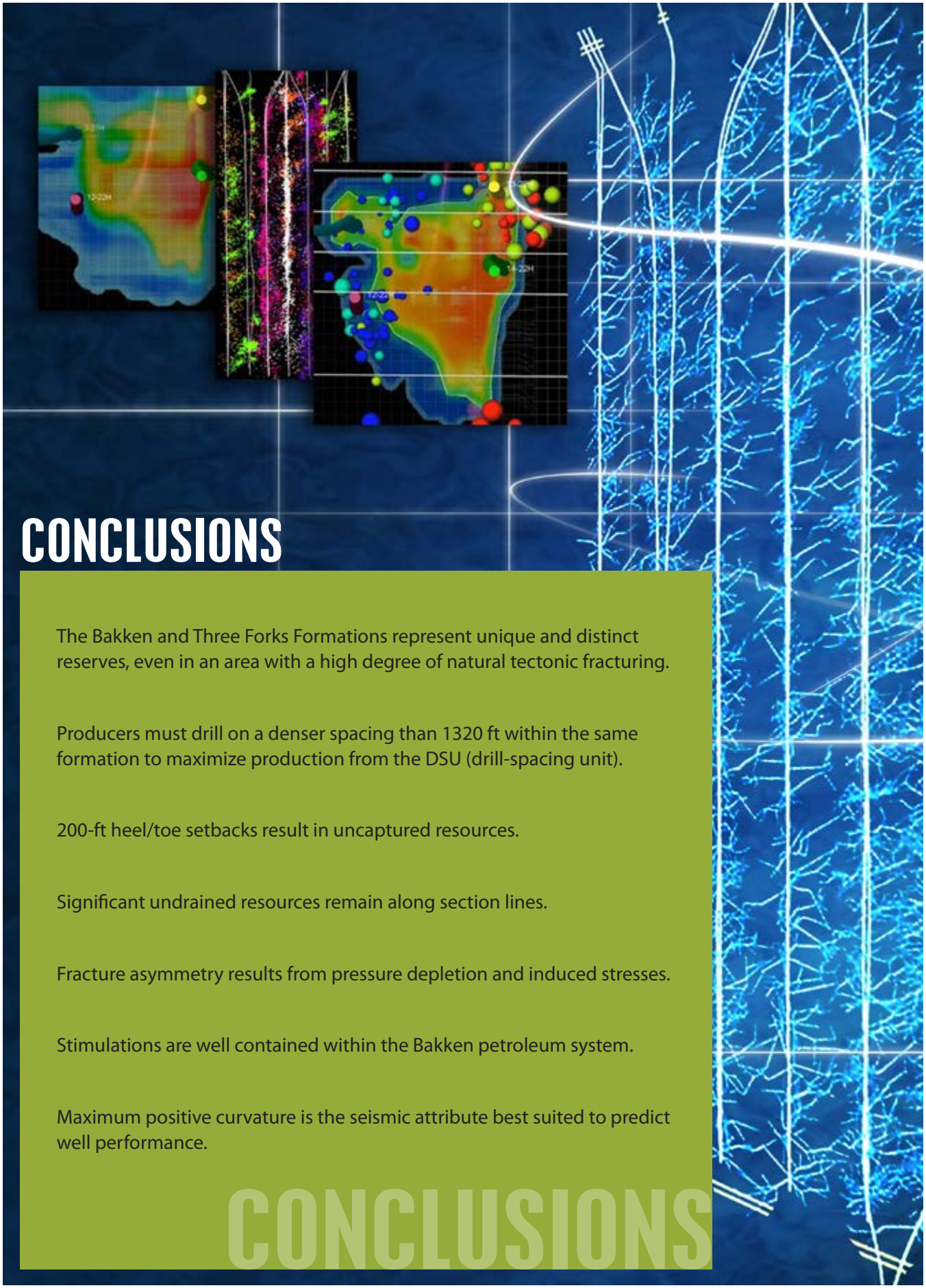
The microseismic data set collected was **uniquely comprehensive** and carefully designed to ensure high quality. Continental recorded treatment of 283 stages among ten wellbores extending across the entire 1- by 2-square-mile unit in this project. Comparatively, most microseismic projects usually include only a single treatment wellbore and record the stimulation of only five to 40 stages.

The diverse and multidisciplined data set was analyzed with a variety of methods. Where appropriate, data from one source were integrated with data from another to **improve analyses**. Where possible, results from prior analyses were incorporated into subsequent ones. Where different analyses used different data to analyze the same property, results were reconciled. The variety of available data allowed a **unique opportunity to compare and reconcile** multiple analyses.

The subsurface portion of the work resulted in a **one-of-a-kind effort** to give a 3-dimensional picture of what happens during and after hydraulic fracture treatments in multistage horizontal wells in the Middle Bakken as well as the first, second, and third benches of the Three Forks Formation. **This had not been previously attempted.**

This activity provided previously unknown information regarding potential Bakken development, helping to determine the optimal number of wellbores that need to be placed in each zone for proper development. Knowing the appropriate number of wellbores needed will help the industry know how many wells will ultimately need to be drilled in spacing units in North Dakota in the Bakken Pool.

The potential economic impact of understanding the number of wells needed to be drilled in the future for primary development, alone, will lend **confidence** to the effort to build infrastructure in the region and will develop estimates for potential oil industry employment over the long term.



CONCLUSIONS

The Bakken and Three Forks Formations represent unique and distinct reserves, even in an area with a high degree of natural tectonic fracturing.

Producers must drill on a denser spacing than 1320 ft within the same formation to maximize production from the DSU (drill-spacing unit).

200-ft heel/toe setbacks result in uncaptured resources.

Significant undrained resources remain along section lines.

Fracture asymmetry results from pressure depletion and induced stresses.

Stimulations are well contained within the Bakken petroleum system.

Maximum positive curvature is the seismic attribute best suited to predict well performance.

CONCLUSIONS

PROGRAM WORK CONTINUES

BPOP is currently in its third year of activity. Hawkinson Project work is formally complete, but strong interest from program members in the implications of the results of the Hawkinson Project means that **informal activity in these areas will continue.** The membership is currently discussing additional verification of these groundbreaking findings, which may lead to new recommendations to the state of North Dakota regarding DSU development.

The **EERC continues work in several tasks under Optimization of Wellsite Operations** and intends to continue to do so as long as program funding and member interest exist. Flaring minimization, water management, TENORM disposal, and saltwater spills continue to be hot topics demanding focused attention. Industry has also expressed interest in well failure analysis, storm water management, and artificial lift improvements. The Program stands **ready to address** any issues common to all members of this productive and unique consortium-driven program.

The current period of performance ends in June 2016.

To discuss BPOP's activities or results, contact:

John A. Harju
Vice President for Strategic Partnerships
(701) 777-5157
jharju@undeerc.org

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University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

www.undeerc.org

Bakken Production Optimization Program

EXECUTIVE SUMMARY

EERC

UND UNIVERSITY OF NORTH DAKOTA

APPENDIX B

RESUMES OF KEY PERSONNEL

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
Phone: (701) 777-5157, Fax: (701) 777-5181, E-Mail: jharju@undeerc.org

Principal Areas of Expertise

Mr. 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.

Qualifications

B.S., Geology, University of North Dakota, 1986.

Postgraduate course work in Management, Economics, Marketing, Education, Climatology, Weathering and Soils, Geochemistry, Geochemical Modeling, Hydrogeochemistry, Hydrogeology, Contaminant Hydrogeology, Advanced Physical Hydrogeology, and Geostatistics.

Professional Experience

2002–Present: EERC, UND, Grand Forks, North Dakota.

July 2015–Present: Vice President for Strategic Partnerships. Mr. 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 strategic energy and environmental initiatives focused on conventional and unconventional oil and gas development; zero-emission coal utilization; CO_2 capture and sequestration; energy and water sustainability; hydrogen and fuel cells; advanced air emission control technologies, emphasizing SO_x, NO_x, air toxics, fine particulate, and mercury control; renewable energy; wind energy; water management; flood prevention; global climate change mitigation; waste utilization; energy efficiency; and contaminant cleanup.

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

2002–2003: Senior Research Advisor. Mr. Harju's responsibilities included development, marketing, management, and dissemination of market-oriented research; development of programs focused on the environmental and health effects of power and natural resource production, contaminant cleanup, water management, and analytical techniques; publication and presentation of results; client interactions; and advisor to internal staff.

1999–2002: Vice President, Crystal Solutions, LLC, Laramie, Wyoming. Mr. 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, Illinois.

2000–2002: Principal Scientist, Produced Water Management. Mr. Harju's responsibilities included development and deployment of 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. Mr. Harju's responsibilities included project and program management related to the development of environmental technologies and informational products related to the North American oil and gas industry; formulation of RFPs, proposal review, and contract formulation; technology transfer activities; and staff and contractor supervision. Mr. Harju served as Manager of the Environmentally Acceptable Endpoints project, a multiyear programmatic effort focused on a rigorous determination of appropriate cleanup levels for hydrocarbons and other energy-derived contaminants in soils. He also led GRI/GTI involvement with numerous industry environmental consortia and organizations, including PERF, SPE, AGA, IPEC, and API.

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

1988–1996: EERC, UND, Grand Forks, North Dakota.
1994–1996: Senior Research Manager, Oil and Gas Group. Mr. Harju's responsibilities included the following:

- Program Manager for program to assess 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, National Mine Land Reclamation Center for Western Region.
- Co-Principal Investigator on project exploring feasibility of underground coal gasification in southern Thailand.
- Consultant to International Atomic Energy Agency for program entitled "Solid Wastes and Disposal Methods Associated with Electricity Generation Fuel Chains."

1994: Research Manager.
1990–1994: Hydrogeologist.
1989–1990: Research Specialist.
1988–1989: Laboratory Technician.

Synergistic Activities
Member, National Petroleum Council
Outgoing Chairman, Interstate Oil & Gas Compact Commission, Chairman, Energy Resources, Research and Technology Committee
Member, U.S. Department of Energy Unconventional Resources Technology Advisory Committee
Member, Rocky Mountain Association of Geologists

Publications and Presentations
Has authored and coauthored more than 100 publications.

JAY C. ALMLIE
Principal Engineer, Mid/Downstream Oil & Gas Group Lead
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Phone: (701) 777-5260, Fax: (701) 777-5181, E-Mail: jalmlie@undeerc.org

Principal Areas of Expertise

Mr. Almlie's principal areas of interest and expertise include oil and gas production optimization, oilfield NORM (naturally occurring radioactive material) waste management, hydrogen generation, data acquisition and control systems, pipeline transport, and program/project management.

Qualifications

B.S., Mechanical Engineering, and B.S., Engineering Management, University of North Dakota, 1995.
Proficient in the use of LabView, AutoCad, Autodesk Inventor, MS Excel, MS Project, MathCAD, Rockwell Software RSLogix, and RSView Studio.

Professional Experience

2009–Present: Principal Engineer, Mid/Downstream Oil & Gas Group Lead, EERC, UND. Mr. Almlie's responsibilities include supervision and direction of a diverse group of researchers focused on oil and gas production optimization, pipeline transport, emission control technology development, and hydrogen generation technology development. Mr. Almlie is responsible for technical, managerial, and business development aspects of this work. Mr. Almlie has managed several successful multimillion-dollar projects during his tenure in this position.

2006–2009: Research Manager, Environmental Technologies, EERC, UND. Mr. Almlie's responsibilities included supervising a team of researchers focused on mercury emission control, particulate matter emission control, and hydrogen production. Mr. Almlie was also involved technically in projects in each of these areas.

2002–2006: Research Engineer, Environmental Technologies, EERC, UND. Mr. Almlie's responsibilities included projects involving mercury control, particulate matter emission control, and emission control for diesel systems.

2000–2002: Lead Mechanical Engineer–Water Systems, International Space Station Habitability Outfitting, and Deputy Project Manager, International Space Station Galley, Lockheed Martin Space Operations Company, Houston, Texas. Mr. Almlie's responsibilities included supervision of the Galley Potable Water System and Waste and Hygiene Compartment Crew Hygiene System design teams, development of system architecture and component specs, design of water system engineering development units, and thermal/fluid mechanics analysis and testing on water systems.

1995–2000: Mechanical Engineer, Hernandez Engineering, Inc. Mr. Almlie's responsibilities included involvement in several projects:

- Lead mechanical engineer for a Space Shuttle thermal control system upgrade, including performing thermal design, analysis, and test functions and serving as project manager for the $1 million research project. This was one of 10 projects identified by the National Research Council as leading contenders to extend the life of the Space Shuttle fleet.

- Lead mechanical engineer for water recovery systems, including designing, testing, and analyzing a potable water tank/radiation protection system for a crew habitat vehicle; and performing project management functions.
- Test engineer for the International Space Station Active Thermal Control System (ATCS), including thermal/vacuum testing on ISS Active Thermal Control components and participating in Analysis and Integration Team activities to ensure ISS Thermal Control System function on-orbit.

1994–1995: Research Assistant, School of Engineering and Mines, UND. Mr. Almlie's responsibilities included computational fluid mechanics model generation for combustion applications using Fluent software.

Summer 1994: Engineering Intern, Orbital Sciences Corporation, Inc., Dulles, Virginia. Mr. Almlie's responsibilities included performing launch vehicle dynamic separation analyses, designing payload separation system components, performing multiple stress/strain analyses on payload carrier structures.

1991–1993: Mechanical Engineering Cooperative Education Intern, Eagle Engineering, Inc., Houston, Texas. Mr. Almlie's responsibilities included authoring a satellite ground tracking code, coauthoring a payload separation simulation code, and performing payload fairing separation analysis for Orbital Sciences Corporation's Pegasus rocket.

Publications and Presentations

Has coauthored several professional publications.

Patents and Technology Disclosures

Radiation Shield Water Tank: Microgravity Water Tank with Capillary Air/Liquid Separation Used for Radiation Shielding. June 6, 2005. NASA Technology Disclosure.

Water Membrane Evaporator. July 22, 2005. NASA Technology Disclosure.

Miller, S.J.; Zhuang, Y.; Almlie, J.C. Advanced Particulate Matter Control Apparatus and Methods. U.S. Patent 8,092,768 B2, Jan 10, 2012.

Miller, S.J.; Almlie, J.C. Removal of Residual Particulate Matter from Filter Media. U.S. Patent 8,882,926, Nov 11, 2014.

CHAD A. WOCKEN
Principal Engineer, Fuels and Renewable Energy Lead
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
Phone: (701) 777-5273, Fax: (701) 777-5181, E-Mail: cwocken@undeerc.org

Principal Areas of Expertise

Mr. Wocken's principal areas of research include developing alternative fuel and chemical processes and innovative energy technologies. Currently, he is leading projects focused on developing and advancing alternative chemical and fuel production processes at the bench, lab, and pilot scale; and optimizing processes associated with oil and gas production and midstream operations. Mr. Wocken currently manages a group of researchers and a lab facility containing batch and continuous reactor systems capable of testing a variety of thermochemical processes.

Qualifications

B.S., Chemical Engineering, University of North Dakota, 1994

Certifications: U.S. Army Corps of Engineers Construction Quality Management, 40-hour OSHA Health and Safety, 8-hour HAZWOPER Supervisor, 10-hour Construction Safety and Health.

Professional Experience

2009–Present: Principal Engineer, Fuels and Renewable Energy Lead (2009–September 2015, Senior Research Manager; 2001–2009, Research Engineer), EERC, UND.

Project/Program Management

- Comanaged a Defense Advanced Research Projects Agency (DARPA)-funded project that successfully developed technology to produce drop-in compatible jet fuel for the military from renewable feedstock. Activities included planning work activities, developing and executing a risk-based project management plan, coordinating activities of five project partners to meet project goals, and communicating with the DARPA project manager.
- Managed the scale-up and design of a 300-barrel/day renewable fuel pilot plant capable of producing specification-compliant jet and diesel fuels from renewable oil feedstock.

Technology Development and Research

- Conducted a technical and economic assessment of alternative uses for associated gas in an effort to reduce the amount of gas being flared in the Williston Basin. Technologies evaluated included gas-processing operations to recover natural gas liquids, the use of rich gas in internal combustion engines for transportation and power, and traditional petrochemical unit operations.
- Performed a system-level engineering evaluation of integrated algae production at a coal-fired power plant to assess carbon uptake, emission control requirements, relative scale, and the viability of water and waste heat utilization.
- Designed, fabricated, and operated several fixed-catalyst bed reactor systems to evaluate a variety of thermocatalytic processes to produce renewable fuels and chemicals.
- Conducted testing at coal-fired power plants, and developed control technologies to reduce atmospheric emission of particulate matter, mercury, and other contaminants.

1995–2001: Project Engineer, URS/Radian International, Salt Lake City, Utah (1997–2001), and Milwaukee, Wisconsin (1995–1997).

Process Design, Operation, and Optimization

- Designed groundwater remediation systems to remove BTEX compounds and chlorinated solvents from groundwater. The projects consisted of site evaluation, technology selection and design of several groundwater circulation wells, air sparge/soil vapor extraction treatment systems, and groundwater extraction with air stripper treatment technology. Design aspects included mass balance calculations, equipment design (pumps, pipe sizing, blowers, filters, etc.), equipment selection and specification, bid/construction specifications, and design drawing development.
- Performed start-up and long-term operations for a variety of groundwater remediation systems. Responsibilities included troubleshooting equipment/system malfunctions, process optimization, writing operations and maintenance manuals, establishing performance verification criteria, defining operational cost, and directing technicians' work.
- Conducted detailed reviews of industrial wastewater treatment systems to identify alternative treatment technologies, process optimizations, cost-saving measures, water reuse and zero discharge alternatives, and regulatory considerations.

Construction Oversight

- Provided on-site quality control oversight for several construction projects consisting of mechanical equipment installation, instrumentation and process control, building and road construction, excavation, and underground utility installation. Daily responsibilities included evaluating work for conformance with construction drawings and specifications; conducting progress meetings; coordinating subcontractor work activities; and facilitating communication between the design firm, client, and subcontractors.

Project Management

- Served as project manager for several large projects that were completed successfully. Activities included developing cost proposals, managing budget and schedule, equipment and subcontractor acquisition, and maintaining effective communication with the client.

1994–1995: Process Engineer, Archer Daniels Midland, Clinton, Iowa.

Plant Operation

- Supervised operations and personnel at a wet corn mill oil extraction and refining plant. Tasks consisted of prioritizing work activities, scheduling maintenance and repairing process equipment, reviewing quality control, and extensive system troubleshooting and failure analysis.

Publications and Presentations

Has authored or coauthored numerous publications.

BETHANY A. KURZ
Principal Hydrogeologist, Laboratory Analysis Group Lead
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Phone: (701) 777-5050, Fax: (701) 777-5181, E-Mail: bkurz@undeerc.org

Principal Areas of Expertise

Ms. Kurz's principal areas of interest and expertise include the evaluation of water supply sources for the oil and gas industry, produced water and drilling waste management, and characterization of geologic media for carbon storage and/or CO_2-based enhanced oil recovery.

Qualifications

M.S. (Summa Cum Laude), Hydrogeology, University of North Dakota, Grand Forks, ND, 1998.
B.S. (Summa Cum Laude), Geochemistry, Bridgewater State University, Bridgewater, MA, 1995.
Computer: ArcGIS, SWAT, ERMapper, ERDAS Imagine, MS Word, Excel, Access, Project Manager, Power Point, Corel Draw, Surfer, MODFLOW, WATSUTRA, Aquifer Test.
Analytical: Ion chromatograph, total organic carbon analyzer, inductively coupled plasma emission spectrometer, gas chromatograph, ion-selective electrodes, laser-induced breakdown spectroscopy (LIBS).
Fieldwork: Monitoring well and in situ microcosm (ISM) installation; soil vapor extraction system (SVE) design, installation, and optimization; groundwater sampling, analysis, and monitoring; wind-monitoring system installation; and wind data collection and analysis.

Professional Experience

2011–Present: Principal Hydrogeologist, Laboratory Analysis Group Lead, EERC, UND. Ms. Kurz oversees several of the EERC's analytical research laboratories that focus on classical and advanced wet-chemistry analyses; petrochemical and geomechanical evaluation of rocks and soils; and mineralogical assessment of natural materials using optical microscopy, x-ray fluorescence, x-ray diffraction, and scanning electron microscopy. Additional activities include the development and testing of proppants for use in hydraulic fracturing, evaluation of water supply sources for the oil and gas industry, produced water management, and characterization of geologic media for carbon storage.

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, development of strategies to address future water shortages, 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 and Wind Energy 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. She also assisted in research related to wind energy development in the region, with an emphasis on wind resource assessment, education and outreach, database development, and windsmith training curriculum development.

1997–1998: Research Assistant, Water Quality Laboratory, Department of Geology and Geological Engineering, UND. Ms. Kurz's duties included the operation and maintenance of a water quality laboratory containing several analytical instruments, including an ion chromatograph, inductively coupled plasma emission spectrometer, total organic carbon analyzer, and several ion selective electrodes.

Publications and Presentations

Has coauthored more than 60 professional publications and presentations.

JAMES A. SORENSEN
Principal Geologist
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
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Principal Areas of Expertise
Mr. Sorensen's principal areas of interest and expertise include tight oil resource assessment and development, carbon dioxide utilization and storage in geologic formations, and environmental issues associated with the oil and gas industry.

Education
B.S., Geology, University of North Dakota, 1991.
Postgraduate course work in Geology and Hydrogeology, 1993–1995.

Professional Experience
1999–Present: Principal Geologist, EERC, UND. Mr. Sorensen currently serves as manager and co-principal investigator for several research programs, including the Plains CO_2 Reduction (PCOR) Partnership, a multiyear program focused on developing strategies for reducing carbon dioxide emissions in nine states and four Canadian provinces. He has also conducted projects to develop an improved understanding of the Bakken petroleum system, including efforts to examine the potential to use carbon dioxide for enhanced oil recovery in the Bakken. Responsibilities include supervision of research personnel, preparing and executing work plans, budget preparation and management, writing technical reports and papers, presentation of work plans and results at conferences and client meetings, and proposal writing and presentation.

1997–1999: Program Manager, EERC, UND. Mr. Sorensen managed projects on topics that included produced water management, environmental fate of natural gas-processing chemicals, coalbed methane, and gas methane hydrates.

1993–1997: Geologist, EERC, UND. Mr. Sorensen conducted a variety of field-based hydrogeologic investigations throughout the United States and Canada. Activities were primarily focused on the subsurface mobility of constituents associated with 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 Memberships
Society of Petroleum Engineers

Publications and Presentations
Has coauthored nearly 200 publications.

BRADLEY G. STEVENS, P.E.
Senior Research Engineer, Civil Engineering and Renewables
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
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Principal Areas of Expertise
Mr. Stevens' principal areas of interest and expertise include soil, groundwater, and industrial process water remediation; process instrumentation and control; wind power generation; hydrogen production; and oil and gas production.

Qualifications
B.S., Civil Engineering, University of North Dakota, 1989.

Professional Experience
2011–Present: Senior Research Engineer, Civil Engineering and Renewables, EERC, UND. Mr. Stevens' responsibilities include execution of wide-ranging projects under the EERC's Bakken Production Optimization Program, including the study of alternative natural gas use, saline and hydrocarbon soil remediation, and statistical analysis of various oil and gas industry segments.

2005–2011: Research Manager/Engineer, EERC, UND. Mr. Stevens' responsibilities included management of the EERC's Plains Organization for Wind Energy Resources® (POWER®) wind energy program. POWER management duties included strategic planning, fiscal management, program presentation, proposal preparation, and personnel management. In addition, technical duties included installation and setup of wind-monitoring equipment, assessment and analysis of wind resource data, wind turbine production estimates, and theoretical project economics. Other responsibilities included supervision of the design, installation, and operation of an electrolysis-derived hydrogen production and dispensing system.

1998–2005: Research Engineer, Remediation, EERC, UND. Mr. Stevens' responsibilities included the following: management, testing, data analysis, and report preparation for the commercial application of a centrifugal membrane filtration; project management, specification, construction, and demonstration of a freeze–thaw process for the utilization of marginal waters; participation in the Red River Water Management Consortium (RRWMC) as a technical staff member advising RRWMC members regarding pertinent water supply and water quality issues; management and operation of and data analysis and report preparation for a sorption and regeneration process for mercury removal from primary and secondary liquid wastes assessment; and data analysis activities related to wind energy.

1992–1998: Project Manager/Engineer, Summit Envirosolutions, Inc., Minneapolis, Minnesota. Mr. Stevens' responsibilities included the following: specification and coordination of the installation of remote data acquisition equipment for municipalities in Minnesota for use as aquifer resource management tools; specification, installation, and maintenance of groundwater flow control and flow measurement equipment in association with a research and development cooperative agreement with NASA involving state-of-the-art methods of remote data acquisition, patented as RealFlow®; design, installation, and maintenance of permanent and mobile remediation systems in Minnesota, Wisconsin, Nevada, and Arizona, including groundwater pump-and-treat systems, soil vapor extraction systems, and

coupled air sparging–soil vapor extraction systems; and management of 20 projects in Minnesota, Wisconsin, and Illinois involving mechanical and electrical control and data retrieval for remedial systems including telemetry-based remedial systems. Other pertinent experience included work with programmable logic controllers and ladder logic programming and training in the use of Intellution FIX DMACS human–machine interface software.

1990–1992: Project Engineer, Delta Environmental Consultants, Inc., St. Paul, Minnesota. Mr. Stevens' responsibilities included the design, permitting, installation, and operation of treatment systems for remediation of contaminated groundwater and soils. Sites ranged from automotive service stations to railroad maintenance yards for projects located in a five-state region. Remediation technologies included subsurface air sparging and soil vapor extraction. Other project responsibilities included data interpretation and permit compliance for 14 remediation systems for a major oil company; supervising excavation of contaminated soils; and permitting and supervising in-place abandonment of a 12,000-gal underground storage tank.

1988–1990: Research/Engineering Technician, EERC, UND. Mr. Stevens' responsibilities included the design, construction, operation and maintenance, data collection and reduction, and formal report preparation for bench-scale treatability programs involving single-stage, two-stage, coupled nitrification–denitrification activated sludge systems, activated carbon adsorption, and ion exchange treatment of coal-processing waters. He maintained and operated the pure oxygen plug flow reactor for the biological treatment of synthetic wastewater. He also assisted in production of a pilot-scale waste water treatment facility; design and analysis of bench-scale wastewater treatment models.

Professional Memberships
Registered Professional Engineer – North Dakota No. PE-4340, Minnesota No. 25387

Patents
Barrett, D.P.; Davis, R.J.; Dustman, J.E.; Gibas, D.R.; Stevens, B.G.L.; Wilson, B.T. Measuring System for Measuring Real-Time Groundwater Data. U.S. Patent 5,553,492, Sept 10, 1996.

Publications and Presentations
Has authored or coauthored numerous publications.

LAWRENCE J. PEKOT
Principal Engineer, Reservoir Engineering Group Lead
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Principal Areas of Expertise

Mr. Pekot's principal areas of interest and expertise include unconventional reservoir engineering, including CO_2 storage and enhanced oil recovery (EOR), coalbed methane (CBM), enhanced CBM (ECBM), shale gas, natural gas storage, and hydraulic fracturing; integrated project management; numerical simulation; and field studies and reserve evaluations.

Qualifications

B.S., Civil Engineering, Pennsylvania State University, 1978.
B.S., Geological Science, Pennsylvania State University, 1978.

Professional Experience

September 2015–Present: Principal Engineer, Reservoir Engineering Group Lead, EERC, UND. Mr. Pekot's responsibilities include:

- Leading reservoir engineering evaluations for CO_2 enhanced oil recovery (EOR), CO_2 storage, and unconventional hydrocarbon recovery projects.
- Leading a group of reservoir engineers on multiphase flow, geomechanical, thermal, and geochemical interaction simulations.

2013–2015: International Project Manager, Schlumberger Carbon Services, Denver, Colorado. Mr. Pekot's responsibilities included:

- Management of CO_2 evaluation projects outside of the United States, Australia, and Canada.
- Supervision of site selection studies, simulation, appraisal planning, risk analysis, injection testing and monitoring technologies, regulatory compliance, cost estimation, and reporting.
- Supervision and mentoring of junior staff.

2008–2013: Technical Manager for Europe/Africa, Schlumberger Carbon Services, Paris, France. Mr. Pekot's responsibilities included:

- Technical oversight of carbon storage evaluation projects and opportunities in Europe and Africa, including work in the United Kingdom, Ireland, Spain, Italy, Poland, Romania, Bulgaria, Libya, South Africa, and Australia.
- Coordination of projects and resources between Schlumberger's Consulting and Carbon Services businesses.
- Strategic, technical, and business development assistance for unconventional reservoir problems, including natural gas storage, geothermal, CBM, and EOR.
- Management of corporate special projects and resource evaluations.
- Project peer reviews for other business units.
- Introduction of corporate project management procedures to Carbon Services.
- Junior staff mentoring and introduction to the corporate technical advancement system.

2004–2007: Principal Consultant, Schlumberger Data and Consulting Services, Pittsburgh, Pennsylvania. Mr. Pekot's responsibilities included:

- Engineering studies for tight gas, gas storage, shale, and coalbed methane (CBM) properties in the United States and Canada.
- Reserve reporting evaluations for conventional, CBM, and CO_2 flood properties.
- EOR CO_2 flood evaluations of Michigan Basin pinnacle reef reservoirs.
- Saline formation test site modeling for CO_2 storage in Ohio and Texas; one done for Schlumberger R&D.
- Initial evaluation and carbon sequestration site prescreening for carbon storage for the New York Clean Coal Power Initiative.
- Two CO_2 sequestration site screening evaluations for U.S. electric utility clients.
- A Pacific Basin overview study of CO_2 EOR and ECBM potential for a Japanese client.

1995–2003: Vice President, Advanced Resources International, Inc., Washington, D.C. Mr. Pekot's responsibilities included:

- Development, maintenance, and marketing of the firm's technical software programs, COMET for reservoir simulation and METEOR for analytic type curve evaluations.
- Serving as a reservoir engineering advisor for the U.S. Federal Energy Regulatory Commission.
- Performing or supervising well testing and numerical simulation evaluations of numerous gas, oil, gas storage, CBM, enhanced coalbed methane (ECBM), and other unconventional reservoirs, including projects in Australia, Canada, China, Czech Republic, India, Poland, South Africa, and the United States.
- Exploration, appraisal, and development planning.
- ECBM simulation.
- Evaluation of geologic storage options for greenhouse gas sequestration potential.
- Shale gas well performance evaluation.
- Estimated reserves for merger and acquisition economic evaluations.
- Field demonstration of advanced simulation technologies for gas storage wells.
- Well testing and evaluation methodologies for gas storage remediation candidate selection.
- Supervision of the reservoir simulation and design of the development plan for the first gas storage reservoir in the People's Republic of China.

1991–1995: Principal Consultant, Scandpower A/S (now known as SPT Group of Schlumberger), Oslo, Norway. Mr. Pekot's responsibilities included:

- Administrative supervision of a team of four engineering consultants.
- Project management.
- Technical assistance to junior staff.
- Software marketing and technical support.
- Consulting for
  - PEMEX (Mexico).
  - Norsk Hydro, where he used state-of-the-art engineering techniques and simulation software (ECLIPSE) to help optimize the $2 billion oil development plan for the Troll Field in the North Sea, edited the reservoir engineering proposal for a $150 million field expansion, and prepared and delivered numerous presentations to license holders and government authorities.
  - Saga Petroleum, where he developed an engineering and geologic database for the unitized Snorre Field to be used in field ownership redetermination and conducted a reservoir simulation study to determine optimum recovery techniques for the Gullfaks South reservoir.

1978–1991: Senior Petroleum Engineer, Phillips Petroleum Company, Stavanger, Norway, and Houston, Texas. Mr. Pekot's responsibilities included the following:

- Senior Joint Venture Engineer for Gulf of Mexico properties (3 years), including profit and loss accountability for a $20 million capital and expense budget; economic evaluation for $60 million development of a new gas field; technical and economic evaluations for rehabilitation of a large, old oil field, where production doubled and reserves increased 50%; evaluation of deep-water exploration leases; technical and economic analysis for drilling, well workovers, process equipment upgrades, platform construction, and rehabilitation, writing project justifications and obtaining approvals; and Reserves evaluations.
- Senior Engineer (4 years), including supervision of a team of engineers for numerical simulation of North Sea oil and gas fields; setting group objectives and scheduling and delegating assignments; junior staff performance evaluation and career counseling; drilling and workover proposal justifications; economic analysis; reservoir management plan maintenance and updates; evaluation of oil and gas reserves under depletion and various gas and water injection development proposals; and temporary section leader, supervising ten engineers.
- Associate Production Geologist (2 years), including wellsite geology; correlating geological and geophysical data and creating maps and cross sections, geological field study for the development of the Tommeliten gas fields, coauthoring and editing the geologic field study for the $1 billion Ekofisk Field waterflood project, and serving on the project team that developed a North Sea geological database.
- Staff Reservoir Engineer (3 years), including wellsite testing and analysis of new gas production wells, well test analysis and selection of new drilling locations, evaluation of field production problems, technical report writing, corrective action recommendations, and unitized field operations; found new reserves located in formations previously considered uneconomical.
- General land-based production (1 year), including EOR projects, drilling, and workover operations, and land surveying and piping design.

Professional Affiliations

Member, Society of Petroleum Engineers Distinguished Lecture Review Committee, 2006–2011
Technical Reviewer, *International Journal of Coal Geology*

Publications and Presentations

Has authored or coauthored numerous publications.

APPENDIX C

LETTER OF COMMITMENT

Faisal Rasdi
Bakken Development Supervisor

Marathon Oil
555 San Felipe St, Houston TX 77056
Telephone: 713-296-1856
frasdi@marathonoil.com

May 23, 2016

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: Marathon Oil Company – Cost-Share Contribution for the Project Entitled "Bakken Production and Optimization Program – 2.0"

Marathon Oil Company (Marathon) is pleased to partner with the University of North Dakota Energy & Environmental Research Center (EERC) in the Bakken Production and Optimization Program (BPOP) – Phase II to develop knowledge that will support the optimization of oil production from the Bakken and Three Forks Formations in North Dakota.

Marathon will provide in-kind contributions that will enable this program to proceed. Specifically, Marathon will incur the costs to locate, drill, complete, and collect samples from a new well to be drilled during the program period of performance. The well will be used by the project technical team for the application of unique integrated field and laboratory characterization approaches toward reservoir characterization and resource assessment. Marathon has estimated the total gross cost of drilling, completing and sampling this well to be approximately $7,280,000. Please find attached a table enumerating the total estimated gross expense for this well. The EERC and Marathon technical teams will work closely and coordinate the efforts to maximize the value of Marathon's in-kind contribution. Marathon will report actual expenses to the EERC on an annual basis.

Marathon understands that the key findings generated by these activities will be shared with other BPOP members during the performance period of the Phase II program. Marathon also recognizes that the key findings will be included in a report to BPOP sponsors that will be made publicly available through the North Dakota Industrial Commission (NDIC) within 6 months of the completion of BPOP-2.0.

Marathon also understands that the EERC will utilize the reported actual incurred costs for the purposes of documenting cost share required by the NDIC. Project period of performance is expected to be July 1, 2016, through June 30, 2019.

Should you have any questions, please do not hesitate to contact me by phone at (713) 296-1856 or by e-mail at frasdi@marathonoil.com.

Sincerely,

Faisal Rasdi
Marathon Oil Company

Attachment:

SUMMARY OF ESTIMATED DRILLING WELL COSTS	TOTAL COST
TOTAL LOCATION COST	$ 130,000
TOTAL DRILLING COST	$ 3,217,000
TOTAL COMPLETION COST (CMP.001 + CMP.002 + CMP.003)	$ 3,204,150
TOTAL SURFACE EQUIPMENT	$ 735,000
GRAND TOTAL COST	$ 7,286,150

APPENDIX D

BUDGET JUSTIFICATION

BUDGET JUSTIFICATION
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.

Labor: Estimated labor includes direct salaries and fringe benefits. Salary estimates are based on the scope of work and prior experience on projects of similar scope. Salary costs incurred are based on direct hourly effort on the project. Fringe benefits consist of two components which are budgeted as 61% of direct labor. The first component 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. Only the actual approved rate will be charged to the project. The second component 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. The following table represents a breakdown by labor category and hours for technical staff for the proposed effort.

Labor Categories	No. Labor Hours
Research Scientists/Engineers	34,652
Research Technicians	2,065
Mechanics/Operators	250
Senior Management	821
Technical Support Services	1,240
	39,028

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, etc., are based on historical costs. Miscellaneous travel costs may include taxis, parking fees, Internet charges, long-distance phone, copies, faxes, shipping, and postage.

Equipment: Not applicable.

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(s): The program will contract with capable experts to conduct analysis of economic impacts of various program-derived suggestions resulting from the "system of systems" approach to oil production analysis.

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. The project will not be charged for any costs exceeding the applicable GSA meal rate. 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.

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

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

Shop and operation recharge fees are for expenses directly associated with the operation of the pilot plant, including safety training, personal safety items (protective eyeglasses, boots, gloves), and annual physicals for pilot plant personnel. The estimated cost is based on the estimated hours for pilot plant personnel.

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

Facilities and Administrative Cost: The facilities and administrative rate of 50.5% (indirect cost rate) included in this proposal is approved by the Department of Health and Human Services. Facilities and administrative cost is calculated on 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. The facilities and administrative rate has been applied to each line item presented in the budget table.

In-Kind Cost Share: Marathon Oil will contribute the in-kind cost share required to locate, drill, complete, and collect core samples and live oil samples from a new well to be drilled during the program's period of performance. The value of this in-kind cost share is $7,280,000.