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July 26, 2023

Mr. Reice Haase
Deputy Executive Director
North Dakota Industrial Commission
State Capitol, 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Mr. Haase:

Subject: Quarterly Report Entitled "Unitized Legacy Oil Fields: Prototypes for Revitalizing Conventional Oil Fields in North Dakota"; Contract No. G-045-086
EERC Fund 23459

Attached is a copy of the subject quarterly status report for the period April 1 – June 30, 2023.

If you have any questions, please contact the project manager, Todd Jiang, by phone at (701) 777-5343 or by email at tjiang@undeerc.org.

Sincerely,

DocuSigned by:
4E5F948EDBBF43C...
Todd Jiang
Principal Reservoir Engineer

TJ/ro

Attachment

c: Karen Tyler, NDIC
Brent Brannan, NDIC

UNITIZED LEGACY OIL FIELDS: PROTOTYPES FOR REVITALIZING CONVENTIONAL OIL FIELDS IN NORTH DAKOTA

Research Performance Progress Report (quarterly)

(for the period April 1 – June 30, 2023)

Prepared for:

Reice Haase

North Dakota Industrial Commission
State Capitol 14th Floor
600 East Boulevard Avenue Dept. 405
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Contract No. G-045-086

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July 2023

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EXECUTIVE SUMMARY

The Energy & Environmental Research Center (EERC) was awarded a contract by the North Dakota Industrial Commission (NDIC) to pursue the Unitized Legacy Oil Fields: Prototypes for Revitalizing Conventional Oil Fields in North Dakota project. The goal of this research program is to enable revitalization of unitized conventional oil fields in North Dakota, ultimately resulting in increased daily oil production and prolonging the operational lifetime of those fields. The three major objectives to meet this goal are to 1) evaluate waterflood optimization and CO_2 enhanced oil recovery (EOR) potential and implementation approaches specific to Madison producing field(s) or other legacy conventional fields producing from suitable horizons; 2) explore operational strategies that address key technical challenges, optimize current facilities, and systematically consider necessary new facilities; and 3) frame project results and experience as a prototype for revitalizing analogous conventional oil fields in North Dakota in anticipation of CO_2 EOR. These objectives are being executed through two corresponding tasks:

- Task 1.0 – Assessing the Potential of a Unitized Legacy Oil Field
- Task 2.0 – Developing a Prototype to Revitalize a Unitized Legacy Oil Field

To maintain the operational timeline of project partner, Eagle Energy Partners Tundra (EEP Tundra), the following accomplishments were achieved during the preceding calendar quarter: 1) continued assisting EEP Tundra on analyzing the water injection and production behavior in the water flooding pattern; 2) conducted a detailed simulation study to reveal the effects of formation stimulation and CO_2 flooding on improving oil production in the Foreman Butte Field; 3) conducted different improved oil recovery (IOR)/EOR laboratory investigations using methods like water flooding, gas flooding, and surfactant flooding on the core samples collected from Foreman Butte; 4) began synthesis of finished Foreman Butte simulation cases; and 5) started applying the workflow in an effort to analyze a different conventional oil field in North Dakota to assess its IOR/EOR predictive performance. EEP Tundra and the EERC will also continue to work with the Oil and Gas Research Council and the North Dakota Petroleum Council to identify and implement opportunities for EOR education in North Dakota.

Progress on project milestones and deliverables will continue to be tracked and reported in accordance with the NDIC contract.

UNITIZED LEGACY OIL FIELDS: PROTOTYPES FOR REVITALIZING CONVENTIONAL OIL FIELDS IN NORTH DAKOTA
Quarterly Progress Report
April 1 – June 30, 2023

INTRODUCTION

The Energy & Environmental Research Center (EERC) will conduct this North Dakota Industrial Commission (NDIC)-funded project in close collaboration with project partner, Eagle Energy Partners Tundra (EEP Tundra). Information generated by this project will positively affect ultimate recovery from North Dakota's conventional oil pools and will lead to additional projects, processes, ideas, and activities to facilitate implementation of oil exploration and production technologies presently not used in the state. The potential to revitalize conventional oil fields and increase ultimate recovery will bring new investment to North Dakota, resulting in the growth of oil and gas jobs, wealth, and tax revenues. The goal of this 3-year research program is to enable the revitalization of unitized conventional oil fields in North Dakota, ultimately resulting in increased daily oil production and prolonging the operational lifetime of those fields.

Major objectives to be accomplished to meet the stated goal are to 1) evaluate waterflood optimization and CO_2 enhanced oil recovery (EOR) potential and implementation approaches specific to the Madison or other suitable production horizons; 2) develop cost-effective operational strategies that address key technical challenges, optimize current facilities, and systematically consider necessary new facilities; and 3) frame the results from this project as a prototype for revitalizing analogous conventional oil fields in North Dakota in anticipation of tertiary CO_2 EOR. The first objective will be achieved by using new and existing geologic and reservoir engineering characterization data (e.g., core analyses, well logs, oil analyses) and modeling/simulation to optimize waterflood operations in preparation for near-term CO_2-based EOR operations. To achieve the second objective, results of new characterization and geologic assessments will be combined with refined performance forecasts to conduct a CO_2 EOR scenario analysis. The results will be used to develop strategies for the design and operation of prudent EOR schemes that will be applicable to other unitized fields producing from similar pools. The third objective will be achieved through the synthesis of project results into a guidance document for producers and investors looking to revitalize analogous conventional unitized fields in North Dakota with CO_2-based EOR.

Project activities are organized within two tasks: 1) assessing the potential of a unitized legacy oil field and 2) developing a prototype to revitalize a unitized legacy oil field.

ACCOMPLISHMENTS

Task 1.0 – Assessing the Potential of a Unitized Legacy Oil Field

The goal of Task 1.0 is to gather, assess, and construct much of the data needed to complete the overall goal of the proposed project.

Subtask 1.1 – Data Reconnaissance and Conditioning

Subtask 1.1 focuses on compiling, organizing, managing, screening, vetting, digitizing, and interpreting the various types of data for integration into Subtasks 1.2 and 1.3 and reporting. Much of the data needed is available through either publicly available sources (e.g., NDIC database, scholarly studies) or available from EEP Tundra. A gap analysis process will identify missing key data and guide new data acquisition. Existing data (e.g., well logs, well files, core data, fluid, and rock properties) are anticipated to be in a variety of formats and will require conditioning prior to use.

Significant accomplishments for Subtask 1.1 during the reporting period include the following:

- Collecting and reviewing additional well data from a different field to assess the potential applicability of applying the workflow and the improved oil recovery (IOR)/EOR methods.

Subtask 1.2 – Reservoir Modeling and Engineering

Subtask 1.2 activities include geologic and engineering characterization of the study field. Geologic and simulation models representative of the geology and physical performance of the producing horizon will be constructed, history-matched, and calibrated. The geologic and simulation models will be assessed based on sensitivity and uncertainty in performance to define and prioritize data needs.

Significant accomplishments for Subtask 1.2 during the reporting period include the following:

- Analyzed the water injection and production behavior in the water flooding pattern to identify the possible flow paths between wells in the reservoir. The results were summarized and provided to EEP Tundra as supplemental materials for extending the water injection permission order.

- Had a meeting with EEP Tundra's reservoir engineer who will assist in the development of the Foreman Butte Field. The team went through all essential data, modeling and simulation progress, challenges, and potential methods to further develop this field.

- Conducted a detailed simulation study to reveal the effects of formation stimulation and CO_2 flooding on improving oil production in the Foreman Butte Field. The focus was assessing the skin factor and bottomhole flowing pressure and their influence on oil production and water cut. A CO_2 EOR assessment with regard to injection rates and well spacing was evaluated.

- Presented the paper "Developing a High-Efficiency Method for Field-Scale Simulation of a Tight and Naturally Fractured Reservoir in the Williston Basin" at the 2023 Unconventional Resources Technology Conference (URTeC) in Houston, Texas.

Subtask 1.3 – Operability Assessment

Existing facilities, infrastructure, and data monitoring used in the Foreman Butte oil field will be assessed with the development strategies and operating scenarios investigated in Subtask 1.2. Data collection, management, and a facility upgrade plan for the fields will be developed.

Significant accomplishments for Subtask 1.3 during the reporting period include the following:

- Reviewed the production behavior, conducting rate-transient analysis using production histories and scant pressure data that are available, and used this to calculate drainage areas for each well.

- Identified "sweet spot" for production potential based on multiple parameters, including above drainage area calculations. Generated oil cut vs. cumulative oil production for the unplugged wells in this sweet spot to determine remaining reserves potential for each.

- Reviewed the current production methods on active wells, reviewing needs to increase production of wells to increase oil production, and discussed with vendor on performing well tests with submersible equipment.

- Reviewed the limitations of current equipment.

- Provided saltwater disposal (SWD) system layout within field to partner.

Subtask 1.4 – Strategic Characterization

Based on the results of Subtasks 1.2 and 1.3, new data will be collected, analyzed, and interpreted (e.g., well logs, pressure testing, production profiles, core testing) to support the research program. The data from this subtask will be used to calibrate and improve geologic and simulation model performance (Subtask 1.2), evaluate operating scenarios, and inform development strategies to revitalize the selected field (Subtask 1.3).

Significant accomplishments for Subtask 1.4 during the reporting period include the following:

- A set of core samples was selected from the Foreman Butte wells to investigate the IOR/EOR performance of using different methods, including water flooding, gas flooding, and surfactant flooding. The core samples were cleaned, and the basic properties like density, porosity, permeability, etc. were measured.

- Performed laboratory experiments to study the oil recovery performance of water flooding, surfactant flooding, and gas flooding using composite core samples. Results showed that there is a considerable oil saturation remaining in the core samples after flooding, surfactant can recover part of the residual oil after water flooding, and gas flooding can further increase the oil recovery when the water saturation is reduced first.

Task 2.0 – Prototype to Revitalize a Unitized Legacy Oil Field

Task 2.0 will synthesize Task 1.0 activities and results (e.g., performance response derived from scenario analysis) to assess potential development strategies for CO_2 EOR that can be applied to revitalize analog legacy oil fields in North Dakota. This information will be incorporated into a guidance document and included as part of the final report (Deliverable [D] 6).

Significant accomplishments for Task 2.0 during the reporting period include the following:

- Examined available geophysical data from NDIC database for another conventional oil field, the Cedar Creek Field. These data were aggregated and organized in preparation for both petrophysical well log analysis and 3D geologic modeling.

- Started synthesizing Foreman Butte study and applying workflow in modeling the Cedar Creek Field by collecting well logs and well files from the NDIC database. Multiple wells were selected from the field for a more detailed study. The files are being processed to create an overall profile of the section that was selected for modeling.

- Constructed an EOR database encompassing a total of 464 EOR projects that have been conducted in 18 countries worldwide. 170 of them employed CO_2 EOR techniques, with the remaining projects utilizing other EOR methods.

- Team member attended the Society of Petroleum Engineers Western Reginal Meeting the week of May 22–25. They met industry and academic representatives and discussed conventional oilfield development, challenges, future activities, and technology developments that could continue to unlock the untapped resource to prolong the fields' production life.

- Team members participated in the Rock Flow Dynamics' Annual Technology Summit held in Houston, Texas, on May 10. The summit provided the team an opportunity to understand the advanced simulation technology and package that could potentially assist in speeding up the predictive simulation process.

FINANCIAL INFORMATION

This project is sponsored by NDIC, with in-kind cost-share support from EEP Tundra. At the time of this reporting, EEP Tundra has provided certification of $34,885 of in-kind expenditures toward its committed cost-share amount. The in-kind contribution certification letter was received by the EERC on July 17, 2023, which listed documented costs incurred by EEP Tundra from April 1 through June 30, 2023, that are associated with this project. Table 1 shows the budget of $6,000,000 over 3 years for this project and expenses through June 30, 2023.

Table 1. Project Cost

Sponsors	Budget	Actual Expenses as of 6/30/23	Balance
NDIC	$3,000,000	$1,912,152	$1,087,848
Industry Share - In-Kind	$3,000,000	$2,670,997	$329,003
Total	**$6,000,000**	**$4,583,149**	**$1,416,851**

FUTURE ACTIVITIES

The planned activities for the next quarter are as follows:

- Continue the evaluation of existing pumping equipment and SWD facilities to increase oil production with higher drawdown on wells.

- Evaluate the availability/use of submersible pumping equipment to increase well drawdown while monitoring bottomhole pressure.

- Conduct a simulation study to evaluate the effects of other IOR methods such as infill drilling and multilateral completion on oil production performance in the Foreman Butte Field.

- Perform production and injection data analysis for the wells selected from the Cedar Creek Field. The data will be used to assess the well performance in the field and develop a simulation model for the selected section.

- Conduct a petrophysical analysis of publicly available digitized well log data for the Cedar Creek Field. Petrophysical analysis will consist of new porosity and permeability estimations within the target formation.

- Complete a 3D geologic model of the Cedar Creek Field. The model will include structural surfaces and petrophysical properties.

- Collect and analyze different field data for another field from the Madison group. Identify if a better EOR operation opportunity is present compared to the Foreman Butte Field. Start developing a new CO_2 EOR scoring system for the conventional oil fields in North Dakota using different analytical and machine-learning methods. Most of the current screening methods do not consider the deep formation depth while many reservoirs in North Dakota have depths beyond the range of these methods.

- Continue to perform experimental work on EOR evaluation. Detailed parameters like contact angle, interfacial tension, injection, and production rate/pressure, etc. will be measured in the lab.

- EERC staff, including members of the project team, will be participating in a multiday event during the week of August 7–11. This in-person-only event will occur at the EERC facility in Grand Forks, North Dakota, and will comprise training on EERC functions related to research management, project execution, team meetings, and team building.

PROGRAM MANAGEMENT AND REPORTING

Continue with project progress and assembling deliverables to carry through with timely quarterlies and final reports.