



April 27, 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 January 1 – March 31, 2023.

If you have any questions, please contact me by phone at (701) 777-5343 or by email at [tjiang@undeerc.org](mailto:tjiang@undeerc.org).

Sincerely,

DocuSigned by:  
  
4E5F948EDBBF43C...

Todd Jiang  
Principal Reservoir Engineer

TJ/ro

Attachment

c: Karen Tyler, NDIC  
Brent Brannan, NDIC



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

Research Performance Progress Report (quarterly)

*(for the period January 1 – March 31, 2023)*

*Prepared for:*

Reice Haase

North Dakota Industrial Commission  
State Capitol 14th Floor  
600 East Boulevard Avenue Department 405  
Bismarck, ND 58505-0840

Contract No. G-045-086

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

### **Quarterly Progress Report January 1 – March 31, 2023**

#### **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<sub>2</sub> 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<sub>2</sub> 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) fine-tuned history-matching simulation; 2) performed and evaluated a detailed water injection simulation of the waterflooding effect on offset wells; 3) completed D3 – Facilities Assessment – Opportunities and Challenges for Revitalization: listing required/preferred infrastructure for the operation and management of a waterflood as a precursor to CO<sub>2</sub>; 4) conducted minimum miscibility pressure (MMP) measurements of six oil samples collected from different fields/formations in North Dakota; and 5) started collecting reservoir and fluid data from other conventional reservoirs. 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  
January 1 – March 31, 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub>-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<sub>2</sub> 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<sub>2</sub>-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 are 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:

- Identifying other legacy conventional fields and needed reservoir and fluid data. The information and data collected will further be utilized for potential EOR evaluation.

#### ***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:

- The abstract “Developing a High-Efficiency Method for Field-Scale Simulation of a Tight and Naturally Fractured Reservoir in the Williston Basin” was accepted to present at the 2023 Unconventional Resources Technology Conference (URTeC). The manuscript is being written up based on the simulation activities performed for Task 1.2.
- A small-scale model with eight wells in the waterflooding pattern was cut out from the history-matched model. Skin factor was integrated into the simulation model and fractures were tuned to further improve the accuracy of the simulation results.

- A detailed water injection simulation was performed based on the field operational plan proposed by EEP. The injectivity of the injector and the waterflooding effect on offset wells were evaluated.
- The potential effects of skin factor and bottomhole flowing pressure on oil production performance were studied. Results showed that oil production performance could be improved by either reducing near-wellbore skin damage by performing a wellbore cleanout treatment or by reducing well bottomhole flowing pressure through changing pumps.
- Since the oil in the Foreman Butte Field is produced from a high-temperature, high-salinity reservoir, where IOR (improved oil recovery) and EOR operations could be more challenging to perform, three surfactant samples were acquired to investigate the EOR effects by altering the rock wettability in the reservoir.

### ***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:

- Prepared D3 Report Facilities Assessment: Opportunities and Challenges for Revitalization highlighting the next steps for developing areas with primary production and unitized fields to the next stage to enhance oil recovery through waterflooding or CO<sub>2</sub> EOR development.
- Continued working with EEP in support of its ongoing operations to enhance production based on opportunities within the current production operations.
- Reviewed the availability of rental submersible pump installations without purchasing equipment to assess increasing oil production through higher production rates.

### ***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:

- Minimum miscibility pressure (MMP) measurements were performed for the six oil samples collected from different fields/formations in North Dakota. Results showed that adding rich gas components like ethane, propane, butane, etc., to the CO<sub>2</sub> stream can effectively reduce the MMP between oil and gas.

### **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<sub>2</sub> 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:

- Started collecting reservoir and fluid data from conventional reservoirs such as Cedar Hills, Cedar Creek, Dickinson Lodgepole Mounds, etc., in North Dakota. Similar to Ratcliffe, natural fractures were reported for a few formations with long oil production history.

## **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 \$64,084 of in-kind expenditures toward its committed cost-share amount. The in-kind contribution certification letter was received by the EERC on April 20, 2023, which listed documented costs incurred by EEP Tundra from January 1, 2023 through March 31, 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 March 31, 2023.

**Table 1. Project Cost**

<b>Sponsors</b>	<b>Budget</b>	<b>Actual Expenses as of 3/31/23</b>	<b>Balance</b>
NDIC	\$3,000,000	\$1,528,813	\$1,471,187
Industry Share - In-Kind	\$3,000,000	\$2,636,112	\$363,888
<b>Total</b>	<b>\$6,000,000</b>	<b>\$4,164,925</b>	<b>\$1,835,075</b>

## **FUTURE ACTIVITIES**

The planned activities for the next quarter are as follows:

- Conduct a detailed simulation study to reveal the effects of different IOR/EOR strategies, including formation stimulation, infill drilling, multiple lateral completion, and CO<sub>2</sub> flooding, on improving oil production in the Foreman Butte field.
- Prepare estimate for development of a waterflood or CO<sub>2</sub> EOR project within EEP's Foreman Butte Field based on findings from Subtask 1.2.
- Select a set of core samples from the Foreman Butte wells to investigate the IOR/EOR performance of using different methods, including waterflooding, gas flooding, and surfactant flooding.
- Perform laboratory experiments to study the effects of different gas and surfactants on interfacial tension using the core and oil samples collected from the Foreman Butte Field.
- Continue to collect and analyze data for other conventional reservoirs in North Dakota and identify potential EOR methods to recover additional oil from the old oil fields in the state.
- Assess the development of EOR methods for other conventional reservoirs in North Dakota based on availability of CO<sub>2</sub> to the projects.
- Cut a section out of the history-matched model to perform a detailed water injection simulation based on the existing field operation. The injectivity of the injector and the waterflooding effect on offset wells will be evaluated.
- Conduct a simulation study to test different IOR/EOR methods for increasing oil recovery in the selected section. The methods include but are not limited to near-wellbore stimulation, multiple lateral drilling, infill drilling, waterflooding, CO<sub>2</sub> (or rich gas) flooding, CO<sub>2</sub> (or rich gas) huff 'n' puff (HnP), etc.
- Perform a series of experimental measurements, including MMP, interfacial tension (IFT), contact angle (CA), etc., to understand the oil-gas interactions under a variety of injection conditions.
- Continue review of operations with the operator, reviewing updates to cleanout or stimulation treatments on the wells.
- Finalize the document "Carbonate Reservoir Characterization and Modeling."

## **PROGRAM MANAGEMENT AND REPORTING**

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