



October 27, 2022

Ms. Karlene Fine  
Executive Director  
North Dakota Industrial Commission  
State Capitol, 14th Floor  
600 East Boulevard Avenue, Department 405  
Bismarck, ND 58505-0840

Dear Ms. Fine:

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 an updated version of the subject quarterly status report for the period July 1 through September 30, 2022. My apologies for any inconvenience this may cause.

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](mailto:tjiang@undeerc.org).

Sincerely,

DocuSigned by:  
*James Sorensen*

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James A. Sorensen

Director of Subsurface R&D

JAS/kal

Attachment



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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 July 1 – September 30, 2022)*

*Prepared for:*

Karlene Fine

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

Contract No. G-045-086

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October 2022

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CONVENTIONAL OIL FIELDS IN NORTH DAKOTA**  
**Quarterly Progress Report**  
**July 1 – September 30, 2022**

**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) completed geomodel update and geomodel was quality-assured/quality-controlled before passing to reservoir engineering evaluation; 2) initiated reservoir simulation models with embedded discrete fracture model fractures network; 3) identified additional oil samples, including Madison and Cut Bank, for studying EOR potential in other North Dakota legacy oil fields; and 4) identified and planned different gas component mixtures to conduct vanishing interfacial tension tests. 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**  
**July 1 – September 30, 2022**

**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 will be 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:

- Identified additional oil samples, including Madison and Cut Bank, for studying EOR potential in other North Dakota legacy oil fields.
- Planned different gas component mixtures to conduct vanishing interfacial tension (VIT) tests to determine minimum miscibility pressure (MMP).
- Provided a plan for sampling to perform programmed pyrolysis analysis before and after CO<sub>2</sub> extraction.

#### ***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:

- Preliminary reservoir models with embedded discrete fracture model (EDFM) fractures were applied to some of the wells and are complete. The history-matching performance was generally improved for wells with EDFM fractures. The reservoir team developed Python codes to automatically generate EDFM fractures for all of the wells in the reservoir models to improve history-matching performance.

### ***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:

- Monitored results of recent cleanout efforts and well workover activities conducted by EEP Tundra.
- Evaluated the benefits of well workovers and cleanouts on the production response to observe any production increase over the historical production rate.
- Estimated and reviewed bottomhole pressures (BHPs) within the field taken after an extended shut-in period. Monitored well BHP with location within the field for trends or generalization.

### ***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:

- Core Laboratories performed high-pressure mercury injection (HPMI) for eight samples with different rock sets of carbonate formation.
- Identified oil samples, including Madison and Cut Bank, for studying EOR potential in old North Dakota oil fields.
- Reviewed published papers discussing CO<sub>2</sub> and hydrocarbon gas MMPs for these oil samples.

### **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:

- Continued to identify legacy oil fields producing from the Madison Group (and other suitable producing horizons) for potential CO<sub>2</sub> EOR candidates.
- Detailed the need for availability of pertinent information on legacy oil fields—current fluid levels and wellbore diagrams, historical well workover histories, etc.
- A detailed geologic characterization, modeling, and simulation approach was used to evaluate the field’s historical performance so that a potential operational plan could be developed as a guide to revitalize a similar conventional reservoir.
- Composing a technology transfer document to provide a template for data assessment, reservoir description, petrophysical analysis, modeling, and simulation specific to the carbonate reservoirs that comprise the majority of conventional North Dakota oil fields that can be used by operators to determine development strategies to revitalize these mature fields.

## 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 \$2,538,457 of in-kind expenditures toward its committed cost-share amount. The in-kind contribution certification letter was received by the EERC on October 11, 2022, which listed documented costs incurred by EEP Tundra through September 30, 2022, that are associated with this project. Table 1 shows the budget of \$6,000,000 over 3 years for this project and expenses through September 30, 2022.

**Table 1. Project Cost**

<b>Funding Source</b>	<b>Cash</b>	<b>Expended</b>	<b>Balance</b>
NDIC	\$3,000,000	\$994,470	\$2,005,530
EEP Tundra – In-Kind	\$3,000,000	\$2,538,457	\$461,543
<b>Total</b>	\$6,000,000	\$3,532,927	\$2,467,073

## FUTURE ACTIVITIES

The planned activities for the next quarter are as follows:

- Continue to tune the parameters for natural fractures in the EDFM model.

- Perform detailed history matching to calibrate the simulation model based on the historical production and injection data in the field.
- Develop an EOR database for the EOR cases collected from the public domain. Parameters will include key geologic and reservoir properties, including reservoir depth, temperature, porosity, permeability, etc.
- Test a variety of machine learning algorithms based on the EOR database to identify the suitable ones that can be used to identify whether an EOR method is feasible or not based on key geologic and reservoir properties.
- Predict water flooding performance in the Foreman Butte Field using a simulation model that has historical data matched. Conduct VIT tests to determine MMP values for additional oil samples and planned different gas component mixtures (CO<sub>2</sub>/ethane, CO<sub>2</sub>/propane) under reservoir temperatures.
- Based on the MMP results, identify different gas component mixtures to perform interfacial tension measurements for additional oil samples.
- Review opportunities for expansion of the project based on findings from Subtask 1.4 and evaluation of EOR opportunities.

## **PROGRAM MANAGEMENT AND REPORTING**

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