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April 26, 2024

Mr. Reice Haase
Deputy 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 26645

Attached is a copy of the subject quarterly status report for the period January 1 – March 31, 2024.

If you have any questions, please contact me 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: Brent Brannan, North Dakota Industrial Commission
Erin Stieg, North Dakota Industrial Commission

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, 2024)

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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April 2024

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EXECUTIVE SUMMARY

Funded by the North Dakota Industrial Commission (NDIC), the Energy & Environmental Research Center (EERC), in partnership with Eagle Energy Partners Tundra (EEP Tundra), is undertaking this research program 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 EEP Tundra's operational timeline, the following activities and accomplishments occurred during the quarter:

- Continued to assist EEP Tundra in analyzing data collected from field operations, offering recommendations to address challenges observed in the field.
- Conducted various laboratory assessments and investigations, including analysis of oil characterizations from an external lab, working on improved oil recovery (IOR)/EOR using methods such as waterflooding, gas flooding, and surfactant flooding on core samples collected from Foreman Butte.
- Continued synthesis of finished Foreman Butte simulation cases.
- Assessed IOR/EOR predictive performance of the field from the upper Red River Formation geologic model, analyzing the effectiveness of utilizing CO_2 for revitalization.

EEP Tundra and the EERC will also continue to work with the Oil and Gas Research Council and 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, 2024

INTRODUCTION

The Energy & Environmental Research Center (EERC) is conducting 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, growing 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 lifetimes of those fields.

Major objectives to be accomplished to meet this 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, and 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 synthesizing 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 are available from either public sources (e.g., the NDIC database and scholarly studies) or 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:

- Developed a comprehensive database with all the minimum miscibility pressure (MMP) datasets included. Each dataset includes multiple variables: independent variables are gas and oil compositions, reservoir temperature, and mole weight of heavy hydrocarbons in the oil; and the dependent variable is MMP. The database served as the main data source for machine learning (ML) study on MMP prediction.

- Developed an ensemble of ML models to determine oil–gas MMP for CO_2 with various impurities. The models are able to calculate MMP when oil and gas properties are available. Results showed that the calculation can reproduce most of the MMP measurements reported in the public domain.

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:

- Selected a subsection of the upper Red River Formation from the Cedar Creek Field for the simulation study of primary depletion, waterflooding, and CO_2 EOR in the field. The model includes five wells, two vertical and three horizontal.

- Processed the historical production and injection data for the selected wells for simulation and analyzed oil production and performance of water injection and gas injection in the chosen section. Results indicated better production and injection responses attributable to distinct reservoir properties.

- Processed the well trajectory and perforation data from NDIC for the five wells; two horizontal wells have multiple branches completed at different times. The data were converted into grids suitable for use in the simulation model.

- Converted the rescue model into a simulation model for the selected section, integrating all processed historical data and equation of state. The model will be utilized for a detailed CO_2 EOR study once the history match is completed.

- Tuned the upper Red River Formation reservoir simulation model for a section with five wells. The model includes both vertical and horizontal wells with 60 years of injection and production historical data. Primary depletion, waterflooding, and gas EOR operations were all included in the simulation.

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 current production methods on active wells and resulting production volumes, assessing the need to increase oil production. Discussed with a vendor the possibility of performing well tests with submersible equipment. EEP Tundra is currently testing the installation of larger pumping equipment on selected wells. Additionally, the company has requested and received a proposal from a service provider for an electric submersible pump (ESP) installation to assist in enhancing fluid production. EEP Tundra is currently planning to install an ESP in a well in the second quarter of 2024.

- Continued discussions with EEP Tundra and reviewed operational issues observed in wells, such as paraffin, scale, asphaltene, and other problems. Discussed and presented options for combating these issues.

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, and 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:

- Performed bump and gas flooding tests after surfactant flooding using the Forman Butte rocks to evaluate the maximum theoretical oil recovery in the field. Tested the possible formation damage effect during the water and surfactant flooding processes by flipping the rock samples and flooding with the same injection rate.

- Performed liquid-unloading experiments using a set of tight rocks selected from the Foreman Butte Field. Results showed that salt deposition is a potential issue in the gas flooding process because of the high salinity of the formation water. Injecting water and surfactant solutions into the rock after gas flooding could mitigate the formation damage effect.

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 6.

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

- Refined prediction of oil production and CO_2 demand for potential CO_2 EOR development of 12 legacy oil fields along the Dakota Gasification Company pipeline in Williams and McKenzie Counties.

- Performed a series of CO_2 EOR simulation activities to investigate the EOR potential in the Cedar Creek Field considering the irregular well distribution that includes both vertical and horizontal wells. The field has irregular well patterns because of the geologic conditions.

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 $201,552.25 of in-kind expenditures toward its committed cost-share amount. The in-kind contribution certification letter was received by the EERC on April 3, 2024, which listed documented costs incurred by EEP Tundra from January 1 through March 31, 2024, 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, 2024.

Table 1. Project Cost

Sponsors	Budget	Actual Expenses as of 03/31/24	Balance
NDIC	$3,000,000	$2,696,259	$303,741
Industry Share – In-Kind	$3,000,000	$3,000,000	$0
Total	**$6,000,000**	**$5,696,259**	**$303,741**

FUTURE ACTIVITIES

Activities planned for the next quarter are as follows:

- Monitor results seen on selected wells with increased production rates resulting from workovers or increased pumping capacity.
- Evaluate the use of ESPs to increase production from selected wells, monitoring the results from the planned ESP installation during this quarter.
- Complete all the remaining simulation evaluations and synthesize the results.
- Summarize all the experimental and simulation work performed on the project.
- Write up the final report and submit it to all partners for review.

PROGRAM MANAGEMENT AND REPORTING

The project team prepared two abstracts. The first, "Utilizing CO_2 EOR to Revitalize Conventional Legacy Oil Fields in North Dakota," was submitted to the 17th Greenhouse Gas Control Technology Conference. The second, "CO_2 EOR and Storage in the Williston Basin," was submitted to the 2024 American Institute of Chemical Engineers Annual Meeting.

The project team will continue project progress and assembling deliverables to carry through with timely quarterlies and the final report.