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Energy & Environmental Research Center
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October 21, 2022

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

Dear Ms. Fine:

Subject: Quarterly Status Report for the Period of July 1 – September 30, 2022, "Field Study to Determine the Feasibility of Developing Salt Caverns for Hydrocarbon Storage in Western North Dakota"; Contract No. G-054-104

Attached please find the Energy & Environmental Research Center (EERC) Quarterly Status Report for the subject project. If you have any questions, please contact me by phone at (701) 777-5181 or by email at ssmith@undeerc.org.

Sincerely,

DocuSigned by:
Steve Smith
92138D2CF98E498...

Steven A. Smith
Assistant Director, Integrated Analytical Solutions

SAS/rlo

Attachment

c/att: Brent Brannan, North Dakota Industrial Commission

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FIELD STUDY TO DETERMINE THE FEASIBILITY OF DEVELOPING SALT CAVERNS FOR HYDROCARBON STORAGE IN WESTERN NORTH DAKOTA

Quarterly Project Status Report

(for the period July 1 – September 30, 2022)

Prepared for:

Karlene Fine

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

Contract No. G-054-104

Prepared by:

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October 2022

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FIELD STUDY TO DETERMINE THE FEASIBILITY OF DEVELOPING SALT CAVERNS FOR HYDROCARBON STORAGE IN WESTERN 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) Oil and Gas Research Program (OGRP), NDIC No. G-054-104, to conduct a study on the feasibility of developing salt caverns in geologic formations in North Dakota for underground storage of energy resources, including natural gas, liquified natural gas, and hydrogen, as directed by Section 14 of North Dakota Senate Bill 2014. The EERC, in partnership with Bakken Energy, Neset Consulting Services, and the University of North Dakota Department of Petroleum Engineering, will validate the suitability of salt formations for cavern development and provide stakeholders with information needed to assess the techno-economic viability of storing hydrocarbons and/or hydrogen in engineered salt caverns in North Dakota. This update is for July 1 through September 30, 2022.

The focus of the work this quarter was on completing field operations. The drilling of the stratigraphic test well (HALITE 1), which began last quarter, was completed. Although there were challenges drilling the intermediate section, the coring and logging operations went smoothly. Approximately 230 feet of core was collected from the Dunham Salt and the Pine Salt. Well logging was also performed. HALITE 1 was plugged and abandoned on July 24, 2022, and wellsite reclamation was approved on September 2, 2022.

Core was transported to RESPEC's laboratory in South Dakota for processing, testing, and interpretation. Preliminary results are promising. Most of the cored Dunham interval appears to have a high halite concentration and salt grains that have been proven conducive for salt cavern operations. The overlying and underlying formations are tight and of thicknesses that promote cavern stability. Significant halite is present in the Pine interval, but there are also other impurities. Thenardite, the most prevalent impurity, is soluble in water which is encouraging for cavern development. The overlying and underlying formations are also tight and of thicknesses that promote cavern stability. The Pine salts become thicker in central and southern North Dakota. Testing of the core and its mechanical properties will be completed next quarter.

Work on other tasks was put on hold while the drilling invoices were received. $2.5 million was moved from the underground storage project, G-049-092, to assist in completing this project. When the final drilling costs are tallied, the budget, schedule, and scope of work will be reevaluated and work will resume on the remaining tasks.

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FIELD STUDY TO DETERMINE THE FEASIBILITY OF DEVELOPING SALT CAVERNS FOR HYDROCARBON STORAGE IN WESTERN NORTH DAKOTA
Quarterly Progress Report
July 1 – September 30, 2022

INTRODUCTION

The Energy & Environmental Research Center (EERC) was awarded a contract by the North Dakota Industrial Commission (NDIC) Oil and Gas Research Program (OGRP), NDIC No. G-054-104, to conduct a study of the feasibility of developing salt caverns in geologic formations in North Dakota for underground storage of energy resources, including natural gas, liquified natural gas, and hydrogen, as directed by Section 14 of North Dakota Senate Bill 2014. The EERC, in partnership with Bakken Energy, Neset Consulting Services (Neset), and the University of North Dakota (UND) Department of Petroleum Engineering, will validate the suitability of salt formations for cavern development and provide stakeholders with information needed to assess the techno-economic viability of storing hydrocarbons and hydrogen in engineered salt caverns in North Dakota.

This study follows a preliminary evaluation of the potential of salt cavern development completed by the EERC in December 2020. The 2020 study identified three salt formations deemed worthy of further investigation for characterization activities to inform future cavern development studies.

The goal of this field study is to validate the depth, thickness, and geologic and geomechanical suitability of the North Dakota salt formations for salt cavern development. The anticipated outcome is key information needed by the state, the oil and gas industry, and other interested parties to assess the techno-economic viability of storing hydrocarbon gases and hydrogen in engineered salt caverns.

This project will incorporate field, laboratory, modeling/simulation, and engineering analysis and design to determine the potential for salt cavern development in North Dakota. The work will be conducted in seven tasks.

ACCOMPLISHMENTS DURING REPORTING PERIOD

Project Management

This task includes the necessary activities to direct the project to meet all technical, schedule, and budget requirements. Work under this task will ensure that project plans, results, and decisions are appropriately documented and project reporting and briefing requirements are satisfied.

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Significant accomplishments during the reporting period include the following:

- The third quarterly report was submitted on July 22, 2022.
- EERC staff, including members of the project team, participated in a multiday event during the week of July 25–29. This in-person-only event occurred at the EERC facility in Grand Forks, North Dakota, and comprised training on EERC functions related to research management and execution, team meetings, and team building.
- Frequent communications were provided discussing the status of the drilling and delays encountered; the impact of the delays on the remaining scope of work, schedule, and budget; and a prioritized list of remaining work.

Site Screening and Characterization

In this task, potential locations with amenable salt formations will be identified and targeted for screening and characterization. Screening criteria will be based on the interpretation of publicly available wireline logs, thickness, confinement, and depth. Several potential site locations will be identified, and some small-scale, localized geologic modeling will be performed to inform decision making.

Significant accomplishments during this reporting period include the following:

- This task is complete.

Site Selection/Land Permitting

In this task, the potential project locations identified in the Site Screening and Characterization task will be evaluated with project partners. Surface and subsurface rights will be secured. Permits will be secured in preparation for drilling.

Significant accomplishments during this reporting period include the following:

- This task is now complete.

Drilling and Core Collection

As part of this task, a stratigraphic test well will be drilled at the selected site. The well will be logged, and core will be collected through the target salt formations. Neset will provide general contracting services and will work closely with the EERC throughout the process from planning to site closure.

Significant accomplishments during this reporting period include the following:

- Drilling of HALITE 1 began last quarter, and the intermediate section was near completion at the beginning of this quarter. The Changes and Challenges section of this

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report provides an overview of the challenges encountered in completing field operations.

- HALITE 1 drilling, coring, logging, plugging and abandoning (P&A), and site reclamation were completed, thereby meeting Milestone (M) 7.
  - –On July 10–12, approximately 110' of core was collected from the Dunham, including 28' of cap rock, 67' of Dunham salt, and 14' of underlying rock. Figure 1 and Figure 2 show salt core collected from the Dunham.
  - –On July 13–14, approximately 120' of core was collected from the Pine, including 28' of cap rock, 56' of Pine salt, and 35' of underlying rock. Figure 3 and Figure 4 show salt core collected from the Pine.
  - Well logging was completed on July 15–16, 2022. Logging Run 1 consisted of triple combo and spectral gamma ray. Logging Run 2 consisted of elemental capture spectroscopy, dipole sonic, inclinometer, and an imaging log.
  - The P&A of the well was completed, and the drilling rig was released on July 24, 2022.
  - The reclamation of the wellsite was approved on September 2, 2022, and the location was grass-seeded on September 27, 2022.

- This task is complete.

Figure 1. Example 1 of Dunham salt core.

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Figure 2. Example 2 of Dunham salt core.

Figure 3. Example 1 of Pine salt core.

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Figure 4. Example 2 of Pine salt core.

Core Testing and Interpretation

This task includes all core testing and interpretation. Tests will be performed to identify bulk characteristics of the formation, including lithology, thickness, porosity, permeability, mineralogy, geomechanical competency of the overlying and underlying sealing formations, geomechanical properties of the salts, and dissolution properties of the salts.

Significant accomplishments during this reporting period include the following:

- A RESPEC engineer was on location during core collection to assist with coring operations and transported the core to the RESPEC laboratory in Rapid City, South Dakota for testing.

- The core was logged, and testing has begun.

- Preliminary results from the Dunham are encouraging.
  - Most of the cored interval appears to have high halite concentration.
  - Individual salt grains are of a size that has proven success in commercial operations.
  - Overlying and underlying formations are tight and have thicknesses that will promote cavern roof stability.

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- Preliminary results from the Pine also show some promise.
  - Significant halite is present, but other impurities exist. Thenardite is the most prevalent impurity; however, thenardite is soluble in water which is encouraging for cavern development.
  - Overlying and underlying formations are tight and have thicknesses that will promote cavern roof stability.
  - The Pine becomes much thicker (hundreds of feet) in central and southern North Dakota.

Geologic and Geomechanical Modeling

As part of this task, modeling will be performed based on site-specific data generated through the drilling and core testing. Geologic models will be developed to inform the subsurface geologic regime and evaluate the regional structural and stratigraphic trends. Geomechanical modeling will incorporate information derived from the geologic models and the site-specific data and will inform the overall cavern dimensions and operational stability.

Significant accomplishments during this reporting period include the following:

- This task is on hold while the project scope, cost, and budget are reevaluated.

Engineering Analysis and Design

This task includes the detailed engineering design and analysis that will be performed to identify surface equipment needs; design specifications; brine-handling, use, and disposal practices; and monitoring needs. The EERC will also seek advisement from external engineering teams with expertise in developing and operating salt caverns used for hydrocarbon storage. Site-specific implementation plans for future cavern development will be created.

Significant accomplishments during this reporting period include the following:

- This task is on hold while the project scope, cost, and budget are reevaluated.

FINANCIAL INFORMATION

This study is sponsored by NDIC OGRP. Table 1 presents the expected budget and expenses to date for the study.

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Table 1. Salt Cavern Study – Expected Budget and Expenses to Date

Sponsors	Expected Budget	Actual Expenses as of 9/30/2022	Balance
NDIC Share – Cash	$12,000,000	$8,653,789	$3,346,211
Bakken Energy – In-Kind*	$500,000	$0	$500,000
Total	**$12,500,000**	**$8,653,789**	**$3,846,211**

* The Bakken Energy in-kind cost share was for securing land options and surface and subsurface rights for drilling the stratigraphic test well. By using a preexisting well pad for siting the stratigraphic test well, this need no longer exists. A contract modification is in progress.

CHANGES AND CHALLENGES

Several unexpected problems were encountered while drilling that increased the drilling costs. Challenges encountered last quarter in drilling the intermediate section are the largest contributors to the cost variance. These unanticipated costs resulted in the inability to complete the core analysis, geologic and geomechanical modeling, and engineering analysis and design activities with the original project budget. The challenges and changes encountered this quarter are described below, while challenges encountered last quarter can be found in July's quarterly report.

- Drilling began last quarter and was completed this quarter. At the end of June, the surface casing was set and the intermediate section was being drilled. Heavier-weight drilling mud was used to counter the pressure increases that might be encountered through the Inyan Kara Formation to minimize the risk of potential loss of well control. The heavier drilling mud and original wellbore caused drilling fluid losses in formations above the Inyan Kara (the Pierre, Greenhorn, and Mowry). Continuing into July, 6 days were spent attempting to heal loss zones above the Inyan Kara. The intermediate casing point changed from the Swift Formation to the Mowry Formation to stop losses. The intermediate casing was set on July 3, 2022.

- Casing was cemented and set by July 5, 2022.

- The drilling, coring, and logging of the salts went well. Dunham core was collected in two coring runs July 10–12, 2022, and Pine core was collected in one coring run July 13–14, 2022. Well logging was completed in two logging runs on July 15–16, 2022.

- The original drilling plan called for drilling through the base of the Last Salts. Drilling to the Charles Formation and modular dynamics testing (MDT) were cut as cost-saving measures.

- Well P&A was not initiated until July 21 because of cement availability issues. Cement plugs were pumped on July 22, 2022.

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PLANNED FUTURE ACTIVITIES

The following activities are planned for the next quarter.

Project Management

- When final drilling costs are tallied, review the project budget, schedule, and scope of work.

Site Screening and Characterization

- This task is complete.

Site Selection/Land Permitting

- This task is complete.

Drilling and Core Collection

- This task is complete.

Core Testing and Interpretation

- Complete core testing and interpretation.

Geologic and Geomechanical Modeling

- Incorporate site-specific data into the geologic model.
- Begin geomechanical simulations to determine potential cavern dimensions and operational stability.
- Plan additional modeling for alternative locations in the Williston Basin where cavern development has potential.

Engineering Analysis and Design

- Continue identifying surface equipment needs, design specifications, brine disposal options, brine handling for cavern operations, and other operational considerations for cavern development and use.