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Energy & Environmental Research Center (EERC)

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

Project Status Update
NDIC Agreement No. G-054-104
July 26, 2022

Charles Gorecki
CEO

SALT CAVERN STORAGE

2021 Legislative Assembly

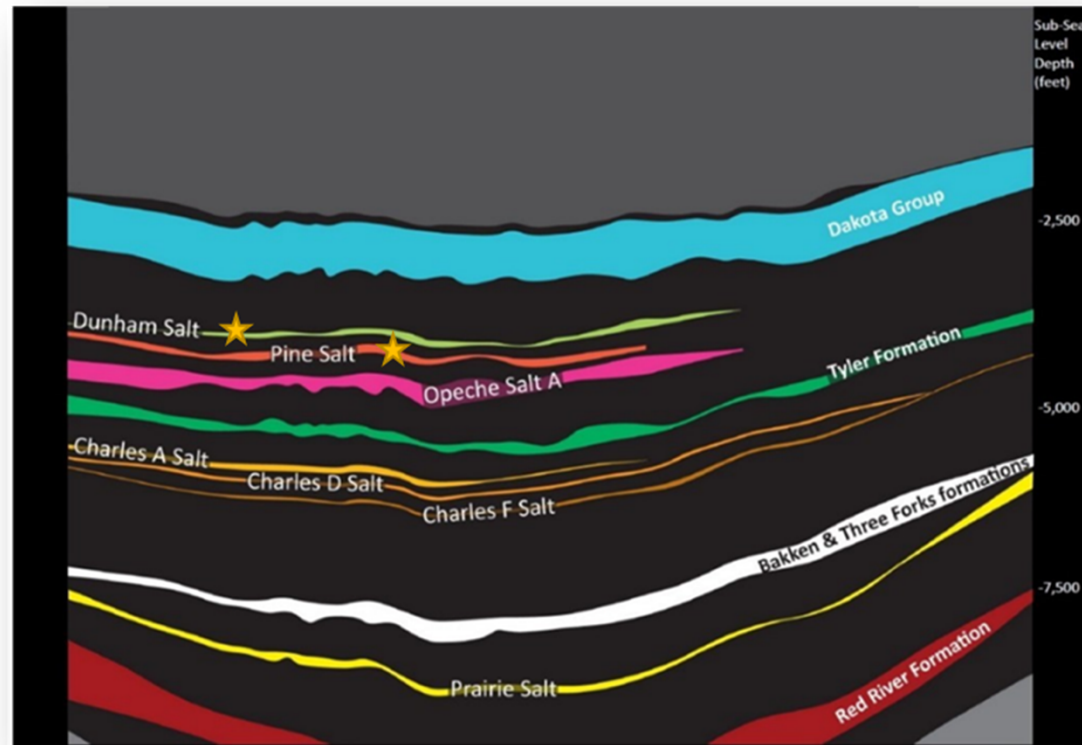
The Energy & Environmental Research Center (EERC) proposes to directly address the intent of Section 14 of Senate Bill 2014 of the Sixty-Seventh Legislative Assembly of North Dakota, which states: "Pursuant to the continuing appropriation under section 57-51.1-07.3, the industrial commission shall use up to \$9,500,000, or so much of the sum as may be necessary, from the oil and gas research fund to contract with the energy and environmental research center for an underground energy storage study."

Project Goal: To use field-, laboratory-, and modeling-based efforts to validate the depth, thickness, and geologic/geomechanical suitability of North Dakota salt formations for subsurface gas or liquid storage cavern development.

Anticipated Results

- A summary of the key findings from the site-specific geologic investigation.
- Site-specific cavern design and engineering considerations based on the successful drilling and coring of a well.
- Key lessons learned from active cavern storage projects for future development efforts.
- An implementation plan highlighting the viability of storing hydrocarbon gases and hydrogen in engineered salt caverns.

★ Target formations for core collection (Dunham and Pine)



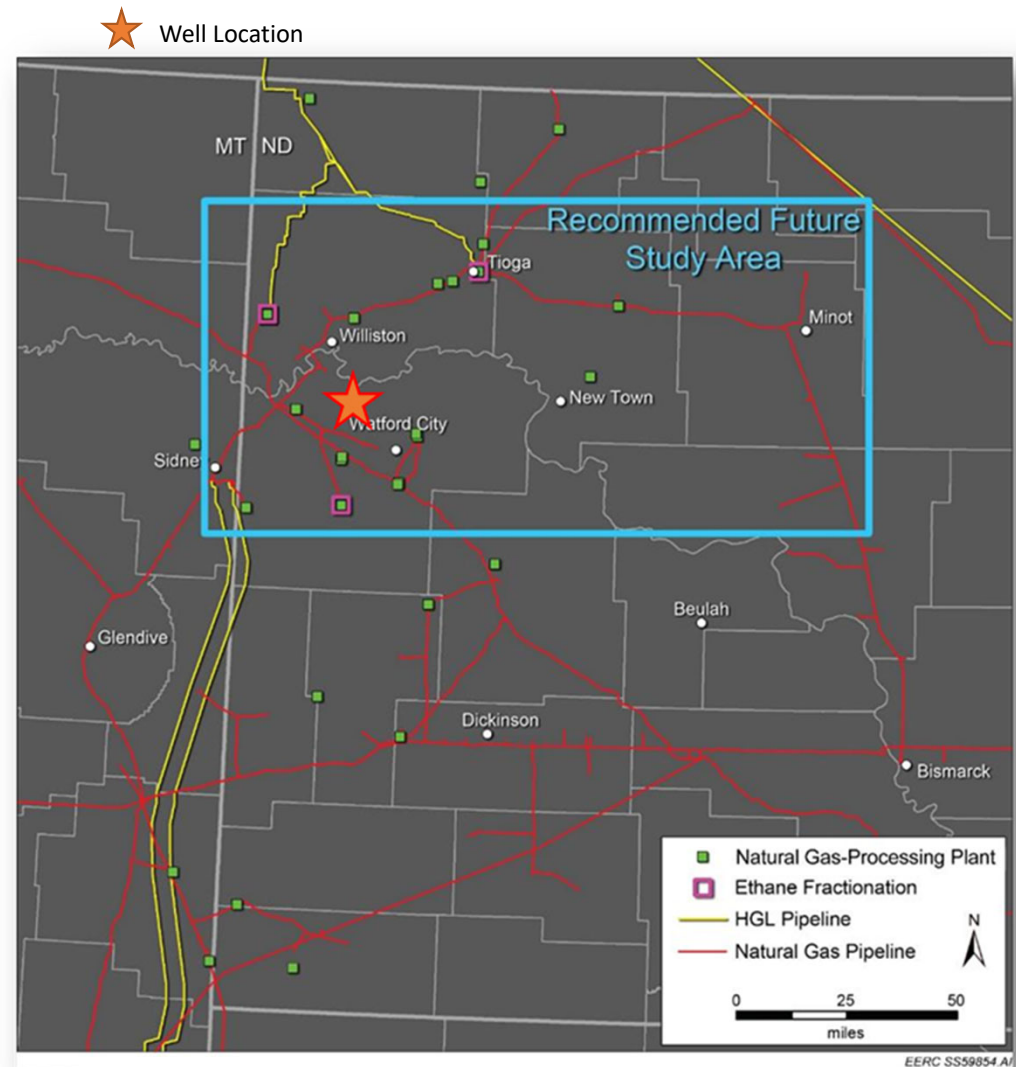
(extracted and modified from Nesheim and LeFever, 2009).

SALT CAVERN STORAGE: INDUSTRY ADVISORY BOARD



SITE SELECTION

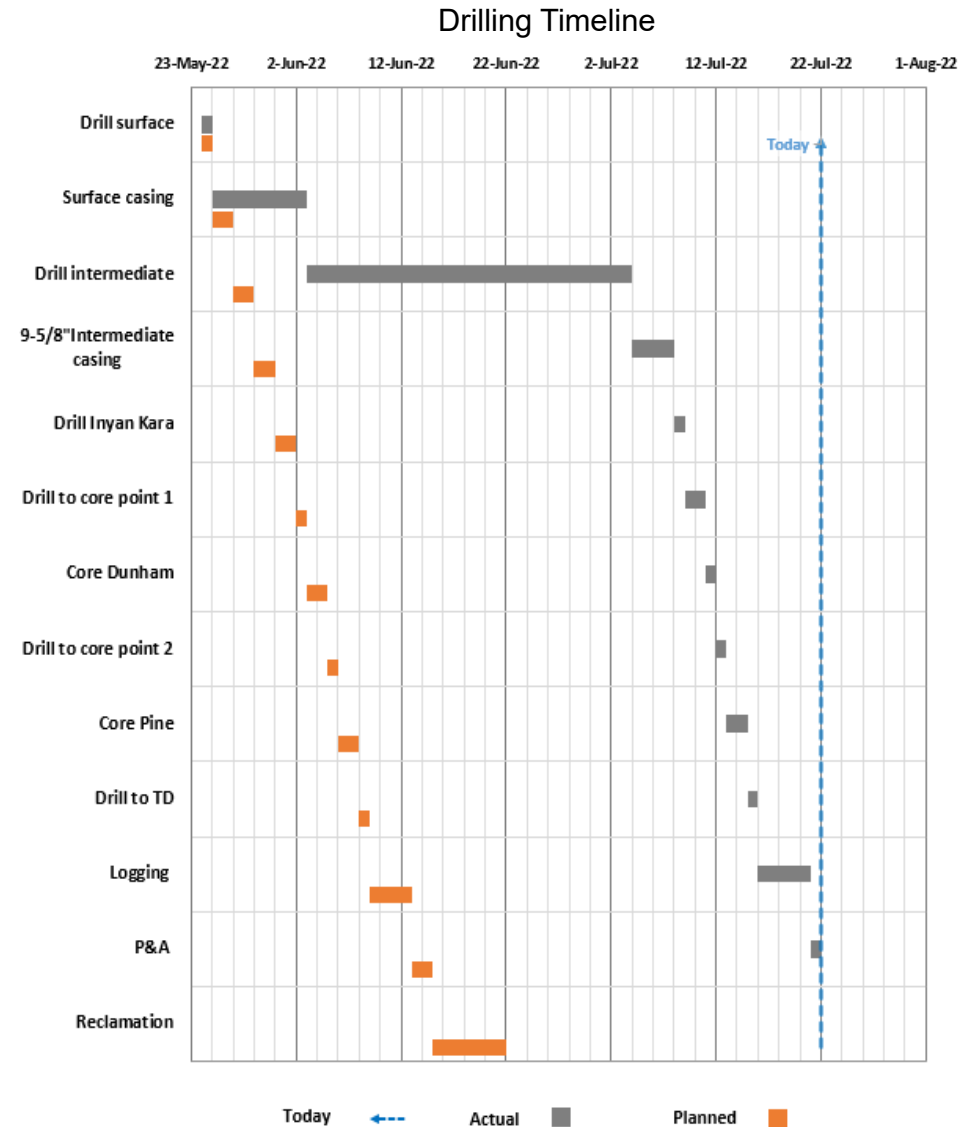
- Preexisting well pad for abandoned well
- Wellsite selected in the recommended study area detailed in the EERC's 2020 feasibility study (OGRP Contract No. G-000-004)
- Surface use agreements and drilling permit secured
- Pad constructed during the week of May 15, 2022
- Rig move began May 20, 2022



Taken from Smith et al. (2020). Study to determine the feasibility of developing salt caverns for hydrocarbon storage in western North Dakota (OGRP Contract No. G-000-004).

DRILLING SUMMARY

- Drilling initiated May 24, 2022.
- Drilled surface to 2204' on May 24, 2022.
- Ran in with casing May 25:
 - Casing parted May 25.
 - Fishing operations needed to retrieve casing.
 - 4 days' rig time to retrieve fish and set surface casing in place at 1935'.
 - 3 days' waiting on cement for surface.
- During drilling to intermediate casing (Inyan Kara), fluid losses were encountered on June 4.
 - This required additional remediation including setting cement plugs at surface casing shoe.
 - 12 days spent treating mud with loss circulation material, setting cement plugs, and waiting on cement.
 - Drilling resumed on June 17, bit bounced off plug and started sidetracking the original wellbore.
 - Attempts were made to reenter the original wellbore, unsuccessful. Received NDIC approval to drill ahead on June 23.
- Drilling and fluid losses continued. Six days spent trying to heal loss zones.
- Intermediate casing set to 5,054' on July 3 in Mowry Formation.
- No problems drilling through the Inyan Kara. Drilled to first core point.
- Drilling, coring, and logging were completed July 16:
 - Well was drilled to a total depth of 7,469 feet.
- P&A was not initiated until July 21 due to lack of cement and cement crew availability
- P&A was completed July 23.
- Site reclamation will be initiated following P&A. Reclamation includes:
 - Scoria removal from pad, regrading terrain to preexisting surveys, replanting native vegetation.
 - A detailed plan will be submitted to NDIC for approval prior to initiating work.



WELL SUMMARY

Dunham Salt Core



Dunham Core Recovery

- 28' caprock
 - 67' Dunham Salt
 - 14' underlying formation
- 91% recovery

Pine Salt Core



Pine Core Recovery

- 28' caprock
 - 56' Pine Salt
 - 35' underlying formation
- 99% recovery

North Dakota stratigraphic column formations (left) and members (right) (Modified from Murphy et al., 2009).

PIPER	BOWEN FERMIGON TAMPCO
	KLINE
	PICARD
	FOE
	DUNHAM
SPEARFISH	SAUDE
	PINE
	BELFIELD
MINNEKAHTA	
OPECHE	
BROOM CREEK	
AMSDEN	ALASKA BENCH
TYLER	
OTTER	
KIBBEY	
CHARLES	

Age (Millions of Years Present)	Age Units	Rock Units
23.0	Quaternary	White River Grp
		Golden Valley Fm
	Paleogene	Fort Union Grp
65.5	Cretaceous	Hell Creek Fm
		Fox Hills Fm
		Pierre Fm
		Judith River Fm
		Eagle Fm
		Niobrara Fm
		Carlile Fm
		Greenhorn Fm
		Belle Fourche Fm
		Mowry Fm
	Dakota Group	Skull Creek Fm
		Newcastle Fm
		Irtyan Kara Fm
145.5	Jurassic	Swift Fm
		Riardon Fm
201.6	Triassic	Piper Fm
		Spearfish Fm
251.0	Permian	Minnekahta Fm
		Opeche Fm
		Broom Creek Fm
299.0	Pennsylvanian	Amsden Fm
		Tyler Fm
		Otter Fm
318.0	Mississippian	Kibbey Fm
		Charles Fm
359.0	Devonian	Mission Canyon
		Lodgepole Fm
		Bakken Fm
		Three Forks
		Dupree
416.0	Silurian	Dawson Bay
		Wongopiss
444.0	Ordovician	Interlake Fm
		Stonewall Fm
488.0	Cambrian	Stony Mountain Fm
		Red River Fm

Measured Depth (ft)

1,935 ← 13-3/8" Surface casing

5,054 ← 9-5/8" Intermediate casing

6,815 ← Dunham Salt

7,180 ← Pine Salt

TD 7,469'

8,511 ← Charles Salt

BUDGET

- P&A is to be complete 7/22. Reclamation of the site will follow.
 - Associated well costs will be refined/collated as invoicing is received over the next 30 days. **Note that costs incurred to date likely exceed the \$9.5 million that was appropriated and awarded.**
- **Significant unplanned time spent drilling and setting casing in the surface and intermediate sections of the well. This is the primary reason for cost overruns.
- The estimate shown in Column 2 includes cost for completion of the programmatic elements outlined in the original Oil and Gas Research Program proposal (June 2021) and the estimated overrun on drilling/coring/P&A.

Project Associated Expense	Original Budget 2021-0187 NDIC Share	Estimate of Total Cost at Completion	Variance
Labor	\$3,016,919	\$2,332,583	-\$684,336
Travel	\$35,969	\$49,329	\$13,360
Equipment > \$5000	\$16,300	\$0	-\$16,300
Supplies	\$14,515	\$19,678	\$5,163
Subcontract – Naset Consulting	\$4,000,000	\$10,000,000	\$6,000,000
Consultant – Engineering Design Advise ment (TBD)	\$250,000	\$0	-\$250,000
Communications	\$500	\$65	-\$435
Printing & Duplicating	\$1,010	\$1,556	\$546
Food		\$200	\$200
Laboratory Fees & Services			
EERC Natural Materials Analytical Research Lab	\$112,392	\$40,700	-\$71,692
EERC Graphics Services	\$19,382	\$675	-\$18,707
EERC Document Production Services		\$20,920	\$20,920
EERC Engineering Services Fee	\$1,507	\$2,614	\$1,107
EERC Field Safety Fee	\$20,448	\$25,556	\$5,108
EERC Geoscience Fee	\$0	\$15,894	\$15,894
EERC Shops & Ops	\$0	\$638	\$638
EERC Software Tech	\$0	\$97	\$97
Petroleum Engineering – Triaxial Testing	\$67,200	\$29,043	-\$38,157
Outside Lab – Core Labs	\$80,000	\$0	-\$80,000
Outside Lab – Wagner Petrographic	\$8,000	\$0	-\$8,000
Outside Lab – RESPEC	\$0	\$281,500	\$281,500
Freight & Laundry	\$0	\$184	\$184
Professional Development	\$0	\$6,500	\$6,500
Total Direct Costs	\$7,644,142	\$12,827,732	\$5,183,590
Facilities & Administration	\$1,855,858	\$1,451,991	-\$403,867
Total Cash Requested from NDIC	\$9,500,000	\$14,279,723	\$4,779,723

PRIORITIES FOR COMPLETING PROGRAM

- Data collected from the Dunham and Pine Formations are believed to provide a significant basis for evaluating the viability for engineered cavern development in deeper salt formations in North Dakota.
- The EERC has initiated work on each of the priority items presented below. Because core testing on salt is considered time-sensitive, processing is taking place, and testing is being evaluated to determine the appropriate start date. Work on Priorities 2 and 3 are on hold as cost overruns are assessed and decisions are made.
- The EERC proposes the completion of the following lists of priorities satisfying the scope of work the EERC committed to fulfill to OGRP. Additional funding associated with the completion of this work is estimated at approximately \$4.8 million (includes well cost overrun and completion of Priorities 1–3) as shown in the budget variance presented previously.

Priority 1: Core Testing and Interpretation: Performed on core collected from the overlying sealing formation, salt formations and interbeds, and underlying formation. The results of this work are time-sensitive and are related directly to Priority 2 – Geologic and Geomechanical Modeling, which is needed to evaluate the feasibility of salt cavern development within the respective salt formations:

- Core processing – description, core preparation and boxing, core gamma ray, and photography.
- Core testing – porosity, permeability, mineralogy, geomechanical stability to inform geologic and geomechanical modeling/simulation.
- Interpretation – reporting on results of laboratory testing.

Priority 1 Estimated Cost: \$658,900

Priority 2: Geologic and Geomechanical Modeling: Performed on site-specific data generated through drilling, core collection, and laboratory testing to assess the feasibility of salt cavern development:

- Local-scale geologic modeling of the drilling site based on regional publicly available data, site-specific coring and logging, and laboratory test results.
- Geomechanical simulation to determine potential cavern dimensions and operational stability.
- Additional modeling for alternate locations in the Williston Basin where cavern development has potential.

Priority 2 Estimated Cost: \$1,481,200

Priority 3: Engineering Analysis and Design

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

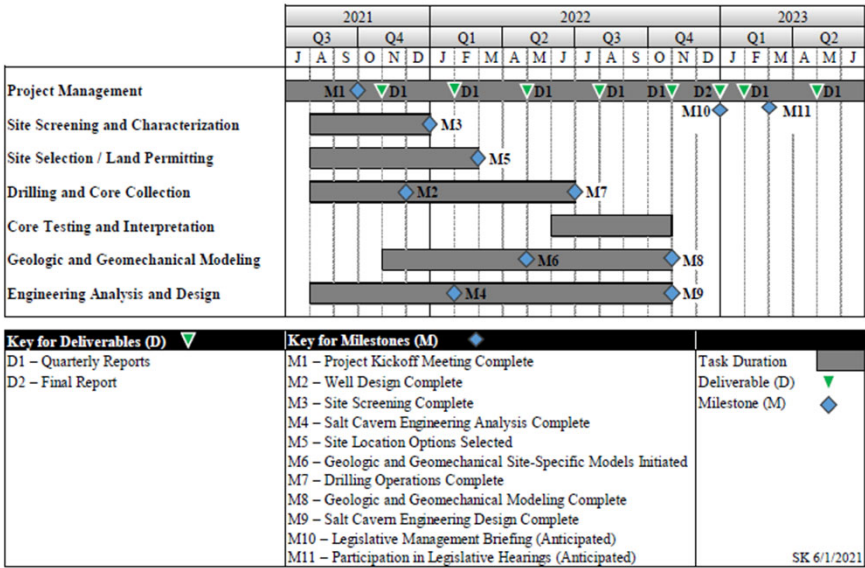
Priority 3 Estimated Cost: \$723,900

Estimated management cost for
Priorities 1–3: \$220,000
Total Estimated Cost: \$3,084,000

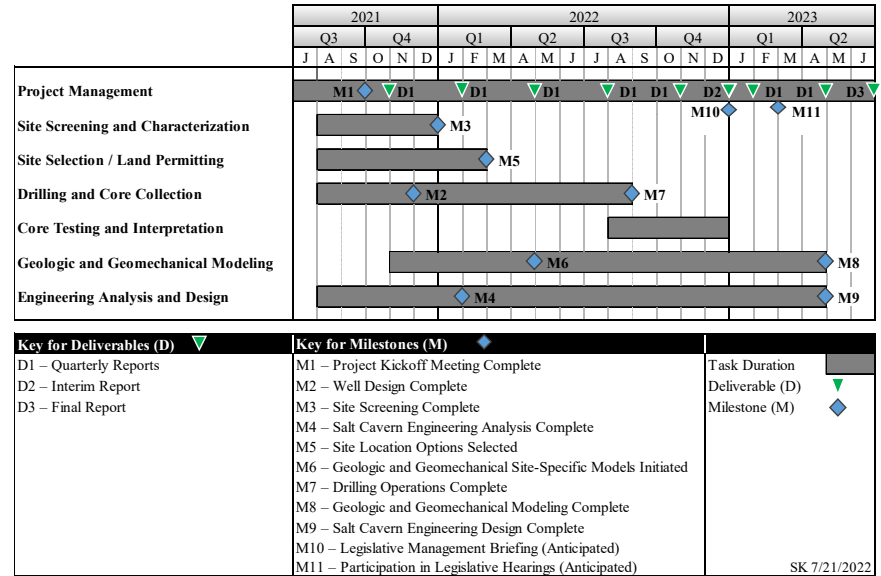
REVISED PROJECT TIMELINE

- Drilling delays necessitate a change to the originally proposed project timeline.
- The original timeline proposed a project completion coincident with the start of the 2023 ND Legislative session.
- The revised timeline allows for completion by June 2023 as originally proposed.
- Site screening and selection are complete
- Drilling and P&A are complete. Site reclamation is expected to be complete by the end of July.
- Core testing is initiated because of the time-sensitive nature of testing salt cores.
- The remaining tasks have been initiated but are on hold while budget considerations are discussed.
- The EERC proposes the completion of the provided lists of priorities to satisfy the scope of work the EERC committed to fulfill to OGRP. Additional funding associated with the completion of this work is estimated at approximately \$4.8 million (includes well cost overrun and completion of Priorities 1–3) as shown in the budget variance presented previously.

Original Gantt Chart



Revised Gantt Chart





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A wide-angle photograph of a university campus at sunset. The sun is low on the horizon, casting a warm glow over the scene. In the foreground, there are trees with yellowing leaves. In the background, there are several large, multi-story brick buildings, likely university halls or administrative buildings. A parking lot with several cars is visible in the middle ground.

THANK YOU

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