Critical Challenges. Practical Solutions.

Energy & Environmental Research Center (EERC)

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

North Dakota Oil and Gas Research Council Meeting

Bismarck, ND

July 21, 2021

John Harju

Vice President, Strategic Partnerships

BACKGROUND

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:

- The EERC proposes 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.

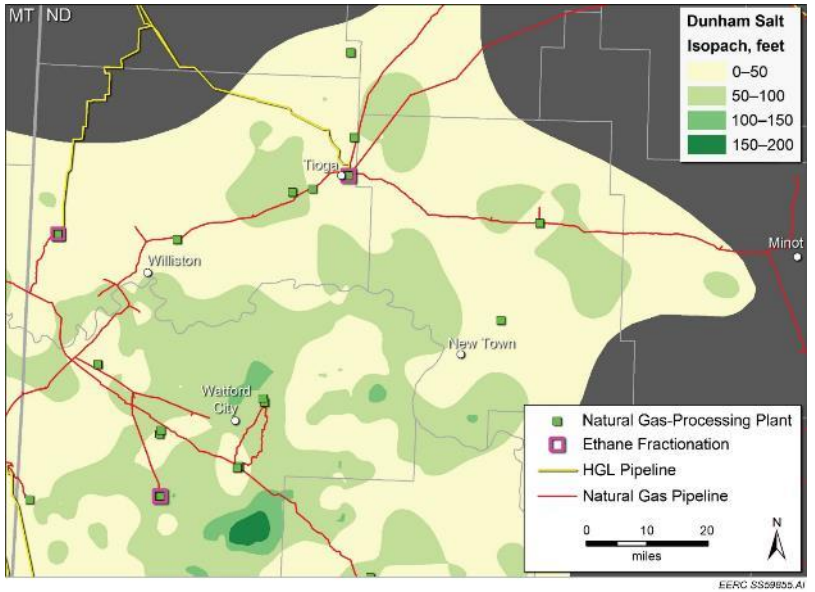
PROJECT OBJECTIVES

This study will be accomplished by carrying out several project objectives including:

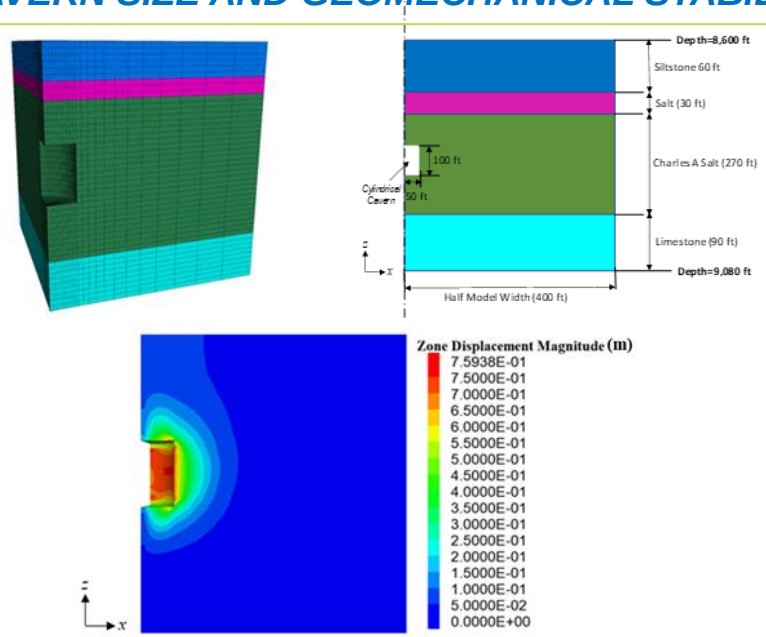
- An assessment of the presence, depth, and composition of identified salt formations.
- The sealing potential of overlying and underlying geologic strata.
- Geomechanical stability modeling and simulation.
- Site-specific engineering design recommendations for future cavern development pilot studies.

- The EERC will partner with Bakken Midstream for securing land options, surface and subsurface rights, and project advisement.

GEOLOGICAL REVIEW



CAVERN SIZE AND GEOMECHANICAL STABILITY



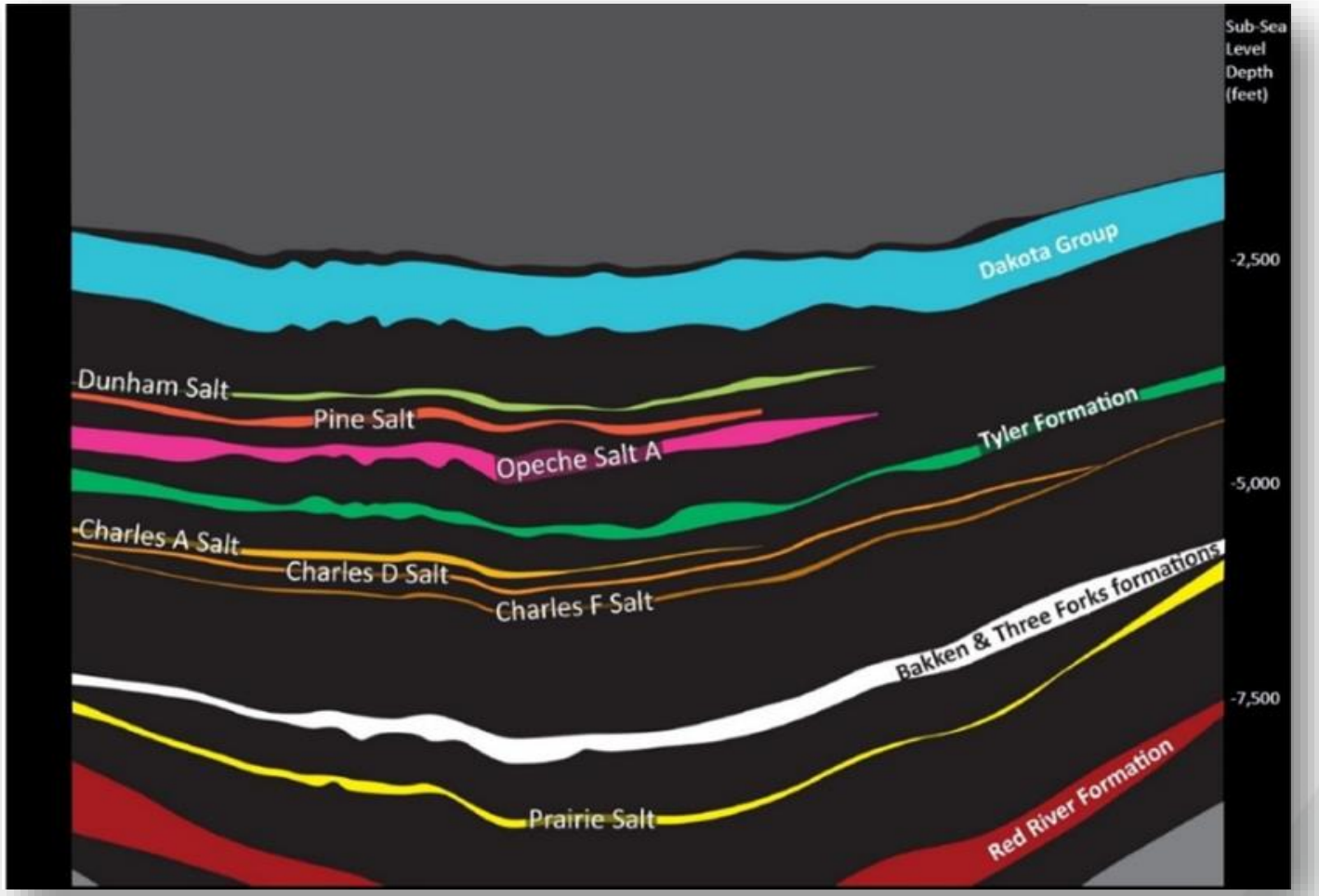
SCOPE OF WORK

Site Screening and Characterization

- Site locations with amenable salt formations will be identified and targeted for screening and characterization.
- Screening criteria will be based on:
  - The interpretation of wireline logs obtained from publicly available data sets.
  - Depth (<6000 ft), thickness, confinement.
- During this activity, small-scale, localized geologic modeling will be performed to inform decision making.

Task Milestone: Identification of characterization well drilling location.

NORTH DAKOTA SALT FORMATIONS



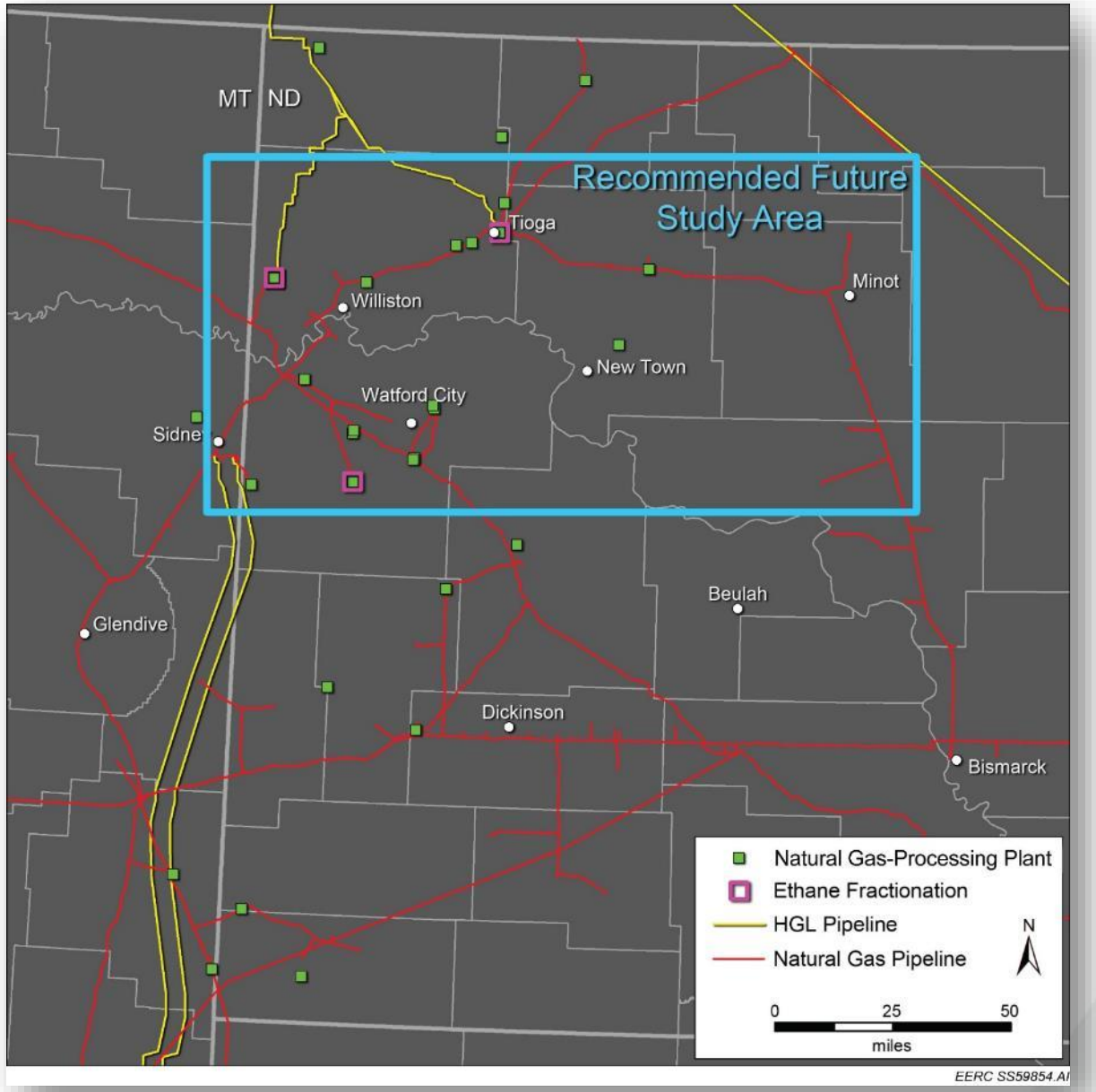
(extracted and modified from Nesheim and LeFever, 2009)

SCOPE OF WORK (cont.)

Site Selection/Land Permitting

- The EERC will work with project partners to evaluate potential project site locations identified in the Site Screening and Characterization task.
- It is anticipated that securing land options and surface and subsurface rights will be conducted by Bakken Midstream in close collaboration with the EERC.

Task Milestone: Acquisition of surface and subsurface land rights and permits in preparation for drilling.



Smith et al., 2020

SCOPE OF WORK (cont.)

Drilling and Core Collection

- Site preparation
- Drilling
- Coring
- Logging
- Well abandonment and site closure

Neset Consulting Service will provide general contracting services and work with EERC teams throughout the well-planning to site closure process.

Task Milestone: Successful core collection through target salt formations.

SCOPE OF WORK (cont.)

Core Testing and Interpretation

- Routine analyses to identify the bulk characteristics of the formations including:
  - Lithology, thickness, porosity, permeability, and mineralogy.
  - Geomechanical competency of the overlying and underlying sealing formations.
  - Geomechanical properties of salts.
  - Dissolution properties of salts encountered.

Task Milestone: Laboratory data sets generated and provided to modeling and simulation teams for interpretation.

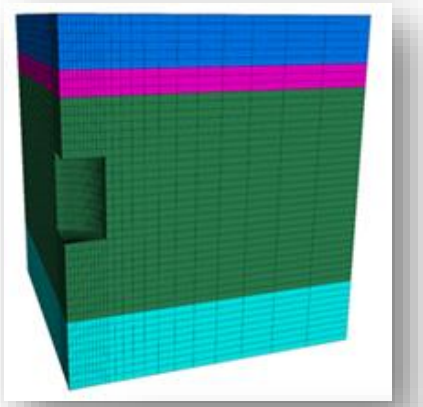
SCOPE OF WORK (cont.)

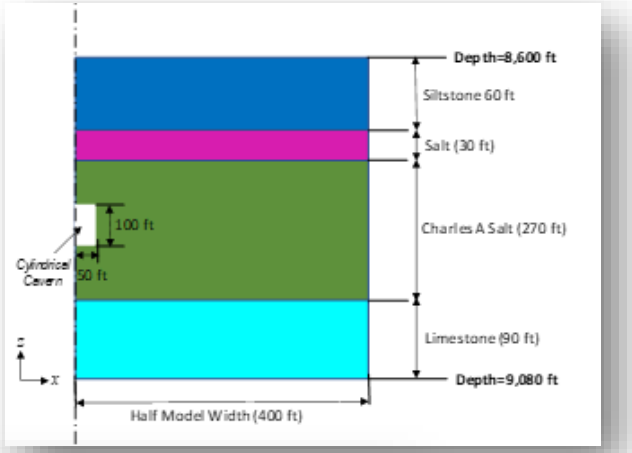
CAVERN SIZE AND GEOMECHANICAL STABILITY

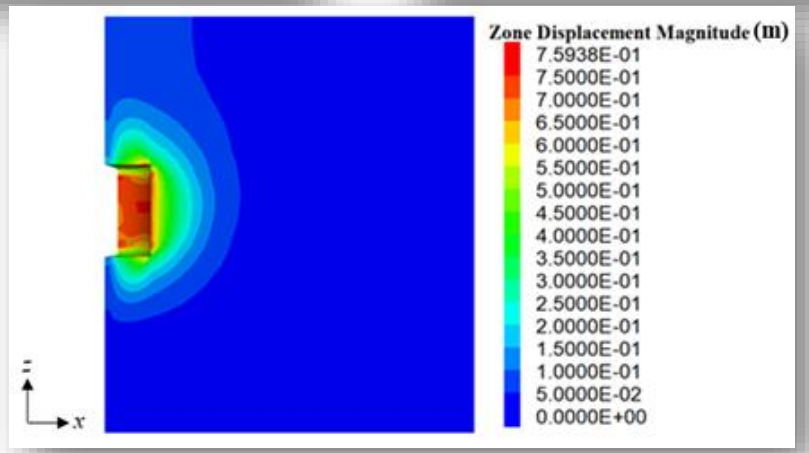
Geologic and Geomechanical Modeling

- Based on site-specific data generated through the drilling, logging, and core-testing process.
- Geologic models will be developed to understand the subsurface geologic regime and evaluate regional structural and stratigraphic trends that may impact cavern development.
- Geomechanical modeling will incorporate information derived from geologic modeling, wireline logging, formation testing, and laboratory data sets and will inform the overall cavern dimensions and operational stability.

Task Milestone: Informed recommendations regarding the feasibility of cavern development in North Dakota salts.







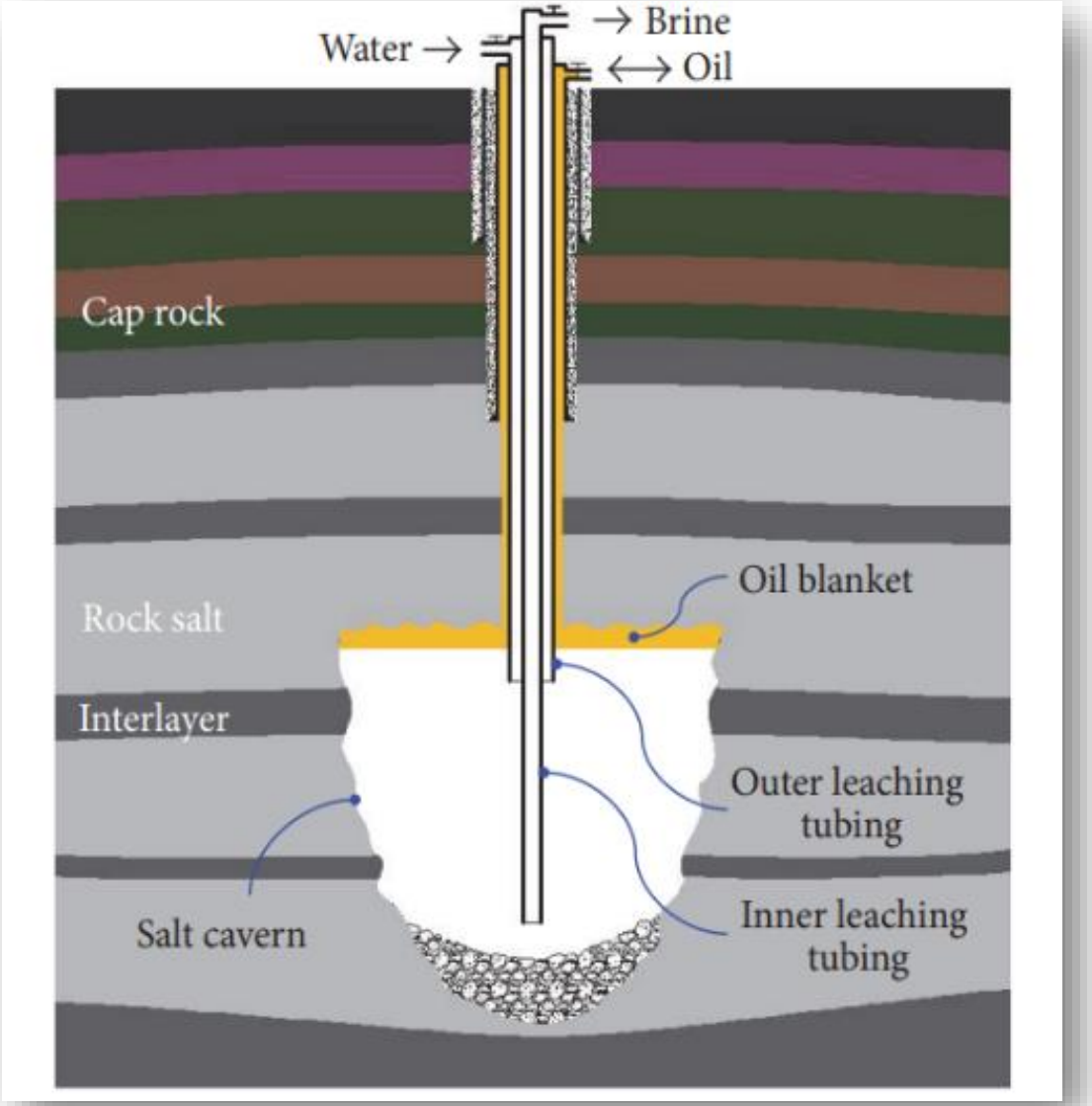
SCOPE OF WORK (cont.)

Engineering Analysis and Design

- Detailed engineering design and analysis will be performed to identify surface equipment needs; design specifications; brine handling, use, and disposal practices; and monitoring needs.
- Advisement will be sought from external engineering teams with expertise in developing and operating salt caverns used for hydrocarbon storage. These consultants are yet to be determined.

Task Milestone: Site-specific implementation plans for future cavern development.

CAVERN DESIGN AND OPERATIONAL CONSIDERATIONS



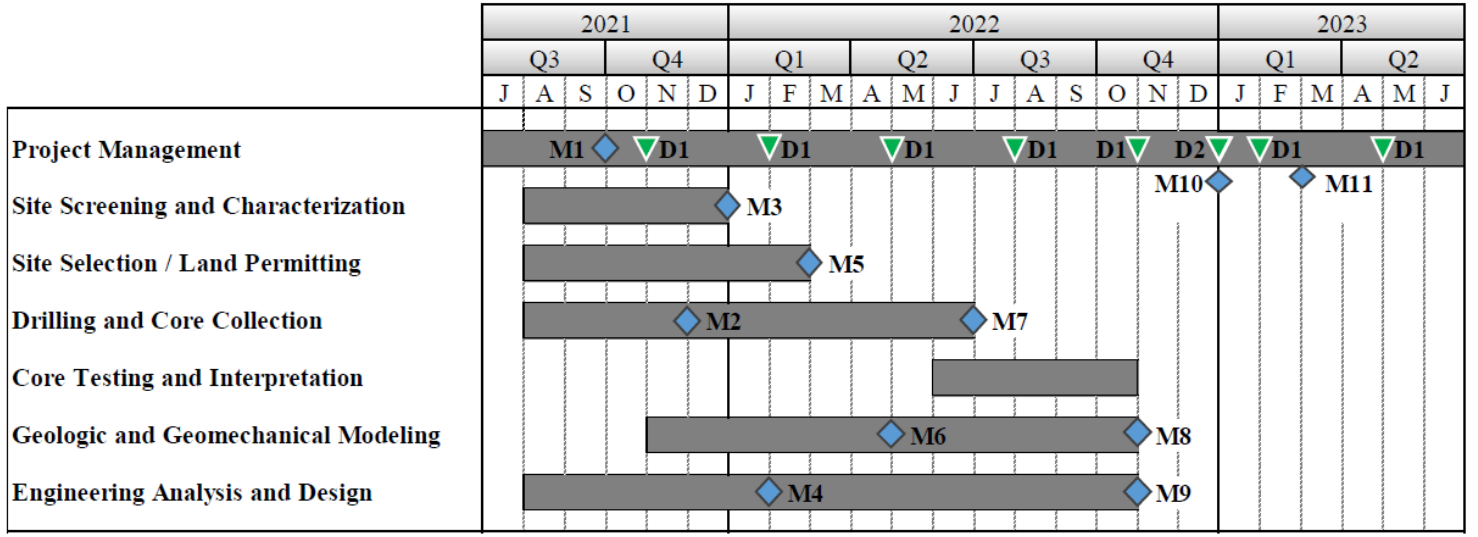
ANTICIPATED RESULTS

A final report that includes:

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

DELIVERABLES/TIMELINE

- The EERC will prepare and deliver quarterly reports summarizing progress and milestone accomplishments.
- The EERC will provide a final report detailing the results and recommendations determined during the investigation.
- The project duration is 2 years. The final report will be submitted for consideration in advance of the 2023 legislative session.



Key for Deliverables (D)	Key for Milestones (M)	
D1 – Quarterly Reports	M1 – Project Kickoff Meeting Complete	Task Duration
D2 – Final Report	M2 – Well Design Complete	Deliverable (D)
	M3 – Site Screening Complete	Milestone (M)
	M4 – Salt Cavern Engineering Analysis Complete	
	M5 – Site Location Options Selected	
	M6 – Geologic and Geomechanical Site-Specific Models Initiated	
	M7 – Drilling Operations Complete	
	M8 – Geologic and Geomechanical Modeling Complete	
	M9 – Salt Cavern Engineering Design Complete	
	M10 – Legislative Management Briefing (Anticipated)	
	M11 – Participation in Legislative Hearings (Anticipated)	SK 6/1/2021

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THANK YOU

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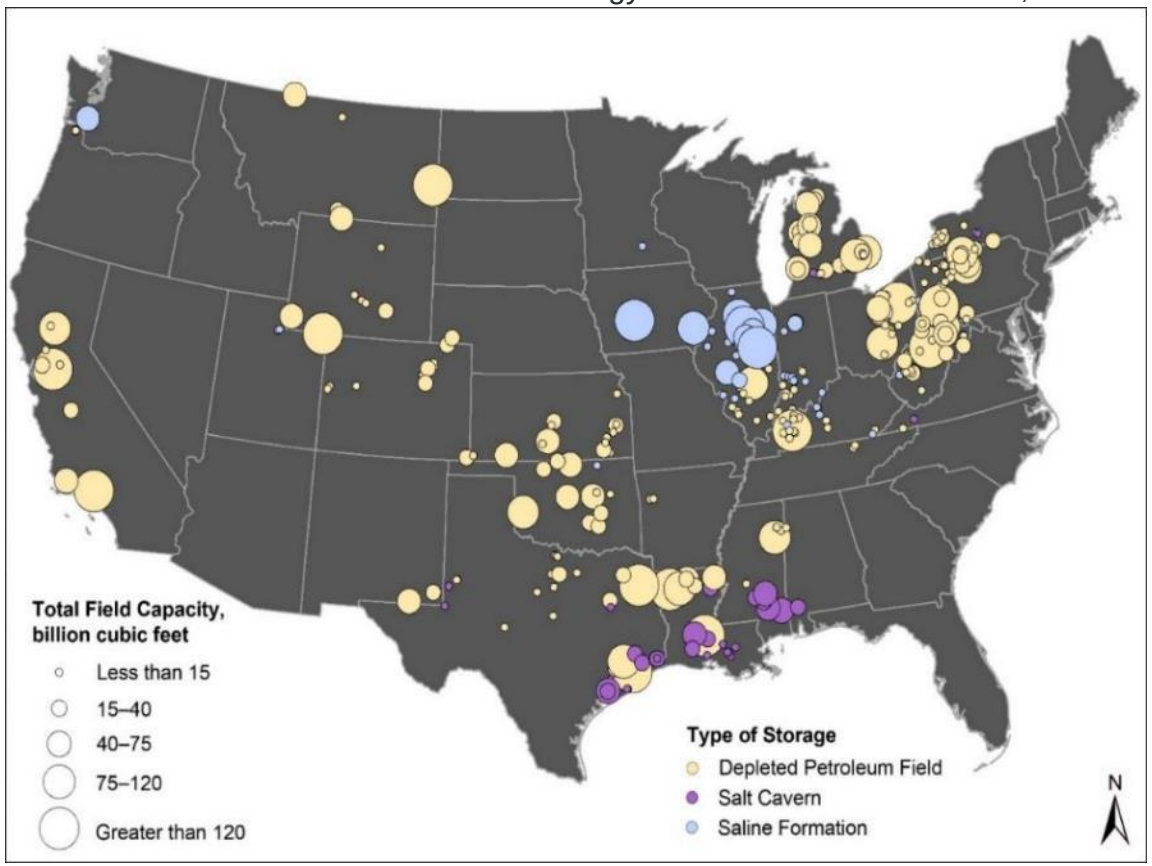
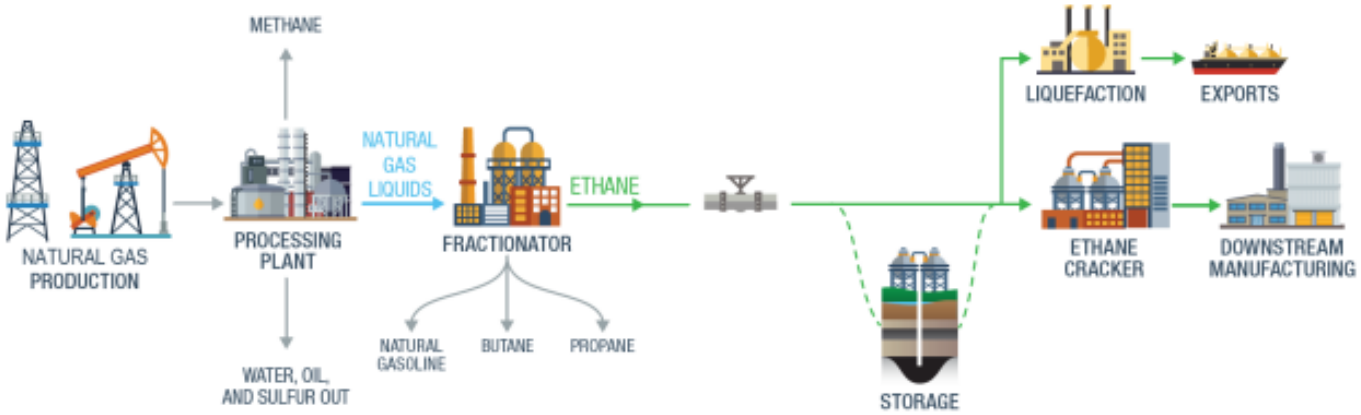
GAS STORAGE

SUPPLEMENTAL MATERIAL

- Gas storage is a proven technology that began in 1915.
- Typically, gas storage is used to supplement energy demands associated with seasonal heating needs.
- Over 300 gas storage locations in the United States are active.
- Salt caverns are an integrated element in the petrochemical process.
- Natural gas liquid (NGL) hubs are coincident with oil- and gas-producing regions or areas where export capability exists.

Energy Information Administration, 2020a



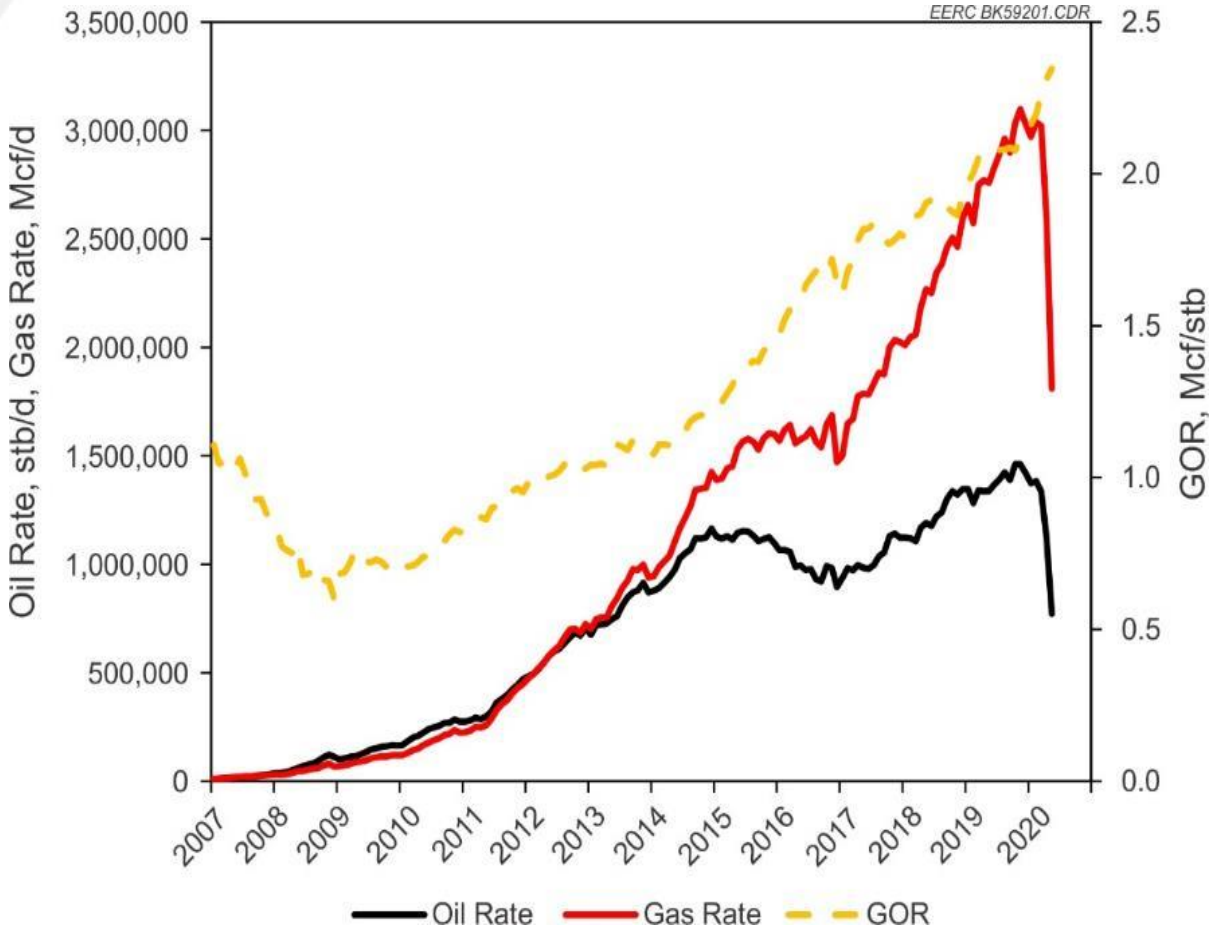


U.S. Department of Energy, 2018

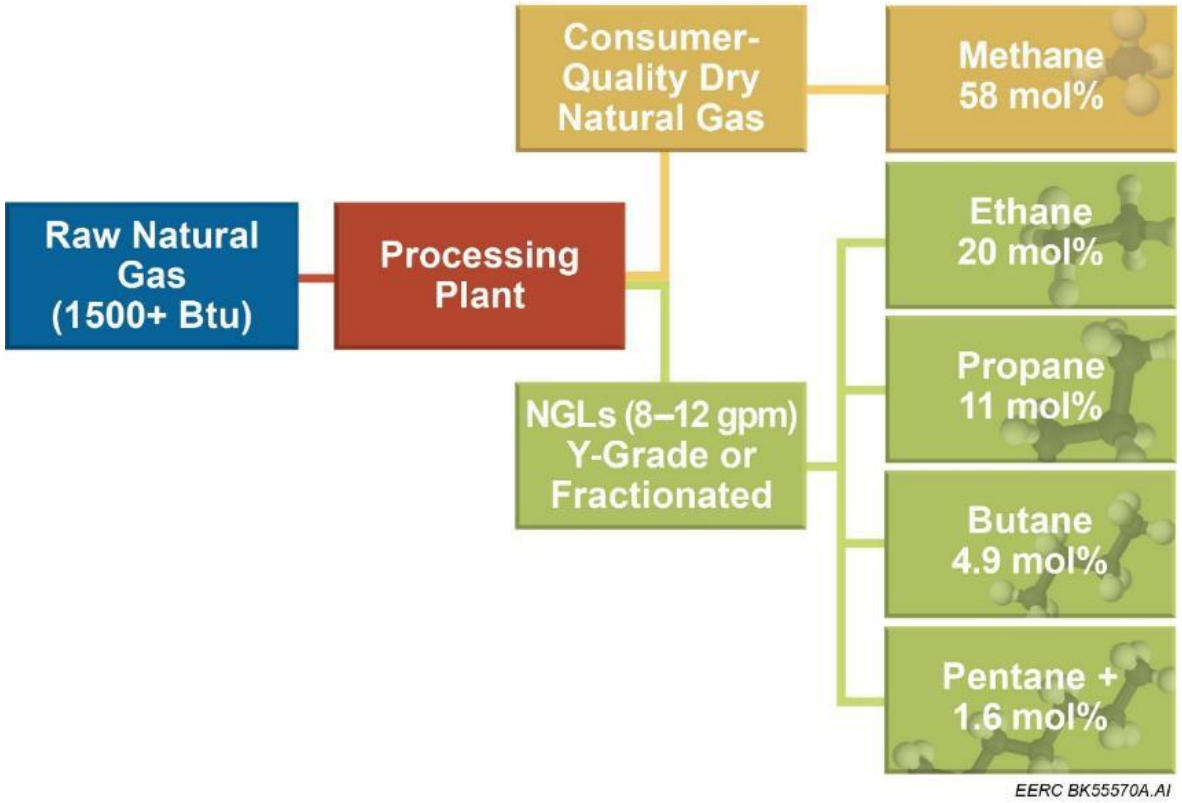
NORTH DAKOTA GAS PRODUCTION

SUPPLEMENTAL MATERIAL

With continued increases in oil production, the gas-to-oil ratio (GOR) is expected to follow a similar trend.



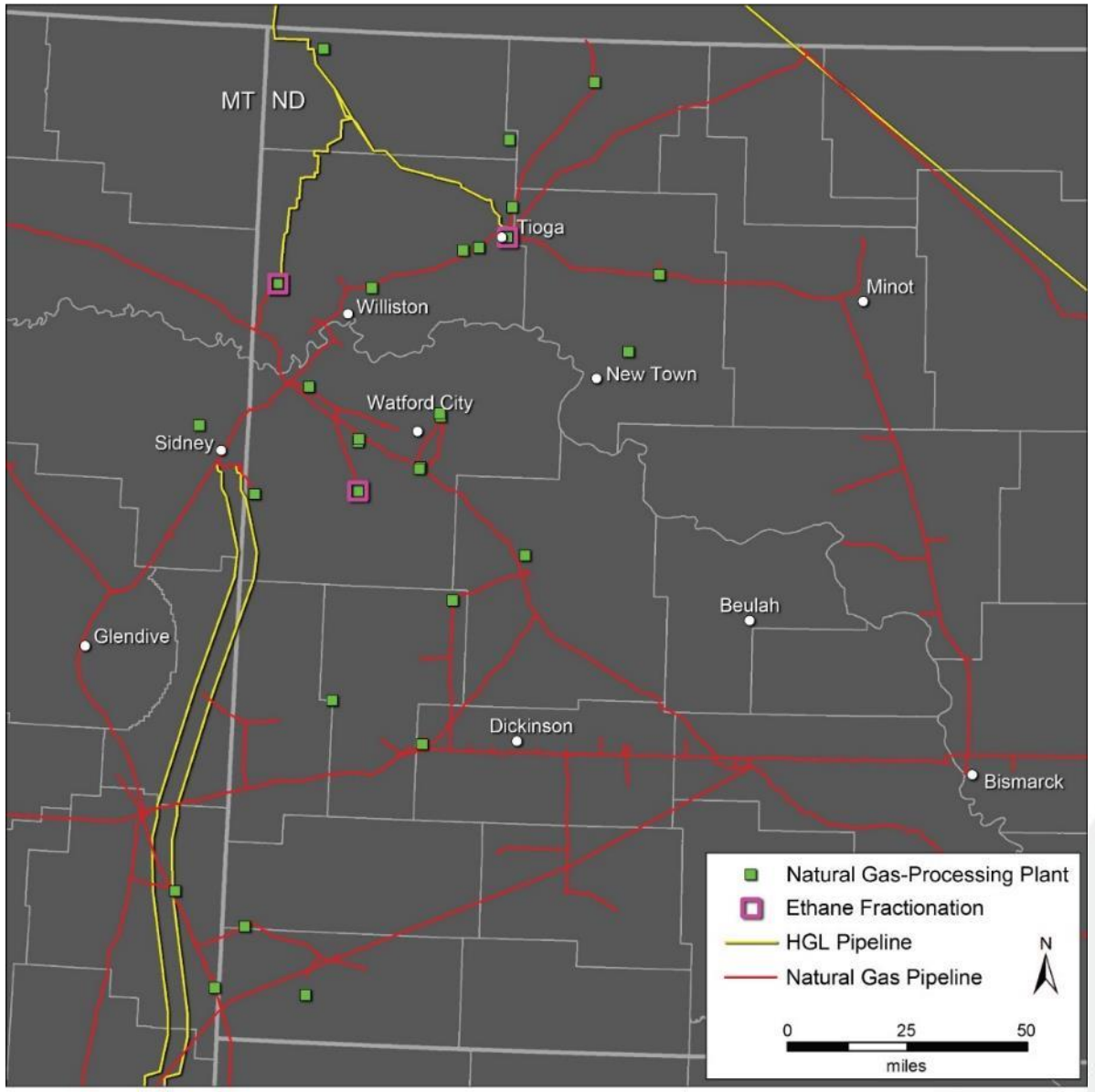
NGLs are present in as much as 35% of processed gas in North Dakota. Ethane accounts for 20% of these NGLs.



NORTH DAKOTA GAS PROCESSING AND PIPELINES

SUPPLEMENTAL MATERIAL

- Increasing oil/gas production in North Dakota has resulted in significant investment in gas transportation infrastructure.
- Ethane and hydrocarbon gas liquids (HGLs) are captured at three processing plants.
- HGL pipelines deliver product to Canadian and U.S. markets.

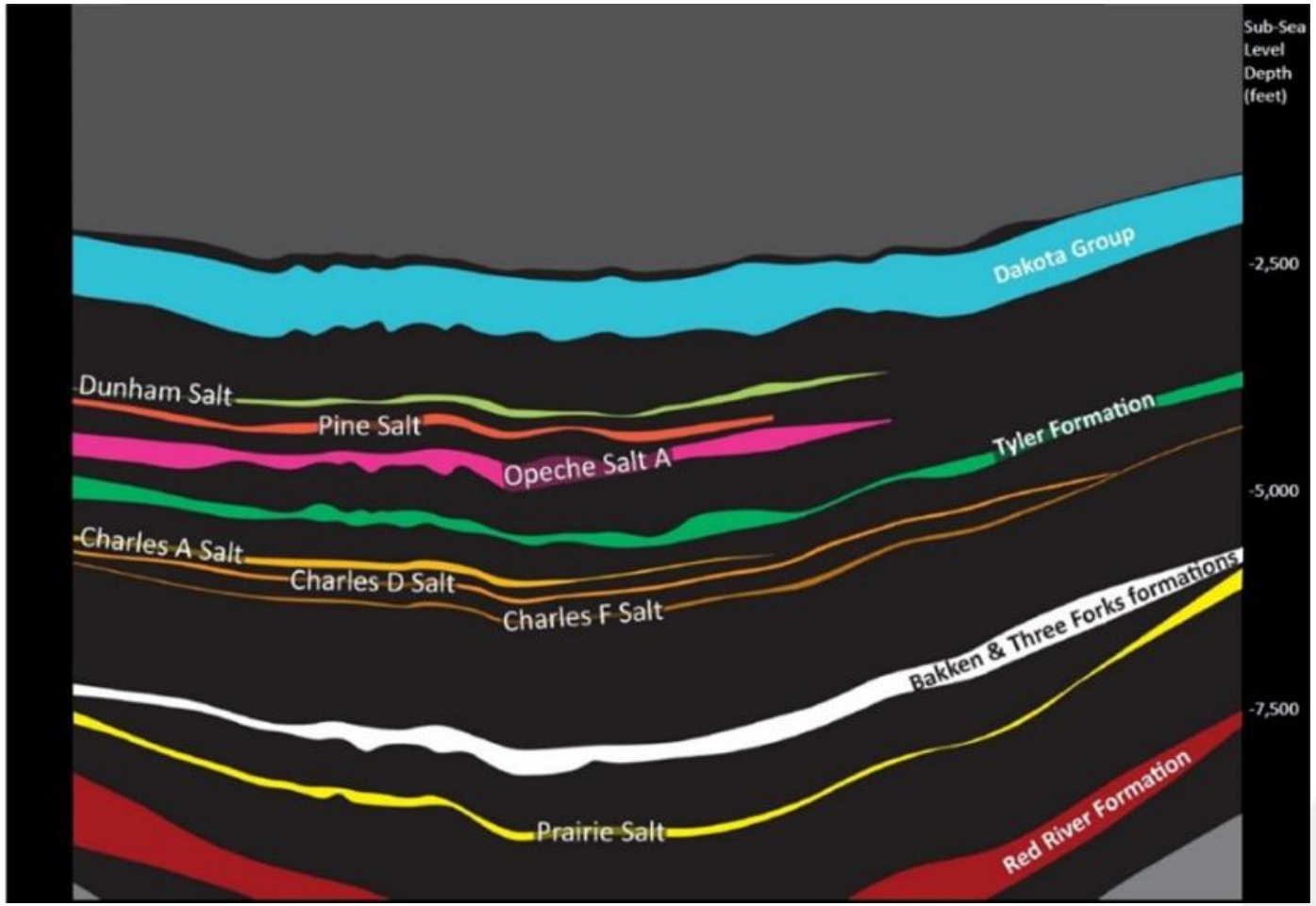


GEOLOGICAL REVIEW

SUPPLEMENTAL MATERIAL

- North Dakota geologic formations were investigated to identify salt formations with potential for cavern development.
- Critical success criteria include thickness, depth (temperature <180°F), and extent.
- Formations in the study with depths of less than 6500 ft were considered “likely” candidates.
- Screening included proximity to gas supply, water resources, railroads, and water disposal.

NORTH DAKOTA SALT FORMATIONS



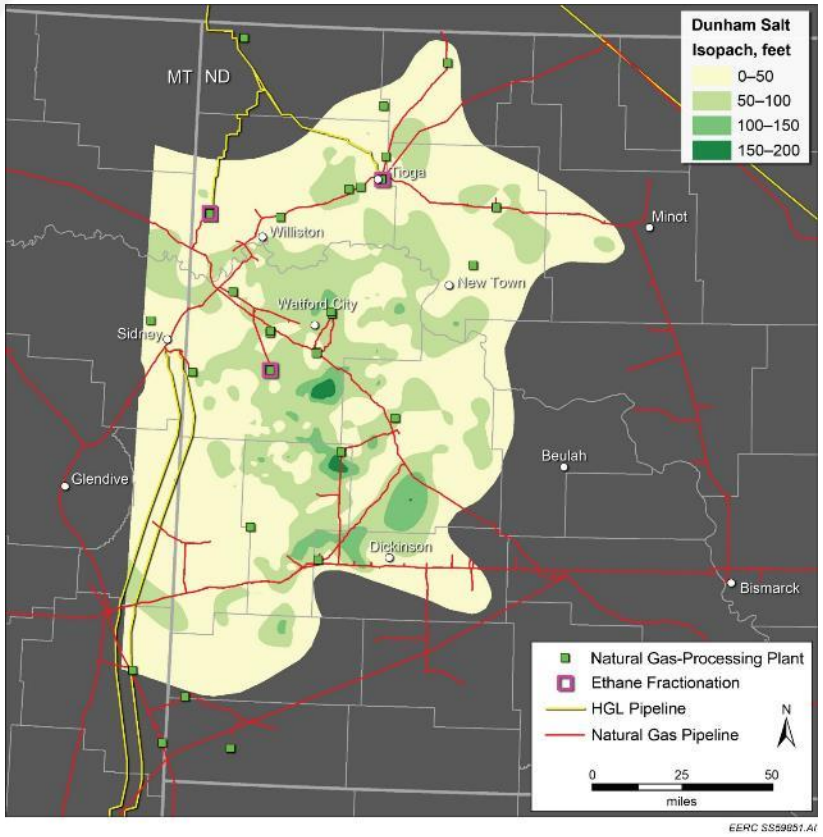
(extracted and modified from Nesheim and LeFever, 2009)

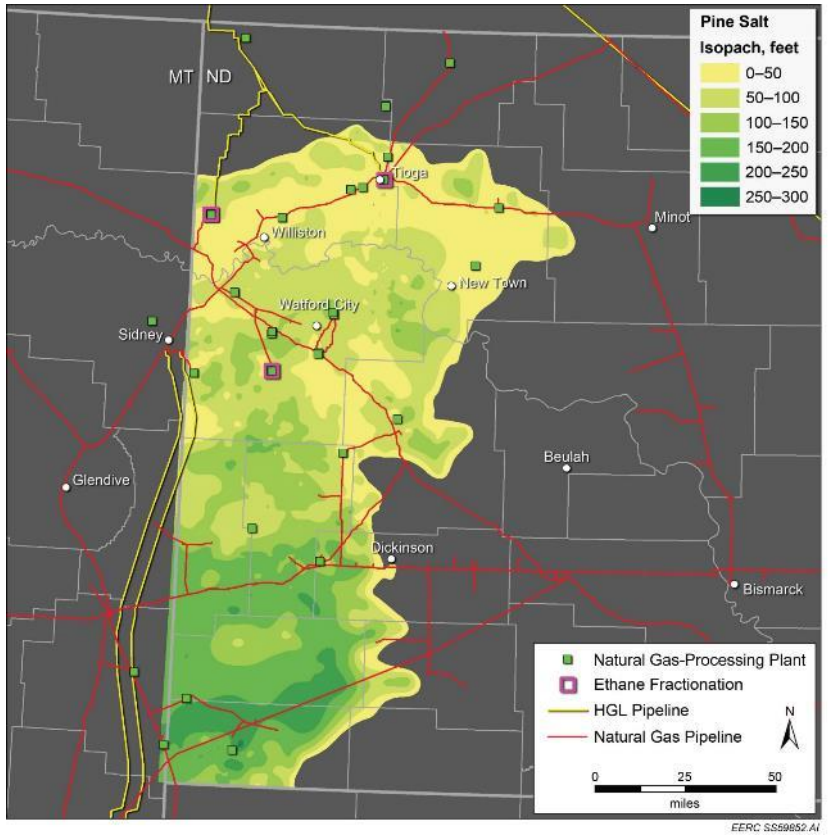
GEOLOGICAL REVIEW - SUPPLEMENTAL MATERIAL

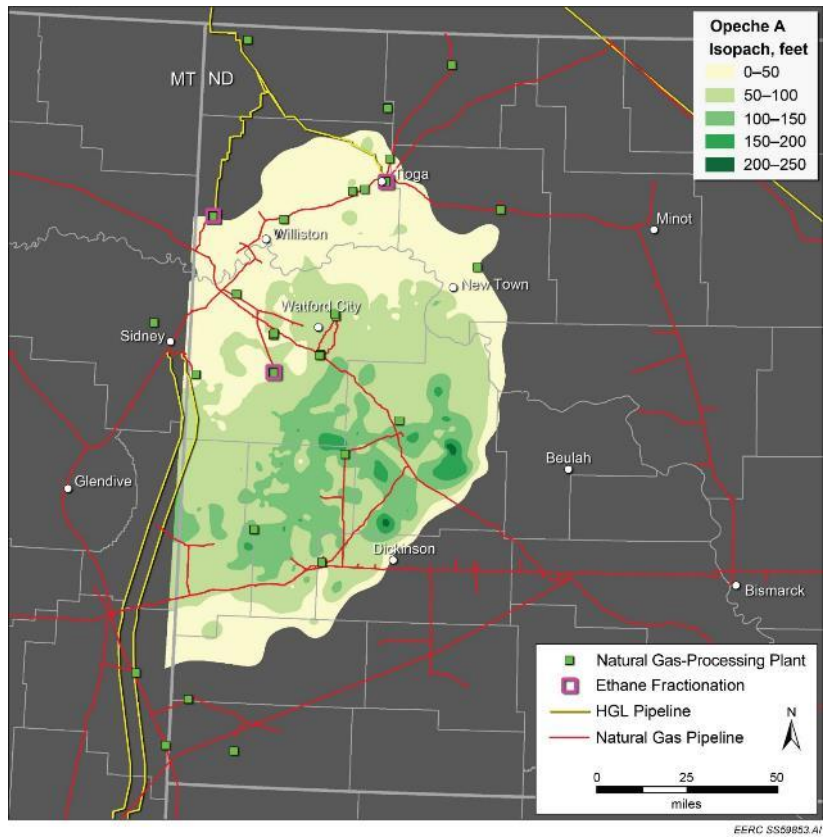
Candidate Salts

- Dunham Salt – thickness <200 ft max., depth <6800 ft
- Pine Salt – thickness <300 ft max., depth <7200 ft
- Opeche A Salt thickness <250 ft max., depth <7400 ft

Images show extent, thickness, and proximity to regional infrastructure.

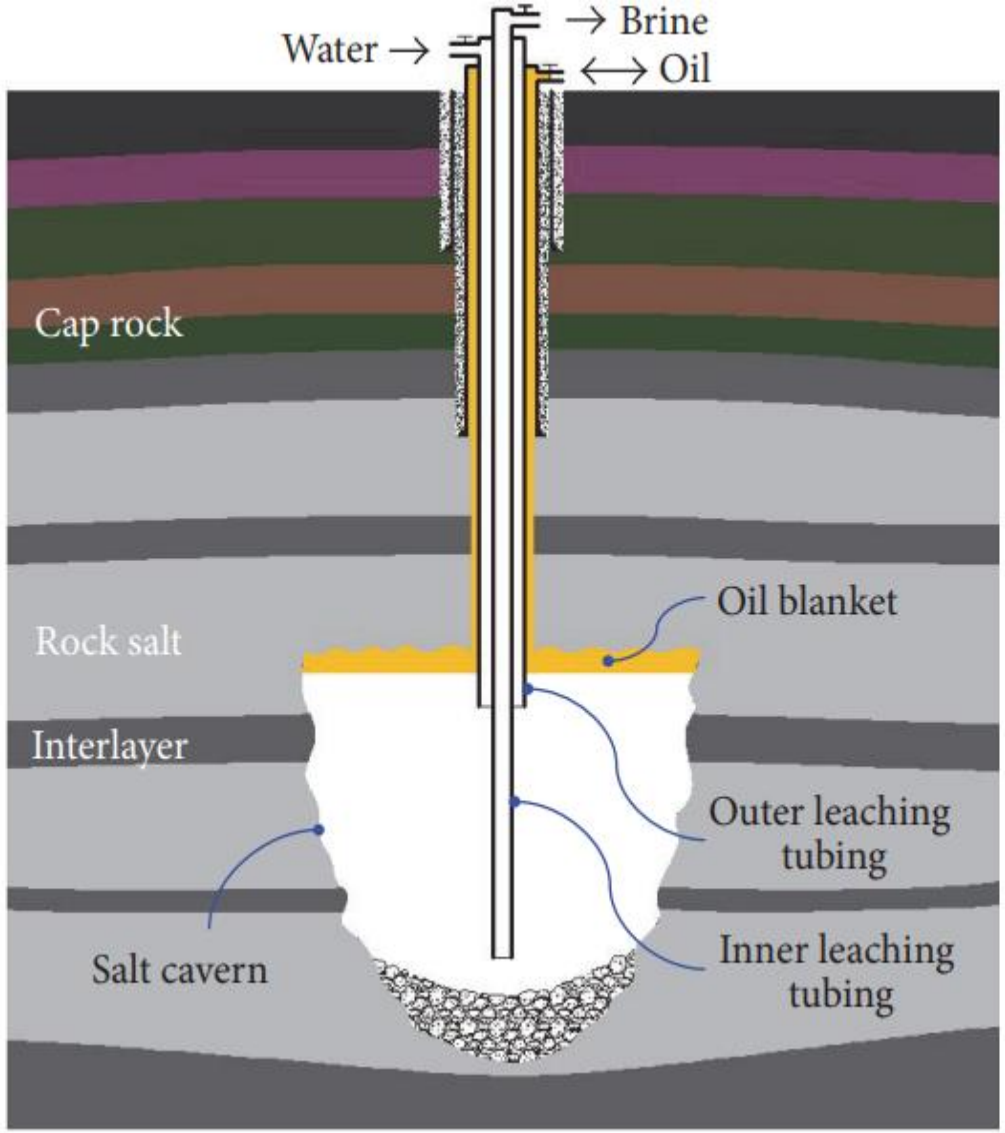






CAVERN DEVELOPMENT/OPERATION - SUPPLEMENTAL MATERIAL

- Caverns are created by injecting fresh or saline water into salt formations and producing salt to the surface. The process is referred to as ***solution mining.***
  - Diesel or hydrocarbons are commonly injected during cavern creation to prevent dissolution of the upper cavern and control geometry.
- Upon completion of the cavern, brine used in the development is displaced to the surface with NGLs.
- Commonly, this brine is stored on the surface for future on-demand NGL recovery.
- Caverns are commonly operated using constant pressure through the injection of brine for retrieval of NGLs.
  - Geomechanical stability is promoted using this constant pressure technique as pressure cycling is minimized.

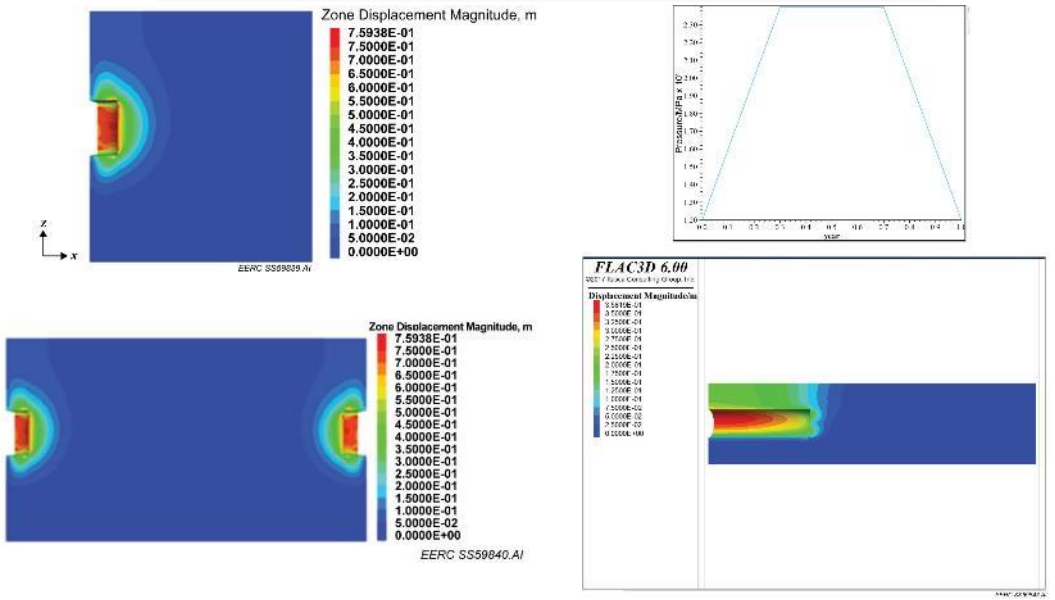


GEOMECHANICAL STABILITY OF SALT CAVERNS

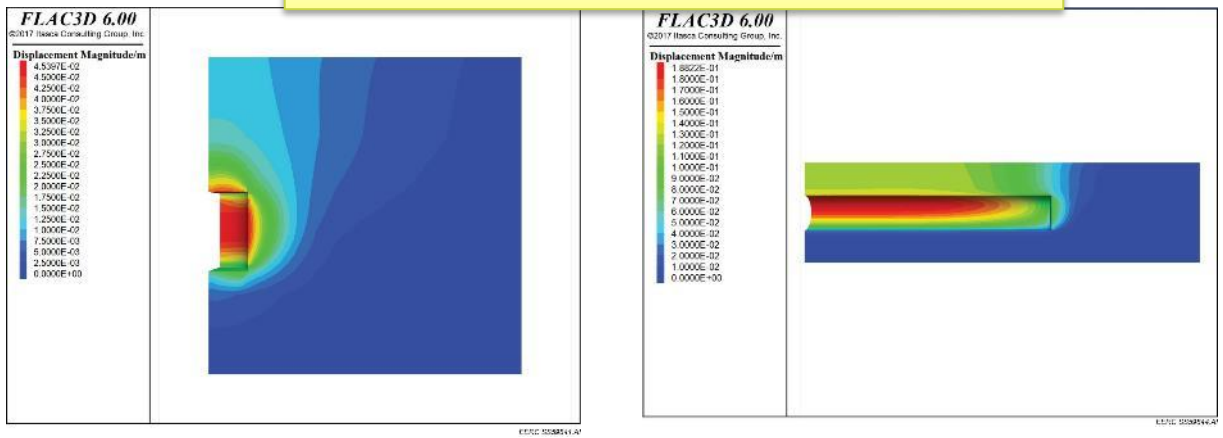
SUPPLEMENTAL MATERIAL

- Simulations of mechanical stability were performed for multiple cavern geometries under cyclic and constant pressure scenarios.
- Single-cavern and multiple-cavern simulations were performed.
- Effects of temperature were evaluated in select simulations.
- Displacement of the cavern roof and cap rock was minimized during constant pressure injection.

Simulation Performed under Cyclic Pressure



Simulation Performed under Cyclic Pressure



REGULATORY REVIEW

SUPPLEMENTAL MATERIAL

- Regulations pertaining to the development and operation of salt caverns were reviewed in states and provinces where the technology is used.
  - Alberta, Saskatchewan, Kansas, Louisiana, Texas, and Michigan.
  - Information obtained may provide insight for future North Dakota regulation.
- North Dakota regulations pertaining to development and operation of salt caverns were reviewed.
  - NDIC – Geological Survey regulates development and operation of salt cavern dissolution mining and brine disposal.
  - NDIC – Oil and Gas Division regulates NGL production, geologic storage of NGLs, and all injection well construction.
  - North Dakota Public Service Commission – Oversight regarding gas processing and transmission via pipelines.

KEY FINDINGS

SUPPLEMENTAL MATERIAL

- The Dunham, Pine, and Opeche salt beds were identified as candidates for salt cavern development and NGL storage.
- Preliminary simulation results suggest the development of small caverns is achievable in North Dakota salt beds. The use of multiple caverns was found to be a viable design approach and geomechanically stable.
- Regulations pertaining to the development of salt caverns, mineral ownership, brine handling, and injection are under the purview of three state agencies: NDIC's Geological Survey and Department of Mineral Resources – Oil and Gas Division and the North Dakota Public Service Commission.
- Regulations – Several additional factors need consideration if NGLs are to be injected into the subsurface for storage.
  - Leasing of the salt formation (i.e., mineral extraction).
  - How to define the extent and volume of the solution-mined cavern.
  - Pore space ownership and storage of NGLs is not well defined.
  - Clarity regarding rules governing the use of surface brine storage ponds as part of salt cavern NGL storage facility operations.
- Engineering assessments were performed – evaluated major equipment/components, including compression, brine pumps, surface brine ponds, and electrical needs. Additional operational costs including labor, maintenance of surface equipment, and cooling water needs warrant further investigation.