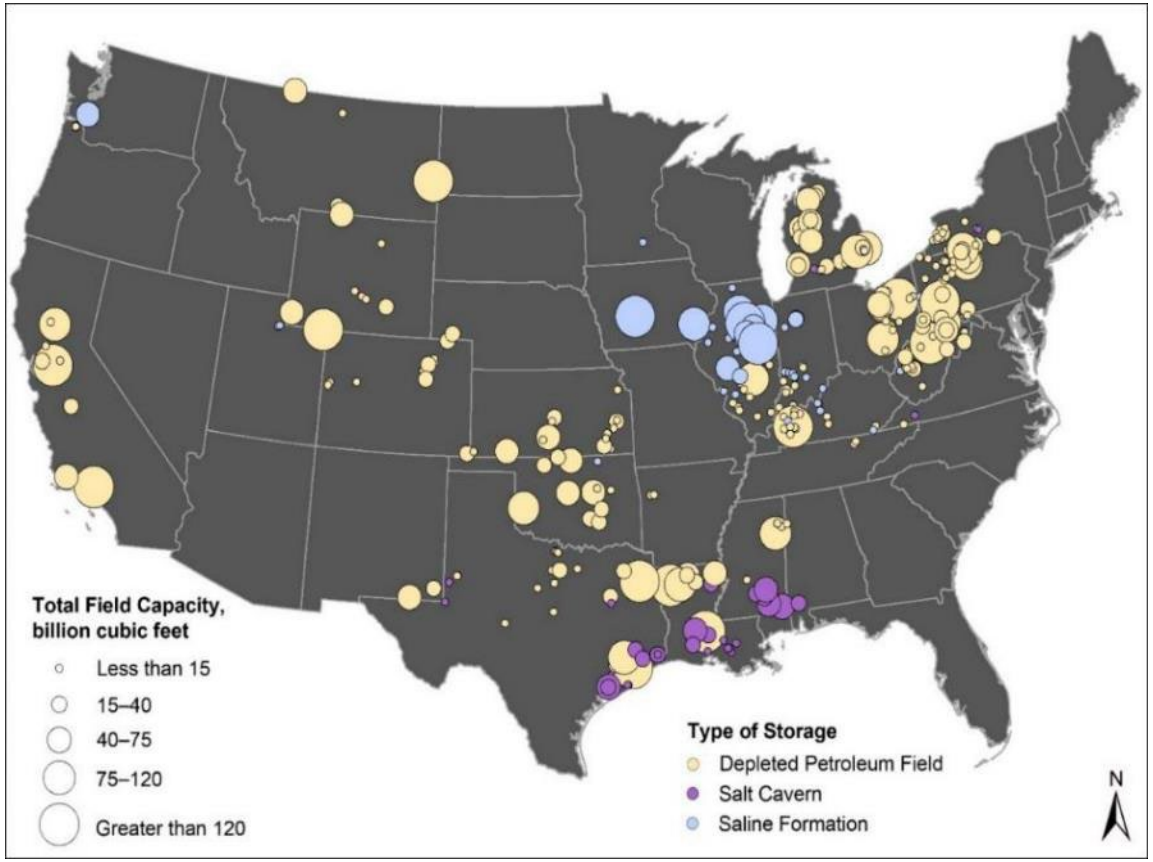
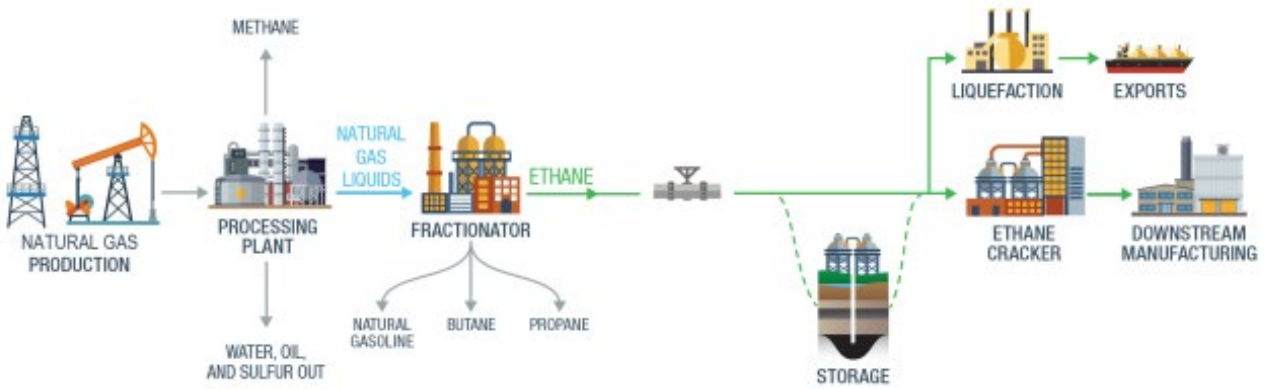
GAS STORAGE

- 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.
- Engineered salt caverns are an integrated element in the petrochemical process.
- NGL (natural gas liquid) hubs are coincident with oil- and gas-producing regions or areas where export capability exists.

Energy Information Administration, 2020



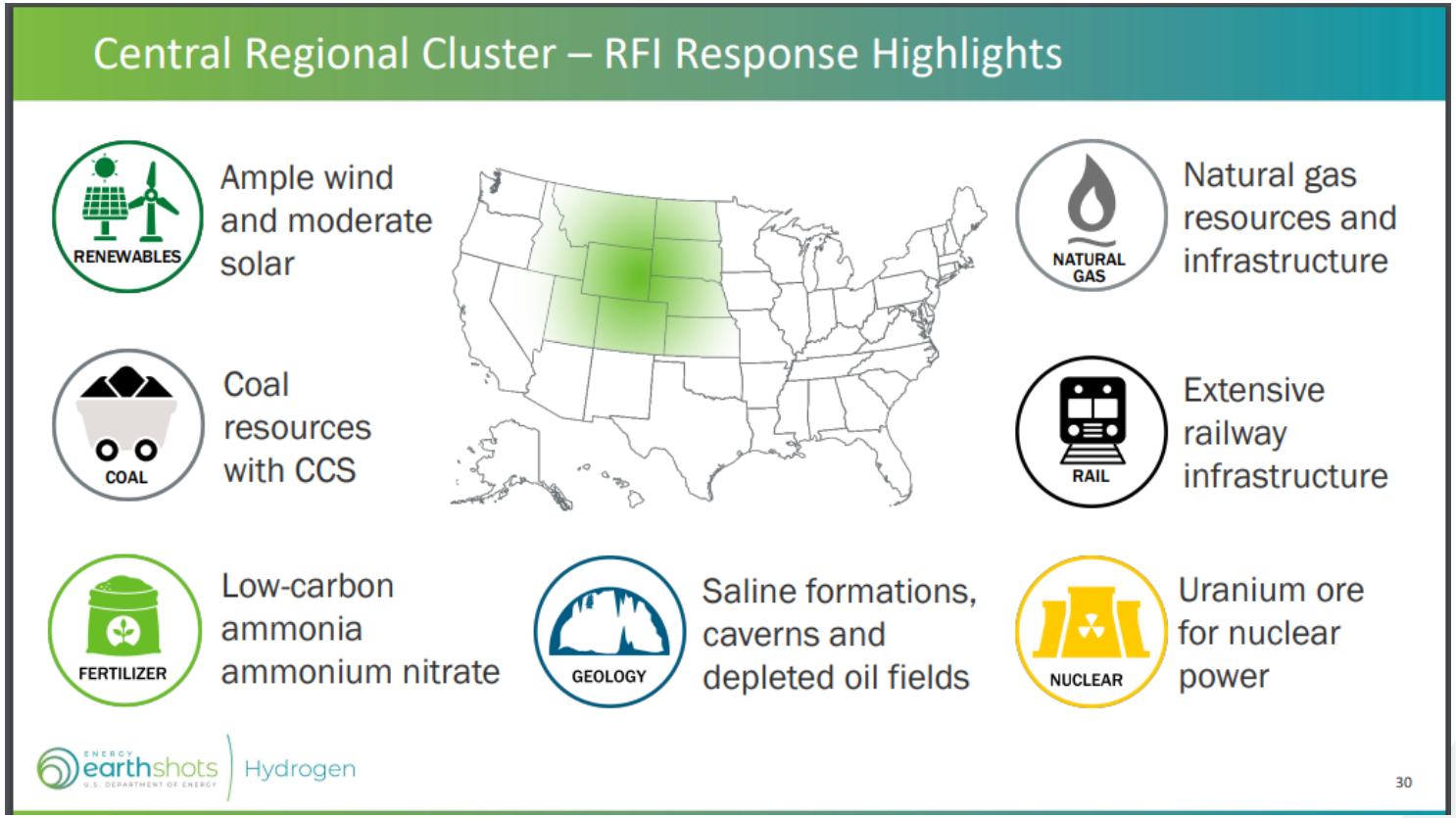


U.S. Department of Energy, 2018

NORTH DAKOTA INNOVATION

The U.S. government is investing billions of dollars into hydrogen research, technology development, and deployment through the Bipartisan Infrastructure Bill.
Salt cavern storage is a necessary operational element!

- North Dakota's leadership has a vision of growth through innovation that precedes this investment.
- North Dakota is committed to investment into energy research, technology, and deployment.
- North Dakota has a demonstrated history of responsibly managing six of the seven topic areas noted in the U.S. Department of Energy's (DOE's) Central Region Cluster concept.
- North Dakota has a long-standing commitment to sustainable development.
- North Dakota has Class VI primacy and permitted carbon capture and storage (CCS) projects!
- North Dakota has investments into depleted oil and gas and saline formation potential for hydrogen and/or hydrocarbon product storage.
- North Dakota is invested in the development of hydrogen hubs for commercial development opportunities.
- North Dakota is invested in preliminary study for engineered salt cavern and saline potential (2020).



DOE Update on Hydrogen Shot, RFI Results, and Summary of Hydrogen Provisions in the Bipartisan Infrastructure Law 8/21

2021 SALT CAVERN STORAGE PROJECT

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.”

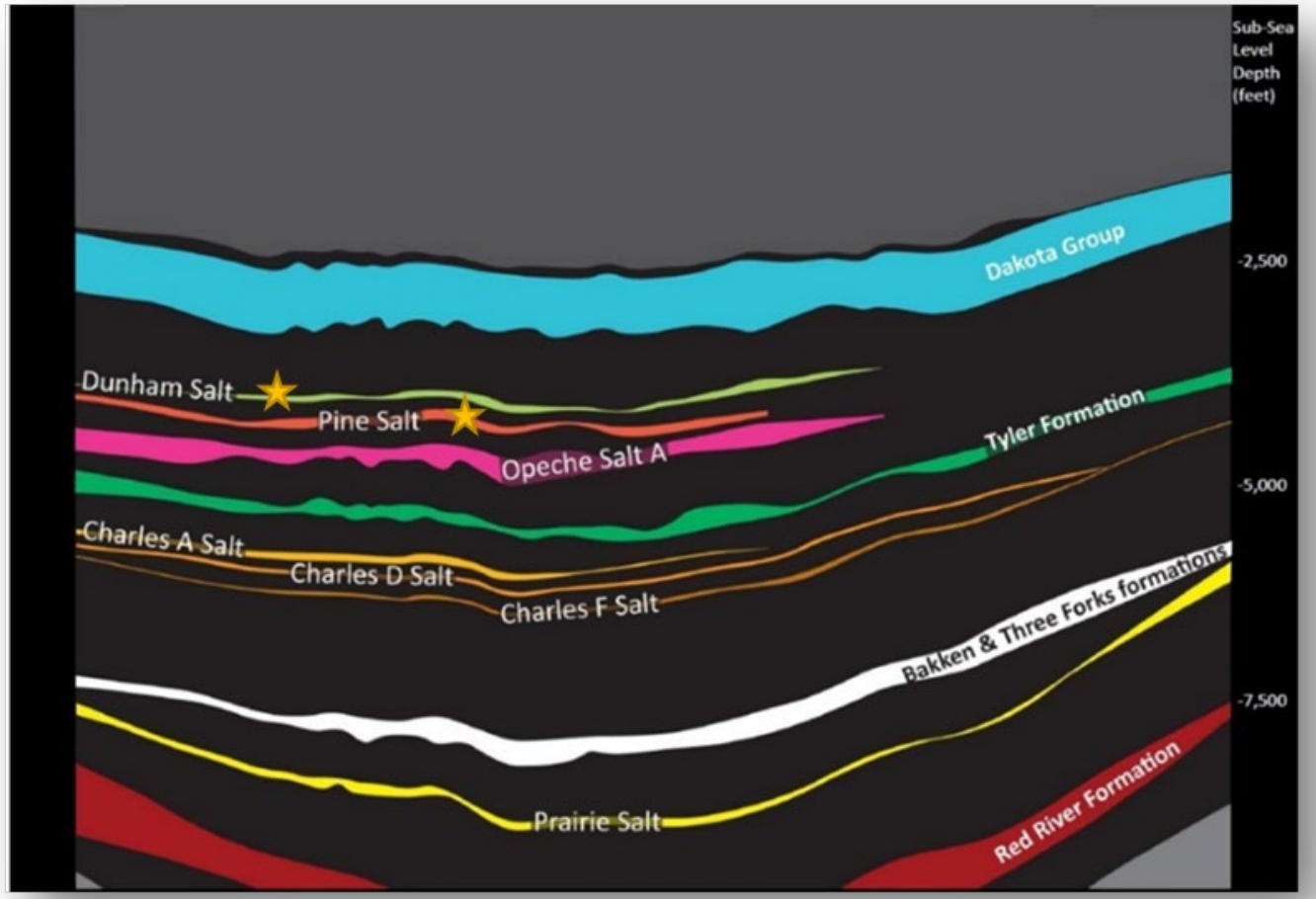
Project Goal: *To use field-, laboratory-, and modeling-based efforts to validate the depth, thickness, and geologic/ geomechanical suitability of North Dakota salt formations for subsurface gas or liquid storage cavern development.*

Anticipated Results

A final report that includes:

- 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).

CHARACTERIZATION OF SALT FORMATIONS

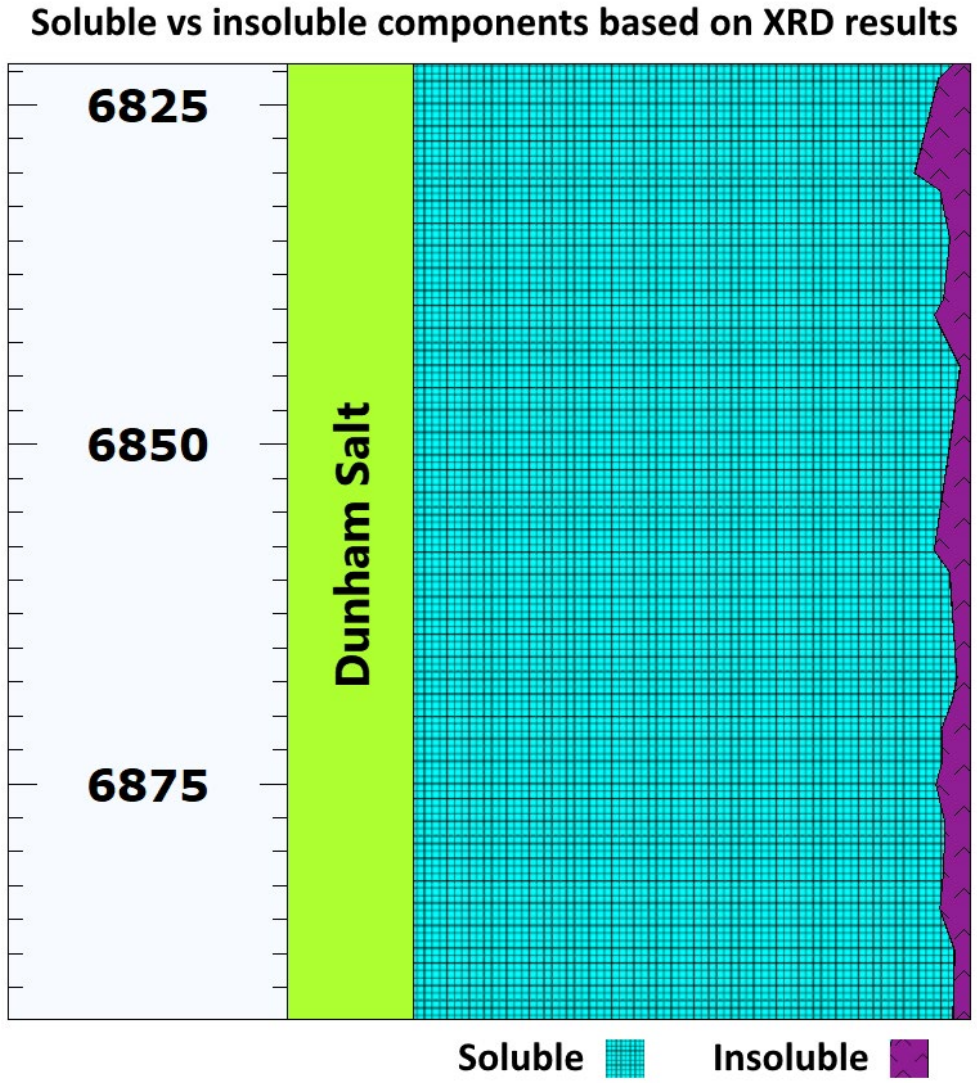
- A significant goal of the research was to drill a characterization well to investigate North Dakota's salt members.
- Core and logs were collected from target salt formations.
- Preliminary results indicate that North Dakota salts have thicknesses and composition similar to other areas in North America where caverns are developed in bedded salts.

Salt cavern storage could support petrochemical and energy industries.

DUNHAM SALT COMPOSITION

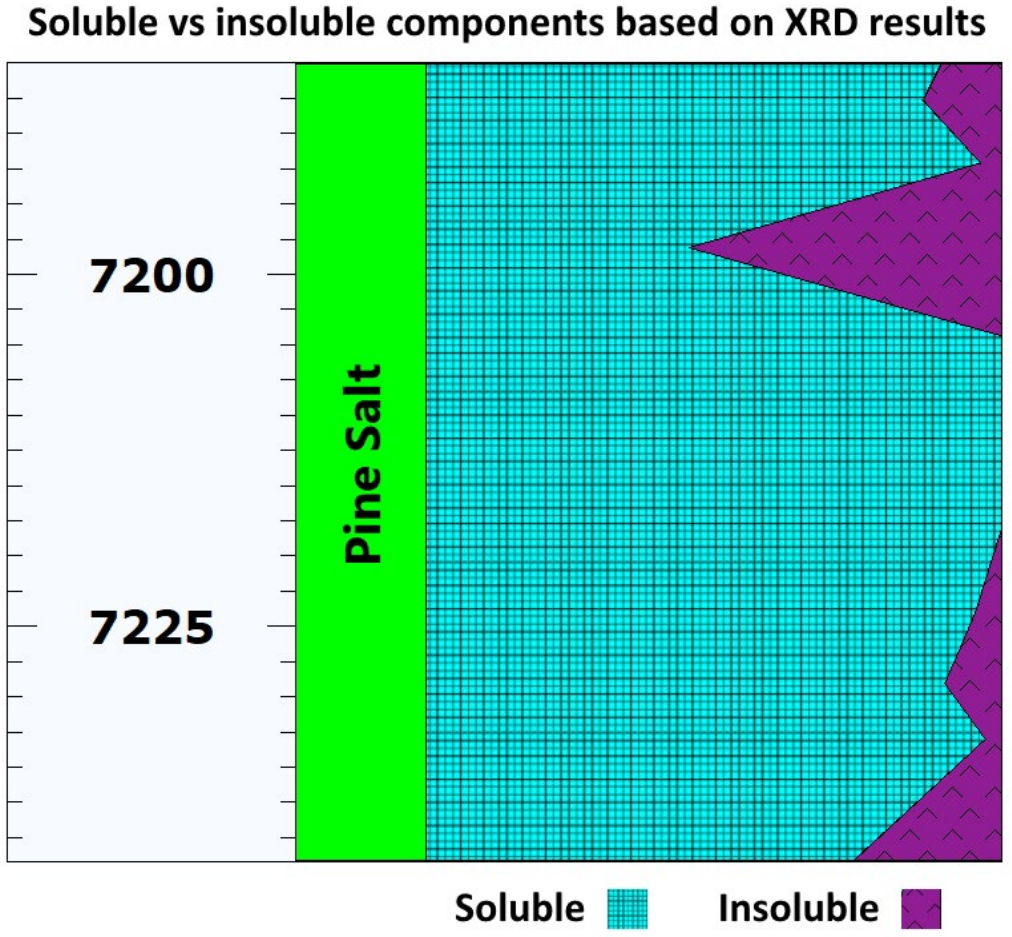
Halite 1 Results

- Dunham salt comprises nearly 100% halite:
  - Halite is soluble in water, a necessary factor for creating engineered salt caverns.
- Minor insoluble impurities exist:
  - This is common to bedded salt formations where caverns have successfully been developed and operated.
- This is encouraging for North Dakota salt cavern development near the Halite 1 site.
- Additional locations of thicker salt accumulation are under evaluation.



PINE SALT COMPOSITION

- Two soluble salts are prevalent in the Pine Member: halite and thenardite (sodium sulfate):
  - Thenardite is soluble in water but needs further evaluation to determine mechanical stability during cavern operation.
  - The EERC is currently investigating other areas in North Dakota to determine if thenardite persists or if halite becomes predominant in the Pine Member.
  - Because the Pine reaches ~300 feet in net salt thickness near Dickinson, further investigation through drilling and core collection is warranted.

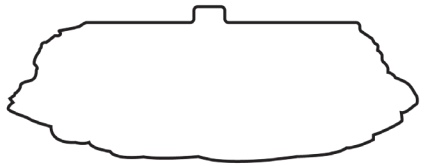


POTENTIAL FOR CAVERN DEVELOPMENT AND USE

Dunham Salt Core

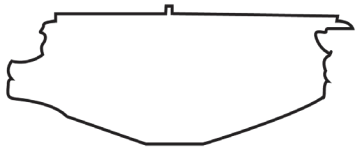
Pine Salt Core

Arizona



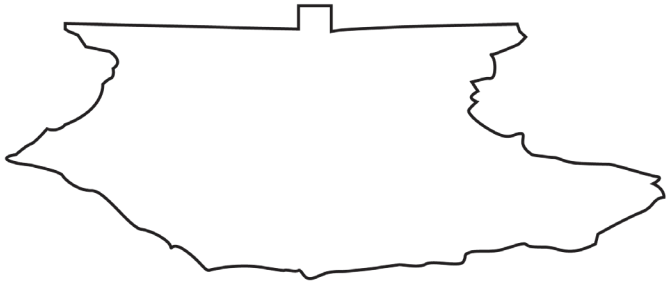
Average Depth 900 ft
Average Height 60 ft
Average Width 160 ft

Kansas



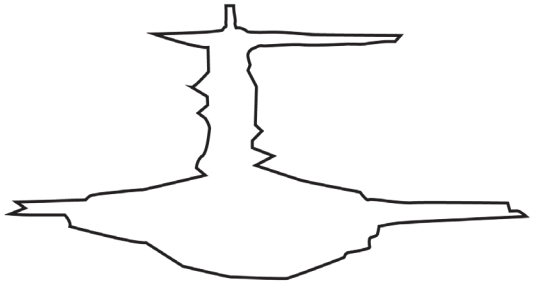
Average Depth 700 ft
Average Height 60 ft
Average Width 150 ft

Saskatchewan



Average Depth 5000 ft
Average Height 120 ft
Average Width 240 ft

Alberta



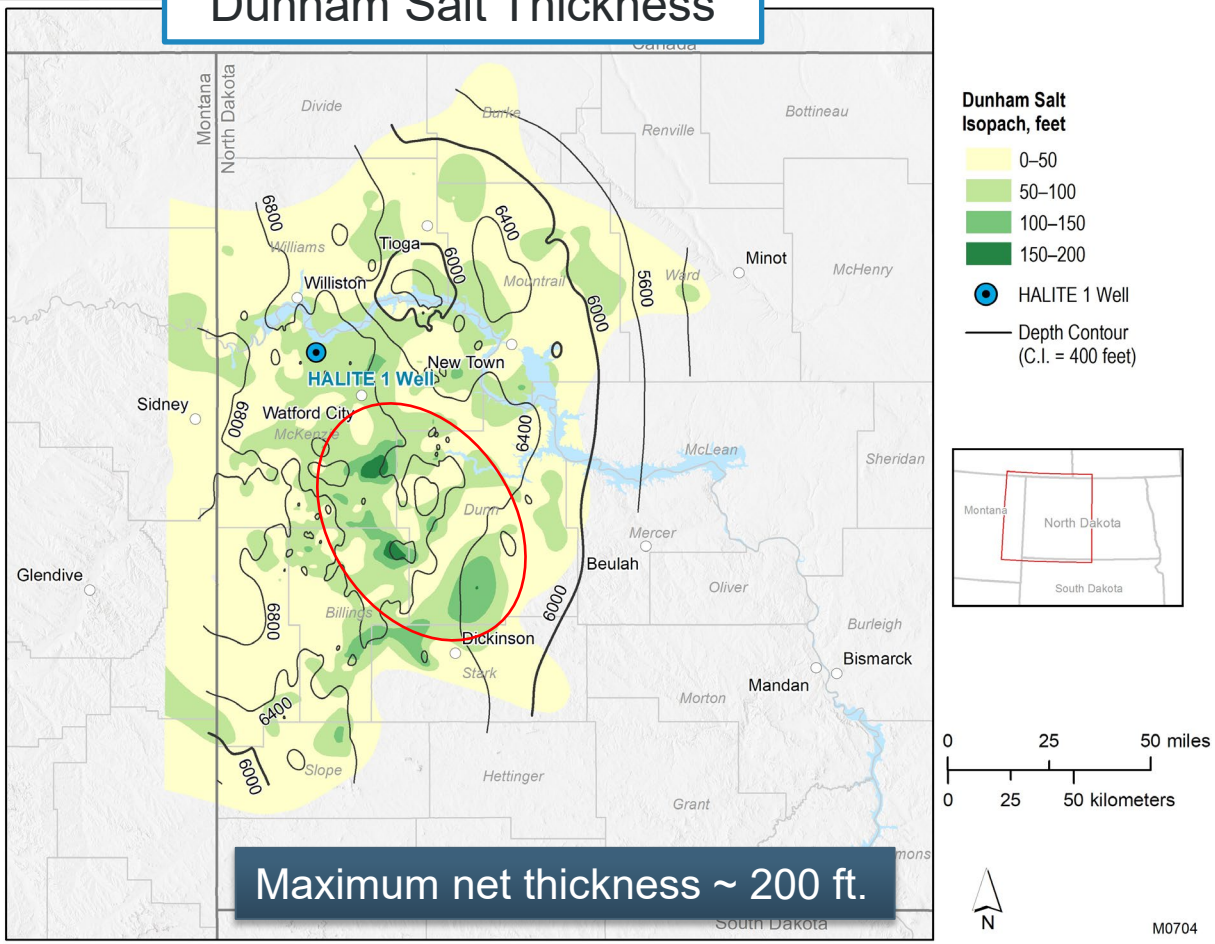
Average Depth 5700 ft
Average Height 120 ft
Average Width 210 ft

Preliminary results indicate that North Dakota salt members are thick enough and have the right composition to develop similar-sized caverns.

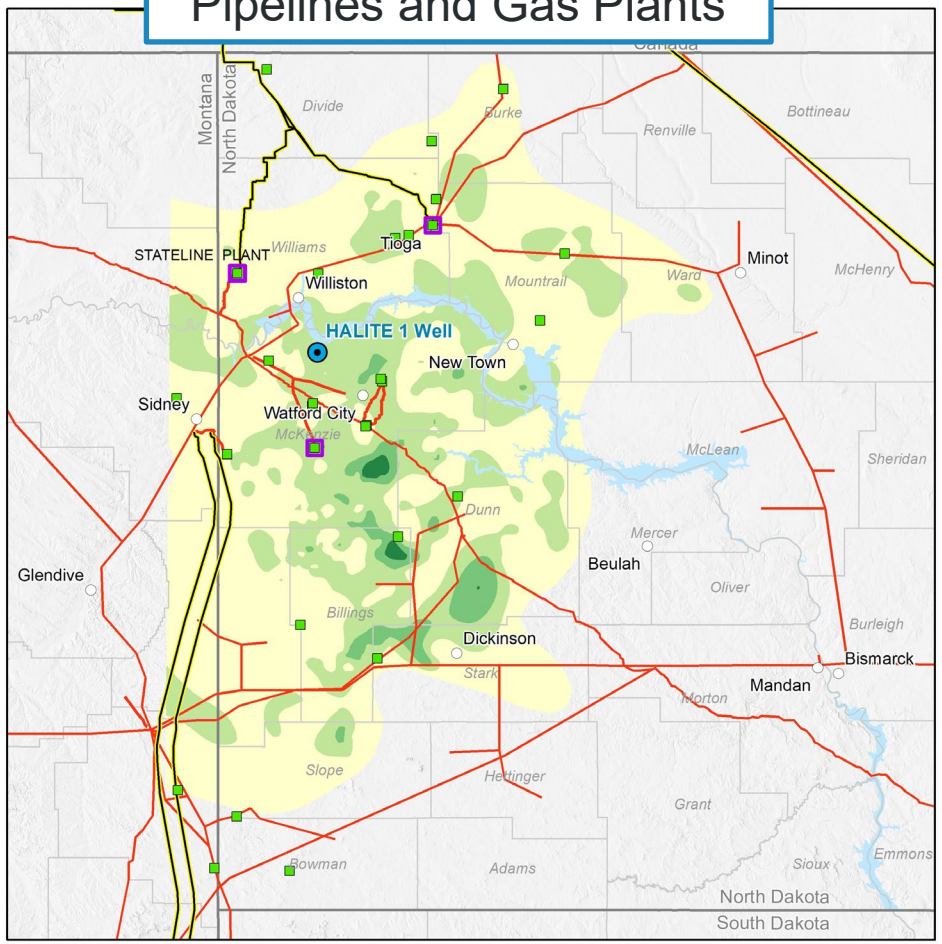
- *Caverns have been developed in bedded salts with similar properties to North Dakota's.*
- *The Lotsberg Salt in Alberta is the most comparable.*

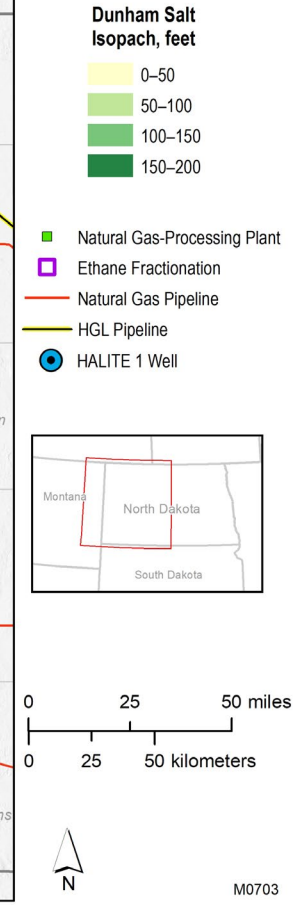
ALTERNATE LOCATION SCREENING: DUNHAM

Dunham Salt Thickness



Pipelines and Gas Plants

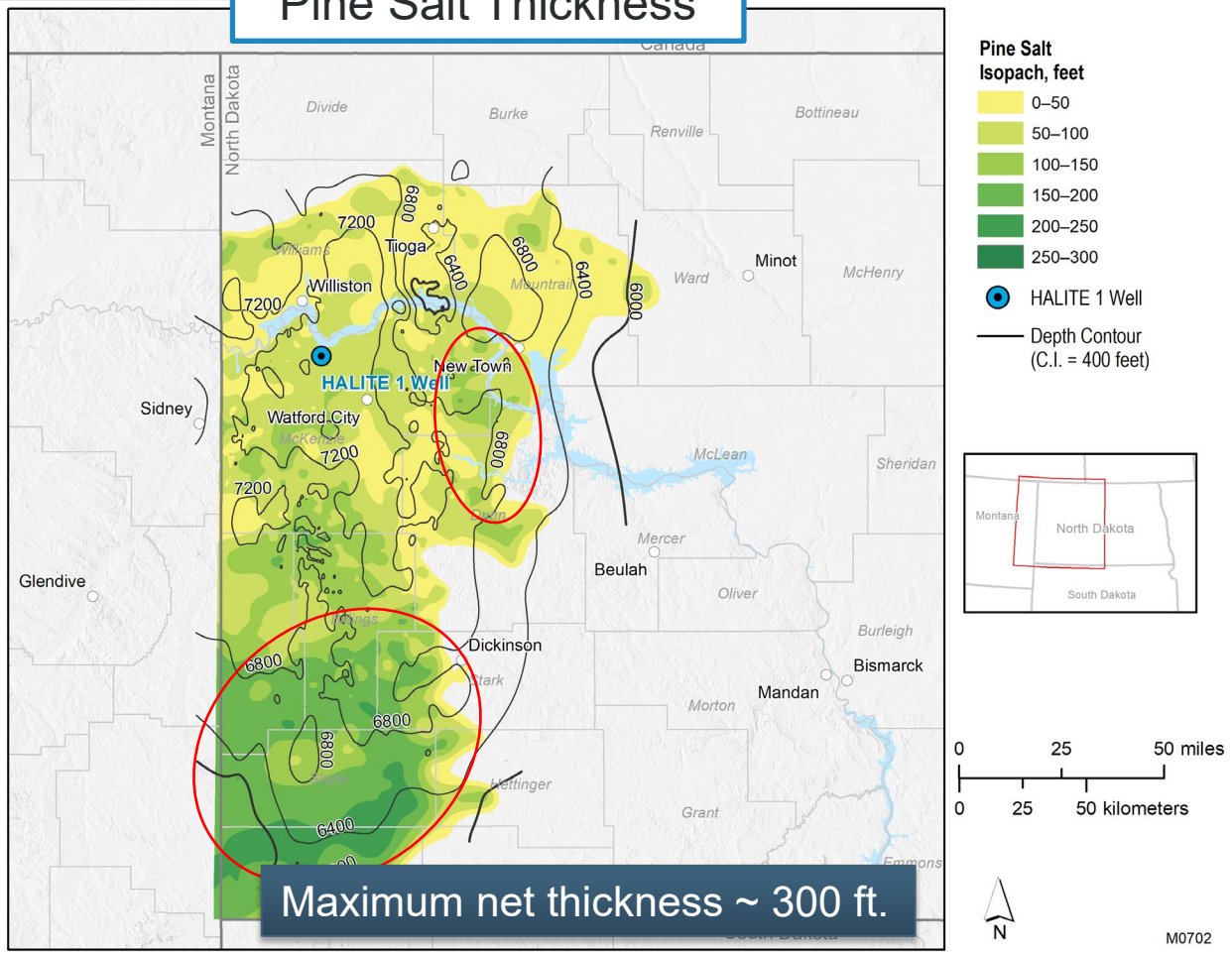




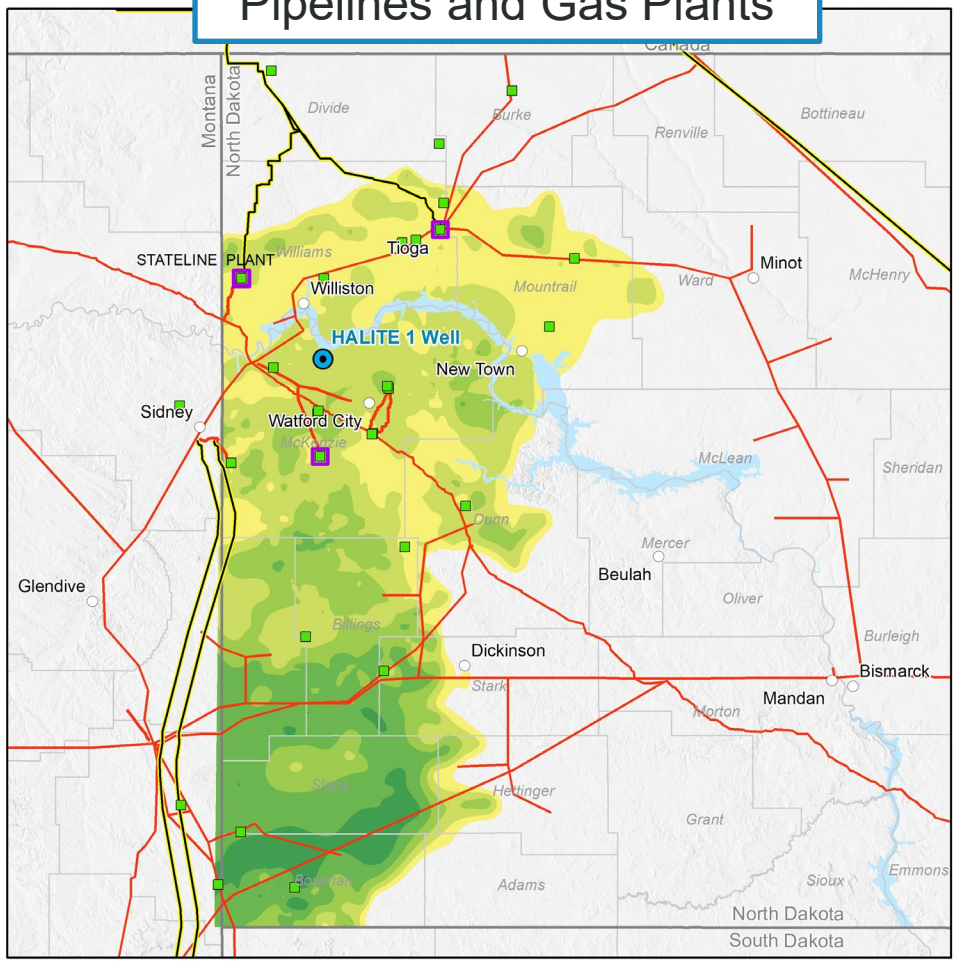
Additional screening will be focused within areas that likely have thicker accumulations of salt.

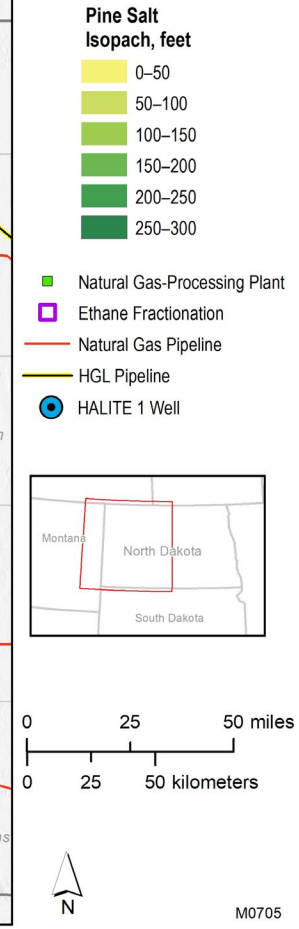
ALTERNATE LOCATION SCREENING: PINE

Pine Salt Thickness



Pipelines and Gas Plants

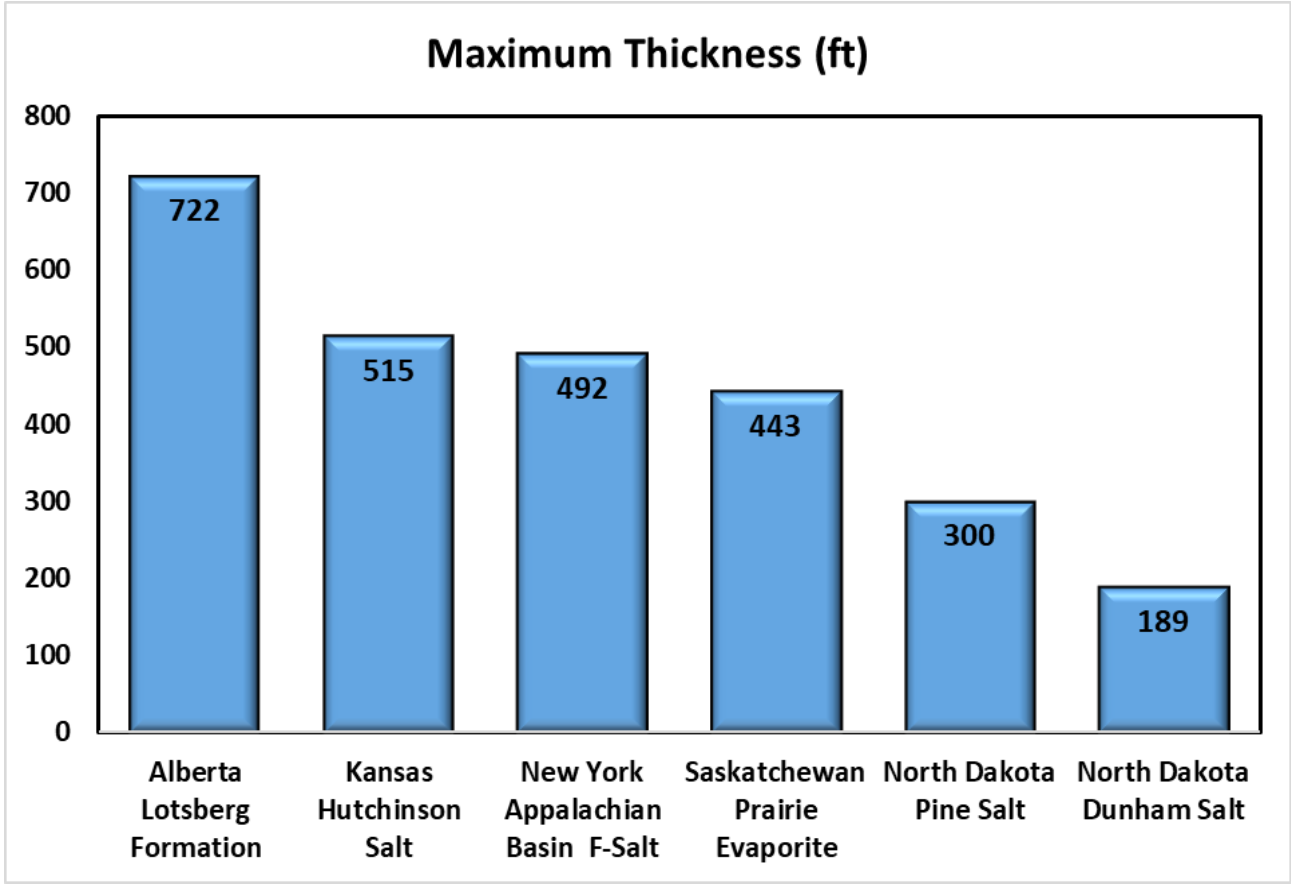




Additional screening will be focused within areas that likely have thicker accumulations of salt.

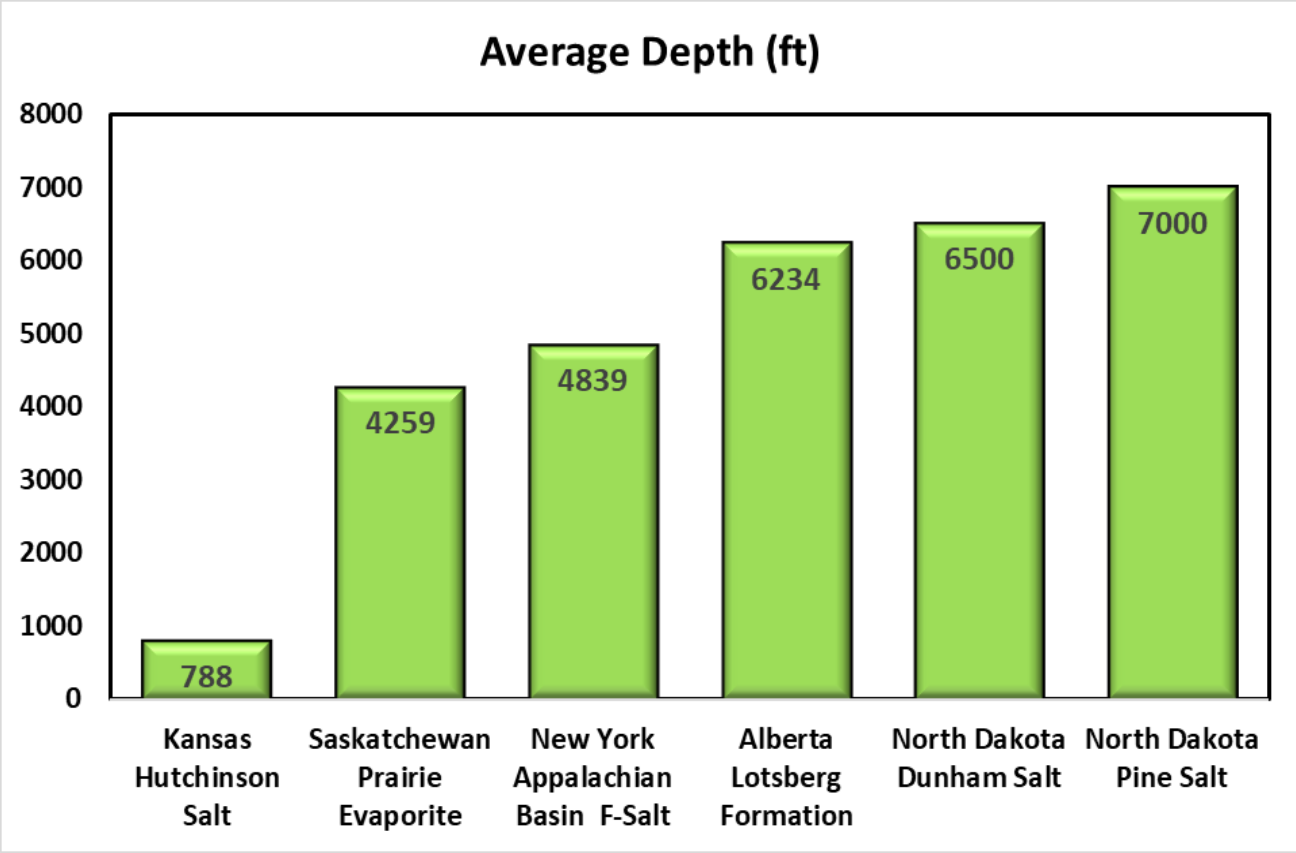
COMPARISON OF NORTH DAKOTA SALTS TO OTHER SALTS

Compared to other bedded salts where caverns are operated in North America, North Dakota salts are thinner.

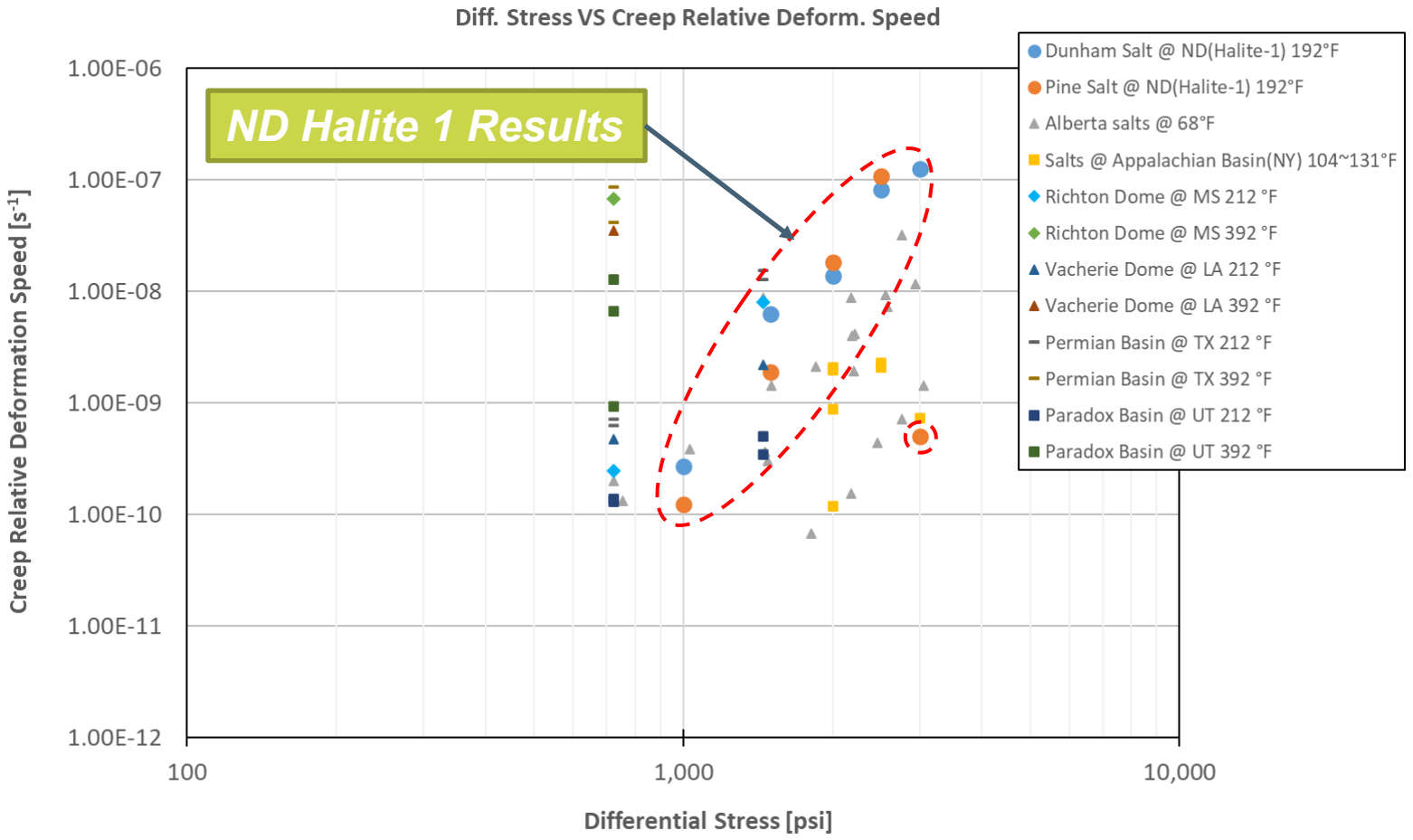


COMPARISON OF NORTH DAKOTA SALTS TO OTHER SALTS

- The top depth of the Dunham and Pine Salts in North Dakota are generally deeper than the other salts in this comparison:
  - The average depth of the Dunham and Pine Salts is comparable to the Alberta Lotsberg Formation.
  - Natural gas and liquid product storage caverns have been constructed and are operated within the Lotsberg Formation in Alberta (Research Report No. 2003-5-SMRI).
  - Rock salt in the Lotsberg Formation is mainly composed of coarse crystalline, clear halite, comparable to Dunham Salt.



CREEP PROPERTIES COMPARISON



- Salt creep properties define long-term cavern stability under operational conditions.
- Generally, salt creep *deforms faster* under *higher temperature* or *higher load difference*.
- Maintaining small load difference during operation is an engineering control to slow cavern closure.

Dunham Salt and Pine Salt of Halite 1 show similar creep properties to other regions, even if testing temperature is higher than Alberta and New York samples.

SUMMARY

- Halite 1 was drilled, cored, and logged to determine the quality of salt encountered and feasibility of cavern development and operation.
  - 60’ of Dunham and 60’ of Pine Salts were retrieved. This is the total salt thickness at this location.
  - Core testing is complete.

- Cavern design and operational stability modeling are ongoing at the Halite 1 site.

- Interpretations are ongoing, but preliminary results show:
  - Dunham Salts at Halite 1 have crystal size and depth similar to currently operated caverns in Alberta.
  - Mechanical properties (creep) are considered “fast creeping” compared to other locations, primarily due to depth.
  - Dunham Salt is nearly 100% halite (good for cavern development and operation)
  - Pine Salt has significant halite present, but additional soluble impurities exist and are under evaluation.
- Additional sites with thick salt accumulations (net 300’) in the Williston Basin are under evaluation to determine:
  - Salt quality (impurities)
  - Net and gross salt thickness
  - Cavern size and mechanical stability under different operational constraints
  - Product storage potential

GUIDANCE

- Cavern development and operation in North Dakota have been shown to be feasible through the Dakota Salt and Chemical Company Operation near Williston, North Dakota (1960s).
- A rule of thumb for cavern dimensions, height to diameter, is approximately 1 to 2.
- Caverns can be engineered to suit the geological constraint presented by bedded salts. ***Height, width, shape?***
- Cavern geometry is a function of operational considerations for product usage (i.e. seasonal heating/cooling, offtake capacity, industrial process needs etc.). ***How much product do you want to store and how quickly do you need to produce it?***
- Preliminary results suggest that the Dunham Salt near the Halite 1 site has properties similar to bedded salts where commercial development and operation have been ongoing for decades. ***Alberta, Saskatchewan, Europe.***
- The Pine Salt at Halite 1 has a soluble mineral that is being investigated to determine its impact on cavern development and operation.
  - This needs to be completed before recommending cavern development in the Pine near Halite 1 (June 2023).
- Investigation of areas in North Dakota where salt accumulations are thicker need to be completed (June 2023) prior to making recommendations for statewide commercial development.
  - Current modeling and simulation work based on the results of Halite 1 give confidence that the mineral, halite, and halite with impurities can be distinguished through log-based evaluation.
  - Completion of this current evaluation will allow for understanding the potential for cavern development at sites other than the Halite 1 well site.
- Liquid and gas cavern storage can be accomplished on a reduced footprint.
  - Deviated drilling reduces surficial well spacing and aerial extent needed for multi-cavern development if needed.
  - Knowledge from existing cavern development and operation allows for efficient design of surface facilities
  - Gas storage can be operated without surficial brine ponds, but the lifespan of the cavern may be compromised.

RECOMMENDATIONS

- Fund a staged project to support development of an engineered solution mined salt cavern to advance research knowledge gained from drilling, coring and testing the Halite 1 well (EERC, 2021/2023).The following is recommended.
    1. Select a location in the Dunham or Pine Salt of the Williston Basin that has geologic properties that correlate to the data collected from Halite 1.
    2. Drill, core, log and test the salt member to confirm predicted characterization and site selection criteria (depth, thickness, impurity content).
    3. Test collected core, perform geomechanical modeling and simulation at this site.
    4. Based on the findings of these additionally collected data, design and develop the site for engineered microcaverns (estimated 40” in height and 160” in diameter) to inform the development of full-scale caverns for liquid- or gas-phase product storage in North Dakota.

- These proposed recommendations will provide significant evidence for proceeding with commercial development in the state and support new markets, increased liquid and gas production with offtake storage capacity, and the fundamental research for future hub development opportunities in the state.