SUMMIT CARBON SOLUTION PIPELINE PROJECT

GULF PROJECT NUMBER: 1927

# FROST HEAVE STUDY

GULF INTERSTATE ENGINEERING
Houston, Texas F-2830

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# 1 PURPOSE

The purpose of this Frost Heave Study is to address Summit Carbon Solutions Pipeline Project objectives involving pipeline integrity when installing and operating pipelines in regions where frozen soil and frost depths may require additional consideration.

# 2 PROJECT DESCRIPTION AND SCOPE OF STUDY

Summit Carbon Solutions (SCS) plans to develop a new interstate $CO_2$ capture, transportation, and sequestration project. The Project will capture $CO_2$ from multiple sources throughout Iowa, Minnesota, Nebraska, South Dakota, and North Dakota and deliver the $CO_2$ to injection sites in North Dakota for permanent geological sequestration.

The main objectives of this Study are to assess potential impacts to the proposed pipeline from permafrost and frost heave across the five-state footprint.

# 3 PERMAFROST POTENTIAL IMPACTS

Permafrost is rock or soil that remains completely frozen for at least two straight years. Areas shaded in blue in Figure 3-1 are underlain by permafrost. As Figure 3-1 shows, the SCS pipeline system does not traverse any areas underlain by either continuous or discontinuous permafrost.

Therefore, permafrost is not an issue that needs to be addressed by this project and will not be discussed further in this study.

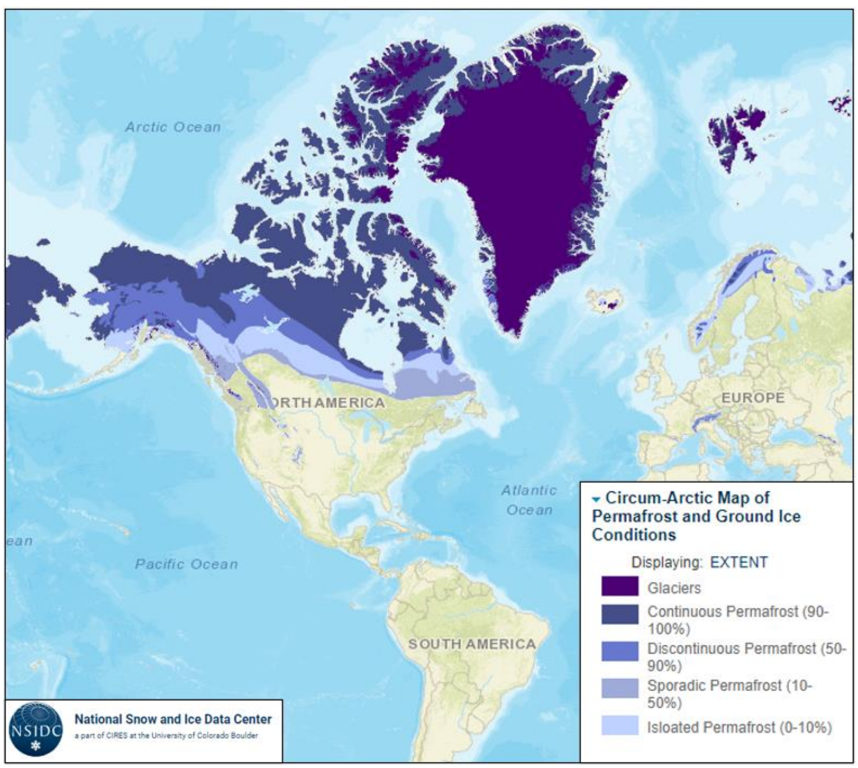


Figure 3-1: Arctic Map of Permafrost and Ground Ice Conditions

# 4 FROST HEAVE

## 4.1 Description

Frost heave is the result of the formation of ice lenses by segregation of water from the soil as the ground freezes[1]. Ice lenses are lens-shaped masses of almost pure ice that form in frozen soil or rock. Lens formation takes place at, or a short distance behind, the freezing front at any depth where conditions are favorable and continues until those conditions change.[2] Lens growth may be sustained by the addition of groundwater drawn from warmer zones below the freezing front. The amount of vertical displacement (heave) is roughly equal to the combined thicknesses of the underlying ice lenses. This results in greater displacement at the surface when compared to areas of greater depth.

## 4.2 Frost Heave Conditions

Three conditions must be met to create the possibility of frost heave to the extent that it would threaten the pipelines integrity:

1. The soil must contain a significant amount of silt (i.e. Silty Clay, Clayey Silt, Sandy Silt, Silty Sand, or Silt), to promote upward groundwater movement, via capillary action, to the freezing front;
2. There must be a source of groundwater near (immediately below) the freezing front; and
3. Soil freezing and ice lensing both need to occur at a depth below the bottom of the pipe.

If any of the three conditions listed above are not met, frost heave should not occur.

## 4.3 Frost Penetration

Several factors influence seasonal frost penetration depth:

1. Vegetation cover (vegetation tends to insulate and retard frost penetration);
2. Snow cover (snow cover tends to insulate and retard frost penetration);
3. The number of degree days below freezing;
4. Soil grain size (coarse grained soils are more conductive, allowing greater frost penetration than fine grained soils); and
5. Moisture content (the higher the moisture content, the more time it takes for a given soil to freeze).

The United States Department of Agriculture records soil temperature at various depths at monitoring stations located throughout the US[3]. Five USDA locations spread throughout the project footprint were utilized to gather ground temperature data. Each location was reviewed, but the Mandan location was selected for this report as it is the furthest north and most likely to see the greatest frost depth.

This station records soil moisture and temperature to a depth of 40-inches.

Figure 4-2 depicts daily soil temperature at a depth of 40-inches over the last decade. As the graph shows, the soil approaches freezing conditions in most years but does not drop below the freezing point for any extended duration.

Figure 4-1: USDA's Mandan Station

[1] Taber,S.,1929,Frost heaving: Journal of Geology, v. 37, p. 428-461.
[2] Manz, L., July 2011, Frost Heave, Geo News, p. 18-24
[3] https://www.nrcs.usda.gov/resources/data-and-reports/soil-climate-analysis-network

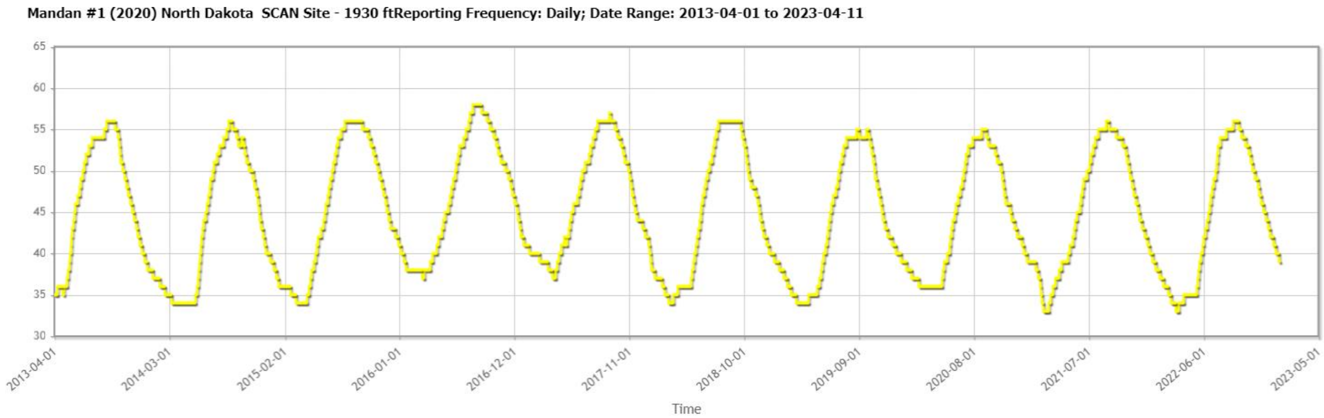


Figure 4-2: Soil Temperature at 40-inches Depth During Last Decade

# 5 Frost Heave Considerations

## 5.1 Soil Types and Ground Water

Based on the USDA Soil Survey Geographic Database, there are soils that could be classified as frost susceptible where 10% or more particles pass through a No. 200 sieve[4].

Ground water heights can range significantly across the pipeline route and can also fluctuate seasonally. Geotechnical reports reviewed show ground water ranging from 6.5 to over 100 feet below ground surface[5].

## 5.2 Pipeline Depth of Cover

SCS will be installing the pipelines with a minimum depth of cover of 48 inches from top of pipe. The bottom of the pipelines will range from 51 inches to 72 inches minimum dependent upon the diameter of the pipe installed. This depth of cover significantly reduces the risk of multiple underlying ice lenses forming beneath the pipeline and resulting frost heave. As shown by the USDA monitoring station data, the historical data for each of the five monitoring stations across the project footprint shows that the soil temperatures necessary to create frost to a depth greater than 51 inches is not probable. At the Mandan location, which is the most likely to see the greatest frost depths, the soil temperature nears the freezing point at 40 inches of soil depth over some of the years reviewed but not for extended durations that would indicate frost penetration beyond 51 inches.

## 5.3 Construction Practices and Operating History

While vintage pipelines operating in similar areas and conditions have a proven track record of reliability, the implementation of modern pipeline materials, welding practice and installation procedures only further increase the starting integrity of modern pipeline systems. SCS pipe materials all meet specific ductility requirements, and the installed pipeline welds will be fully evaluated by non-destructive testing. Due to the advancement of material testing and construction requirements, the ability of a pipeline to withstand deformation (plastic strain) due to external loads such as frost heave is increased due to better ductility of the pipe material and better welding practices.

# 6 Conclusion

For frost heave to occur three conditions must be met. The soil needs to contain a significant amount of silt, groundwater needs to be present, and the depth of freezing must occur below the pipe. Due to the depth of

[4] https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
[5] Professional Service Industries, Inc., Geotechnical Data Report, PSI Project No. 599103-1

burial alone, the likelihood of frost heave on any buried portion of the SCS system is highly unlikely. Where conditions may allow frost to reach beyond 51 inches, the likelihood of the soil being susceptible to frost heave (silt) is also unlikely given that frost penetration occurs more slowly with fine-grained soils of high moisture content.

Water table depths vary from location to location across the pipeline from over a hundred feet below the pipe to depths above assumed trench bottom. The likelihood of frost depths significantly beyond 51 inches with a water table slightly below is probabilistically small. In a situation where frost could reach beyond 51 inches, the amount of movement expected at such a depth would be very small given the relation to the thickness of any underlying ice lenses and the unconstrained expansion that would occur above.

Today’s materials and construction practices have evolved including the introduction of more ductile steels allowing greater allowable deformation (strain) due to external loads (frost heave) thus further preventing any likelihood of frost heave creating a pipeline integrity issue.