Appendix 2-1

Soil Temperature Calculations

Project Note

Date:	January 20, 2006
Subject:	Subsurface Soil Temperatures, Fairbanks – Wasilla Spur Line
From:	Mike Cox, P.E.
Company:	Michael Baker Jr., Inc.

Background

Michael Baker Jr (Baker) conducted a brief study to estimate the subsurface soil temperatures along the Department of Energy (DOE) Fairbanks to Wasilla Spur Line route. The intent of the spur line route is to deliver natural gas to South Central, Alaska from the large diameter Natural Gas pipeline connecting the North Slope of Alaska with Alberta Canada.

The scope of work did not include conducting field investigations to determine actual soil properties along the route. Analysis was conducted to provide soil temperatures "fit-for-purpose" of completing the preliminary/conceptual engineering study. *Temperatures provided in this project note should only be used as rough estimates as the variables that affect subsurface soil temperature can vary drastically from site to site.*

Purpose

Subsurface soil temperatures will be used in engineering studies and specifically developed models for the purpose of approximating the rate of heat transfer through the wall of the pipeline. This study will analyze the thermal interaction of the pipe and the surrounding soil. These thermal characteristics will aid in investigating the impact of pipeline operating temperatures on facility equipment at the various compressor stations along the route.

Baker is analyzing operating scenarios for both peak and minimum flow conditions. According to ENSTAR Natural Gas Company, these conditions coincide with the months of January (peak) and July (minimum) in South Central, Alaska. Soil temperatures were estimated at depths up to four feet below ground surface (bgs), in compliance with Alaska Department of Transportation (ADOT) pipeline burial regulations. Temperatures down to six feet bgs are shown graphically.

Procedures

Subsurface soil temperatures are dependant on many variables including the ambient air temperature, soil type(s), soil moisture content(s), vegetative type and thickness, snow coverage, ground elevation, slope aspect, wind etc. As an example, the Cantwell area will typically experience colder soil temperatures as compared with the Byers Lake area. This is primarily due to amount of snow that insulates the ground near Byers Lake as compared with the Cantwell area that is typically void of snow as a result of the increased amount of localized wind. Without conducting a geotechnical field investigation to identify these variables, including the installation and reading of thermistor strings, site specific subsurface soil temperatures are difficult to estimate accurately.

In General, our approach in estimating ground temperatures included generating temperature attenuation with depth curves, or whiplash curves, depicting the relationship between soil temperatures at various depths bgs. Graphs were generated using calculations to estimate the extreme ground temperature at a given depth of five different soil types. Selection of soil types were based on their apparent presence along the Fairbanks to Wasilla Spur Line route. The soil types included; gravel (GP/GW), poorly graded gravel with silt (GP-GM), sand (SP/SW), silty sand (SM) and silt (ML). Soil types and apparent locations were identified in the Denali Pipeline Project Environmental Assessment Report, dated November 1, 1993.

Soil temperatures at select depths were determined using guidance according to *Arctic Heat and Mass Transfer* by John P. Zarling. A brief description of how these curves were generated is described below.

Calculating Winter and Summer Ground Temperatures

The temperature attenuation curves at depth were generated using:

$$T_z = T_m \pm A_s \exp\left(-z/\sqrt{\alpha\, p/\pi}\right) + g\, z$$

Where,

T_z = Temperature, °F at depth z
A_s = Surface Temperature Amplitude, °F
A_s = ½ (Max Temp – Min Temp)
p = Period, 8766 hrs

T_m = Mean annual air temperature, °F
z = depth, ft bgs
α = Thermal Diffusivity, ft^2/hr
g = Thermal Gradient, 1.7°F per 100 feet

The thermal diffusivity for each type of soil under frozen, α_f, and unfrozen, α_u, conditions was calculated by:

$$\alpha = \frac{k}{\rho c}$$

Where,

α = Thermal diffusivity, ft^2/hr
ρ = Dry density, lb/ft^3

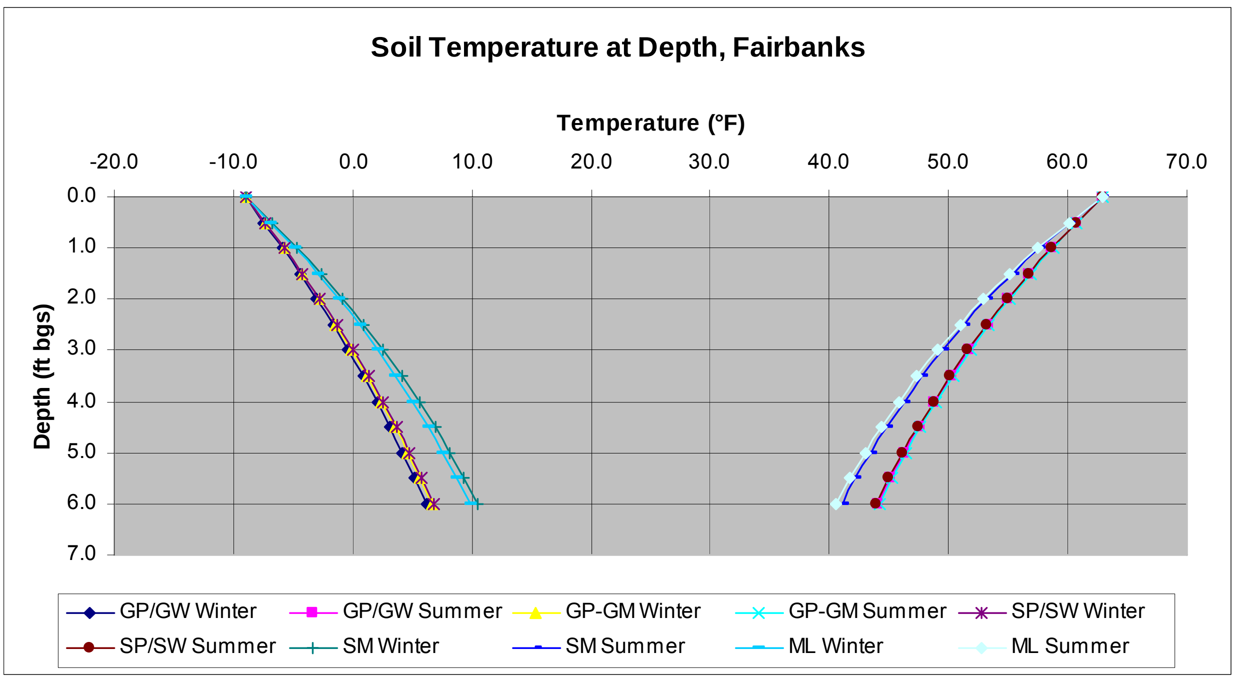
k = Thermal Conductivity, BTU/ft hr°F
c = Specific Heat, BTU/lb °F

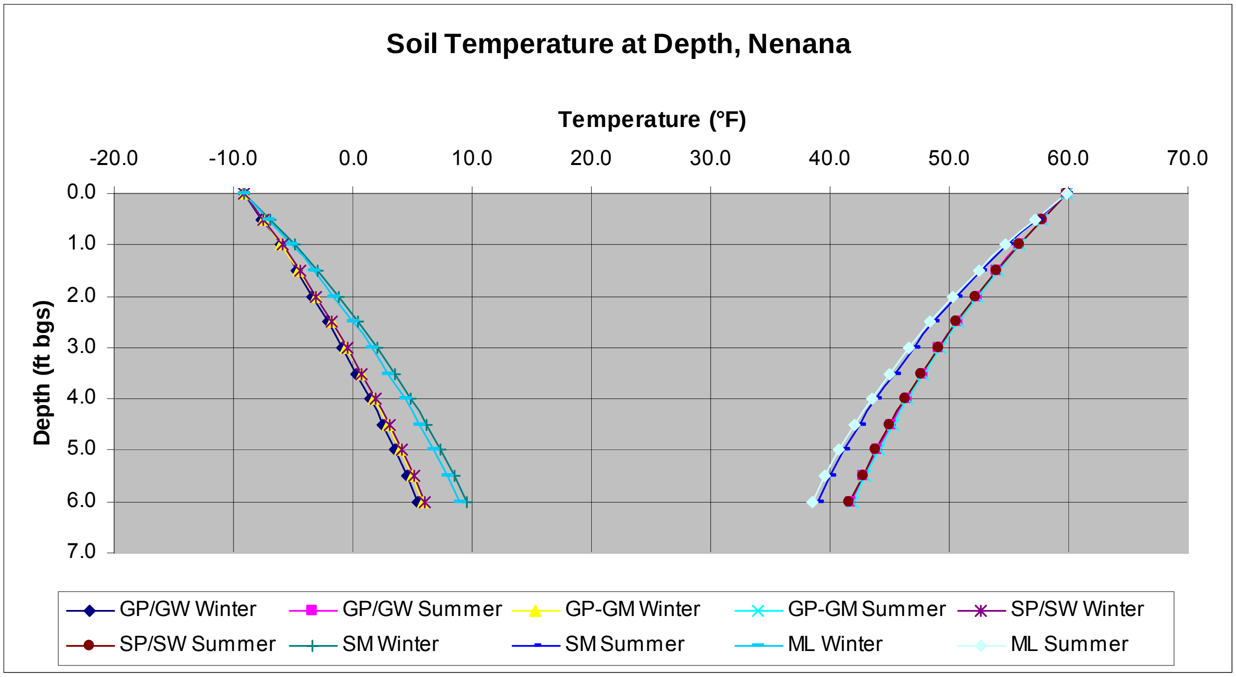
Soil properties used in the calculations represent the average value of the select soil type range. Actual conditions are expected to vary along the route within each soil type. Soil properties and the calculated thermal diffusivity for select soil types are presented in Table 1.

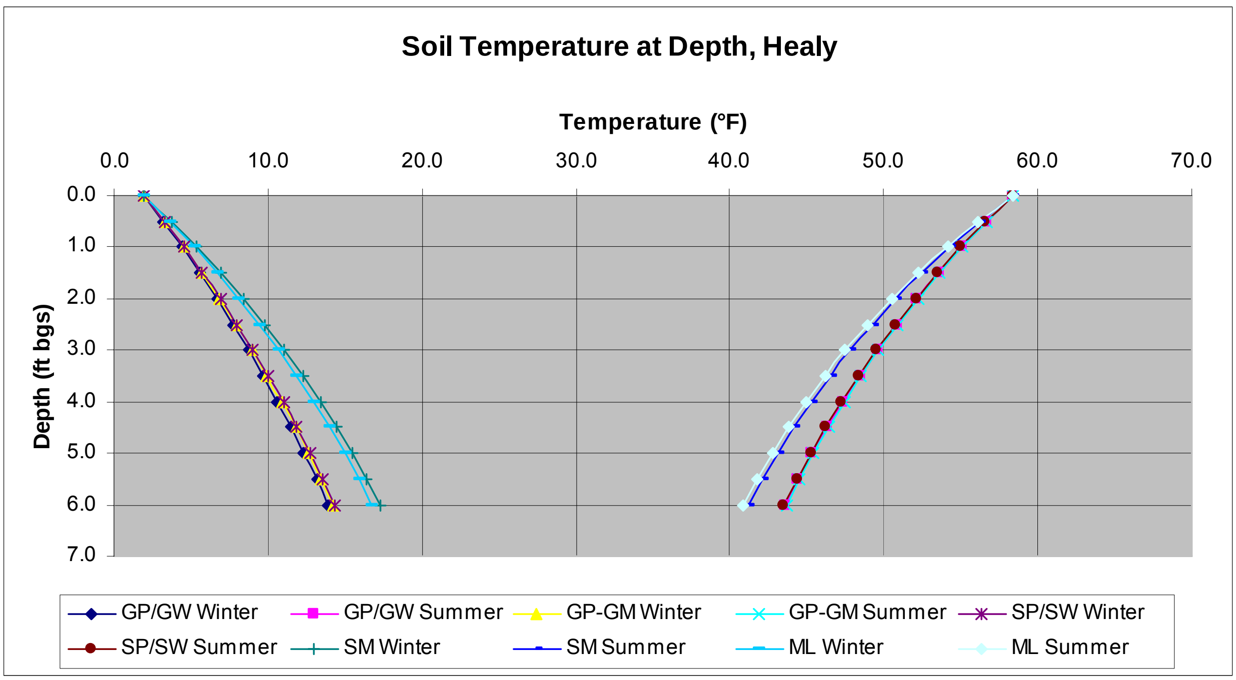
Table 1 – Whiplash Curve Parameters

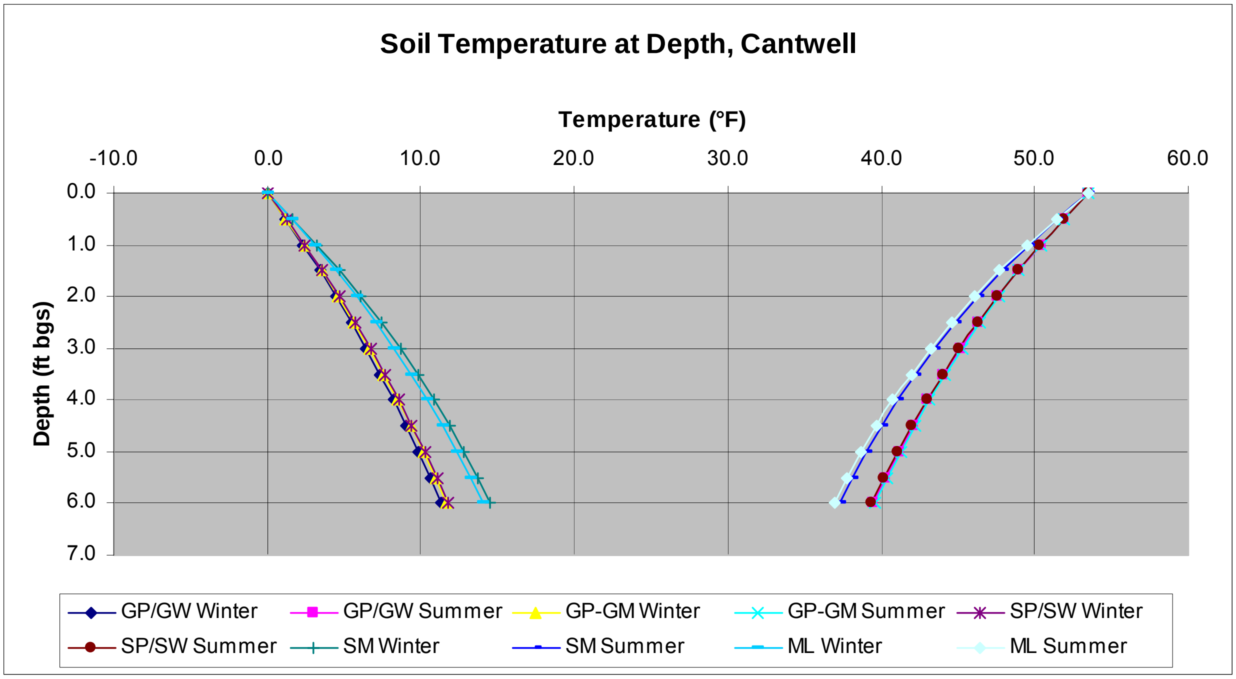
Ref 7, pg. 78		*Ref. 5, pg. 35-19*		*Ref. 3, p. 228*		*Ref. 3, p. 150-153*		Calculated Diffusivity, ft²/hr	
Soil Description	**Soil Type USCS**	Dry Density ρ,lb/ft³	Moisture ω, %	Specific Heat, BTU/lb °F		Thermal Conductivity, BTU/ft hr °F		Frozen	Unfrozen
				c_f	c_u	k_f	k_u	α_f	α_u
Gravel	**GP/GW**	125	11	0.43	0.58	2.33	1.67	0.0431	0.0231
Gravel with silt	**GP-GM**	120	11	0.42	0.53	2.00	1.50	0.0400	0.0236
Sand	**SP/SW**	115	12	0.41	0.54	1.83	1.42	0.0390	0.0226
Silty Sand	**SM**	117	13	0.43	0.61	1.08	1.04	0.0214	0.0146
Silt	**ML**	110	18	0.45	0.64	1.17	0.96	0.0236	0.0136

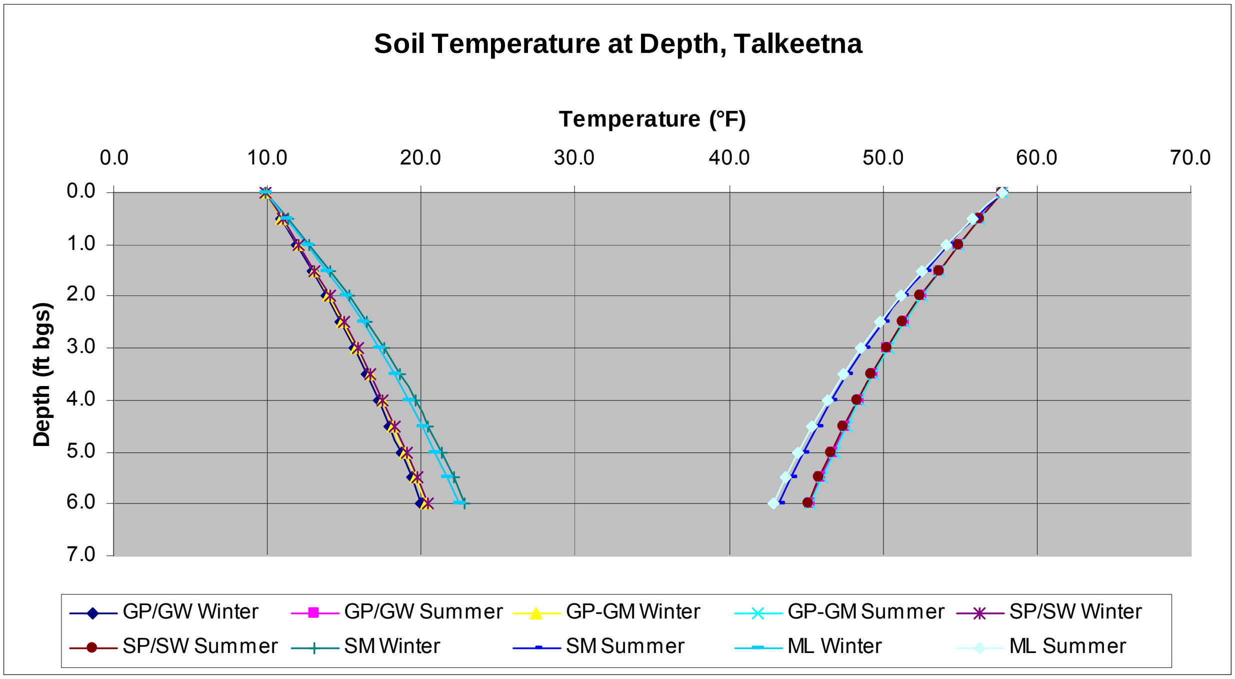
The following graphs show the calculated soil temperatures from 0 to 6 feet bgs at various locations along the Fairbanks to Wasilla Spur Line Route. Both maximum and minimum temperatures are presented graphically for five different soil types.

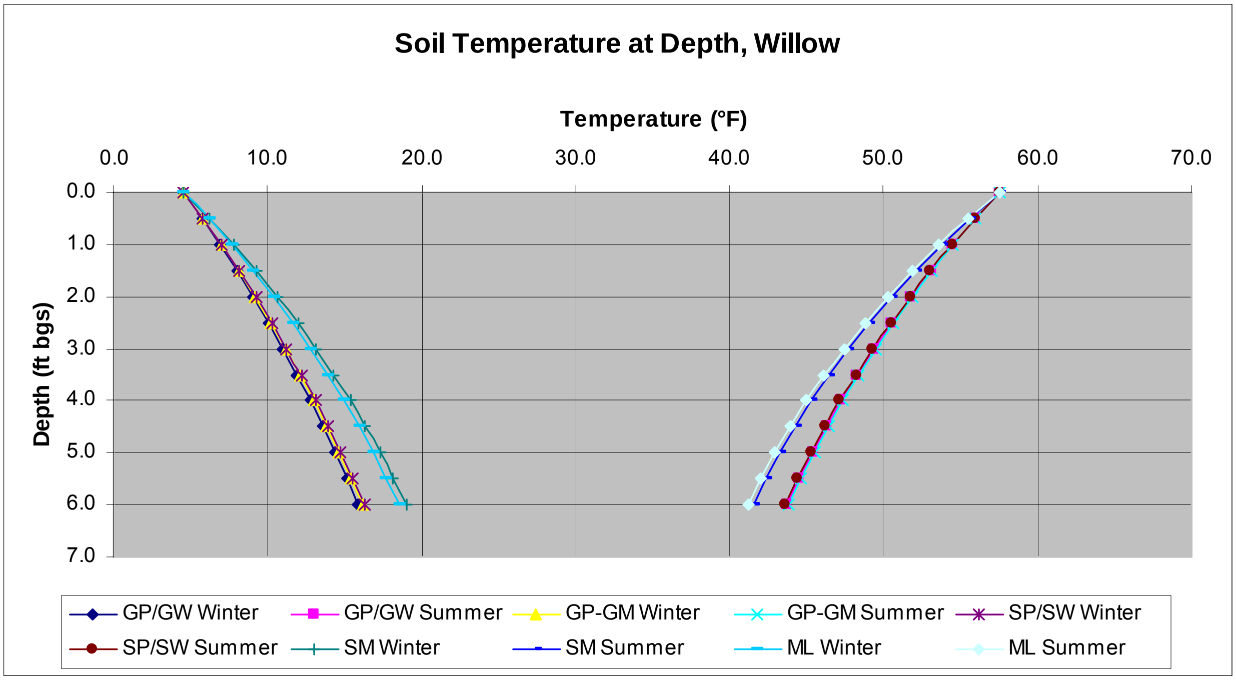


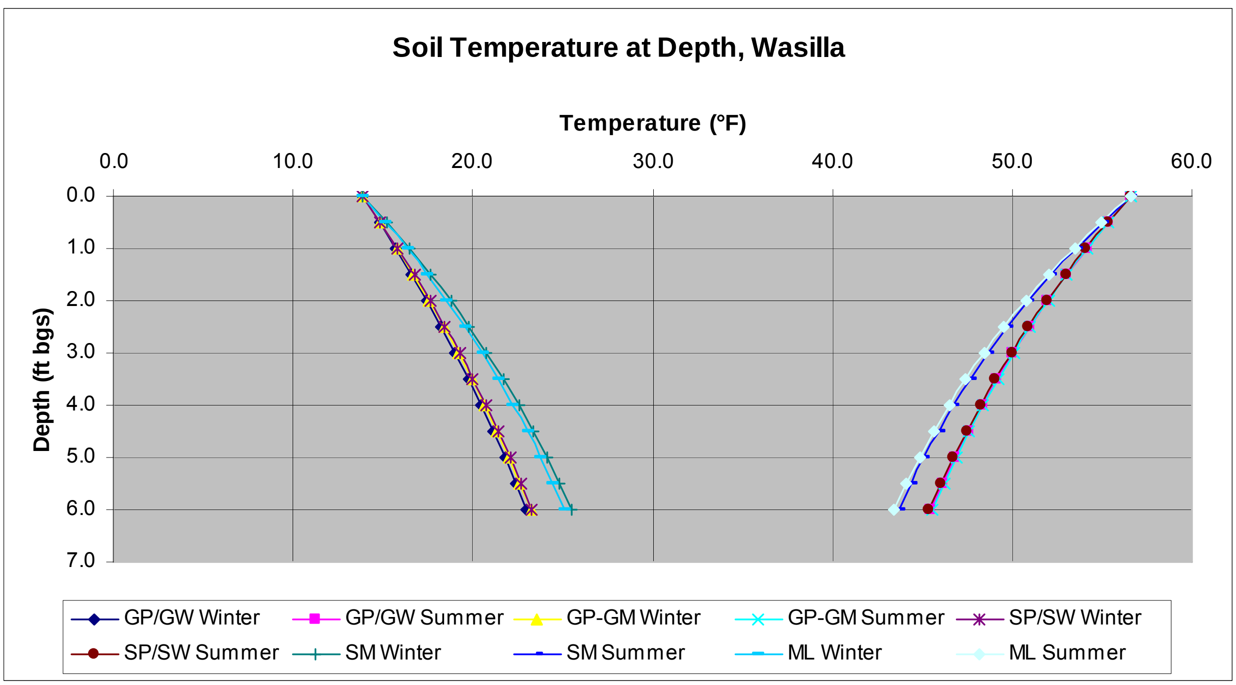

Soil Temperature at Depth, Nenana
Temperature (°F)
-20.0
-10.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
Depth (ft bgs)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
GP/GW Winter
GP/GW Summer
GP-GM Winter
GP-GM Summer
SP/SW Winter
SP/SW Summer
SM Winter
SM Summer
ML Winter
ML Summer


Soil Temperature at Depth, Healy
Temperature (°F)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
Depth (ft bgs)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
GP/GW Winter
GP/GW Summer
GP-GM Winter
GP-GM Summer
SP/SW Winter
SP/SW Summer
SM Winter
SM Summer
ML Winter
ML Summer


Soil Temperature at Depth, Cantwell
Temperature (°F)
-10.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Depth (ft bgs)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
GP/GW Winter
GP/GW Summer
GP-GM Winter
GP-GM Summer
SP/SW Winter
SP/SW Summer
SM Winter
SM Summer
ML Winter
ML Summer


Soil Temperature at Depth, Talkeetna
Temperature (°F)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
Depth (ft bgs)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
GP/GW Winter
GP/GW Summer
GP-GM Winter
GP-GM Summer
SP/SW Winter
SP/SW Summer
SM Winter
SM Summer
ML Winter
ML Summer


Soil Temperature at Depth, Willow
Temperature (°F)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
Depth (ft bgs)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
GP/GW Winter
GP/GW Summer
GP-GM Winter
GP-GM Summer
SP/SW Winter
SP/SW Summer
SM Winter
SM Summer
ML Winter
ML Summer


Soil Temperature at Depth, Wasilla
Temperature (°F)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Depth (ft bgs)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
GP/GW Winter
GP/GW Summer
GP-GM Winter
GP-GM Summer
SP/SW Winter
SP/SW Summer
SM Winter
SM Summer
ML Winter
ML Summer

Summary

The maximum and minimum temperatures in the calculations presented are dependent on the mean annual air temperatures at each location. The data used for the mean annual air temperatures are considered equal to surface temperatures, and thus, the curves generated by these calculations represent estimated extreme temperature values at given depths. Estimated winter and summer ground temperatures, for each soil type, at a depth of four feet bgs are provided on Table 2.

Table 2 – Fairbanks to Wasilla Spur Line Route Subsurface Soil Temperatures

			Estimated Temperatures, °F	
Location	Soil Description	USCS Symbol	Winter @ 4 ft bgs	Summer @ 4 ft bgs
Fairbanks	Silty Sand	SM	5.6	46.2
	Silt	ML	5.0	45.8
Nenana	Silty Sand	SM	4.9	43.9
	Gravel	GP/GW	1.5	46.4
Healy	Gravel	GP/GW	10.6	47.3
	Gravel with Silt	GP-GM	10.9	47.4
Cantwell	Gravel with Silt	GP-GM	8.5	43.1
	Sand	SP/SW	8.6	43.0
	Silty Sand	SM	10.9	41.1
Talkeetna	Silty Sand	SM	19.6	46.6
	Gravel	GP/GW	17.2	48.4
Willow	Silty Sand	SM	15.4	45.3
Wasilla	Silty Sand	SM	22.6	46.8

Additional consideration should be given for the presence and or absence of permafrost along the Fairbanks to Wasilla Spur Line Route. A detailed study of permafrost was not included in this task. However, generally speaking permafrost is typically discontinuous to sporadic between Fairbanks and Cantwell with both thaw-unstable and thaw-stable soils present. Fine-grained soils and north-facing slopes are mostly frozen. South-facing slopes, lakes and stream crossings are unfrozen to sporadically frozen. South of Cantwell, permafrost is mostly absent although pockets may occur where protected by thick organics. A generalized approach states that if the mean annual air temperature is 31 degrees F or higher then there is most likely no permafrost. Consequently a mean annual air temperatures of 20 degrees or colder almost always produce permafrost. The gray area includes mean annual air temperatures between 28 and 24 degrees in which both permafrost and non-permafrost areas may exist.

References

1. An Introduction to Frozen Ground Engineering, Anderson & Ladanyi 1994
2. Monthly average air temperatures – http://www.wrcc.dri.edu/htmlfiles/ak/ak.avg.html
3. Construction in Cold Regions, T. McFadden & F.L. Bennett, 1991
4. Degree Days and Heat Conduction in Soils, F.J. Sanger, CRREL
5. Civil Engineering Reference Manual, M. Lindeburg, 2001
6. Arctic Heat and Mass Transfer, J. Zarling, 1994
7. Principles of Geotechnical Engineering, B. Das, 1994

Project Number: 107115 **Date:** 7/11/2006
Subject: Soil Temperature Calculations **Checked by:** MTA
Computed by: WLS

Description:

This calculation is used to estimate the soil temperature at a depth of 4 feet. The temperatures will be used to evaluate compressor stations along the proposed Natural Gas Spur Line from Fairbanks to ENSTAR Tie-in.

References:

(1) An Introduction to Frozen Ground Engineering, Anderson & Ladanyi, 1994
(2) Monthly average air temperatures - http://www.wrcc.dri.edu/htmlfiles/ak/ak.avg.html
(3) Construction in Cold Regions, T. McFadden & F.L. Bennett, 1991
(4) Degree Days and Heat Conduction in Soils, F.J. Sanger, CRREL
(5) Civil Engineering Reference Manual, M. Lindeburg, 2001
(6) Arctic Heat and Mass Transfer, J. Zarling, 1994

Attachments:

Temperature attenuation with depth curves (whiplash curves) for gravel, silt, sand, and organic soil types at each location along route.

Calculations:

Assumptions:

The graphs and equations are dependent on the mean annual temperature and the maximum temperature variation at each location. Based on ADOT Regulations, four feet of cover is assumed for burried pipes. Calculations do not consider seasonal snow cover, vegetation, slope aspect, local climate influences, etc.

(Reference 2)

Mean Air Temperature (°F)

Years of Record	55	55	28	21	55	15	
	Fairbanks	**Nenana**	**Healy**	**Cantwell**	**Talkeetna**	**Willow**	**ENSTAR End**
Jan	-9.80	-9.70	4.10	1.70	10.80	5.00	9.50
Feb	-2.70	-3.80	8.80	6.20	16.00	10.00	11.00
Mar	10.90	7.90	15.70	13.00	21.70	20.00	18.00
Apr	31.30	27.40	31.23	26.50	33.90	33.00	28.00
May	48.60	45.90	46.50	40.50	45.50	42.00	45.00
June	60.00	57.40	57.00	51.50	55.40	54.00	55.00
July	62.10	59.30	59.80	55.20	58.70	58.00	57.80
Aug	56.50	54.20	55.20	50.30	55.50	55.00	56.00
Sept	44.90	43.00	43.60	40.00	46.20	46.00	46.00
Oct	24.90	27.70	26.00	23.10	31.90	30.00	32.00
Nov	3.60	2.50	10.30	8.30	18.10	12.00	17.00
Dec	-7.10	-7.30	3.40	4.50	11.60	8.00	12.00
Avg, T_m	26.93	25.38	30.14	26.73	33.78	31.08	32.28
Max	62.10	59.30	59.80	55.20	58.70	58.00	57.80
Min	-9.80	-9.70	3.40	1.70	10.80	5.00	9.50
A_s	35.95	34.50	28.20	26.75	23.95	26.50	24.15

A_s (Surface Temperature Aplitude) = (Max Temp - Min Temp)/2

Calculating Diffusivity, α *(Reference 3, pg. 329)*

$\alpha_f = k_f / \rho c_f$ — k_f=Thermal Conductivity, Btu/ft hr°F, frozen
c_f= Specific Heat, Btu/lb °F, frozen
ρ = Dry Density, lb/ft^3

$\alpha_u = k_u / \rho c_u$ — k_u=Thermal Conductivity, Btu/ft hr°F, unfrozen
c_u= Specific Heat, Btu/lb °F, unfrozen
ρ = Dry Density, lb/ft^3

Soil Type	Dry Density ρ,lb/ft^3 (*Ref. 5, pg. 35-19*)	Moisture ω, % (*Ref. 5, pg. 35-19*)	Specific Heat, BTU/lb °F c_f (*Ref. 3, p. 228*)	c_u	Thermal Conductivity BTU/ft hr °F k_f (*Ref. 3, p. 150*)	k_u	Calculated Diffusivity ft^2/hr Frozen α_f	Unfrozen α_u
GP/GW (1)	125	11	0.43269	0.58	2.33	1.67	0.0431	0.0231
GR-SIL (2)	120	11	0.41667	0.53	2.00	1.50	0.0400	0.0236
SP/SW (S) (3)	115	12	0.40865	0.54	1.83	1.42	0.0390	0.0226
OH	80	33	0.40064	0.61	1.00	0.58	0.0312	0.0120
SIL	110	18	0.44872	0.64	1.17	0.96	0.0236	0.0136

Notes:
(1) The dry density and moisture content value is representative of both GP and GW
(2) The dry density and moisture content value is representative of both GR and SIL
(3) The dry density and moisture content value is representative of both SP and SW

Temperature, in °F at depth, z for each soil type and location

$$T_z = T_m \pm A_s \exp\left(-z / \sqrt{\alpha\, p / \pi}\right) + g\, z$$

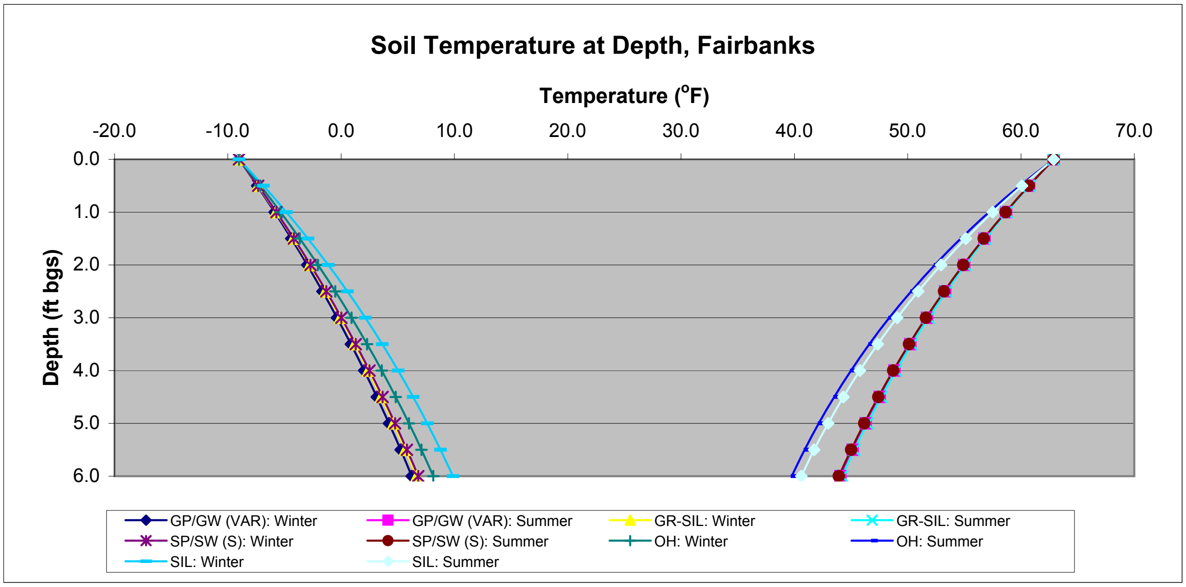
(Reference 6, pg. 31)

$$A_s = \frac{(\max temp - \min temp)}{2}$$

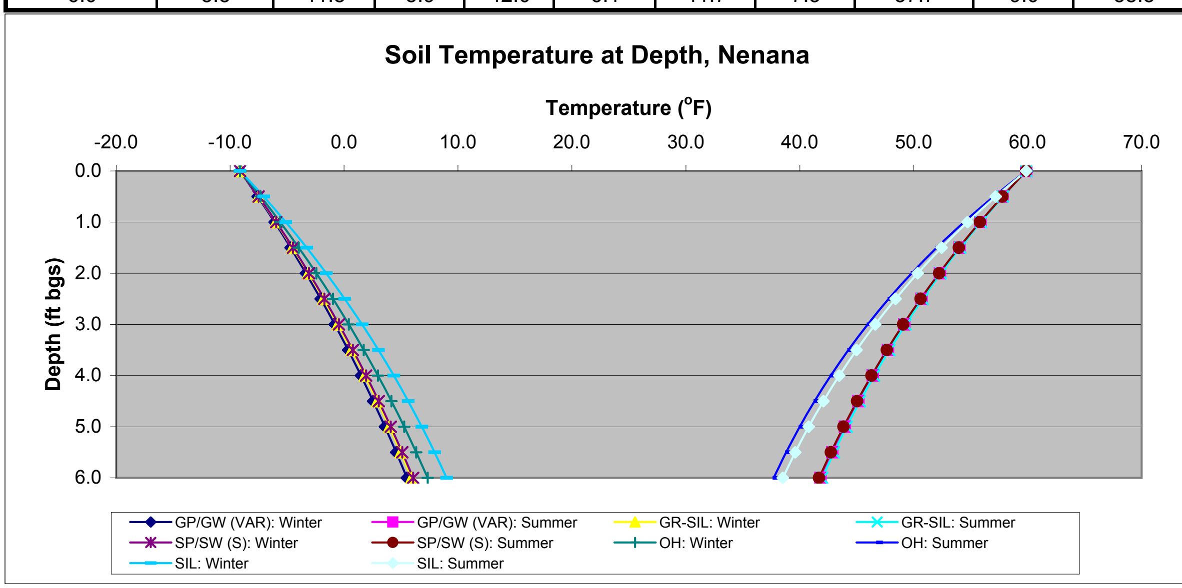
T_z: Temperature at depth, °F
T_m: Mean Annual Air Temperature, °F
A_s: Surface Temperature Aplitude, °F
z: depth, ft bgs

p: period (hours in a year) = 365.25 days x 24 hours — 8766 hours
α: Thermal diffusivity, ft^2/hr
g: Geothermal gradient, 1.7°F per 100 ft *(Reference 3, pg. 87)*

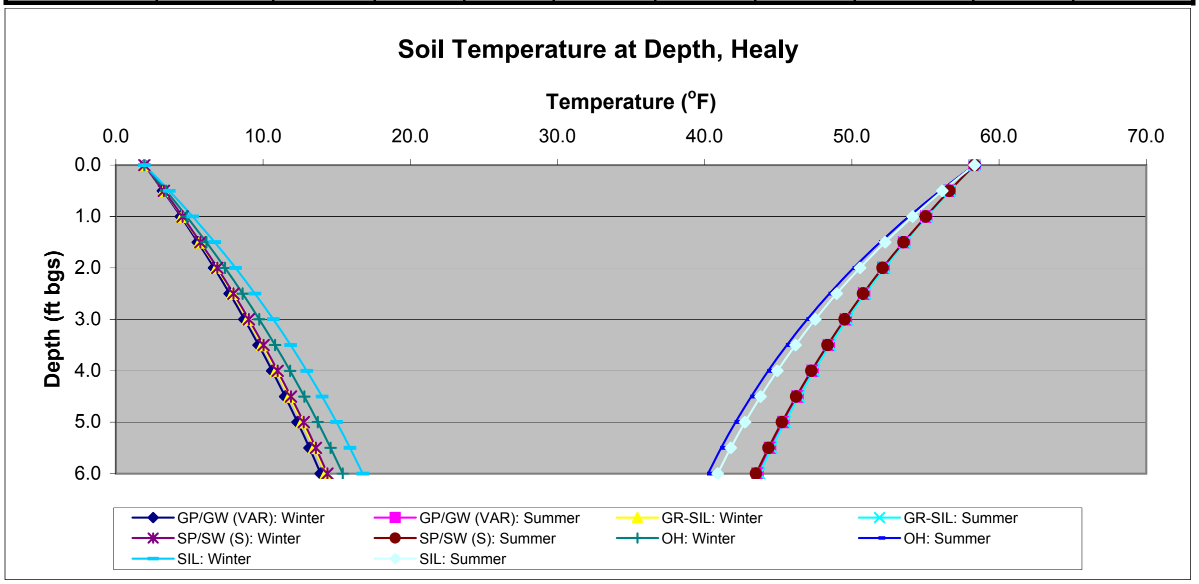
Fairbanks depth, z (ft bgs)	**GP/GW (VAR)** Winter	Summer	**GR-SIL** Winter	Summer	**SP/SW (S)** Winter	Summer	**OH** Winter	Summer	**SIL** Winter	Summer
	Calculated T_z(+): Summer & T_z(-): Winter									
0.0	-9.0	62.9	-9.0	62.9	-9.0	62.9	-9.0	62.9	-9.0	62.9
0.5	-7.4	60.7	-7.3	60.7	-7.3	60.7	-7.1	59.9	-6.9	60.1
1.0	-5.9	58.7	-5.8	58.7	-5.7	58.6	-5.3	57.2	-4.8	57.5
1.5	-4.4	56.8	-4.2	56.8	-4.2	56.7	-3.7	54.7	-2.9	55.1
2.0	-3.0	55.0	-2.8	55.1	-2.7	54.9	-2.0	52.4	-1.1	52.9
2.5	-1.6	53.3	-1.4	53.4	-1.3	53.2	-0.5	50.3	0.6	50.9
3.0	-0.4	51.7	-0.1	51.8	0.0	51.6	0.9	48.4	2.1	49.1
3.5	0.9	50.2	1.2	50.4	1.3	50.1	2.3	46.6	3.6	47.4
4.0	2.0	48.8	2.4	49.0	2.5	48.7	3.6	45.0	5.0	45.8
4.5	3.2	47.5	3.5	47.7	3.7	47.4	4.8	43.5	6.4	44.3
5.0	4.2	46.3	4.6	46.4	4.8	46.2	6.0	42.2	7.6	43.0
5.5	5.3	45.2	5.7	45.3	5.8	45.0	7.1	40.9	8.8	41.7
6.0	6.2	44.1	6.7	44.2	6.8	43.9	8.1	39.8	9.9	40.6



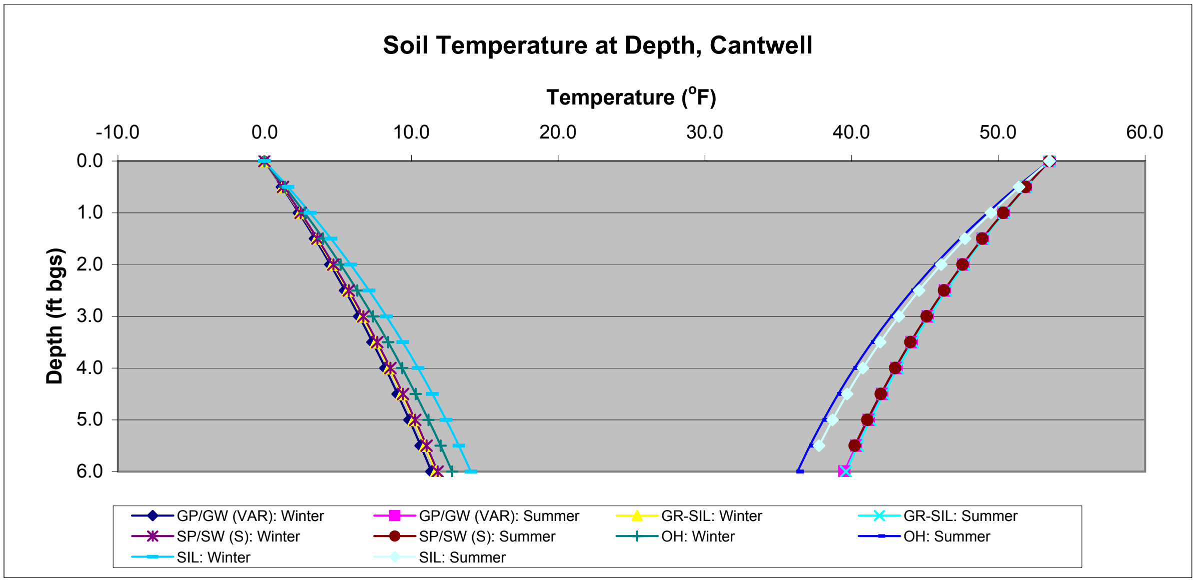
Nenana	Calculated T_z(+): Summer & T_z(-): Winter									
depth, z	**GP/GW (VAR)**		**GR-SIL**		**SP/SW (S)**		**OH**		**SIL**	
(ft bgs)	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0.0	-9.1	59.9	-9.1	59.9	-9.1	59.9	-9.1	59.9	-9.1	59.9
0.5	-7.6	57.8	-7.5	57.8	-7.5	57.8	-7.3	57.0	-7.1	57.2
1.0	-6.1	55.9	-6.0	55.9	-6.0	55.8	-5.6	54.4	-5.1	54.7
1.5	-4.7	54.0	-4.5	54.1	-4.5	54.0	-4.0	52.0	-3.3	52.4
2.0	-3.3	52.3	-3.1	52.4	-3.1	52.2	-2.4	49.8	-1.6	50.3
2.5	-2.1	50.7	-1.8	50.8	-1.7	50.6	-1.0	47.8	0.1	48.4
3.0	-0.8	49.2	-0.5	49.3	-0.5	49.1	0.4	46.0	1.6	46.6
3.5	0.4	47.7	0.7	47.9	0.8	47.6	1.7	44.3	3.0	45.0
4.0	1.5	46.4	1.8	46.5	1.9	46.3	3.0	42.7	4.4	43.5
4.5	2.6	45.2	2.9	45.3	3.0	45.0	4.2	41.3	5.6	42.1
5.0	3.6	44.0	4.0	44.1	4.1	43.8	5.3	40.0	6.8	40.8
5.5	4.6	42.9	5.0	43.0	5.1	42.7	6.3	38.8	7.9	39.6
6.0	5.5	41.8	5.9	42.0	6.1	41.7	7.3	37.7	9.0	38.5



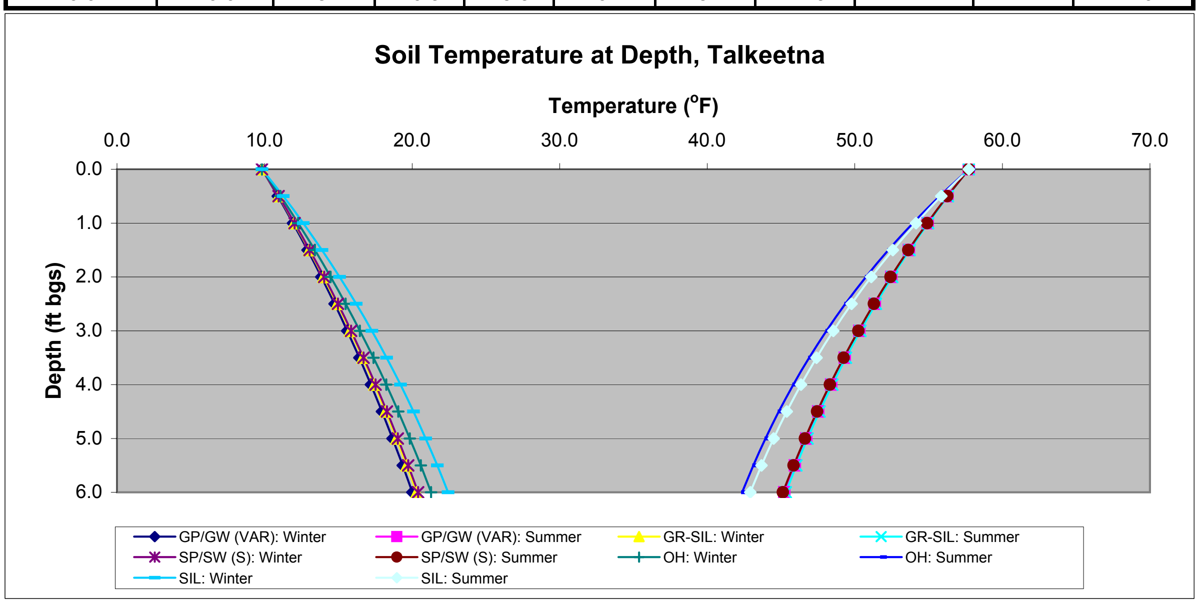
Healy	Calculated T_z(+): Summer & T_z(-): Winter									
depth, z	GP/GW (VAR)		GR-SIL		SP/SW (S)		OH		SIL	
(ft bgs)	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0.0	1.9	58.3	1.9	58.3	1.9	58.3	1.9	58.3	1.9	58.3
0.5	3.2	56.6	3.2	56.7	3.3	56.6	3.4	56.0	3.6	56.1
1.0	4.4	55.1	4.5	55.1	4.5	55.0	4.8	53.9	5.2	54.1
1.5	5.6	53.6	5.7	53.6	5.7	53.5	6.1	51.9	6.7	52.3
2.0	6.7	52.2	6.8	52.2	6.9	52.1	7.4	50.1	8.1	50.5
2.5	7.7	50.8	7.9	50.9	8.0	50.8	8.6	48.5	9.5	49.0
3.0	8.7	49.6	9.0	49.7	9.0	49.5	9.7	47.0	10.7	47.5
3.5	9.7	48.4	9.9	48.5	10.0	48.3	10.8	45.6	11.9	46.2
4.0	10.6	47.3	10.9	47.4	11.0	47.2	11.8	44.3	13.0	44.9
4.5	11.5	46.3	11.8	46.4	11.9	46.2	12.8	43.2	14.0	43.8
5.0	12.3	45.4	12.7	45.5	12.8	45.2	13.7	42.1	15.0	42.7
5.5	13.1	44.4	13.5	44.6	13.6	44.3	14.6	41.1	15.9	41.8
6.0	13.9	43.6	14.3	43.7	14.4	43.5	15.4	40.2	16.8	40.9



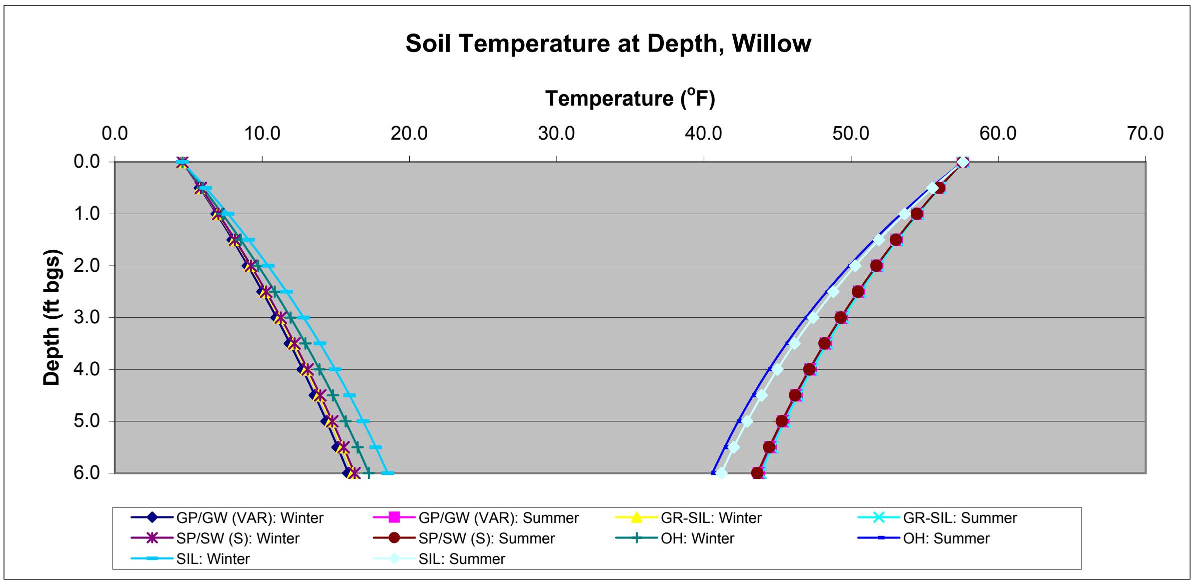
Cantwell	Calculated T_z(+): Summer & T_z(-): Winter									
depth, z	GP/GW (VAR)		GR-SIL		SP/SW (S)		OH		SIL	
(ft bgs)	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0.0	0.0	53.5	0.0	53.5	0.0	53.5	0.0	53.5	0.0	53.5
0.5	1.2	51.9	1.2	51.9	1.2	51.9	1.4	51.3	1.6	51.4
1.0	2.3	50.4	2.4	50.4	2.4	50.3	2.7	49.3	3.1	49.5
1.5	3.4	49.0	3.5	49.0	3.6	48.9	4.0	47.4	4.5	47.7
2.0	4.5	47.6	4.6	47.7	4.7	47.6	5.2	45.7	5.9	46.1
2.5	5.5	46.4	5.7	46.4	5.7	46.3	6.3	44.1	7.1	44.6
3.0	6.4	45.2	6.6	45.3	6.7	45.1	7.4	42.7	8.3	43.2
3.5	7.3	44.1	7.6	44.2	7.7	44.0	8.4	41.4	9.4	41.9
4.0	8.2	43.1	8.5	43.1	8.6	43.0	9.4	40.2	10.5	40.8
4.5	9.1	42.1	9.3	42.2	9.4	42.0	10.3	39.1	11.4	39.7
5.0	9.9	41.2	10.2	41.3	10.3	41.1	11.2	38.1	12.4	38.7
5.5	10.6	40.3	10.9	40.4	11.0	40.2	12.0	37.2	13.2	37.8
6.0	11.4	39.5	11.7	39.6	11.8	39.4	12.8	36.3	14.1	36.9



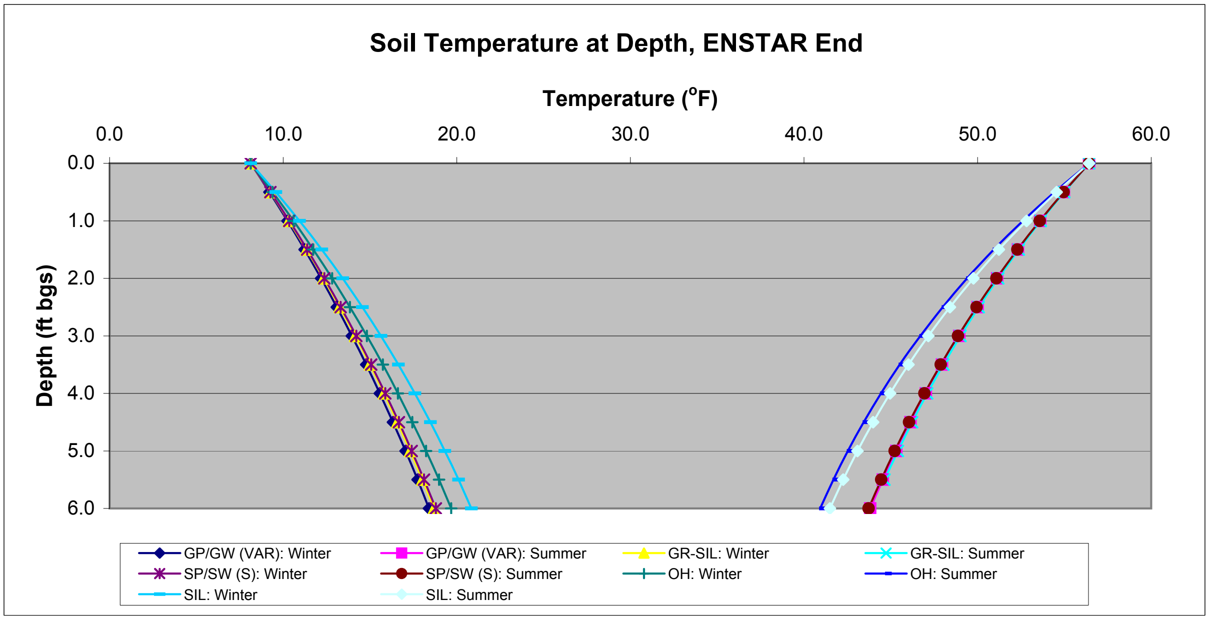
Talkeetna	Calculated $T_z(+)$: Summer & $T_z(-)$: Winter									
depth, z	**GP/GW (VAR)**		**GR-SIL**		**SP/SW (S)**		**OH**		**SIL**	
(ft bgs)	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0.0	9.8	57.7	9.8	57.7	9.8	57.7	9.8	57.7	9.8	57.7
0.5	10.9	56.3	10.9	56.3	11.0	56.3	11.1	55.7	11.3	55.9
1.0	11.9	54.9	12.0	55.0	12.0	54.9	12.3	53.9	12.6	54.2
1.5	12.9	53.7	13.0	53.7	13.1	53.6	13.4	52.3	13.9	52.6
2.0	13.9	52.5	14.0	52.5	14.0	52.4	14.5	50.8	15.1	51.1
2.5	14.7	51.4	14.9	51.4	15.0	51.3	15.5	49.4	16.2	49.8
3.0	15.6	50.3	15.8	50.4	15.9	50.2	16.5	48.1	17.3	48.5
3.5	16.4	49.3	16.6	49.4	16.7	49.2	17.4	46.9	18.3	47.4
4.0	17.2	48.4	17.4	48.5	17.5	48.3	18.2	45.8	19.2	46.4
4.5	18.0	47.5	18.2	47.6	18.3	47.4	19.1	44.8	20.1	45.4
5.0	18.7	46.7	18.9	46.8	19.0	46.6	19.8	43.9	20.9	44.5
5.5	19.4	45.9	19.6	46.0	19.7	45.9	20.6	43.1	21.7	43.7
6.0	20.0	45.2	20.3	45.3	20.4	45.1	21.3	42.4	22.4	42.9



Willow	Calculated $T_z(+)$: Summer & $T_z(-)$: Winter									
depth, z	GP/GW (VAR)		GR-SIL		SP/SW (S)		OH		SIL	
(ft bgs)	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0.0	4.6	57.6	4.6	57.6	4.6	57.6	4.6	57.6	4.6	57.6
0.5	5.8	56.0	5.8	56.0	5.8	56.0	6.0	55.4	6.2	55.5
1.0	6.9	54.5	7.0	54.5	7.0	54.5	7.3	53.4	7.7	53.6
1.5	8.0	53.1	8.1	53.1	8.2	53.0	8.5	51.6	9.1	51.9
2.0	9.0	51.8	9.2	51.8	9.2	51.7	9.7	49.9	10.4	50.3
2.5	10.0	50.5	10.2	50.6	10.3	50.5	10.9	48.3	11.6	48.8
3.0	11.0	49.4	11.2	49.4	11.3	49.3	11.9	46.9	12.8	47.4
3.5	11.9	48.3	12.1	48.4	12.2	48.2	12.9	45.6	13.9	46.2
4.0	12.7	47.3	13.0	47.3	13.1	47.2	13.9	44.4	15.0	45.0
4.5	13.6	46.3	13.9	46.4	13.9	46.2	14.8	43.3	15.9	43.9
5.0	14.4	45.4	14.7	45.5	14.8	45.3	15.7	42.3	16.9	42.9
5.5	15.1	44.5	15.4	44.6	15.5	44.4	16.5	41.4	17.7	42.0
6.0	15.8	43.7	16.2	43.8	16.3	43.6	17.3	40.6	18.5	41.2



ENSTAR End	Calculated $T_z(+)$: Summer & $T_z(-)$: Winter									
depth, z	GP/GW (VAR)		GR-SIL		SP/SW (S)		OH		SIL	
(ft bgs)	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0.0	8.1	56.4	8.1	56.4	8.1	56.4	8.1	56.4	8.1	56.4
0.5	9.2	55.0	9.2	55.0	9.3	55.0	9.4	54.4	9.6	54.6
1.0	10.2	53.6	10.3	53.6	10.3	53.6	10.6	52.6	10.9	52.8
1.5	11.2	52.3	11.3	52.4	11.4	52.3	11.7	50.9	12.2	51.2
2.0	12.2	51.1	12.3	51.2	12.4	51.1	12.8	49.4	13.4	49.8
2.5	13.1	50.0	13.3	50.1	13.3	49.9	13.8	48.0	14.6	48.4
3.0	14.0	48.9	14.1	49.0	14.2	48.9	14.8	46.7	15.6	47.2
3.5	14.8	48.0	15.0	48.0	15.1	47.9	15.7	45.5	16.6	46.0
4.0	15.6	47.0	15.8	47.1	15.9	46.9	16.6	44.4	17.6	45.0
4.5	16.3	46.1	16.6	46.2	16.7	46.1	17.4	43.4	18.5	44.0
5.0	17.0	45.3	17.3	45.4	17.4	45.2	18.2	42.5	19.3	43.1
5.5	17.7	44.5	18.0	44.6	18.1	44.5	19.0	41.7	20.1	42.3
6.0	18.4	43.8	18.7	43.9	18.8	43.7	19.7	40.9	20.8	41.5



Conclusions:

The maximum and minimum temperatures in the calculations presented are dependent on the mean annual air temperatures, the calculated diffusivity and the general conditions at the ground surface at each location. The data used for the mean annual air temperatures are considered to equal surface temperatures, therefore, the curves generated by these calculations represent estimated extreme temperature values at given depths.