

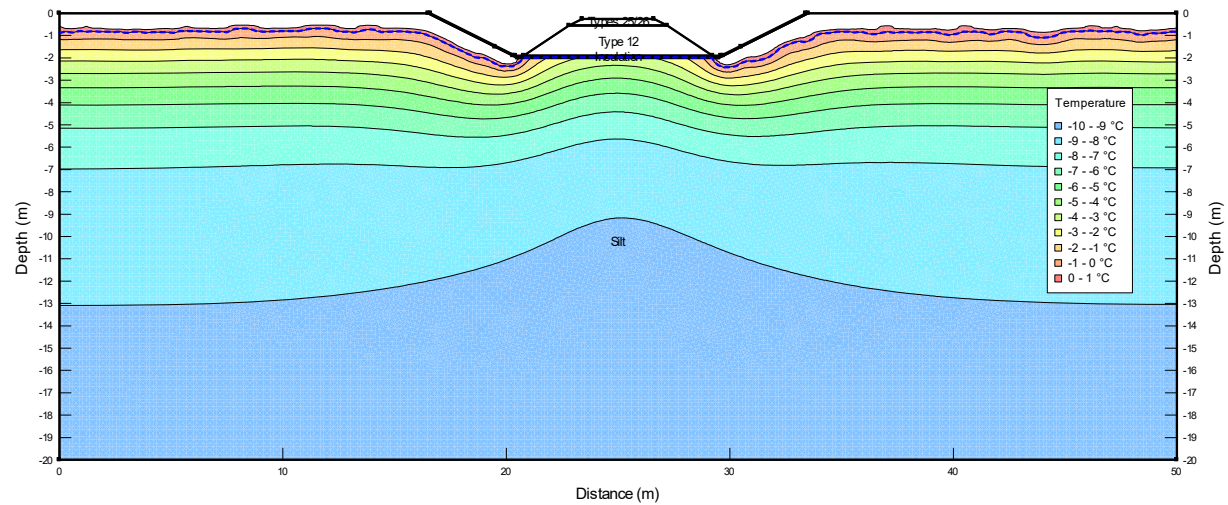


Figure 5: Results of Case A-5

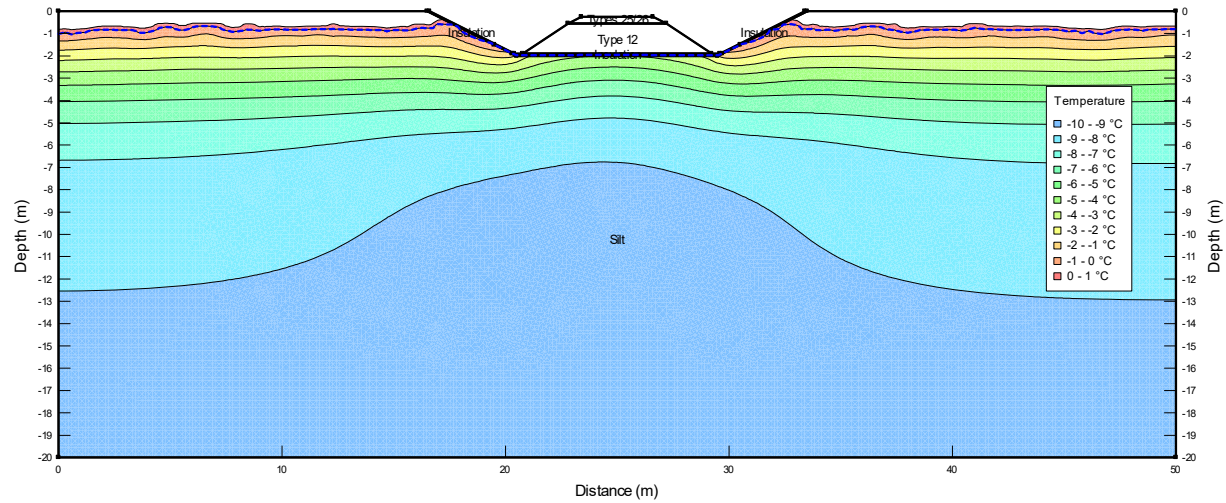


Figure 6: Results of Case A-6

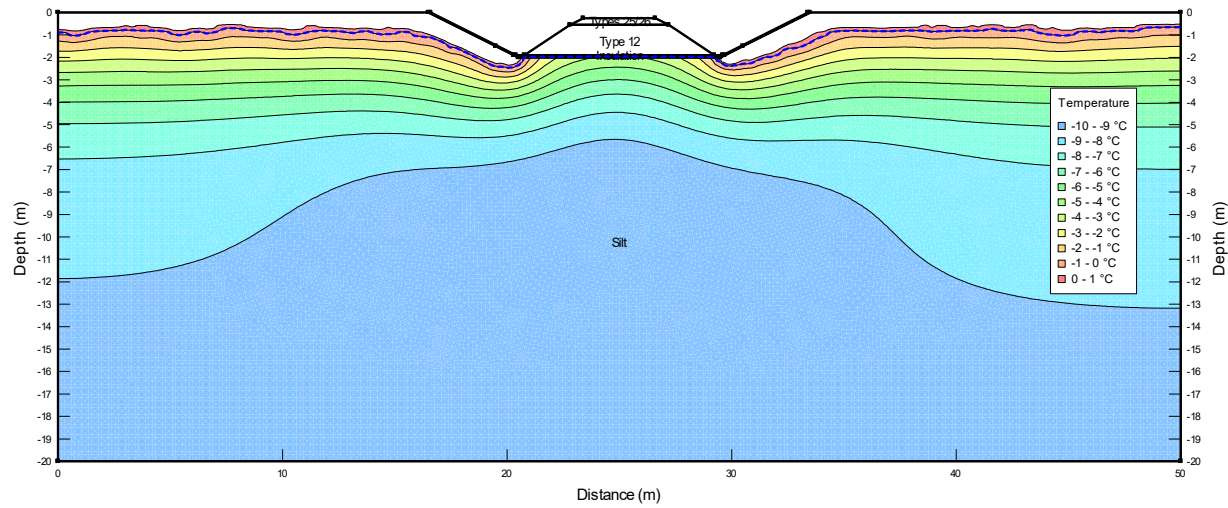


Figure 7: Results of Case A-7

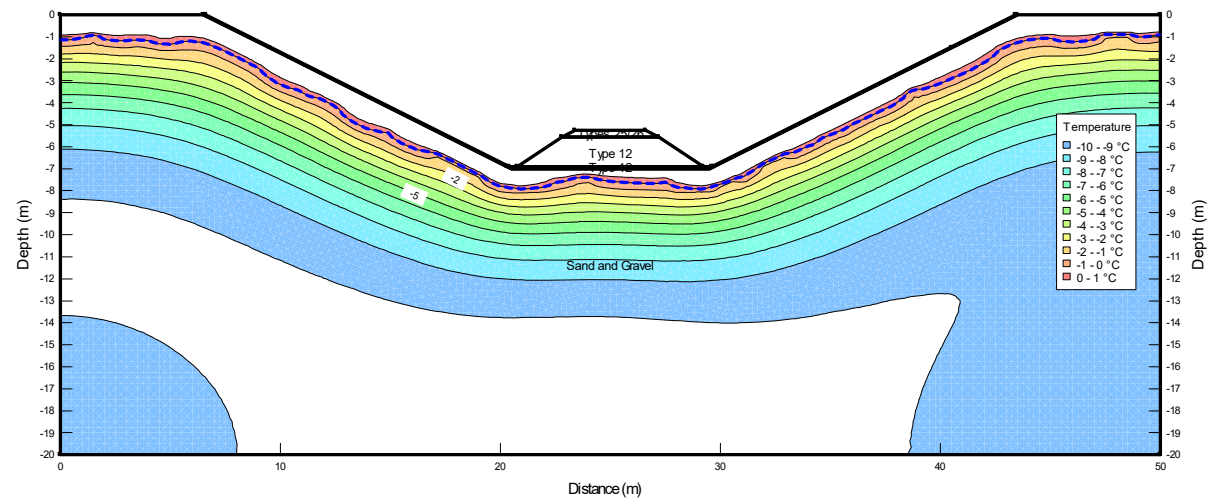


Figure 8: Results of Case B-1

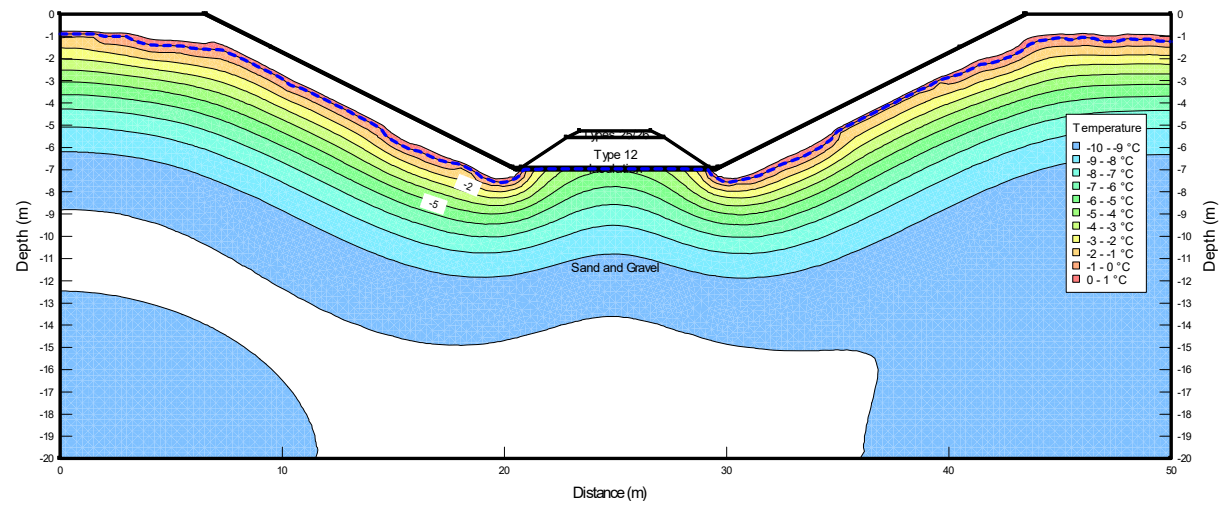


Figure 9: Results of Case B-2

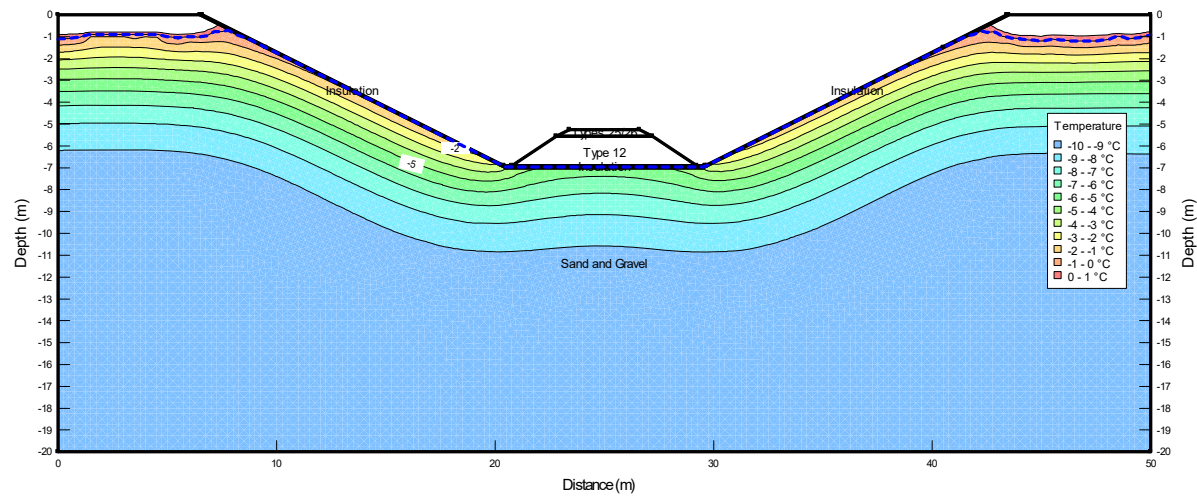


Figure 10: Results of Case B-3

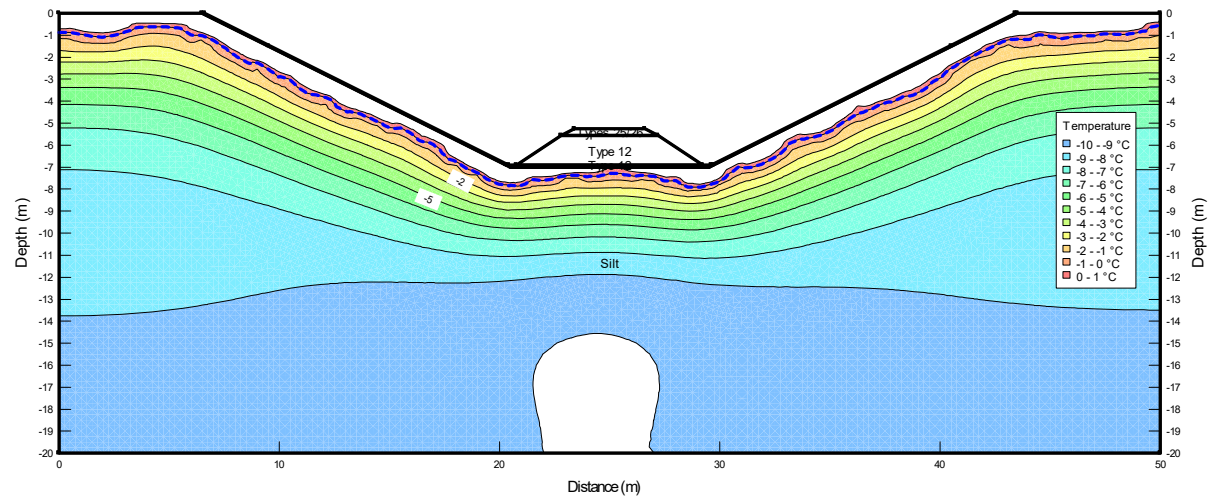


Figure 11: Results of Case B-4

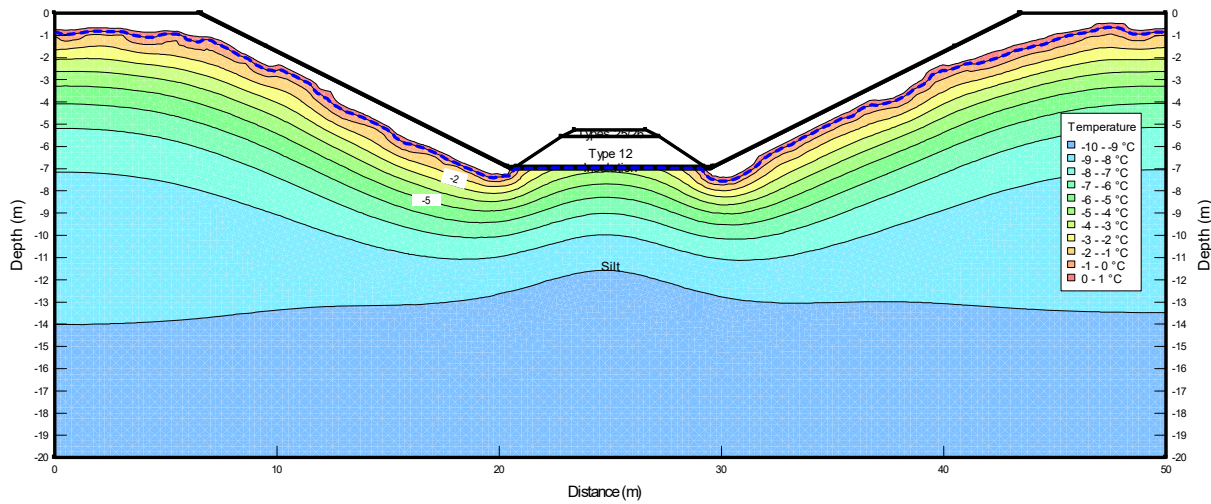


Figure 12: Results of Case B-5

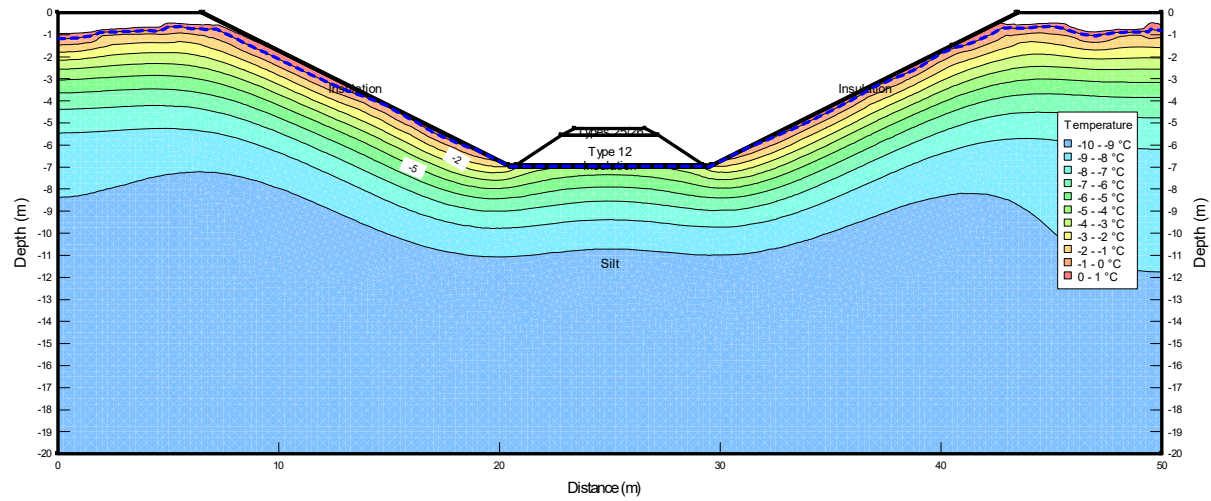


Figure 13: Results of Case B-6

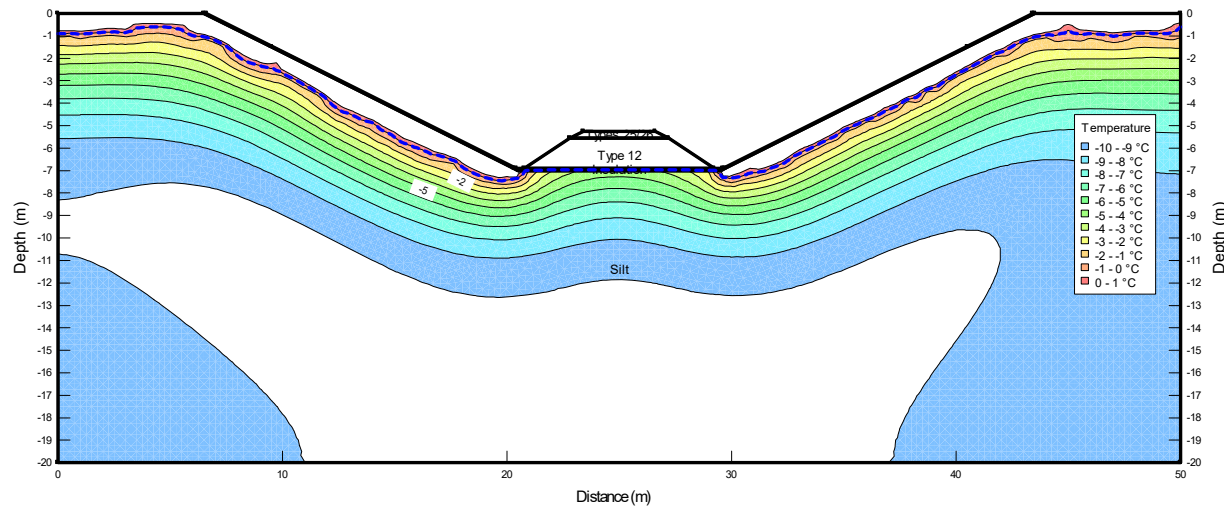


Figure 14: Results of Case B-7

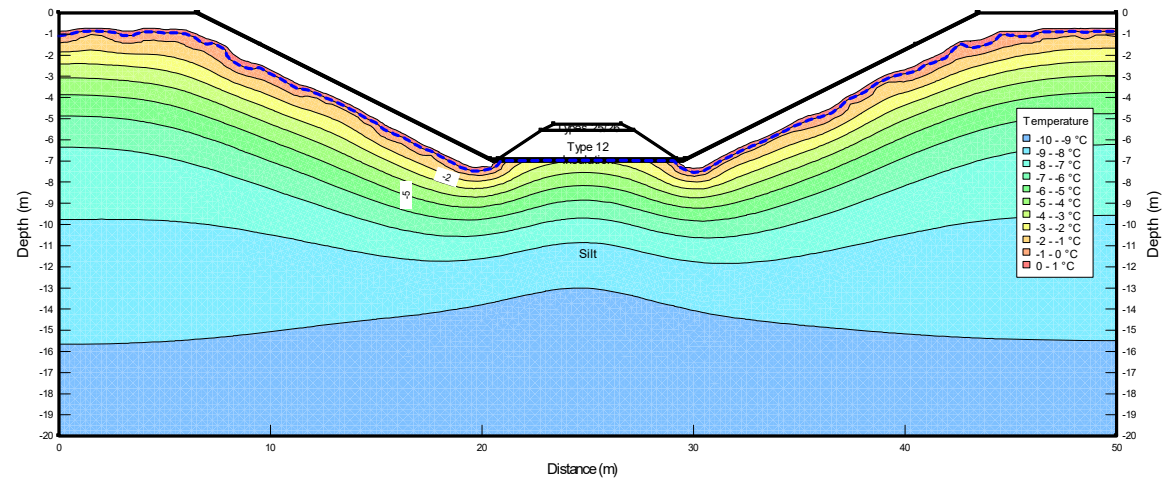


Figure 15: Results of Case B-5b – Climate Change Consideration

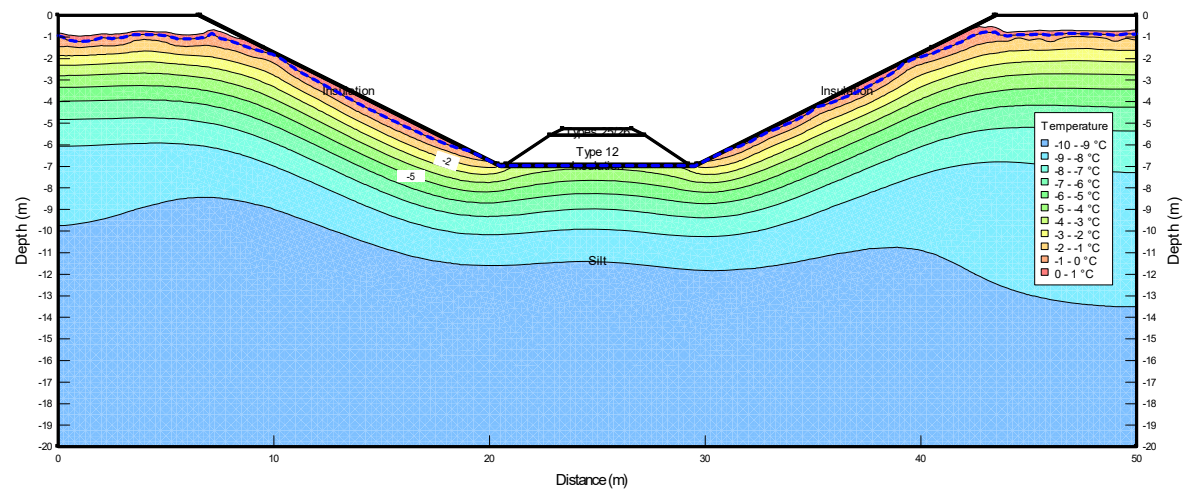


Figure 16: Results of Case B-6b – Climate Change Consideration

Appendix H

Thermal Modeling on Culverts

APPENDIX H

THERMAL MODELLING ON CULVERTS

1. Soil parameters

3 types of soils: ice-rich (silt), ice -poor (sand and gravel), Fills (Types 9,12,26, ballast/sub-ballast)

Table H1 - Assumed and Calculated Thermal Properties

Material	Frozen Thermal Conductivity (J/s/m/°C)	Unfrozen Thermal Conductivity (J/s/m/°C)	Frozen Volumetric Heat Capacity (J/m³/°C)	Unfrozen Volumetric Heat Capacity (J/m³/°C)	Insitu Water content (%)	Insitu Volumetric Water content (m³/m³)
Fill (Types 9,12 and 26, Ballast/Sub-ballast)	4.5	3.0	2,400,000	3,000,000	2	3.6
Silt	2.0	1.3	2,200,000	2,200,000	30	45
Sand/Gravel	3.0	2.0	2,600,000	2,600,000	15	25.5
Insulation	0.035	0.035	37,500	37,500	0	0

2. Assumptions

Climate Change model for 20 year design life (2019 to 2039)

Culvert cases being considered as shown in Table H2.

Table H2- Definition of Cases being Modelled

Culvert Barrel Diameter (mm)	Number of Barrels	Fill Heights (m)	Subsurface
900	1	2.1, 3, 4, 5, 10	Sand and Gravel (ice-poor) and Silt (ice-rich)
	3		
1200	1	2.4, 3, 4, 5, 10	
	3		
1500	1	2.7, 3, 4, 5, 10	
	4		
1800	1	3, 4, 5, 10	
	12		

3. Thermal Modelling Output Runs

Each set of runs contain different heights of embankment and type of soil (silt representing ice-rich soils, and sand and gravel representing ice-poor soils):

Figure H-1 – Typical Culvert Section (<4 m Fill)

Figure H-2 – Typical Culvert Section (>4 m Fill)

Figures H-3 – 900 mm dia. Multiple Culverts

Figures H-4 – 900 mm dia. Single Culverts

Figures H-5 – 1200 mm dia. Multiple Culverts

Figures H-6 – 1200 mm dia. Single Culverts

Figures H-7 – 1500 mm dia. Multiple Culverts

Figures H-8 – 1500 mm dia. Single Culverts

Figures H-9 – 1800 mm dia. Multiple Culverts

Figures H-10 – 1800 mm dia. Single Culverts

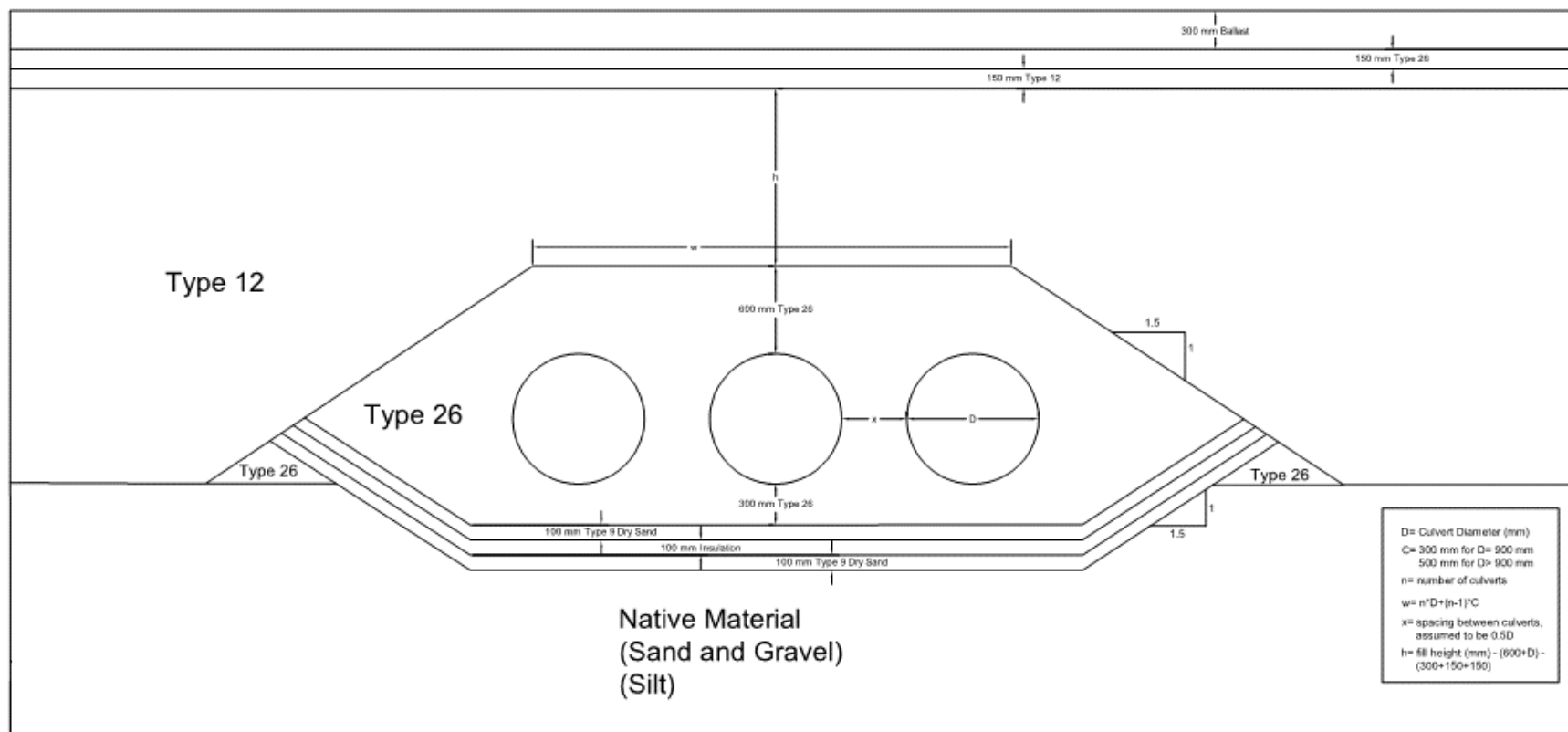


Figure H-1

Typical Culvert Section (< 4 m Fill)

Project Number	H353004	Rev	A
By	MY	4/22/2019	
Checked By	-	-	

Baffinland Iron Ore Mines
Mary River Expansion Stage 3

HATCH

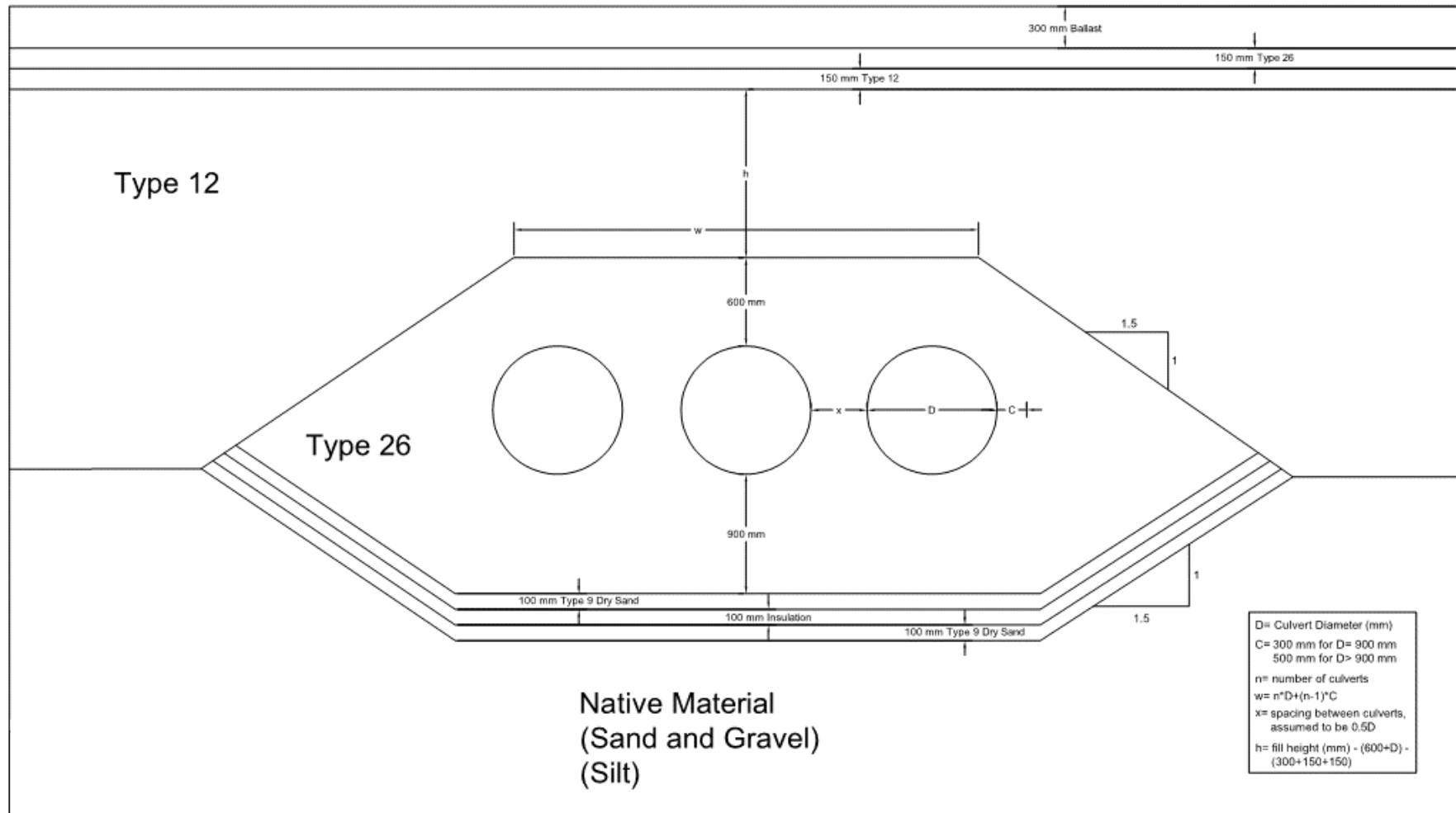


Figure H-2

Typical Culvert Section (> 4 m Fill)

Project Number	H353004	Rev	A
By	MY	4/22/2019	
Checked By	-	-	

Baffinland Iron Ore Mines
Mary River Expansion Stage 3

HATCH

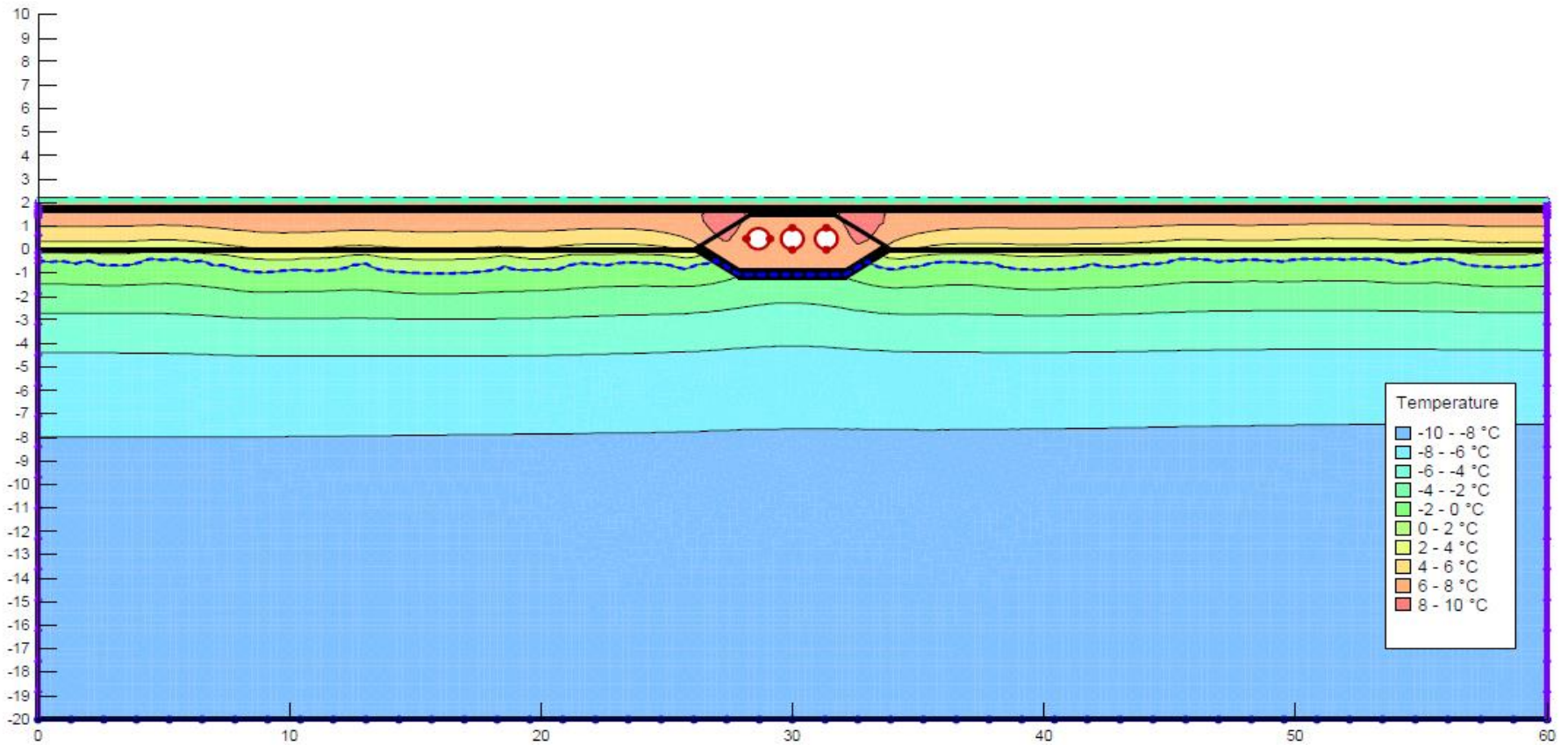


Figure H-3

**Culvert Thermal
Modeling Results**

Culvert Diameter	900mm	Project Number	H353004	Rev	
Fill Height	2.1m	By	MY	4/22/2019	
Native Material	Sand and Gravel	Checked By	-	-	



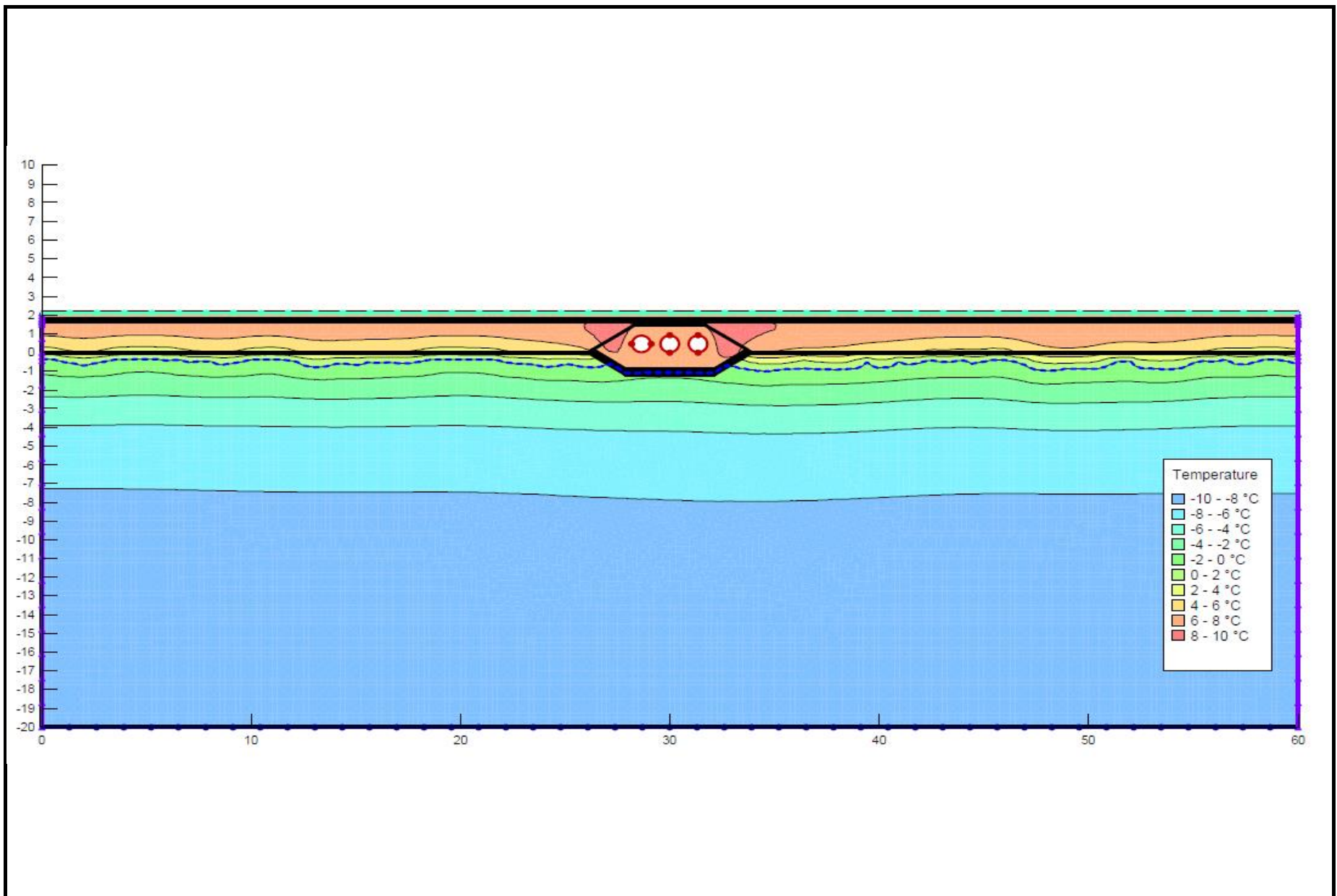


Figure H-3

**Culvert Thermal
Modeling Results**

Culvert Diameter	900mm	Project Number	H353004	Rev	
Fill Height	2.1m	By	MY	4/22/2019	
Native Material	Silt	Checked By	-	-	

HATCH

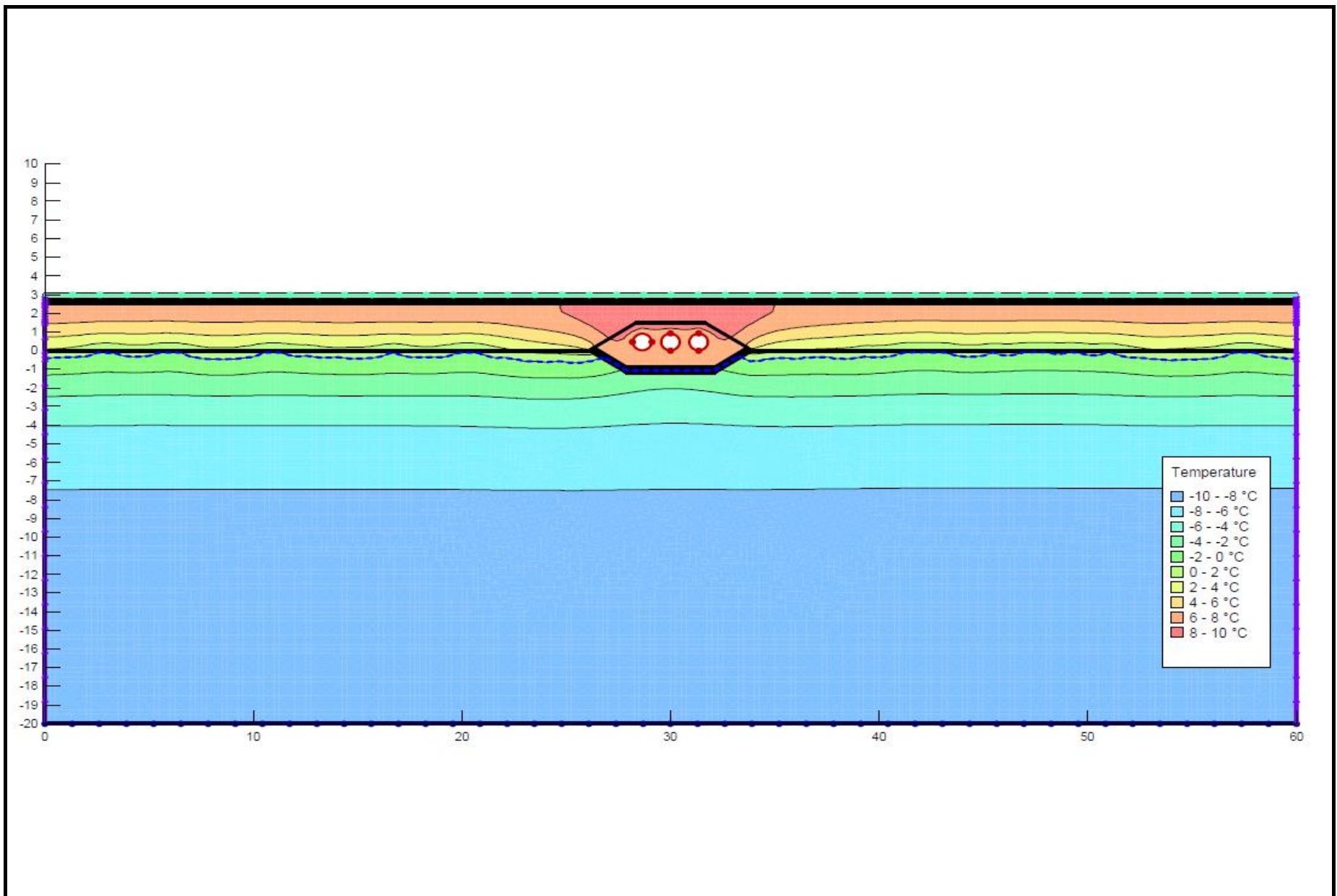
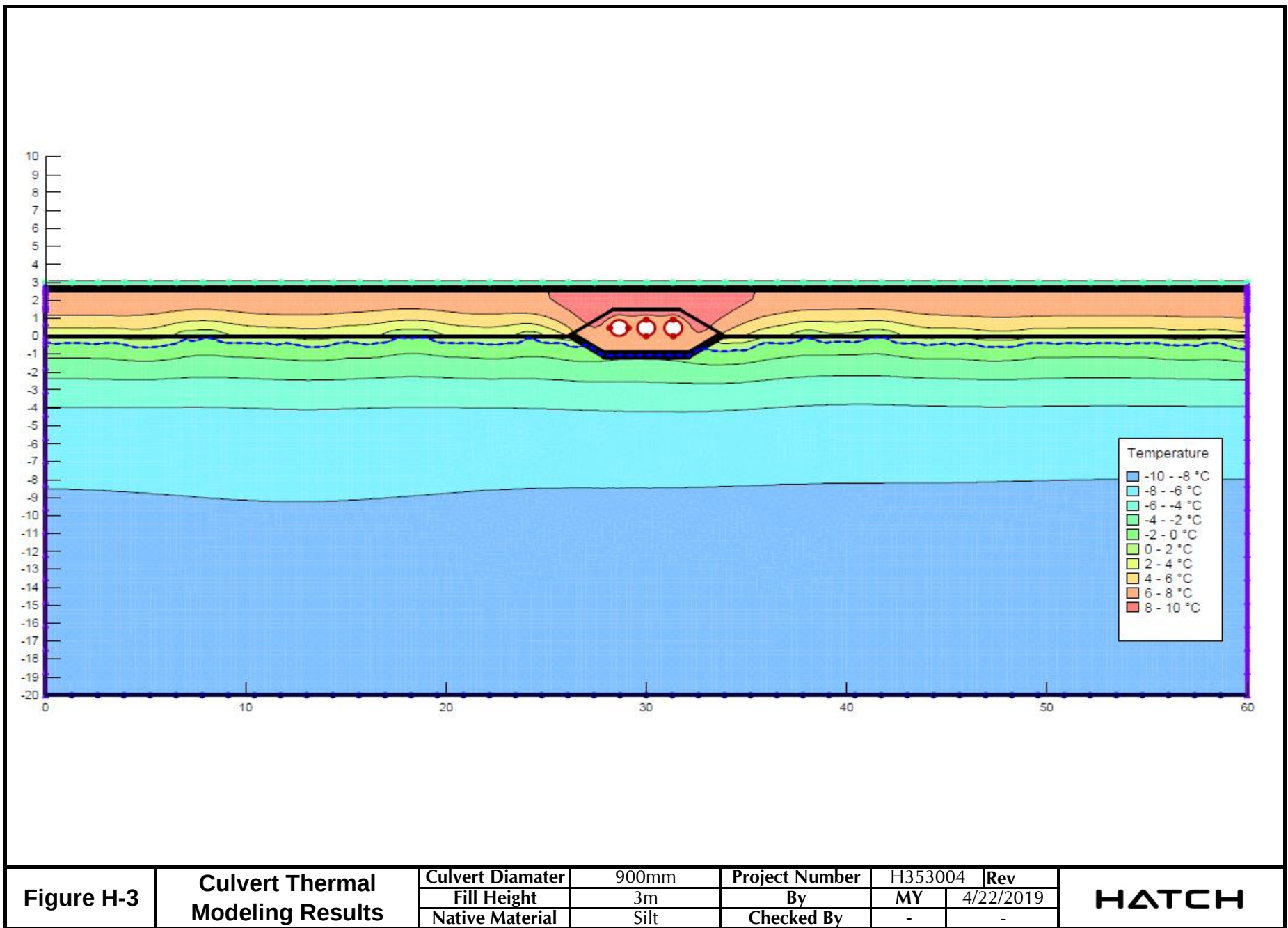


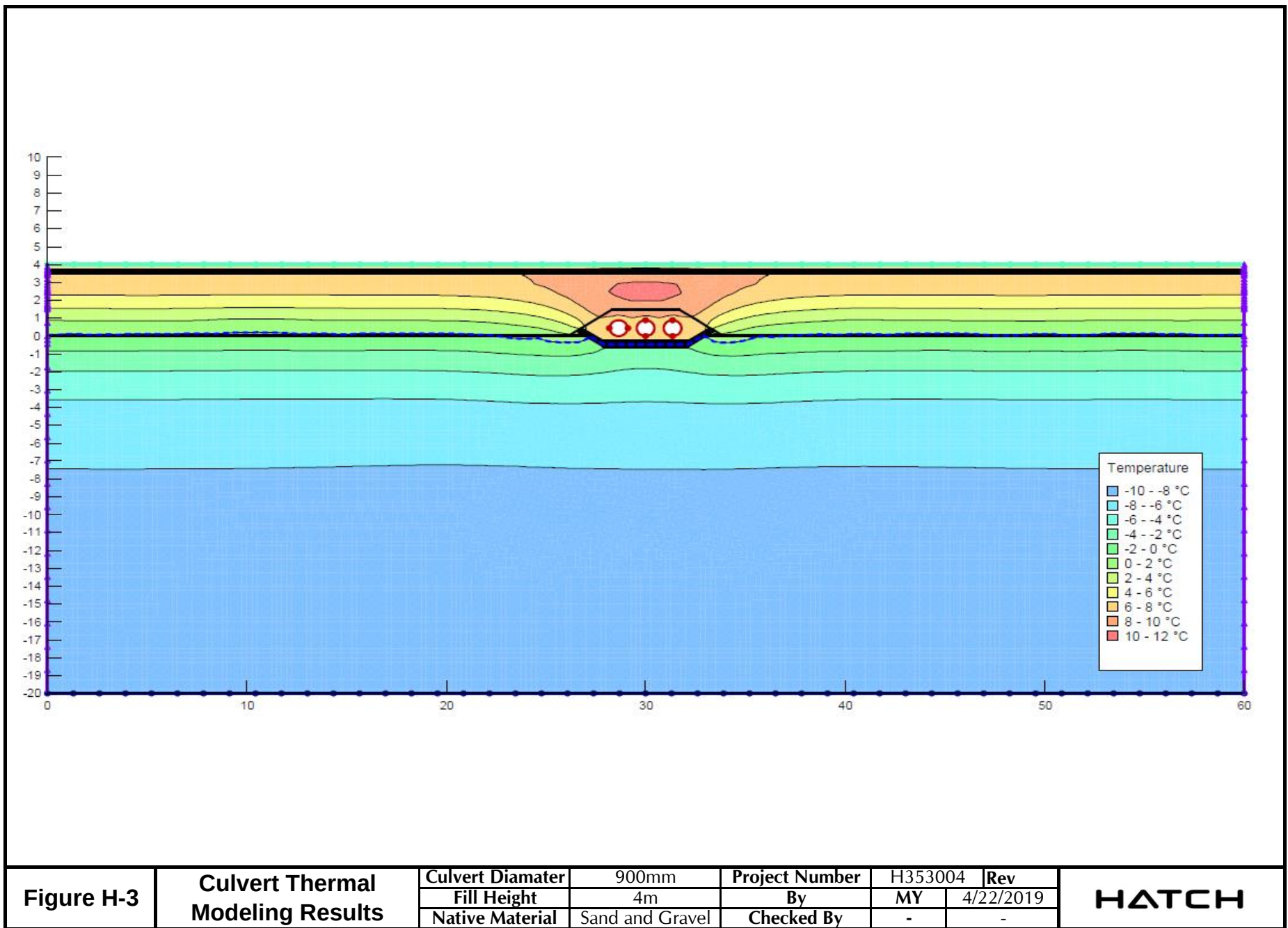
Figure H-3

**Culvert Thermal
Modeling Results**

Culvert Diameter	900mm	Project Number	H353004	Rev	
Fill Height	3m	By	MY	4/22/2019	
Native Material	Sand and Gravel	Checked By	-	-	

HATCH





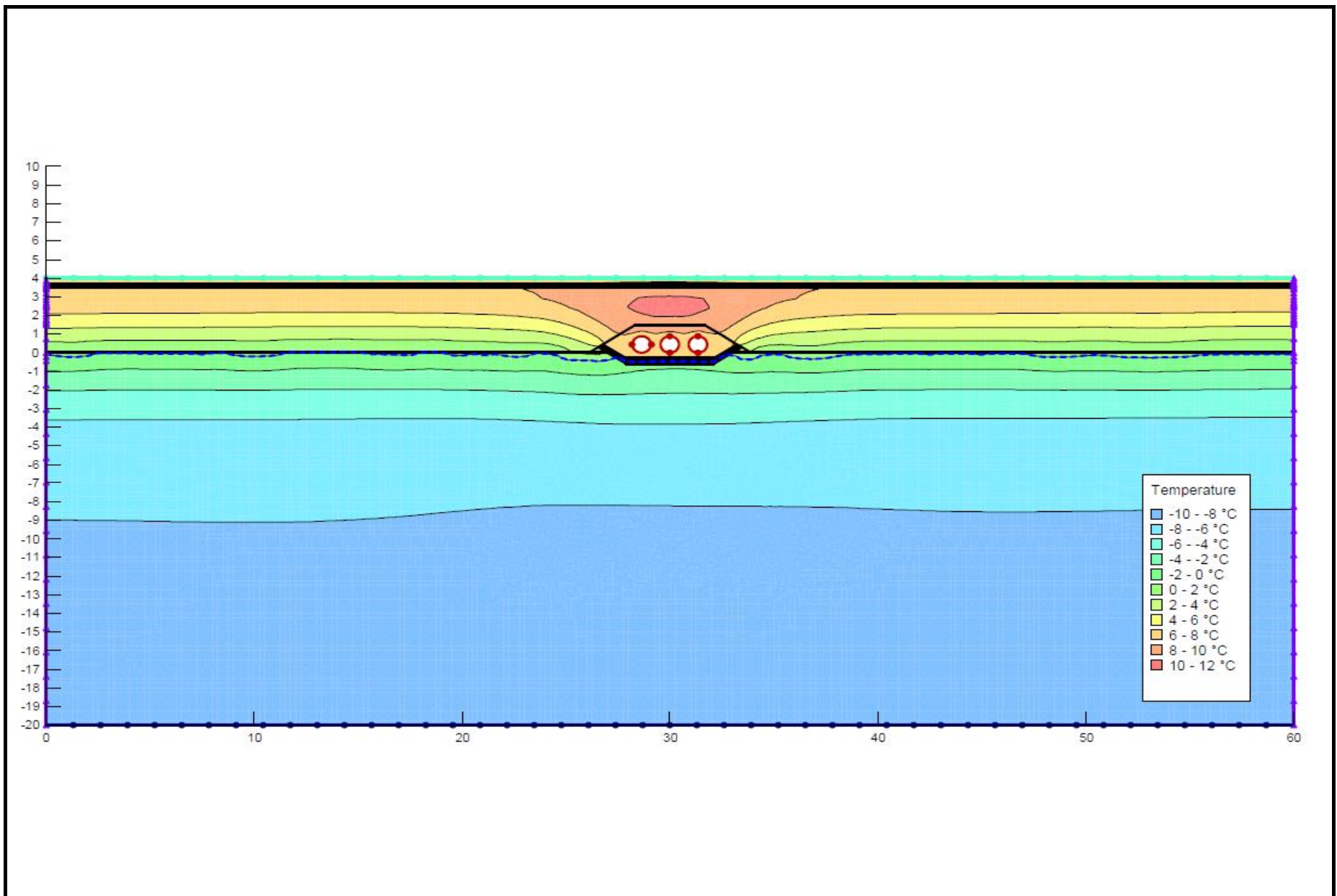


Figure H-3

**Culvert Thermal
Modeling Results**

Culvert Diamater	900mm	Project Number	H353004	Rev	
Fill Height	4m	By	MY	4/22/2019	
Native Material	Silt	Checked By	-	-	

HATCH

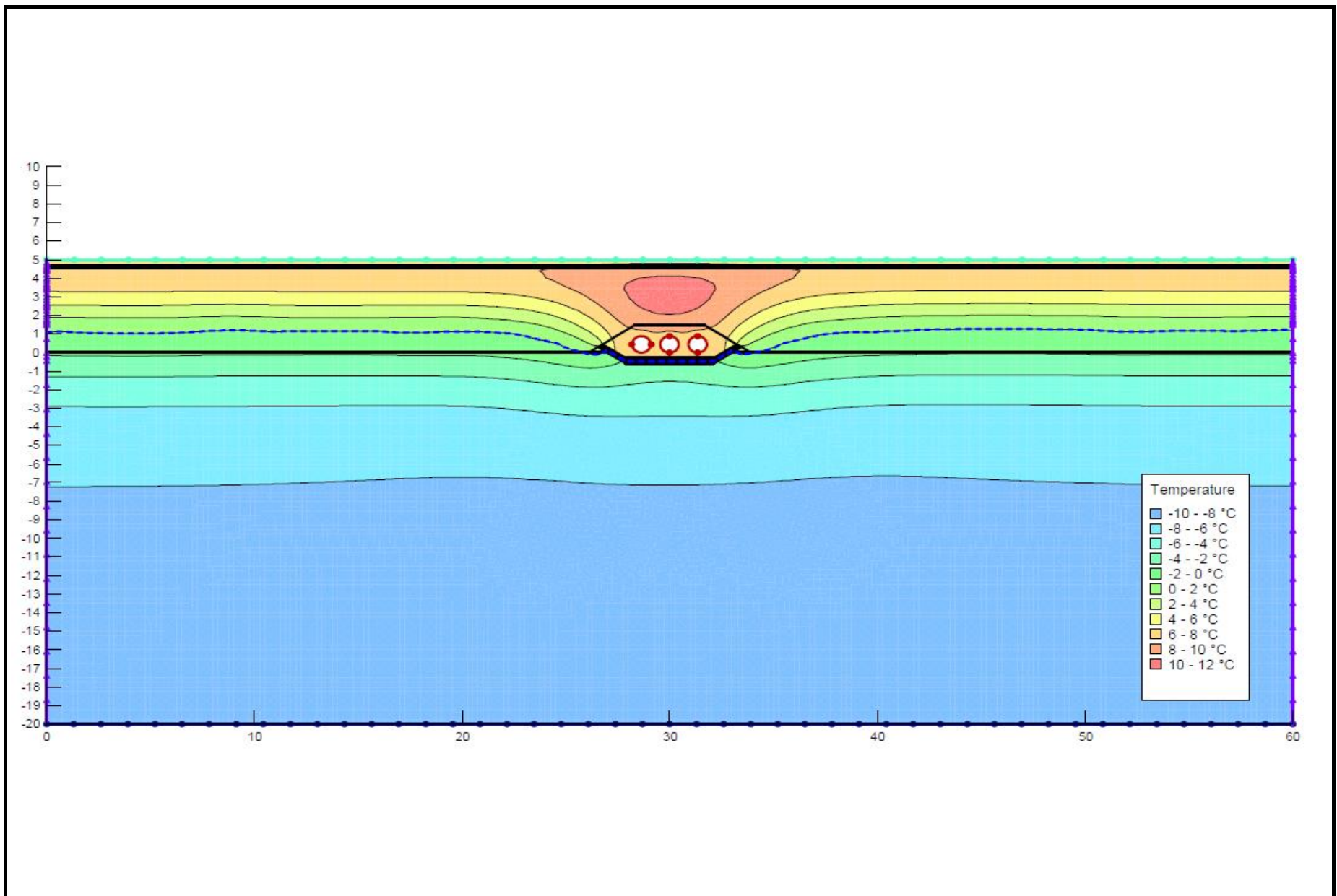


Figure H-3

**Culvert Thermal
Modeling Results**

Culvert Diameter	900mm	Project Number	H353004	Rev	
Fill Height	5m	By	MY	4/22/2019	
Native Material	Sand and Gravel	Checked By	-	-	

HATCH

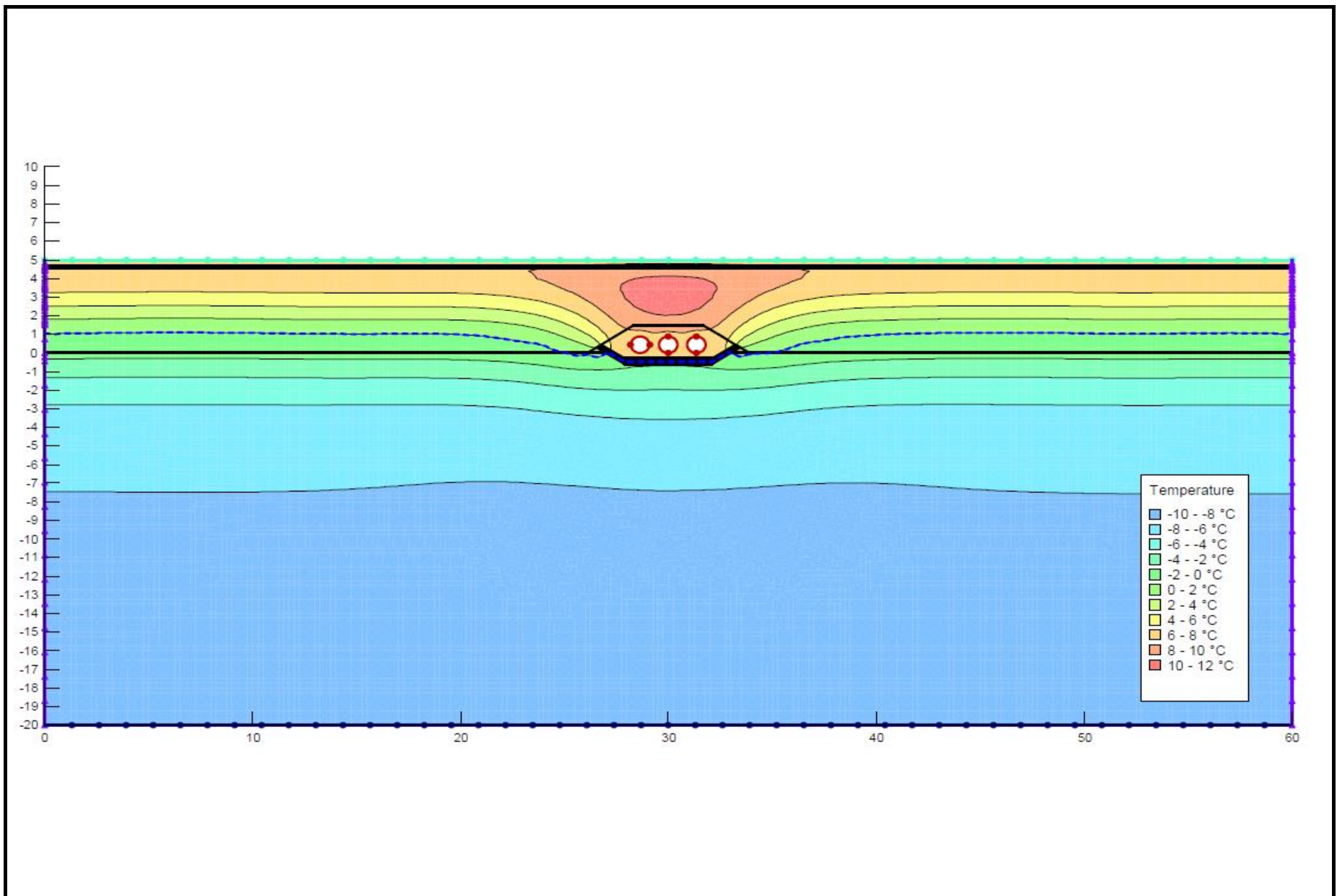


Figure H-3

**Culvert Thermal
Modeling Results**

Culvert Diamater	900mm	Project Number	H353004	Rev	
Fill Height	5m	By	MY	4/22/2019	
Native Material	Silt	Checked By	-	-	

HATCH

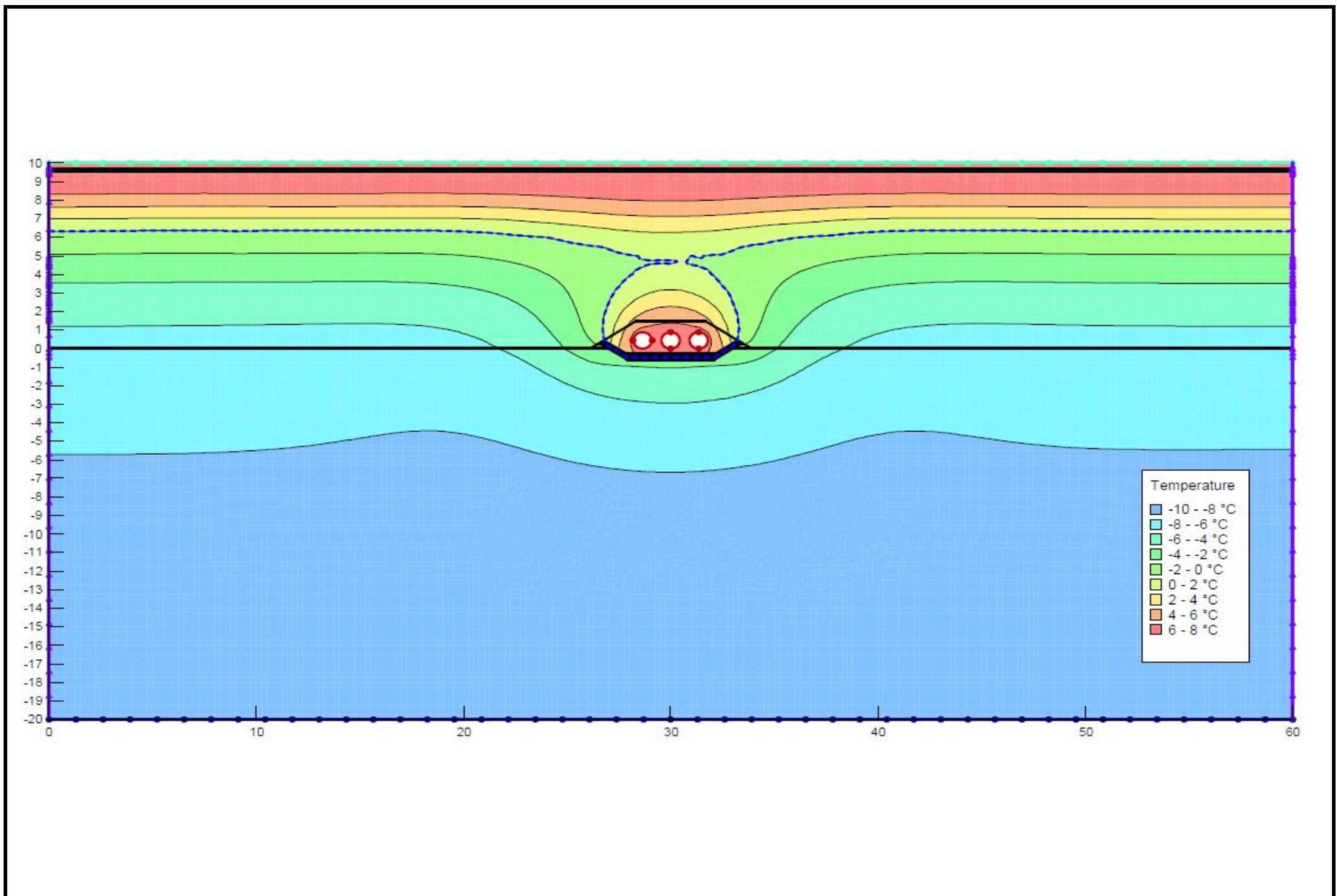


Figure H-3

**Culvert Thermal
Modeling Results**

Culvert Diameter	900mm	Project Number	H353004	Rev	
Fill Height	10m	By	MY	4/22/2019	
Native Material	Sand and Gravel	Checked By	-	-	

HATCH

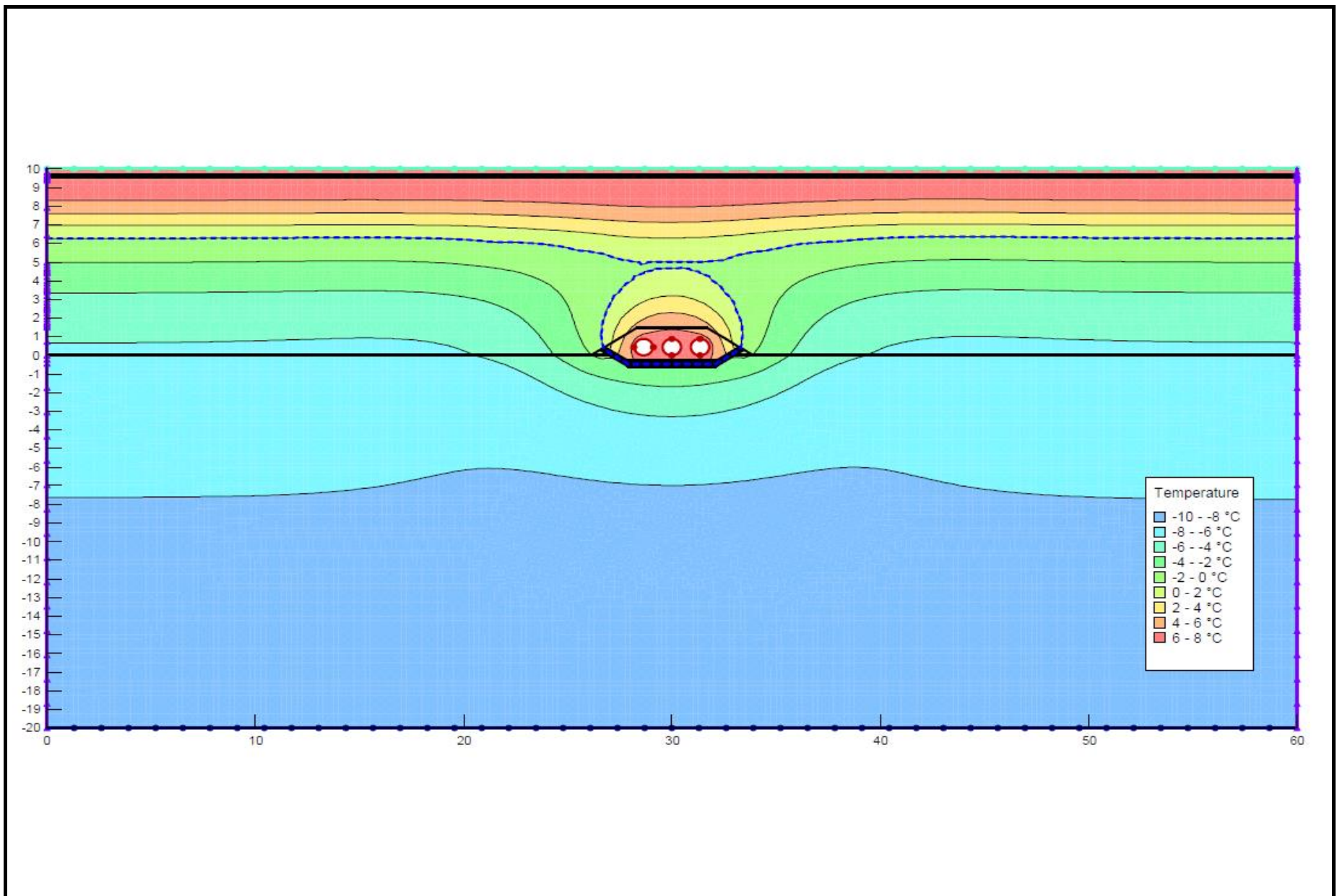
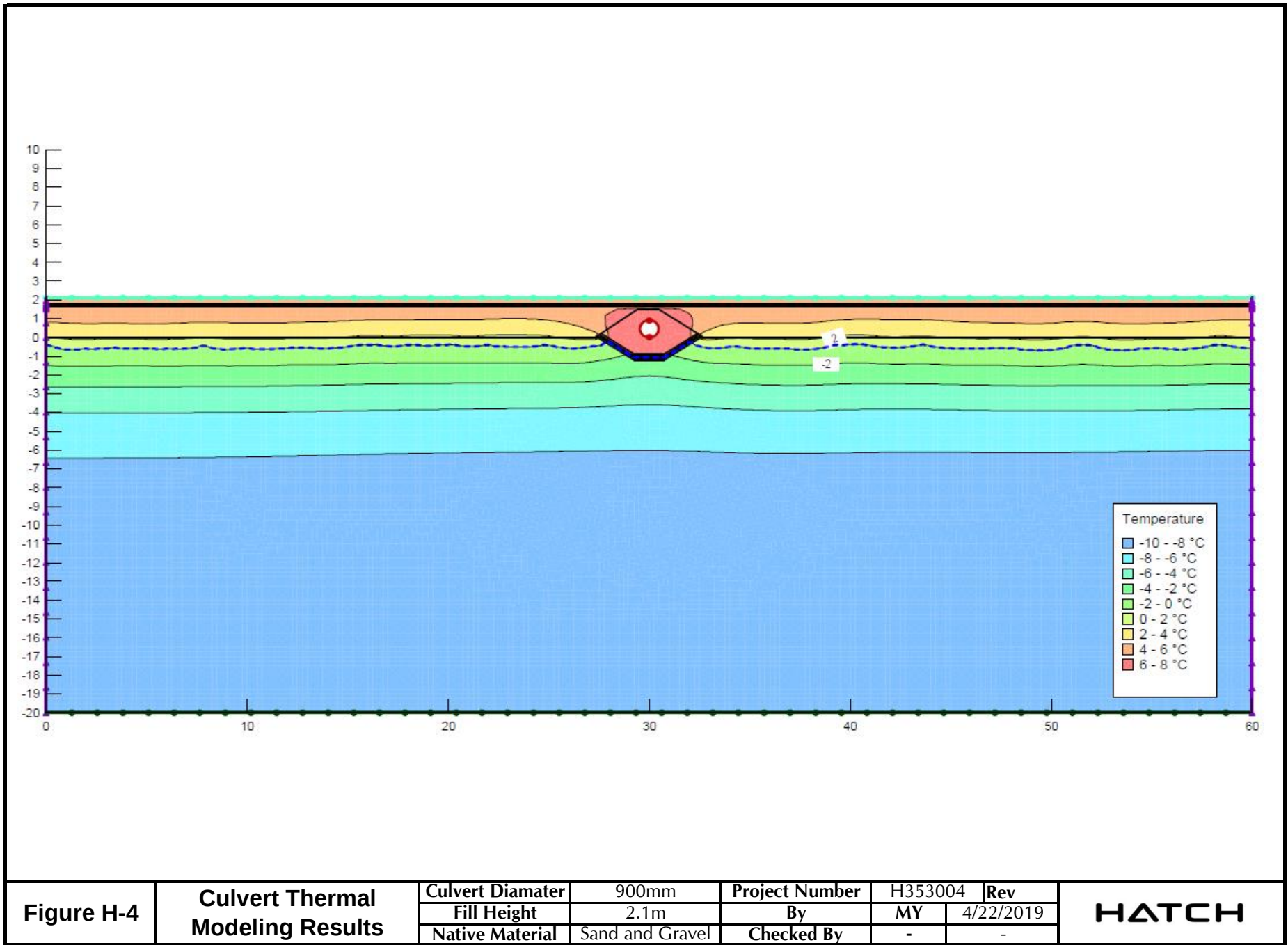


Figure H-3

**Culvert Thermal
Modeling Results**

Culvert Diamater	900mm	Project Number	H353004	Rev	
Fill Height	10m	By	MY	4/22/2019	
Native Material	Silt	Checked By	-	-	

HATCH



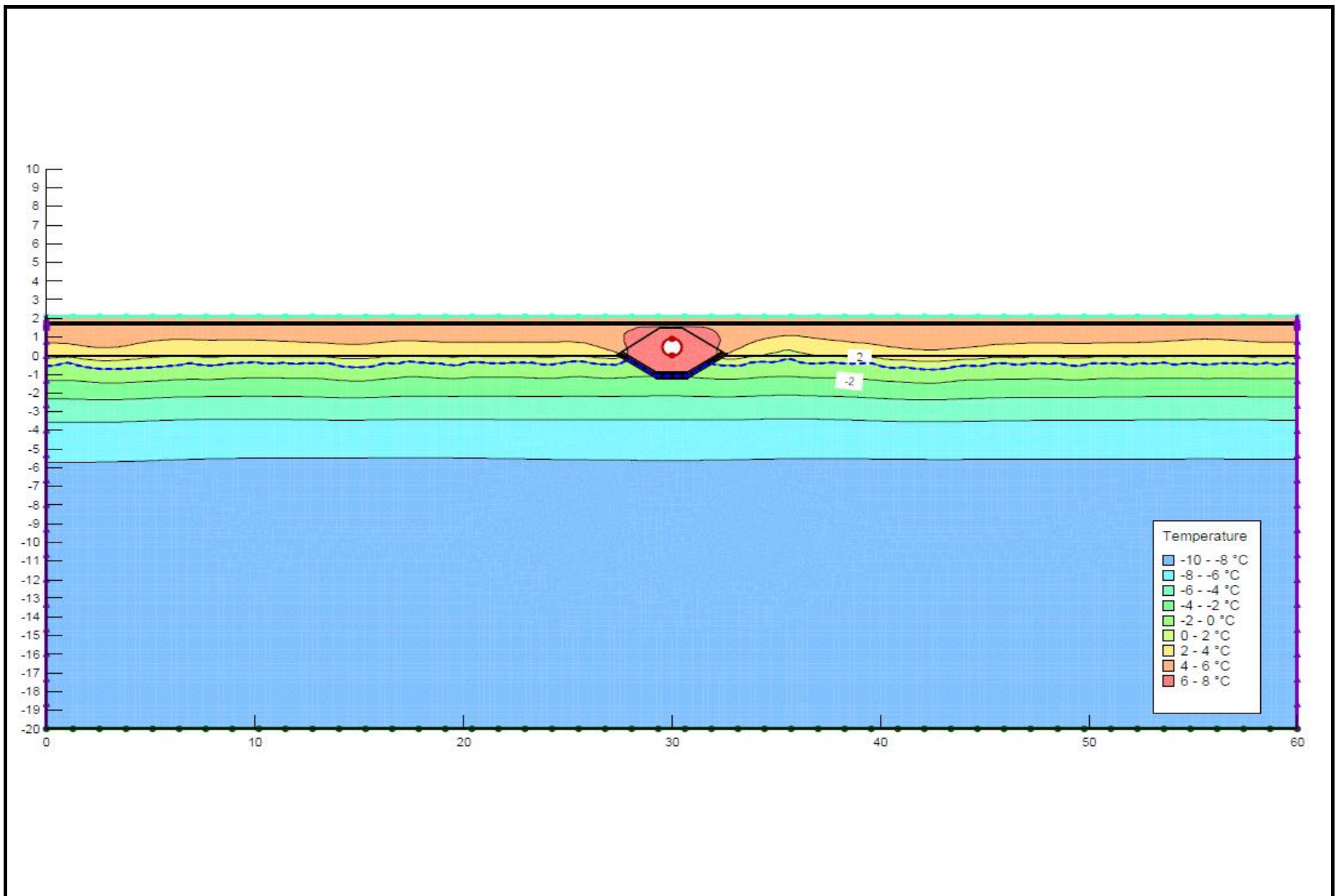


Figure H-4

**Culvert Thermal
Modeling Results**

Culvert Diameter	900mm	Project Number	H353004	Rev	
Fill Height	2.1m	By	MY	4/22/2019	
Native Material	Silt	Checked By	-	-	

HATCH

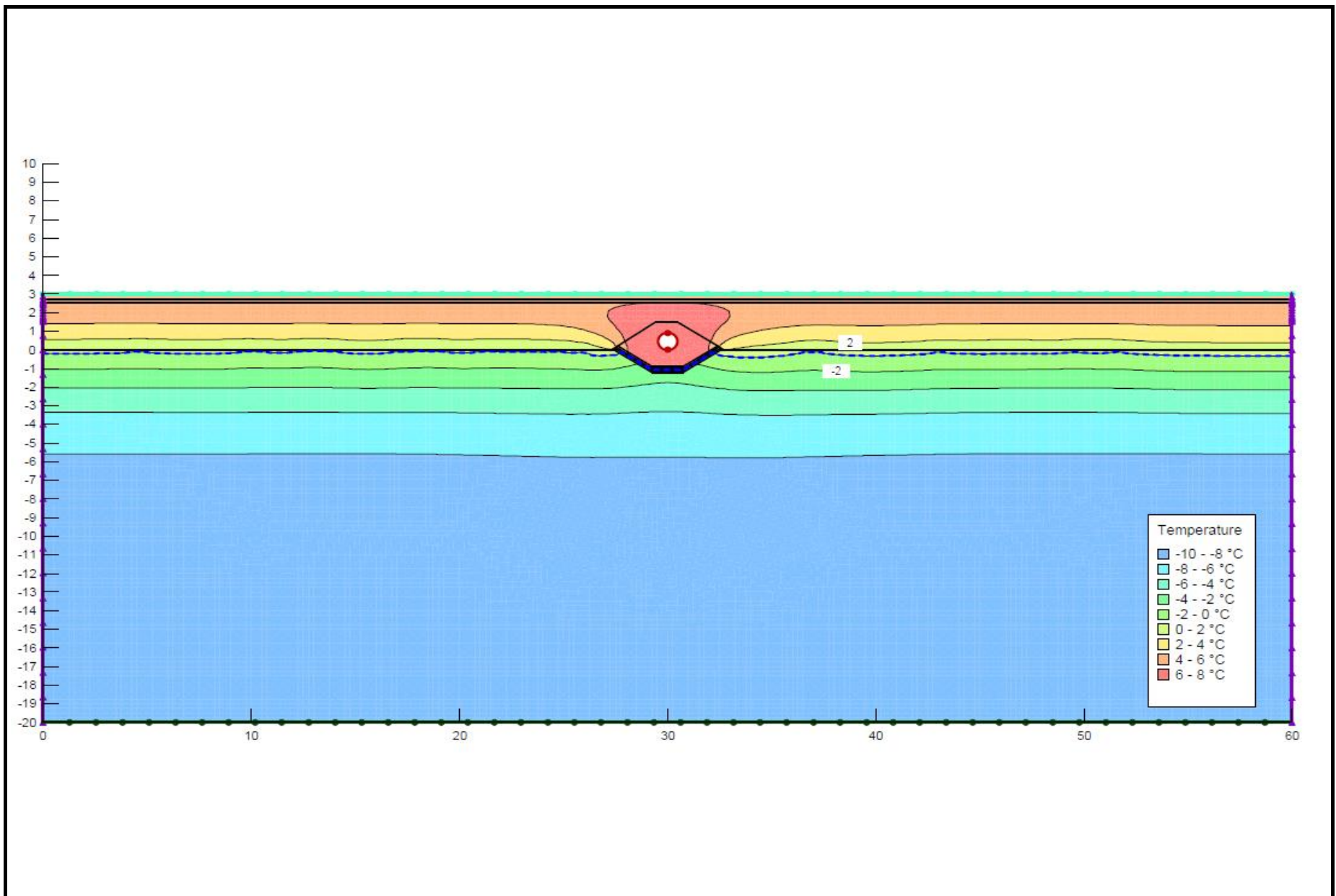


Figure H-4	Culvert Thermal Modeling Results	Culvert Diameter	900mm	Project Number	H353004	Rev	HATCH
		Fill Height	3m	By	MY	4/22/2019	
		Native Material	Sand and Gravel	Checked By	-	-	

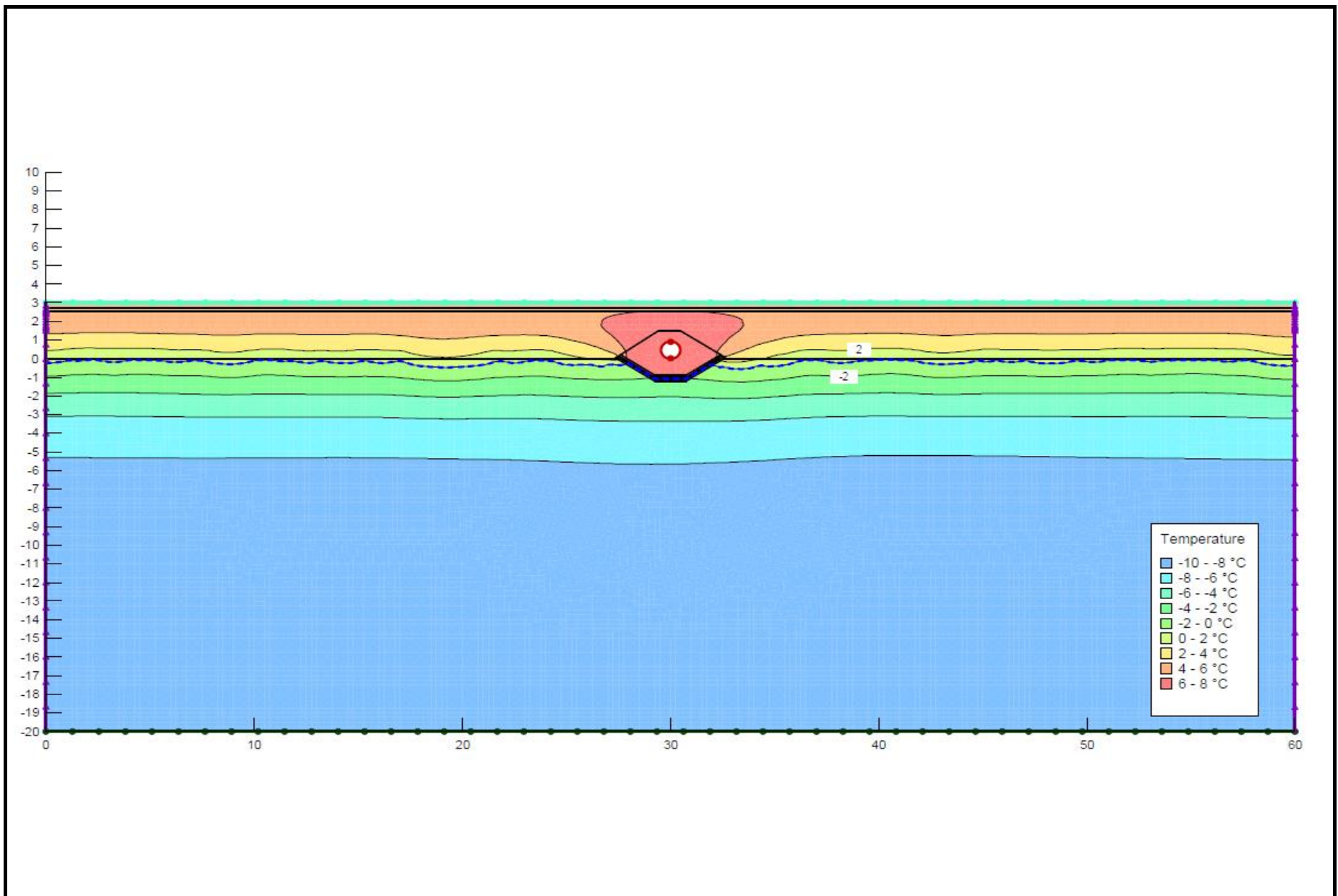


Figure H-4	Culvert Thermal Modeling Results	Culvert Diameter	900mm	Project Number	H353004	Rev	
		Fill Height	3m	By	MY	4/22/2019	
		Native Material	Silt	Checked By	-	-	

HATCH

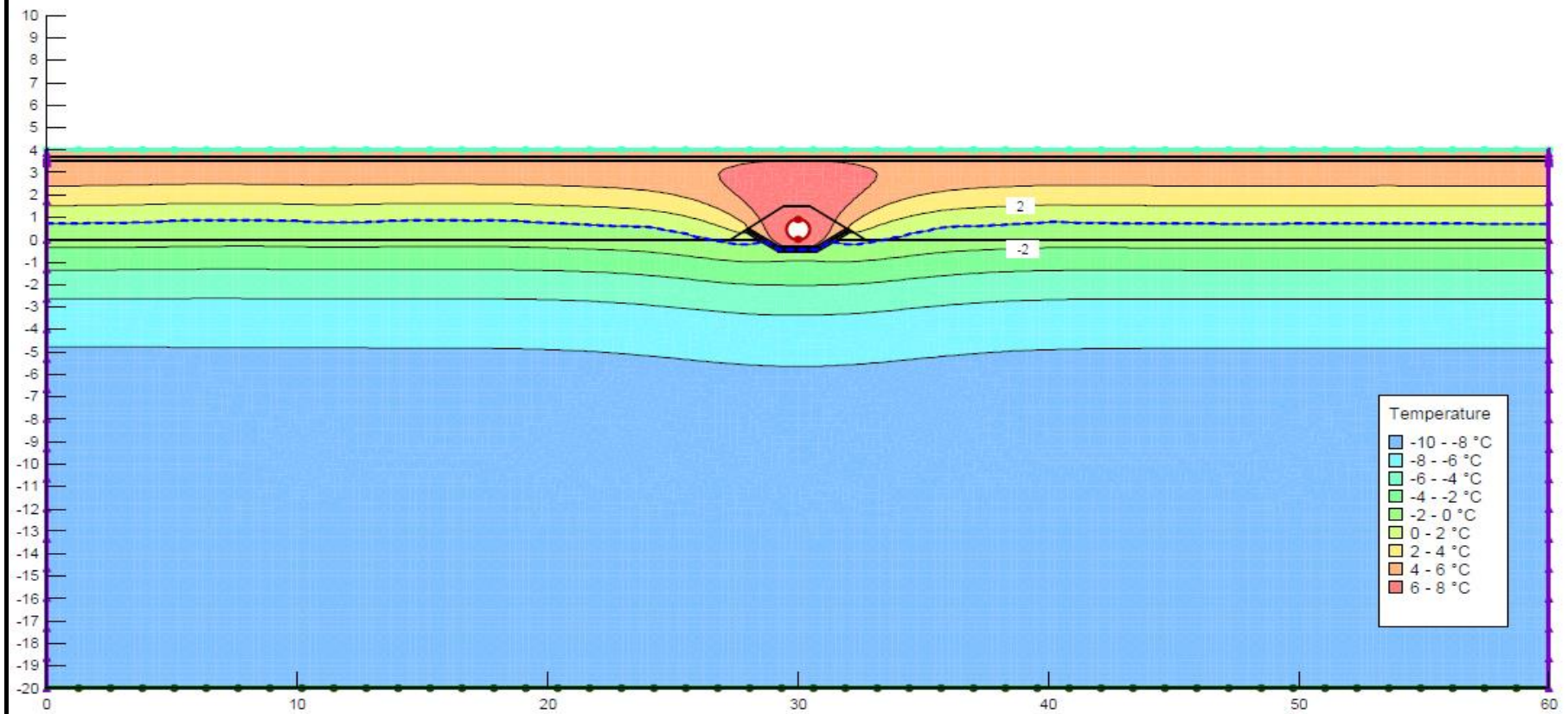


Figure H-4

**Culvert Thermal
Modeling Results**

Culvert Diameter	900mm	Project Number	H353004	Rev	
Fill Height	4m	By	MY	4/22/2019	
Native Material	Sand and Gravel	Checked By	-	-	

HATCH

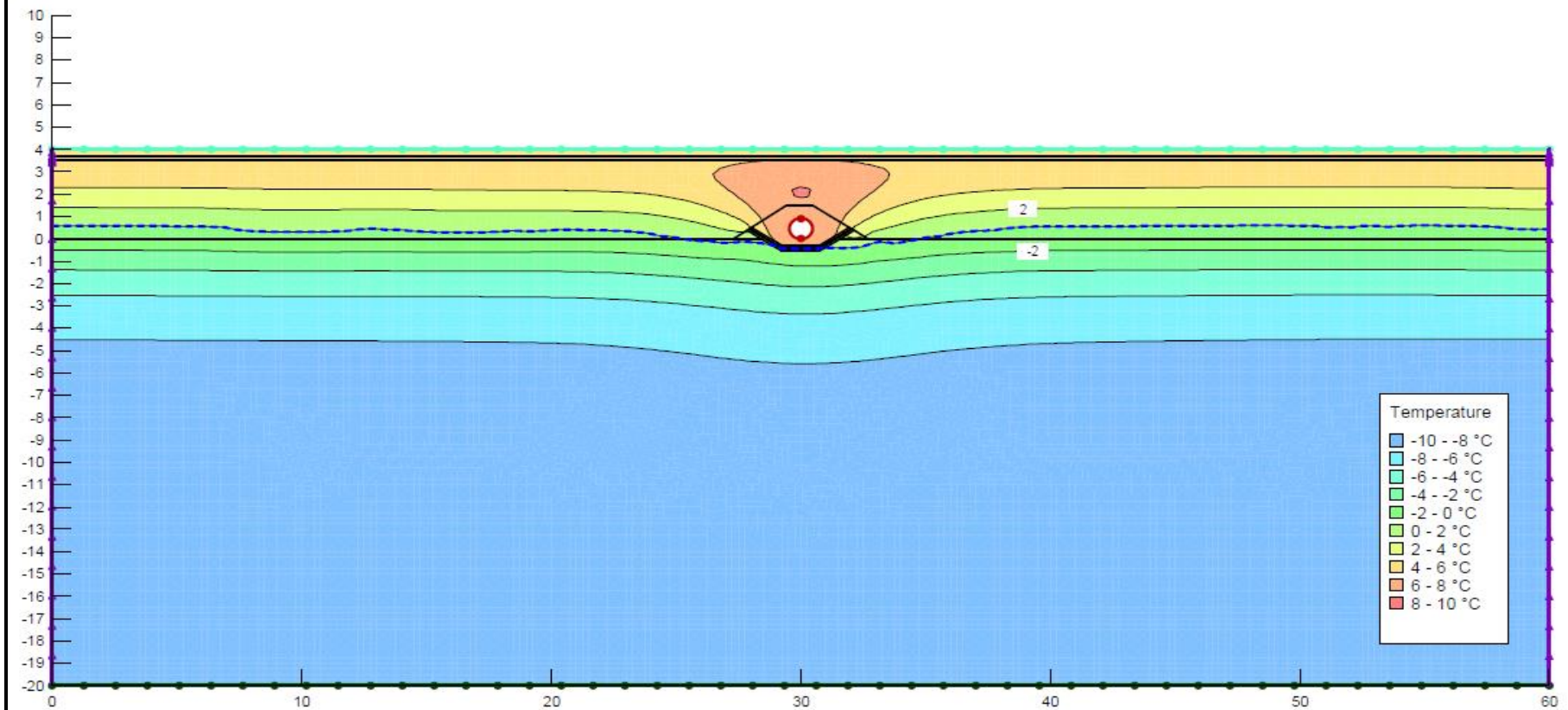


Figure H-4

**Culvert Thermal
Modeling Results**

Culvert Diameter	900mm	Project Number	H353004	Rev	
Fill Height	4m	By	MY	4/22/2019	
Native Material	Silt	Checked By	-	-	

HATCH

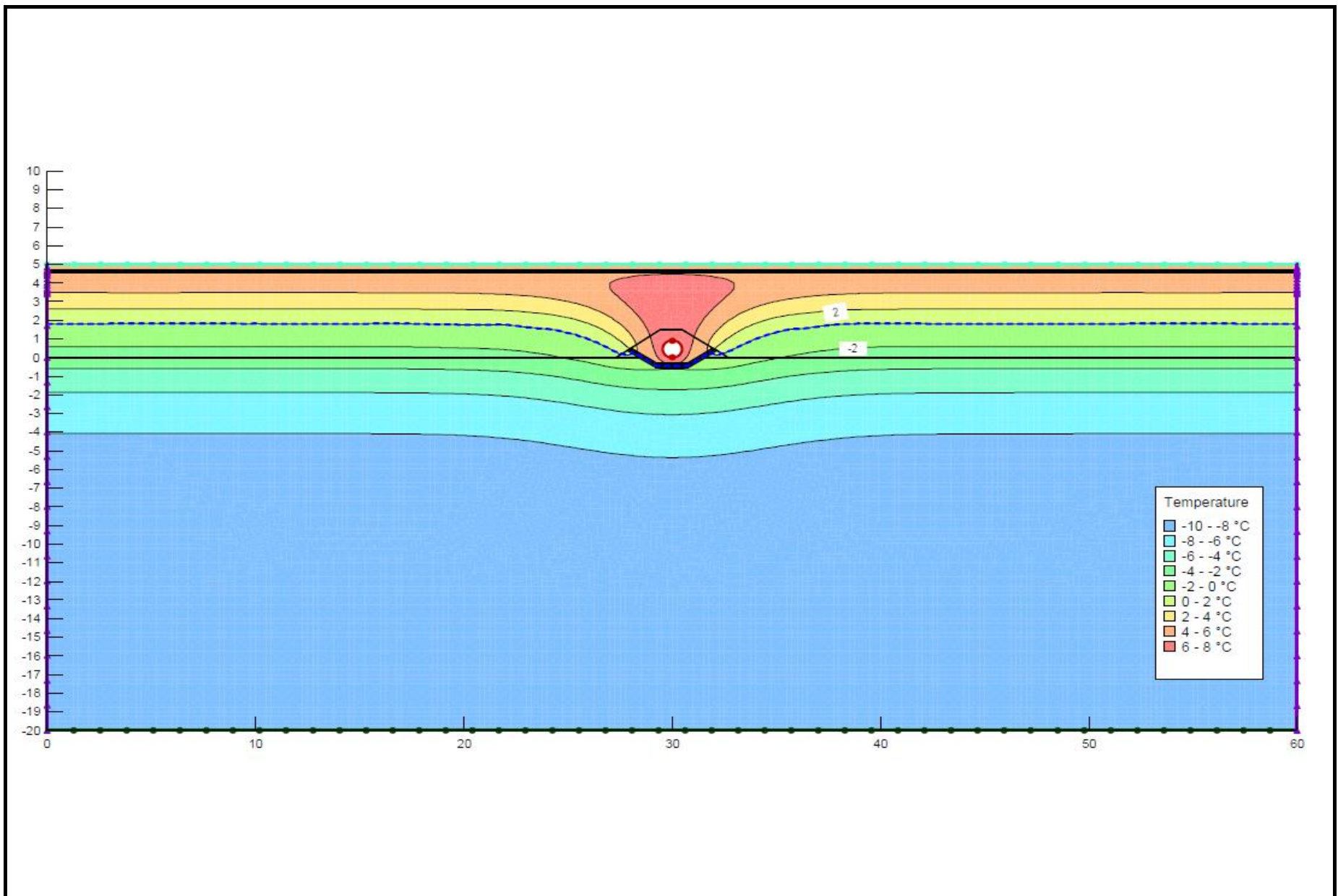


Figure H-4	Culvert Thermal Modeling Results	Culvert Diameter	900mm	Project Number	H353004	Rev	HATCH
		Fill Height	5m	By	MY	4/22/2019	
		Native Material	Sand and Gravel	Checked By	-	-	

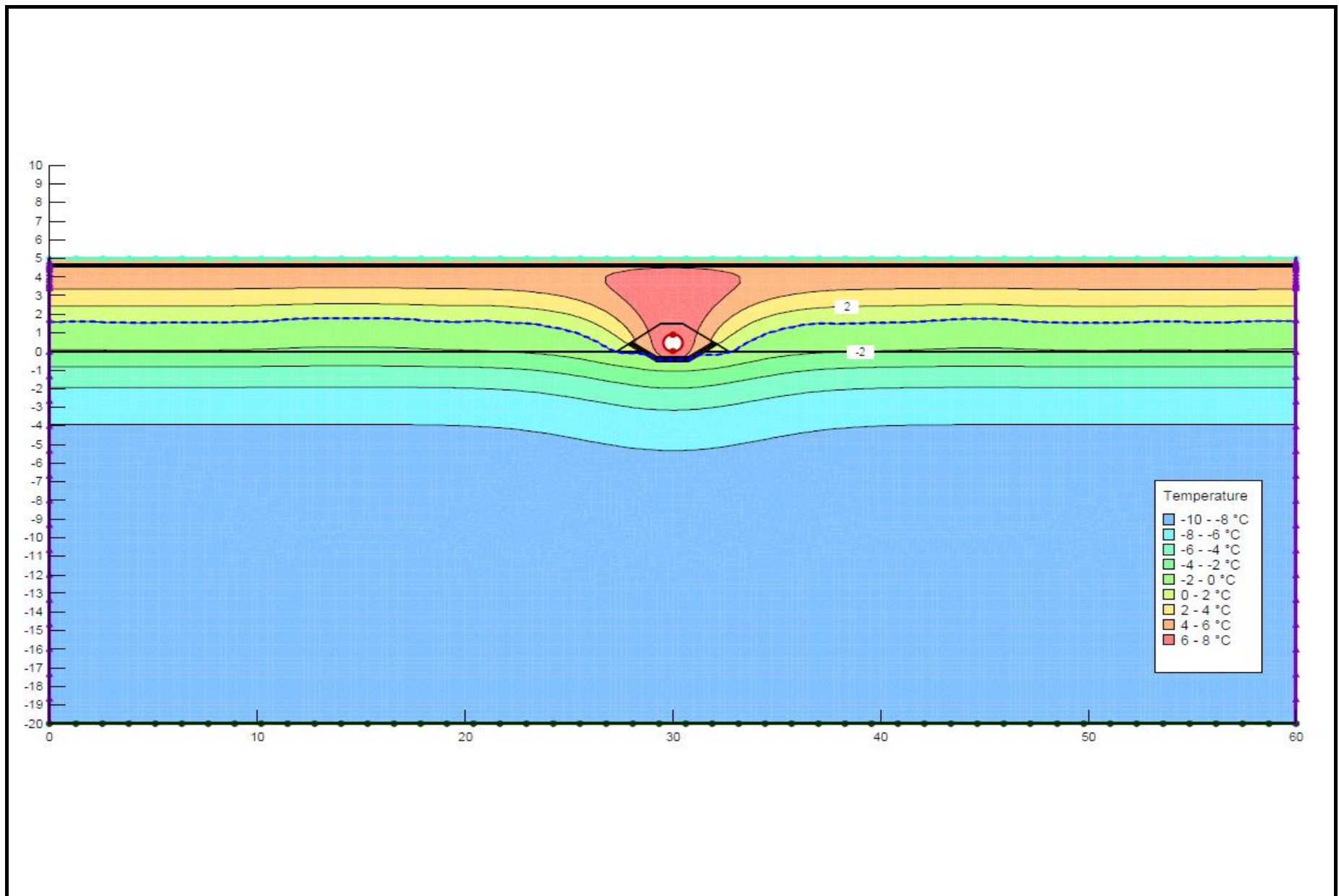


Figure H-4

**Culvert Thermal
Modeling Results**

Culvert Diameter	900mm	Project Number	H353004	Rev	
Fill Height	5m	By	MY	4/22/2019	
Native Material	Silt	Checked By	-	-	

HATCH

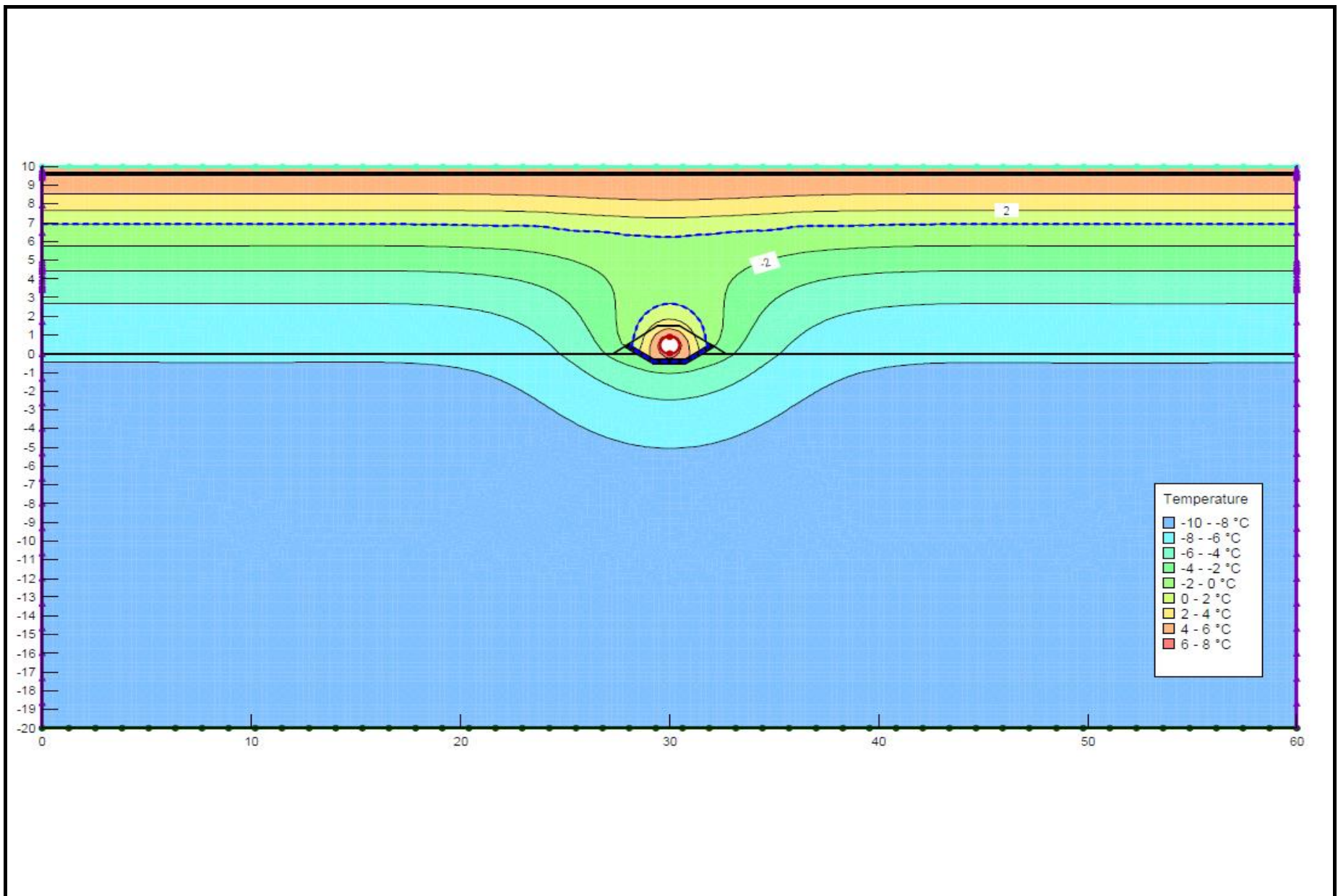


Figure H-4	Culvert Thermal Modeling Results	Culvert Diameter	900mm	Project Number	H353004	Rev	HATCH
		Fill Height	10m	By	MY	4/22/2019	
		Native Material	Sand and Gravel	Checked By	-	-	

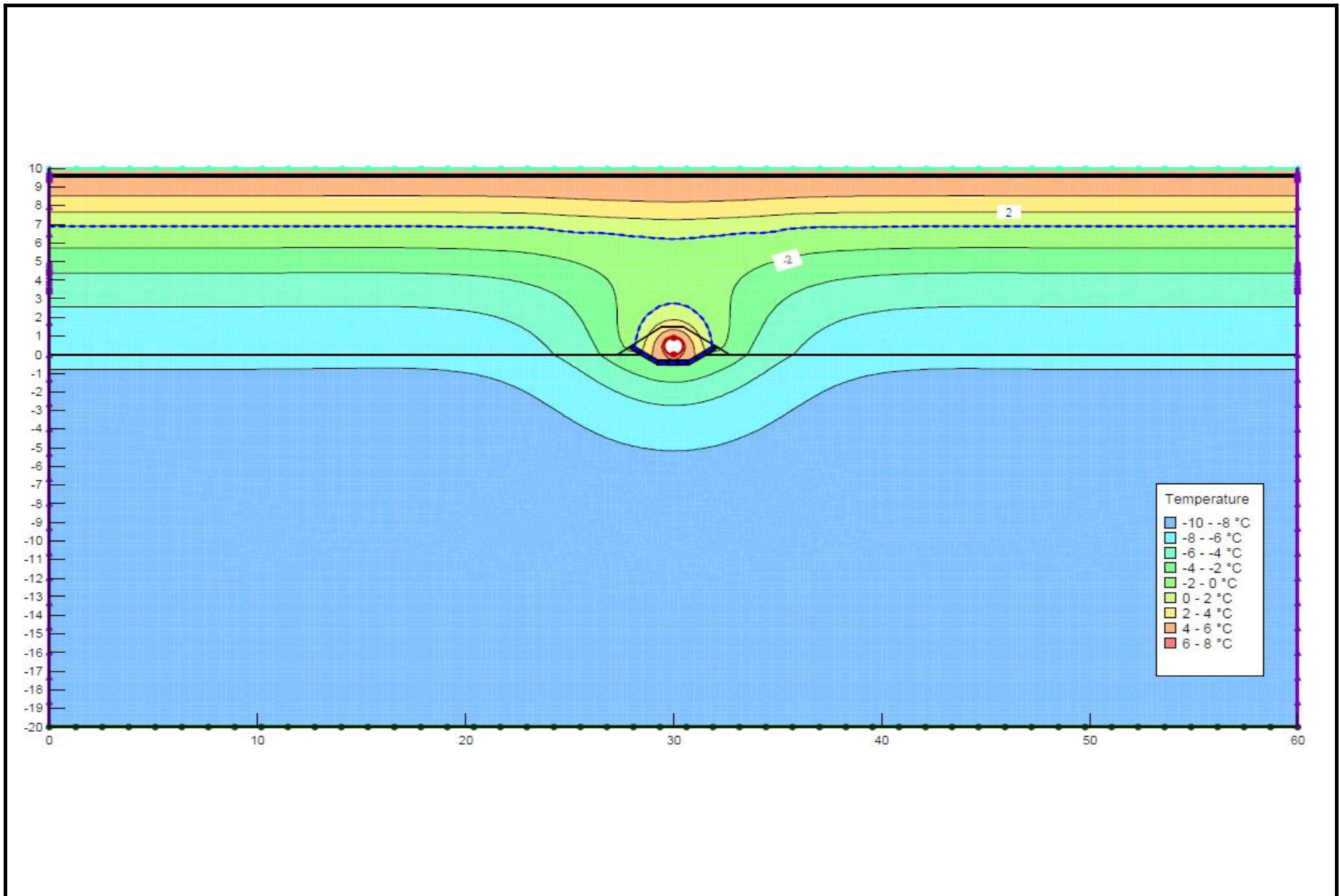
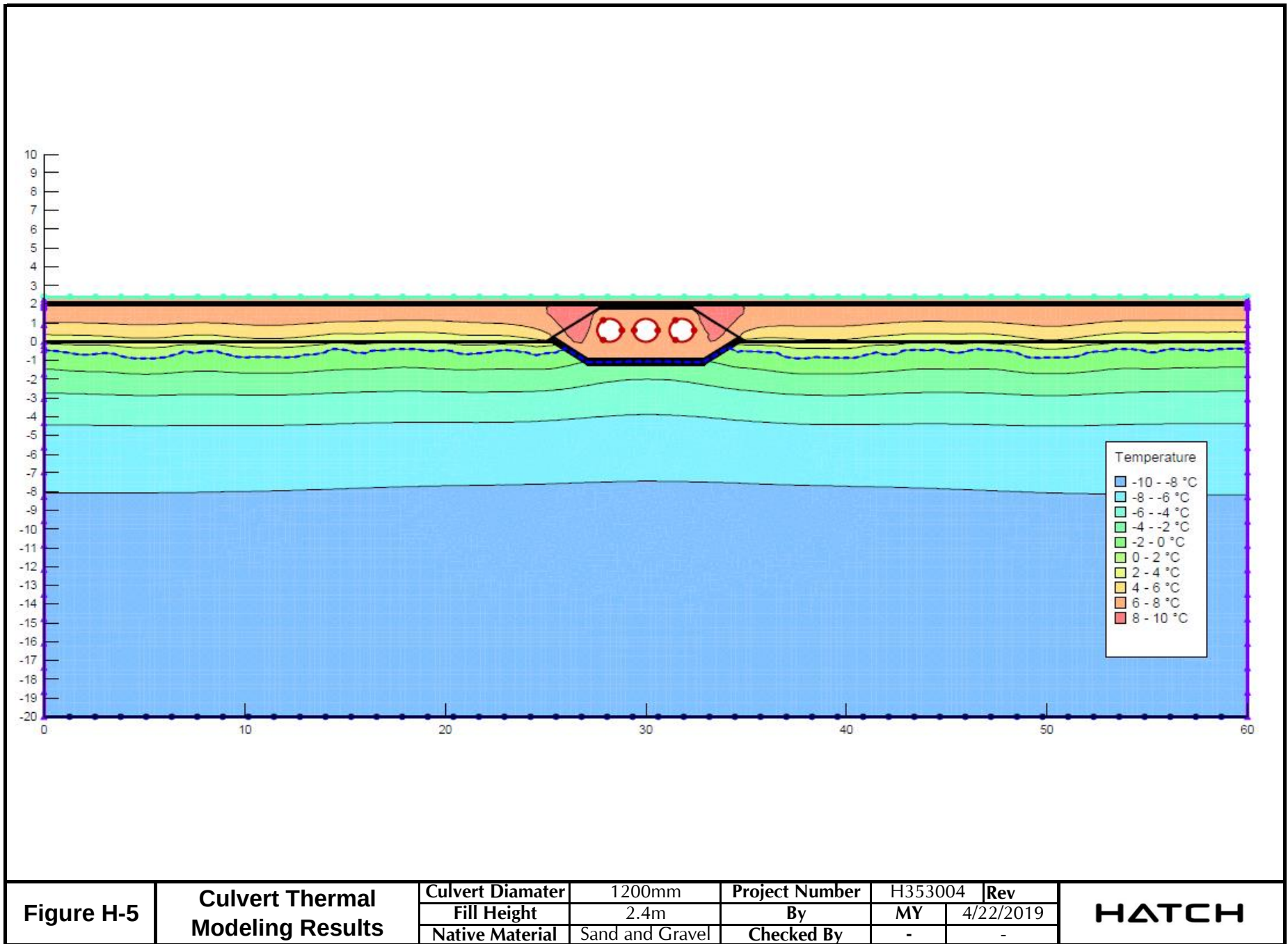


Figure H-4

**Culvert Thermal
Modeling Results**

Culvert Diameter	900mm	Project Number	H353004	Rev
Fill Height	10m	By	MY	4/22/2019
Native Material	Silt	Checked By	-	-

HATCH



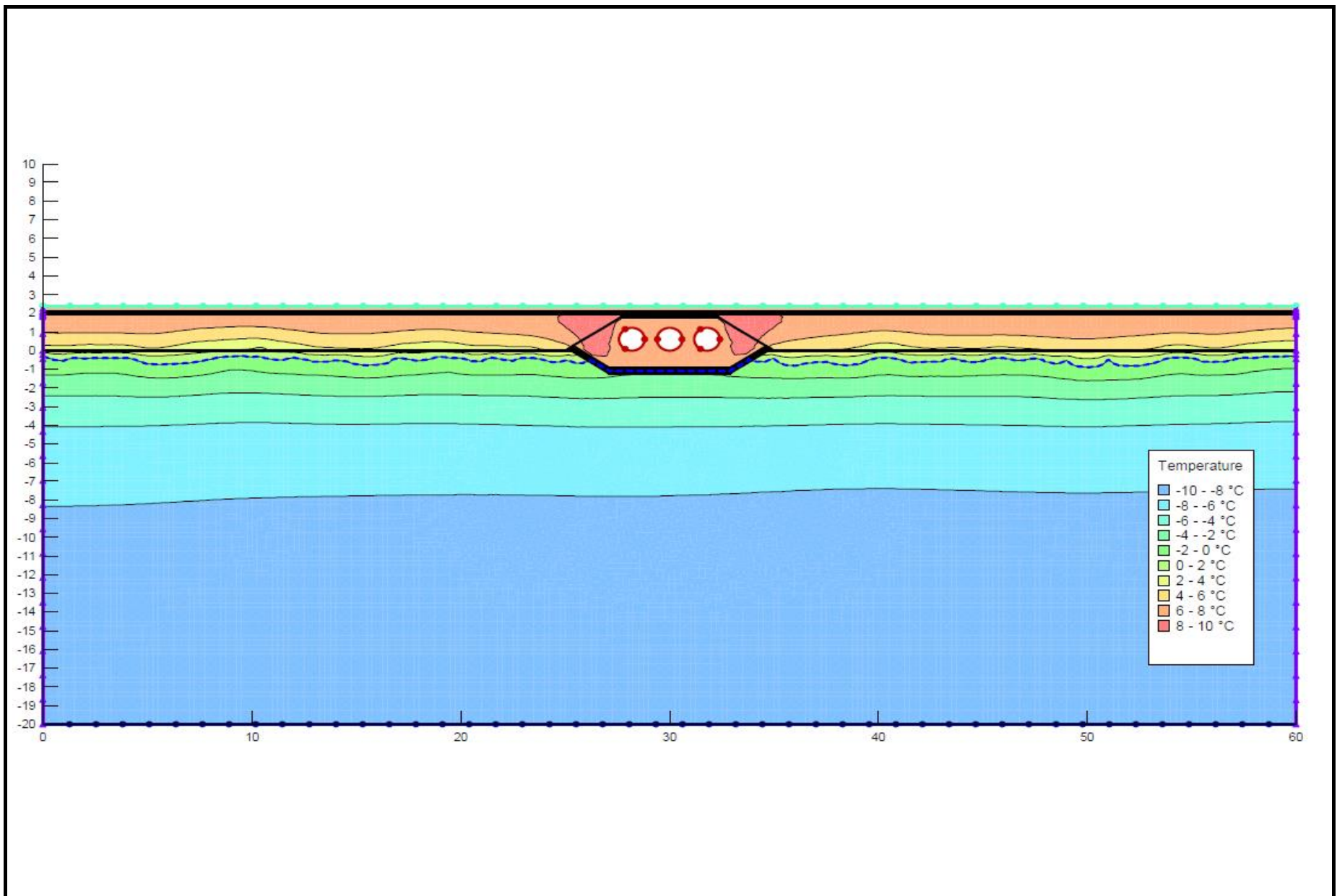
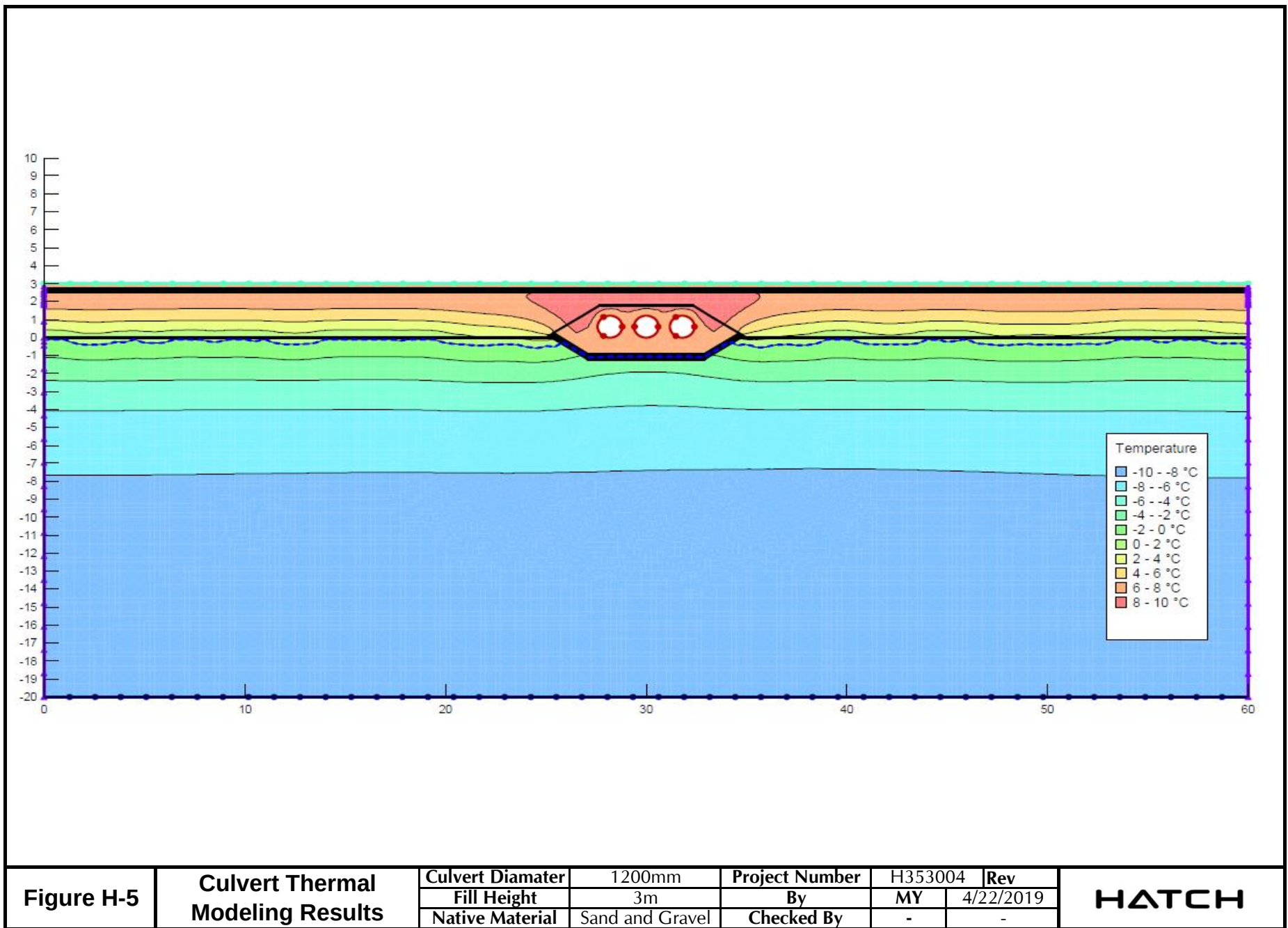


Figure H-5	Culvert Thermal Modeling Results	Culvert Diameter	1200mm	Project Number	H353004	Rev	HATCH
		Fill Height	2.4m	By	MY	4/22/2019	
		Native Material	Silt	Checked By	-	-	



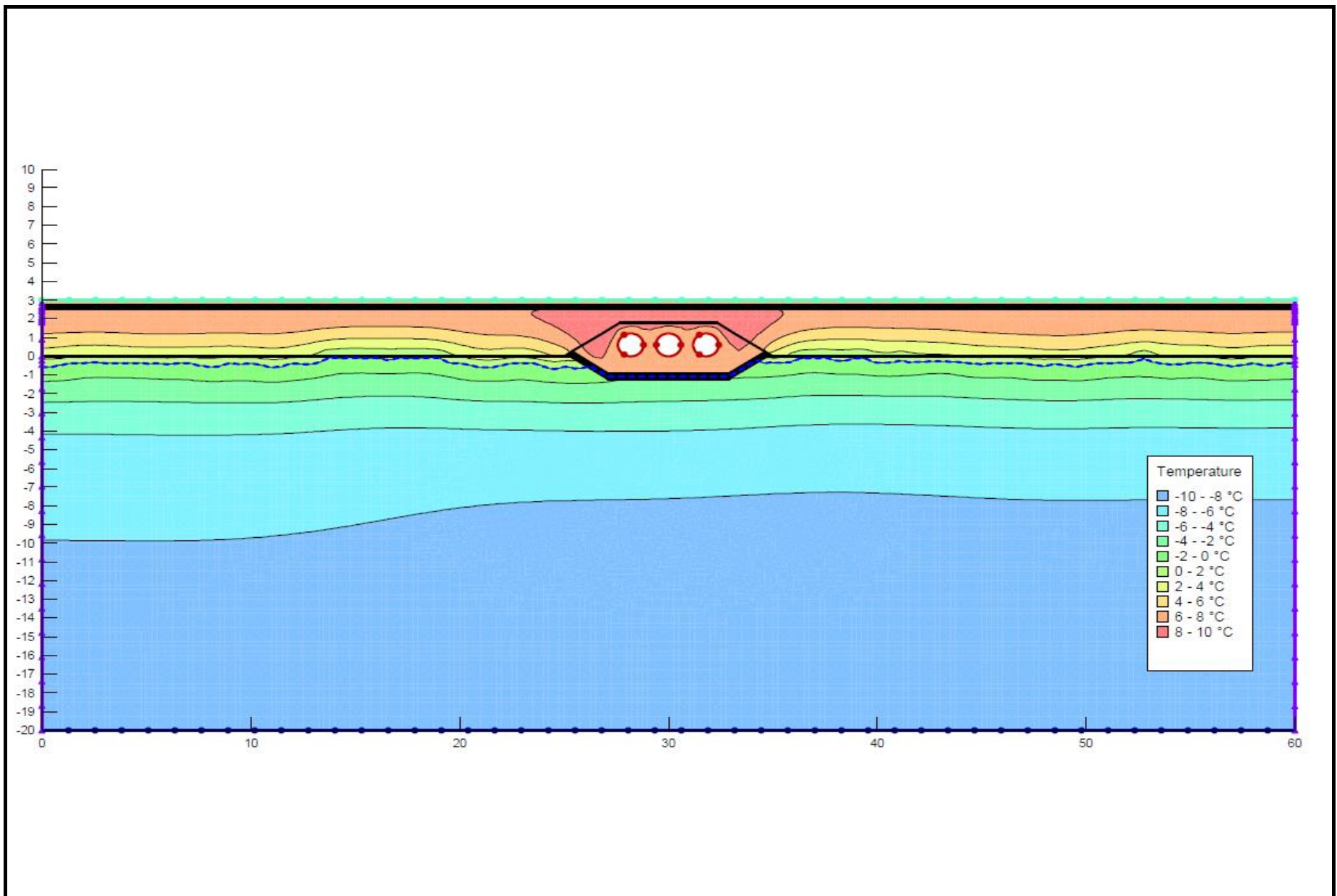


Figure H-5	Culvert Thermal Modeling Results	Culvert Diameter	1200mm	Project Number	H353004	Rev	HATCH
		Fill Height	3m	By	MY	4/22/2019	
		Native Material	Silt	Checked By	-	-	

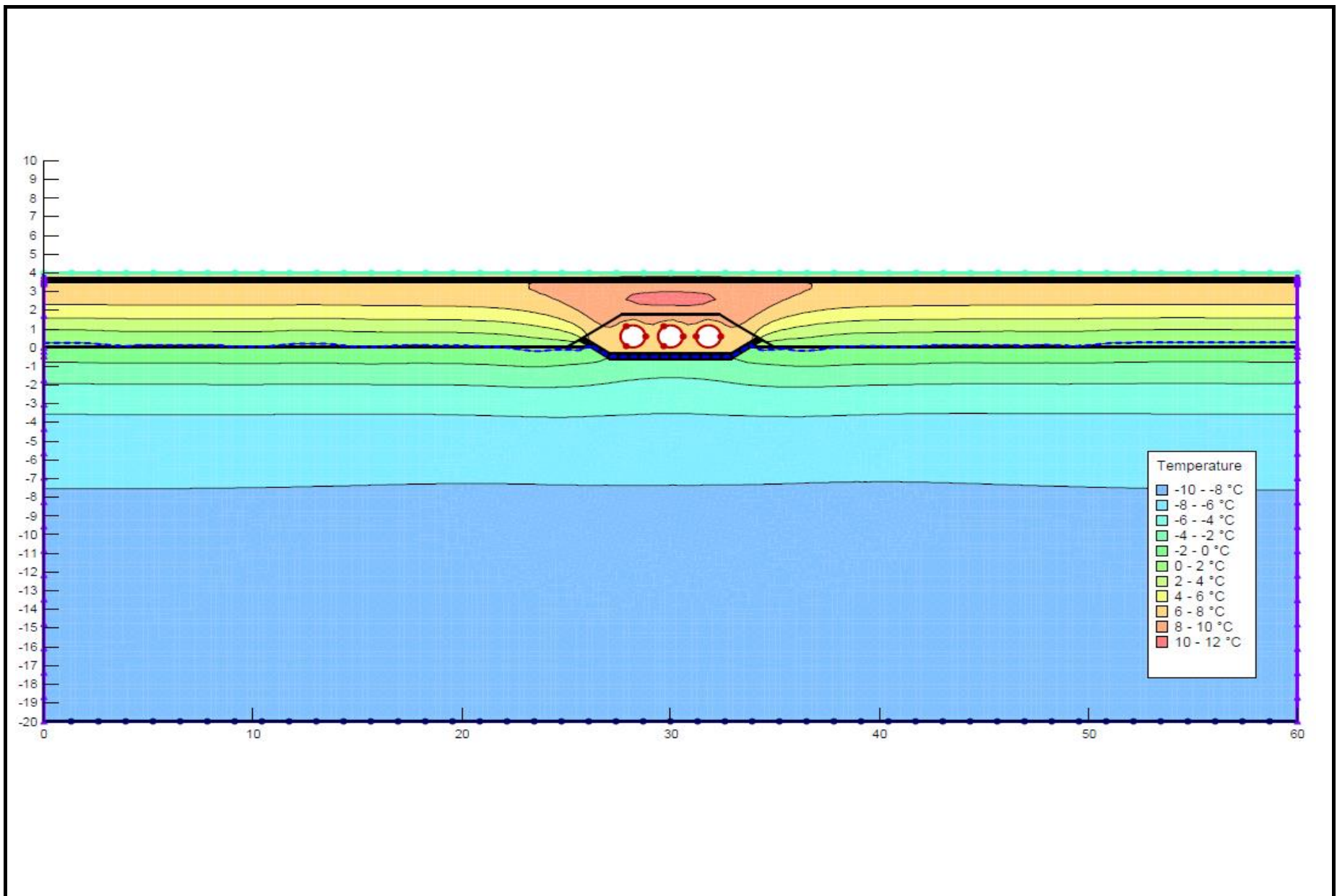
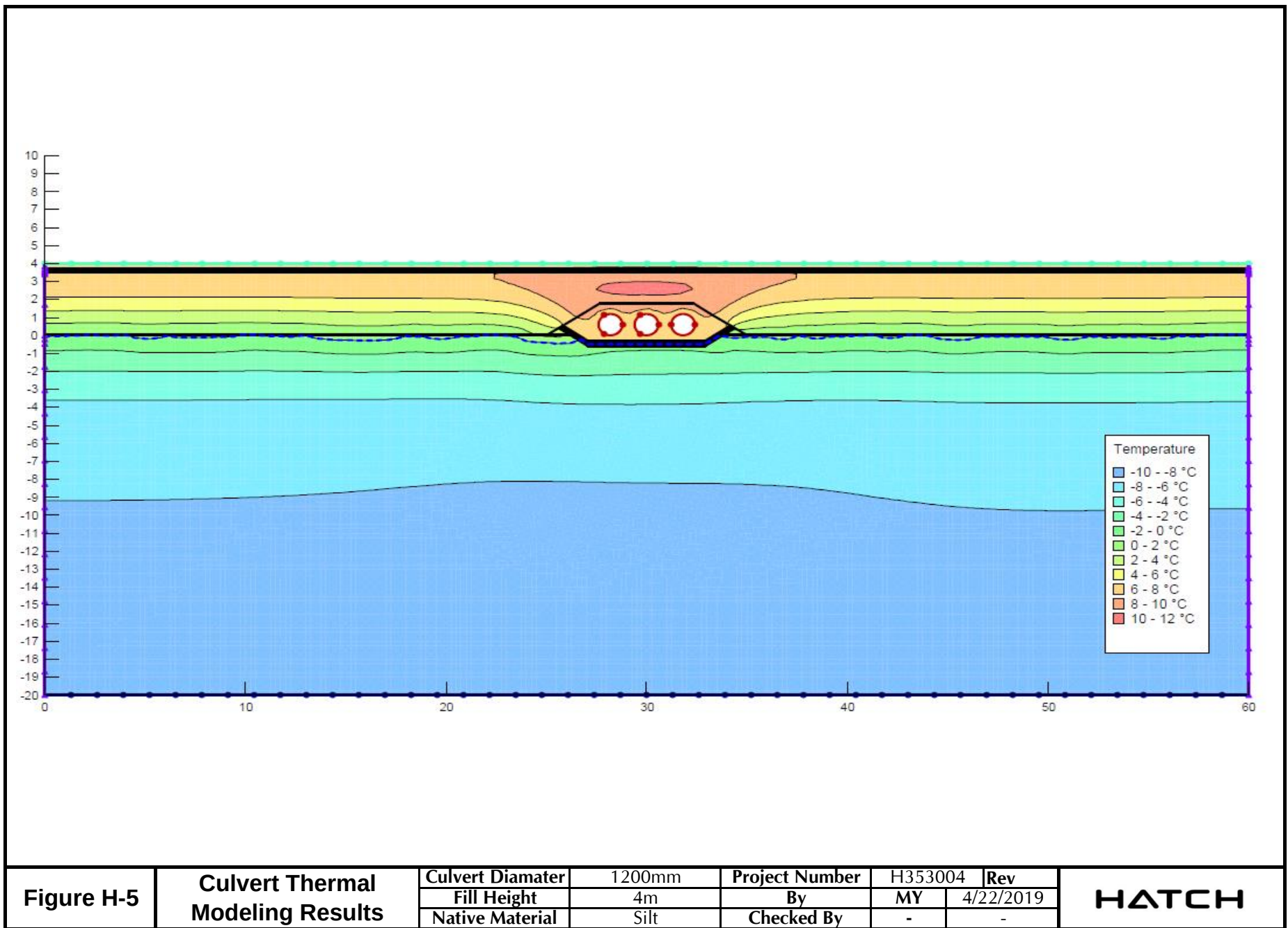


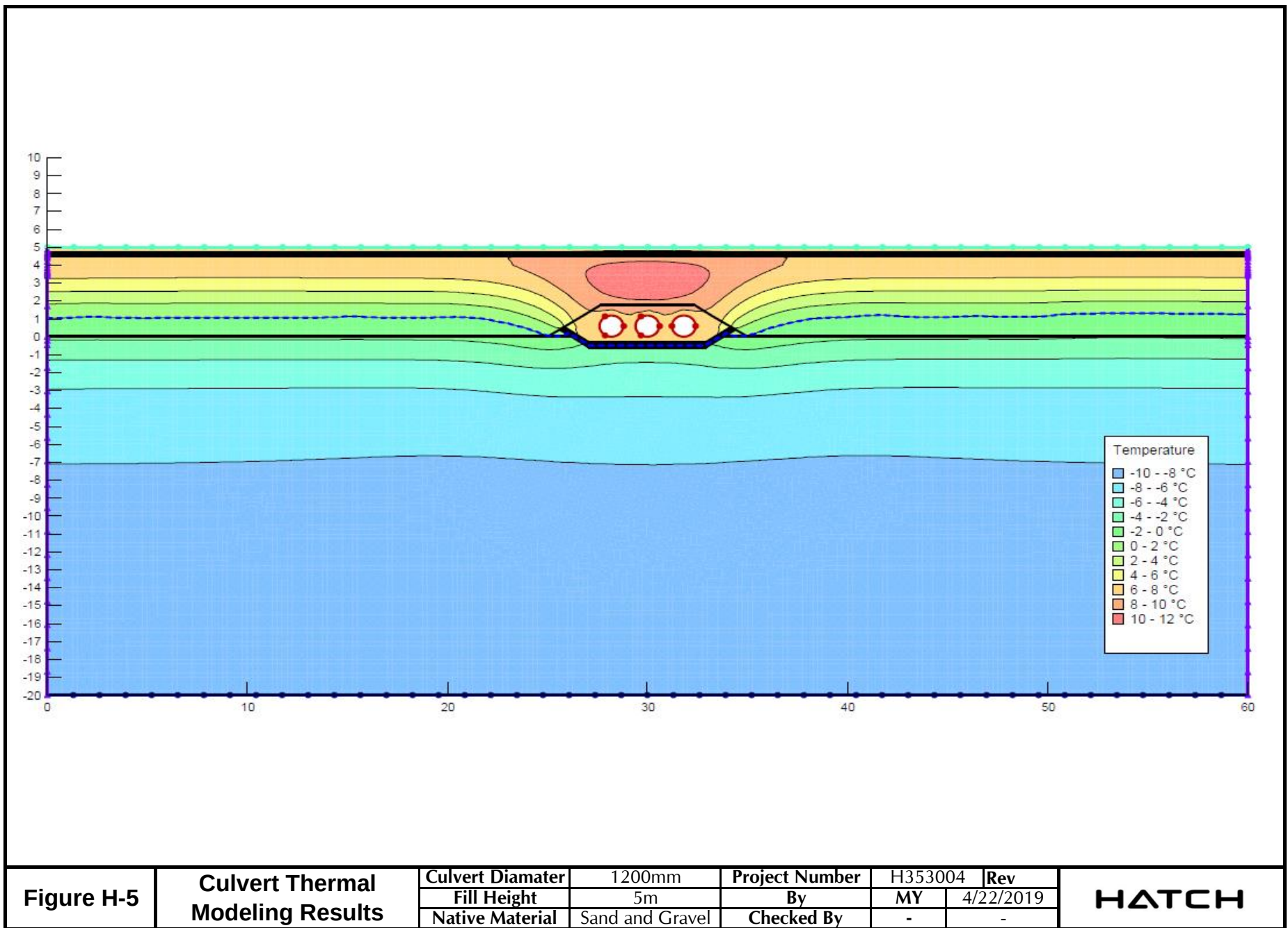
Figure H-5

**Culvert Thermal
Modeling Results**

Culvert Diameter	1200mm	Project Number	H353004	Rev	
Fill Height	4m	By	MY	4/22/2019	
Native Material	Sand and Gravel	Checked By	-	-	

HATCH





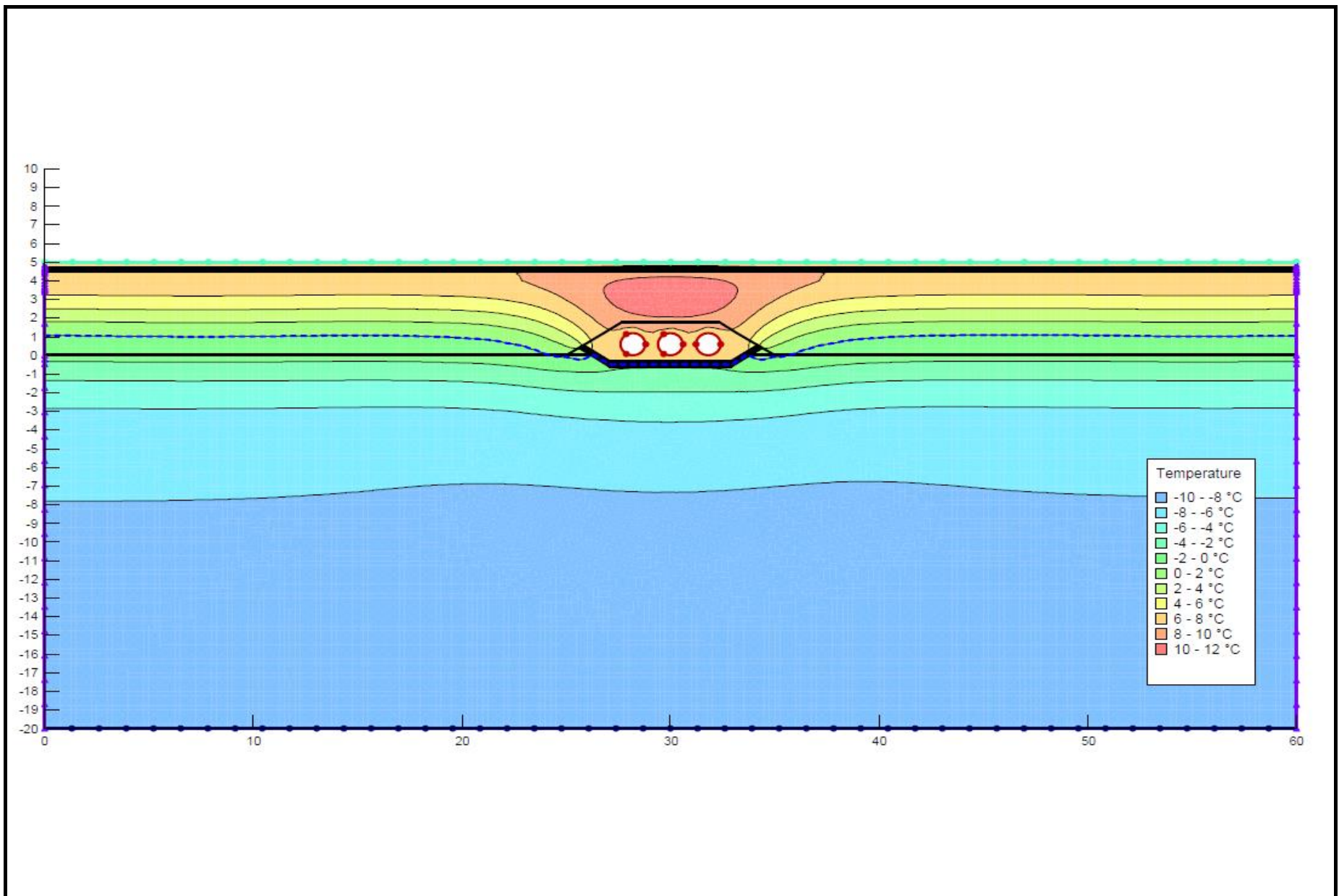


Figure H-5	Culvert Thermal Modeling Results	Culvert Diamater	1200mm	Project Number	H353004	Rev	HATCH
		Fill Height	5m	By	MY	4/22/2019	
		Native Material	Silt	Checked By	-	-	

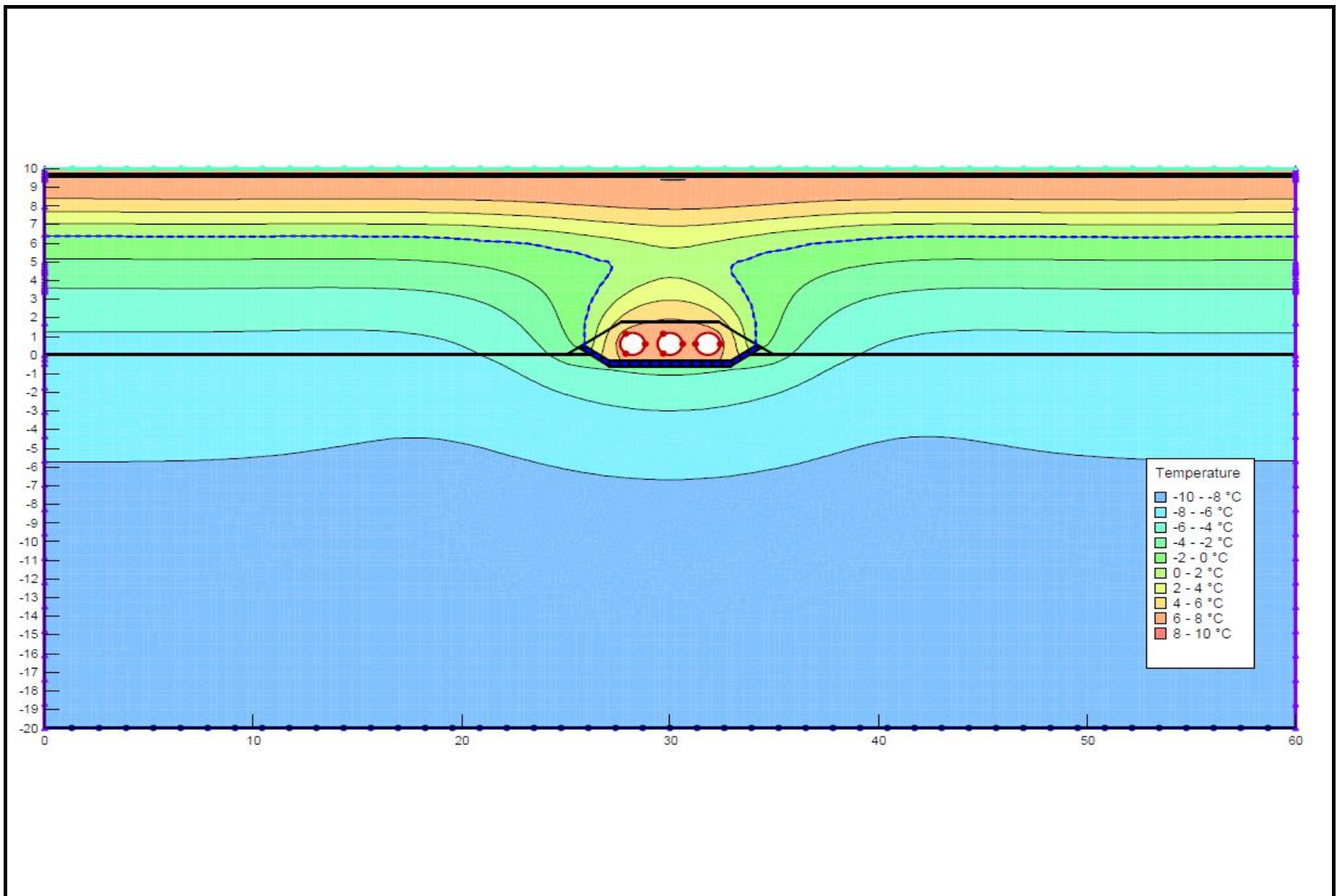


Figure H-5

**Culvert Thermal
Modeling Results**

Culvert Diameter	1200mm	Project Number	H353004	Rev	
Fill Height	10m	By	MY	4/22/2019	
Native Material	Sand and Gravel	Checked By	-	-	

HATCH

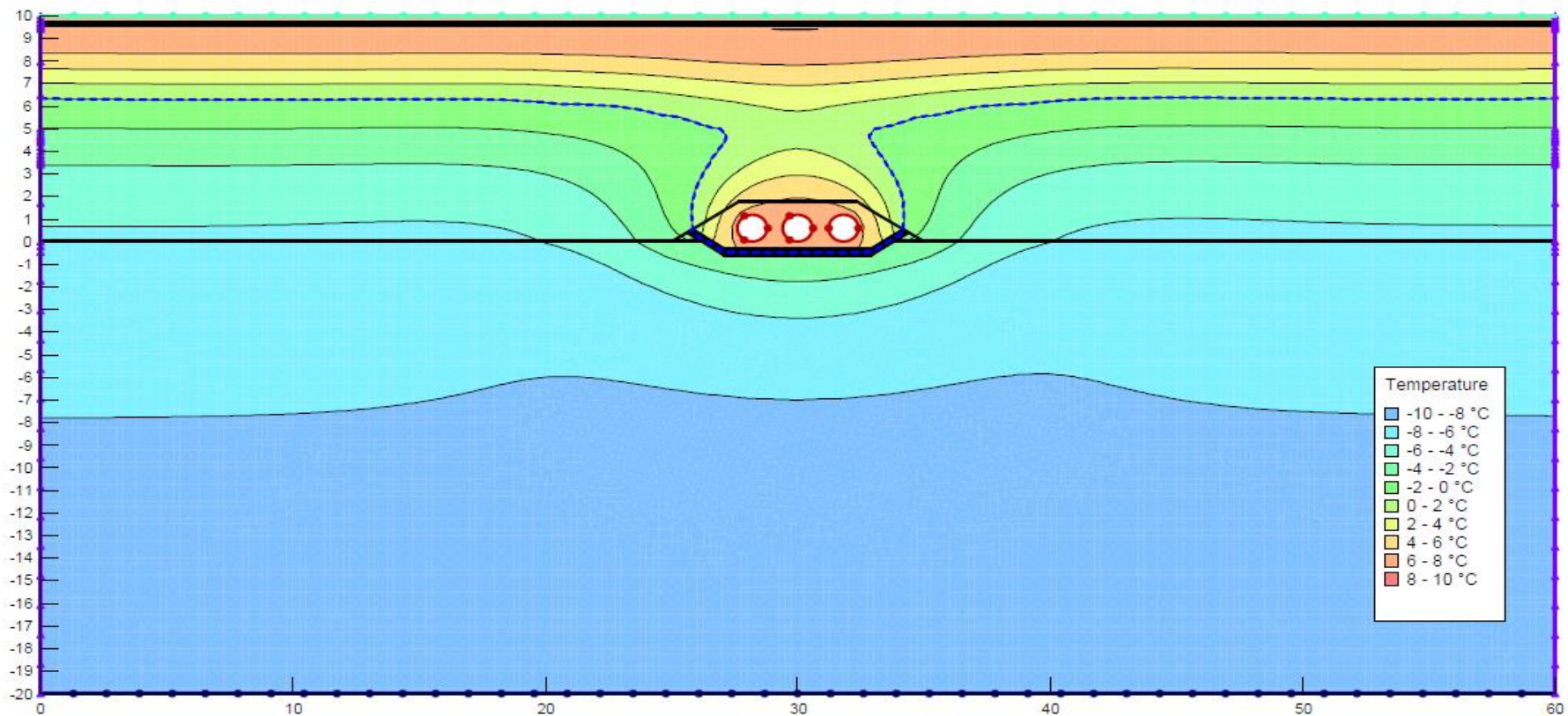


Figure H-5

**Culvert Thermal
Modeling Results**

Culvert Diameter	1200mm	Project Number	H353004	Rev	
Fill Height	10m	By	MY	4/22/2019	
Native Material	Silt	Checked By	-	-	

HATCH

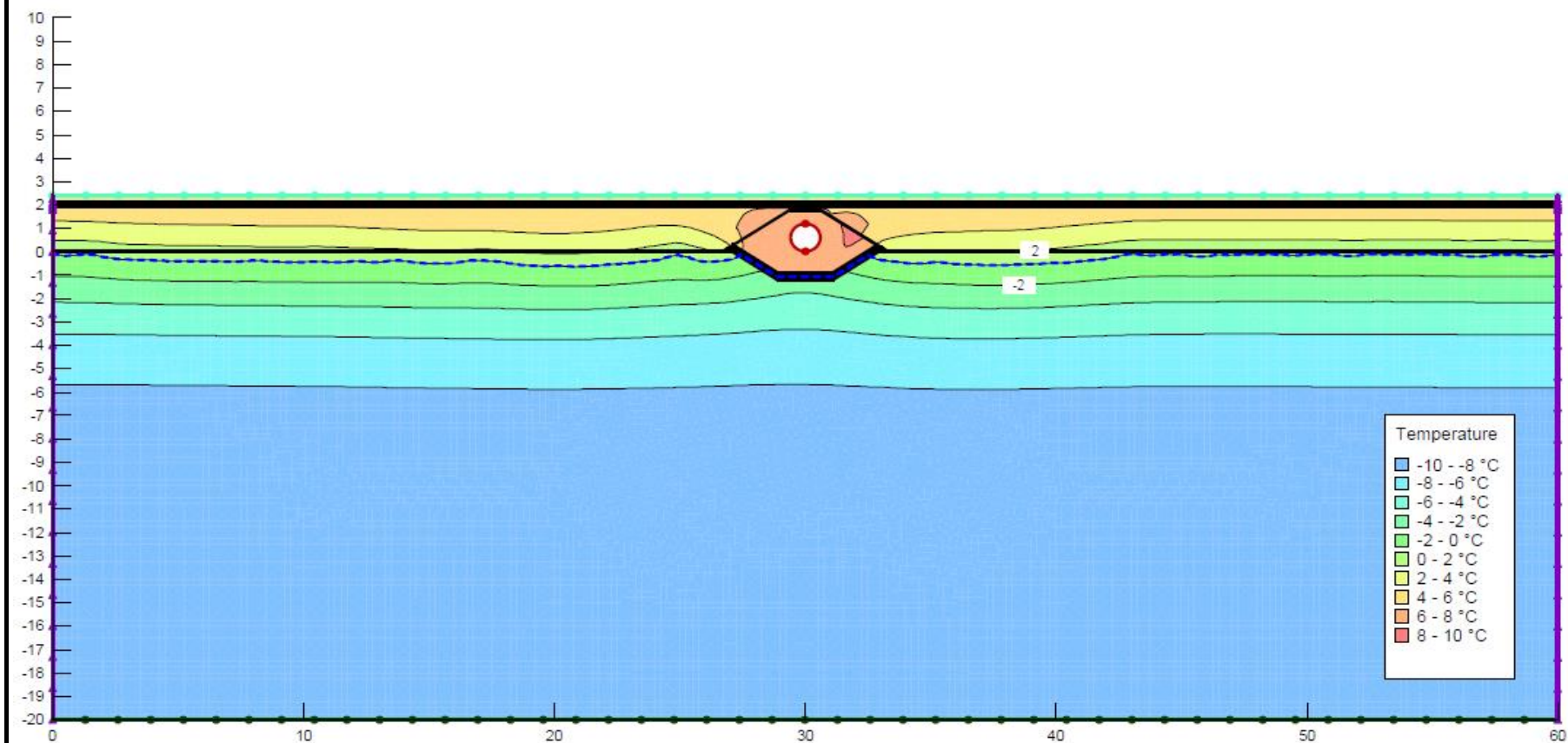


Figure H-6	Culvert Thermal Modeling Results	Culvert Diameter	1200mm	Project Number	H353004	Rev	HATCH
		Fill Height	2.4m	By	MY	4/22/2019	
		Native Material	Sand and Gravel	Checked By	-	-	

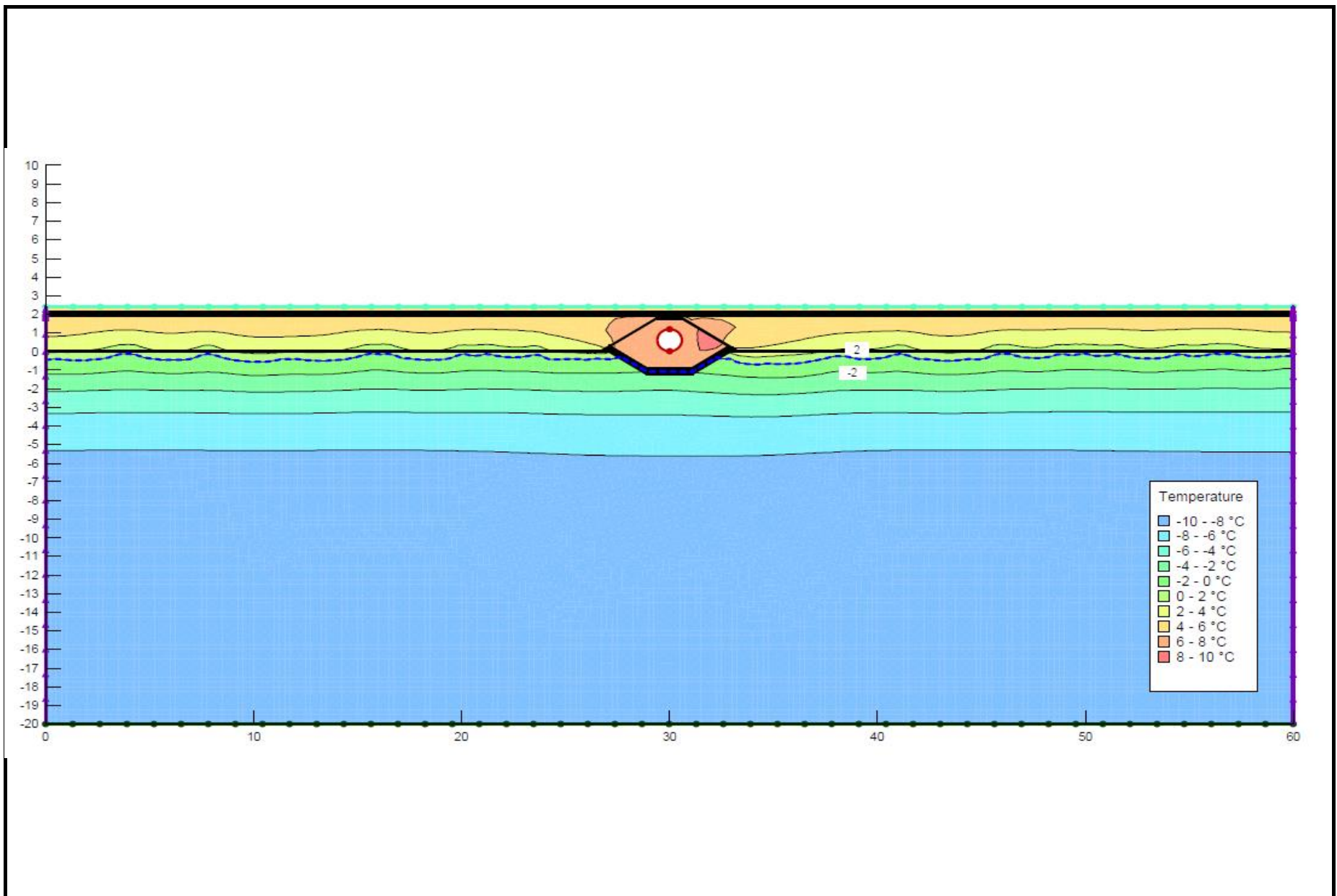


Figure H-6

**Culvert Thermal
Modeling Results**

Culvert Diameter	1200mm	Project Number	H353004	Rev	
Fill Height	2.4m	By	MY	4/22/2019	
Native Material	Silt	Checked By	-	-	

HATCH

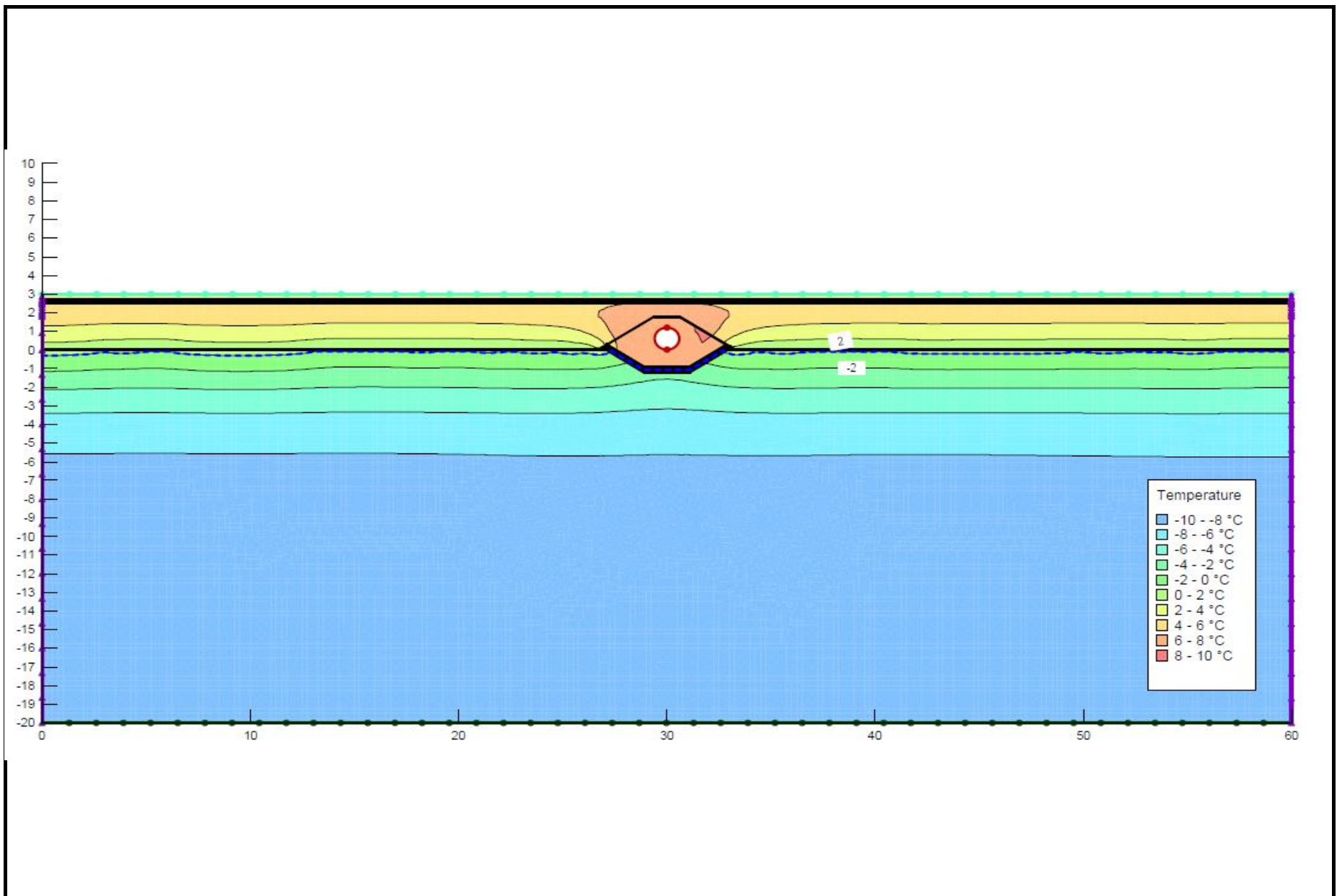


Figure H-6	Culvert Thermal Modeling Results	Culvert Diameter	1200mm	Project Number	H353004	Rev	HATCH
		Fill Height	3m	By	MY	4/22/2019	
		Native Material	Sand and Gravel	Checked By	-	-	

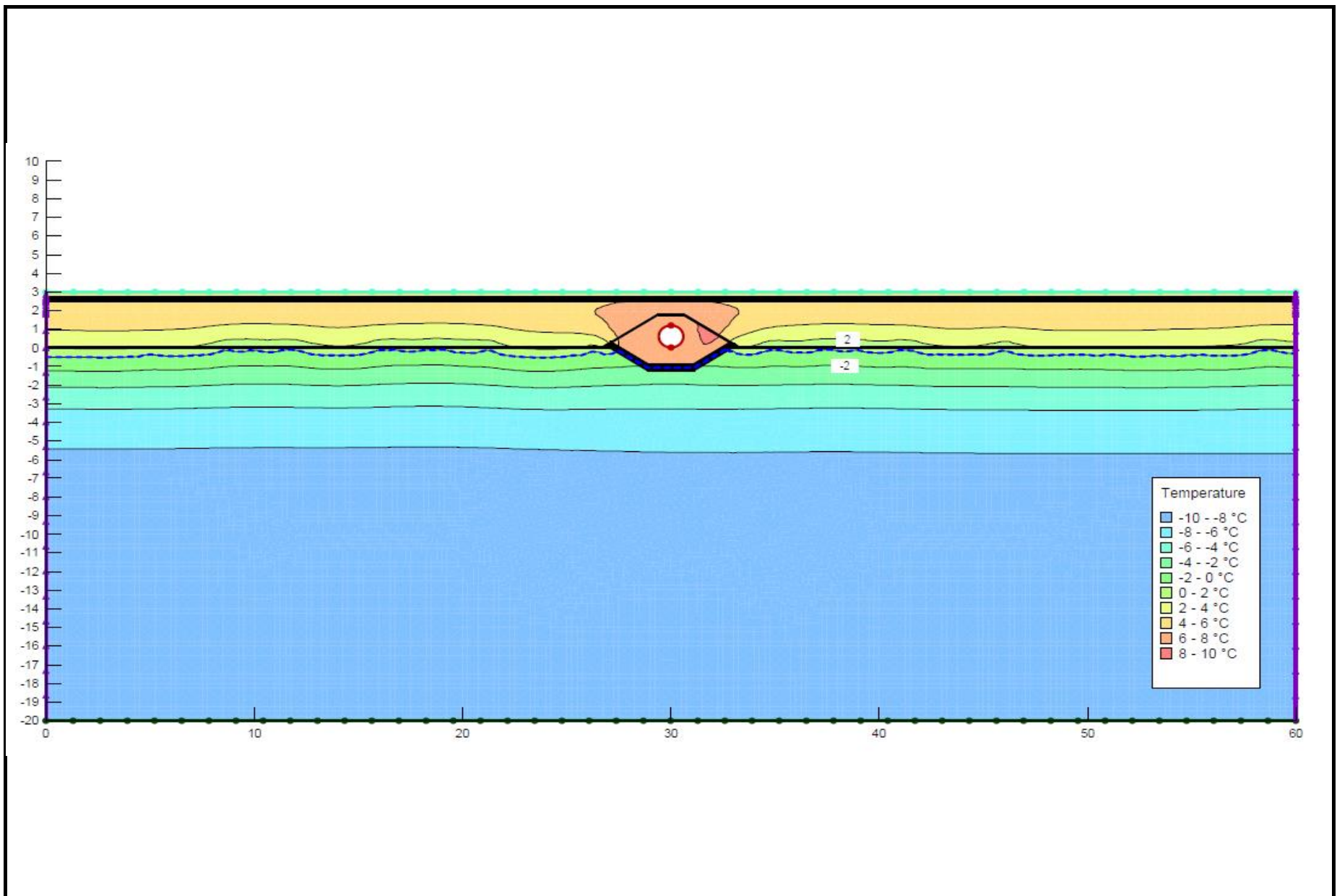
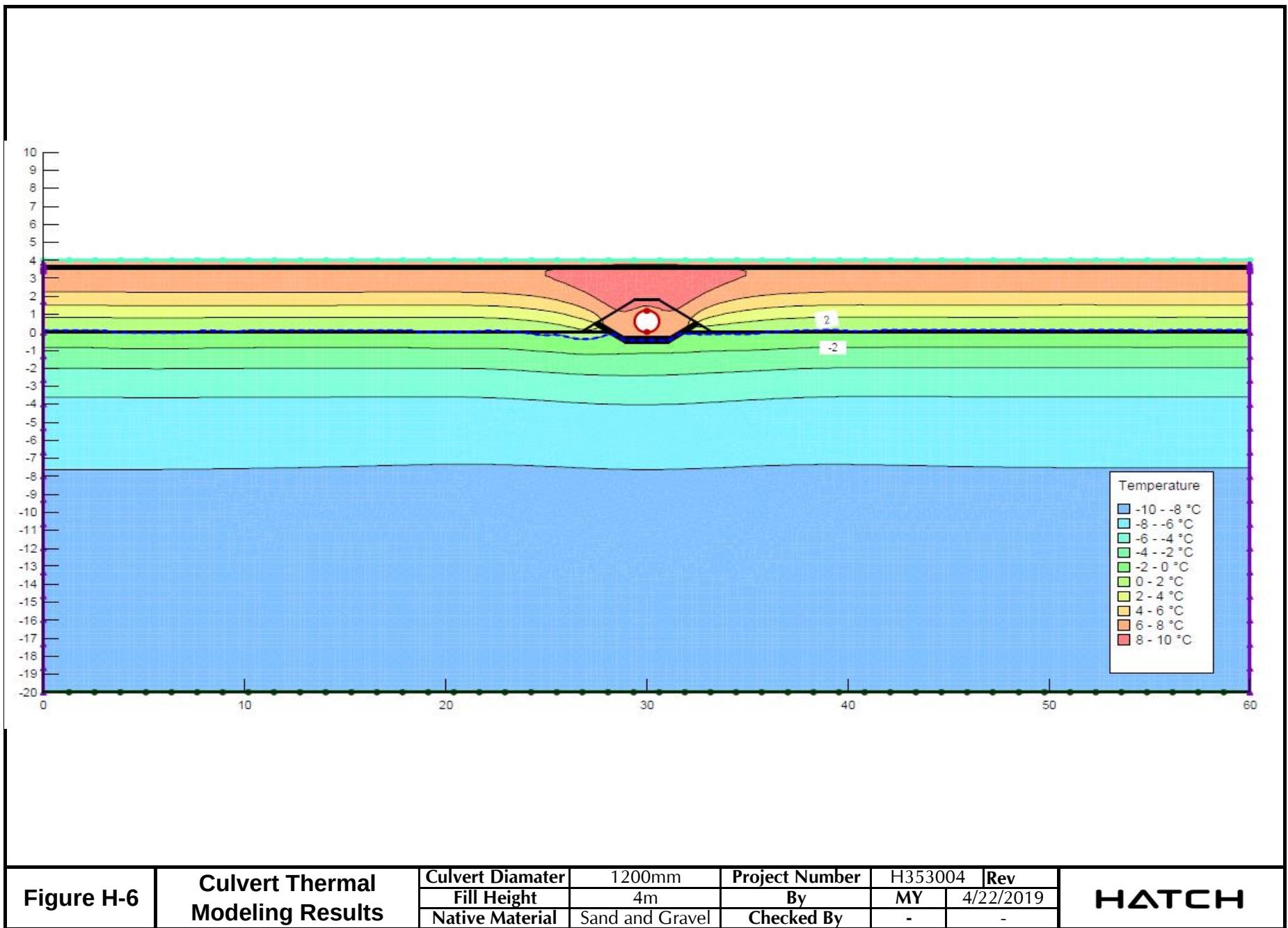


Figure H-6

**Culvert Thermal
Modeling Results**

Culvert Diameter	1200mm	Project Number	H353004	Rev	
Fill Height	3m	By	MY	4/22/2019	
Native Material	Silt	Checked By	-	-	

HATCH



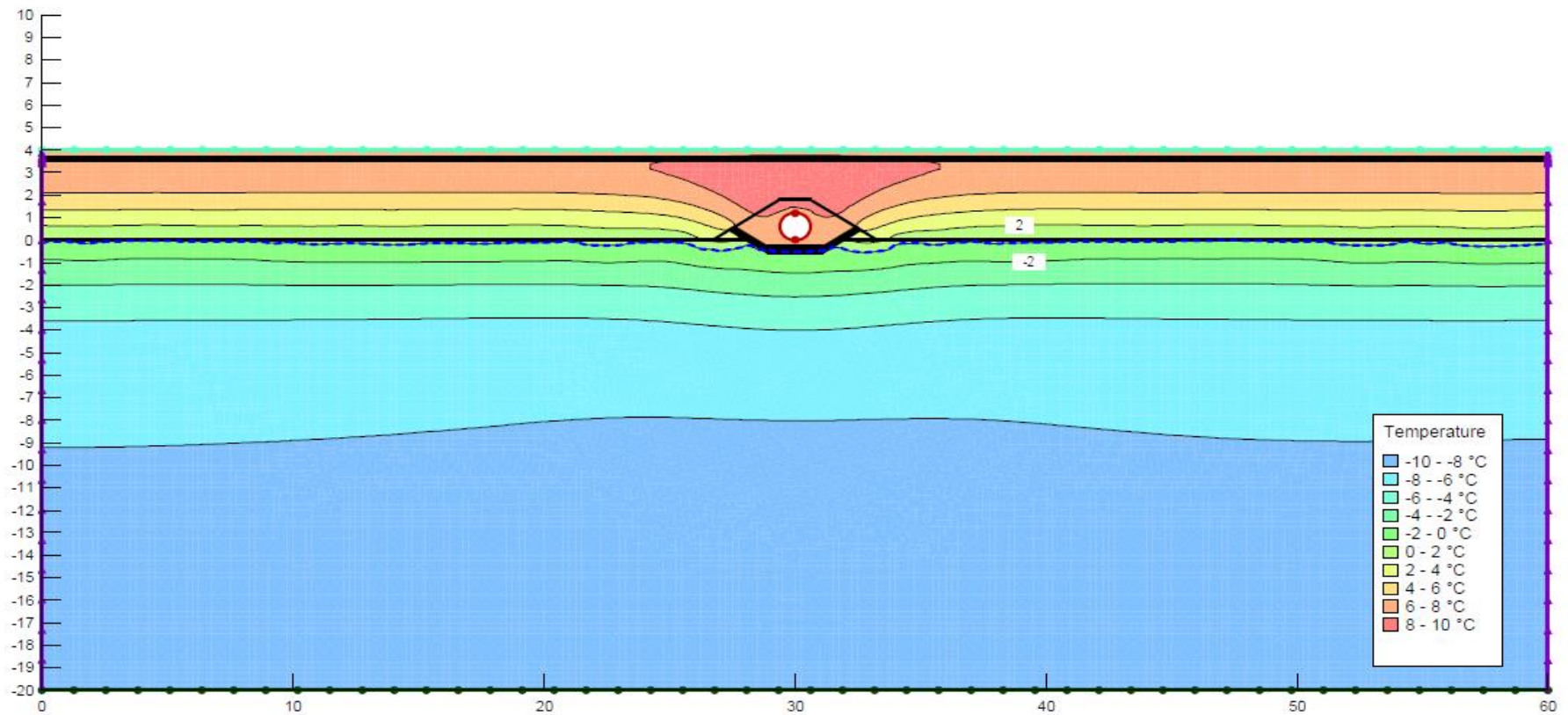


Figure H-6

Culvert Thermal Modeling Results

Culvert Diameter	1200mm	Project Number	H353004	Rev	
Fill Height	4m	By	MY	4/22/2019	
Native Material	Silt	Checked By	-	-	

HATCH

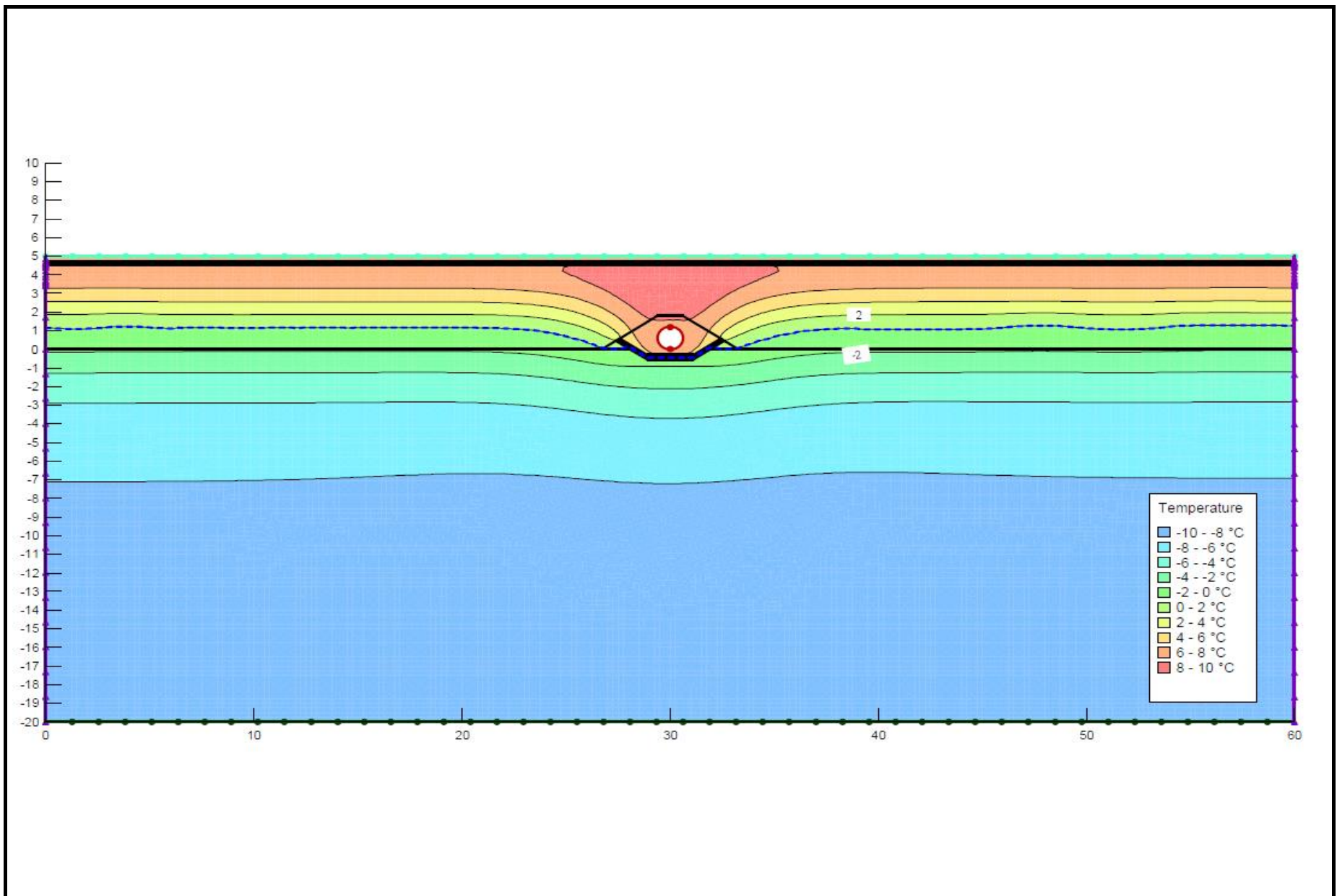


Figure H-6

**Culvert Thermal
Modeling Results**

Culvert Diameter	1200mm	Project Number	H353004	Rev	
Fill Height	5m	By	MY	4/22/2019	
Native Material	Sand and Gravel	Checked By	-	-	

HATCH

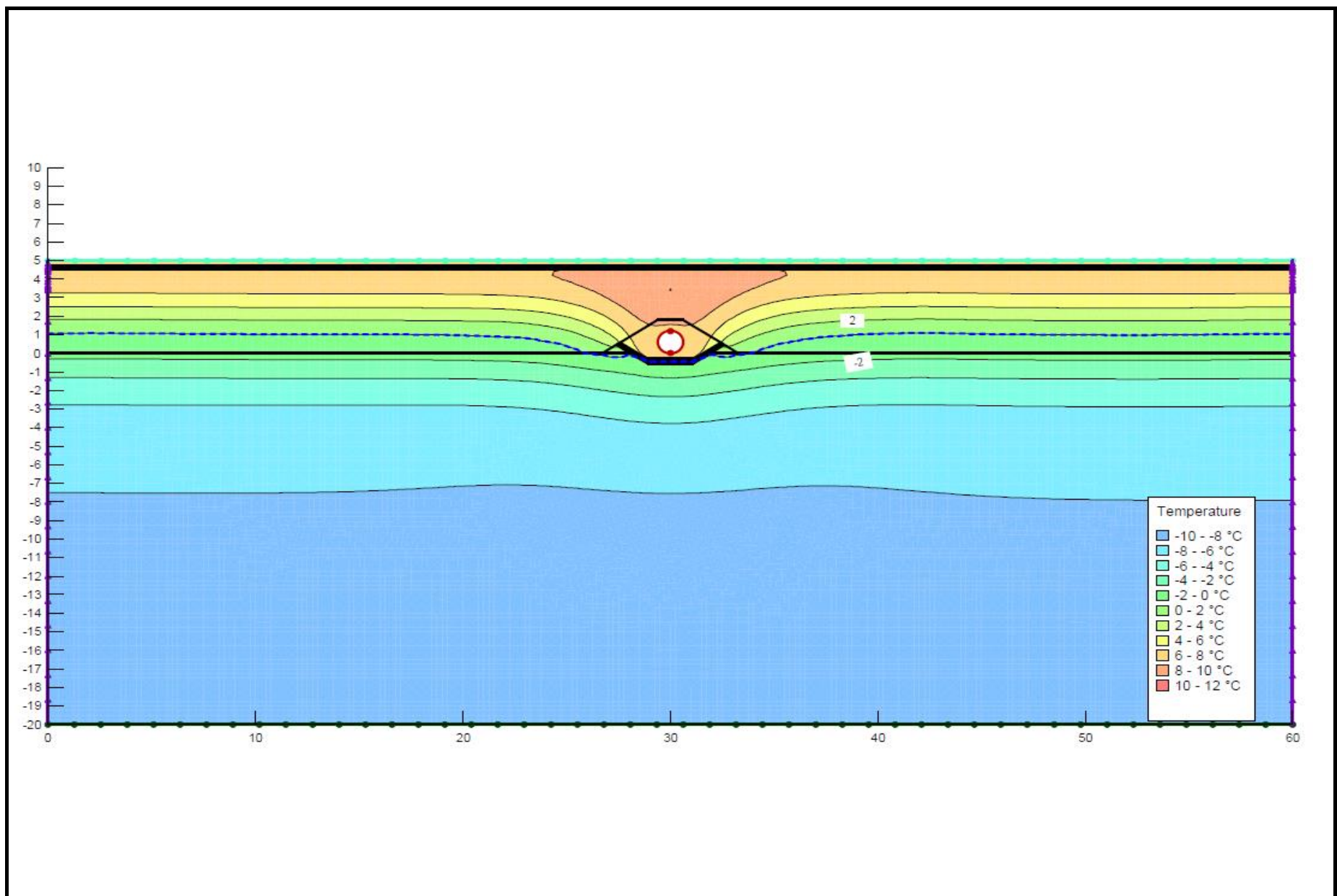


Figure H-6	Culvert Thermal Modeling Results	Culvert Diameter	1200mm	Project Number	H353004	Rev	HATCH
		Fill Height	5m	By	MY	4/22/2019	
		Native Material	Silt	Checked By	-	-	

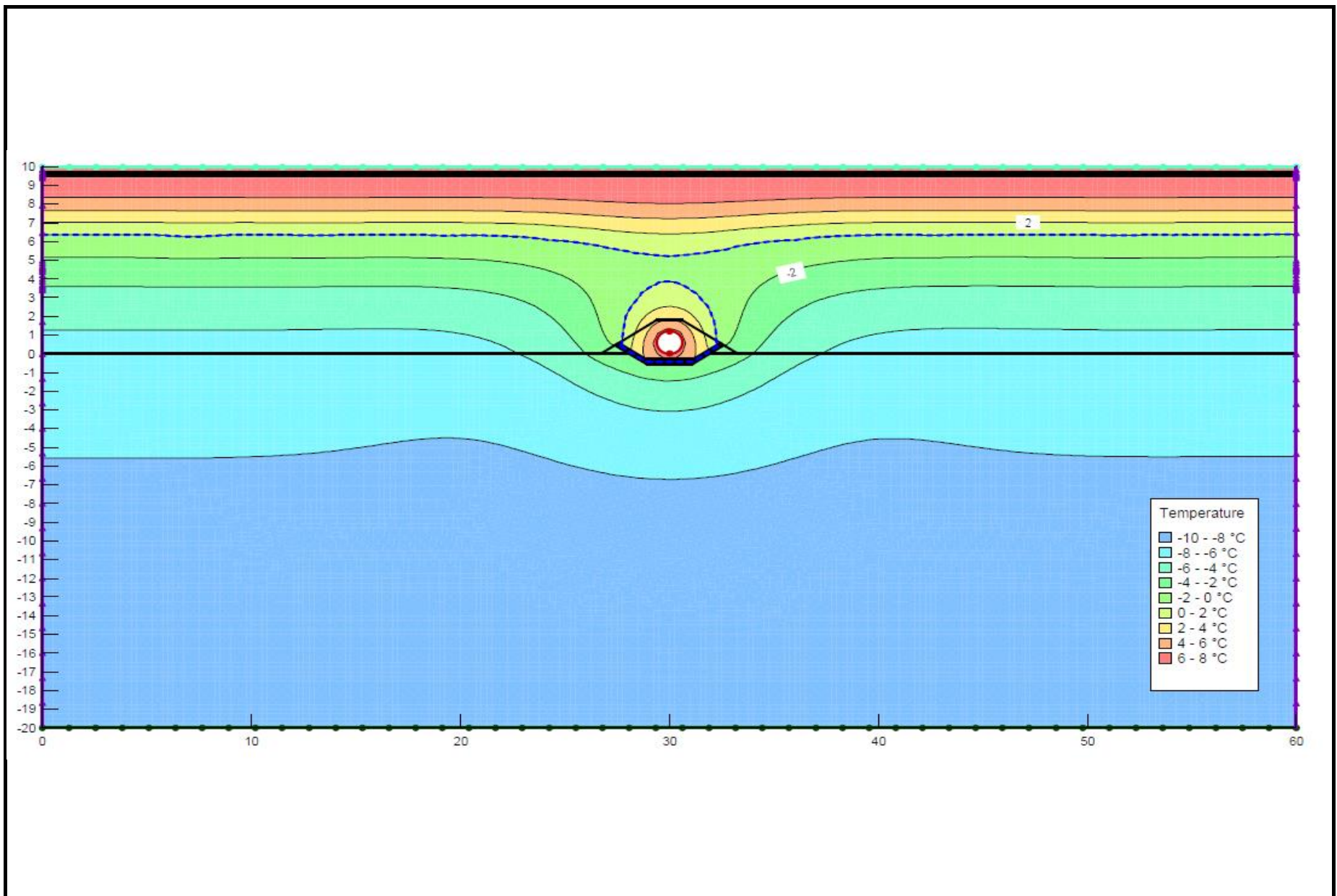


Figure H-6	Culvert Thermal Modeling Results	Culvert Diameter	1200mm	Project Number	H353004	Rev	HATCH
		Fill Height	10m	By	MY	4/22/2019	
		Native Material	Sand and Gravel	Checked By	-	-	

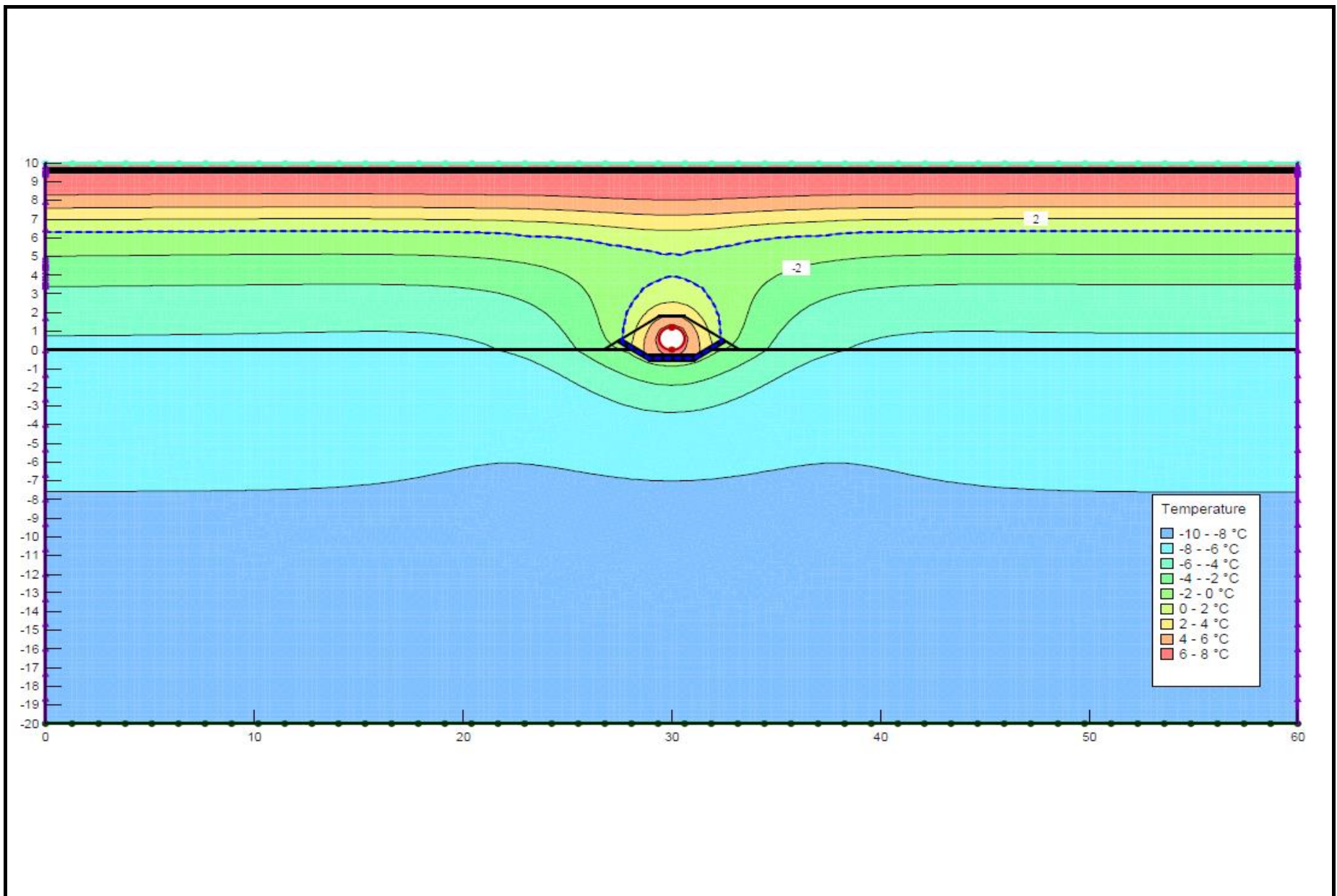


Figure H-6

Culvert Thermal Modeling Results

Culvert Diameter	1200mm	Project Number	H353004	Rev	
Fill Height	10m	By	MY	4/22/2019	
Native Material	Silt	Checked By	-	-	

HATCH

