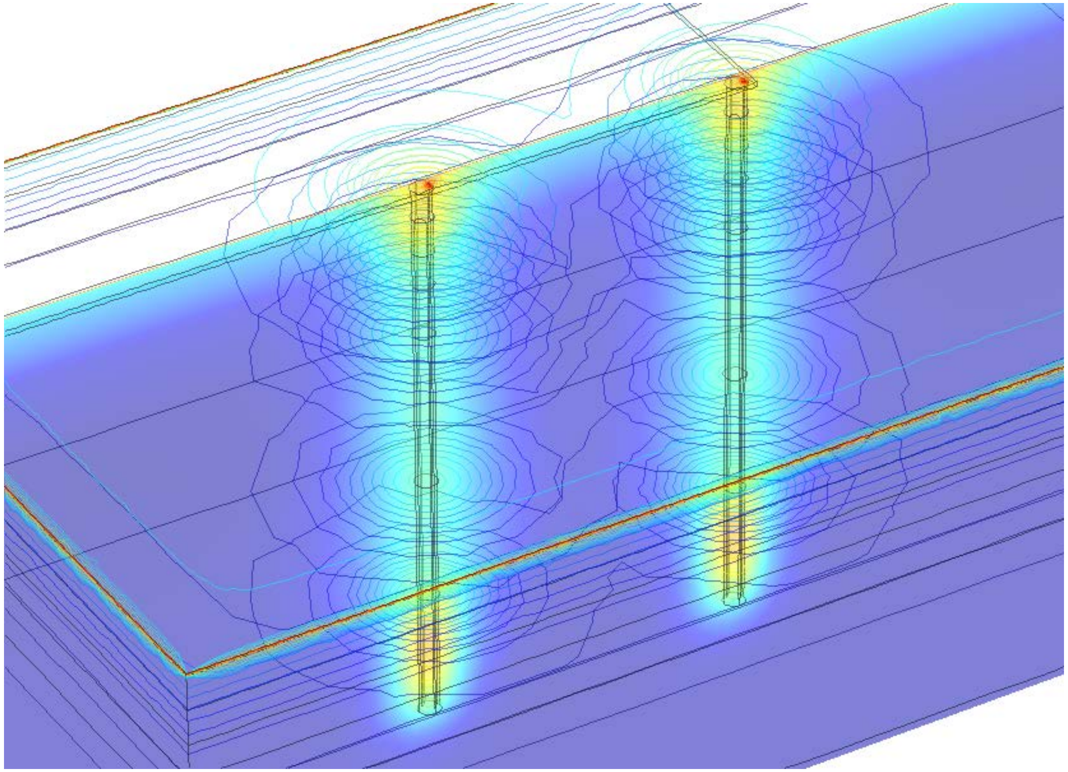
Calibration of a Geothermal Energy Pile Model using COMSOL



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COMSOL CONFERENCE 2014 BOSTON

The University of Vermont

What is a geothermal energy pile?

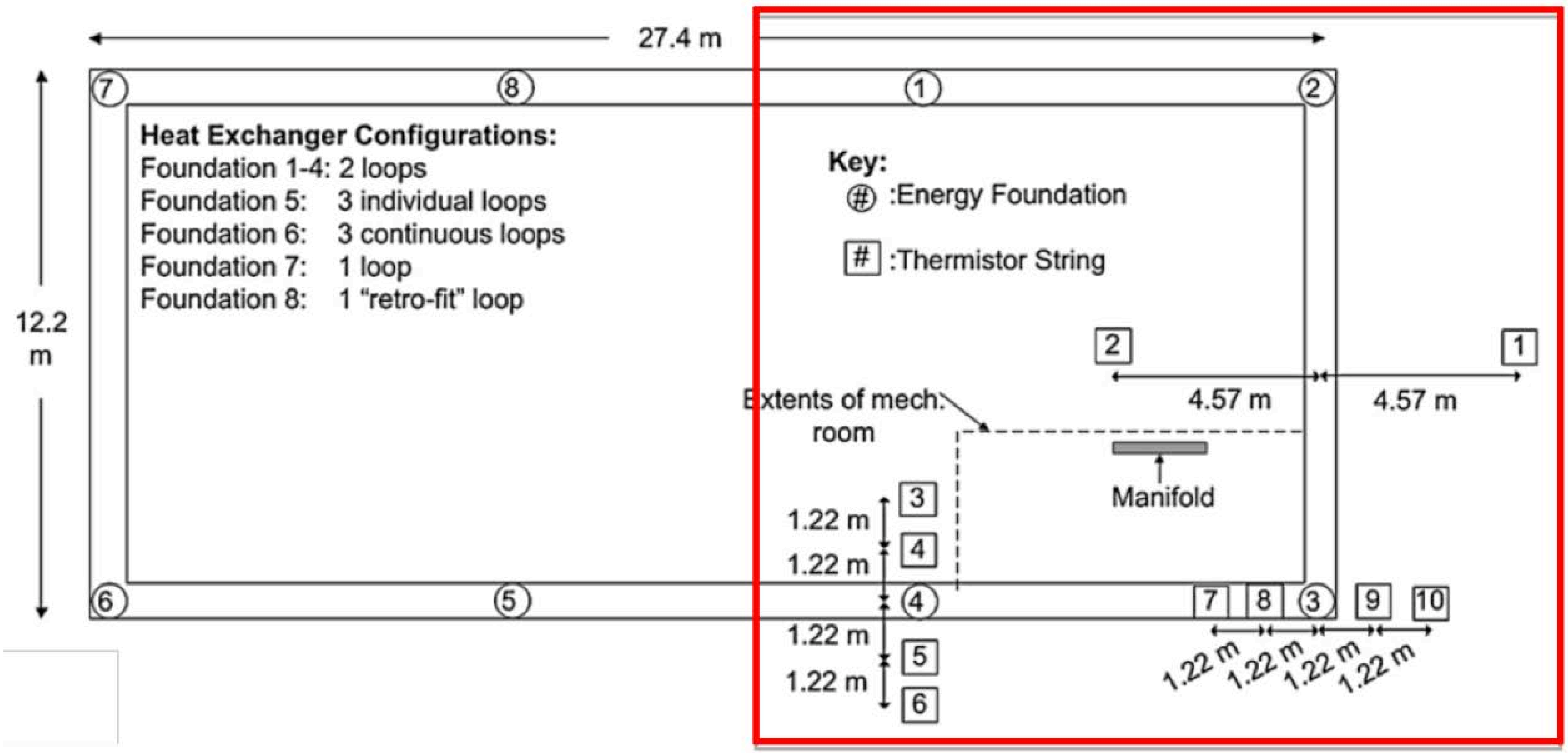
- Building foundation element
- Embedded heat exchangers
  - Reject/extract heat to/from subsurface

http://www.uponor.com/~/media/countryspecific/international/news/news/uponor-energy-pile-250x250.jpg?w=250&h=250&as=1

Overview

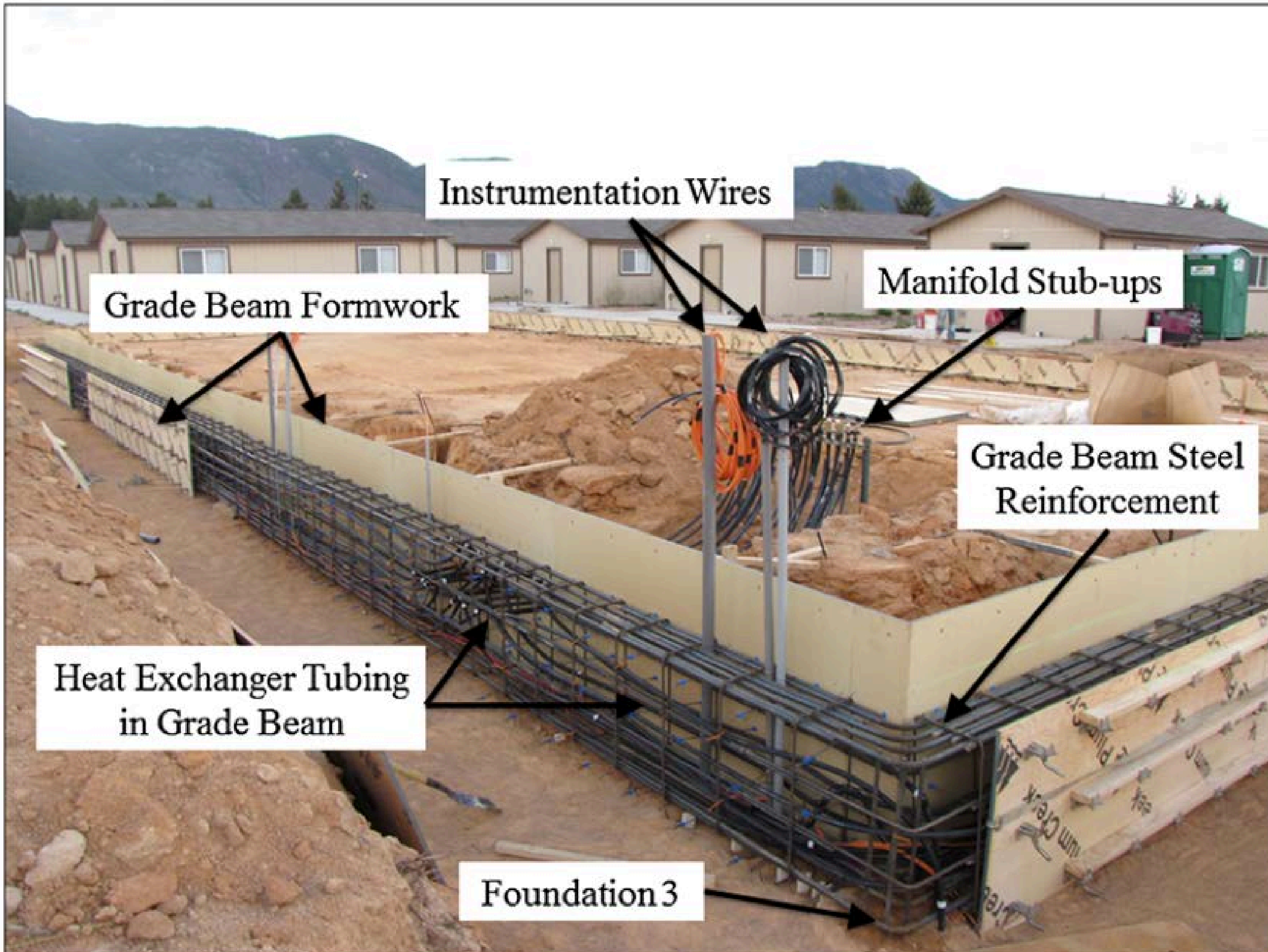
- United States Air Force Academy experimental geothermally heated/cooled building
  - Equipped with temperature and strain sensors
- Thermal Response Tests performed and field observations collected
- Numerical simulations performed
  - Heat transfer and Pipeflow physics coupled

Foundation Plan View



Murphy, K., McCartney, J., Henry, K. 2014a

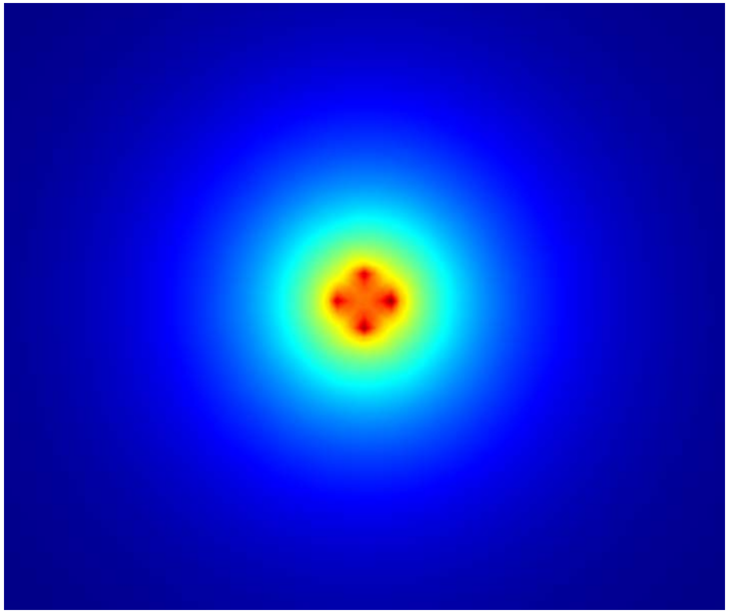
Overview



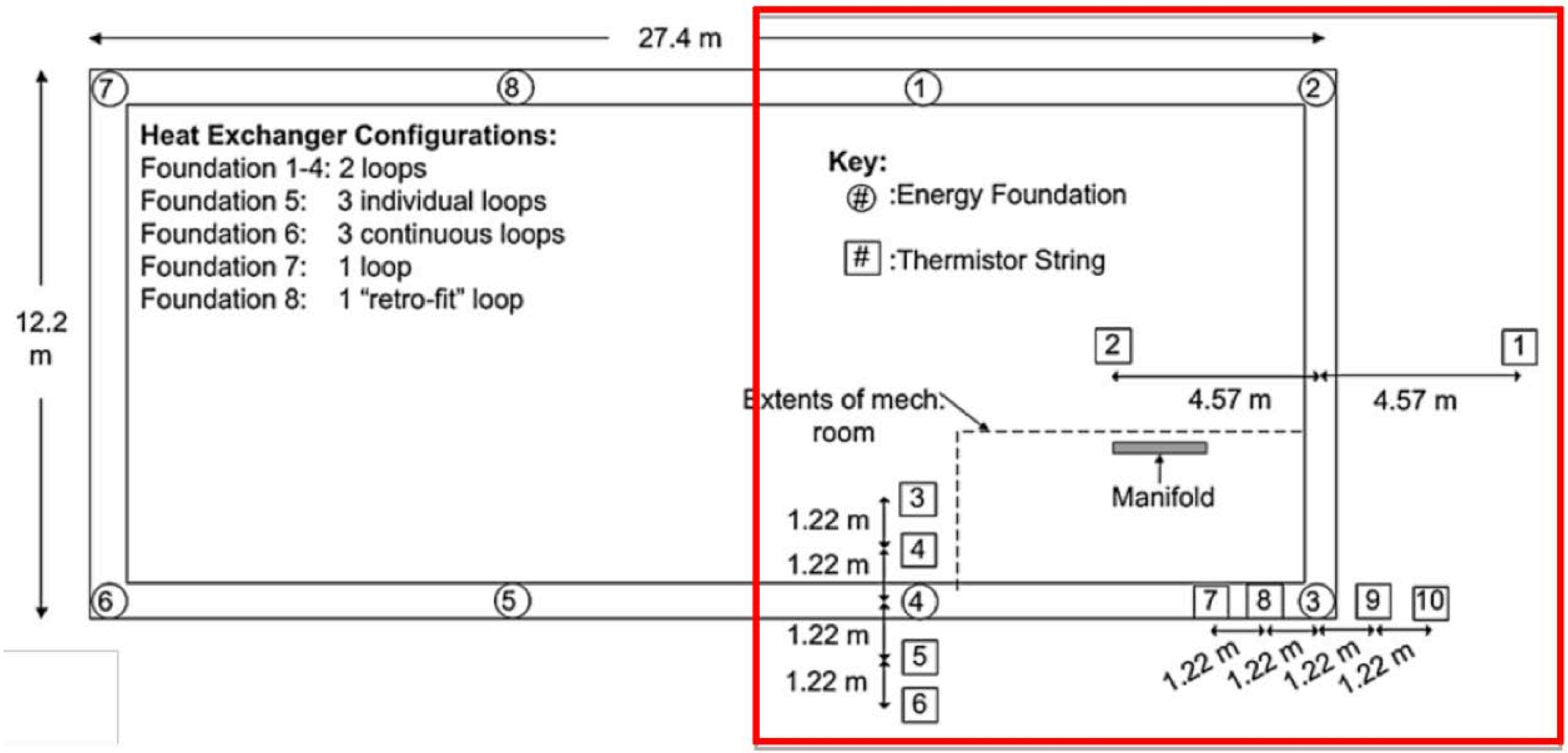
Murphy, K., McCartney, J., Henry, K. 2014a

Motivation

- Develop a model of a group of geothermal energy piles
  - Evaluate long-term interaction of piles with soil
  - Incorporate structural mechanics
  - Manipulate parameters of interest



Model Geometry



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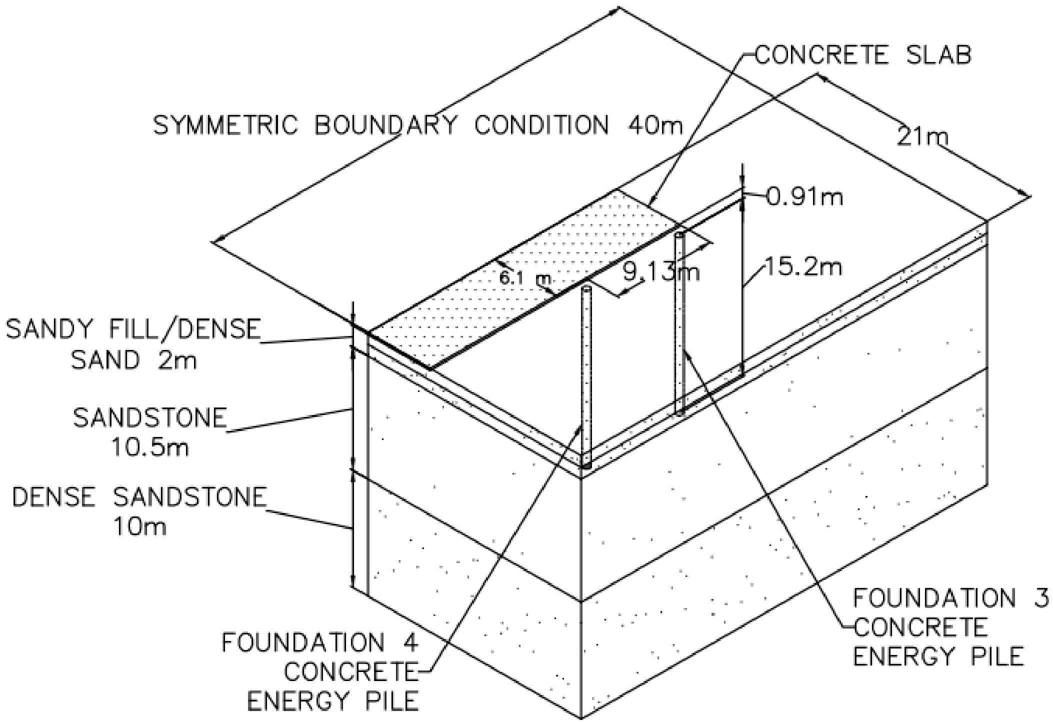
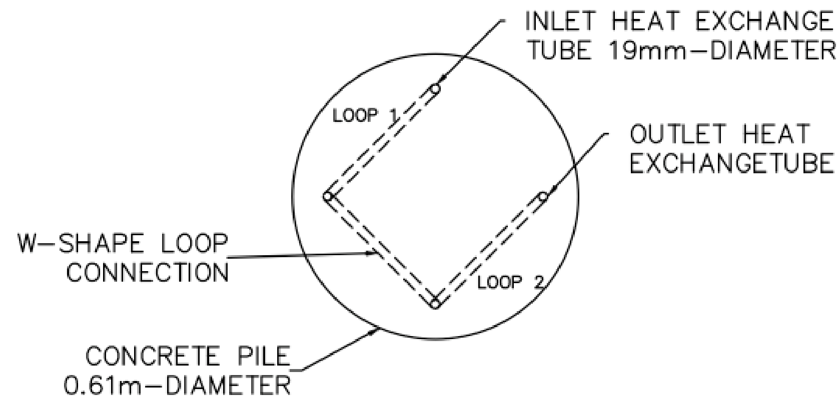


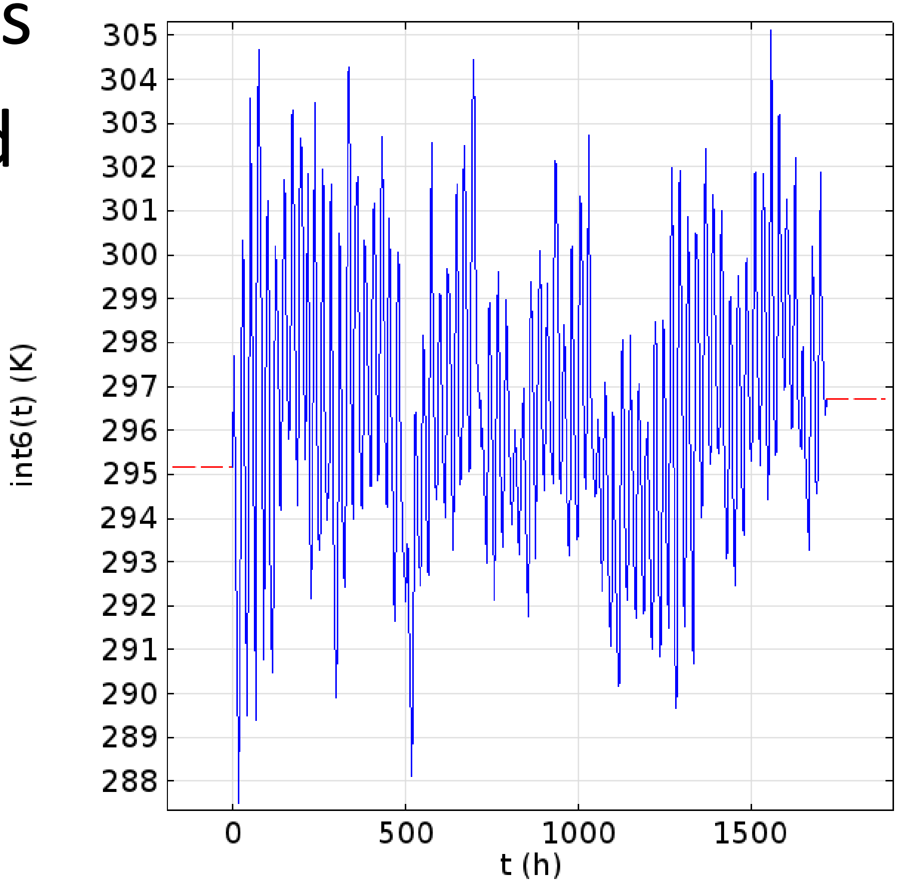
COMSOL MODEL GEOMETRY – ISOMETRIC VIEW



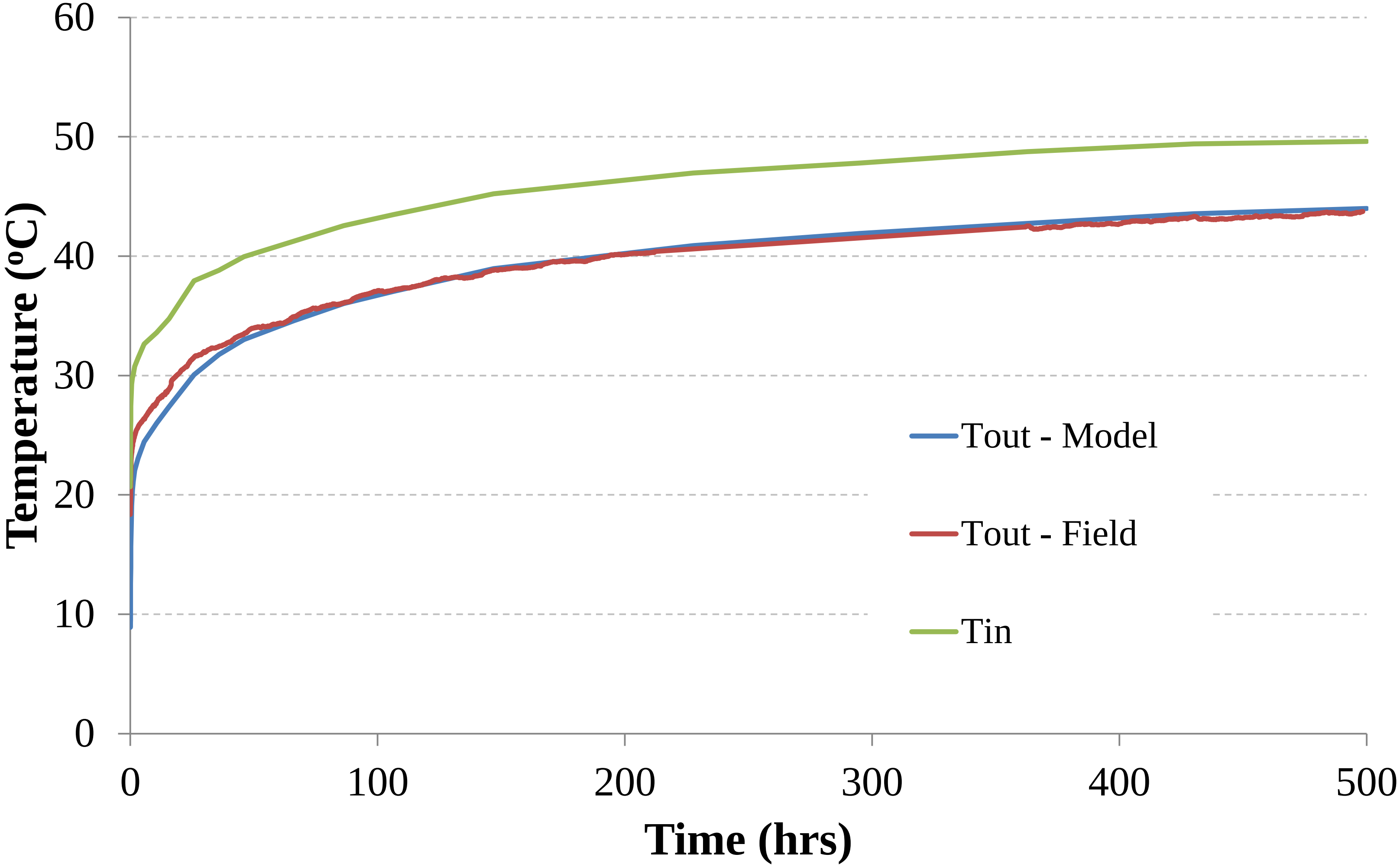
CONCRETE ENERGY PILE – PLAN VIEW

Initial & Boundary Conditions

- Atmospheric observations
- Heat exchanger inlet fluid temperature & flow rate observations
- Subsurface temperature gradients
- Symmetric boundary (adiabatic)



Inlet/outlet Temperatures



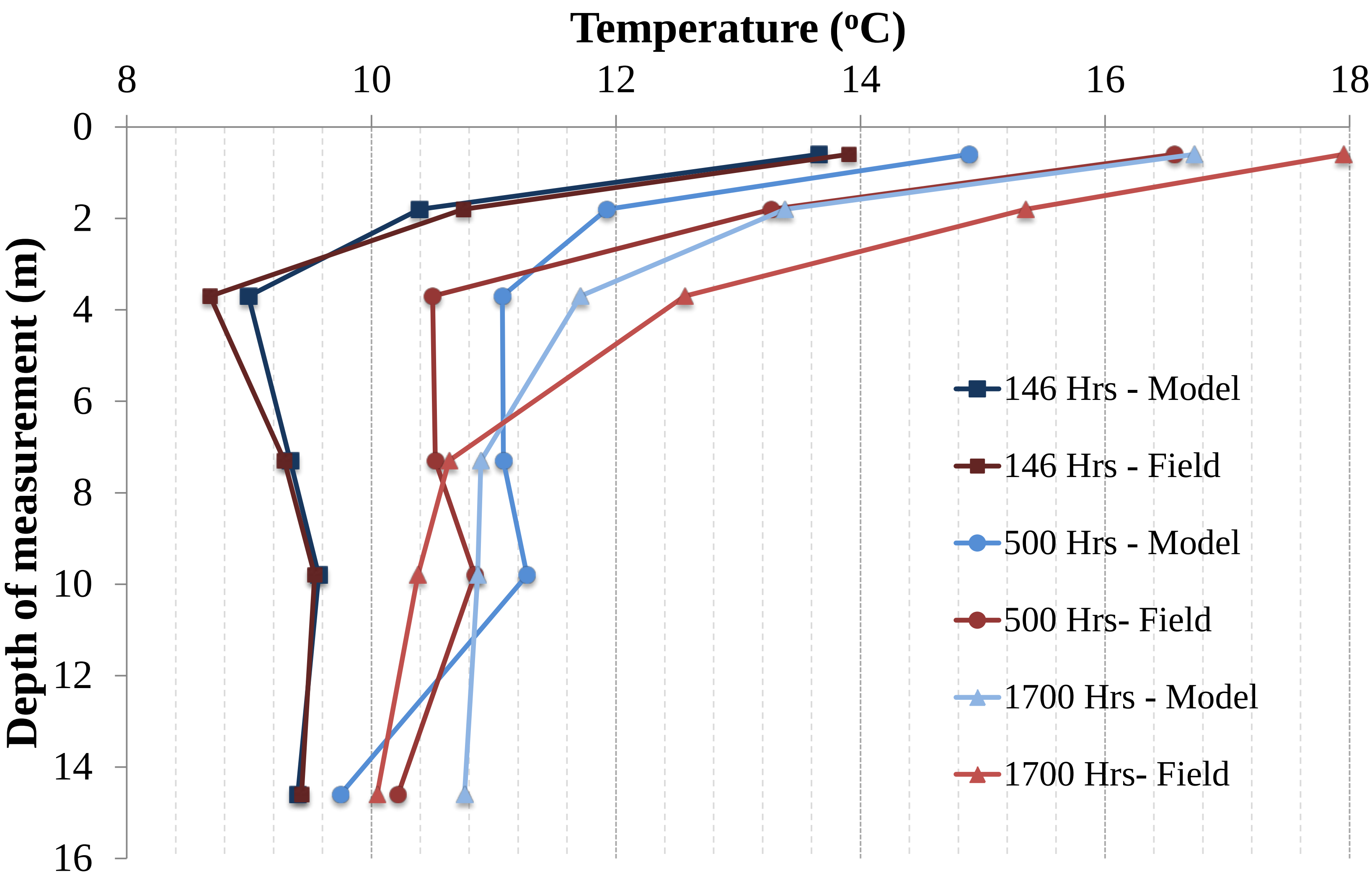
Thermal Response Test Details

- Apply constant amount of power to circulated fluid
  - Determine subsurface thermal properties
- Duration = 71 days (6/18/13-7/9/13)
- 500 hrs of active heat rejection
- 1200 hrs of cooling observation

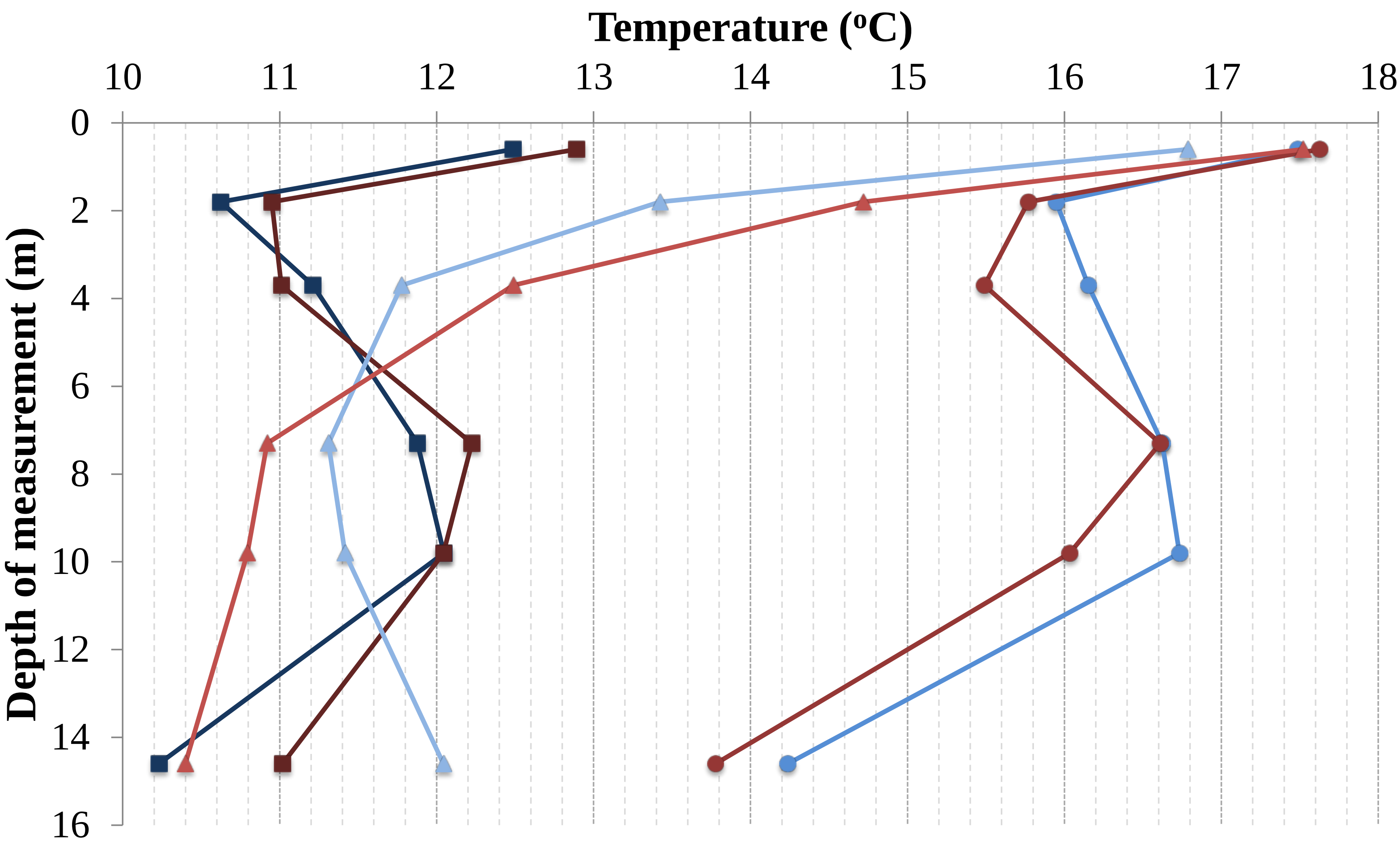
Calibration methodology

- Compare observations from Foundation 4, Borehole 4, and Borehole 6 to probed locations within model
- Adjust thermal conductivities and heat capacities of individual soil layers
  - Minimize difference between model output and field data!

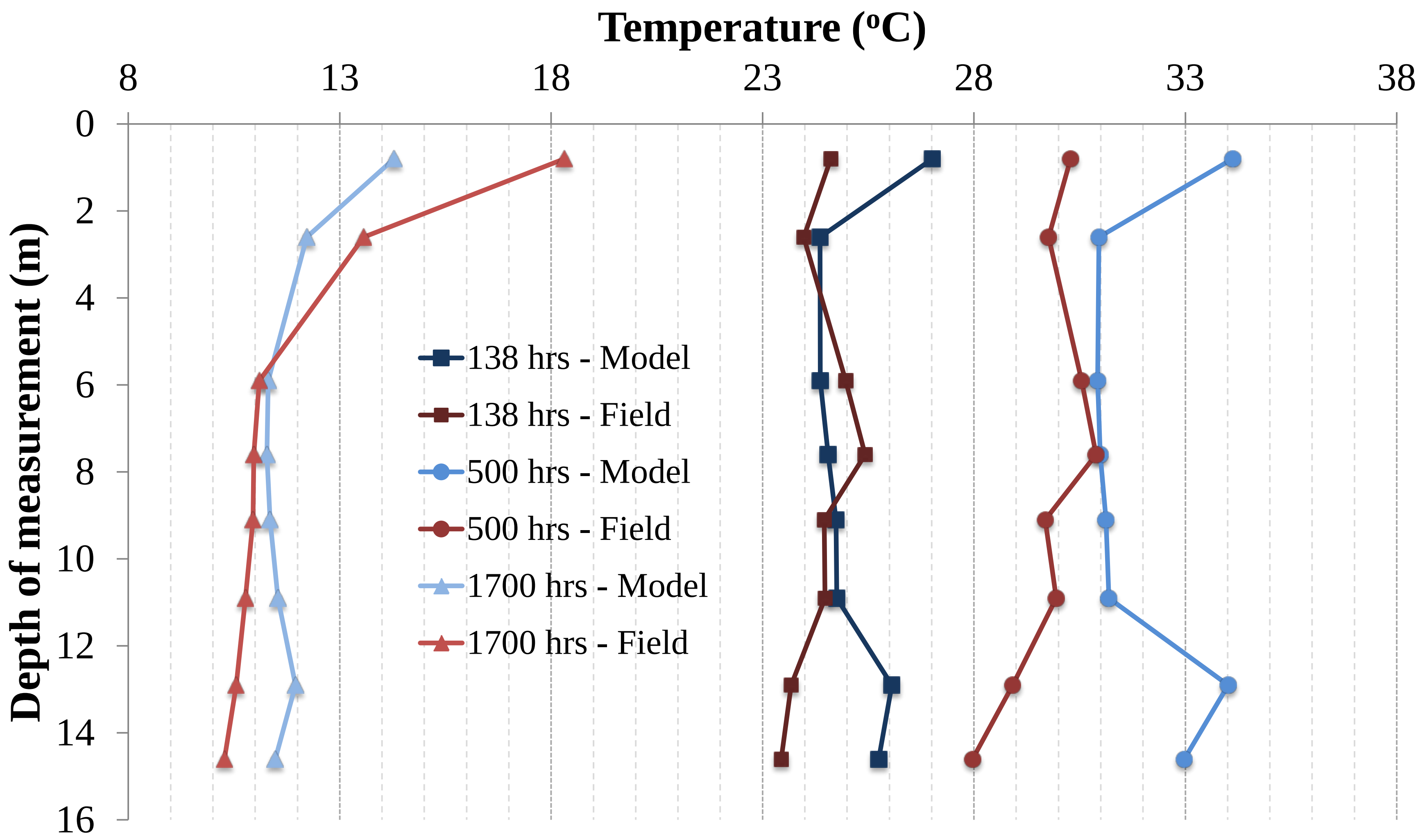
Results – Borehole 6



Results – Borehole 4



Results – Foundation 4



Model Parameter Results

	Property				
Material	**Model Thermal Conductivities, k (W/mK)**	**Murphy et. Al 2014a Thermal Conductivities, k (W/mK)**	**Model Heat Capacities , Cp (J/kg K)**	**Model Densities, ρ (kg/m^3)**	**Porosity (%)**
Sandy Fill	**1.1**	**1.12**	860	1875	0.43
Dense Sand	**0.75**	**0.78**	935	1957	0.43
Sandstone	**2.0**	**2.0-2.3**	900	2200	0.15
Dense Sandstone	0.7	-	1000	2300	0.15
Concrete	1.4	-	840	2400	-
Water	0.58	-	3267	1.008	-
Air	0.023	0.58	1	1.2	-
HDPE	0.48	-	-	-	-

Conclusions

- Model performed well during active heat rejection and fair for long term cooling observation
- Difficulty predicting temperatures at toe and surface
  - Possible groundwater rise or denser rock
  - Surface phenomena (radiation, wind, rain etc.)

Acknowledgements

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