Simulating the Effect of Groundwater Flow and Heterogeneity on Borehole Thermal Energy Storage

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Abstract

In Borehole Thermal Energy Storage (BTES), also called closed loop ground source heat pumps (GSHP) or closed systems, the thermal energy is stored and recovered with a closed hydraulic circuit consisting of one or more boreholes with vertical heat exchangers. The heat exchangers consist of plastic tubes wherein a fluid (commonly a water-glycol mixture) is circulated and absorbs the thermal energy (heat and cold) from the ground. Commonly, the number of heat exchangers is calculated using average values for the thermal properties of the subsurface, groundwater flow is generally not considered. Subsurface heterogeneity and groundwater flow, however, can have an important impact on the number of required heat exchangers and the associated cost of a BTES system.

In this project the effect of both groundwater flow and heterogeneity on BTES systems is evaluated. For this purpose, COMSOL Multiphysics® was used to simulate groundwater flow (Subsurface Flow Module) and heat transport (Heat Transfer Module) in the subsurface. The subsurface was divided into different geological layers (aquifers and aquitards), each with different hydrogeological and thermal parameters. To simulate the effect of groundwater flow, a groundwater gradient was imposed.

The results clearly show the effect of both heterogeneity and groundwater flow on the temperature distribution around the borehole heat exchangers. In the aquifers, the effect of the groundwater flow is clearly much larger than in the aquitards. Particularly in the case of the presence of aquifers, it will therefore be important to consider groundwater flow and subsurface heterogeneity for dimensioning a BTES system.

Figures used in the abstract

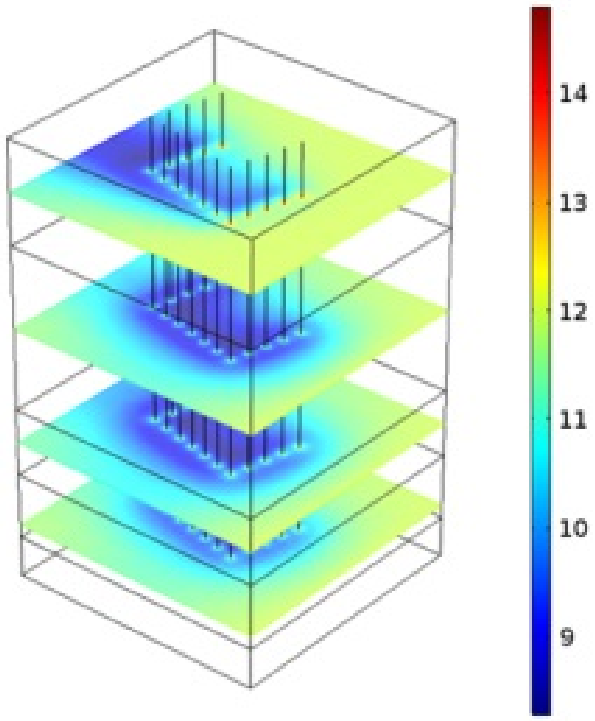

Figure 1: Temperature distribution (°C) around borehole heat exchangers after 20 years at the end of a cooling cycle.