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Numerical modeling of geothermal heat pump system: evaluation of site specific groundwater thermal impact

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A pilot plant using a geothermal open-loop heat pump system has been realized in the city of Vicenza (Northern Italy), in order to meet the heating and cooling needs of the main monumental building in the historical center, the Palladian Basilica. The low enthalpy geothermal system consists of a pumping well and a reinjection well, both intercepting the same confined aquifer; three other monitoring wells have been drilled and then provided with water level and temperature dataloggers. After about 1 year and a half of activity, during a starting experimental period of three years, we have now the opportunity to analyze long term groundwater temperature data series and to evaluate the numerical modeling reliability about thermal impact prediction.
The initial model, based on MODFLOW and SHEMAT finite difference codes, has been calibrated using pumping tests and other field investigations data, obtaining a valid and reliable groundwater flow simulation. But thermal parameters, such as thermal conductivity and volumetric heat capacity, didn't have a site specific direct estimation and therefore they have been assigned to model cells referring to bibliographic standards, usually derived from laboratory tests and barely representing real aquifer properties. Anyway preliminary heat transport results have been compared with observed temperature trends, showing an efficient representation of the thermal plume extension and shape.
The ante operam simulation could not consider heat pump real utilization, that happened to be relevantly different from the expected project values; so the first numerical model could not properly simulate the groundwater temperature evolution. Consequently a second model has been implemented, in order to calibrate the mathematical simulation with monitored groundwater temperature datasets, trying to achieve higher levels of reliability in heat transport phenomena interpretation. This second step analysis focuses on aquifer thermal parameters calibration and includes a new finite element FEFLOW simulation, as an useful comparison between different approaches to heat transport modeling.