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Development of monitoring and modelling tools as basis for sustainable thermal management concepts of urban groundwater bodies

Matthias H. Mueller (1), Jannis Epting (1), Mandy Köhler (2), Falk Händel (2,3), and Peter Huggenberger (1)

(1) Department of Environmental Sciences, Applied and Environmental Geology, University of Basel, Bernoullistrasse 32, 4056 Basel, Switzerland, (2) Institute for Groundwater Management, Technische Universität Dresden, Bergstrasse 66, 01069 Dresden, Germany, (3) Department Monitoring and Exploration Technologies, UFZ-Helmholtz Centre for Environmental Research, Permoserstrasse 15, 04318 Leipzig, Germany

Increasing groundwater temperatures observed in many urban areas strongly interfere with the demand of thermal groundwater use. The groundwater temperatures in these urban areas are affected by numerous interacting factors: open and closed-loop geothermal systems for heating and cooling, sealed surfaces, constructions in the subsurface (infrastructure and buildings), artificial groundwater recharge, and interaction with rivers. On the one hand, these increasing groundwater temperatures will negatively affect the potential for its use in the future e.g. for cooling purposes. On the other hand, elevated subsurface temperatures can be considered as an energy source for shallow geothermal heating systems. Integrated thermal management concepts are therefore needed to coordinate the thermal use of groundwater in urban areas. These concepts should be based on knowledge of the driving processes which influence the thermal regime of the aquifer.

We are currently investigating the processes influencing the groundwater temperature throughout the urban area of Basel City, Switzerland. This involves a three-dimensional numerical groundwater heat-transport model including geothermal use and interactions with the unsaturated zone such as subsurface constructions reaching into the aquifer. The cantonal groundwater monitoring system is an important part of the data base in our model, which will help to develop sustainable management strategies. However, single temperature measurements in conventional groundwater wells can be biased by vertical thermal convection. Therefore, multilevel observation wells are used in the urban areas of the city to monitor subsurface temperatures reaching from the unsaturated zone to the base of the aquifer. These multilevel wells are distributed in a pilot area in order to monitor the subsurface temperatures in the vicinity of deep buildings and to quantify the influence of the geothermal use of groundwater.

Based on time series of the conventional groundwater wells, the multilevel observation wells and the different boundary conditions we characterize the groundwater temperature regimes using a regional groundwater heat-transport model. In the urban area of Basel, mean annual groundwater temperatures are significantly increasing with 0.05 K per year in the period of 1994 to 2014, which is most likely due to anthropogenic influences. Overall, mean annual groundwater temperatures of Basel are 3.0 ± 0.7 K higher compared to the mean annual air temperature, which is considered the expectable natural groundwater temperature. Additionally, the findings highlight the importance of appropriate monitoring systems for quantifying the effect of buildings which lie within the saturated zone on the development of groundwater temperatures.