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Characterisation of Seasonal Temperature Variation in a Shallow, Urban Aquifer: Implications for the Sustainable Development of Ground Source Heating Systems

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Groundwater thermally enhanced by the Urban Heat Island effect can be utilised by ground source heating systems (GSHSs). However, the near subsurface is subject to seasonal temperature variation reflected in shallow groundwater that can differ by several degrees throughout the year. To sustainably manage the near surface thermal resource an understanding of factors which control variation in groundwater temperature and how these are transmitted through the aquifer is needed.

We show that even in relatively small urban areas (Cardiff, U.K., situated on a shallow gravel aquifer) the Zone of Seasonal Fluctuation (ZSF) can vary in depth by 8m. GSHSs are more efficient if they are sited below the ZSF, where temperatures are more stable.

In Spring 2014, 48 groundwater monitoring boreholes were profiled at a 1m resolution to measure groundwater temperature across Cardiff. These were reprofiled that Autumn and compared to the Spring temperatures, defining the ZSF. The average depth to the base of the ZSF was 9.5mbgl but ranged from 7.1-15.5mbgl.

The amplitude of the differences between Spring and Autumn temperatures also varied. To better understand the high spatial variability 60 boreholes were instrumented with in situ temperature loggers, recording at half-hourly intervals. The first year's data revealed the amplitudes of temperature variation within boreholes with loggers at similar depths were not always consistent. It was also noted that lag times between air temperature and groundwater temperature were not uniform across the sites. The data also showed that where gravels occurred at shallower depths the ZSF tended to be shallower and lag times shorter.

The wide spatial variability of the ZSF may be partially explained by differing landuse. Those boreholes in open, grassed areas showed a deeper ZSF than those in built-up areas but built-up areas generally showed the greatest variation between Spring and Autumn temperature profiles, suggesting heat loss from buildings and underground infrastructure plays a part. Natural and anthropogenic factors affecting spatial and temporal groundwater temperatures, either separately or in combination, that have been considered in this study include landuse, depth, lithology/lithostratigraphy, material properties, hydrogeological setting, thermal conductivity, buried infrastructure, land surface temperature, weather effects and solar radiation.

This study shows that urban groundwater temperatures can vary greatly across a small area, which has implications for the successful development, and long-term performance of open- and closed-loop GSHSs, and the environmental regulation of these systems. Key to the effective wide-scale use of GSHSs is an understanding of the hydrogeological setting, chiefly how heat is transferred across the aquifer. This study attempts to provide insight into an array of factors which determine heat transfer in the ZSF.