

# Groundwater modelling with Modflow 6 to support sustainable heat recovery from a shallow urban coastal aquifer

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If we are to achieve targets to reduce greenhouse gas emissions then low-enthalpy ground source heating may provide a secure and low carbon form of space heating. The measured shallow groundwater temperatures under the City of Cardiff were found to be 2°C warmer than predicted, attributed to the subsurface urban heat island effect. For geothermal resource mapping and regulation, heat advection and the urban groundwater flow system need to be understood. Here, we develop a groundwater and recharge model of the shallow aquifer in Cardiff.

Cardiff is located on a flat coastal plain adjacent to the Bristol Channel. Following the construction of the Cardiff Bay Barrage in 1999, mud flats with a tidal range of ~10 m were turned in to a freshwater lake at a fixed elevation of 4.5 m a.o.D. The city is underlain by Triassic Mercia Mudstone, which is overlain by Quaternary superficial deposits, and consists of the sand and gravel aquifer of gaciofluvial origin, and lower permeability confining units, the tidal flat deposits. From before the construction of the Cardiff Bay Barrage, an extensive groundwater monitoring network was set in place, of which 194 boreholes are still operating. This well instrumented urban environment provides the opportunity to help understanding urban groundwater flow system, with recharge and discharge from urban infrastructure, rivers, docks, the Cardiff Bay barrage and the sea.

We have built a distributed recharge model using ZOODRM and a groundwater model using Modflow 6 for the shallow aquifer in Cardiff city. Using a step wise approach of increasing model complexity, we find that the model better represents observed hydraulic heads by including leakage into the sewer network, which we represent as drains in the numerical model and losses from mains water. Model calibration using Monte Carlo thus far has shown the non-uniqueness of fluxes in interaction with the sewer network, docks the sea, and the rivers for a similar goodness of fit with the observed water levels. Consistently however, we find that the groundwater system is strongly influenced by the sewer network.

For future work, we aim to better represent the sewer network within the groundwater model, e.g. by considering sewer age across the city. Once a steady state model has been achieved, we will be able to use our model to help environmental regulators to sustainably manage subsurface heat recovery and storage at a city scale.