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Discussion on 'Borehole temperature log from the Glasgow Geothermal Energy Research Field Site: a record of past changes to ground surface temperature caused by urban development', *Scottish Journal of Geology*, 56, 134-152, https://doi.org/10.1144/sjg2019-033

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In their analysis of temperature data, Watson and Westaway (2020) make substantial use of initial open information provided by the UK Geoenergy Observatory: Glasgow Geothermal Energy Research Field Site. They also offer criticisms on site location, heat resource size, design and costs; however, these criticisms appear to be based on a misunderstanding of the purpose of the Glasgow Observatory. In order to mitigate misapprehensions for future Observatory users, we write in reply. The Glasgow Observatory has been developed as a multidisciplinary research facility; it is not a demonstrator of maximum mine water heat resource, which is by implication what Watson and Westaway (2020) would deem a success.

Location

The focus of the UK Geoenergy Observatory in Glasgow is research infrastructure for very low enthalpy mine water geothermal and heat storage in an urban area with a complex prior land use (Monaghan *et al.* 2017, 2019). Due to open in 2020, researchers will have access to boreholes fitted with state-of-the-art instrumentation, as well as having the opportunity to deploy and test their own equipment. Data collected during construction and an ongoing baseline from borehole and surface instruments are, and will be, freely available on the ukgeos.ac.uk data portal.

The location in the east end of Glasgow was chosen by a Science Advisory Group and NERC Project Board, with the British Geological Survey (BGS) tasked to deliver and operate this NERC facility. An important consideration was that the area is representative of towns and cities across the UK for which mine energy could form a resource for heat abstraction and storage, with the challenges of an urban area close to heat demand, a complex prior land use, limited land availability and relatively shallow mine workings. Monaghan *et al.* (2017, p.11) summarize that this 'forms a realistic exemplar for study as a subsurface monitoring laboratory', which includes 'understanding of low-temperature heat resources balanced with their impacts on people and the subsurface–surface environment' (Adams *et al.* 2019). The wider area also benefited from previous data from the Clyde Urban SuperProject, providing regional characterization to a greater level of detail than is typical, making it an ideal platform for conducting research.

Resource size and cost

In their discussion section, Watson and Westaway (2020, p. 149) estimate the mine water heat resource size at the Glasgow Observatory, noting that 'detailed calculations depend on the hydrology, which has not yet been determined', stating that the resource available is quite small.

The Observatory is intentionally designed at the scale of a small, low temperature mine water scheme. The borehole spacing has been designed to provide data and imaging of induced changes (Monaghan *et al.* 2019, mine water borehole overview p. 10) on measurable time-scales for research monitoring, as opposed to at a scale for maximum mine water heat abstraction. For example, for research around resource sustainability, heat dispersion and thermal breakthrough processes under different conditions, the borehole spacing and design will provide flexibility that would not be possible in schemes designed to supply heat users.

Watson and Westaway (2020) then use the resource size in a cost comparison with other energy types (gas) in relation to the cost of the Observatory. This comparison is misleading: the £9 million cost of the Observatory is not representative of a commercial mine water heat scheme as it includes boreholes with two types of downhole sensor cable, environmental baseline monitoring boreholes, a range of surface monitoring equipment, surface research compounds designed for 15-year lifespan by a wide range of researchers and planning permission for those, an open data portal and associated IT infrastructure, core scans and production of open datasets for research community use (infrastructure described in Monaghan *et al.* 2019). This infrastructure would not be justified for a system intended to solely deliver heat. Additionally, planning permission was granted on the basis that the Glasgow Observatory is a research site. During communication with local communities and businesses it has been made clear it is not a heat supply scheme.

Borehole depth

In the discussion section, Watson and Westaway (2020) give a critique of the depth of borehole GGC01 drilled in 2018, in relation to gathering of thermal data. The Glasgow Observatory aims to enable a multiplicity of disciplines, including geothermics, and being inevitably constrained within a cost and time-scale, many trade-offs and balances were required in the design. In this case, GGC01 was drilled to 199 m, as boreholes >200 m deep require additional planning and environmental permitting at additional cost and time-scale. This borehole provided a cored reference section, preserved geomicrobiology and drilling samples (e.g. used in Chambers *et al.* 2019; Walls *et al.* 2020), downhole logs and hosts a string of 5 broadband seismometers (e.g. used to observe seismic 'quietening' due to Covid-19: Hicks 2020; Lecocq *et al.* 2020).

Groundwater flow and prior land use

In the discussion section, Watson and Westaway (2020, p.148) state 'the possibility of changes to the pattern of groundwater flow, resulting from GGERFS activities such as well testing and possible future heat production, a significant issue' in relation to prior land contamination in the Dalmarnock–Shawfield area (250–500 m from the site of GGC01). An increased evidence base on shallow groundwater flow systems and deeper mine water schemes is certainly a topic for research in areas with complex prior land use, it is important to note:

- GGC01 at Dalmarnock is the seismic monitoring borehole. It was fully cased on completion, and no pumping is planned for this borehole (Kearsey *et al.* 2019). GGERFS mine water boreholes are located at Cuningar Loop 1.4 km to the east (Monaghan *et al.* 2020).
- Boreholes at Cuningar Loop are arranged in spatial and depth arrays including in the near top bedrock and superficial deposits precisely to monitor and provide the evidence base for natural and induced changes from the subsurface to surface environment. A vital part of the Glasgow Observatory is providing open data and infrastructure to assess potential environmental impacts from mine water abstraction on the shallower bedrock, superficial deposits and human-made ground (Adams *et al.* 2019; Monaghan *et al.* 2019).
- Land contamination is highly variable and site specific – various programmes of remediation are ongoing during urban regeneration including at Dalmarnock and Shawfield.

Conclusion

In conclusion, Watson and Westaway (2020) make full use of the initial open datasets provided by the UK Geoenergy Observatory in Glasgow, exemplifying the value of such an at-scale Observatory in a representative urban setting. The Observatory is not a demonstrator for the maximum abstraction and supply of heat. Rather it is research infrastructure to support the evidence-base, development of processes and innovation around mine water energy resources and environmental management. In this reply we hope to have corrected the misleading comments in Watson and Westaway (2020) and we look forward to welcoming future Observatory users to run experiments, test equipment and protocols and take advantage of the open-access data portal.

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Data availability UK Geoenergy Observatories data referred to in the original article and this reply are openly available at www.ukgeos.ac.uk

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