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NATURAL ENVIRONMENT RESEARCH COUNCIL
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Lessons Learned from Establishing a City-wide Groundwater Temperature Observatory

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1. Introduction

Climate change is forcing us to look to novel methods of energy production. Shallow groundwater beneath cities is thermally enhanced by the Urban Heat Island effect, potentially providing a resource for ground source heating. A thermal resource map of Cardiff was created using data from groundwater temperature profiles at 168 monitoring boreholes across the city. Subsequently, groundwater temperature sensors were installed at fixed depths in a subset of these boreholes to monitor long-term temperature trends, forming one of the largest city-scale groundwater temperature observatories of its kind. Data from these sensors creates a record of baseline conditions & can be used to support the development of ground source heating. It also has implications for scientific study into seasonal groundwater temperature variation, aquifer properties & heat flow. Different techniques to capture & disseminate the data have been employed across the city with varying degrees of success.

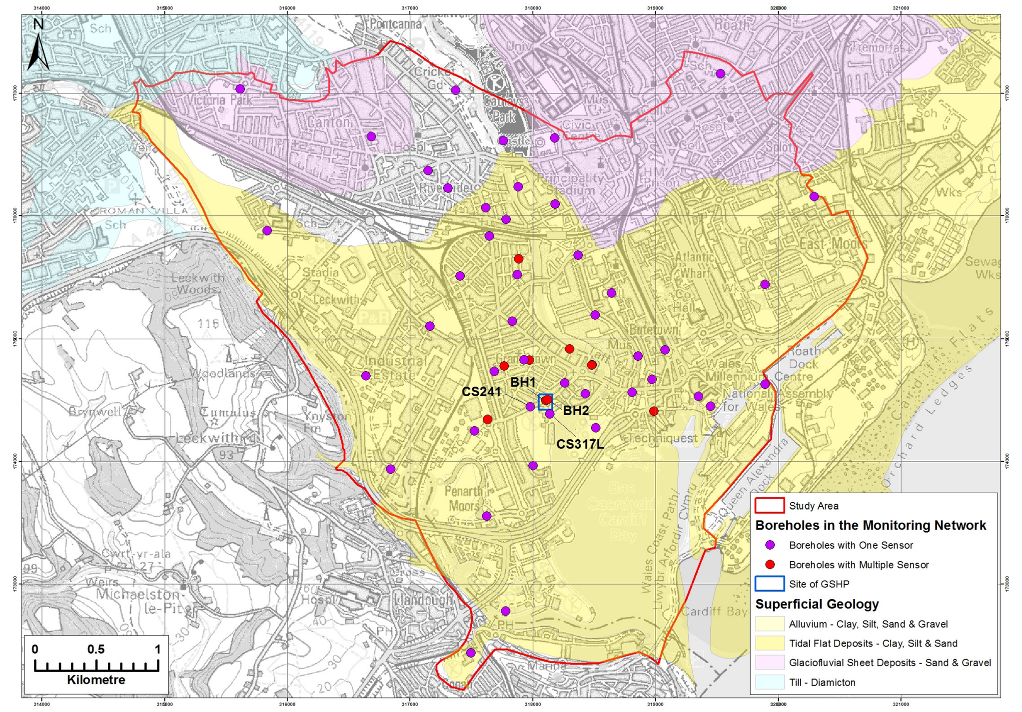

Fig. 1. Map of the monitoring network shows existing sensor locations. DiGMap 1:50,000 British Geological Survey © NERC. Contains Ordnance Survey data © Crown Copyright & database rights 2018.

2. Rationale

- Study area defined by a pre-existing groundwater level monitoring site & its boreholes
- Baseline mapping & monitoring aids planners in the sustainable use of subsurface heat
- A proof-of-concept, shallow, open-loop ground source heat pump (GSHP) is being monitored to understand the long-term effects of operating such systems on the aquifer
- The data can inform the development of district heating schemes & monitor the effects of mass-uptake of heat extraction
- Real implications for CO_2 reduction, energy security & fuel poverty
- Data improves understanding of geotechnical properties of the aquifer unit, provides insight into heat transport & seasonal temperature variation, & can be used in 3D hydrogeological modelling

3. Instrumenting a City

- 99 groundwater temperature sensors installed in 62 boreholes recording temperature every 30 minutes since June 2015
- Network currently comprises Hobo Temp Pro V2 & OTT Hydrometry® Orpheus Mini loggers. Soon to be replaced with Solinst Leveloggers with direct read cables
- 6 boreholes are telemetered
- Sensors are installed both within & below the Zone of Seasonal Fluctuation (some boreholes have multiple installations)
- Sensors installed across the city
- Sensors installed both up & down gradient of a GSHP, & within the system boreholes & plant room
- Manual whole borehole temperature profiles taken at regular intervals
- Air, soil & river temperatures also monitored

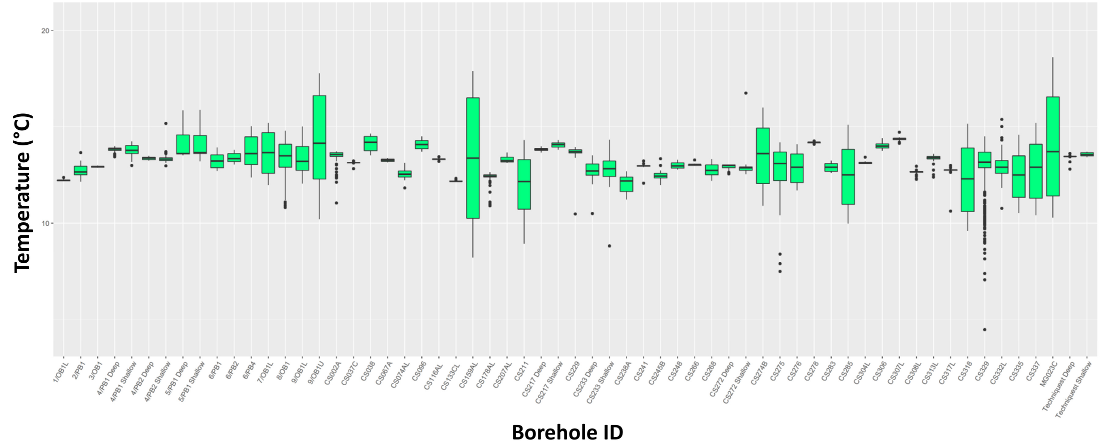

Fig. 2. Box plot shows the range in groundwater temperature over the monitoring period.

4. Ground Source Heating

A GSHP was installed at a test site in the city & has been heating a nursery school since 2015. Baseline groundwater temperature mapping identified a potential thermal resource, while the test site & surrounding area have been instrumented with telemetry & manual sensors to monitor groundwater temperatures before, during & after installation of the proof of concept system.

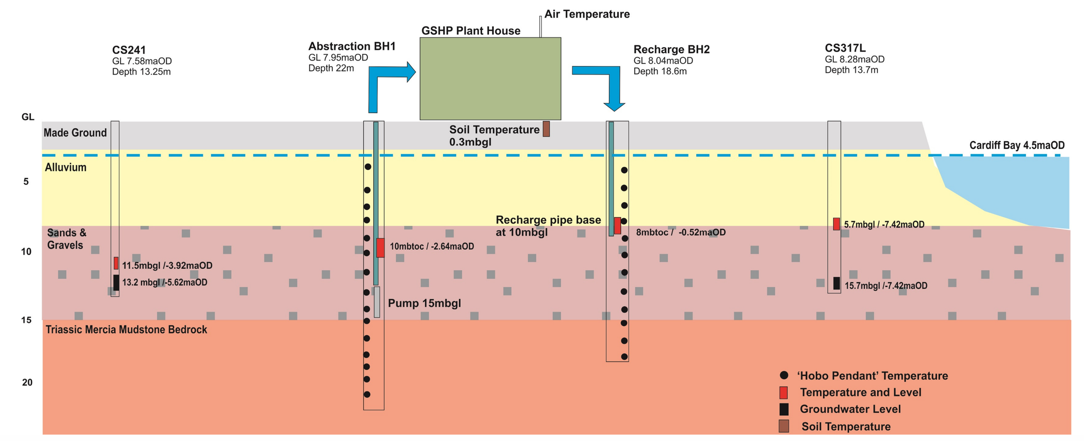

Fig. 3. Conceptual model of the GSHP site showing the locations of monitoring points & instrumentation.

5. Data Portals

- Non-telemetered sensors have to have their data manually downloaded & saved as .csv files which can be read into a database
- The database feeds into an online data portal where groundwater temperatures at each site in the network can be viewed
- Telemetered sites stream their data live to the portal via Adcon Telemetry
- Data from the GSHP site can be seen in real time, with system performance monitored
- Data portals provide a way to archive large datasets & allow you to visualise & interrogate data by site
- Anomalies can be easily visually identified
- The open-source nature of the portal makes the data useful to developers & scientists

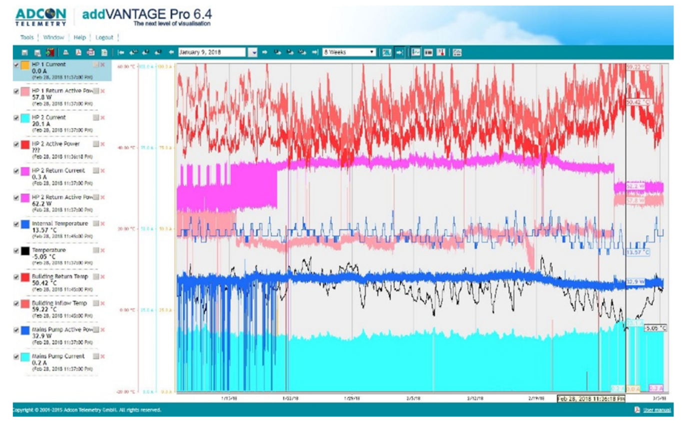

Fig. 4. Example of the telemetry data being streamed into an online viewer. This screen capture shows data from the GSHP site.

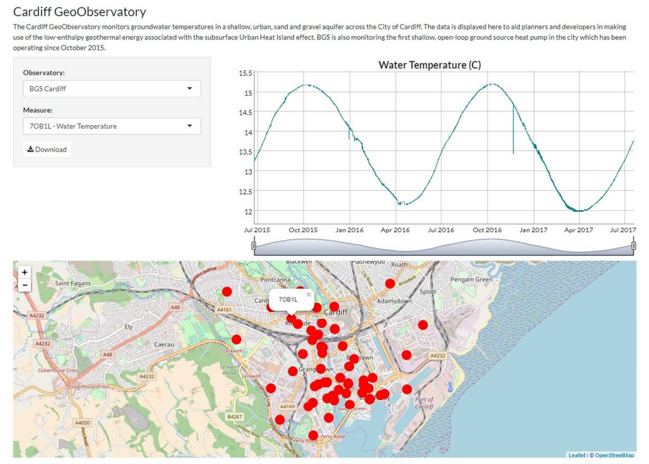

Fig. 5. The data portal where the manually downloaded groundwater temperatures are archived & displayed.

6. Telemetry Versus Manual Downloads

- Manual sensors are time consuming, require the sensor to be removed for downloading, carry a risk of data loss from sensor failure not being detected until the next download, give no opportunity to view live data, require post-processing & are subject to human error. Data are batch uploaded to portals & problems are identified only after the event.
- Manual sensors are simple, cheap, independent of infrastructure & have few components
- Telemetry is expensive, difficult to initially set up & reliant on external infrastructure. Failures can mean complete loss of data & live streams are of no use if they go down.
- Telemetry is easy to maintain once set up, saves staff time & effort, enables an automated transfer of data to portals, provides real-time data, allows for faster identification of problems & can be left to operate without intervention.

7. Rationalising the Network

- After an initial monitoring period the number of sites can reasonably be reduced
- Ongoing costs & staff time together with some of the boreholes being decommissioned in 2020 contributed to the decision to downsize the network
- Sites that will continue to be monitored in the rationalised network are shown in Figure 6
- Sites have been chosen to include a range of lithologies, sensor depths, 'good' data & anomalies
- The spatial distribution of the data was considered
- Major redevelopment of the city is planned in the next decade so boreholes that may provide data to support this have also been prioritised
- Boreholes are located in confined & unconfined areas & some were selected due to their role in monitoring the GSHP
- The deepest boreholes were also selected
- Solinst Leveloggers with direct read cables will replace existing manual sensors to speed up downloads
- Telemetered sites will continue
- Telemetry considered for all sites but decided against due to costs & the potential for gaps in the data during the initial installation period
- The telemetered sites took time to set up & fine-tune & it was decided this time investment would delay the smooth transition between the two systems at this time
- Direct read cables seen as a middle ground

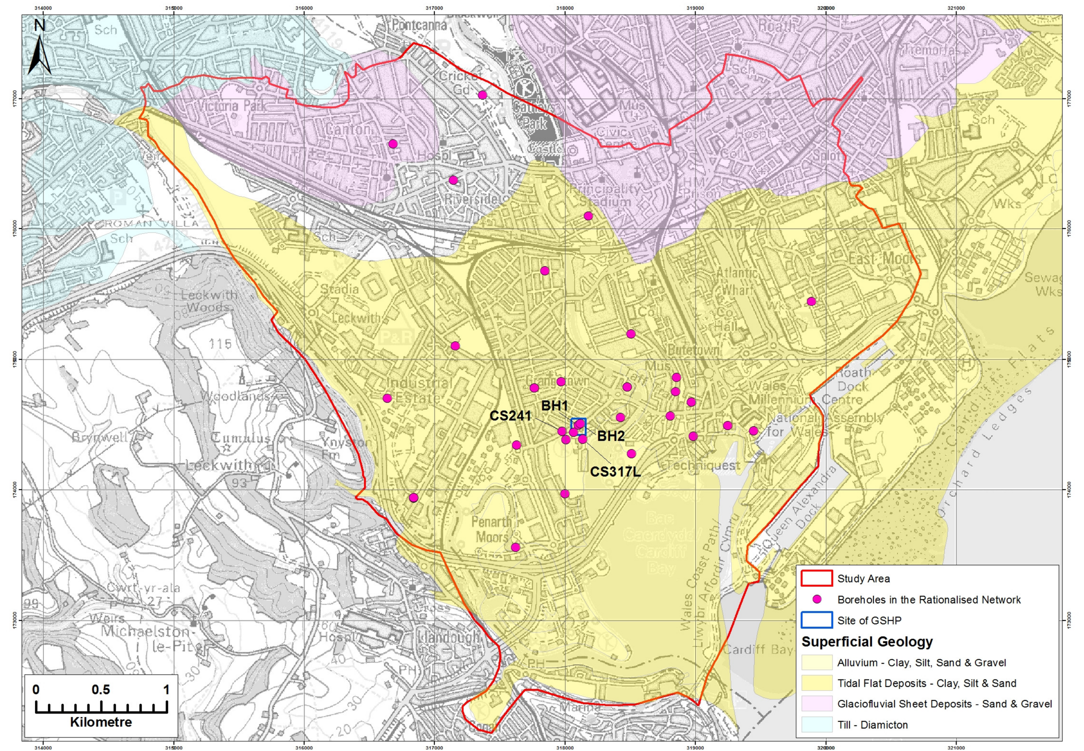

Fig. 6. Map showing locations of the sensors in the rationalised network including a mixture of Solinst Leveloggers with direct read cables & telemetry. DiGMap 1:50,000 British Geological Survey © NERC. Contains Ordnance Survey data © Crown Copyright & database rights 2018.

8. Lessons Learned

- Manual sensors are an inexpensive way to kick start a network & test out sensor locations but long-term observatories may benefit from being telemetered from the start
- Direct read cables speed up downloading time for manual sensors
- Manual sensors are an inexpensive alternative to telemetry & may be well suited to easily accessible sites but telemetry may be better for sites with limited access
- Large networks may benefit from telemetry
- Large networks are data-rich, improving accuracy, but manual sensors require a lot of man-power to maintain & process, & the initial costs of telemetry can be very high
- It may be possible to get the same story from fewer sites but it is better to downsize an existing network than start small
- Telemetry has the advantage of real time data but this isn't always needed. May be useful for monitoring GSHPs
- It is important to get data portals working early on

9. Next Steps

- Deploy the new sensors & downsize the network
- Statistical analysis of data
- Investigate the science questions in the data e.g. seasonal variability
- Install more GSHPs/district heating systems & monitor these
- Upscale to other cities
- Mobile phone alerts when data thresholds are triggered

10. Key Findings

- Cardiff has the U.K.'s first high-resolution, city-wide groundwater temperature network
- Baseline mapping is an important tool for assessing resources & monitoring sustainable exploitation
- Opportunities to retrofit existing infrastructure should not be missed
- Observatories provide vital information & are worth the initial set-up problems
- The manual sensors worked well - only one sensor failure across the network
- Direct read cables speed up the process & for small sites may be more financially worth it than telemetry
- Larger or more remote sites might benefit from telemetry
- Long-term monitoring may better telemetered but duration not always known at start
- Staff time costs of downloading manual sensor networks may outweigh initial set up fees of telemetry
- Telemetry is a useful way of monitoring active systems such as the GSHP as real-time problems can be identified but it may be less critical to see live data elsewhere
- Open-source data portals are good for storing & displaying data & for disseminating information to those who could benefit from it. They are also useful for diagnostics
- Automation of telemetered data into data portals makes the task easier but can present initial challenges to set up
- There will always be something more you wished you had monitored

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