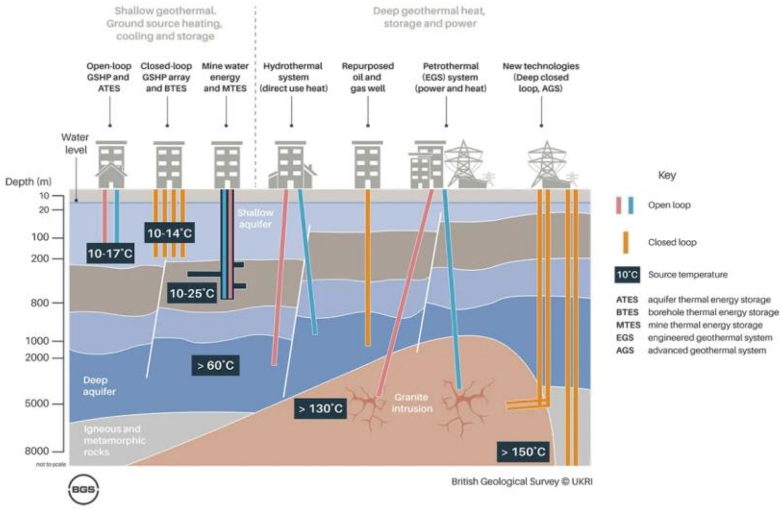
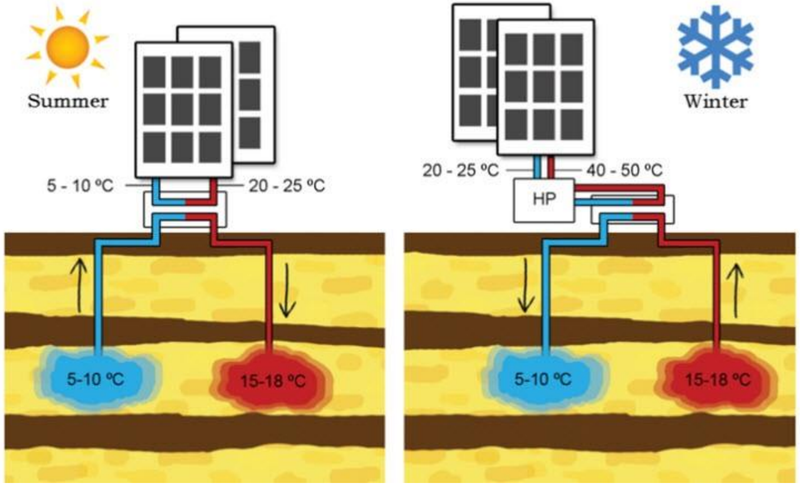
CHRISTOPHER BROWN

Exploring the UK Geoenergy Observatory in Cheshire: Applications for Heating and Cooling

British Geological Survey

What is geothermal and underground thermal energy storage (UTES)?





Bloemendal & Hartog, 2018

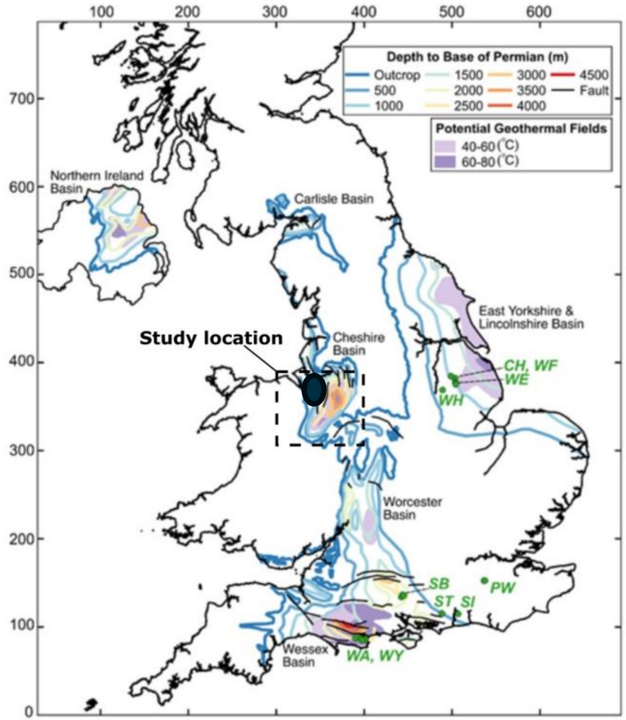
- Energy stored as heat in the ground - many ways to exploit
- UTES stores heat/coolth underground to shift supply and demand
- Stable ground temperatures also source of cooling

Importance of geothermal/UTES development and subsurface testing

- Government committed to 20 % of UK space heating demand coming from low carbon heat networks by 2050 (DESNZ, 2025)
- Large requirement for thermal energy source and reduce electrification.
- Substantial increases in cooling loads
- Need to improve energy security
  - ➢ Shallow and deep aquifers widespread for geothermal and UTES development
  - ➢ Closed-loop systems can be developed in most locations
  - ➢ Significant potential for large scale development, yet, limited to small scale systems (and few deep/UTES)
- Subsurface testing can be useful to help reduce risk and improve subsurface understanding

Cheshire Basin location and geothermal potential

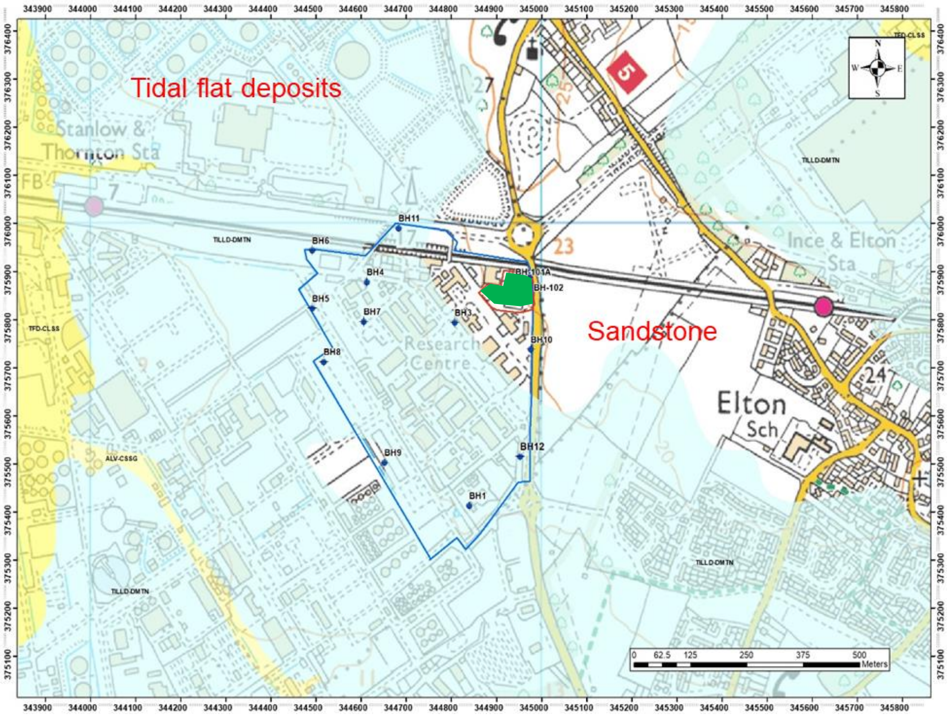
- Cheshire Basin located in northwest England
- Significant potential up to 40,000 TWh, but not all of this is recoverable (Brown, 2023)
- High quality Permo-Triassic aquifers
- Significant thickness of sandstone (>2 km) in places
- Basal temperatures at ~4 km over 100°C (e.g., Downing and Gray, 1986; Brown, 2023).
- Good for geothermal and underground thermal energy storage



Watson et al., 2020

Cheshire Observatory Location

- Thornton Science Park, Cheshire
- On outcrop of Chester Formation (SSG aquifer); surrounded by tidal flat deposits
- Bedrock at 0.5 – 2 m beneath made ground and asphalt
- Located in the Cheshire Science Corridor and Cheshire Energy hub (energy innovation district including HyNet NW Industrial Cluster)



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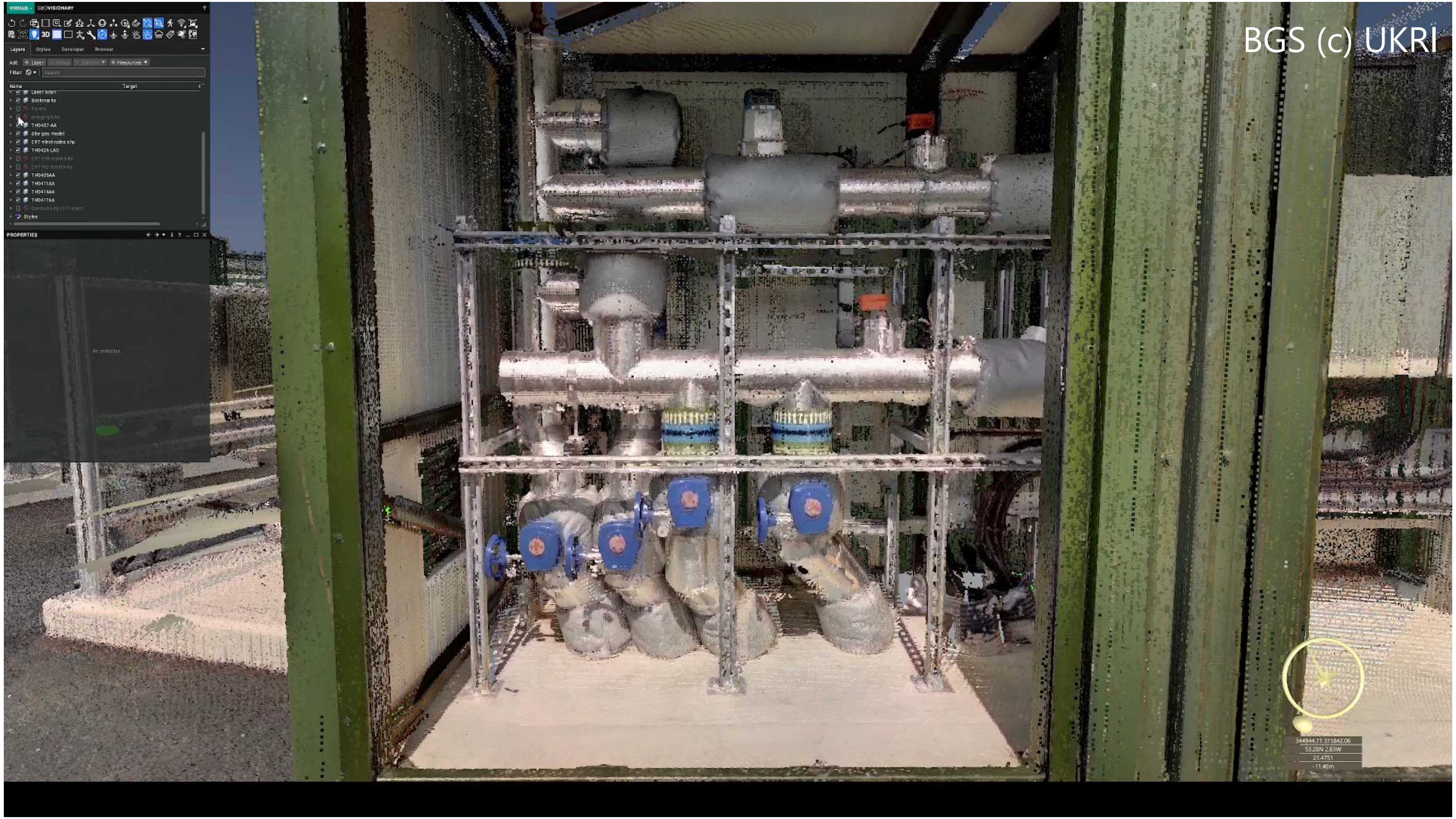
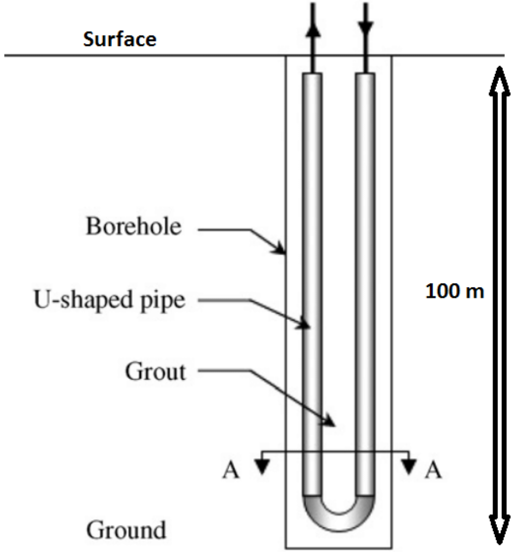
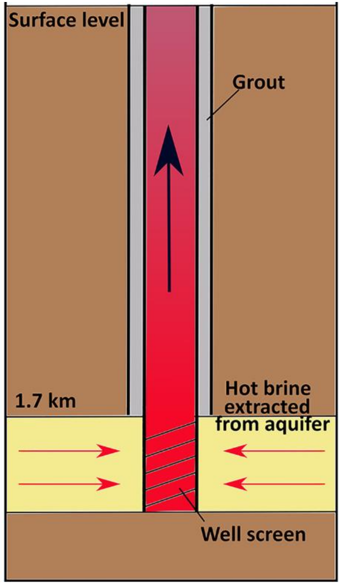
Virtual Reality Tour




Key
100m borehole with heat exchanger loop installed to 95m bgl in thermal grout
100m borehole with 8 port multilevel sampler installed to 99m bgl for groundwater monitoring
100m piezometer borehole with 1m screen section from 98- 99m bgl for groundwater monitoring
Resistance tomography and fibre optic cables to ca. 100m bgl
100m open bedrock borehole with depth- adjustable packer and pump assembly for groundwater abstraction or reinjection
100m open bedrock borehole for geophysical and hydrogeological investigations. Fitted with 100m removable FLUTe liner to prevent vertical flow
Resistance tomography and fibre optic cables to ca. 15m bgl.
100m open bedrock borehole for geophysical and hydrogeological investigations. Fitted with 100m removable FLUTe liner and 100m fibre optic cable
TH0415
InSAR reflector
TH0411
Wellhead enclosure for abstraction/ reinjection well
TH0414
TH0424
Data centre
Site office
TH0407
TH0408
TH0423
TH0421
Wellhead enclosure for heat exchanger borehole
TH0422
TH0420
TH0419
TH0417
TH0412
TH0413
TH0410
TH0418
TH0416
Workshop
Storage
Plant room
Plant plinth
TH0406
Pipework and cable gantry
2 x 20m³ water storage tanks
TH0404
TH0409
TH0405
BGS (c) UKRI

Cheshire Observatory capabilities and infrastructure





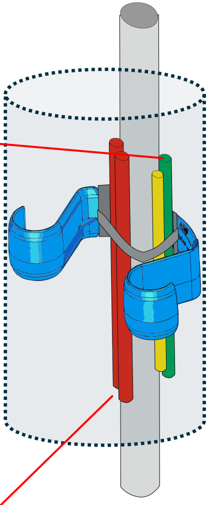
Note: open-loop diagram not representative of Cheshire well design

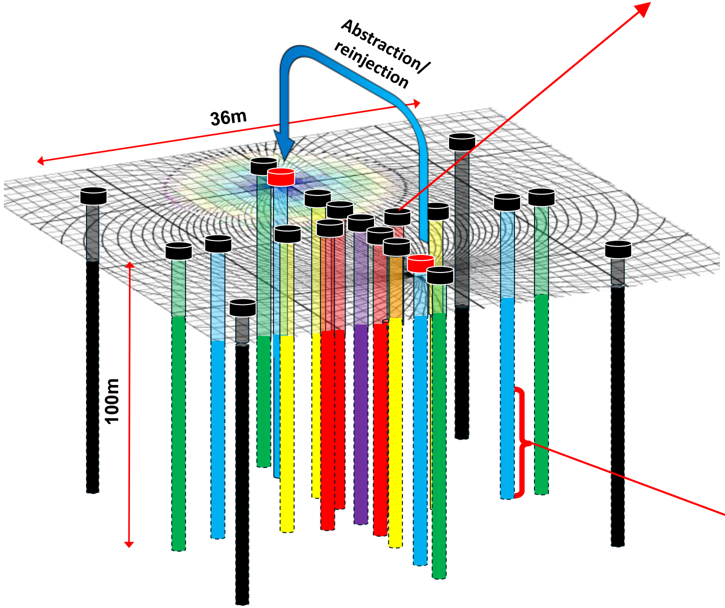
- Closed-loop (Johra, 2018)
- Open-loop (Brown and Howell, 2023)

Cheshire Observatory Capabilities

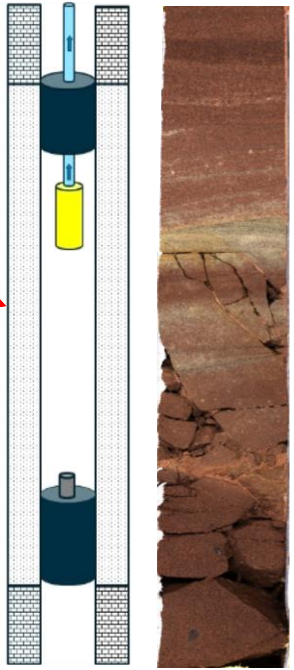
Photos are BGS (c) UKRI

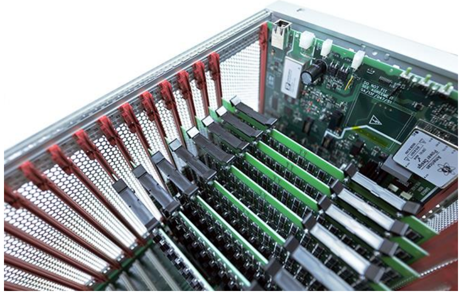
Silixa fibre optic monitoring systems





Multilevel GW monitoring





Electrical resistance tomography: BGS PRIME

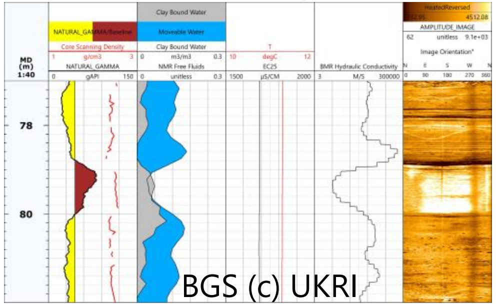
Borehole heat exchangers

1000m of archived core and scan data

Adjustable packers in abstraction/ reinjection wells

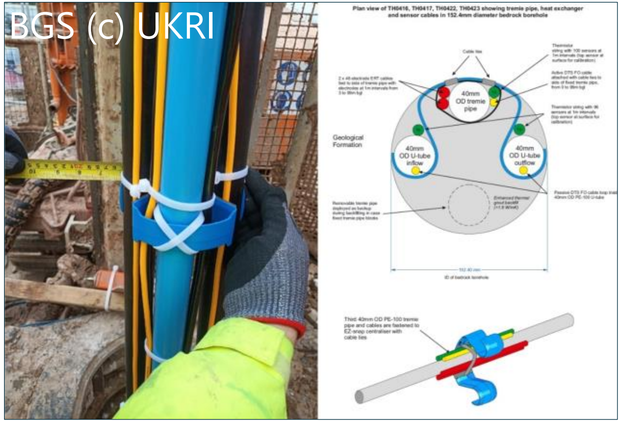
Rock Volume characterisation

- 18 sets of geophysical wireline logs
- Physical and chemical property core scan data
- Pre and post- drilling profiles of aquifer porewater chemistry
- Archive core samples for microbiological characterisation
- Baseline monitoring of groundwater levels and chemistry



High resolution monitoring systems

- 1800m of fibre optic cable in boreholes equipped with distributed temperature and acoustic sensing
- 4 x 95m U-tube borehole heat exchangers which can be independently heated or cooled (range 0 to 50°C)
- Over 1100 electrical resistance tomography electrodes at 1m vertical spacing
- 4 x Waterloo 401 multilevel wells each with sample ports at 8 depths
- Control of groundwater flow velocity via 4 reversible groundwater abstraction/ reinjection wells



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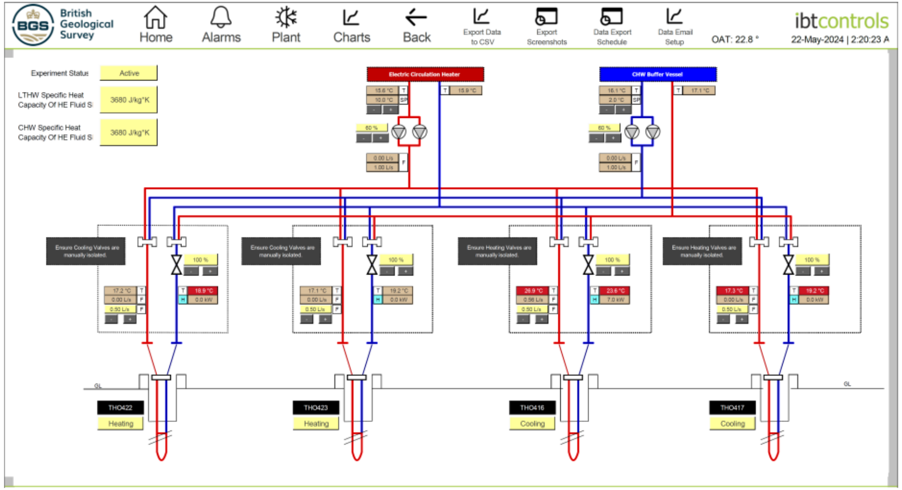
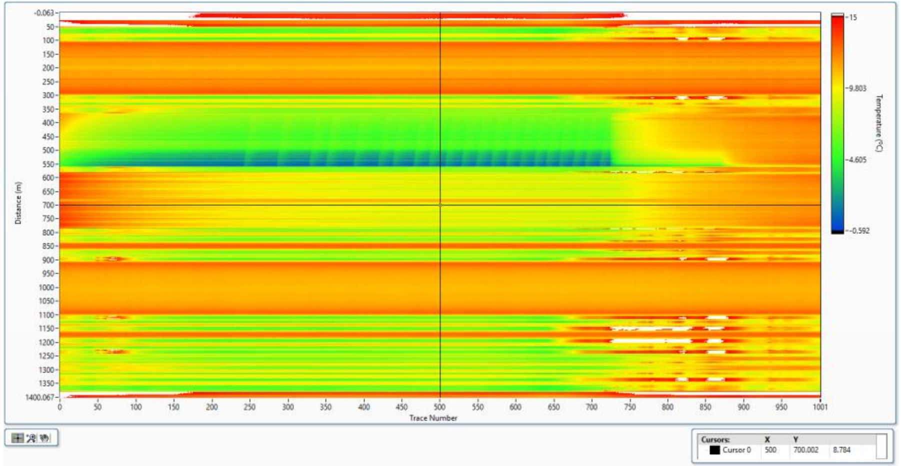
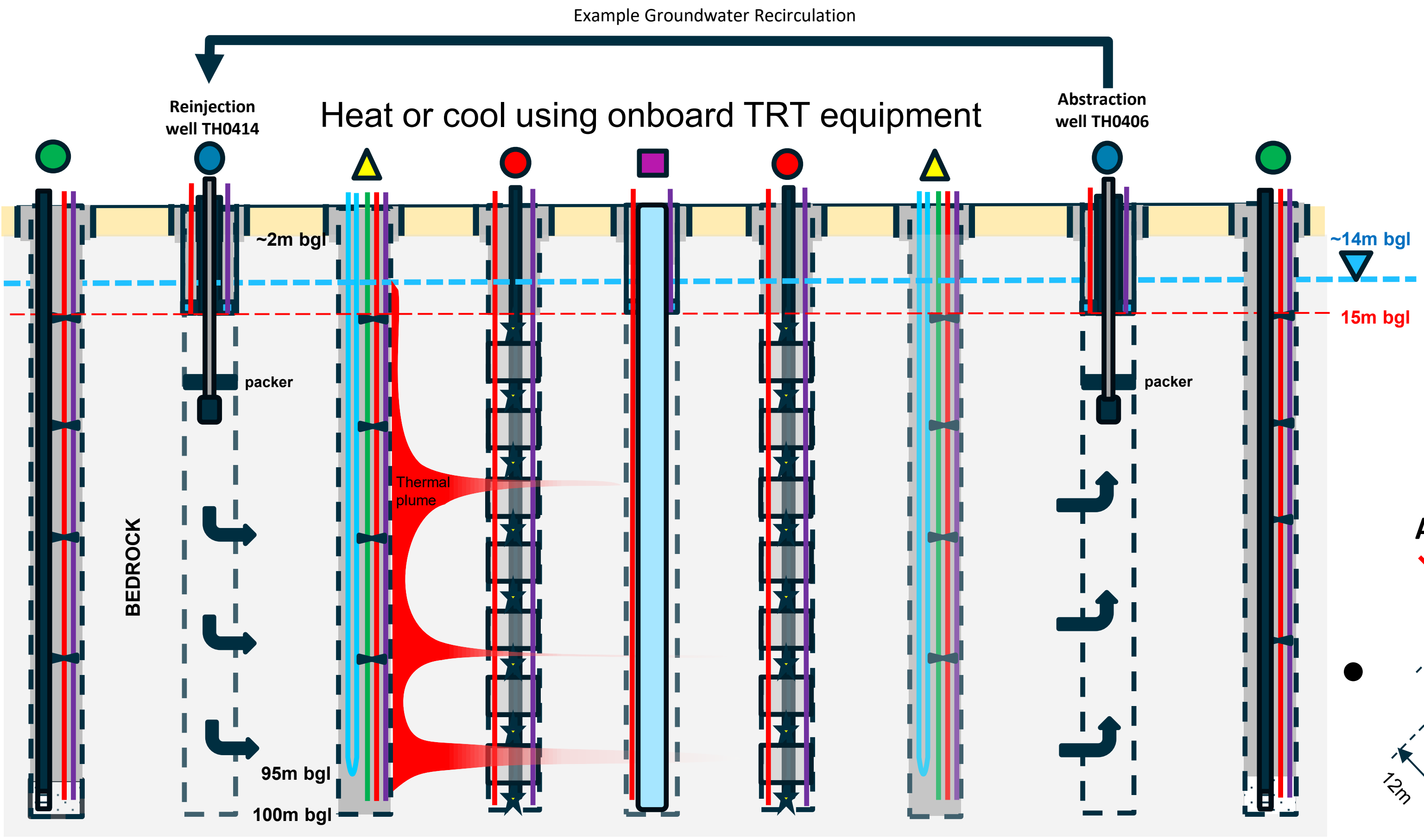
Control centre

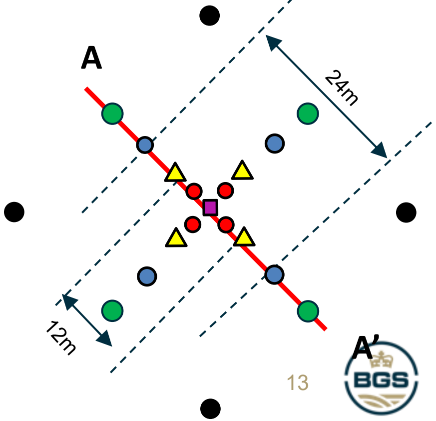




Commissioning tests and fracture flow



	KEY
Blue circle	Abstraction/ reinjection well with adjustable packers for hydraulic control
Red circle	Waterloo 401 multilevel well for groundwater sampling and level logging, with FO and ERT cabling to 100m
Purple square	Well with removable liner for monitoring, sampling, geophysics or tracer injection
Yellow triangle	Heat exchanger borehole with FO, thermistor and ERT cabling to 100m
Green circle	Deep (98-99m) piezometer well with FO and ERT cabling to 100m

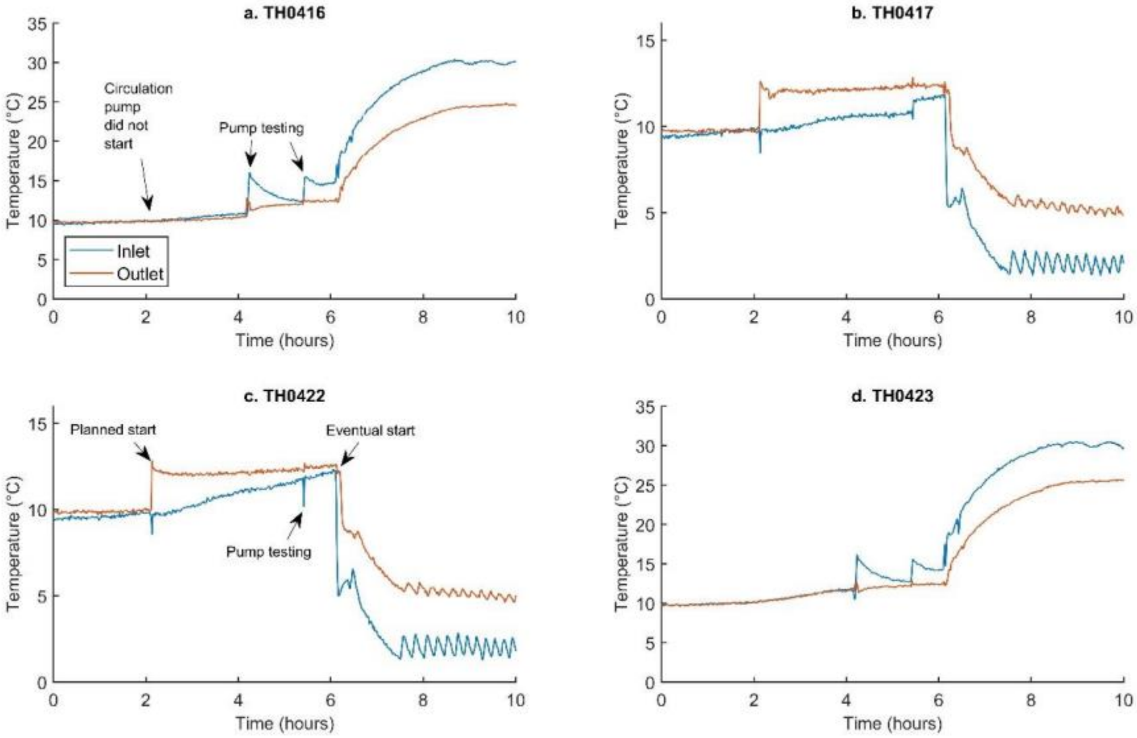


Research Testing and Characterisation

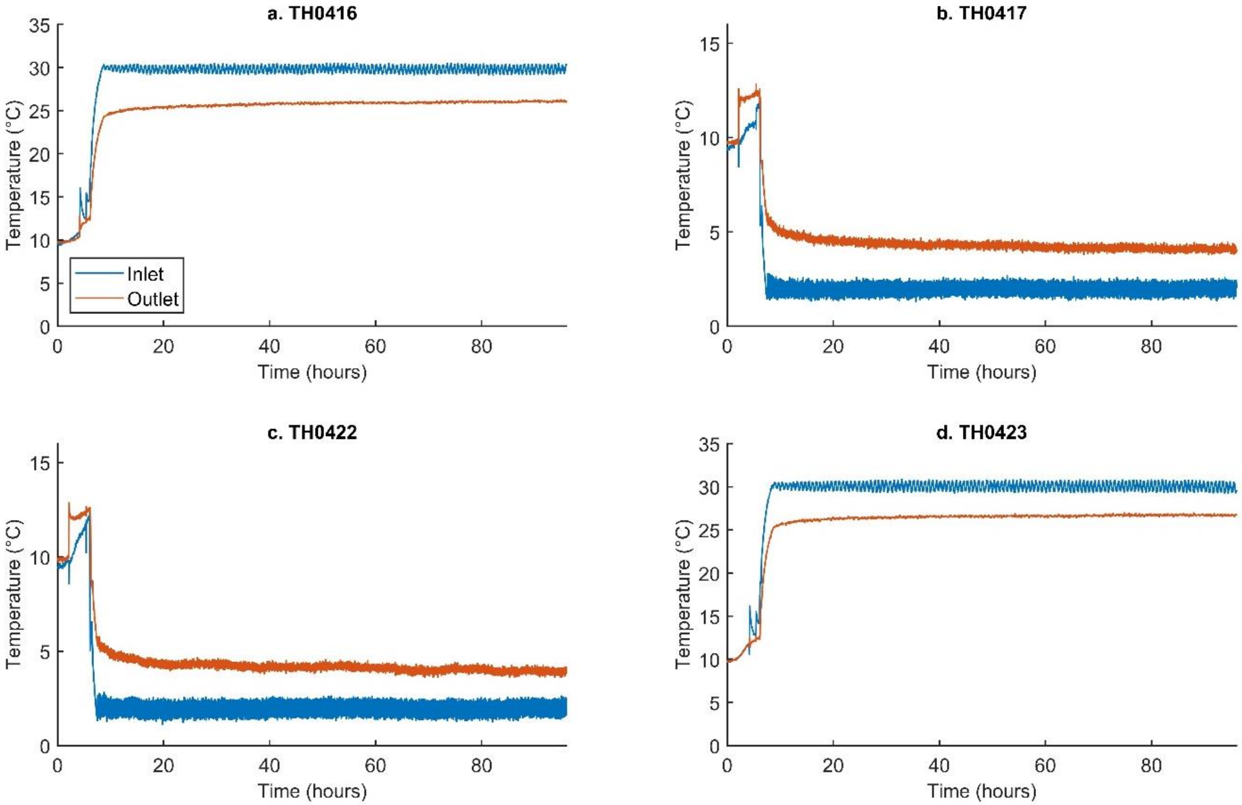
REEF-UKC seed corn experiments

- U-tube – 40 mm OD in 4 boreholes, flow rate 0.5 l/s.
- Injecting heat and coolth (i.e., heat injection and extraction) simultaneously for ~90 hours.
- Heat injection set point of 30 °C and heat extraction set point of 1 °C .
- How does this impact thermal performance test analysis?

Results – fluid temperatures



Results – fluid temperatures



Borehole	Estimated Thermal Conductivity (W/mK)
TH0416	3.65
TH0417	3.03
TH0422	2.43
TH0423	3.56

Results

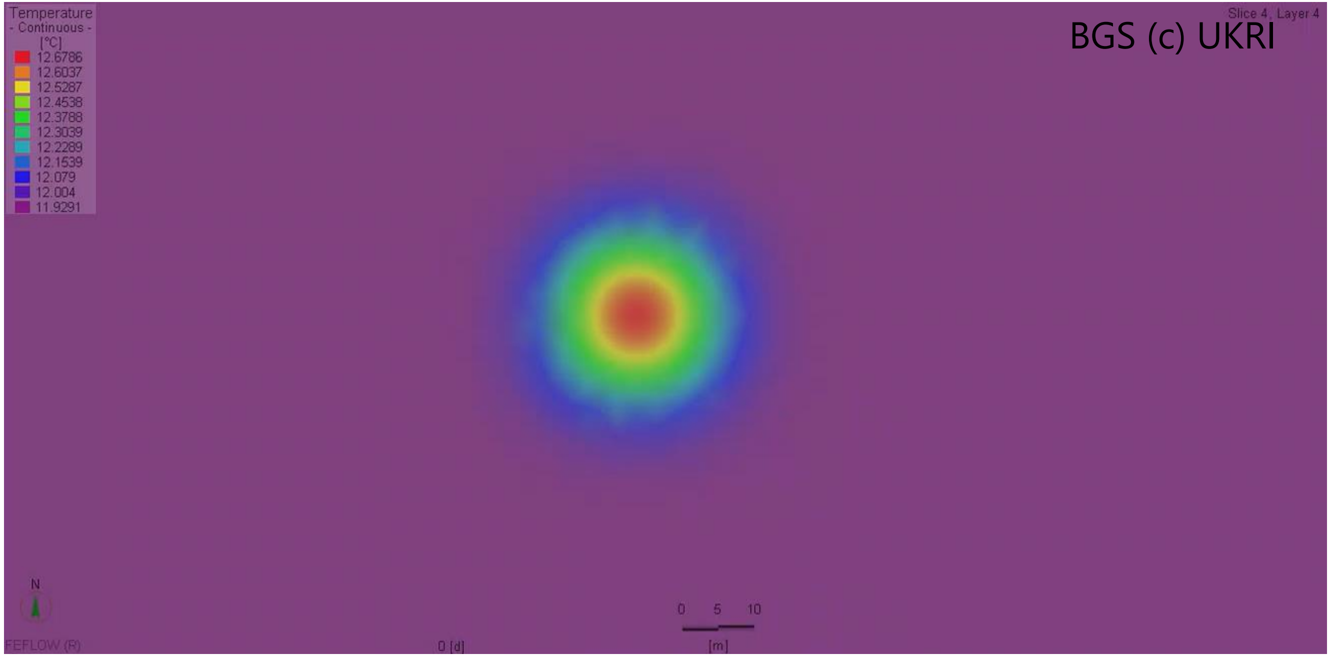
- Lower effective thermal conductivity estimates in heat extraction boreholes.
- Similar observations underpredicting by 15 % in conventional TRTs (Witte, 2001; Jia et al., 2019).
- Hypothesised this could be due to a natural convection effect in the aquifer.

Could also be associated to:

- ➢ Oscillations in data
- ➢ Analysis method from Aydin et al. (2019)
- ➢ Flow rate variations, uncertainty in grout material or natural convection.
- ➢ Differences in heat input/extraction rate ~38 W/m v ~70 W/m.

Results

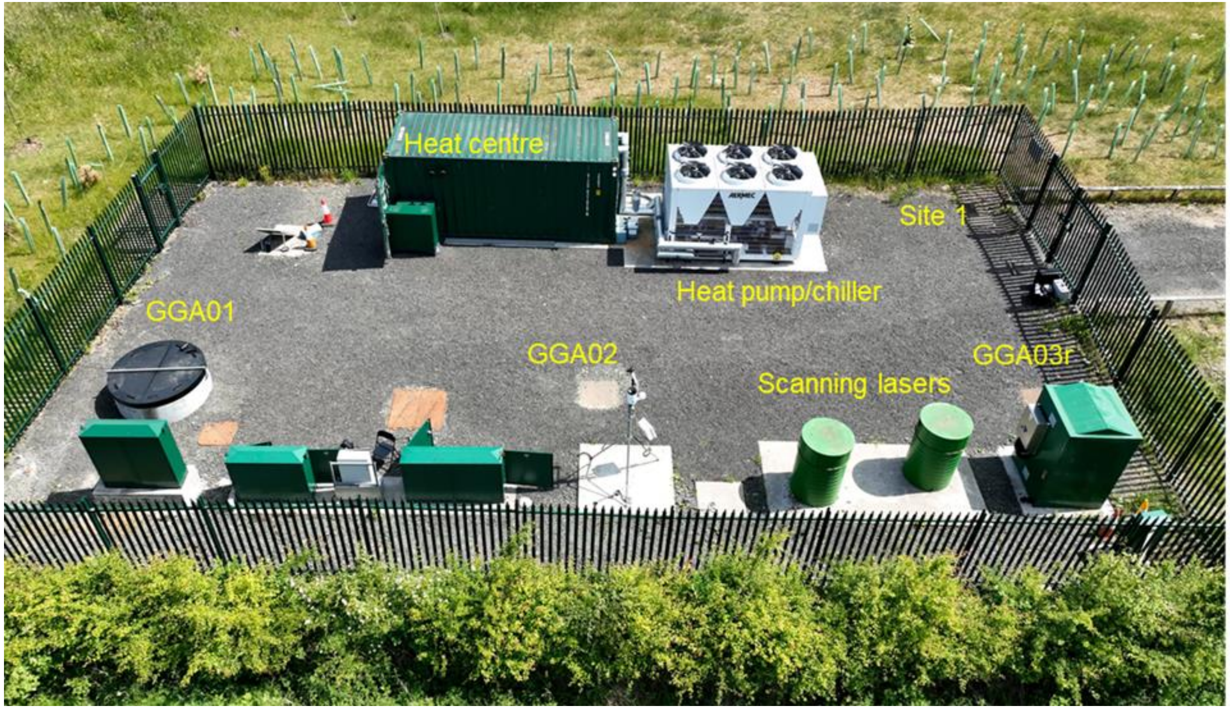
- Using ground properties we can then predict thermal response of the ground during operation for heating and cooling
- Help with design and build of GSHPs
- Design new tests



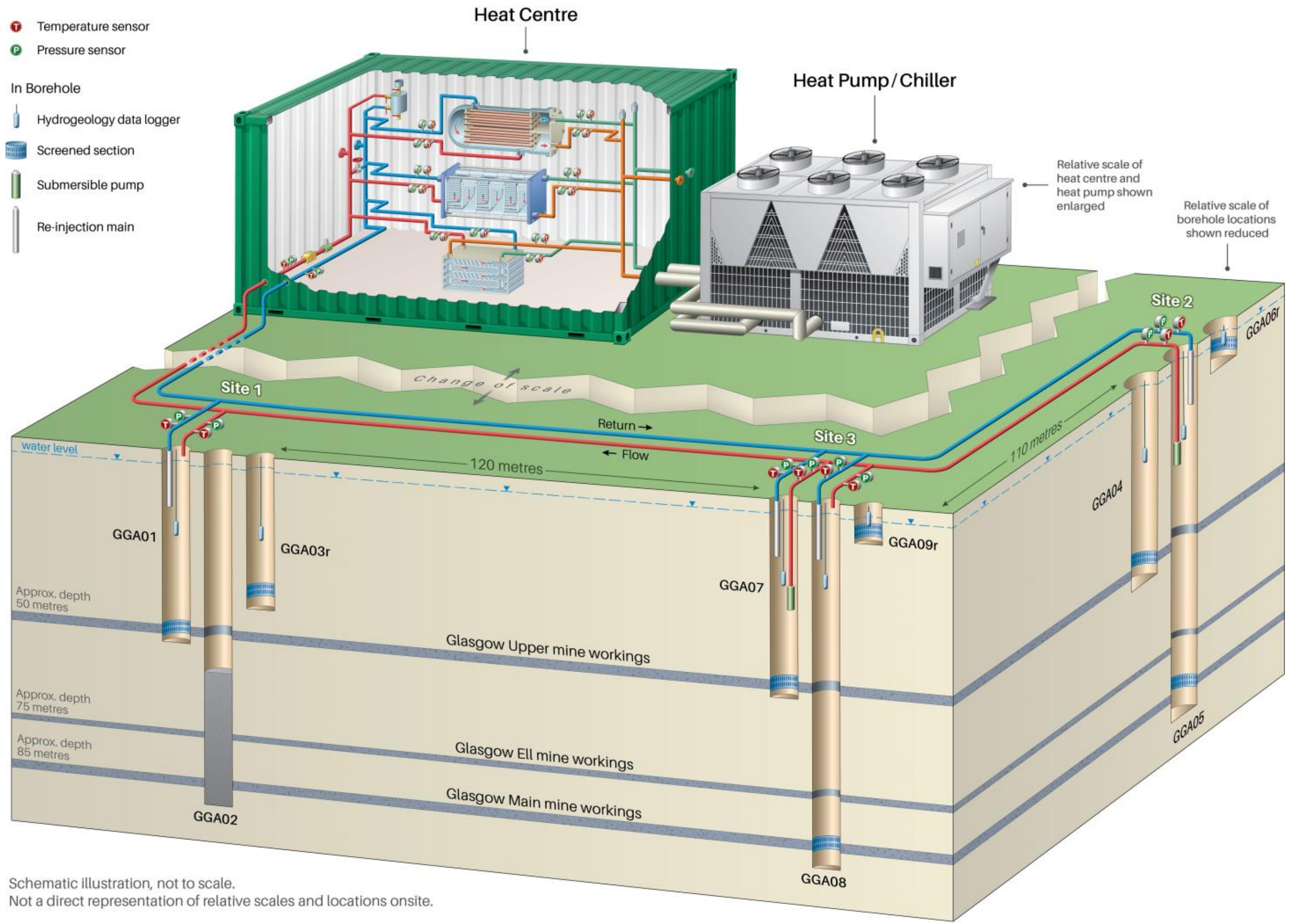
Summary and Outlook

- Significant opportunity for subsurface testing to derisk geothermal and UTES for heating and cooling
- Help to exploit local systems to the Cheshire Basin acting as an analogue
- Develop new methods for site testing and characterisation
- Help understand thermal, hydraulic, mechanical and chemical processes

Additional site at Glasgow to evaluate mine water geothermal systems


Heat centre
Site 1
Heat pump/chiller
GGA01
GGA02
GGA03r
Scanning lasers

BGS (c) UKRI



Temperature sensor
Pressure sensor
In Borehole
Hydrogeology data logger
Screened section
Submersible pump
Re-injection main
Heat Centre
Heat Pump/Chiller
Relative scale of heat centre and heat pump shown enlarged
Relative scale of borehole locations shown reduced
Change of scale
Site 1
Site 2
Site 3
Return
Flow
120 metres
110 metres
water level
GGA01
GGA02
GGA03r
GGA04
GGA05
GGA06r
GGA07
GGA08
GGA09r
Approx. depth 50 metres
Approx. depth 75 metres
Approx. depth 85 metres
Glasgow Upper mine workings
Glasgow Ell mine workings
Glasgow Main mine workings
Schematic illustration, not to scale.
Not a direct representation of relative scales and locations onsite.

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Summary: research and innovation opportunities

Optimised drilling strategies

Synthesis of learnings from Observatory construction

Drilling decision trees

Interactions between GSH/C & other infrastructure

Legacy mine workings

Wells, other GSH systems, buildings, tunnels, etc.

Best practice GSH/C well design

Construction materials

Tailoring completion design to geology

Operational GSH/C performance

Effect of operating regime on thermal performance, system reliability and environmental effects

Rock characterisation

Multiscale, adaptive SI approaches

Live data management and visualisation tools

Advanced 3D flow & transport modelling

Models & digital twins

Big data techniques

4D tracer migration tests

Effects of heating & cooling on aquifers

Chemistry

Microbiology

Aquifer properties

In-situ monitoring of subsurface systems

Sensor development and testing

Optimised monitoring strategies

ACKNOWLEDGEMENTS

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Acknowledgments

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The Geoenergy Observatories have been realised through the skill and dedication of a great many (100s of) colleagues from BGS, NERC and the staff of the principal contractors, drillers and specialist engineering subcontractors

A big thank you to the members of the UKGEOS Science Advisory Group, Clyde Gateway, University of Chester and experts from the UK and international subsurface research community who have advised on different aspects of the Observatory design

THANK YOU

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