Investigating the key controls on mine-water heat in legacy flooded coal mines in the UK: What is the thermal footprint of past mining activities?

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I - Introduction:

● Residential heating : ~50% of the energy consumption & ~20% of the GHG emissions in the UK.
● 9% of the population lives in formed mine areas; today, all underground coal mines are closed.
● Water rebound in abandoned mines is either in progress or completed; pumping implemented by the Coal Authority at some locations to avoid mine-water discharge at the surface.
● Recovering heat from mine-water using GSHP can provide local population with low-carbon heating (e.g. Dawdon mine-water heating project).
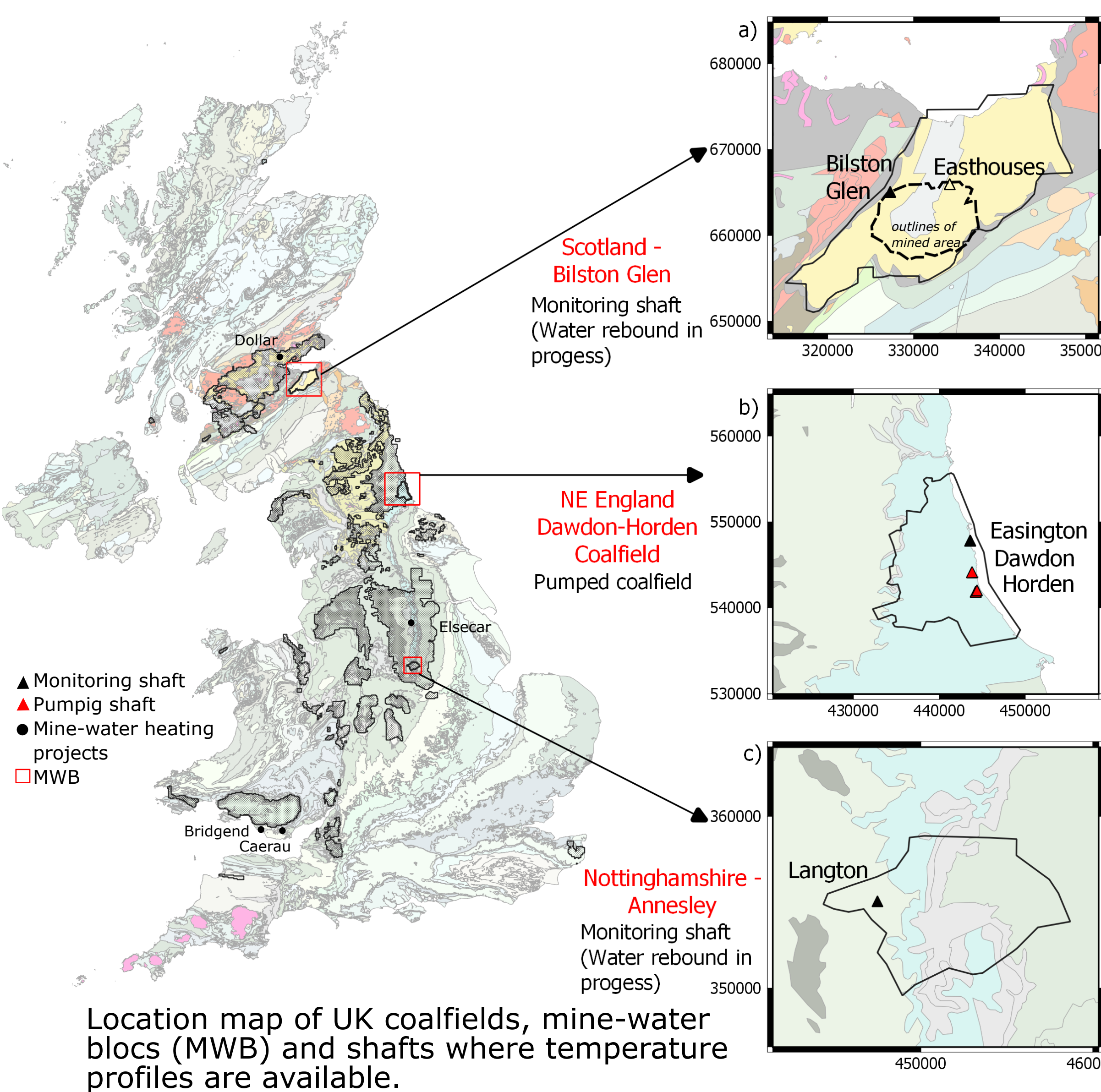
Problematic: Data revealed a lack of correlation between local equilibrium temperature in the mine-water block (MWB) and temperature profiles measured in mine shafts (Farr et al., 2020).

Objective: Investigate the long-term impact of pumping activities during mining on the temperature distribution in mines after water rebound to explain those discrepancies.
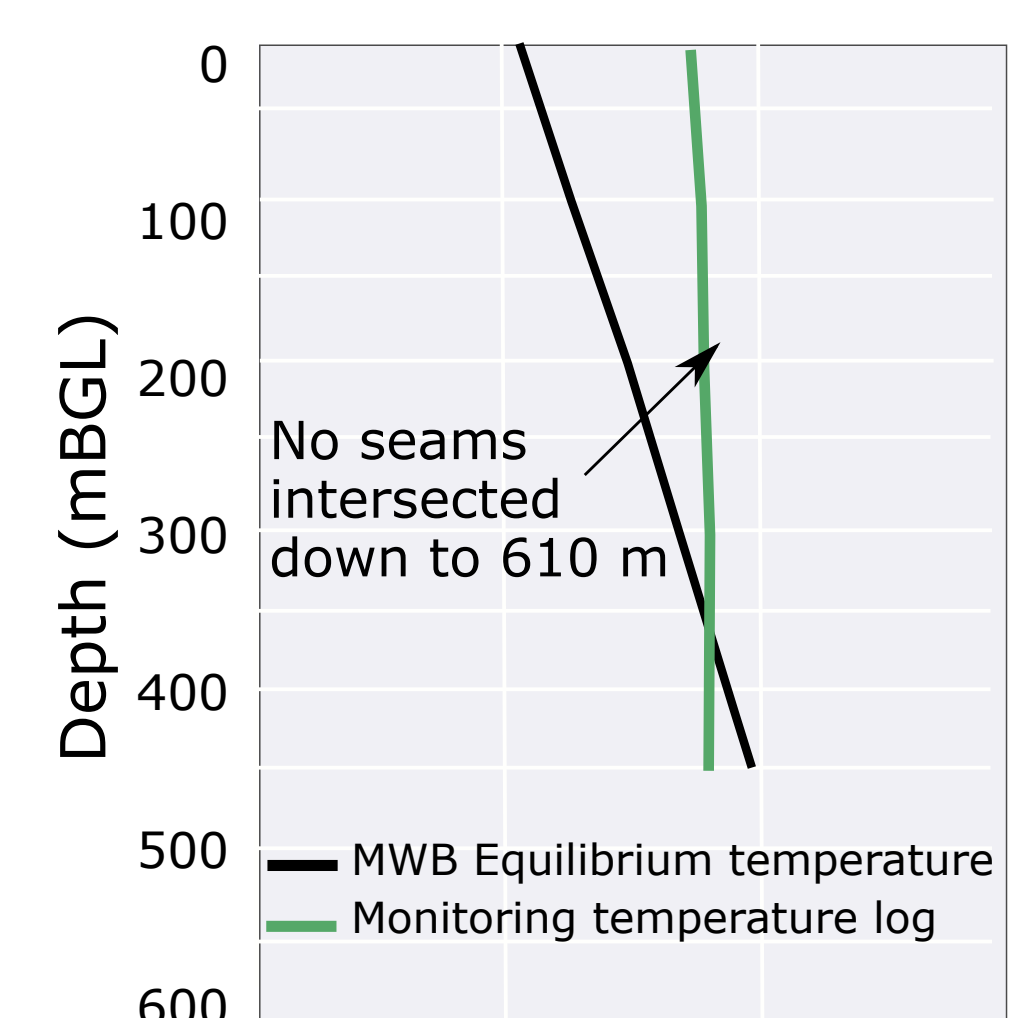
Key Message: We demonstrate the potential existence of new geothermal gradients in flooded mines. This suggests the importance of considering past mining activities & flooding history when performing geothermal potential assessments.
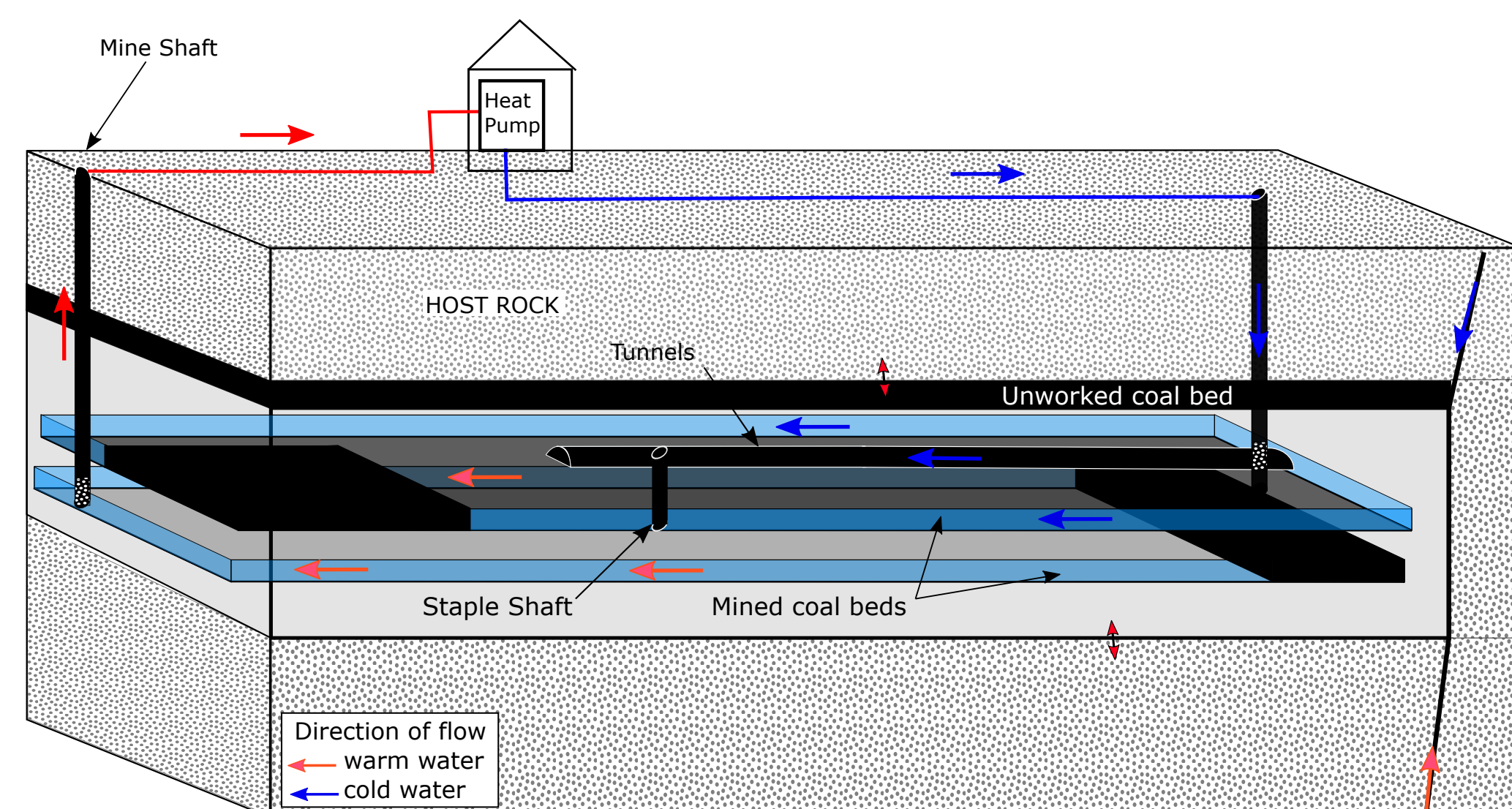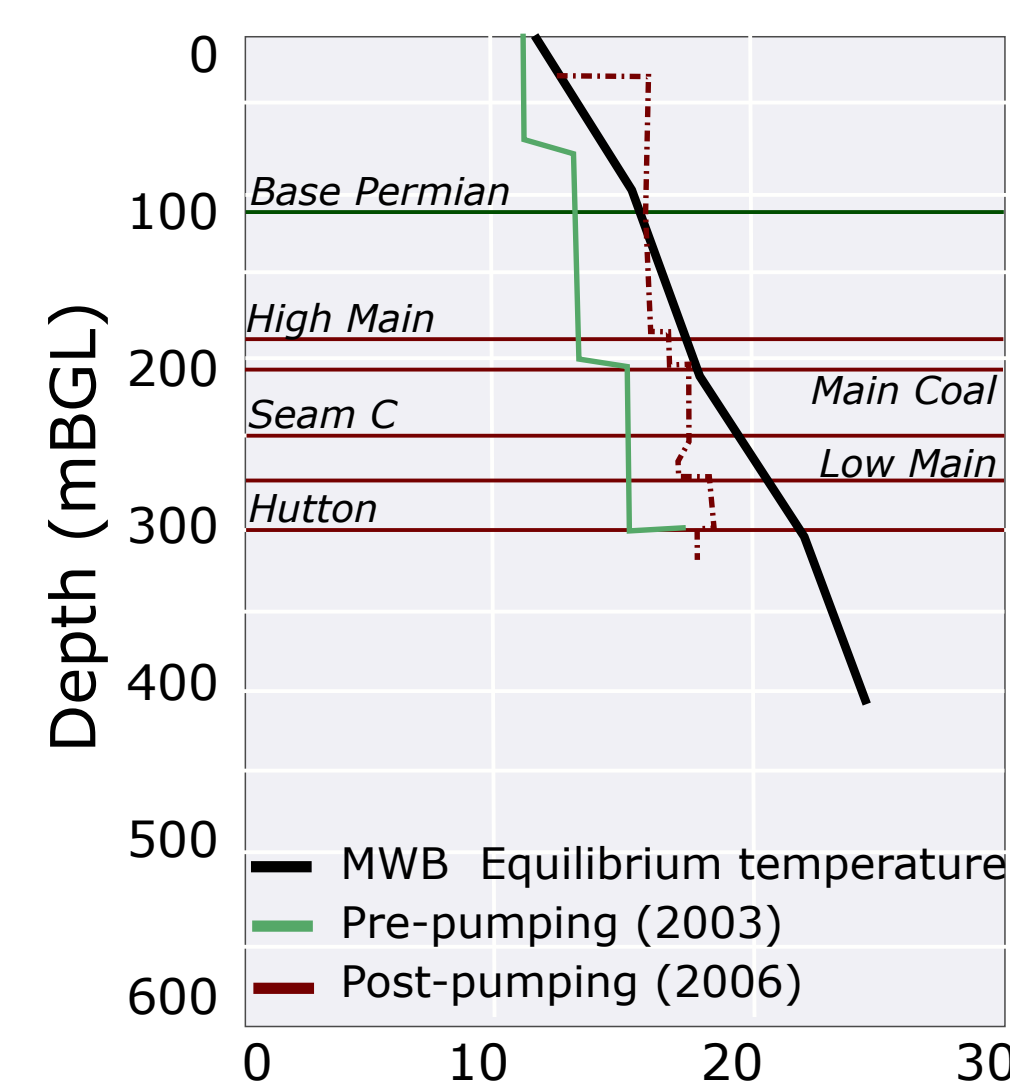

Conceptual model of coal mine working and Ground-Source Heat Pump (GSHP) system with direction of groundwater flow
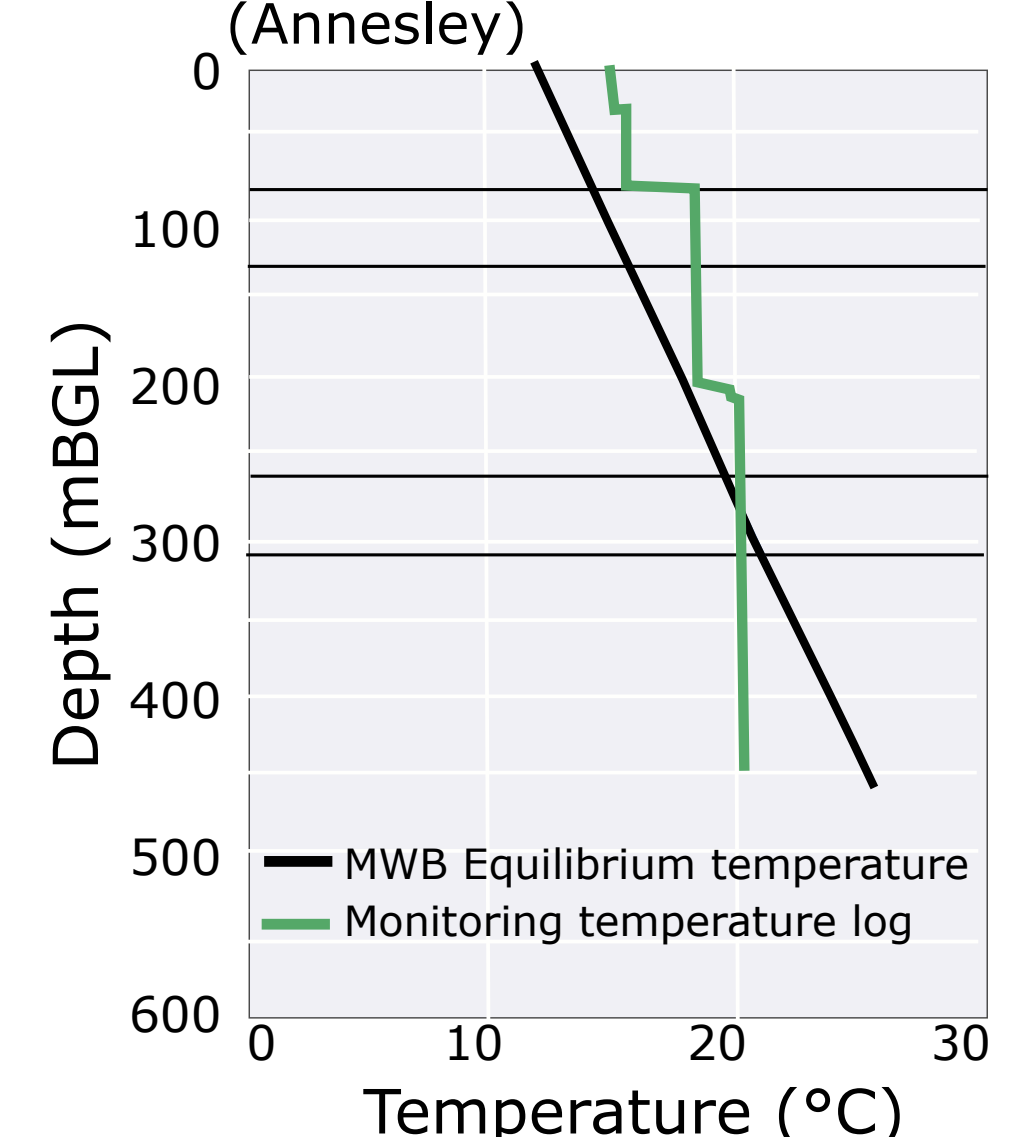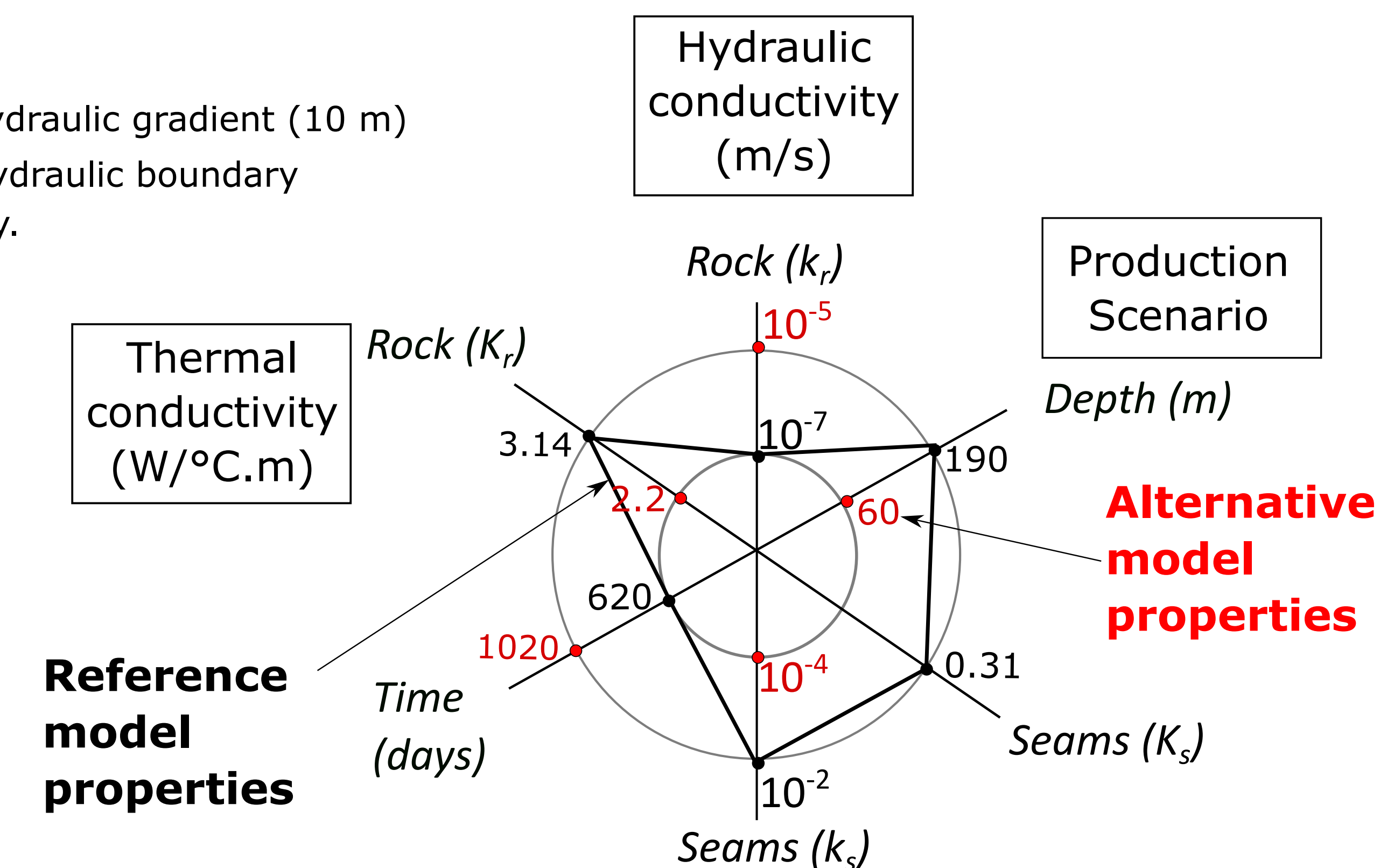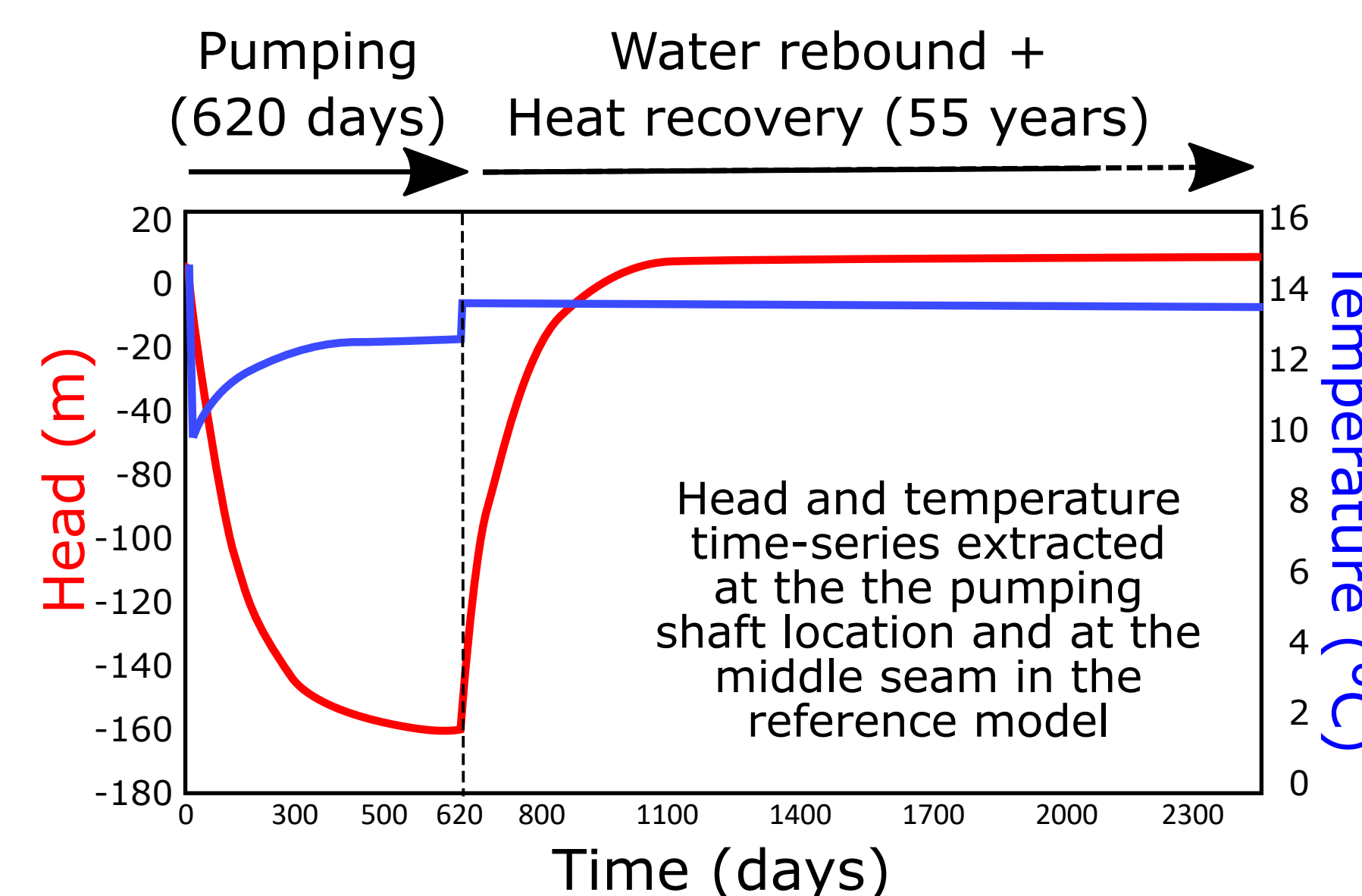

a) Bilston Glen shaft (Lothian, Scotland)

No seams intersected down to 610 m

— MWB Equilibrium temperature
— Monitoring temperature log

b) Horden shaft (Dawdon-Horden)

Base Permian
High Main
Seam C — Main Coal
Hutton — Low Main

— MWB Equilibrium temperature
— Pre-pumping (2003)
— Post-pumping (2006)

c) Langton shaft (Annesley)

— MWB Equilibrium temperature
— Monitoring temperature log

Location map of UK coalfields, mine-water blocs (MWB) and shafts where temperature profiles are available.

▲ Monitoring shaft
▲ Pumpig shaft
● Mine-water heating projects
☐ MWB

Scotland - Bilston Glen
Monitoring shaft (Water rebound in progess)

NE England Dawdon-Horden Coalfield
Pumped coalfield

Nottinghamshire - Annesley
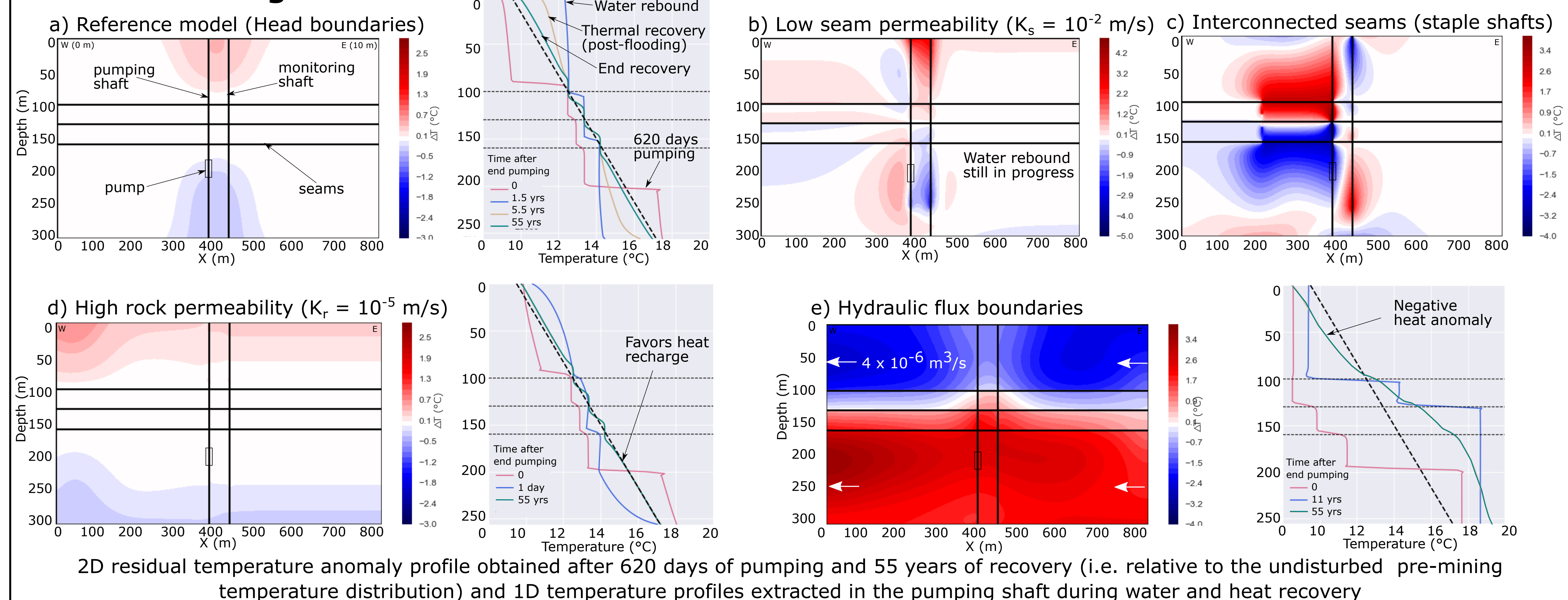Monitoring shaft (Water rebound in progess)

II - Methods

● Finite-element hydro-thermal modelling using OpenGeoSys
● Reference model (a): 2D Mine of simple geometry with westward regional hydraulic gradient (10 m)
● Sensitivity analysis on the effects of rock properties, production scenario, hydraulic boundary conditions and seams interconnectivity on the residual temperature anomaly.

Pumping (620 days) → Water rebound + Heat recovery (55 years)

Head and temperature time-series extracted at the the pumping shaft location and at the middle seam in the reference model

Hydraulic conductivity (m/s)
Thermal conductivity (W/°C.m)
Production Scenario
Rock (k_r)
Rock (K_r)
Depth (m)
Time (days)
Seams (K_s)
Seams (k_s)
Alternative model properties
Reference model properties

III - Modelling results

a) Reference model (Head boundaries)
pumping shaft / monitoring shaft
pump / seams

Water rebound
Thermal recovery (post-flooding)
End recovery
620 days pumping
Time after end pumping: 0, 1.5 yrs, 5.5 yrs, 55 yrs

b) Low seam permeability ($K_s = 10^{-2}$ m/s)
Water rebound still in progress

c) Interconnected seams (staple shafts)

d) High rock permeability ($K_r = 10^{-5}$ m/s)
Favors heat recharge
Time after end pumping: 0, 1 day, 55 yrs

e) Hydraulic flux boundaries
4×10^{-6} m³/s
Negative heat anomaly
Time after end pumping: 0, 11 yrs, 55 yrs

2D residual temperature anomaly profile obtained after 620 days of pumping and 55 years of recovery (i.e. relative to the undisturbed pre-mining temperature distribution) and 1D temperature profiles extracted in the pumping shaft during water and heat recovery

IV - Key outcomes:

● Long-term perturbations of the geothermal gradient around shafts resulting from mine-water advection in highly permable mining voids (i.e. convective heat flow) and mixing.
● Residual temperature anomaly depend on the k_r, k_s, the nature of hydraulic recharge during rebound and the seam interconnectivity.
● In our scenario, new temperature steady-state reached after ~50 years from the end of mining

V - Next step:

● Evaluation of the time to return to equilibrium considering a realistic mining history (i.e. duration, ventilation, hydraulic recharge)
● Investigation of the impact of the mine geometry on the long-term heat potential of flooded mines
● Calibration and validation of models based on data from the Dawdon-Horden coalfield

References: Farr, G. et al., 2020. The temperature of Britain's coalfield. doi: 10.1144/qjegh2020-109