British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Assessing the feasibility of high-density subsurface heat extraction in urban areas

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Background

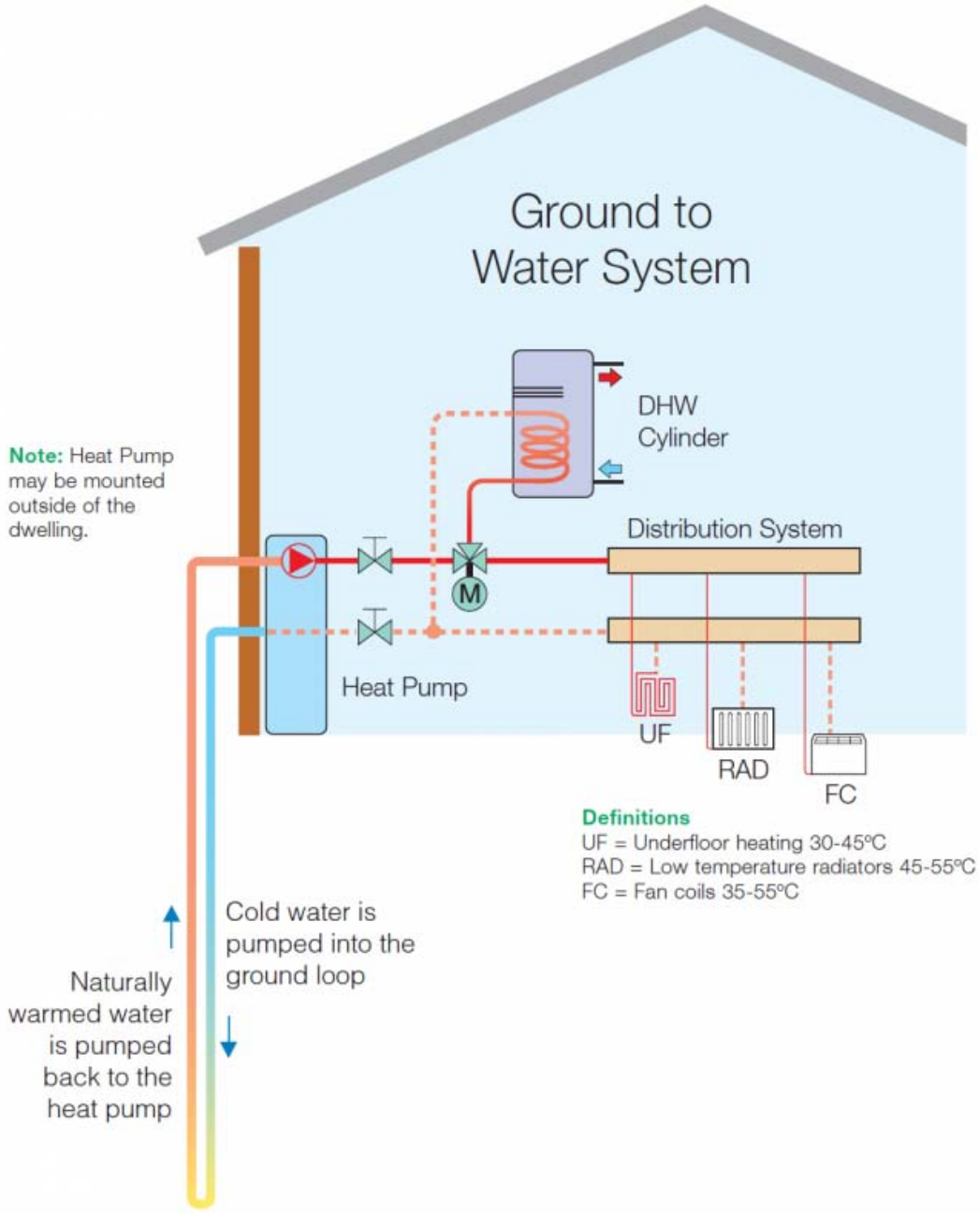
- UK carbon reduction target: 80% by 2050.
- EU renewable energy target: 12% of heat from renewable sources by 2020

→ Increasing use of subsurface use for heating/ cooling using ground source heat pumps (GSHP)

- More suitable for rural areas (?) but could GSHP heating counterbalance effect of urban heat island ?

Objective:

To test the feasibility of high-density GSHP installations in an urban setting



Source: http://ynni-i-ffynnu.co.uk/technologies/groundsource/

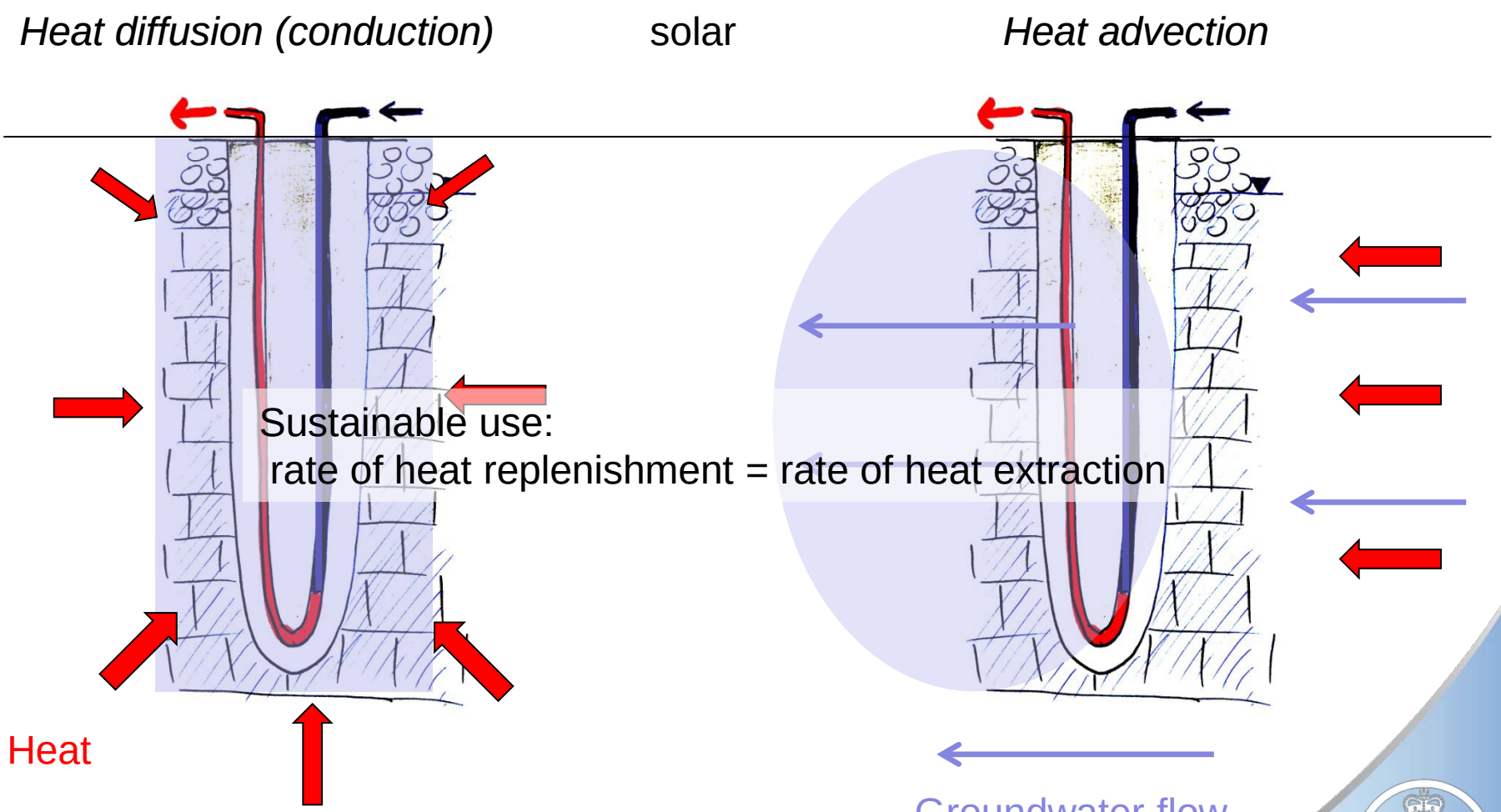
Closed loop GSHP system

<u>Heating mode</u>

Cold fluid from building circulated through loop in the ground

Warm fluid from ground pumped through heat pump where heat is extracted to supply heating/ hot water

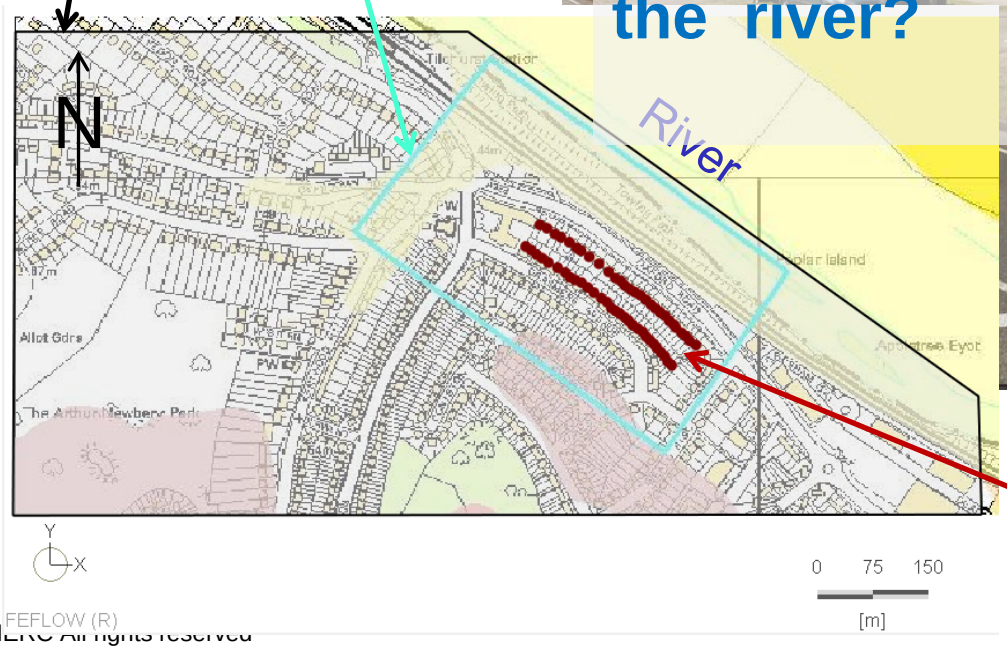
Closed loop GSHP system



Model area

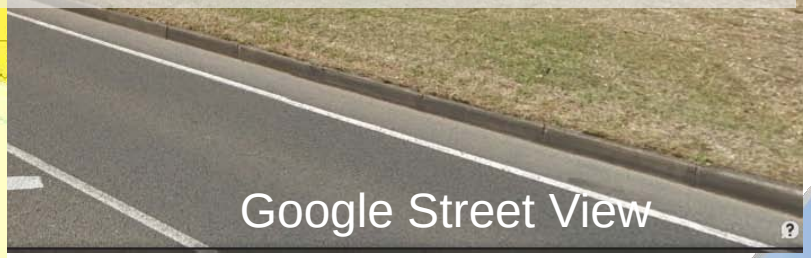
Model area

Area of interest

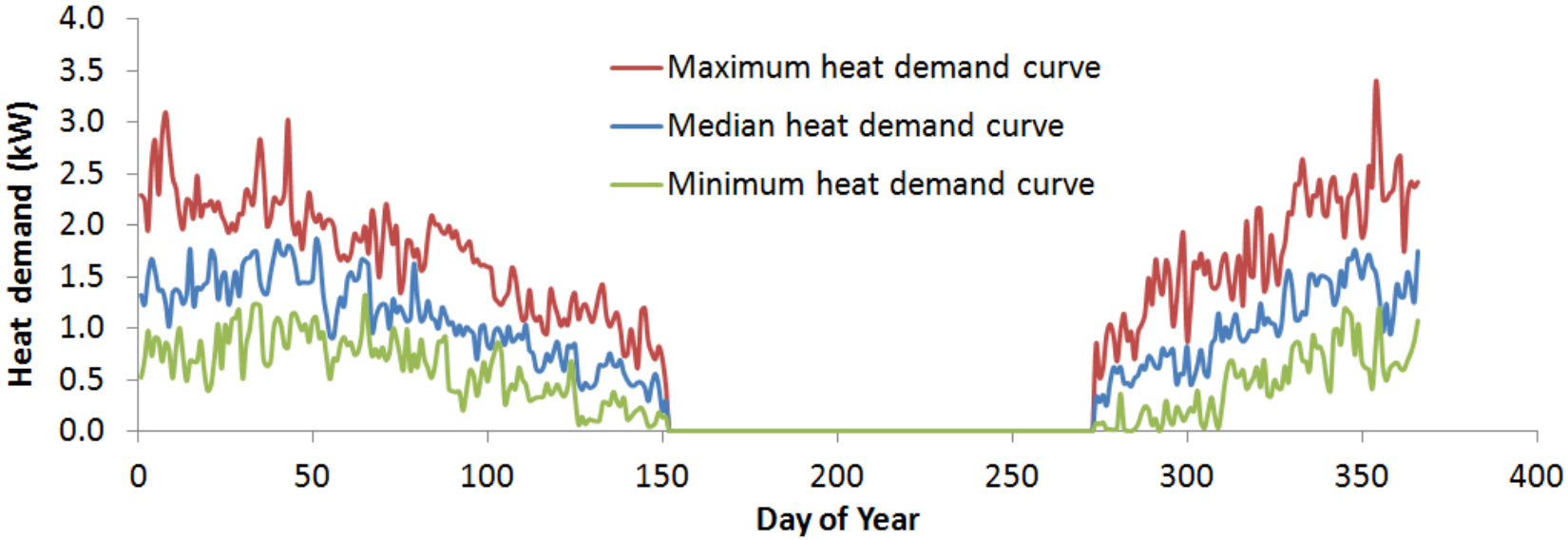


Is operation of high-density GSHP array for heating domestic properties sustainable?

What is the impact of heat extraction on the systems within the array / on the river?



Heat demand



based on:

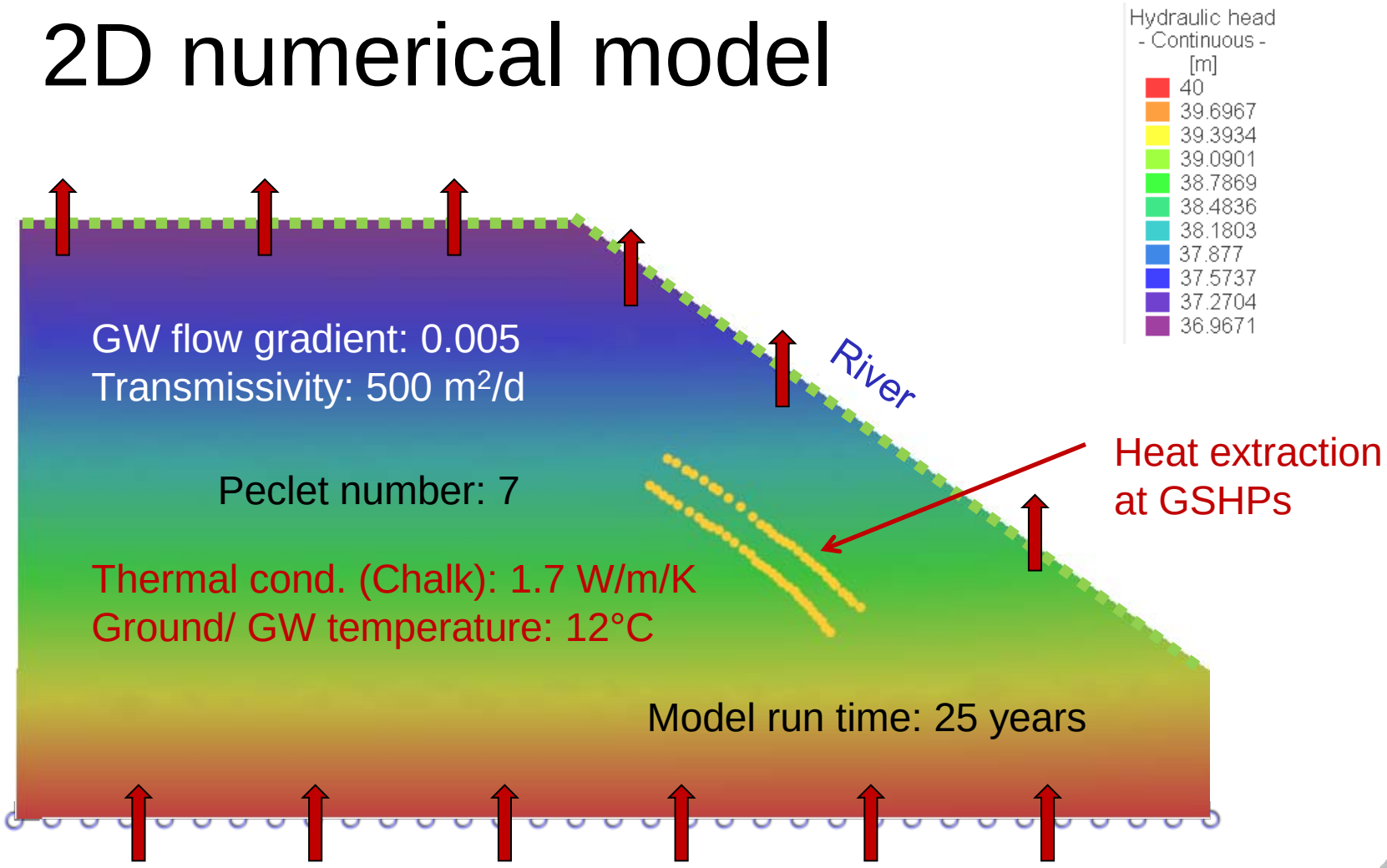
- Degree-days (2007 -2015) (base T =15.5 °C)
- Indoor temperature= 20 °C
- Heat loss : U'=0.4 kW/K (1930's 3 bed room, semi)
- Heating season: 1 October - 31 May

Heat pump and ground loop design

Coefficient of performance (COP_{HP}):	3.0
Peak load:	**3.4 kW**
Run hours (per year):	1800
Ground temperature :	12 °C
Thermal conductivity of ground (Chalk):	1.7 W/m/K
Max heat extraction per unit length BHE*:	34 W/m
Ground loop length:	**100 m**

** MCS 022: Ground heat exchanger look-up tables*

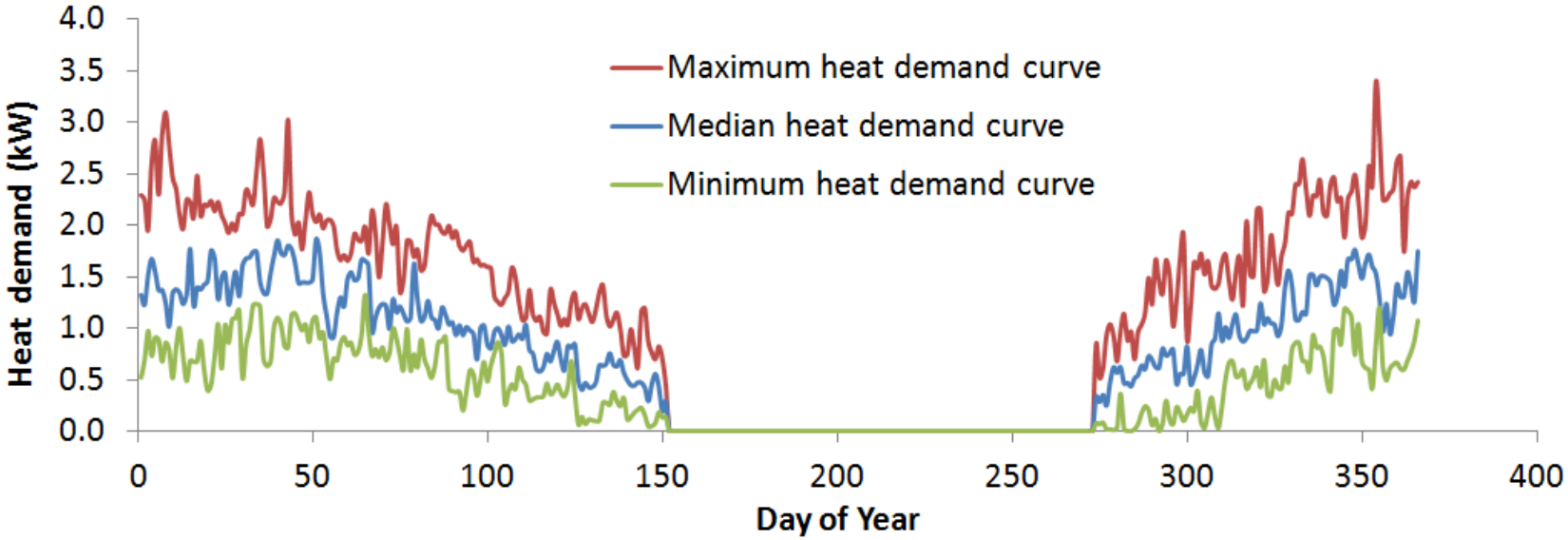
2D numerical model



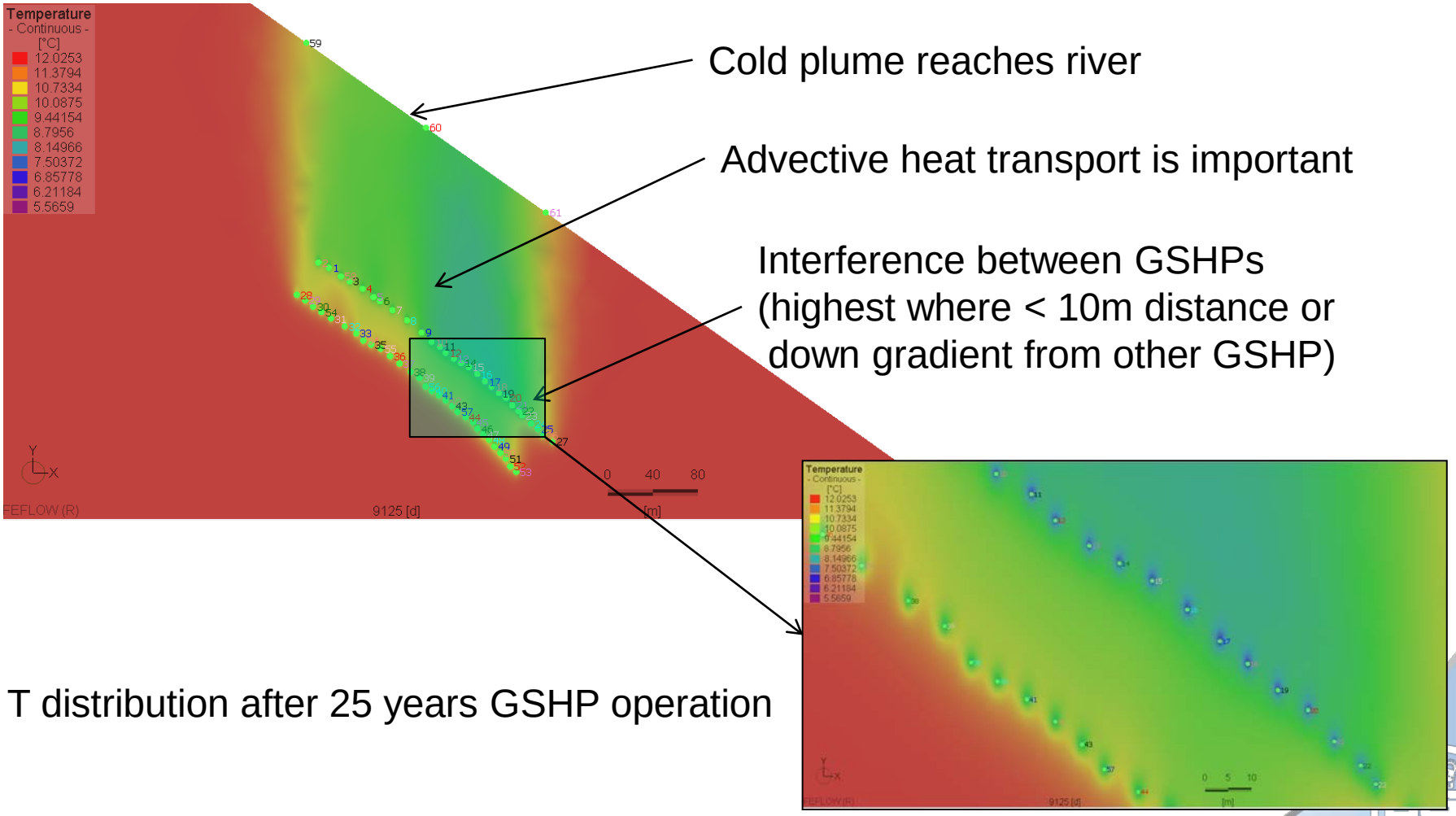
Model Runs to test:

- **Different heat demand scenarios**
- Different gw gradient/ transmissivity/ thermal conductivity values
- Different GSHP arrangements to minimise interactions between systems
- Different heat loss reduction measures to reduce demand

Heat demand scenarios



Maximum heat demand



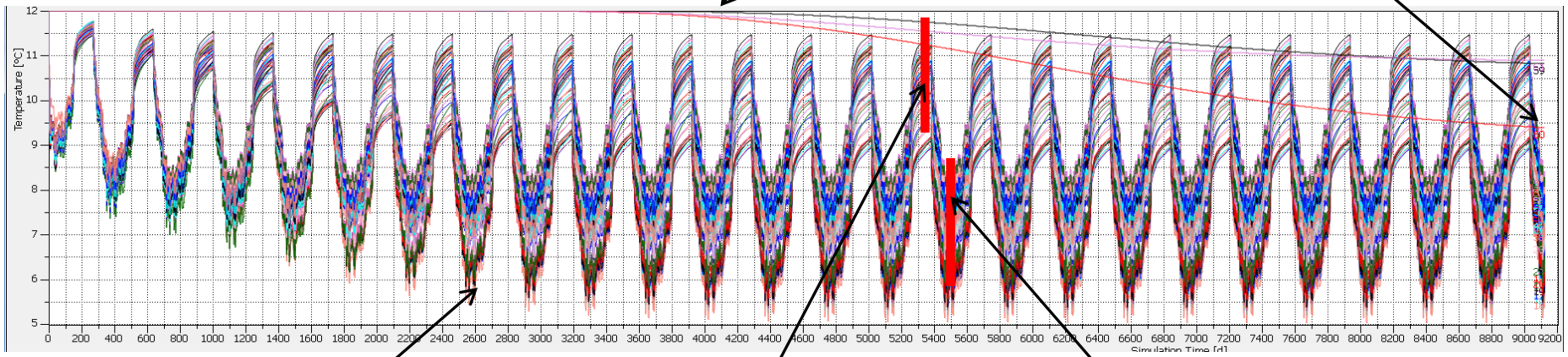
T distribution after 25 years GSHP operation

Maximum heat demand

Cold plume reaches river after ~ 10 years

Temporal Pattern

Inflow to river at 9.5°C



Equilibrium after 8-9 years

Min T (heat extraction) : 5.0 – 8.0°C

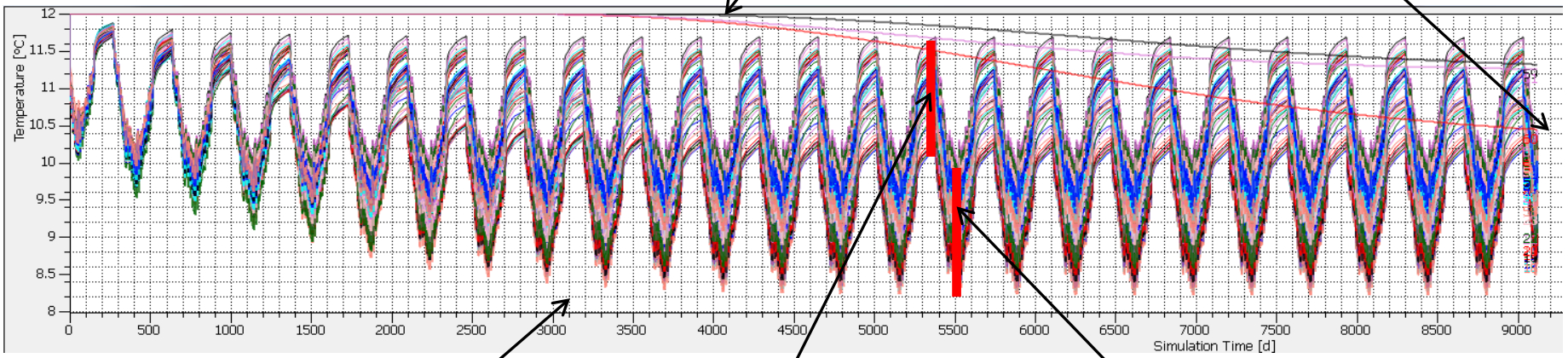
Max T (recovery): 9.0 – 11.6°C

Median heat demand

Cold plume reaches river after ~ 10 years

Temporal Pattern

Inflow to river at **10.5°C**



Equilibrium after 8-9 years

Min T (heat extraction) **:** **8.25 – 10.0°C**

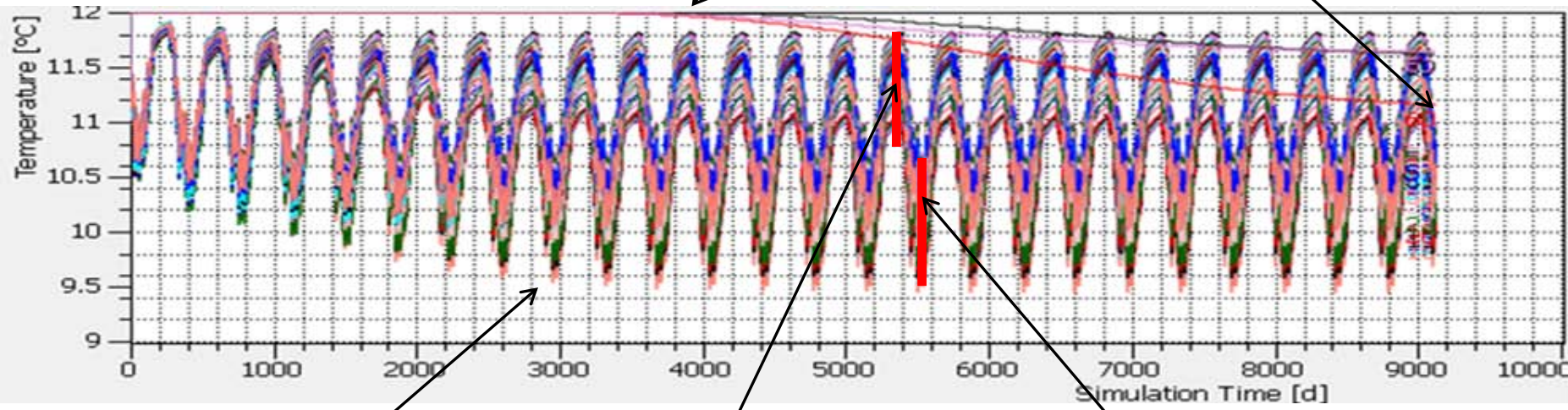
Max T (recovery): **10.5 – 11.7°C**

Minimum heat demand

Cold plume reaches river after ~ 10 years

Inflow to river at **11.3°C**

Temporal Pattern



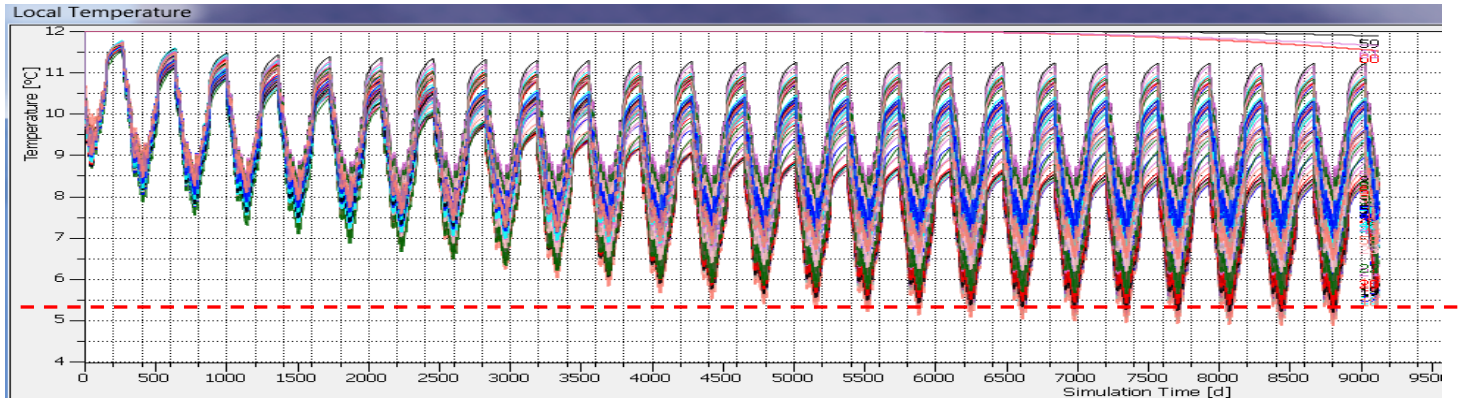
Equilibrium after 8-9 years

Min T (heat extraction) **:** **9 – 10.5°C**

Max T (recovery): **10.7 – 11.7°C**

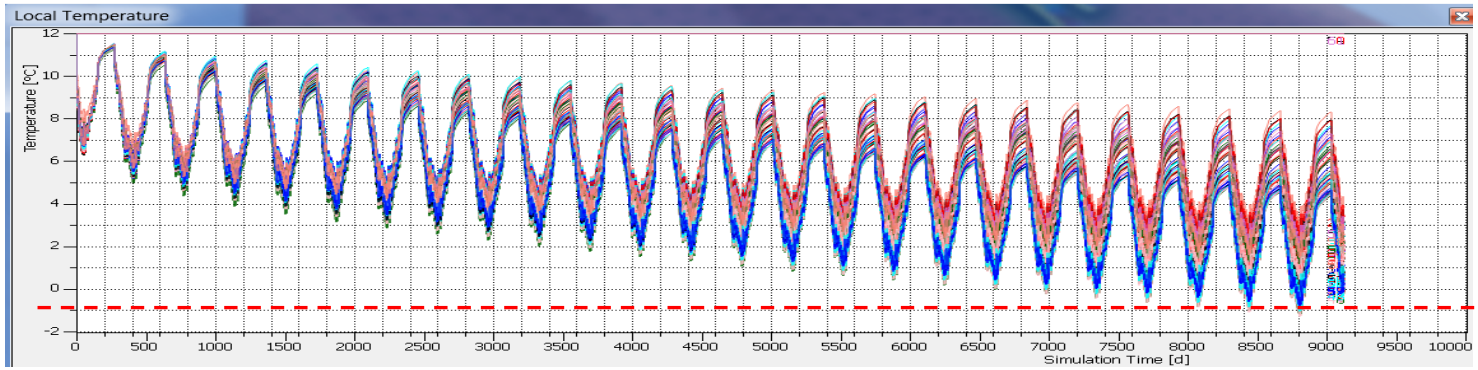
GW flow gradient

Gradient= 0.0025



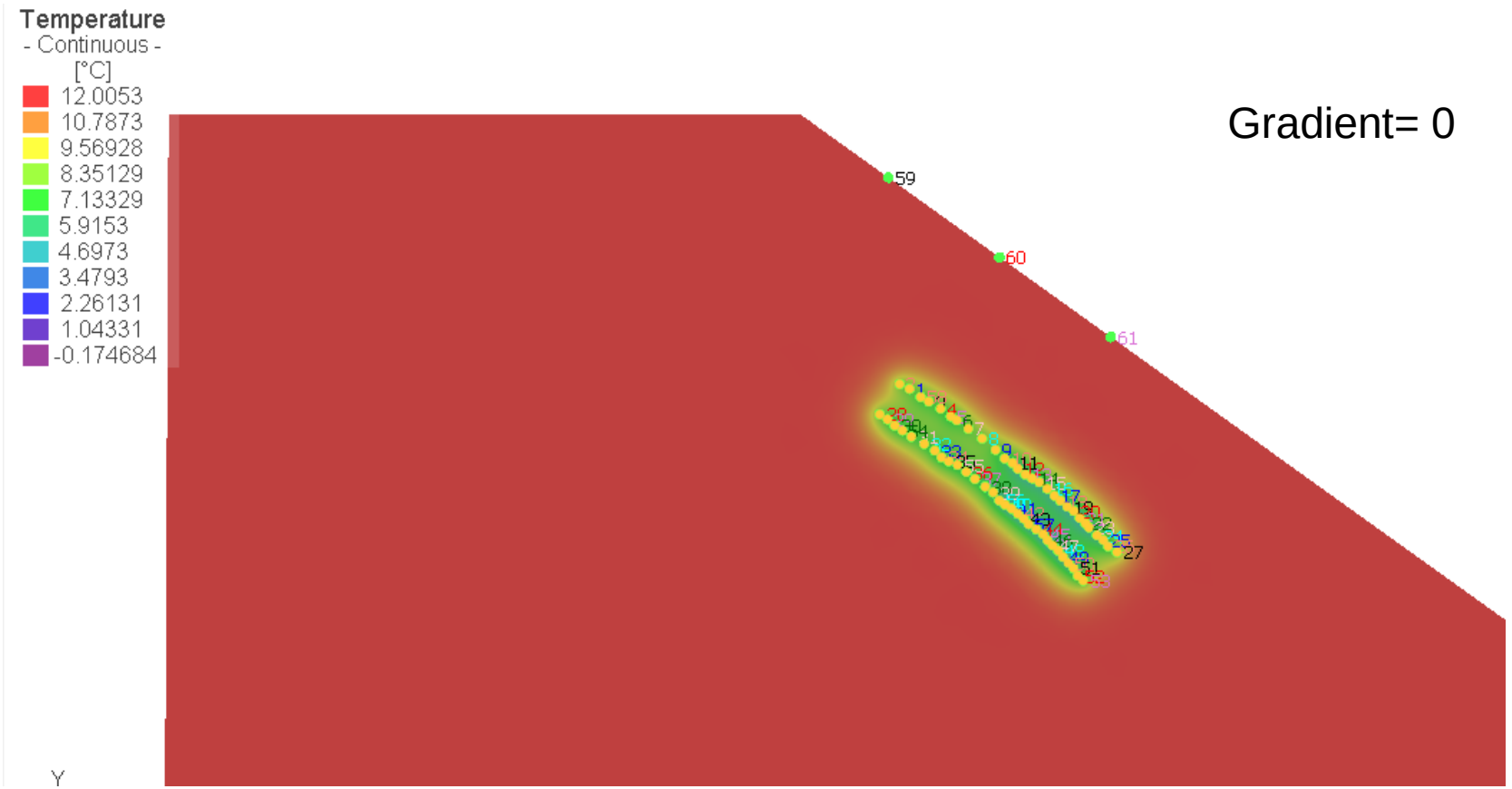
5°C

Gradient= 0



0°C

GW flow gradient



Gradient= 0

Is operation of high density GSHP array sustainable?

- High density heat extraction was found to be sustainable where gw flow enhances heat transport (Peclet numbers > 3)

- Sustainability and heat pump performance improved with increasing flow velocity (GW gradient/ Transmissivity)

What is the impact of heat extraction on systems within the array / on the river?

- Interference between systems occurred, but loss in overall efficiency was small for tested scenarios

- Array impacts on river (150 m downstream from installations) in all scenarios where gw flow is present

Conclusions

- **High density GSHP installation in urban can be feasible and sustainable** provided that GSHP arrangements and spacing are designed to balances heat extraction requirements and systems interference

- Where gw flow/advection is significant, spread of plume and its **impacts on installations/ receptors down gradient** must be considered

- Locations of existing GSHP systems are generally not known → recording of **GSHP locations by local planning offices (?)** recommended to avoid interference between systems/ support sustainable design and operation

Thank you for your attention.

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