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Aplicações de sistemas geotérmicos – Casos de estudo

Ground Source Energy Systems for Low Carbon Cooling, Heating & Hot Water

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Durham, England, UK

(SUBSTITUIR POR LOGO DO ORADOR)

29 SETEMBRO 2023

Ground Source Energy Systems for Low Carbon Cooling, Heating & Hot Water

There are a number of basic types of Ground Energy System:

1) *CLOSED LOOP*
2) *OPEN LOOP*
3) *OTHER, e.g. Energy Piles, Rivers, Walls, etc*

CLOSED LOOP

This is by far the most common system. A fluid variously called ANTIFREEZE, HEAT TRANSFER FLUID, OR BRINE is pumped around a network of pipes laid below the ground. A temperature gradient is created in the surrounding ground that allows heat to flow to or away from the network of pipes. The network of pipes can be in a series of boreholes or pipe coils laid in trenches or a combination of both.

OPEN LOOP

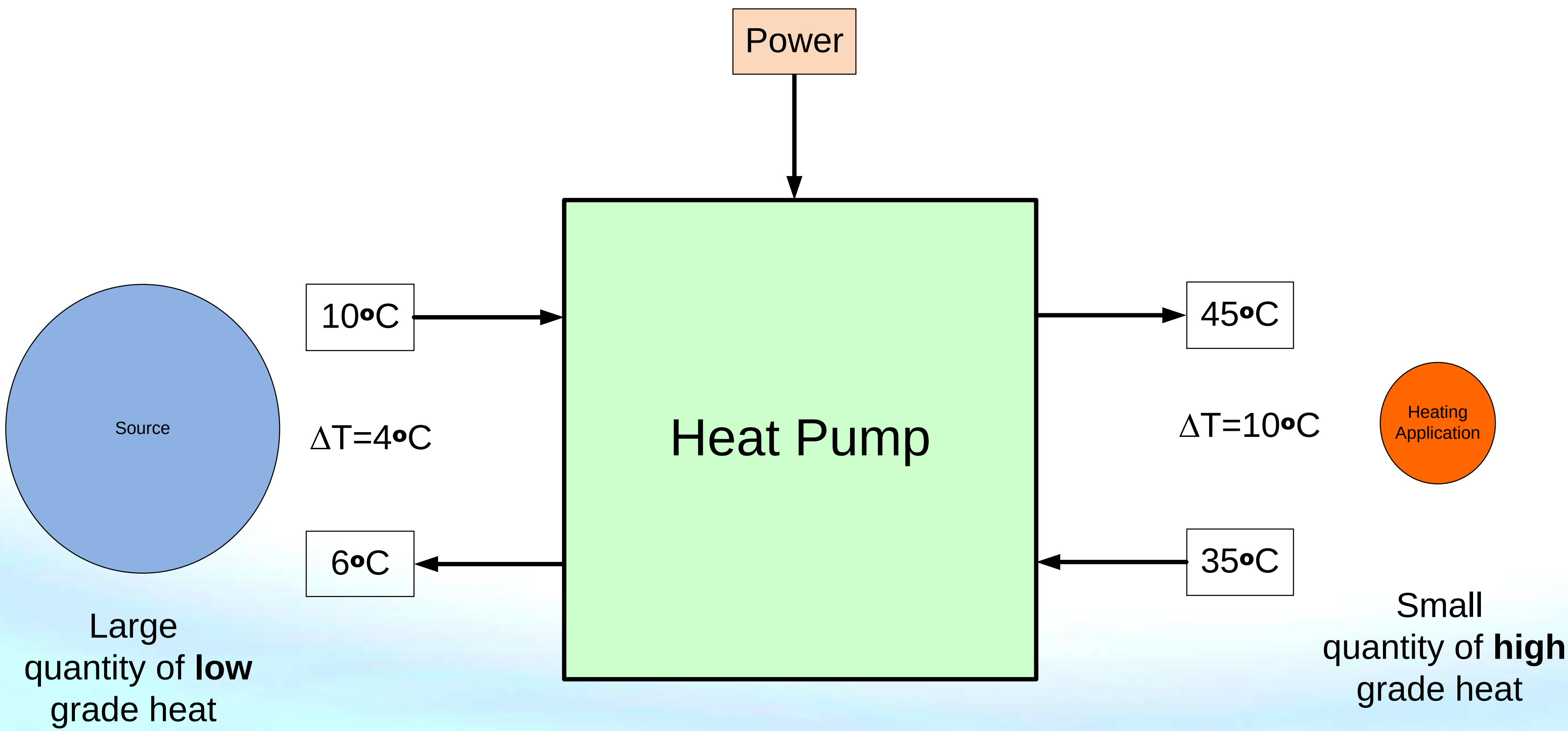
These systems rely on high groundwater flows and are restricted to sites overlying a suitable aquifer that is not also a protected source of drinking water. Instead of using a special fluid, GROUNDWATER is pumped out of a borehole, or series of boreholes, and through the HEAT PUMP before being injected into another set of boreholes or discharged to a water course above ground.

RELATED SYSTEMS

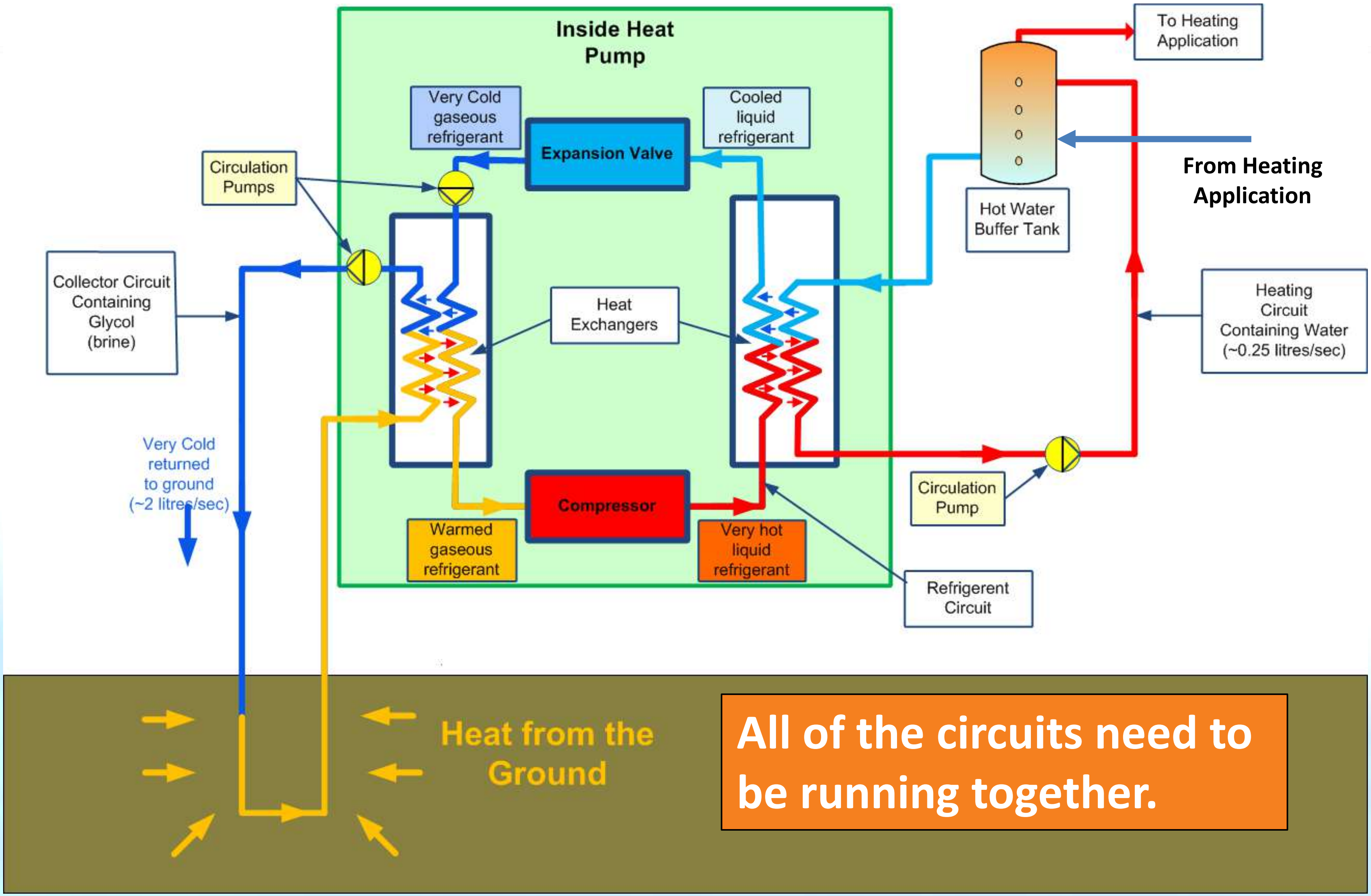
HEAT PUMPS can also be used in connection with Closed Loop Systems installed in LAKES and Open Loop Systems using RIVER WATER. These are not strictly Ground Energy Systems. Passive Cooling Systems using Lakes and Rivers have been used for a very long time. Ancient Egypt and Babylon had palaces, temples, and food stores cooled in this way.

OGI Office Meadowfield, Durham

But how do heat pumps work?



HEAT PUMP CIRCUITS



All of the circuits need to be running together.

A Ground Source Heat Pump

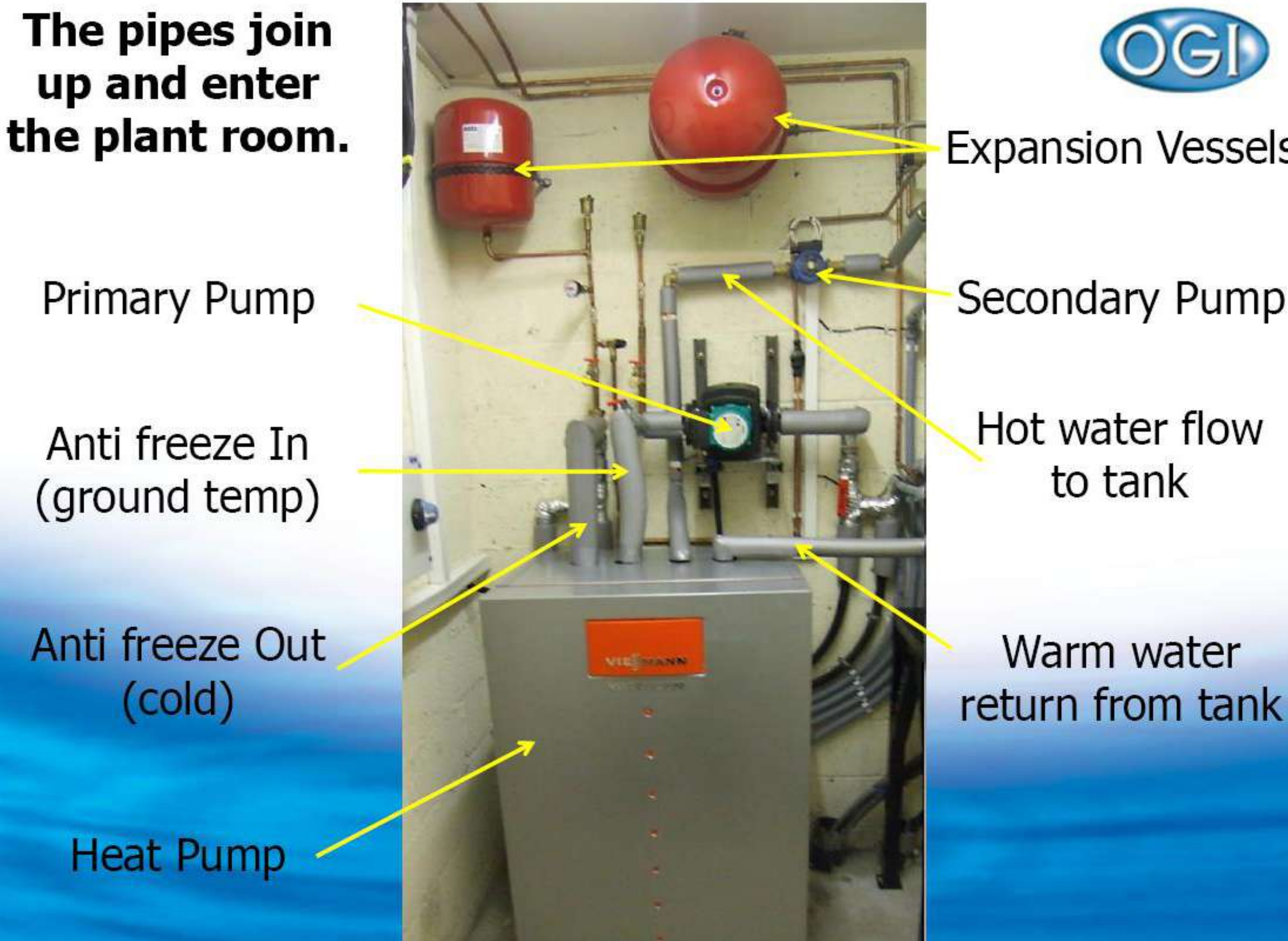
Abstracts low temperature energy from the ground

via ground collectors :

Trenches

Boreholes

The pipes join up and enter the plant room.



Minister praises region's green campaigners

CLIMATE Change Minister Ed Miliband praised North-East environment campaigners during a visit to the region.

Mr Miliband said he was very impressed by Climate Durham, a green coalition of residents, business and other groups, describing it as an "excellent organisation".

The Secretary of State for Energy and Climate Change was speaking after an hour-long question-and-answer session with more than 100 people in Durham Town Hall.

He said: "My message to people is: get involved in Durham. It's about going green but also about a sense of community."

Janie Bickersteth, chairwoman of Climate Durham, said Mr Miliband's visit was an endorsement of its community action.

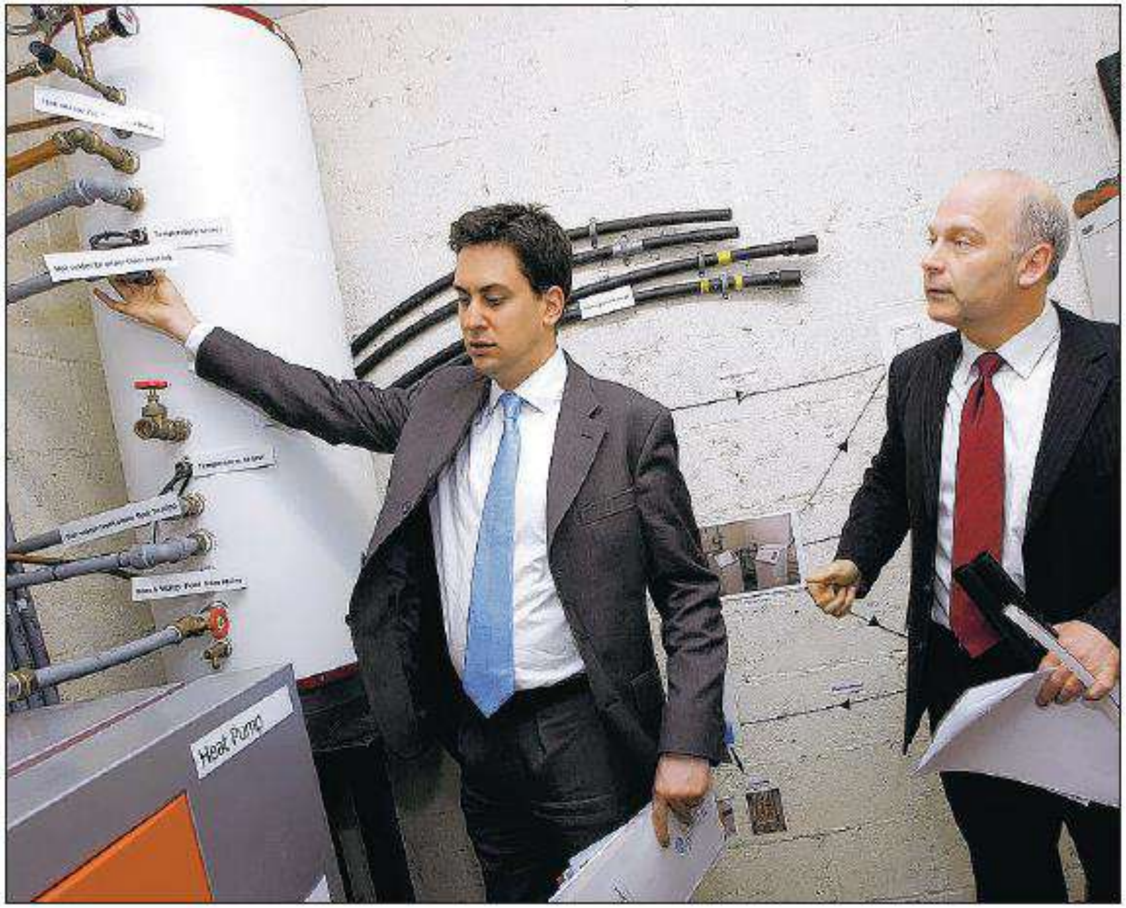
"He was very keen to stress individual actions do make a difference," she said.

"He really listened to the questions, in particular from the schools, which I'm really pleased about."

Mr Miliband was joined by Durham City MP Roberta Blackman-Woods. She said: "I have supported Climate Durham since its foundation and believe we are very lucky to have an organisation like it here in our area.

"They are striving to make the issue of climate change both everyday and real for people."

Mr Miliband also visited OGI Groundwater Specialists, in Meadowfield, near Durham.



VISIT: Government minister Ed Miliband, left, with Stephen Thomas, managing director of OGI Groundwater Specialists

Picture: CHRIS BOOTH

OGI Office Meadowfield, Durham

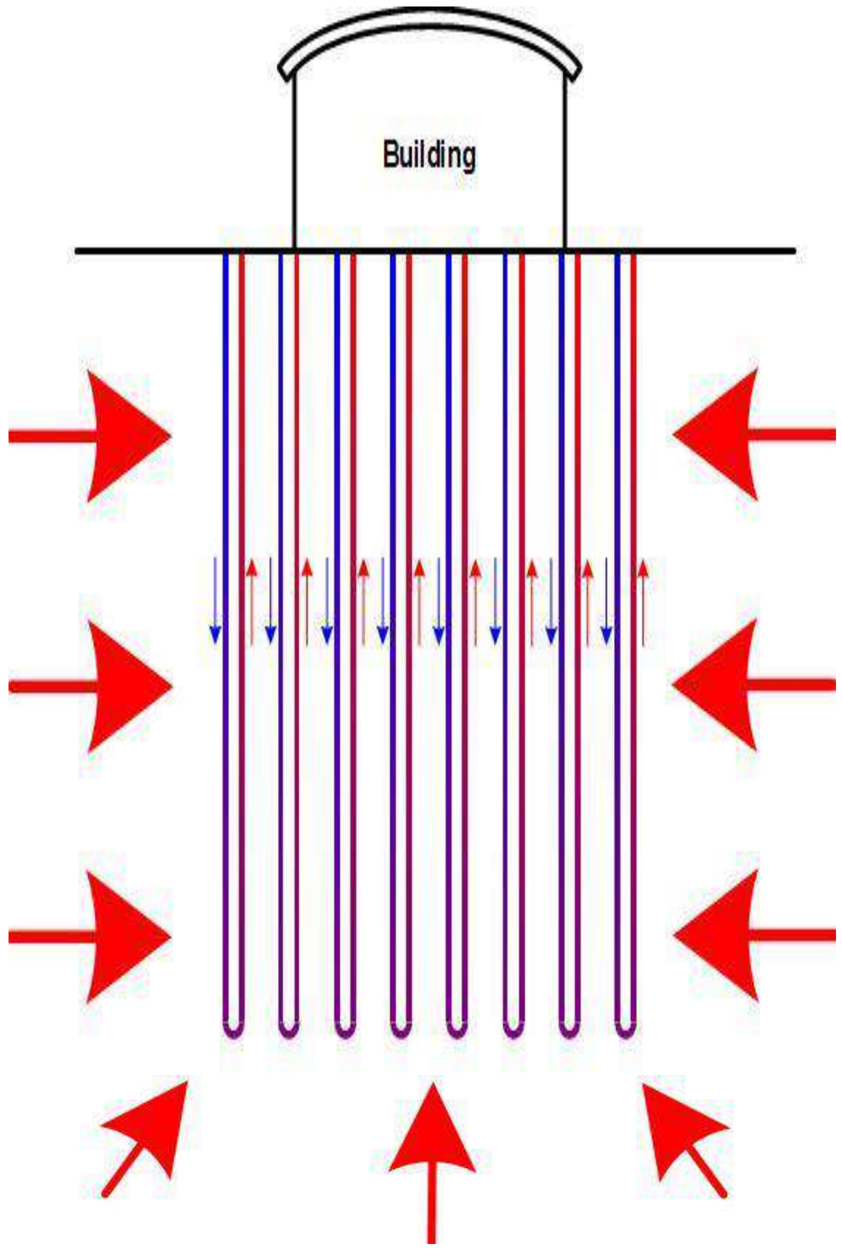
OGI Office Meadowfield, Durham

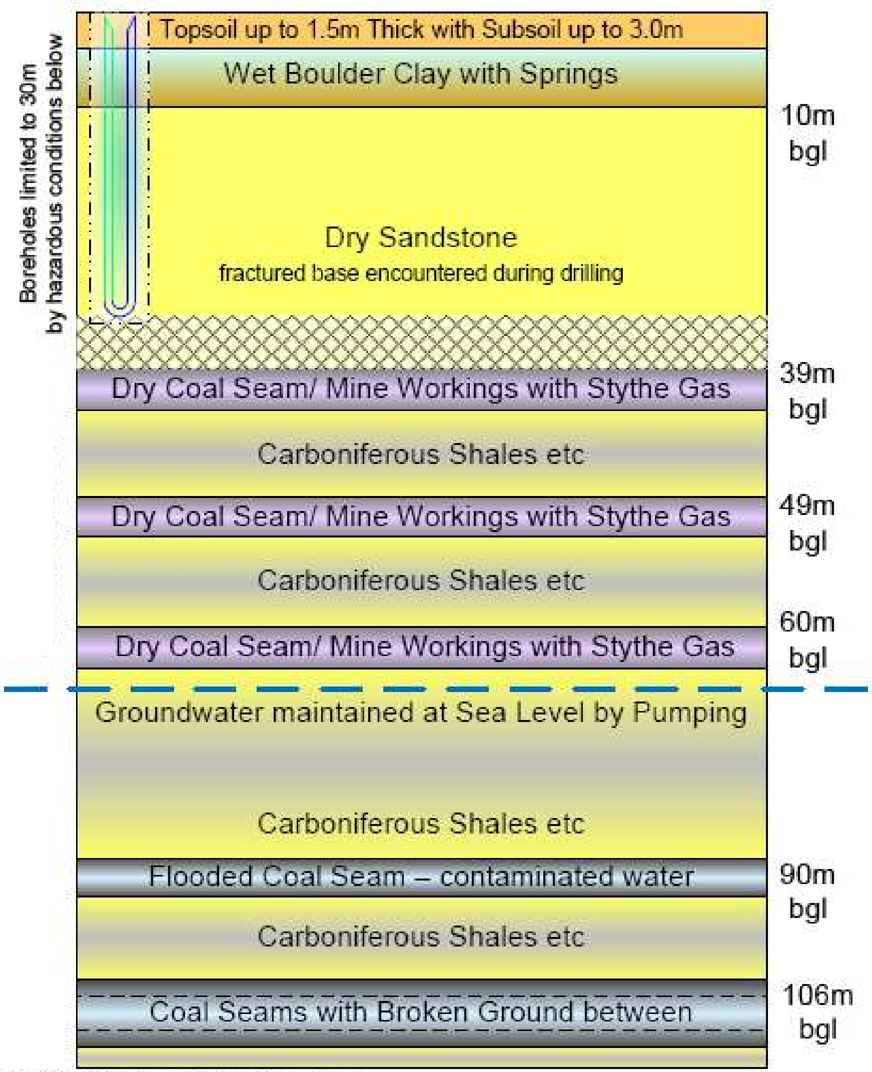
OGI Office Meadowfield, Durham, UK

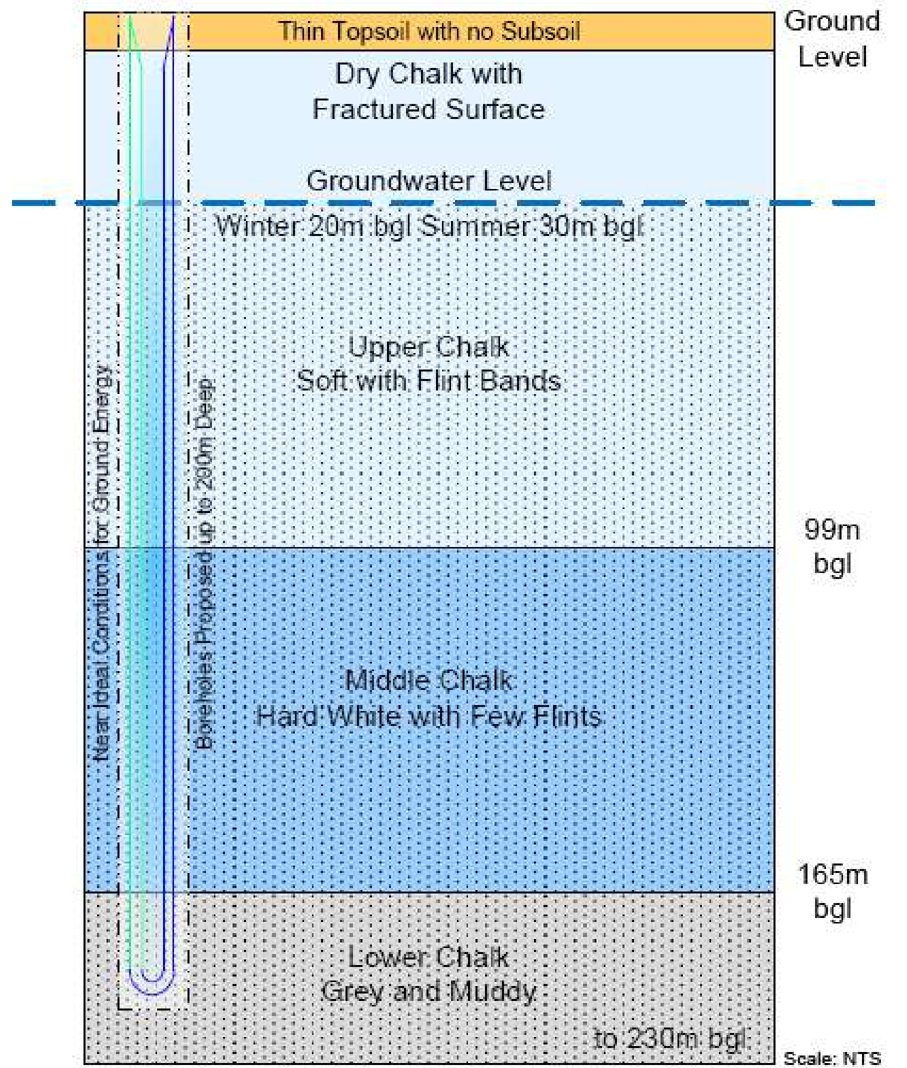

OGI Offices in Meadowfield, Durham

For larger buildings with less ground, boreholes are required

Ground Source Closed Loop Borehole Field







The first task on any Ground Energy Project is to carry out a Desktop Study to evaluate the underlying Geology. This will have a big impact on the amount of Heating and / or Cooling that can be provided. The System Design will have to be modified for features below ground. These illustrations are from two sites for the same client that had completely different geology.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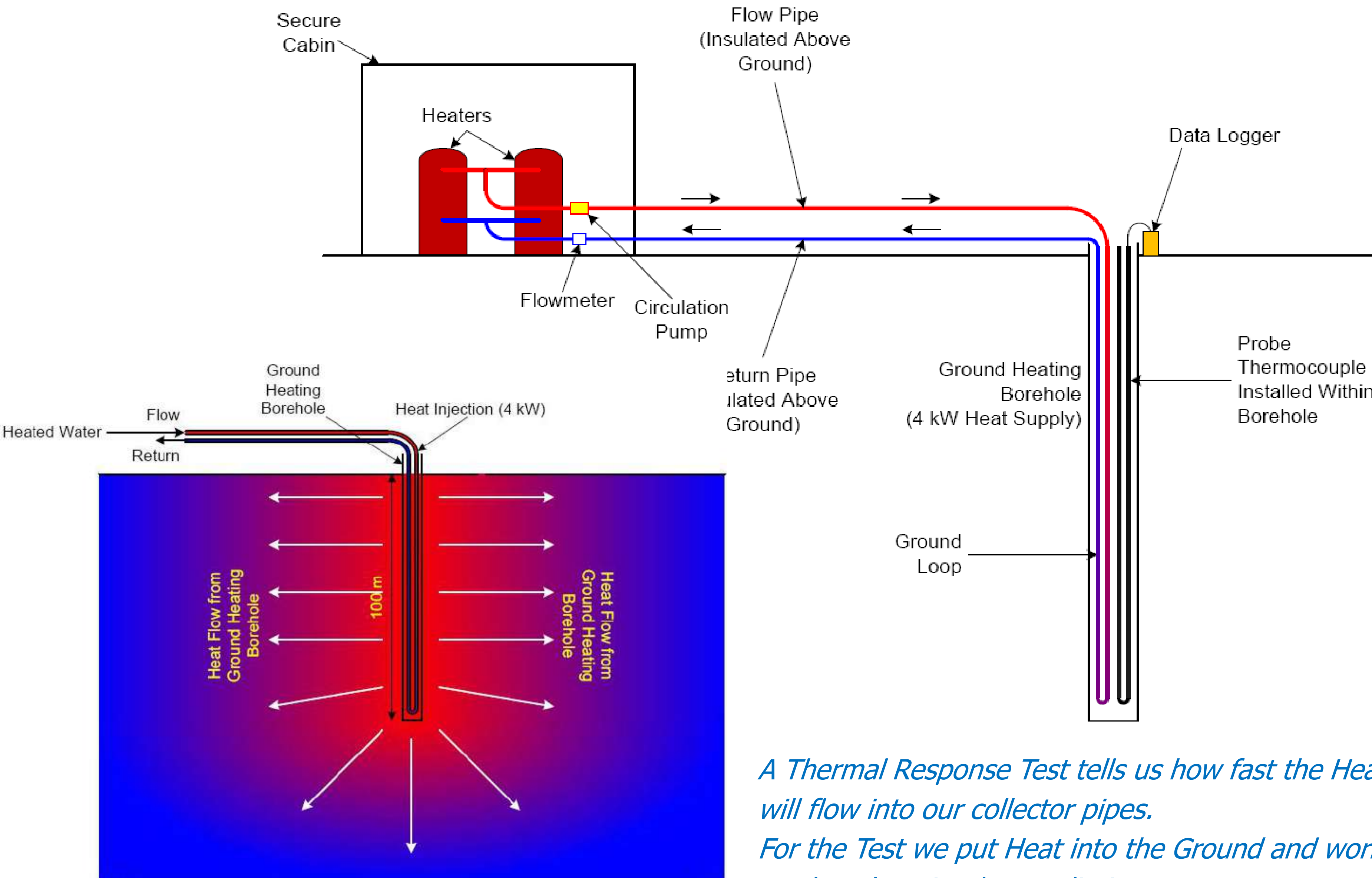
Thermal Response Test (TRT)

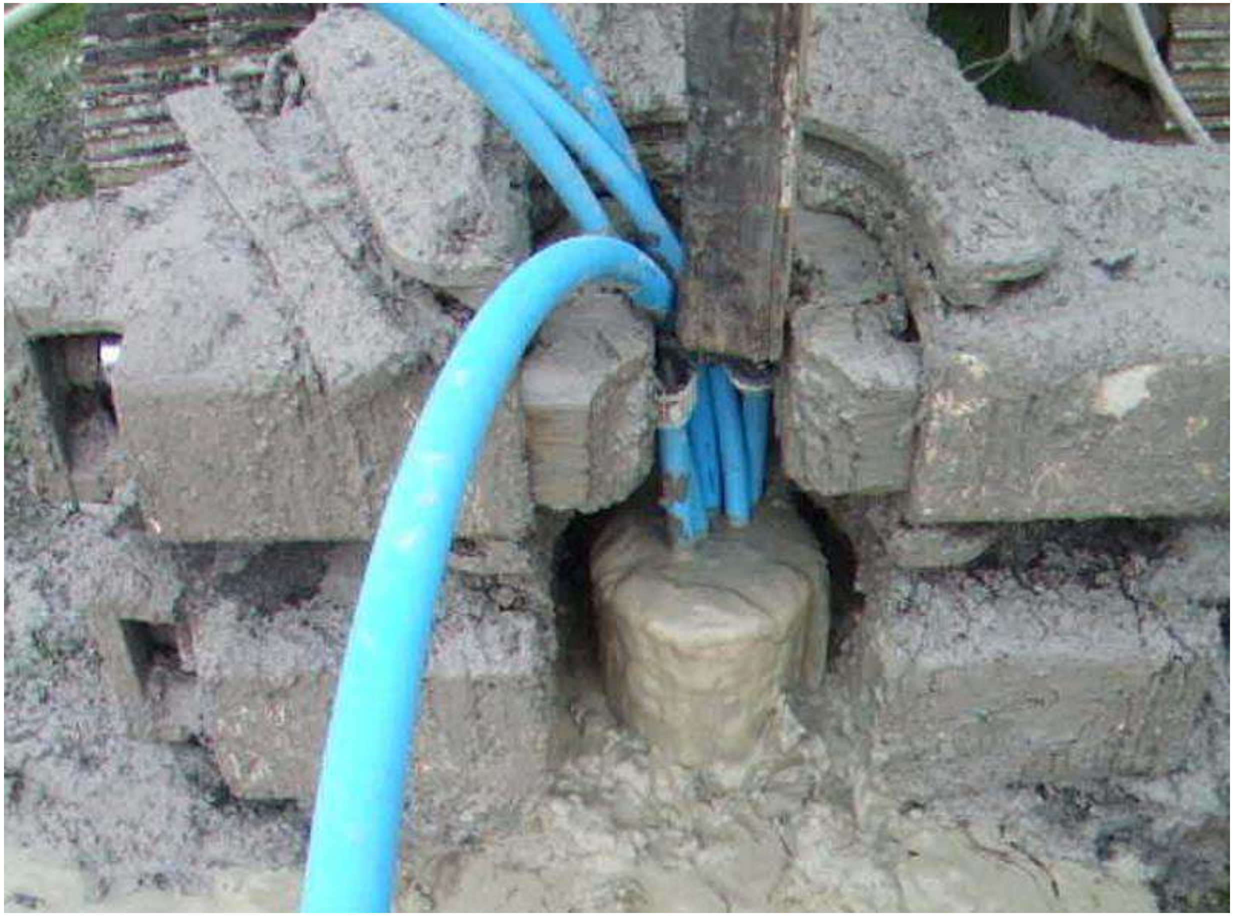


A Thermal Response Test tells us how fast the Heat will flow into our collector pipes.
For the Test we put Heat into the Ground and work out how long it takes to dissipate.

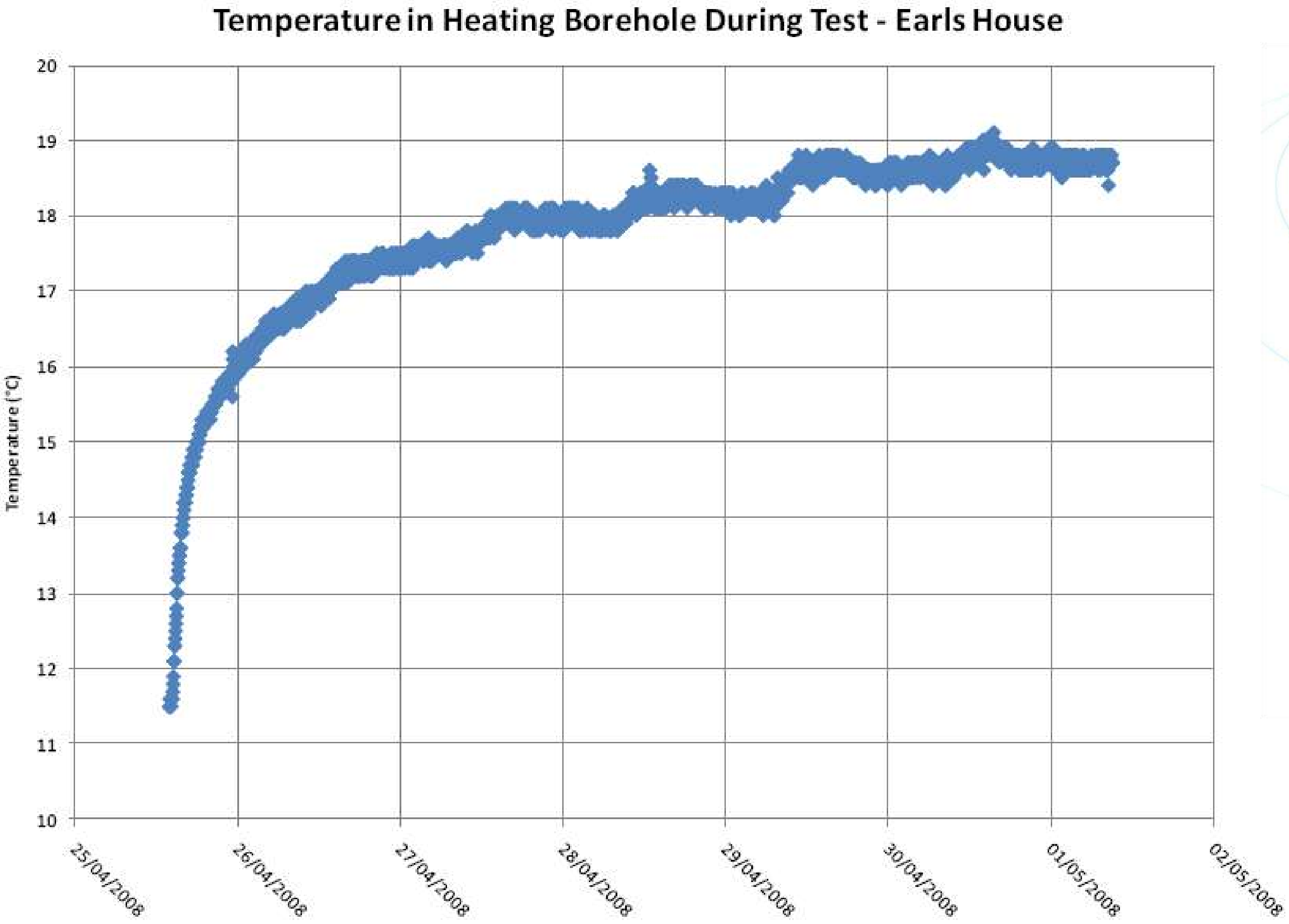
Ground Source
Closed Loop
Drilling

Medical Centre

Ground Source



Grouting Stage



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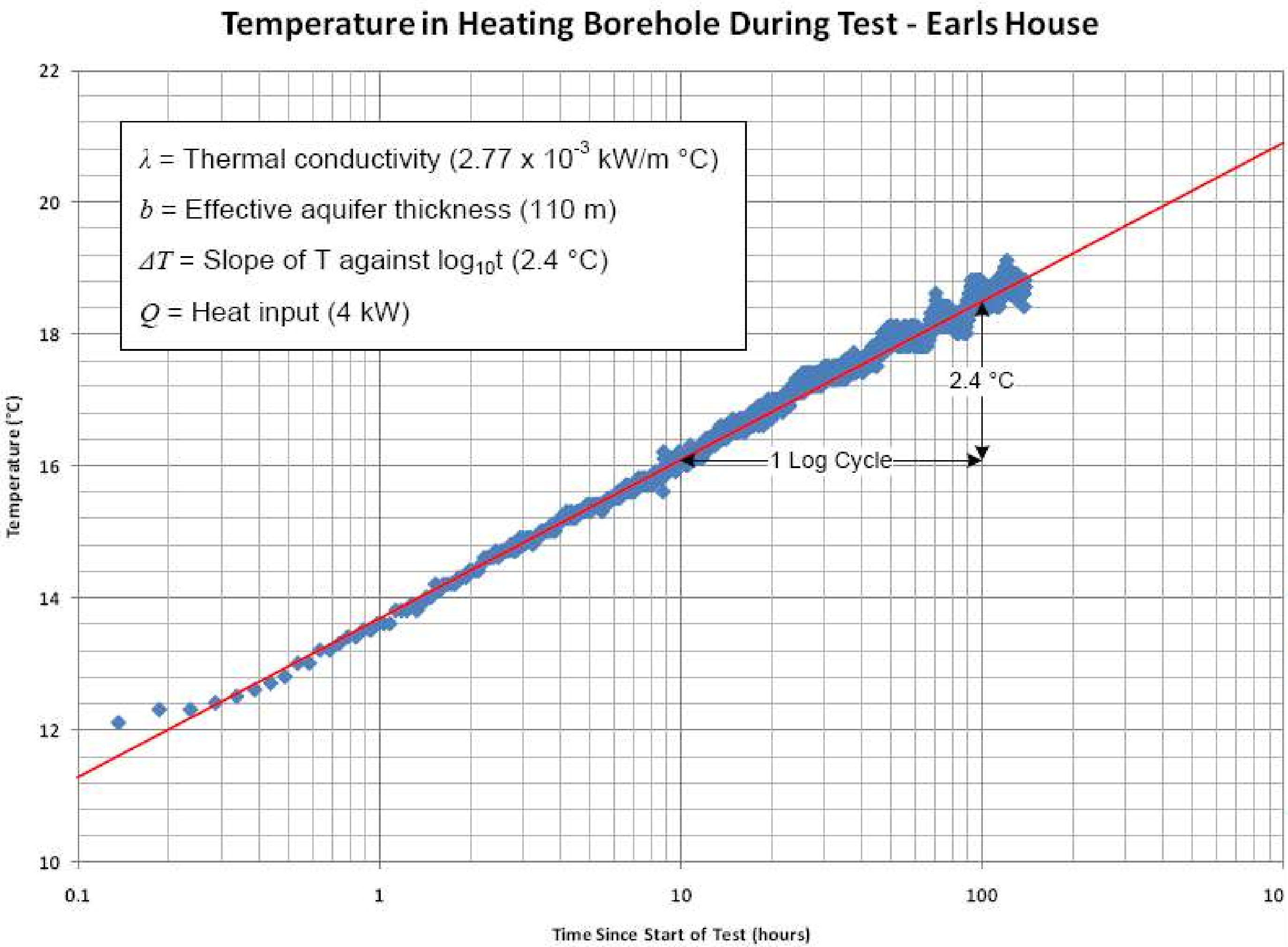
The results of the Conductivity when presented as raw data...



$$\lambda b = \frac{2.3Q}{4\pi\Delta T} = \frac{2.3 \times 4}{4\pi \times 2.4} = \frac{9.2}{30.16} = 0.305 \text{ kW/°C}$$

$$\lambda = 0.305 / 110 = 2.77 \times 10^{-3} \text{ kW/(m °C)}$$

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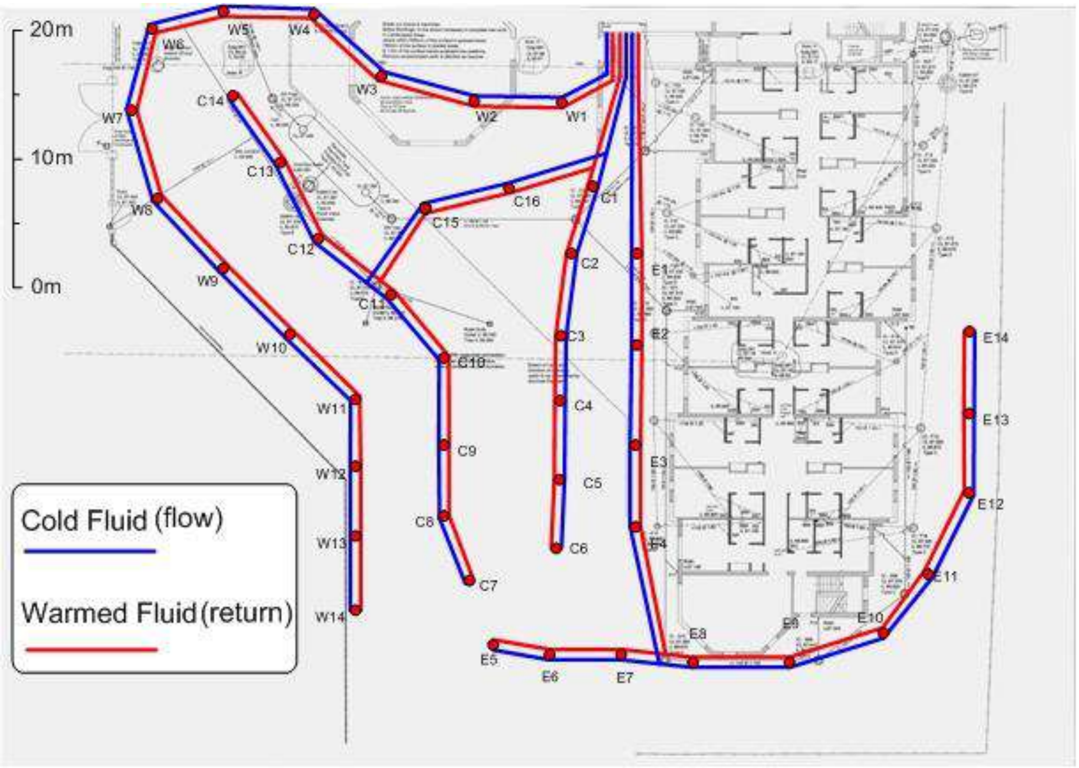
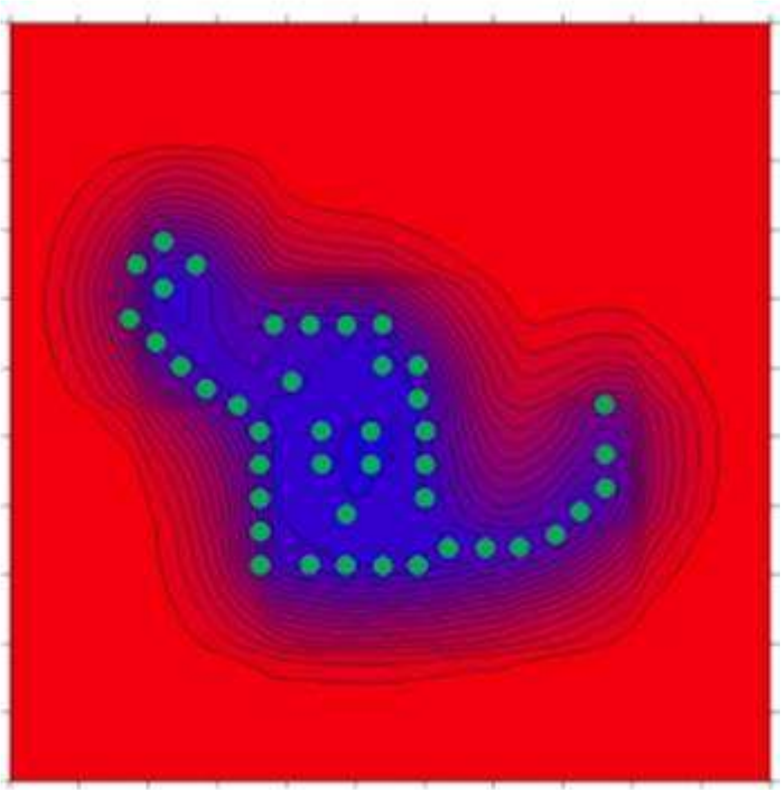
...but after analysis provide us with the results we need to start designing the Ground Energy System.

Ground Source - Design

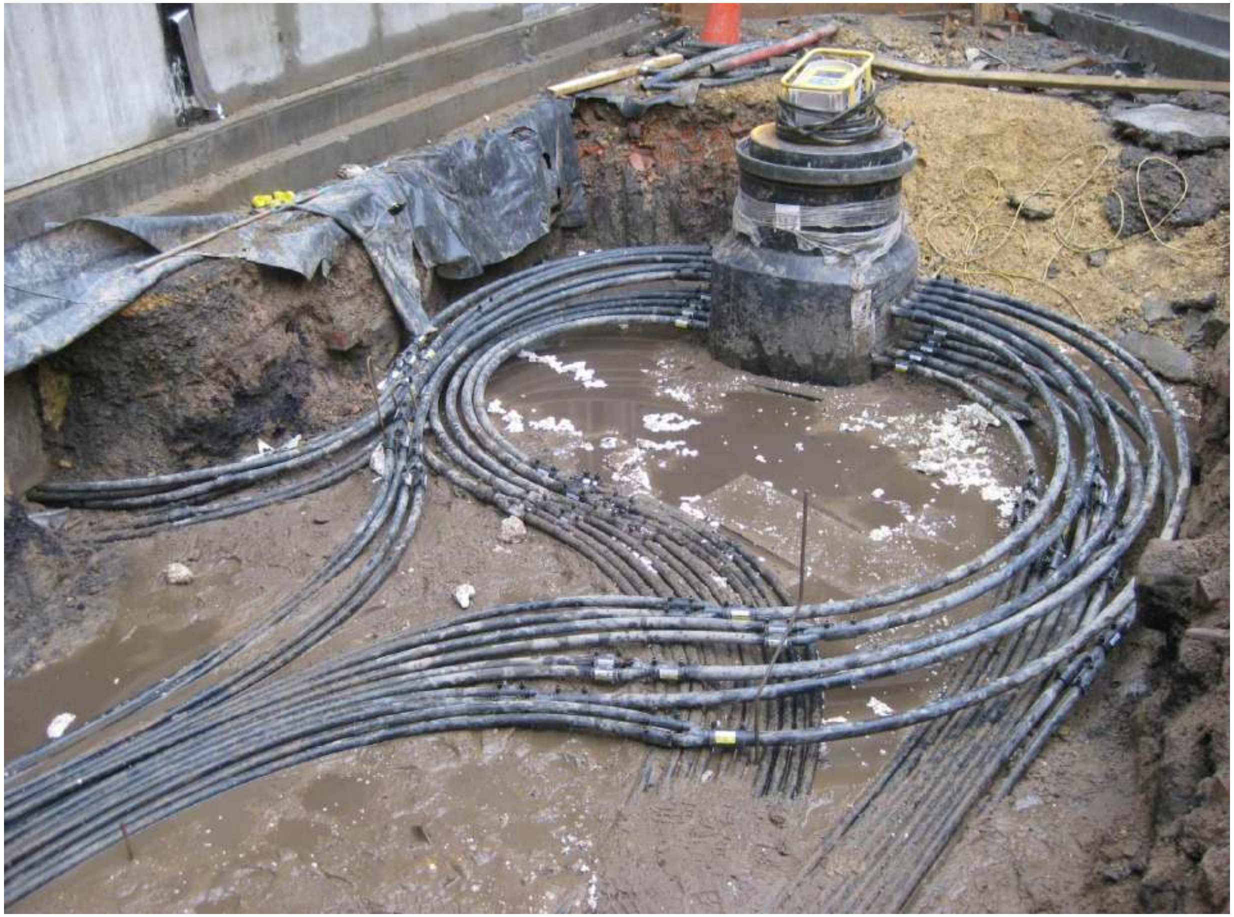




Ground Source – Meticulous skill & care is critical

Electrofusion of heat transfer pipes to the vertical heat collector pipes

Separation of pipes is critical



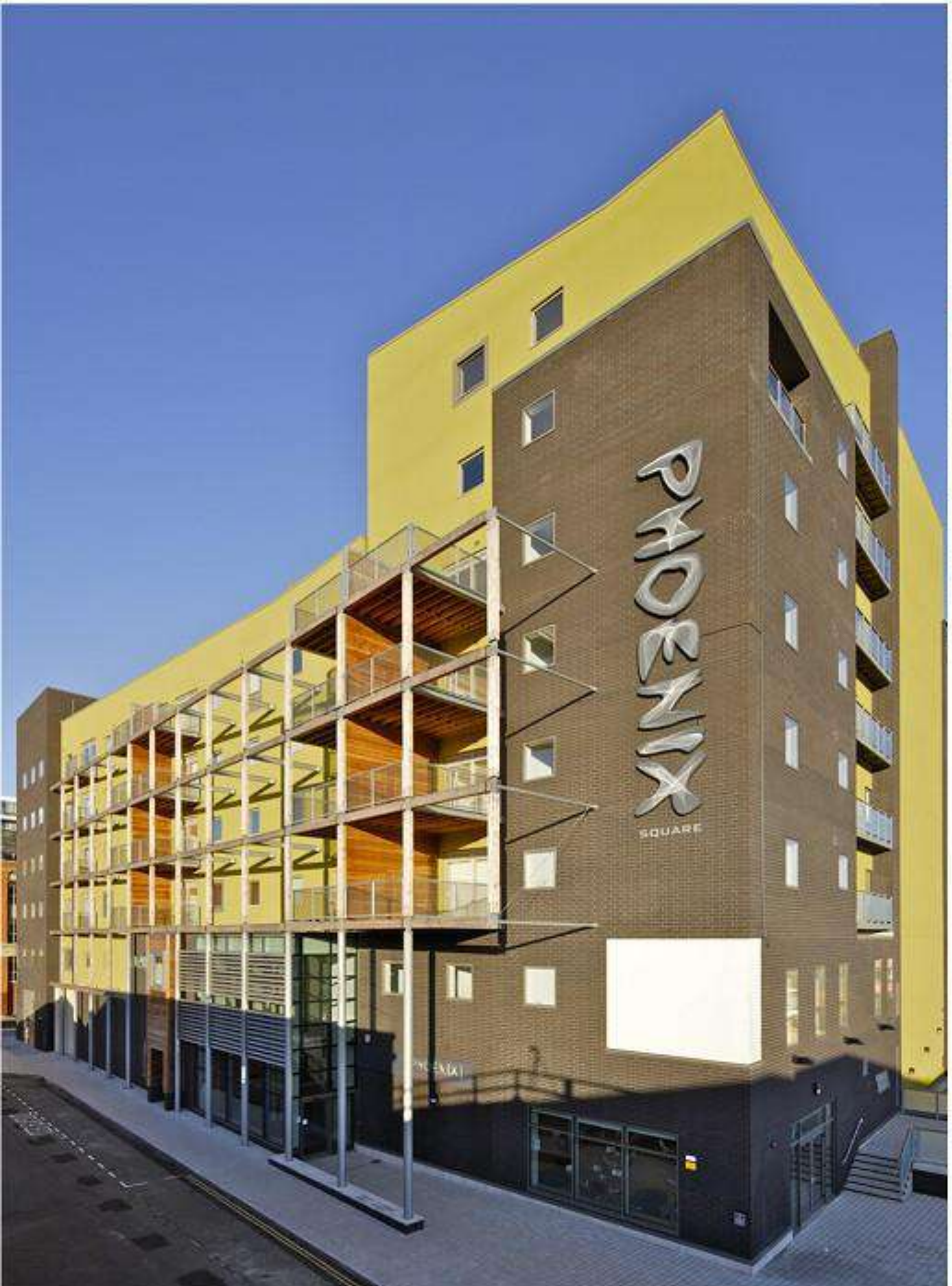
Fusion at the manifold chamber is also critical

Fusion at the manifold chamber is also critical

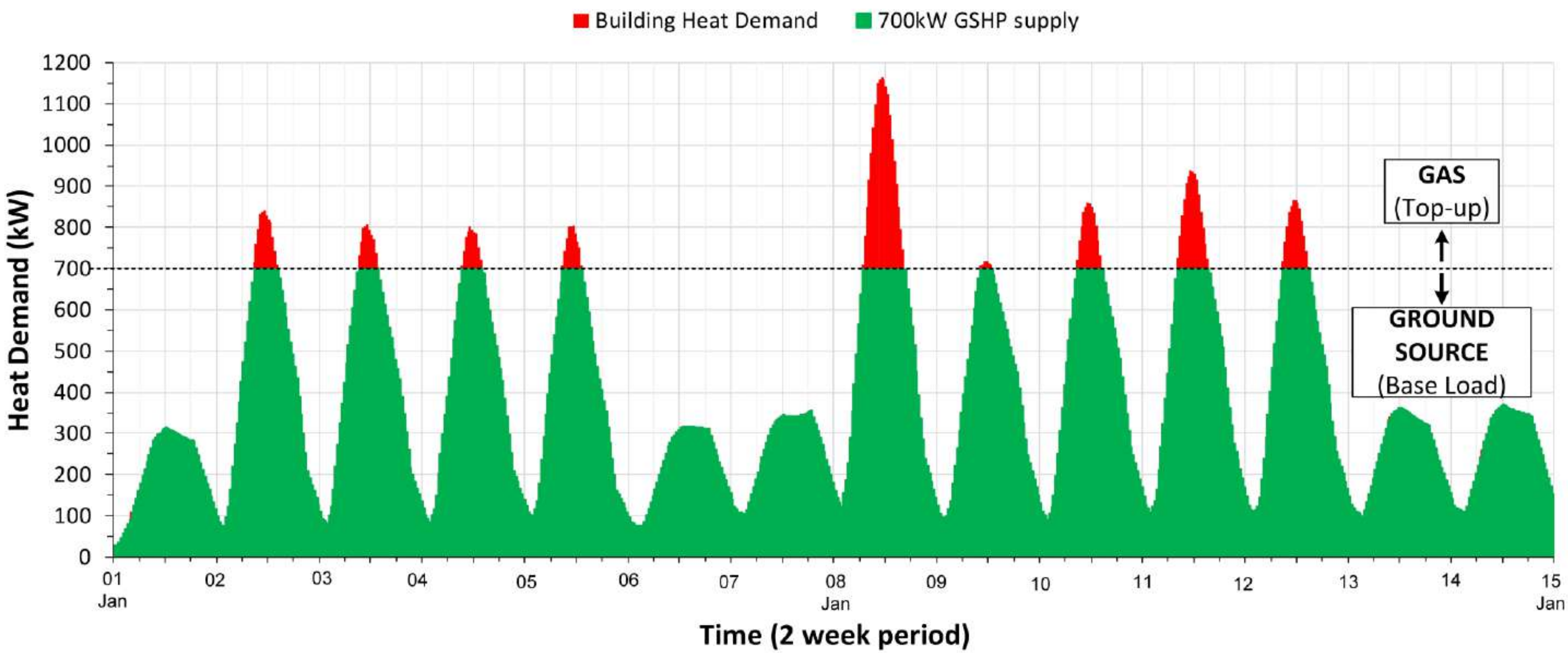
Ground Source

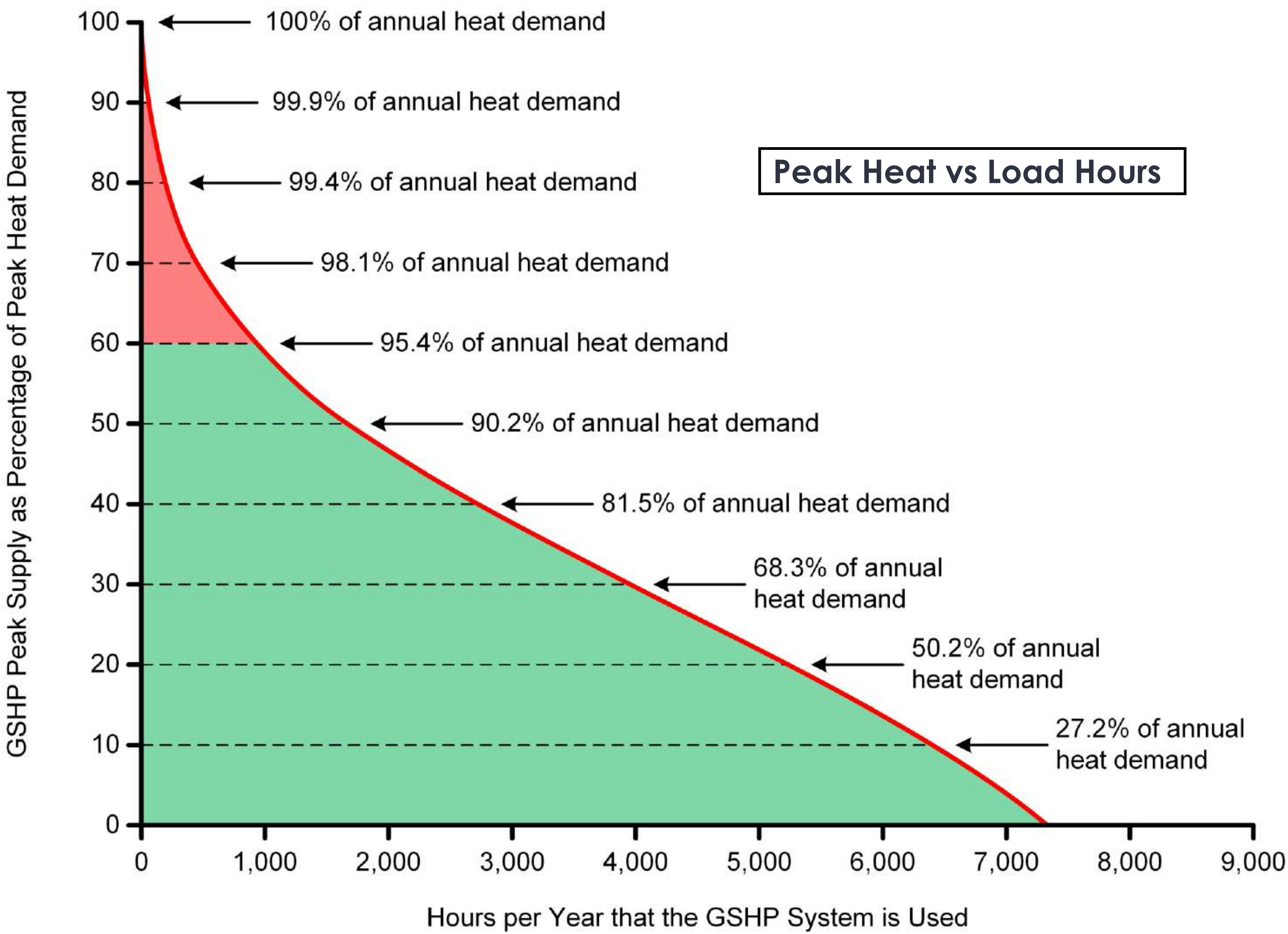
Choice of manifold chamber is important

Manifolds can be inside the building

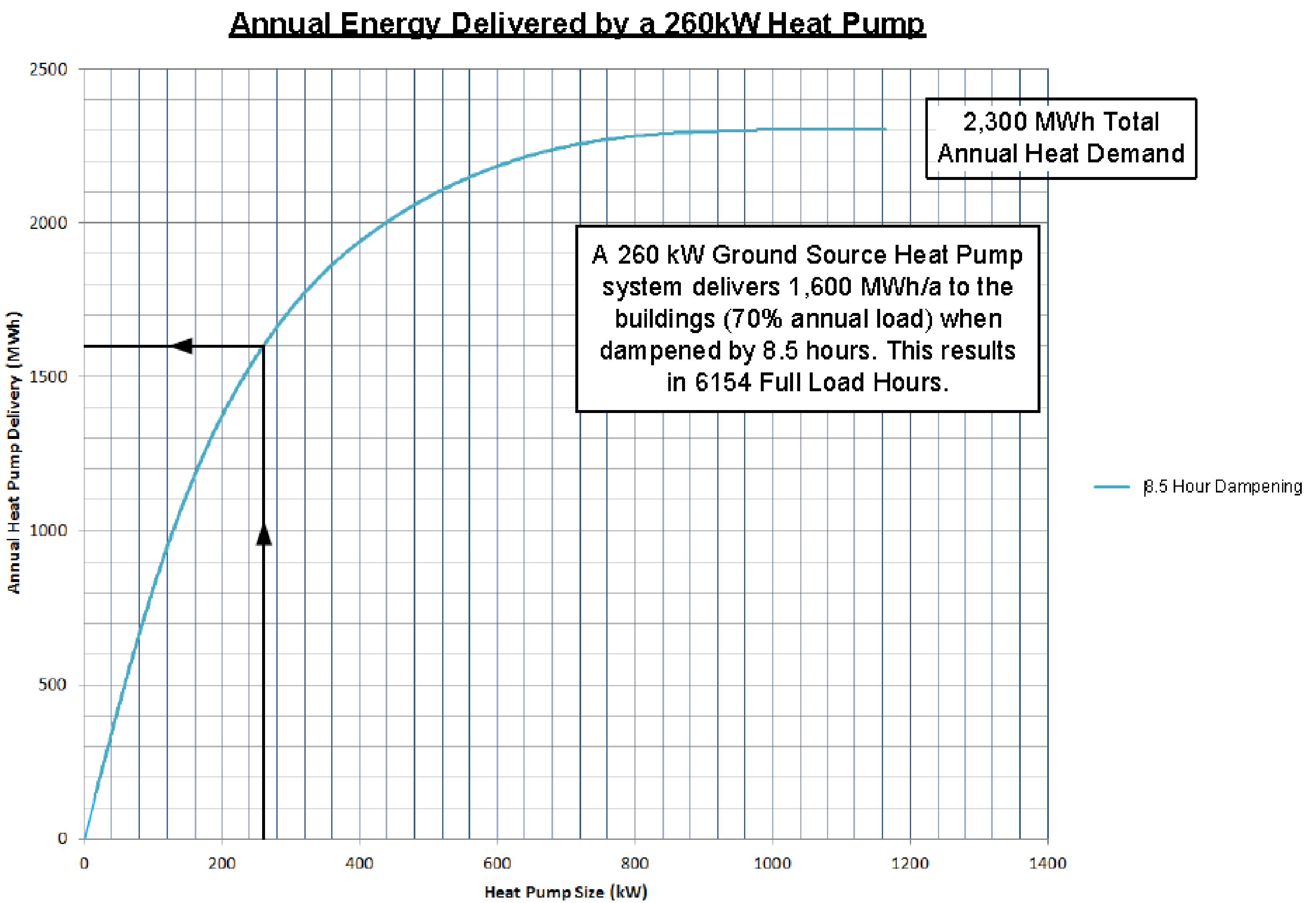

PHOENIX
SQUARE

Peak Heat vs Base Load




Peak Heat vs Load Hours
GSHP Peak Supply as Percentage of Peak Heat Demand
100% of annual heat demand
99.9% of annual heat demand
99.4% of annual heat demand
98.1% of annual heat demand
95.4% of annual heat demand
90.2% of annual heat demand
81.5% of annual heat demand
68.3% of annual heat demand
50.2% of annual heat demand
27.2% of annual heat demand
100
90
80
70
60
50
40
30
20
10
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
Hours per Year that the GSHP System is Used

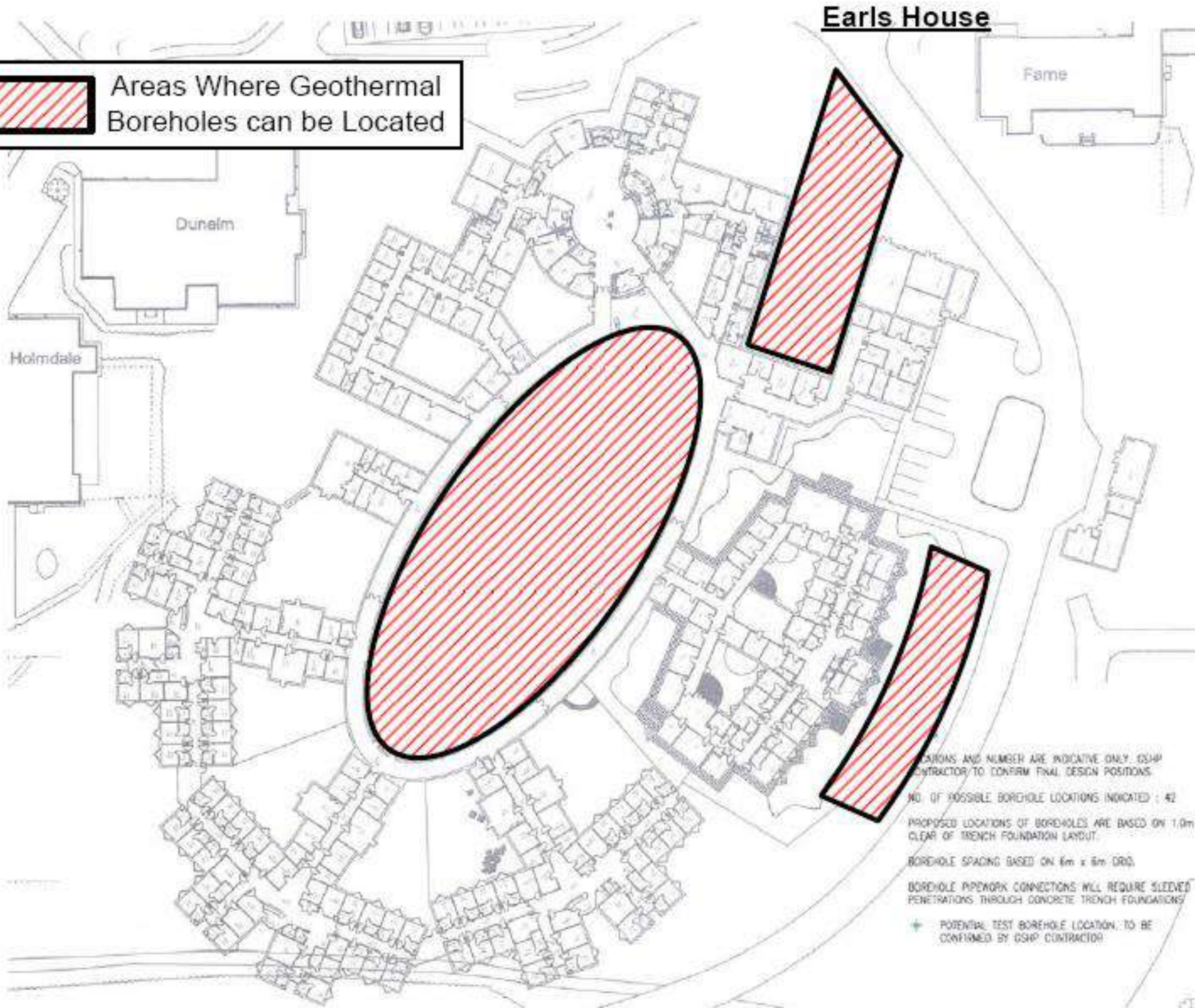
MWh/a vs kW

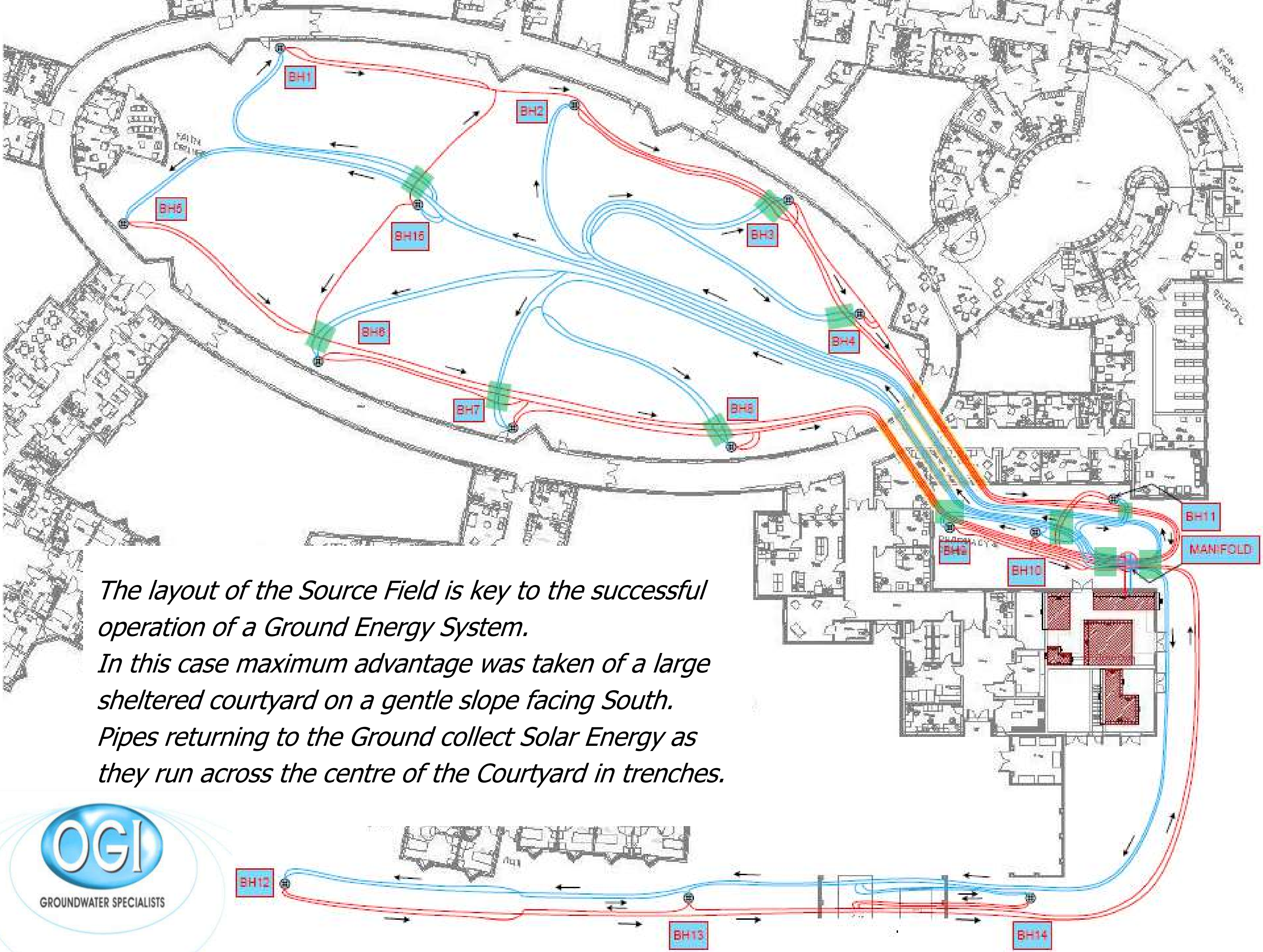


Annual Energy Delivered by a 260kW Heat Pump
2500
2000
1500
1000
500
0
Annual Heat Pump Delivery (MWh)
0
200
400
600
800
1000
1200
1400
Heat Pump Size (kW)
2,300 MWh Total Annual Heat Demand
A 260 kW Ground Source Heat Pump system delivers 1,600 MWh/a to the buildings (70% annual load) when dampened by 8.5 hours. This results in 6154 Full Load Hours.
8.5 Hour Dampening

Ground Source Heating & Cooling Project – Durham, UK

Lanchester Road Hospital
Durham, UK


Earls House
Areas Where Geothermal Boreholes can be Located
Farne
Dunelm
Holmdale
CATIONS AND NUMBER ARE INDICATIVE ONLY. GSHP
NTRACTOR TO CONFIRM FINAL DESIGN POSITIONS.
NO. OF POSSIBLE BOREHOLE LOCATIONS INDICATED : 42
PROPOSED LOCATIONS OF BOREHOLES ARE BASED ON 1.0m CLEAR OF TRENCH FOUNDATION LAYOUT.
BOREHOLE SPACING BASED ON 6m x 6m GRID.
BOREHOLE PIPEWORK CONNECTIONS WILL REQUIRE SLEEVED PENETRATIONS THROUGH CONCRETE TRENCH FOUNDATIONS
POTENTIAL TEST BOREHOLE LOCATION, TO BE CONFIRMED BY GSHP CONTRACTOR



The layout of the Source Field is key to the successful operation of a Ground Energy System.
In this case maximum advantage was taken of a large sheltered courtyard on a gentle slope facing South.
Pipes returning to the Ground collect Solar Energy as they run across the centre of the Courtyard in trenches.

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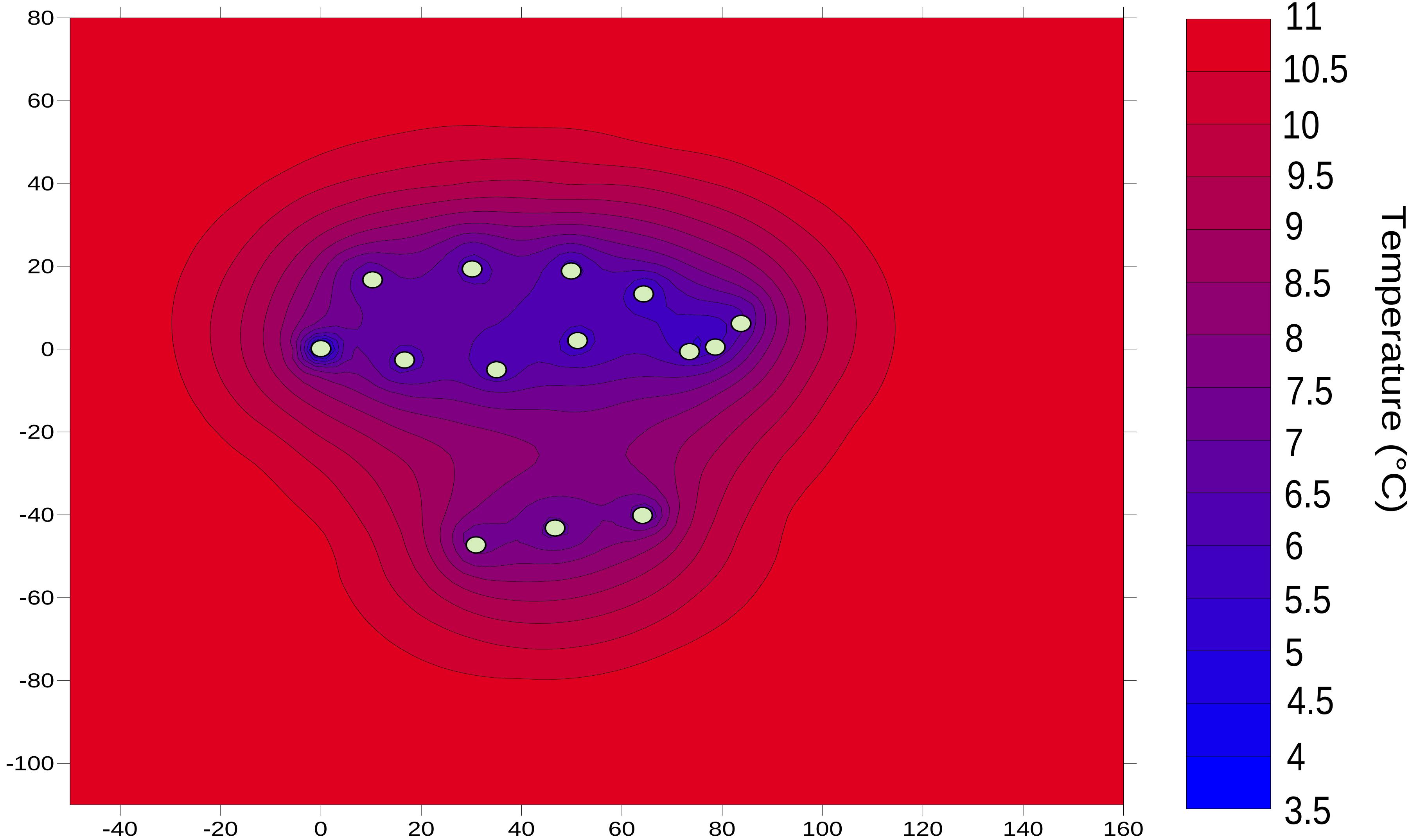

Combining the Test Results with the Geography of the Site allows us to predict the way that Heat will flow into the Collector Pipes from the Source Field. This modelling process helps us to design the optimum borehole and trench layout.

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With the Ground Conditions and size of Source Field Established various options can be considered for the way Ground Energy is used in the building:

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SPACE HEATING

Ground Energy is a low grade form of Heat and is best supplied at Low Temperatures, typically below 45ºC.
This requires Large Surface Area Emitters such as Underfloor Heating.
Efficiency is improved if the Heat Pump modulates the temperature of the emitter to take account of seasonal variations in the outside temperature.

HOT WATER HEATING

While Ground Energy supplies water at the right temperature for washing, domestic hot water systems normally operate above 55ºC to protect against the growth of bacteria in distribution pipes.
The most efficient way of using Ground Energy to produce Domestic Hot Water is in combination with another heat source. On smaller systems requiring intermittent sterilisation this can be an immersion heater: on larger systems a biomass or gas boiler may be a better solution.

COOLING

The Ground is normally cold enough to provide cooling without use of the Heat Pump exhaust.
This is Passive Cooling.
When the Heat Pump is producing heat it will also generate cooling through its exhaust.
This is Active Cooling.
If no Heat is required at the same time as Active Cooling, a Heat Dump is required.
The Ground can be used as a Heat Dump, in which case Seasonal Heating Efficiencies are improved.

Lanchester Road Hospital has SPACE HEATING and PASSIVE COOLING.

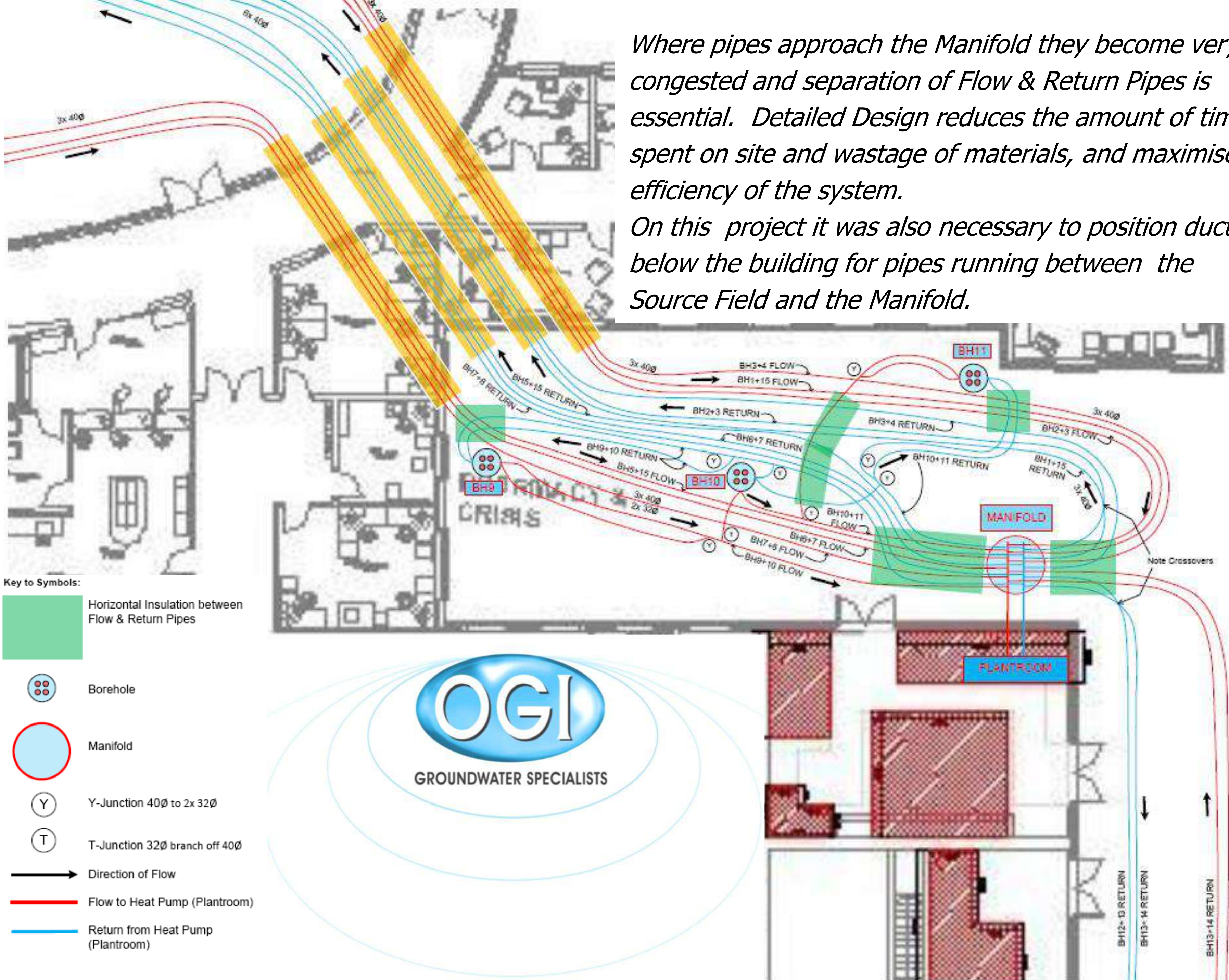
Boreholes are frequently drilled before any other work starts on site: in almost ideal conditions

Conditions are never ideal when the time comes to connect to the borehole loops. They must then be relocated and cleaned out before trench pipes can be connected.

The OGI Site Engineer directs excavation of trenches for collector pipes

Laying the Trench Pipes presents new challenges and hazards: Large Pipe Coils have to be manoeuvred amongst mounds of excavated and bedding material while other building work takes place all around.

Where pipes approach the Manifold they become very congested and separation of Flow & Return Pipes is essential. Detailed Design reduces the amount of time spent on site and wastage of materials, and maximises efficiency of the system.
On this project it was also necessary to position ducts below the building for pipes running between the Source Field and the Manifold.



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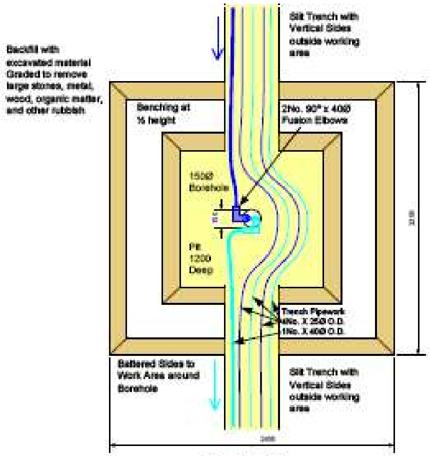
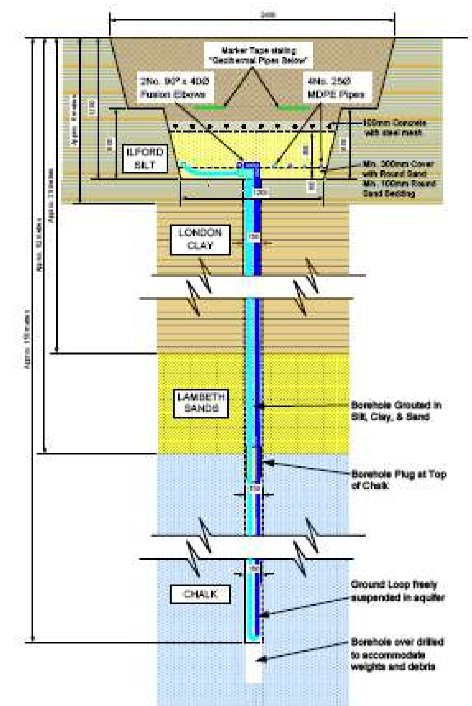
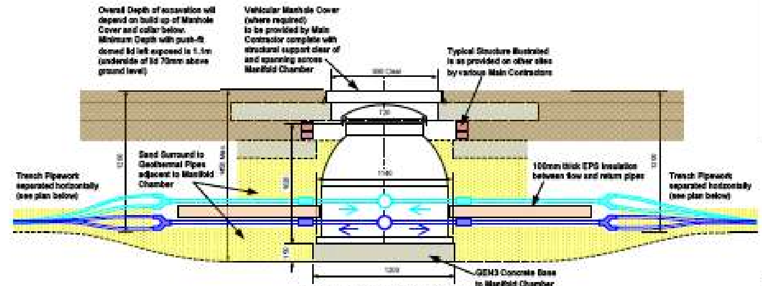


Borehole Plan

Borehole Connections

Borehole Section





Manifold Cross Section

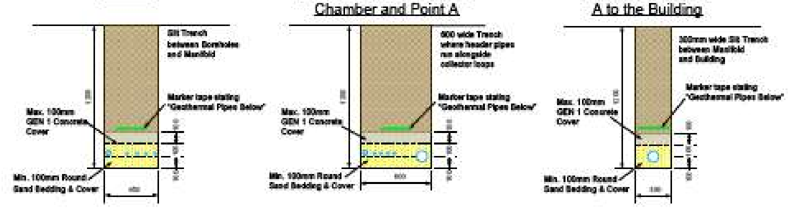
Straight Fusion Connectors
Connections to Manifold: 20No. X 40Ø O.D
Connections between Y-pieces: 32No. X 40Ø O.D
Contingency: 18No. X 40Ø O.D
Total: 70No. X 40Ø O.D
(contingency allows for short pipe lengths between some Y-pieces as illustrated)
90° Fusion Elbows
Connections to Boreholes: 8No. X 40Ø O.D.
Connections to Manifold: 8No. X 40Ø O.D.
Total: 16No. X 40Ø O.D. (no contingency)
Y-Branches
16No. X 50Ø O.D. X 40Ø O.D. x 40Ø O.D
Each Large Y-branch requires:
Straight Fusion Reducer: 16No. X 50Ø x 40Ø.
32No. X 40Ø O.D. X 32Ø O.D. x 32Ø O.D
Each Small Y-branch requires
Straight Fusion Reducers: 32No. X 32Ø x 25Ø.
Insulation Boards 100mm Thick
8No. X 600x1200 (Approx.)

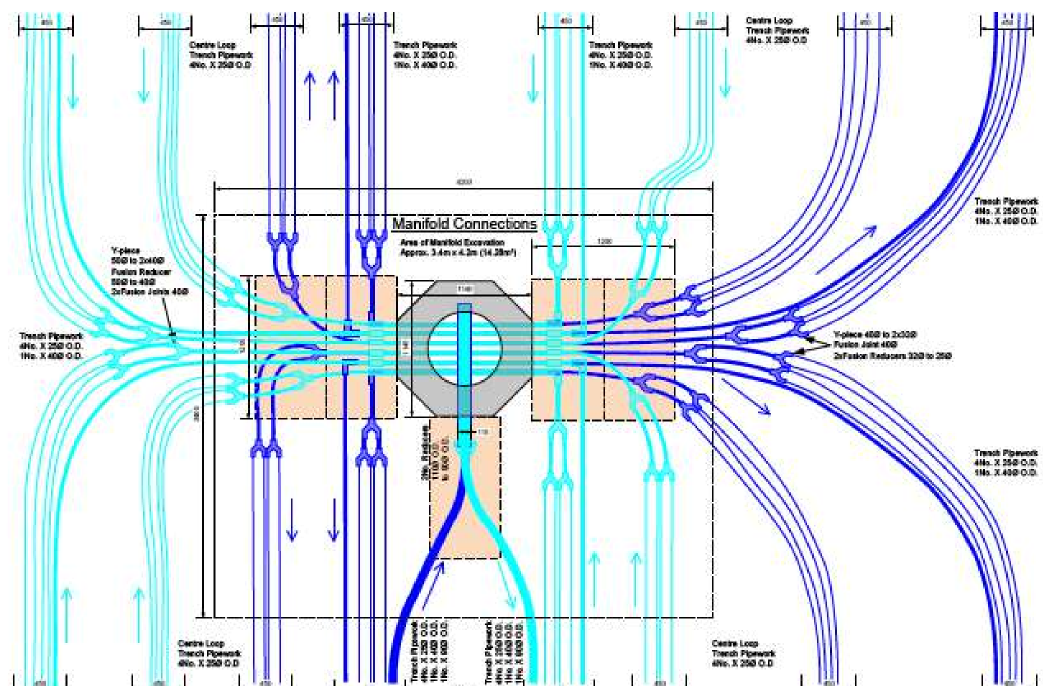
25Ø pipe should not be jointed except at Y-piece.
40Ø should only be jointed at manifold and boreholes.
Each ground loop nominal 100m overall length.
Total length of 25Ø pipe = 32x100m = 3,200m.
Total length of 40Ø pipe = 4x100m = 400m, plus 20m contingency for forming manifold connections.

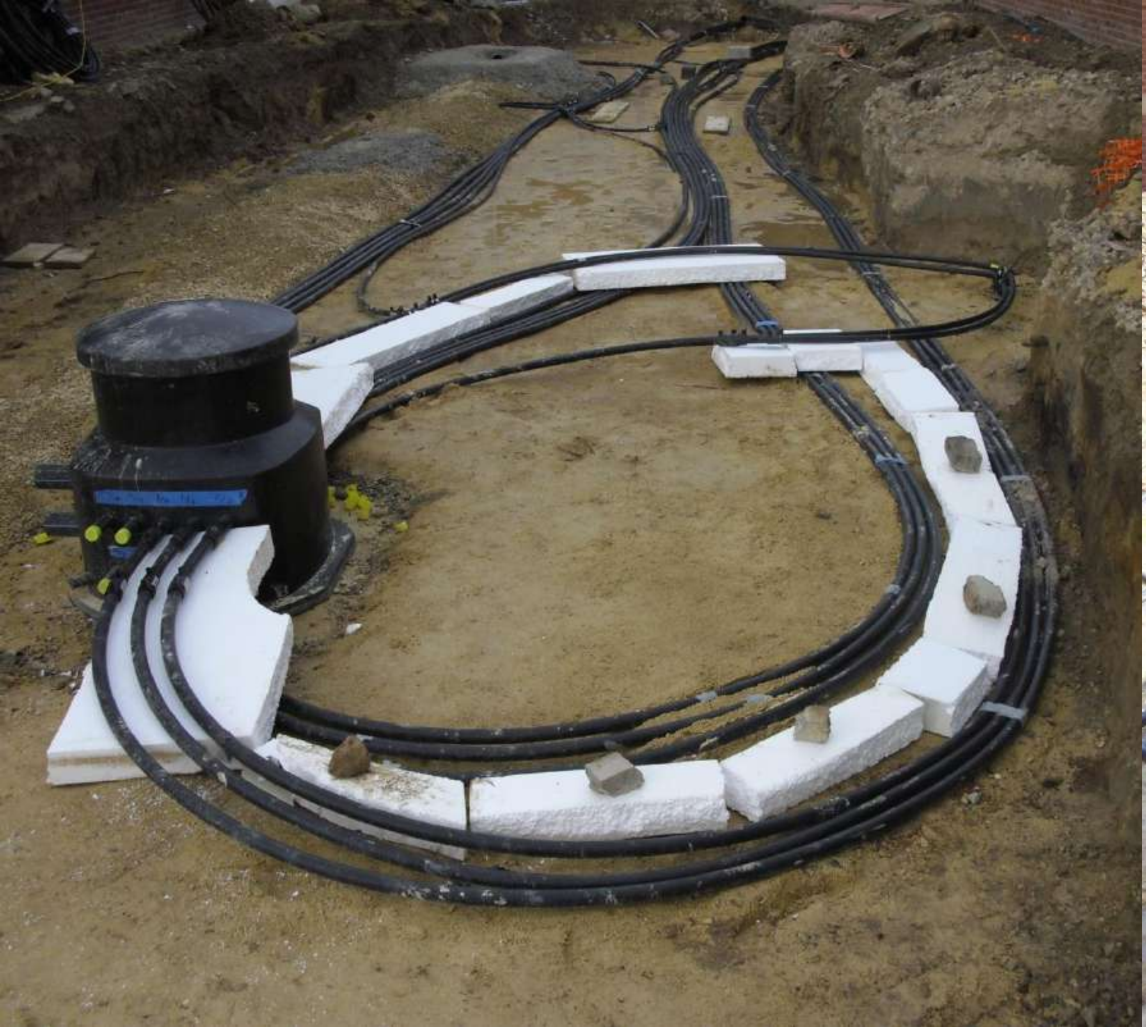
Typical Trench Section

Header Pipe Trench Section between Manifold Chamber and Point A

Header Pipe Trench Section from Point A to the Building







The Final Installation can look very neat before it is buried but the practicalities of forming pipe connections in muddy ground amongst other services should never be underestimated.

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The working conditions during construction (above) might not provide any idea of what to expect during a subsequent maintenance visit (right).

Once the Source Field is complete, all pipes must be pressure tested, flushed, sterilised, and filled with antifreeze (Heat Transfer Fluid).
OGI have developed equipment to perform these functions in unpredictable and highly variable site conditions.

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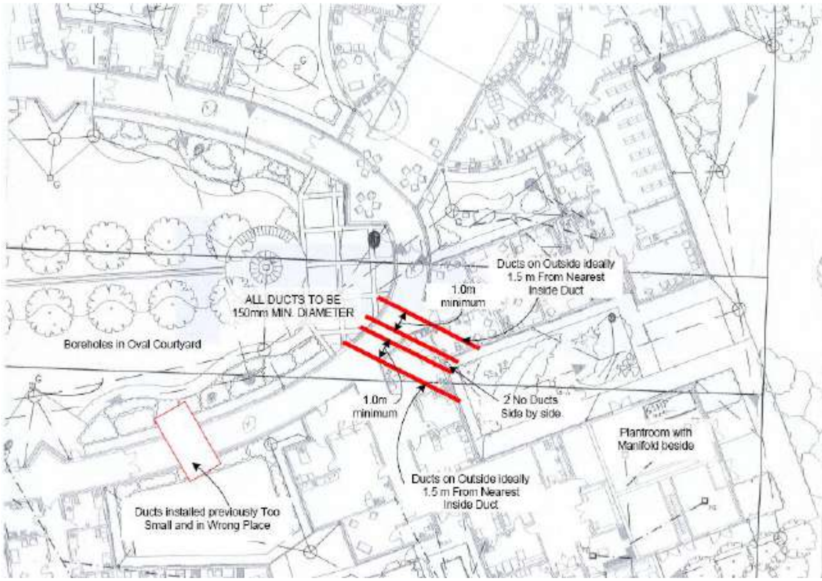

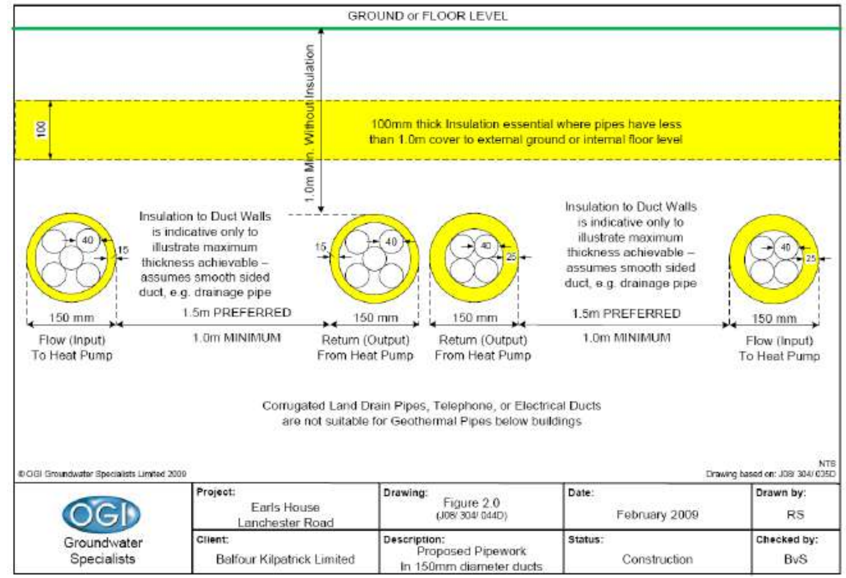

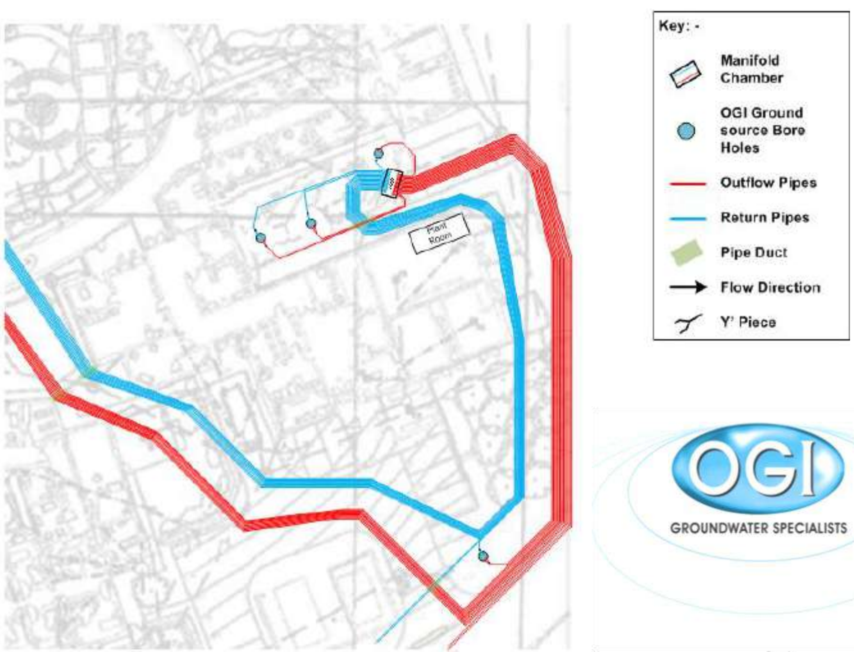

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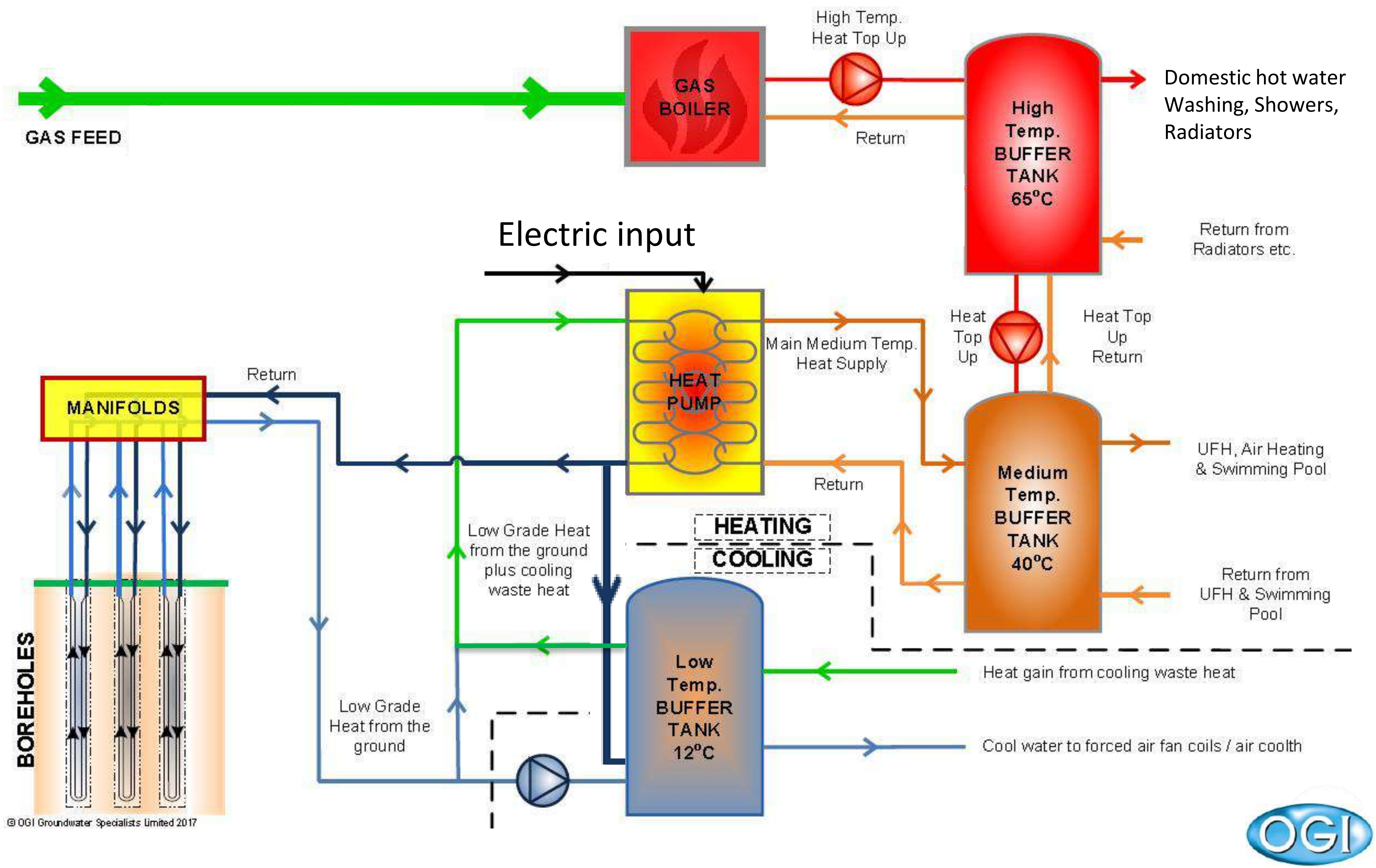
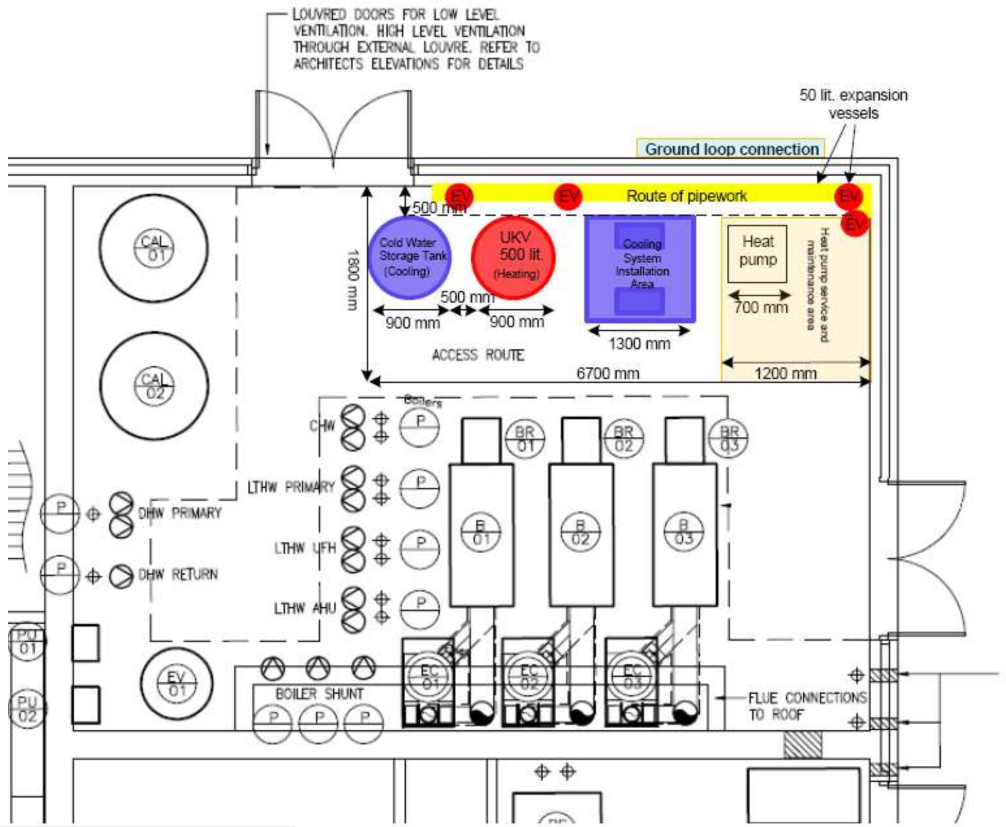
Top Left are the positions of ducts as required. Bottom Left is the increased pipe run required to reach the Manifold Chamber and Plantroom. Above is a detail for insulated ducts routed below a floor slab.

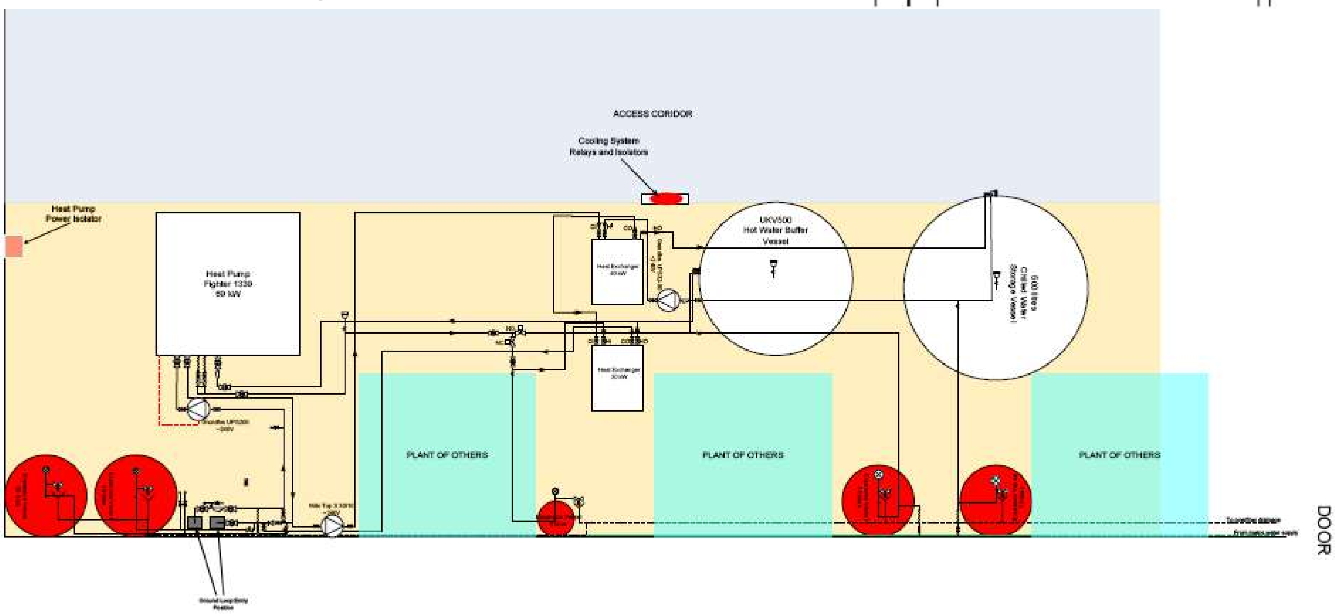
The Ground Energy Source Field
vanishes beneath a landscaped courtyard

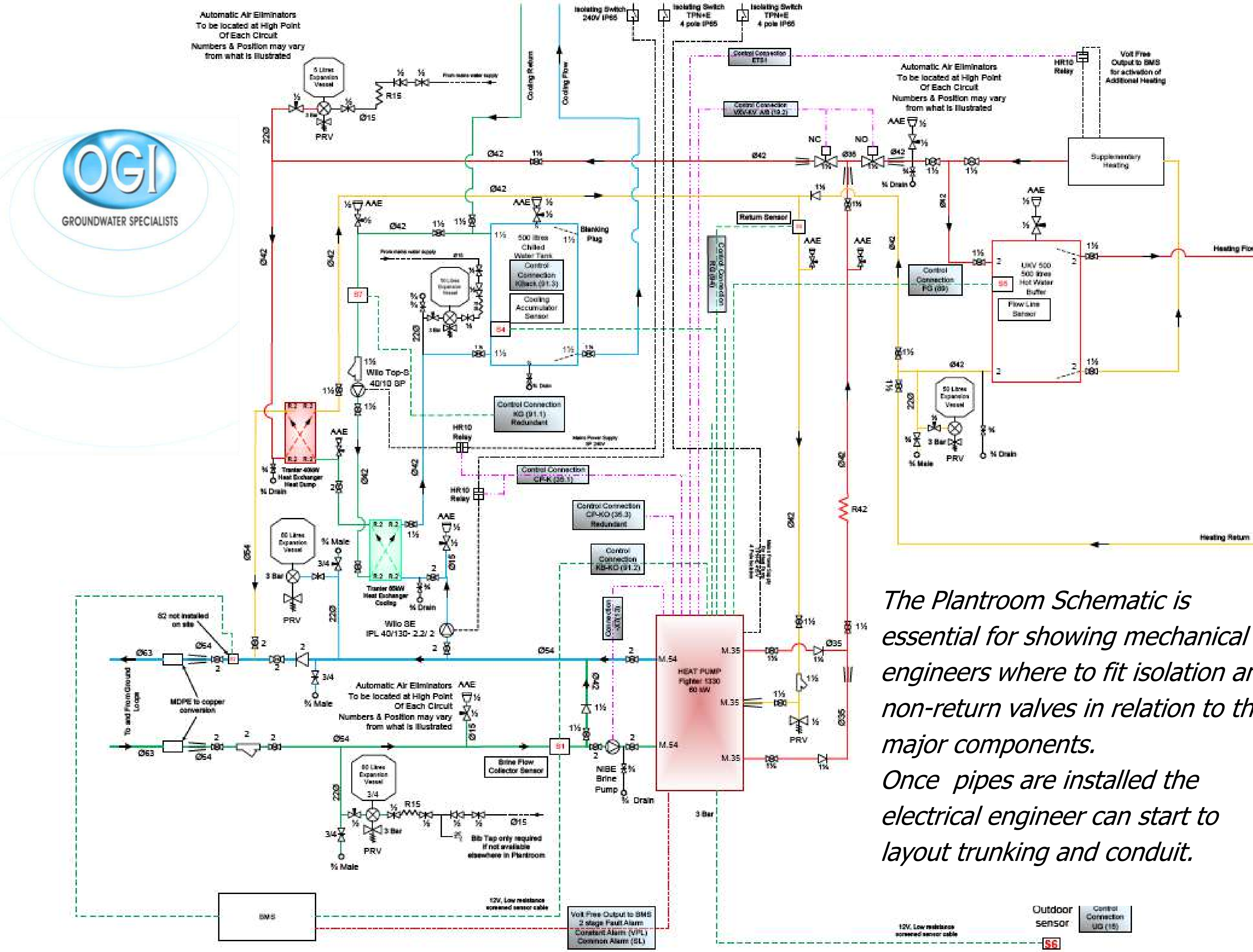
LANCHESTER ROAD HOSPITAL (ACTIVE COOLING)



With the ground works designed and in many instances complete, attention is turned to the inside of the building and coordination with the rest of the mechanical and electrical services.
The first task is to establish how much space in the plantroom the Ground Energy System will occupy.
The sketches below & right identify key pieces of equipment with sizes where known.
It is important to obtain as much space as possible at the outset. Not only will some pieces of equipment turn out to be larger than expected, space will almost certainly be robbed to provide for unrelated functions.
In this case a Control Panel and a Pressurisation Unit occupied a large part of the area.



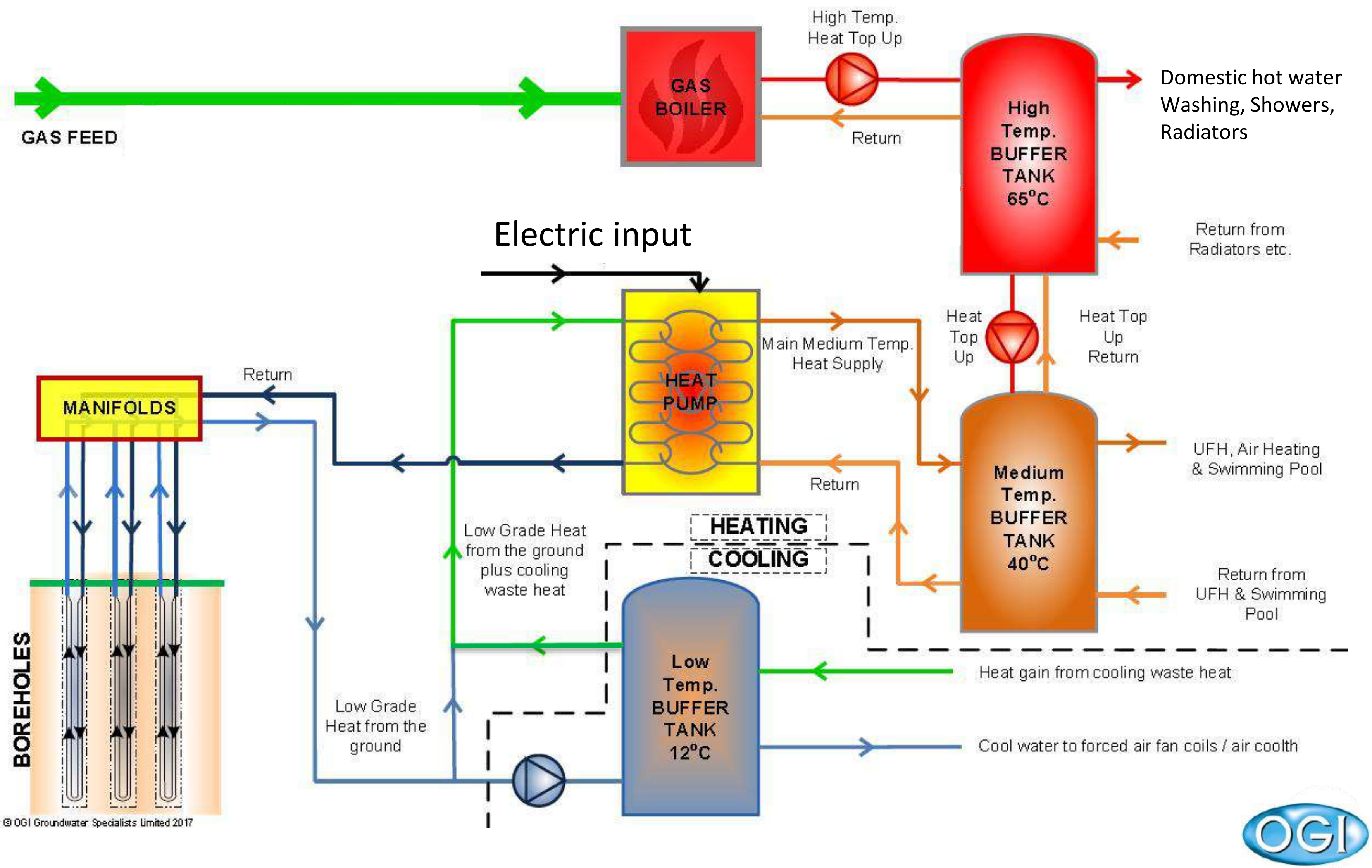




The Plantroom Schematic is essential for showing mechanical engineers where to fit isolation and non-return valves in relation to the major components.

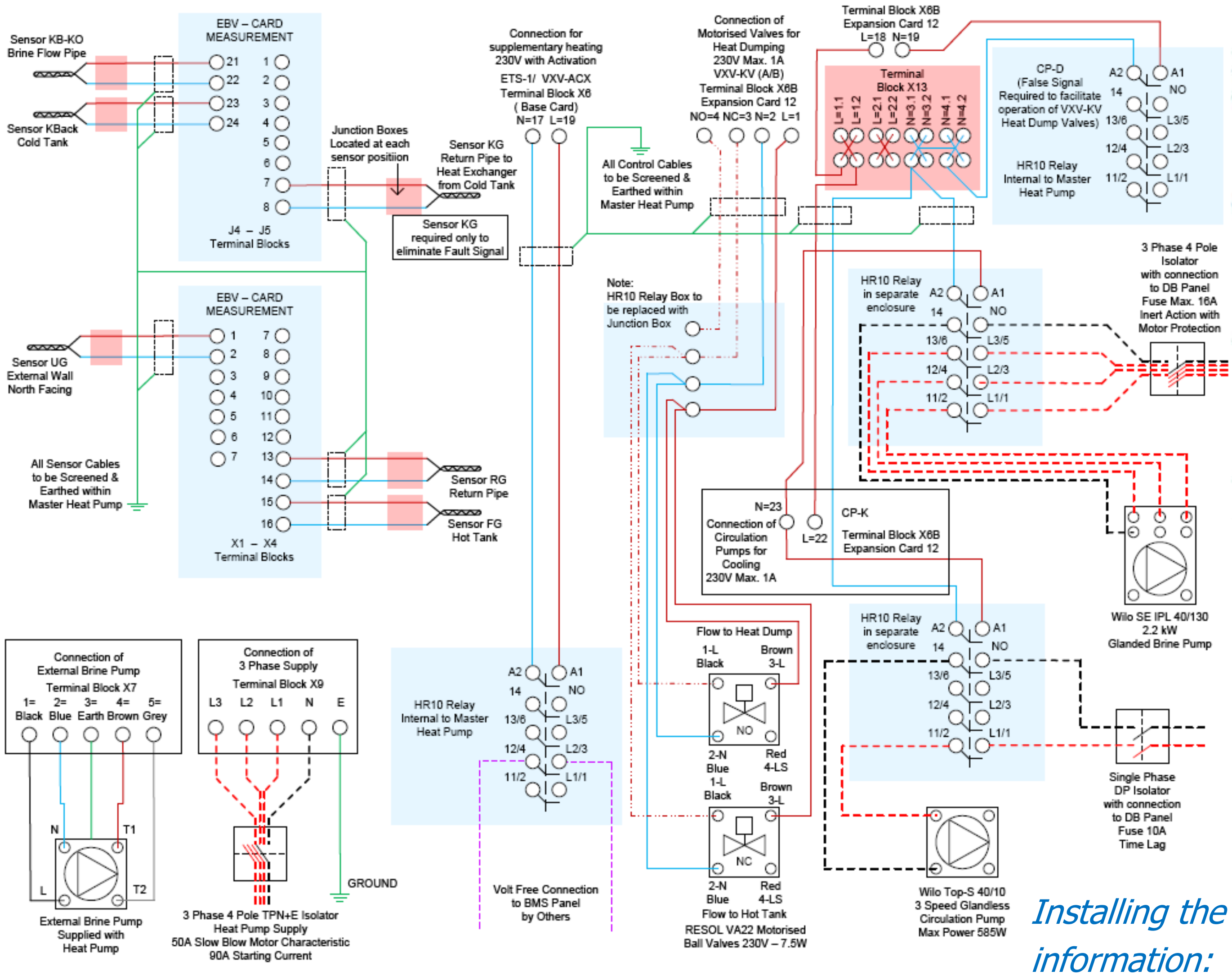
Once pipes are installed the electrical engineer can start to layout trunking and conduit.

LANCHESTER ROAD HOSPITAL (PASSIVE COOLING)



This view of the plantroom close to completion shows a complete array of equipment. The black top bottom left belongs to a pressurisation unit supplying top up water to the hot and cold distribution pipes. Behind that are expansion vessels and the chilled water buffer tank clad in silver, with connections incomplete. The red panels to the right belong to gas boilers, with the mechanical services control panel behind. The pale grey hot buffer tank conceals most of the Heat Pump that has front and top panels removed.

The back of the Heat Pump is where all connections are made.
The blue plates behind belong to the 90kW Heat Exchanger used to provide active and passive cooling.
Everything in this view was clad in thick insulation after pressure testing.



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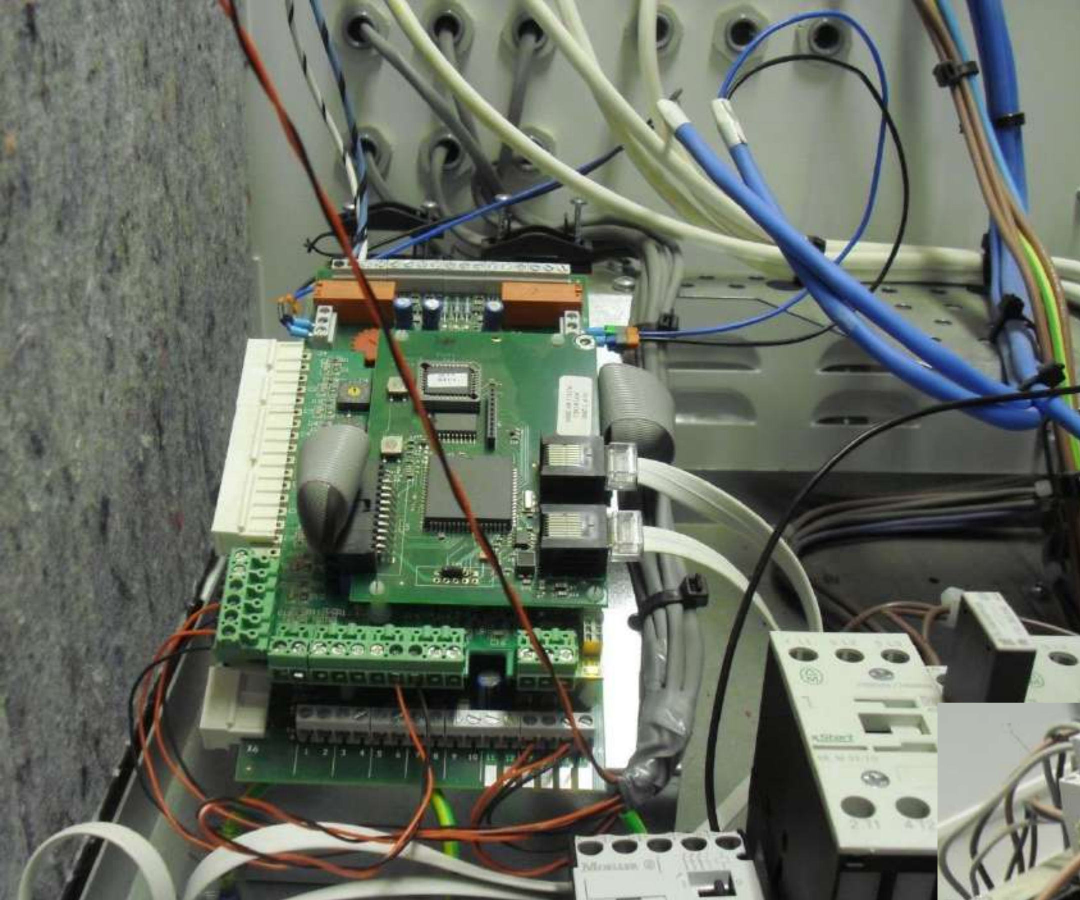
Installing the electric wiring requires more information: In most instances a competent electrical engineer will be able to work directly from the manufacturer's Installation Manual and Wiring Diagrams.

In this instance a specialist cooling requirement made the issue of a detailed connection diagram essential.

This non-standard solution allows for passive and active cooling to operate at the same time as heating or independently.



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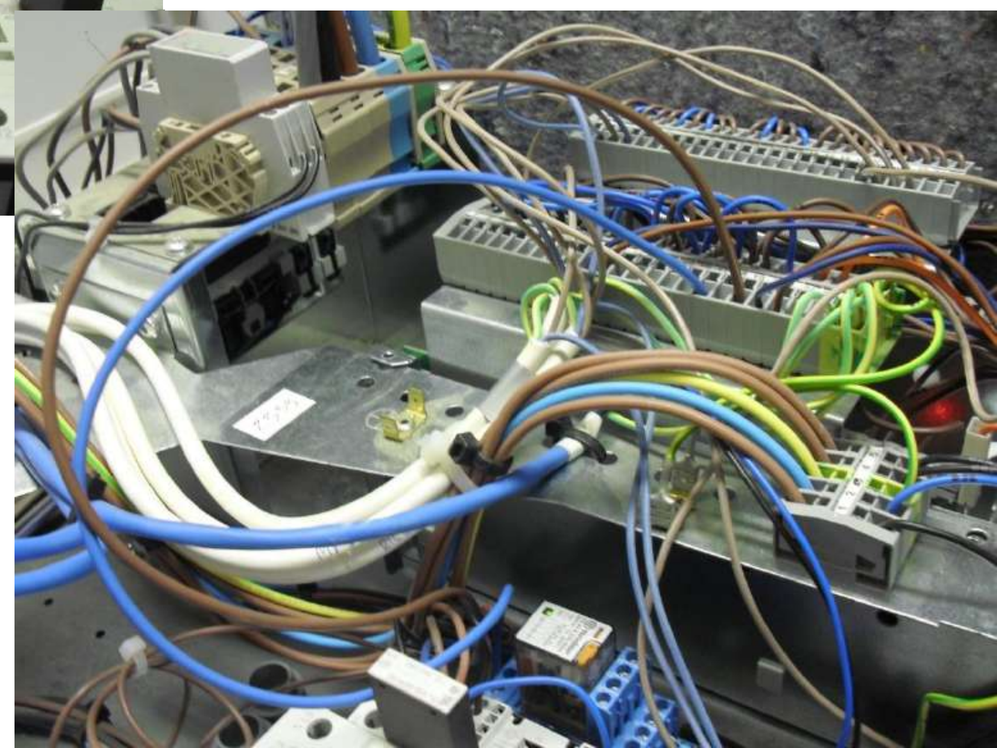
This is not work for the self appointed expert. The NIBE Heat Pump is a piece of leading edge technology and with the top cover removed can prove intimidating to the uninitiated.

A cool head and nimble fingers are required to ensure that the correct logic is applied when making external connections to sensors, pumps, and motorised valves.



The Energy Resource within the Ground is not infinite.
Most of the Heat comes from the Sun in the form of radiation absorbed by the Ground during the Summer.
During the Winter the Ground Temperature will fall steadily.
Ground Energy Systems must be designed to ensure a balance between different seasons.

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HEATING SEASON

In the Autumn the external temperature will at some point drop below the desired internal temperature.
This is the start of the Heating Season, when the Heat Pumps are at their most efficient.
As the Winter progresses the efficiency of the Heat Pump will gradually reduce.
When Heating demands are high, it is normally sensible to have another source of heating available.

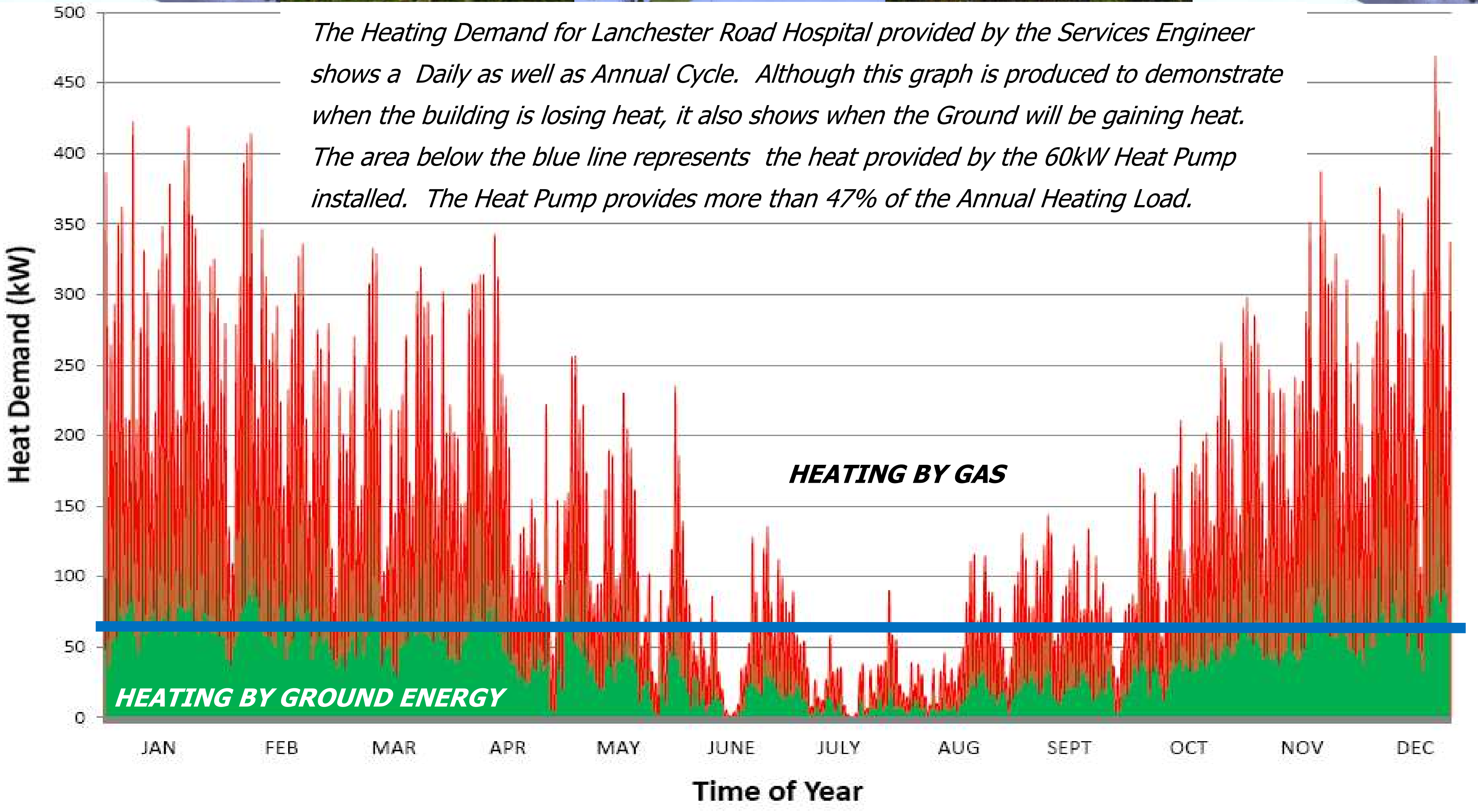
COOLING SEASON

The demand for cooling in theory starts when there is no longer a demand for heating.
In practice there may be an overlap when both are required, or a long period when neither are needed.
When Active Cooling using the Ground as a Heat Dump is used, the Cooling Season will be reduced but a longer Heating Season can be sustained with higher efficiencies.
Passive Cooling will also replenish the Ground Resource, but at a much slower rate.

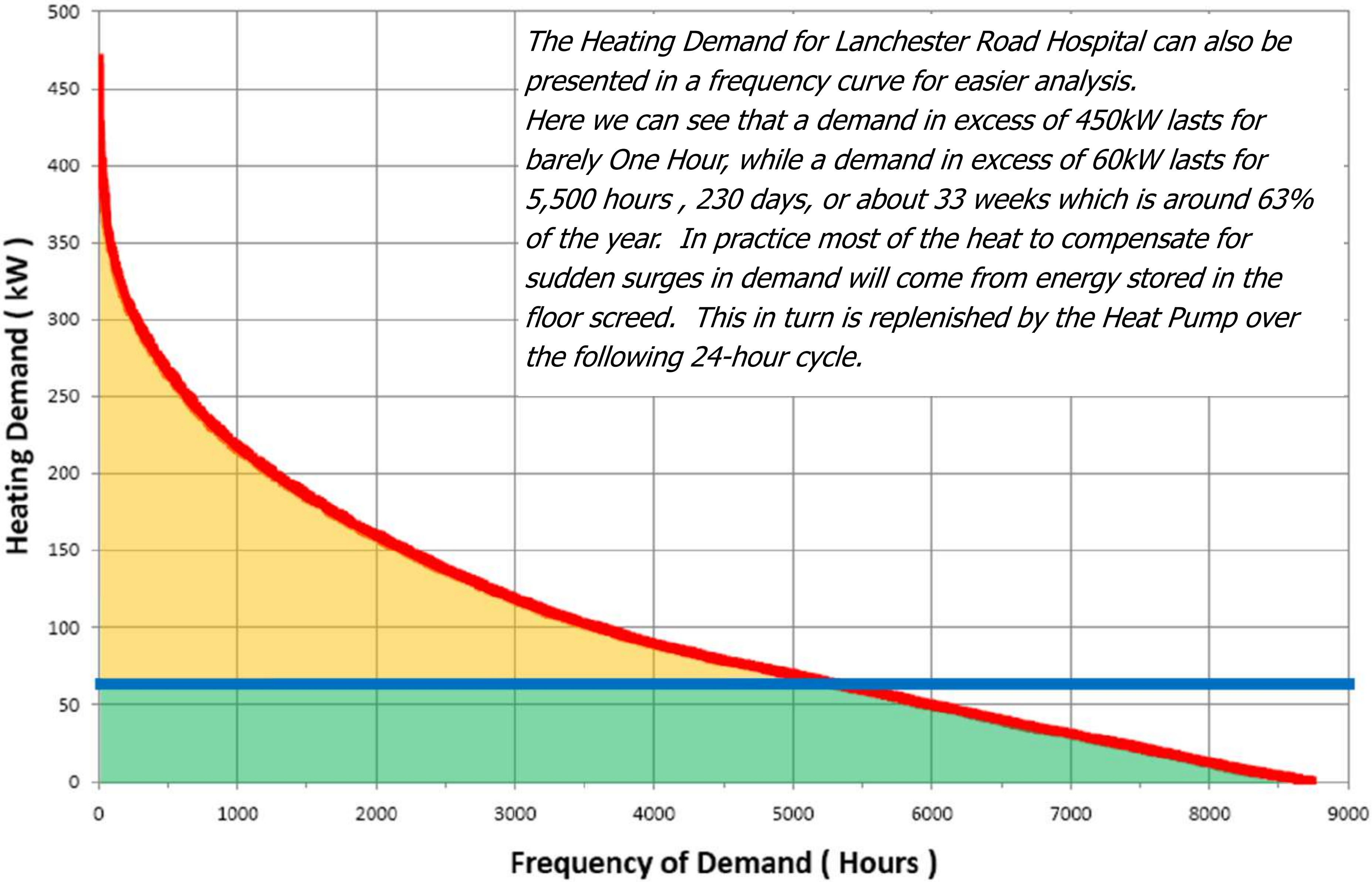
DEGREE MINUTES

The Heat Pump is designed to monitor the rate at which Heating and Cooling occurs using DEGREE MINUTES, and maintain a running total of the amount of energy consumed and supplied.
This information is used to switch compressors and circulation pumps on and off in a pattern that ensures maximum efficiency.
Efficiency is reduced if the Heat Pump is switched on or off and this data is lost as a result.

The Heating Demand for Lanchester Road Hospital provided by the Services Engineer shows a Daily as well as Annual Cycle. Although this graph is produced to demonstrate when the building is losing heat, it also shows when the Ground will be gaining heat. The area below the blue line represents the heat provided by the 60kW Heat Pump installed. The Heat Pump provides more than 47% of the Annual Heating Load.



HEATING BY GROUND ENERGY : MORE THAN 47% OF THE HEAT OVER THE COURSE OF A YEAR



The relationship between the internal supply temperature and external temperature is not linear.
An assumption is made with NIBE Heat Pumps that the preferred ambient temperature is 20 °C.
This leads to a series of graphs known as Heating Curves.
Each Curve is suitable for a different combination of installation type and location.

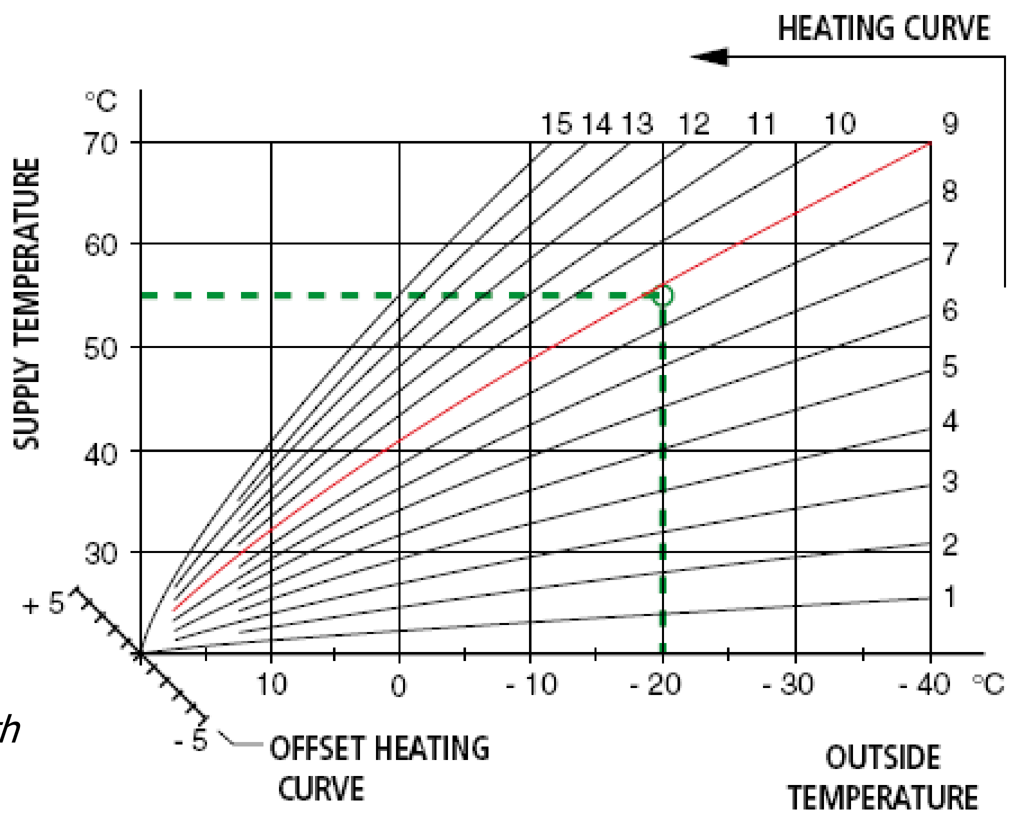
HEATING CURVE

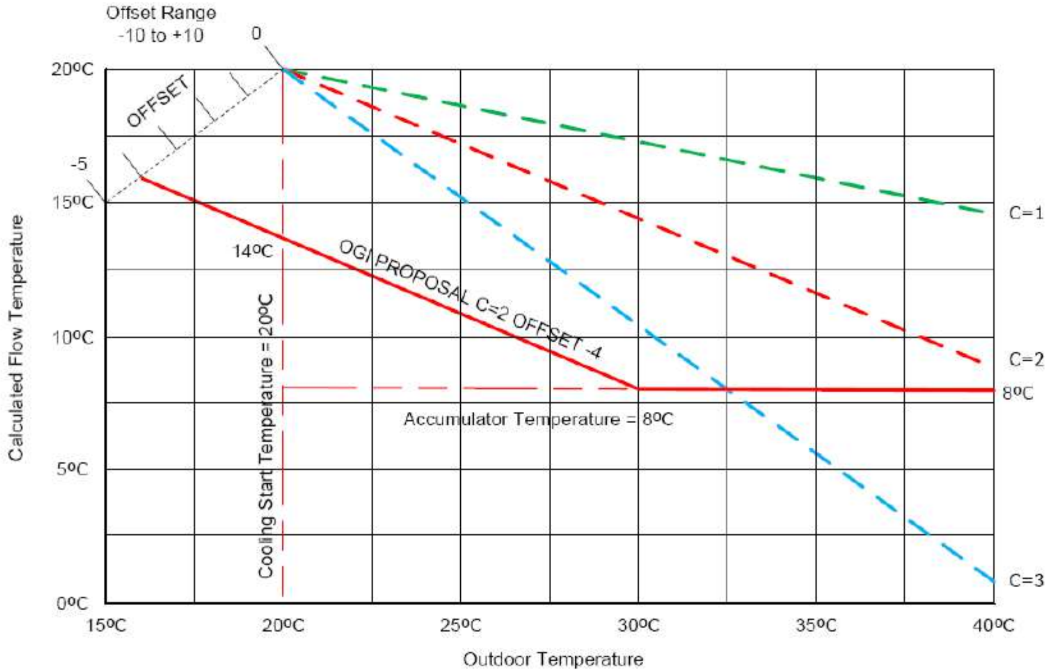
As the outside temperature drops the internal supply temperature must rise to take account of heat losses from the building.
The size of the emitter used in the building determines how quickly the supply temperature should rise.
For underfloor heating systems in a temperate climate a curve of 9 is normally used providing a supply temperature of 55 °C when it is -20 °C Outside.

OFFSET

In many buildings a higher or lower ambient temperature may be desirable.
This is achieved by offsetting all the curves.

Lanchester Road Hospital was commissioned with a Heating Curve of 12 and offset of +2.



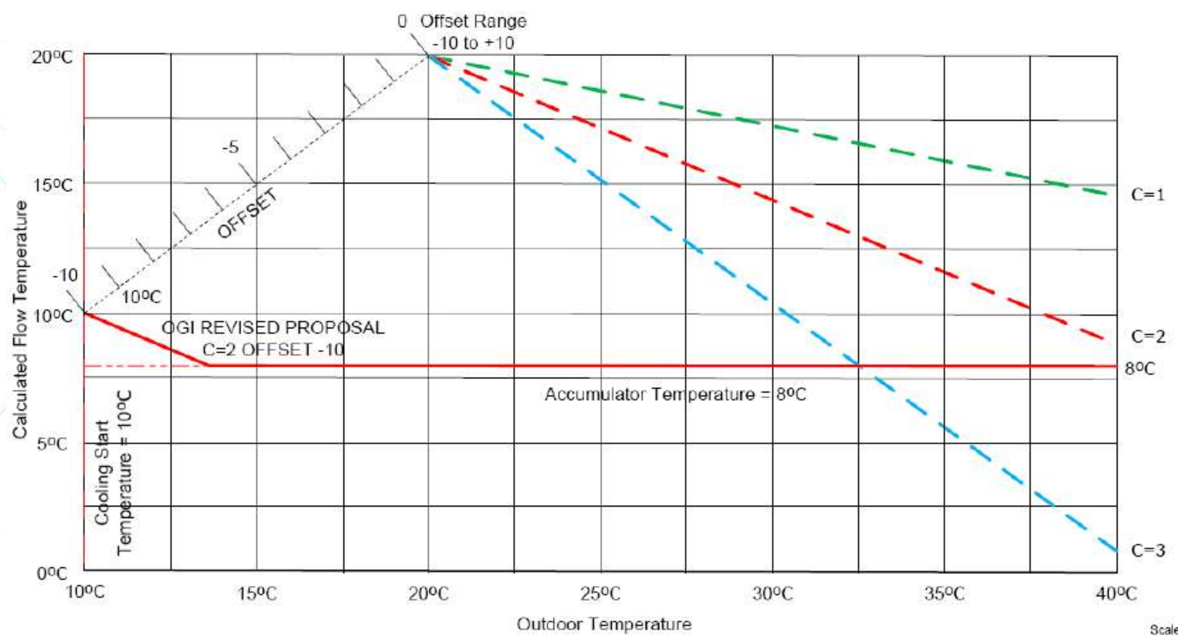


The final task is to agree the output targets with the Building Operator before the Heat Pumps are commissioned and operational settings applied .

In this instance the Consultant Services Engineer decided that a cooling temperature of +8 ºC was required even when the outside temperature was less than +15 ºC .

This meant changing the cooling curve offset from -4 (left) to -10 (below).

GROUNDWATER SPECIALISTS

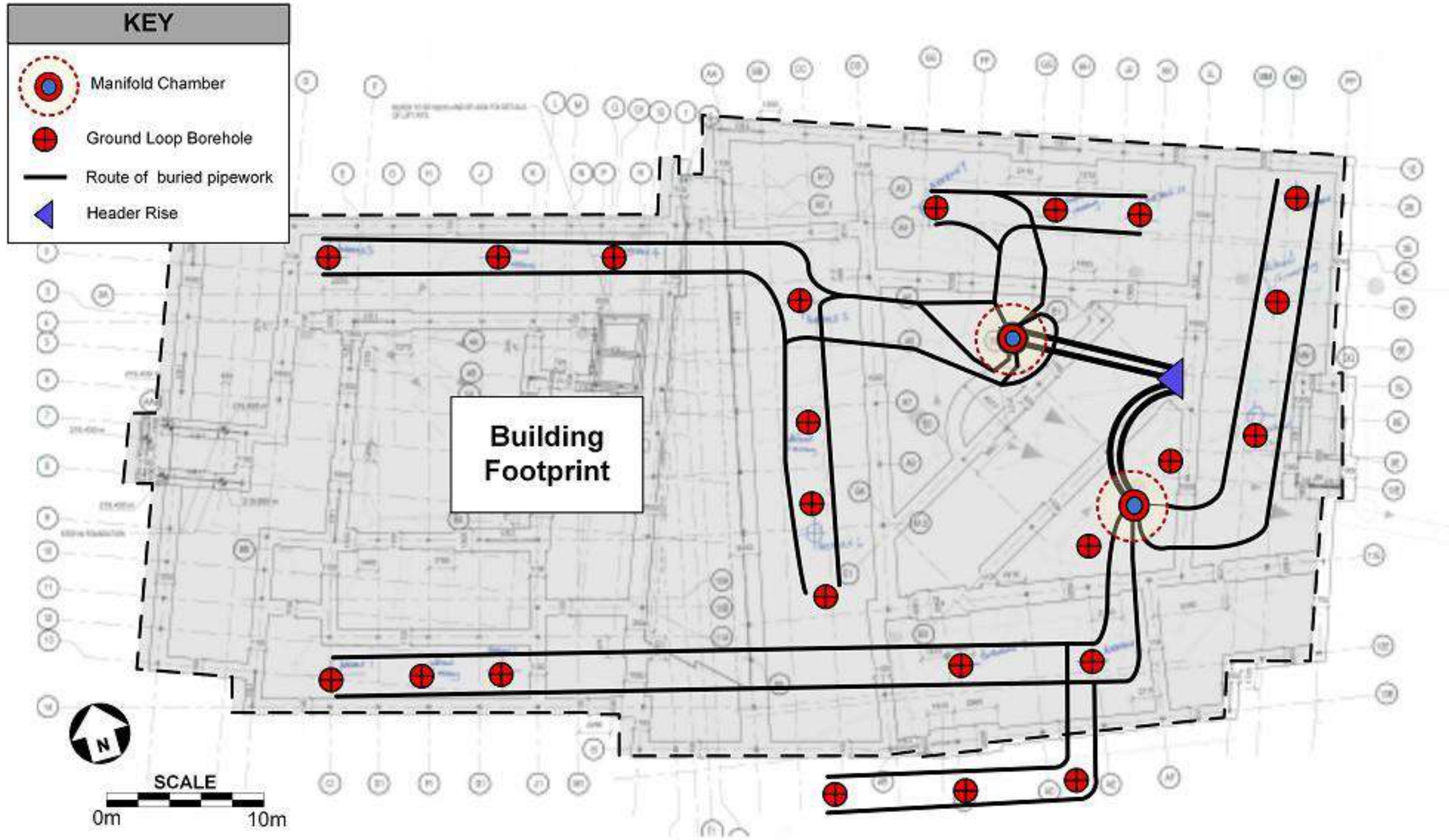


Modern Psychiatric Hospital with Low Carbon Heating & Cooling

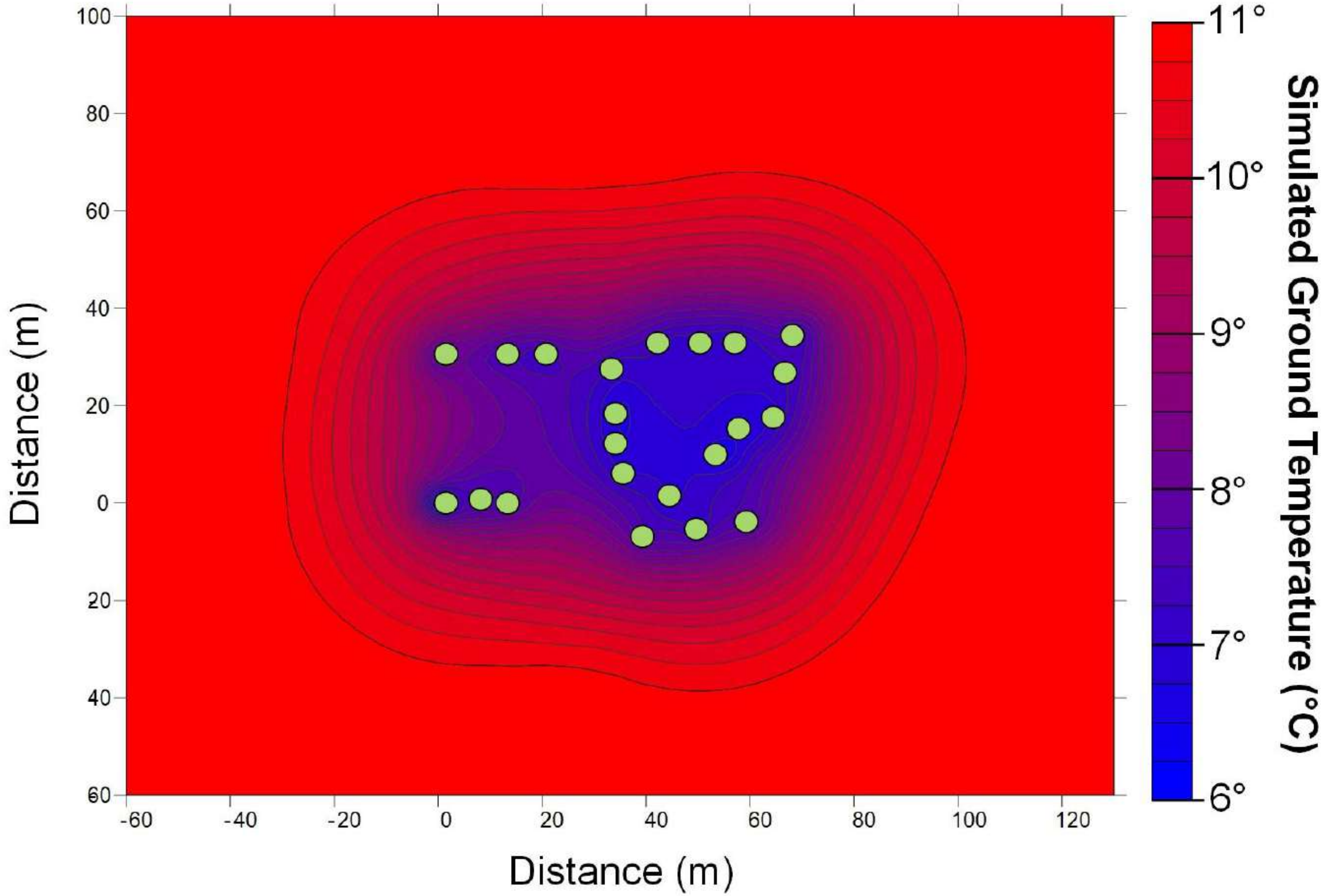
Primary Care Centre

Stanley, UK

Primary Care Centre - Stanley, UK



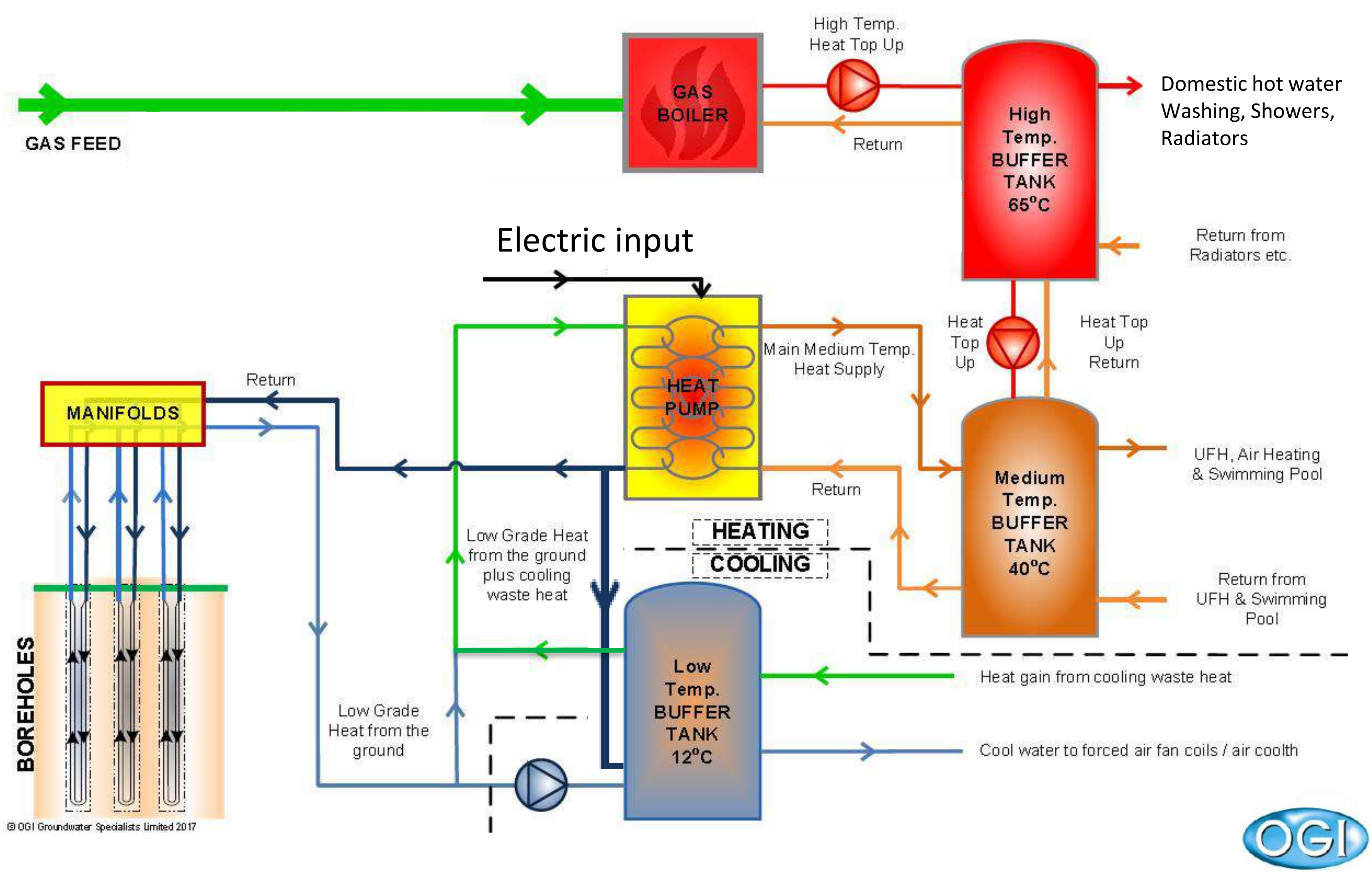
Primary Care Centre - Stanley, UK



Trenches prepared for connecting heat collector pipes

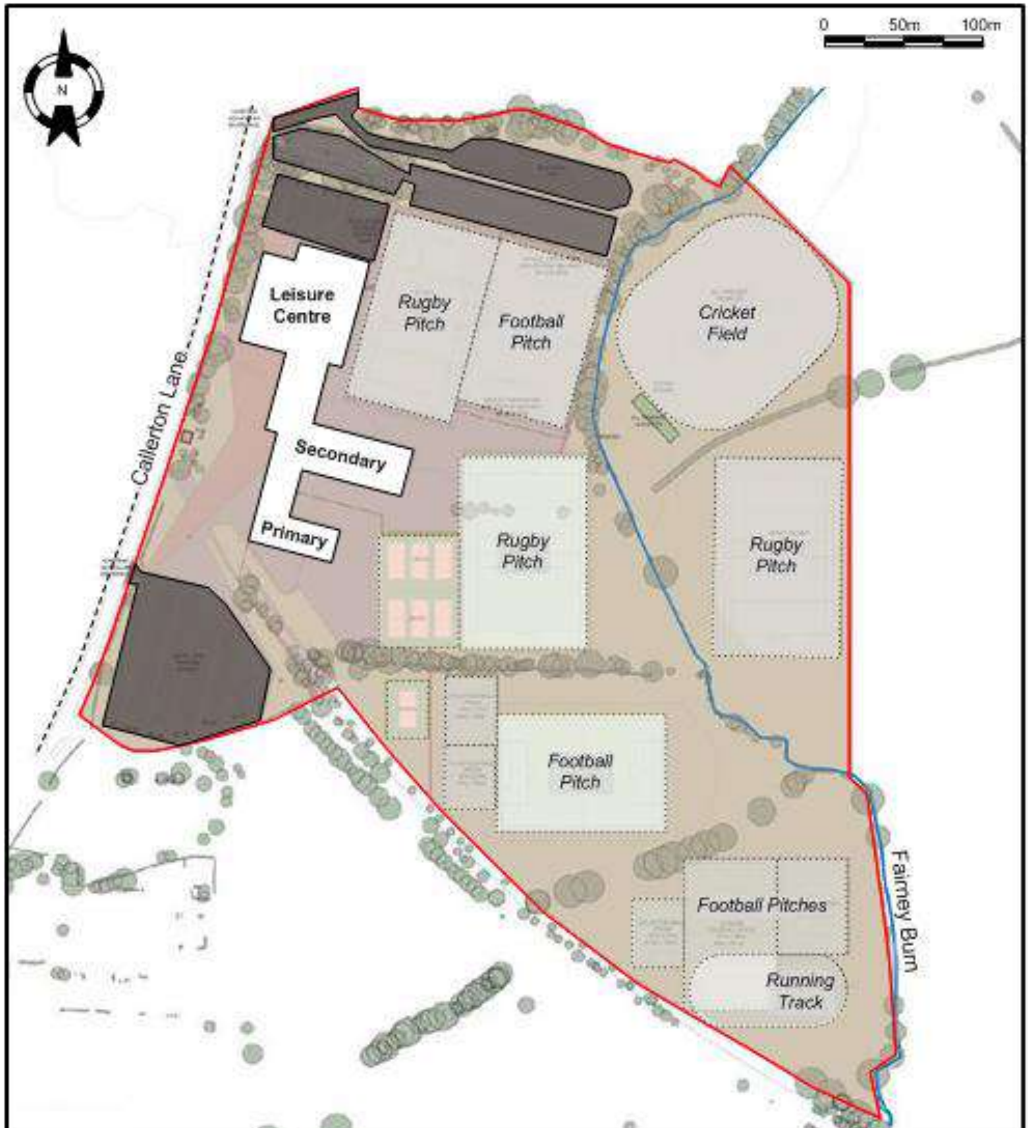
Fusing Connection of pipes with the Manifold Chamber

STANLEY CARE CENTRE (ACTIVE COOLING)



Plant Room housing Low Carbon Heating & Cooling System

PONTELAND



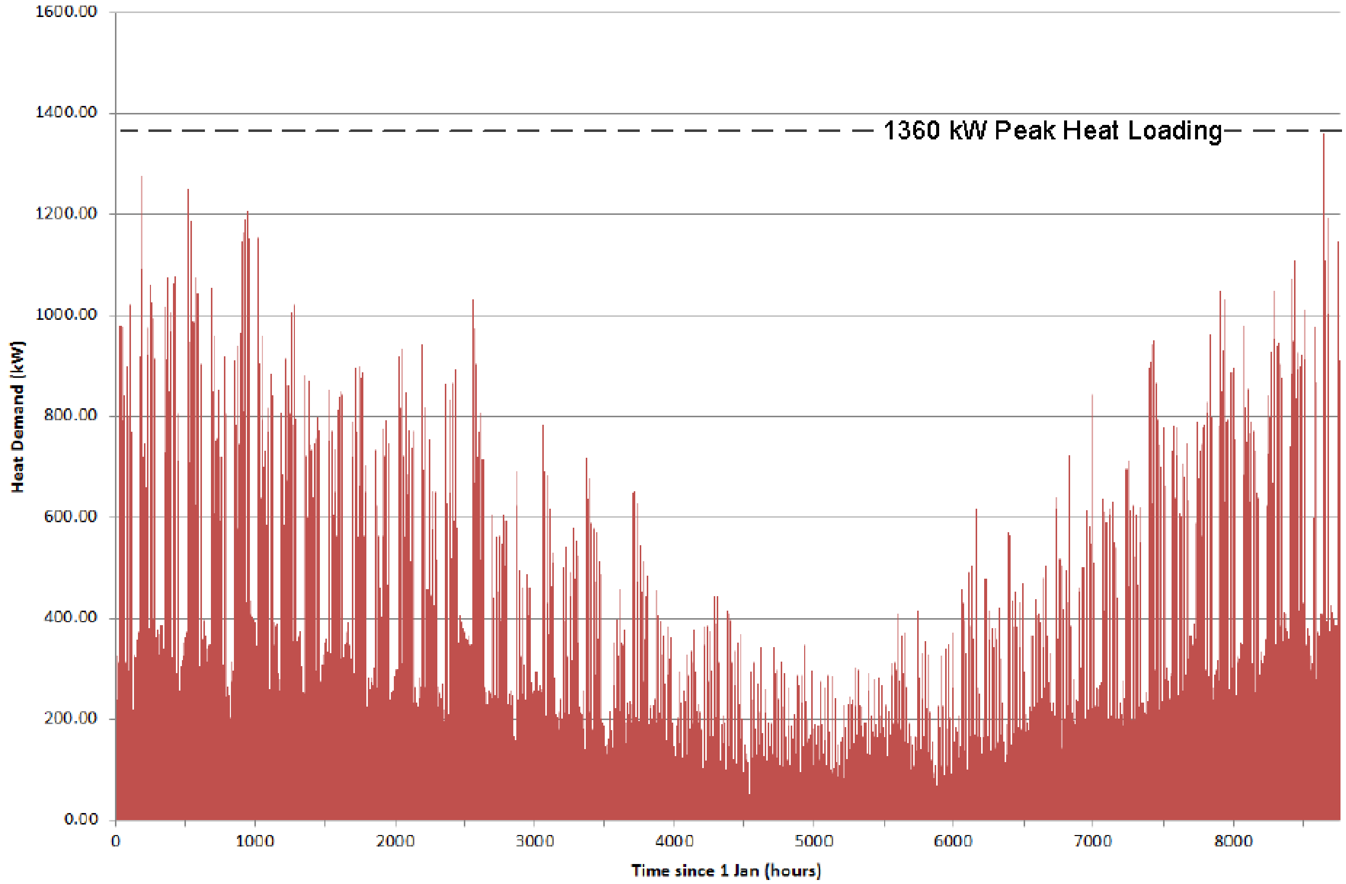
- Primary school, Secondary school and Leisure centre.
- Combined heating system required for all three buildings.
- Cooling system to accommodate the leisure centre and secondary school IT rooms.
- Underfloor heating 1500m^2
- Required temp output 40°C

PONTELAND

Peak heat loading required = 1360 kW

Required annual heat loading = 2300 MWh/a

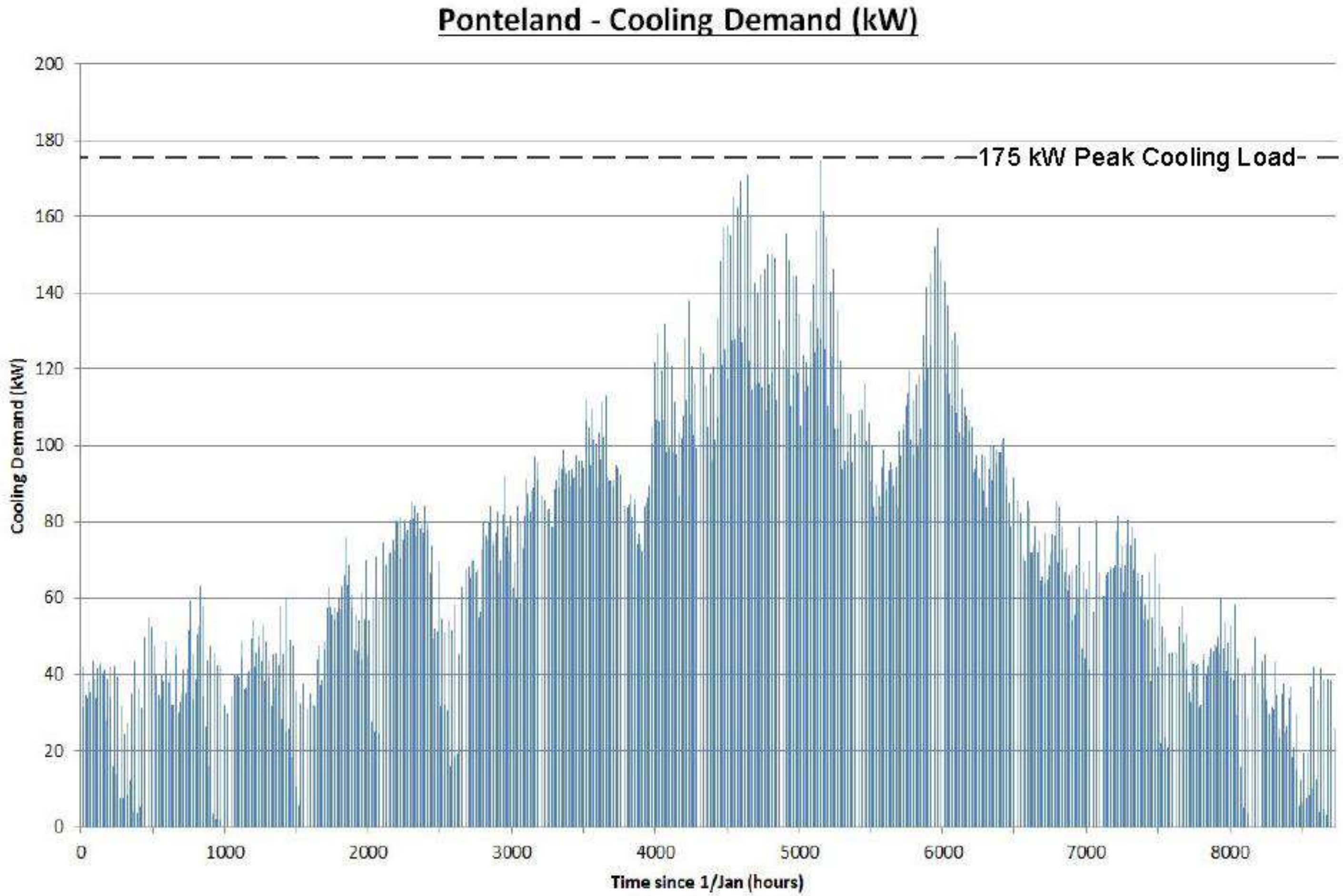
Ponteland – Heat Demand



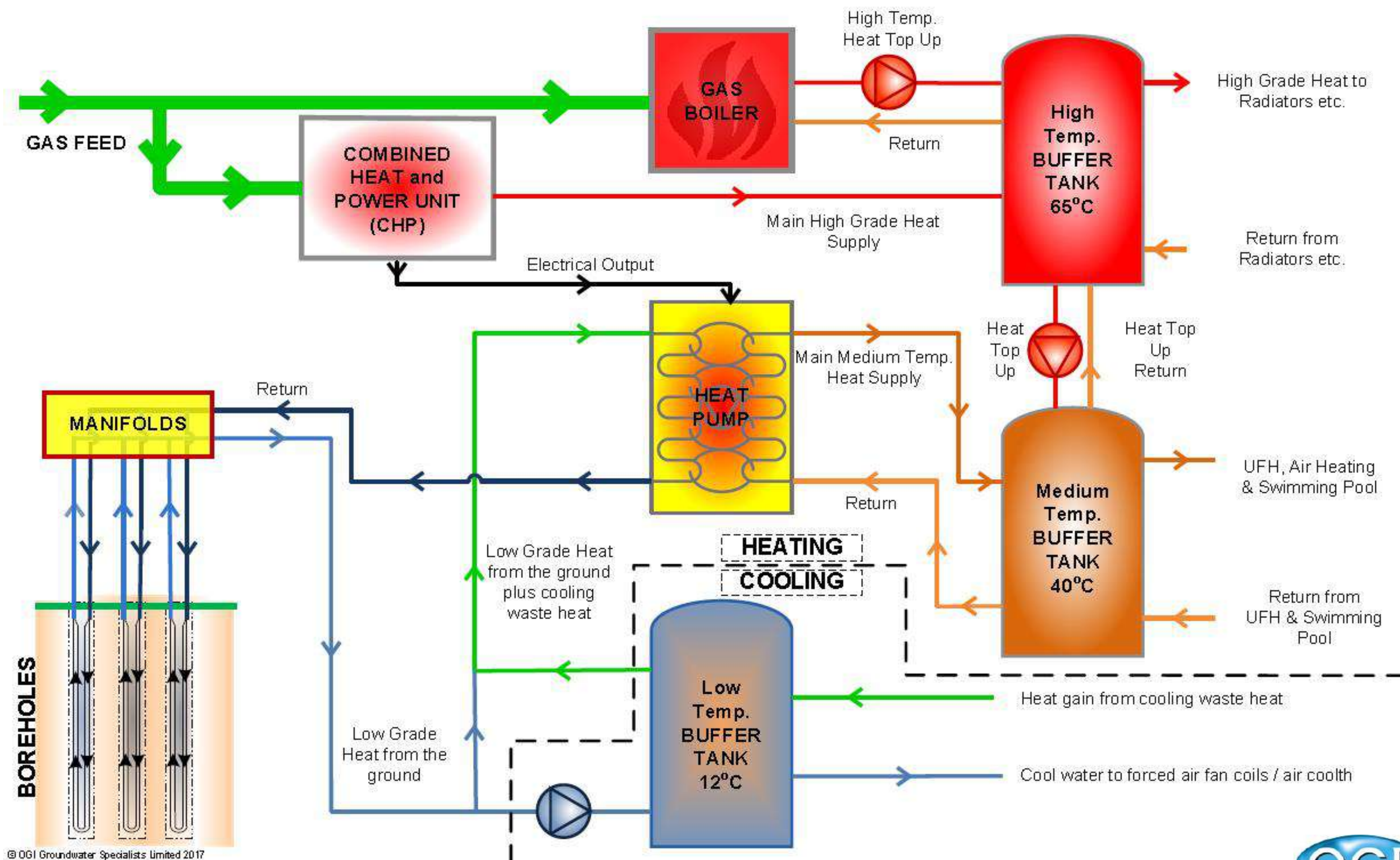
PONTELAND

Peak heat loading required = 1360 kW

Required annual heat loading = 2300 MWh/a

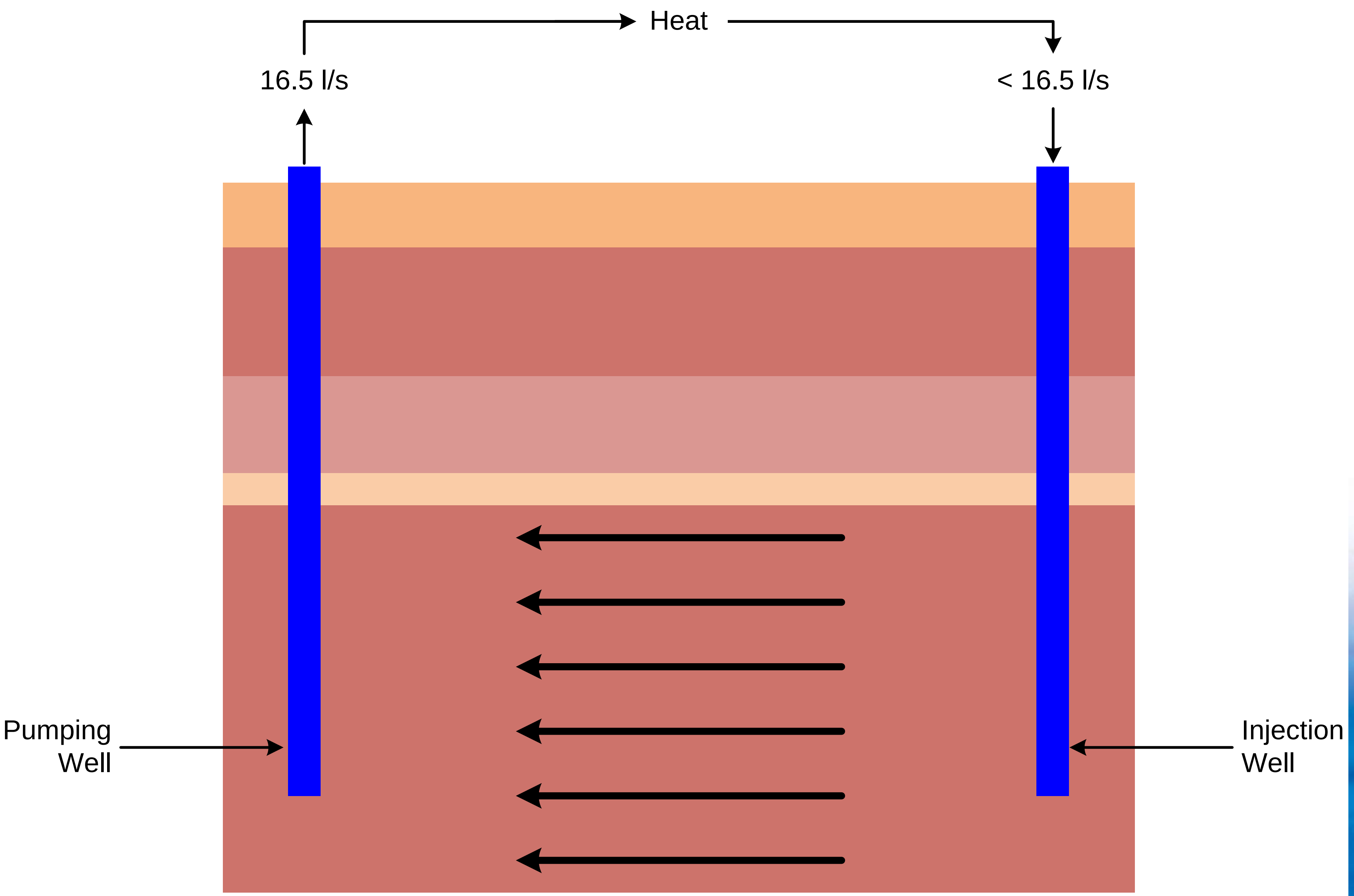


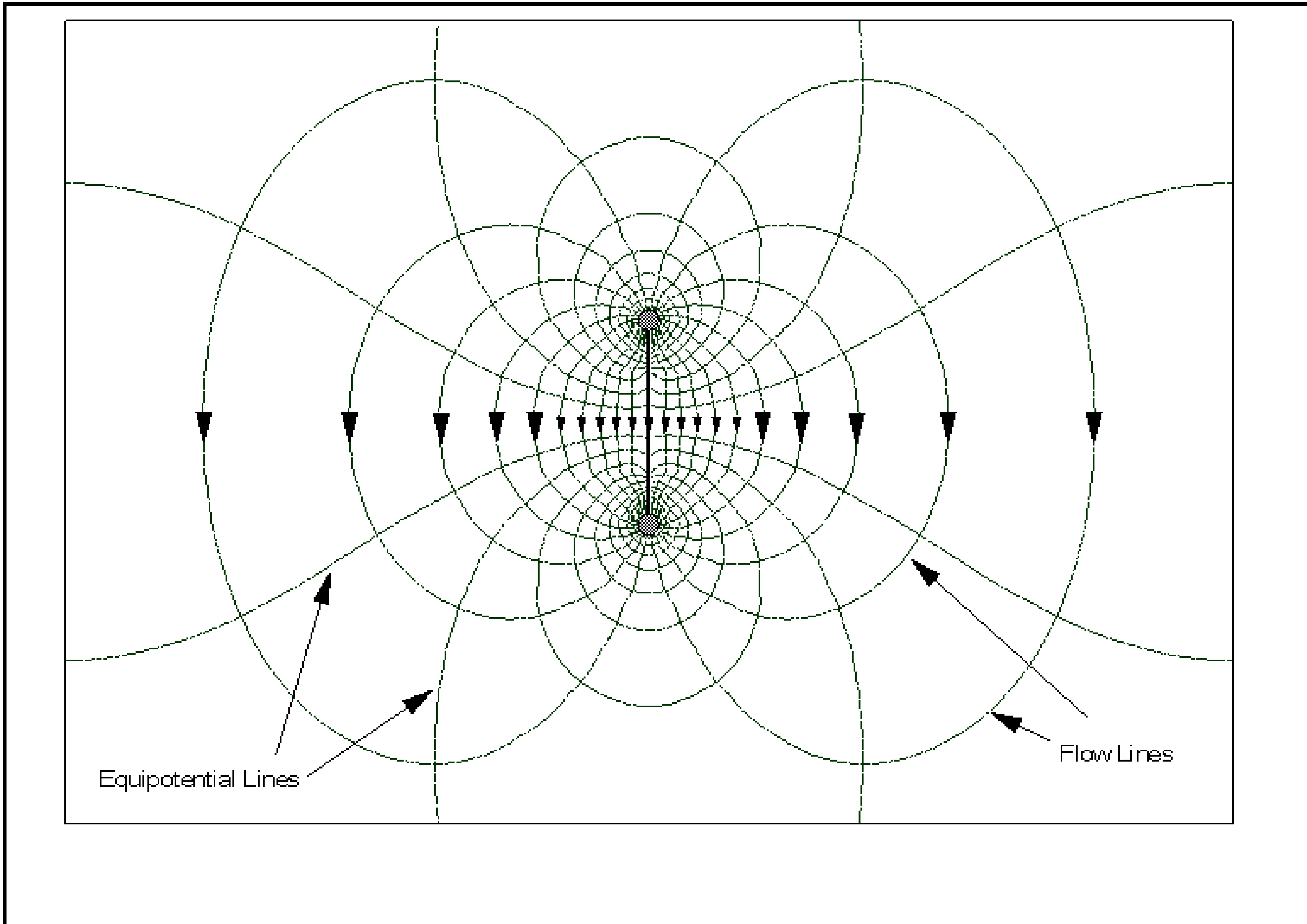
PONTELAND (PASSIVE COOLING)



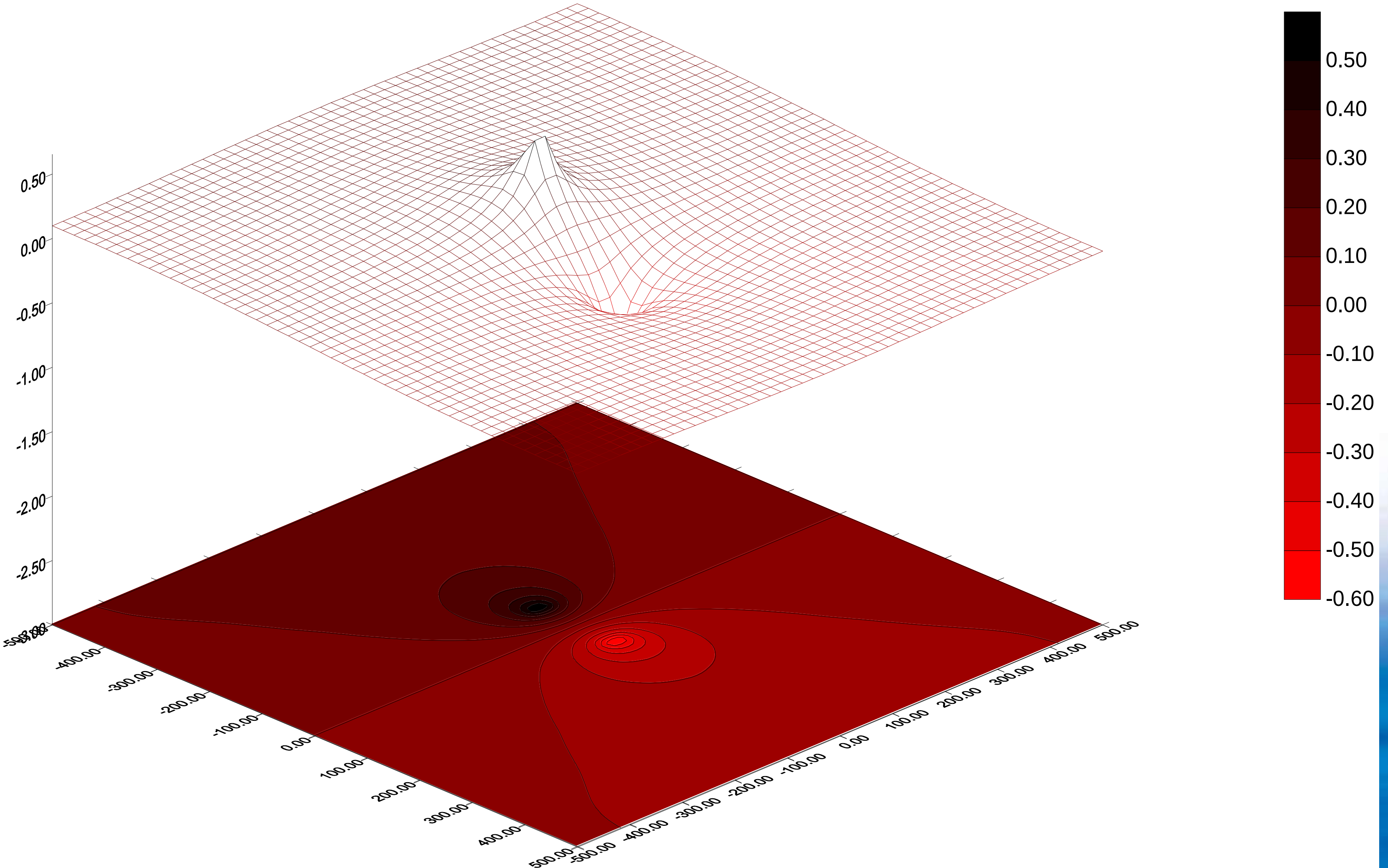
Groundwater Energy

- Groundwater energy, sometimes called ‘open loop’ systems, provide energy to the heat pump by abstracting heat from pumped groundwater from an aquifer.
- The water leaving the heat pump (cold after heating the building, warm after cooling the building) can be piped to a watercourse or pumped back into the aquifer.
- Good practice is to balance annual heating and cooling energy.

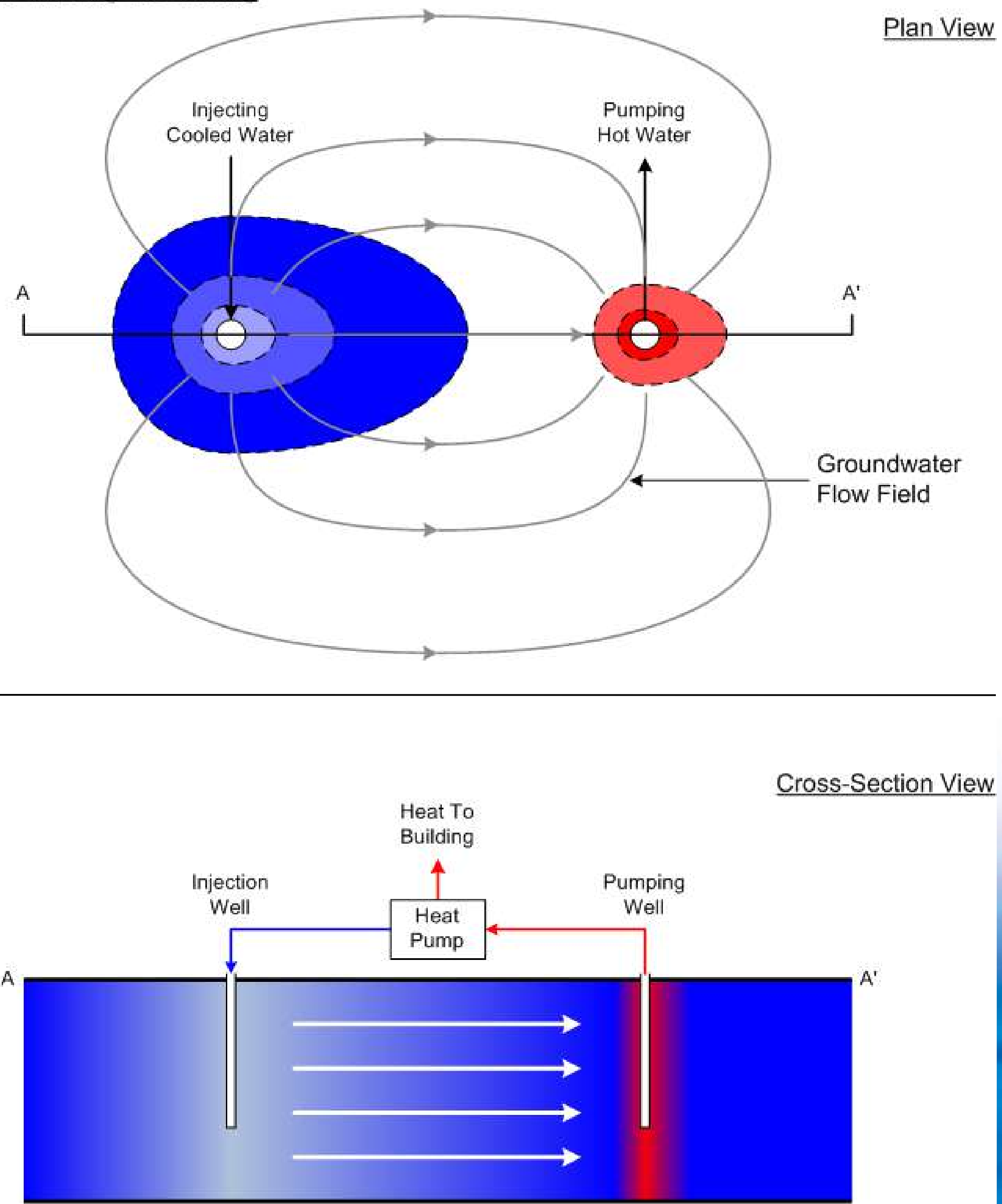

Heat
16.5 l/s
< 16.5 l/s
Pumping Well
Injection Well


Equipotential Lines
Flow Lines

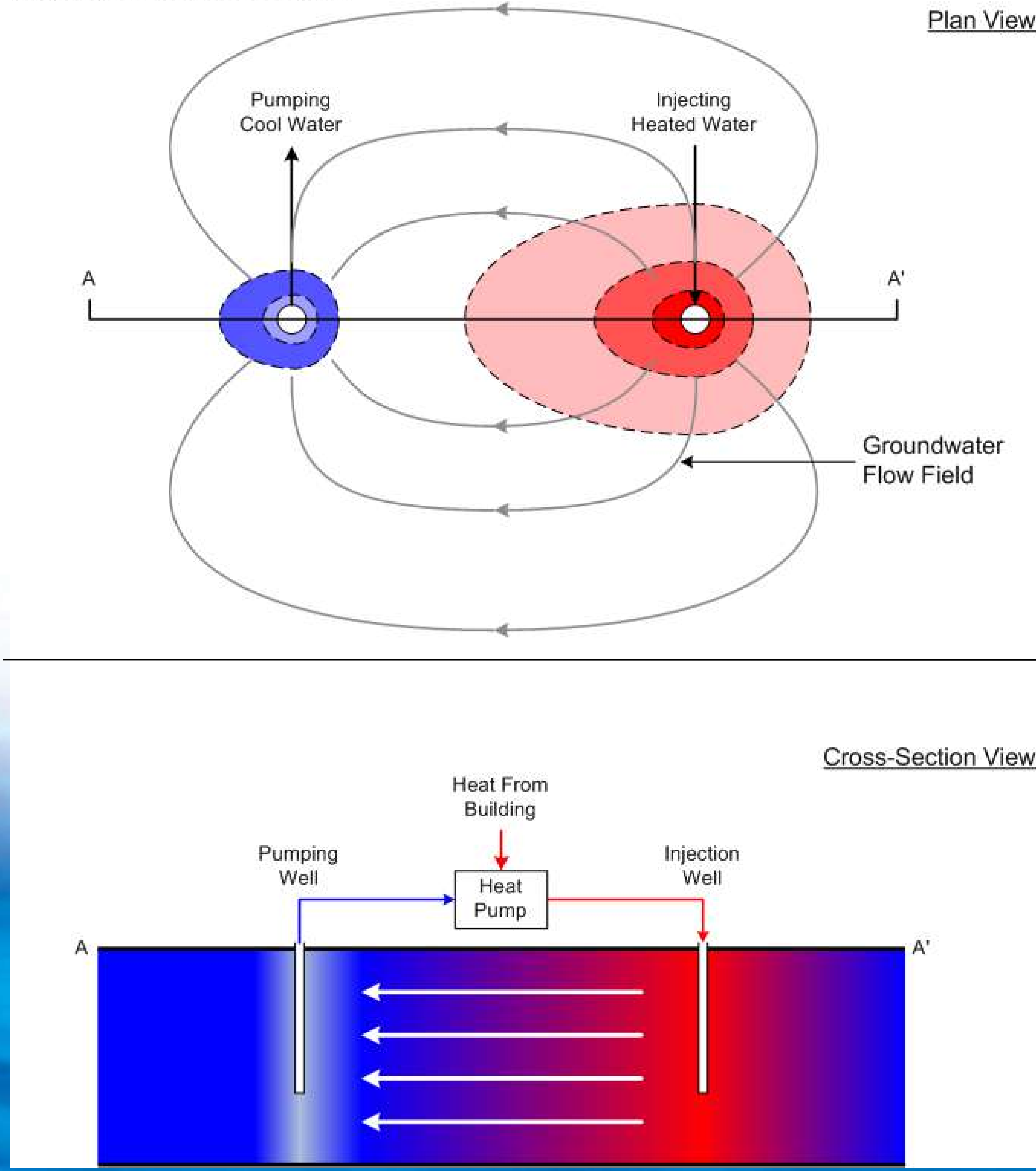
Steady state piezometric level distribution for open loop Geothermal system (Test Problem)



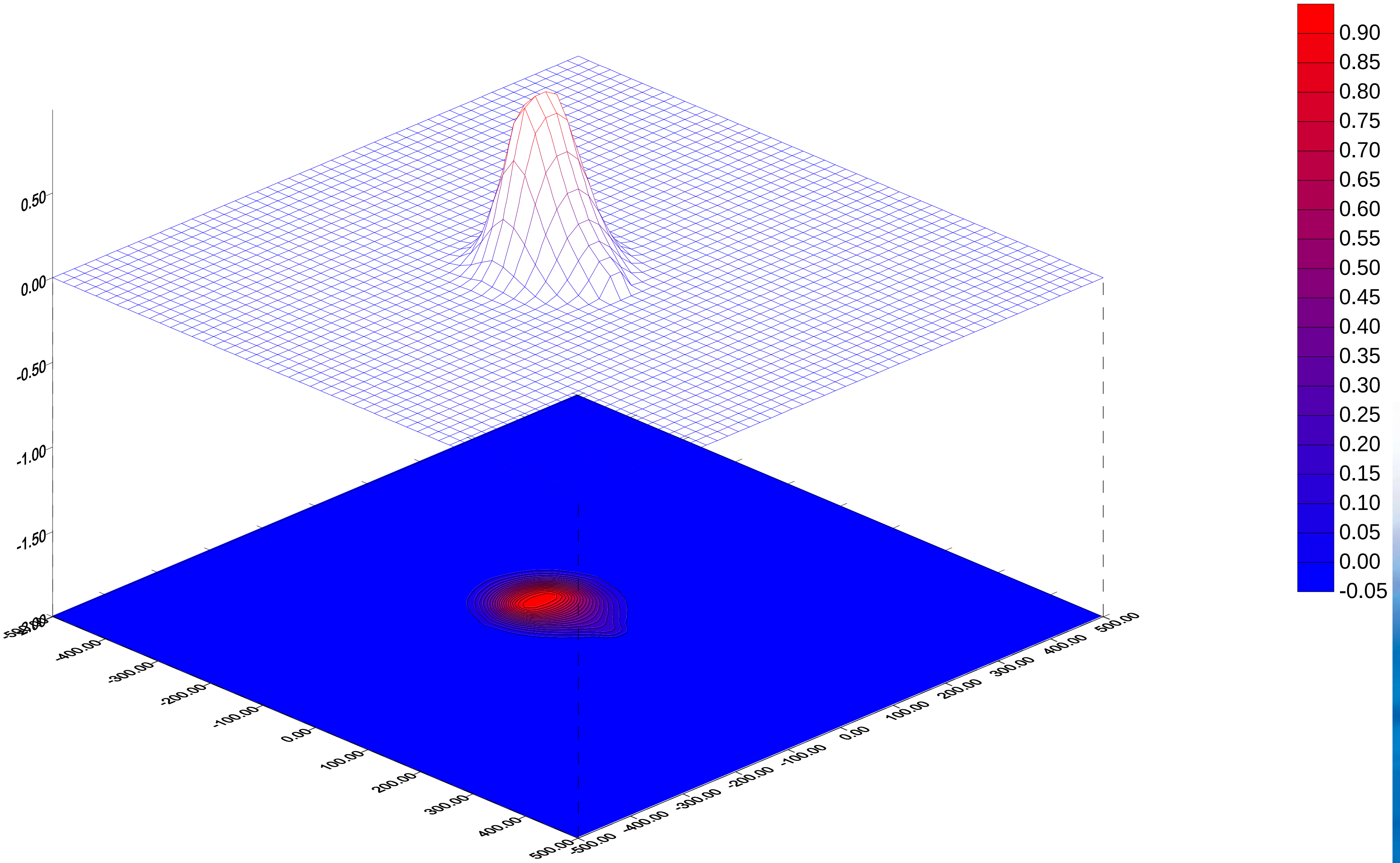
Winter Heating of Building

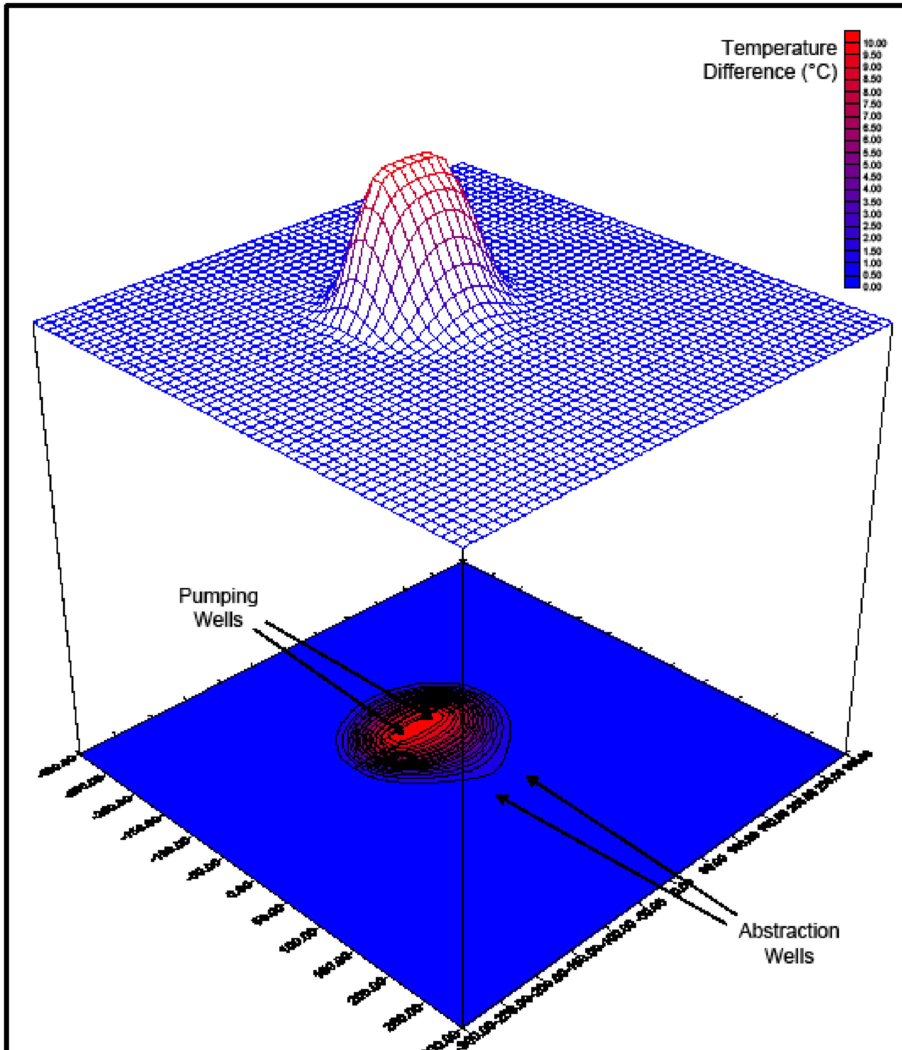


Summer Cooling of Building



Temperature distribution for open loop Geothermal system at 10 days
(Test Problem)

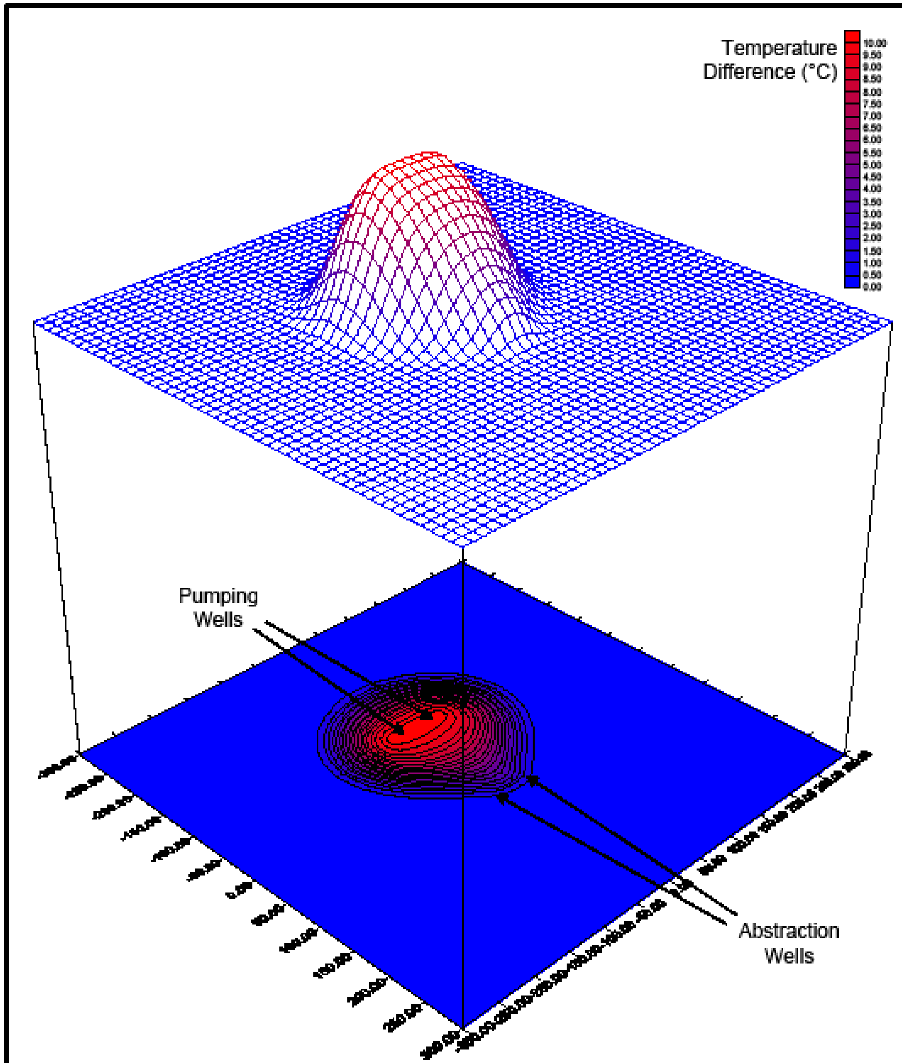




2.341 mm

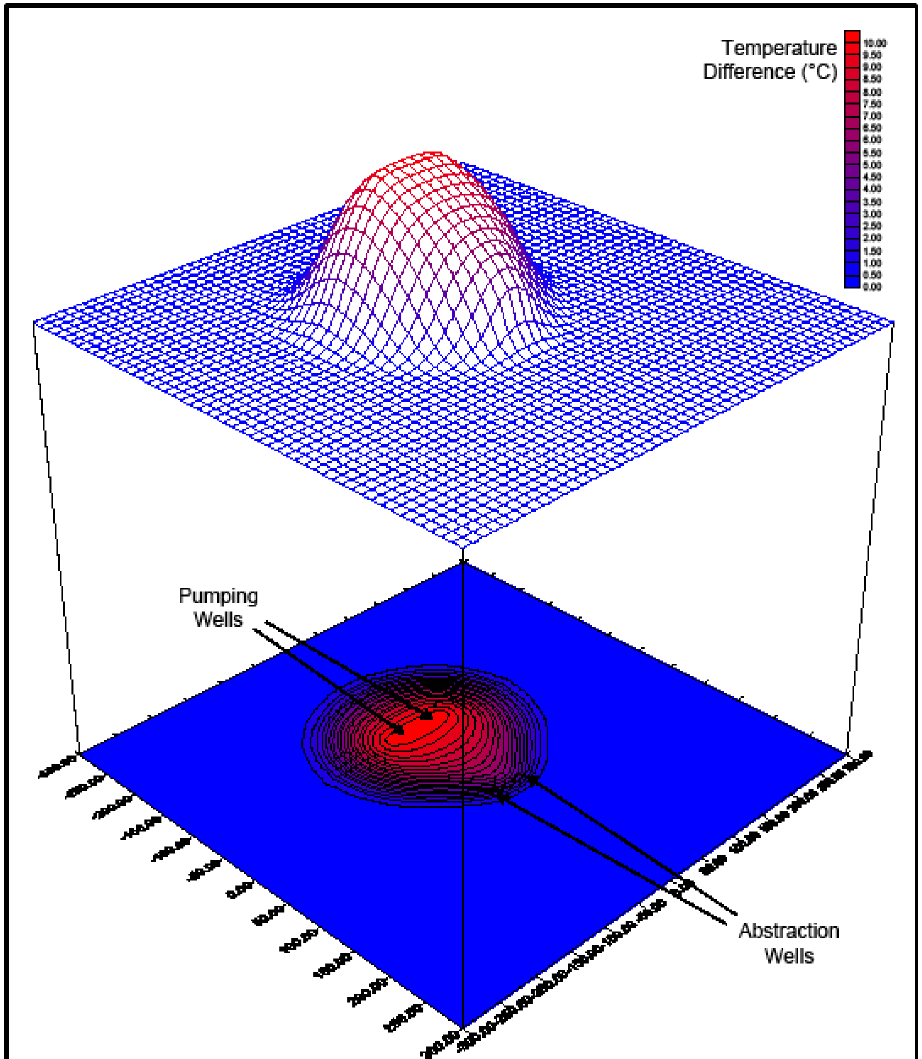
Scale: None
Drawing based on: Model 035S

OGI Groundwater Specialists	Project: Ground Source Live	Drawing: Figure 1
	Client: GeoDrilling	Description: Time Step 1
	Date: 12th March 2009	Drawn by: JG / Checked by: ST



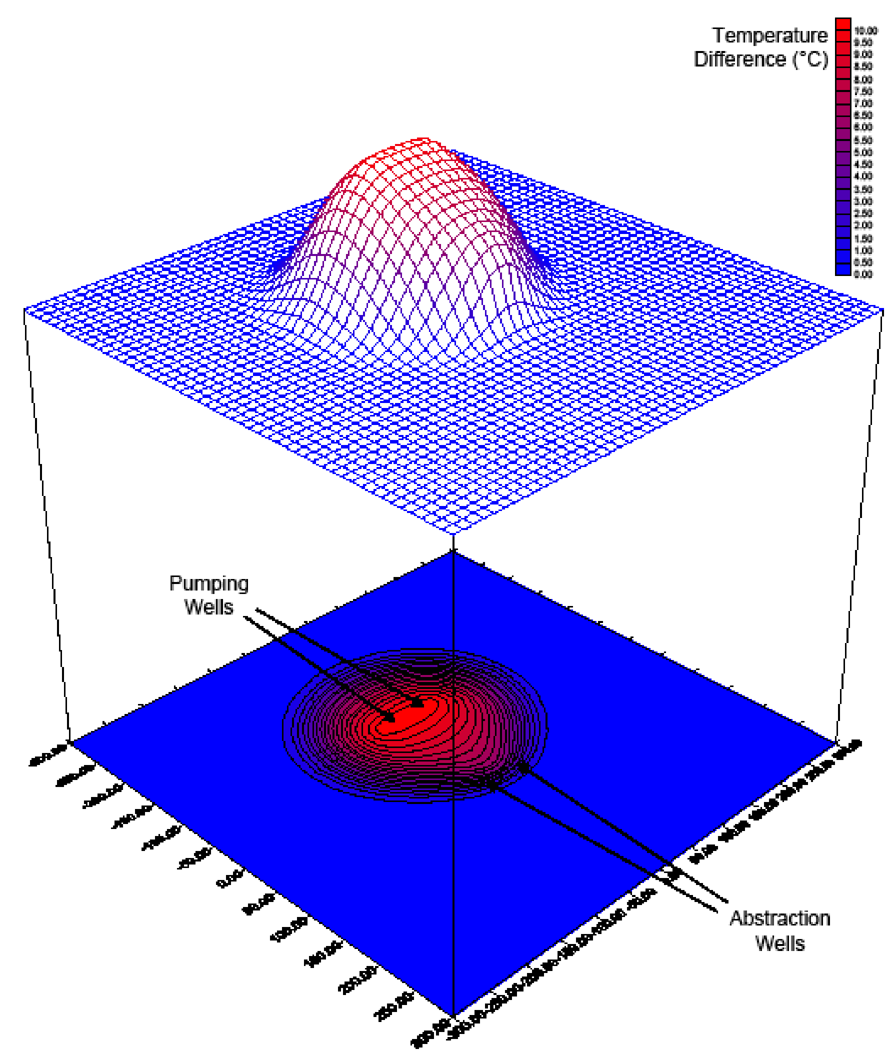
Scale: None
Drawing based on: Model 035S

OGI Groundwater Specialists	Project: Ground Source Live	Drawing: Figure 2	
	Client: GeoDrilling	Description: Time Step 2	
	Date: 12th March 2009	Drawn by: JG	Checked by: ST



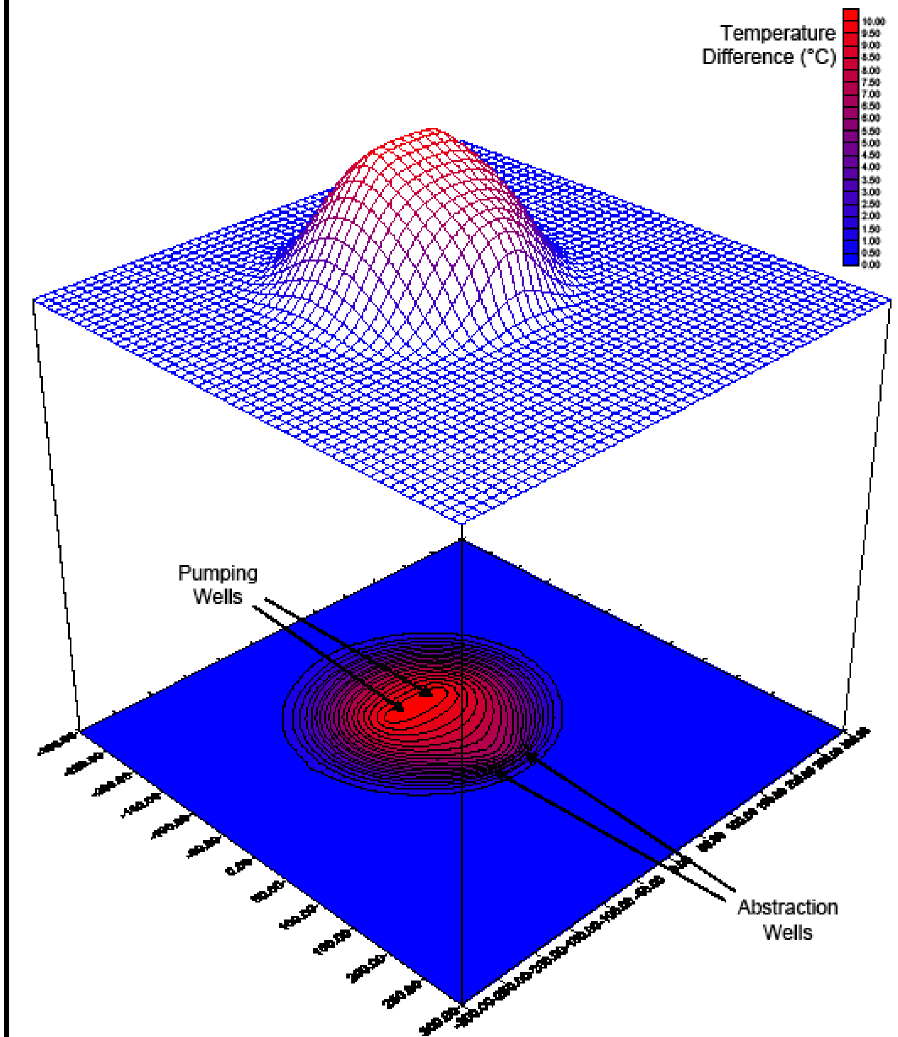
Scale: None
Drawing based on: Model 035S

OGI Groundwater Specialists	Project: Ground Source Live	Drawing: Figure 3	
	Client: GeoDrilling	Description: Time Step 3	
	Date: 12th March 2009	Drawn by: JG	Checked by: ST



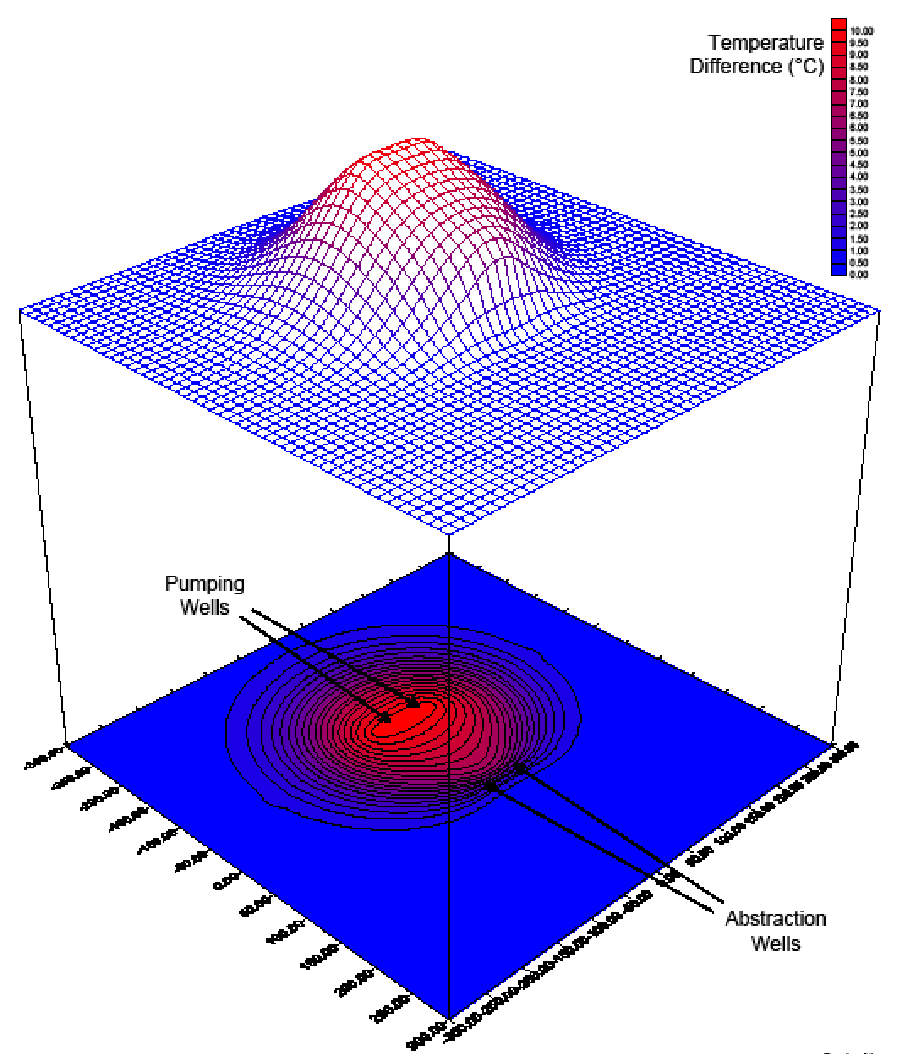
Scale: None
Drawing based on: Model 035S

Groundwater Specialists	Project: Ground Source Live	Drawing: Figure 4	
	Client: GeoDrilling	Description: Time Step 4	
	Date: 12th March 2009	Drawn by: JG	Checked by: ST



Scale: None
Drawing based on: Model 035S

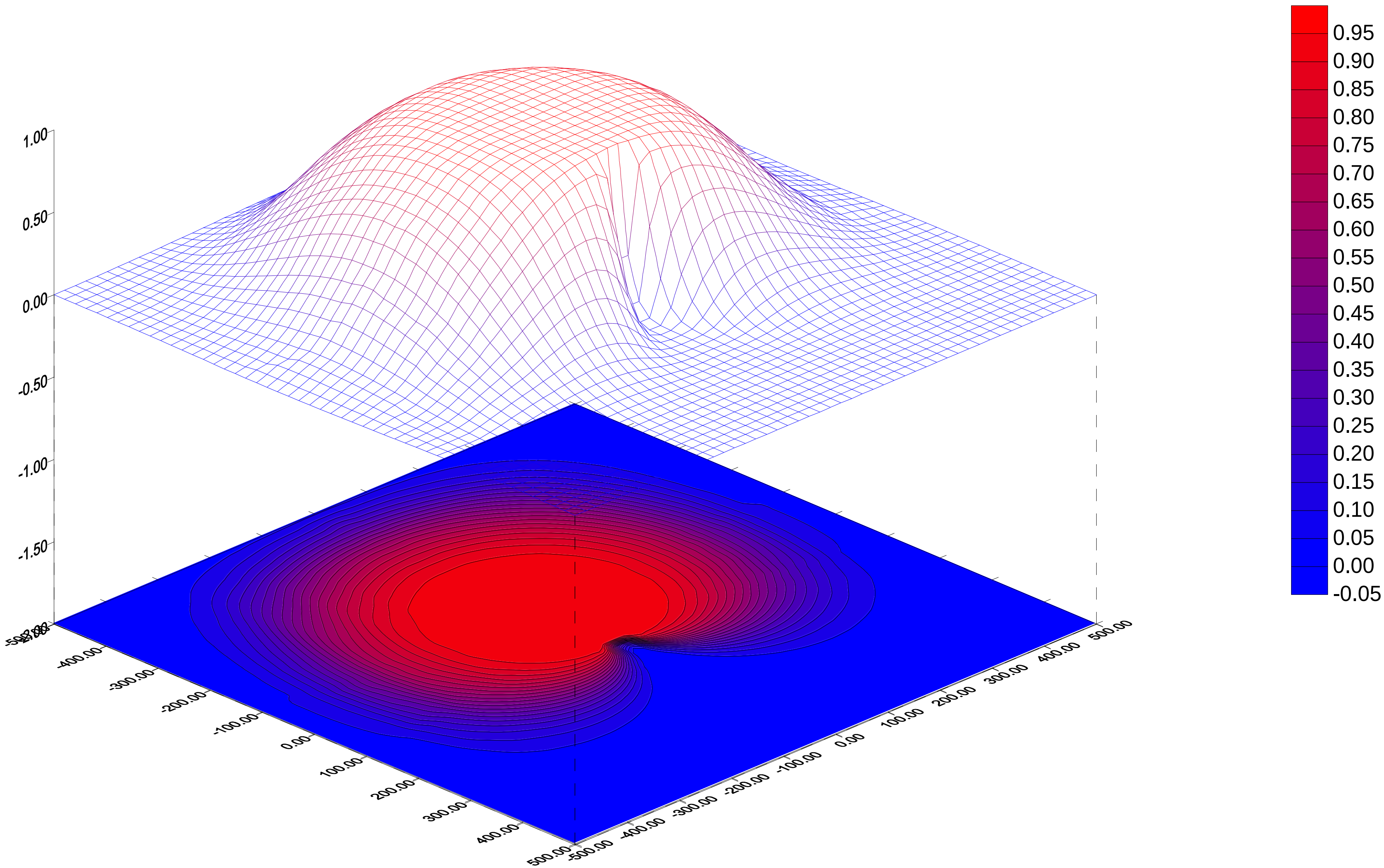
Groundwater Specialists	Project: Ground Source Live	Drawing: Figure 5
	Client: GeoDrilling	Description: Time Step 5
	Date: 12th March 2009	Drawn by: JG / Checked by: ST

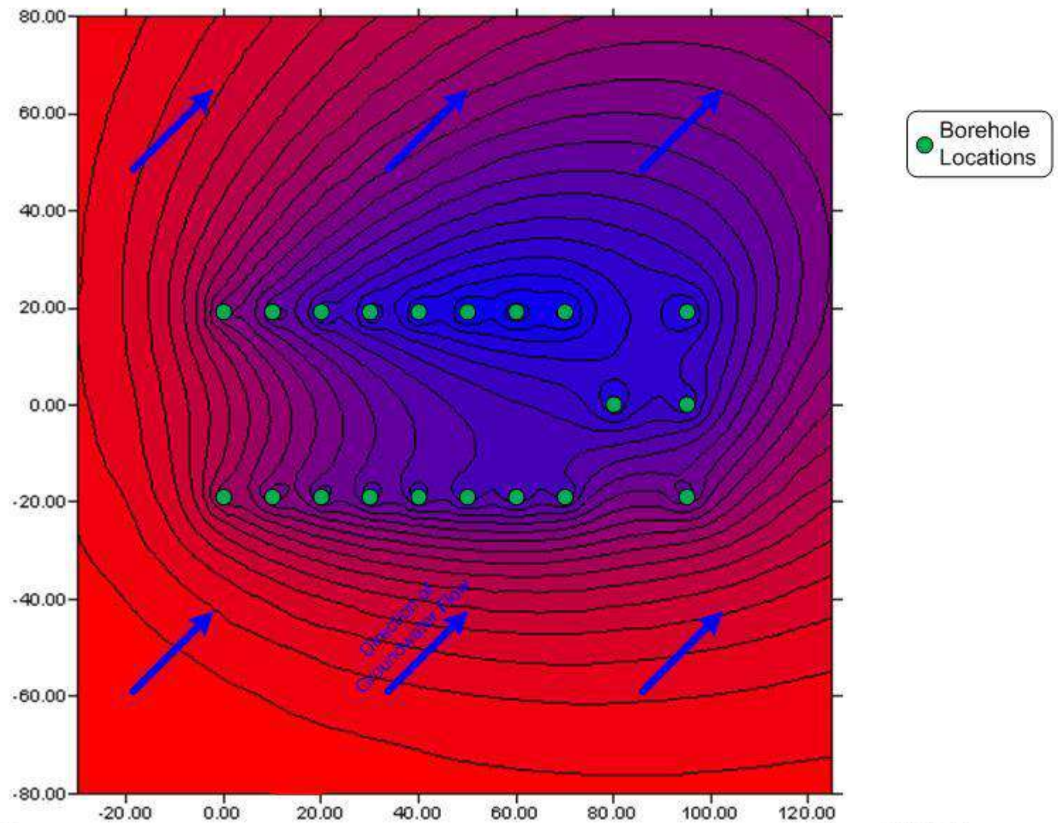


Scale: None
Drawing based on: Model 034S

Groundwater Specialists	Project: Ground Source Live	Drawing: Figure 6	
	Client: GeoDrilling	Description: Time Step 6	
	Date: 12th March 2009	Drawn by: JG	Checked by: ST

Temperature distribution for open loop Geothermal system at 1000 days
(Test Problem)

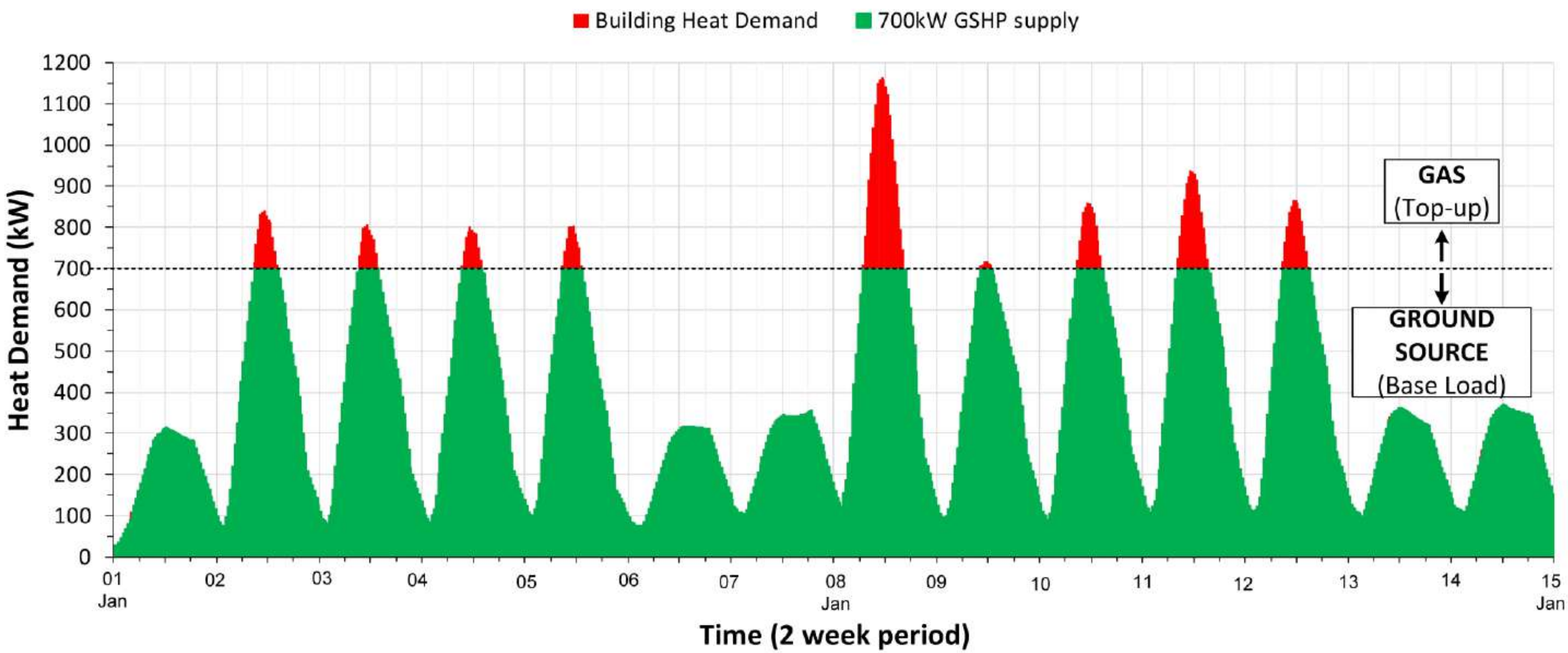


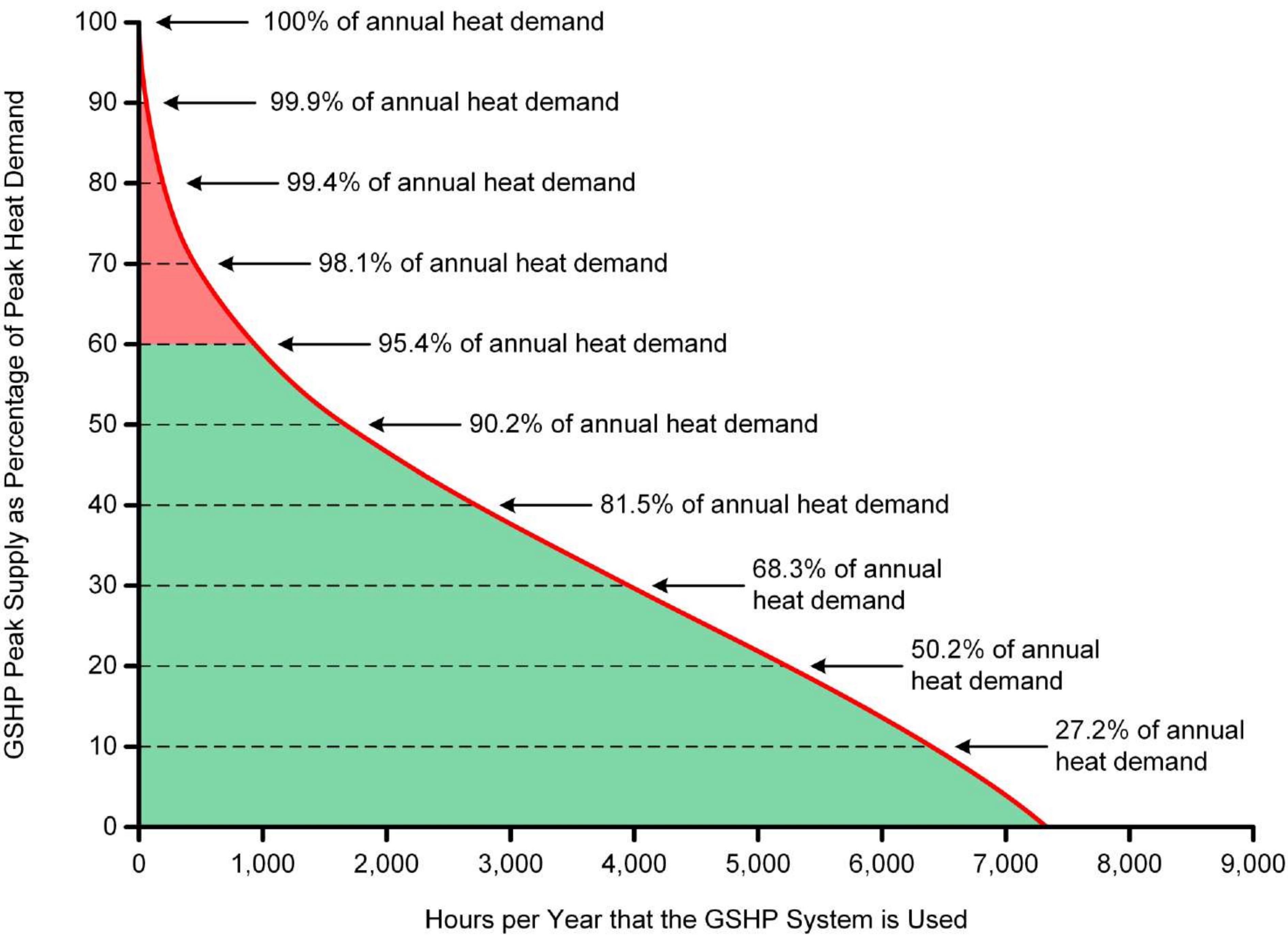


Source: J08/299/010S

OGI Groundwater Specialists	**Project:** Ground Source Live	**Drawing:** Figure 7	**Date:** 12th March 2009	
	Client: GeoDrilling	**Description:** Ground Temperature at 50 Years With Groundwater Flow	**Drawn by:** RS	**Checked by:** BS

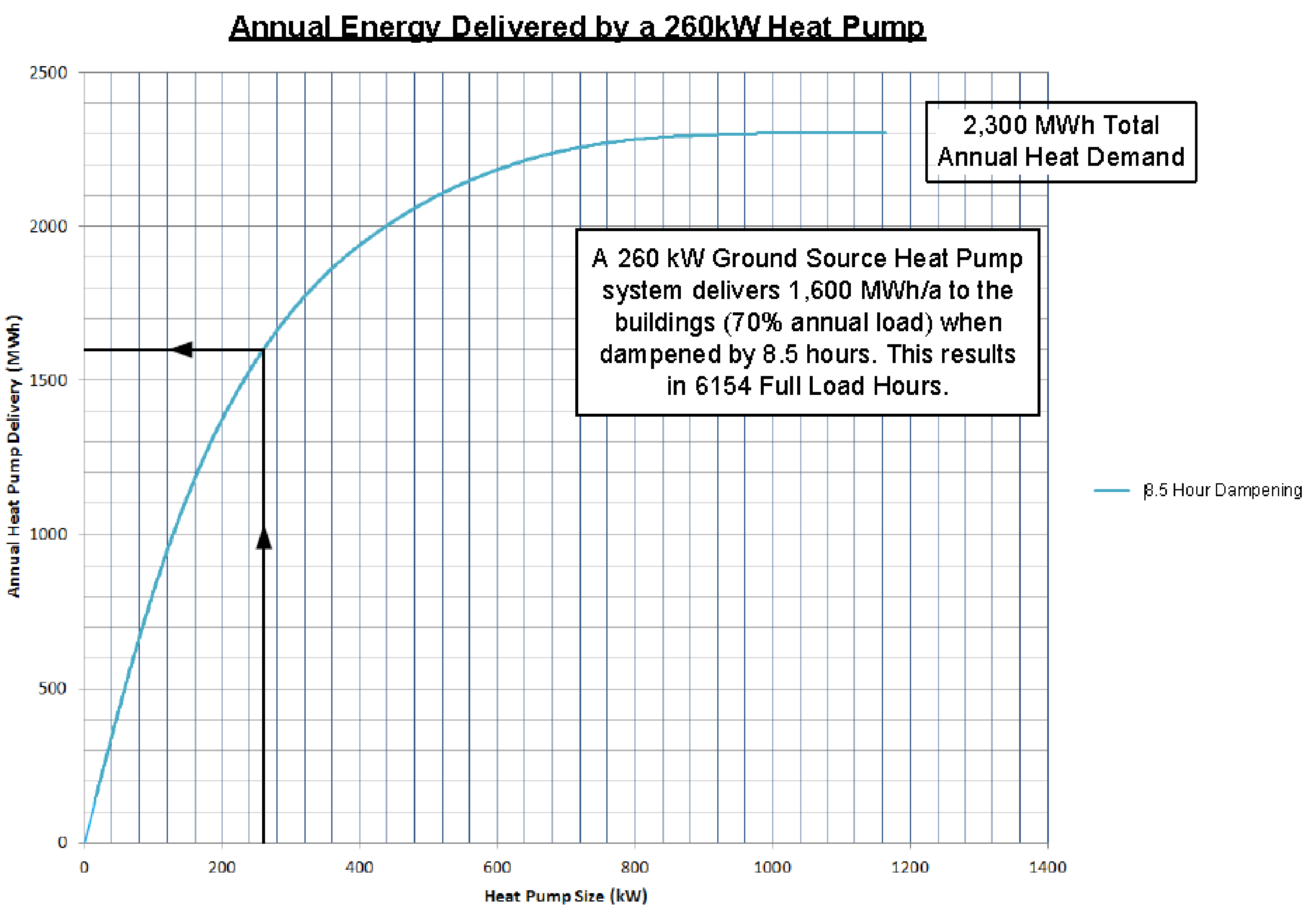
Peak Heat vs base Load





100% of annual heat demand
99.9% of annual heat demand
99.4% of annual heat demand
98.1% of annual heat demand
95.4% of annual heat demand
90.2% of annual heat demand
81.5% of annual heat demand
68.3% of annual heat demand
50.2% of annual heat demand
27.2% of annual heat demand
GSHP Peak Supply as Percentage of Peak Heat Demand
Hours per Year that the GSHP System is Used
0
10
20
30
40
50
60
70
80
90
100
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000

MWh/a vs kW


Annual Energy Delivered by a 260kW Heat Pump
2500
2000
1500
1000
500
0
0
200
400
600
800
1000
1200
1400
Heat Pump Size (kW)
Annual Heat Pump Delivery (MWh)
2,300 MWh Total Annual Heat Demand
A 260 kW Ground Source Heat Pump system delivers 1,600 MWh/a to the buildings (70% annual load) when dampened by 8.5 hours. This results in 6154 Full Load Hours.
8.5 Hour Dampening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Thank you and Goodbye
Obrigado e Adeus
OGI