UNIVERSITY OF CAMBRIDGE

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GSHP Application at City Scale
Case Study of Westminster

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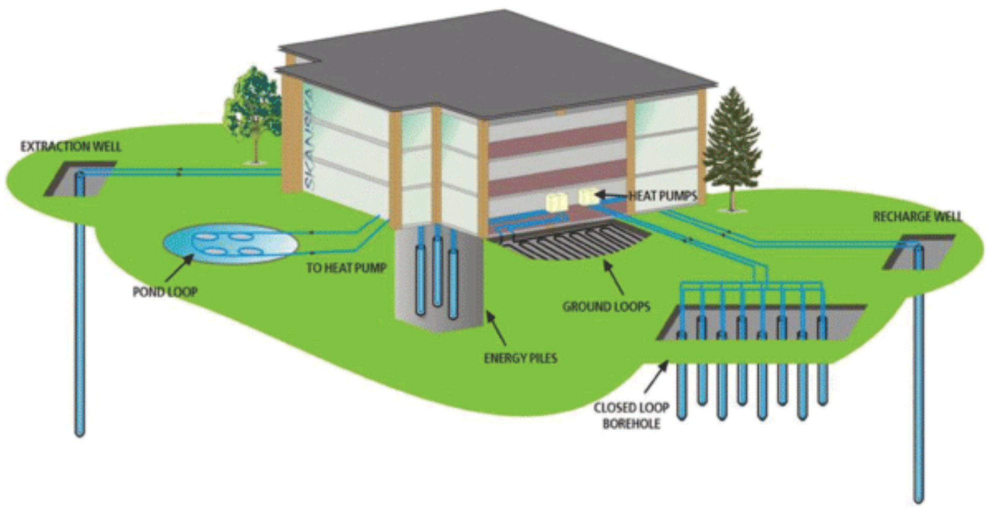
Aim

- Develop a ‘City-scale geothermal simulation tool’;
- Examine the geothermal energy potential at a certain city;
- Identify how many GSHPs can be installed in contributing to the heating and cooling demand of buildings and infrastructures at the city scale.



Theoretical Geothermal Potential Calculation

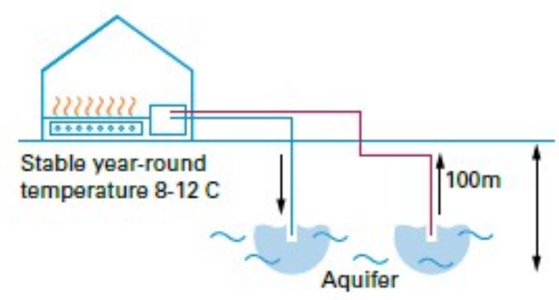
$$Q = Q_w + Q_s = V(nC_w + (1-n)C_s)\Delta T$$

Q is the total theoretical heat potential content (kJ), Q_w and Q_s are the heat content stored in ground water and solid (soil) respectively (kJ), V is the volume of the ground (m^3), n is the porosity, C_w and C_s are the volumetric heat capacities of water and solid in kJ/(m^{3}K) respectively, and DT is the temperature change of the whole ground in Kelvin.

	London		Beijing	
	Min	Max	Min	Max
Thickness (m)	150	150	150	150
Area(km^2)	1707	1707	16808	16808
Volume of urban ground (m^3)	2.56×10^{11}	2.56×10^{11}	2.52×10^{12}	2.52×10^{12}
Porosity	0.05[a]	0.2[a]	0.2 [a]	0.3[a]
Temperature reduction (K)	4	6	4	6
Potential heat content (kJ)	9.91×10^{14}	2.26×10^{15}	1.48×10^{16}	2.73×10^{16}
Potential heat content per km^2 (kJ km^{-2})	5.81×10^{11}	1.32×10^{12}	8.82×10^{11}	1.62×10^{12}
Average heating demand (kJ km^{-2} year^{-1})	5.5×10^{10}[b]		1.6×10^{10}[c]	
Capacity for heating	10.6	24.0	55.1	101.3

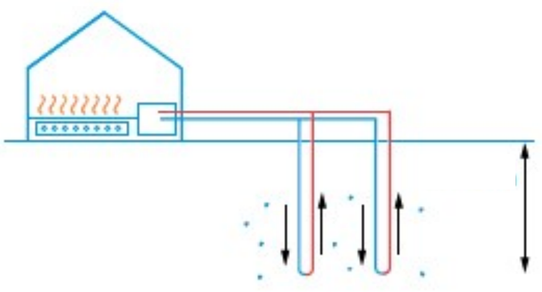
Type of GSHP

Open Loop System



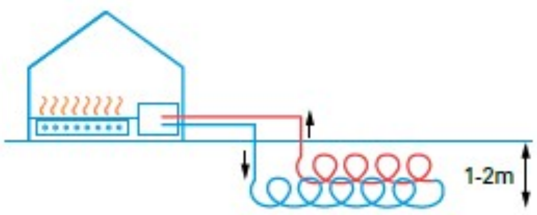
- Groundwater is extracted from and return to a suitable aquifer below the site.
- Output is dependant on how much water can be extracted.
- More efficient than closed loop systems.
- Generally more cost efficient than a closed loop system.
- Can used cooling effect of groundwater without running a heat pump.

Closed Vertical Loop System



- A heat exchange fluid is circulated through pipes laid vertically in boreholes in the ground.
- Can be used in most ground types in the earth or in ground water.
- Relatively small plots of space
- Contact with soil that varied little in temperature and thermal properties
- Consume the smallest amount of pipe and pumping energy
- Can yield the more efficient performance compared with horizontal loop system

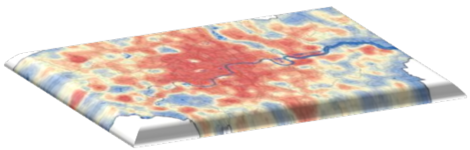
Closed Horizontal Loop System



- A heat exchange fluid is circulated through pipes laid horizontally in trenches in the ground
- A large area of ground is required – larger than vertical systems

City Scale Geothermal Capacity Simulator

Heat Consumption Map



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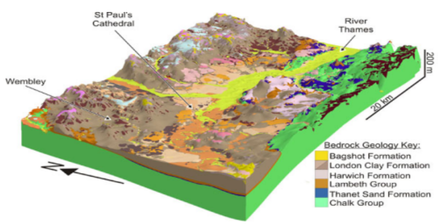
Geological Map



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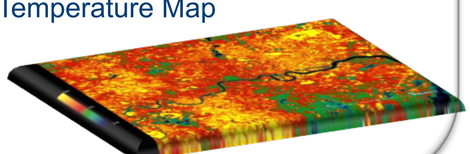
Temperature Map



Cylinder and Line Source Method

GSHP Design Code

- Borehole Installation Map
- Ratio of Capacity to Demand Map

(C/D ratio is calculated as calculated as the ratio of the maximum possible number of boreholes within the building's permitted area to the required borehole number.)

Conditions:
Distance Between Boreholes is minimum 6 meters;
Identify the areas for borehole installation;
Each Borehole Length;
Other restrictions…

Case Study of Westminster

There are 95,817 buildings within this district and 83% of the floor area is made up of residences (42%), offices (32%), and retail (9%). The remaining 17% of the built-up floor area includes hotels, schools, hospitals and leisure facilities.

Borehole Installation Area

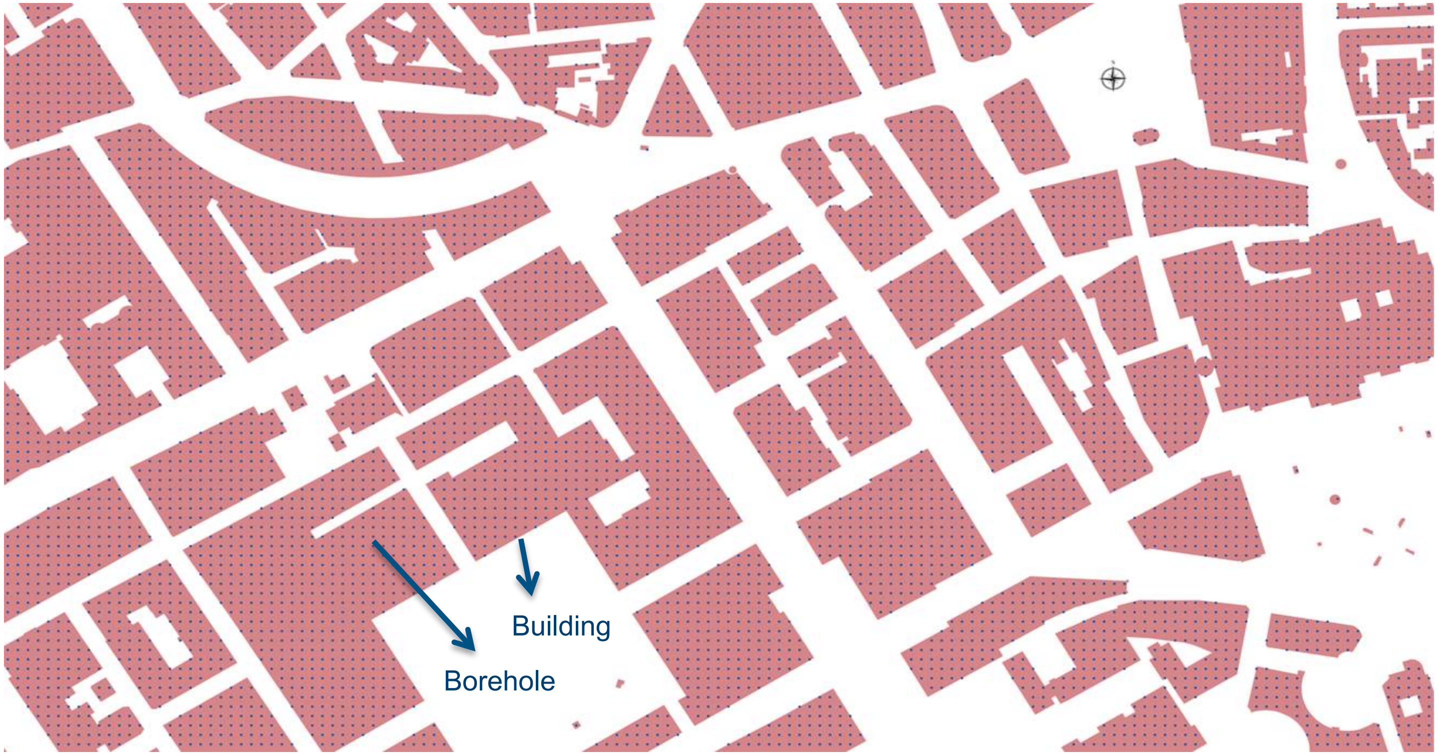
- Scenario 1: Install Boreholes under Buildings (Borehole Length:150m)

- Scenario 2: Install Boreholes around Buildings (Borehole Length:150m)

Scenario 1: Install Boreholes under Buildings

Minimum Distance between two closest boreholes should be 6 meters.

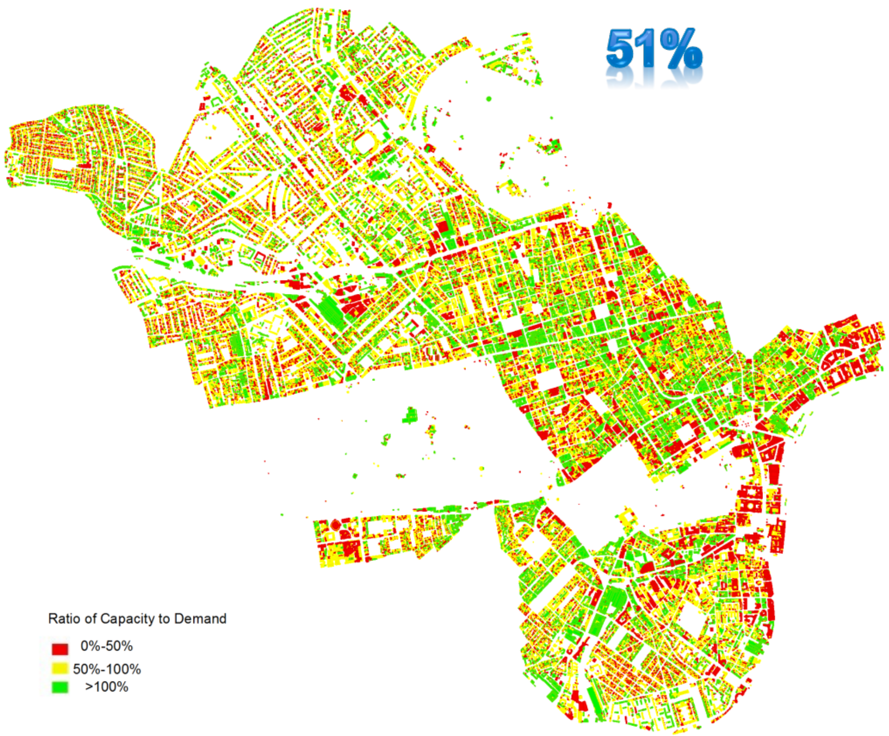
(6 meters refers to MIS by DECC)



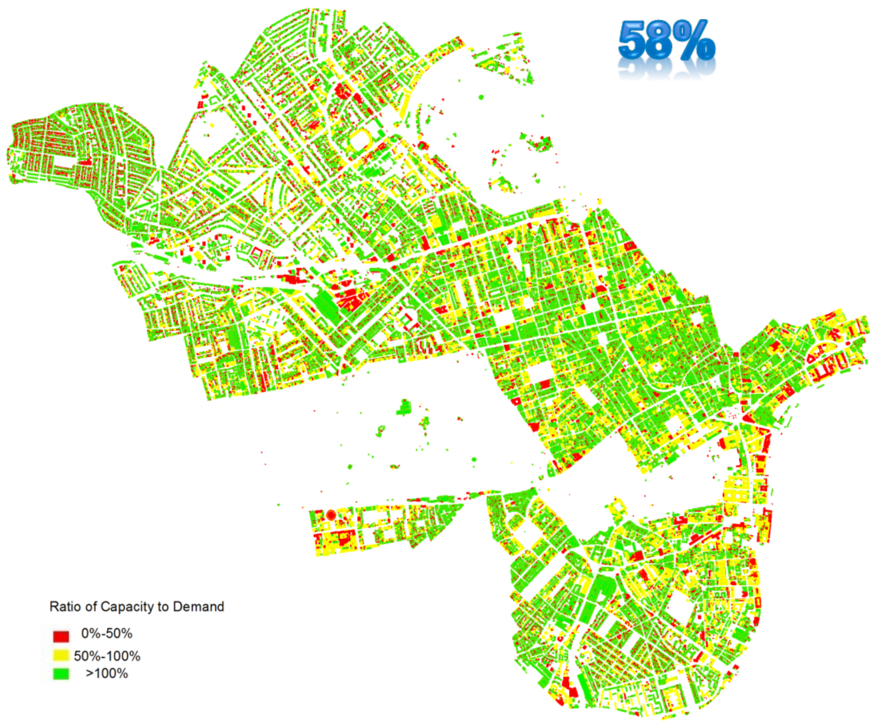
A corner of Westminster

Scenario 1: Ratio of Capacity to Demand Map

- Heating & Cooling



- Heating Only

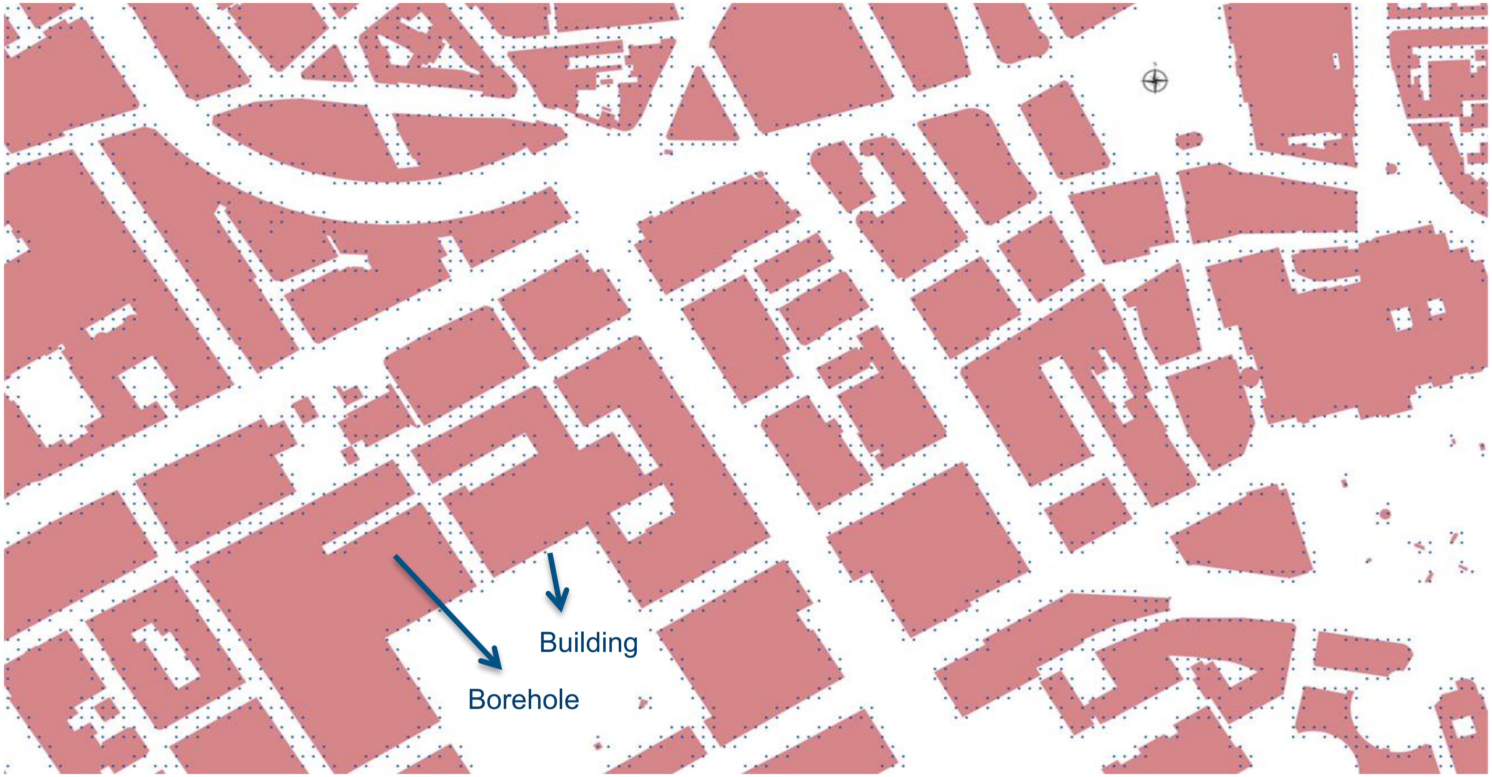


Borehole Length:150m

Scenario 2: Install Boreholes around Buildings

Minimum Distance between two closest boreholes should be 6 meters.

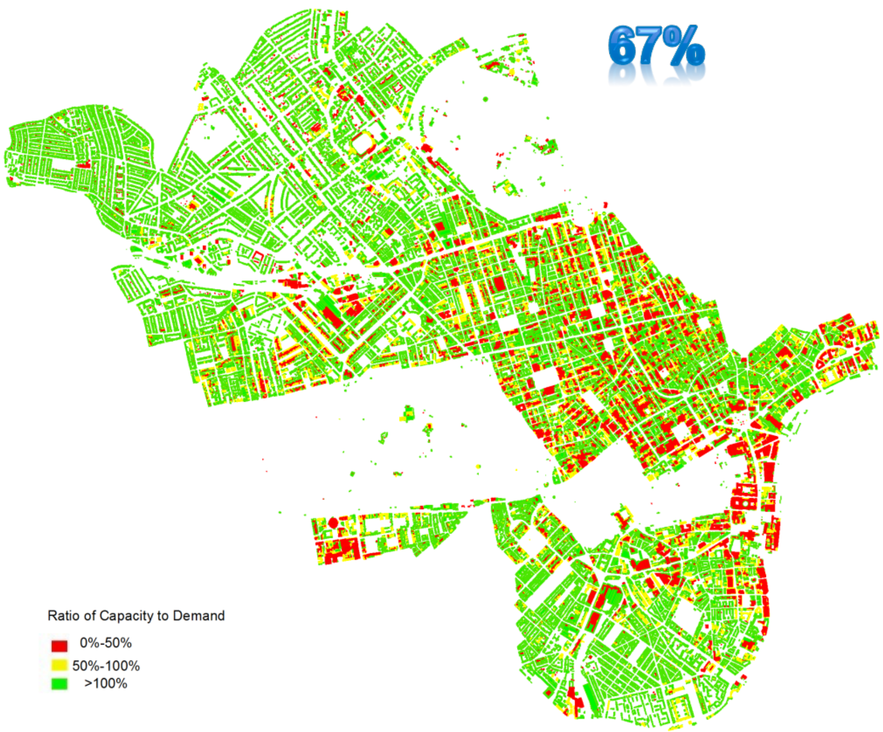
(6 meters refers to MIS by DECC)



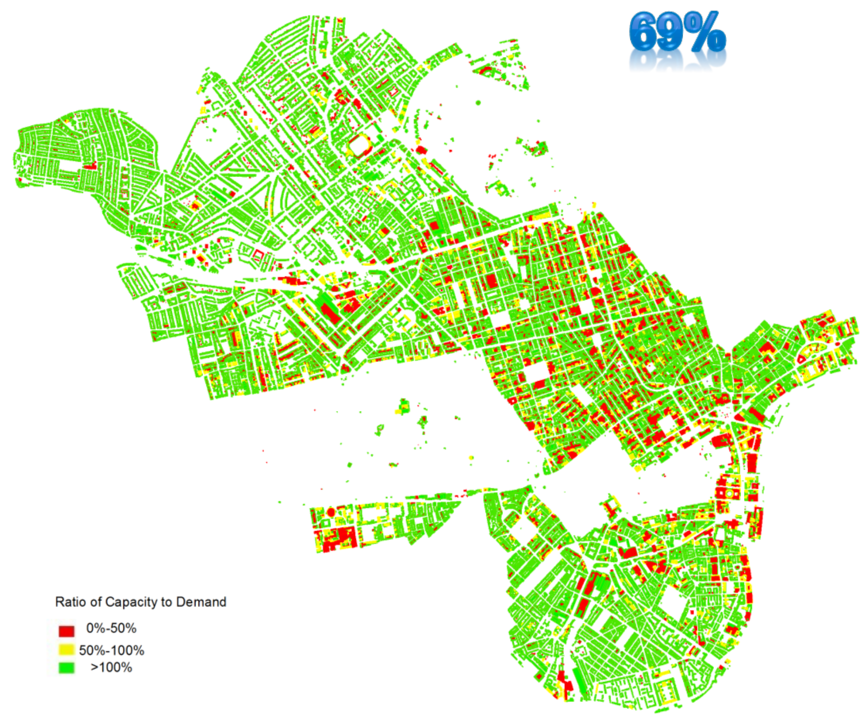
A corner of Westminster

Scenario 2: Ratio of Capacity to Demand Map

- Heating & Cooling

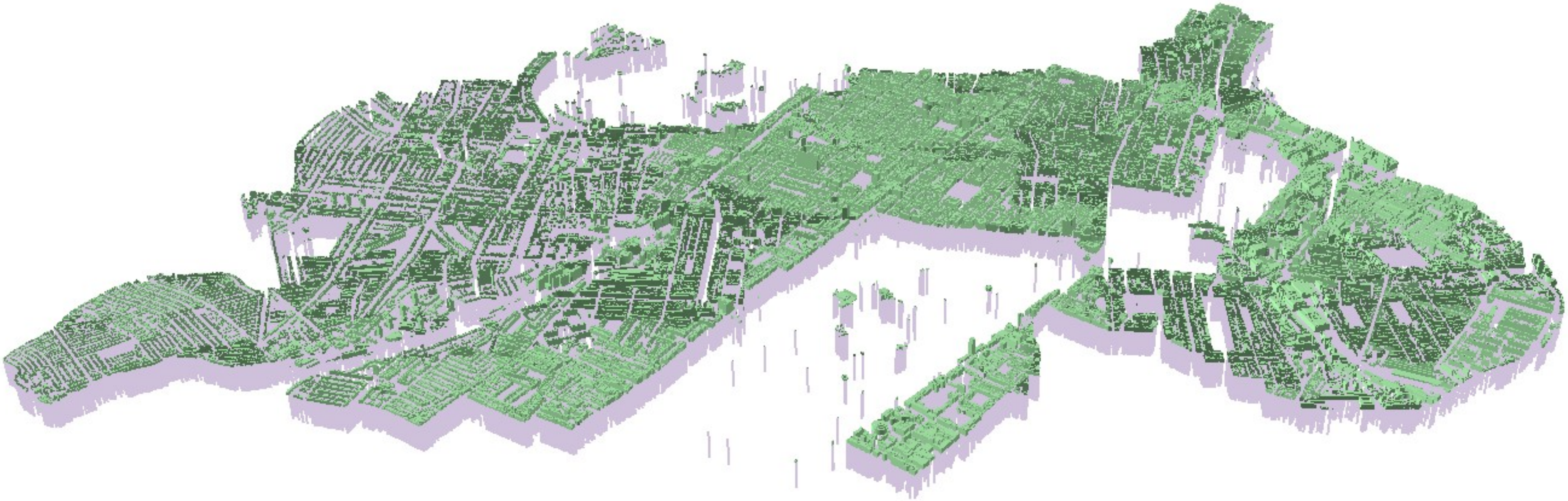


- Heating Only



Borehole Length:150m

3D GSHP Installation Map



THANKS FOR LISTENING