Energy Foundations
In The UK
7th June 2011

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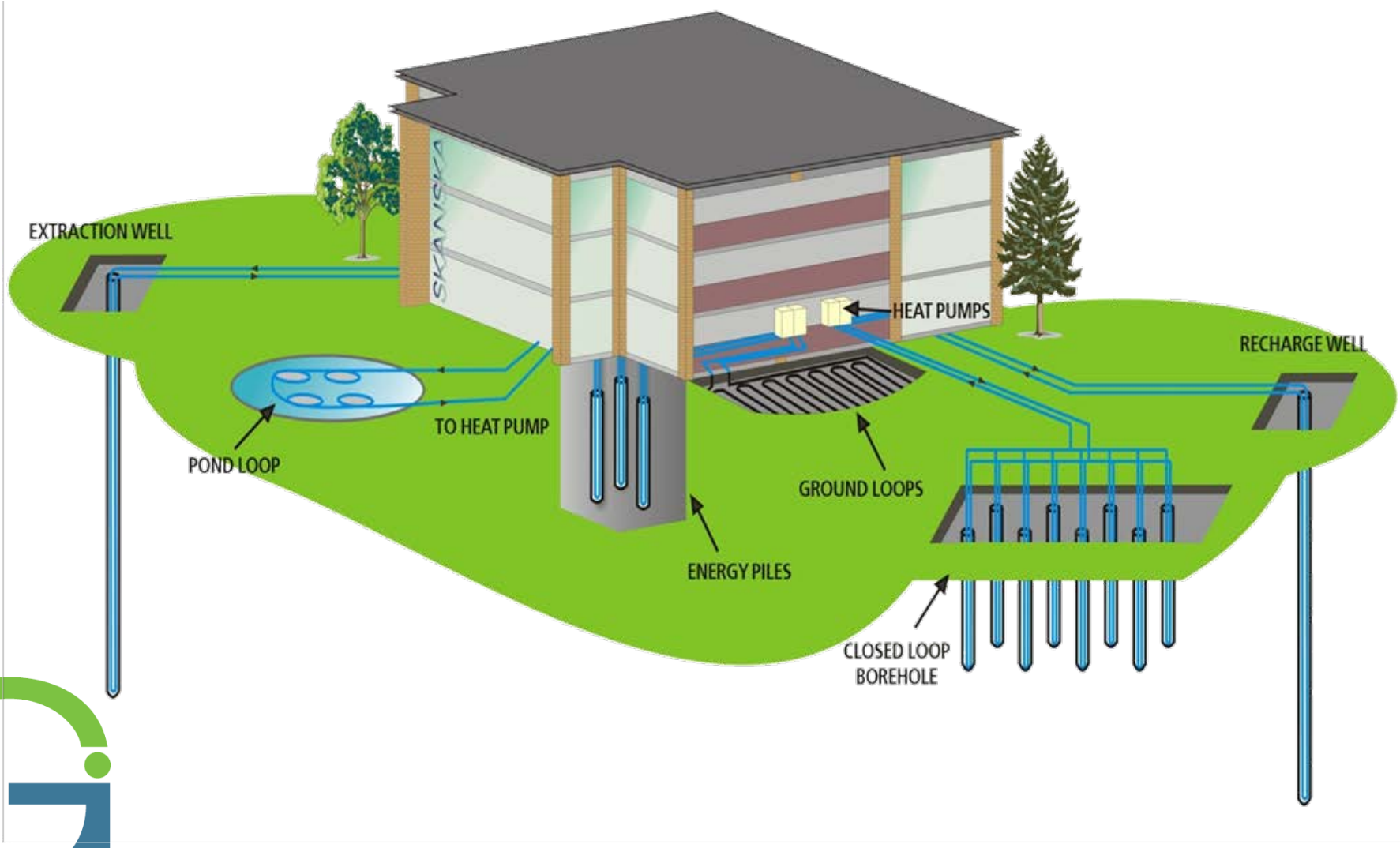
Geothermal Solutions



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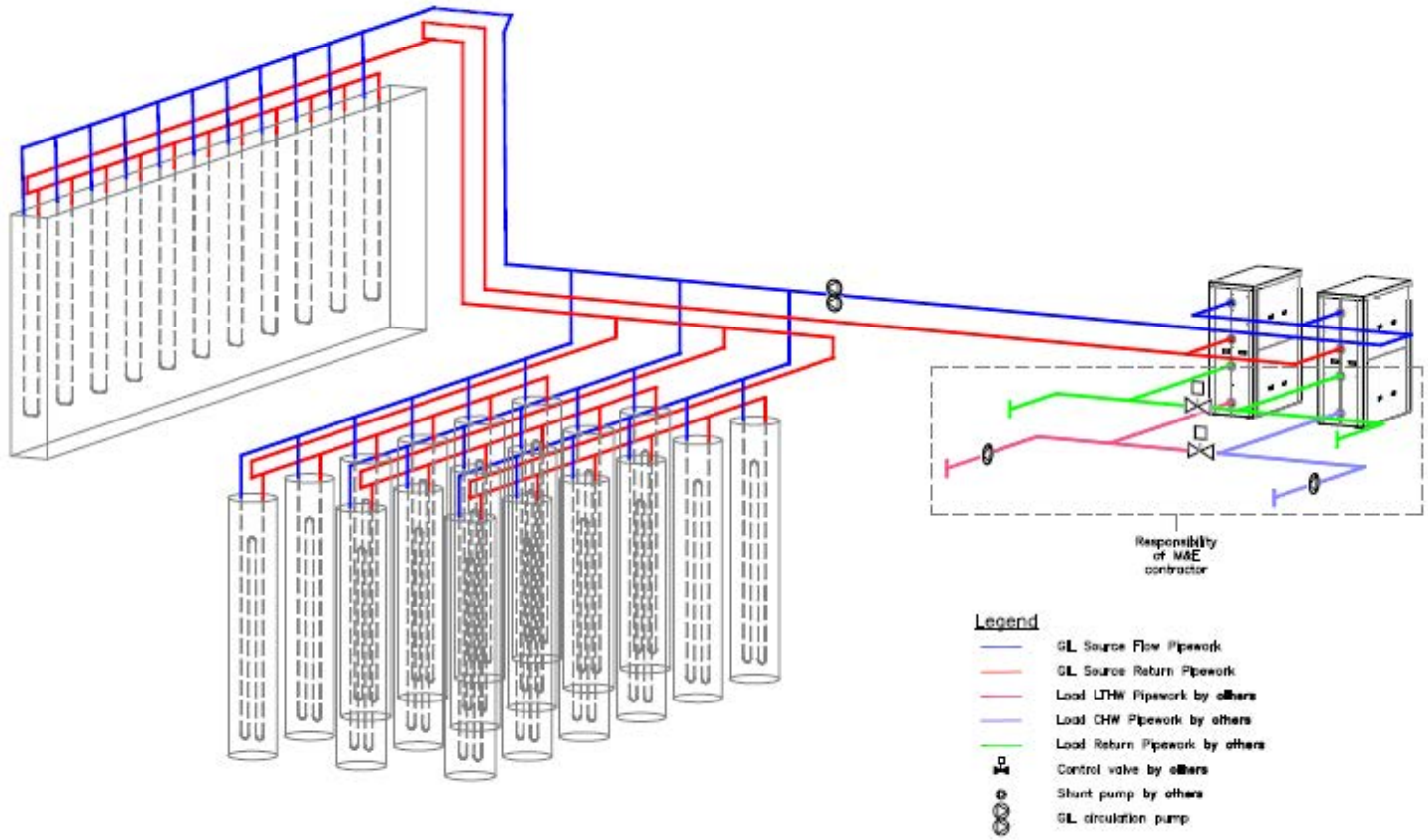
Energy Foundations



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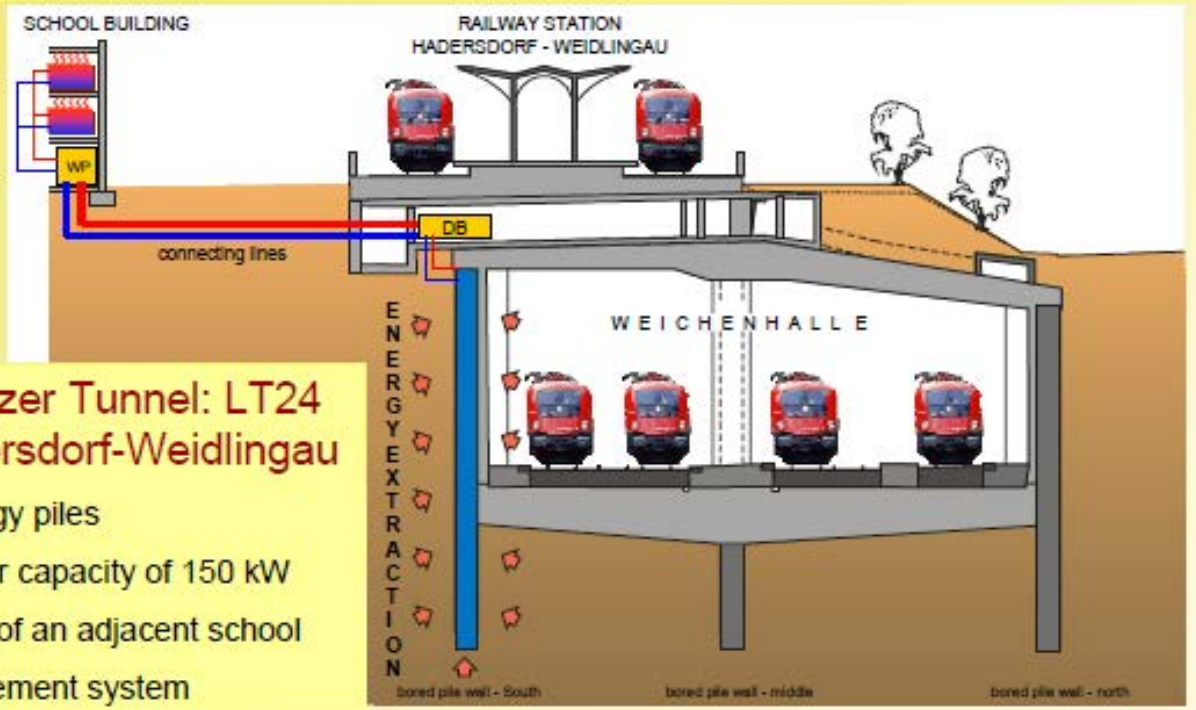
Energy Walls

Case History – Cut and Cover Tunnel



Lainzer Tunnel: LT24 Hadersdorf-Weidlingau

- 59 energy piles
- absorber capacity of 150 kW
- heating of an adjacent school
- measurement system

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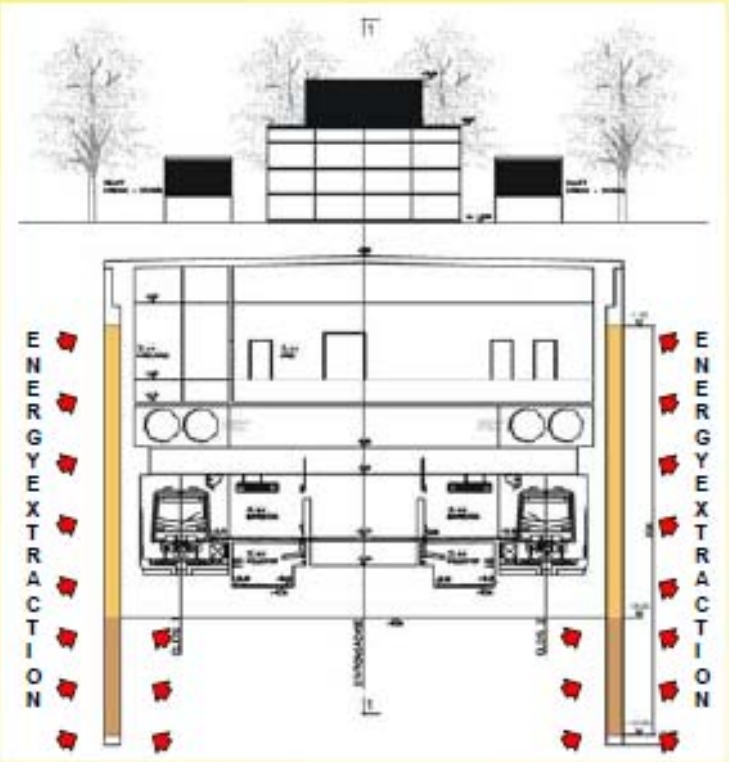
Energy Walls

Case History – Cut and Cover Tunnel

subway line U2 in Vienna
(under construction)



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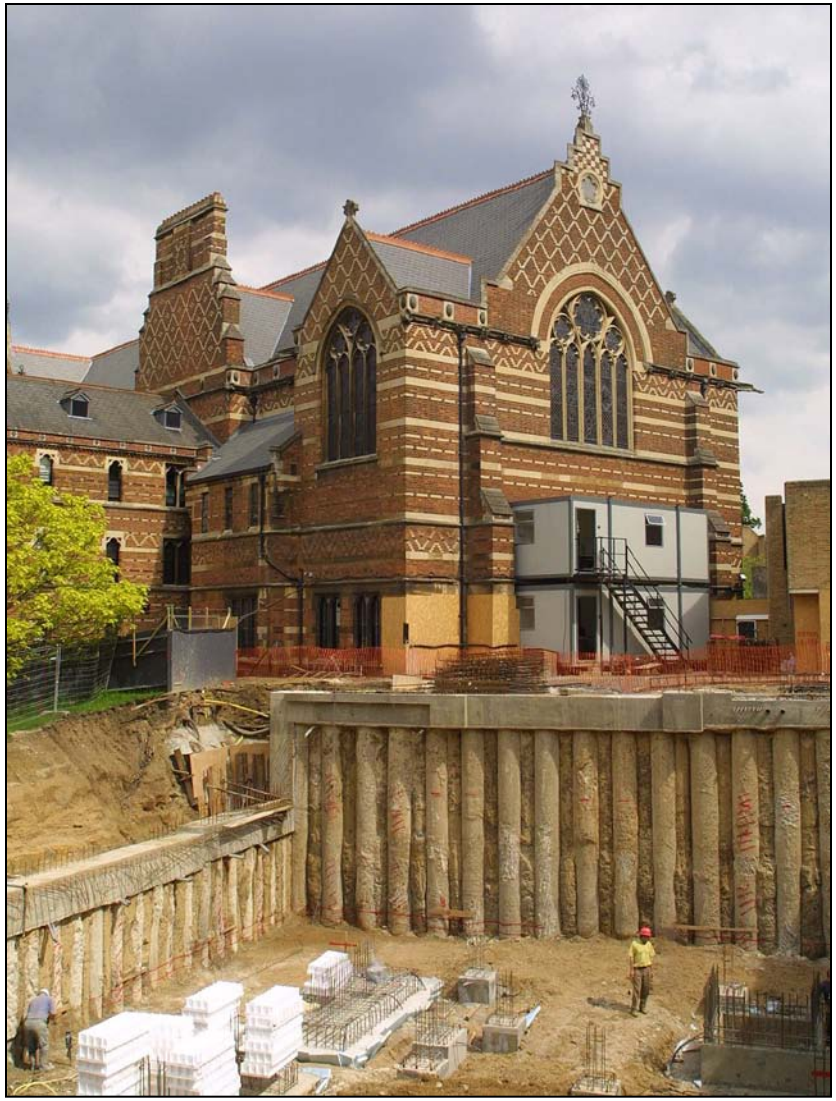
First Energy Pile® & Wall Project in the UK
Keble College – Oxford 2001

- EnergyPiles ®
  - 29 Wall 750mm dia Rotary Piles 12.5m
  - 61 450mm dia bearing Piles 5m
- Heating 85kW Cooling 65kW
- Completed:
  - 2002 and reported performing well



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Bulgari Hotel Knightsbridge
First Energy Diaphragm Wall Project in UK

- System:
  - Diaphragm Wall & Energy Piles®
- Size:
  - 150kW Heating
  - 150kW Cooling
- Collector type:
  - 50 Energy Piles
  - 150m Energy D. Wall
- On Site:
  - D. Wall & Piling completed 2010
  - currently Headering up

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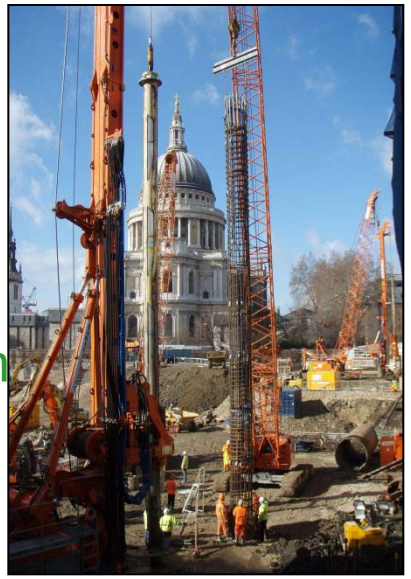
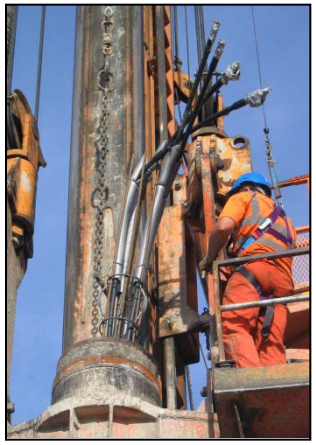
Geothermal Loops Have Now Been Installed Successfully In All Foundation Types



- Small / large diameter bored piles –

  Westminster Academy / One New Change
- Piles under bentonite or dry bore – Bankside London
- CFA piles - Canterbury University/ Belfast Police station
- Driven Cast In-situ piles. North Kent Police Station
- Driven Precast Piles – Balmore Glasgow
- Diaphragm walls - Bulgari Hotel Knightsbridge / Crossrail Stations



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Opportunities For Crossrail

1km of Diaphragm Wall or Piles - 40m deep could provide..

- 500kW of Peak Heating (enough to heat over 50 Homes)
- 500kW of Peak Cooling
- Save 350 tonnes of CO2 per Annum
- Reduce Energy Bill by approx £90k per annum when compared against conventional systems

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Crossrail

Crossrail Installations

Currently installing / planned for loops to be installed into walls and Piles to proved 200kW - 1MW for oversite developments above stations at…

- Liverpool Street
- Farringdon Street
- Tottenham Court Road
- Dean St
- Bond St
- Paddington

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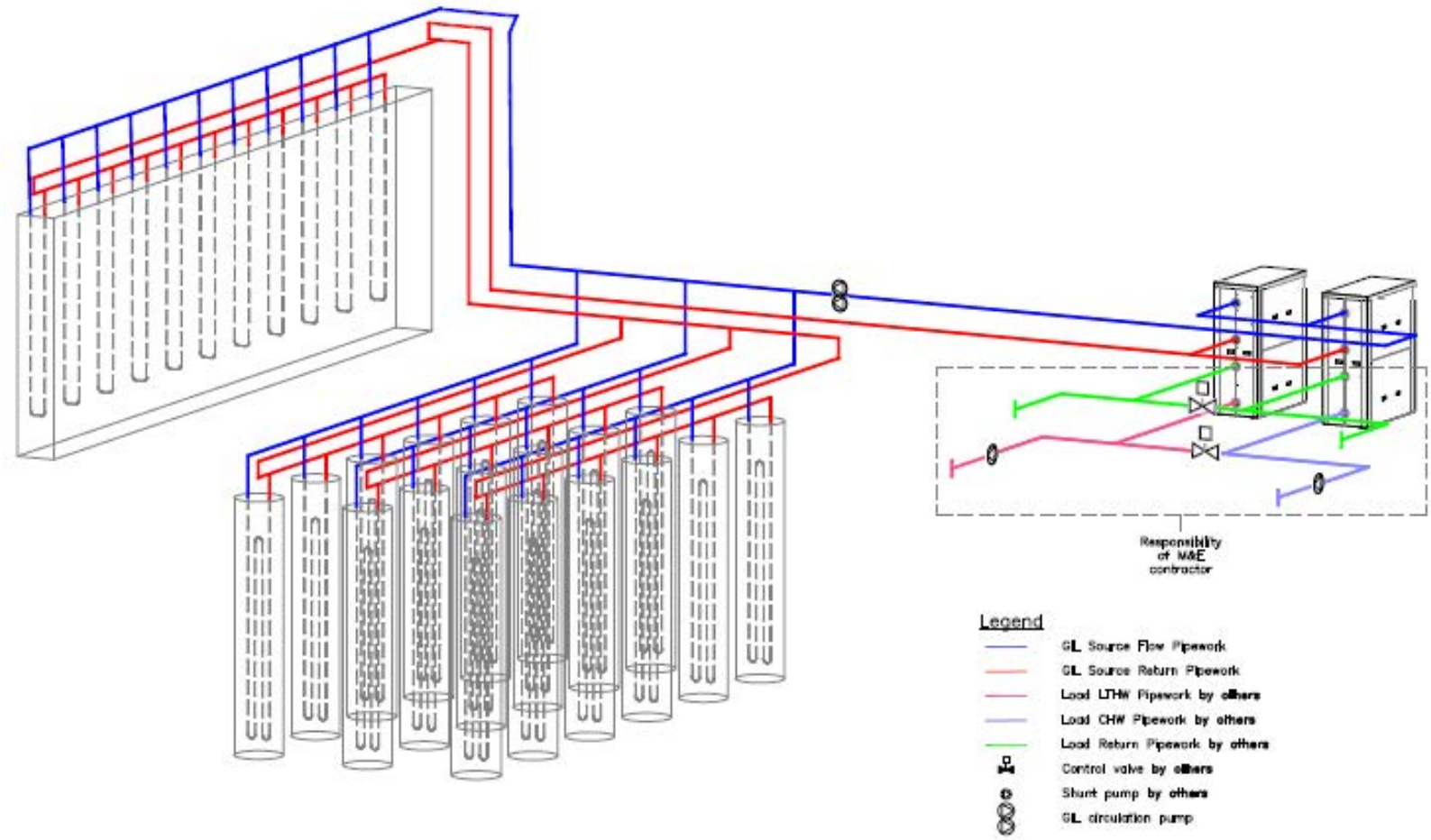
Crossrail

Bulgari Hotel Knightsbridge / Crossrail Station Box Schematic



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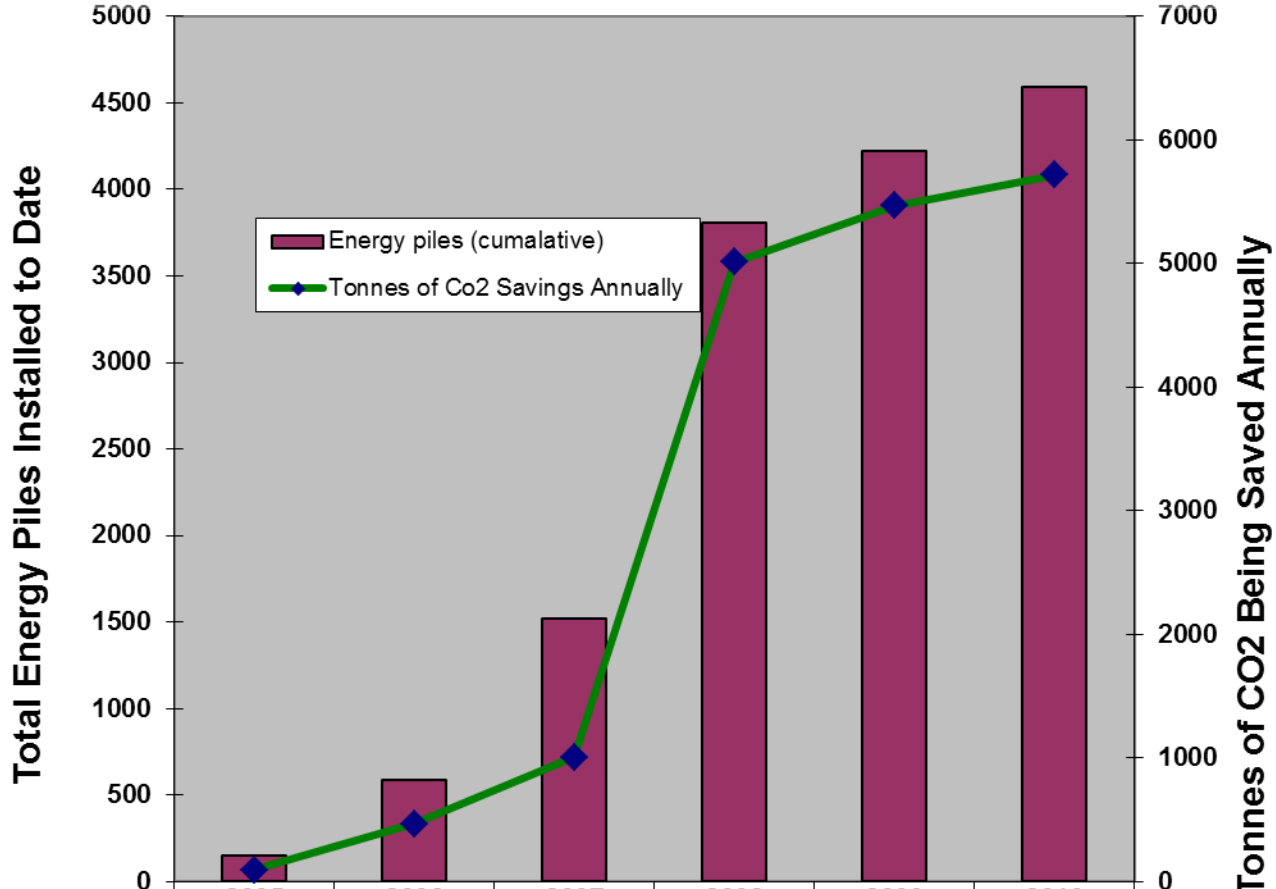
EnergyPiles® Installed in the UK to Date

Provide 9.2MW Heating & 8.7MW Cooling & Saving 6700Tonnes of CO2 Annually



	2005	2006	2007	2008	2009	2010
Energy piles (cumalative)	150	590	1519	3804	4219	4591
Tonnes of Co2 Savings Annually	92.8	467.2	1005.2	5010.6	5469.4	5714.9

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What Are The Benefits Of Using The Buildings Foundations

- Low extra over cost for geothermal installation
- Minimal impact on piling program
- Using building piles as thermal mass
- Heat recovery between seasons
- Provides a Stable & Sustainable energy source
- Makes excellent Value Engineering sense

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Simple Cost Comparison of Borehole Loop Against Energy Pile

Item	Borehole Loop	Energy Pile(Rotary)
Diameter	125mm	600mm
Number of loops	One	Two
Length	100m (3.5kW)	27m x 2No (3.5kW)
Boring / installation cost	£35/m x 100m = £3500	Boring included + rig / crew time
Thermal Grout	£5/m x100m = £500	N/A
Pipe – 32mm ID	£3/m – 1 loop= £300	£3 x 2 x (27m x 2) = £324
Total Installation	£4300	£324 + rig / crew time
Header pipes	20m at £3/m = £60 + trenching	2x20m at £3/m = £120 + placement
Grand Total for 3.5kW	**£4360**	**£440 + rig / crew time**
Cost per kW	£1245	£125
Construction work	Not on critical path	On Critical path

Bulgari Hotel Knightsbridge - Loop Installation into Energy Wall

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Pre-installation Quality Control & Testing

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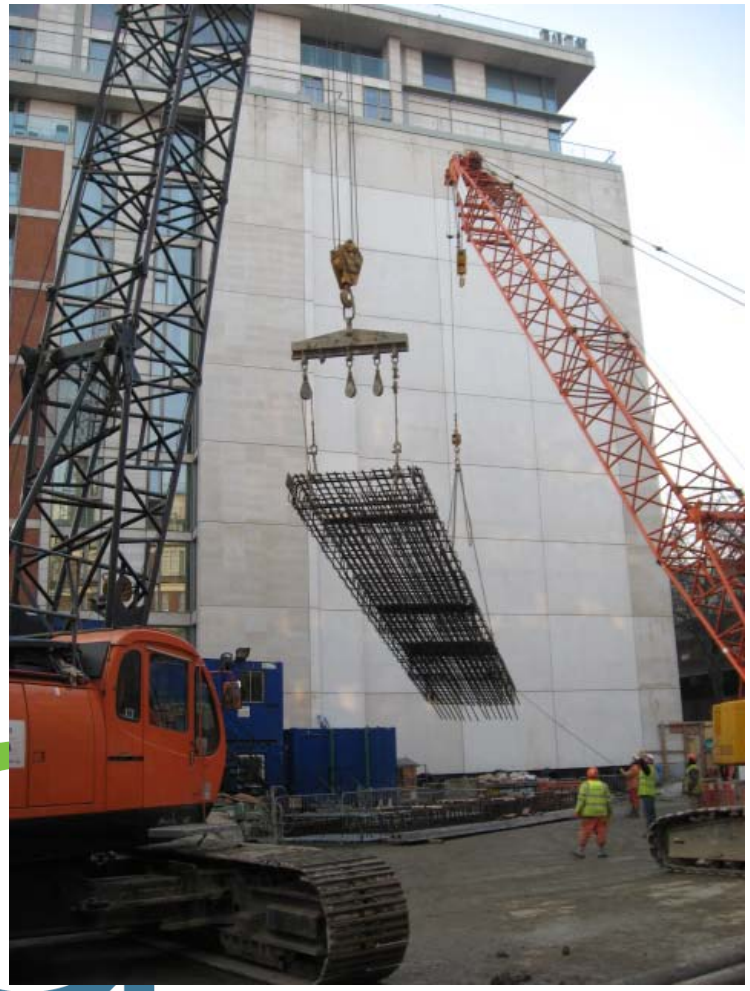
Lifting the Diaphragm Wall Cage



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Installing the Loops

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Installing the Loops

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Installing the second cage

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Fixing the loops to the cage

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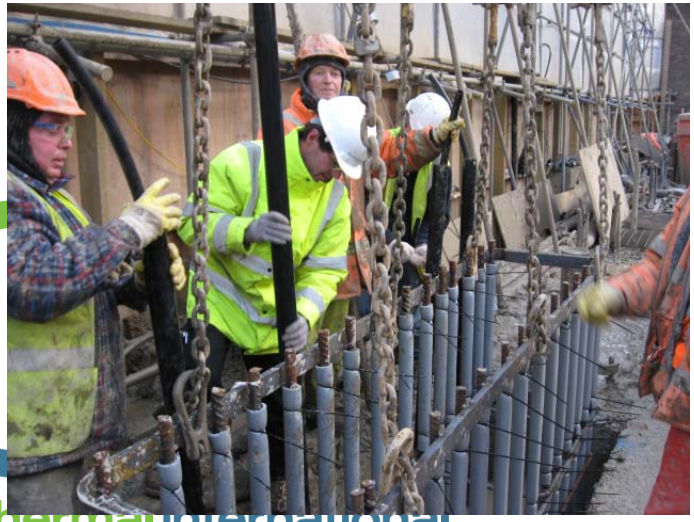
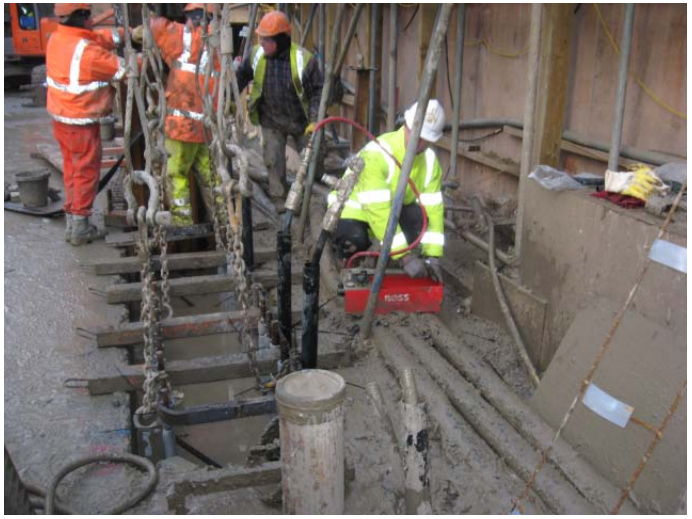
Trimming and Protecting



Pre-concrete Pressure Test



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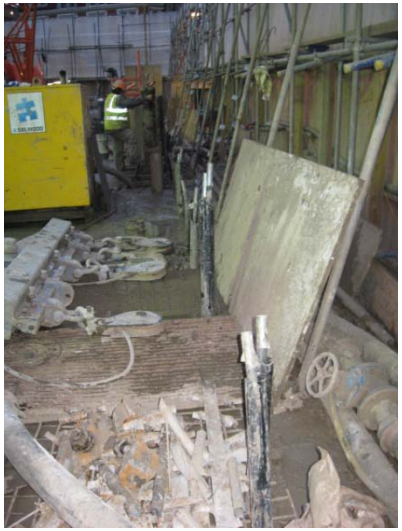
Concreting the Diaphragm Wall



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Key Lessons Learnt

- Ensure early coordination between all parties at all stages of the project
  - Design team
  - Construction team
- Keep it simple
  - Minimise joints in loops where possible
  - Prefabricate loops
  - Rigorous Pressure testing regime
- Build-ability issues
  - Good Preparation
  - Good coordination between Contractors
  - Avoid men having to place hands in cages

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What are the issues with installing loops in wall piles and diaphragm walls?

- What are the effects of transferring heat into foundations to provide cooling?
- What are the effects of cooling foundations to provide heating?
- What are the thermal effects of removing soil from one face to form basement?

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Key Energy Pile® / Wall Research to date

- **Brandl 2006** – reported on several projects across Austria concluded that shaft resistance, base pressure and bearing resistance of soil are not affected by heat absorption and that temperature induced settlement or heave negligible

- **Laloui 2006** – Identified that the heating-cooling process of the building foundations induces significant modifications in the soil-structure leading to additional stresses in the piles, decrease of the lateral friction and the possibility of a gap between the pile and the soil

- **Bourne Webb et al 2009 -** temperature change in piles leads to increases and decreases in shaft resistance and axial load. Working stresses in pile should be kept low, and maintain high factor of safety on shaft to withstand heating and cooling loads

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Lambeth College Geothermal Trial

- System:
  - EnergyPiles®
- Collector type
  - Rotary Bored Pile depth 23m

7 Week Trial
Completed
July 2007

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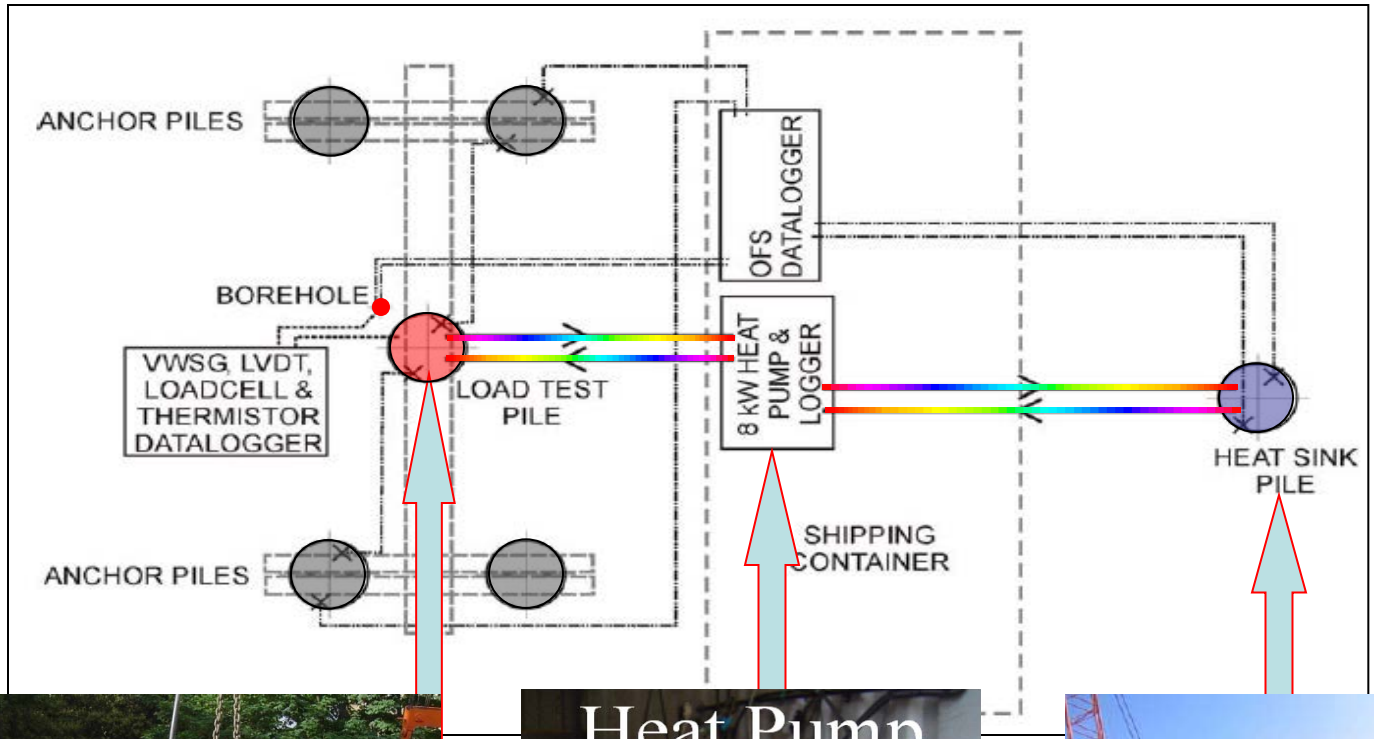
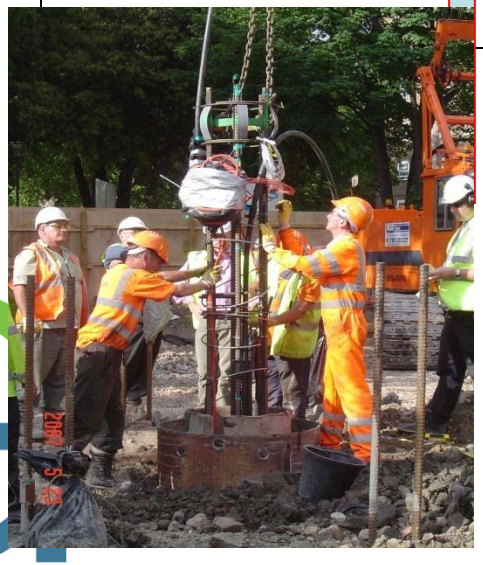
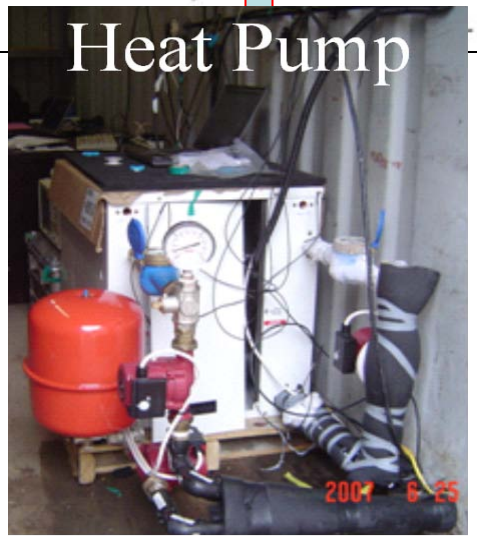
UNIVERSITY OF CAMBRIDGE

Cementation
SKANSKA

Schematic of Test Layout







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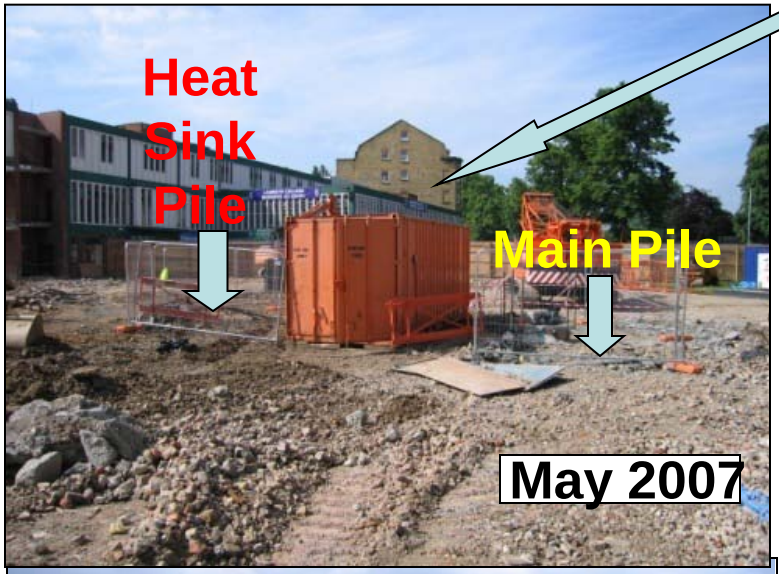
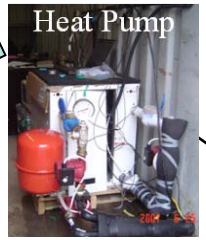
Schematic of Test Layout





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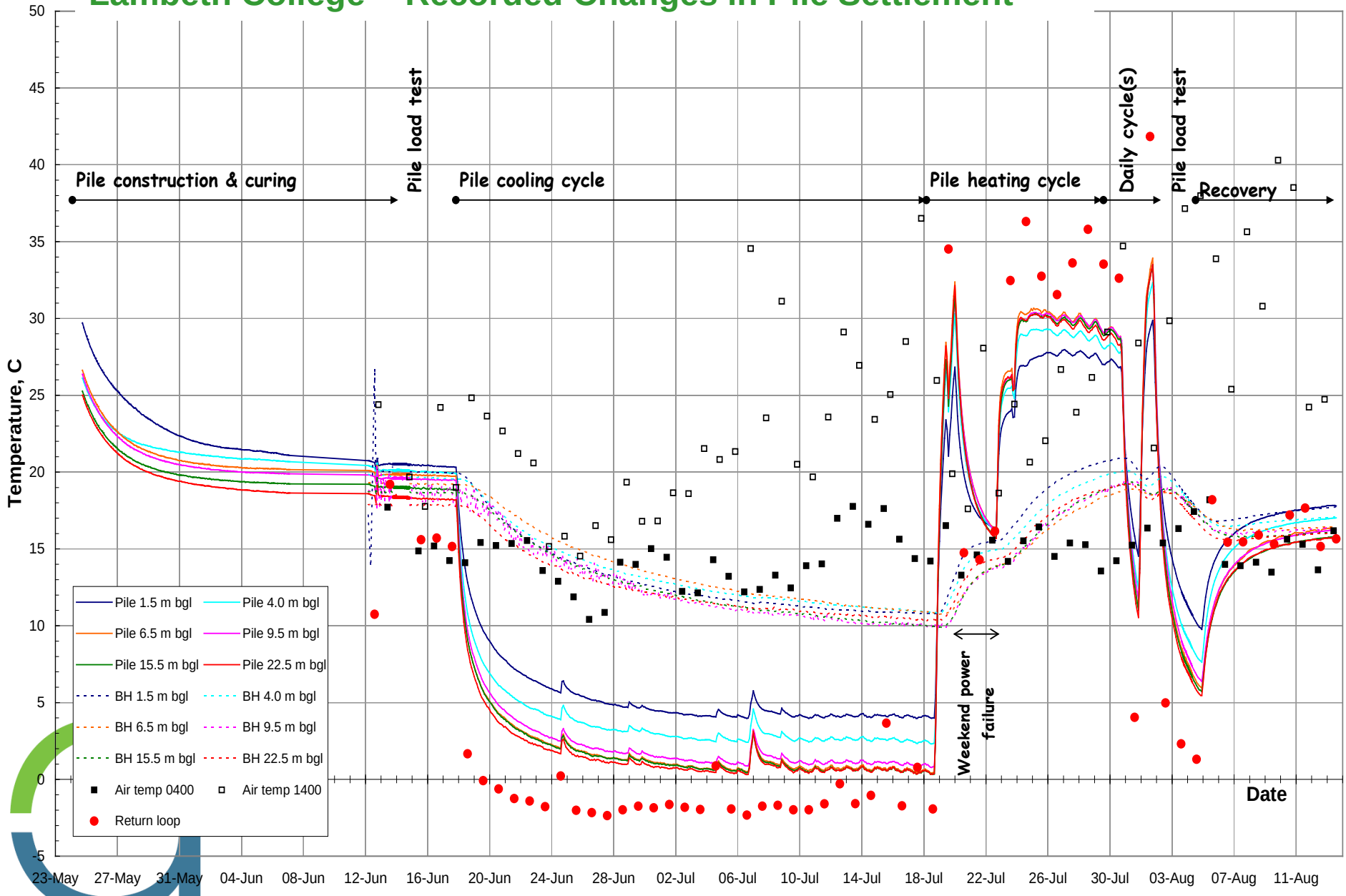
Lambeth College - Recorded Changes in Pile Settlement



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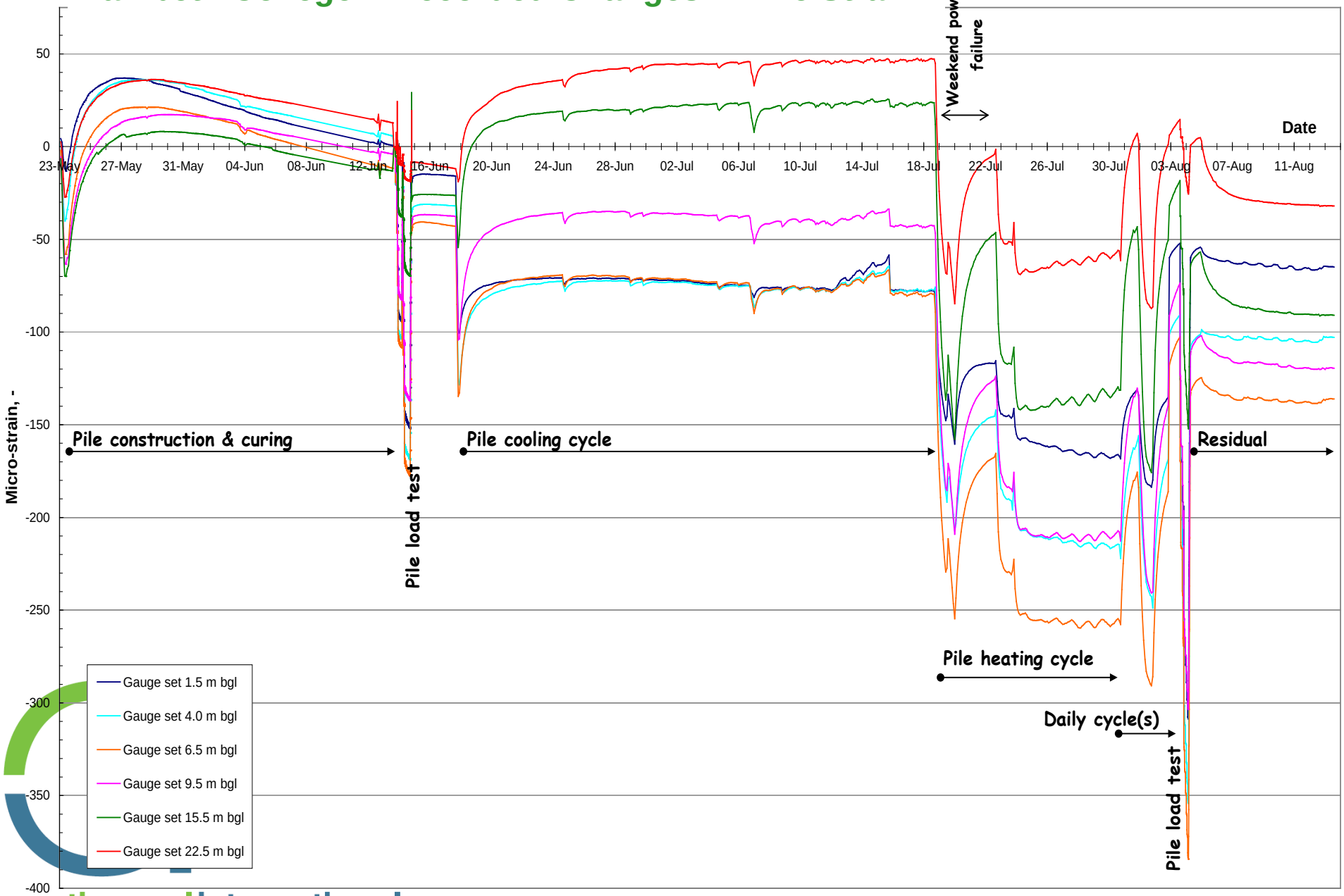
Lambeth College - Recorded Changes in Pile Strain



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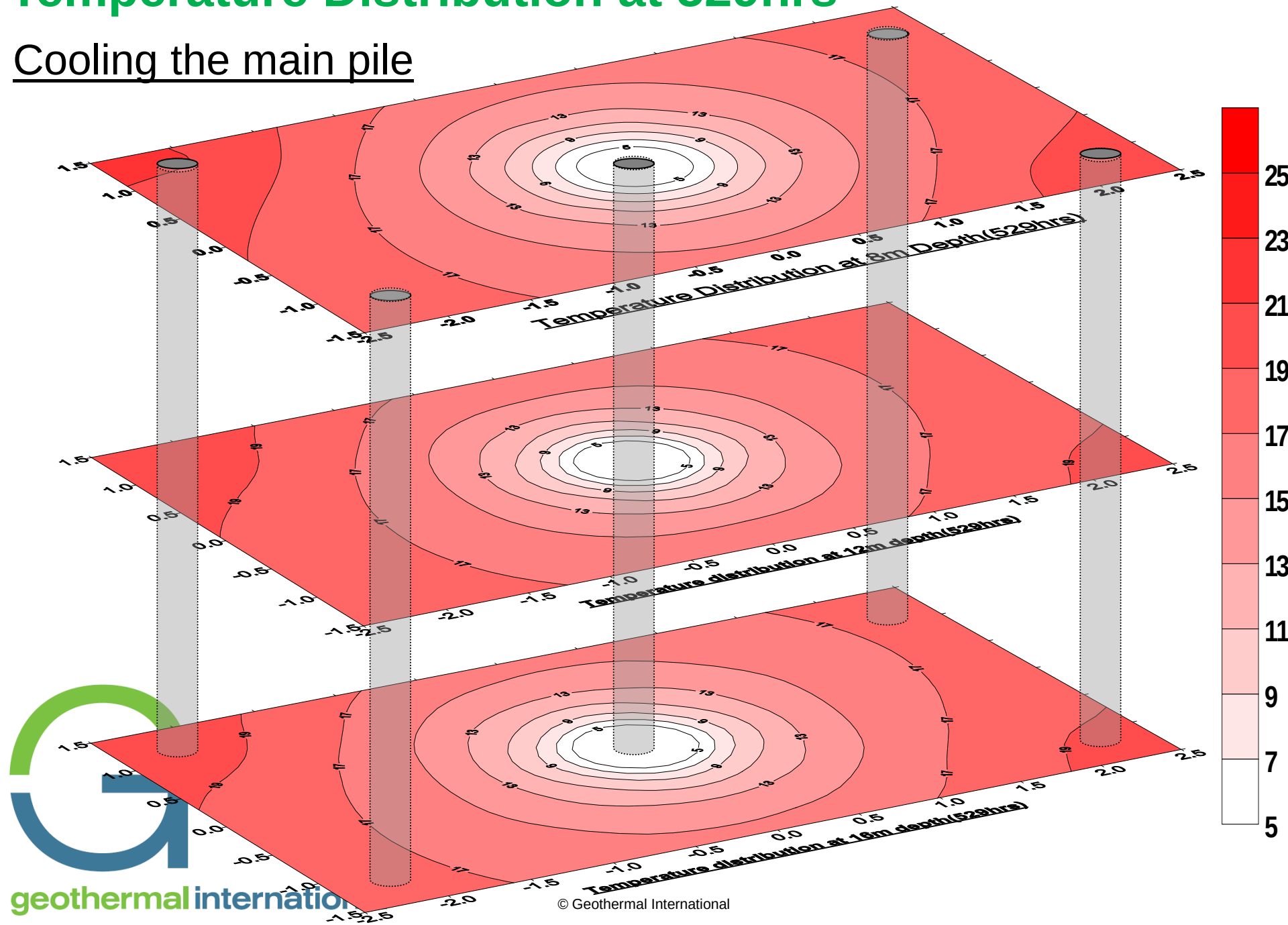
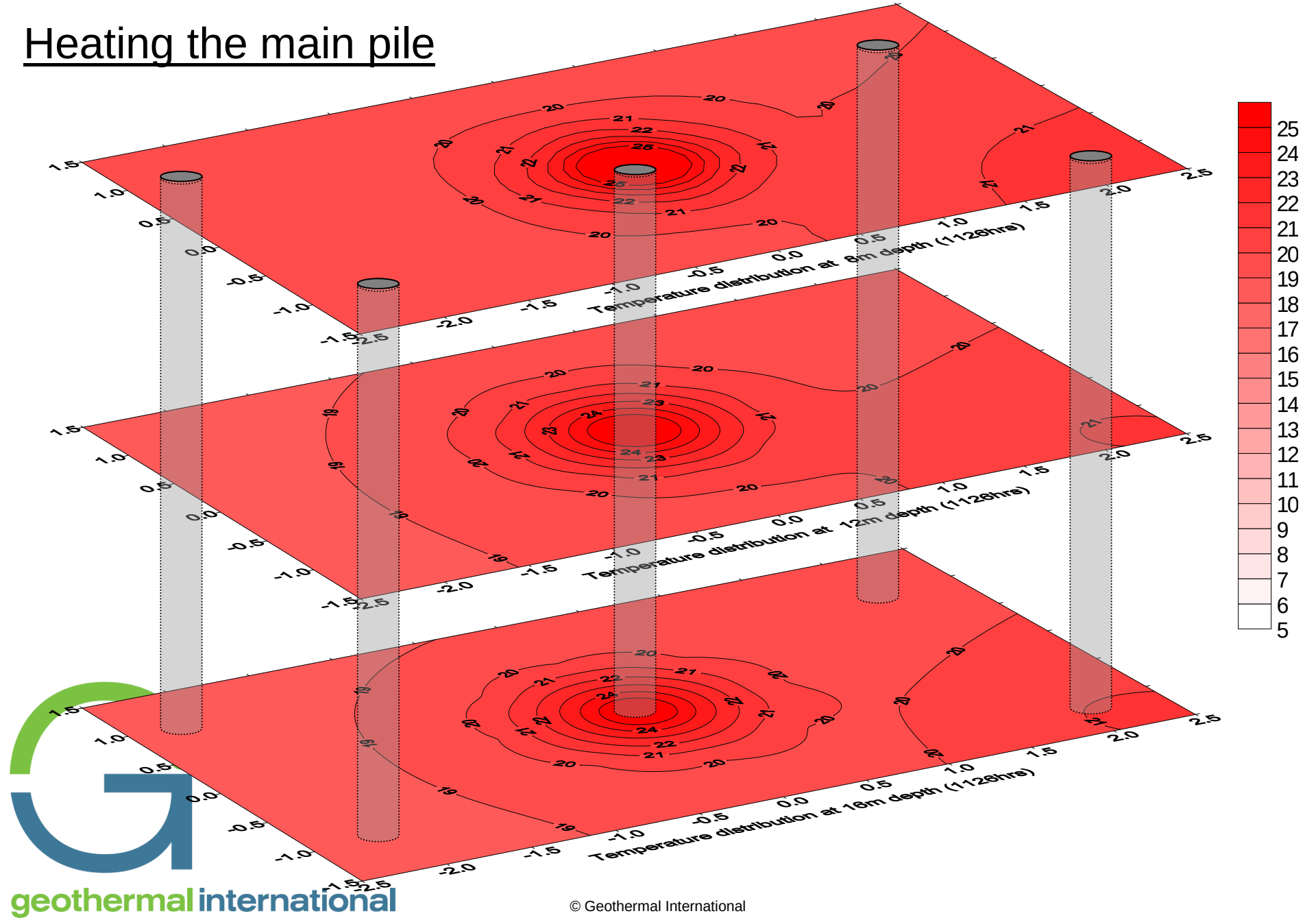
Temperature Distribution at 529hrs

Cooling the main pile



Temperature Distribution at 1126hrs

Heating the main pile



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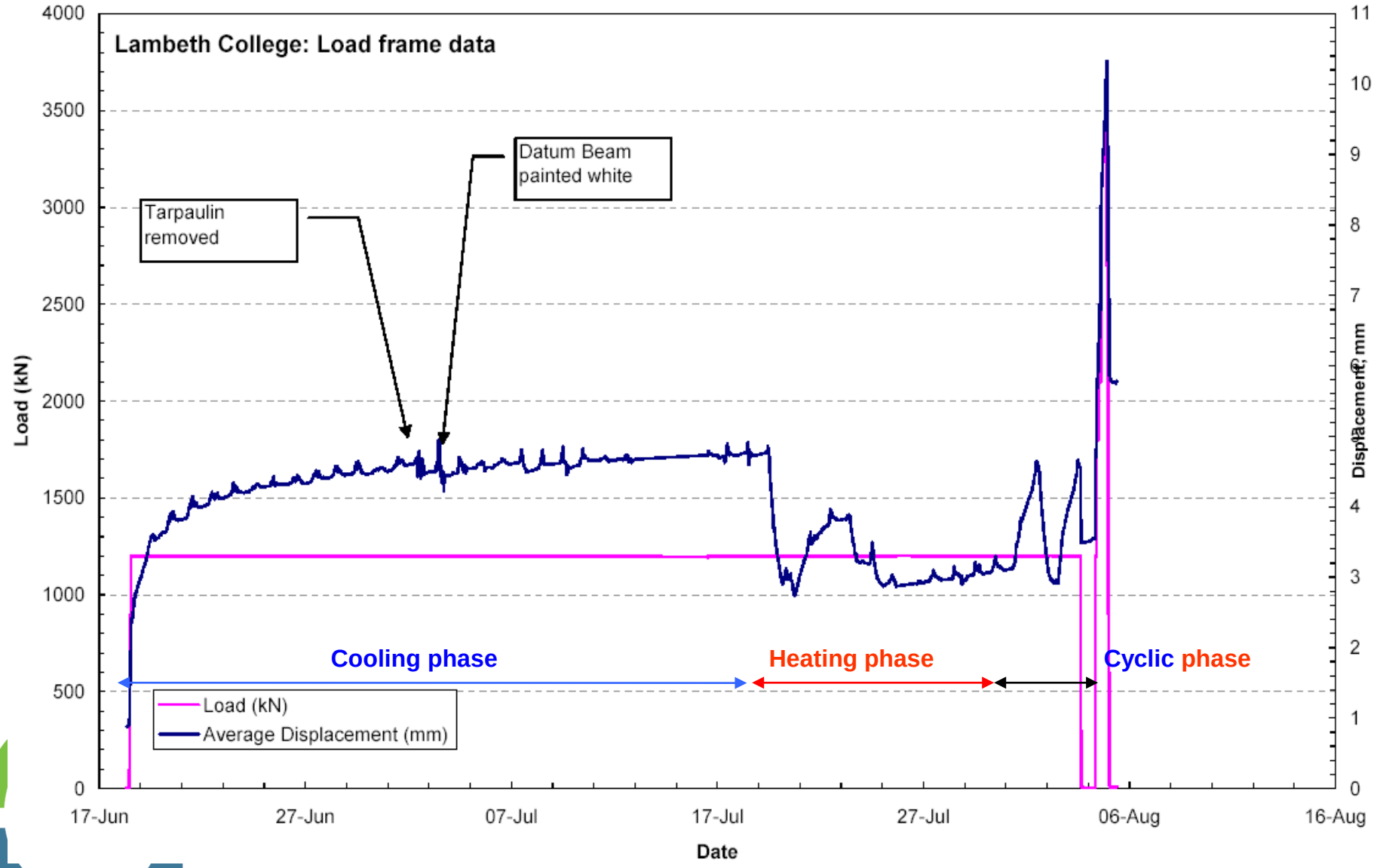
Load & Settlement v Time



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Key Points of Heat Pump Operation
Lambeth College Trial

- Heat pump was circulating coolant at -7°C into test pile continuously for 24 hours a day for 4 weeks… That's 672 Hours!!
- Pile settlement increased by 2mm due to thermal contraction
- No sign of ground freezing after 672hours
- After 672 hours heat pump was changed to cooling cycle thereby circulating 45°C water for 24 hours a day . Thermal shock?
- Pile recovered by 2mm when heated
- THIS WAS AN EXTREME TEST!!!
- A GROUND SOURCED HEAT PUMP SYSTEM IS NOT DESIGNED TO OPERATE THIS WAY

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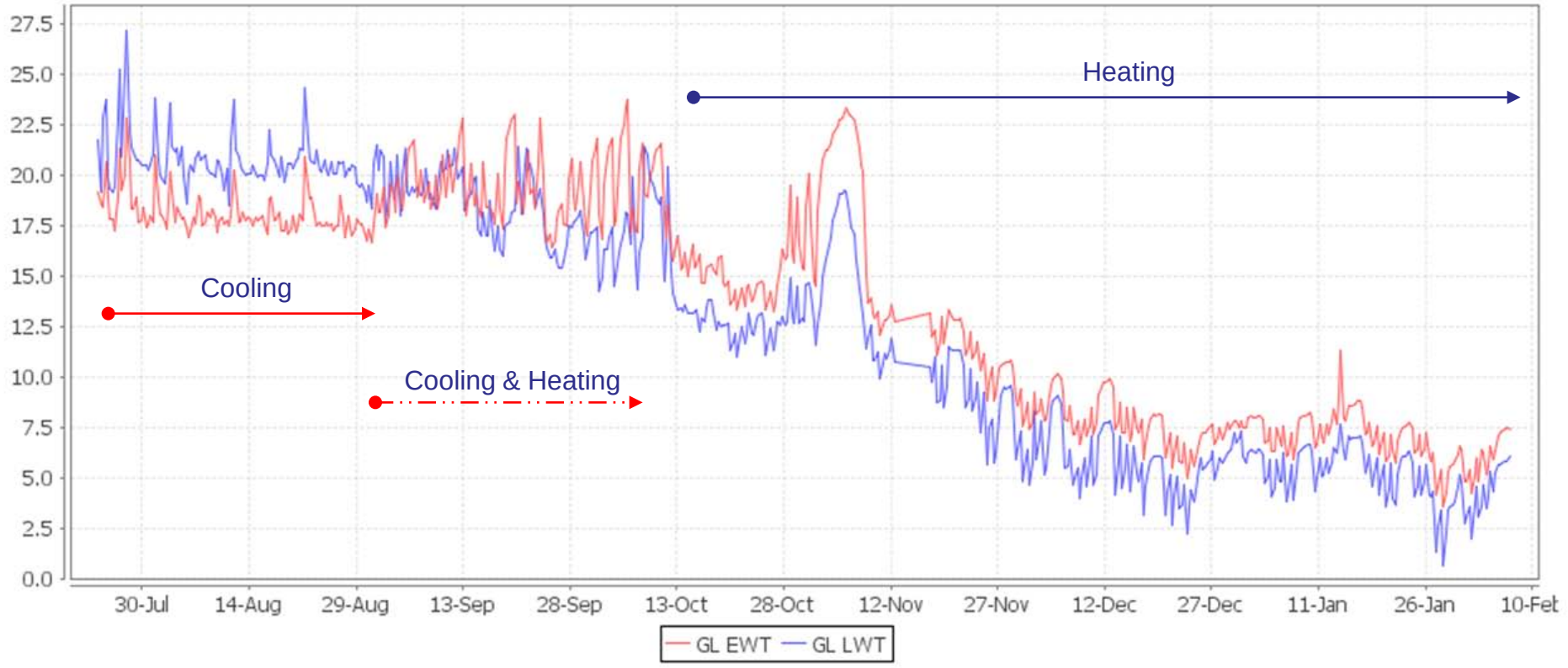
SO.. What Happens To The Foundations In Reality?

- Ground loop outlet and inlet temperature from a 2 year old Energy Pile installation producing 500kW Heating and Cooling at a University over this winter... The coldest on record?



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Heat Pump Output Key Facts

- Peak heating and cooling outputs generally occur for short periods of time each year. 2-3 weeks a year. **Not for 672 hours continuously!!**
- Heat pump at maximum heating (cooling ground Loop) generally for only10% of the year.
- Heat pump will run annually on average at around 30% of its total capacity
- Operationally system runs 4-5 hours in heating mode on average, first thing in the morning then will switch to cooling cycle
- In the case study - Last winter there were only 2 days when it was operating at maximum output for 24hours a day. Minimum leaving loop temperature was 1°C a few days later it was back up to 5°C. **Thus no chance of freezing the ground**
- Heat pump will not cycle from maximum cooling to maximum heating – Typical daily cycle range is 4- 8°C **Not -7°C to 45°C in one day**

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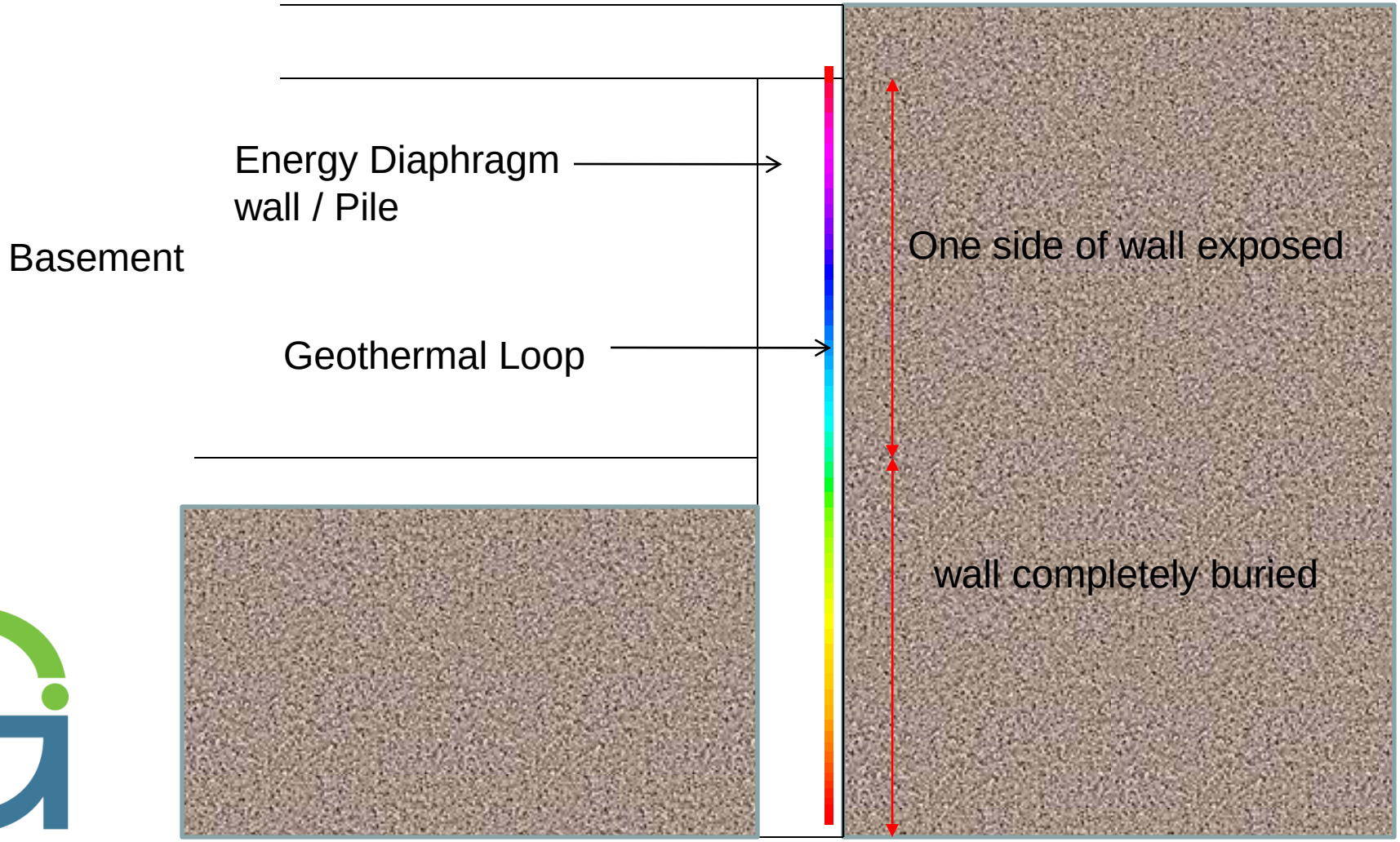
What conductivity values should be used in ground loop design on retaining walls?



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Geothermal International Research & Development at Bulgari Hotel Knightsbridge

Stage 1: Installation of loops in diaphragm wall - completed

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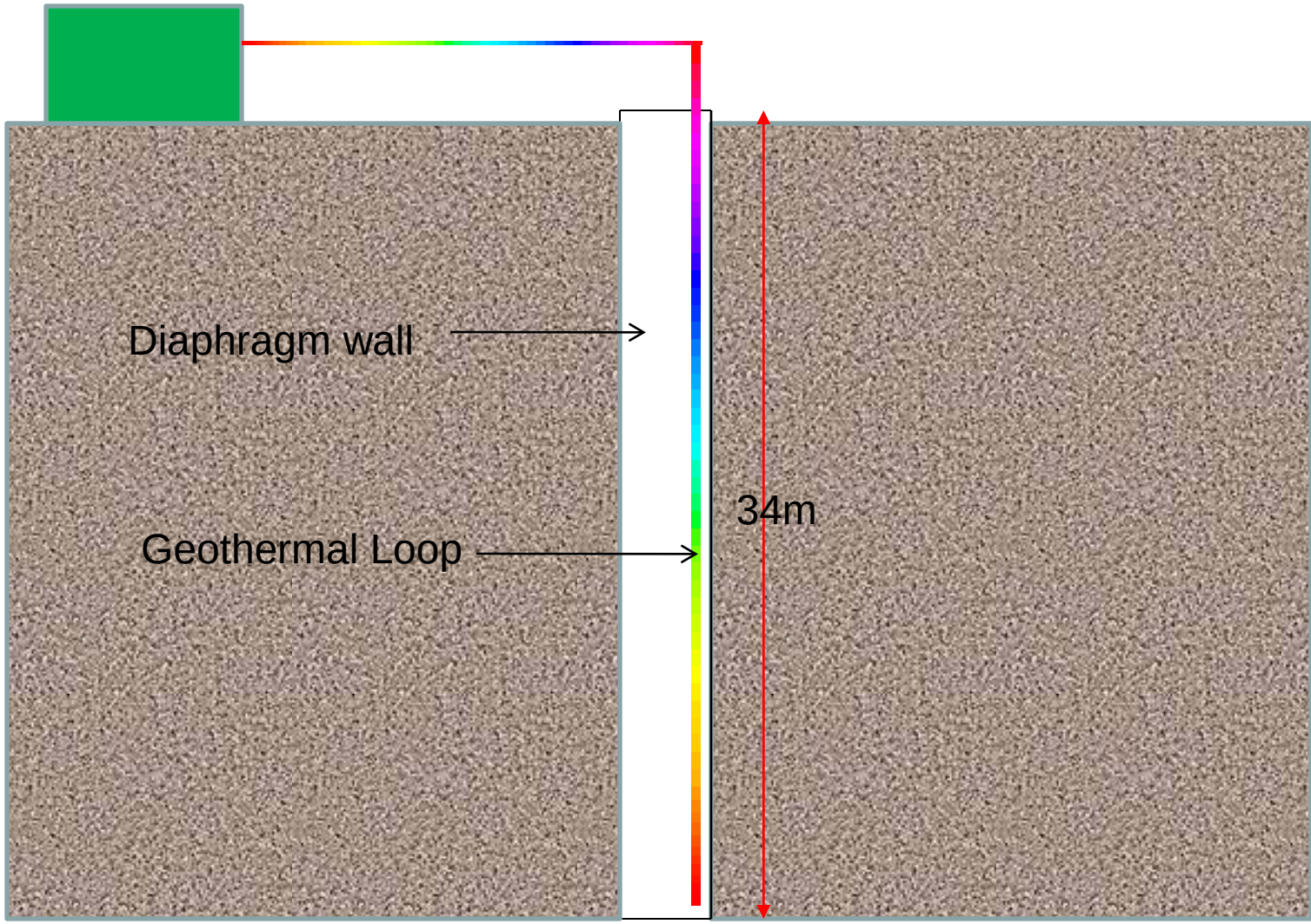
Stage 2: Undertake conductivity test prior to excavation – February 2010



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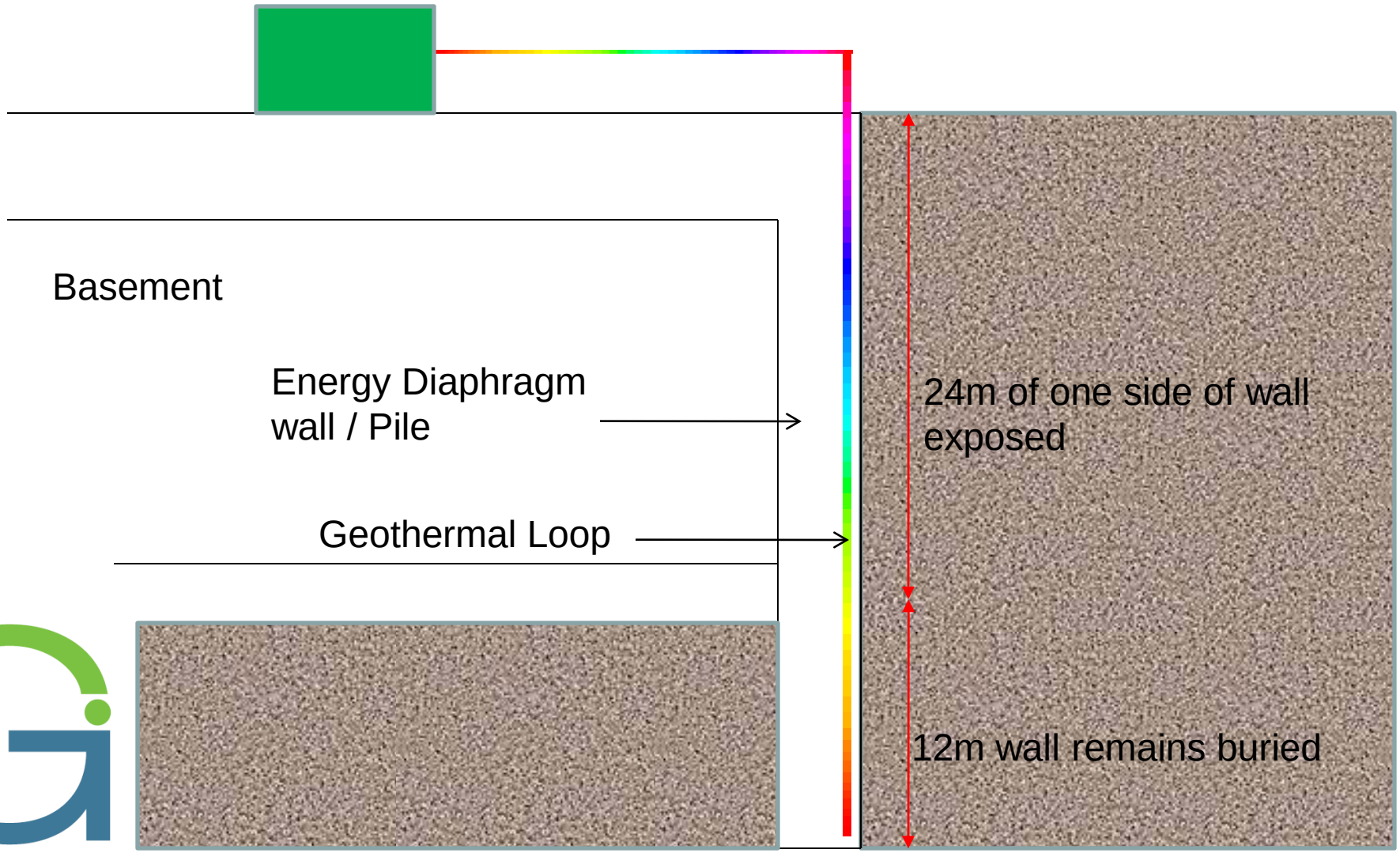
Stage 3: Conduct second conductivity test once excavation complete – May 2011



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Conductivity Result To Date

Once basement excavated…

- Thermal Resistance increased by 20%
- Conductivity value fell by 13%

- GI Currently assessing impact of results on our Design tools
- Paper to follow
- Initial results show current GI design approach is very conservative

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Sensible Energy Foundation Design Practice Based Upon Current Knowledge

- Early coordination between Geotechnical and Ground loop design team to agree levels of system redundancy and installation technique
- Ground loop designer to ensure heat extraction should equal ground recharge either naturally or by cooling demand **- based upon annual building heating and cooling profile**
- Ground loop design model to be based upon 100 year design life, and check ground temperatures during this period should not change by more than 2°C as a result of the GSHP
- Ensure system control strategy monitors ground loop temperature
- Maintain standard recommended FOS on shaft and end bearing
- Maintain high concrete strength by ensuring concrete stresses have a comfortable margin at 0.4fCu.
- Place geothermal loops on outside face of cages where possible

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Thanks For Listening

For More Information on Ground sourced heating and Cooling Systems Go To www.geothermalint.co.uk

Or

Contact Tony Amis at ta@geothermalint.co.uk

or on 07595 278428

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