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Geoenvironmental Research Centre
Canolfan Ymchwil Ddaearamgylcheddol



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Europe & Wales: Investing in your future
European Regional Development Fund

Horizontal Loop - Monitoring Systems

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Seren
Sustainable Earth Energy



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Overview



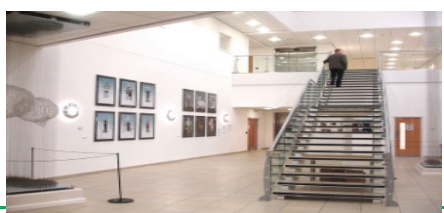

Current State of Monitoring

Seren Step forward for monitoring- Work in Progress

- Site detail
- Selection of sensors
- On site Sensors Arrangement
- Data Acquisition system and Data Management
- Site Investigation
- So far collected data

Potential usage of data

High Profile Projects in Wales

Project	Ground Source Heat Pump	Borehole/ Ground Loop	Depth of borehole (m)	BREEAM Rating	
Energy Centre, Bangor	Heating	16 Boreholes	100	Excellent	
IBEARS, Aberystwyth University	Heating	NA	NA	Excellent	
School Of Optometry and Vision Sciences, Cardiff University	Heating and Cooling	56 Boreholes	100	NA	
National Assembly for Wales, Cardiff	Heating and Cooling	27 Boreholes	100	NA	



Monitoring GSHP Systems

Current State

- Sites
 - School Of Optometry and Vision Sciences
 - National Assembly for Wales
- Monitors
 - Hot and Cold tank temperatures
 - Inflow and Outflow temperature of the borehole
- Points are just live values, meaning no history on them.....

Why?

- To find answer to the question of **Sustainability of GSHPs**
- **Long-term behaviour** of GSHPs
- **Significant market penetration**: a proof of long-term reliable operation



Monitoring Parameters – Seren Attempt

Ground Data

- Soil Temperature

Climate Data

- Solar Radiation
- Rainfall
- Ambient Air Temperature

Operation Parameters

- Flow rate
- Temperature Differential across the Heat Extractor

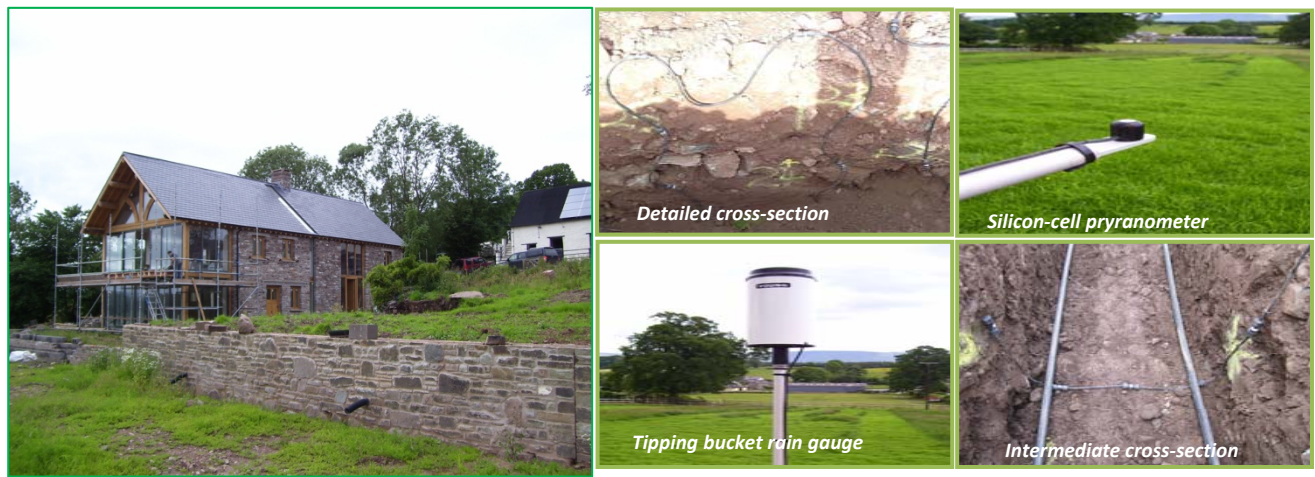
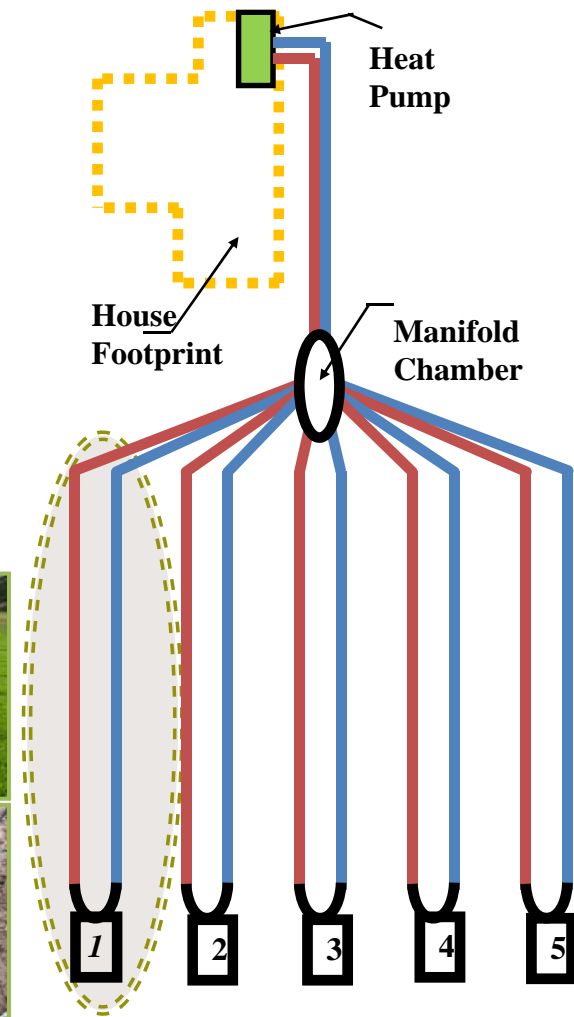
Recording time

- 15 mins

Site Details



Location	Lower Pentre Farm located in Ffynnon Gynydd, Powys
Building Type	Refurbished old cottage
GSHP system	Provides building space heating and hot water need
Horizontal ground Loop	5 Nos. 75 m long trenches
Depth of Trench	1.8 m
Monitored since	May 2012



Basis of Sensor Selection

Parameter	Reason
Robustness	Resist the in-situ ground conditions
Durability and Longevity	Duration of monitoring
Operating Range	Within the anticipated temperature range
Water Resistance	Subject to saturated soil condition
Precision and Accuracy	Capable of measuring the temperature to the appropriate data resolution
Data Logging	Compatible with the selected data logging equipment

Specification of sensors

Temperature- Thermistor String

Property	Details
Measurement precision	$\pm 0.2^{\circ} \text{C}$
Operating temperature	-80°C to $+75^{\circ} \text{C}$
Stability	0.01 $^{\circ} \text{C}$ or better per 100 months at 0 $^{\circ} \text{C}$
Resistance at 25 $^{\circ} \text{C}$	2252, 3k, 5k, 10k ohms
Cable type	Direct burial rated 22 gauge water blocked instrumentation cable

Rainfall – Tipping Bucket Rain Gauge

Property	Details
Accuracy	2 % up to 25 mm/hr, 3 % up to 50 mm/hr
Operating temperature	-20°C to $+50^{\circ} \text{C}$
Resolution	0.1 mm per tip
Catchment area	200 cm^2
Dimensions	18 cm diameter, 39 cm high (including mounting base)

Specification of sensors

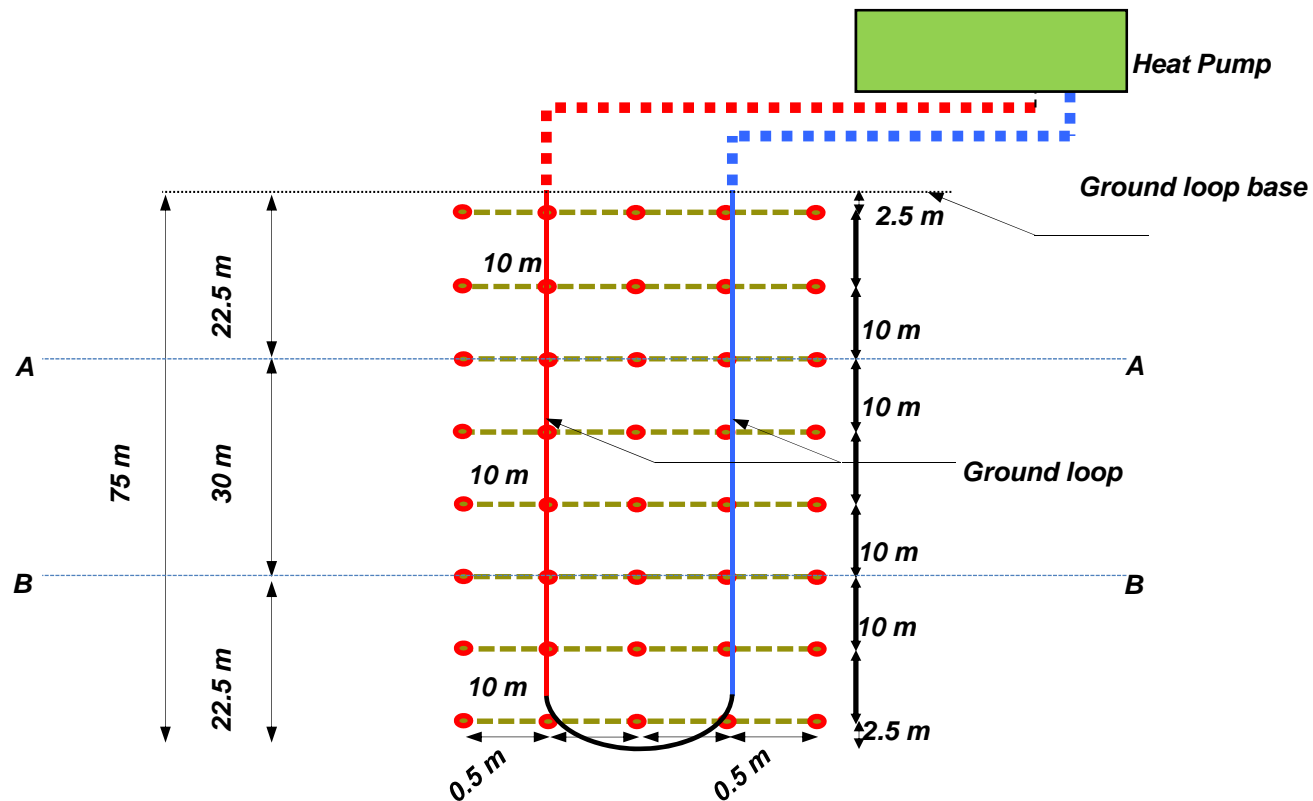
Solar Radiation - Pyranometer

Property	Details
Absolute accuracy	±5 %
Uniformity	± 3 %
Sensitivity	Custom calibrated to exactly 5.00 W/m ² per mV
Dimensions	2.40 cm diameter, 2.75 cm high
Mass	70 g (excluding signal wire)
Input power	None, self-powered
Materials	Anodized aluminium with cast acrylic lens

Thermal Conductivity - KD2 Probe

Property	Details
Thermal conductivity reading accuracy	±2.5 %
Specific heat capacity reading accuracy	±2.5 %
Thermal diffusivity reading accuracy	±5.0 %
Operating Temperature	-50°C to +150°C
Range of conductivity measurements	0.02 to 4 W/m.K
Range of specific heat capacity measurements	0.5 to 4 MJ/m ³ K
Probe dimensions	10 cm long, 0.24 cm diameter

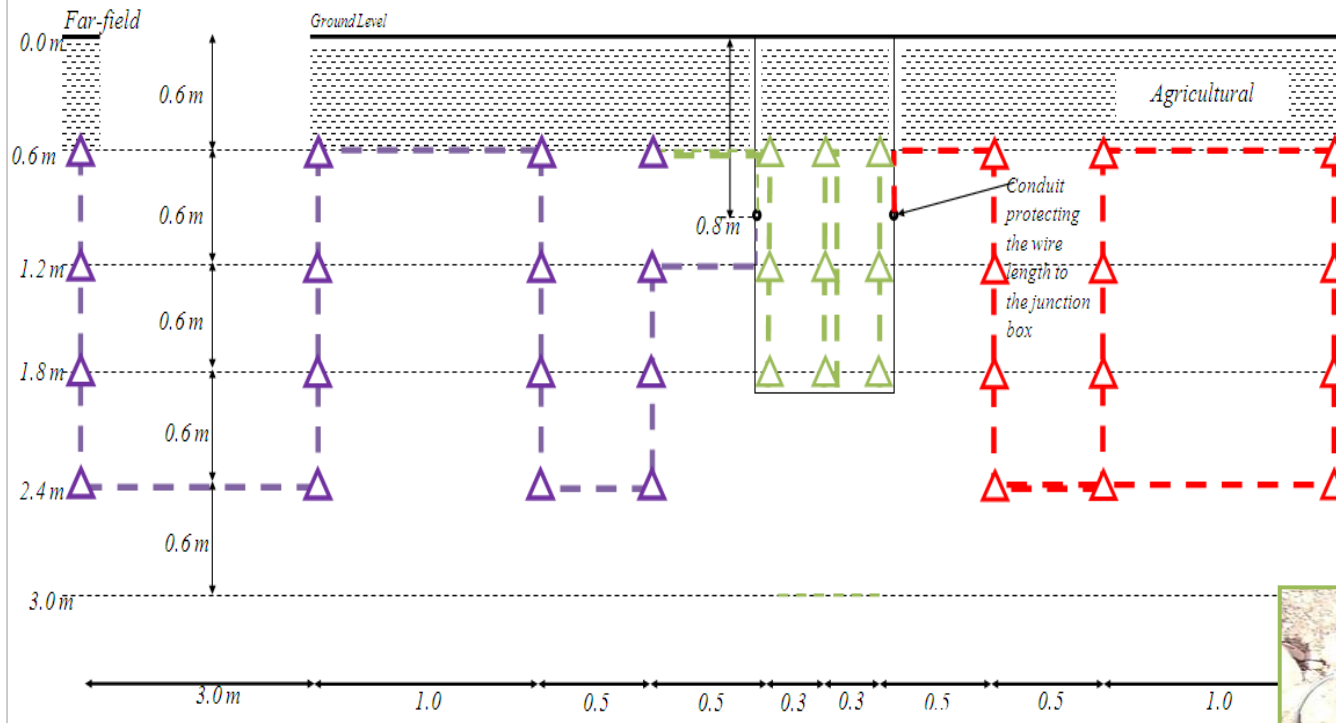
Layout of Sensors-Intermediate



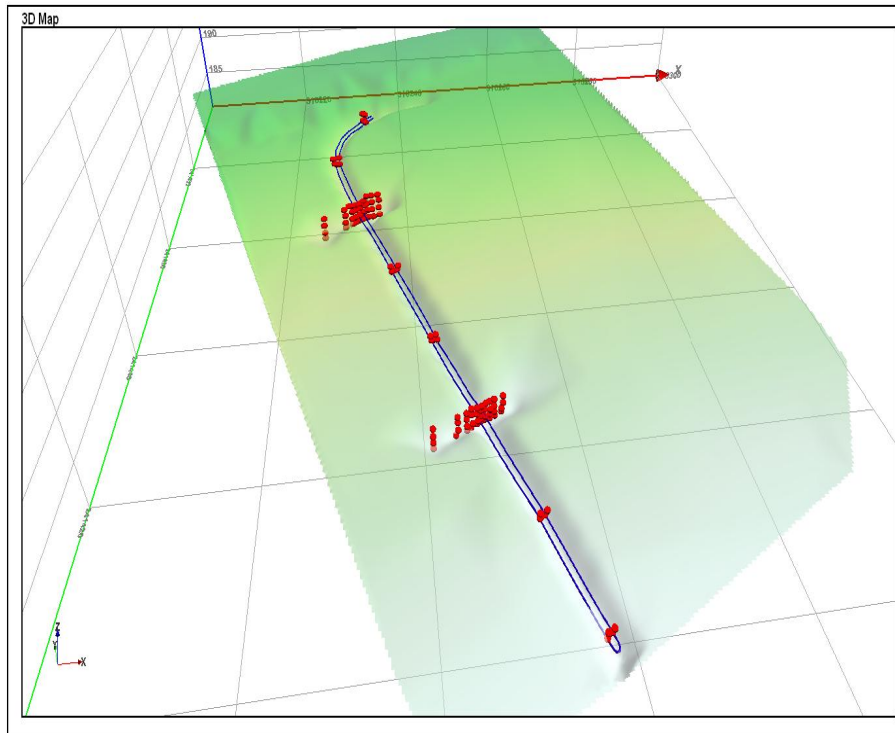
The objective of these sensors is to record the temperature of ground laying immediately adjacent to the ground loop.

Layout of Sensors- Detailed

Detailed Cross-Section A



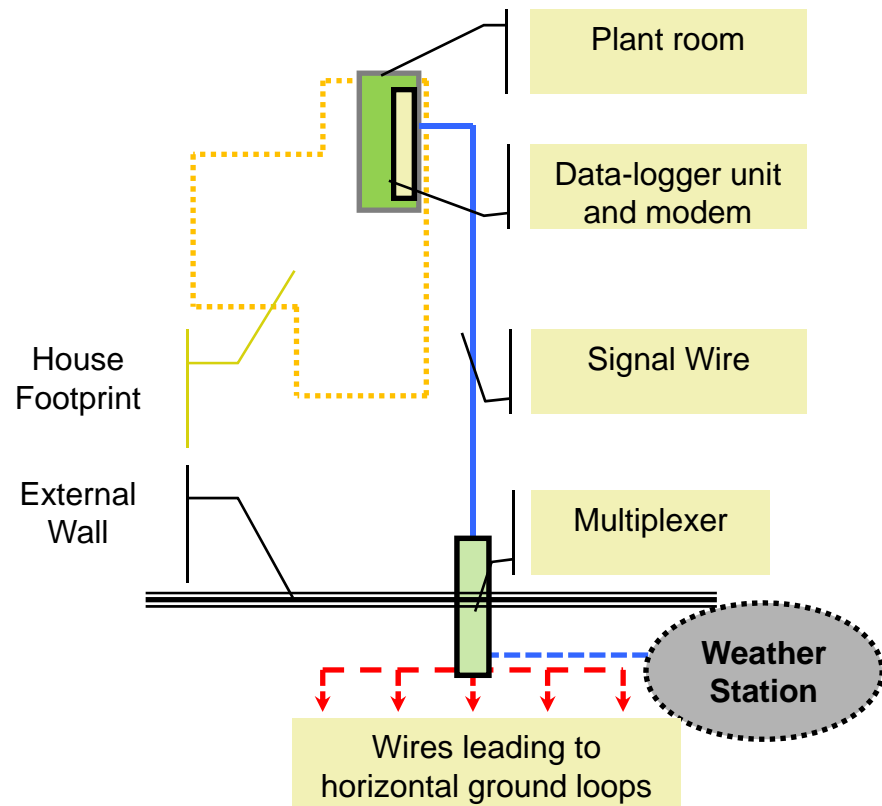
Topographical Survey



3D view of sensors position

Three dimensional position of sensor and sampling points are located using GPS (Global Positioning System).

Data Acquisition System



Data Logger-Campbell Scientific CR 1000

Property	Details
Analogue inputs	16 single-ended or 8 differentially individually configured
Maximum scan rate	100 Hz
Digital ports	8 I/Os or 4 RS232 COM
Memory	2 MB Flash (operating system) 4 MB (CPU usage, program storage and data storage)
Power requirements	9.6 – 16V, DC
Dimensions	23.9 x 10.2 x 6.1 cm

- Enabled the system to be continually monitored
- Enabled logged data to be remotely downloaded off-site.



Data Management Tool



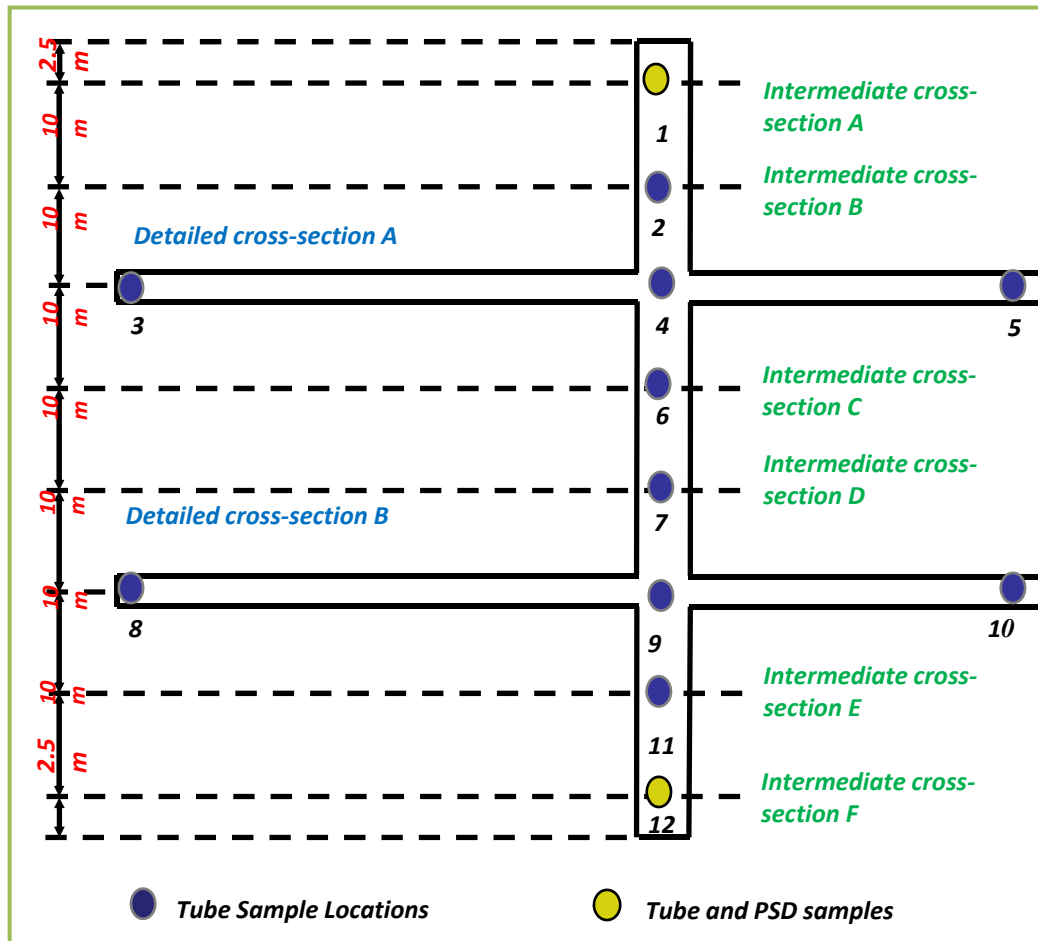
Identify and extract data based on:

Time ranges

Temperature ranges

Specific sensors groups

Site Investigation



Soil Properties determined

Thermal conductivity

Specific heat capacity

Moisture content

Porosity

Bulk unit weight

Particle Size Distribution (PSD)

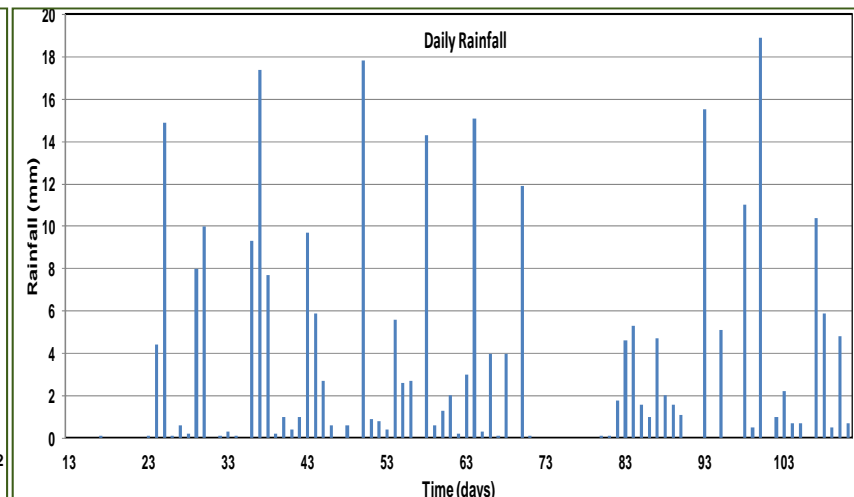
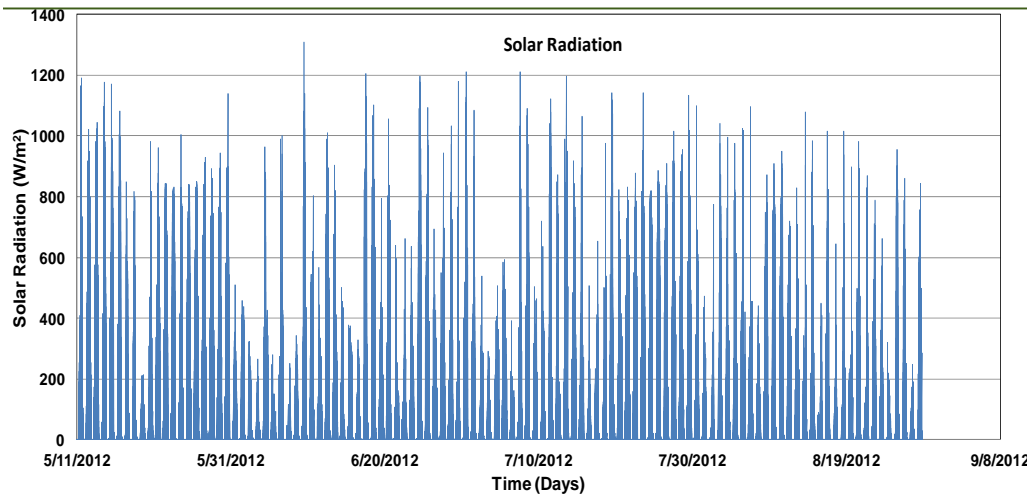
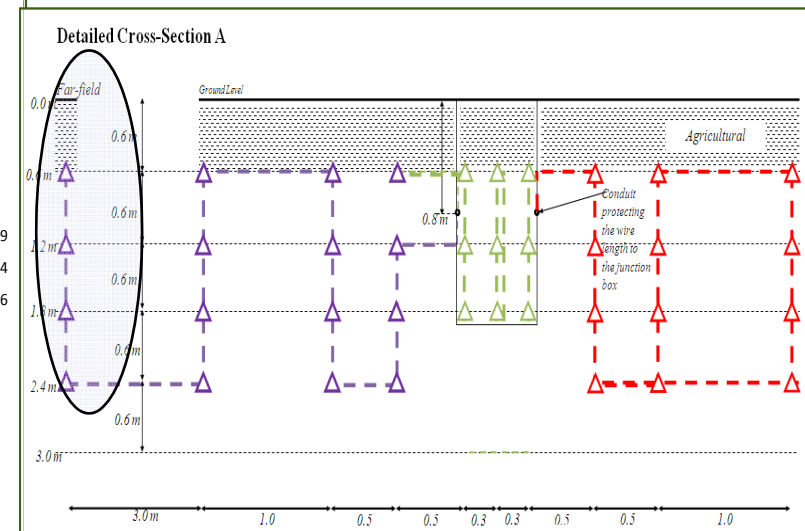
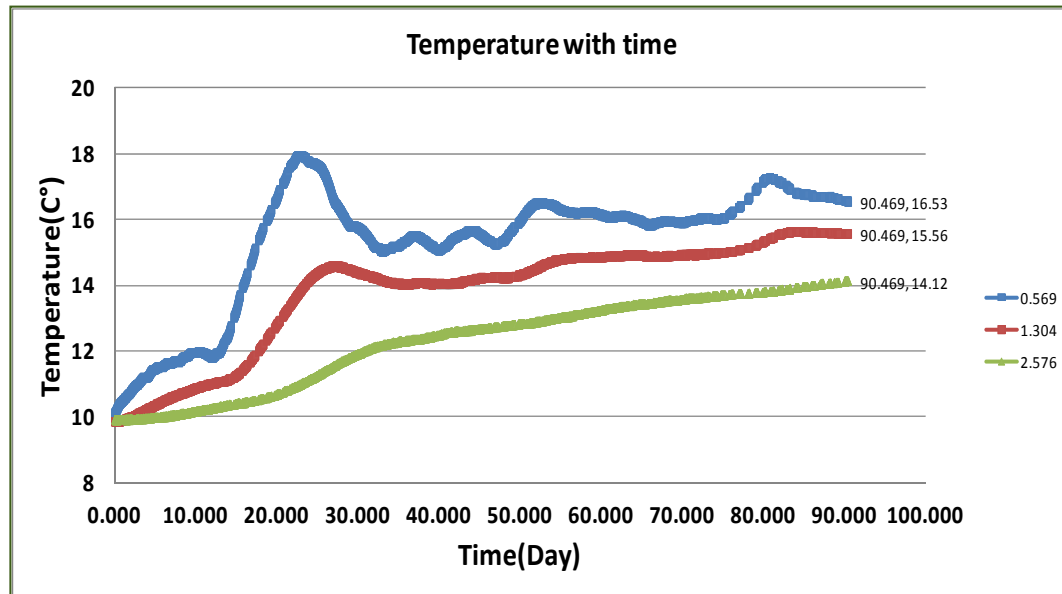
Mineral content

Soil Characterisation

Soil Properties	Min.	Max.	Avg.	Test Type
Thermal Conductivities	2.06	2.87	2.44	In-site
Moisture content	8	15	12	Lab
Bulk Unit Weight	13	19	16	Lab
Mineral Content	Quartz			Lab
Soil classification				Lab
Sample 1:	Fine Grained soil (Inorganic silt, ML) >70% passing 75 μ m			
Sample 2:	Coarse Grained soil (Gravel) <36% passing 4.5 mm			

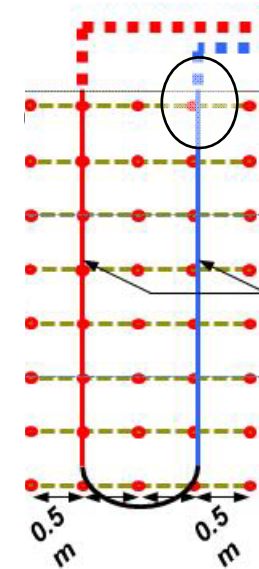
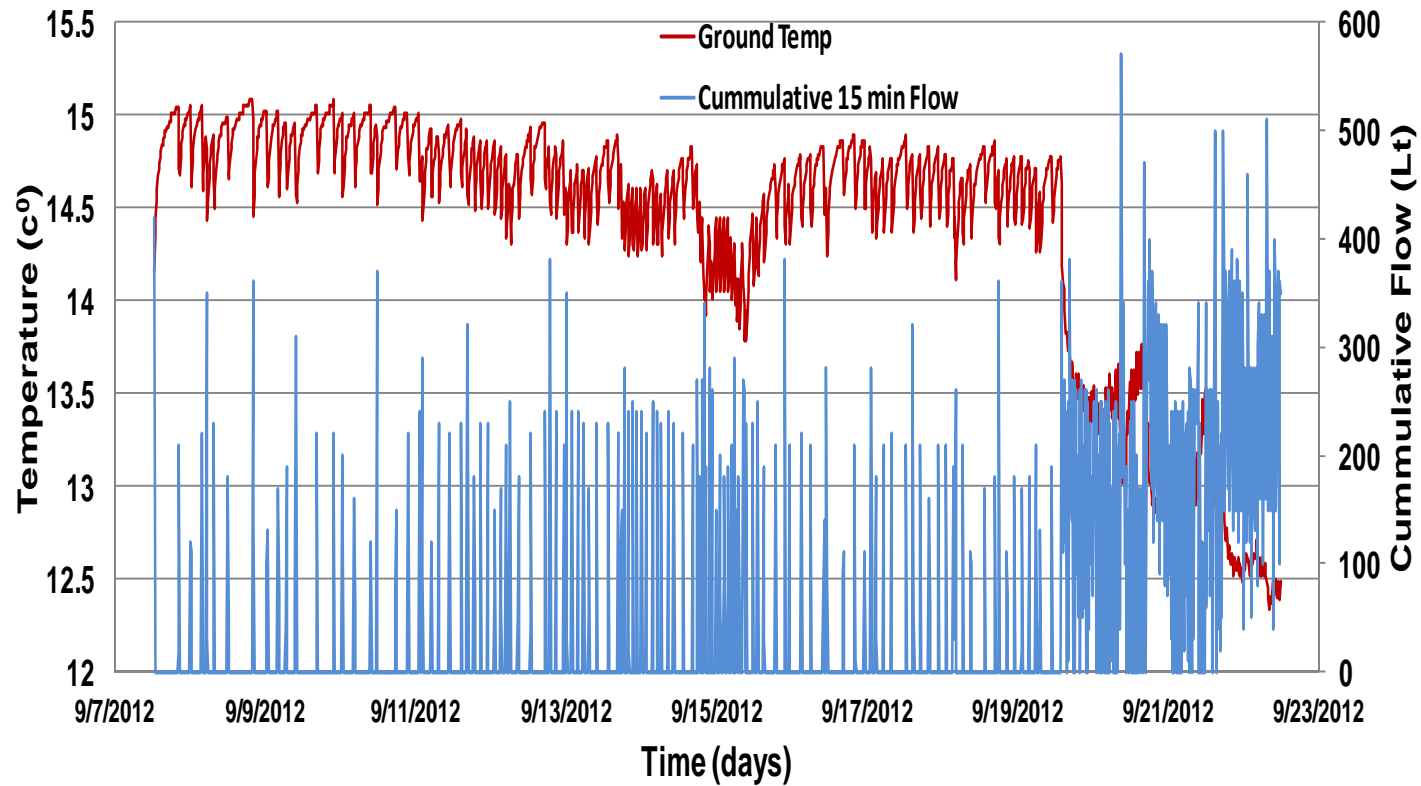


Data Collection- Undisturbed Ground Temperature





Data Collection – Heat Extraction Process



Potential usage of data

- ✓ Good case study
- ✓ Unique set of data, since many relevant parameters will be digitally recorded over several years
- ✓ Measured temperature will be used to calibrate the numerical model
- ✓ Calibrated model can in turn be used to forecast the future behaviour of the GSHP system.

