Closed Loop Borehole System

A Cottage, Somewhere

GEOREPORT

LEGEND

ATES	Aquifer Thermal Energy Storage
COP	Coefficient of Performance
EA	Environment Agency
GSHC	Ground Source Heating and Cooling
m bgl	Metres Below Ground Level
m bwt	Metres Below Well Top
m OD / mAOD	Metres Above Ordnance Datum
RWL	Rest Water Level
PWL	Pumped Water Level
SPF	Seasonal Performance Factor
TD	Total Depth
uPVC	Unplasticised Polyvinyl Chloride

Ref: J:\Work Aids\Example Prognosis and Georeports\Georeport\Georeport.doc

GEOREPORT

Information Supplied

Address:	A Cottage, Somewhere
Site Grid Reference:	AB 123 456
Elevation:	100mAOD
Type of System:	Closed loop
Required energy load:	10kW

Summary

- There are no superficial deposits recorded although a thin layer of drift should be expected. Any Superficial deposits will be underlain by Upper Coal Measures to a depth of over >200m.

- The Upper Coal Measures contain coal bearing strata. Therefore the driller should be aware of the following possible hazards:

    - coal workings
    - mine gas risk

  Assessment of these risks is beyond the scope of this report.

- The rest groundwater level beneath the site is expected to be 15-20 m below the surface.

- There is a general requirement to inform the BGS of the intent to drill a borehole greater than 15m in depth and to supply the construction / geological information to them on completion.

- Before drilling through any coal bearing strata permission must be gained from the Coal Authority prior to drilling.

- A contaminated land survey is beyond the scope of this report. It is recommended that a historical land use survey is undertaken in order to identify any potential sources of contamination or that any made ground encountered should be stored separately and appropriately before being removed from site and sent to a suitably licensed waste facility.

- The peak energy requirement of the site has been provided as 10kW. Based on the assumptions given, a single 194m deep closed loop borehole length is required at this location. However, we recommend two closed loop boreholes; each to a depth of 97m, penetrating the Middle Coal Measures. The boreholes should be spaced at least 15m from each other.

Site Description (Figure 1)

- Site located at an elevation of approx 100mAOD.
- A pond is located 150m south west of the site at 100mAOD.
- A small stream is located 200m AOD south east of the site at 90mAOD.
- There are numerous springs in the area the closest being 1km south west at 90mAOD.

Geology (Figure 2)

Formation / Group		***Description***	***Expected Thickness***
Superficial Deposits		None indicated although a thin layer of drift should be expected	1-2m (< 5m)
Upper Coal Measures	Radstock Member	Mudstones and Siltstones interbedded with thick well cemented Sandstones, muddy coal seams and marine bands. Sandstone bed 10-15m thick present at surface.	>200m

Geological Structure

- The strata beneath the site dip at approximately 18 degree angle to the east.
- The closest fault is located 50m north of the site, down throwing strata to the north.
- The Hunstrete Fault is located 200m east, down throwing strata to the east.
- Potential worked coal seams may be present within the top 100m beneath the site.

Borehole Stability / Drilling Risks

It is likely that any superficial deposits will be unstable and should be cased out prior to drilling.

There is a risk that broken ground associated with local faults could be present beneath the site.

There is likelihood that the borehole may encounter coal seams or coal mine workings. These pose a potential risk of loss of drilling fluid / loss of grout. Moreover, there is a potential risk of encountering mine gas or contaminated mine water. Prior to drilling, permission must be obtained from the Coal Authority, who will advise on measures to minimise risks related to gas and mine water.

Hydrogeology

Rest Groundwater Level	The rest water level beneath the site is expected to be between 15 – 20mbgl. A perched water level may be present within the sandstone at shallow depth.	
Aquifers	Superficial Deposits	N/A
	Upper Coal Measures	The Upper Coal Measures are classed as a minor aquifer. Groundwater flow occurs through fractures within sandstone units. If flooded mine workings are intersected then yields can be greatly increased.

Thermal Conductivity

Formation / Group	***Thermal Conductivity (W/mK)***
Upper Coal Measures (Westphalian)	1.79

Average Thermal Conductivity (Weighted arithmetic mean, based on 100 m borehole):

- Best estimate of average Thermal Conductivity (weighted arithmetic mean): ~ 1.79
- Conservative estimate of thermal conductivity (best estimate - 15%): ~ 1.52

BGS Records

There are no relevant BGS boreholes close to the site

Borehole Siting

There is a risk that the borehole may encounter unrecorded and potentially worked coal seams. These pose a potential risk of loss of drilling fluid / loss of grout. Moreover, there is a potential risk of encountering mine gas or contaminated mine water.

A coal mine search should be made with the Coal Authority prior to drilling.

Use of 'Air flush' in residential areas is not recommended and is likely to be prohibited by the Coal Authority

Borehole Construction (Figure 3 and Appendix A)

A total borehole length 194m is required (Appendix A).

We recommend that two closed loop boreholes are drilled to a depth of 97m. The boreholes should be spaced at least 15m from each other.

The boreholes should be backfilled around the closed loop U-tube using thermally enhanced grout. We recommend that a grout with a thermal conductivity of at least 1.6 W/m/K should be specified.

Regulation

Consent and licence not required for closed loop boreholes.

Permission from the Coal Authority is required before drilling through coal-bearing strata.

Discussion

The geology beneath the site has been evaluated on the basis of readily available 1:50 000 scale maps; England and Wales Sheet 123 and Sheet 456.

A contaminated land risk assessment is beyond the scope of this report and it is recommended that an historical land use survey is undertaken prior to drilling. Alternatively, any made ground encountered could be considered contaminated, stored separately from any other spoil and sent to a suitably accredited waste disposal facility.

The borehole length in this report has been calculated using in house DCLB v. 2.1 software. When using this tool, we have assumed the following:

(i) The peak load of the heat pump is 10 kW. The maximum duration of peak load on the coldest day is assumed to be 13 hours.
(ii) The heating load required is equal to 2400 peak load operational hours:
10 kW x 2400 hrs = 24 MWh
(iii) The heating season duration is 7 months

Peak load minimum mean carrier fluid temperature	Does not drop below -5^{o}C
Winter baseload mean carrier fluid temperature	Does not drop below 0^{o}C
Seasonal Performance Factor of heat pump	3.5
Assumed Borehole Diameter (mm)	150
Undisturbed Ground Temperature (^{o}C)	12.15
Borehole Thermal Resistance (Km/W)	0.13
Assumed volumetric heat capacity of ground	2.20 MJ/m^{3}/K (use site specific value from BGS if available)

The client should be aware that no heating load figures have been provided to other than the projected peak load. The above figures are thus generic assumptions for which can assume no responsibility. The client should carefully check that the assumptions in (i) to (iii) above correspond to his/her requirements, as the dimensioning of the ground loop will be significantly affected by assumed loading figures.

The length of borehole required will be related to the thermal conductivity of the ground (among other factors). Our best estimate of the average ground thermal conductivity is 1.79 W/m/K. In order to account for unavoidable natural uncertainty and to allow a factor of safety, this value has been reduced by a factor of 15% to 1.52 W/m/K before being applied to the DCLB model (Appendix B).

Using a conservative estimate of the average thermal conductivity of the geological sequence: namely **1.52 W/m/K**, we calculate that a borehole length of **194 m** will be adequate to support an installed heat pump capacity of 10 kW (Appendix B), with the assumed annual heating load described above.

We recommend two closed loop boreholes; each to a depth of 97m, penetrating the Upper Coal Measures. The boreholes should be spaced at least 15m from each other. The boreholes should be backfilled with a thermally enhanced, low permeability grout around the U-tube.

The boreholes should be drilled to equal depths to prevent hydraulic imbalance leading to low ground loop return temperatures and ultimately failure of the system.

Pipe diameters and carrier fluid type should be selected to yield turbulent fluid flow within the borehole U-tube (to maximise heat transfer) and laminar flow in the surficial “header” pipes (to minimise heat loss), under the operational fluid flow rate.

Further detailed analysis is unwarranted for this scale of development. It is considered that the assumptions made in the assessment provide a conservative factor of safety.

There is a general requirement to inform the BGS of the intent to drill a borehole greater than 15m in depth and, following drilling, to supply the resulting constructional/geological information to them.

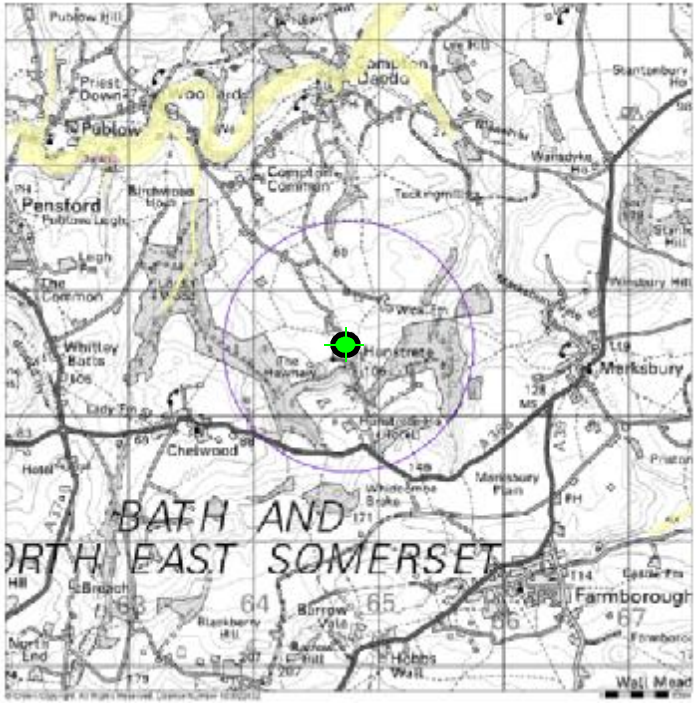
Based on the information provided, consent to construct the borehole will not be required from the EA as the proposed system is a closed loop system and therefore no abstraction of natural water will be undertaken.

This report has been prepared based on limited geological and thermogeological information. Although we have applied our experience and expertise to the data available, no guarantee can be made as to the performance of the system.

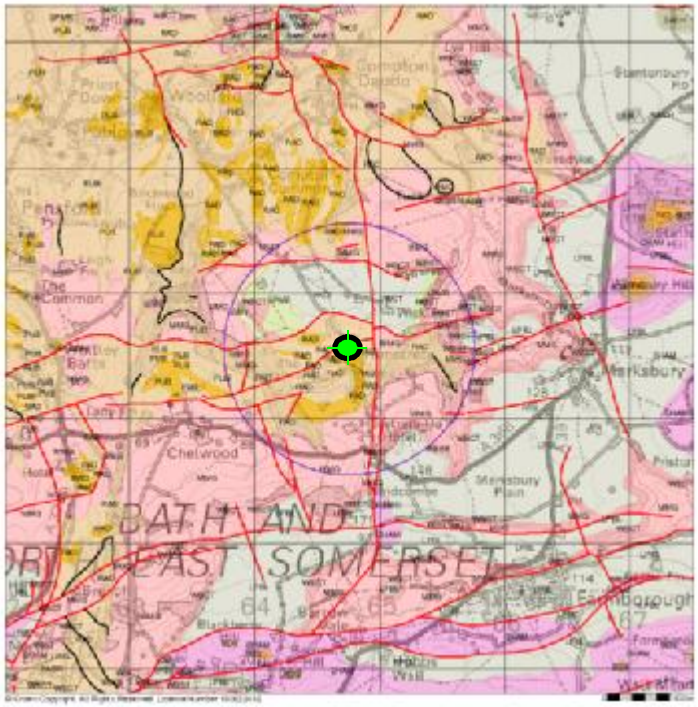
Development of boreholes has an inherent risk. Developers should be aware that it is possible that unforeseeable ground conditions may exist that result in increased development costs.

Completed by	***Date***	***Checked by***	***Date***

Superficial Geology



Solid Geology



Alluvium

Inferior Oolite Group

Liassic Group

Penarth Group

Mercia Mudstone Group

Coal Measures (Predominantly Mudstone)

Coal Measures (Sandstone)

Site Location

Fault

Coal Outcrop

Ref: S:\Example Report\ Figure2 Geology.cdr Date: 18/12/09	**A Client**
Figure 2	A Cottage - Geology

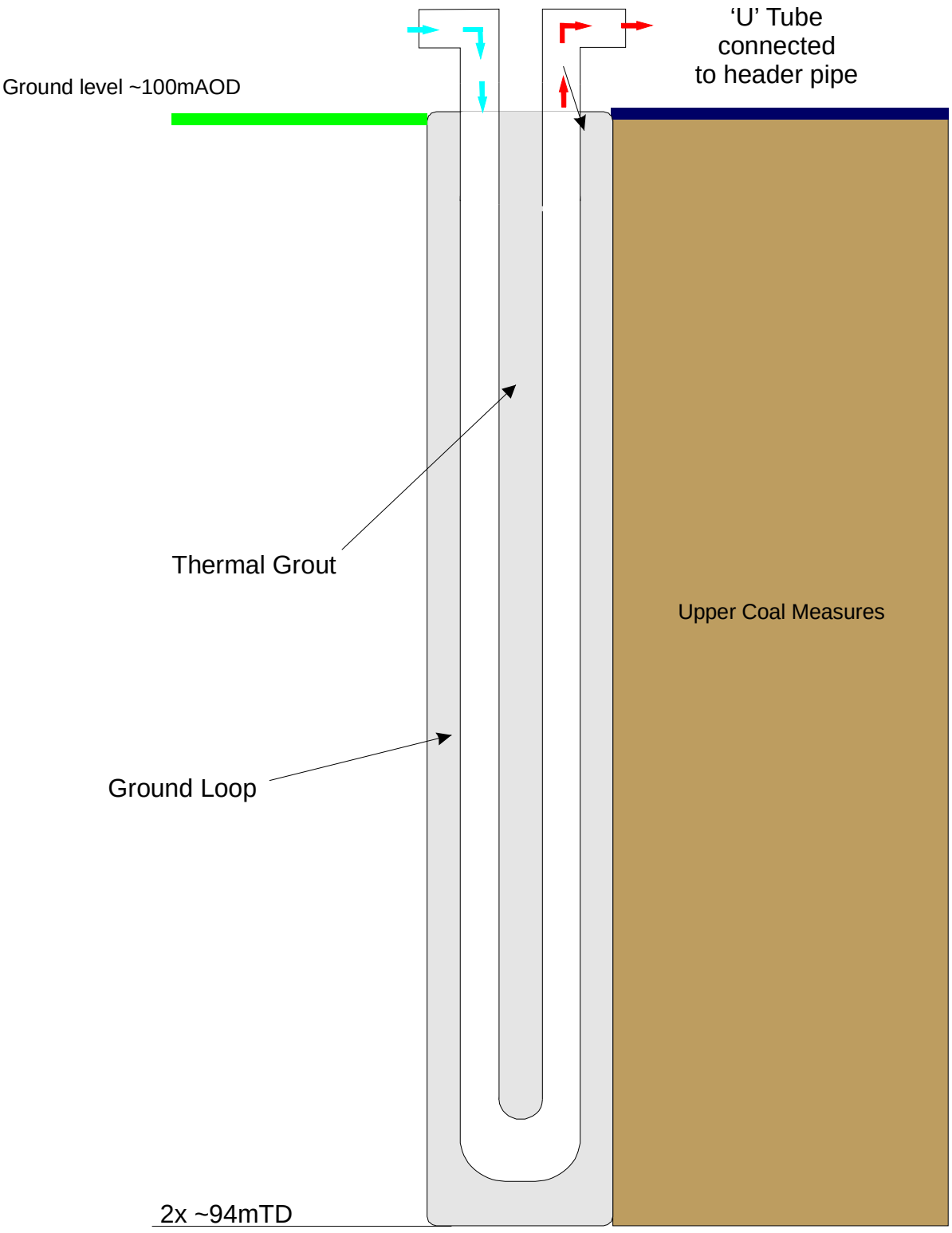


Diagram assumes the to supply the 10kW energy demand
Two Closed Loop boreholes to 94m should be drilled
Diameters to be confirmed by drilling contractor depths
may vary depending on the geology encountered

Ref: S:\Example Report\ borehole schematic Date: 23/12/09	**A Client**
Figure 3	A Cottage - Borehole Schematic

Input parameters - thermogeology			HEATING
Undisturbed ground temperature	12.0	°C	*Default assumption = 12°C*
Thermal conductivity	1.52	W/m/K	
Ground volumetric heat capacity	2.20	MJ/m3/K	*Default assumption = 2.2 MJ/m3/K*
Thermal diffusivity	6.91E-07	m2/s	*Calculated*
Euler's Constant	0.57721567		
SQRT 4.5	2.12132034		

Input parameters - borehole			
Borehole diameter	150	mm	*Default assumption = 150 mm*
Borehole thermal resistance	0.13	Km/W	*Default assumption = 0.13 Km/W*
Borehole Length	194	m	

Input parameters - loads and heat pump			
Heat Pump Capacity	10	kW	*Assumed to be peak load*
Seasonal Performance Factor	3.5		*Default assumption = 3.5*
Assumed peak hours per year	2400	hrs	*Default assumption = 2400 hrs*
Heating season duration	7	months	*Default assumption = 7 mths*
Winter heating load	24	MWh	*Calculated*
Duration of peak load on coldest day	13	hrs	*Default assumption = 13 hrs*
Month of heating season with peak	4		*Default assumption = 4 (Jan)*
Average duration of peak heat	11.3	hr/day	*Calculated*
Simulation period	25	years	*Default assumption = 25 years*

Domestic Closed Loop Borehole (DCLB v. 2.1) 11/11/08

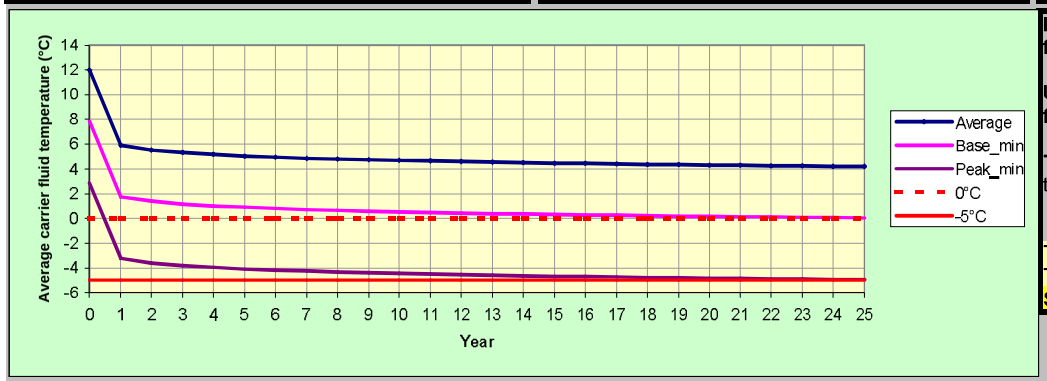
The DCLB program is developed by © David Banks t/a Holymoor Consultancy, 2008, of 8 Heaton Street, Chesterfield, Derbyshire, S40 3AQ. Its use is licensed to JDIH (Water and Environment) Ltd. Of Draycott, Derbyshire.

DCLB is designed to give an approximate solution to the extraction of small quantities of heat from a single closed loop borehole. The approximation is achieved using three additive step functions, corresponding to (i) An annual, year on year baseload, (ii) an additional winter heating season load, (iii) a short duration peak load. ***The user is deemed to understand the limitations of this spreadsheet and to be aware of the assumptions underlying its use.*** For UK conditions, it is suggested that a heating season of 7 months duration gives good comparison with more sophistocated programs such as EED. For rigorus simulation of borehole performance, the user is directed to commercial software such as Earth Energy Designer (EED).**This program requires the XNUMBERS add-in for Excel to function correctly (http://en.wikipedia.org/wiki/XNUMBERS).**

Peak Load		
Heat extraction	7143	W
Borehole radius	0.075	m
t	0.54	days
t (sec)	46800	seconds
q (W/m)	36.82	W/m
U	4.35E-02	
Temp drop in rock mass	12.15	°C
Temp drop at borehole	4.79	°C
Temp. at time t	-4.94	°C
Temp must not drop below	-5.00	°C

Winter Seasonal Load		
Heat extraction	3353	W
Borehole radius	0.075	m
t	213	days
t (sec)	18408096	seconds
q (W/m)	17.28	W/m
U	1.11E-04	
Temp drop in rock mass	9.70	°C
Temp drop at borehole	2.25	°C
Temp. at time t	0.05	°C
Temp must not drop below	0.00	°C

Average Annual Load		
Heat extraction	1956	W
Borehole radius	0.075	m
t	9131	days
t (sec)	788940000	seconds
q (W/m)	10.08	W/m
U	2.58E-06	
Temp drop in rock mass	6.49	°C
Temp drop at borehole	1.31	°C
Temp. at time t	4.20	°C



Lower compliance limit	40707	seconds
for valid approximation	11	hours
Upper compliance limit	17.1	years
for valid approximation	=ts/10	
Time for steady state	5.39E+09	seconds
ts	62385	days
	171	years
Temp drop in rock mass	7.50	°C
Temp drop at borehole	1.31	°C
Steady State Temperature	3.19	°C