

Closed Loop Borehole System

A Cottage, Somewhere

GEOREPORT



for

A Client

by

Carbon Zero Consulting
Cedars Farm Barns
Market Street
Draycott
Derbyshire
DE72 3NB

Tel. 0844 8550115
Fax. 01332 874850
E-mail. info@carbonzeroco.com
Web. www.carbonzeroco.com

LEGEND

ATES	Aquifer Thermal Energy Storage
COP	Coefficient of Performance
CZC	Carbon Zero Consulting
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

© Carbon Zero Consulting Ltd. 2010

Carbon Zero Consulting is a specialist division of Carbon Zero Consulting Ltd. Registered in England & Wales No. 6647619. Registered office: Cedars Farm Barn, Market Street, Draycott, Derbyshire, DE72 3NB, UK

Any report provided by Carbon Zero Consulting Ltd. ("CZC") is for the client's use and may be reproduced by the client for internal use. The report must not be issued to third parties without the express written consent of CZC. If the report is released to any third party, CZC will not accept responsibility or liability of any nature to that third party to whom the report (or part thereof) is released. Moreover, CZC will accept no liability for damage or loss as a result of any report being made known to, or relied upon by, a third party, unless expressly agreed with CZC in writing.

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.



James Dodds MSc CGeol FGS
Director

Site Description (Figure 1)		
<ul style="list-style-type: none"> • 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)		
<i>Formation / Group</i>	<i>Description</i>	<i>Expected Thickness</i>
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		
<ul style="list-style-type: none"> • 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		
<p>It is likely that any superficial deposits will be unstable and should be cased out prior to drilling.</p> <p>There is a risk that broken ground associated with local faults could be present beneath the site.</p> <p>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.</p>		
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		
<i>Formation / Group</i>	<i>Thermal Conductivity (W/mK)</i>	
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 CZC's 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°C
Winter baseload mean carrier fluid temperature	Does not drop below 0°C
Seasonal Performance Factor of heat pump	3.5
Assumed Borehole Diameter (mm)	150
Undisturbed Ground Temperature (°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 Carbon Zero Consulting, other than the projected peak load. The above figures are thus generic assumptions for which Carbon Zero Consulting 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.

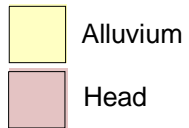
Development of boreholes has an inherent risk. Developers should be aware that it is possible that unforeseeable ground conditions may exist that result in increased development costs.

Carbon Zero Consulting standard terms of engagement apply to this report. Copies can be supplied on request.

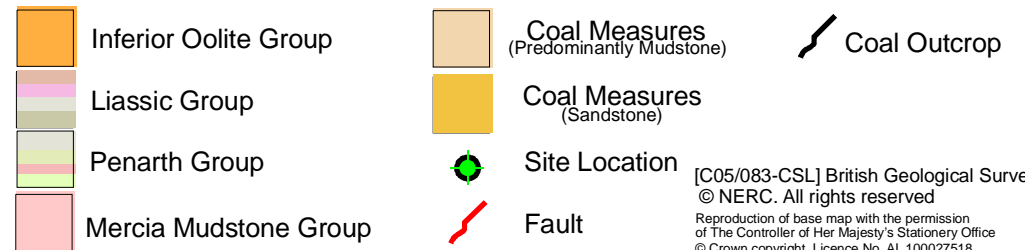
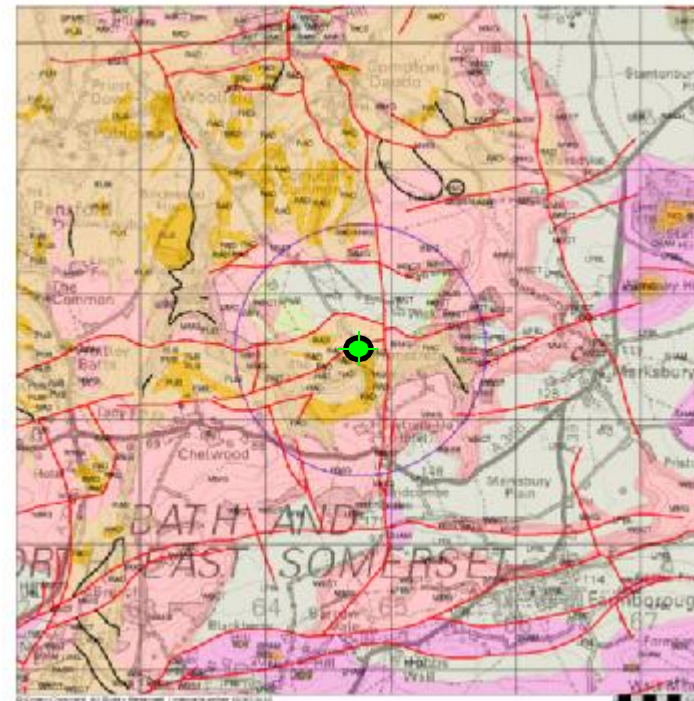


Completed by	Date	Checked by	Date

Superficial Geology



Solid Geology



[C05/083-CSL] British Geological Survey.
 © NERC. All rights reserved.
 Reproduction of base map with the permission
 of The Controller of Her Majesty's Stationery Office
 © Crown copyright. Licence No. AL 100027518



Ref: S:\Example Report\
 Figure2 Geology.cdr
 Date: 18/12/09

A Client

Figure 2

A Cottage - Geology

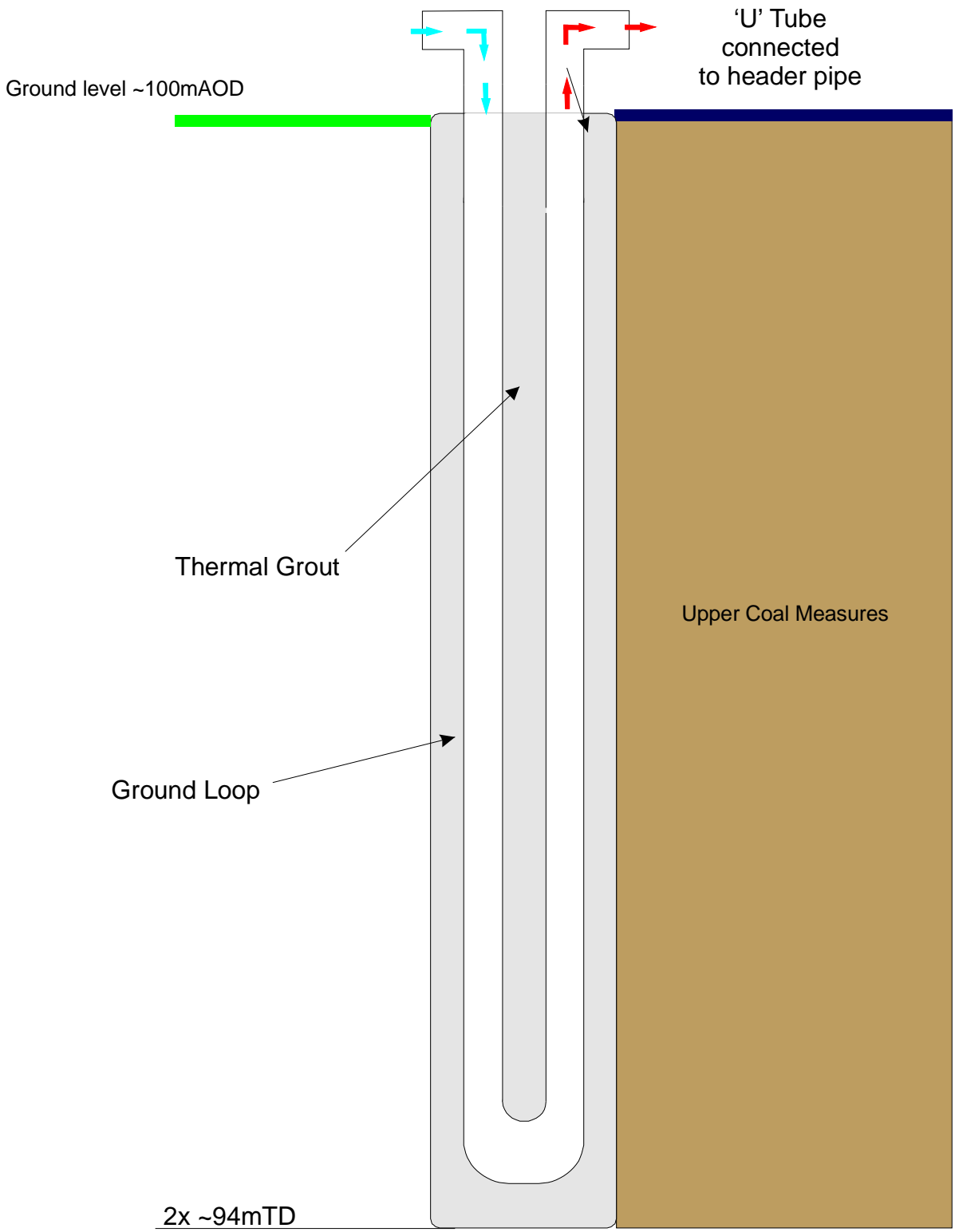


Diagram assumes the to supply the 10kW energy demand
 Two Closed Loop boreholes to 94m should be drilled
 Diameters to be confirmed by drilling contractor depths
 may vary depending on the geology encountered



Ref: S:\Example Report\
 borehole schematic
 Date: 23/12/09

A Client

Figure 3

A Cottage - Borehole Schematic

Input parameters - thermogeology	
Undisturbed ground temperature	12.0 °C
Thermal conductivity	1.52 W/m/K
Thermal volumetric heat capacity	2.20 MJ/m ³ /K
Thermal diffusivity	6.91E-07 m ² /s
Euler's Constant	0.57721567
SQRT 4.5	2.12132034

HEATING
 Default assumption = 12 °C
 Default assumption = 2.2 MJ/m³/K
 Calculated

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

Default assumption = 150 mm
 Default assumption = 0.13 Km/W

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

Assumed to be peak load
 Default assumption = 3.5
 Default assumption = 2400 hrs
 Default assumption = 7 mths
 Calculated
 Default assumption = 13 hrs
 Default assumption = 4 (Jan)
 Calculated
 Default assumption = 25 years



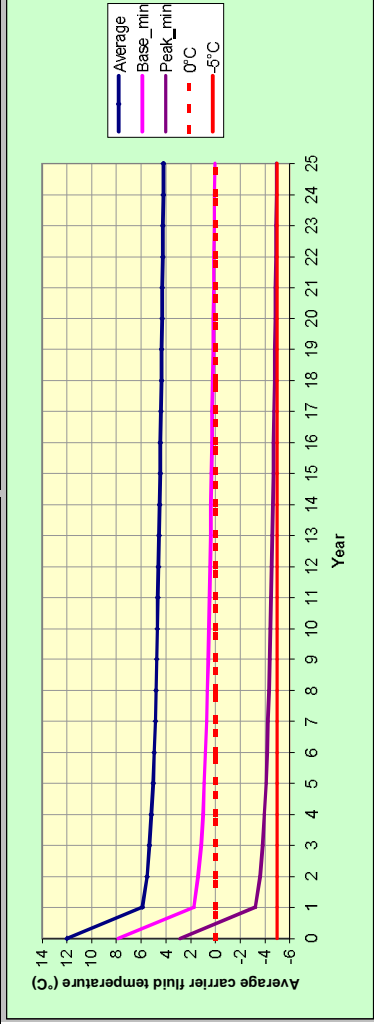
Domestic Closed Loop Borehole (DCLB v. 2.1) 11/11/08
 The DCLB program is developed by © David Banks t/a Holywood Consultancy, 2008, of 8 Heaton Street, Chesterfield, Derbyshire, S40 3AQ. Its use is licensed to JDJH (Water and Environment) Ltd. Of Draycott, Derbyshire.

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 base load, (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 sophisticated programs such as EED. For rigorous 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	7.143 W
Borehole radius	0.075 m
t (sec)	0.54 days
q (W/m)	46800 seconds
U	36.82 W/m
	4.35E-02
Temp drop in rock mass	12.75 °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 (sec)	213 days
q (W/m)	18408096 seconds
U	17.28 W/m
	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 (sec)	9131 days
q (W/m)	788940000 seconds
U	10.08 W/m
	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 for valid approximation	40707 seconds 11 hours
Upper compliance limit for valid approximation	17.1 years =ts/10
Time for steady state	5.39E+09 seconds 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