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## Project FRACFLOW - Report on the Drilling and Completion of Boreholes, Tilmanstone, Kent

M J Bird, J P Bloomfield, D K Buckley, I N Gale,
K Griffiths, A T Williams and P Williams

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# 1. INTRODUCTION

This short technical note describes the drilling programme, preliminary logging activities, and hydraulic tests associated with two boreholes that have been drilled at the Tilmanstone Research Site, near Eastry, Kent as part of the FRACFLOW project. FRACFLOW is a project funded by the European Commission under the Environment and Climate Programme 1994–1998 ($4^{th}$ Framework Programme). The full project title is 'Contaminant transport, monitoring techniques, and remediation strategies in cross European fractured Chalk'. Partners in the project are the Geological Survey of Denmark (GEUS), Ben Gurion-University of the Negev (Israel), the British Geological Survey (BGS), Karlsruhe University (Germany) and the Hebrew University of Jerusalem (Israel).

The project is a three-year study, initiated in December 1997, with two overall objectives:

- to characterize flux and transport of organic and inorganic contaminants through fractured Chalk systems in Europe, and

- to identify generic contaminant monitoring and remediation strategies for various contaminant and hydrogeological scenarios in fractured Chalk across Europe.

These objectives are to be achieved by using a range of hydrogeological, geochemical, biological and petrophysical techniques at laboratory and field scale. As part of the study, two contaminated sites are being investigated in the UK. One at Tilmanstone in Kent and another at the Cambridgeshire research site. Two field sites will also be used in Denmark. These are at Sigerslev Quarry and the Drastrup test site.

This short report presents results from the initial stage of the development of the Tilmanstone site. The following sections briefly describe the nature of the contamination in the Tilmanstone area and give details of the borehole locations and drilling programme. These include information on the construction and completion of the two boreholes. There then follows a description of the logs that are available to date, including lithological logs and a range of geophysical logs. The report is concluded with a short description of three packer tests that have been performed on the vertical borehole at Lower Venson Farm.

The aim of the report is to collate all data collected to date for use by partners in the FRACFLOW project as well as University College London (who are also undertaking research at Tilmanstone). No attempt has been made to interpret the data at this stage. This report is to be used as a basis for which other investigations will be undertaken.

## 1.1 Groundwater Contamination at the Tilmanstone Site

Discharge of minewater from Tilmanstone colliery at the ground surface (onto unconfined Chalk) has resulted in an area of more than 30 km$^2$ of the Chalk aquifer becoming contaminated with saline water (Carneiro, 1996). Between 1907 and 1974 an estimated 318 000 tonnes of chloride were discharged, with only a limited amount, about 15% (Headworth et al, 1980) dissipated by stream flow. The plume is estimated to be about 100 m thick with a maximum concentration of 1000 mg/l (Carneiro, 1996).

## 1.2 Site and Borehole Location

The study area is located in the North and South Stream catchment, east Kent, south-east England, Figure 1, about 2.5 km north east of the discharge area at Tilmanstone. The boreholes were drilled on land owned by Southern Water Services Ltd, at the site known as Lower Venson Farm (TR 303 531). There are three earlier boreholes at the site that were drilled in the mid-1970s by the then National River Authority for the purposes of monitoring the development of the plume. The positions of the new boreholes, in relation to the pre-existing boreholes at the site and other local features, are shown on the site plan, Figure 2.

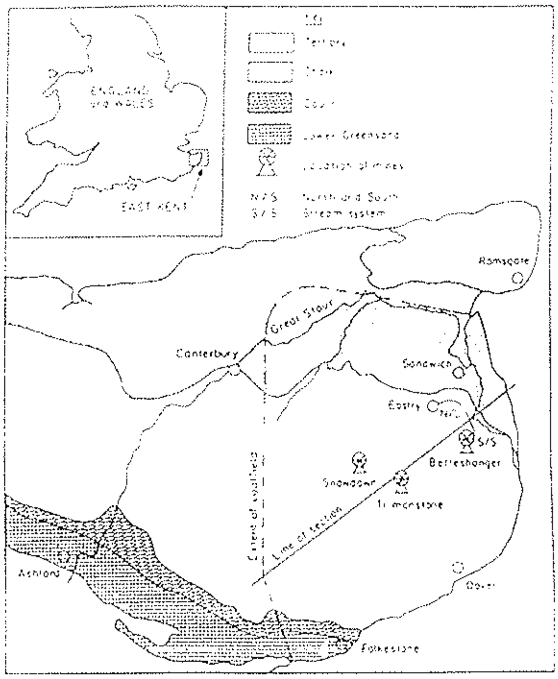



**Figure 1** **Location map with simplified geological map of East Kent showing the position of the Tilmanstone mine, the Chalk outcrop and the location of the Tilmanstone study site south west of the village of Eastry (from Headworth et al, 1980).**

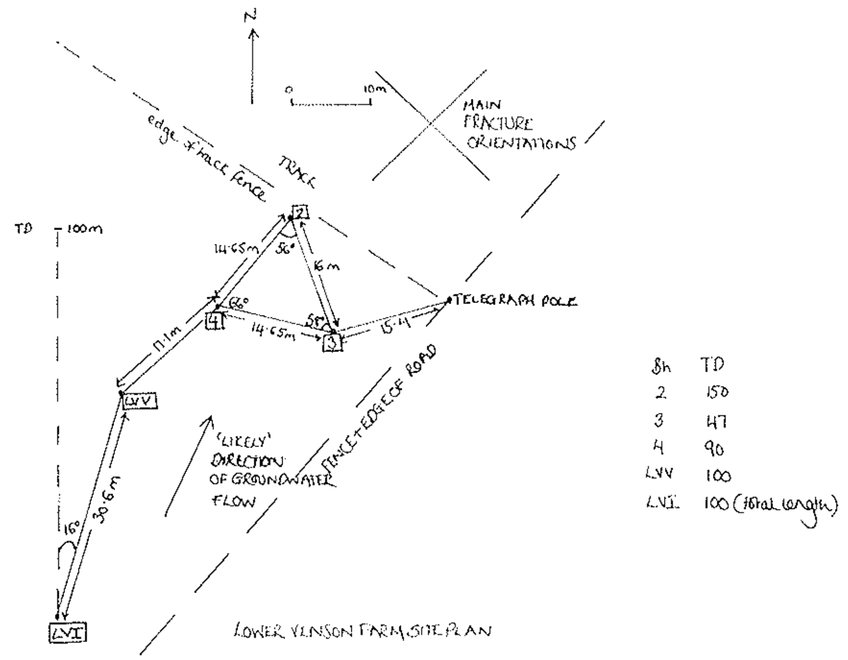



**Figure 2** **Plan of the Tilmanstone study site. The positions of the two new boreholes, LVI and LVV, are indicated as well as the location of the three pre-existing Environment Agency boreholes (boreholes 2, 3 and 4).**

Two boreholes were drilled at the Tilmanstone site, with four specific aims. These were as follows:

- To characterize the fracture distributions at the site. This information will be used in the development of conceptual and stochastic models (site specific and generic) of contaminant transport in fractured Chalk.
- To provide pore water and fracture water profiles. These will be used to investigate the present day distribution of chloride contamination at the site.
- To provide boreholes for hydrogeological investigations, such as packer tests, pumping tests and tracer tests. The boreholes will also be used to monitor plume development on completion of the hydraulic tests.
- To provide samples of chalk matrix and chalk fracture surfaces for use in the chemical and microbiological work packages of FRACFLOW.

One of the two boreholes at Tilmanstone was inclined so that there was a greater chance of sampling more sub-vertical fractures should they be present.

## 2. DRILLING PROGRAMME AND BOREHOLE COMPLETION DETAILS

### 2.1 Lower Venson Inclined (LVI) Borehole

The first borehole was drilled at an angle of 30 degrees to the vertical in a due north direction and is known as BGS LVI (British Geological Survey, Lower Venson Inclined). It was fully core drilled by the air flush rotary method from 0.5 metres below ground level (mbgl) to a "drilled length" of 100 m. It was terminated at a true depth of 86.6 mbgl, the base being 50 m north of the top of the borehole. Drilling commenced on 2 June 1999 with "TL" being reached on 24 June. Drilling details, including size of core and hole are available from the drilling log (see Table A.1 in the Appendix).

The borehole was completed on 8 July 1999. At the time of drilling, 26 m of 172 mm internal diameter (ID) temporary steel casing was inserted into the hole to keep it open against a collapsing/squeezing formation. On completion, a string of plastic casing 26.26 m long x 141mm ID was inserted down the inside of the steel casing and rested on a ledge down the borehole, provided by reaming during the insertion of the steel casing. The uppermost edge of the casing is c.0.1 mbgl. The steel casing was then withdrawn. A rubber retaining ring was forced down the annulus between the outside of the plastic casing and the borehole wall, to a depth of c.1.5 - 2 mbgl. A layer of bentonite pellets was inserted down the annulus for a few centimetres and a small quantity of water added to allow the pellets to go off and expand. A grout mix of liquid bentonite/cement powder and water was then inserted down the annulus to fill it to just below the top of the casing. A steel borehole wellhead assembly consisting of a tube (of 205mm ID) and cap was then added. The tube was placed over the plastic casing and pushed into the grout before setting, the top of the steel and the top of the plastic being co-incidental. A lockable push-on type cap was then placed over the steel tube and locked with a padlock through matching rings in the tube and cap. Figure 3 illustrates the borehole construction/completion. Note that the casing below a depth of c.1.5-2 mbgl is not grouted and is in contact with collapsed formation and this may be regarded as uncased hole in some circumstances.

The surface completion of the inclined borehole consists of a small, shallow pit covered with a standard, medium duty (5 ton) galvanised steel manhole cover in a plastic frame, set in concrete. The pit may be large enough and deep enough to enable a small piece of equipment e.g. logger box, to be installed in it. This surface completion is intended to be temporary until such time as other project participants provide a replacement structure. Figure 4 is a schematic illustration of the surface completion.

### 2.2 Lower Venson Vertical (LVV) Borehole

A second borehole was drilled vertically and is known as BGS LVV (British Geological Survey, Lower Venson Vertical). It is sited 30 m along the drilled line of LVI in a northerly direction and 10 m to the east of the borehole line. It was fully core drilled by the air flush rotary method from 0.5 mbgl to a drilled depth of 100 m. Drilling commenced on 25 June 1999 with TD being reached on 7 July. Drilling details e.g. size of core, hole etc., are available from the drilling log (see Table A.2 in the Appendix).

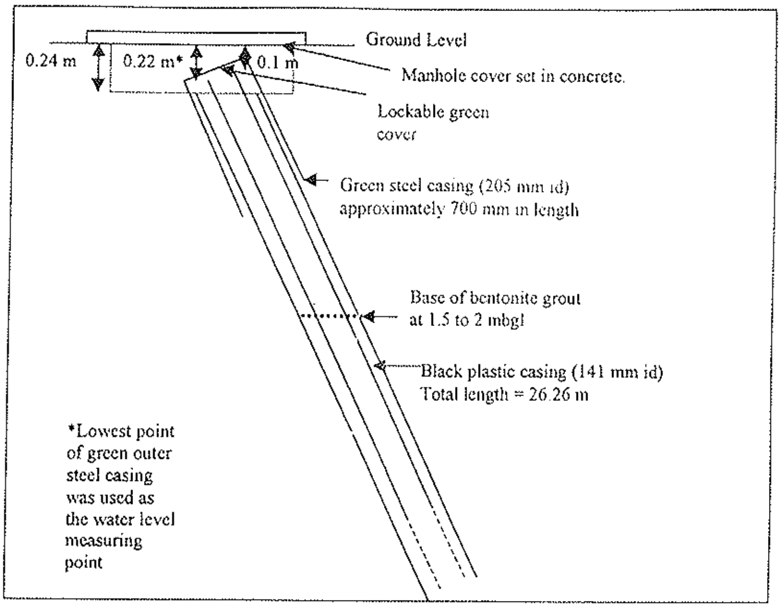



**Figure 3** Schematic illustration of the construction and completion of borehole LVI.

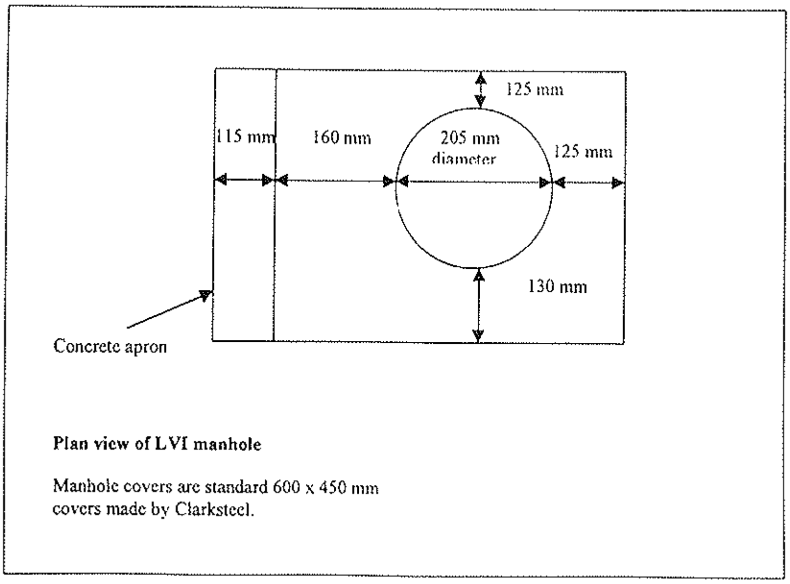



**Figure 4** Schematic illustration of the surface completion of borehole LVI.

The borehole was completed on 14 July 1999. At the time of drilling, 8 m x 172 mm ID temporary steel casing was inserted into the hole to keep it open. On completion, a string of plastic casing 14.56 m long x 141 mm ID was inserted. The uppermost edge of the casing was at approximately ground level. Unlike the inclined borehole, it was not possible to insert the plastic casing down inside the steel casing as there was no way of holding the plastic whilst the steel was withdrawn. In this case the steel casing was withdrawn, the borehole was reamed out to c.200 mm diameter to the same depth as the plastic casing string length, and the plastic casing inserted. A rubber retaining ring was forced down the annulus between the outside of the plastic casing and the borehole wall to a depth of c. 1.5-2 mbgl. A layer of bentonite pellets was inserted down the annulus for a few centimetres and a small quantity of water added to allow the pellets to go off and expand. A mix of liquid bentonite/cement powder and water was then inserted down the annulus to fill it up to just below the top of the casi..g. A steel borehole wellhead assembly consisting of a tube (of 205 mm ID) and cap was then added. The tube was placed over the plastic casing and pushed into the grout before setting, the top of the steel and the top of the plastic being co-incidental. A lockable push-on type cap was then placed over the steel tube and locked with a padlock through matching rings in the tube and cap. Figure 5 illustrates the borehole construction/completion. Again, note that the casing below a depth of c.1.5-2 mbgl is in contact with collapsed formation and this may be regarded as uncased hole in some circumstances.

Unlike the surface completion of the inclined borehole, there is no small, shallow pit at the vertical borehole. The wellhead completion is at ground level and is covered with a standard, medium duty (5 ton) galvanised steel manhole cover in a plastic frame, set in concrete. This surface completion is intended to be temporary until such time as other project participants provide a replacement structure. Figure 6 is a schematic illustration of the surface completion.

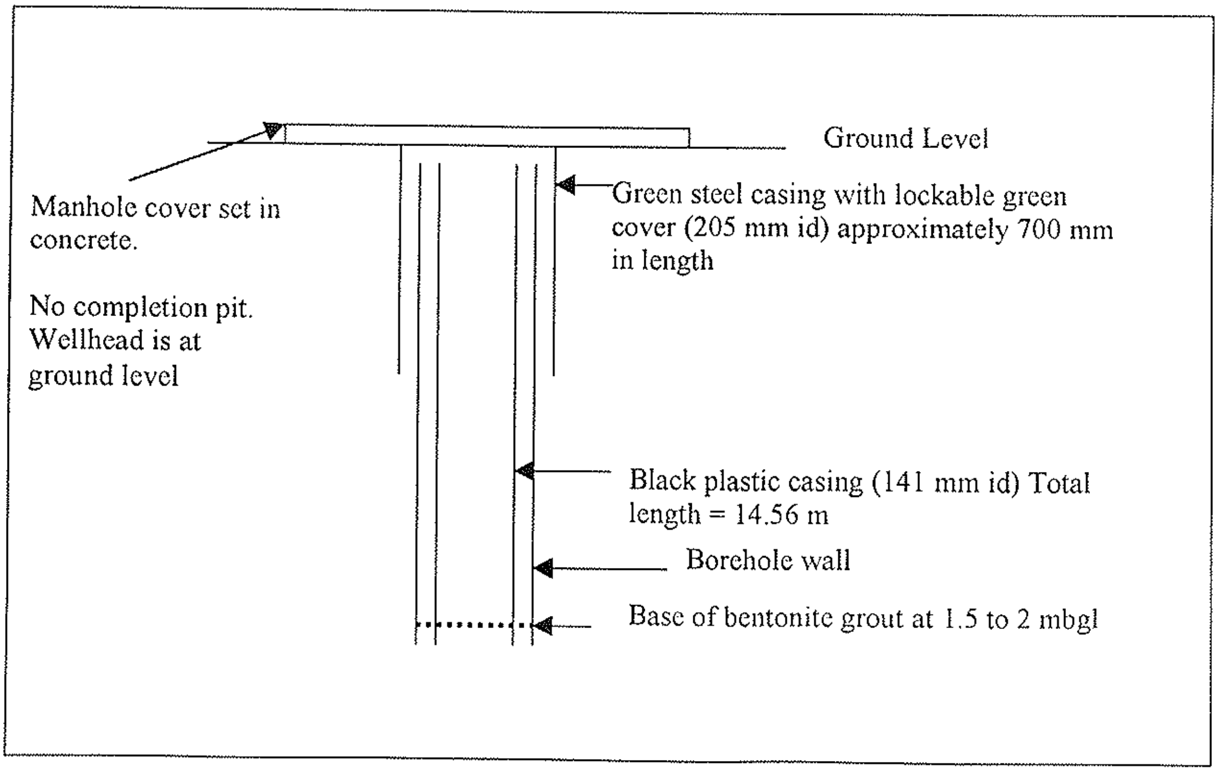
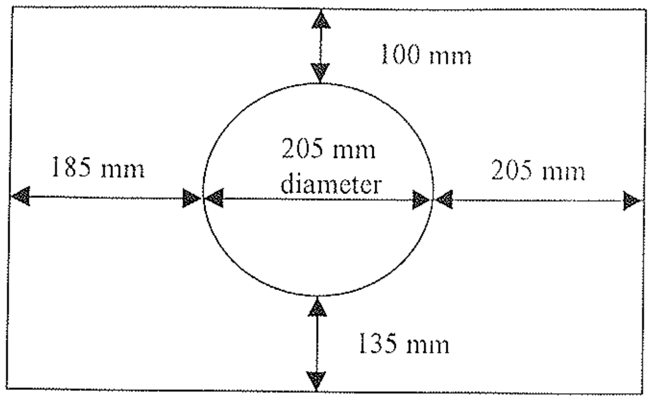



**Figure 5** **Schematic illustration of the construction and completion of borehole LVV.**




**Plan view of LVV manhole**
(no pit, wellhead is at ground level)
Manhole covers are standard 600 x 450 mm covers made bv Clarksteel.

**Figure 6** **Schematic illustration of the surface completion of borehole LVV.**

## 3. PRELIMINARY BOREHOLE LOGS

Geophysical logs of borehole LVI and LVV were performed on the 28 June 1999 and 8 July 1999 respectively. These included caliper, gamma, resistivity, magnetic susceptibility, temperature, SP, fluid conductivity and flowmeter logs. The logs are presented in Figures A.1 and A.2 in the appendix. Also in the appendix, Tables A.3 and A.4 are the lithological logs of the core from the inclined and vertical boreholes respectively.

During drilling a number of water samples were obtained from various depths. These have been analysed for electrical conductivity (SEC). In addition, material from core from LVV was centrifuged to obtain samples of pore water for chemical analysis of selected major ions. Electrical conductivity measurements have been obtained for these pore water samples. The conductivity profiles are presented in Figure A.3 in the appendix.

## 4. PACKER TESTING

Two complete packer tests and one partial packer test were performed on borehole LVV on the 13th and 14th July, the inclined borehole, LVI, was not packer tested. The packer string that was used is as described in Price and Williams (1989) and is shown schematically in Figure 7.

### 4.1 Packer Testing Procedure

The following procedure was adopted for the packer tests

(1) The packer string was lowered to the appropriate depth. This was calculated using the measurements from the top of the interval to the top of the packer string.

(2) The position of packer string was then confirmed by measuring length of drill rods 'sticking-up' above datum (in the case of these tests the datum was ground-level).

(3) The water level in the borehole was then measured and monitored for the duration of the test.

(4) A transmitter was used to measure water level in the test interval. At this stage of the test this was the same as that in the borehole.

(5) The pressure required to fully inflate packers was calculated (about 6 bars above the pressure in the test interval). However, this did not need to be exact – and it was possible to use the approximation of 1 bar for each 10 m of water above test interval.

(6) When the water level and transmitter reading were steady the packers were inflated slowly. The water level dipper was left in the borehole just above the water table so that it could then give an audible warning if the inflation failed and the gas started air-lifting the hole.

(7) During inflation of the packers the water level, transmitter readings and inflation pressure were monitored. When the packers sealed there was usually a small but significant change in these readings.

(8) When all the readings were stable the pump was started. The water level, transmitter reading and flow meter were continually monitored during pumping. The water level in the borehole should not change too much (if it did this would indicate packer leakage). When stable flow rate and transmitter readings were achieved the results were noted and the pump rate was changed. This step was repeated a number of times.

(9) Before turning the pump off at the end of the test a water sample was taken.

(10) The pressure readings and water level were monitored after the pump was finally switched off and when the readings were stable the packers were deflated and the packer string moved to a different interval or removed from the borehole.

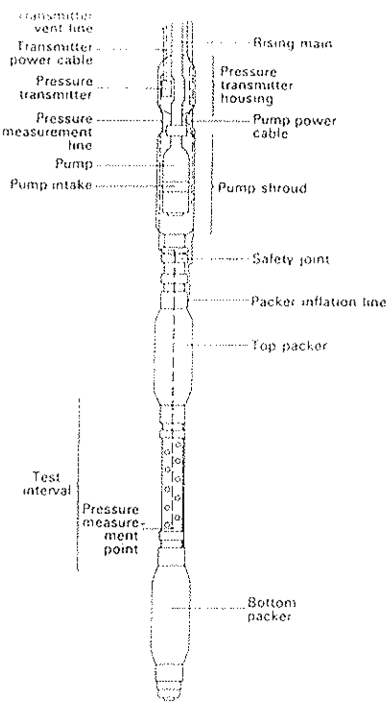



**Figure 7** **Schematic illustration of the packer string used during the testing of borehole LVV (after Price and Williams, 1989).**

### 4.2 Packer Test Programme

The first interval tested was between 30.18 and 33.05 mbgl. The criteria for selection of the interval were relatively smooth borehole walls and an absence of flints, to enable a good seal and to reduce the possibility of puncturing the packer. This position was chosen on the basis of the caliper log (Figure A.2) and the lithological log (Table A.4). The diary of the first test interval is given in Table A.5. The test was started with the flow control valve fully open and the pressure stabilized within 15 minutes. The rate was then lowered to 12 l/min and a second stable pressure reading obtained. During the test the water level in the borehole changed by 2 cm compared to 9 cm in the test interval. The calculated hydraulic conductivity is shown in Table A.6.

The second test was in the interval 45.48-48.35 mbgl. The position was chosen as it was suitable for a packer test and was at the limit of the pump cable. The timetable and results are shown in Tables A.5 and A.6. Note that there was some loss of pressure in the packers during the later stages of the test.

The third test was conducted in the interval 75.98–78.85 mbgl. However, this test was not successful, as it was not possible to inflate the packers sufficiently to give a good seal in the borehole. As the drawdown in the borehole (4 cm) was similar to that in the test interval (7 cm) it is felt that the permeability calculated in Table A.6 for the third test should not be relied upon. Nevertheless, the interval was pumped and a water sample was taken.

The transmitter used in the packer tests was calibrated against a standard transducer. The calibration curve is shown in Figure A.4 and the data listed in Table A.7. Also shown in Figure A.4 are the transmitter readings taken at the same time as water level readings taken in the open hole. The linearity of the transmitter is seen to be good.

## 5. REFERENCES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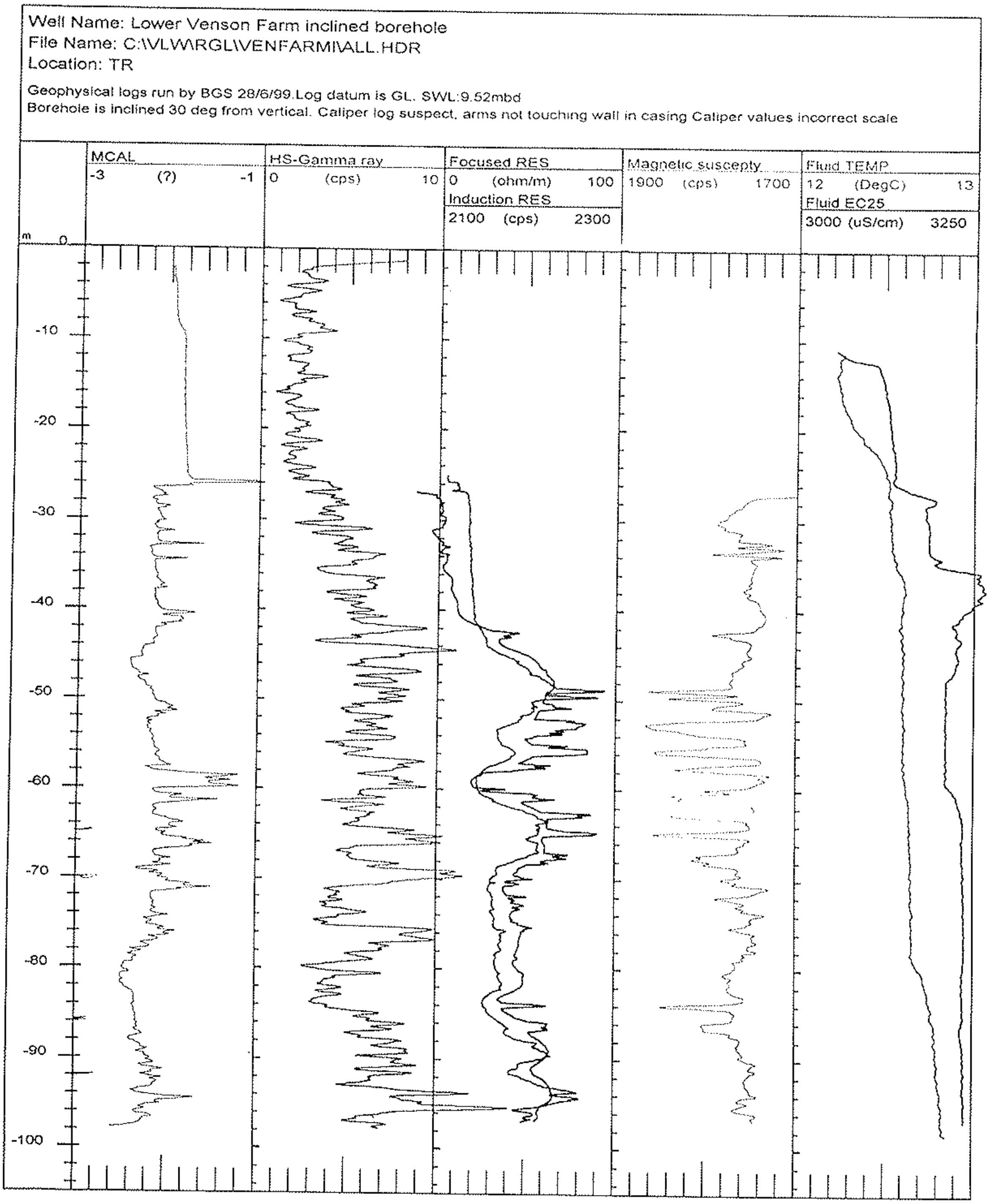



**Figure A.1** Geophysical logs for Lower Venson Inclined (LVI) borehole.

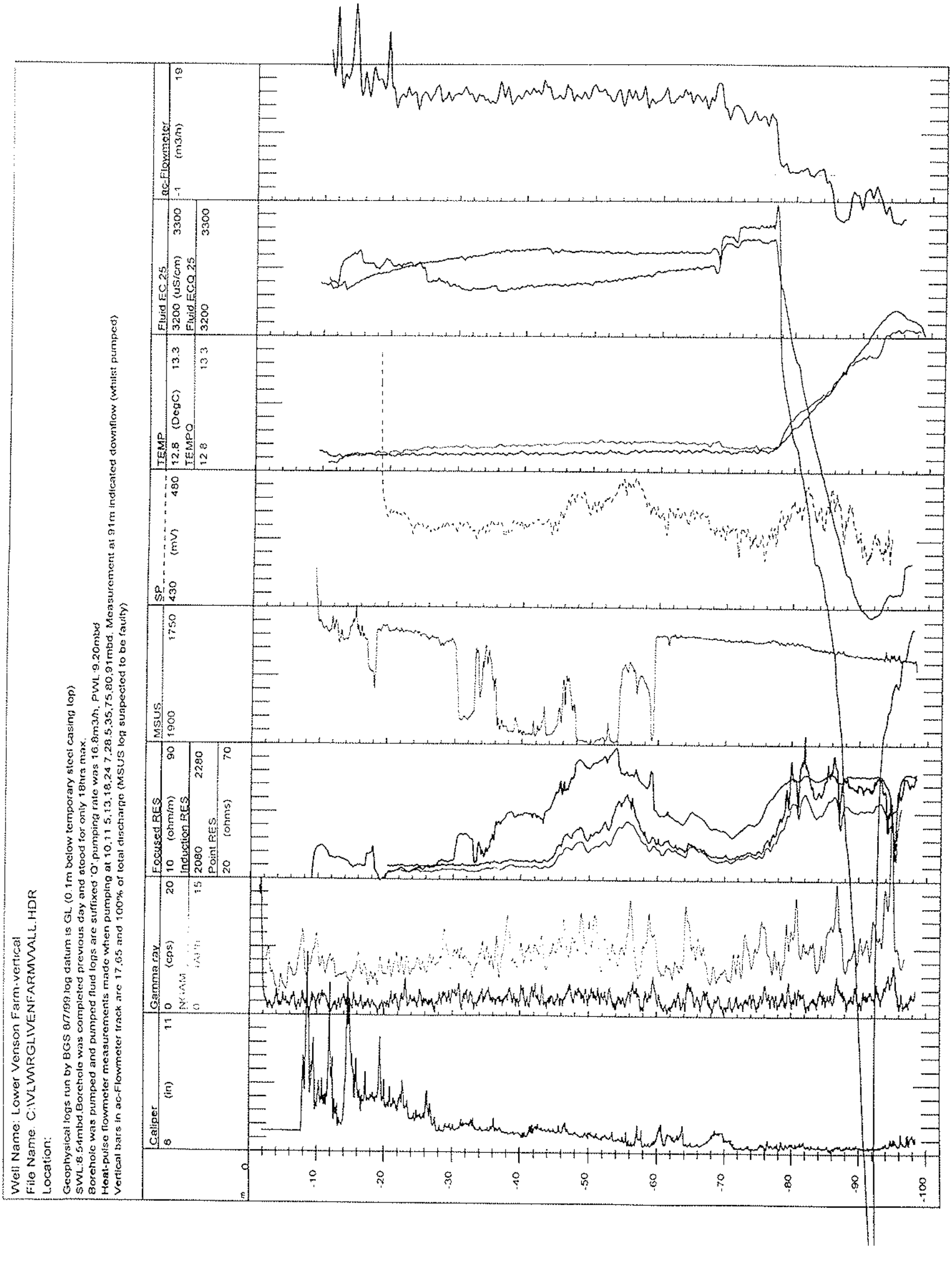
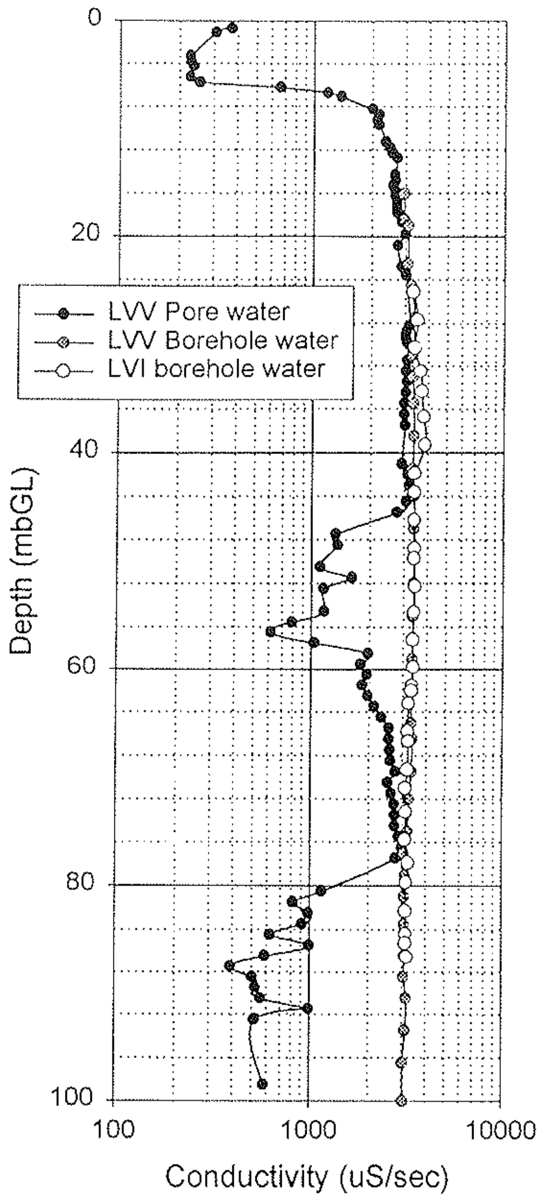



**Figure A.2** Geophysical logs for Lower Venson Vertical (LVV) borehole.



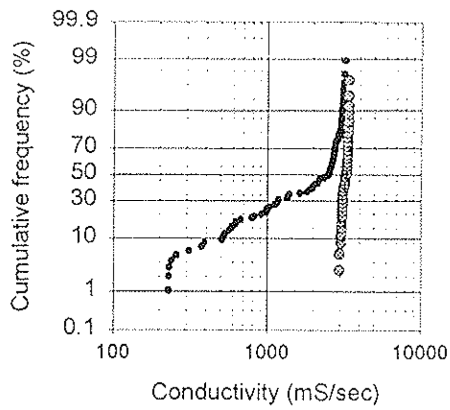




**Figure A.3** **Borehole water and centrifuged pore water conductivity profiles from LVV and borehole water conductivity profile from LVI. The figure also shows a normal probability plot of the two LVV conductivity data sets.**

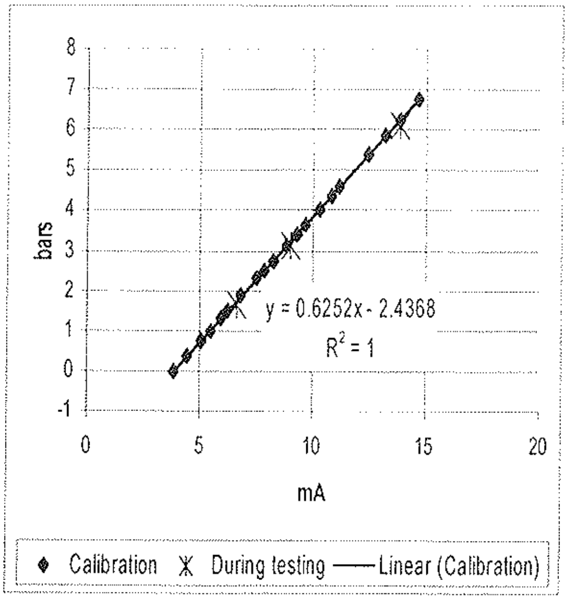



**Figure A.4 Transmitter calibration**

**Table A.1** **Lower Venson Inclined Borehole (LVI) drillers' log**

| Date | Depth at end of day (mbd) | Core run (mbd) NB. to obtain true depth below GL multiply by 0.866 | Core recovery | Water level at start and end of day (mbd) | Flow level (mbd) | Cond. µS/sec | Comment |
|---|---|---|---|---|---|---|---|
| 2/6/99 | | | | | | | Rig set-up at borehole site to drill at 30 degrees to vertical.<br>Sizes: Rock roller = 159 mm (6.25")<br>Core bit = 106 mm (4.17") id, 145 mm (5.71") od = SWF<br>Casing = 172 mm (6.77") id, 195mm (7.68") od |
| 3/6/99 | 10 | 0-0.5 | 0% | | | | Rock rollered through topsoil |
| | | 0.5-1.5 | 10% | | | | Chalk ending on flint |
| | | 1.5-2 | 0% | | | | Rock rollered through flint |
| | | | | | | | 2 m casing inserted |
| | | 2-5 | 80% | | | | Chalk and flint |
| | | 5-7 | 75% | | | | Chalk and flint |
| | | | | | | | 4 m additional casing inserted - total now 6 m |
| | | 7-10 | 50% | | | | Chalk and flint |
| 4/6/99 | 22 | 10-13 | 70% | | | 2170 (13 m) | Chalk and flint |
| | | 13-16 | 80% | | | No sample at 16m | Chalk and flint<br>First water inflow at 13 m. Volume increases from 13m. |
| | | 16-19 | 75% | | | 2650 (19 m) | Chalk and flint |
| | | 19-22 | 3% | | | 3010 (22 m) | Flint |
| 7/6/99 | 26 | 22-25 | 20% | 9.10 | | | Broken flint |
| | | 25-26 | 50% | 9.50 | | | Chalk and flint |
| | | | | | | | Due to poor condition of rock, with partial borehole collapse and squeeze, borehole reamed and cased to 26m and flushed. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | ING agreed to re-circulate water because it would not go down BH2 quickly enough |
| 8/6/99 | 35 | 26-29 | 17% | 9.20 | 28 | 3320 (29 m) | Chalk and flint |
| | | 29-32 | 75% | | | 3510 (32 m) | Chalk and flint |
| | | 32-35 | 50% | 9.00 | | 3400 (35 m) | Chalk and flint |
| 9/6/99 | 35 | | | | | | No drilling – driller called away |
| 10/6/99 | 39.35 | | | | | | Pumping drilling water down inclined borehole after each core run (tanks are full after each run). |
| | | 35-37.35 | 100% | 9.20 | | 3650 (37.35 m) | 35.00-35.10 flint, 35.10-37.10 Chalk with small flints, 37.10-37.35 very soft Chalk |
| | | 37.35-39.35 | 20% | 9.00 | | 3710 (39.35 m) | 37.35-37.70 fractured flint, 37.70-39.35 very soft Chalk |
| 11/06/99 | 45.35 | 39.35-42.35 | 100% | 9.10 | | 3800 (42.35 m) | Chalk with flint nodules and soft bands |
| | | 42.35-45.35 | 98% | 9.00 | | 3860 (45.35 m) | Chalk with flint nodules and soft bands.<br>Core jamming in barrel at end of run |
| 14/06/99 | 48.35 | 45.35-48.35 | 80% | 9.10/9.40 | | 3420 (48.35 m) | Chalk.<br>Bob Perry returned. One run only - compressor breakdown |
| 15/06/99 | 57.35 | 48.35-50.35 | 50% | 9.20 | 51 | | Chalk |
| | | 50.35-53.35 | 33% | | | 3410 (53.35 m) | Chalk |
| | | 53.35-56.35 | 100% | | | 3420 (56.35 m) | Chalk |
| | | 56.35-57.35 | 100% | 9.30 | | 3410 (57.35 m) | Chalk |
| 16/06/99 | 66 | 57.35-60.35 | 85% | 9.10 | | 3450 (60.35 m) | Chalk/flint |
| | | 60.35-63 | 70% | | | 3410 (63 m) | Chalk |
| | | 63-66 | 75% | 9.35 | | 3380 (66 m) | Chalk |
| 17/06/99 | 69 | 66-69 | 35% | 9.10/9.10 | | 3400 (69 m) | Chalk/flint.<br>One run only. Core liner stuck in barrel due to flints - had to dismantle barrel to free. Poor recovery due to flints |
| 18/06/99 | 71.6 | 69-71 | 90% | 9.10 | | 3350 (71 m) | Chalk/flint |
| | | 71-71.6 | 80% | 9.35 | | 3340 (71.6 m) | Short run ended on flint |
| 21/06/99 | 80 | 71.6-73 | 75% | 9.14 | | 3230 (73 m) | Chalk |
| | | 73-76 | 85% | | | 3200 (76 m) | Chalk |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 76-77 | 100% | | | 3220 (77 m) | Chalk |
| | | 77-80 | 75% | 9.40 | | 3200 (80 m) | Chalk |
| 22/06/99 | 90 | 80-82 | 50% | 9.20 | | 3120 (82 m) | Chalk/flint |
| | | 82-84.5 | 100% | | | 3150 (84.5 m) | Chalk/flint |
| | | 84.5-87.5 | 95% | | | 3130 (87.5 m) | Chalk/flint |
| | | 87.5-90 | 70% | 9.40 | | 3250 (90 m) | Chalk/flint |
| 23/06/99 | 98.5 | 90-92 | 80% | 9.30 | | 3170 (92 m) | Chalk/flint |
| | | 92-95 | 80% | | | 3140 (95 m) | Chalk/flint |
| | | 95-97.5 | 90% | | | 3150 (97.5 m) | Chalk |
| | | 97.5-98.5 | 100% | 9.30 | | 3140 (98.5 m) | Chalk/flint |
| 24/06/99 | 100 | 98.5-100 | 100% | 9.30/9.35 | | 3200 (100 m) | Chalk.<br>Drill rods inserted, borehole flushed prior to geophysical logs being run by BGS. **END OF BOREHOLE** |
| 8/7/99 | | | | | | | Borehole completed. 27m x 141mm ID plastic casing inserted. 26m temporary casing removed. Plastic casing grouted with bentonite + bentonite/cement to c. 1.5-2m bgl. |

**Table A.2 Lower Venson Vertical Borehole (LVV) drillers' log**

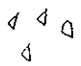
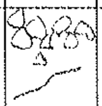
| Date | Depth at end of day (mbd) | Core run (mbd) | Core recovery | Water level at start and end of day (mbd) | Flow level (mbd) | Cond. µS/sec | Comment |
|---|---|---|---|---|---|---|---|
| 25/6/99 | 0.5 | 0-0.5 | 0% | | | | Rig moved from inclined borehole site and set up at vertical borehole site. Rock rollered through topsoil. |
| 28/6/99 | 18.5 | 0.5-3 | 35% | | | | Chalk and flint |
| | | 3-5 | 75% | | | | Chalk |
| | | 5-8 | 70% | | | | Chalk |
| | | | | | | | Borehole reamed out, 8m casing inserted |
| | | 8-11 | 70% | | | | Chalk |
| | | 11-13 | 95% | | | | Chalk |
| | | 13-14 | 0% | | | | Rock rollered through flint |
| | | 14-16 | 95% | | | 2980 | Chalk |
| | | 16-18.5 | 85% | 8.45 | | 2990 | Chalk |
| 29/6/99 | 35.5 | 18.5-19.5 | 20% | 8.30 | | 3120 (19 m) | Chalk and flint |
| | | 19.5-22.5 | 50% | | | 3120 | Chalk and flint |
| | | 22.5-24.5 | 70% | | | 3230 | Chalk and flint |
| | | 24.5-27.5 | 5% | | | 3370 | Flint causing poor recovery of Chalk |
| | | 27.5-28 | 0% | | | | Rock rollered through flint |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 28-31 | 80% | | | 3320 | Chalk |
| | | 31-33 | 80% | | | 3330 | Chalk |
| | | 33-35.5 | 85% | 8.50 | | 3360 | Chalk and flint |
| 30/6/99 | 55 | 35.5-38.5 | 90% | 8.40 | | 3380 | Chalk and flint |
| | | 38.5-41.5 | 35% | | | 3340 | Chalk and flint |
| | | 41.5-44 | 75% | | | 3400 | Chalk and flint |
| | | 44-47 | 65% | | | 3410 | Chalk and flint |
| | | 47-49.5 | 85% | | | 3400 | Chalk and flint |
| | | 49.5-52 | 85% | | | 3400 | Chalk and flint |
| | | 52-55 | 60% | 8.50 | | 3390 | Chalk |
| 1/7/99 | 66.5 | 55-57 | 90% | 8.45 | | 3380 | Chalk |
| | | 57-59 | 75% | | | 3360 | Chalk |
| | | 59-62 | 85% | | | 3360 | Chalk |
| | | 62-65 | 80% | | | 3340 | Chalk |
| | | 65-66.5 | 75% | 8.50 | | 3380 | Chalk and flint |
| 2/7/99 | 72 | 66.5-69.5 | 85% | 8.45 | | 3350 | Chalk |
| | | 69.5-72 | 80% | 8.50 | | 3260 | Chalk and flint |
| 5/7/99 | 81 | 72-75 | 100% | 8.45 | | 3220 | Chalk |
| | | 75-77 | 80% | | | 3090 | Chalk and flint |
| | | 77-79 | 75% | | | 3130 | Chalk and flint |
| | | 79-81 | 75% | 8.35 | | 3110 | Chalk and flint |
| 6/7/99 | 90.5 | 81-82.5 | 80% | 8.45 | | | Chalk and flint |
| | | 82.5-83.5 | 80% | | | 3110 | Chalk and flint |
| | | 83.5-86.5 | 65% | | | 3110 | Chalk (soft) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 86.5-88.5 | 75% | | | 3080 | Chalk |
| | | 88.5-90.5 | 70% | 8.45 | | 3170 | Chalk (very soft) |
| 7/7/99 | 100 | 90.5-93.5 | 33% | 8.45 | | 3140 | Chalk with (mainly) flint<br>Driller recorded WL as 9.45m but assumed to be 8.45m |
| | | 93.5-96.5 | 0% | | | 3050 | No recovery due to flint being forced down borehole by drill bit. |
| | | 96.5-97 | 0% | 8.45 | | | Rock rollered through ?flint. Borehole cleaned out.<br>Driller recorded WL as 9.45m but assumed to be 8.45m |
| | | 97-100 | 50% | | | 3060 | Chalk and flint. Poor recovery - flint damage of plastic liner Rock roller inserted to base of hole. Air circulated to clean out borehole. **END OF BOREHOLE**. |
| 8/7/99 | | | | | | 3230 (pumped sample) | Geophysical logs. Borehole pumped for c.2.5 hours at c.17 m3/hr. Discharge started "milky" but had cleared by 90 minutes pumping. Water level at 1530 hrs (start of pumping) = 8.54 mbgl. Maximum drawdown = 0.65m, water level rose during latter stage of pumping as hole developed. |
| 13/7/99 | | | | | | | Packer testing borehole for transmissivity values and discrete water sample collection. 8m temporary casing removed. c.15m x 141mm diameter plastic casing inserted from GL and bentonite and bentonite/cement grouted in from GL to c. 2mbgl. Wellhead assembly and manhole cover installed. |

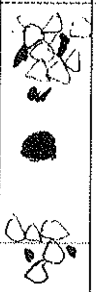
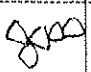
Table A.3 Lithological log of core recovered from Lower Venson Inclined (LVI) borehole.

Lithological log for Lower Venson Farm inclined borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| No samples taken | 0 | 3/6/99 | 0 | | Core losses | | Temporary casing to 6 m depth. Blue nodular flint – ruined drill bit, no recovery |
| | 1 | | | |  | | Drill bit used to rock roll between 1.5 and 2 m. |
| | 2 | | | |  | Unstructured creamy white chalk rubble with broken flint. Roots and soil and small fracture surfaces throughout the interval. | |
| | 3 | | | | | | |
| | 4 | | | |  | Unstructured chalk putty with small broken flint fragments. | 60 cm core loss assigned at base |
| | 5 | | 80 | |  | Chalk rubble with small clasts (< 3 cm), mainly drilling induced. Some irregular natural fractures heavily stained red with soil and roots on their surface | |
| | 6 | | | | | | 40 cm core loss assigned at base |



* “Depth” does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 7 | | 49 | |  | Chalk putty passing into chalk rubble | |
| | 8 | | | | | | 1.52 m core losses assigned to base of run |
| | 9 | | | | | | |
| | 10 | 4/6/99 | 77 | 46 o |  | 10.0 –10.75 unstructured chalk rubble with broken flint fragments. Nodular flint at base. 10.75 – 10.95 single chalk block bounded by inclined fracture on upper surface (with orange staining). 10.9 – 13.0 chalk rubble with broken flint fragments. | |
| | 11 | | | | | | |
| | 12 | | | | | | 70 cm core loss at end of the run |
| | 13 | | 77 | |  | As above. Light orange stained fracture parallel to the core axis at 13.45 m | |



* "Depth" does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

# Lithological log for Lower Venson Farm inclined borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 14 | | | | | | |
| | 15 | | | |  | Nodular flint at base | 70 cm core loss at base after flint horizon |
| | 16 | | 60 | |  | Chalk rubble with broken flint fragments predominant in the top 20 cm. Good fitted fabric to the chalk rubble between 16.2 and 16.8 but fractures are probably drilling induced. | |
| | 17 | | | |  | Chalk rubble | |
| | 18 | | | | | | |
| | 20 | | 6 | |  | Flint fragments | Very poor recovery. |
| | 20 | | | | | | |



* "Depth" does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 21 | | | | | | |
| | 22 | 7/6/99 | 13 | |  | Large blue nodular flint | |
| | 23 | | | | | | |
| | 24 | | | | | | |
| | 25 | | 52 | |  | Chalk putty with large nodular blue flint and flint fragments | |
| | 26 | 8/6/99 | 17 | | | | Hole collapsed at 26 m. Had to be reamed out and cased. Core losses therefore assumed to occur at the top of the run |
| | 27 | | | | | | |

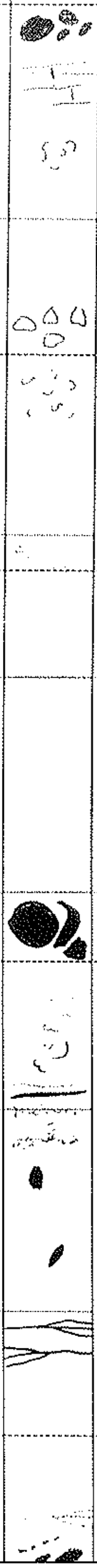


* "Depth" does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 28 | | | | | Crushed blue flint, orange staining from 0 to 20 cm passing into soft white chalk. Trace fossils present. Last 21 cm are chalk and flint rubble | |
| | 29 | | 67 | | | 29.0-29.55 blocky, cream-white chalk with trace fossils. Iron oxide staining in the matrix. Soft. 29.55-29.85 fine chalk rubble. 29.85-30.30 cream-white chalk with trace fossils 30.30-31.0 chalk rubble with blue flint fragments passing into chalk putty near base. Orange stained. | |
| | 30 | | | | | | |
| | 31 | | | | | | 1 m core loss at base of the run |
| | 32 | | 55 | | | Soft, creamy-white chalk rubble with blue flint fragments. Orange staining in the matrix associated with trace fossils. Top 35 cm is fossiliferous - contains shelly fragments (inoceramids?) 33.20 Large nodular flint. 33.40 Incipient patterned chalk. | |
| | 33 | | | | | | 1.34 m losses assigned at end of the run where the chalk becomes more rubbly. |
| | 34 | | | | | | |



* "Depth" does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 35 | 10/6/99 | 100 | |  | 35.0-35.10 crushed blue flint passes into soft white chalk, blocky fractured (probably drilling induced – no mineralisation on surfaces). Occasional trace fossils with infrequent orange staining passing into chalk rubble at end of the run. | |
| | 36 | | | | | | |
| | 36.4 | | 100 | | | 36.4-36.6 Soft, white chalk with trace fossils. Passes into 35 cm of broken chalk (drilling induced). 20 cm of crumbly chalk putty. | |
| | 37 | | | | | | |
| | 37.35 | | 18 | | | | |
| | 38 | | | | | | 1.64 m core losses assumed to have occurred above the flint horizon. |
| | 39 | | | | | 35 cm thick band of large blue flint fragments | |
| | 39.35 | 11/6/99 | 98 | | | Grey-white chalk with bedding defined by indistinct marls. Trace fossils and orange staining in matrix. 39.95 – 40.25 blocks separated by rubbly chalk. At 39.9 bedding plane fracture. Well-developed flaser marls at 41.1 and 41.25. Blocky fractured (drilling induced). Flint fragments at 40.30 and 40.65. | |
| | 40 | | | | | | |
| | 41 | | | | | | 4 cm loss at base |
| | 41.35 | | 97 | | | Soft white chalk. Trace fossils in matrix. Inclined fracture at 41.95 (25°) | |



* "Depth" does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 42 | | | | | Manganese spotting, calcite mineralisation and clay coating on fracture. Matrix heavily orange stained between 41.6 and 41.7 in association with thin flaser marls. 41.91- 42.06 Nodular flint and flint fragments 42.31-42.35 Crushed blue flint. | |
| | 43 | | | | | | 7 cm core loss at base |
| | 43.35 | | 99 | | | Slightly harder white chalk. Fractured (drilling induced). Chalk rubble at base. Thin flaser marls at 43.93, 44.02, 44.17 & 44.43. 3 cm thick marl at 44.64. At end of 1st m core broken along marl surfaces- evidence of shearing. | |
| | 44 | | | | | | |
| | 45 | | | | | | 3 cm loss at base |
| | 45.35 | 14/6/99 | 73 | | | Top 30 cm chalk rubble with large broken blue flint fragments. 45.3-45.7 chalk rubble. 45.7-46 white chalk with orange staining in the matrix. Thin marls at 46.2, 46.45, 46.85, 46.9 and 47.2. 47.2 blue flint 47.25-47.35 relatively hard chalk. 47.35-47.55 chalk rubble | |
| | 46 | | | | | | |
| | 47 | | | | | | 80 cm core losses assigned to base |
| | 48 | | | | | | |
| | 48.35 | 15/6/99 | 42 | | | To 48.7 putty chalk with fine flint fragments & fragments of nodular chalk | |



* "Depth" does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 49 | | | | | Passing into soft chalk rubble. Last 22 cm of run - putty chalk. | 1.17 m loss at base |
| | 50 | | | | | | |
| | 50.35 | | 34 | | | Fine-grained gravel of crushed flint (orange stained) primarily due to drilling damage might indicate open bedding plane fracture associated with flint. Moderately hard white chalk with drilling induced fractures. Trace and body fossils with local orange staining in matrix. At 51.2, small flint cast in trace fossil burrow. Last few cm's, unstructured chalk rubble. | |
| | 51 | | | | | | |
| | 52 | | | | | | |
| | 53 | | | | | | 1.97 m core loss at end of run |
| | | | 98 | | | Massive, moderately hard white chalk. Some orange staining of the matrix. Trace fossils present throughout. Marl at 53.98. Large nodular flint at 54.65. | |
| | 54 | | | | | | |



* "Depth" does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 55 | | | | | Creamy white chalk with orange staining in the matrix. Heavy staining at 55.75 associated with vuggy cavity. Indistinct marl from 55.7 to 55.75 | |
| | 56 | | | | | | 5 cm core loss at base. |
| | 56.35 | | 100 | | | Drilling induced flint rubble between 56.6 and 56.85. Drilling induced blue flint rubble from 56.95 to 57.35. | |
| | 57 | | | | | | |
| | | 16/6/99 | 76 | | | 57.35 –57.5 and 57.9 – 58 nodular flints. Chalk as above with trace fossils. | |
| | 58 | | | | | Marl at 58.4, 59, 59.07 & 59.25. Chalk and flint rubble 58.7-58.95. Patterned chalk below marl at 59.25. | |
| | 59 | | | | | Chalk rubble at base | |
| | 60 | | | | | | 72 cm loss at base |
| | 60.35 | | 56 | | | Moderately hard white chalk. Trace fossils with iron staining up to 61.15. Passes into soft, white chalk and flint rubble. | |
| | 61 | | | | | | 1.17 m loss. |

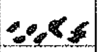
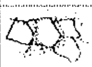


* "Depth" does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 62 | | | | | | |
| | 63 | | 68 | | | Top 10 cm, nodular flint, passes into massive moderately hard creamy white chalk. Orange staining in the matrix with trace and body fossils. 64-64.15 putty chalk with blue flint rubble passing into moderately soft, creamy white chalk with orange staining in the matrix. Marl at 64.6. From 64.6 to 64.75, hard extensively orange stained chalk (hardground?) 64.75 to end of run, chalk rubble and unstructured chalk containing broken flints and orange stained fragments. | |
| | 64 | | | | | | |
| | 65 | | | | | | 95 cm loss at end of run |
| | 66 | | 39 | | | Predominantly chalk rubble and flint passing into creamy white chalk with trace fossils. Fine gravel at base containing crushed flints – may mark an open bedding horizon associated with flints. | |
| | 67 | | | | | | 1.83 m losses assigned at end of run. |
| | 68 | | | | | | |



* "Depth" does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 69 | 18/6/99 | 88 | |  | To 69.10, nodular flint. Moderately hard, creamy white chalk with trace fossils passing into locally heavily orange stained, hard, creamy white chalk with trace fossils from 69.55 to 70.5 (hardground) 70.5 to 70.65 broken, nodular flint. | |
| | 70 | | | |  | | 24 cm loss at base |
| | 71 | | 68 | |  | Broken blue nodular flint | 19 cm lost |
| | | 21/6/99 | 61 | |  | Well-fractured (drilling induced?) chalk rubble with crushed flint at 72.05. 72.25 to 72.45 soft creamy white chalk with trace fossils. | |
| | 72 | | | |  | | 55 cm loss at base |
| | 73 | | 68 | |   | Chalk putty to 73.1. 73.1 to 73.6 soft, white cha'k with trace fossils and orange staining in the matrix. 73.6 to 73.88 unstructured chalk putty and rubble. Last 10 cm flint rubble. | |
| | 74 | | | | | | 47 cm loss at base |
| | | | 100 | |  | Chalk putty to 74.6. 74.6 to 76, soft, white chalk with trace fossils and orange staining in the matrix. Between 75 – 75.35 chalk rubble in soft chalk putty matrix. Marl (?) at 75.75. | |
| | 75 | | | |  | | |

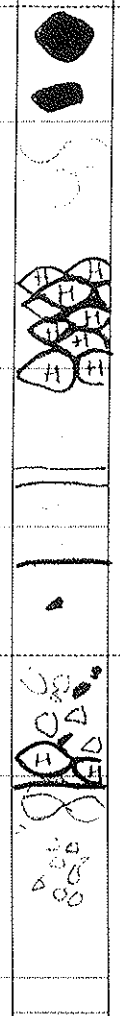


* "Depth" does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 76 | | 100 | | | Finely crushed flint at top of run. 76 – 76.25 hard, orange – white chalk (hardground) with orange staining in the matrix passing into nodular chalk. Occasional trace fossils. | |
| | 77 | | 69 | / | | Moderately hard grey-white chalk with steeply inclined fracture plane with slickensides. Top 25 cm heavily fractured. 77.25 to 77.9 hard, grey-white nodular chalk with incipient marl seams at 77.38 and 77.45. 77.9 to 78, flint rubble. | |
| | 78 | | | | | | |
| | 79 | | | | | Heavily fractured creamy white chalk in chalk slurry (drilling induced?) Small marls at 78.35 and 78.85 | 92 cm loss at base |
| | 80 | 22/6/99 | 100 | / / | | Finely crushed orange-stained flint at top of run possibly indicating open or enlarged bedding plane fracture. Relatively massive creamy white chalk with trace fossils and orange staining in the matrix passing into fractured chalk. Marl at 80.05. Passes into grey nodular chalk with trace fossils and orange staining. Small tabular flint at 81.6 | |
| | 81 | | | | | | |
| | 82 | | 59 | break | | Relatively hard, massive, orange-white chalk with trace fossils and orange staining in the matrix. Small nodular flint at 82.12 | Drilling induced fractures? |



* "Depth" does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 83 | | | | | | 1.03 m loss at base |
| | 84 | | | | | | |
| | | | 100 | |  | Top 20 cm and between 84.83 and 84.93 massive, blue nodular flint. Creamy white chalk. Between 84.95 and 85.1- grey-white nodular chalk passes into massive, hard orange-white chalk (hardground). Thin marls at 86.7 and 86.8. Orange staining and trace fossils. | |
| | 85 | | | | | | |
| | 86 | | | | | | |
| | 87 | | | | | 86.9 – hard grey-white nodular chalk with 1 cm thick marl at 87.3. Small blue flint at 87.45 | |
| | | | 1.77 of 2.5 | | | Chalk and flint rubble to 87.9. 87.9 to 88.05 creamy white hardground with marl at 88.02. Passes into grey nodular chalk with orange staining in the matrix. 88.2 to end, fine-grained chalk rubble (drilling induced?) | |
| | 88 | | | | | | |
| | 89 | | | | | | 83 cm core loss assigned to base of run |



* "Depth" does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 90 | 23/6/99 | 87 | | | Top 10 cm creamy white nodular chalk with small shell fragments passes into relatively massive nodular chalk with occasional small blue nodular flints. At 91 m large bi-valve fossil. 91.3 blue nodular flint. 91.3 to end, grey chalk hardground. | |
| | 91 | | | | | | 27 cm loss |
| | 92 | | 78 | |  | 92 to 92.2 large blue nodular flint. 92.2 to 92.4 hardground passes into nodular chalk. At 92.8, 2 to 3 mm thick marl band. Large flint at 93.6. Towards run end passes into chalk rubble. | |
| | 93 | | | | | | |
| | 94 | | | | | | 67 cm loss |
| | 95 | | 92 | |  | Chalk rubble with small flint fragments up to 95.25. Relatively massive grey-white nodular chalk with 5 cm thick marl band at 95.5. Nodular chalk has marl-rich matrix. | |
| | 96 | | | | | 96 – 96.05 flint, passes into hard grey chalk with trace fossils and orange staining in the matrix. Relatively massive. At 97, Soft dark grey marl with localised orange staining | |



* "Depth" does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 97 | | | | | | 20 cm loss |
| | | | 96 | | | 97.5 – 98 creamy white chalk with orange stained matrix and occasional small flint fragments. 98 – 98.2 nodular grey chalk passing into soft, brown chalk rubble with a sand-like texture (high silica content) | |
| | 98 | | | | | | |
| | | 24/6/99 | 100 | | | Relatively massive, moderately hard grey-white nodular chalk to 99.9. 99.9 to 100, chalk and flint rubble (drilling induced?) | |
| | 99 | | | | | | END OF BOREHOLE |
| | 100 | | | | | | |
| | | | | | | | |



* "Depth" does not take into account the inclination of the borehole and values are therefore drilled lengths not actual depths.

Table A.4 Lithological log of core recovered from Lower Venson Vertical (LVV) borehole.

Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| 0.5-0.8 | 0 | 25/6/99<br><br>28/6/99 | <br><br>32 | | | 0.5 to 0.8 reddy brown clay soil with flint fragments.<br>0.8 to 0.95 nodular flint in soft putty chalk.<br>0.95 to 1.3 very soft putty chalk | Core starts at 0.5 m. Only 80 cm core in first 2.5 m run |
| 0.8-1.3 | 1 | | | | | | |
| | 2 | | | | | | |
| 3.0-3.5<br><br>3.5- 4.0 | 3 | | 70 | | | Orange-stained unstructured, very soft chalk with occasional flint fragments up to 4.0 m. | 1.4 m recovery from 2 m interval |
| 4.0-4.5 | 4 | | | | | Deep brown-orange staining on irregular fracture surfaces. | |
| 5.0-5.5<br><br>5.5-6.0 | 5 | 73 | | | | Very soft unstructured creamy white chalk with dark orange-brown heavily stained fine-grained chalk gravel at 5.45 m. 5.45-5.75 possible flow or recharge horizon. | 2.2 m of 3 m core |
| 6.0-6.5<br><br>6.5-7.0 | 6 | | | | | Unstructured chalk rubble down to 6.1 m.<br>6.1 to end of run: soft, white blocky chalk with drilling induced fracturing.<br>5.8 to 6.0 extensive orange staining on fracture surfaces. Relatively thick clay drapes. | |

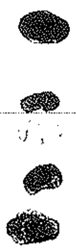
Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| 7.0-7.2 | 7 | | | | | | 80 cm core loss at base |
| 8.0-8.5<br>8.5-9.0 | 8 | | 60 | | | Unstructured chalk rubble with flint fragments at 8.1, 8.6 and 8.7 | 1.8 m recovery from 3 m run |
| 9.0-9.5<br>9.5-9.8 | 9 | | | | | 9.65-9.8 soft chalk putty | 1.2 m core loss at base |
| | 10 | | | | | | |
| 11.0-11.5<br>11.5-12.0 | 11 | | 94 | | | Soft white chalk with trace fossils and orange staining in the matrix. Blockily fractured (drilling induced?). 11.35-11.55 and 12.25-12.45 chalk rubble. Fracture surfaces (11.35-11.55) orange-stained with Mn oxide spotting. Small broken flint fragments in rubble. | 1.88 of 2 m |
| 12.0-12.5<br>12.5-12.9 | 12 | | | | | | |
| | 13 | | 0 | | | | No core |

Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| 14.0-14.5<br>14.5-15.0 | 14 | | 100 | | | Soft creamy white chalk.<br>14 to 14.75 Blocky fractures (drilling induced?).<br>14.75-16.0 blocks of chalk in chalk putty (drilling induced).<br>Flints at 15.4 | |
| 15.0-15.5 | 15 | | | | | | |
| 15.5-16.0<br><br>16.0-16.5 | 16 | | 88 | | | As above with flint fragments at 17.1, 17.4 and 18.1 | 2.2 of 2.5 m run |
| 17.0-17.5<br>17.5-18.0 | 17 | | | | | | |
| 18.0-18.2 | 18 | | | | | | 30 cm loss at base |
| 18.5-18.9 | 18.5 | 29/6/99 | 30 | | | Flint. No chalk core | |
| | 19 | | | | | | |
| 19.5-20.0 | 19.5 | 53 | | | | 19.5-19.75 large, blue and nodular. Small flints at 19.9, 20.7. Between 20.15 and 20.5, and 20.8 and 21.05 moderately hard, creamy white chalk with trace fossils and orange staining in the matrix. | 1.6 of 3 m |
| <br><br>20.5-21.1 | 20 | | | | | | |

Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 21 | | | | | | 1.4 m loss at base |
| | 22 | | | | | | |
| 22.5-23.0 | | | 65 | |  | 22.5 to 22.65, 22.95, 23.35 and 23.55 large nodular blue flints. Creamy white chalk with trace fossils and orange staining in matrix. Extensive drilling induced damage 22.5 to 23 & 23.5 to 23.8. | 1.3 of 2 m |
| 23.0-23.4<br>23.4-23.8 | 23 | | | | | | |
| | 24 | | | | | | 70 cm loss at end of run |
| | | | | | | | 20 cm recovery |
| | 25 | | 6 | | | | |
| | 26 | | | | | | |
| | 27 | | | | | | |
| | | | 0 | | | | |

Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| 28.0-28.5<br>28.5-29.0 | 28 | | 77 | | | Soft creamy white chalk with trace fossils and orange staining in matrix. Flints at 28-28.1 and 29.4. Chalk blocky fractured –(drilling induced?) | 2.3 m recovery from 3 m run |
| 29.0-29.5<br>29.5-30.0 | 29 | | | | | Last 15 cm – putty chalk | |
| | 30 | | | | | | 70 cm ?losses |
| 31.0-32.0 | 31 | | 88 | | | Soft, crumbly creamy white chalk with trace fossils and orange staining in the matrix. Well-fractured (drilling induced?) 31.25-31.35 & 31.75-31.85 blue flint fragments. Mn spotting on fracture surface at 32.65 and at 32.1 and 31.4. 31.85 to 32.25 rubbly chalk. Last 10 cm rubbly putty chalk. | 1.75 of 2 m |
| 32.0-33.0 | 32 | | | | | | |
| 33.0-34.0 | 33 | | 84 | | | Chalk as above with significant orange-staining between 33.3 and 33.8. 34.4 -34.5 & 34.65 to 35.5 chalk rubble. Some platy shelly fragments in rubble. Large blue nodular flint at 34.05. Small flint at 33.4. | 2.1 of 2.5 m |
| 34.0-35.0 | 34 | | | | | | |

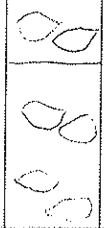
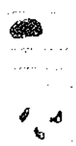
Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| 35.0-36.0 | 35 | | | | | | 40 cm loss at base |
| | | 30/6/99 | 92 | | | Creamy white chalk with trace fossils and orange-staining in the matrix (esp. between 35.5 & 35.65, and 36.4 and 36.5). Horizontal (drilling induced?) fractures. Indistinct grey trace fossil at 36.21. 35.9 to 36.1 large platy shell fragments associated with Fe-staining. Orange-stained trace fossils at 36.6 and 38.15. Slightly harder, creamy-white fractured chalk (drilling induced fractures). 37.35-37.5 & 37.7 to 37.9 rubbly chalk and with shelly fragments 37.5-37.67 nodular chalk. 37.17-37.2 flaser marls. Less defined marls at 36.75, 37.35 & 37.27. | 2.75 of 3 m |
| 36.0-37.0 | 36 | | | | | | When breaking core fractures along green grey coated marl surface. |
| 37.0 | 37 | | | | | | |
| 38.0 | 38 | | | | | | 25 cm core loss at base |
| | | | 53 | 33 cm | | Blue nodular flint | 1.58 of 3 m |
| | 39 | | | | | | Core losses assigned to occur after the flint horizon. Core is very rubbly and probably represents material from the whole from the whole of the run interval. |
| 40.5-41.5 | 40 | | | | | Creamy-white rubbly chalk fragments (drilling induced?) Mn coating at 40.55. Some iron-stained fragments. | |
| | 41 | | | | | | |
| | 41.5 | | 75 | | | 41.5 to 42 large blue nodular flints | 1.88 of 2.5 m |

Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| 41.5-42.5 | 42 | | | | | Orange-cream chalk (hardground) with large blue flint fragments at 41.7. Fractured (drilling induced). Trace fossils. 42.55-42.68 very large nodular flint. Chalk becomes slightly nodular. | |
| 42.5-43.5 | 43 | | | | | Friable fractured creamy grey chalk after 42.05. Body fossils. Last 10 cm chalk putty. | 62 cm loss at base |
| 44.0-45.0 | 44 | | 57 | | | Creamy white chalk with trace fossils. Hard chalk fragments in softer matrix. 44.42 to 42.65 rubbly putty chalk. | 1.7 of 3 m |
| 45.0-46.0 | 45 | | | | | 45.5 to 45.7 soft drilling induced putty chalk | 1.3 m loss at base |
| | 46 | | | | | | |
| 47.0-48.0 | 47 | | 80 | | | Large blue fractured flint to 47.1. Soft blocky-fractured (drilling induced) orange-stained chalk. Thin marls at 48.28 and 48.7 m | 2.02 of 2.5 m |
| 48.0-49.0 | 48 | | | | | | |

Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| | 49 | | | | | | 48 cm core loss |
| | | | 97 | |  | Creamy-grey chalk to 50.9 with blue nodular flint fragments at 49.7. 49.5 to 49.9 harder nodular chalk with orange-stained matrix. Thin marl at 50.37. Nodular chalk up to 51.2. 51.2 to end of run (drilling induced?) chalk putty with occasional flint fragments. | 1.97 of 2 m |
| 50.0-51.0 | 50 | | | |  | | |
| 51.0-52.0 | 51 | | | |  | | 53 cm loss assigned at base |
| 52.0-53.0 | 52 | | 55 | |  | 52.2 to 52.4 flint rubble. Flint fragment at 53.5 m. Highly damaged drilling induced chalk putty to 52.85. Fractured chalk to end of run. | 1.65 of 3 m |
| | 53 | | | |  | | 1.35 loss |
| 54.0-55.0 | 54 | | | | | | |
| 55.0-56.0 | 55 | 1/7/99 | 88 | |  | 55 to 55.6 hard, creamy-white chalk (occasional fractures – drilling induced?) 55.6 to 55.95 soft chalk putty containing chalk and flint fragments. Blue nodular flint at 55.4. | 1.75 of 2 m |

Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| 56.0-57.0 | 56 | | | | | 55.97 to end of run blocky (nodular) chalk with orange staining at 56.2. | 25 cm loss at base |
| 57.0-58.0 | 57 | | 79 | | | 25 cm of moderately hard creamy-white chalk passing into hardground. Orange-staining in matrix. Large blue flint fragments up to 57.8. Lens of grey siliceous-rich chalk at 57.6 and 58.5. Below 57.8 grey-white chalk. Trace fossils in matrix with small flint fragments at 58.3. | 1.57 of 2 m |
| 58.0-59.0 | 58 | | | | | | 43 cm loss |
| 59.0-60.0 | 59 | | 82 | | | Creamy-white, nodular fractured (drilling induced) chalk. Grey siliceous lenses and flint at 82.60. Chalk rubble 59.6-59.7. Thin grey marls/ trace fossils between 59.7 and 59.9. | 2.45 of 3 |
| 60.0-61.0 | 60 | | | | | 60-61 friable, nodular chalk with orange-staining in the matrix. Nodular blue flint 60.8-60.9. | |
| 61.0-62.0 | 61 | | | | | As above but less fractured. | 65 cm loss at base |
| 62.0-63.0 | 62 | | 79 | | | Creamy-white fractured (drilling induced) chalk with small broken flints at 62.1 and 62.6 | 2.37 of 3 m |

Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| 63.0-64.0 | 63 | | | | | Blocky, fractured friable chalk. Platy flint and broken flint fragments at 63.25. Nodular flints at 63.65 and 64.1. From 63.7 to end chalk is friable and soft. | |
| 64.0-65.0 | 64 | | | | | | 63 cm loss at base |
| 65.0-66.0 | 65 | | 67 | | | Large blue fractured nodular flint in top 15 cm. Grey drilling induced putty chalk to 66 m. | 1 of 1.5 m |
| 66.0-67.0 | 66 | | | | | | 50 cm loss at base |
| | | 2/7/99 | 91 | | | Blocky grey chalk with orange-staining and trace fossils in matrix from 67.5 to 68.5. Marls at 66.78, 66.85, 67.17 & 67.58. Four thin marls between 68.71 and 68.78. 5 cm thick marl at 68 m. Large nodular flint at 68.05 and small flints from 68.35 to 68.45. Orange-staining in matrix of nodular chalk between 67.65 and 68.0. | 2.73 of 3 m flint snagged core barrel lining |
| 67.0-68.0 | 67 | | | | | | |
| 68.0-69.0 | 68 | | | | | | |
| 69.0-70.0 | 69 | | | | | | 27 cm loss at base |
| | | | 81 | | | Massive, nodular, hard white chalk with orange-staining and trace fossils | 2.03 of 2.5 m |

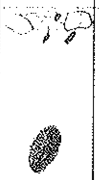
Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| 70.0-71.0 | 70 | | | | | in the matrix. Thin marls at 70.1 and at 71.55. Large blue nodular flint 69.9 to 70.05 and smaller blue flint at 71.05. | |
| 71.0-72.0 | 71 | | | | | | 47 cm loss at end of run. |
| 72.0-73.0 | 72 | 5/7/99 | 100 | | | Creamy-grey moderately hard chalk. Relatively massive. 72.33-72.62 and 72.27-72.35 broken core with flint fragments. At 73.32 and 72.3 fracture surfaces with Mn spotting. | 3 m of 3 m |
| 73.0-74.0 | 73 | | | | | | |
| 74.0-75.0 | 74 | | | | | Top 3 cm – putty chalk. 74.03-74.45 hard, massive, fractured grey-white chalk. Flint at 74.25. 74.45-75 nodular chalk with orange-stained hardground. Augen in the nodular chalk. | |
| 75.0-76.0 | 75 | | 73 | | | Creamy grey massive chalk, nodular after 75.1, with drilling induced fractures and putty between the fractures at 75.1<br>Marls at 75.56 (discontinuous), 75.77, 75.78 & 75.84 | |
| 76.0-77.0 | 76 | | | | | 75.99-76.03 broken horizon. 76.03-76.45 more fractured nodular chalk | 55 cm loss |

Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| 77.0-78.0 | 77 | | 58 | | | Grey-cream, hard nodular chalk. Flint fragments at 77.3, 77.5, 77.7 & 77.82 (burrow). Chalk is very hard below 77.5 with some sandier clasts. Broken core between 77.29-77.35, 77.51-77.58 and 77.67-77.86. | 77 to 79 m, 1.15 recovery of 2 m |
| | 78 | | | | | | 85 m loss at base |
| | 79 | | 70 | | | Rounded, nodular, hard, lightly orange-stained chalk clasts to 79.2 (hardground?). Grey-cream nodular chalk to 80.15. 79. 47-79.53 fracture with Mn spotting and grey calcite slickensides at 45o to core axis. Mn spots on smaller fracture at 79.94. 80.15 broken nodular flint. 80.25-80.30 broken flint band, below flint chalk fragments in a softer matrix. Harder grey (more siliceous?) band at 79.4. | 1.4 m from 2 m |
| 80.0-81.0 | 80 | | | | | | 60 cm loss |
| 81.0-82.0 | 81 | 6/7/99 | | | | 81-81.05, 5 cm thick grey marl. Creamy-white nodular chalk with broken softer sections between 81.23-81.4 and 81.7-81.8. Broken blue flint at 82.0 m. | 1.2 of 2.5 m |
| 82.0-83.0 | 82 | | | | | | 30 cm loss |
| | | | 75 | | | Nodular grey-white chalk with rubbly section (drilling induced) between 82.9 & 83. | 0.75 of 1 m |
| 83.0-84.0 | 83 | | | | | 83.5-83.73 – very hard rounded chalk fragments (possibly derived from unpreserved hardground). Blue flint fragments in drilling induced rubble. | 25 cm loss |
| | | | 60 | | | | |

## Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| 84.0-85.0 | 84 | | | |  | Orange-staining at 83.9. Chalk blocks in broken chalk rubble and flint fragments especially between 84 & 84.1. Grey, more siliceous bands at 83.8 and 84.05. Large blue flint fragments at 84.7. | |
| 85.0-86.0 | 85 | | | | | | 1.2 m core loss (from 3 m run) |
| 86.0-87.0 | 86 | | | | | | |
| | | | 80 | |  | Chalk rubble with flint fragments in the top 40 cm. Marl at 86.77. Dark grey very soft putty (drilling induced?) to end of run. | 1.6 m of 2 m |
| 87.0-88.0 | 87 | | | | | | |
| 88.0-89.0 | 88 | | | | | | 40 cm loss |
| | | | 80 | | | Putty as above | 1.6 of 2 m run |
| 89.0-90.0 | 89 | | | | | | |
| 90.0-91.0 | 90 | | | | | | 40 cm loss |
| | | 7/7/99 | 27 | | | | 0.8 of 3 m |

Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| 91.0-92.0 | 91 | | | | | | 2.2 m loss at base |
| 92.0-93.0 | 92 | | | | | | |
| | 93 | | | | | | |
| | | | 0 | | | | No recovery |
| | 94 | | | | | | |
| | 95 | | | | | | |
| | 96 | | | | | | |
| | 97 | | 50 | | | Chalk putty as above with some more massive, fractured grey chalk blocks. | 1.5 m of 3 m |

Lithological log for Lower Venson Farm vertical borehole

| Sample | Depth | Date | Core recovery % | Fracture | Graphic log | Descriptive log | Comments |
|---|---|---|---|---|---|---|---|
| 98.0-99.0 | 98 | | | | | | 1.5 m losses assigned to base of run |
| | 99 | | | | | | END OF BOREHOLE |
| | 100 | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**Table A.5** **Diary of the three packer tests performed on the Lower Venson Vertical (LVV) borehole.**

**Test 1** **Interval tested 30.18-33.05 mbgl**

Details 13 rods Stick-up =0.50m to top of threads
Stick-up =0.42m to join

| Time | WL | Datum | Transducer | Event | |
|---|---|---|---|---|---|
| 12:15 | 9.310 | top of threads | 6.6690 | | |
| 12:25 | 9.310 | | | | |
| 13:35 | | | 6.6651 | Start inflating packers | |
| 13:40 | 9.300 | | 6.6673 | Packers at 5 bars | |
| 14:00 | 9.750 | | 6.6725 | Packers at 7 bars | |
| 14:10 | 9.375 | | 6.6737 | Packers to 8 bars | |
| 14:13 | 9.415 | | | | |
| 14:17 | | | 6.6743 | Packers at 8 bars | |
| 14:18 | 9.395 | | 6.6745 | Top put on rods | Change in water level in annulus |
| 14:29 | 9.395 | | 6.6745 | | = ~7.5 cm lower |
| 14:30 | | | | Test started | Change in level in test interval = |
| 14:50 | 9.415 | | 6.6603 | Rate changed | ~6 cm higher |
| 15:10 | 9.395 | | 6.6697 | Pump off | |

**Test 2** **Interval tested 45.48-48.35 mbct**

Details 21 rods Stick-up =0.92m bottom of thread (join)
Stick-up =0.998m top of thread

| Time | WL | Datum | Transducer | Event | |
|---|---|---|---|---|---|
| 16:30 | 9.815 | top of rod | 9.0940 | | |
| 16:36 | | | | Start inflating packers | |
| 16:44 | 9.810 | | 9.0948 | Packers at 8 bars | |
| 16:56 | 9.800 | join | 9.0979 | Packers at 9 bars | |
| 17:00 | | | 9.1003 | Packers up to 10 bars | Change in water level in annulus |
| 17:10 | 9.815 | join | 9.1014 | Packers stable 10 bars | = ~8 cm lower |
| 17:15 | | | 9.1018 | Test started | Change in level in test interval = |
| 17:30 | 9.835 | | 9.0881 | Rate increased | ~4.5 cm higher |
| 18:00 | 9.850 | | 9.0500 | Test stopped | |
| 18:10 | 9.810 | | | | |
| 18:11 | | | 9.1040 | Start deflating packers | |

**Test 3** **Interval tested 75.98-78.85 mbgl**

Details 36 rods Stick-up =0.60m bottom of thread (join)
Stick-up =0.98m top of thread

| Time | WL | Datum | Transducer | Event | |
|---|---|---|---|---|---|
| 12:25 | 9.430 | join | 13.8846 | | |
| 12:30 | | | | Start inflating packers | |
| 13:30 | 9.450 | | 13.8874 | Regulator will not give required pressure - only 11 bars (need 13) | |
| 13:40 | | | | Start pump | |
| 13:44 | 9.490 | | 18.8748 | | Change in level in test interval |
| 13:48 | 9.480 | | 13.8736 | | during pumping = 9 cm |
| 13:55 | 9.485 | | 13.8757 | Sample taken, pump off | Change in level in borehole during pumping = 5 cm |

Table A.6 **Results of packer tests giving calculated hydraulic conductivities for each of the packer tests.**

| Test 1 | 30.18-33.05 mbgl | Test 2 | 45.48-48.35 mbgl | Test 3 | 75.98-78.83 mbgl |
|---|---|---|---|---|---|
| Initial | 6.6745 mA | Initial | 9.1018 mA | Initial | 13.8874 mA |
| Final | 6.6604 mA | Final | 9.0881 mA | Final | 13.8757 mA |
| Rate | 44.7 l/min | Rate | 16.5 l/min | Rate | 44.2 l/min |
| Drawdown | 0.090 m | Drawdown | 0.087 m | Drawdown | 0.075 m |
| **K** | **137.54 m/d** | K | **52.25 m/d** | K | **163.90 m/d** |
| Initial | 6.6745 mA | Initial | 9.1018 mA | | |
| Final | 6.6697 mA | Final | 9.05 mA | | |
| Rate | 11.7 l/min | Rate | 44 l/min | | |
| Drawdown | 0.031 m | Drawdown | 0.330106 m | | |
| **K** | **105.75 m/d** | K | **36.85 m/d** | | |

**Table A.7 Transmitter calibration**

| **Transmitter reading** mA | **Transducer reading** bars |
|---|---|
| 3.8920 | -0.01 |
| 4.4730 | 0.36 |
| 5.1275 | 0.77 |
| 5.5138 | 1.01 |
| 5.9839 | 1.31 |
| 6.3016 | 1.51 |
| 6.8867 | 1.87 |
| 7.5850 | 2.30 |
| 7.9267 | 2.52 |
| 8.3030 | 2.76 |
| 8.8750 | 3.11 |
| 9.3523 | 3.41 |
| 9.7009 | 3.63 |
| 10.3426 | 4.03 |
| 10.8479 | 4.34 |
| 11.2250 | 4.58 |
| 12.5021 | 5.38 |
| 13.2558 | 5.85 |
| 13.9214 | 6.27 |
| 14.6951 | 6.75 |
| 3.8922 | -0.01 |