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Keywords: Forsmark, hydrogeology, hydraulic tests, pumping tests, flow meter logging, water sampling, hydraulic parameters, transmissivity, flow anomaly.

Abstract

Borehole KFM03A was the third deep (c 1000 m) cored borehole drilled within the frame of on-going site investigations in the Forsmark area. The borehole is telescopic drilled, implying that the upper part, 0–100 m, is percussion drilled with a larger diameter than the diameter of the core drilled part (76 mm).

In connection with the drill start of borehole KFM03A, six other, however more shallow boreholes, were drilled in the vicinity of KFM03A. Three of them, HFM06, HFM07 and HFM08, are percussion drilled boreholes in hard rock.

Pumping tests and flow logging were performed in HFM06 and HFM08, and water samples were collected in conjunction with the pumping tests. The main aim of the hydraulic tests was to obtain a hydraulic and hydrogeochemical characterization of the boreholes. Another purpose was to verify and investigate the character of interpreted reflectors from earlier performed reflection seismic measurements. No other borehole tests had been carried out in the HFM06 and HFM08 prior to this campaign.

No hydraulic tests were performed in HFM07 and KFM03A, since these boreholes yielded almost no water during drilling. The flow rate in HFM07 during clear pumping after drilling amounted at 3.6 L/min, a flow rate too low to motivate further hydraulic tests. The drilling indicated vaguely, that this limited inflow was concentrated at 49.6 m. In KFM03A the flow rate during drilling was even lower.

In HFM06, four probably sub-horisontal zones were indicated, all of them encountered at a shallower depth than 71 m below top of casing. The upper three of the zones (c 22, 43 and 62 m respectively) all displayed transmissivities in the order of c $5\cdot10^{-5}$ m^2/s. The transmissivity of the lowermost zone (at approximately 70 m) was determined at c $2\cdot10^{-4}$ m^2/s.

Two major flow anomalies were detected in HFM08, probably representing sub-horisontal zones. One of these, at 137.5–139 m, showed a transmissivity as high as c $1\cdot10^{-3}$ m^2/s, whereas the transmissivity of the other, at 89.5–90 m, was lower, c $6\cdot10^{-5}$ m^2/s.

Pressure registrations in the boreholes revealed that borehole HFM06 was affected by the pumping tests in HFM08. The transmissivity and storativity from this interference test was estimated at $5\cdot10^{-4}$ m^2/s and $1\cdot10^{-4}$, respectively. No significant responses were observed in HFM07 when pumping in HFM08.

During percussion drilling of the large-diameter part of KFM03A, no responses were obtained in either of boreholes HFM06, HFM07 and HFM08.

Sammanfattning

Borrhål KFM03A var det tredje ca 1000 m djupa kärnborrhålet som borrades inom ramen för de pågående platsundersökningarna i Forsmarksområdet. Borrhålet är utfört som ett s k teleskopborrhål, vilket innebär att avsnittet 0–100 m är hammarborrat med grövre dimension än det kärnborrade avsnittet mellan 100 och 1000 m, som håller diametern 76 mm.

I samband med borrstarten för KFM03A borrades ytterligare sex borrhål i närområdet. Tre av dessa, HFM06, HFM07 och HFM08, är hammarborrhål i berg.

Provpumpning och flödesloggning utfördes HFM06 and HFM08. Samtidigt togs vattenprover. Inga andra borrhålstester hade utförts i de aktuella borrhålen före denna kampanj. De huvudsakliga syftena med de hydrauliska testerna i hammarborrhålen var, för det första, att utföra en hydraulisk karaktärisering av borrhålen och, för det andra, att undersöka grundvattenkemin. Ett ytterligare syfte var att verifiera och undersöka egenskaperna hos tolkade reflektorer från tidigare utförda reflektionsseismiska undersökningar.

Inga provpumpningar utfördes i HFM07 och KFM03A då resultatet från borrningen visade att dessa gav nästan inget vatten. Renspumpning av HFM07 gav endast 3.6 L/min och borrningen gav en svag indikation av inflöde vid 49.6 m. I KFM03A var flödet under borrningen ännu lägre.

I HFM06 påträffades fyra, sannolikt sub-horisontella zoner, samtliga på grundare djup än 71 m under foderrörets överkant. De tre övre zonerna (vid ca 22, 43 respektive 62 m) hade samtliga transmissiviteter av storleksordningen ca $5 \cdot 10^{-5}$ m^2/s, medan den understa zonen (ca 70 m) uppvisade en transmissivitet av ca $2 \cdot 10^{-4}$ m^2/s.

I HFM08 påträffades två sannolikt sub-horisontella zoner, varav en högtransmissiv, ca $1 \cdot 10^{-3}$ m^2/s, på 137.5–139 m djup, och en med lägre transmissivitet, ca $6 \cdot 10^{-5}$ m^2/s, vid 89.5–90 meter.

Tryckregistrering i HFM06 under pumpning i HFM08 påvisade att HFM06 påverkades vid denna pumpning. Transmissivitet respektive storativitet skattades till $5 \cdot 10^{-4}$ m^2/s respektive $1 \cdot 10^{-4}$. Inga klara responser kunde däremot påvisas i HFM07 vid pumpning i HFM08.

Vid hammarborrning av den grova delen av teleskopborrhålet KFM03A erhölls inga responser i varken HFM06, HFM07 eller HFM08.

Contents

1 Introduction

The initial phase of the on-going site investigations in the Forsmark area includes drilling and multi-disciplinary investigations of three c 1000 m deep cored boreholes, see Figure 1-1. Of these, borehole KFM03A is the third one to be completed. The borehole is telescopic drilled, implying that the upper part, 0–100 m, is percussion drilled with a larger diameter than that of the core drilled part, which is 76 mm. The percussion drilled interval was drilled in two steps. The first step resulted in a borehole diameter of c 165 mm and the second in a diameter of 200 mm. Finally, core drilling was started below the reamed part and is still in progress (June 20003).

In connection with the drill start of borehole KFM03A, six other, however more shallow boreholes, were drilled at drillsite DS3, i.e. in the vicinity of KFM03A. Three of them, HFM06, HFM07 and HFM08, are percussion drilled boreholes in hard rock, whereas the remaining three boreholes are monitoring wells drilled through the unconsolidated overburden at drillsite DS3, see Figure 1-2.

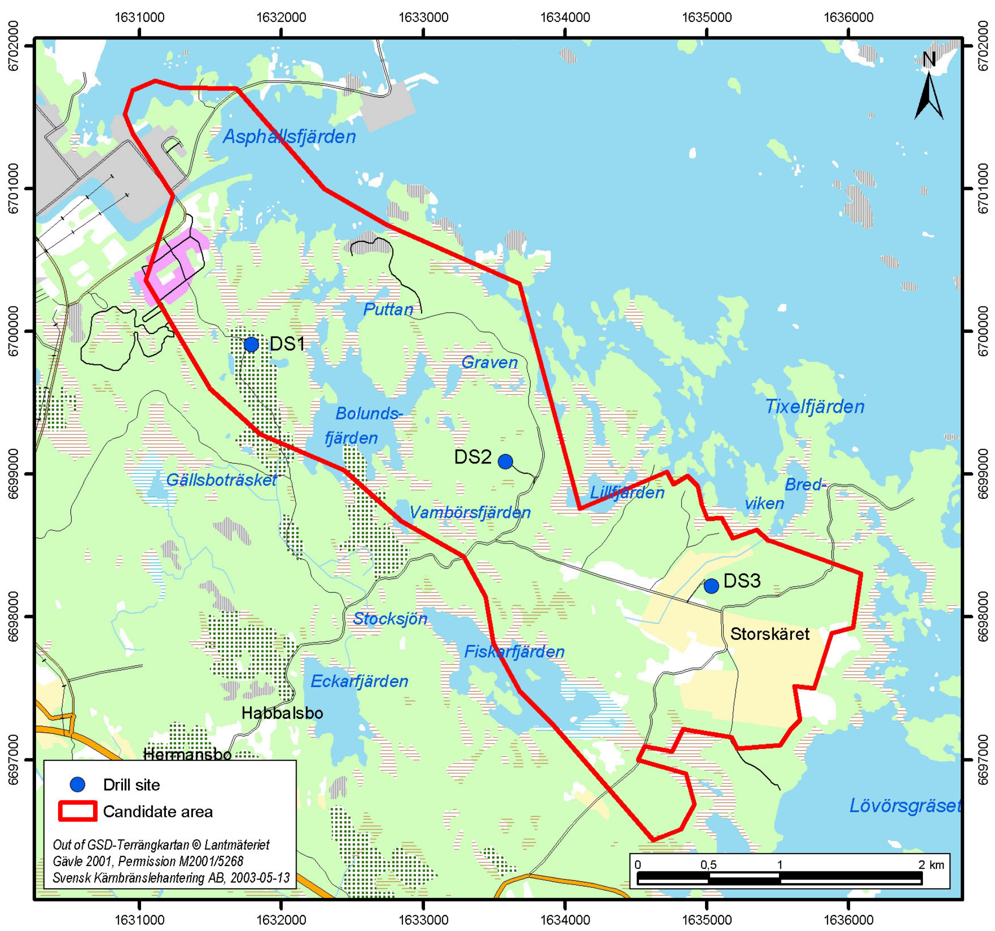


Figure 1-1. The investigation area at Forsmark including the candidate area selected for more detailed investigations. The drillsites for the earliest drilled deep cored boreholes are marked with blue dots. Borehole KFM03A is situated at drillsite DS3.

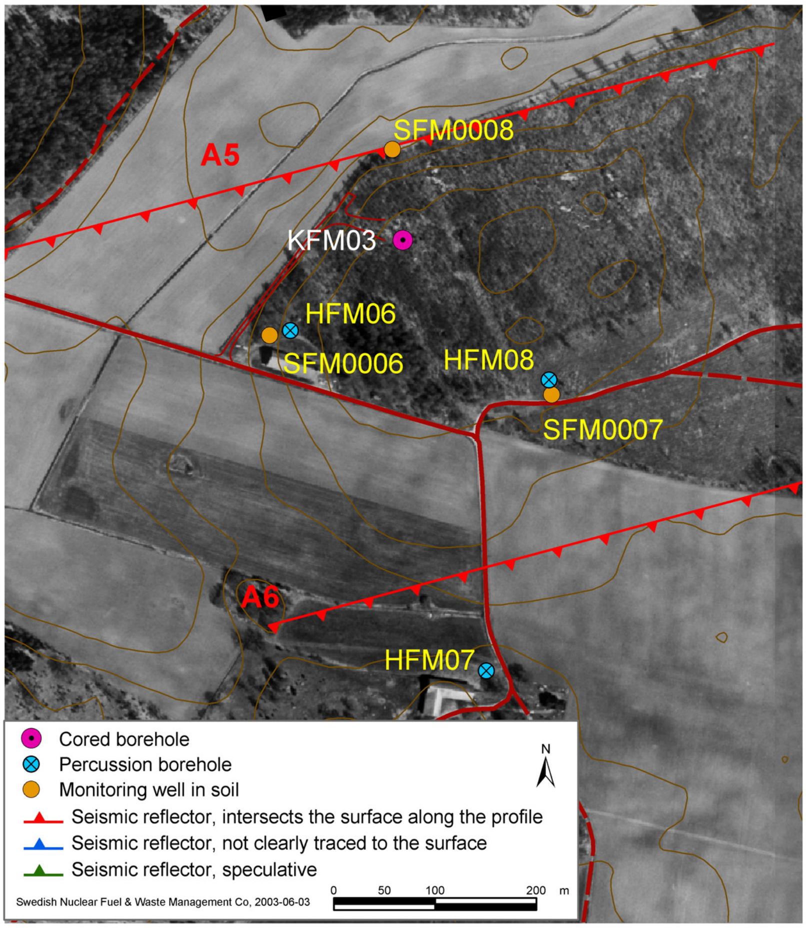


Figure 1-2. *Map showing the location of boreholes att drillsite DS3 at Forsmark. Boreholes HFM07 and HFM08 have switched ID since the Activity Plan AP PF 400-02-39 (SKB internal controlling document) was prepared.*

Borehole HFM06 was drilled primarily to serve as supply well for the flushing water needed for drilling the cored part of KFM03A, whereas HFM07 and HFM08 were drilled to serve for monitoring of the groundwater level and for groundwater sampling /1/.

This report presents results from pumping tests and flow logging in boreholes HFM04 and HFM05, performed with a specially designed equipment system, the HTHB test system. Water samples were collected during pumping. The results of the chemical investigations are reported in /2/. During the pumping tests in HFM08, pressure was registered in HFM06, thus enabling the evaluation of interference test data. During one of two pumping tests in HFM08, the pressure was registered also in HFM07.

Hydraulic tests were planned to be performed in HFM07 and KFM03A (0–100 m) as well. Due to the minor inflow of water in those boreholes during drilling, these tests were however excluded from the test campaign.

No other borehole tests had been carried out in the actual boreholes before the campaign described in this report.

2 Objectives

Pumping tests, flow logging and groundwater sampling were performed in HFM06 and HFM08. The main objectives of the tests were firstly, to obtain a hydraulic characterization (e.g. to reveal the occurrence of possible sub-horizontal fracture zones) and secondly, to investigate the groundwater chemistry for general hydrogeochemical characterization. Regarding HFM06, the water chemistry was of particular interest, since the borehole was intended to be used as a flushing water well when drilling the cored part of KFM03A.

During drilling of the percussion drilled part of KFM03A, groundwater pressure was registered in the near-by percussion boreholes HFM06, HFM07 and HFM08. During the pumping tests in HFM08, groundwater pressure was registered in HFM06. Furthermore, during one of the two pumping tests in HFM08, groundwater pressure was registered in HFM07. The main objective of these pressure registrations was to test the possible existence of hydraulic connection between all, or some of the boreholes mentioned and, if so, calculate hydraulic parameters from observed responses.

3 Scope

3.1 Boreholes tested

Coordinates and other data on the tested boreholes are given in Table 3-1. The reference point in the boreholes is always top of casing (ToC). The Swedish National coordinate system (RT90 2.5 g W) is used to indicate position in the x-y-plane together with RHB70 in the z-direction. Northing and Easting refer to the intersection of the boreholes with the ground surface. The reported borehole diameters in Table 3-1 refer to the final diameter of the boreholes after drilling to full depth. The borehole diameter (measured as the diameter of the drill bit) usually decreases c 1–2 mm/100 m along the borehole in the type of rock prevailing at Forsmark, due to successively increased wear of the drill bit.

Table 3-1. Pertinent data on the boreholes tested (from SICADA).

Borehole								**Casing**		**Drilling finished**
ID	**Elevation** of top of casing (ToC) (m.a.s.l.)	**Borehole length** from ToC (m)	**Bh-diam**. (below casing) (m)	**Inclin.** -top of bh (from horizontal plane) (º)	**Direction** -top of bh (from local N) (º)	**Northing**	**Easting**	**Length** (m)	**Inner diam.** (m)	**Date** (YYYY-MM-DD)
HFM06	6.64	110.70	0.134	-84.57	2.44	6 697 752	1 634 522	12.00	0.160	2003-01-14
HFM07	5.78	122.50	0.140	-84.52	342.32	6 697 416	1 634 716	18.00	0.160	2003-01-28
HFM08	7.13	143.50	0.137	-84.44	348.69	6 697 703	1 634 778	18.00	0.160	2003-02-12

3.2 Tests performed

None of the boreholes were tested prior to the test campaign described in this report. The tests performed in the boreholes are listed in Table 3-2. In conjunction with the flow logging, temperature- and electric conductivity logging of the borehole water was also carried out.

During the pumping tests, water samples were collected and submitted for analysis, see Section 6.2. Of primary interest was to decide if the borehole water in HFM06 was of sufficient quality to be used as flushing water for drilling of the cored part of borehole KFM03A.

Furthermore, measurements of hydraulic responses were performed in adjacent percussion boreholes while drilling the core borehole KFM03A (0–100 m).

In conjunction with the flow logging, temperature logging of the borehole water was also performed. No reliable data of electrical conductivity was obtained due to malfunction of a sensor. In spite of that, the relative variations of electrical conductivity were used

Table 3-2. Borehole tests performed.

Bh ID	Test section (m)	Test type[1]	Test config.	Test no	Test start date and time (YYYY-MM-DD tt:mm)	Test stop date and time (YYYY-MM-DD tt:mm)
HFM06	12 – 110.7	1B	Open hole	1	2003-01-21 09:58	2003-01-22 08:54
HFM06	19.5 – 105	6, L-Te, L-EC	Open hole	1	2003-01-21 17:06	2003-01-21 20:34
HFM06	12 – 110.7	1B	Open hole	2	2003-01-22 09:35	2003-01-22 13:35
HFM06	12 – 21.5	6, L-Te, L-EC	Open hole	1	2003-01-22 12:47	2003-01-22 13:25
HFM08	18 – 143.5	1B	Open hole	1	2003-02-17 22:30	2003-02-19 04:30
HFM08	18 – 140	6, L-Te, L-EC	Open hole	1	2003-02-18 12:34	2003-02-18 17:32
HFM08	18 – 93	1B	Above packer	1	2003-02-20 04:00	2003-02-20 18:25
HFM06	12 – 110.7	2	Open hole	1	2003-02-18 08:42	2003-02-19 04:30
HFM06	12 – 110.7	2	Open hole	2	2003-02-20 04:00	2003-02-21 09:39
HFM07	18 – 122.5	2	Open hole	1	2003-02-20 08:47	2003-02-21 10:14
HFM06	0 – 16.5	3	Above packer	1	2003-03-17	2003-03-28
HFM06	17.5 – 34.5	3	Between packers	1	2003-03-17	2003-03-28
HFM06	35.5 – 50.5	3	Between packers	1	2003-03-17	2003-03-28
HFM06	51.5 – 66.5	3	Between packers	1	2003-03-17	2003-03-28
HFM06	67.5 –110.7	3	Below packer	1	2003-03-17	2003-03-28
HFM08	0 – 81.0	3	Above packer	1	2003-03-17	2003-03-28
HFM08	82 – 100.5	3	Between packers	1	2003-03-17	2003-03-28
HFM08	101.5 – 143.5	3	Below packer	1	2003-03-17	2003-03-28
HFM07	0 – 122.5	3	Open hole	1	No info.	No info.

[1)] 1B: Pumping test-submersible pump, 6: Flow logging–Impeller. L-EC: EC-logging, L-Te: temperature logging
[1)] 2: Observation borehole during pumping test, 3: Observation borehole during drilling of KFM03A (0–100m)

qualitatively when interpreting the results (i.e. identifying zones of higher transmissivity from flow logging data). While pumping in HFM08, pressure loggers were submerged into HFM06 and HFM07, thus allowing the pumping tests in HFM08 to be evaluated as interference tests with HFM06 and HFM07 as observation wells. For HFM07 though, the pressure logger was active only during the latter of the two pumping tests in HFM08.

Manual observations of the groundwater level in the pumped boreholes were also made during the tests as a back-up for the automatic registrations.

4 Description of equipment

4.1 Overview

The equipment used for these tests is referred to as HTHB (Swedish abbreviation for Hydraulic Test System for Percussion Boreholes), which is described in SKB MD 326.001-15, Version 1.0 (Mätsystembeskrivning för HTHB-utrustning. Handhavandedel).

The HTHB-unit is designed for percussion boreholes to perform pumping- and injection tests, either in open boreholes (or above a single packer), see Figure 4-1, or in isolated sections of the boreholes (Figure 4-2) down to a total depth of 200 m. With the HTHB-unit, it is also possible to perform a impeller flow logging survey along the borehole during an open-hole pumping test (Figure 4-1). The pumping tests can be performed with either a constant hydraulic head or, alternatively, with a constant flow rate. For injection tests, the deepest position of the upper packer is limited to c 80 m below ToC.

All equipment included in the HTHB-system is, when not in use, stored on a trailer and can easily be transported with a standard car. The down the hole-equipment consists of a submersible borehole pump with housing, expandable packers, pressure sensors and a pipe string and/or hose. During impeller flow logging, sensors measuring temperature and electric conductivity as well as the down-hole flow rate are also used. The equipment on the ground includes a control valve for manual adjustment of the total flow/injection rate, which is monitored by an electromagnetic flow meter. A data logger samples data at a frequency determined by the operator.

The packers are normally expanded by water (nitrogen gas is used to pressurize the water) unless the depth to the groundwater level is large. In such cases, the packers are expanded by nitrogen gas. A folding pool is used to collect and store the discharged water from the borehole for subsequent use in injection tests.

4.2 Measurement sensors

Technical specifications of the measurement sensors included in the HTHB-equipment system together with corresponding data of the system are shown in Table 4-1.

Specific pressure sensors were used for logging pressure in boreholes HFM06 and HFM07 while pumping tests were performed in HFM08. Those pressure sensors were of type BAT TL30 with built-in memory for 4000 data points. The sensors were configured to register pressure as head (i.e. vertical height of water above pressure sensor, in meter). The measuring interval for the sensors is 0–40 m and resolution is 0.01 m. Before lowered in to the borehole, the sensors were adjusted to register 0 m at air pressure.

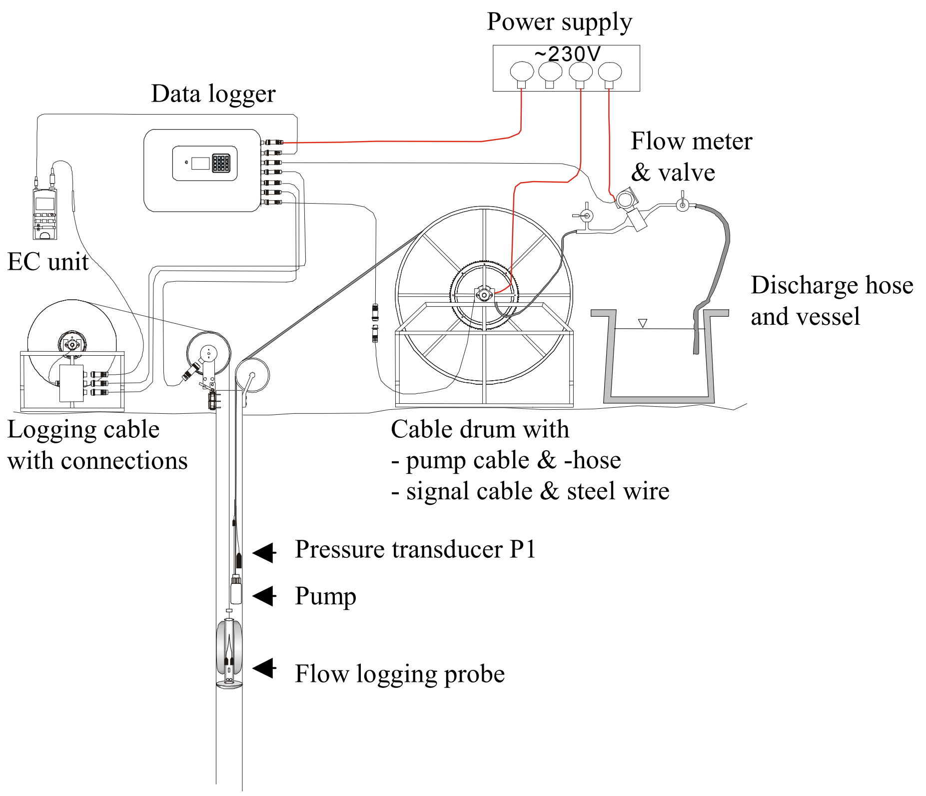


Figure 4-1. *Schematic test set-up for a pumping test in an open borehole in combination with flow logging with HTHB.*

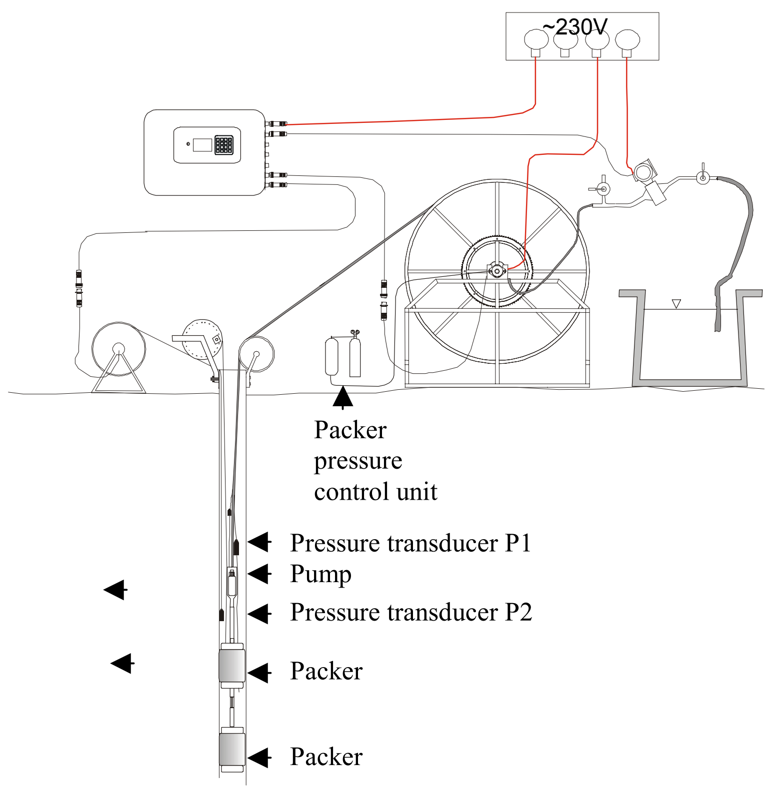


Figure 4-2. *Schematic test set-up for a pumping test in an isolated borehole section with HTHB.*

Table 4-1. Technical data of sensors together with estimated data of the HTHB test system (based on current laboratory experience).

Technical specification					
Parameter		**Unit**	**Sensor**	**HTHB system**	**Comments**
Absolute pressure	Output signal	mA	4 – 20		
	Meas. range	kPa	0 – 1500	0 – 1500	
	Resolution	kPa	0.05		
	Accuracy	kPa	± 1.5 *	± 10	Depending on uncertainties of the sensor position
Temperature	Output signal	mA	4 – 20		
	Meas. range	°C	0 – 50	0 – 50	
	Resolution	°C	0.1		
	Accuracy	°C	± 0.6	± 0.6	
Electric Conductivity	Output signal	V	0 – 2		
	Meas. range	mS/m	0 – 50000	0 – 50000	With conductivity meter
	Resolution	% o.r.**		1	
	Accuracy	% o.r.**		± 10	
Flow (Spinner)	Output signal	Pulses/s	c 0.1 – c 15		
	Meas. range	L/min		2 – 100	115 mm borehole diameter
				3 – 100	140 mm borehole diameter
				4 – 100	165 mm borehole diameter
	Resolution***	L/min		0.2	140.0 mm borehole diameter
	Accuracy***	% o.r.**		± 20	and 100 s sampling time
Flow (surface)	Output signal	mA	4 – 20		Passive
	Meas. range	L/min	1 – 150	5 – c 80 ****	Pumping Tests
	Resolution	L/min	0.1	0.1	
	Accuracy	% o.r.**	± 0.5	± 1	

* Includes hysteresis, linearity and repeatability
** Maximum error in % of actual reading (% o.r.)
*** Applicable to a pipe with a diameter of 140.0 mm when sampling time is 100 s
**** For injection tests, minimal flow rate is 1 L/min

Errors in reported borehole data (diameter etc) and other external factors may significantly increase the error in measured data. For example, the flow logging probe is very sensitive to variations in the borehole diameter, cf Figure 4-3. Borehole deviation and uncertainties in the borehole inclination may also affect the accuracy of measured data.

The flow-logging probe is calibrated for different borehole diameters (e.g. different pipe diameters), i.e. 111.3, 135.5, 140 and 160 mm. During calibration the probe is installed in a vertically orientated pipe and a water flow is pumped through. Spinner rotations and the total discharge are measured. Calibration gives excellent correlation ($R^2 > 0.99$) between total discharge and the number of spinner rotations. The calibration also clearly demonstrates the sensitivity of the probe in relation to deviations in the borehole diameter, cf Figure 4-3.

The recorded flow at each position during flow logging was found to be rather insensitive to the measurement time (50, 100, 200 s), provided that sufficient stabilisation time is allowed to a change in flow. The stabilisation time may be up to 30 s at flow rates close to the lower measurement limit, whereas this time is almost instantaneous at high flow rates.

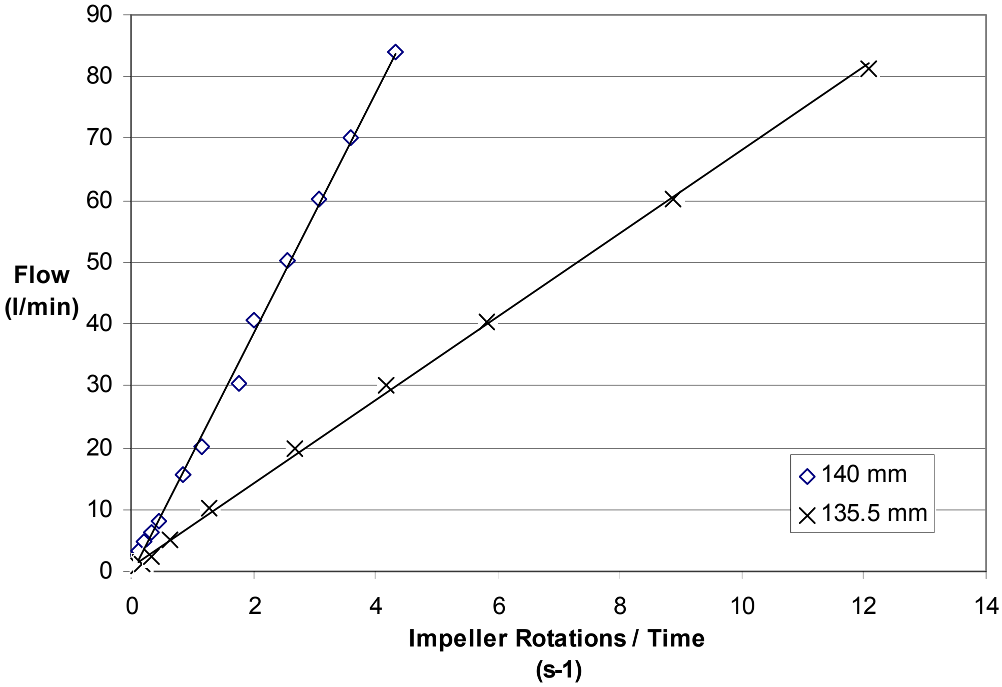


Figure 4-3. *Total flow as a function of impeller rotations for two borehole diameters (140 and 135.5 mm).*

Table 4-2 lists the position of sensors for each test. The following types of sensors are used: pressure (p), temperature (Te), electric conductivity (EC) together with the (lower) level of the submersible pump (Pump). Positions are given in metre from the reference point, i.e. top of casing (ToC), lower part. The sensors measuring temperature and electric conductivity are located in the impeller flow-logging probe and the position is thus varying (top-bottom-top of section) during a test. For specific information about the position at a certain time, the actual data files have to be consulted.

Equipment affecting the wellbore storage coefficient is given in terms of diameter of the submerged component. Position is given as "in section" or "above section". The volume of the submerged pump (~ 4 dm^3) is in most cases of minor importance.

In addition, the theoretical wellbore storage coefficient, C, for the actual test configurations and the geometrical data of the boreholes (Table 3-1) have been calculated, see Section 5.4.1. These values on C may be compared with the estimated ones from the test interpretations described in Chapter 6.

Table 4-2. Position of sensors (from ToC) and of equipment that may affect well-bore storage for the different hydraulic tests performed.

Borehole information				Sensors		Equipment affecting wellbore storage (WBS)			
ID	**Test interval (m)**	**Test config**	**Test type[1]**	**Type**	**Position (m b ToC)**	**Function**	**Position relative test section [2]**	**Outer diameter (mm)**	**C (m^3/Pa) for test [3]**
HFM06	12-110.7	Open hole	1B 6	Pump-intake P (P1) EC-sec Te-sec	17 13.72	Pump Pump hose Signal cable Flowlogging probe	In Section In Section In Section In Section	37 13.5 50	$2.0 \cdot 10^{-6}$
HFM06	12-110.7	Open hole	1B 6	Pump-intake P (P1) EC-sec Te-sec	8.3 5.02	Pump Pump hose Signal cable Flowlogging probe	In Section In Section In Section In Section	37 13.5 50	$2.0 \cdot 10^{-6}$
HFM08	18-143.5	Open hole	1B 6	Pump-intake P (P1) EC-sec Te-sec	14 10.72	Pump Pump hose Signal cable Flowlogging probe	In Section In Section In Section In Section	37 13.5 50	$2.0 \cdot 10^{-6}$
HFM08	18-93	Above a single packer	1B	Pump-intake P (P1) P (P2)	40 36.72 38.22	Pump Pump hose Signal cable	In Section In Section In Section	37 8	$2.0 \cdot 10^{-6}$

[1)] 1B: Pumping test-submersible pump, 6: Flow logging–Impeller incl. EC-logging (EC-sec) and temperature logging (Te-sec)

[2)] Position of equipment that can affect well-bore storage. Position given as "In Section" or "Above Section"

[3)] Based on the casing diameter for the open-hole tests and the nominal borehole diameter (140 mm) together with the compressibility of water for the test in isolated section, respectively (net values)

4.3 Borehole equipment used for measuring hydraulic response in adjacent boreholes during drilling

The equipment used for measuring hydraulic response while drilling the first 100 metres of the telescopic borehole KFM03A consists of hydraulic packers and pressure sensors provided with internal loggers. The packers used were of the type Petrometallic Pb11-42 with a sealing length of one meter. The packers were installed using a specially designed winch fitted on the casing. The desired distances between the packers were achieved using an appropriate number of connecting rods. In order to hydraulically connect the desired test intervals with the ground surface, all packers were equipped with five run-throughs. The run-throughs are connected to the top of the borehole by nylon tubing.

The uppermost 15 metres of the tubing has a diameter allowing the pressure sensors to be lowered into the tube. The pressure sensors were of the type mini-TROLL SSP 100. The scanning interval of the pressure transducers was set to 10 seconds. Pressure values were set to be logged every 60 seconds unless the condition of a 0.5 cm changes in the water column from the previously logged value is fulfilled. The percussion boreholes were individually instrumented in accordance with Table 3-2.

5 Execution

The pumping tests and flow logging were performed according to Activity Plan AP PF 400-02-39 (SKB internal controlling document) in accordance with the methodology descriptions for single-hole pumping tests, SKB MD 321.003, Version 1.0 (Metodbeskrivning för hydrauliska enhålspumptester), and flow logging, SKB MD 322.009, Version 1.0 (Metodbeskrivning för flödesloggning).

5.1 Preparations

All sensors included in HTHB are calibrated at GEOSIGMAs engineering workshop in Uppsala. Calibration is generally performed on a yearly basis, but more often if needed. If a sensor is replaced at the test site, calibration of the new sensor can be carried out in the field (except the impeller probe) or alternatively, in the laboratory after the measurements.

During these measurements, HTHB-equipment no 1 (HTHB1), the first of two manufactured HTHB-systems, was used. Since two of the sensors belonging to HTHB1 were out of order (P2 and temperature), those were borrowed from HTHB2, and accordingly the calibration constants used were those obtained when calibrating these sensors together with HTHB2.

An equipment check was performed at the site prior to the tests to establish the operating status of sensors and other equipment. In addition, calibration constants were implemented and checked.To check the function of the pressure sensors P1 and P2 (cf Figures 4-1 and 4-2), the pressure in air was recorded and found to be as expected. Submerged in water while lowering, both P1 and P2 coincided well to the total head of water ($p/\rho g$). The temperature sensor showed expected values in both air and water.

The impeller used in the flow logging equipment worked well as indicated by the rotation on the logger while lowering. The sensor for electric conductivity showed non-relevant values when checked in solutions of known electrical conductivity. Thereof, absolute values of electrical conductivity are most certainly incorrect, although the possibility of finding anomalies remained.

The measuring wheel (used to check the position of the flow logging probe) and the sensor attached to it indicated a length that corresponded well to the pre-measured cable length. The function of the flow meter was checked once by a Volume-Time measurement. The control measurement corresponded well to the value obtained from the flow meter.

5.2 Procedure

5.2.1 Overview

The pumping tests were mainly carried out as single-hole, constant flow rate tests followed by a pressure recovery period. The intention was to obtain approximately steady-state conditions during the flow logging. To meet this condition, the flow rate had to be slightly decreased in the early phase of some tests to achieve steady-state conditions faster, e.g. first pumping test in HFM08. In spite of this, the period with constant flow rate was quite dominant in all tests. One of the tests, 18–93 m in HFM08, was performed as a constant drawdown test, mainly due to practical problems of finding an appropriate constant flow rate (indications from the drilling did not coincide with the drawdown obtained in this section).

The flow logging was performed while pumping. Discrete flow measurements were made at fixed step lengths (10 m), starting from the bottom and moving the flow probe upwards along the borehole. When the first detectable flow anomaly was indicated, the flow probe was lowered 10 m, and repeated measurements with a shorter step length (2 m) were made to locate the position of the flow anomaly more exactly. Finally, a step length of 0.5 m was used to determine the detailed position of the anomaly. After characterization of the first anomaly, the flow logging continued with a length increment of 2 m, until the next flow anomaly was encountered. The flow logging survey was terminated at a short distance below the submersible pump in the borehole.

5.2.2 Details

Single-hole pumping tests

Prior to the tests, function checks and cleaning of equipment, as well as time synchronisation of clocks and data loggers were performed according to the Activity Plan. Short flow capacity tests were carried out to identify an appropriate flow rate for the tests. All pumping tests and flow meter loggings were carried out after completion of the boreholes at full drilling depths, using the HTHB-unit. The pumped water from the boreholes was discharged on the ground, sloping downhill from the pumping borehole.

The main test in each borehole was a c 10 h long pumping test in the open hole in combination with flow logging, followed by a recovery period of c 12-h. In borehole HFM06, a short pumping test (c 3.5 h with lower flow rate) in combination with flow logging was carried out to enable flow logging in the upper part of the borehole. Likewise, in borehole HFM08, a short pumping test (c 5 h) was carried out above a single-packer to further investigate a zone at ~ 90 m identified during flow logging. In general, the sampling interval of pressure during the pumping tests was according to Table 5-1.

Table 5-1. Sampling intervals used for pressure registration during the pumping tests.

Time interval (s) from start/stop of pumping	Sampling interval (s)
1-300	1
301-600	10
601-3600	60
>3600	600

The hydraulic tests in the boreholes were performed in the following order of time: HFM06, HFM08. Pressure was logged in HFM06 and HFM07 when pumping tests were performed in HFM08.

The test program performed in the boreholes was mainly according to the Activity Plan with a few exceptions (decided by the Activity Leader and Investigation Leader):

- An extra, short pumping test was performed in HFM06, to enable flow logging in the upper part of the borehole. Recovery was not measured, since the main intent with this pumping test was to perform flow logging.

- A pumping test above a single packer in HFM08 (option in the Activity Plan), to get more information from a zone at ~ 90 m which gave a only a weak flow anomaly during flow logging due to a zone of much higher transmissivity situated below ~ 90 m.

- Pressure was recorded in HFM06 and HFM07 during pumping tests in HFM08.

Compared to the methodology description for single-hole pumping tests, some deviations were made regarding the recommended test times:

- The recommended test time (24 h + 24 h for drawdown/recovery) for the longer tests during flow logging was decreased to c 10 h + 10 h due to practical reasons (mainly to avoid uncontrolled pumping over-night and to eliminate the risk of freezing, theft/sabotage etc). Experience from similar tests also indicates that c 10 h of pumping and 10 h of recovery in general is sufficient to estimate the hydraulic properties of the borehole regarding, e.g. wellbore storage effects and other disturbing factors.

- The recommended test time (3 h + 3 h for drawdown/recovery) for tests in borehole sections was increased to c 5 h + 5 h in HFM08 to decrease the effect of the borehole storage.

- Flow logging was not performed from the bottom of HFM06 but started from borehole length 105 m and continued upwards due to problems with lowering the flow logging probe deeper in the borehole (because the borehole diameter was significantly smaller than the nominal).

Measuring pressure interferences in adjacent boreholes during pumping tests

While pumping in HFM08, the pressure was measured in HFM06 and HFM07 with BAT pressure sensors. The purpose of these pressure measurements was to investigate the response in HFM06 and HFM07 to pumping tests in HFM08. Before lowering the pressure sensors in HFM06 and HFM07, they were adjusted to register 0 m of vertical water column at the present air pressure.

Flow meter logging

Before start of the flow logging, the probe was lowered to the bottom of the borehole. While lowering along the borehole (max. speed = 0.5 m/s), temperature- and electric conductivity data were sampled.

Flow logging was performed during a pumping test, starting from the bottom of the hole going upwards. The logging started when the pressure in the borehole was approximately stable. The time needed to complete the flow logging survey depends on the length and character of the borehole. In general, between 3–7 hours are needed for a percussion borehole of 100–200 m length.

In HFM06 as well as in HFM08, the flow logging started 3–4 hours after start of pumping and lasted c 4.5 h. The extra flow logging of HFM06 started c 3 h after start of pumping and lasted c 0.5 h.

Measuring pressure interferences in adjacent boreholes during drilling

Monitoring of groundwater pressure in adjacent percussion boreholes during drilling of the first 100 metres of KFM03A served as a preliminary check of possible hydraulic connections between the cored borehole and the percussion boreholes. The test can be described as a simplified interference test. Previously performed reflection seismic measurements indicated a seismic reflector within the first 100 metres of KFM03A. One possible interpretation of this reflector is that it represents a water-bearing zone.

The drilling was planned to be halted at every water-bearing zone in order to facilitate directed disturbance that can be evaluated hydraulically. The pumping should be kept constant while the drilling is halted. When drilling is completed, the recovery should be measured in the percussion boreholes and in KFM03A at least as long as the duration of the pumping phase.

5.3 Data handling

Data obtained with HTHB is downloaded from the logger (Campbell CR5000) to a laptop with the program PC9000 and are, already in the logger, transformed to engineering units. All files are comma-separated (*.DAT) when copied to a computer. Data files used for transient evaluation are further converted to *.mio-files by the code Camp2mio. The operator can choose the parameters to be included in the conversion (normally pressure and discharge). Data from the flow logging are evaluated in Excel and therefore not transformed to *.mio-files. A list of the data files from the data logger is shown in Appendix 1.

Data from BAT TL30 pressure sensors in HFM06 and HFM07, used for interference tests, were stored in ASCII-text files. Under the assumption of a water density ρ = 1000 kg/m^3, the pressure was converted from metre of water column to pressure in kPa. (Before these pressure sensors were lowered into the boreholes, their offsets were adjusted to register zero pressure at the present air pressure, see section 4.1.) Thereafter, the text-files were manually converted to a mio-compatible format.

Data from mini-TROLL SSP 100 pressure sensors in HFM06, HFM07 and HMF08 used for measuring pressure interferences during drilling of KFM03A (0–100 m), were downloaded using the win-SITU software. The downloaded data can be saved as binary file or text file. Thereafter, the text-files were manually converted to a mio-compatible format.

Processed data files (*.mio-files) from the hydraulic tests with pressure versus time data were converted to drawdown- and recovery files by the code PUMPKONV and plotted in different diagrams listed in the methodology instruction for analysis of injection- and single-hole pumping tests, SKB MD 320.004, Version 1.0, (Metodinstruktion analys av injektions- och enhålspumptester) by the code SKB-plot.

5.4 Analyses and interpretation

5.4.1 Single-hole pumping tests

As discussed in Section 5.2.1, the pumping tests were generally performed as constant flow rate tests, although some minor adjustments of the flow rate were made. During the end of all pumping tests, pseudo-radial flow developed during some period. Consequently, methods for single-hole, constant-flow rate tests in an equivalent porous medium were used by the analyses and interpretation of the tests. For the exception with constant drawdown, pseudo-radial flow occurred by the end of the test, and methods for single hole, constant head tests in an equivalent porous medium were used by the analyses and interpretation of the tests.

Firstly, a qualitative evaluation of the actual flow regimes (pseudo-linear, pseudo-radial and pseudo-spherical flow) and possible outer boundary conditions during the tests was performed. The qualitative evaluation was made from analyses of log-log diagrams of drawdown and/or recovery data together with the corresponding pressure derivatives versus time.

From the results of the qualitative evaluation, appropriate interpretation models for the tests were selected. The quantitative, interpretation of the hydraulic parameters (e.g. transmissivity and skin factor) was primarily based on the identified transient pseudo-radial flow regime during the tests in log-log and lin-log data diagrams. For tests indicating a fractured- or borehole storage dominated response, corresponding type curves were used by the analyses.

If possible, transient analysis was made both on the drawdown- and recovery phase of the tests. The recovery data was plotted versus equivalent time. The analysis of the drawdown- and recovery data was generally made both according to Theis-Walton's and Cooper-Jacob's methods (for constant head, Jacob-Lohman was used for the drawdown phase), cf standard textbooks. In addition, a preliminary steady-state analysis (e.g. Moye's formula) was made for all tests for comparison.

The transient analysis of tests dominated by wellbore storage was made according to the single-hole methods described in /3/. The estimation of the borehole storage coefficient C in appropriate pumping tests was based on the early borehole response with 1:1 slope in a log-log diagram. These values on C may be compared with the wellbore storage coefficient calculated below, based on actual borehole geometrical data and assumed fluid properties (net values). The estimated values on C from the test data may differ from the net values due to deviations of the actual geometrical borehole properties from the anticipated, e.g. the borehole diameter. Furthermore, the effective compressibility is usually higher than the water compressibility in an isolated section due to e.g. packer compliance resulting in a higher C-value.

For pumping tests in an open borehole (and in the interval above a single packer) the wellbore storage coefficient may be calculated as:

$$C = \pi \, r_{we}^2 / \rho g \qquad (5\text{-}1)$$

For an isolated pumped section (and the section below a single packer) the corresponding well-bore storage coefficient may be calculated as:

$$C = \pi \, r_w^2 \cdot L_w \cdot c_w \qquad (5\text{-}2)$$

r_{we} = borehole radius where the changes of the groundwater level occur (either r_w or r_c)
r_w = nominal borehole radius (m)
r_c = inner radius of the borehole casing (m)
ρ = density of water (kg/m^3)
g = acceleration of gravity (m/s^2)
L_w = section length (m)
c_w = compressibility of water (Pa^{-1}).

5.4.2 Flow logging

The measured parameters during the flow meter logging (flow, temperature and electric conductivity of the borehole fluid) are firstly plotted versus borehole length. From these plots, flow anomalies were identified along the borehole, i.e. borehole intervals over which (in this case) changes of flow rates exceeding c 1 L/min occur. The magnitude of the inflow at the flow anomaly is determined by the actual change in flow rate over the interval. In some cases, the flow changes are accompanied by corresponding changes in temperature and/or electric conductivity of the fluid.

Flow logging can only be carried out from the bottom of a borehole up to a certain distance below the submersible pump (when logging from the bottom of the hole upwards). The remaining part of the borehole (i.e. from the pump to the casing) cannot be flow-logged, although high inflow zones may sometimes be located in this part. Such superficial inflows may be identified by comparing the cumulative flow at the top of the flow-logged interval (Q_T) with the discharged flow rate (Q_p) from the hole at the surface during the flow logging. If the latter flow rate is significantly higher than the cumulative flow rate, one or several inflow zones are likely to exist above the flow-logged interval.

The transmissivity (T) of the entire borehole was calculated from the analysis of the pumping test during flow logging. The cumulative transmissivity at the top of the flow-logged interval (T_{FT}=ΣT_i) was then calculated according to the methodology description for Impeller flow logging, SKB MD 322.009, (assuming zero natural flow in the borehole):

$$T_{FT} = \sum T_i = T \cdot (Q_T / Q_p) \qquad (5\text{-}3)$$

The cumulative flow at the top of the flow logged interval is denoted Q_T. If $Q_T < Q_p$, one or several flow anomalies may be located above the flow-logged interval. In such cases, the (order of magnitude) of the transmissivity of these anomalies may also be estimated from Equation (5-3). However, a discrepancy between Q_T and Q_p may also be due to deviations of the actual borehole diameter from the assumed one by the calibration of the flow measurements, cf Section 4.2.

The transmissivity of an individual flow anomaly (T_i) was estimated from the measured inflow (ΔQ_i) at the anomaly and the calculated transmissivity of the entire borehole (T):

$$T_i = T \cdot (\Delta Q_i / Q_p) \qquad (5\text{-}4)$$

For comparison, estimates of the transmissivities of the identified flow anomalies were also made from the specific flows, simply by dividing the measured inflow (ΔQ_i) at the anomaly by the drawdown (s_{FL}) in the borehole (assuming negligible head losses). The sum of the specific flows may then be compared with the total transmissivity (and specific flow) of the borehole.

The cumulative transmissivity $T_F(L)$ along the borehole length (L) as determined from the flow logging may be calculated:

$$T_F(L) = T \cdot Q(L)/Q_p \qquad (5\text{-}5)$$

where Q(L) = cumulative flow along the borehole length (L).

The lower limit of transmissivity (T_{min}) in flow logging may be estimated in asimilar way as Equation (5-3):

$$T_{min} = T \cdot (Q_{min}/Q_p) \qquad (5\text{-}6)$$

In a 140.0 mm borehole, Qmin=3 L/min , see Table 4-1, whereas Q_p is the actual flow rate during flow logging.

6 Results

6.1 Nomenclature and symbols

The nomenclature and symbols used for the results of the pumping tests and flow logging are according to the methodology instruction for analysis of single-hole injection- and pumping tests, SKB MD 320.004, Version 1.0 (Metodinstruktion för analys av injektions- och enhålspumptester), and the methodology description for impeller flow logging, SKB MD 322.009, Version 1.0 (Metodbeskrivning för flödesloggning), cf Section 3.2. Additional symbols used are explained in the text.

6.2 Water sampling

Water samples were collected during the pumping tests in the boreholes at drillsite DS3 at Forsmark (Figure 1-2) and submitted for analysis, see Table 6-1. The results of the water analyses are described in /2/.

Table 6-1. Data of water samples collected during the pumping tests in the boreholes at drillsite DS3 at Forsmark and submitted for analysis.

Bh ID	Date and time of sample	Pumped section (m)	Pumped volume (m^3)	Sample type	Sample ID no	Remarks
HFM06	2003-01-21 11:55	12-110.7	6.7	WC080	4463	Open-hole test
“	2003-01-21 16:52	12-110.7	14.4	WC080	4464	Open-hole test
“	2003-01-21 21:00	12-110.7	32.5	WC080	4465	Open-hole test
HFM08	2003-02-18 09:30	18-143.5	3.9	WC080	4521	Open-hole test
“	2003-02-18 18:05	18-143.5	37	WC080	4522	Open-hole test
“	2003-02-20 13:40	18-93	14	WC 080	4535	Open-hole test

6.3 Single-hole pumping tests

Below, the results of the pumping tests are presented test by test. Corrections of measured data, e.g. for changes of the barometric pressure or tidal fluctuations, were not made by the data analysis. No such data, nor data on air temperature or precipitation were available during the test periods in point. However, in single-hole tests such corrections are generally not necessary for an adequate data analysis, unless very small drawdowns are applied in the boreholes.

6.3.1 Borehole HFM06, 12–110.7 m, 2003-01-21

General test data for the open-hole pumping test in combination with flow logging of borehole HFM06 are presented in Table 6-2.

Table 6-2. General test data for the open-hole pumping test in borehole HFM06.

General test data			
Borehole	HFM06		
Test type *	Constant Rate withdrawal and recovery test		
Test section (open borehole/packed-off section):	open borehole		
Test No	1		
Field crew	S. Jönsson, J. Olausson / GEOSIGMA AB		
Test equipment system	HTHB1		
General comment	Single pumping borehole		
	Nomen-clature	**Unit**	**Value**
Borehole length	L	m	110.7
Casing length	L_c	m	12
Test section- secup	Secup	m	12
Test section- seclow	Seclow	m	110.7
Test section length	L_w	m	98.7
Test section diameter **	$2 \cdot r_w$	mm	134
Test start (start of pressure registration)		yymmdd hh:mm	030121 09:57
Packer expanded		yymmdd hh:mm:ss	-
Start of flow period		yymmdd hh:mm:ss	030121 10:04:03
Stop of flow period		yymmdd hh:mm:ss	030121 21:02:03
Test stop (stop of pressure registration)		yymmdd hh:mm	030122 08:54
Total flow time	t_p	min	658
Total recovery time	t_F	min	711

* Constant Head injection and recovery or Constant Rate withdrawal and recovery
** Nominal diameter is 140 mm

Pressure and groundwater level data

Pressure data	**Nomen-clature**	**Unit**	**Value**	**GWL * (masl)**
Absolute pressure in borehole before start of flow period	p_i	kPa	173.2	0.55
Absolute pressure in test section before stop of flow period	p_p	kPa	132.6	-3.51
Absolute pressure in test section at stop of recovery period	p_F	kPa	172.3	0.46
Maximal pressure change during flow period	dp_p	kPa	40.6	-

* Calculated from pressure data and position of pressure sensor, under the assumption of ρ=1000 kg/m^3

Manual groundwater level measurements			**GW level**	
Date YYYY-MM-DD	**Time tt:mm:ss**	**Time ** (min)**	**(m bToC)**	**(m a s l)**
2003-01-20	13:20	----	5.91	0.76
2003-01-20	17:20	----	5.91	0.76
2003-01-20	17:50	----	5.89	0.78
2003-01-21	09:15	-49	5.88	0.79
2003-01-21	21:01	657 F	10.07	-3.39
2003-01-21	08:52	709 R	6.03	0.64

** Four manual groundwater level measurements were done before start of the test, one at the end of the flow period and one at the end of the recovery period (F=time from start of flow period, R=time from stop of flow period)

Flow data

Flow data	**Nomen-clature**	**Unit**	**Value**
Flow rate from test section just before stop of flow period	Q_p	m^3/s	$9.97 \cdot 10^{-4}$
Mean (arithmetic) flow rate during flow period *	Q_m	m^3/s	$9.03 \cdot 10^{-4}$
Total volume discharged during flow period ($=Q_m \cdot t_p$)	V_p	m^3	35.6

* Time-weighted average value of flow rate (from datafile)

Manual measurements (M) or readings (R) *			**Flow rate**
Date YYYY-MM-DD	**Time tt:mm:ss**	**Time ** (min)**	**(L/min)**
2003-01-21	17:06	422	60.0 R
2003-01-21	17:12	428	60.0 R
2003-01-21	17:22	438	60.0 R
2003-01-21	17:27	443	60.0 R
2003-01-21	17:41	457	60.0 R
2003-01-21	18:06	482	60 R
2003-01-21	18:17	493	60.1 R
2003-01-21	18:28	504	60.1 R
2003-01-21	18:43	519	60.0 R
2003-01-21	18:53	529	60.0 R
2003-01-21	19:09	545	60 R
2003-01-21	19:22	558	60 R
2003-01-21	19:31	567	60 R
2003-01-21	19:50	586	60 R
2003-01-21	20:04	600	60 R
2003-01-21	20:18	614	60 R

* R indicates manual readings on logger display
** Time from start of flow period (irrespective of the c 1 hour interruption of flow period)

Comments on the test

The test was carried out as a pumping test with a constant flow rate with the intention to achieve (approximately) steady-state conditions during the flow logging. Flow logging was performed between 2003-01-21 17:06 and 2003-01-21 20:32.

Due to failure in the power supply, the pumping test was interrupted twice, at first between c 12:50 and c 13:50 (i.e. 1 h) and then between 14:15 and 14:17 (i.e. 2 min). The flow period lasted for approximately 11 h (including the interruptions in the pumping) and the recovery period for approximately 11.5 h.

Interpreted flow regimes

Selected test diagrams are presented in Figures A2:1-1–A2:1-5 in Appendix A2:1.

The initial phase of the flow period and recovery period indicated a pseudo-linear flow (slope ~1:2 in the log-log diagram) in Figure A2:1-2 and A2:1-4.

For the flow period, a pseudo-radial flow regime is indicated by the end of the phase (c 500–700 min), although the phase is disturbed by the interruptions of the pumping. For the recovery period, the pseudo-radial flow regime develops earlier, at c 100 min, and comes to an end already at c 200 min. After the period of pseudo-radial flow regime, indications of outer (no-flow) boundary effects appear by the end of the recovery period.

Interpreted parameters

The transient, quantitative interpretation of the flow- and recovery period of the test is shown in the diagrams in Figures A2:1-1 to A2:1-5 in Appendix A2:1. The results are presented in the Test Summary Sheet and in Tables 6-15–6-17 in Section 6.5.

6.3.2 Borehole HFM06, 12–110.7 m, 2003-01-22

General test data for the open-hole pumping test in combination with flow logging of borehole HFM06 are presented in Table 6-3.

Table 6-3. General test data for the open-hole pumping test in borehole HFM06.

General test data			
Borehole	HFM06		
Test type *	Constant Rate withdrawal and recovery test		
Test section (open borehole/packed-off section):	open borehole		
Test No	2		
Field crew	S. Jönsson, J. Olausson / GEOSIGMA AB		
Test equipment system	HTHB1		
General comment	Single pumping borehole		
	Nomen-clature	**Unit**	**Value**
Borehole length	L	m	110.7
Casing length	L_c	m	12
Test section- secup	Secup	m	12
Test section- seclow	Seclow	m	110.7
Test section length	L_w	m	98.7
Test section diameter **	$2 \cdot r_w$	mm	134
Test start (start of pressure registration)		yymmdd hh:mm	030122 09:35
Packer expanded		yymmdd hh:mm:ss	-
Start of flow period		yymmdd hh:mm:ss	030122 09:48:12
Stop of flow period		yymmdd hh:mm:ss	030122 13:31:02
Test stop (stop of pressure registration)		yymmdd hh:mm	030122 13:35
Total flow time	t_p	min	223
Total recovery time	t_F	min	4

* Constant Head injection and recovery or Constant Rate withdrawal and recovery
** Nominal diameter is 140 mm

Pressure and groundwater level data

Pressure data	**Nomen-clature**	**Unit**	**Value**	**GWL * (masl)**
Absolute pressure in borehole before start of flow period	p_i	kPa	121.6	0.51
Absolute pressure in test section before stop of flow period	p_p	kPa	109.7	-0.69
Absolute pressure in test section at stop of recovery period	p_F	kPa	116.7	0.02
Maximal pressure change during flow period	dp_p	kPa	11.9	---

* Calculated from pressure data and position of pressure sensor, under the assumption of ρ=1000 kg/m^3

Manual groundwater level measurements			**GW level**	
Date YYYY-MM-DD	**Time tt:mm:ss**	**Time ** (min)**	**(m bToC)**	**(m a s l)**
2003-01-22	09:40	-8 F	6.02	0.65
2003-01-22	09:45	-3 F	6.02	0.65
2003-01-22	13:29	4 F	7.29	-0.62

** F=time from start of flow period, R=time from stop of flow period

Flow data

Flow data	**Nomen-clature**	**Unit**	**Value**
Flow rate from test section just before stop of flow period	Q_p	m^3/s	$4.15 \cdot 10^{-4}$
Mean (arithmetic) flow rate during flow period *	Q_m	m^3/s	$4.16 \cdot 10^{-4}$
Total volume discharged during flow period ($=Q_m \cdot t_p$)	V_p	m^3	5.6

* Time-weighted average value of flow rate (from datafile)

Manual measurements (M) or readings (R) **			**Flow rate**
Date YYYY-MM-DD	**Time tt:mm:ss**	**Time *** (min)**	**(L/min)**
2003-01-22	12:47	179	25.0 R
2003-01-22	12:52	184	25.0 R
2003-01-22	13:01	193	25.0 R
2003-01-22	13:11	203	25.0 R

** R indicates manual readings on logger display
*** Time from start of flow period

Comments on the test

This short pumping test was performed to enable flow logging in the upper part of the borehole. Thus, recovery was not measured.

Interpreted flow regimes

Pseudo-radial flow regime is indicated from c 120 min.

Interpreted parameters

The transient, quantitative interpretation of the flow- and recovery period of the test is demonstrated in the diagrams in Figures A2:2-1 to A2:2-3 in Appendix A2:2. The results are shown in the Test Summary Sheet and in Tables 6-15–6-17 in Section 6.5.

6.3.3 Borehole HFM08, 18–143.5 m

General test data for the open-hole pumping test in combination with flow logging of borehole HFM08 are presented in Table 6-4.

Table 6-4. General test data for the 18–143.5 m open-hole pumping test in borehole HFM08.

General test data			
Borehole	HFM08		
Test type *	Constant Rate withdrawal and recovery test		
Test section (open borehole/packed-off section):	open borehole		
Test No	1		
Field crew	J. Källgården, J. Olausson / GEOSIGMA AB		
Test equipment system	HTHB1		
General comment	Pumping borehole, interference measured in HFM06		
	Nomen-clature	**Unit**	**Value**
Borehole length	L	m	143.5
Casing length	L_c	m	18
Test section- secup	Secup	m	18
Test section- seclow	Seclow	m	143.5
Test section length	L_w	m	125.5
Test section diameter **	$2 \cdot r_w$	mm	137
Test start (start of pressure registration)		yymmdd hh:mm	030217 22:30
Packer expanded		yymmdd hh:mm:ss	-
Start of flow period		yymmdd hh:mm:ss	030218 08:26:15
Stop of flow period		yymmdd hh:mm:ss	030218 18:28:00
Test stop (stop of pressure registration)		yymmdd hh:mm	030219 09:15
Total flow time	t_p	min	602
Total recovery time	t_F	min	600

* Constant Head injection and recovery or Constant Rate withdrawal and recovery
** Nominal diameter is 140 mm

Pressure and groundwater level data

Pressure data	**Nomen-clature**	**Unit**	**Value**	**GWL * (masl)**
Absolute pressure in borehole before start of flow period	p_i	kPa	137.8	-0.35
Absolute pressure in test section before stop of flow period	p_p	kPa	123.4	-1.79
Absolute pressure in test section at stop of recovery period	p_F	kPa	133.1	-0.82
Maximal pressure change during flow period	dp_p	kPa	14.4	-

* Calculated from pressure data and position of pressure sensor, under the assumption of ρ=1000 kg/m^3

Manual groundwater level measurements			**GW level**	
Date YYYY-MM-DD	**Time tt:mm:ss**	**Time (min)**	**(m bToC)**	**(m a s l)**
2003-02-17	16:30:00	-------	6.98	0.18
2003-02-18	08:23:00	-3 **	6.98	0.18
2003-02-18	10:15:00	109 ***	7.93	-0.76
2003-02-19	09:16:00	888 ***	7.32	-0.16

** From start of flow period
*** From stop of flow period

Flow data

Flow data	**Nomen-clature**	**Unit**	**Value**
Flow rate from test section just before stop of flow period	Q_p	m^3/s	$1.08 \cdot 10^{-3}$
Mean (arithmetic) flow rate during flow period *	Q_m	m^3/s	$1.09 \cdot 10^{-3}$
Total volume discharged during flow period ($=Q_m \cdot t_p$)	V_p	m^3	39.2

* Time-weighted average value of flow rate (from datafile)

Manual measurements (M) ** **or readings (R)** ***			**Flow rate**
Date YYYY-MM-DD	**Time tt:mm:ss**	**Time from start of flow period (min)**	**(L/min)**
2003-02-18	08:27:10	1	64.8 R
2003-02-18	09:00	34	65.5 M
2003-02-18	18:05	579	65 R

** Functioning check of flow meter
*** R indicates manual readings on logger display

Comments on the test

The test was carried out as a pumping test with a constant flow rate with the intention to achieve (approximately) steady-state conditions during the flow logging. Flow logging was performed between 2003-02-18 12:26 and 2003-02-18 17:30. Due to the high transmissivity, only a small drawdown was obtained (14.4 kPa) which might have been affected of external factors. Complete recovery was not obtained (10.7 kPa) even though the recovery period was extended to 14.5 h (to be compared with the 10 h drawdown phase). However, for transient evaluation of data, a recovery of 10 h has been considered as sufficient.

Interpreted flow regimes

Selected test diagrams are presented in Figures A2:3-1–A2:3-5 in Appendix A2:3.

The initial phase of both the flow- and recovery period indicated pseudo-linear flow, although the early part of the pressure derivative curve was rather unstable. After a short transition period, a rather well defined pseudo-radial flow regime (hereafter denoted PRF1) developed between c 1–10 min of the flow period and between c 2–7 min of the recovery period. Due to the quick response and short persistence, the first pseudo-radial flow regime was interpreted as a fracture zone intersecting the borehole. After this period, effects of no-flow boundaries were indicated from the pressure drawdown derivative.

By the end of the flow-period, another pseudo-radial flow regime (hereafter denoted PRF2) was identified after c 200 min. The second pseudo-radial flow regime (PRF2) during the flow-period is probably representing a larger bedrock volume enclosing the borehole. The recovery period also indicated effects of no-flow boundaries after the first pseudo-radial flow regime. No well-defined second pseudo-radial flow regime was observed during the recovery period. By the end of the recovery period, more pronounced indications of outer (no-flow) boundary effects appeared. The responses during the late parts of the flow – and recovery periods were thus not quite consistent. The reason to this discrepancy is not clear.

Interpreted parameters

The transient, quantitative interpretation of the flow- and recovery period of the test is shown in Figures A2:3-1 – A2:3-5 in Appendix A2:3. Quantitative analysis was made from both the flow- and recovery period in lin-log and log-log diagrams according to the methods described in Section 5.4.1.

The results are displayed in the Test Summary Sheet and in Tables 6-15–6-17 in Section 6.5.

6.3.4 Borehole HFM08, 18–93 m

General test data for the open-hole pumping test in combination with flow logging of borehole HFM08 are presented in Table 6-5.

Table 6-5. General test data for the pumping test 18–93 m above a single packer in borehole HFM08.

General test data			
Borehole	HFM08		
Test type *	Constant Drawdown and recovery test		
Test section (open borehole/packed-off section):	above a single packer located at 92-93 m		
Test No	1		
Field crew	J. Källgården, J. Olausson / GEOSIGMA AB		
Test equipment system	HTHB1		
General comment	Pumping borehole, interferences measured in HFM06 and HFM07		
	Nomen-clature	**Unit**	**Value**
Borehole length	L	m	143.5
Casing length	L_c	m	18
Test section- secup	Secup	m	18
Test section- seclow	Seclow	m	93
Test section length	L_w	m	75
Test section diameter **	$2 \cdot r_w$	mm	137
Test start (start of pressure registration)		yymmdd hh:mm	030220 04:00
Packer expanded		yymmdd hh:mm:ss	030219 15:41:00
Start of flow period		yymmdd hh:mm:ss	030220 09:01:56
Stop of flow period		yymmdd hh:mm:ss	030220 13:52:55
Test stop (stop of pressure registration)		yymmdd hh:mm	030220 18:25
Total flow time	t_p	min	291
Total recovery time	t_F	min	272

* Constant Head injection and recovery or Constant Rate withdrawal and recovery or Constant Drawdown and recovery
** Nominal diameter is 140 mm

Pressure and groundwater level data

Pressure data	Nomen-clature	Unit	Value	GWL (masl)
Absolute pressure in borehole before start of flow period	p_i	kPa	391.4	-0.77
Pressure in section below the packer before start of flow period	p_{bi}	kPa	914.1	-0.45
Absolute pressure in test section before stop of flow period	p_p	kPa	303.8	-9.53
Pressure in section below the packer at stop of flow period	p_{bp}	kPa	909.4	-0.92
Absolute pressure in test section at stop of recovery	p_F	kPa	390.5	-0.86
Pressure in section below the packer at stop of recovery	p_{bF}	kPa	912.0	-0.66
Maximal pressure change during flow period	dp_p	kPa	87.5	-
Maximal pressure change in section below the packer during the flow period	dp_{bp}	kPa	4.7	-

Manual groundwater level measurements			GW level	
Date YYYY-MM-DD	**Time tt:mm:ss**	**Time (min)**	**(m bToC)**	**(m a s l)**
2003-02-19	14:33:00	-	7.27	-0.106
2003-02-20	08:56:00	-6 *	6.94	0.223
2003-02-20	09:21:00	20 *	16.20	-8.994
2003-02-20	09:42:00	41 *	16.12	-8.914
2003-02-20	10:58:00	117 *	16.12	-8.914
2003-02-20	12:15:00	194 *	16.12	-8.914
2003-02-20	13:40:00	279 *	16.09	-8.884
2003-02-20	16:24:00	151 **	7.35	-0.185

* From start of flow period
** From stop of flow period

Flow data

Flow data	Nomen-clature	Unit	Value
Flow rate from test section just before stop of flow period	Q_p	m^3/s	$8.13 \cdot 10^{-4}$
Mean (arithmetic) flow rate during flow period *	Q_m	m^3/s	$8.59 \cdot 10^{-4}$
Total volume discharged during flow period ($=Q_m \cdot t_p$)	V_p	m^3	15.0

* Time-weighted average value of flow rate (from datafile)

Manual measurements (M) or readings on logger display (R)			Flow rate
Date YYYY-MM-DD	**Time tt:mm:ss**	**Time from start of flow period (min)**	**(L/min)**
2003-02-20	09:02	0	65 R
2003-02-20	09:16	14	59 R
2003-02-20	09:24	22	52 R
2003-02-20	09:24	22	53.5 R
2003-02-20	09:29	27	56.7 R
2003-02-20	09:40	38	55.2 R
2003-02-20	09:57	55	52.2 R
2003-02-20	10:15	73	51.7 R
2003-02-20	10:20	78	51.3 R
2003-02-20	10:37	95	51.1 R
2003-02-20	10:54	112	50.9 R
2003-02-20	10:58	116	50.7 R
2003-02-20	11:32	150	50.3 R
2003-02-20	11:52	170	49.9 R
2003-02-20	12:15	193	49.8 R
2003-02-20	13:22	260	49.0 R
2003-02-20	13:38	276	49.4 R

Comments on the test

The test was carried out as a pumping test with a constant drawdown above a single packer. The duration of the drawdown and recovery phases was in both cases c 5 h. In the pumped section a drawdown of 87.5 kPa was obtained and a recovery of 86.7 kPa. Early during the pumping phase, it was difficult to adjust the flow rate to a reasonable level, which led to a quick decision to perform a constant drawdown test instead. Thereafter, controlling a constant head was successfully accomplished, with a few disturbances around 5–7 min and 35–40 min.

Interpreted flow regimes

Selected test diagrams are presented in Figures A2:4-1–A2:4-7 in Appendix A2:4.

An approximate pseudo-radial (approaching pseudo-spherical) flow regime was observed after c 45 min of pumping with a constant flow rate. During recovery, a similar pseudo-radial flow regime was observed after c 100 min. Wellbore storage effects were identified during the initial phase of recovery, indicating a lower transmissivity than for the entire borehole (18–143.5 m).

Worth to mention is a small pressure response observed in the borehole section below the tested section. This response was almost linear versus time in a log-log-diagram (cf Figures A2:4-6 and A2:4-7 in Appendix A2:4) during both drawdown and recovery. This fact my either be a result of a leakage around the packer or a natural hydraulic connection between test section and the section below.

Interpreted parameters

The transient, quantitative interpretation of the flow- and recovery periods of the test is shown in relevant diagrams in Appendix A2:4. Quantitative analysis was in this case made from both periods in lin-log and log-log diagrams according to the methods described in Section 5.4.1. The results are illustrated in the Test Summary Sheet and in Tables 6-15–6-17 in Section 6.5.

6.3.5 Observation borehole HFM06 during pumping in HFM08:18–143.5 m

General test data for observation borehole HFM06 during pumping in borehole HFM08, section 18–143.5 m, are presented in Table 6-6.

Table 6-6. General test data for observation borehole HFM06 during the pumping test in HFM08: 18–143.5 m.

General test data			
Borehole	HFM06		
Test type(s) *	2		
Test section:	Open borehole		
Test No	1		
Field crew	G. Nilsson/SKB PLU		
Test equipment system	Pressure sensor BT TL30		
General comments	Pumping in HFM08: 18-143.5 m		
	Nomen-clature	**Unit**	**Value**
Borehole length	L	m	110.7
Casing length	L_c	m	12
Test section- secup	Secup	m	12
Test section- seclow	Seclow	m	110.7
Test section length	L_w	m	98.7
Test section diameter **	2·rw	mm	134
Test start (start of pressure registration)		yymmdd hh:mm	030218 08:42
Packer expanded		yymmdd hh:mm:ss	-
Start of flow period		yymmdd hh:mm:ss	030218 08:26:15
Stop of flow period		yymmdd hh:mm:ss	030218 18:28:00
Test stop (stop of pressure registration)		yymmdd hh:mm	030220 08:02
Total flow time	t_p	min	602
Total recovery time ***	t_F	min	600

* 2: Interference test
** Nominal diameter is 140 mm
*** For evaluation of recovery, only 600 min has been used (to evaluate the same time as for the flow period), even though the pressure registration lasted much longer

Pressure and water level data

Water level data in observation borehole HFM06	**Nomen-clature**	**Unit**	**Value**	**GWL (masl)**
Level in borehole before start of flow period	h_i	m	8.66	0.37
Level in borehole before stop of flow period	h_p	m	8.38	0.09
Level in borehole at stop of recovery period	h_F	m	8.54	0.25
Maximal drawdown in borehole during flow period	s	m	0.28	--

Interpreted flow regimes

Selected test diagrams are presented in Figures A2:5-1–A2:5-5 in Appendix A2:5. The drawdown period exhibits a short period of pseudo-radial flow regime by the end of the period (starts at c 350 min). During the recovery period, no such regime was developed.

Interpreted parameters

Quantitative analysis was made from the flow period in both lin-log and log-log diagrams according to the methods described in Section 5.4.1. The transient, quantitative interpretation of the flow period of the test is indicated in diagrams in Appendix A2:5. The interpretation is based on the assumed pseudo-radial flow regime mentioned above.

For estimating storativity (S) a distance parameter, r_s, is needed, which represents the linear distance from the "point of application" in the pumping borehole (i.e. a point corresponding to the major inflow in the pumping borehole) to the "point of application" in the observation borehole (i.e. a point in the observation borehole representing the highest hydraulic conductivity). These points were estimated from the results of flow logging (see section 6.4) and are listed in Table 6-7. Based upon information from SICADA about borehole positions, inclination and directions, the position for each of the two points was calculated (see Table 6-7) from basic geometric formulas. From the positions in Table 6-7, the distance between points of application, r_s, was calculated to 279 m.

The results from observation borehole HFM06 are presented in the Test Summary Sheet and in Tables 6-15 to 6-17 in section 6.5.

Table 6-7. Calculated positions for "points of application" used for estimating the distance to the observation borehole HFM06.

	Northing [m]	**Easting [m]**	**BH length (m b TOC)**	**Elevation [m a s l]**
Pumping borehole HFM08	6 697 716.403	1 634 790.630	138.25	-130.47
Observation borehole HFM06	6 697 745.402	1 634 521.908	70	-63.05

6.3.6 Observation borehole HFM06 during pumping in HFM08: 18–93 m

General test data for observation borehole HFM06 during pumping in borehole HFM08, section 18–93 m, are presented in Table 6-8.

Table 6-8. General test data for observation borehole HFM06 during pumping in HFM08: 18–93 m.

General test data			
Borehole	HFM06		
Test type(s) *	2		
Test section:	Open borehole		
Test No	2		
Field crew	G. Nilsson/SKB PLU GEOSIGMA AB		
Test equipment system	Pressure sensor BT TL30		
General comments	Pumping in HFM08: 18-93 m		
	Nomen-clature	**Unit**	**Value**
Borehole length	L	m	110.7
Casing length	L_c	m	12
Test section- secup	Secup	m	12
Test section- seclow	Seclow	m	110.7
Test section length	L_w	m	98.7
Test section diameter **	2·rw	mm	134
Test start (start of pressure registration)		yymmdd hh:mm	030220 04:00
Packer expanded		yymmdd hh:mm:ss	-
Start of flow period		yymmdd hh:mm:ss	030220 09:01:56
Stop of flow period		yymmdd hh:mm:ss	030220 13:52:55
Test stop (stop of pressure registration)		yymmdd hh:mm	030221 09:39
Total flow time	t_p	min	291
Total recovery time ***	t_F	min	272

* 2: Interference test
** Nominal diameter is 140 mm
*** For evaluation of recovery, only 272 min has been used (to evaluate approx. the same time as for the flow period and the same time as the recovery in the pumping borehole), even though pressure registration lasted much longer

Pressure and water level data

Water level data in observation borehole HFM06	Nomen-clature	Unit	Value	GWL (masl)
Level in borehole before start of flow period	h_i	m	8.70	0.41
Level in borehole before stop of flow period	h_p	m	8.55	0.26
Level in borehole at stop of recovery period	h_F	m	8.59	0.30
Maximal drawdown in borehole during flow period	s	m	0.15	--

Manual water level measurements in observation borehole HFM06				
Date YYYY-MM-DD	**Time tt:mm:ss**	**Time (min)**	**GW level (m b. ToC)**	**GW level (m a s l)**
2003-02-20	08:53	-	6.06	0.61
2003-02-20	11:05	123 *	6.12	0.55
2003-02-20	13:20	258 *	6.20	0.47
2003-02-20	16:17	144 **	6.20	0.47
2003-02-20	17:40	227 **	6.19	0.48

* Time from start of flow period
** Time from stop of flow period

Interpreted flow regimes

Selected test diagrams are presented in Figures A2:6-1–A2:6-5 in Appendix 2:6. Both the drawdown- and recovery curves for HFM06 show an influence from the pumping test in HFM08. However, the test time seems too short. No well defined flow regime is identified.

Interpreted parameters

No hydraulic parameters were interpreted.

6.3.7 Observation borehole HFM07 during pumping in HFM08: 18–93 m

General test data for observation borehole HFM07 during pumping in borehole HFM08, section 18–93 m, are presented in Table 6-8.

Table 6-9. General test data for observation borehole HFM07 during pumping in HFM08: 18–93 m.

General test data			
Borehole	HFM07		
Test type(s) *	2		
Test section:	Open borehole		
Test No	1		
Field crew	G. Nilsson/SKB PLU		
Test equipment system	Pressure sensor BT TL30		
General comments	Pumping in HFM08: 18 - 93 m		
	Nomen-clature	**Unit**	**Value**
Borehole length	L	m	122.5
Casing length	L_c	m	18
Test section- secup	Secup	m	18
Test section- seclow	Seclow	m	122.5
Test section length	L_w	m	104.5
Test section diameter **	2·rw	mm	140
Test start (start of pressure registration)		yymmdd hh:mm	030220 08:47
Packer expanded		yymmdd hh:mm:ss	-
Start of flow period		yymmdd hh:mm:ss	030220 09:01:56
Stop of flow period		yymmdd hh:mm:ss	030220 13:52:55
Test stop (stop of pressure registration)		yymmdd hh:mm	030221 10:14
Total flow time	t_p	min	291
Total recovery time ***	t_F	min	272

* 2: Interference test
** Nominal diameter is 140 mm
*** For evaluation of recovery, only 272 min has been used (to evaluate approx. the same time as for the flow period and the same time as the recovery period in the pumping borehole), even though pressure registration lasted much longer

Pressure and water level data

Water level data in observation borehole HFM07	**Nomen-clature**	**Unit**	**Value**	**GWL (masl)**
Level in borehole before start of flow period	h_i	m	6.70	-1.59
Level in borehole before stop of flow period	h_p	m	6.66	-1.63
Level in borehole at stop of recovery period	h_F	m	6.68	-1.61
Maximal drawdown in borehole during flow period	s	m	0.04	--

No manual measurements of water level data were performed in HFM07.

Interpreted flow regimes

One test diagram from HFM07 is shown in Appendix A2:7. No clear effect from the pumping test in HFM08 is seen.

Interpreted parameters

No hydraulic parameters are interpreted.

6.4 Flow logging

6.4.1 Borehole HFM06

Two flow loggings were made in HFM06. The first logging was performed during a c 10 h pumping test 2003-01-21 in the interval 19.5–105 m. The results from the first flow logging showed that the flow rate at 19.5 m was less than the pumping rate at surface. Therefore, the second flow logging was performed to investigate whether additional inflows existed above 19.5 m.

To enable flow logging above 19.5 m, the pump was positioned higher up in the borehole and the pumping rate was decreased compared to the first flow logging. Thus, with less drawdown and the pump positioned higher up, flow logging could be performed within the interval 12–21 m. The second flow logging was accomplished during a shorter pumping test (c 4 h) 2003-01-22, since the main objective was to perform the complementary flow logging and not a pumping test.

Flow logging within the interval 19.5–105 m

General test data for the flow logging within the interval 19.5–105 m in borehole HFM06 are presented in Table 6-10.

Comments on test 19.5–105 m

The flow logging was performed between 2003-01-21 17:06 and 2003-01-21 20:32. The diameter of borehole HFM06 deviated from the nominal dimension. While controlling the borehole with a gauge (i.e. the flow logging probe without sensors), lowering the gauge below 105 m was troublesome. Therefore, the flow logging was not continued below 105 m. As a result of the borehole diameter being significantly smaller than nominal, calibration constants valid for a 135.5 mm pipe was used for the flow logging.

The flow logging was made from 105 m, proceding upwards. The first detectable flow anomaly was found at 71 m. The step length between each flow measurement was maximally 5 m in the borehole interval 105–75 m and maximally 2 m in the interval 19.5–70 m.

Logging results 19.5–105 m

The measured flow distribution along the hole during the flow logging, together with the relative variations in electric conductivity (EC) and temperature (Te) of the borehole fluid is presented in Figure 6-1.

Table 6-10. General test data for the flow logging within the interval 19.5–105 m in borehole HFM06.

General test data			
Borehole	HFM06		
Test type(s) *	6, L-EC, L-Te		
Test section:	Open borehole		
Test No	1		
Field crew	S. Jönsson, J. Olausson / GEOSIGMA AB		
Test equipment system	HTHB1		
General comments	Single pumping borehole		
	Nomen-clature	**Unit**	**Value**
Borehole length		m	110.7
Pump position (lower level)		m	17
Flow logged section - Secup		m	19.5
Flow logged section - Seclow		m	105
Test section diameter **	2·rw	mm	134
Start of flow period		yymmdd hh:mm	030121 10:04
Start of flow logging		yymmdd hh:mm	030121 17:06
Stop of flow logging		yymmdd hh:mm	030121 20:32
Stop of flow period		yymmdd hh:mm	030121 21:02

* 6: Flow logging-Impeller, L-EC: EC-logging, L-TE: temperature logging
** Nominal diameter is 140 mm

Pressure, groundwater level and flow data

Pressure data	**Nomen-clature**	**Unit**	**Value**	**GWL * (masl)**
Absolute pressure in borehole before start of flow period	p_i	kPa	173.2	0.55
Absolute pressure in test section before stop of flow period	p_p	kPa	132.6	-3.51
Pressure drawdown	dp_{FL}	kPa	40.6	-
Groundwater level	**Nomen-clature**	**Unit**	**G.w-level (m b ToC)**	**G.w-level (m a s l)**
Level in borehole, at undisturbed conditions, open hole	h_i	m	5.88	0.79
Level (steady state) in borehole, at pumping rate Q_p	h_p	m	10.07	-3.39
Drawdown during flow logging at pumping rate Q_p **	s_{FL}	m	-	4.15 ****
Flow data	**Nomen-clature**	**Unit**	**Flow rate**	
Pumping rate at surface	Q_p	m^3/s	$9.97 \cdot 10^{-4}$	
Cumulative flow rate at Secup at pumping rate Q_p ***	Q_T	m^3/s	$7.62 \cdot 10^{-4}$	
Measurement limit for flow rate during flow logging	Q_{Measl}	m^3/s	$5 \cdot 10^{-5}$	

* Calculated from pressure data and position of pressure sensor, under the assumption of ρ=1000 kg/m^3
** The drawdown was not perfectly stable during flow logging, it increased 0.1 m during flow logging
*** Probably incorrect value due to deviations in borehole dimension
**** Calculated as average drawdown (from pressure data)

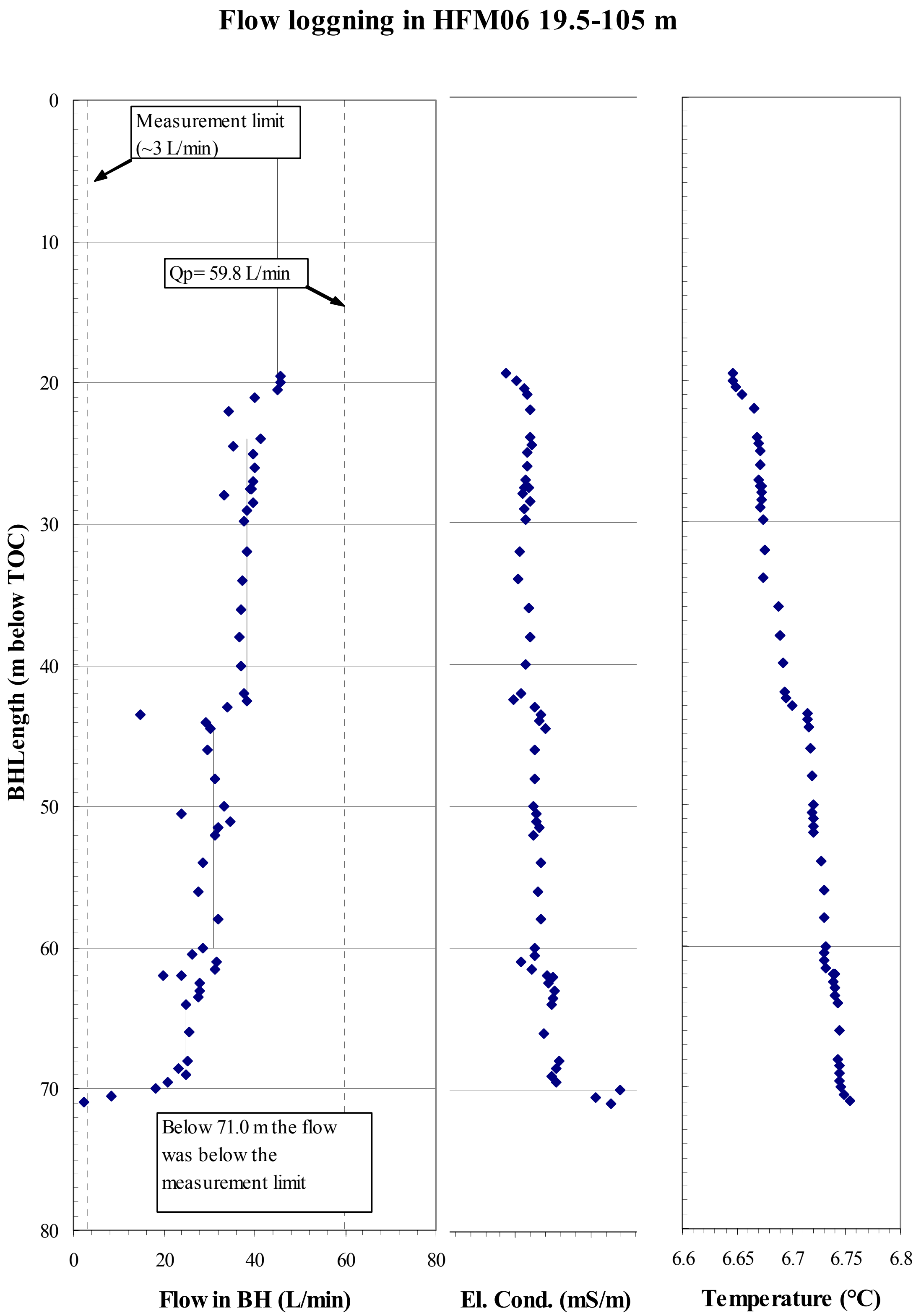


Figure 6-1. *Measured flow distribution along the interval 19.5–105 m in the hole during the flow logging, together with the relative variations in electric conductivity (EC) and temperature (Te) of the borehole fluid in borehole HFM06.*

As can be concluded from the figure, only ~ 76% of the total flow rate at the surface was identified within the flow logged interval. Three smaller, approximately equal inflows appear within the interval, at 20.5–23.0 m, 42.5–44.0 m, 60.0–64.0 m, and a larger at 69.0–71.0 m. All of these inflows are supported by anomalies in electrical conductivity.

With the information given in Figure 6-1, the difference between Q_T and Q_p may be interpreted as either an effect of the borehole diameter being larger than 135.5 mm at 19.5 m (i.e. exceeding the diameter of the pipe for which the used calibration constants are valid), or as a result of the borehole having one or several additional inflows above 19.5 m. To make this clear, a supplementary flow logging was performed within the interval 12–21 m as described above. The results of this extra flow logging are presented below.

Flow logging within the interval 12–21 m

General test data for the flow logging in the interval 12–21 m in borehole HFM06 are presented in Table 6-11.

Table 6-11. General test data for the flow logging within the interval 12–21 m in borehole HFM06.

General test data			
Borehole	HFM06		
Test type(s) *	6, L-EC, L-Te		
Test section:	Open borehole		
Test No	1		
Field crew	S. Jönsson, J. Olausson / GEOSIGMA AB		
Test equipment system	HTHB1		
General comments	Single pumping borehole		
	Nomen-clature	**Unit**	**Value**
Borehole length		m	110.7
Pump position (lower level)		m	8.3
Flow logged section – Secup		m	12
Flow logged section – Seclow		m	21
Test section diameter **	2·rw	mm	134
Start of flow period		yymmdd hh:mm	030122 09:48
Start of flow logging		yymmdd hh:mm	030122 12:47
Stop of flow logging		yymmdd hh:mm	030122 13:20
Stop of flow period		yymmdd hh:mm	030122 13:31

* 6: Flow logging-Impeller, L-EC: EC-logging, L-TE: temperature logging

** Nominal diameter is 140 mm

Pressure, groundwater level and flow data

Pressure data	**Nomen-clature**	**Unit**	**Value**	**GWL * (masl)**
Absolute pressure in borehole before start of flow period	p_i	kPa	121.6	0.51
Absolute pressure in test section before stop of flow period	p_p	kPa	109.7	-0.69
Pressure drawdown	dp_{FL}	kPa	11.9	-
Groundwater level	**Nomen-clature**	**Unit**	**G.w-level (m b ToC)**	**G.w-level (m a s l)**
Level in borehole, at undisturbed conditions , open hole	h_i	m	6.02	0.65
Level (steady state) in borehole, at pumping rate Q_p	h_p	m	7.29	-0.62
Drawdown during flow logging at pumping rate Q_p	s_{FL}	m	1.3	--
Flow data	**Nomen-clature**	**Unit**	**Flow rate**	
Pumping rate at surface	Q_p	m^3/s	$4.15 \cdot 10^{-4}$	
Cumulative flow rate at Secup at pumping rate Q_p **	Q_T	m^3/s	$3.22 \cdot 10^{-4}$	
Measurement limit for flow rate during flow logging	Q_{Measl}	m^3/s	$5 \cdot 10^{-5}$	

* Calculated from pressure data and position of pressure sensor, under the assumption of ρ=1000 kg/m^3
** Probably incorrect value due to deviations in borehole dimension

Comments on the test 12 – 21 m

This flow logging was a supplementary logging to obtain information above the highest probe position, 19.5 m, in the previous flow logging.

Logging results 12 – 21 m

The measured flow distribution along the hole during the flow logging, together with the temperature (Te) and relative variations in electric conductivity (EC) of the borehole fluid is presented in Figure 6-2.

From Figure 6-2 it is obvious that no inflow occurs above 19.5 m. Therefore, it is assumed that all inflow to the borehole prevails within the previously flow logged interval 19.5–105 m. The difference between Q_T and Q_p is interpreted as a result of the borehole diameter (at least from 19.5 m and upwards) being larger than 135.5 mm (i.e. larger than the diameter of the pipe for which the used calibration constants are valid).

However, it should be observed, that Figure 6-2 may indicate a small another anomaly between 14 and 16 m, however not clear enough to be evaluated as a separate anomaly. The EC and Te both indicate an anomaly at this borehole length as does the flow, although less distinctly. The flow rate of the anomaly, however, falls below 1 L/min, i.e. below the measurement limit.

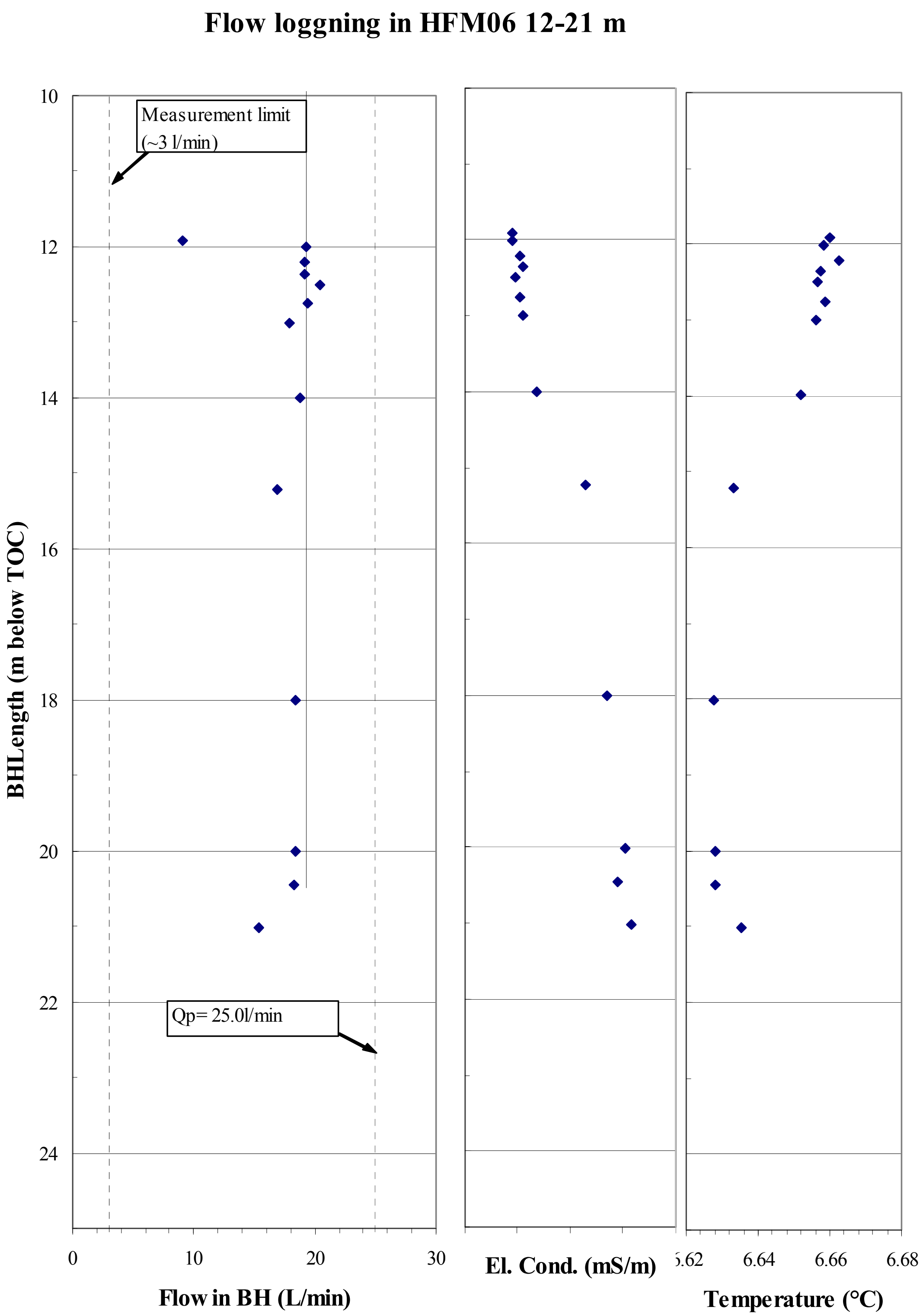


***Figure 6-2.** Measured flow distribution along 12–21 m in the borehole during the flow logging, together with the relative variations in electric conductivity (EC) and temperature (Te) of the borehole fluid in borehole HFM06.*

Consequently, the results shown in Figure 6-2 support the assumption that the difference between Q_T and Q_p is a result of the borehole diameter exceeding 135.5 mm, at least within the interval 12–19.5 m.

Combined logging results for HFM06

Flow anomalies (ΔQ_i) are given in Table 6-12 together with values corrected regarding borehole diameter ($\Delta Q_{i,corr}$),. The correction was done assuming $Q_T = Q_p$ and thus $\Delta Q_{i,corr} = (\Delta Q_i / Q_T) \cdot Q_p$. The cumulative transmissivity along the flow-logged borehole interval (ΣT_i) was estimated from Equation (5-3) under assumption of $Q_T = Q_p$, i.e. $\Delta Q_{i,corr}$ was used. The transmissivity of the flow anomalies (T_i) was estimated from Equation (5-4) with $\Delta Q_{i,corr}$ instead of ΔQ_i. An estimation of the transmissivity of the interpreted flow anomalies was also made by their specific flow ($\Delta Q_{i,corr}/s_{FL}$).

The results of the flow logging in borehole HFM06 are presented in Table 6-12 below.

Figure 6-3 illustrates the estimated, cumulative transmissivity along the borehole from the flow logging. Since the detailed positions of the flow anomalies in the borehole are not known, the change in transmissivity at the anomalies is represented by a sloping line across the anomaly. The estimated lower measurement limit of T and the total T of the borehole are also shown in the figure. The lower limit of transmissivity (T_{min}) was estimated according to Equation (5-6).

Table 6-12. Results of the flow logging in borehole HFM06. Q_T=cumulative flow on top of the logged interval, Q_p=pumped flow rate from borehole, $\Delta Q_{i,corr}$ = flow anomaly corrected regarding borehole diameter, T=transmissivity of the entire borehole from transient interpretation of pumping test, s_{FL}=total drawdown during flow logging.

HFM06 Flow anomalies		Q_T *=$7.54 \cdot 10^{-4}$ (m^3/s)		Q_p=$9.97 \cdot 10^{-4}$ (m^3/s)	T=$3.3 \cdot 10^{-4}$ (m^2/s)	s_{FL}=4.15 m	
Interval (m b ToC)	**B.h. length (m)**	**ΔQ_i * (m^3/s)**	**$\Delta Q_{i,corr}$ ** (m^3/s)**	**$\Delta Q_{i,corr}/Q_p$ ** (%)**	**T_i ** (m^2/s)**	**$\Delta Q_{i,corr}/s_{FL}$ ** (m^2/s)**	**Supporting information**
20.5-23.0	2.5	$1.15 \cdot 10^{-4}$	$1.52 \cdot 10^{-4}$	15.3	$5.0 \cdot 10^{-5}$	$3.7 \cdot 10^{-5}$	EC
42.5-44.0	1.5	$1.22 \cdot 10^{-4}$	$1.61 \cdot 10^{-4}$	16.2	$5.3 \cdot 10^{-5}$	$3.9 \cdot 10^{-5}$	EC
60.0-64.0	4	$1.00 \cdot 10^{-4}$	$1.32 \cdot 10^{-4}$	13.3	$4.4 \cdot 10^{-5}$	$3.2 \cdot 10^{-5}$	EC
69.0-71.0	2	$4.17 \cdot 10^{-4}$	$5.51 \cdot 10^{-4}$	55.3	$1.8 \cdot 10^{-4}$	$1.3 \cdot 10^{-4}$	EC
Total		**$\Sigma \Delta Q_i$= $7.54 \cdot 10^{-4}$**		**$\Sigma(\Delta Q_{i,corr}/Q_p)$ = 100**	**ΣT_i= $3.3 \cdot 10^{-4}$**	**$\Sigma 2.4 \cdot 10^{-4}$**	
Difference		Q_p-Q_T=$2.43 \cdot 10^{-4}$					

* Probably underestimated due to larger borehole diameter than assumed by the flow calibration (135.5 mm)
** Based on the assumption that $Q_T = Q_p$ (i.e. total inflow is assumed to be located within the flow logged interval)

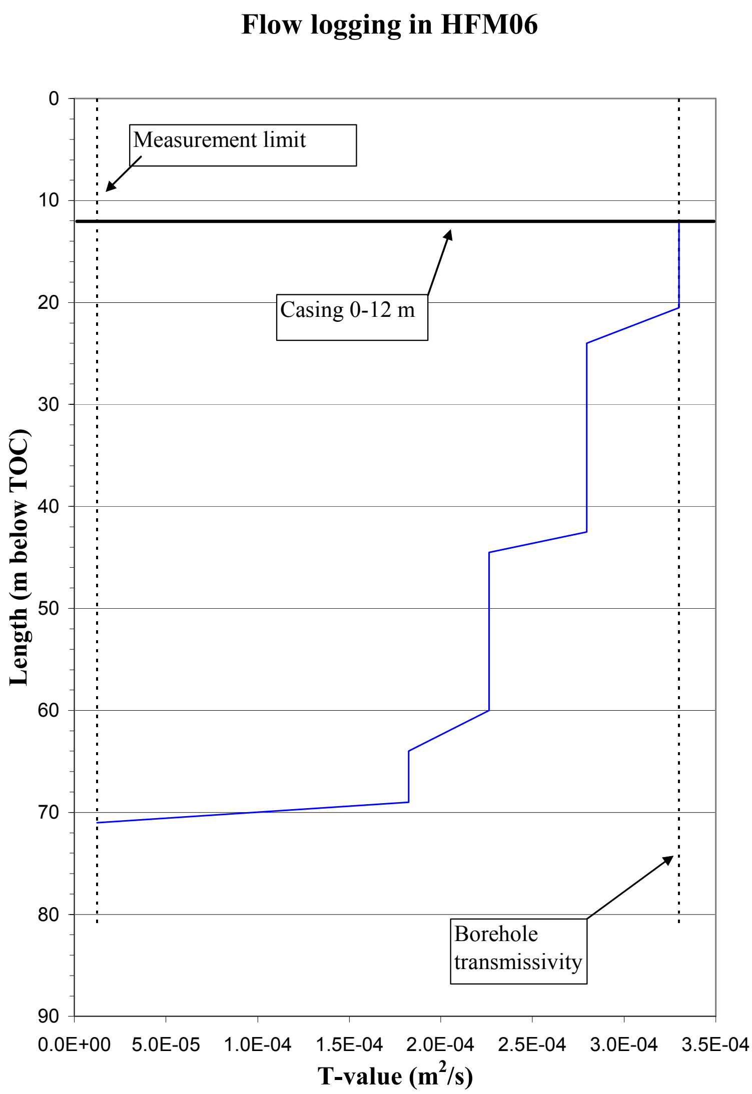


Figure 6-3. *Estimated, cumulative transmissivity along the borehole from the flow logging in HFM06. Below c 71 m the transmissivity falls below the measurement limit.*

6.4.2 Borehole HFM08

General test data for the flow logging in borehole HFM08 are presented in Table 6-13.

Table 6-13. General test data for the flow logging in conjunction with the pumping test in borehole HFM08.

General test data			
Borehole	HFM08		
Test type(s) *	6, L-EC, L-Te		
Test section:	Open borehole		
Test No	1		
Field crew	J. Källgården, S. Jönsson / GEOSIGMA AB		
Test equipment system	HTHB1		
General comments	Single pumping borehole		
	Nomen-clature	**Unit**	**Value**
Borehole length	L	m	143.5
Pump position (lower level)		m	14
Flow logged section - Secup		m	18
Flow logged section - Seclow		m	141
Test section diameter **	2·rw	mm	137
Start of flow period		yymmdd hh:mm	030218 08:26
Start of flow logging		yymmdd hh:mm	030218 12:26
Stop of flow logging		yymmdd hh:mm	030218 17:30
Stop of flow period		yymmdd hh:mm	030218 18:28

*   6: Flow logging-Impeller, L-EC: EC-logging, L-TE: temperature logging
** Nominal diameter is 140 mm

Pressure, groundwater level and flow data

Pressure data	Nomen-clature	Unit	Value	GWL (masl)
Absolute pressure in borehole before start of flow period	p_i	kPa	137.8	-0.35
Absolute pressure in test section before stop of flow period	p_p	kPa	123.4	-1.79
Pressure drawdown	dp_{FL}	kPa	14.4	-

Groundwater level	Nomen-clature	Unit	G.w-level * (m b ToC)	G.w-level * (m a s l)
Level in borehole, at undisturbed conditions , open hole	h_i	m	7.51	-0.35
Level (steady state) in borehole, at pumping rate Q_p	h_p	m	8.96	-1.79
Drawdown during flow logging at pumping rate Q_p **	s_{FL}	m	1.45	1.44

Flow data	Nomen-clature	Unit	Flow rate
Pumping rate at surface	Q_p	m^3/s	$1.08 \cdot 10^{-3}$
Cumulative flow rate at Secup at pumping rate Q_p ***	Q_T	m^3/s	$1.53 \cdot 10^{-3}$
Measurement limit for flow rate during flow logging	Q_{Measl}	m^3/s	$5.00 \cdot 10^{-5}$

* Calculated value from pressure registrations

** The drawdown was not perfectly stable during flow logging, but increased from c 1.1 m to 1.4 m a s l during the flowperiod

*** Probably overestimated value due to deviations between actual and assumed borehole dimension

Comments on the test

The flow logging was performed in conjunction with the pumping test in borehole HFM08 between 2003-02-18 12:26 and 2003-02-18 17:30. Thus the logging started after c 4 h of pumping, even though steady-state was not fully developed. Drawdown increased during the flow logging period from 1.1 to 1.4 m.

The flow logging was started at 141 m depth and continued upwards. The first detectable flow anomaly was indicated at 139 m. The step length between the flow measurements was maximally 3 m. Where an anomaly was found, the step length was shortened to 0.5 m.

Logging results

The measured flow distribution along the hole during the flow logging, together with the relative variations in electric conductivity (EC) and temperature (Te) of the borehole fluid is presented in Figure 6-4.

As seen in the figure, the cumulative flow on top of the flow logged interval is significantly higher than the pumped flow rate from the borehole, cf “Difference” in Table 6-14. This probably depends on the fact that the true borehole diameter is smaller than the assumed one by the flow calibration (140 mm). It is assumed that all flow towards the borehole occurs within the flow logged interval, and that the flow difference is only due to the deviation of the borehole diameter.

Figure 6-4 also makes it clear, that the dominating inflow occurs at 137.5–139 m. Furthermore, a change in flow rate is seen around 110.5 m. However, this change is assumed to be the result of a change in borehole diameter. From drilling, the following information about the drill bit diameter was obtained: When starting at 18 m, the drill bit diameter amounted at 138.7 mm. At 110.5 m it had decreased to 138.2 mm, whereafter the bit was sharpened to 137.9 mm. Finally, at completion of drilling (at 143.5 m), the drill bit had diminished to 137.0 mm. Deduced from that, the apparent change in flow rate at 110.5 m is an effect of the abruptly decreased borehole diameter after sharpening of the drill bit.

Moreover, indications of another flow anomaly are observed within the interval c 20–25 m. Electrical conductivity shows variations in the interval c 20–25 m although the temperature is stable. The discrepancy between T_1 from the pumping test at 18–93 m in HFM08 (see section 6.3.4) and T_i for 89.5–90 m supports the possibility of an anomaly around c 20–25 m. In spite of that, the overall indications of an anomaly must be regarded as relatively weak.

Flow anomalies (ΔQ_i) are listed in Table 6-14 together with values corrected regarding borehole diameter ($\Delta Q_{i,corr}$). The correction was done assuming $Q_T = Q_p$, and thus $\Delta Q_{i,corr} = (\Delta Q_i / Q_T) \cdot Q_p$. The cumulative transmissivity along the flow-logged borehole interval (ΣT_i) was estimated from Equation (5-3) under assumption of $Q_T = Q_p$, i.e. $\Delta Q_{i,corr}$ was used. The transmissivity of the flow anomalies (T_i) was determined from Equation (5-4) with $\Delta Q_{i,corr}$ instead of ΔQ_i. An assessment of the transmissivity of the interpreted flow anomalies was also made by their specific flow ($\Delta Q_{i,corr}/s_{FL}$).

By the calculations above, it is assumed that all flow towards the borehole occurs within or below the flow logged interval and that the flow difference between Q_T and Q_P, as well as the apparent flow anomaly at 110.5 m, are only due to the deviations of the borehole diameter.

Figure 6-5 shows the estimated, cumulative transmissivity along the borehole from the flow logging. Since the detailed positions of the flow anomalies in the borehole are not known, the change in transmissivity at the anomalies is represented by a sloping line across the anomaly. The estimated lower measurement limit of T and the total T of the borehole are also shown in the figure.

Table 6-14. Results of the flow logging in borehole HFM08. Q_T=cumulative flow on top of the logged interval, Q_p=pumped flow rate from borehole, $\Delta Q_{i,corr}$ = flow anomaly corrected regarding borehole diameter, T=transmissivity of the entire borehole from transient interpretation of pumping test, s_{FL}=total drawdown.

HFM08 Flow anomalies		$Q_T = 1.53 \cdot 10^{-3}$ (m^3/s)		$Q_p = 1.08 \cdot 10^{-3}$ (m^3/s)	$T = 1.3 \cdot 10^{-3}$ (m^2/s)	s_{FL}=1.44 m	
Interval (m b ToC)	**B.h. length (m)**	**ΔQ_i (m^3/s)**	**$\Delta Q_{i,corr}$ ** (m^3/s)**	**$\Delta Q_{i,corr}/Q_p$ ** (%)**	**T_i ** (m^2/s)**	**$\Delta Q_{i,corr}/s_{FL}$ ** (m^2/s)**	**Supporting information**
89.5-90	0.5	$6.67 \cdot 10^{-5}$*	$4.71 \cdot 10^{-5}$	4.3	$5.7 \cdot 10^{-5}$	$3.27 \cdot 10^{-5}$	Te
137.5-139.5	2	$1.47 \cdot 10^{-3}$*	$1.04 \cdot 10^{-3}$	95.7	$1.2 \cdot 10^{-3}$	$7.20 \cdot 10^{-3}$	Te
Total		**$\Sigma \Delta Q_i$= $1.53 \cdot 10^{-3}$**	**$\Sigma \Delta Q_{i,corr}$= $1.08 \cdot 10^{-3}$**	**$\Sigma(\Delta Q_i/Q_p)$ = 100**	**ΣT_i = $1.3 \cdot 10^{-3}$**	**$\Sigma(\Delta Q_i/s_{FL})$ = $7.23 \cdot 10^{-4}$**	
Difference		Q_p-Q_T= $-4.50 \cdot 10^{-4}$					

* Probably overestimated due to smaller borehole diameter than assumed in the flow calibration (140 mm)

** Based on the assumption that Q_p= Q_T (the total flow assumed to be located within the flow logged interval)

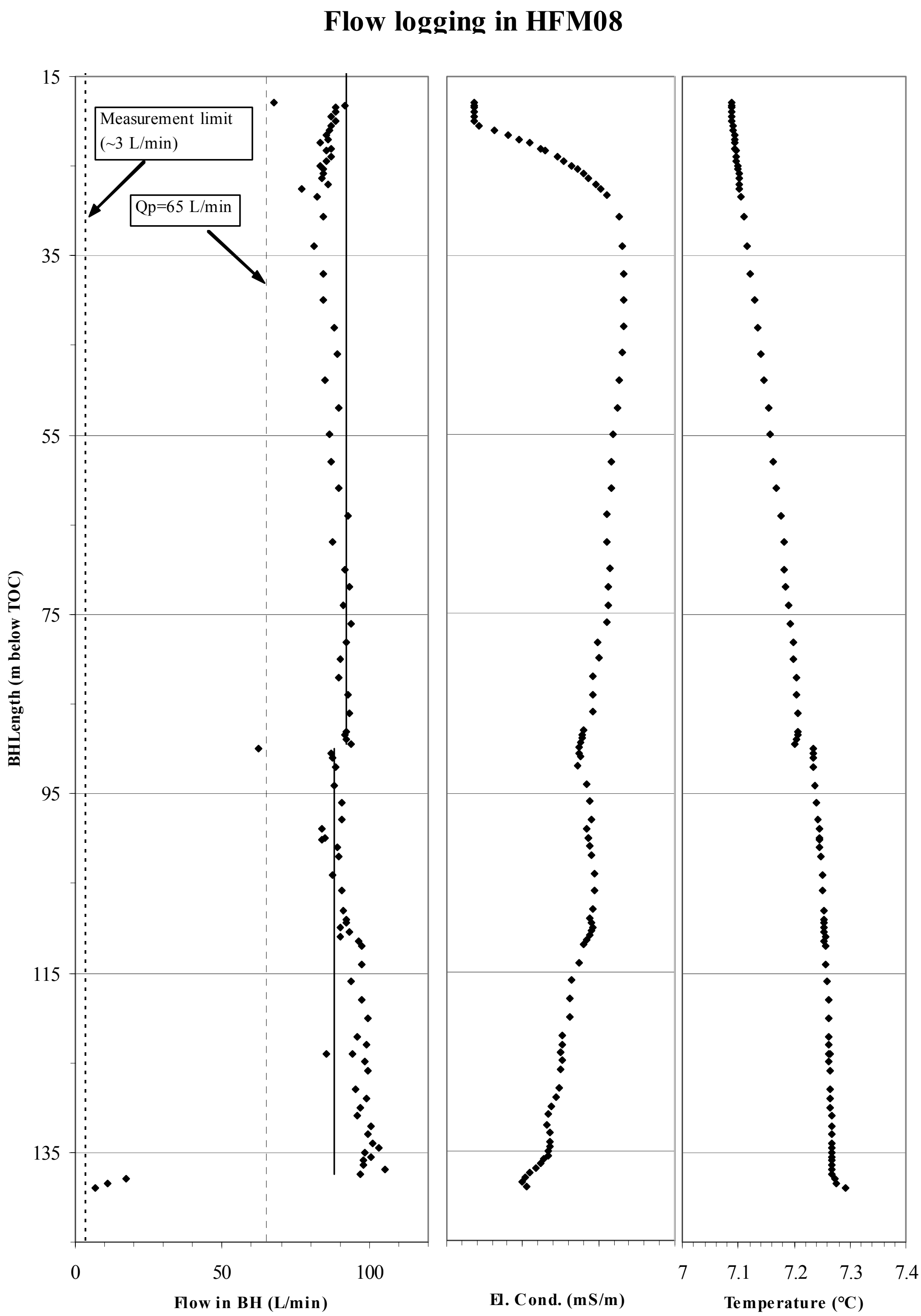


Figure 6-4. *Measured flow distribution along the borehole during the flow logging together with the relative variations of electric conductivity (EC) and temperature (Te) of the borehole fluid in borehole HFM08.*

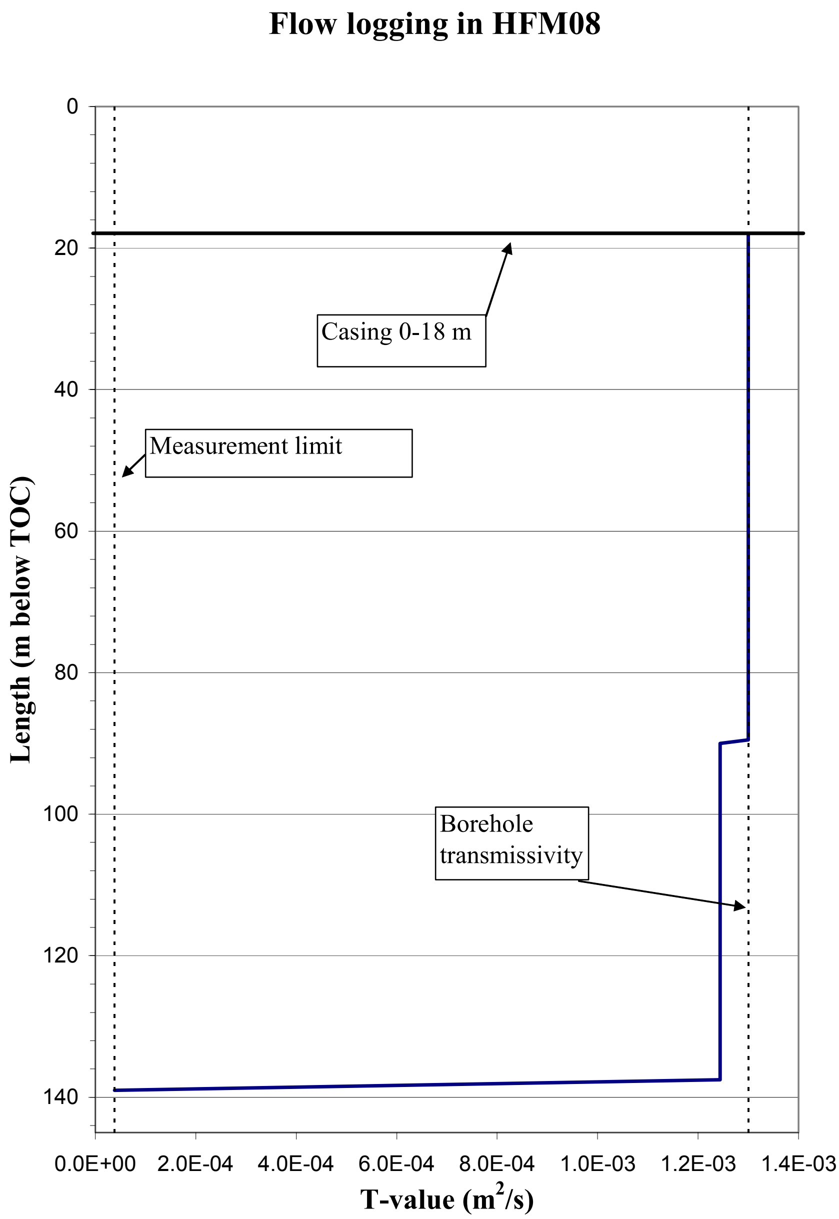


Figure 6-5. *Estimated, cumulative transmissivity along the borehole HFM08 from the flow logging. Below 139 m the transmissivity falls below the measurement limit.*

6.5 Pressure interferences during drilling of KFM03A (0–100 m)

From previously performed reflection seismic measurements, a seismic reflector was interpreted between the ground surface and a depth of c 100 m att the site where the deep telescopic borehole KFM03A was planned to be drilled. The reflector may represent a water-bearing zone, a transition of rock density etc. Prior to drilling of KFM03A, three percussion boreholes, HFM06, HFM07 and HFM08 were drilled for different purposes, see Chapter 1. In order to enable the study of possible hydraulic connections between the telescopic borehole and the percussion drilled boreholes, i.e. to perform an interference test, the latter were supplied with groundwater level monitoring equipment before start of drilling of KFM03A. The condition for carrying out the planned interference tests was that at least one water bearing zone was penetrated during drilling of the first 100 meters of KFM03A. However, a very limited groundwater inflow occurred during drilling of KFM03A, 0–100 m. Accordingly, no hydraulic respones occurred in the near-by situated percussion drilled boreholes, and analyses or interpretations of collected data were excluded.

6.6 Summary of hydraulic tests

A compilation of measured test data from the hydraulic tests carried out in the boreholes HFM06 and HFM08 are shown in Table 6-15. In Tables 6-16 and 6-17 calculated hydraulic parameters of the formation respectively the borehole from the tests are illustrated. The dominating flow regime prevailing during the test served as the basis for analysis and interpretation. More detailed flow logging results are presented in Sect. 6.4.

Table 6-15. Summary of test data for the pumping test and measured pressure interferences in boreholes HFM06, HFM07 and HFM08 in the Forsmark area. Section type: 1=pumping borehole, 2=observation borehole.

Pumping Borehole	Borehole ID	Section (m)	Section type	Test No	p_i (kPa)	p_p (kPa)	p_F (kPa)	Q_p (m^3/s)	Q_m * (m^3/s)	V_p ** (m^3)
HFM06	HFM06	12-110.7	1	1	173.2	132.6	172.3	$9.97 \cdot 10^{-4}$	$9.03 \cdot 10^{-4}$	35.6
HFM06	HFM06	12-110.7	1	2	121.6	109.7	116.7	$4.15 \cdot 10^{-4}$	$4.16 \cdot 10^{-4}$	5.6
HFM08	HFM06	12-110.7	2	1	86.6	83.8	85.4	-	-	-
HFM08	HFM06	12-110.7	2	1	87.0	85.5	85.9	-	-	-
HFM08	HFM07	18-122.5	2	1	67.0	66.6	66.8	-	-	-
HFM08	HFM08	18-143.5	1	1	137.8	123.4	133.1	$1.08 \cdot 10^{-3}$	$1.09 \cdot 10^{-3}$	39.2
HFM08	HFM08	18-93	1	1	391.4	303.8	390.5	$8.13 \cdot 10^{-4}$	$8.59 \cdot 10^{-4}$	15.0

* Time-weighted average value of flow rate (from datafile)

** $V_p = Q_p \cdot t_p$

Table 6-16. Summary of calculated hydraulic parameters of the formation from the hydraulic tests performed in boreholes HFM06 and HFM08 in the Forsmark area. Type: 1=pumping borehole, 2=observation borehole section, 6: flow logging.

Bore-hole ID	Section (m)	Flow Anomaly interval (m)	Type	Test No	Q/s (m^2/s)	T_{Moye} (m^2/s)	T_1 (m^2/s)	T_2 (m^2/s)	T_i (m^2/s)	Q/s-L (m^2/s)	Q/s-U (m^2/s)	S (-)
HFM06	12-110.7	-	1	1	$2.45\cdot10^{-4}$	$2.97\cdot10^{-4}$	$3.32\cdot10^{-4}$	-	-	$2\cdot10^{-6}$	$2\cdot10^{-3}$	-
HFM06	12-110.7	-	1	2	$3.45\cdot10^{-4}$	$4.22\cdot10^{-4}$	$4.60\cdot10^{-4}$	-	-	$2\cdot10^{-6}$	$2\cdot10^{-3}$	-
HFM06	-	20.5-23.0	6	-	-	-	-	-	$5.0\cdot10^{-5}$			-
HFM06	-	42.5-44.0	6	-	-	-	-	-	$5.3\cdot10^{-5}$			-
HFM06	-	60.0-64.0	6	-	-	-	-	-	$4.4\cdot10^{-5}$			-
HFM06	-	69.0-71.0	6	-	-	-	-	-	$1.8\cdot10^{-4}$			-
HFM06	12-110.7	-	2	1	-	-	$4.72\cdot10^{-4}$	-	-			$1.3\cdot10^{-4}$
HFM08	18-143.5	-	1	1	$7.51\cdot10^{-4}$	$9.35\cdot10^{-4}$	$1.29\cdot10^{-3}$	$2.46\cdot10^{-4}$	-	$2\cdot10^{-6}$	$2\cdot10^{-3}$	-
HFM08	-	89.5-90	6	-	-	-	-	-	$5.7\cdot10^{-5}$			-
HFM08	-	137.5-139.5	6	-	-	-	-	-	$1.2\cdot10^{-3}$			-
HFM08	18-93	-	1	1	$9.29\cdot10^{-5}$	$1.08\cdot10^{-4}$	$1.98\cdot10^{-4}$		-	$2\cdot10^{-6}$	$2\cdot10^{-3}$	-

Table 6-17. Summary of calculated hydraulic parameters of the borehole from hydraulic test performed in boreholes HFM06, HFM07 and HFM08 in the Forsmark area.

Borehole ID	Section (m)	Type	Test no	S* (-)	C (m^3/Pa)	ζ (-)
HFM06	12-110.7	1	1	$1\cdot10^{-4}$	$2.6\cdot10^{-6}$	-0.5
HFM06	12-110.7	1	2	$1\cdot10^{-4}$	-	-0.3
HFM08	18-143.5	1	1	$1\cdot10^{-4}$	-	-3.3
HFM08	18-93	1	1	$1\cdot10^{-4}$	$2.3\cdot10^{-6}$	5.3

The lower measurement limit for the HTHB-system, presented in the tables below, is expressed in terms of specific flow (Q/s). For pumping tests, the practical lower limit is based on the minimal flow rate Q, for which the system is designed (5 L/min), and an for practical purposes estimated maximal allowed drawdown in a percussion borehole, c 50 m, cf Table 4-1. These values correspond to a practical lower measurement limit of Q/s–L=$2\cdot10^{-6}$ m^2/s of the pumping tests. For injection tests, the minimal flow rate is c 1 L/min, leading to a practical lower measurement limit of Q/s–L=$4\cdot10^{-7}$ m^2/s.

Similarly, the practical, upper measurement limit of the HTHB-system is estimated from the maximal flow rate (c 80 L/min) and a minimal drawdown of c 0.5 m, which is considered significant in relation to e.g. background fluctuations of the pressure prior to and during the test. These values correspond to an estimated, practical upper measurement limit of Q/s–U=$2\cdot10^{-3}$ m^2/s for both pumping tests and injection tests.

In Table 6-16, the parameter explanations are according to the methodology instruction for analysis of injection- and single-hole pumping tests. The parameters are also explained in the text above, except the following parameters:

T_{Moye} = Steady-state transmissivity calculated from Moye's formula.

T_1 = Transmissivity from transient evaluation of the test. When more than one period of pseudo-radial flow occurs during a test, this T-value represents transmissivity estimated from the first period.

T_2 = Transmissivity from transient evaluation of the second period of pseudo-radial flow.

Q/s–L = Lower measurement limit.

Q/s–U = Upper measurement limit.

S = Calculated storativity from observation borehole during the actual test. If such values are available, they are normally used as S* in other tests.

S* = Assumed value on storativity used in single-hole tests for calculation of the skin factor.

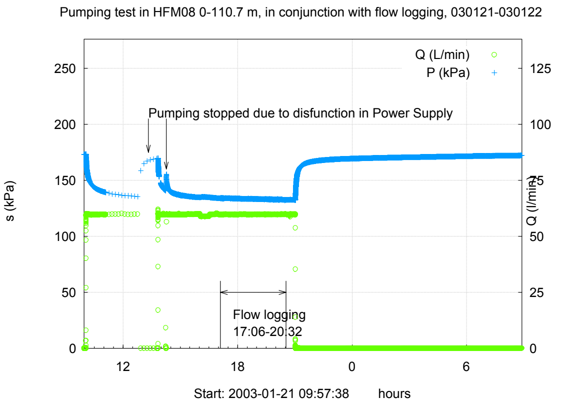
C = Wellbore storage coefficient.

ζ = Skin factor.

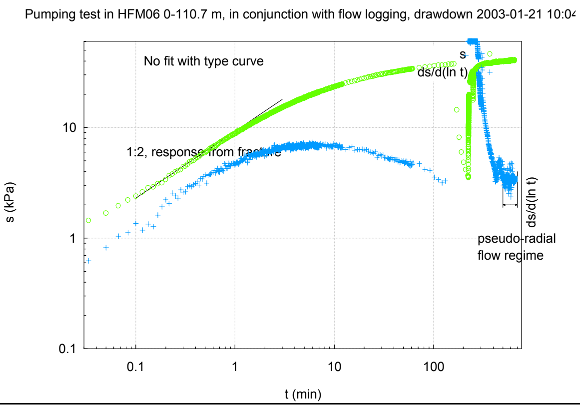
Test Summary Sheet

Project:	PLU	Test type:	1B
Area:	Forsmark	Test no:	1
Borehole ID:	HFM06	Test start:	2003-01-21 09:57
Test section (m):	12-110.7	Responsible for test performance:	GEOSIGMA AB S. Jönsson
Section diameter, $2 \cdot r_w$ (m):	0.134	Responsible for test evaluation:	GEOSIGMA AB J-E Ludvigson

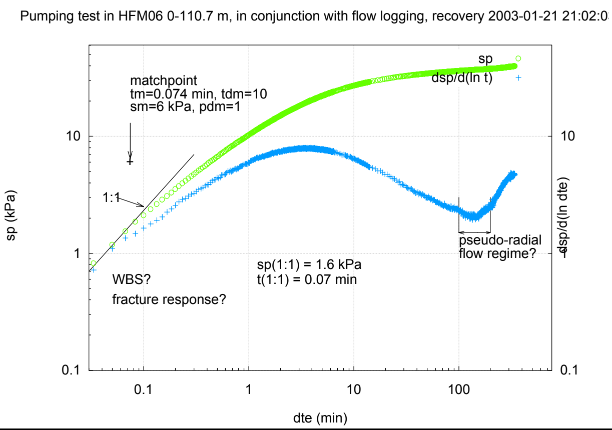
Linear plot Q and p



Log-Log plot incl. derivate- flow period



Log-Log plot incl. derivative- recovery period



Flow period		**Recovery period**	
Indata		**Indata**	
p_0 (kPa)	173.2		
p_i (kPa)	173.2		
p_p (kPa)	132.6	p_F (kPa)	172.3
Q_p (m^3/s)	$9.97 \cdot 10^{-4}$		
tp (min)	658	t_F (s)	711
S*	$1 \cdot 10^{-4}$	S*	$1 \cdot 10^{-4}$
EC_w (mS/m)	-		
Te_w(gr C)	-		
Derivative fact.	0.2	Derivative fact.	0.2
Results		**Results**	
Q/s (m^2/s)	$2.5 \cdot 10^{-4}$		
T_{Moye}(m^2/s)	$3.0 \cdot 10^{-4}$		
Flow regime:	PRF	Flow regime:	PRF
t_1 (min)	500	dt_{e1} (min)	100
t_2 (min)	658	dt_{e2} (min)	200
T_w (m^2/s)	$2.4 \cdot 10^{-4}$	T_w (m^2/s)	$3.3 \cdot 10^{-4}$
S_w (-)	-	S_w (-)	-
K_{sw} (m/s)	-	K_{sw} (m/s)	-
S_{sw} (1/m)	-	S_{sw} (1/m)	-
C (m^3/Pa)	-	C (m^3/Pa)	$2.6 \cdot 10^{-6}$
C_D (-)	-	C_D (-)	-
ξ (-)	-2.7	ξ (-)	-0.5
T_{GRF}(m^2/s)	-	T_{GRF}(m^2/s)	-
S_{GRF}(-)	-	S_{GRF}(-)	-
D_{GRF} (-)	-	D_{GRF} (-)	-

Interpreted formation and well parameters.			
Flow regime:	PRF	C (m^3/Pa)	$2.6 \cdot 10^{-6}$
t_1 (min)	100	C_D (-)	-
t_2 (min)	200	ξ (-)	-0.5
T_T (m^2/s)	$3.3 \cdot 10^{-4}$		
S (-)	-		
K_s (m/s)	-		
S_s (1/m)	-		

Comments: Pseudo-radial flow occurs during both the flow and recovery period.

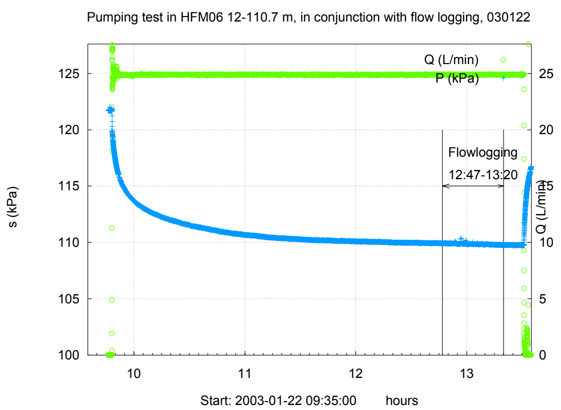
Initial fracture response during flow period. The initial response during recovery period show more WBS-effects.

No-flow boundary effects during the recovery phase.

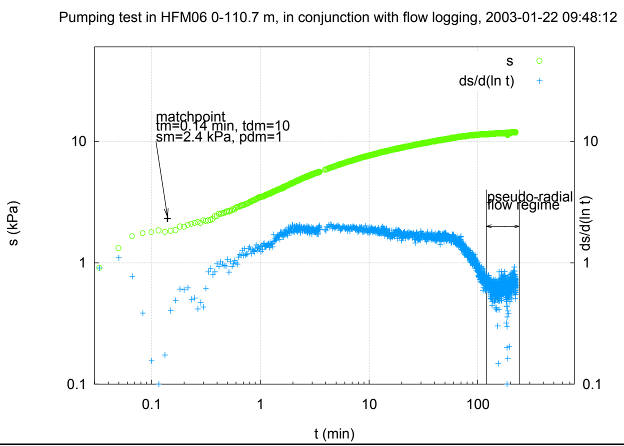
Test Summary Sheet

Project:	PLU	Test type:	1B
Area:	Forsmark	Test no:	2
Borehole ID:	HFM06	Test start:	2003-01-22 09:35
Test section (m):	12-110.7	Responsible for test performance:	GEOSIGMA AB S. Jönsson
Section diameter, $2 \cdot r_w$ (m):	0.134	Responsible for test evaluation:	GEOSIGMA AB J-E Ludvigson

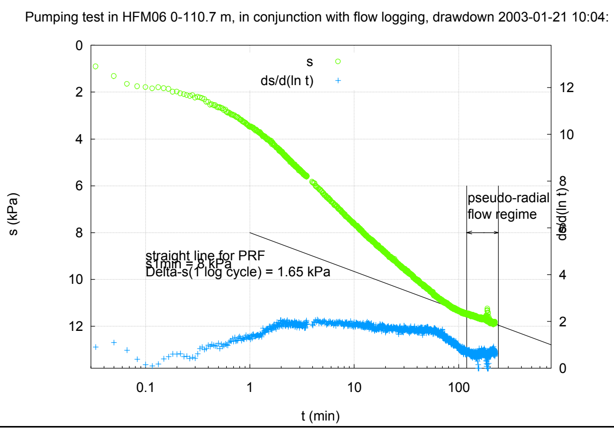
Linear plot Q and p



Log-Log plot incl. derivate- flow period



Lin-Log plot incl. derivative- flow period



Flow period		**Recovery period**	
Indata		**Indata**	
p_0 (kPa)	121.6		
p_i (kPa)	121.6		
p_p(kPa)	109.7	p_F (kPa)	116.7
Q_p (m^3/s)	$4.15 \cdot 10^{-4}$		
tp (min)	223	t_F (s)	4
S*	$1 \cdot 10^{-4}$	S*	-
EC_w (mS/m)	-		
Te_w(gr C)	-		
Derivative fact.	0.2	Derivative fact.	-
Results		**Results**	
Q/s (m^2/s)	$3.5 \cdot 10^{-4}$		
T_{Moye}(m^2/s)	$4.2 \cdot 10^{-4}$		
Flow regime:	PRF	Flow regime:	-
t_1 (min)	120	dt_{e1} (min)	-
t_2 (min)	223	dt_{e2} (min)	-
T_w (m^2/s)	$4.6 \cdot 10^{-4}$	T_w (m^2/s)	-
S_w (-)	-	S_w (-)	-
K_{sw} (m/s)	-	K_{sw} (m/s)	-
S_{sw} (1/m)	-	S_{sw} (1/m)	-
C (m^3/Pa)	-	C (m^3/Pa)	-
C_D (-)	-	C_D (-)	-
ξ (-)	-0.3	ξ (-)	-
T_{GRF}(m^2/s)	-	T_{GRF}(m^2/s)	-
S_{GRF}(-)	-	S_{GRF}(-)	-
D_{GRF} (-)	-	D_{GRF} (-)	-

Interpreted formation and well parameters.

Flow regime:	PRF	C (m^3/Pa)	-
t_1 (min)	120	C_D (-)	-
t_2 (min)	223	ξ (-)	-0.3
T_T (m^2/s)	$4.6 \cdot 10^{-4}$		
S (-)	-		
K_s (m/s)	-		
S_s (1/m)	-		

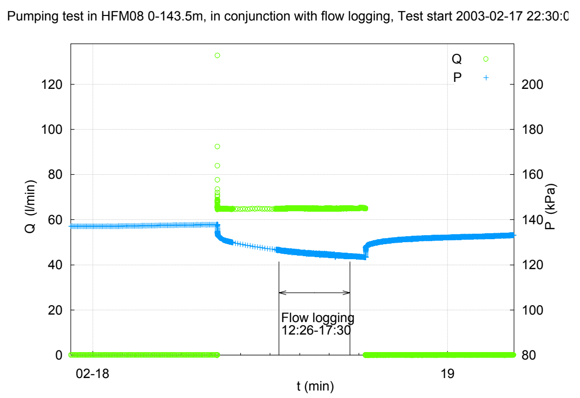
Comments: Short pumping test to enable flow logging in the upper part of the borehole. Recovery was not measured.

Pseudo-radial flow is indicated by the end of flow period (c. 120 min). The interpretation is uncertain.

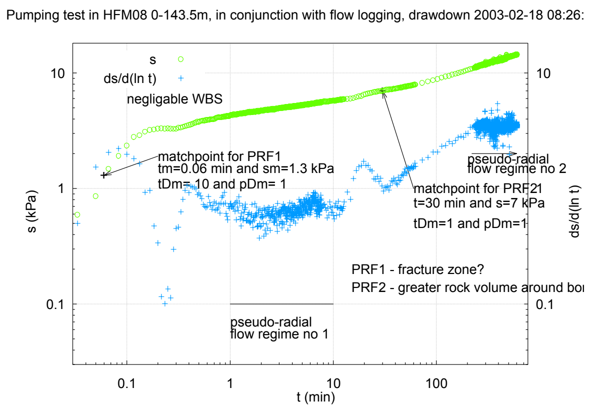
Test Summary Sheet

Project:	PLU	Test type:	1B
Area:	Forsmark	Test no:	1
Borehole ID:	HFM08	Test start:	2003-02-17 22:30
Test section (m):	18-143.5	Responsible for test performance:	GEOSIGMA AB J. Källgården
Section diameter, $2\cdot r_w$ (m):	0.137	Responsible for test evaluation:	GEOSIGMA AB J-E Ludvigson

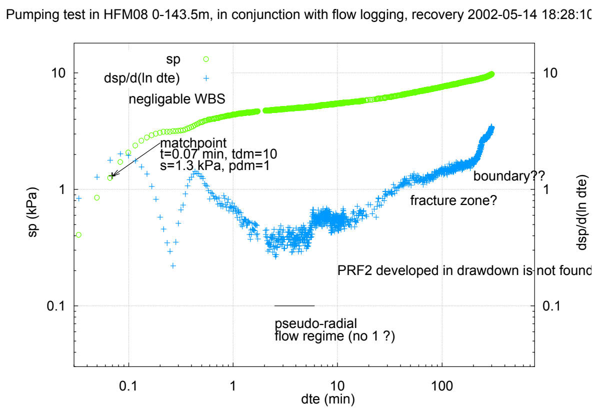
Linear plot Q and p



Log-Log plot incl. derivate- flow period



Log-Log plot incl. derivative- recovery period



Flow period		**Recovery period**	
Indata		**Indata**	
p_0 (kPa)	137.8		
p_i (kPa)	137.8		
p_p(kPa)	123.4	p_F (kPa)	133.1
Q_p (m^3/s)	$1.08\cdot 10^{-3}$		
tp (min)	602	t_F (s)	600
S*	$1\cdot10^{-4}$	S*	$1\cdot10^{-4}$
EC_w (mS/m)	-		
Te_w(gr C)	-		
Derivative fact.	0.2	Derivative fact.	0.2
Results		**Results**	
Q/s (m^2/s)	$7.5\cdot10^{-4}$		
T_{Moye}(m^2/s)	$9.4\cdot10^{-4}$		
Flow regime:	PRF1	Flow regime:	PRF1
t_1 (min)	1	dt_{e1} (min)	2.5
t_2 (min)	10	dt_{e2} (min)	6
T_w (m^2/s)	$1.3\cdot10^{-3}$	T_w (m^2/s)	$2.3\cdot10^{-3}$
S_w (-)	-	S_w (-)	-
K_{sw} (m/s)	-	K_{sw} (m/s)	-
S_{sw} (1/m)	-	S_{sw} (1/m)	-
C (m^3/Pa)	-	C (m^3/Pa)	-
C_D (-)	-	C_D (-)	-
ξ (-)	-3.3	ξ (-)	-0.6
T_{GRF}(m^2/s)	-	T_{GRF}(m^2/s)	-
S_{GRF}(-)	-	S_{GRF}(-)	-
D_{GRF} (-)	-	D_{GRF} (-)	-

Interpreted formation and well parameters.

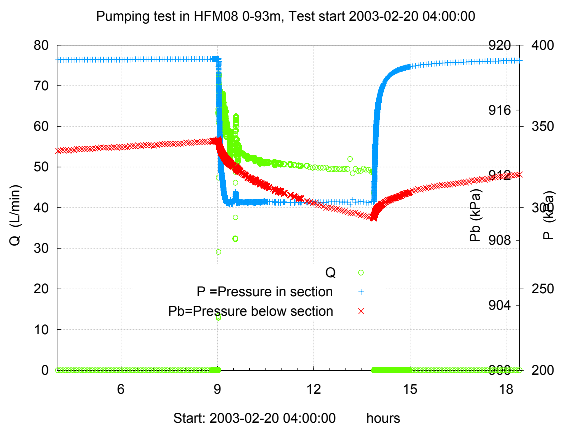
Flow regime:	PRF	C (m^3/Pa)	-
t_1 (min)	1	C_D (-)	-
t_2 (min)	10	ξ (-)	-3.3
T_T (m^2/s)	$1.3\cdot10^{-3}$		
S (-)	-		
K_s (m/s)	-		
S_s (1/m)	-		

Comments: No WBS-effects are seen during the test. A short pseudo-radial flow regime is seen after a few minutes for both test phases. For the flow phase, a second pseudo-radial flow regime (denoted PRF2 to separate from PRF1 presented above) is seen by the end of flow phase. Evaluation of PRF2 gave T= $2.46\cdot10^{-4}$. By the end of recovery phase further no-flow boundary effects are seen.

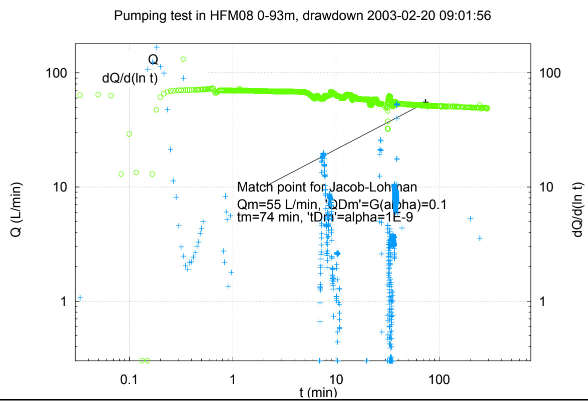
Test Summary Sheet

Project:	PLU	Test type:	1B
Area:	Forsmark	Test no:	1
Borehole ID:	HFM08	Test start:	2003-02-20 04:00
Test section (m):	18-93	Responsible for test performance:	GEOSIGMA AB J. Källgården
Section diameter, $2 \cdot r_w$ (m):	0.137	Responsible for test evaluation:	GEOSIGMA AB J-E Ludvigson

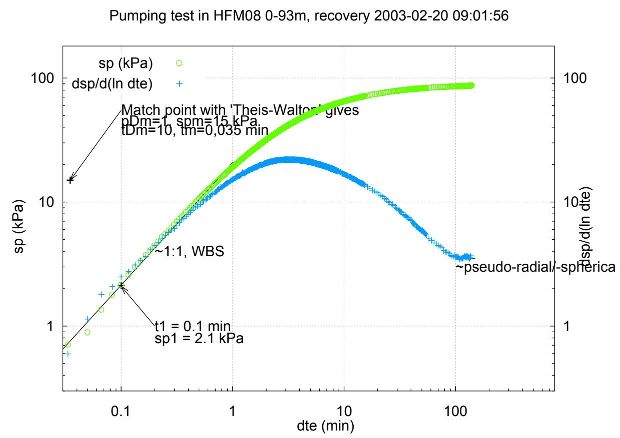
Linear plot Q and p



Log-Log plot incl. derivate- flow period



Log-Log plot incl. derivative- recovery period



Flow period		**Recovery period**	
Indata		**Indata**	
p_0 (kPa)	391.4		
p_i (kPa)	391.4		
p_{bi} (kPa)	914.1		
p_p (kPa)	303.8	p_F (kPa)	390.5
p_{bp} (kPa)	909.4	p_{aF} (kPa)	912.0
Q_p (m^3/s)	$8.13 \cdot 10^{-4}$		
tp (min)	291	t_F (s)	272
S*	$1 \cdot 10^{-4}$	S*	$1 \cdot 10^{-4}$
EC_w (mS/m)	-		
Te_w(gr C)	-		
Derivative fact.	0.2	Derivative fact.	0.2
Results		**Results**	
Q/s (m^2/s)	$9.3 \cdot 10^{-5}$		
T_{Moye}(m^2/s)	$1.1 \cdot 10^{-4}$		
Flow regime:	PRF	Flow regime:	PRF
t_1 (min)	50	dt_{e1} (min)	100
t_2 (min)	291	dt_{e2} (min)	150
T_w (m^2/s)	$1.7 \cdot 10^{-4}$	T_w (m^2/s)	$2.0 \cdot 10^{-4}$
S_w (-)	-	S_w (-)	-
K_{sw} (m/s)	-	K_{sw} (m/s)	-
S_{sw} (1/m)	-	S_{sw} (1/m)	-
C (m^3/Pa)	-	C (m^3/Pa)	$2.3 \cdot 10^{-6}$
C_D (-)	-	C_D (-)	-
ξ (-)	3.5	ξ (-)	5.3
T_{GRF}(m^2/s)	-	T_{GRF}(m^2/s)	-
S_{GRF}(-)	-	S_{GRF}(-)	-
D_{GRF} (-)	-	D_{GRF} (-)	-

Interpreted formation and well parameters.			
Flow regime:	PRF	C (m^3/Pa)	$2.3 \cdot 10^{-6}$
t_1 (min)	100	C_D (-)	-
t_2 (min)	150	ξ (-)	5.3
T_T (m^2/s)	$2.0 \cdot 10^{-4}$		
S (-)	-		
K_s (m/s)	-		
S_s (1/m)	-		

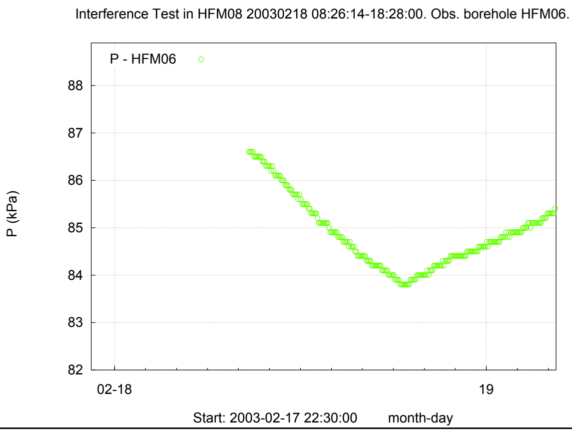
Comments: A pseudo-radial (approaching pseudo-spherical) flow regime is seen in both the flow and recovery period.

WBS effects are seen in the initial phase of recovery.

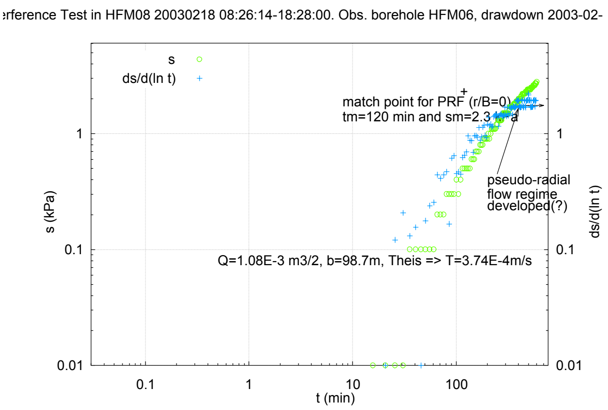
Test Summary Sheet

Project:	PLU	Test type:	2
Area:	Forsmark	Test no:	1
Borehole ID:	HFM06	Test start:	2003-02-18 08:42
Test section (m):	12-110.7	Responsible for test performance:	SKB PLU/ G. Nilsson GEOSIGMA AB/ J. Källgården
Section diameter, $2 \cdot r_w$ (m):	0.134	Responsible for test evaluation:	GEOSIGMA AB J-E Ludvigson

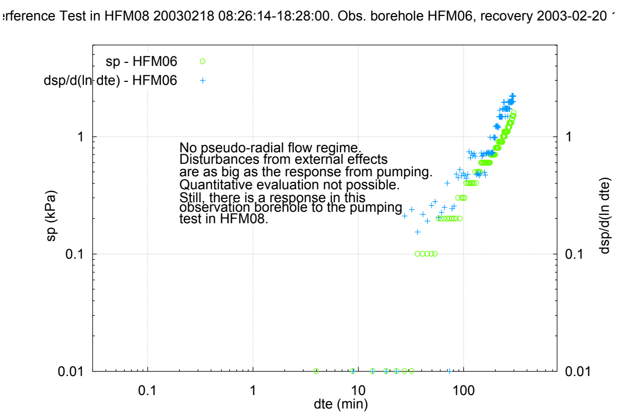
Linear plot Q and p



Log-Log plot incl. derivate- flow period



Log-Log plot incl. derivative- recovery period



Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa)	86.6		
p_i (kPa)	86.6		
p_p(kPa)	83.8	p_F (kPa)	85.4
Q_p (m^3/s)	-		
tp (min)	602	t_F (min)	600
S*	-	S*	-
EC_w (mS/m)	-		
Te_w(gr C)	-		
Derivative fact.	0.2	Derivative fact.	0.2
Results		**Results**	
Q/s (m^2/s)	-		
T_{Moye}(m^2/s)	-		
Flow regime:	PRF	Flow regime:	-
t_1 (min)	350	dt_{e1} (min)	-
t_2 (min)	602	dt_{e2} (min)	-
T_w (m^2/s)	$4.7 \cdot 10^{-4}$	T_w (m^2/s)	-
S_w (-)	$1.3 \cdot 10^{-4}$	S_w (-)	-
K_{sw} (m/s)	-	K_{sw} (m/s)	-
S_{sw} (1/m)	-	S_{sw} (1/m)	-
C (m^3/Pa)	-	C (m^3/Pa)	-
C_D (-)	-	C_D (-)	-
ξ (-)	-	ξ (-)	-
		-	
T_{GRF}(m^2/s)	-	T_{GRF}(m^2/s)	-
S_{GRF}(-)	-	S_{GRF}(-)	-
D_{GRF} (-)	-	D_{GRF} (-)	-

Interpreted formation and well parameters.

Flow regime:	PRF	C (m^3/Pa)	-
t_1 (min)	350	C_D (-)	-
t_2 (min)	602	ξ (-)	-
T_T (m^2/s)	$4.7 \cdot 10^{-4}$		
S (-)	$1.3 \cdot 10^{-4}$		
K_s (m/s)	-		
S_s (1/m)	-		

Comments:

For evaluating Storativity from the interference, points of application was determined from flow loggings and r_s calculated to 279 m. Pseudo-radial flow regime is seen by the end of the flow phase. The recovery period may be influenced by external effects, e.g. tidal effects etc.

7 References

/1/ **Claesson L-Å, Nilsson G, 2003.** Forsmark site investigation. Drilling of a flushing water well, HFM06, and two groundwater monitoring wells, HFM07 and HFM08, at drillsite DS3. SKB P-03-58, Svensk Kärnbränslehantering AB.

/2/ **Almén K-E, Andersson J-E, Carlsson L, Hansson K, Larsson N-Å, 1986.** Hydraulic testing in crystalline rock. A comparative study of single-hole test methods. Technical Report 86-27, Svensk Kärnbränslehantering AB.

/3/ **Nilsson A-C, 2003.** Sampling and analyses of water from percussion drilled boreholes in hard rock at drillsite DS3. Results from the percussion boreholes HFM06 and HFM08 (in prep).

Appendix 1

List of test data files

Files are named "*bhnamn_secup_yymmdd_XX*", where *yymmdd* is the date of test start, *secup* is top of section and XX is the original file name from the HTHB data logger. If necessary, a letter is added (a, b, c, ..) after "*secup*" to separate identical names. XX can be one of five alternatives: *Ref_Da* containing constants of calibration and background data, *FlowLo* containing data from pumping test in combination with flow logging. *Spinne* contains data from spinner measurements, *Inject* contains data from injection test and *Pumpin* from pumping tests (no combined flow logging).

Bh ID	Test section (m)	Test type[1]	Test no	Test start Date, time YYYY-MM-DD tt:mm:ss	Test stop Date, time YYYY-MM-DD tt:mm:ss	Datafile, start Date, time YYYY-MM-DD tt:mm:ss	Datafile, stop Date, time YYYY-MM-DD tt:mm:ss	Data files of raw and primary data	Content (parameters)2	Comments
HFM06	19.5-105	6, L-Te, L-EC	1	2003-01-21 17:06:00	2003-01-21 20:33:31	2003-01-21 17:21:00	2003-01-21 20:33:31	HFM06_19.5_030121_Spinne00.DAT	P, Q, T, Sp, EC	Absolute values of EC are not correct
HFM06	19.5-105		1			2002-12-18 11:17:09	2003-01-22 08:54:05	HFM06_19.5_030121_Ref_Da00.DAT	C, R	
HFM06	0-110.7	1B, 6, L-Te, L-EC	1	2003-01-21 10:04:00	2003-01-22 08:54:05	2003-01-20 15:48:25	2003-01-22 08:54:05	HFM06_000_030121_FlowLo00.DAT	P, Q, T, EC	Absolute values of EC are not correct
HFM06	0-110.7		1			2002-12-18 11:17:09	2003-01-22 08:54:05	HFM06_000_030121_Ref_Da00.DAT	C, R	
HFM06	12-21.5	6, L-Te, L-EC	1	2003-01-22 12:47:00	2003-01-22 13:24:35	2003-01-21 17:21:00	2003-01-22 13:24:35	HFM06_12.0_030122_Spinne00.DAT	P, Q, T, Sp, EC	Extra flow logging in the upper part of the borehole. Absolute values of EC are not correct
HFM06	12-21.5		1			2002-12-18 11:17:09	2003-01-22 13:29:28	HFM06_12.0_030122_Ref_Da00.DAT	C, R	
HFM06	0-110.7	1B, 6, L-Te, L-EC	1	2003-01-22 09:48:00	2003-01-22 13:35:00	2003-01-20 15:48:25	2003-01-22 13:35:00	HFM06_000_030122_FlowLo00.DAT	P, Q, T, EC	Only drawdown phase. Pumping was performed to enable the extra flow logging. Absolute values of EC are not correct
HFM06	0-110.7		1			2002-12-18 11:17:09	2003-01-22 13:29:28	HFM06_000_030122_Ref_Da00.DAT	C, R	
HFM08	0-143.5	1B, 6, L-Te, L-EC	1	2003-02-17 18:00:00	2003-02-19 09:15:00	2003-02-17 16:16:59	2003-02-19 10:20:25	HFM08_000_030217_FlowLo01.DAT	P, Q, T, EC	Absolute values of EC are not correct.
HFM08			1			2003-02-17 08:18:00	2003-02-19 15:25:53	HFM08_000_030217_Ref_Da01.DAT	C, R	
HFM08	18-138.98	6, L-Te, L-EC	1	2003-02-18 12:34:23	2003-02-18 17:32:01	2003-02-18 12:34:23	2003-02-18 17:32:01	HFM08_000_030218_Spinne00.DAT	P, Q, T, Sp, EC	Absolute values of EC are not correct.

Bh ID	Test section (m)	Test type[1]	Test no	Test start Date, time YYYY-MM-DD tt:mm:ss	Test stop Date, time YYYY-MM-DD tt:mm:ss	Datafile, start Date, time YYYY-MM-DD tt:mm:ss	Datafile, stop Date, time YYYY-MM-DD tt:mm:ss	Data files of raw and primary data	Content (parameters)2	Comments
HFM08			1			2003-02-17 08:18:00	2003-02-19 15:25:53	HFM08_000_030217_Ref_Da01.DAT	C, R	
HFM08	0-93	1B	1	2003-02-19 16:00:00	2003-02-20 18:25:14	2003-02-19 14:27:07	2003-02-20 18:36:21	HFM08_000_030220_Pumpin00.DAT	P, Q	
HFM08	0-93		1			2003-02-17 08:18:00	2003-02-20 18:36:21	HFM08_000_030220_Ref_Da00.DAT	C, R	

1: 1A: Pumping test-wire-line equipment., 1B: Pumping test-submersible pump, 1C: Pumping test-airlift pumping, 2: Interference test, 3: Injection test, 4: Slug test, 5A: Difference flow logging-PFL-DIFF_sequential, 5B: Difference flow logging-PFL-DIFF_overlapping, 6: Flow logging-Impeller, Logging-EC: L-EC, Logging temperature: L-T, Logging single point resistance: L-SPR

2: P =Pressure, Q =Flow, Te =Temperature, EC =El. conductivity. SPR =Single Point Resistance, C =Calibration file, R =Reference file, Sp= Spinner rotations

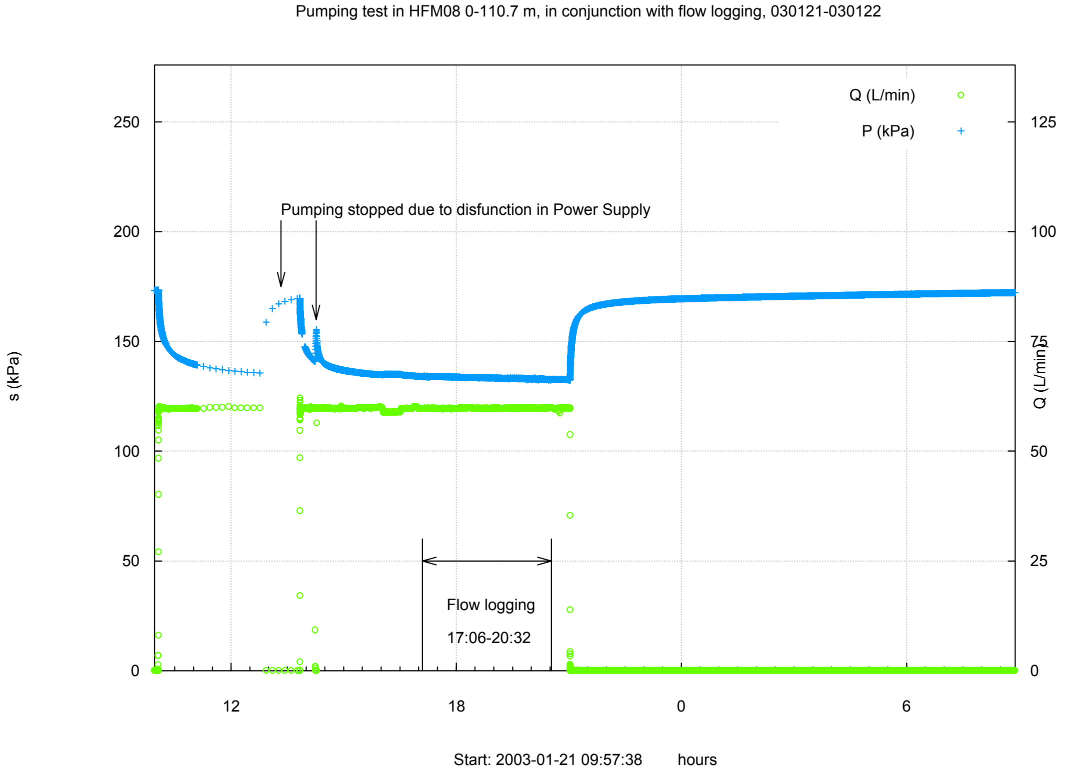


Figure A2:1-1. *Linear plot of pressure and flow versus time (t) during the pumping test in the interval 18–110.7 m in HFM06, 2003-01-21.*

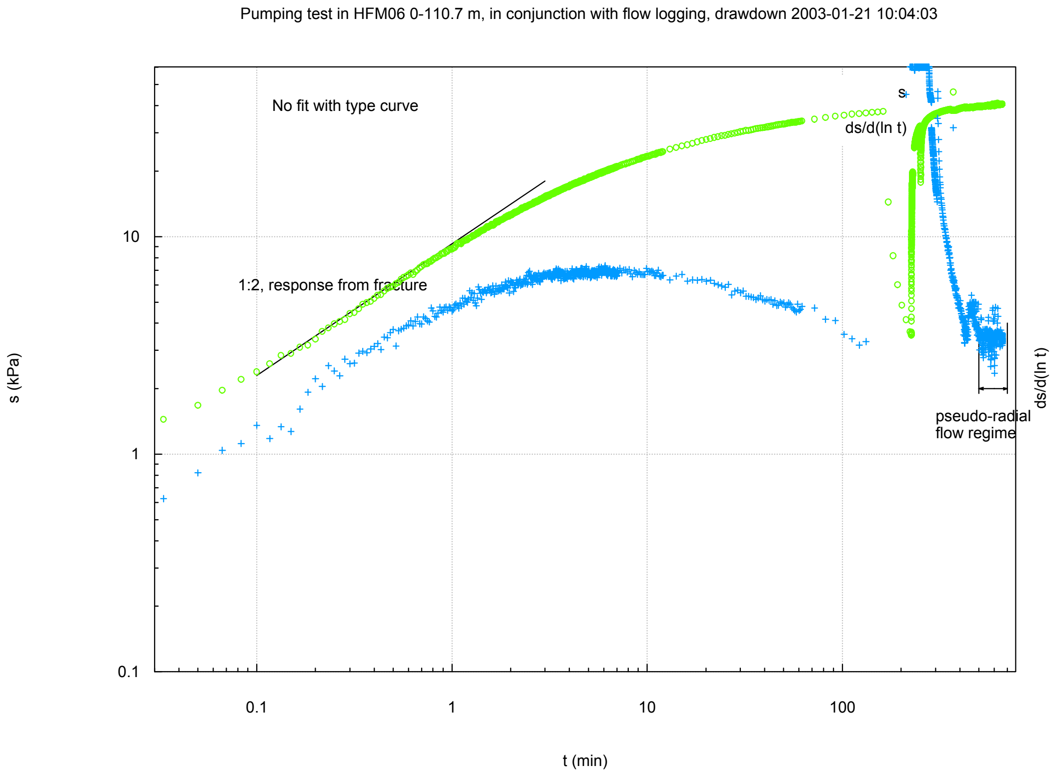


Figure A2:1-2. *Log-log plot of drawdown (s) and drawdown derivative, ds/d(ln t) versus time (t) from the pumping test in the interval 18–110.7 m in HFM06, 2003-01-21.*

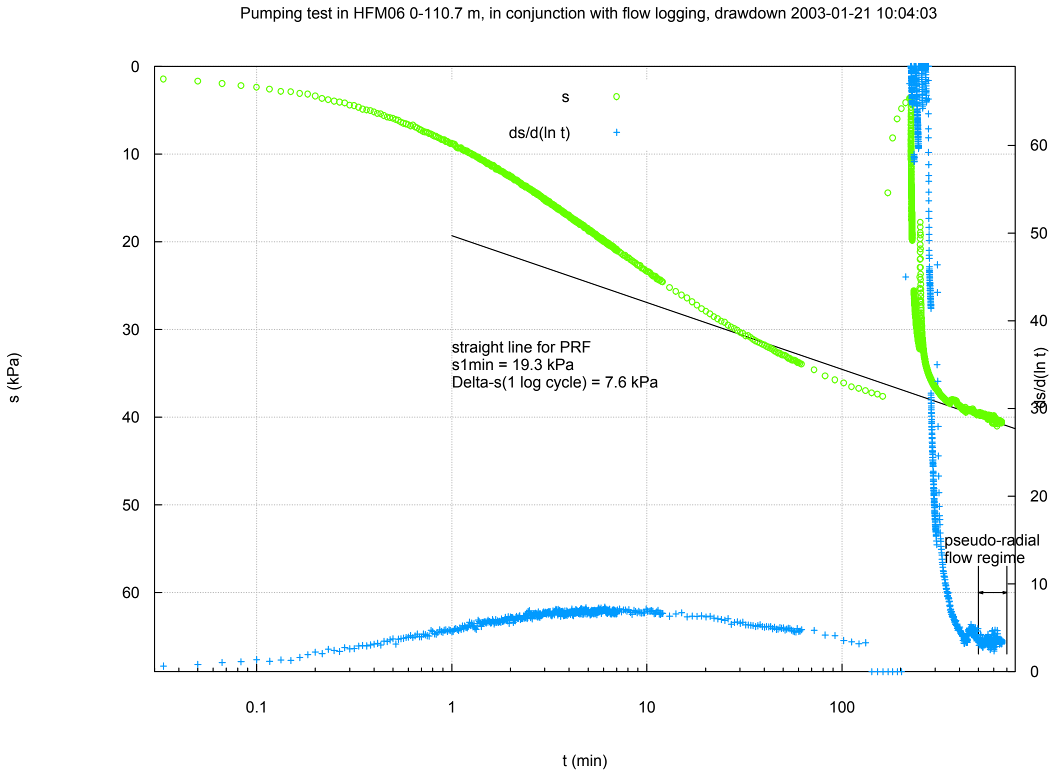


Figure A2:1-3. *Lin-log plot of drawdown (s) and -derivative versus time (t) from the pumping test in the interval 18–110.7 m in HFM06, 2003-01-21.*

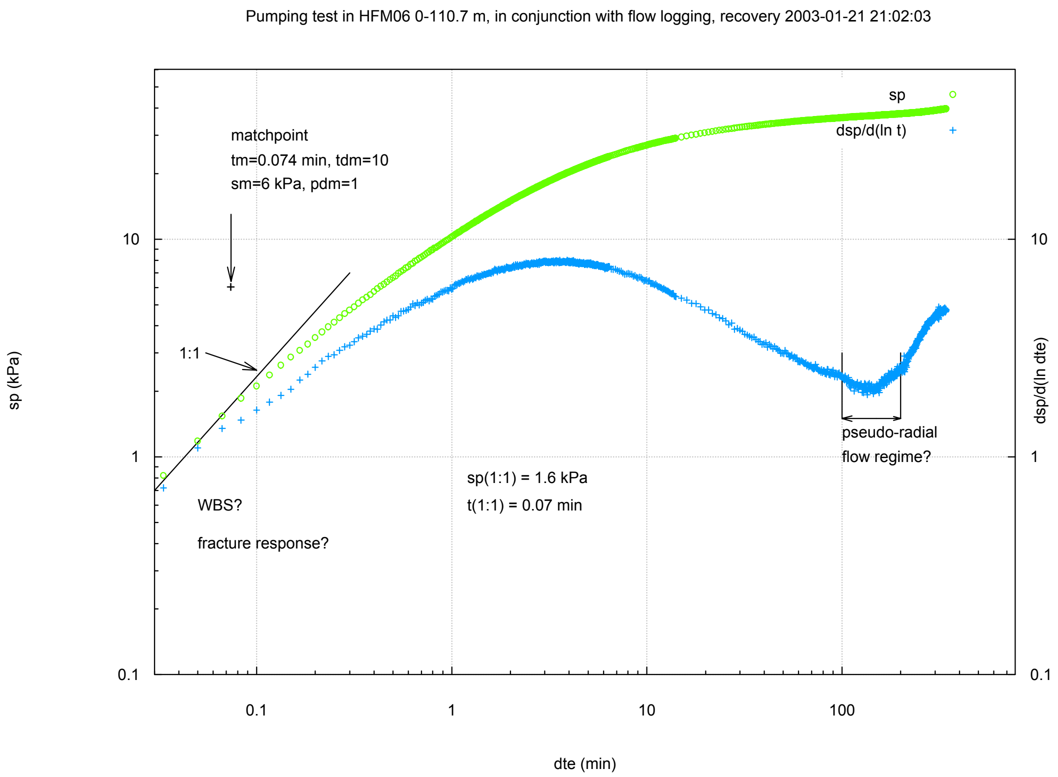


Figure A2:1-4. *Log-log plot of pressure recovery (sp) and -derivative, dsp/d(ln dte) versus equivalent time (dte) from the pumping test in the interval 0–110.7 m in HFM06, 2003-01-21.*

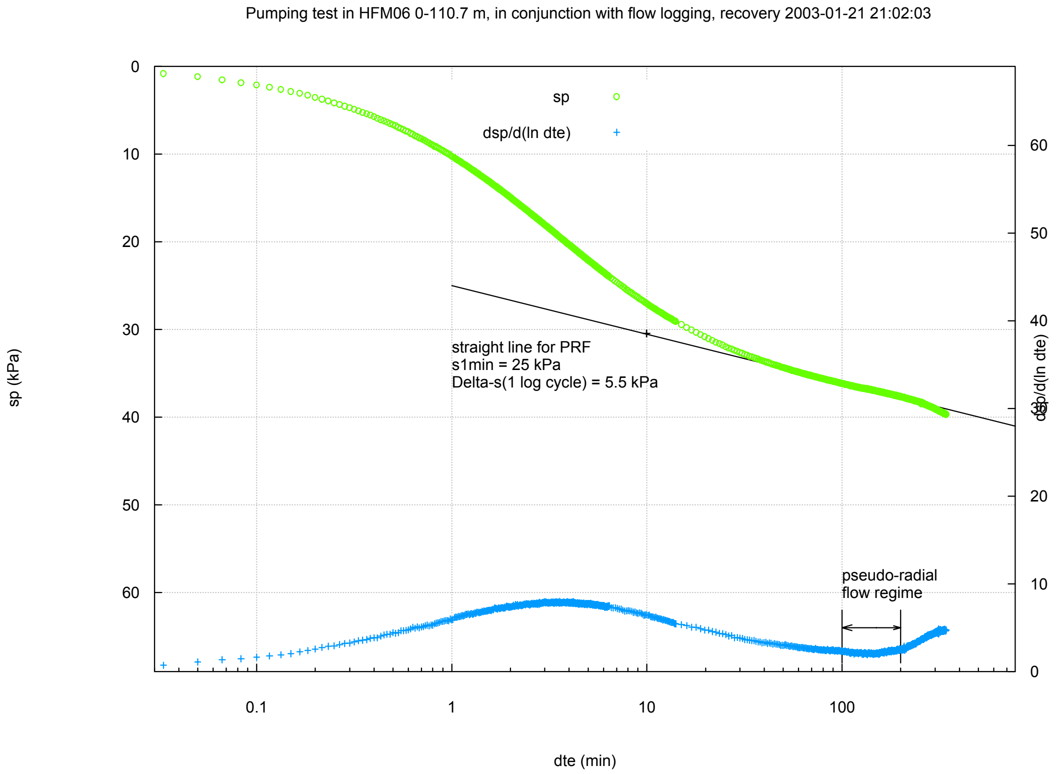


Figure A2:1-5. *Lin-log plot of pressure recovery (sp) versus equivalent time (dte) from the pumping test in the interval 0–110.7 m in HFM06, 2003-01-21.*

Appendix A2:2

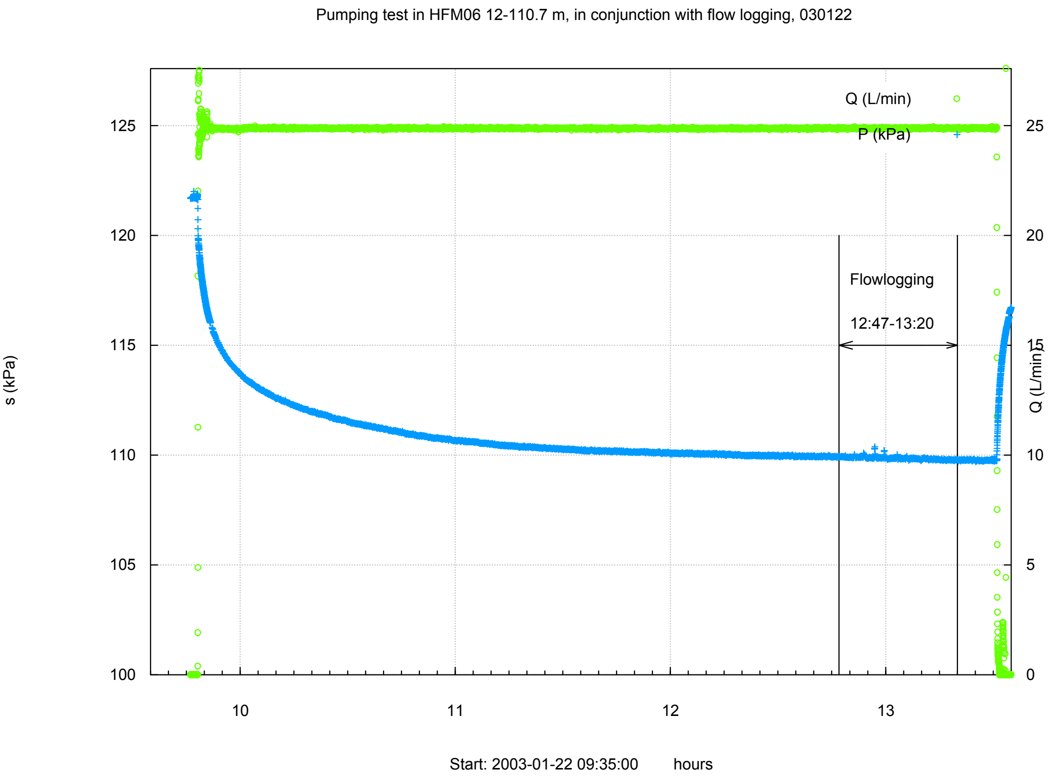


Figure A2:2-1. Linear plot of flow and pressure versus time (t) during pumping test in the interval 12–110.7 m in HFM06, 2003-01-22.

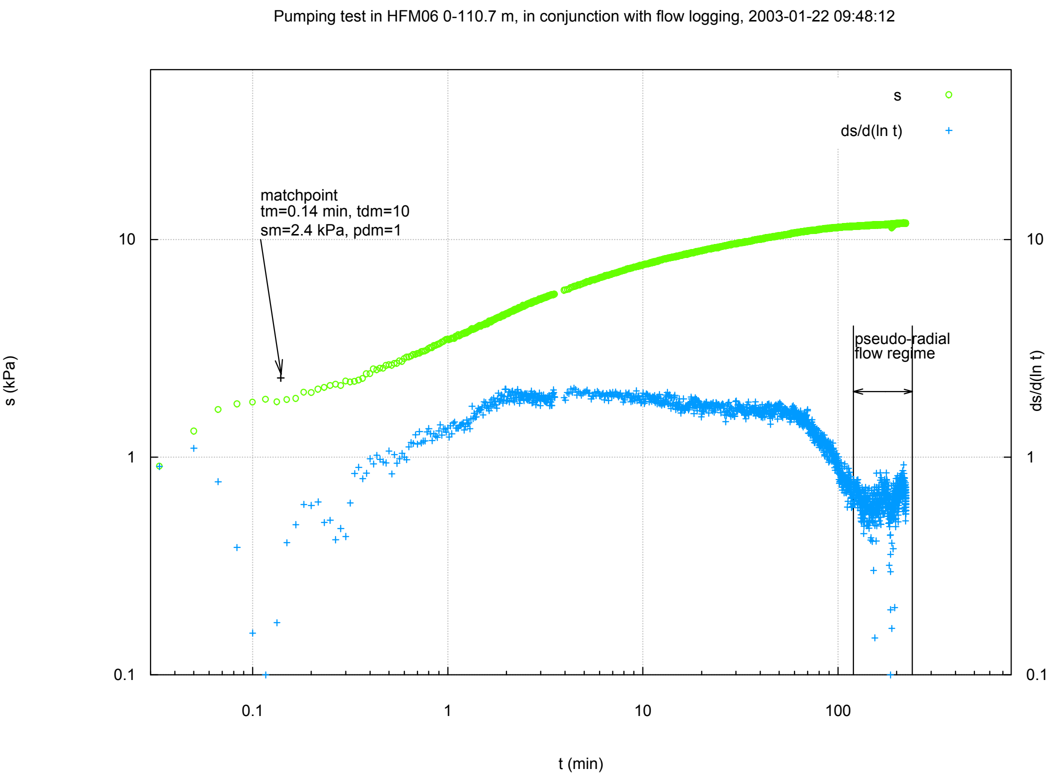


Figure A2:2-2. Log-log plot of drawdown (s) and drawdown derivative, ds/d(ln t) versus time, from pumping test in the interval 12–110.7 m in HFM06, 2003-01-22.

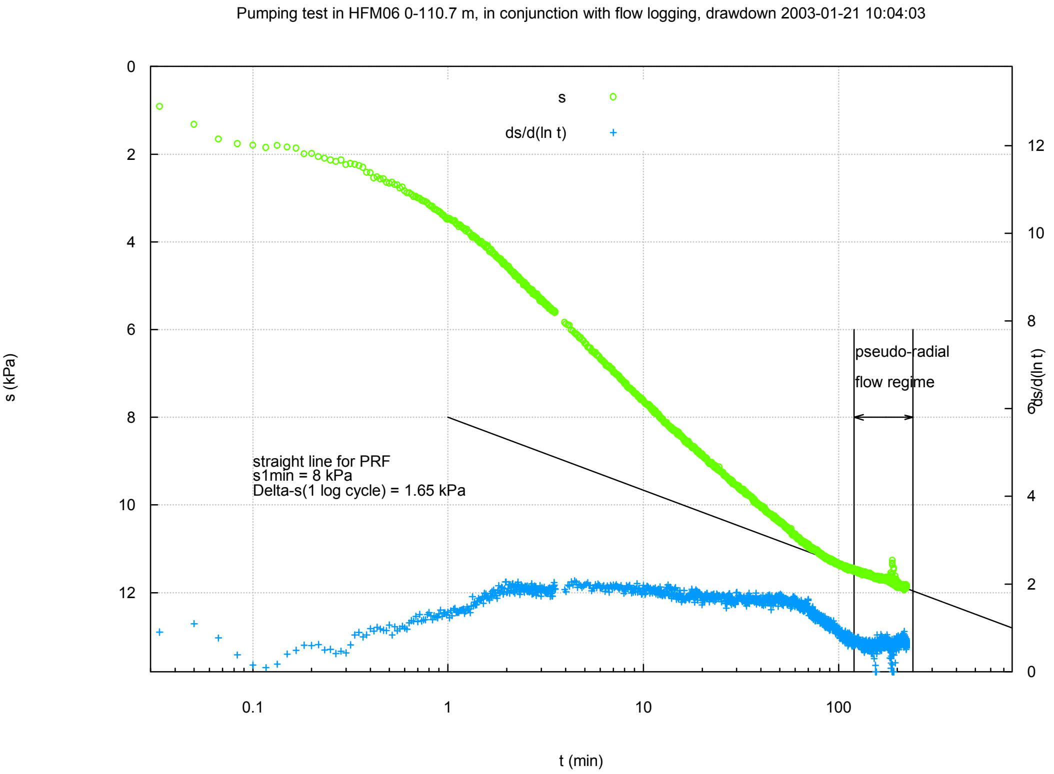


Figure A2:2-3. *Lin-log plot of drawdown (s) and -derivative versus time (t) from pumping test in the interval 12–110.7 m in HFM06, 2003-01-22.*

Appendix A2:3

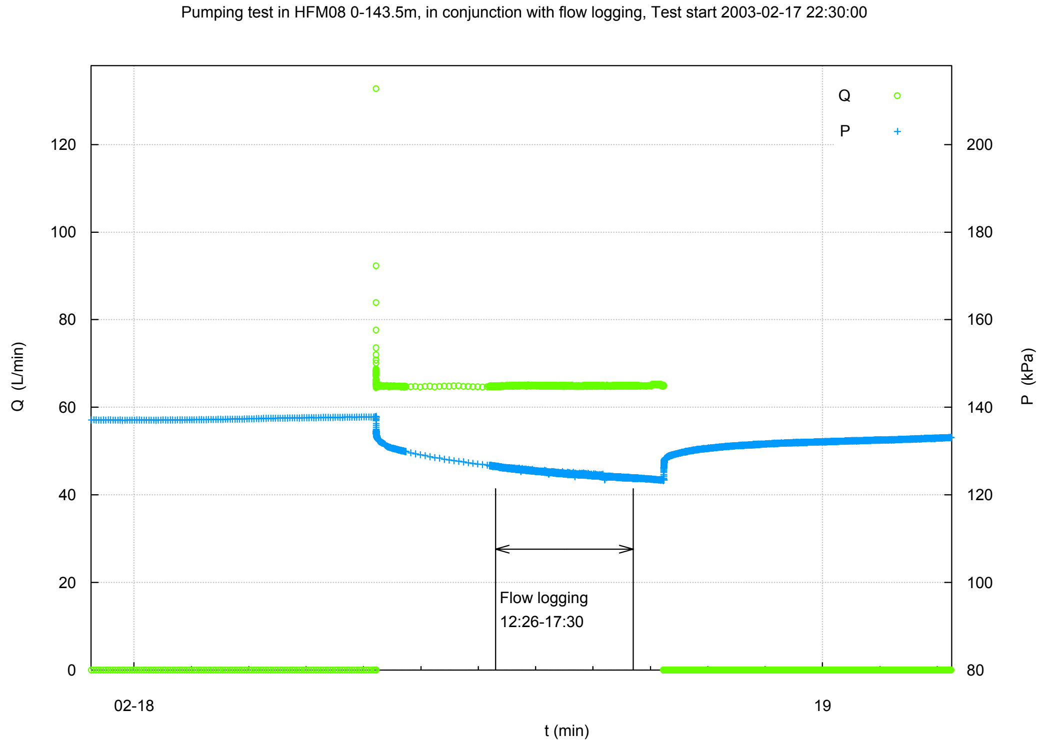


Figure A2:3-1. Linear plot of flow rate (Q) and pressure (p) versus time during the open-hole pumping test in HFM08 (18–143.5 m) in conjunction with flow logging.

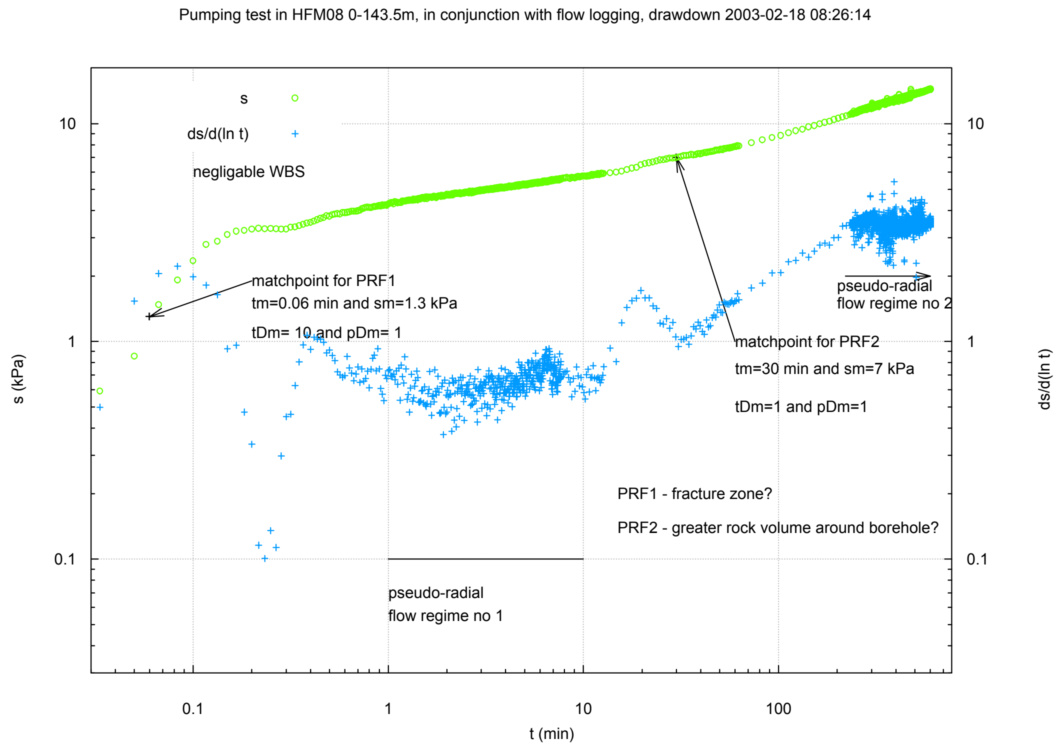


Figure A2:3-2. Log-log plot of drawdown (s) and drawdown derivative, ds/d(ln t), versus time (t) during the open-hole pumping test in HFM08(18–143.5 m).

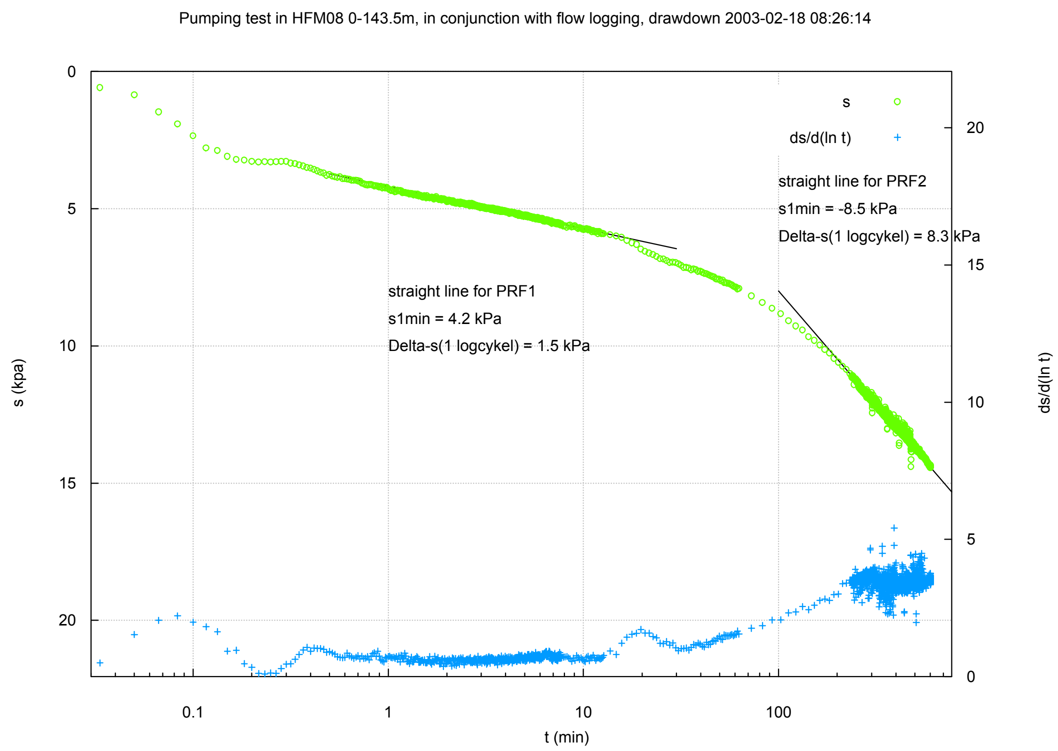


Figure A2:3-3. *Lin-log plot of drawdown (s) versus time (t) during the open-hole pumping test in HFM08 (18–143.5 m).*

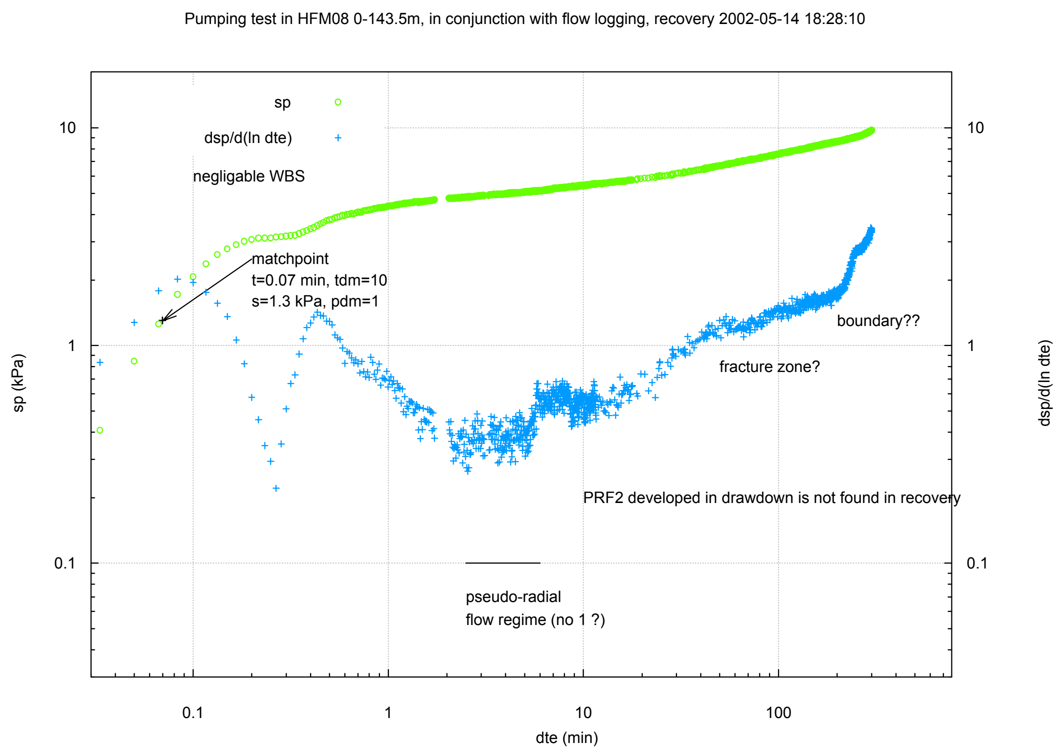


Figure A2:3-4. *Log-log plot of pressure recovery (sp) and -derivative, dsp/d(ln dte) versus equivalent time (dte) from the open-hole pumping test in HFM08 (18–143.5m).*

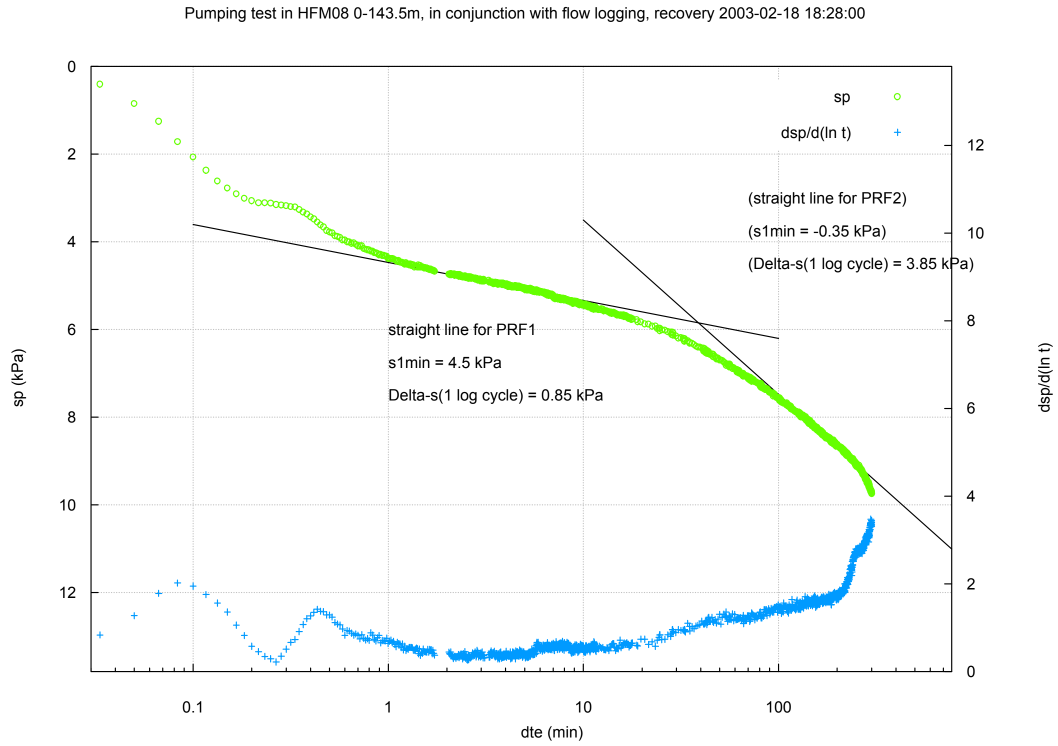


Figure A2:3-5. *Lin-log plot of pressure recovery (sp) versus equivalent time (dte) from the open-hole pumping test in HFM08 (18–143.5 m).*

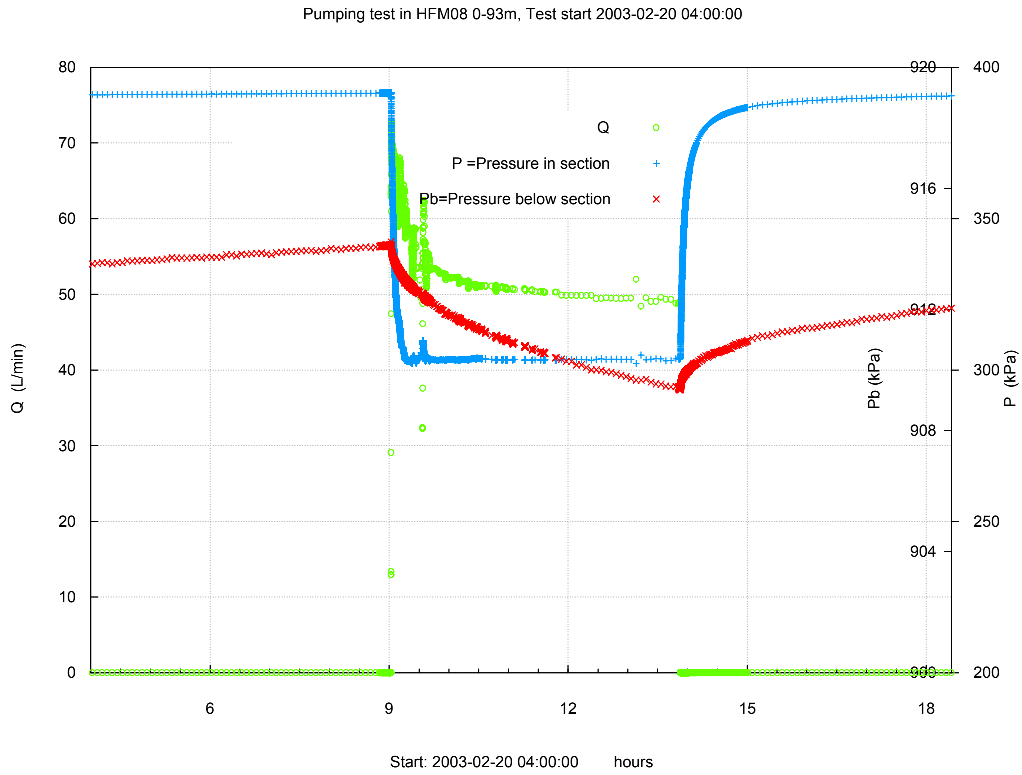


Figure A2:4-1. Linear plot of flow rate (Q) and pressure (p and pb respectively) versus time during the open-hole pumping test in HFM08 (18–93 m).

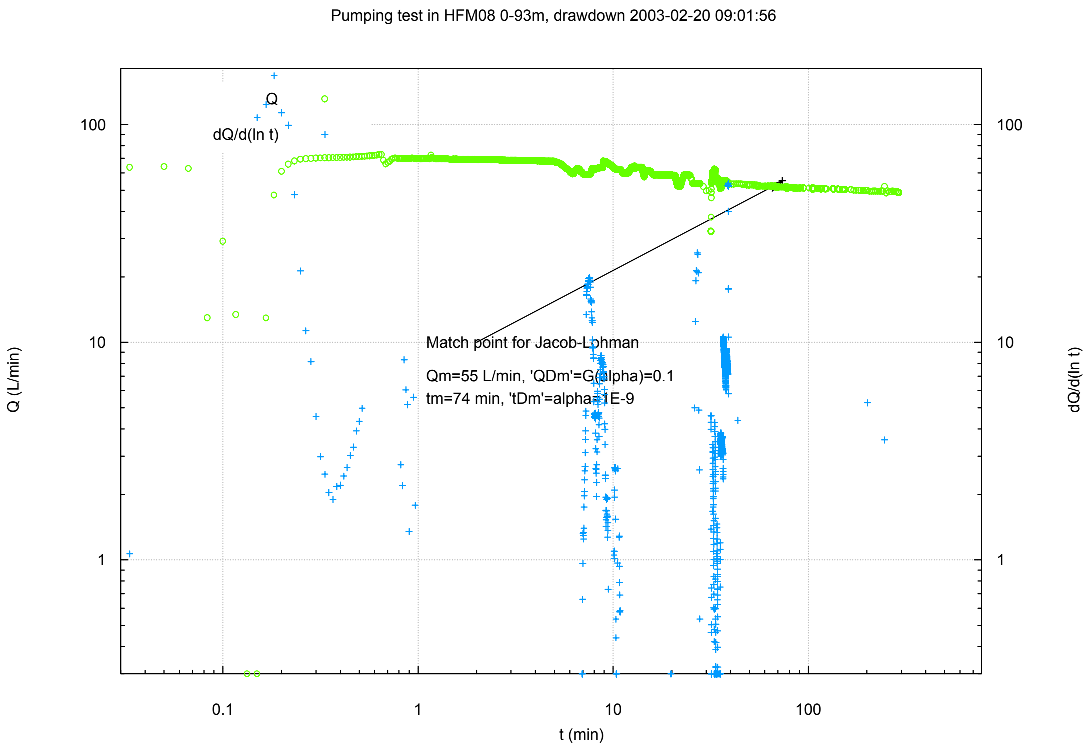


Figure A2:4-2. Log-log plot of flow rate (Q) and flow rate derivative, dQ/d(ln t), versus time (t) during the open-hole pumping test in HFM08 (18–93 m).

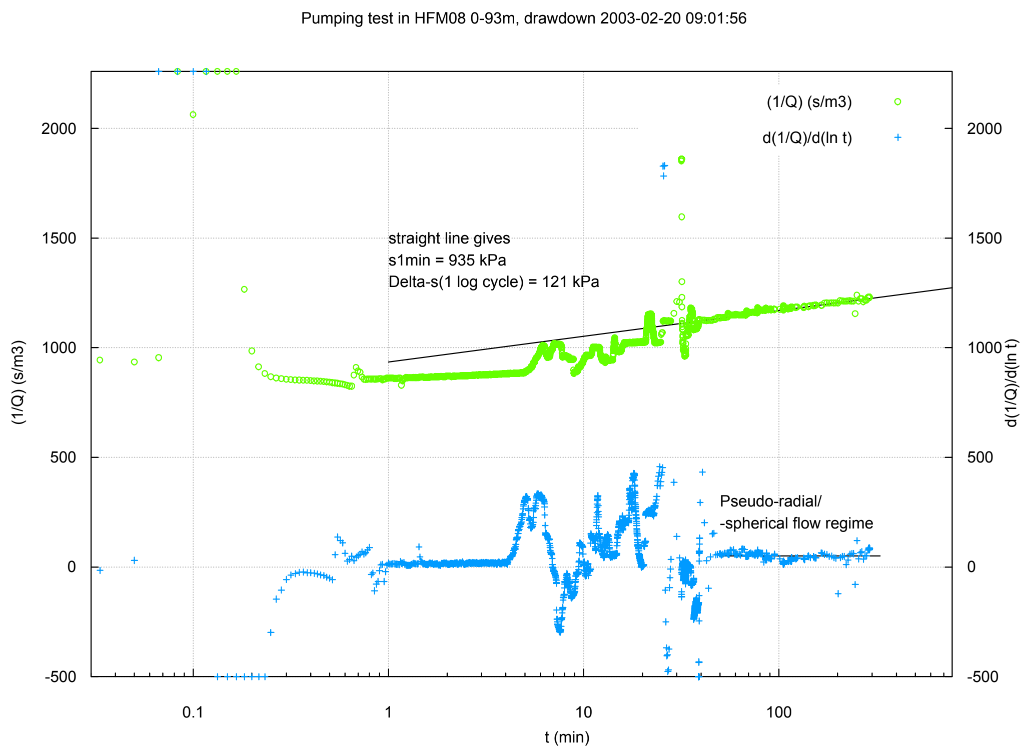


Figure A2:4-3. *Lin-log plot of the inverted flow rate (1/Q) and derivative of inverted flow rate versus time (t) during the open-hole pumping test in HFM08 (18–93 m).*

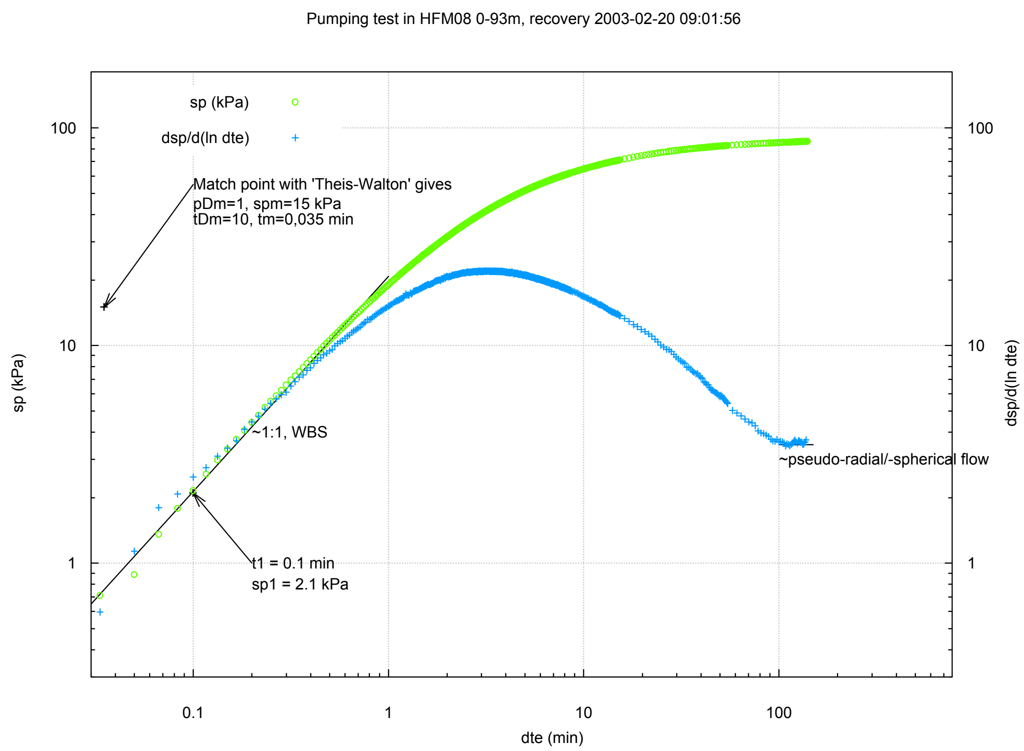


Figure A2:4-4. *Log-log plot of pressure recovery (sp) and -derivative, dsp/d(ln dte) versus equivalent time (dte) from the open-hole pumping test in HFM08 (18–93 m).*

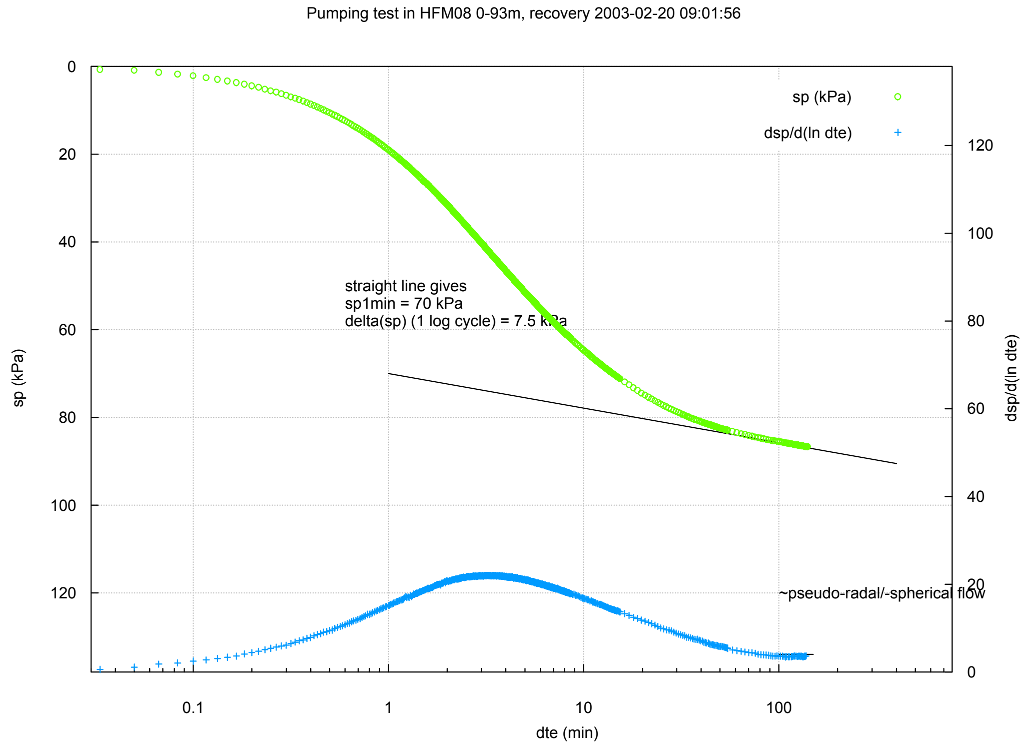


Figure A2:4-5. *Lin-log plot of pressure recovery (sp) versus equivalent time (dte) from the open-hole pumping test in HFM08 (18–93 m).*

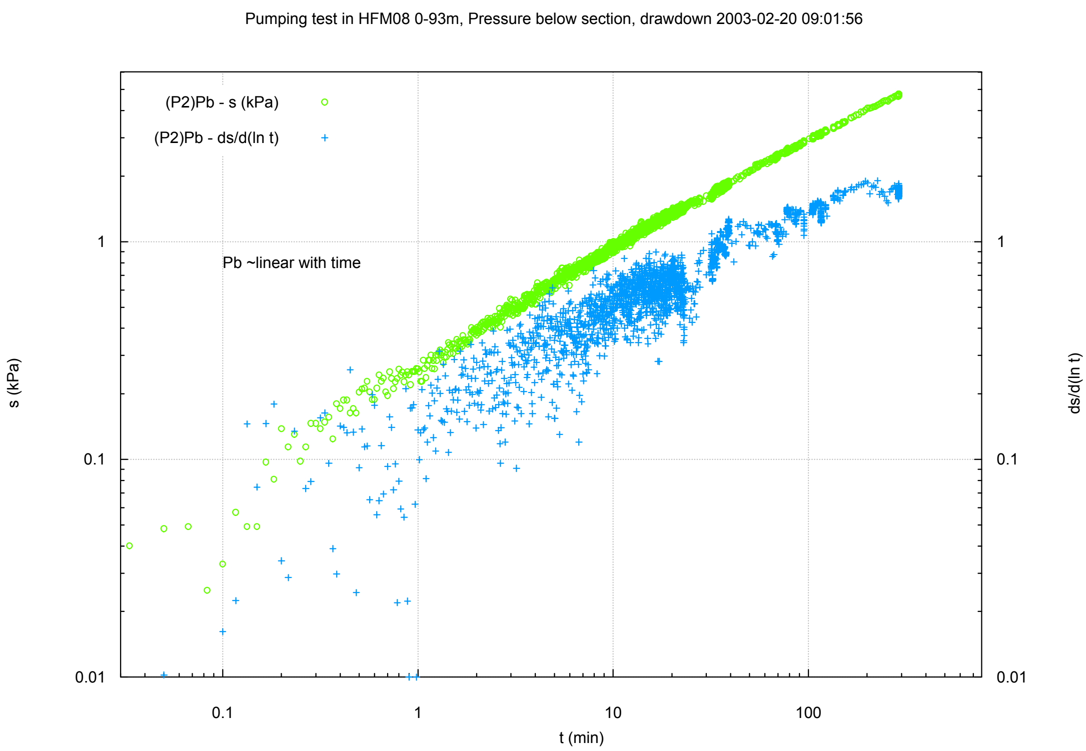


Figure A2:4-6. *Log-log plot of drawdown below section (Pb-s) and -derivative (ds/d(ln t)) versus time during the pumping test in the interval 18–93 m in HFM08.*

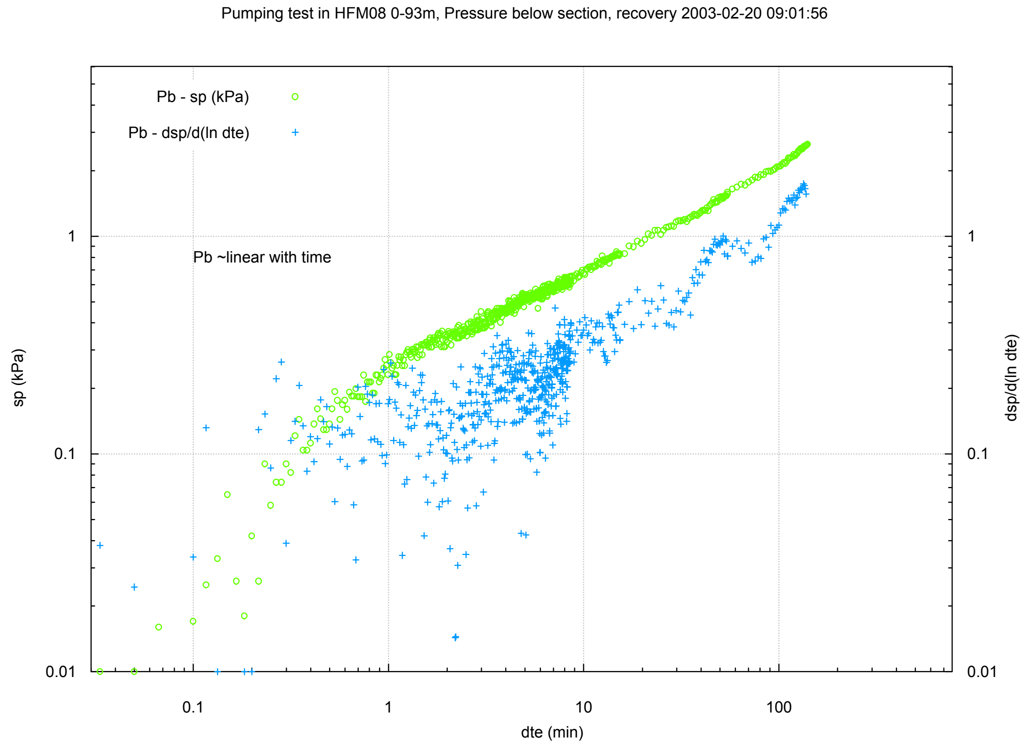


Figure A2:4-7. *Log-log plot of recovery below section (Pb-sp) and -derivative (dsp/d(ln t)) versus time during the pumping test in the interval 18–93 m in HFM08.*

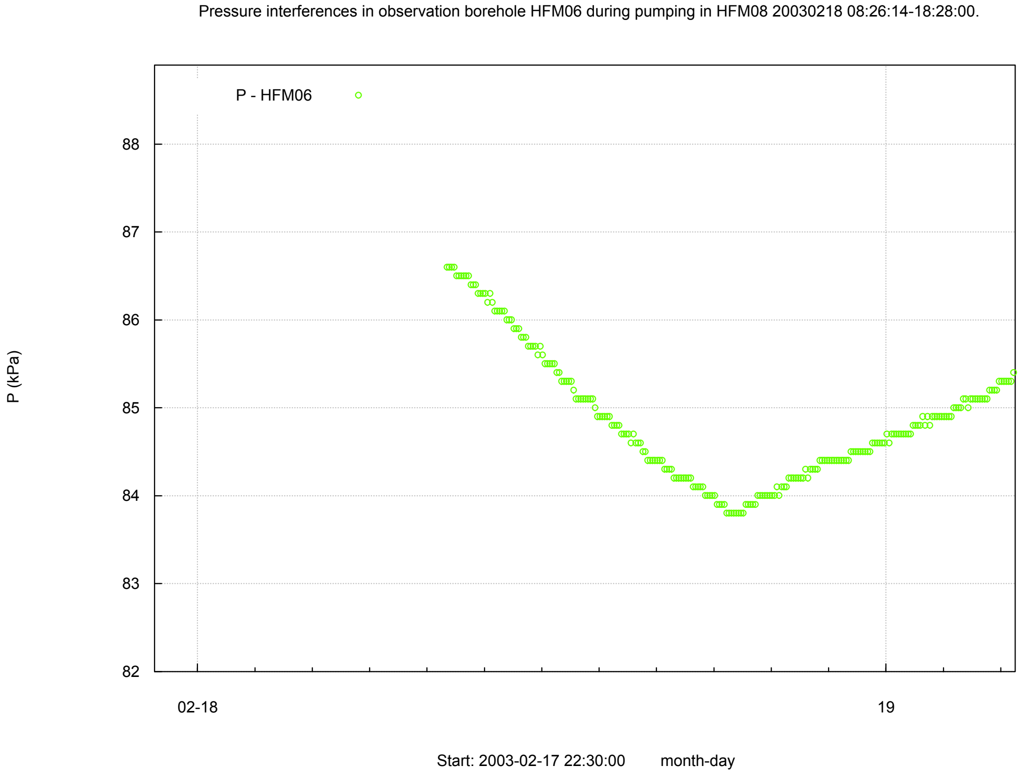


Figure A2:5-1. *Linear plot of pressure (P) in observation borehole HFM06 versus time during the pumping test in HFM08 (18–143.5 m).*

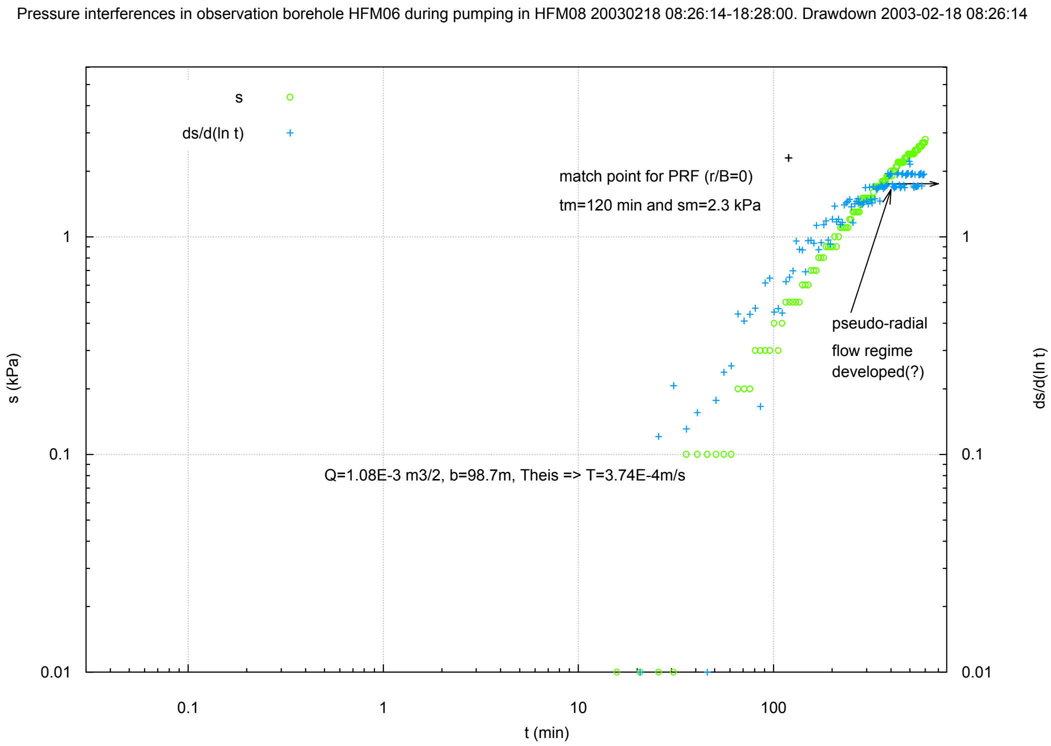


Figure A2:5-2. *Log-log plot of drawdown and derivative of drawdown in observation borehole HFM06 versus time during the pumping test in HFM08 (18–143.5 m).*

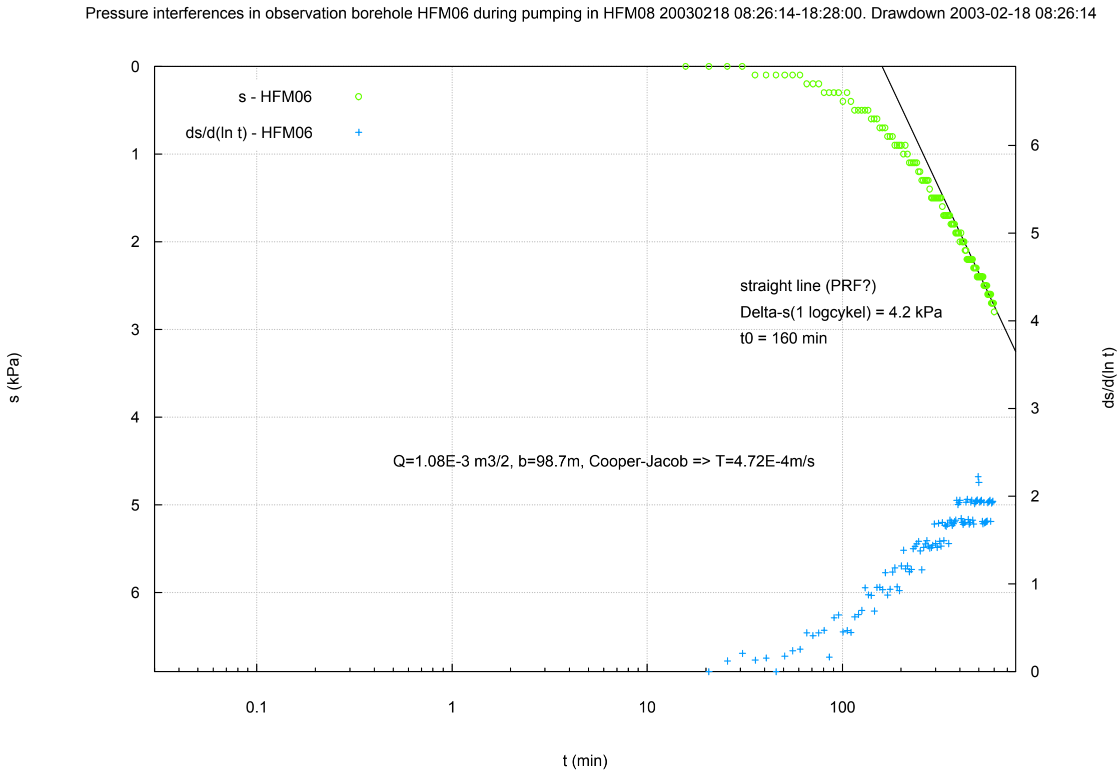


Figure A2:5-3. *Lin-log plot of drawdown and derivative of drawdown in observation borehole HFM06 versus time during the pumping test in HFM08 (18–143.5 m).*

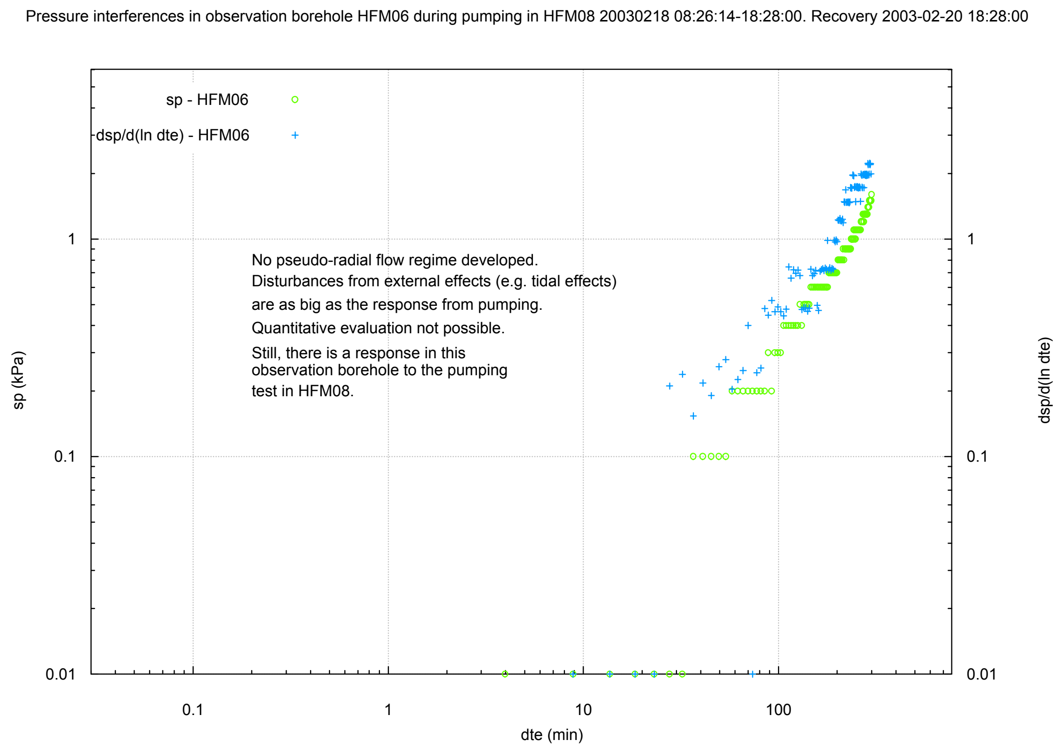


Figure A2:5-4. *Log-log plot of recovery and derivative of recovery in observation borehole HFM06 versus time during the pumping test in HFM08 (18–143.5 m).*

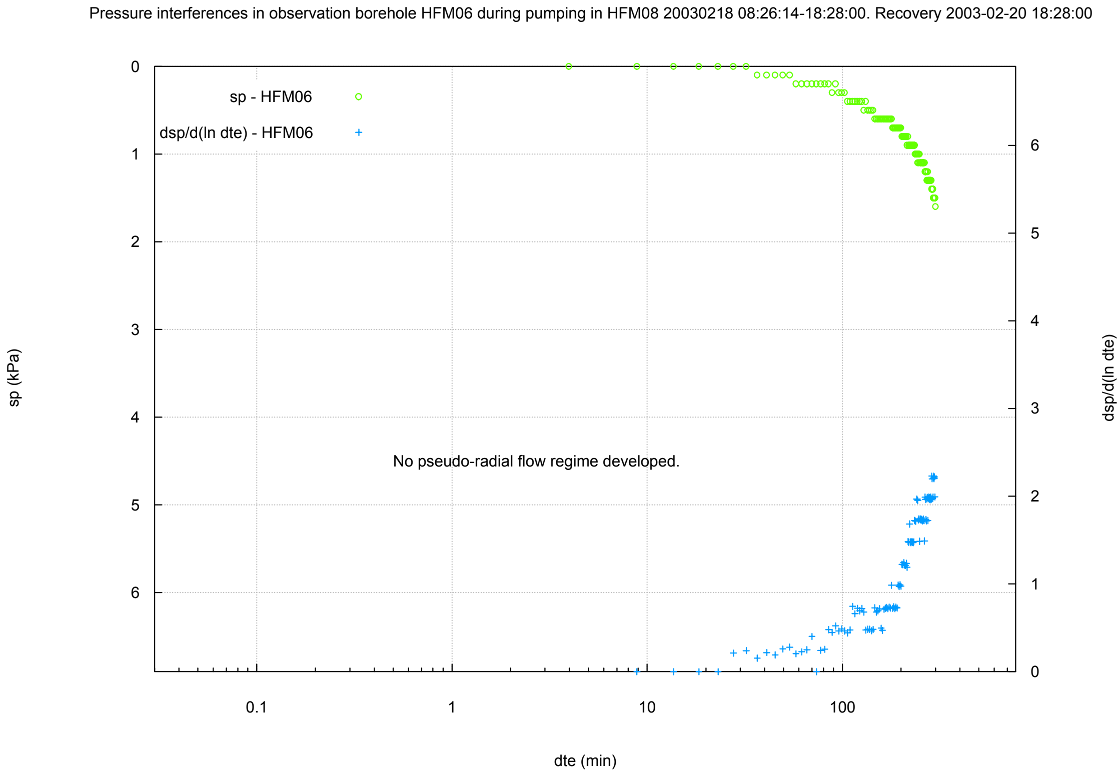


Figure A2:5-5. *Lin-log plot of recovery and derivative of recovery in observation borehole HFM06 versus time during the pumping test in HFM08 (18–143.5 m).*

Appendix A2:6

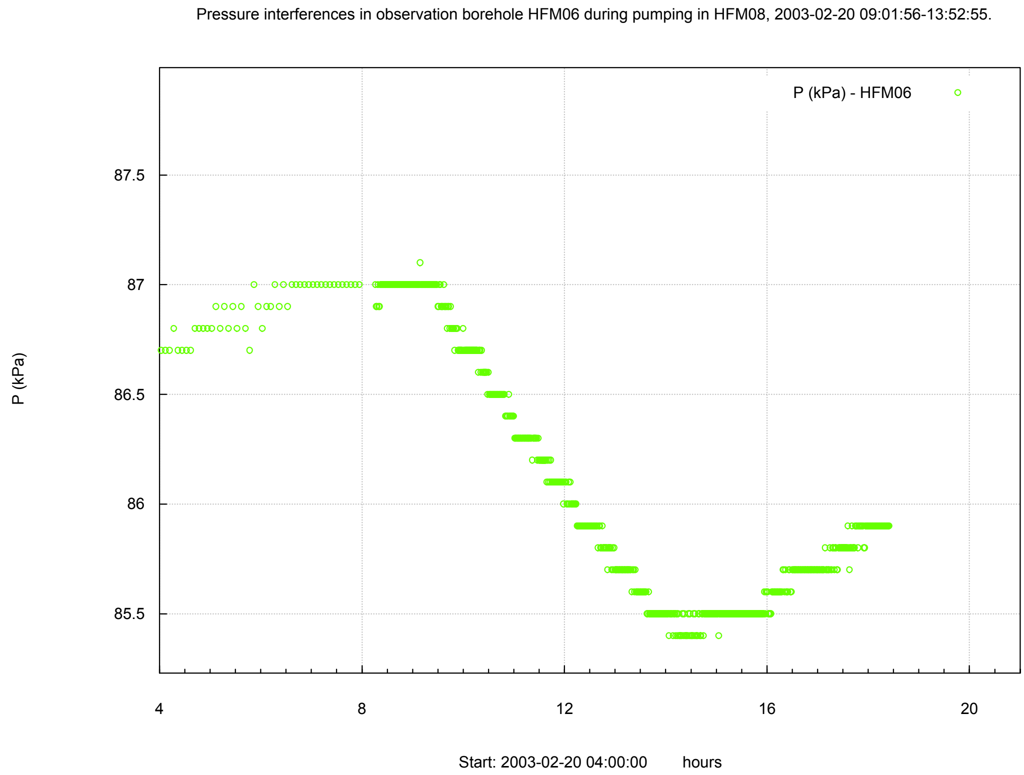


Figure A2:6-1. Linear plot of pressure (P) in observation borehole HFM06 versus time during the pumping test in HFM08 (18–93 m).

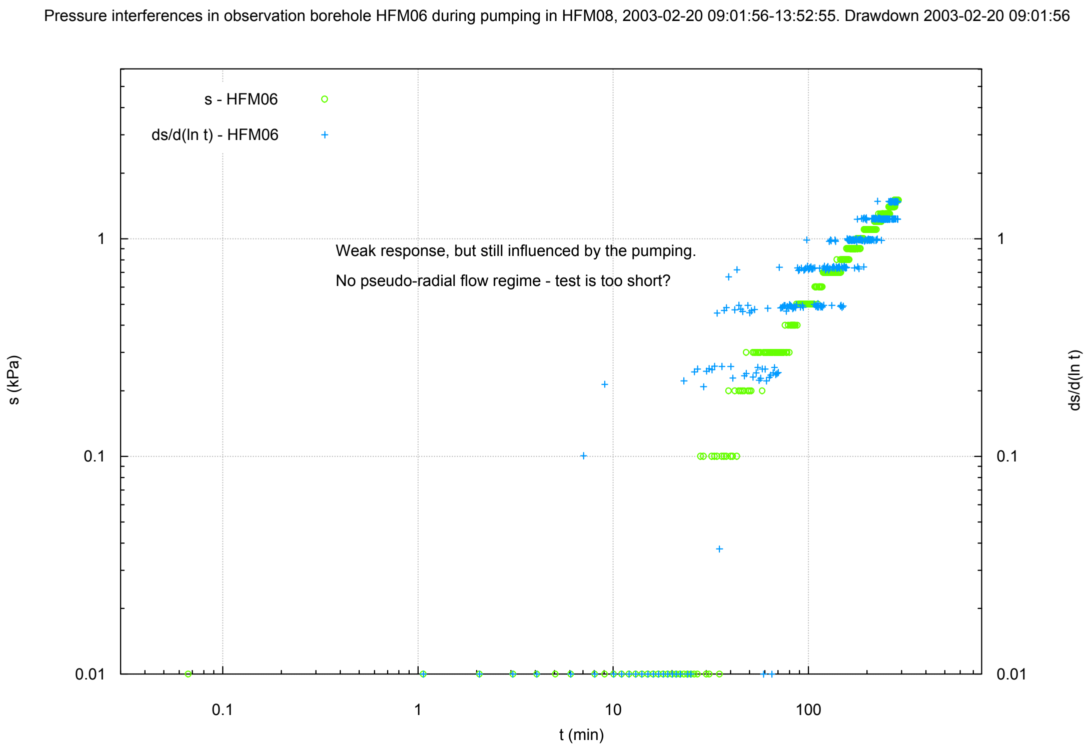


Figure A2:6-2. Log-log plot of drawdown and derivative of drawdown in observation borehole HFM06 versus time during the pumping test in HFM08 (18–93 m).

Pressure interferences in observation borehole HFM06 during pumping in HFM08, 2003-02-20 09:01:56-13:52:55. Drawdown 2003-02-20 09:01:56

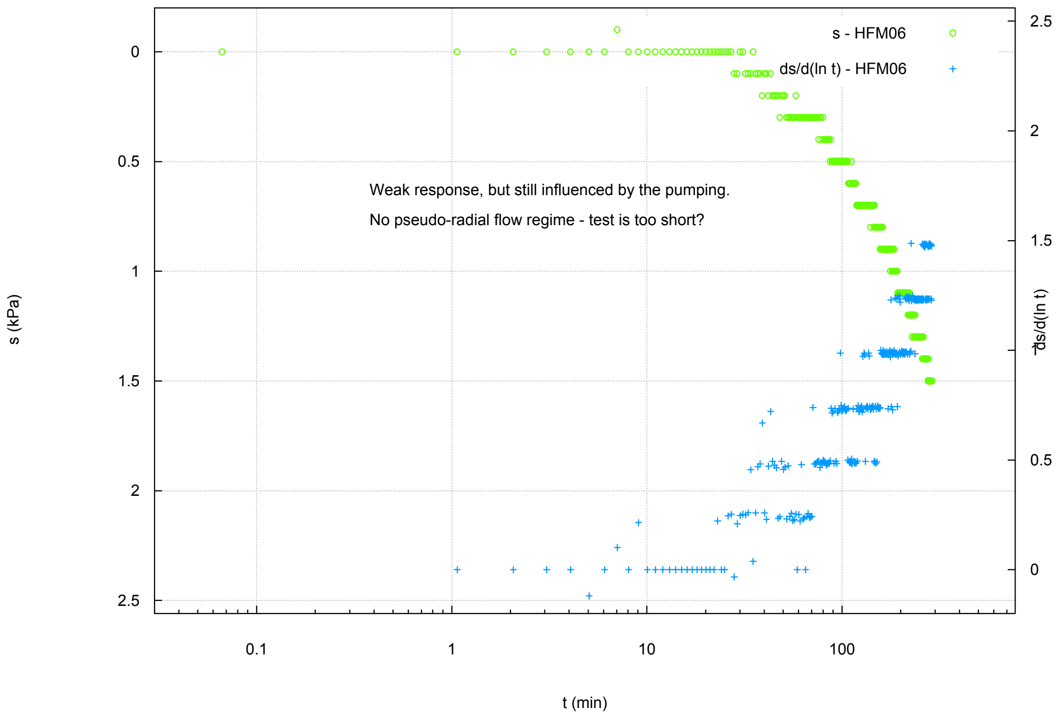


Figure A2:6-3. *Lin-log plot of drawdown and derivative of drawdown in observation borehole HFM06 versus time during the pumping test in HFM08 (18–93 m).*

Pressure interferences in observation borehole HFM06 during pumping in HFM08, 2003-02-20 09:01:56-13:52:55. Recovery 2003-02-20 13:52:55

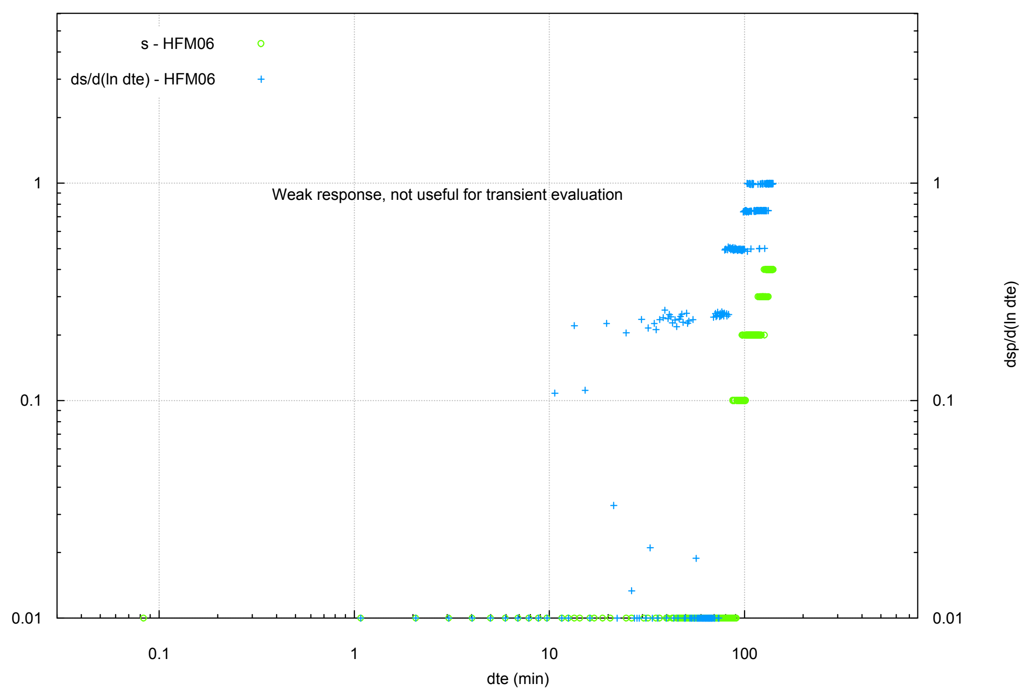


Figure A2:6-4. *Log-log plot of recovery and derivative of recovery in observation borehole HFM06 versus time during the pumping test in HFM08 (18–93 m).*

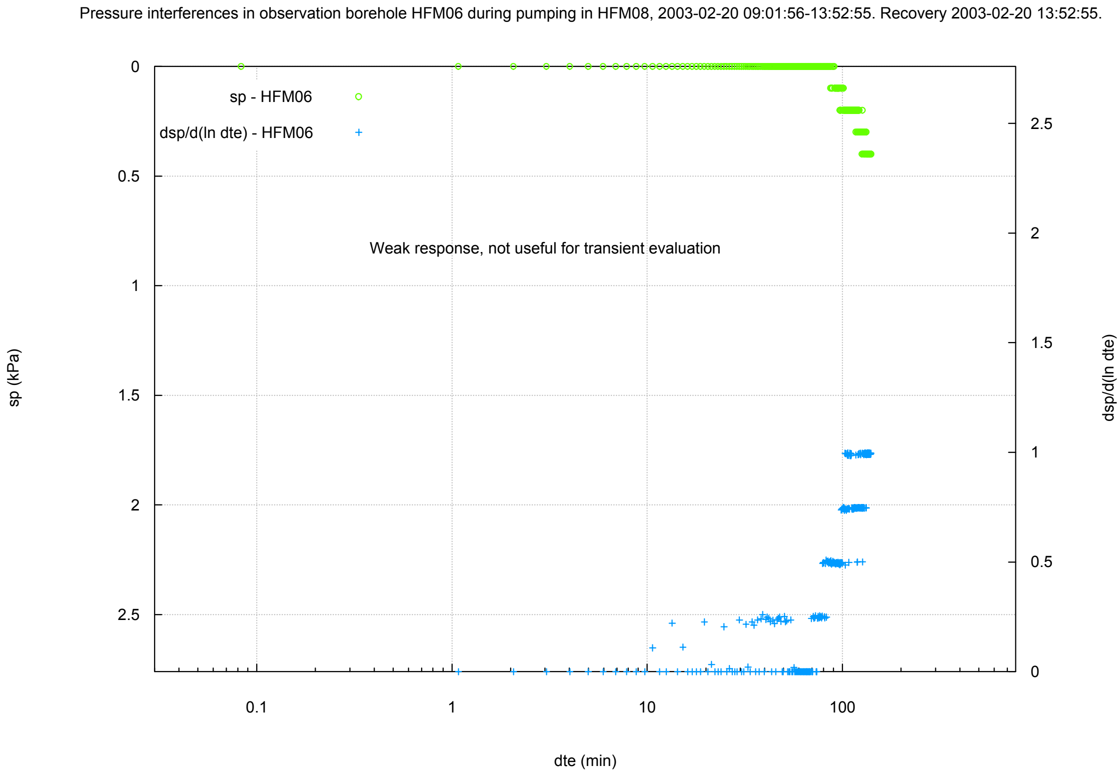


Figure A2:6-5. *Lin-log plot of recovery and derivative of recovery in observation borehole HFM06 versus time during the pumping test in HFM08 (18–93 m).*

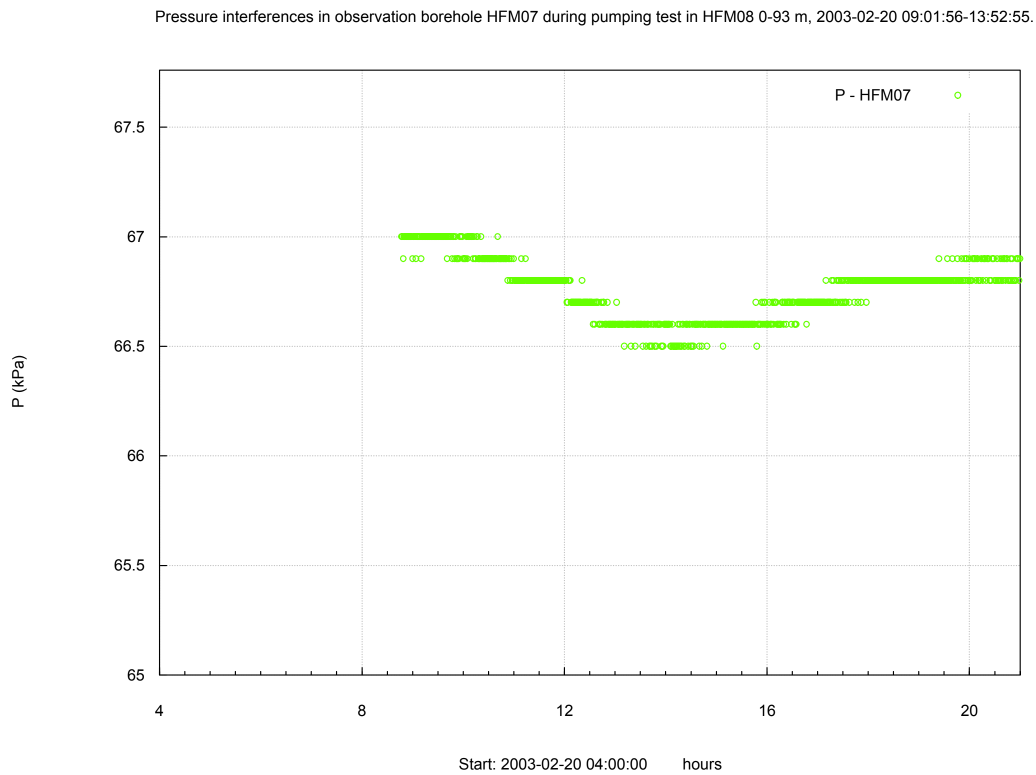


Figure A2:7-1. *Linear plot of pressure (P) in observation borehole HFM07 versus time during the pumping test in HFM08 (18–93 m).*

Appendix 3

SINGLEHOLE TESTS, Pumping and injection, s_hole_test_d; General information

idcode	**secup**	**seclow**	seclen_class	test_type	formation_type	start_date (YYYY-MM-DD hh:mm)	stop_date (YYYY-MM-DD hh:mm)	start_flow_period (YYYY-MM-DD hh:mm:ss)	stop_flow_period (YYYY-MM-DD hh:mm:ss)	flow_rate_end_qp
Borehole	Borehole secup (m)	Borehole seclow (m)	(m)	Test type (1-6)	Formation type (-)	Date and time for test, start YYYYMMDD hh:mm		Start flow/ injection hhmmss	Stop flow/ injection hhmmss	Qp (m**3/s)
HFM06	12.00	110.70		1B	1	20030121 09:57	20030122 08:54	20030121 10:04:03	20030121 21:02:03	9.97E-04
HFM08	18.00	143.50		1B	1	20030217 22:30	20030219 09:15	20030218 08:26:15	20030218 18:28:00	1.08E-03
HFM08	18.00	93.00		1B	1	20030220 04:00	20030220 18:25	20030220 09:01:56	20030220 13:52:55	8.14E-04
HFM06	12.00	110.70		1B	1	20030122 09:35	20030122 13:35	20030122 09:48:12	20030122 13:31:02	4.15E-04

value_type_qp (-1, 0 or 1)	q_measl_l	q_measl_u	tot_volume_vp	mean_flow_rate_qm	dur_flow_phase_tp	dur_rec_phase_tf	initial_head_hi	head_at_flow_end_hp	final_head_hf	initial_press_pi	press_at_flow_end_pp	final_press_pf	fluid_temp_tew	fluid_elcond_ecw
	Q-measl-L (m**3)/s	Q-measl-U (m**3)/s	V_p (m**3)	Q_m (m**3/s)	tp (s)	t_F (s)	h_i (m a sl)	h_p (m a sl)	h_F (m a sl)	p_i (kPa)	p_p (kPa)	p_F (kPa)	Te_w (^{o}C)	EC_w (mS/m)
0	8.3E-05	1.3E-03	35.6	9.03E-04	39480	42660	0.55	-3.51	0.46	173.20	132.60	172.30		
0	8.3E-05	1.3E-03	39.2	1.09E-03	36120	36000	-0.35	-1.79	-0.82	137.80	123.40	133.10		
0	8.3E-05	1.3E-03	15.0	8.59E-04	17460	16320	-0.77	-9.53	-0.86	391.40	303.80	390.50		
0	8.3E-05	1.3E-03	5.6	4.16E-04	13380	240	0.51	-0.69	0.02	121.6	109.70	116.70		

fluid_salinity_tdsw	fluid_salinity_tdswn	reference	comments
TDS_w (mg/ L)	TDS_{wm} (mg/ L)	Reference	Comments (-)

SINGLEHOLE TESTS, Pumping and injection, s_hole_test_obs

idcode	**secup**	**seclow**	start_date (YYYY-MM-DD hh:mm)	obs_secup	obs_seclow	pi_above	pp_above	pf_above	pi_below_	pp_below	pf_below
Borehole	Borehole secup (m)	Borehole seclow (m)	Date and time for test, start YYYYMMDD hh:mm	Upper limit of observation section(m)	Lower limit of observation section (m)	p_{ai} (kPa)	p_{ap} (kPa)	p_{aF} (kPa)	p_{bi} (kPa)	p_{bp} (kPa)	p_{bF} (kPa)
HFM08	18.00	93.00	20030220 04:00	94.00	143.50				914.11	909.40	912.02

SINGLEHOLE TESTS, Pumping and injection, s_hole_test_ed1; Basic evaluation

idcode	**secup**	**seclow**	start_date (YYYY-MM-DD hh:mm)	seclen_class	spec_capacity_q_s	value_type_q_s (-1, 0 or 1)	transmissivity_tq	transmissivity_moye	formation_width_b	width-of_channel b	tb
Borehole	Borehole secup (m)	Borehole seclow (m)	Date and time for test, start YYYYMMDD hh:mm	(m)	Q/s (m^2/ s)		T_Q (m^2/ s)	T_M (m^2/ s)	b (m)	B (m)	TB (1D) (m^3/ s)
HFM06	12.00	110.70	20030121 09:57		2.50E-04	0		3.00E-04	98.7		
HFM08	18.00	143.50	20030217 22:30		7.50E-04	0		9.40E-04	125.5		
HFM08	18.00	93.00	20030220 04:00		9.29E-05	0		1.08E-04	75		
HFM06	12.00	110.70	20030122 09:35		3.50E-04	0		4.20E-04	98.7		

l_measl_tb	u_measl_tb	sb	assumed_sb	leakage_factor_lf	transmissivity_tt	value_type_tt (-1, 0 or 1)	l_measl_q_s	u_measl_q_s	storativity_s	assumed_s	leakage_koeff
TB-measl-L (1D) (m^3/ s)	TB-measl-U (1D) (m^3/ s)	SB (1D) (m)	SB* (1D) (m)	L_f (1D) (m)	T_T (2D) (m^2/ s)		Q/s-measl-L (m^2/ s)	Q/s-measl-U (m^2/ s)	S (2D) (-)	S* (2D) (-)	K´/b´ (2D) (1/s)
					3.32E-04	0	2.0E-06	2.0E-03		1.00E-04	
					1.29E-03	0	2.0E-06	2.0E-03		1.00E-04	
					1.98E-04	0	2.0E-06	2.0E-03		1.00E-04	
					4.60E-04	0	2.0E-06	2.0E-03		1.00E-04	

hydr_kond_ks	value_type_ks (-1, 0 or 1)	l_meas_limit_ks	u_meas_limit_ks	spec_storage_ss	assumed_ss	lp	c	cd	skin	storativity_ratio	interflow_coeff	dt1	dt1	comments
K_S (3D) (m/s)		$K_{S\text{-measl-L}}$ (3D) (m/s)	$K_{S\text{-measl-U}}$ (3D) (m/s)	S_S (3D) (1/m)	S_S* (3D) (1/m)	L_p (m)	C (m**3/Pa)	C_D (-)	ξ (2D) (-)	ω (-)	λ (-)	t_1 (s)	t_2 (s)	Comments (-)
							2.62E-06		-0.5			6000	12000	
						138.25			-3.3			60	600	First PRF-period
							2.30E-06		5.27			6000	9000	
									-0.3			7200	13380	

PLU Injection and Pumping tests. General information

SICADA Header	**Header**	**Unit**	*Explanation*
Idcode	Borehole		ID for borehole
Secup	Borehole secup	m	Length coordinate along the borehole for the upper limit of the test section
Seclow	Borehole seclow	(-)	Length coordinate along the borehole for the lower limit of the test section
Test_type	Test type (1- 7)	(-)	1: Pumpingtest-wireline eq., 2: Pumpingtest-submersible pump, 3: Pumpingtest-airlift pumping, 4: Injection test, 5: Slug test, 6: Flowlogging-PFL-DIFF, 7: Flowlogging-Impeller
start_date	Date for test start	Y	Date for the start of the pumping or injection test (YYYYMMDD hh:mm)
start_flow_period	Start flow / injection		Date and time for the start of the pumping or injection period (YYMMDD hh:mm:ss)
stop_flow_period	Start flow / injection		Date and time for the end of the pumping or injection period (YYMMDD hh:mm:ss)
lp	L_p	m	Hydraulic point of appication, based on hydraulic conductivity distribution (if available) or the midpoint of the borehole test section
mean_flow_rate_end_qm	Q_m	m^3/s	Arithmetricmean flow rate of the pumping/injection period.
flow_rate_end_qp	Q_p	m^3/s	Flow rate at the end of the pumping/injection period.
value_type_qp		m^3/s	Code for Q_p-value; -1 means Q_p<lower measurement limit, 0 means measured value, 1 means Q_p> upper measurement value of flowrate
q_measl_l	Q-measl_L	m^3/s	Estimated lower measurement limit for flow rate
q_measl_u	Q-measl_U	m^3/s	Estimated upper measurement limit for flow rate
total_volume_vp	V_p	m^3	Total volume pumped (positive) or injected (negative) water during the flow period.
dur_flow_phase_tp	t_p	s	Time for the flowing phase of the test
dur_rec_phase_tf	t_F	s	Time for the recovery phase of the test
initial_head_hi	h_i	m	Initial formation hydraulic head. Measured as water level in open stand pipes from borehole section with

			reference level in the local coordinates system with z=0 m.
head_at_flow_end_hp	h_p	m	Final hydraulic head at the end of the pumping/injection period. Measured as water level in open stand pipes from borehole section with reference level in the local coordinates system with z=0 m.
final_head_hf	h_F	m	Final hydraulic head at the end of the recovery period. Measured as water level in open stand pipes from borehole section with reference level in the local coordinates system with z=0 m.
initial_press_pi	p_i	kPa	Initial formation pressure.
press_at_flow_end_pp	p_p	kPa	Final pressure at the end of the pumping/injection period.
final_press_pf	p_F	kPa	Final pressure at the end of the recovery period.
fluid_temp_tew	Te_w	gr C	Fluid temperature in the test section representative for the evaluated parameters
fluid_elcond_ecw	EC_w	mS/m	Electrical conductivity of the fluid in the test section representative for the evaluated parameters
fluid_salinity_tdsw	TDS_w	mg/L	Total salinity of the fluid in formation at test section based on EC.
fluid_salinity_tdswn	TDS_{wn}	mg/L	Total salinity of the fluid in formation at test section based on water sampling and chemical analysis.
reference	references		SKB report No for reports describing data and evaluation
comments	comments		Short comment to data

Data from observation sections during single hole pump- or injection tests. As a rule the observation sections are located above or below the tested interval in the same borehole.

SICADA Header	**Header**	**Unit**	*Explanation*
Idcode	Borehole		ID for borehole
Secup	Borehole secup	m	Length coordinate along the borehole for the upper limit of the injected or pumped test section
Seclow	Borehole seclow	m	Length coordinate along the borehole for the lower limit of the injected or pumped test section
start_date	Date for		Date for the start of the pumping or injection test (YYYYMMDD hh:mm)

	test start		
obs_secup		m	Length coordinate along the borehole for the upper limit of the observation section
obs_seclow		m	Length coordinate along the borehole for the lower limit of the observation section
pi_above	p_{ai}	kPa	Initial formation pressure of the observation section, which is located above the test section in the borehole
pp_above	p_{ap}	kPa	Final pressure at the end of the pumping/injection period in the observation section, which is located above the test section in the borehole
pf_above	p_{aF}	kPa	Final pressure at the end of the recovery period in the observation section, which is located above the test section in the borehole
pi_below	p_{bi}	kPa	Initial formation pressure of the observation section, which is located below the test section in the borehole
pp_below	p_{bp}	kPa	Final pressure at the end of the pumping/injection period in the observation section, which is located below the test section in the borehole
pf_below	p_{bF}	kPa	Final pressure at the end of the recovery period in the observation section, which is located below the test section in the borehole

PLU interference test, evaluated data of observation sections

SICADA Header	Header	Unit	Explanation
idcode	ID Obs. Borehole		ID for obsevation borehole
secup	Borehole secup	m	Length coordinate along the borehole for the upper limit of the observation section
seclow	Borehole seclow	(-)	Length coordinate along the borehole for the lower limit of the observation section
start_date	Date for test start		Date for the start of the interference test (YYYY-mm_dd hh:mm)
stop_date	Date for test stop		Date for the stop of the interference test (YYYY-mm_dd hh:mm)
test_borehole	ID- Pumped borehole	(-)	ID for pumped or injected borehole
test_secup		(m)	Length coordinate along the borehole for the upper limit of pumped or injected section

test_seclow		(m)	Length coordinate along the borehole for the lower limit of pumped or injected section
formation_width_b	b	m	b: Interpreted formation thickness or section lengthrepresentative for evaluated T ot TB.
width_of_channel_b	B	m	B: Interpreted witdth of a formation with evaluated TB
tbo	TB_o	m^3/s	TB_o: 1D model for evaluation of formation properties. T=transmissivity, B=width of formation
l_meas_limit_tb	TB-measl-L	m^2/s	Estimated measurement limit for evaluated TB. If estimated TB equals TB-measlim in the table actual TB is considered to be equal or less than TB-measlim
u_meas_limit_tb	TB-measl-U	m^2/s	Estimated measurement limit for evaluated TB. If estimated TB equals TB-measlim in the table actual TB is considered to be equal or greater than TB-measlim
sbo	SB_o	m	SB_o: 1D model for evaluation of formation properties. S= Storativity, B=width of formation
leakage_factor_lfo	L_{f0}	m	1D model for evaluation of Leakage factor
transmissivity_tto	T_{t0}	m^2/s	2D model for evaluation of formation properties. T=transmissivity
l_meas_limit_t	T-measl-L	m^2/s	Estimated measurement limit for evaluated T (T_T, T_Q, T_M). If estimated T equals T-measlim in the table actual T is considered to be equal or less than T-measlim
u_meas_limit_t	T-measl-U	m^2/s	Estimated measurement limit for evaluated T (T_T, T_Q, T_M). If estimated T equals T-measlim in the table actual T is considered to be equal or greater than T-measlim
storativity_so	S_o	(-)	2D model for evaluation of formation properties. S= Storativity
leakage_coeff_o	K'/b'_0	(1/s)	2D model for evaluation of leakage coefficient. K´= hydraulic conductivity in direction of leaking flow for the aquitard, b´= Saturated thickness of aquitard (leaking formation)
hydr_kond_kso	K_{So}	m/s	3D model for evaluation of formation properties. K=Hydraulic conductivity
l_meas_limit_ks	$K_{S\text{-measl-L}}$	m/s	Estimated measurement limit for evaluated K_S. If estimated K_S equals K_S-measlim in the table actual K_S is considered to be equal or less than K_S-measlim
u_meas_limit_ks	$K_{S\text{-measl-U}}$	m/s	Estimated measurement limit for evaluated K_S. If estimated K_S equals K_S-measlim in the table actual K_S is considered to be equal or greater than K_S-measlim
spec_storage_sso	S_{So}	1/m	3D model for evaluation of formation properties. Ss=Specific Storage
dt1	dt_1	s	Estimated start time after pump/injection start OR recovery start, for the period used for the evaluated parameter
dt2	dt_2	s	Estimated stop time after pump/injection start OR recovery start, for the period used for the evaluated parameter
Comments	Comments		Short comment to the evaluated parameters (Optional)

INTERFERENCE TESTS - OBSERVATION SECTIONS: plu_inf_test_obs_d

idcode	**secup**	**seclow**	test_type	formation_type	**test_borehole**	**test_secup**	test_seclow	start_date (YYYY-MM-DD hh:mm)	stop_date (YYYY-MM-DD hh:mm)	start_flow_period (YYYY-MM-DD hh:mm:ss)	stop_flow_period (YYYY-MM-DD hh:mm:ss)
ID Obs. Borehole	Borehole secup (m)	Borehole seclow (m)	Test type (1-7)	Formation type (-)	ID Pumped Borehole	Test secup	Test seclow	Date for test, start YY-MM-DD	Date for test, stop YY-MM-DD	Start flow hh:mm:ss	Stop flow hh:mm:ss
HFM06	12.00	110.70	2	1	HFM08	18	143.5	20030217 22:30	20030219 09:15	20030218 08:26:15	20030218 18:28:00
HFM06	12.00	110.70	2	1	HFM08	18	93	20030220 04:00	20030220 18:25	20030220 09:01:56	20030220 13:52:55
HFM07	18	122.5	2	1	HFM08	18	143.5	20030217 22:30	20030219 09:15	20030218 08:26:15	20030218 18:28:00

lp	radial_distance_rs	shortest_distance_rt	time_lag_press_ dtl	initial_head_ hi	head_at_flow_end_ hp	final_head_ hf	initial_press_ pi	press_at_flow_end_ pp	final_press _pf	fluid_temp _teo	fluid_elcond __eco
Lp (m)	r_s (m)	r_t (m)	dt_L (s)	h_i (m a s l)	h_p (m a s l)	h_F (m a s l)	p_i (kPa)	p_p (kPa)	p_F (kPa)	Te_o (^{o} C)	EC_o (mS/m)
70	279		30000	0.37	0.09	0.25					
				0.41	0.26	0.30					
				-1.59	-1.63	-1.61					

fluid_salinity _tdso	fluid_salinity _tdsom	reference	comments
TDS_o (mg/ L)	TDS_{om} (mg/ L)	Reference	Comments (-)

INTERFERENCE TESTS - OBSERVATION SECTIONS: plu_inf_test_obs_ed

idcode	**secup**	**seclow**	start_date (YYYY-MM-DD hh:mm)	stop_date (YYYY-MM-DD hh:mm)	**test_borehole**	**test_secup**	test_seclow	formation_width_b	width_of_channel_b	tbo	l_meas_limit_tb
ID Obs. Borehole	Borehole secup (m)	Borehole seclow (m)	Date for test, start YY-MM-DD	Date for test, stop YY-MM-DD	ID Pumped Borehole	Test secup	Test seclow	b (m)	B (m)	TB_o (1D) (m^3/ s)	TB-measl-L (1D) (m^3/ s)
HFM06	12.00	110.70	20030217 22:30	20030219 09:15	HFM08	18	143.5	98.7			
HFM06	12.00	110.70	20030220 04:00	20030220 18:25	HFM08	18	93	98.7			
HFM07	18	122.5	20030217 22:30	20030219 09:15	HFM08	18	143.5	104.5			

u_meas_limit_tb	sbo	leakage_factor_lfo	transmissivity_tto	l_meas_limit_t	u_meas_limit_t	storativity_so	leakage_coeff_o	hydr_kond_kso	l_meas_limit_ks	u_meas_limit_ks	spec_storage_sso
TB-measl-U (1D) (m^3/ s)	SB_o (1D) (m)	L_{f0} (1D) (m)	T_o (2D) (m^2/ s)	T-measl-L (2D) (m^2/ s)	T-measl-U (2D) (m^2/ s)	S_o (2D) (-)	K'/b'_o (2D) (1/s)	K_{so} (3D) (m/s)	K_S-measl-L (3D) (m/s)	K_S-measl-U (3D) (m/s)	S_{so} (3D) (1/m)
			4.72E-04	2.00E-06	2.00E-03	1.30E-04					

dt1	dt2	
t_1 or dt_1 (s)	t_2 or dt_2 (s)	Comments (-)
21000	36000	
		No evaluation was made (small response)
		No evaluation was made (small response)

PLU interference tests, Observation section data

SICADA Header	Header	Unit	Explanation
idcode	ID Obs Borehole		ID for observation borehole
secup	Borehole secup	m	Length coordinate along the borehole for the upper limit of observation section
seclow	Borehole seclow	(m)	Length coordinate along the borehole for the lower limit of observation section
start_date	Date for test start	Date	Date for the start of the pumping/injection test (YYYY-MM-DD hh:mm)
stop_date	Date for test stop	Date	Date for the stop of the pumping/injection test (YYYY-MM-DD hh:mm)
test_type	Test type (1- 7)	(-)	1: Pumpingtest-wireline eq., 2: Pumpingtest-submersible pump, 3: Pumpingtest-airlift pumping, 4: Injection test, 5: Slug test, 6: Flowlogging-PFL-DIFF 7: Flowlogging-Impeller
test_borehole	ID. pumped Borehole	(-)	ID for pumped or injected borehole
test_secup	Test secup	(m)	Length coordinate along the borehole for the upper limit of pumped or injected section
test_seclow	Test seclow	(m)	Length coordinate along the borehole for the lower limit of pumped or injected section
start_flow_period	Start flow		Time for the start of the pumping/injection period (YYYY-MM-DD hh:mm:ss)
stop_flow_period	Stop flow		Time for the stop of the pumping/injection period (YYYY-MM-DD hh:mm:ss)
lp	Hydr. p. a. (L_p)	m	Hydraulic point of application. Based on the hydraulic conductivity distribution (if available) or the midpoint of the borehole section
radial_distance_rs	r_s	m	Radial distance from point of application of T (or K)-distribution (or mid-point) of test section to point of applicationT(or K)-distribution (or mid-point) of obsevation section
shortest_distance_rt	r_t	m	Shortest distance from point of application of T (or K)-distribution (or mid-point) of test section to point of applicationT(or K)-distribution (or mid-point) of obsevation section via interptered major conductive features. In the "Comments" the Model version X.Y used shall be reported.
time_lag_press_dtl	dt_L	s	Time lag for pressure response to reach observation well after stop pumping/injecting, based on a reponse of 0.1m in the observation section
initial_head_hi	h_i	m	Initial formation hydraulic head. Measured as water level in open stand pipes from borehole section with reference level in the local coordinates system with z=0 m.
head_at_flow_end	h_p	m	Final hydraulic head at the end of the pumping/injection period. Measured as water level in open stand

_hp			pipes from borehole section with reference level in the local coordinates system with z=0 m.
final_head_hf	h_F	m	Final hydraulic head at the end of the recovery period. Measured as water level in open stand pipes from borehole section with reference level in the local coordinates system with z=0 m.
initial_press_pi	p_i	kPa	Initial formation pressure.
press_at_flow_end_pp	p_p	kPa	Final pressure at the end of the pumping/injection period.
final_press_pf	p_F	kPa	Final pressure at the end of the recovery period.
fluid_temp_teo	Te_o	gr C	Fluid temperature in formation at observation section
fluid_elcond_eco	EC_o	mS/m	Electrical conductivity of the fluid in formation at observation section
fluid_salinity_tdso	TDS_o	mg/L	Total salinity of the fluid in formation at observation section based on EC
fluid_salinity_tdso	TDS_{om}	mg/L	Total salinity of the fluid in formation at observation section based on water sample and chemical analysis
reference	References		SKB report No for reports describing data and evaluation
comment	Comments		Short comment to the evaluated parameters (Optional)

Index o — Observation borehole or observation section (o short for observation)

PLU interference test, evaluated data of observation sections

SICADA Header	Header	Unit	Explanation
idcode	ID Obs. Borehole		ID for obsevation borehole
secup	Borehole secup	m	Length coordinate along the borehole for the upper limit of the observation section
seclow	Borehole seclow	(-)	Length coordinate along the borehole for the lower limit of the observation section
start_date	Date for test start		Date for the start of the interference test (YYYY-mm_dd hh:mm)
stop_date	Date for test stop		Date for the stop of the interference test (YYYY-mm_dd hh:mm)
test_borehole	ID- Pumped borehole	(-)	ID for pumped or injected borehole

test_secup		(m)	Length coordinate along the borehole for the upper limit of pumped or injected section
test_seclow		(m)	Length coordinate along the borehole for the lower limit of pumped or injected section
formation_width_b	b	m	b: Interpreted formation thickness or section lengthrepresentative for evaluated T ot TB.
width_of_channel_b	B	m	B: Interpreted witdth of a formation with evaluated TB
tbo	TB_o	m^3/s	TB_o: 1D model for evaluation of formation properties. T=transmissivity, B=width of formation
l_meas_limit_tb	TB-measl-L	m^2/s	Estimated measurement limit for evaluated TB. If estimated TB equals TB-measlim in the table actual TB is considered to be equal or less than TB-measlim
u_meas_limit_tb	TB-measl-U	m^2/s	Estimated measurement limit for evaluated TB. If estimated TB equals TB-measlim in the table actual TB is considered to be equal or greater than TB-measlim
sbo	SB_o	m	SB_o: 1D model for evaluation of formation properties. S= Storativity, B=width of formation
leakage_factor_lfo	L_{f0}	m	1D model for evaluation of Leakage factor
transmissivity_tto	T_{t0}	m^2/s	2D model for evaluation of formation properties. T=transmissivity
l_meas_limit_t	T-measl-L	m^2/s	Estimated measurement limit for evaluated T (T_T, T_Q, T_M). If estimated T equals T-measlim in the table actual T is considered to be equal or less than T-measlim
u_meas_limit_t	T-measl-U	m^2/s	Estimated measurement limit for evaluated T (T_T, T_Q, T_M). If estimated T equals T-measlim in the table actual T is considered to be equal or greater than T-measlim
storativity_so	S_o	(-)	2D model for evaluation of formation properties. S= Storativity
leakage_coeff_o	K'/b'_0	(1/s)	2D model for evaluation of leakage coefficient. K´= hydraulic conductivity in direction of leaking flow for the aquitard, b´= Saturated thickness of aquitard (leaking formation)
hydr_kond_kso	K_{So}	m/s	3D model for evaluation of formation properties. K=Hydraulic conductivity
l_meas_limit_ks	$K_{S\text{-measl-L}}$	m/s	Estimated measurement limit for evaluated K_S. If estimated K_S equals K_S-measlim in the table actual K_S is considered to be equal or less than K_S-measlim
u_meas_limit_ks	$K_{S\text{-measl-U}}$	m/s	Estimated measurement limit for evaluated K_S. If estimated K_S equals K_S-measlim in the table actual K_S is considered to be equal or greater than K_S-measlim
spec_storage_sso	S_{So}	1/m	3D model for evaluation of formation properties. Ss=Specific Storage
dt1	dt_1	s	Estimated start time after pump/injection start OR recovery start, for the period used for the evaluated parameter
dt2	dt_2	s	Estimated stop time after pump/injection start OR recovery start, for the period used for the evaluated parameter
Comments	Comments		Short comment to the evaluated parameters (Optional)

FLOWLOGG-IMPELLER TESTS-plu_impeller_basic

idcode	secup	seclow	test_type	formation_type	start_date (YYYY-MM-DD hh:mm)	stop_date (YYYY-MM-DD hh:mm)	start_flowlogging (YYYY-MM-DD hh:mm:ss)	stop_flowlogging (YYYY-MM-DD hh:mm:ss)	q_measl_l	q_measl_u
Borehole	**Borehole secup** (m)	**Borehole seclow** (m)	**Test type** (1-7)	**Formation type** (-)	**Date and time of test, start** YYYYMMDD hh:mm	**Date and time of stop of flow period**	**Date and time of flowl., start** YYYYMMDD hh:mm	**Date and time of flowl., stop** YYYYMMDD hh:mm	**Q-measl-L** (m^3/s)	**Q-measl-U** (m^3/s)
HFM06	19.50	105.00	6	1	20030121 09:57	20030122 08:54	20030121 17:06	20030121 20:32	5.0E-05	1.7E-03
HFM06	12.00	21.00	6	1	20030122 09:48	20030122 13:31	20030122 12:47	20030122 13:20	5.0E-05	1.7E-03
HFM08	18.00	141.00	6	1	20030217 22:30	20030218 18:28	20030218 12:26	20030218 17:30	5.0E-05	1.7E-03

surface_flow_qp	dur_flow_phase_tp	dur_flowlog_tfl	initial_head_ho	head_first_pump_hp	drawdown_sfl	reference	comments
Q_p (m^3/s)	**tp** (s)	**t_{FL}** (s)	**h_0** (m a s l)	**h_p** (m a s l)	**s_{FL}** (m)	**Reference** (-)	**Comments** (-)
9.97E-04	39480	12360	0.79	-3.39	4.18		
4.15E-04	13380	1980	0.65	-0.62	1.27		Extra flow logging
1.08E-03	36120	18240	-0.35	-1.79	1.44		

plu_impell-main_res

idcode	secup	seclow	l_corr	fluid_temp_tewo	fluid_elcond_ecwo	fluid_salinity_tdswo	cum_flow_qo	fluid_temp_tew	fluid_elcond_ecw	fluid_salinity_tdsw	cum_flow_q1t
Borehole	**Borehole secup** (m)	**Borehole seclow** (m)	**L Corrected** (m)	**Te_{w0}** (^{o}C)	**EC_{w0}** (mS/m)	**TDS_{w0}** (mg/ L)	**Q_0** (m**3/s)	**Te_w** (^{o}C)	**EC_w** (mS/m)	**TDS_w** (mg/ L)	**Q_{1T}** (m**3/s)
HFM06	19.50	105.00									7.62E-04
HFM06	12.00	21.00									3.33E-04
HFM08	18.00	141.00									1.53E-03

cum_flow_qt		transmissitivy_hole_t	cum_transmissivity_tf	l_meas_limit_tf	u_meas_limit_tf	reference	comments
Q_T (m**3/s)	**Q_{Tcorr}**	**T Entire hole** (m^2/ s)	**T_{FT}** (m^2/ s)	**T_F-measl-L** (m^2/ s)	**T_F-measl-U** (m^2/ s)	**Reference** (-)	**Comments** (-)
7.62E-04	9.97E-04	3.32E-04	3.32E-04	2.0E-06	2.0E-03		Final bh. Diam=134 mm, Flow calibration=135.5 mm
3.33E-04	4.15E-04	3.32E-04	3.32E-04	2.0E-06	2.0E-03		Final bh. Diam=134 mm, Flow calibration=135.5 mm
1.53E-03	1.08E-03	1.29E-03	1.29E-03	2.0E-06	2.0E-03		Final bh. Diam=137 mm, Flow calibration=140 mm

FLOWLOGG-IMPELLER TESTS plu_impeller_anomaly

idcode	secup	seclow	upper_limit	lower_limit	fluid_temp tew	fluid_elcond_ ecw	fluid_salinity tdsw	deltaqi		spec_cap_deltaqi_ sfl	bi
Borehole	**Borehole secup** (m)	**Borehole seclow** (m)	**Upper limi** L (m)	**Lower limi** L (m)	**Te_w** (^{o} C)	**EC_w** (mS/m)	**TDS_w** (mg/ L)	**$deltaQ_i$** (m**3/s)	**$deltaQ_{icorr}$** (m**3/s)	**$deltaQ_{icorr}/s_{FL}$** (m**2/s)	**b_i** (m)
HFM06	19.50	105.00	20.5	23				1.15E-04	1.50E-04	3.60E-05	2.5
HFM06	19.50	105.00	42.5	44				1.22E-04	1.63E-04	3.90E-05	1.5
HFM06	19.50	105.00	60	64				1.00E-04	1.34E-04	3.20E-05	4
HFM06	19.50	105.00	69	71				4.17E-04	5.52E-04	1.32E-04	2
HFM06	12.00	21.00	Inga ytterligare flödesanomalier påträffades inom detta intervall vid den kompletterande flödesloggningen								
HFM08	18.00	141.00	89.5	90				6.67E-05	4.71E-04	3.27E-05	0.5
HFM08	18.00	141.00	137.5	139.5				1.47E-03	1.04E-03	7.21E-04	2

transmissivity_ ti	l_meas_limit_ti	u_meas_limit_ti	reference	comments
T_i (m^2/ s)	**T_i-measl-L** (m^2/ s)	**T_i-measl-U** (m^2/ s)	**Reference** (-)	**Comments** (-)
5.00E-05				Assumption:Q_T=Q_p
5.30E-05				Assumption:Q_T=Q_p
4.40E-05				Assumption:Q_T=Q_p
1.85E-04				Assumption:Q_T=Q_p
5.70E-05				Assumption:Q_T=Q_p
1.20E-03				Assumption:Q_T=Q_p

SICADA - description of plu_impell_main_res

--- Short Description **:** Flowlogging with impeller, evaluated data of the entire hole

--- Long Description: ---

Flowlogging with impeller, evaluated data of the entire hole

Column Name	Header	Unit	Description
start_date	Date/time test start	date	Date for the start of the test (YYYY-MM-DD hh:mm)
stop_date	Date/time test stop	date	Date for the stop of the test (YYYY-MM-DD hh:mm)
idcode	Borehole	idcode	Object or borehole identification code
secup	Borehole secup	m	Upper section limitof logged interval(m)
seclow	Borehole seclow	m	Lower section limit logged interval (m)
l_corr	L , Corrected	m	Corrected length to point considered representative for measured value
cum_flow_q	Q	m**3/s	Cumulative flow rate:Q1-Qo. Position for measurement is related to L_0 (corrected length)
cum_flow_qo	Q_0	m^3/s	Natural (undisturbed) measured cummulative flow rate. Position for measurement is related to L (corrected lenght)
cum_flow_q1t	Q_{1T}	m^3/s	Cummulative flow rate:Q_1 at the top of measured interval
cum_flow_qt	Q_T	m^3/s	Cummulative flow rate:Q_1 at the top of measured interval
transmissitivy_hole_t	T(Entire hole)	m**2/s	Evaluated transmissivity for the entire hole section that isconsidered representative for the flowlogging (also reported in data file for single-hole interpretation)
cum_transmissivity_tf	T_F	m**2	Cumulative transmissivity based on impeller measurement. 2D model for evaluation of formation properties of the test section. T_F = Óti = T*(Q_T/Q_p)
cum_transmissivity_tft	T_{FT}	m**2	Cumulative transmissivity of the entire measured interval, based on impeller measurement
l_meas_limit_tf	T_F-measl-L	m**2/s	Estimated lower measurement limit for evaluated T_F. If estimated T_F equals T-measlim in the table, the actual T_F is considered to be equal or less than T_F - measlim
u_meas_limit_tf	T_F-measl-U	m**2/s	Estimated upper measurement limit for evaluated T_F. If estimated T_F equals T-measlim in the table, the actual T_F is considered to be equal or greater than T_F - measlim
fluid_temp_tewo	Te_{w0}	gr C	Natural (undisturbed) fluid temperature in the test section representative for the evaluated parameters. Position for measurement is related to L (corrected length)
fluid_elcond_ecwo	EC_{w0}	mS/m	Natural (undisturbed) electrical conductivity of the fluid in the test section representative for the evaluated parameters. Position for measurement is related to L (corrected length)
fluid_salinity_tdswo	TDS_{w0}	mg/L	Natural (undisturbed) total salinity of the fluid in the test section representative for the evaluated parameters based on EC. Position for measurement is related to L (corrected length)
fluid_temp_tew	Te_w	gr C	Fluid temperature in the test section representative for the evaluated parameters. Position for measurement is related to L (corrected length)
fluid_elcond_ecw	EC_w	mS/m	Electrical conductivity of the fluid in the test section representative for the evaluated parameters. Position for measurement is related to L (corrected length)
fluid_salinity_tdsw	TDS_w	mg/L	Total salinity of the fluid in the test section representative for the evaluated parameters based on EC. Position for measurement is related to L (corrected length)

reference	Reference	text_30	SKB number for reports describing data and results
comments	Comments	text_60	Short comment to evaluated data (optional)

SICADA - description of plu_impeller_basic_d

--- Short Description: -- **:** Flow logging using impeller, basic data

--- Long Description: ---

Sicada_header	Header	Unit	Description
start_date	date	date	Date for the stop of the test (YYYY-MM-DD hh:mm)
stop_date	Date for test stop	date	Date for the stop of the test (YYYY-MM-DD hh:mm)
secup	Borehole secup	m	Lengt coordinate along the borehole for the upper limit of the logged section (Based on corrected length L)
seclow	Borehole seclow	m	Lengt coordinate along the borehole for the lower limit of the logged section. (Based on corrected length L)
start_flowlogging	date and ..	date_s	Date and time of flowlogging start(YYYY-MM-DD hh:mm:ss)
stop_flowlogging	date and..	date_s	Date and time of flowlogging start(YYYY-MM-DD hh:mm:ss)
test_type	Test type (1-7)	code_chr_2	1A: Pumping test - wireline eq., 1B:Pumping test-submersible pump, 1C: Pumpingtest-airlift pumping, 2: Interference test, 3: Injection test, 4: Slug test, 5A: Difference flow logging-PFL-DIFF-comb.Sequential and overlapping, 5B: Difference flow logging-PFL-DIFF-Overlapping, 6: Flow logging-Impeller 7: Grain size analysis
formation_type	Formation type	code_chr_2	1: Rock, 2: Soil (supeficial deposits)
q_measl_l	Q-measl-L	m^3/s	Estimated lower measurement limit for borehole flow rate in flowlogging probe
q_measl_u	Q-measl-U	m^3/s	Estimated upper measurement limit for borehole flow rate in flowlogging probe
surface_flow_qp	Q_p	m^3/s	Flow rate at surface during flowlogging
dur_flow_phase_tp	tp	s	Time for the flowing phase of the test
dur_flowlog_tfl	t_{FL}	s	Duration of the flowlogging survey
drawdown_sfl	s_{FL}	m	Average drawdown of the water level in open borehole during flowlogging
initial_head_ho	h_0	m	Initial hydraulic head. Measured as water level in open borehole with reference level in the local coordinates system with z=0 m.
head_first_pump_hp	h_p	m	Stabilised hydraulic head during first pumping period. Measured as water level in open borehole with reference level in the local coordinates system with z=0 m.
reference	References		SKB report No for reports describing data and evaluation
comments	varchar(60)	comment_text	Short comment to the evaluated parameters (optional))

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SICADA - description of plu_impeller_anomaly

--- Short Description: --- Evaluated data of interpreted anomalies

--- Long Description: ---

Table 'plu_impeller_anomaly' Data and evaluated parameters of interpreted anomalies

Column Name	**Header**	**Unit**	**Description**
start_date	Date/time for test start	date	Date (yymmdd hh:mm)
stop_date	Date/time for test stop	date	Date (yymmdd hh:mm)
idcode	Borehole	idcode	Object or borehole identification code
secup	Borehole secup	m	Upper section limit (m)
seclow	Borehole seclow	m	Lower section limit (m)
upper_limit	Upper limit	m	Corrected length coordinate along the borehole for the upper limit of the flow anomaly
lower_limit	Lower limit	m	Corrected length coordinate along the borehole for the lower limit of the flow anomaly
fluid_temp_tew	Te_w	centigrade	Natural (undisturbed) fluid temperature in the test section representative for the evaluated parameters. Position for measurement is related to L (corrected lenght)
fluid_elcond_ecw	EC_w	mS/m	Natural (undisturbed) electrical conductivity of the fluid in the test section representative for the evaluated parameters. Position for measurement is related to L (corrected lenght)
fluid_salinity_tdsw	TDS_w	mg/L	Natural (undisturbed) total salinity of the fluid in the test section representative for the evaluated parameters based on EC. Position for measurement is related to L (corrected lenght)
deltaqi	$deltaQ_i$	m**3/s	deltaQi : Flow rate of interpreted flow anomaly i
spec_cap_deltaqi_sw	$deltaQ/S_w$	m**2/s	$deltaQi/s_{FL}$: Specific capacity of interpreted flow anomaly
bi	b_i	m	Interpreted formation thickness representative for evaluated Ti of anomaly i.
transmissivity_ti	T_i	m**2/s	Evaluated transmissivity of flow anomaly i considered representative for the flow logging
l_meas_limit_ti	T_i-measlim-L	m**2/s	Estimated lower measurement limit for evaluated $T_{i.}$ If estimated T_i equals T-measlim in the table actual T_i is considered to be equal or less thanT_i-measlim
u_meas_limit_ti	T_i-measlim-L	m**2/s	Estimated upper measurement limit for evaluated $T_{i.}$ If estimated T_i equals T_i-measlim in the table actual T_i is considered to be equal or greater thanT_i-measlim
comments	Comments	text_50	Short comment on evaluated parameters

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