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Forsmark site investigation

Pumping tests and flow logging

Boreholes HFM24, HFM32

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May 2006

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Abstract

Primarily borehole HFM24 was drilled to provide flush water to the core drilling of borehole KFM10A, while HFM32 was drilled to examine the groundwater conditions in the rock under Lake Bolundsfjärden. Of special interest is to find out whether inflow or outflow conditions are prevailing in the rock, that is whether the pressure gradient is directed upward or downward.

The main objectives of the hydraulic tests in the percussion boreholes HFM24 and HFM32 were to investigate the hydraulic characteristics (e.g. occurrence and hydraulic transmissivity of different hydraulic conductors) and the water chemistry characteristics of the boreholes.

Pumping tests in conjunction with flow logging were performed in the two boreholes. In order to supplement the results from the flow logging, a short pumping test was conducted in HFM32 below a single packer located below the deepest inflow point found during the flow logging. During the drilling of HFM32 now inflow was encountered between the end of the casing and the highest flow logged location (c 2.5 m below the casing) and in HFM24 it was possible to carry out the flow logging all the way up to the casing. Therefore, no further tests to detect any possible flow anomalies above highest flow logged location were done in the boreholes.

Water sampling was performed to investigate the hydrochemistry of the groundwater in all boreholes in conjunction with the pumping tests. No other borehole tests had been carried out in the actual boreholes before this campaign.

The total borehole transmissivity of HFM24 was estimated to $1.1 \cdot 10^{-4}$ m^2/s. The flow logging indicated six conductive sections at a borehole length of 18–49.5 m (see Table 6-14).

The total transmissivity of borehole HFM32 was estimated to $9.4 \cdot 10^{-4}$ m^2/s. Six conductive parts were found during the flow logging in the borehole interval 12.3–30.3 m. The pump test in the lower part of the borehole (below a packer at 49–50 m) resulted in a transmissivity of $2.7 \cdot 10^{-5}$ m^2/s. See further Table 6-14.

Sammanfattning

HFM 24 borrades i första hand för att förse kärnborrningen av KFM10A med spolvatten, medan huvudsyftet med HFM32 var för att undersöka grundvattenförhållandena i berget under Bolundsfjärden. Speciellt vill man veta om det råder utströmnings- eller inströmningsförhållanden i bergrunden, dvs. om man har en uppåtriktad eller nedåtriktad tryckgradient mellan olika hydrauliska ledare i borrhålet.

Huvudsakliga syftet med de hydrauliska tester i hammarborrhål HFM24 and HFM32 som presenteras i denna rapport var att undersöka hydrauliska egenskaper (t ex förekomst och hydraulisk transmissivitet av enskilda hydrauliska ledare) och vattenkemi.

Pumptester i kombination med flödesloggning utfördes i båda borrhålen. För att komplettera resultatet från flödesloggningen utfördes ett kortare pumptest under en enkelmanschett i HFM32, placerad strax under den djupaste inflödespunkten. I HFM32 hade borrningen inte visat på några inflöden mellan foderrörets nedre kant och det högsta spinnerläget (ca 2.5 m under foderrörskanten) och i HFM24 kunde flödesloggningen utföras ända upp till foderrörskanten. Därför gjordes inga ytterligare tester för att påvisa eventuella anomalier ovanför högsta spinnerläge.

Vattenprover för undersökning av grundvattnets hydrokemiska egenskaper togs i samband med pumptesterna i borrhålen. Före denna mätinsats hade inga andra hydrauliska tester genomförts i dessa borrhål.

Totala transmissiviteten för HFM24 uppskattades till $1{,}1 \cdot 10^{-4}$ m^2/s. Flödesloggningen indikerade 6 konduktiva avsnitt mellan 18 och 49,5 m borrhålslängd, se tabell 6-14.

För HFM32 uppskattades den totala transmissiviteten till $9{,}4 \cdot 10^{-4}$ m^2/s. Sex konduktiva sektioner påträffades under flödesloggningen i borrhålsavsnittet 12,3–30,3 m. Pumptestet i den nedre delen av borrhålet (under en manschett på 49–50 m) resulterade i en transmissivitet på $2{,}7 \cdot 10^{-5}$ m^2/s. Se vidare tabell 6-14.

Contents

1 Introduction

This document reports the results of the hydraulic testing of boreholes HFM24 and HFM32 within the Forsmark site investigation. The tests were carried out as pumping tests combined with flow logging. In addition, a shorter pumping test was performed below a packer at 49–50 m in borehole HFM32. Water sampling was undertaken in both boreholes in conjunction with the tests. No other hydraulic tests had been carried out in the actual boreholes before this campaign.

Borehole HFM24 is situated close to drilling site DS10 and HFM32 on a small islet in Bolundsfjärden, approximately 500 m NE of Drilling Site 10 (at KFM10A), see Figure 1-1.

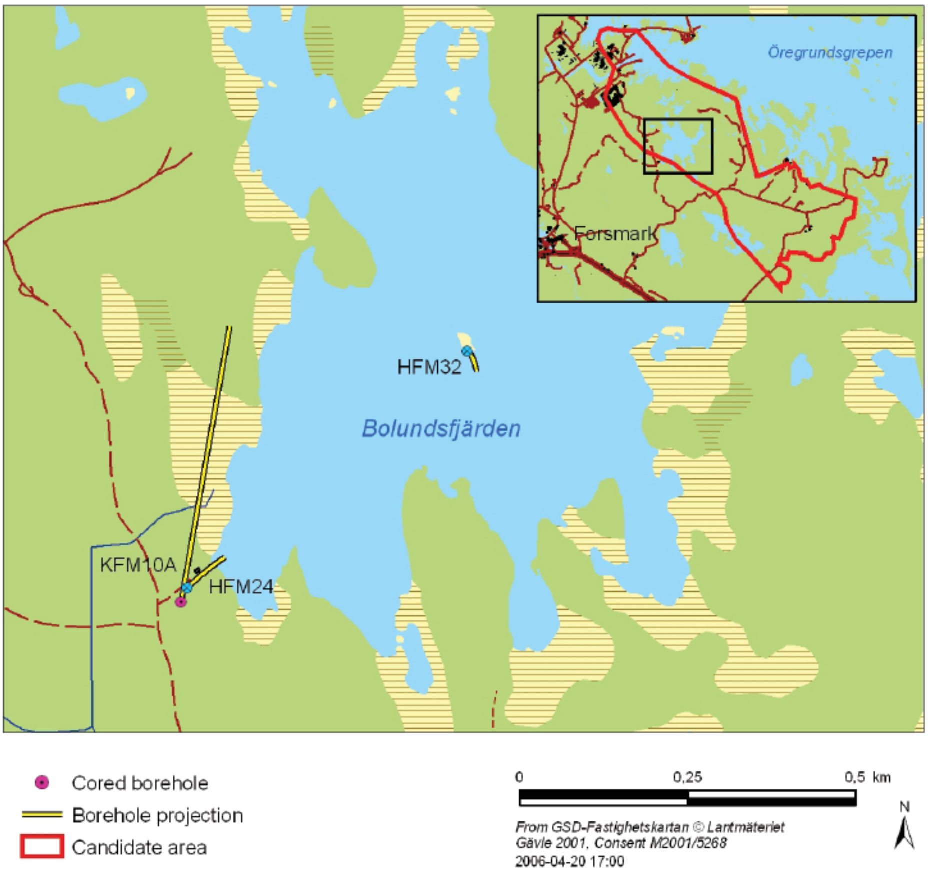


***Figure 1-1.** Map showing the location of boreholes HFM24 and HFM32.*

The work was carried out in accordance to SKB internal controlling documents; see Table 1-1. Data and results were delivered to the SKB site characterization database SICADA, where they are traceable by the Activity Plan number.

Table 1-1. SKB Internal controlling documents for performance of the activity.

Activity Plan	Number	Version
Hydrotester och vattenprovtagning i hammarborrhålen HFM23, HFM24, HFM25, HFM26, HFM27, HFM28 och HFM32	AP PF 400-05-121	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för hydrauliska enhålspumptester	SKB MD 321.003	1.0
Metodbeskrivning för flödesloggning	SKB MD 322.009	1.0
Instruktion för analys av injektions- och enhålspumptester	SKB MD 320.004	1.0
Mätsystembeskrivning för HydroTestutrustning för HammarBorrhål. HTHB	SKB MD 326.001	3.0

2 Objectives

The objectives of the pumping tests and flow logging in boreholes HFM24 and HFM32 were to investigate the hydraulic properties of the penetrated rock volumes, for example by identifying the position and hydraulic character of major inflows (which may represent e.g. sub-horizontal fracture zones). Furthermore, the aim was also to investigate the hydro-chemical properties of the groundwater.

Of special interest in HFM32 is to find out, by dividing the borehole in suitable sections for long term pressure measurements, whether the rock below Lake Bolundsfjärden is acting as an inflow or outflow area for groundwater.

3 Scope

3.1 Boreholes tested

Technical data of the boreholes tested are displayed in Table 3-1. The reference point in the boreholes is always top of casing (ToC). The Swedish National coordinate system (RT90 2.5 gon W) is used in the x-y-plane together with RHB70 in the z-direction. Northing and Easting refer to the top of the boreholes at top of casing. The borehole diameter in Table 3-1, measured as the diameter of the drill bit, refers to the initial diameter below the casing. The borehole diameter decreases more or less along the borehole due to wearing of the drill bit.

Table 3-1. Selected technical data of 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) (°)	Dip-Direction – top of bh (°)	Northing (m)	Easting (m)	Length (m)	Inner diam. (m)	Date (YYYY-MM-DD)
HFM24	3.68	151.35	0.140	–59.6	47.3	6698662	1631719	18.03	0.160	2005-11-29
HFM32	0.97	202.65	0.141	–86.1	116.1	6699015	1632137	6.03	0.160	2006-01-14

3.2 Tests performed

The different test types conducted in boreholes HFM24 and HFM32 as well as the test periods are presented in Table 3-2.

During the pumping tests, water samples were collected and submitted for analysis, see Section 6.2. Manual observations of the groundwater level in the pumped boreholes were also made during the tests.

Table 3-2. Borehole tests performed.

Bh ID	Test section (m)	Test type 1	Test config.	Test start date and time (YYYY-MM-DD tt:mm)	Test stop date and time (YYYY-MM-DD tt:mm)
HFM24	18.0–151.4	1B	Open hole	2006-02-07 07:39	2006-02-08 07:32
HFM24	18.0–150.0	6, L-Te, L-EC	Open hole	2006-02-07 15:48	2006-02-07 18:39
HFM32	6.0–202.7	1B	Open hole	2006-01-17 07:56	2006-01-18 08:25
HFM32	8.3–131.7	6, L-Te, L-EC	Open hole	2006-01-17 14:18	2006-01-17 17:53
HFM32	50.0–202.7	1B	Below packer	2006-01-18 14:00	2006-01-18 17:00

[1]1B: Pumping test-submersible pump, 3: Injection test, 6: Flow logging–Impeller. L-EC: EC-logging, L-Te: temperature logging.

3.3 Equipment check

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 the water while lowering, measured pressure coincided well with the total head of water ($p/\rho g$). The temperature sensor displayed expected values in both air and water.

The sensor for electric conductivity displayed a zero value in air and expected level in borehole. The impeller used in the flow logging equipment worked well as indicated by the rotation read on the data logger while lowering. The measuring wheel (used to measure the position of the flow logging probe) and the sensor attached to it indicated a length that corresponded well to the pre-measured length marks on the signal cable.

4 Description of equipment

4.1 Overview

The equipment used in these tests is referred to as HTHB (Swedish abbreviation for Hydraulic Test System for Percussion Boreholes) and is described in the user manual of the measurement system.

The HTHB unit is designed to perform pumping- and injection tests in open percussion drilled boreholes (Figure 4-1), and in isolated sections of the boreholes (Figure 4-2) down to a total depth (borehole length) of 200 m. With the HTHB unit, it is also possible to perform a 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, however, the upper packer can not be located deeper than c 80 m due to limitations in the number of pipes available.

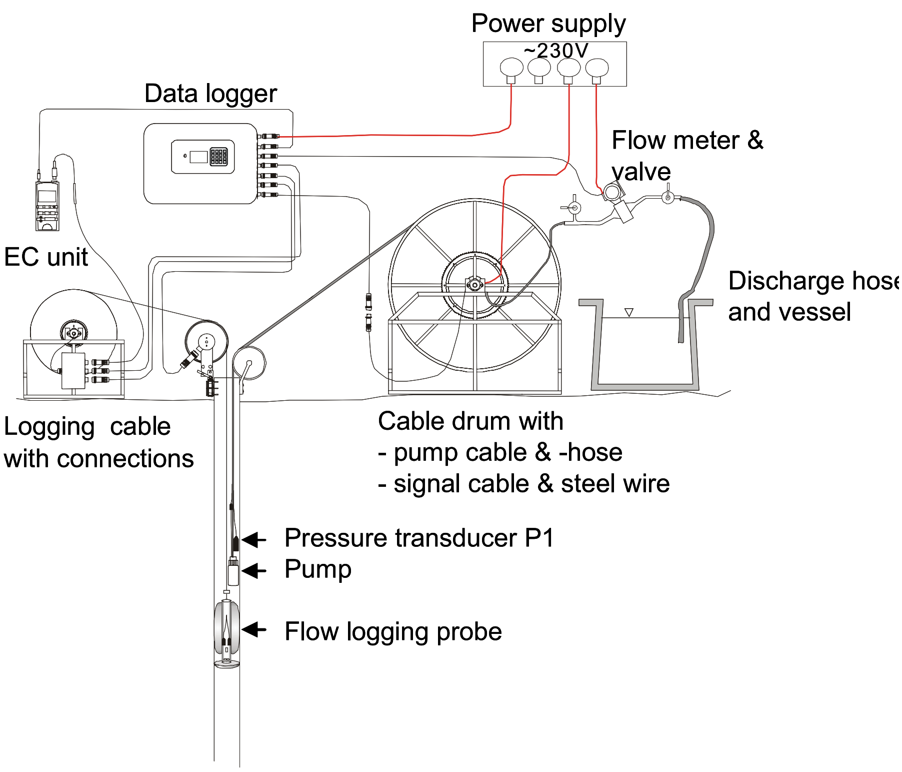


Figure 4-1. *Schematic test set-up for a pumping test in an open borehole in combination with flow logging with HTHB. (From SKB MD 326.001, SKB internal document).*

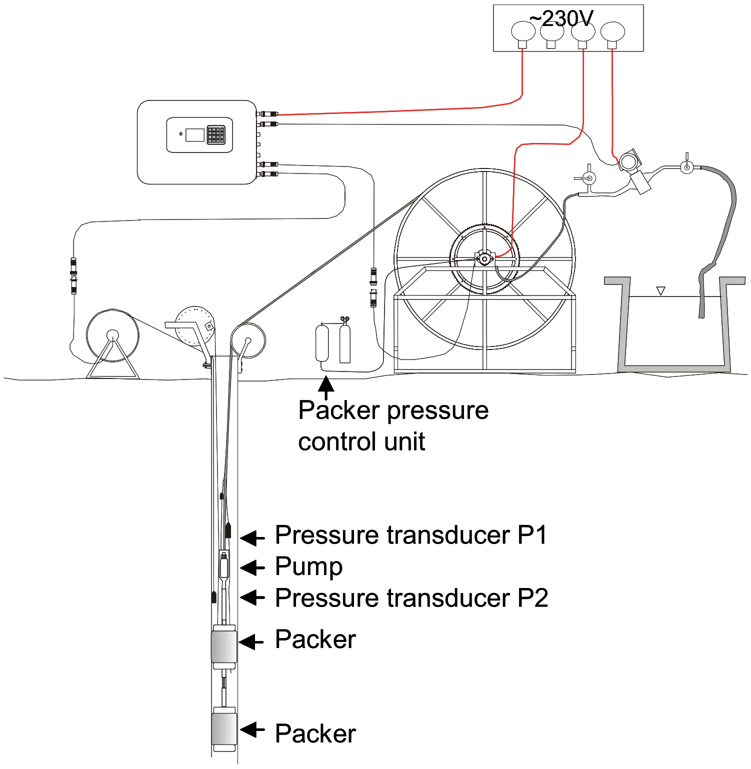


Figure 4-2. *Schematic test set-up for a pumping test in an isolated borehole section with HTHB. (From SKB MD 326.001, SKB internal document).*

All equipment that belongs to the HTHB system is, when not in use, stored on a trailer and can easily be transported by a standard car. The borehole equipment includes a submersible borehole pump with housing, expandable packers, pressure sensors and a pipe string and/or hose. During flow logging, the sensors measuring temperature and electric conductivity as well as down-hole flow rate are also employed. At the top of the borehole, the total flow/injection rate is manually adjusted by a control valve and 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 for pressurization) unless the depth to the groundwater level is large, or the risk of freezing makes the use of water unsuitable. 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 (if required).

4.2 Measurement sensors

Technical data of the sensors used together with estimated data specifications of the HTHB test system for pumping tests and flow logging are given in Table 4-1.

Table 4-1. Technical data of measurement sensors used together with estimated data specifications of the HTHB test system for pumping tests and flow logging (based on current laboratory- and field experiences).

Technical specification					
Parameter		**Unit**	**Sensor**	**HTHB system**	**Comments**
Absolute pressure	Output signal	mA	4–20		
	Meas. range	kPa	0–1,500	0–1,500	
	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	0–50,000	0–50,000	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 mm borehole diameter and 100 s sampling time
	Accuracy***	% o.r.**		± 20	
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	± 0.5	

* Includes hysteresis, linearity and repeatability.
** Maximum error in % of actual reading (% o.r.).
*** Applicable to boreholes with a borehole diameter of 140 mm and 100 s sampling time.
**** For injection tests the minimal flow rate is 1 L/min.

Errors in reported borehole data (diameter etc) 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 determinations of the borehole inclination may also affect the accuracy of measured data.

The flow logging probe is calibrated for different borehole diameters (in reality different pipe diameters), i.e. 111.3, 135.5, 140 and 162 mm. During calibration the probe is installed in a vertically orientated pipe and a water flow is pumped through. The spinner rotations and 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 how sensible the probe is to deviations in the borehole diameter, cf Figure 4-3.

The stabilisation time may be up to 30 s at flows close to the lower measurement limit, whereas the stabilisation is almost instantaneous at high flows.

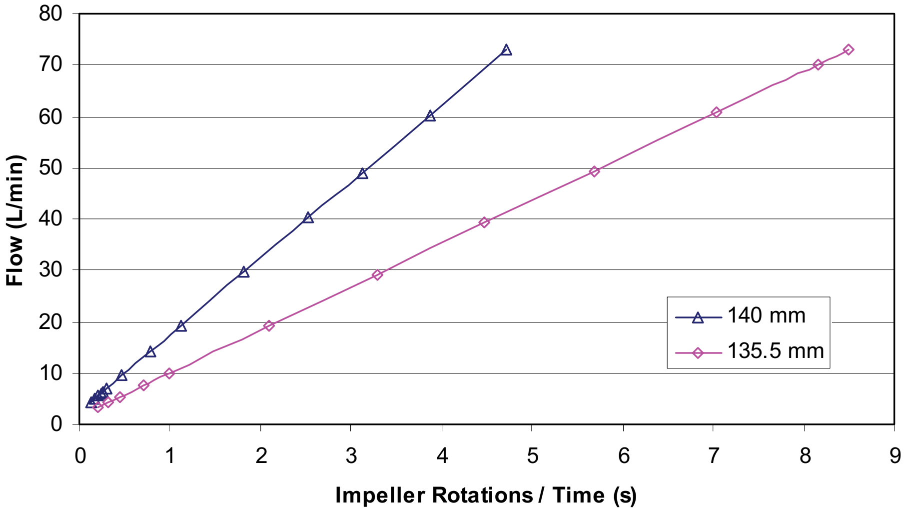


Figure 4-3. *Total flow as a function of impeller rotations for two borehole diameters (140 and 135.5 mm).*

Table 4-2 presents the position of sensors for each test together with the level of the pump-intake of the submersible pump. The following types of sensors are used: pressure (p), temperature (Te), electric conductivity (EC). Positions are given in metres 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 submerged item. Position is given as "in section" or "above section". The volume of the submerged pump (~ 4 dm^3) is not involved in the wellbore storage since the groundwater level always is kept above the top of the pump in open boreholes.

In addition, the theoretical wellbore storage coefficient C for the actual test configurations and geometrical data of the boreholes were 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 wellbore 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[2)] relative test section**	**Outer diameter (mm)**	**C (m^3/Pa) for test[3)]**
HFM24	18.0–151.4	Open hole	1B	Pump-intake	13.9	Pump hose	In section	33.5	$1.9 \cdot 10^{-6}$
			1B			Pump cable	In section	14.5	
			1B			Steel wire	In section	5	
			1B			Polyamide tube	In section	6	
			1B	P (P1)	11.22	Signal cable	In section	8	
			6	EC, Te, Q	17.5–150.0	Signal cable	In section	13.5	
HFM32	6.0–202.7	Open hole	1B	Pump-intake	7.4/5.4[4)]	Pump hose	In section	33.5	$1.9 \cdot 10^{-6}$
			1B			Pump cable	In section	14.5	
			1B			Steel wire	In section	5	
			1B			Polyamide tube	In section	6	
			1B	P (P1)	4.72/2.72	Signal cable	In section	8	
			6	EC, Te, Q	8.5–131.7	Signal cable	In section	13.5	
HFM32	50.0–202.7	Below packer	1B	P (P1)	45.07				$1.0 \cdot 10^{-9}$
				P (P2)	10.00				

[1)] 1B: Pumping test-submersible pump, 3: Injection test, 6: Flow logging–Impeller incl. EC-logging (EC-sec) and temperature logging (Te-sec).
[2)] Position of equipment that can affect wellbore storage. Position given as “In Section” or “Above Section”.
[3)] Based on the casing diameter or the actual borehole diameter (Table 3-1) for open-hole tests together with the compressibility of water for the test in isolated sections, respectively (net values).
[4)] The pump was lifted 2 m at the end of the flow logging to allow for an uppermost logging at 8.5 m borehole length.

5 Execution

5.1 Preparations

All sensors included in the HTHB system are calibrated at the Geosigma engineering service station in Uppsala. Calibration is generally performed on a yearly basis, but more often if needed. The latest calibration was performed in September 2005. If a sensor is replaced at the test site, calibration of the new sensor can be carried out in the field (except the flow probe) or alternatively, in the laboratory after the measurements. Due to a breakage in the signal cable to the electric conductivity sensor during the latest calibration the calibration constants achieved during the former calibration in April 2004 were used for the repaired sensor.

Functioning checks of the equipment used in the present test campaign were performed before each hydraulic test. The results from the functioning checks are presented in Section 3.3.

Before the tests, cleaning of equipment as well as time synchronisation of clocks and data loggers was performed according to the Activity Plan.

5.2 Procedure

5.2.1 Overview

The main pumping tests in HFM24 and HFM32 were carried out as single-hole, constant flow rate tests followed by pressure recovery periods. At the end of the pumping period flow logging was performed. A second pumping test below a single packer at 49–50 m was made in HFM32 to achieve the transmissivity below the lowest detected anomaly at c 30 m.

Before flow logging is started, the intention is to achieve approximately steady-state conditions in the borehole.

The flow logging is performed with discrete flow measurements made at fixed step lengths (5 m until the first flow anomaly is found and 2 m thereafter), starting from the bottom and upwards along the borehole. When a detectable flow anomaly is found, the flow probe is lowered and repeated measurements with a shorter step length (0.5 m) are made to determine a more correct position of the anomaly. The flow logging survey is terminated a short distance below the submersible pump in the borehole.

5.2.2 Details

Single-hole pumping

Before the pumping tests, short flow capacity tests were carried out to select an appropriate flow rate or an appropriate drawdown for the tests. The pumped water from HFM32 was discharged to lake Bolundsfjärden and from HFM24 on the ground, sloping downhill from the borehole.

The main test in each borehole was a c 10 h pumping test in the open hole in combination with flow logging, followed by a recovery period of c 12 h. The pumping test below a packer in HFM32 was 1.5 h long, followed by a recovery of 1.5 h.

A failure in the electric plant supporting the test site at HFM32 with electricity, caused an 18 minutes break in the pumping after ca 2½ h.

In general, the sampling frequency of pressure and flow during the pumping tests was according to Table 5-1. The hydraulic tests in borehole HFM32 were performed before the tests in HFM24.

Table 5-1. Sampling interval 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

Flow logging

Prior to the start of the flow logging, the probe was lowered to the bottom of the borehole. While lowering along the borehole, temperature- and electric conductivity data were sampled.

Flow logging was performed during the long pumping test (10 h), 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 3–5 hours is normal for a percussion borehole of 100–200 m length, cf Section 6.4.

5.3 Data handling

Data are downloaded from the logger (Campbell CR 5000) 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 necessarily transformed to *.mio-files. A list of all data files from the logger is presented in Appendix 1.

Processed data files (*.mio-files) are used to create linear plots of pressure and flow versus time with the code SKBPLOT and evaluation plots with the software AQTESOLV, according to the Instruction for analysis of injection- and single-hole pumping tests (SKB MD 320.004, SKB internal document).

5.4 Analyses and interpretation

5.4.1 Single-hole pumping tests

Firstly, a qualitative evaluation of actual flow regimes (wellbore storage, pseudo-linear, pseudo-radial and pseudo-spherical flow, respectively) and possible outer boundary conditions during the hydraulic tests was performed. The qualitative evaluation was made from analyses of log-log diagrams of drawdown and/or recovery data together with the corresponding derivatives versus time. In particular, pseudo-radial flow (2D) is reflected by a constant (horizontal) derivative in the diagrams. Pseudo-linear and pseudo-spherical flow are reflected by a slope of the derivative of 0.5 and –0.5, respectively in a log-log diagram. Apparent no-flow- and constant head boundaries are reflected by a rapid increase and decrease of the derivative, respectively.

From the results of the qualitative evaluation, appropriate interpretation models for the quantitative evaluation of the tests were selected. In most cases, a certain period with pseudo-radial flow could be identified during the pumping tests. Consequently, methods for single-hole, constant-flow rate and constant drawdown tests for radial flow in a porous medium described in /2/ and /3/ were generally used by the evaluation of the tests. For tests indicating a fractured- or borehole storage dominated response, corresponding type curve solutions were used by the routine analyses.

If possible, transient analysis was applied on both the drawdown- and recovery phase of the tests. The recovery data were plotted versus equivalent time. Transient analysis of drawdown- and recovery data was made in both log-log and lin-log diagrams as described in the Instruction (SKB MD 320.004). In addition, a preliminary steady-state analysis (e.g. Moye's formula) was made for all tests for comparison.

The transient analysis was performed using a special version of the aquifer test analysis software AQTESOLV which enables both visual and automatic type curve matching with different analytical solutions for a variety of aquifer types and flow conditions. The evaluation is performed as an iterative process of type curve matching and non-linear regression on the test data. For the flow period as well as the recovery period of the constant flow rate tests, a model presented by Dougherty-Babu (1984) /3/ for constant flow rate tests with radial flow, accounting for wellbore storage and skin effects, was generally used for estimating transmissivity, storativity and skin factor for actual values on the borehole- and casing radius.

The effective casing radius may be estimated from the regression analysis for tests affected by wellbore storage. The wellbore storage coefficient can be calculated from simulated effective casing radius, see below. The effective wellbore radius concept is used to account for negative skin factors. AQTESOLV also includes models for discrete fractures (horizontal and vertical, respectively) intersecting the borehole, causing pseudo-linear flow.

Rather than assuming a fixed value of the storativity of $1\cdot10^{-6}$ by the analysis according to the instruction SKB MD 320.004, an empirical regression relationship between storativity and transmissivity, Equation 5-1 (Rhén et al. 1997) /4/ was used. Firstly, the transmissivity and skin factor were obtained by type curve matching on the data curve using a fixed storativity value of 10^{-6}. From the transmissivity value obtained, the storativity was then calculated according to Equation 5-1 and the type curve matching was repeated.

$$S = 0.0007\cdot T^{0.5} \qquad (5\text{-}1)$$

S = storativity (–)

T = transmissivity (m^2/s)

In most cases the change of storativity does not significantly alter the calculated transmissivity by the new type curve matching. Instead, the estimated skin factor, which is strongly correlated to the storativity was altered correspondingly.

The nomenclature used for the simulations with the AQTESOLV code is presented in the beginning of Appendix 2.

Estimations of the borehole storage coefficient, C, based on actual borehole geometrical data (net values) according to Equation (5-2) and (5-3), are presented in Table 4-2. The borehole storage coefficient may also be estimated from the early test response with 1:1 slope in a log-log diagram /2/ or alternatively, from the simulated effective casing radius. These values on C may be compared with the net values of the wellbore storage coefficient based on actual borehole geometrical data. The estimated values on C from the test data may differ from the net values due to deviations of the actual geometrical borehole data from the anticipated, e.g. regarding the borehole diameter, or presence of fractures or cavities with significant volumes.

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

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

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

$$C = \pi\, r_w^2 \cdot L_w \cdot c_w \qquad (5\text{-}3)$$

r_{we} = borehole radius where the changes of the groundwater level occur (either r_w or r_c) or alternatively, the simulated effective casing radius

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 flow logging (flow, temperature and electric conductivity of the borehole fluid) were firstly plotted versus borehole length. From these plots, flow anomalies were identified along the borehole, i.e. borehole intervals over which changes of flow exceeding c 1 L/min occur. The size of the inflow at the flow anomaly is determined by the actual change in flow rate over the interval. In most cases, the flow changes are accompanied by changes in temperature and/or electric conductivity of the fluid. If the actual borehole diameter differs from the one assumed by the calibration of the flow probe, corrections of the measured borehole flow rates may be necessary, cf Figure 4-3.

Flow logging can be carried out from the borehole bottom up to a certain distance below the submersible pump (c 2.5 m). 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 here. 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) measured 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. However, one must be careful when interpreting absolute flow values measured by the flow logging probe since it is very sensitive to the borehole diameter. The probe is calibrated in a tube with a certain diameter (see 2.0) but the actual borehole diameter, measured as the diameter of the drill bit, is most often deviating from the nominal diameter. Furthermore, the borehole diameter is normally somewhat larger than the diameter of the drill bit, depending, among other things, on the rock type. The diameter is also decreasing towards depth, due to successive wearing of the drill bit.

To account for varying diameter along the borehole, one may use the logging in the undisturbed borehole when lowering the flow logging probe before pumping. Under the assumption of a linear relationship between borehole diameter and gain in the calibration function, transforming counts per seconds from the flow sensor to engineering units (L/min), and using known borehole diameters at two or more borehole lengths, one can obtain a relationship between gain and borehole length in the actual borehole. Since the absolute value of the measured borehole diameter is uncertain and the measured borehole flow to some degree probably also depends on borehole inclination, it is often necessary to make a final factor correction to achieve correspondence between the measured borehole flow at the top of the flow logged interval and the pumped flow measured by the flow meter at surface. To make these corrections, all significant flow anomalies, also above the pump, must be quantified. Therefore, it may be necessary to supplement the flow logging with injection or pumping tests above the highest logged level in the borehole, unless it is possible to carry out the flow logging to the lower end of the casing, or if other information (e.g. BIPS logging or drilling information) clearly shows that no inflow occurs in this part of the borehole.

The transmissivity (T) of the entire borehole was calculated from the analysis of the pumping test during the flow logging. The cumulative transmissivity at the top of the flow-logged interval ($T_{FT} = \Sigma T_i$) was then calculated according to the Methodology description for Impeller flow logging (assuming zero natural flow in the borehole):

$$T_{FT} = \Sigma T_i = T \cdot Q_T / Q_p \quad (5\text{-}4)$$

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 be estimated from injection or pumping tests above the highest flow-logged borehole length (see above).

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

$$T_i = T \cdot dQ_i / Q_p \quad (5\text{-}5)$$

For comparison, estimations of the transmissivities of the identified flow anomalies were also made from the specific flows, simply by dividing the measured inflow (dQ_i) at the anomaly by the drawdown (s_{FL}) in the hole during the flow logging (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 borehole length (L) as determined from the flow logging may be calculated according to the methodology description for flow logging:

$$T_F(L) = T \cdot Q(L) / Q_p \quad (5\text{-}6)$$

where Q(L) = cumulative flow at borehole length L.

The threshold value of transmissivity (T_{min}) in flow logging may be estimated similar to Equation (5-4):

$$T_{min} = T \cdot Q_{min} / Q_p \qquad (5\text{-}7)$$

In a 140 mm borehole, Q_{min} = 3 L/min, see Table 4-1, whereas Q_p is the actual flow rate during flow logging.

Similarly, the lower measurement limit of transmissivity of a flow anomaly can be estimated from Equation (5-5) using $dQ_{i\,min}$ = 1 L/min ($1.7 \cdot 10^{-5}$ m^3/s) which is considered as the minimal change in borehole flow rate to identify a flow anomaly. The upper measurement limit of transmissivity of a flow anomaly corresponds to the transmissivity of the entire borehole.

5.5 Nonconformities

The hydraulic test program was mainly according to the Activity Plan, however with the following exceptions:

- In borehole HFM32 the flow logging probe could not be lowered below c 130.7 m, probably due to some obstacle in the borehole.
- A failure in the electric plant supporting the test site at HFM32 with electricity, caused an 18 minutes break in the pumping after ca 2½ h.

Compared to the methodology description for single-hole pumping tests (SKB MD 321.003), a deviation was made regarding the recommended test times:

- The recommended test time (24 h+24 h for drawdown/recovery) for the longer pumping tests during flow logging was decreased to c 10 h+12 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 in other boreholes indicates that c 10 h of pumping and 12 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.

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 instruction for analysis of single-hole injection- and pumping tests, SKB MD 320.004, Version 1.0, and the methodology description for impeller flow logging, SKB MD 322.009, Version 1.0. Additional symbols used are explained in the text. The nomenclature for the analyses of the pumping tests by the AQTESOLV code is presented in Appendix 2.

6.2 Water sampling

Water samples were taken during the pumping tests in the boreholes and submitted for analysis, see Table 6-1.

Table 6-1. Water samples collected during the pumping tests in boreholes HFM24 and HFM32 and submitted for analysis.

Bh ID	Date and time of sample	Pumped section (m)	Pumped volume (m^3)	Sample type	Sample ID no	Remarks
HFM24	2006-02-07 08:45	18.0–151.4	4.2	WC080	012065	Open-hole test
“	2006-02-07 12:25	“	17.9	WC080	012064	Open-hole test
“	2006-02-07 18:45	“	42.6	WC080	012059	Open-hole test
HFM32	2006-01-17 09:45	6.0–202.7	7.1	WC080	012035	Open-hole test
“	2006-01-17 14:03	“	22.4	WC080	012034	Open-hole test
“	2006-01-17 18:00	“	37.7	WC080	012036	Open-hole test
“	2006-01-18 15:20	50–202.7	2.1	WC080	012066	Below packer

6.3 Single-hole pumping tests

Below, the results of the single-hole pumping tests are presented test by test. The atmospheric pressure and precipitation were monitored at the site during the testing periods. However, no corrections of measured data, e.g. for changes of the atmospheric pressure or tidal fluctuations, have been made before the analysis of the data. For the actual type of single-hole tests such corrections are generally not needed considering the relatively short test time and large drawdown applied in the boreholes. However, for longer tests with a small drawdown applied, such corrections may be necessary.

Drilling records were checked to identify possible interference on the hydraulic test data from drilling or other activities in nearby boreholes during the test periods. These records show that the drilling of KFM01D at drill site DS1, see Figure 1-1, was in progress during the test periods for HFM24 and HFM32. Also the drilling of KFM02B was ongoing during the short pumping test in section 50–202.7 m in HFM32. However, no obvious influence from these activities on the test results can be seen.

6.3.1 Borehole HFM24: 18.0–151.4 m

General test data for the open-hole pumping test in HFM24 in conjunction with flow logging are presented in Table 6-2.

The atmospheric pressure during the test period in HFM24 is presented in Figure 6-1. The atmospheric pressure varied c 0.5 kPa, i.e. only c 1% of the total drawdown of c 5.6 m in the borehole during the test, and thus the effect of atmospheric pressure variations on the test results is considered negligible. Since the temperature was well below 0°C, no snow melting or rain has affected the ground water levels.

Table 6-2. General test data, pressure, groundwater level and flow data for the open-hole pumping test in borehole HFM24, in conjunction with flow logging.

General test data				
Borehole	HFM24 (18.0–151.4 m)			
Test type[1]	Constant rate withdrawal and recovery test			
Test section (open borehole/packed-off section):	Open borehole			
Test No	1			
Field crew	S. Jönsson and P. Fredriksson, GEOSIGMA AB			
Test equipment system	HTHB			
General comment	Single pumping borehole			
	Nomen-clature	**Unit**	**Value**	
Borehole length	L	M	151.4	
Casing length	L_c	M	18.0	
Test section- secup	Secup	M	18.0	
Test section- seclow	Seclow	M	151.4	
Test section length	L_w	M	133.4	
Test section diameter	$2 \cdot r_w$	Mm	top 139.7 bottom 137.7	
Test start (start of pressure registration)		yymmdd hh:mm	060207 07:31.00	
Packer expanded		yymmdd hh:mm:ss		
Start of flow period		yymmdd hh:mm:ss	060207 07:39:00	
Stop of flow period		yymmdd hh:mm:ss	060207 18:49:00	
Test stop (stop of pressure registration)		yymmdd hh:mm	060208 07:31:40	
Total flow time	t_p	Min	670	
Total recovery time	t_F	Min	763	

Pressure data	**Nomen clature**	**Unit**	**Value**	**GW Level (m.a.s.l.)[2]**
Absolute pressure in test section before start of flow period	p_i	kPa	169.85	1.84
Absolute pressure in test section at stop of flow period	p_p	kPa	114.75	–3.88
Absolute pressure in test section at stop of recovery period	p_F	kPa	165.07	1.34
Maximal pressure change in test section during the flow period	dp_p	kPa	55.10	

General test data					
Manual groundwater level measurements			**GW level**		
Date YYYY-MM-DD	**Time tt:mm.ss**	**Time (min)**	**(m bToC)**	**(m.a.s.l.)**	
2006-02-06	11:03:00	-1236	2.30	1.88	
2006-02-06	16:08:00	–931	2.29	1.89	
2006-02-06	18:11:00	–808	2.29	1.89	
2006-02-07	07:25:00	–14	2.34	1.84	
2006-02-07	08:28:00	49	6.42	–1.67	
2006-02-07	12:29:00	290	8.06	–3.09	
2006-02-07	18:41:00	662	8.98	–3.88	
2006-02-08	07:25:00	1426	2.93	1.34	
Flow data			**Nomenclature**	**Unit**	**Value**
Flow rate from test section just before stop of flow period			Q_p	m^3/s	$1.082 \cdot 10^{-3}$
Mean (arithmetic) flow rate during flow period[3]			Q_m	m^3/s	$1.081 \cdot 10^{-3}$
Total volume discharged during flow period[3]			V_p	m^3	43.45

[1)] Constant Head injection and recovery or Constant Rate withdrawal and recovery or Constant drawdown withdrawal and recovery.
[2)] From the manual measurements of groundwater level.
[3)] Calculated from integration of the transient flow rate curve during the flow period.

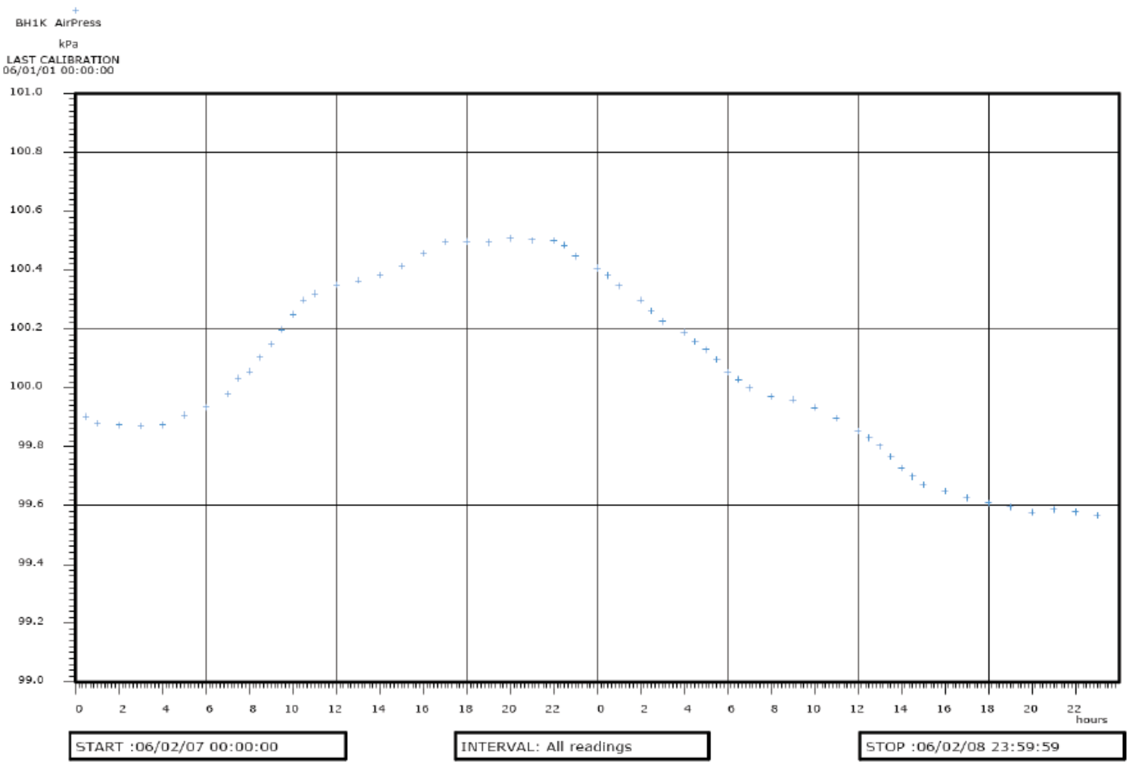


Figure 6-1. *Atmospheric pressure during the test period in HFM24.*

Comments on test

The day before test start, a short capacity test was performed (c 40 min). By the end of the capacity test, the flow rate was c 65 L/min and the drawdown c 3.24 m. The actual pumping test was performed as a constant flow rate test (64.9 L/min) with the intention to achieve (approximately) steady-state conditions during the flow logging. A comparison of the results from the capacity test and pumping test is presented in Table 6-3. Discrepancies between the two may indicate changes in the borehole skin zone due to pumping. Table 6-3 shows a good coincidence in specific capacity from the capacity test and the pumping test indicating stable conditions in the borehole

Table 6-3. Estimated specific capacity from the capacity test and pumping test in borehole HFM24: 18.0–151.4 m.

Test	Duration (min)	Flow rate, Q_p (L/min)	Drawdown, $s_w = p_i – p_p$ (m)	Specific capacity, Q_p/s_w (m^2/s)
Short capacity test	42	64.9	3.24	$3.3·10^{-4}$
Pumping test	42	64.9	3.36	$3.2·10^{-4}$
Pumping test	670	64.9	5.61	$1.8·10^{-4}$

Interpreted flow regimes

Selected test diagrams according to the Instruction for analysis of injection – and single-hole pumping tests are presented in Figures A2-1 to A2-5 in Appendix 2.

During both the drawdown and the recovery period, wellbore storage effects are followed by a dominating pseudo-radial flow after c 30 minutes.

A region of a slightly lower hydraulic conductivity is indicated after c 50 minutes during the drawdown as well as during the recovery.

Interpreted parameters

Transient evaluation of transmissivity was performed for both the flow- and recovery period and the transient, quantitative interpretation is presented in Figures A2-2 to A2-5 in Appendix 2. The quantitative analysis was performed according to the methods described in Section 5.4.1. The transmissivity was estimated by a model assuming pseudo-radial flow /3/ on both the flow- and recovery period. The representative transmissivity (i.e. T_T) is considered from the transient evaluation assuming pseudo-radial flow. The agreement between the drawdown and the recovery period regarding transmissivity and skin factor is good.

The results are shown in the Test Summary Sheets and in Tables 6-13, 6-14 and 6-15 in Section 6.5. The analysis from the flow period was selected as representative for the test.

6.3.2 Borehole HFM32: 6.0–202.7 m

General test data for the open-hole pumping test in HFM32 in conjunction with flow logging are presented in Table 6-4.

The atmospheric pressure during the test period in HFM32 is presented in Figure 6-2. The atmospheric pressure varied c 0.4 kPa, i.e. only c 4% of the total drawdown of c 1.07 m in the borehole during the test, and thus the effect of atmospheric pressure variations on the test results is considered negligible. Since the temperature was well below 0°C, no snow melting or rain has affected the ground water levels.

Table 6-4. General test data, pressure, groundwater level and flow data for the open-hole pumping test in borehole HFM32, in conjunction with flow logging.

General test data				
Borehole	HFM32 (6.03–202.65 m)			
Test type[1]	Constant rate withdrawal and recovery test			
Test section (open borehole/packed-off section):	Open borehole			
Test No	1			
Field crew	S. Jönsson, J. Olausson and P. Fredriksson, GEOSIGMA AB			
Test equipment system	HTHB			
General comment	Single pumping borehole			
	Nomen-clature	**Unit**	**Value**	
Borehole length	L	M	202.65	
Casing length	L_c	M	6.03	
Test section- secup	Secup	M	6.03	
Test section- seclow	Seclow	M	202.65	
Test section length	L_w	M	196.62	
Test section diameter	$2 \cdot r_w$	Mm	top 141 bottom 131.8	
Test start (start of pressure registration)		yymmdd hh:mm	060117 07:47:15	
Packer expanded		yymmdd hh:mm:ss		
Start of flow period		yymmdd hh:mm:ss	060117 07:56:01	
Stop of flow period		yymmdd hh:mm:ss	060117 18:09:01	
Test stop (stop of pressure registration)		yymmdd hh:mm	060118 07:50:25	
Total flow time	t_p	Min	613	
Total recovery time	t_F	Min	821	

Pressure data	**Nomen-clature**	**Unit**	**Value**	**GW Level (m.a.s.l.)[2]**
Absolute pressure in test section before start of flow period	p_i	kPa	137.67	0.42
Absolute pressure in test section at stop of flow period	p_p	kPa	127.10	–0.65
Absolute pressure in test section at stop of recovery period	p_F	kPa	118.63	0.40
Maximal pressure change in test section during the flow period	dp_p	kPa	10.57	

Manual groundwater level measurements			**GW level**	
Date YYYY-MM-DD	**Time tt:mm.ss**	**Time (min)**	**(m bToC)**	**(m.a.s.l.)**
2006-01-16	16:12:00	–944	0.54	0.43
2006-01-16	18:31:00	–805	0.53	0.44
2006-01-17	07:49:00	–7	0.55	0.42
2006-01-17	10:25:00	149	1.52	–0.55
2006-01-17	17:34:00	578	1.62	–0.65
2006-01-17	18:04:00	608	1.62	–0.65
2006-01-18	07:36:00	1420	0.57	0.40
2006-01-18	13:36:00	1780	0.53	0.44

Flow data	**Nomenclature**	**Unit**	**Value**
Flow rate from test section just before stop of flow period	Q_p	m^3/s	$1.083 \cdot 10^{-3}$
Mean (arithmetic) flow rate during flow period[3]	Q_m	m^3/s	$1.083 \cdot 10^{-3}$
Total volume discharged during flow period[3]	V_p	m^3	38.65

1) Constant Head injection and recovery or Constant Rate withdrawal and recovery or Constant drawdown withdrawal and recovery.
2) From the manual measurements of groundwater level.
3) Calculated from integration of the transient flow rate curve during the flow period.

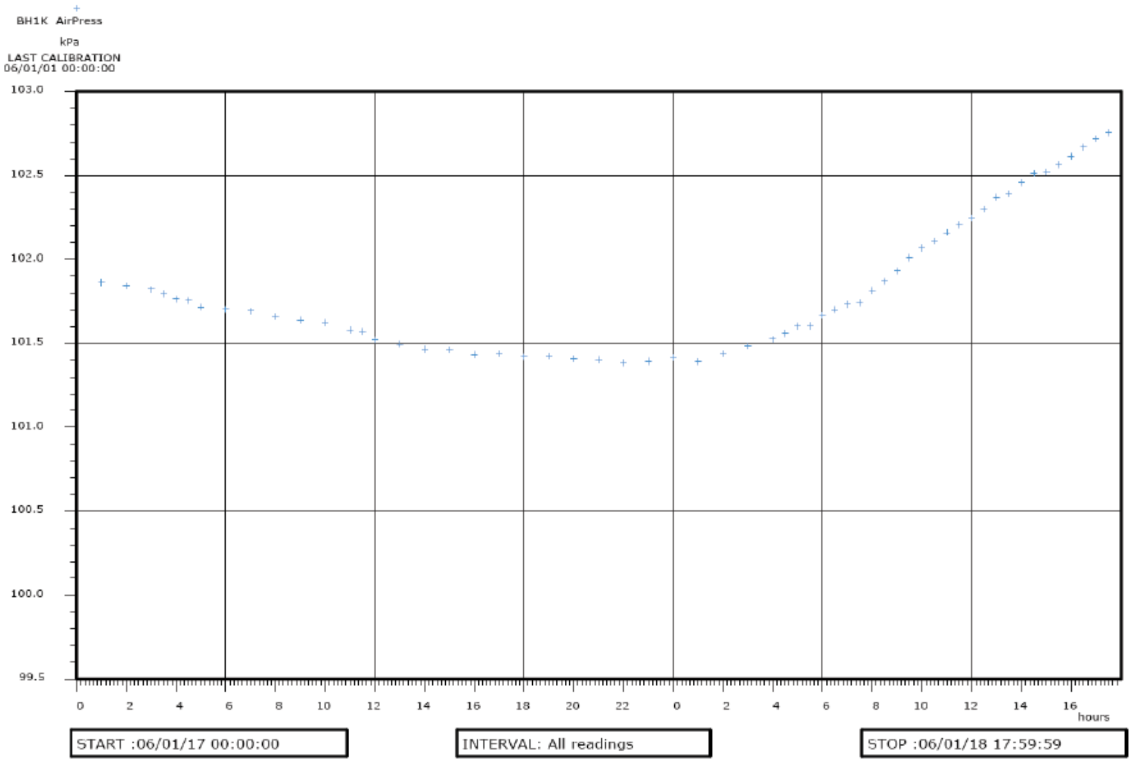


Figure 6-2. *Atmospheric pressure during the test period in HFM32.*

Comments on test

The day before test start, a short capacity test was performed (c 30 min). By the end of the capacity test, the flow rate was c 70.1 L/min and the drawdown c 0.87 m. The actual pumping test was performed as a constant flow rate test (65.0 L/min) with the intention to achieve (approximately) steady-state conditions during the flow logging. A comparison of the results from the capacity test and pumping test is presented in Table 6-5. Discrepancies between the two may indicate changes in the borehole skin zone due to pumping. Table 6-5 shows a good coincidence in specific capacity from the short capacity test and the longer pumping test indicating stable conditions in the borehole skin zone.

Table 6-5. Estimated specific capacity from the capacity test and pumping test in borehole HFM32: 6.0–202.7 m.

Test	Duration (min)	Flow rate, Q_p (L/min)	Drawdown, $s_w = p_i – p_p$ (m)	Specific capacity, Q_p/s_w (m²/s)
Short capacity test	33	70.1	0.87	$1.3 \cdot 10^{-3}$
Pumping test	33	65.0	0.84	$1.3 \cdot 10^{-3}$
Pumping test	613	65.0	1.07	$1.2 \cdot 10^{-3}$

Interpreted flow regimes

Selected test diagrams according to the instruction for analysis of injection – and single-hole pumping tests are presented in Figures A2-6 to A2-10 in Appendix 2.

During the drawdown period initial wellbore storage effects are transitioning to a pseudo-radial flow regime after c 15 minutes, cf Figures A2-7 to A2-8. The 18 minutes break in pumping due to the failure in electric supply is modelled with good fit.

Also during the recovery period, wellbore storage effects are followed by a dominating pseudo-radial flow. By the end of the recovery period, effects of apparent no-flow boundaries or other flow restrictions are indicated.

Interpreted parameters

Transient evaluation of transmissivity was performed for both the flow- and recovery period and the transient, quantitative interpretation is presented in Figures A2-7 to A2-10 in Appendix 2. The quantitative analysis was performed according to the methods described in Section 5.4.1. The transmissivity was estimated by a model assuming pseudo-radial flow /3/ on both the flow- and recovery period. The representative transmissivity (i.e. T_T) is considered from the transient evaluation assuming pseudo-radial flow. The agreement between the drawdown and the recovery period regarding transmissivity and skin factor is good.

The results are shown in the Test Summary Sheets and in Tables 6-13, 6-14 and 6-15 in Section 6-5. The analysis from the flow period was selected as representative for the test.

6.3.3 Borehole HFM32: 50.0–202.7 m

General test data for the pumping test below a packer at 49–50 m in HFM32 are presented in Table 6-6.

The atmospheric pressure during the test period may be seen in Figure 6-1. The atmospheric pressure varied c 0.2 kPa, i.e. only c 0.15% of the total drawdown of c 14.17 m in the bore-hole during the test, and thus the effect of atmospheric pressure variations on drawdown is considered negligible. Since the temperature was well below 0°C, no snow melting or rain has affected the ground water levels.

Table 6-6. General test data, pressure, groundwater level and flow data for the pumping test below a packer at 49–50 m in borehole HFM32.

General test data					
Borehole	HFM32 (50.0–202.7 m)				
Test type[1]	Constant rate withdrawal and recovery test				
Test section (open borehole/packed-off section):	Open borehole				
Test No	1				
Field crew	S. Jönsson, J. Olausson and P. Fredriksson GEOSIGMA AB				
Test equipment system	HTHB				
General comment	Single pumping borehole				
	Nomenclature	**Unit**		**Value**	
Borehole length	L	m		202.7	
Casing length	L_c	m		6.0	
Test section- secup	Secup	m		50.0	
Test section- seclow	Seclow	m		202.7	
Test section length	L_w	m		152.7	
Test section diameter[2]	$2 \cdot r_w$	mm		top 140 bottom 131.8	
Test start (start of pressure registration)		**yymmdd hh:mm**		**060118 13:48**	
Packer expanded		yymmdd hh:mm:ss		060118 13:47	
Start of flow period		yymmdd hh:mm:ss		060118 14:00:00	
Stop of flow period		yymmdd hh:mm:ss		060118 15:30:00	
Test stop (stop of pressure registration)		yymmdd hh:mm		060118 17:00	
Total flow time	t_p	min		90	
Total recovery time	t_F	min		90	
Pressure data		**Nomenclature**	**Unit**	**Value**	**GW Level (m.a.s.l.)**
Absolute pressure in test section before start of flow period		p_i	kPa	537.92	
Absolute pressure in test section at stop of flow period		p_p	kPa	398.91	
Absolute pressure in test section at stop of recovery period		p_F	kPa	529.03	
Maximal pressure change in test section during the flow period		dp_p	kPa	139.0	
Flow data		**Nomenclature**		**Unit**	**Value**
Flow rate from test section just before stop of flow period		Q_p		m^3/s	$4.98 \cdot 10^{-4}$
Mean (arithmetic) flow rate during flow period[2]		Q_m		m^3/s	$4.90 \cdot 10^{-4}$
Total volume discharged during flow period[2]		V_p		m^3	2.65

1) Constant Head injection and recovery or Constant Rate withdrawal and recovery or Constant drawdown withdrawal and recovery.
2) Calculated from integration of the transient flow rate curve.

Comments on test

Since the flow capacity of the isolated test section was not known some flow adjustments during the first minutes of the test were performed. The initial flow was set to c 3 L/min during the first 2 minutes, then increased to c 18 L/min during the following 2 minutes and thereafter 30 L/min during the rest of the flow period.

Interpreted flow regimes

Selected test diagrams according to the instruction for analysis of injection – and single-hole pumping tests are presented in Figures A2-11 to A2-15 in Appendix 2.

During the drawdown period initial wellbore storage effects are transitioning to a pseudo-radial flow regime after c 15 minutes.

During the recovery an initial wellbore storage effect is followed by a transitioning to pseudo-radial flow regime. Eventually two periods with pseudo-radial flow could be interpreted with a somewhat lower transmissivity in the more distant rock. The overall estimated transmissivity for the recovery period was in good accordance with the transmissivity for the drawdown period.

Interpreted parameters

The transient, quantitative interpretation of the flow- and recovery period of the test is presented in Figures A2-12 to A-17 in Appendix 2. Quantitative analysis was applied both on the flow- and recovery period according to the methods described in Section 5.4.1.

The transmissivity was estimated by a model assuming pseudo-radial flow /3/ on both the flow and the recovery period.

The results are exposed in the Test Summary Sheets and in Table 6-13, Table 6-14 and Table 6-15 in Section 6-5. The analysis from the flow period was selected as the representative one.

6.4 Flow logging

6.4.1 Borehole HFM24

General test data for the flow logging in borehole HFM24 are presented in Table 6-7.

Comments on test

The flow logging was made from the bottom of the hole and upwards. The step length between flow logging measurements was maximally 5 m in the borehole interval 131.7–30 m (below first measurable flow). Above 30 m, the step length was at most 2 m.

The measured electric conductivity and temperature are used as supporting information when interpreting flow anomalies.

Table 6-7. General test data, groundwater level and flow data for the flow logging in borehole HFM24.

General test data					
Borehole	HFM24				
Test type (s)[1]	6, L-EC, L-Te				
Test section:	Open borehole				
Test No	1				
Field crew	S. Jönsson, and P. Fredriksson, GEOSIGMA AB				
Test equipment system	HTHB				
General comments	Single pumping borehole				
	Nomenclature	**Unit**		**Value**	
Borehole length		m		151.4	
Pump position (lower level)		m		14.5	
Flow logged section - Secup		m		18.0	
Flow logged section - Seclow		m		150.0	
Test section diameter	$2 \cdot r_w$	mm		top 139.7 bottom 137.7	
Start of flow period		yymmdd hh:mm		060207 07:39	
Start of flow logging		yymmdd hh:mm		060207 14:43	
Stop of flow logging		yymmdd hh:mm		060207 18:40	
Stop of flow period		yymmdd hh:mm		060207 18:49	
Groundwater level		**Nomenclature**	**Unit**	**G.w-level (m b ToC)**	**G.w-level (m.a.s.l.)[2]**
Groundwater level in borehole, at undisturbed conditions, open hole		h_i	m	2.34	1.88
Groundwater level (steady state) in borehole, at pumping rate Q_p		h_p	m	8.98	–3.88
Drawdown during flow logging at pumping rate Q_p		s_{FL}	m		5.68
Flow data		**Nomenclature**	**Unit**	**Flow rate**	
Pumping rate at surface		Q_p	m³/s	$1.08 \cdot 10^{-3}$	
Corrected cumulative flow rate at Secup at pumping rate Q_p		Q_{Tcorr}	m³/s	$1.08 \cdot 10^{-3}$	
Threshold value for borehole flow rate during flow logging		Q_{Measl}	m³/s	$5 \cdot 10^{-5}$	
Minimal change of borehole flow rate to detect flow anomaly		dQ_{Anom}	m³/s	$1.7 \cdot 10^{-5}$	

1) 6: Flow logging-Impeller, L-EC: EC-logging, L-TE: temperature logging.
2) Calculated from the manual measurements of groundwater level.

Logging results

The nomenclature used for the flow logging is according to the methodology description for flow logging. The measured flow distribution along the hole during the flow logging together with the electric conductivity (EC) and temperature of the borehole fluid is presented in Figures 6-3 and 6-4. Figure 6-4 shows the uppermost 55 m where all the detected flow anomalies where found.

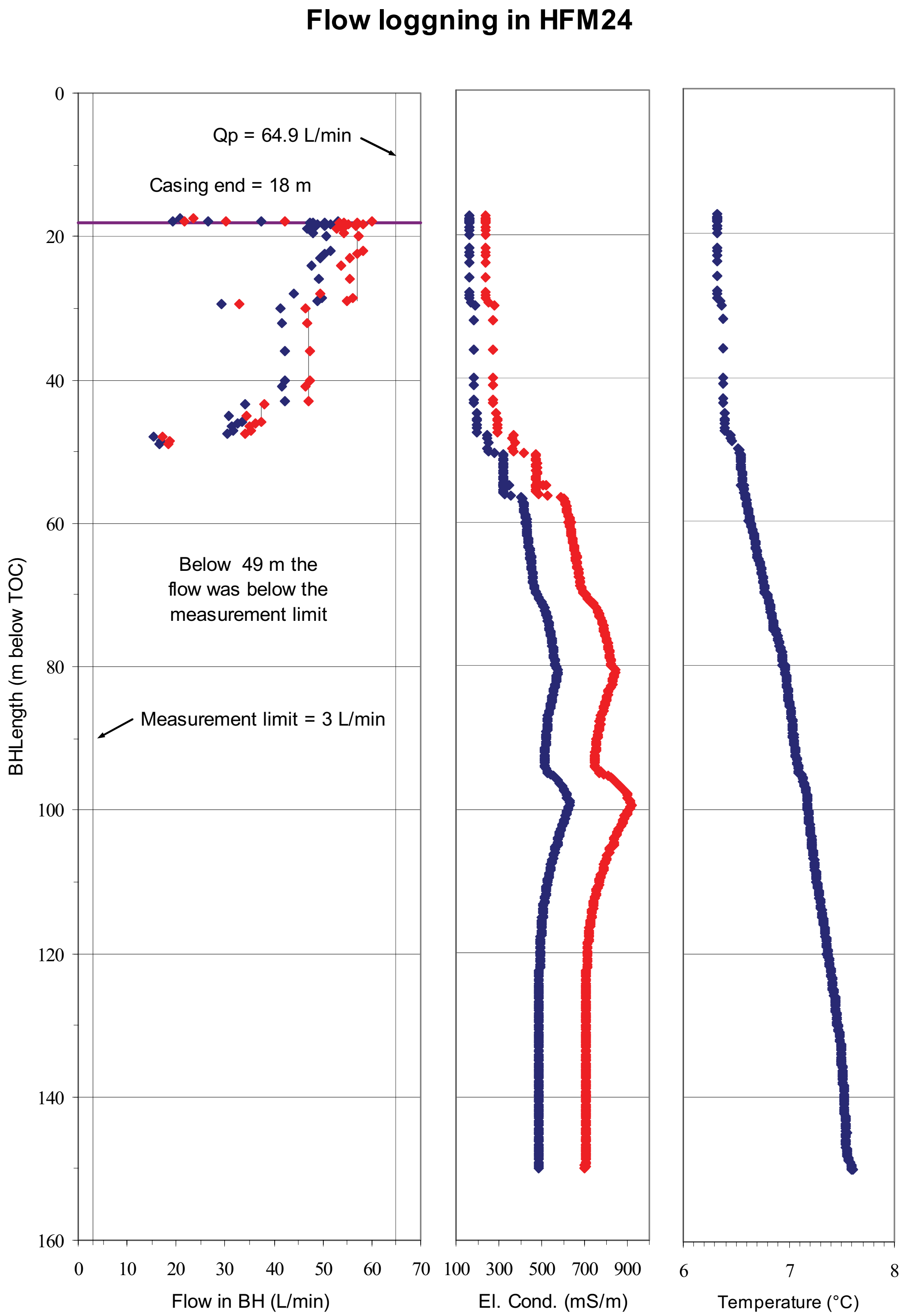


Figure 6-3. *Measured (blue) and corrected (red) inflow distribution together with measured (blue) and temperature compensated (red) electrical conductivity and temperature of the borehole fluid along borehole HMF24 during flow logging. (Totally logged interval.)*

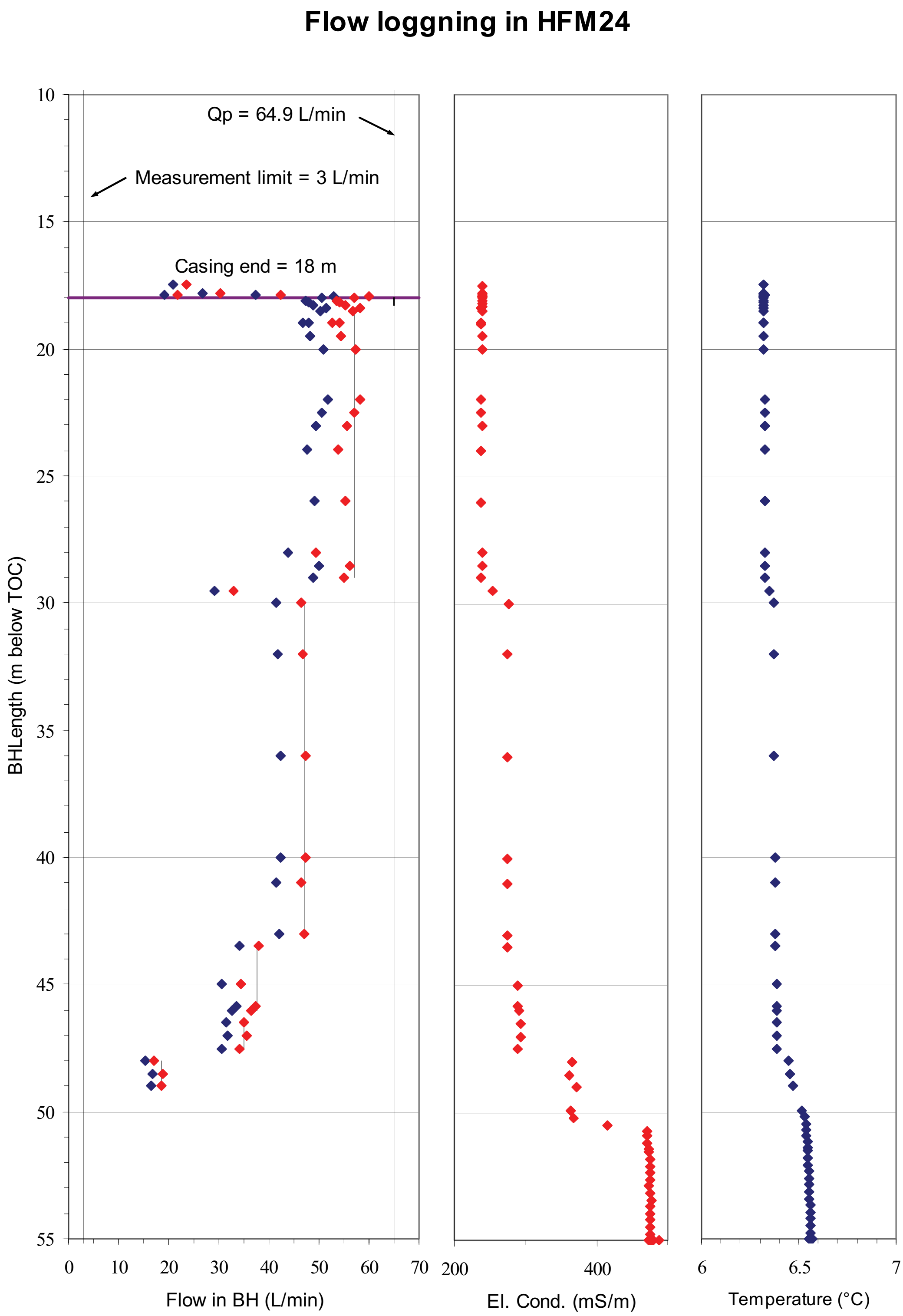


Figure 6-4. *Measured (blue) and corrected (red) inflow distribution together with temperature compensated electrical conductivity and temperature of the borehole fluid along section 10–55 m of the borehole HMF24 during flow logging.*

The figures present measured borehole flow rates with calibration constants for a 140 mm pipe (according to the drilling record the borehole diameter in the upper part is 139.7 mm) and corrected borehole flow rates. The correction is performed in two steps. Firstly the calibration constants used are corrected for variations of the diameter along the borehole using information from the logging in the undisturbed borehole as described in Section 5.4.2. Secondly, if necessary, a scaling to achieve conformance between measured borehole flow at the top of the flow logged interval and the pumped flow rate measured by the flow meter at surface is performed. The correction is performed under the assumption of no inflow above the highest position for flow logging. In this case, it was possible to extend the flow logging to slightly above the end of the casing.

The difference between the highest flow rate measured at the top of the flow logged interval in the borehole and the total pumped flow measured at the surface may be explained by the borehole diameter in the uppermost part of the borehole being greater than the diameter of the pipe used for calibration. Probably also the inclination of the borehole (ca 60°), deviating from 90°, has some influence on the flow measured in the borehole.

A complication in HFM24 was that there is a flow anomaly c 0.5 m below the end of the casing. This anomaly may be seen as a small increase in flow just below the casing and as an increase in electric conductivity at c 18.5 m (see Figure 6-5). At approximately the same location a part of the flow logging probe enters the casing, meaning that at least the upper steering bars of the probe are located in the wider casing. This fact probably causes the measured flow to decrease a little due to changed flow conditions around the probe, an effect which also has been observed in other boreholes. Based on experience from other boreholes and the results in HFM24 this decrease could correspond to c 5 L/min when pumping 60–65 L/min as a total. Therefore, the flow rate change in this uppermost anomaly was estimated at ca 8 L/min.

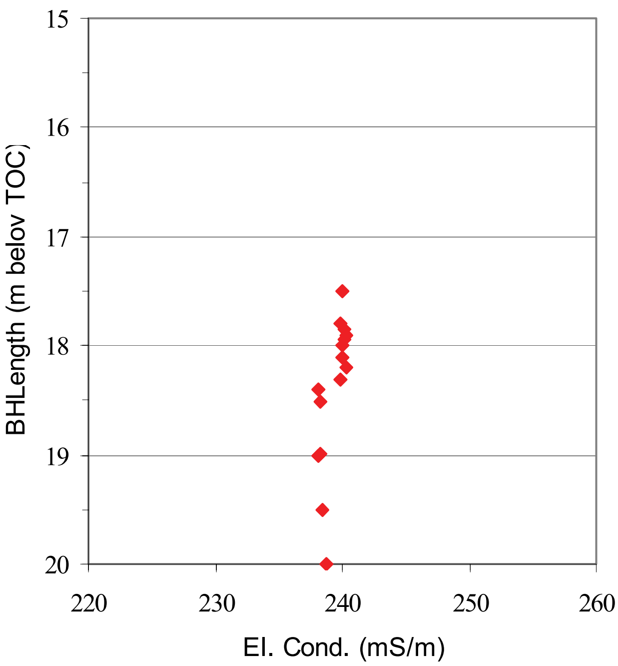


Figure 6-5. *Detailed figure of the electric conductivity of borehole water near the end of the casing (at 18 m) in borehole HMF24 during flow logging.*

Figure 6-4 shows six detected inflows between 18.3 and 49.5 m. All inflows, except the one at 46–46.5 m are supported by the EC-measurements. The small but distinct change in the uppermost flow anomaly is best illustrated in Figure 6-5. For three of the flow anomalies clear change in temperature can also be seen.

The results of the flow logging in borehole HFM24 are presented in Table 6-8 below. The measured inflow at the identified flow anomalies (dQ_i) and their estimated percentage of the total flow is shown. The cumulative transmissivity (T_{FT}) at the top of the flow-logged borehole interval was calculated from Equation (5-4) and the transmissivity of individual flow anomalies (T_i) from Equation (5-5) using the corrected flow values (se above). The transmissivity for the entire borehole used in Equation (5-5) was taken from the transient evaluation of the flow period of the pumping test in conjunction with the flow logging (cf Section 6.3.1). An estimation of the transmissivity of the interpreted flow anomalies was also made by calculating the specific flows (dQ_i/s_{FL}).

Summary of results

Table 6-9 presents a summary of the results from the pumping test in conjunction with flow logging and corrected results from the flow logging.

Table 6-8. Results of the flow logging in borehole HFM24. Q_{Tcorr} = cumulative flow at the top of the logged interval, corrected due to the deviation of the actual borehole diameter from the one used for calibration. Q_p = pumped flow rate from borehole, s_{FL} = drawdown during flow logging. T = transmissivity from the pumping test.

HFM24 Flow anomalies		**$Q_{Tcorr} = 1.08 \cdot 10^{-3}$ (m³/s)**	**$T = 6.94 \cdot 10^{-5}$ (m²/s)**	**s_{FL} = 2.65 m**	**$Q_p = 1.1 \cdot 10^{-3}$ (m³/s)**	
Interval (m b ToC)	B.h. length (m)	dQ_{icorr}[1] (m³/s)	T_i (m²/s)	dQ_{icorr}/s_{FL} (m²/s)	dQ_{icorr}/Q_p (%)	Supporting information
18.0–18.5	0.5	$1.300 \cdot 10^{-4}$	$1.32 \cdot 10^{-5}$	$2.32 \cdot 10^{-5}$	12.0	EC
29.0–30.0	1	$1.667 \cdot 10^{-4}$	$1.69 \cdot 10^{-5}$	$2.97 \cdot 10^{-5}$	15.4	EC, Temp
43.0–43.5	0.5	$1.600 \cdot 10^{-4}$	$1.63 \cdot 10^{-5}$	$2.85 \cdot 10^{-5}$	14.8	EC
46.0–46.5	0.5	$4.167 \cdot 10^{-5}$	$4.24 \cdot 10^{-6}$	$7.43 \cdot 10^{-6}$	3.9	EC?
47.5–48.0	0.5	$2.750 \cdot 10^{-4}$	$2.80 \cdot 10^{-5}$	$4.90 \cdot 10^{-5}$	25.4	EC, Temp
49.0–49.5	0.5	$3.083 \cdot 10^{-4}$	$3.14 \cdot 10^{-5}$	$5.50 \cdot 10^{-5}$	28.5	EC, Temp
Total		$1.08 \cdot 10^{-3}$	$1.10 \cdot 10^{-4}$	$1.93 \cdot 10^{-4}$	100	
Difference		$Q_p - Q_{Tcorr} = 0$	–	–		

[1]) The corrected flow is based on the assumption that all inflow occurs below the top of the flow logged interval, i.e. $Q_T = Q_p = \Sigma dQ_{icorr}$.

Table 6-9. Compilation of results from the different hydraulic tests performed in borehole HFM24.

Test type	**Interval (m)**	**Specific flow Q/s (m²/s)**	**T (m²/s)**
Flow logging	18.0–150.0	$1.9 \cdot 10^{-4}$	$1.1 \cdot 10^{-4}$
Pumping test	18.0–151.4	$1.8 \cdot 10^{-4}$	$1.1 \cdot 10^{-4}$

Figure 6-6 presents the cumulative transmissivity $T_F(L)$ along the borehole length (L) from the flow logging calculated from Equation (5-6). Since the width of the flow anomaly in the borehole is not known in detail, the change in transmissivity at the anomalies is represented by a sloping line across the anomaly. The estimated threshold value of T and the total transmissivity of the borehole are also indicated in the figure, cf Section 5.4.2.

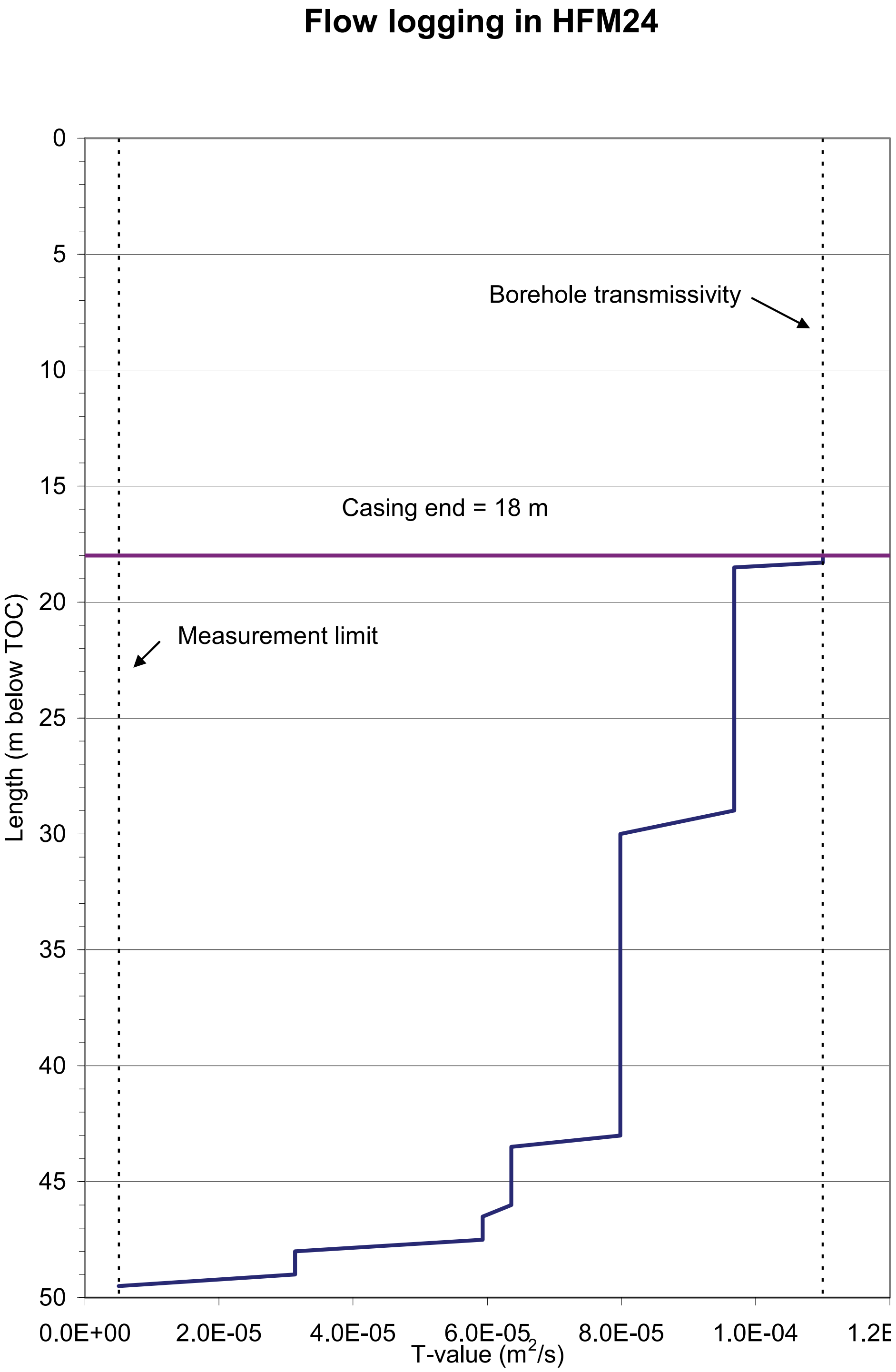


Figure 6-6. *Calculated, cumulative transmissivity along the flow logged interval of borehole HFM24. The total borehole transmissivity was calculated from the pumping test during flow logging.*

6.4.2 Borehole HFM32

General test data for the flow logging in borehole HFM32 are presented in Table 6-10.

Table 6-10. General test data, groundwater level and flow data for the flow logging in borehole HFM32.

General test data					
Borehole	HFM32				
Test type (s)[1]	6, L-EC, L-Te				
Test section:	Open borehole				
Test No	1				
Field crew	S. Jönsson, J. Olausson and P. Fredriksson, GEOSIGMA AB				
Test equipment system	HTHB				
General comments	Single pumping borehole				
	Nomenclature	**Unit**		**Value**	
Borehole length		M		202.7	
Pump position (lower level)		M		8 and 6[2]	
Flow logged section - Secup		M		8.3	
Flow logged section - Seclow		M		131.7	
Test section diameter	$2 \cdot r_w$	Mm		top 141 bottom 133.5	
Start of flow period		yymmdd hh:mm		060117 07:56	
Start of flow logging		yymmdd hh:mm		060117 14:18	
Stop of flow logging		yymmdd hh:mm		060117 17:53	
Stop of flow period		yymmdd hh:mm		060117 18:09	
Groundwater level		**Nomenclature**	**Unit**	**G.w-level (m b ToC)**	**G.w-level (m.a.s.l.)[3]**
Groundwater level in borehole, at undisturbed conditions, open hole		h_i	M	0.55	0.42
Groundwater level (steady state) in borehole, at pumping rate Q_p		h_p	M	1.61	–0.65
Drawdown during flow logging at pumping rate Q_p		s_{FL}	M		1.07
Flow data		**Nomenclature**	**Unit**	**Flow rate**	
Pumping rate at surface		Q_p	m^3/s	$1.08 \cdot 10^{-3}$	
Corrected cumulative flow rate at Secup at pumping rate Q_p		Q_{Tcorr}	m^3/s	$1.08 \cdot 10^{-3}$	
Threshold value for borehole flow rate during flow logging		Q_{Measl}	m^3/s	$5 \cdot 10^{-5}$	
Minimal change of borehole flow rate to detect flow anomaly		dQ_{Anom}	m^3/s	$1.7 \cdot 10^{-5}$	

1) 6: Flow logging-Impeller, L-EC: EC-logging, L-TE: temperature logging.
2) The pump was lifted 2 m at the end of the flowlogging to allow for flow logging up to 8.3 m borehole length.
3) Calculated from the manual measurements of groundwater level.

Comments on test

The flow logging was made in an upward direction from c 131.7 m. The step length between flow logging measurements was maximally 5 m in the borehole interval 131.7–30 m (below first measurable flow). Above 30 m, the step length was at most 2 m.

The measured electric conductivity and temperature are used as supporting information when interpreting flow anomalies.

Logging results

The measured flow distribution along the hole during the flow logging together with the electric conductivity (EC) and temperature of the borehole fluid is presented in Figures 6-7 and 6-8. Figure 6-8 shows the uppermost 35 m where all the detected flow anomalies where found. The figures present one data set of borehole flow rate with calibration constants for a 140 mm pipe (according to the drilling record the borehole diameter in the upper part is 141 mm) and another with corrected borehole flow rate. The correction is made as a scaling of all borehole flow rate data to achieve $Q_{Tcorr} = Q_p$. The correction is performed under the assumption of no inflow above the highest position for flow logging. This assumption is considered as good since the flow logging continued up to c 2.3 m below the casing, and according to the drilling record there was no inflow in this part of the borehole.

However, since all measurable flow anomalies were located above c 30 m it was not considered necessary to make any corrections for decreasing borehole diameter with depth in this case. The difference between the highest flow rate measured in the borehole and the total flow measured at the ground surface can be explained by the borehole diameter in the uppermost part of the borehole being at least 1 mm greater (the borehole diameter is assumed to be the same as the diameter of the drill bit) than the diameter of the pipe used for calibration.

Figures 6-7 and 6-8 show six detected inflows between 12.3 and 29.8 m. All inflows except for the two smallest ones are supported by the EC- and temperature measurements. In Figure 6-7 two small changes in electric conductivity, indicating small inflows, may be seen at c 92.5 and 103 m.

Normally the temperature of the borehole water is decreasing towards the ground surface even in the uppermost part of the borehole. However, in HFM32 the temperature is increasing c 0.8 EC from 100 m to 8 m below top of casing. Two possible reasons for this might be:

1. The logging was performed only three days after drilling of the borehole which may have caused a redistribution of the temperature profile of the borehole water. However, the temperature is somewhat higher than measured in other boreholes in the area during different times of the year and it seems unlikely that the drilling has caused a rise in temperature of the borehole water that would remain after c 6 hours of pumping, preceding the temperature logging.
2. The borehole is situated on a small islet surrounded by water 200–500 m in all directions. The energy balance in the bottom beneath the shallow lake differs from the situation on the firm ground. The bottom water should have a temperature between 1–4 EC when the lake is covered with ice and the body of water and the bottom sediments will retain a certain amount of heat during winter. Biological activity in the bottom sediments could also raise the temperature a certain amount.

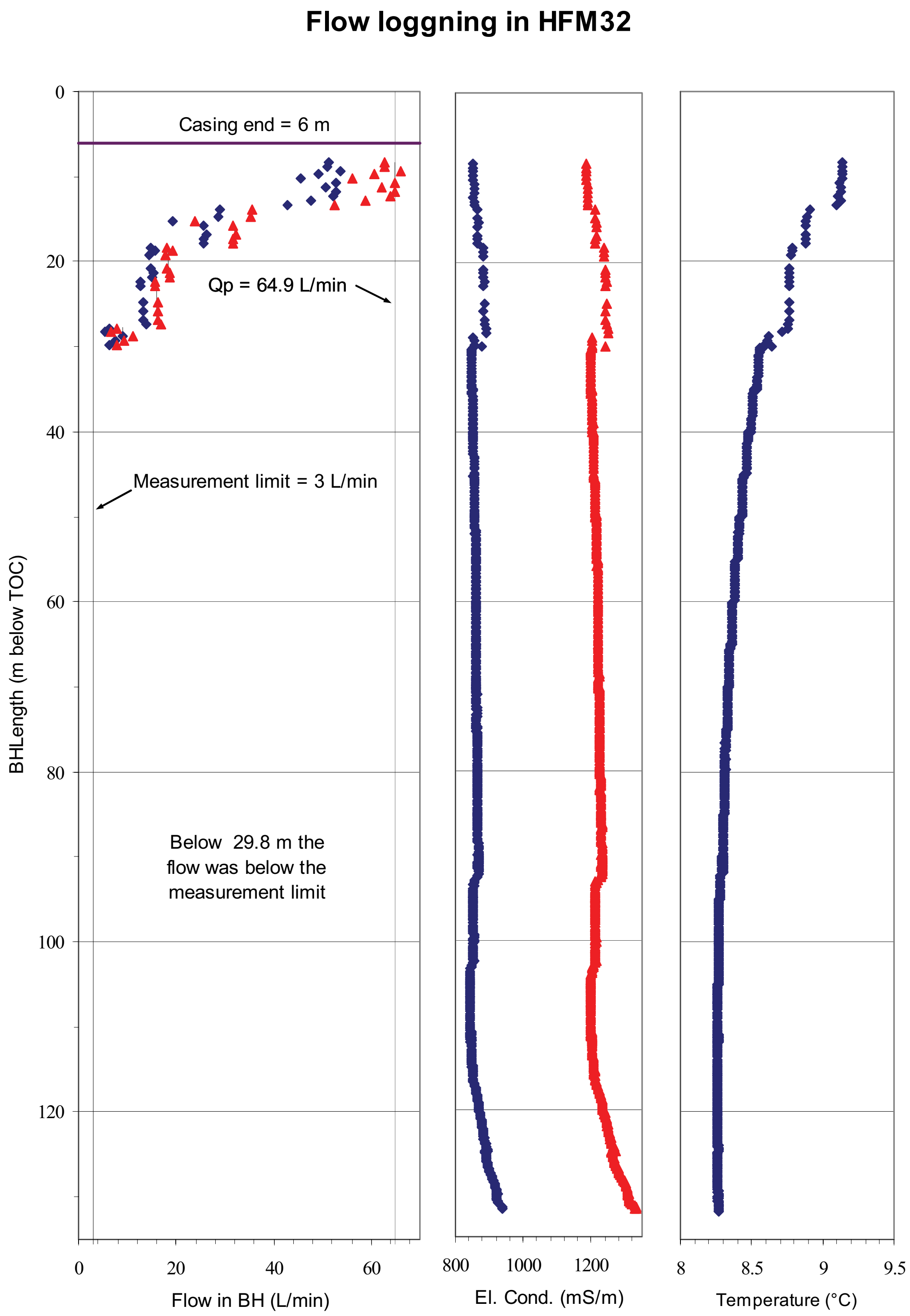


Figure 6-7. Measured (blue) and corrected (red) inflow distribution together with measured (blue) and temperature compensated (red) electrical conductivity and temperature of the borehole fluid along borehole HMF32 during flow logging.

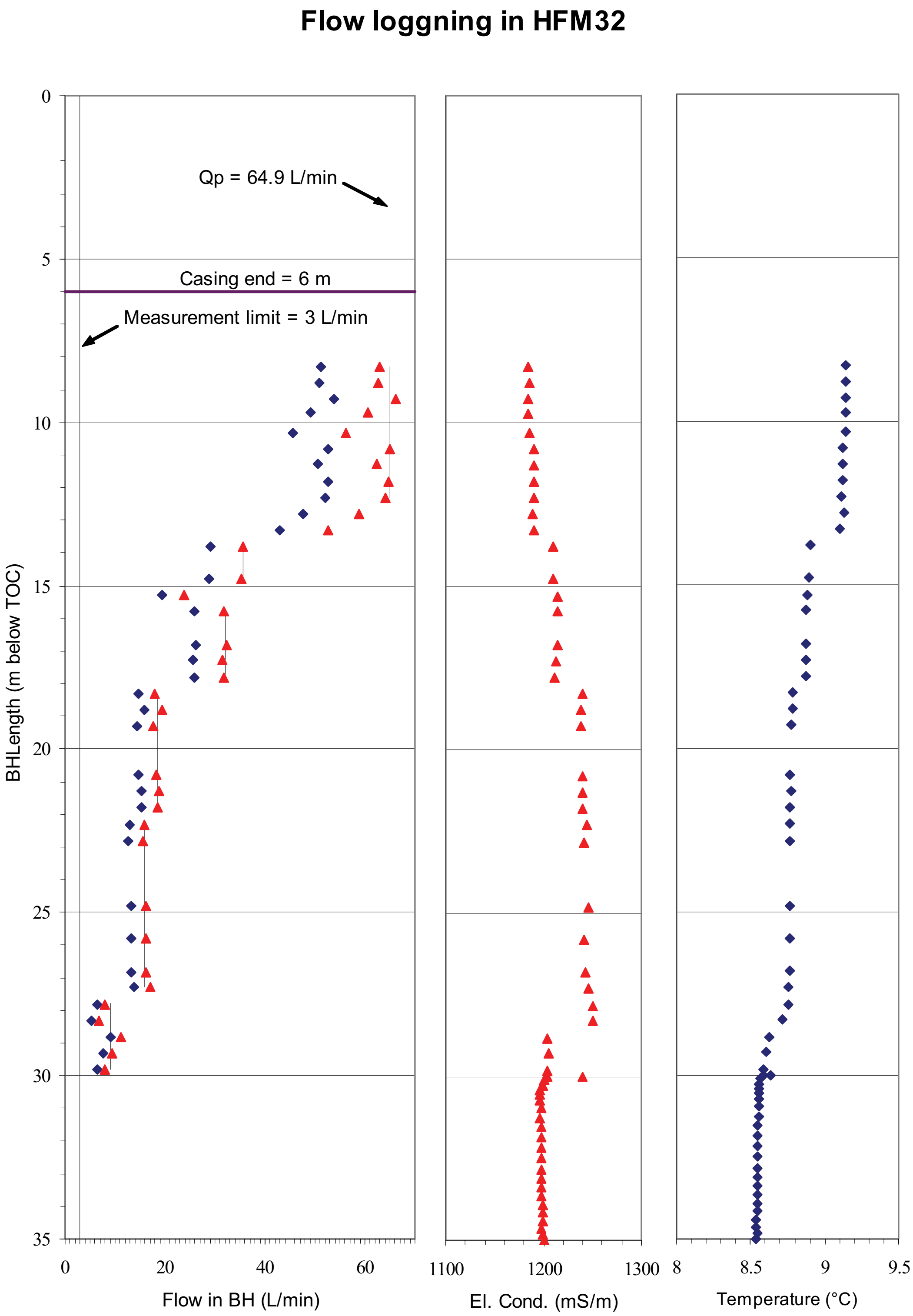


Figure 6-8. *Measured (blue) and corrected (red) inflow distribution together with temperature compensated electrical conductivity and temperature of the borehole fluid along during flow logging of the upper 35 m of borehole HMF32.*

The results of the flow logging in borehole HFM32 are presented in Table 6-11 below. The measured inflow at the identified flow anomalies (dQ_i) and their estimated percentage of the total flow is displayed.

The cumulative transmissivity (T_{FT}) at the top of the flow-logged borehole interval was calculated from Equation (5-4) and the transmissivity of individual flow anomalies (T_i) from Equation (5-5). Transmissivity for the entire borehole used in Equation (5-5) was taken from the transient evaluation of the flow period of the pumping test in conjunction with the flow logging (cf Section 6.3.2). An estimation of the transmissivity of the interpreted flow anomalies was also made by the specific flow (dQ_i/s_{FL}).

Summary of results

Table 6-12 presents a summary of the results from the pumping test in conjunction with flow logging and corrected results from the flow logging together with the results of the pumping test in the lower part of the borehole. The results in Table 6-12 are consistent and show that the major part of the borehole transmissivity is restricted to the flow-logged interval. The value on T achieved for the lower part of the borehole (50–202.7 m) is below the threshold value for the flow logging, which is c $4.4 \cdot 10^{-5}$ m²/s in this case.

Table 6-11. Results of the flow logging in borehole HFM32. Q_{Tcorr} = cumulative flow at the top of the logged interval, corrected due to the deviation of the actual borehole diameter from the one used for calibration. Q_p = pumped flow rate from borehole, s_{FL} = drawdown during flow logging. T = transmissivity from the pumping test.

HFM32 Flow anomalies Interval (m b ToC)	B.h. length (m)	$Q_{Tcorr} = 1.08 \cdot 10^{-3}$ (m³/s) dQ_{icorr}[1] (m³/s)	$T = 6.94 \cdot 10^{-5}$ (m²/s) T_i (m²/s)	s_{FL} = 2.65 m dQ_{icorr}/s_{FL} (m²/s)	$Q_p = 1.1 \cdot 10^{-3}$ (m³/s) dQ_{icorr}/Q_p (%)	Supporting information
12.3–13.8	1.5	$4.90 \cdot 10^{-4}$	$4.3 \cdot 10^{-4}$	$4.6 \cdot 10^{-4}$	45.3	EC, Temp
14.8–15.8	1	$5.83 \cdot 10^{-5}$	$5.1 \cdot 10^{-5}$	$5.5 \cdot 10^{-5}$	5.4	
17.8–18.3	0.5	$2.25 \cdot 10^{-4}$	$2.0 \cdot 10^{-4}$	$2.1 \cdot 10^{-4}$	20.8	EC, Temp
21.8–22.3	0.5	$4.17 \cdot 10^{-5}$	$3.6 \cdot 10^{-5}$	$3.9 \cdot 10^{-5}$	3.9	
27.3–27.8	0.5	$1.17 \cdot 10^{-4}$	$1.0 \cdot 10^{-4}$	$1.1 \cdot 10^{-4}$	10.8	EC, Temp
29.8–30.3	0.5	$1.50 \cdot 10^{-4}$	$1.3 \cdot 10^{-4}$	$1.4 \cdot 10^{-4}$	13.9	EC, Temp
Total		$1.08 \cdot 10^{-3}$	$9.4 \cdot 10^{-4}$	$1.0 \cdot 10^{-3}$	100	

1) The corrected flow is based on the assumption that all inflow occurs below the top of the flow logged interval, i.e. $Q_T = Q_p = \Sigma dQ_{icorr}$.

Table 6-12. Compilation of results from the different hydraulic tests performed in borehole HFM32.

Test type	Interval (m)	Specific flow Q/s (m²/s)	T (m²/s)
Flow logging	8.3–131.7	$1.0 \cdot 10^{-3}$	$9.4 \cdot 10^{-4}$
Pumping test	6.0–202.7	$1.0 \cdot 10^{-3}$	$9.4 \cdot 10^{-4}$
Pumping test in the lower part of the borehole	50.0–202.7	$3.5 \cdot 10^{-5}$	$2.7 \cdot 10^{-5}$

Figure 6-9 presents the cumulative transmissivity $T_F(L)$ along the borehole length (L) from the flow logging calculated from Equation (5-6). Since the width of the flow anomaly in the borehole is not known in detail, the change in transmissivity at the anomalies is represented by a sloping line across the anomaly. The estimated threshold value of T and the total transmissivity of the borehole are also presented in the figure, cf Section 5.4.2.

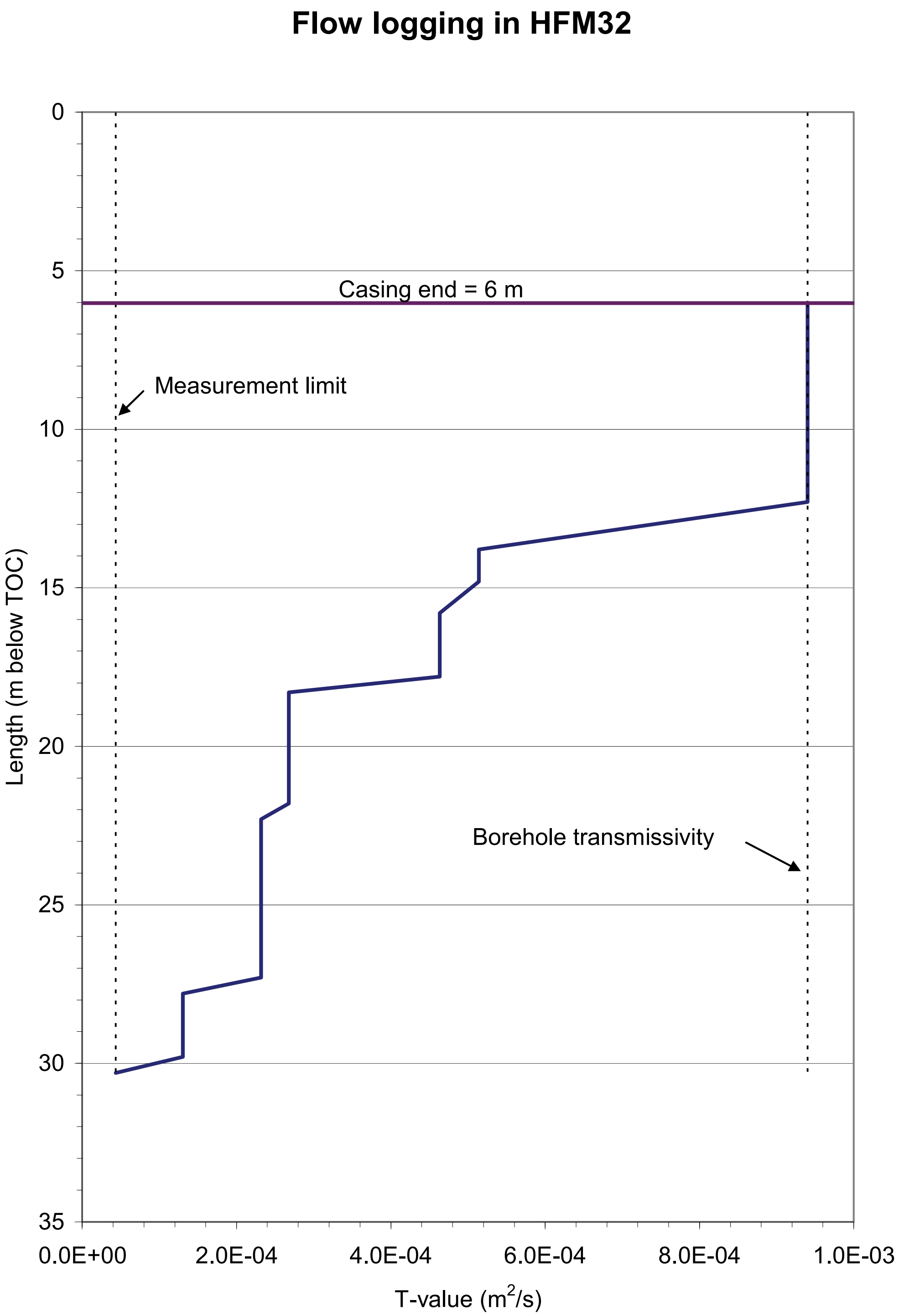


Figure 6-9. *Calculated, cumulative transmissivity along the flow logged interval of borehole HFM32. The total borehole transmissivity was calculated from the pumping test during flow logging.*

6.5 Summary of hydraulic tests

A compilation of measured test data from the pumping tests carried out in the test campaigns is presented in Table 6-13. In Table 6-14, Table 6-15, and in the test summary sheets in Tables 6-16, 6-17 and 6-18 hydraulic parameters calculated from the tests in HFM24 and HFM32 are shown.

In Table 6-14, and Table 6-15, the parameter explanations are according to the instruction for injection- and single-hole pumping tests. The parameters are also explained in the text above, except the following:

Q/s = specific flow for the borehole and flow anomalies (for the latter ones, the corrected specific flow for the borehole diameter is listed)

T_M = steady-state transmissivity calculated from Moye's formula

T_T = judged best estimate of transmissivity (from transient evaluation of hydraulic test or from Moye's formula)

T_i = estimated transmissivity of flow anomaly

S* = assumed value on storativity used in single-hole tests

C = wellbore storage coefficient

ζ = skin factor

Appendix 3 includes the result tables delivered to the database SICADA . The lower measurement limit for the pumping tests with the HTHB system, presented in the result tables, is expressed in terms of specific flow (Q/s). The practical lower limit is based on the minimum flow rate Q, for which the system is designed (5 L/min) and an estimated maximum allowed drawdown for practical purposes (c 50 m) in a percussion borehole, cf Table 4-1. These values correspond to a practical lower measurement limit of Q/s-L = $2 \cdot 10^{-6}$ m^2/s of the pumping tests

Similarly, the practical, upper measurement limit 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 before and during the test. These values correspond to an estimated, practical upper measurement limit of Q/s-U = $2 \cdot 10^{-3}$ m^2/s.

Table 6-13. Summary of test data for the open-hole pumping tests performed with the HTHB system in boreholes HFM24 and HFM32 in the Forsmark candidate area.

Borehole ID	Section (m)	Test type[1]	p_i (kPa)	p_p (kPa)	p_F (kPa)	Q_p (m^3/s)	Q_m (m^3/s)	V_p (m^3)
HFM24	18.0–151.4	1B	169.85	114.75	165.07	$1.082 \cdot 10^{-3}$	$1.081 \cdot 10^{-3}$	43.45
HFM32	6.0–202.7	1B	137.67	127.10	137.90	$1.083 \cdot 10^{-3}$	$1.083 \cdot 10^{-3}$	38.65
HFM32	50.0–202.7	1B	537.92	398.91	529.03	$4.98 \cdot 10^{-4}$	$4.90 \cdot 10^{-4}$	2.65

[1)] 1B: Pumping test-submersible pump.

Table 6-14. Summary of calculated hydraulic parameters of the formation from the hydraulic tests performed with the HTHB system in boreholes HFM24 and HFM32 in the Forsmark candidate area.

Borehole ID	Section (m)	Flow Anomaly interval (m)	Test type[1]	Q/s (m^2/s)	T_M (m^2/s)	T_T (m^2/s)	T_i (m^2/s)	S* (–)
HFM24	18.0–151.4		1B	$1.8·10^{-4}$	$2.5·10^{-4}$	$1.1·10^{-4}$		$7.3·10^{-6}$
HFM24	18.0–150.0 (f)	18.0–18.5	6	$2.32·10^{-5}$			$1.32·10^{-5}$	
HFM24	18.0–150.0 (f)	29.0–30.0	6	$2.97·10^{-5}$			$1.69·10^{-5}$	
HFM24	18.0–150.0 (f)	43.0–43.5	6	$2.85·10^{-5}$			$1.63·10^{-5}$	
HFM24	18.0–150.0 (f)	46.0–46.5	6	$7.43·10^{-6}$			$4.24·10^{-6}$	
HFM24	18.0–150.0 (f)	47.5–48.0	6	$4.90·10^{-5}$			$2.80·10^{-5}$	
HFM24	18.0–150.0 (f)	49.0–49.5	6	$5.50·10^{-5}$			$3.14·10^{-5}$	
HFM32	6.0–202.7		1B	$1.0·10^{-3}$	$1.3·10^{-3}$	$9.4·10^{-4}$		$2.1·10^{-5}$
HFM32	50.0–202.7		1B	$3.5·10^{-5}$	$4.6·10^{-5}$	$2.6·10^{-5}$		$3.4·10^{-6}$
HFM32	8.3–131.9 (f)	12.3–13.8	6	$4.6·10^{-4}$			$4.3·10^{-4}$	
HFM32	8.3–131.9 (f)	14.8–15.8	6	$5.5·10^{-5}$			$5.1·10^{-5}$	
HFM32	8.3–131.9 (f)	17.8–18.3	6	$2.1·10^{-4}$			$2.0·10^{-4}$	
HFM32	8.3–131.9 (f)	21.8–22.3	6	$3.9·10^{-5}$			$3.6·10^{-5}$	
HFM32	8.3–131.9 (f)	27.3–27.8	6	$1.1·10^{-4}$			$1.0·10^{-4}$	
HFM32	8.3–131.9 (f)	29.8–30.3	6	$1.4·10^{-4}$			$1.3·10^{-4}$	

(f) = flow logged interval
[1)]1B: Pumping test-submersible pump, 3: Injection test., 6: Flow logging–Impeller.

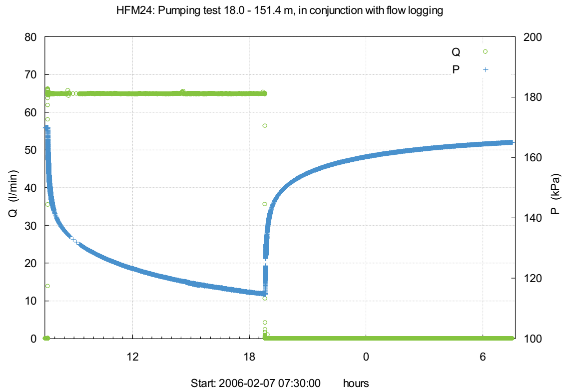
Table 6-15. Summary of calculated hydraulic parameters of the borehole from hydraulic tests performed with the HTHB system in boreholes HFM24 and HFM32 in the Forsmark candidate area.

Borehole ID	Section (m)	Test type	S* (–)	C (m^3/Pa)	ζ (–)
HFM24	18.0–151.4	1B	$7.3·10^{-6}$	$1.9·10^{-6}$	–6.1
HFM32	6.0–202.7	1B	$2.0·10^{-5}$	$1.9·10^{-6}$	–4.3
HFM32	50.0–202.7	1B	$3.4·10^{-6}$	$1.0·10^{-9}$	–3.8

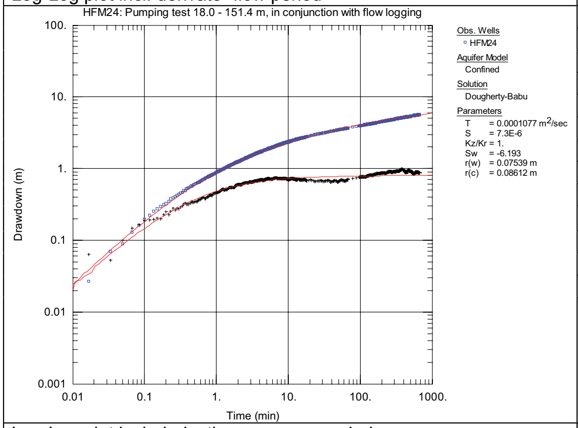
Table 6-16. Test Summary Sheet for the pumping test in HFM24, section 18.0–151.4 m.

Test Summary Sheet			
Project:	PLU	Test type:	1B
Area:	Forsmark	Test no:	1
Borehole ID:	HFM24	Test start:	2006-02-07 07:39:00
Test section (m):	18.0-151.4	Responsible for test performance:	Geosigma AB S. Jönsson
Section diameter, $2 \cdot r_w$ (m):	top 0.1397 bottom 0.1377	Responsible for test evaluation:	Geosigma AB J-E Ludvigson

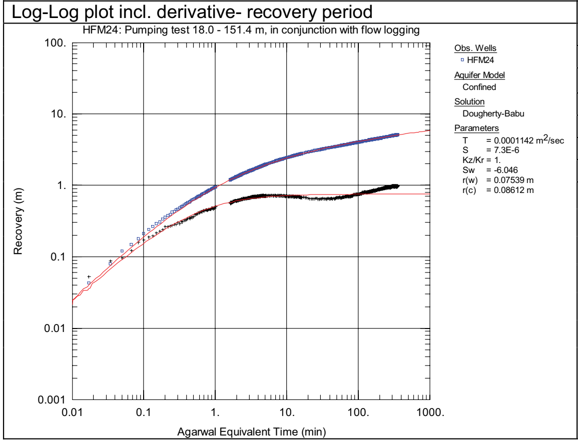
Linear plot Q and p



Log-Log plot incl. derivate- flow period



Log-Log plot incl. derivative- recovery period



Flow period		Recovery period	
Indata		Indata	
p_0 (kPa)	169.85		
p_i (kPa)	169.85		
p_p(kPa)	114.75	p_F (kPa)	165.07
Q_p (m³/s)	$1.082 \cdot 10^{-3}$		
tp (min)	670	t_F (min)	763
S*	$7.3 \cdot 10^{-6}$	S*	$7.3 \cdot 10^{-6}$
EC_w (mS/m)			
Te_w(gr C)			
Derivative fact.		Derivative fact.	
Results		Results	
Q/s (m²/s)	$1.8 \cdot 10^{-4}$		
T_{Moye}(m²/s)	$2.5 \cdot 10^{-4}$		
Flow regime:	WBS->PRF	Flow regime:	WBS->PRF
t_1 (min)	30	dt_{e1} (min)	30
t_2 (min)	670	dt_{e2} (min)	760
T_w (m²/s)	$1.1 \cdot 10^{-4}$	T_w (m²/s)	$1.1 \cdot 10^{-4}$
S_w (-)		S_w (-)	
K_{sw} (m/s)		K_{sw} (m/s)	
S_{sw} (1/m)		S_{sw} (1/m)	
C (m³/Pa)	$2.4 \cdot 10^{-6}$	C (m³/Pa)	
C_D (-)		C_D (-)	
ξ(-)	-6.2	ξ(-)	-6.0
T_{GRF}(m²/s)		T_{GRF}(m²/s)	
S_{GRF}(-)		S_{GRF}(-)	
D_{GRF} (-)		D_{GRF} (-)	

Interpreted formation and well parameters.			
Flow regime:	PRF	C (m³/Pa)	$2.4 \cdot 10^{-6}$
t_1 (min)	30	C_D (-)	
t_2 (min)	670	ξ(-)	-6.2
T_T (m²/s)	$1.1 \cdot 10^{-4}$		
S (-)	$7.3 \cdot 10^{-6}$		
K_s (m/s)			
S_s (1/m)			

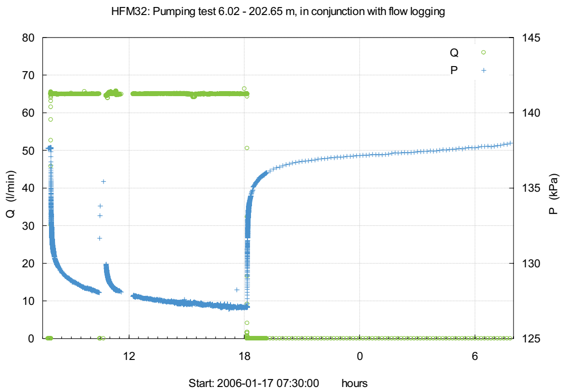
Comments:
During both the drawdown and the recovery period, wellbore storage effects are followed by a dominating pseudo-radial flow after c. 30 minutes

A region of a slightly lower hydraulic conductivity is indicated after c. 50 minutes during the drawdown as well as during the recovery.

Table 6-17. Test Summary Sheet for the pumping test in HFM32, section 6.0 – 202.7 m.

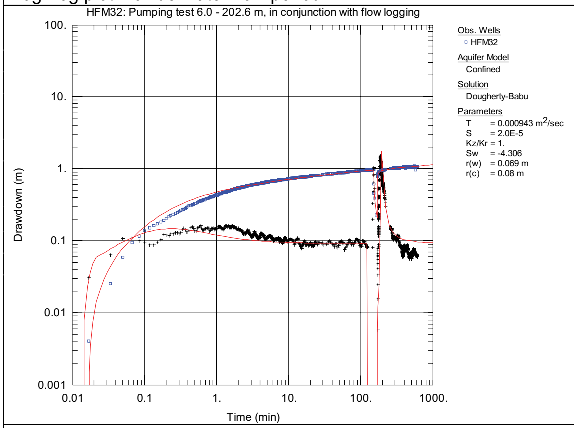
Test Summary Sheet			
Project:	PLU	Test type:	1B
Area:	Forsmark	Test no:	1
Borehole ID:	HFM32	Test start:	2006-01-17 07:56:01
Test section (m):	6.0-202.7	Responsible for test performance:	Geosigma AB S. Jönsson
Section diameter, $2 \cdot r_w$ (m):	top 0.141 bottom 0.132	Responsible for test evaluation:	Geosigma AB J-E Ludvigson

Linear plot Q and p



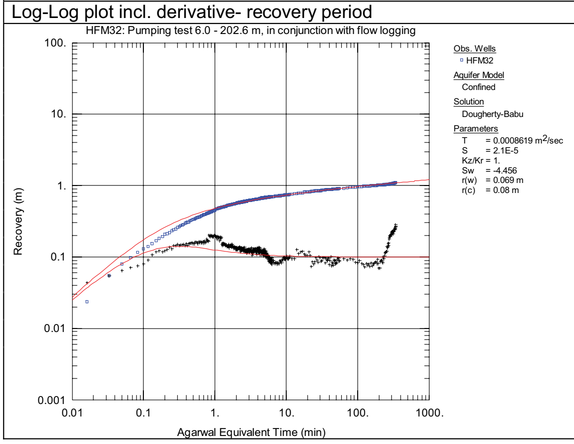
Flow period		Recovery period	
Indata		Indata	
p_0 (kPa)	137.67		
p_i (kPa)	137.67		
p_p(kPa)	127.10	p_F (kPa)	137.90
Q_p (m³/s)	$1.083 \cdot 10^{-3}$		
tp (min)	613	t_F (min)	821
S*	$2.0 \cdot 10^{-5}$	S*	$2.1 \cdot 10^{-5}$
EC_w (mS/m)			
Te_w(gr C)			
Derivative fact.		Derivative fact.	
Results		Results	
Q/s (m²/s)	$1.0 \cdot 10^{-3}$		
T_{Moye}(m²/s)	$1.30 \cdot 10^{-3}$		

Log-Log plot incl. derivate- flow period



Flow period		Recovery period	
Flow regime:	WBS->PRF	Flow regime:	WBS->PRF
t_1 (min)	15	dt_{e1} (min)	15
t_2 (min)	600	dt_{e2} (min)	200
T_w (m²/s)	$9.4 \cdot 10^{-4}$	T_w (m²/s)	$8.6 \cdot 10^{-4}$
S_w (-)		S_w (-)	
K_{sw} (m/s)		K_{sw} (m/s)	
S_{sw} (1/m)		S_{sw} (1/m)	
C (m³/Pa)		C (m³/Pa)	
C_D (-)		C_D (-)	
ξ(-)	-4.3	ξ(-)	-4.5
T_{GRF}(m²/s)		T_{GRF}(m²/s)	
S_{GRF}(-)		S_{GRF}(-)	
D_{GRF} (-)		D_{GRF} (-)	

Log-Log plot incl. derivative- recovery period



Interpreted formation and well parameters.			
Flow regime:	PRF	C (m³/Pa)	
t_1 (min)	15	C_D (-)	
t_2 (min)	600	ξ(-)	-4.3
T_T (m²/s)	$9.4 \cdot 10^{-4}$		
S (-)	$2.0 \cdot 10^{-5}$		
K_s (m/s)			
S_s (1/m)			

Comments:

During the drawdown initial wellbore storage effects are transitioning to a pseudo-radial flow regime after c.10 min.

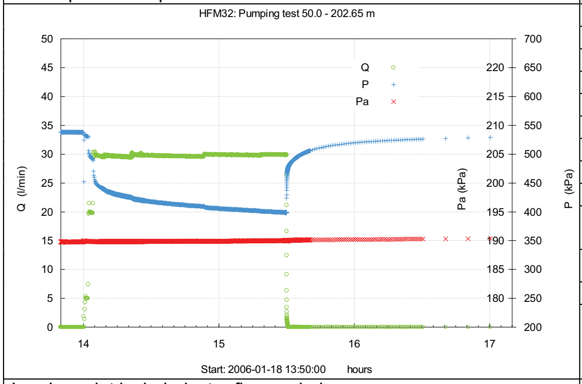
An interruption in the pumping occurred at c. 150 min

Also during the recovery period, initial wellbore storage effects are followed by a dominating pseudo-radial flowregime. By the end of the recovery period, effects of apparent no-flow boundaries or other flow restrictions are indicated.

Table 6-18. Test Summary Sheet for the pumping test in HFM32, section 50.0 – 202.7 m.

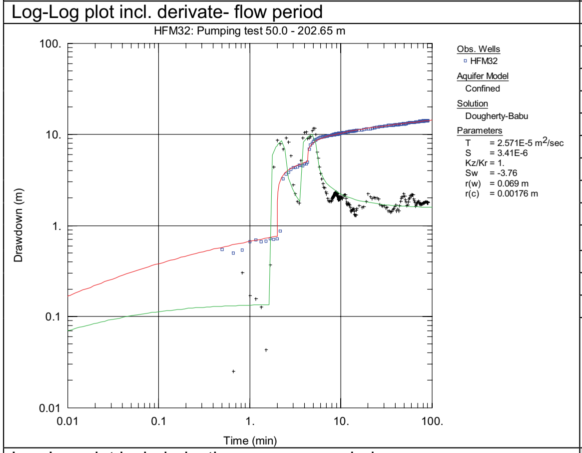
Test Summary Sheet			
Project:	PLU	Test type:	1B
Area:	Forsmark	Test no:	1
Borehole ID:	HFM32	Test start:	2006-01-18 13:48
Test section (m):	50.0-202.7	Responsible for test performance:	Geosigma AB Stig Jönsson
Section diameter, $2 \cdot r_w$ (m):	top 0.141 bottom 0.132	Responsible for test evaluation:	Geosigma AB J-E Ludvigson

Linear plot Q and p

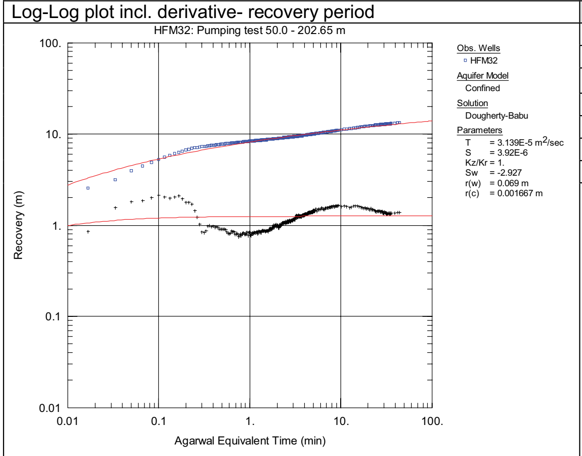


Flow period		Recovery period	
Indata			
p_0 (kPa)	537.92		
p_i (kPa)	537.92		
p_p(kPa)	398.91	p_F (kPa)	529.03
Q_p (m^3/s)	$4.98 \cdot 10^{-4}$		
tp (min)	90	t_F (min)	90
S*	$3.4 \cdot 10^{-6}$	S*	$4.0 \cdot 10^{-6}$
EC_w (mS/m)			
Te_w(gr C)			
Derivative fact.		Derivative fact.	
Results		Results	
Q/s (m^2/s)	$3.5 \cdot 10^{-5}$		
T_{Moye}(m^2/s)	$4.6 \cdot 10^{-5}$		
Flow regime:	PRF	Flow regime:	WBS->PRF
t_1 (min)	15	dt_{e1} (min)	5
t_2 (min)	90	dt_{e2} (min)	45
T_w (m^2/s)	$2.6 \cdot 10^{-5}$	T_w (m^2/s)	$3.1 \cdot 10^{-5}$
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)	$8.9 \cdot 10^{-10}$
C_D (-)		C_D (-)	
ξ(-)	-3.8	ξ(-)	-2.9
T_{GRF}(m^2/s)		T_{GRF}(m^2/s)	
S_{GRF}(-)		S_{GRF}(-)	
D_{GRF} (-)		D_{GRF} (-)	

Log-Log plot incl. derivate- flow period



Log-Log plot incl. derivative- recovery period



Interpreted formation and well parameters.			
Flow regime:	PRF	C (m^3/Pa)	
t_1 (min)	15	C_D (-)	
t_2 (min)	90	ξ(-)	-3.5
T_T (m^2/s)	$2.7 \cdot 10^{-5}$		
S (-)	$3.4 \cdot 10^{-6}$		
K_s (m/s)			
S_s (1/m)			

Comments:

The flow rate was increased in steps during the flow period which makes interpretation of flow regimes difficult in the beginning. A pseudo-radial flow regime is indicated during drawdown, from c. 10 min - 60min.

A transitioning period after initial wellbore storage effects dominates the first part of the recovery period followed by a transition to pseudo-radial flow regime.

7 References

/1/ **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.

/2/ **Morosini M, Almén K-E, Follin S, Hansson K, Ludvigson J-E, Rhén I, 2001.** Metoder och utrustningar för hydrauliska enhålstester. Metod och program aspekter för geovetenskapliga platsundersökningar. Tekniskt Dokument TD-01-63, Svensk Kärnbränslehantering AB.

/3/ **Dougherty D E, Babu D K, 1984.** Flow to a partially penetrating well in a double-porosity reservoir, Water Resour. Res., 20 (8), 1116–1122.

/4/ **Rehn I (ed), Gustafsson G, Stanfors R, Wikberg P, 1997.** Äspö HRL Geoscientific evaluation 1997/5. Models based on site characterization 1986–1995. SKB TR 97-06, Svensk Kärnbränslehantering AB.

Appendix 1

List of 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 (para-meters)[2]	Comments
HFM24	18.8–151.4	1B	1	2006-02-06 18:50:00	2006-02-06 19:45:59	2006-02-06 18:45:10	2006-02-06 19:45:59	HFM24_18.0_060206_Pumpin02.DAT	P, Q	Capacity test
	18.0–151.4	1B	2	2006-02-07 07:39.00	2006-02-08 07:31:40	2006-02-06 16:25:11	2006-02-08 07:31:40	HFM24_18.0_060206_FlowLo02.DAT	P, Q, Te, EC	
						2006-02-06 15:41:31	2006-02-07 19:05:41	HFM24_18.0_060206_Ref_Da02.DAT		This reference file is valid for all tests performed in HFM24.
	18.0–150.0	6	3	2006-02-07 15:48:32	2006-02-07 18:39:44	2006-02-07 15:48:32	2006-02-07 18:39:44	HFM24_18.0_060207_Spinne02.DAT	P, Q, Te, EC, SP	
HFM32	6.03–202.65	1B	4	2006-01-17 07:56.01	2006-01-18 08:25:06	2006-01-16 17:54:32	2006-01-18 08:25:06	HFM32_6.02_060117_FlowLo05.DAT	P, Q, Te, EC	A short capacity test was performed 2006-01-16 with pump start 20:03:00 and pump stop 20:36:00
						2006-01-16 17:44:56	2006-01-17 09:24:23	HFM32_6.02_060116_Ref_Da05.DAT		This reference file is valid for all tests performed in HFM32.
	6.03–202.65	6	5	2006-01-17 15:14:51	2006-01-17 17:53:23	2006-01-17 15:14:51	2006-01-17 17:53:23	HFM32_6.02_060117_Spinne05.DAT	P, Q, Te, EC, SP	
	50.0–202.65	1B	6	2006-01-18 14:00:00	2006-01-18 17:00:15	2006-01-18 13:48:14	2006-01-18 17:00:15	HFM32_50.0_060118_Pumpin05.DAT	P, Q	

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

Appendix 2

Test diagrams

Diagrams are presented for the following tests:

1. Pumping test in HFM24:18.0–151.4 m
2. Pumping test in HFM32: 6.03–202.65 m
3. Pumping test in HFM32: 50.0–202.65 m

Nomenclature in AQTESOLV:

T = transmissivity (m^2/s)

S = storativity (–)

K_Z/K_r = ratio of hydraulic conductivities in the vertical and radial direction (set to 1)

S_w = skin factor

r(w) = borehole radius (m)

r(c) = effective casing radius (m)

K_r = hydraulic conductivity, radial direction (m/s)

S_s = specific storage (1/m)

R_f = fracture radius (m)

Pumping test in HFM24: 18.0–151.4 m

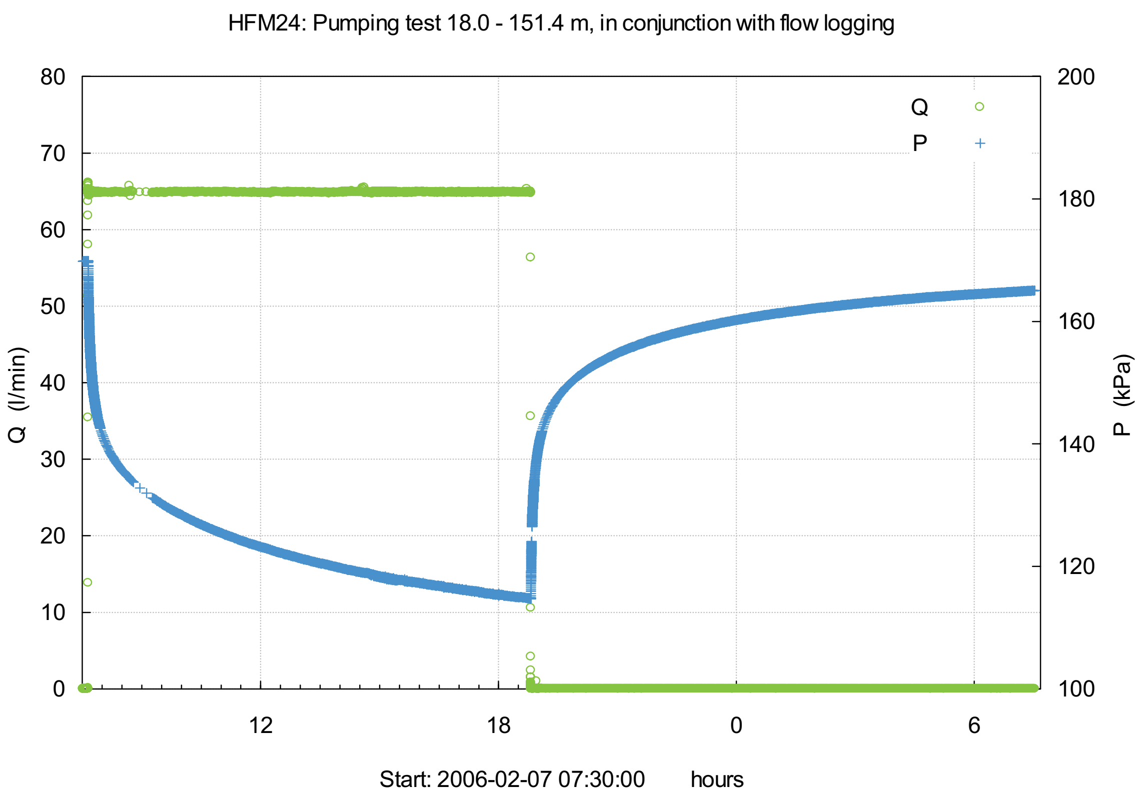


Figure A2-1. *Linear plot of flow rate (Q) and pressure (p) versus time during the open-hole pumping test in HFM24 in conjunction with flow logging.*

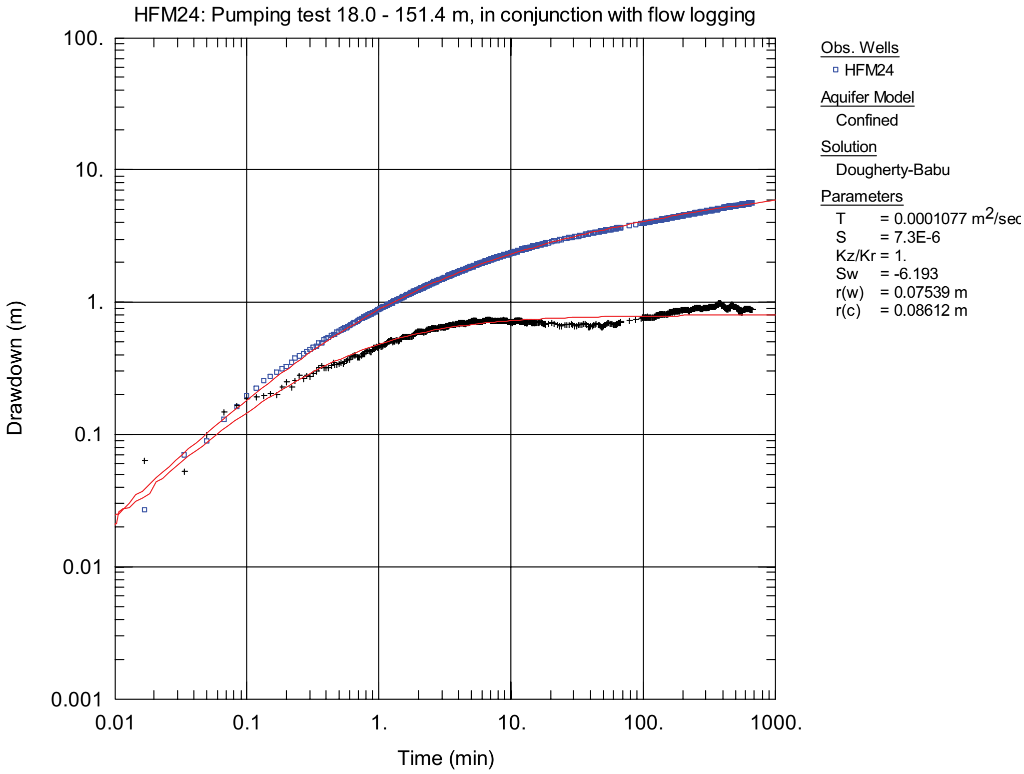


Figure A2-2. *Log-log plot of drawdown (blue □) and drawdown derivative (black +) versus time during the open-hole pumping test in HFM24.*

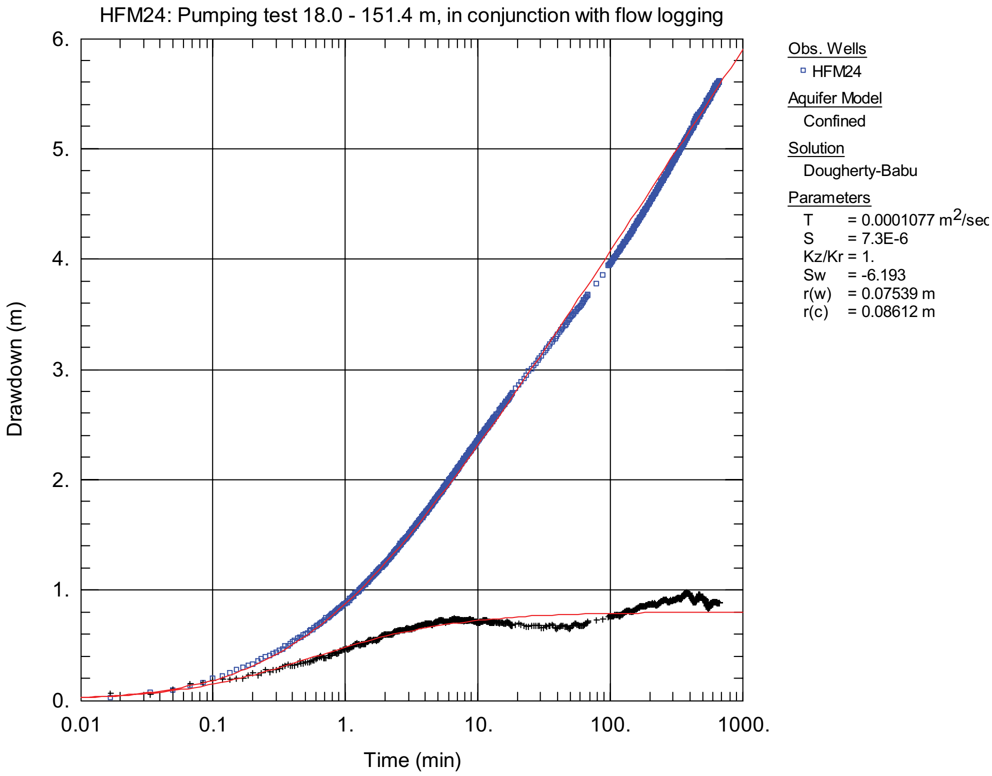


Figure A2-3. *Lin-log plot of drawdown (blue □) and drawdown derivative (black +) versus time during the open-hole pumping test in HFM24.*

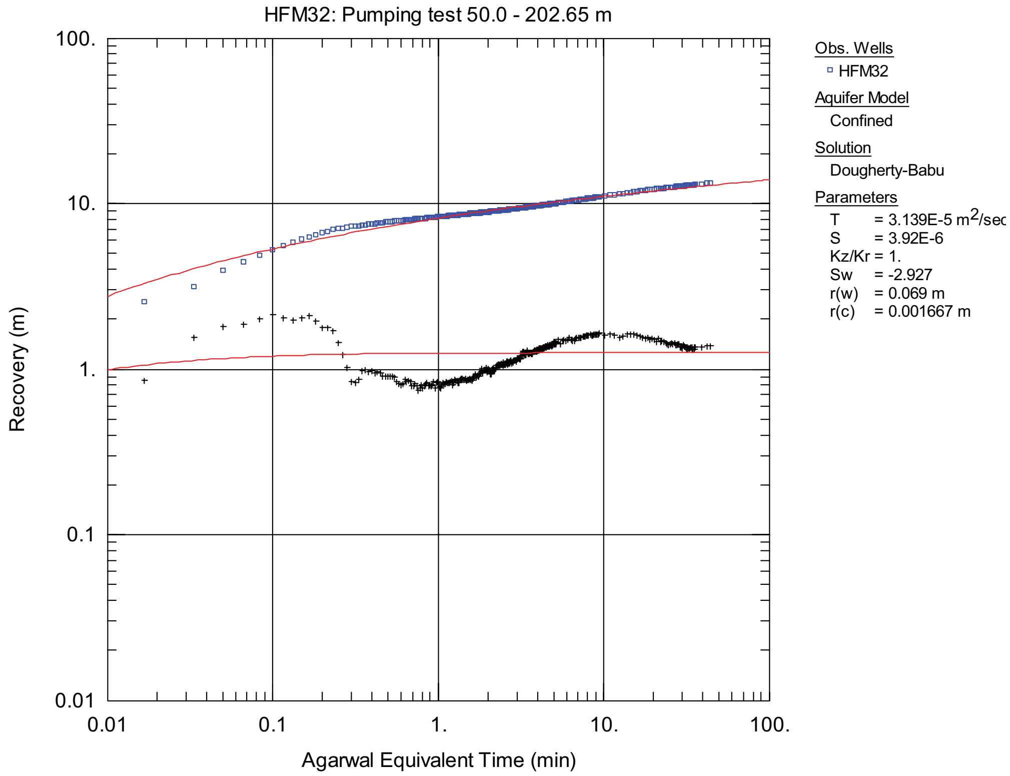


Figure A2-4. *Log-log plot of pressure recovery (blue □) and -derivative (black +) dsp/d(ln dte) versus equivalent time (dte) from the open-hole pumping test in HFM24.*

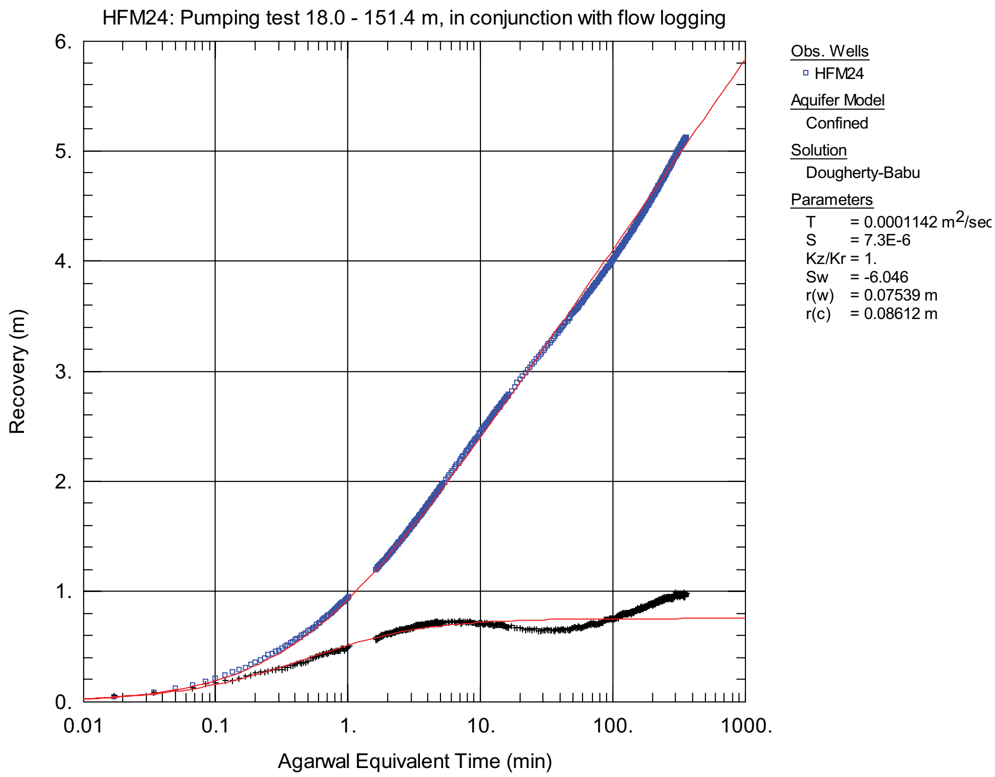


Figure A2-5. *Lin-log plot of pressure recovery (blue □) and -derivative (black +) dsp/d(ln dte) versus equivalent time (dte) from the open-hole pumping test in HFM24.*

Pumping test in HFM32: 6.03–202.65 m

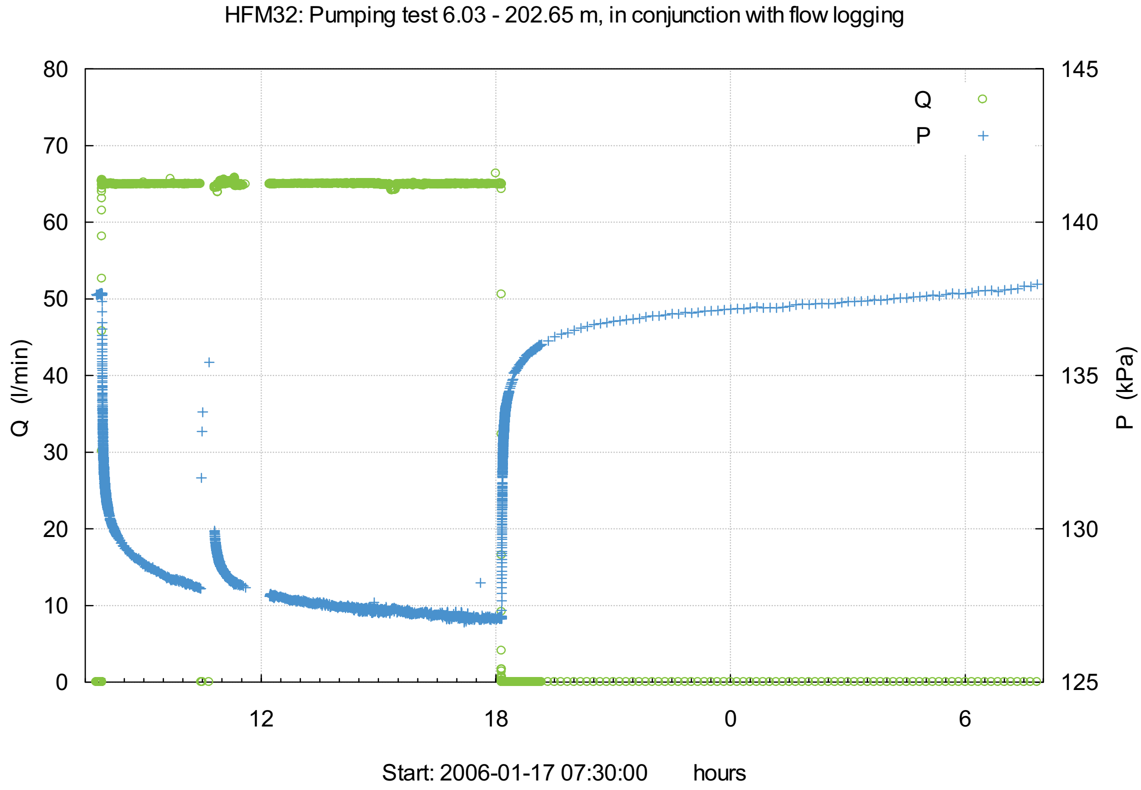


Figure A2-6. *Linear plot of flow rate (Q) and pressure (p) versus time during the open-hole pumping test in HFM32 in conjunction with flow logging.*

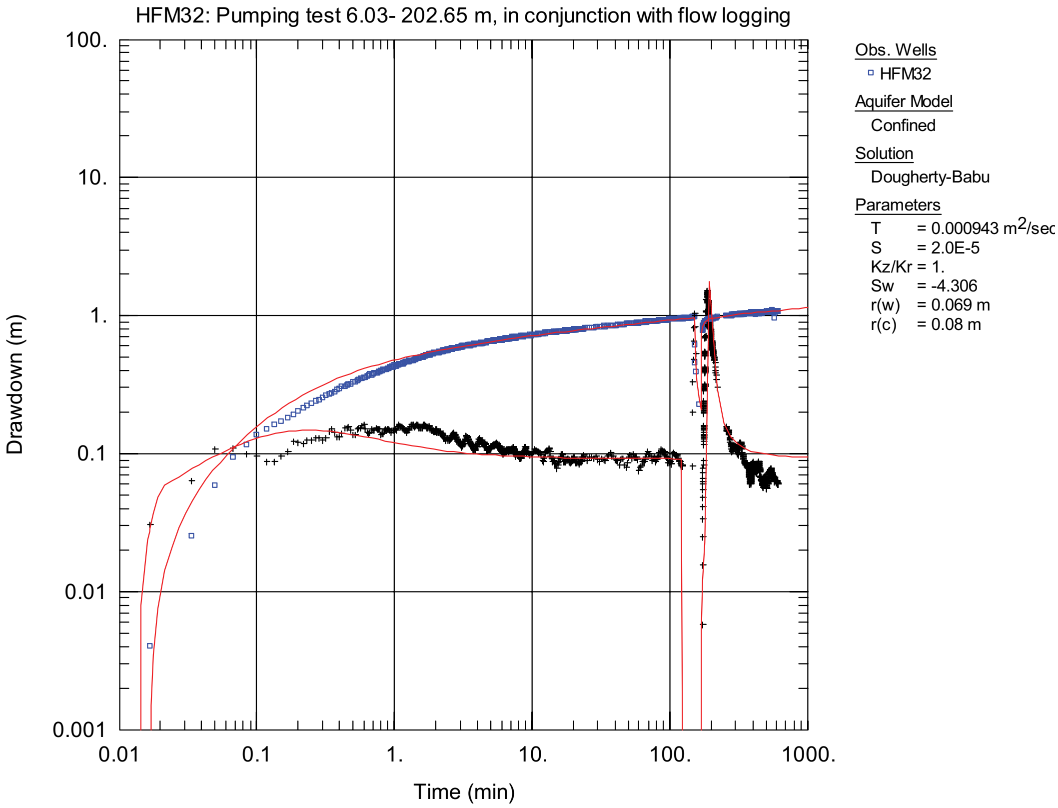


Figure A2-7. *Log-log plot of drawdown (blue □) and drawdown derivative (black +) versus time during the open-hole pumping test in HFM32.*

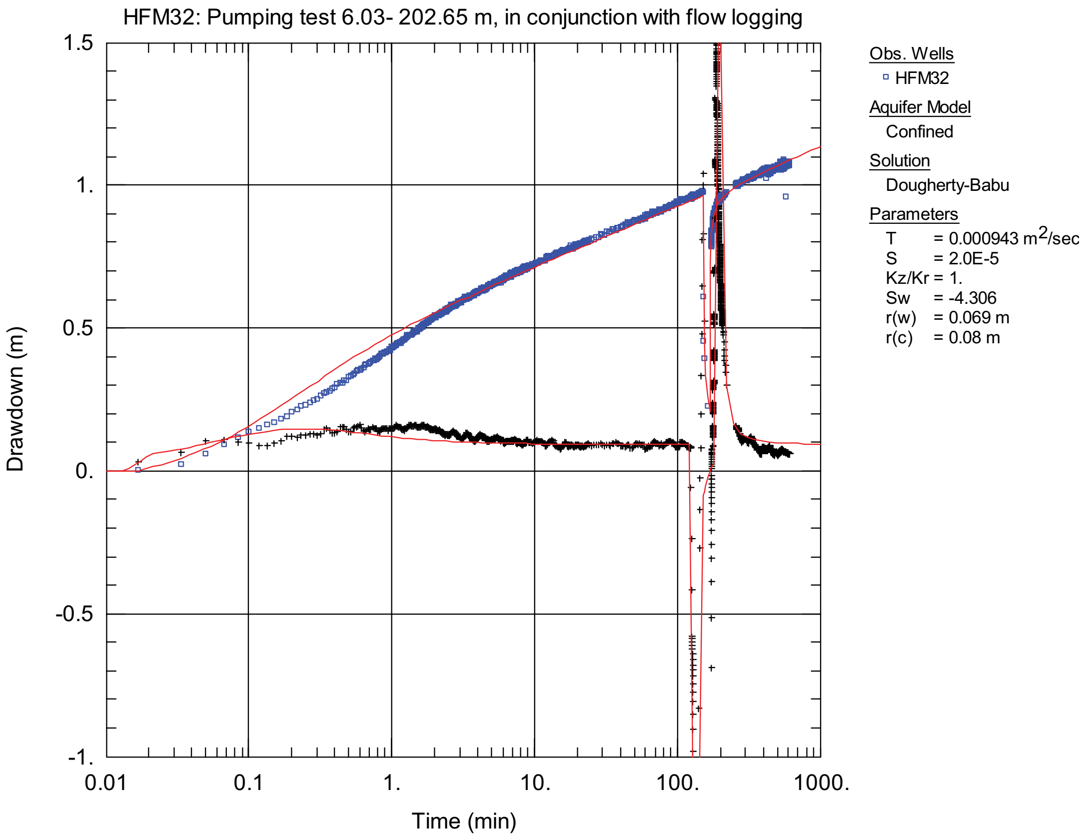


Figure A2-8. *Lin-log plot of drawdown (blue □) and drawdown derivative (black +) versus time during the open-hole pumping test in HFM32.*

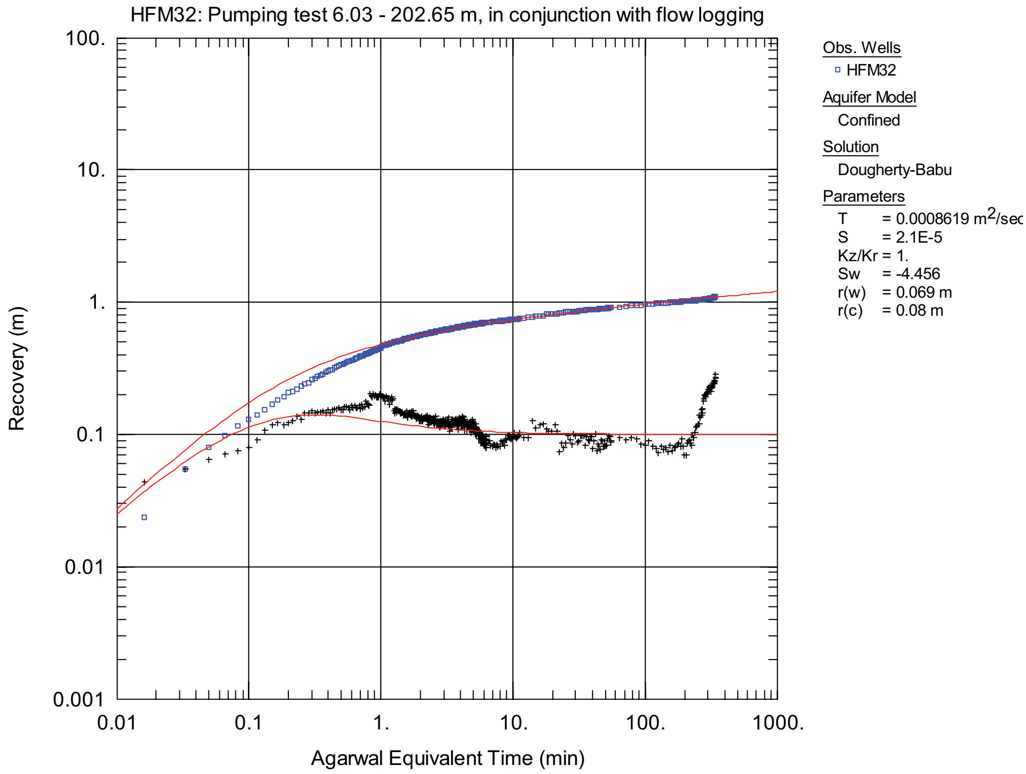


Figure A2-9. *Log-log plot of pressure recovery (blue □) and -derivative (black +) dsp/d(ln dte) versus equivalent time (dte) from the open-hole pumping test in HFM32.*

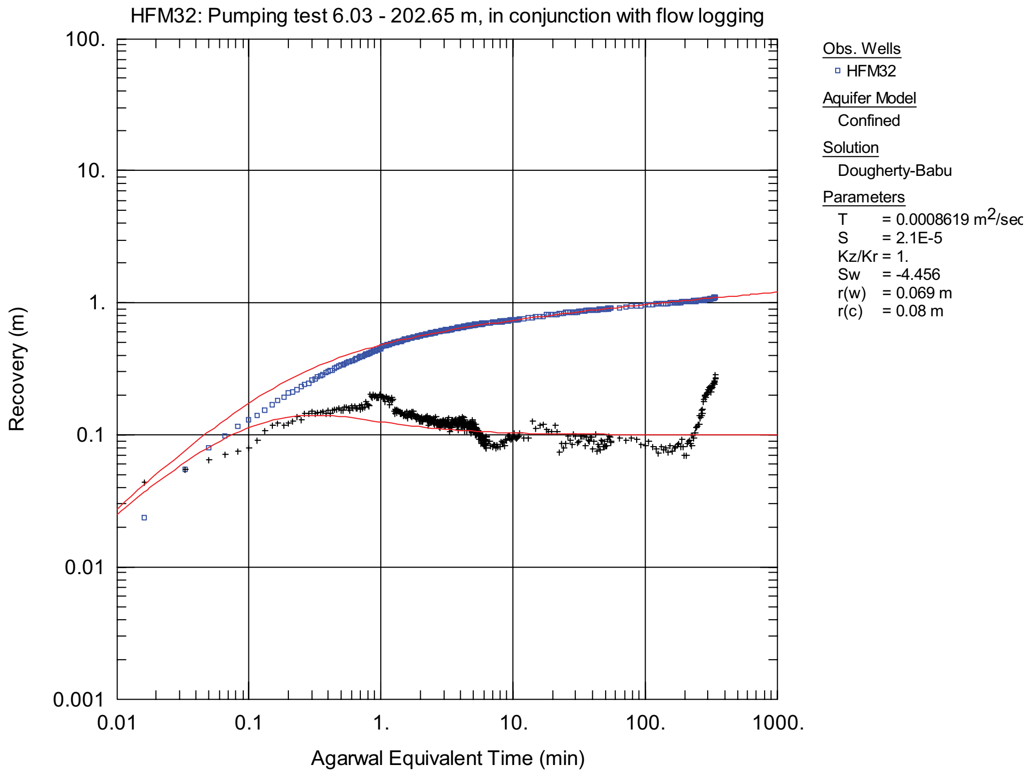


Figure A2-10. *Lin-log plot of pressure recovery (blue □) and -derivative (black +) dsp/d(ln dte) versus equivalent time (dte) from the open-hole pumping test in HFM32.*

Pumping test in HFM32: 50.0–202.65 m

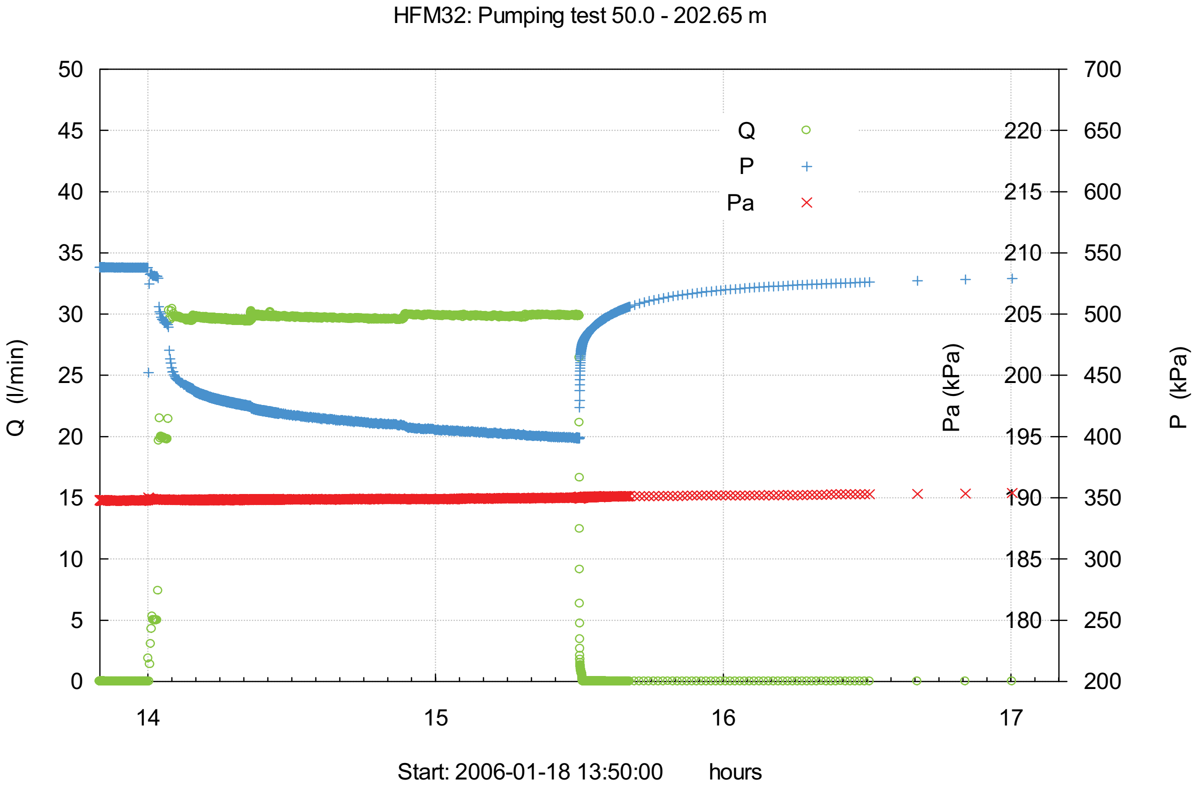


Figure A2-11. *Linear plot of flow rate (Q), pressure in test section (P) and pressure above test section (Pa) versus time during the pumping test below a packer at 48–50 m in HFM32.*

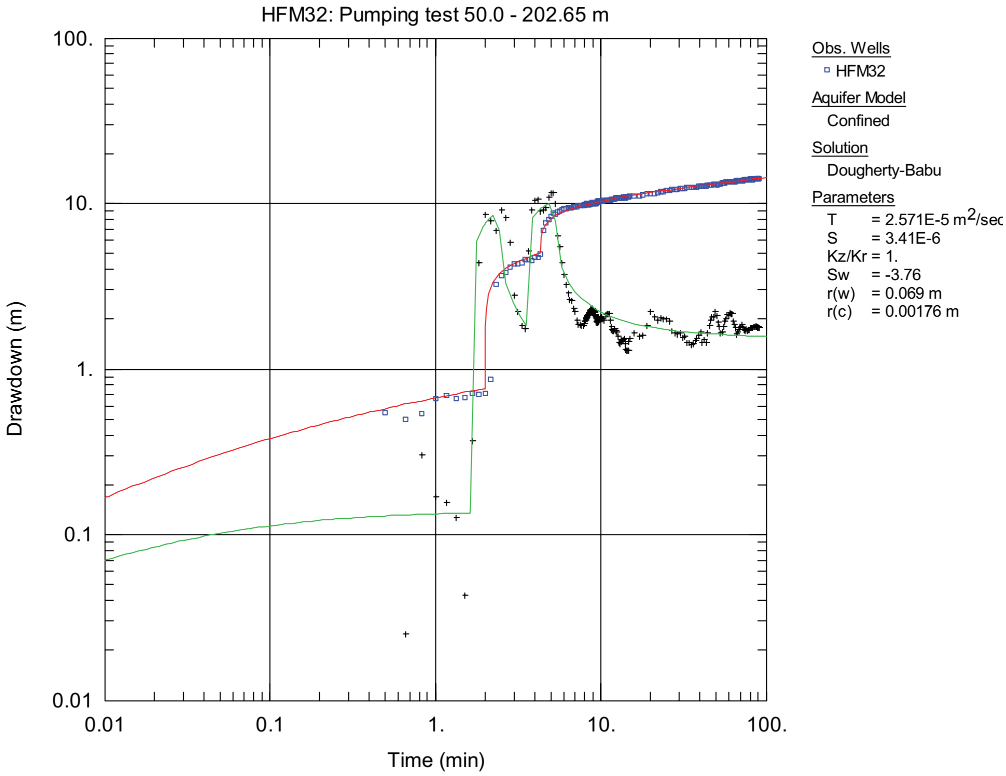


Figure A2-12. *Log-log plot of drawdown (blue □) and drawdown derivative (black +) versus time during the pumping test below a packer at 48–50 m in HFM32.*

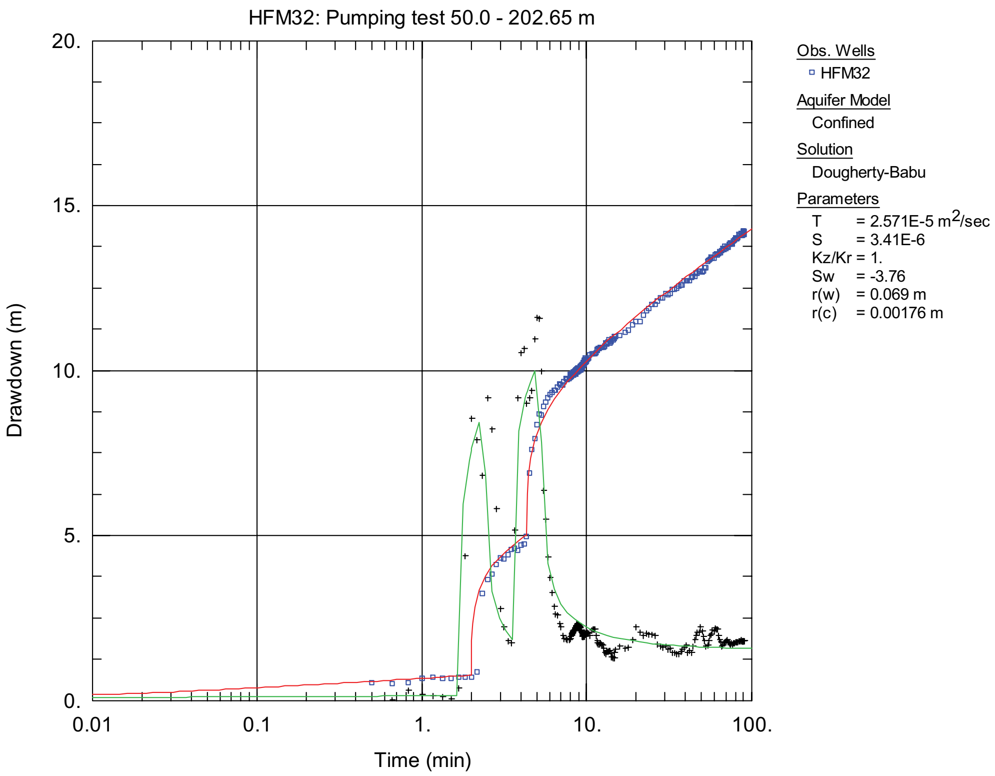


Figure A2-13. *Lin-log plot of drawdown (blue □) and drawdown derivative (black +) versus time during the pumping test below a packer at 48–50 m in HFM32.*

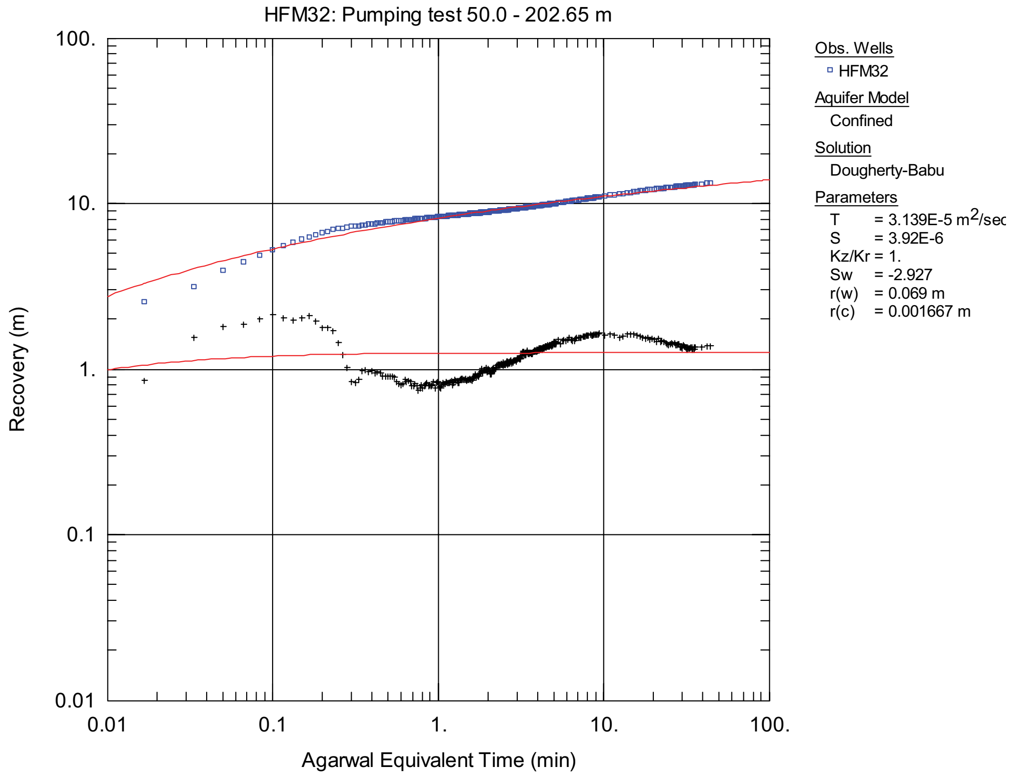


Figure A2-14. *Log-log plot of pressure recovery (blue □) and -derivative (black +) versus time during the pumping test below a packer at 48–50 m in HFM32.*

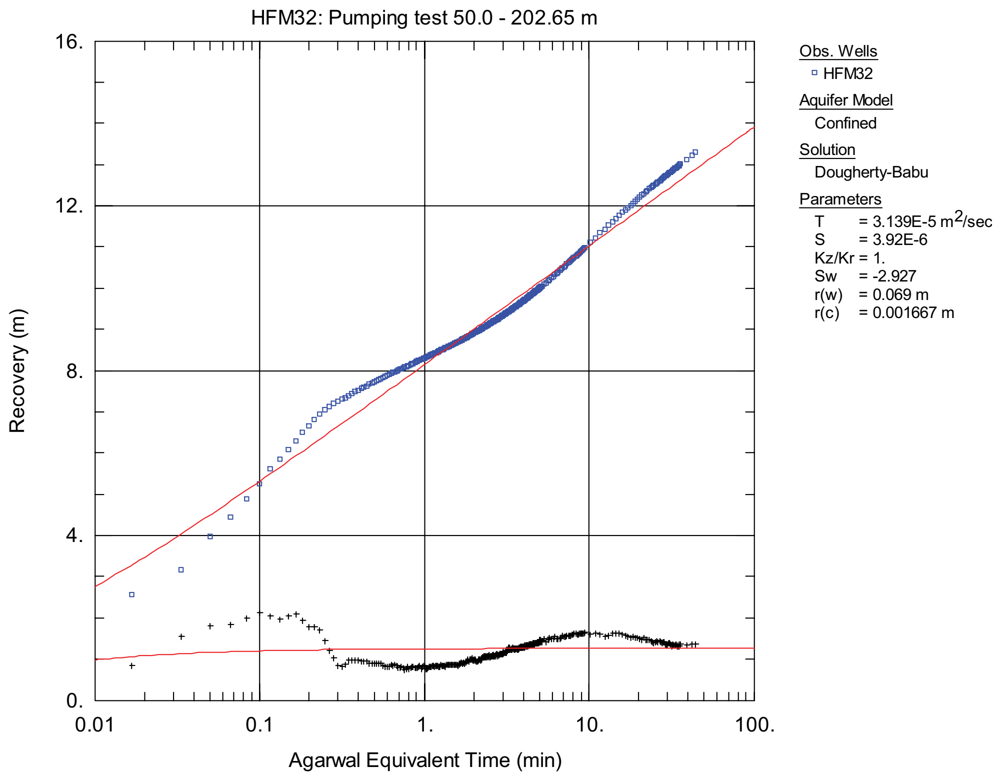


Figure A2-15. *Lin-log plot of pressure recovery (blue □) and -derivative (black +) versus time during the pumping test below a packer at 48–50 m in HFM32.*

Appendix 3

Result tables to Sicada database

The following Result Tables are presented:
1. Result Tables for Single-hole pumping tests
2. Result Tables for flow loggingA. Result Table for Single-hole tests for submission to the Sicada database

A. Result Table for Single-hole tests for submission to the Sicada database

SINGLEHOLE TESTS, Pumping and injection, s_hole_test_d; General information

idcode	start_date	stop_date	secup (m)	seclow (m)	section_no	test_type	formation_type	start_flow_period (yyyymmdd)	stop_flow_period (yyyymmdd)	flow_rate_end_qp (m**3/s)
HFM24	060207 07:39:00	060208 07:31:40	18.00	151.40		1B	1	2006-02-07 07:39:00	2006-02-07 18:49:00	1.0820E-03
HFM32	060117 07:47.00	060118 08:25:06	6.00	202.70		1B	1	2006-01-17 07:56:01	2006-01-17 18:09:01	1.0830E-03
HFM32	060118 13:48:00	060118 17:00:15	50.00	202.70		1B	1	2006-01-18 14:00:00	2006-01-18 15:30:00	4.9800E-04

cont.

value_type_qp	mean_flow_rate_qm (m**3/s)	q_measl__l (m**3/s)	q_measl__u (m**3/s)	tot_volume_vp (m**3)	dur_flow_phase_tp (s)	dur_rec_phase_tf (s)	initial_head_hi (m)	head_at_flow_end_hp (m)	final_head_hf (m)	initial_press_pi (kPa)	press_at_flow_end_pp (kPa)	final_press_pf (kPa)
0	1.0810E-03	8.3333E-05	1.3333E-03	4.3450E+01	40200.00	45780.00	1.84	-3.88	1.34	169.85	114.75	165.07
0	1.0830E-03	8.3333E-05	1.3333E-03	3.8650E+01	36780.00	49260.00	0.42	-0.65	0.40	137.67	127.10	118.63
0	4.9000E-04	8.3333E-05	1.3333E-03	2.6500E+00	5400.00	5400.00				537.92	398.91	529.03

cont.

fluid_temp_tew (oC)	fluid_elcond_ecw (mS/m)	fluid_salinity_tdsw (mg/l)	fluid_salinity_tdswm (mg/l)	reference	comments	lp (m)
						47.00
						15.00
						95.00

Column	Datatype	Unit	Column Description
Site	CHAR		Investigation site name
Activity_type	CHAR		Activity type code
start_date	DATE		Date (yymmdd hh:mm:ss)
stop_date	DATE		Date (yymmdd hh:mm:ss)
Project	CHAR		project code
Idcode	CHAR		Object or borehole identification code
Secup	FLOAT	m	Upper section limit (m)
Seclow	FLOAT	m	Lower section limit (m)
Section_no	INTEGER	number	Section number
test_type	CHAR		Test type code (1–7), see table description
formation_type	CHAR		1: Rock, 2: Soil (superficial deposits)
start_flow_period	DATE	yyyymmdd	Date & time of pumping/injection start (YYYY-MM-DD hh:mm:ss)
stop_flow_period	DATE	yyyymmdd	Date & time of pumping/injection stop (YYYY-MM-DD hh:mm:ss)
flow_rate_end_qp	FLOAT	m**3/s	Flow rate at the end of the flowing period
value_type_qp	CHAR		0:true value,–1<lower meas.limit1:>upper meas.limit
mean_flow_rate_qm	FLOAT	m**3/s	Arithmetic mean flow rate during flow period
q_measl__l	FLOAT	m**3/s	Estimated lower measurement limit of flow rate
q_measl__u	FLOAT	m**3/s	Estimated upper measurement limit of flow rate
tot_volume_vp	FLOAT	m**3	Total volume of pumped or injected water
dur_flow_phase_tp	FLOAT	s	Duration of the flowing period of the test
dur_rec_phase_tf	FLOAT	s	Duration of the recovery period of the test
initial_head_hi	FLOAT	m	Hydraulic head in test section at start of the flow period
head_at_flow_end_hp	FLOAT	m	Hydraulic head in test section at stop of the flow period.
final_head_hf	FLOAT	m	Hydraulic head in test section at stop of recovery period.
initial_press_pi	FLOAT	kPa	Groundwater pressure in test section at start of flow period
press_at_flow_end_pp	FLOAT	kPa	Groundwater pressure in test section at stop of flow period.
final_press_pf	FLOAT	kPa	Ground water pressure at the end of the recovery period.
fluid_temp_tew	FLOAT	oC	Measured section fluid temperature, see table description
fluid_elcond_ecw	FLOAT	mS/m	Measured section fluid el. conductivity,see table descr.
fluid_salinity_tdsw	FLOAT	mg/l	Total salinity of section fluid based on EC,see table descr.
fluid_salinity_tdswm	FLOAT	mg/l	Tot. section fluid salinity based on water sampling,see...
reference	CHAR		SKB report No for reports describing data and evaluation
comments	VARCHAR		Short comment to data
error_flag	CHAR		If error_flag = "*" then an error occured and an error
in_use	CHAR		If in_use = "*" then the activity has been selected as
Sign	CHAR		Activity QA signature
Lp	FLOAT	m	Hydraulic point of application

SINGLEHOLE TESTS, Pumping and injection, s_hole_test_ed1; Basic evaluation

idcode	start_date	stop_date	secup (m)	seclow (m)	section_no	test_type	formation_type	lp (m)	seclen_class (m)	spec_capacity_q_s (m**2/s)	value_type_q_s
HFM24	060207 07:39:00	060208 07:31:40	18.00	151.40		1B	1	47.00		1.80E-04	0
HFM32	060117 07:47.00	060118 08:25:06	6.00	202.70		1B	1	15.00		1.00E-03	0
HFM32	060118 13:48:00	060118 17:00:15	50.00	202.70		1B	1	95.00		3.50E-05	0

cont.

transmissivity_tq (m**2/s)	value_type_tq	bc_tq	transmissivity_moye (m**2/s)	bc_tm	value_type_tm	hydr_cond_moye (m/s)	formation_width_b (m)	width_of_channel_b (m)	tb (m**3/s)	l_measl_tb (m**3/s)	u_measl_tb (m**3/s)	sb (m)	assumed_sb (m)	leakage_factor_lf (m)	transmissivity_tt (m**2/s)	value_type_tt	bc_tt
			2.50E-04	0	0										1.10E-04	0	1
			1.30E-03	0	0										9.40E-04	0	1
			4.60E-06	0	0										2.70E-05	0	1

cont.

l_measl_q_s (m**2/s)	u_measl_q_s (m**2/s)	storativity_s	assumed_s	s_bc	ri (m)	ri_index	leakage_coeff (1/s)	hydr_cond_ksf (m/s)	value_type_ksf	l_measl_ksf (m/s)	u_measl_ksf (m/s)	spec_storage_ssf (1/m)	assumed_ssf (1/m)	c (m**3/pa)	cd	skin	dt1 (s)	dt2 (s)	t1 (s)	t2 (s)
2.E-06	2.E-03	7.30E-06			1167.45	0								1.90E-06		-6.20E+00			1800.00	40200.00
2.E-06	2.E-03	2.00E-05			1951.15	0								1.90E-06		-4.30E+00			900.00	36000.00
2.E-06	2.E-03	3.40E-06			310.62	0								1.00E-09		-3.50E+00			900.00	5400.00

cont.

dte1 (s)	dte2 (s)	p_horner (kPa)	transmissivity_t_nlr (m**2/s)	storativity_s_nlr	value_type_t_nlr	bc_t_nlr	c_nlr (m**3/pa)	cd_nlr	skin_nlr	transmissivity_t_grf (m**2/s)	value_type_t_grf	bc_t_grf	storativity_s_grf	flow_dim_grf	comment (no_unit)
1800.00	45600.00														
900.00	12000.00														
480.00	5400.00														

Column	Datatype	Unit	Column Description
Site	CHAR		Investigation site name
Activity_type	CHAR		Activity type code
start_date	DATE		Date (yymmdd hh:mm:ss)
stop_date	DATE		Date (yymmdd hh:mm:ss)
Project	CHAR		project code
Idcode	CHAR		Object or borehole identification code
Secup	FLOAT	m	Upper section limit (m)
Seclow	FLOAT	m	Lower section limit (m)
Section_no	INTEGER	number	Section number
test_type	CHAR		Test type code (1–7), see table description!
formation_type	CHAR		Formation type code. 1: Rock, 2: Soil (superficial deposits)
Lp	FLOAT	m	Hydraulic point of application for test section, see descr.
seclen_class	FLOAT	m	Planned ordinary test interval during test campaign.
spec_capacity_q_s	FLOAT	m**2/s	Specific capacity (Q/s) of test section, see table descript.
value_type_q_s	CHAR		0:true value,–1:Q/s<lower meas.limit,1:Q/s>upper meas.limit
transmissivity_tq	FLOAT	m**2/s	Tranmissivity based on Q/s, see table description
value_type_tq	CHAR		0:true value,–1:TQ<lower meas.limit,1:TQ>upper meas.limit.
bc_tq	CHAR		Best choice code. 1 means TQ is best choice of T, else 0
transmissivity_moye	FLOAT	m**2/s	Transmissivity,TM, based on Moye (1967)
bc_tm	CHAR		Best choice code. 1 means Tmoye is best choice of T, else 0
value_type_tm	CHAR		0:true value,–1:TM<lower meas.limit,1:TM>upper meas.limit.
hydr_cond_moye	FLOAT	m/s	K_M: Hydraulic conductivity based on Moye (1967)
formation_width_b	FLOAT	m	b:Aquifer thickness repr. for T(generally b = Lw) ,see descr.
width_of_channel_b	FLOAT	m	B:Inferred width of formation for evaluated TB
Tb	FLOAT	m**3/s	TB:Flow capacity in 1D formation of T & width B, see descr.
l_measl_tb	FLOAT	m**3/s	Estimated lower meas. limit for evaluated TB,see description
u_measl_tb	FLOAT	m**3/s	Estimated upper meas. limit of evaluated TB,see description
Sb	FLOAT	m	SB:S = storativity,B = width of formation,1D model,see descript.
assumed_sb	FLOAT	m	SB* : Assumed SB,S = storativity,B = width of formation,see...
Leakage_factor_lf	FLOAT	m	Lf:1D model for evaluation of Leakage factor
transmissivity_tt	FLOAT	m**2/s	TT:Transmissivity of formation, 2D radial flow model,see...
value_type_tt	CHAR		0:true value,–1:TT<lower meas.limit,1:TT>upper meas.limit,
bc_tt	CHAR		Best choice code. 1 means TT is best choice of T, else 0
l_measl_q_s	FLOAT	m**2/s	Estimated lower meas. limit for evaluated TT,see table descr
u_measl_q_s	FLOAT	m**2/s	Estimated upper meas. limit for evaluated TT,see description
storativity_s	FLOAT		S:Storativity of formation based on 2D rad flow,see descr.
assumed_s	FLOAT		Assumed Storativity,2D model evaluation,see table descr.
s_bc	FLOAT		Best choice of S (Storativity) ,see descr.
Ri	FLOAT	m	Radius of influence
ri_index	CHAR		ri index = index of radius of influence :–1,0 or 1, see descr.
Leakage_coeff	FLOAT	1/s	K'/b':2D rad flow model evaluation of leakage coeff,see desc
hydr_cond_ksf	FLOAT	m/s	Ksf:3D model evaluation of hydraulic conductivity,see desc.
value_type_ksf	CHAR		0:true value,–1:Ksf<lower meas.limit,1:Ksf>upper meas.limit,
l_measl_ksf	FLOAT	m/s	Estimated lower meas.limit for evaluated Ksf,see table desc.
u_measl_ksf	FLOAT	m/s	Estimated upper meas.limit for evaluated Ksf,see table descr
spec_storage_ssf	FLOAT	1/m	Ssf:Specific storage,3D model evaluation,see table descr.
assumed_ssf	FLOAT	1/m	Ssf*:Assumed Spec.storage,3D model evaluation,see table des.
C	FLOAT	m**3/pa	C: Wellbore storage coefficient; flow or recovery period
Cd	FLOAT		CD: Dimensionless wellbore storage coefficient

Column	Datatype	Unit	Column Description
Skin	FLOAT		Skin factor;best estimate of flow/recovery period,see descr.
dt1	FLOAT	s	Estimated start time of evaluation, see table description
dt2	FLOAT	s	Estimated stop time of evaluation. see table description
t1	FLOAT	s	Start time for evaluated parameter from start flow period
t2	FLOAT	s	Stop time for evaluated parameter from start of flow period
dte1	FLOAT	s	Start time for evaluated parameter from start of recovery
dte2	FLOAT	s	Stop time for evaluated parameter from start of recovery
p_horner	FLOAT	kPa	p*:Horner extrapolated pressure, see table description
transmissivity_t_nlr	FLOAT	m**2/s	T_NLR Transmissivity based on None Linear Regression...
storativity_s_nlr	FLOAT		S_NLR = storativity based on None Linear Regression,see..
value_type_t_nlr	CHAR		0:true value,–1:T_NLR<lower meas.limit,1:>upper meas.limit
bc_t_nlr	CHAR		Best choice code. 1 means T_NLR is best choice of T, else 0
c_nlr	FLOAT	m**3/pa	Wellbore storage coefficient, based on NLR, see descr.
cd_nlr	FLOAT		Dimensionless wellbore storage constant, see table descrip.
skin_nlr	FLOAT		Skin factor based on Non Linear Regression,see desc.
transmissivity_t_grf	FLOAT	m**2/s	T_GRF:Transmissivity based on Genelized Radial Flow,see...
value_type_t_grf	CHAR		0:true value,–1:T_GRF<lower meas.limit,1:>upper meas.limit
bc_t_grf	CHAR		Best choice code. 1 means T_GRF is best choice of T, else 0
storativity_s_grf	FLOAT		S_GRF:Storativity based on Generalized Radial Flow, see des.
flow_dim_grf	FLOAT		Inferred flow dimesion based on Generalized Rad. Flow model
comment	VARCHAR	no_unit	Short comment to the evaluated parameters
error_flag	CHAR		If error_flag = “*” then an error occured and an error
in_use	CHAR		If in_use = “*” then the activity has been selected as
Sign	CHAR		Activity QA signature

B. Result Table for Flow logging at the Forsmark site investigation for submission to the Sicada database

Plu_impeller_basic_d

idcode	start_date	stop_date	secup (m)	seclow (m)	section_no	start_flowlogging (yyyymmdd)	stop_flowlogging (yyyymmdd)	l (m)	test_type	formation_type
HFM24	2006-02-07 07:39	2006-02-08 07:32	18.00	150.00		2006-02-07 14:43:00	2006-02-07 18:39:00	151.40	6	1
HFM32	2006-01-17 07:47	2006-01-18 08:25	8.30	131.70		2006-01-17 14:18:00	2006-01-17 17:53:00	202.70	6	1

cont.

q_measl_l (m**3/s)	q_measl_u (m**3/s)	pump_flow_q1 (m**3/s)	pump_flow_q2 (m**3/s)	dur_flow_phase_tp1 (s)	dur_flow_phase_tp2 (s)	dur_flowlog_tfl_1 (s)	dur_flowlog_tfl_2 (s)	drawdown_s1 (m)	drawdown_s2 (m)	initial_head_ho (m.a.s.l.)	hydraulic_head_h1 (m.a.s.l.)	hydraulic_head_h2 (m.a.s.l.)	reference	comments
5.0000E-05	1.3333E-03	1.0810E-03		40200.00		10260.00		5.72		1.84	-3.88			
5.0000E-05	1.3333E-03	1.0830E-03		36780.00		12900.00		1.07		0.42	-0.65			

Column	Datatype	Unit	Column Description
Site	CHAR		Investigation site name
start_date	DATE		Date (yymmdd hh:mm:ss)
stop_date	DATE		Date (yymmdd hh:mm:ss)
Secup	FLOAT	m	Upper section limit (m)
Seclow	FLOAT	m	Lower section limit (m)
Sign	CHAR		Activity QA signature
start_flowlogging	DATE	yyyymmdd	Date and time of flowlogging start (YYYY-MM-DD hh:mm:ss)
stop_flowlogging	DATE	yyyymmdd	Date and time of flowlogging stop (YYYY-MM-DD hh:mm:ss)
L	FLOAT	m	Corrected borehole length during logging, see table descr.
test_type	CHAR		Type of test,(1– 7); see table description
formation_type	CHAR		1: Rock, 2: Soil (supeficial deposits)
q_measl_l	FLOAT	m**3/s	Estimated lower measurement limit of borehole flow,see des.
q_measl_u	FLOAT	m**3/s	Estimated upper measurement limit of borehole flow,see desc.
pump_flow_q1	FLOAT	m**3/s	Flow rate at surface during flow logging period 1
pump_flow_q2	FLOAT	m**3/s	Flow rate at surface during flow logging period 2
dur_flow_phase_tp1	FLOAT	s	Duration of flow period 1
dur_flow_phase_tp2	FLOAT	s	Duration of flow period 2
dur_flowlog_tfl_1	FLOAT	s	Duration of the flowlogging survey 1
dur_flowlog_tfl_2	FLOAT	s	Duration of the flowlogging survey 2
drawdown_s1	FLOAT	m	Representative drawdown in borehole during flowlog period 1
drawdown_s2	FLOAT	m	Representative drawdown in borehole during flowlog period 2
initial_head_ho	FLOAT	m.a.s.l.	Initial hydraulic head (open borehole),see table description
hydraulic_head_h1	FLOAT	m.a.s.l.	Represen. hydr.head during flow period 1,see table descr.
hydraulic_head_h2	FLOAT	m.a.s.l.	Represen. hydr.head during flow period 2,see table descr.
reference	CHAR		SKB report number for reports describing data & evaluation
comments	VARCHAR		Short comment to the evaluated parameters (optional))

Plu_impell_mail_res

idcode	start_date	stop_date	secup (m)	seclow (m)	section_no	l (m)	cum_flow_q0 (m**3/s)	cum_flow_q1 (m**3/s)	cum_flow_q2 (m**3/s)	cum_flow_q1t (m**3/s)	cum_flow_q2t (m**3/s)	corr_cum_flow_q1c (m**3/s)	corr_cum_flow_q2c (m**3/s)
HFM24	2006-02-07 14:43	2006-02-07 18:39	18.00	150.00		49.50							
HFM24	2006-02-07 14:43	2006-02-07 18:39	18.00	150.00		49.00							
HFM24	2006-02-07 14:43	2006-02-07 18:39	18.00	150.00		48.00							
HFM24	2006-02-07 14:43	2006-02-07 18:39	18.00	150.00		47.50							
HFM24	2006-02-07 14:43	2006-02-07 18:39	18.00	150.00		46.50							
HFM24	2006-02-07 14:43	2006-02-07 18:39	18.00	150.00		46.00							
HFM24	2006-02-07 14:43	2006-02-07 18:39	18.00	150.00		43.50							
HFM24	2006-02-07 14:43	2006-02-07 18:39	18.00	150.00		43.00							
HFM24	2006-02-07 14:43	2006-02-07 18:39	18.00	150.00		30.00							
HFM24	2006-02-07 14:43	2006-02-07 18:39	18.00	150.00		29.00							
HFM24	2006-02-07 14:43	2006-02-07 18:39	18.00	150.00		18.50							
HFM24	2006-02-07 14:43	2006-02-07 18:39	18.00	150.00		18.30							
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		30.30							
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		29.80							
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		27.80							
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		27.30							
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		22.30							
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		21.80							
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		18.30							
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		17.80							
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		15.80							
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		14.80							
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		13.80							
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		12.30							

cont.

corr_cum_flow_q1tc (m**3/s)	corr_cum_flow_q2tc (m**3/s)	corr_com_flow_q1tcr (m**3/s)	corr_com_flow_q2tcr (m**3/s)	transmissivy_hole_t (m**2/s)	value_type_t	bc_t	cum_transmissivity_tf (m**2)	value_type_tf	bc_tf	l_measl_tf (m**2/s)	cum_transmissivity_tft (m**2)	value_type_tft	bc_tft	u_measl_tf (m**2/s)	reference	comments
6.4900E+01		3.0833E-04		1.10E-04	0	1	5.08475E-06	0	1	1.69E-06	1.10000E-04	0	1			
6.4900E+01		3.0833E-04		1.10E-04	0	1	3.13559E-05	0	1	1.69E-06	1.10000E-04	0	1			
6.4900E+01		5.8333E-04		1.10E-04	0	1	3.13559E-05	0	1	1.69E-06	1.10000E-04	0	1			
6.4900E+01		5.8333E-04		1.10E-04	0	1	5.93220E-05	0	1	1.69E-06	1.10000E-04	0	1			
6.4900E+01		6.2500E-04		1.10E-04	0	1	5.93220E-05	0	1	1.69E-06	1.10000E-04	0	1			
6.4900E+01		6.2500E-04		1.10E-04	0	1	6.35593E-05	0	1	1.69E-06	1.10000E-04	0	1			
6.4900E+01		7.8500E-04		1.10E-04	0	1	6.35593E-05	0	1	1.69E-06	1.10000E-04	0	1			
6.4900E+01		7.8500E-04		1.10E-04	0	1	7.98305E-05	0	1	1.69E-06	1.10000E-04	0	1			
6.4900E+01		9.5167E-04		1.10E-04	0	1	7.98305E-05	0	1	1.69E-06	1.10000E-04	0	1			
6.4900E+01		9.5167E-04		1.10E-04	0	1	9.67797E-05	0	1	1.69E-06	1.10000E-04	0	1			
6.4900E+01		1.0817E-03		1.10E-04	0	1	9.67797E-05	0	1	1.69E-06	1.10000E-04	0	1			
6.4900E+01		1.0817E-03		1.10E-04	0	1	1.10000E-04	0	1	1.69E-06	1.10000E-04	0	1			
6.4900E+01		1.5000E-04		9.40E-04	0	1	4.34515E-05	0	1	1.45E-05	9.40000E-04	0	1			
6.4900E+01		1.5000E-04		9.40E-04	0	1	1.30354E-04	0	1	1.45E-05	9.40000E-04	0	1			
6.4900E+01		2.6667E-04		9.40E-04	0	1	1.30354E-04	0	1	1.45E-05	9.40000E-04	0	1			
6.4900E+01		2.6667E-04		9.40E-04	0	1	2.31741E-04	0	1	1.45E-05	9.40000E-04	0	1			
6.4900E+01		3.0833E-04		9.40E-04	0	1	2.31741E-04	0	1	1.45E-05	9.40000E-04	0	1			
6.4900E+01		3.0833E-04		9.40E-04	0	1	2.67951E-04	0	1	1.45E-05	9.40000E-04	0	1			
6.4900E+01		5.3333E-04		9.40E-04	0	1	2.67951E-04	0	1	1.45E-05	9.40000E-04	0	1			
6.4900E+01		5.3333E-04		9.40E-04	0	1	4.63482E-04	0	1	1.45E-05	9.40000E-04	0	1			
6.4900E+01		5.9167E-04		9.40E-04	0	1	4.63482E-04	0	1	1.45E-05	9.40000E-04	0	1			
6.4900E+01		5.9167E-04		9.40E-04	0	1	5.14176E-04	0	1	1.45E-05	9.40000E-04	0	1			
6.4900E+01		1.0817E-03		9.40E-04	0	1	5.14176E-04	0	1	1.45E-05	9.40000E-04	0	1			
6.4900E+01		1.0817E-03		9.40E-04	0	1	9.40000E-04	0	1	1.45E-05	9.40000E-04	0	1			

Column	Datatype	Unit	Column Description
Site	CHAR		Investigation site name
Activity_type	CHAR		Activity type code
start_date	DATE		Date (yymmdd hh:mm:ss)
stop_date	DATE		Date (yymmdd hh:mm:ss)
Project	CHAR		project code
Idcode	CHAR		Object or borehole identification code
Secup	FLOAT	m	Upper section limit (m)
Seclow	FLOAT	m	Lower section limit (m)
Section_no	INTEGER	number	Section number
L	FLOAT	m	Corrected borehole length
cum_flow_q0	FLOAT	m**3/s	Undisturbed cumulative flow rate, see table description
cum_flow_q1	FLOAT	m**3/s	Cumulative flow rate at pumping flow Q1/head h1,see descr.
cum_flow_q2	FLOAT	m**3/s	Cumulative flow rate at pumping flow Q2/head h2, see descr.
cum_flow_q1t	FLOAT	m**3/s	Cumulative flow at the top of measured interval,pump flow Q1
cum_flow_q2t	FLOAT	m**3/s	Cumulative flow at the top of measured interval,pump flow Q2
corr_cum_flow_q1c	FLOAT	m**3/s	Corrected cumulative flow q1 at pump flow Q1,see tabledescr.
corr_cum_flow_q2c	FLOAT	m**3/s	Corrected cumulative flow q2 at pump flow Q2,see tabledescr.
corr_cum_flow_q1tc	FLOAT	m**3/s	Corrected cumulative flow q1T at pump flow Q1,see...
corr_cum_flow_q2tc	FLOAT	m**3/s	Corrected cumulative flow q2T at pump flow Q2,see...
corr_com_flow_q1tcr	FLOAT	m**3/s	Corrected q1Tc for estimated borehole radius (rwa)
corr_com_flow_q2tcr	FLOAT	m**3/s	Corrected q2Tc for estimated borehole radius (rwa)
transmissitivy_hole_t	FLOAT	m**2/s	T: Transmissivity of the entire hole, see table description
value_type_t	CHAR		0:true value,–1:T<lower meas.limit,1:T>upper meas.limit
bc_t	CHAR		Best choice code: 1 means T is best transm. choice, else 0
cum_transmissivity_tf	FLOAT	m**2	T_F: Cumulative transmissivity, see table description
value_type_tf	CHAR		0:true value,–1:TF<lower meas.limit,1:TF>upper meas.limit
bc_tf	CHAR		Best choice code: 1 means TF is best transm. choice, else 0
l_measl_tf	FLOAT	m**2/s	Lower measurement limit of T_F,see table description
cum_transmissivity_tft	FLOAT	m**2	T_FT: Cumulative transmissivity, see table description
value_type_tft	CHAR		0:true value,–1:TFT<lower meas.limit,1:TFT>upper meas.limit
bc_tft	CHAR		Best choice code: 1 means TFT is best transm. choice,else 0
u_measl_tf	FLOAT	m**2/s	Upper measurement limit of T_F, see table description
reference	CHAR		SKB number for reports describing data and results
comments	CHAR		Short comment to evaluated data (optional)
error_flag	CHAR		If error_flag = "*" then an error occured and an error
in_use	CHAR		If in_use = "*" then the activity has been selected as
Sign	CHAR		Activity QA signature

plu_impeller_anomaly

idcode	start_date	stop_date	secup (m)	seclow (m)	section_no	l_a_upper (m)	l_a_lower (m)	fluid_temp_tea (oC)	fluid_elcond_eca (mS/m)	fluid_salinity_tdsa (mg/l)	dq1 (m**3/s)	dq2 (m**3/s)
HFM24	2006-02-07 15:48	2006-02-07 18:39	18.00	150.00		18.00	18.50					
HFM24	2006-02-07 15:48	2006-02-07 18:39	18.00	150.00		29.00	30.00					
HFM24	2006-02-07 15:48	2006-02-07 18:39	18.00	150.00		43.00	43.50					
HFM24	2006-02-07 15:48	2006-02-07 18:39	18.00	150.00		46.00	46.50					
HFM24	2006-02-07 15:48	2006-02-07 18:39	18.00	150.00		47.50	48.00					
HFM24	2006-02-07 15:48	2006-02-07 18:39	18.00	150.00		49.00	49.50					
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		12.30	13.80					
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		14.80	15.80					
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		17.80	18.30					
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		21.80	22.30					
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		27.30	27.80					
HFM32	2006-01-17 14:18	2006-01-17 17:53	8.30	131.70		29.80	30.80					

cont.

r_wa (m)	dq1_corrected (m**3/s)	dq2_corrected (m**3/s)	spec_cap_dq1c_s1 (m**2/s)	spec_cap_dq2c_s2 (m**2/s)	value_type_dq1_s1	value_type_dq2_s2	ba (m)	transmissivity_tfa (m**2/s)	value_type_tfa	bc_tfa	l_measl_tfa (m**2/s)	u_measl_tfa (m**2/s)	comments
	1.3000E-04		2.3200E-05		0			1.3200E-05	0		1.69E-06		
	1.6670E-04		2.9700E-05		0			1.6900E-05	0		1.69E-06		
	1.6000E-04		2.8500E-05		0			1.6300E-05	0		1.69E-06		
	4.1670E-05		7.4300E-06		0			4.2400E-06	0		1.69E-06		
	2.7500E-04		4.9000E-05		0			2.8000E-05	0		1.69E-06		
	3.0830E-04		5.5000E-05		0			3.1400E-05	0		1.69E-06		
	4.9000E-04		4.6000E-04		0			4.3000E-04	0		1.45E-05		
	5.8300E-05		5.5000E-05		0			5.1000E-05	0		1.45E-05		
	2.2500E-04		2.1000E-04		0			2.0000E-04	0		1.45E-05		
	4.1700E-05		3.9000E-05		0			3.6000E-05	0		1.45E-05		
	1.1700E-04		1.1000E-04		0			1.0000E-04	0		1.45E-05		
	1.5000E-04		1.4000E-04		0			1.3000E-04	0		1.45E-05		

Column	Datatype	Unit	Column Description
Site	CHAR		Investigation site name
Activity_type	CHAR		Activity type code
start_date	DATE		Date (yymmdd hh:mm:ss)
stop_date	DATE		Date (yymmdd hh:mm:ss)
Project	CHAR		project code
Idcode	CHAR		Object or borehole identification code
Secup	FLOAT	m	Upper section limit (m)
Seclow	FLOAT	m	Lower section limit (m)
Section_no	INTEGER	number	Section number
l_a_upper	FLOAT	m	Borehole length to upper limit of inferred flow anomaly
l_a_lower	FLOAT	m	Borehole length to lower limit of inferred flow anomaly
fluid_temp_tea	FLOAT	oC	Measured borehole fluid temperature at inferred anomaly.
fluid_elcond_eca	FLOAT	mS/m	Measured fluid el conductivity of borehole fluid at anomaly
fluid_salinity_tdsa	FLOAT	mg/l	Calculated total dissolved solids of fluid at anomaly, see.
dq1	FLOAT	m**3/s	Flow rate of inferred flow anomaly at pump flow Q1or head h1
dq2	FLOAT	m**3/s	Flow rate of inferred flow anomaly at pump flowQ2 or head h2
r_wa	FLOAT	m	Estimated borehole radius
dq1_corrected	FLOAT	m**3/s	Corrected flow rate of anomaly at pump flow Q1 or see descr.
dq2_corrected	FLOAT	m**3/s	Corrected flow rate of anomaly at pump flow Q2, or see descr
spec_cap_dq1c_s1	FLOAT	m**2/s	dq1/s1.Spec. capacity of anomaly at pump flow Q1 or ..,see
spec_cap_dq2c_s2	FLOAT	m**2/s	dq2/s2.Spec. capacity of anomaly at pump flow Q2 or.,see des
value_type_dq1_s1	CHAR		0:true value,–1:<lower meas.limit,1:>upper meas.limit.
value_type_dq2_s2	CHAR		0:true value,–1:<lower meas.limit,1:>upper meas.limit.
Ba	FLOAT	m	Representative thickness of anomaly for TFa,see description
transmissivity_tfa	FLOAT	m**2/s	Transmissivity of inferred flow anomaly.
value_type_tfa	CHAR		0:true value,–1:TFa<lower meas.limit,1:TFa>upper meas.limit.
bc_tfa	CHAR		Best choice code.1 means TFa is best choice of T, else 0
l_measl_tfa	FLOAT	m**2/s	Lower measurement limit of TFa, see table description
u_measl_tfa	FLOAT	m**2/s	Upper measurement limit of TFa, see table description
comments	CHAR		Short comment on evaluated parameters
error_flag	CHAR		If error_flag = "*" then an error occured and an error
in_use	CHAR		If in_use = "*" then the activity has been selected as
Sign	CHAR		Activity QA signature