P-04-189

Forsmark site investigation

Difference flow logging in borehole KFM03A

Jari Pöllänen, Mikael Sokolnicki
PRG Tec-Oy

August 2004

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

ISSN 1651-4416
SKB P-04-189

Forsmark site investigation

Difference flow logging in borehole KFM03A

Jari Pöllänen, Mikael Sokolnicki
PRG Tec-Oy

August 2004

Keywords: Forsmark, Hydrogeology, Hydraulic tests, Difference flow measurements, AP PF 400-03-24, AP PF 400-04-41, Field note no: Forsmark 165, Forsmark 296.

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

A pdf version of this document can be downloaded from www.skb.se

Abstract

Difference flow logging is a swift method for determination of the transmissivity and the hydraulic head in borehole sections and fractures/fracture zones in core drilled boreholes. This report presents the main principles of the method as well as results of measurements carried out in borehole KFM03A at Forsmark, Sweden, in August 2003 (Campaign 1) and in May 2004 (Campaign 2), using the Posiva flow log. The primary aim of the measurements was to determine the position and flow rate of flow yielding fractures in borehole KFM03A.

The aim of the measurements in Campaign 2 was to re-measure the fracture-specific EC in selected fractures, because comparison of the EC-measurement from campaign 1 with EC-measurement performed with the SKB hydrochemical sampling equipment gave equivoque results. Furthermore, the detailed overlapping flow logging in the borehole interval c 100–400 m, was repeated because the measurements were somewhat uncertain during the first campaign.

The flow rate into or out of a 5 m long test section was measured between 100–1,000 m borehole lengths during natural (un-pumped) as well as pumped conditions. The flow measurements were repeated at the location of the detected flow anomalies using a 1 m long test section, successively transferred with an overlapping of 0.1 m.

Length calibration was made based on length marks milled into the borehole wall at accurately determined positions along the borehole. The length marks were detected by caliper measurements and by single point resistance measurements using sensors connected to the flow logging tool.

A high-resolution absolute pressure sensor was used to measure the total pressure along the borehole. These measurements were carried out together with the flow measurements.

Electric conductivity (EC) and temperature of borehole water was also measured. The EC-measurements were used to study the occurrence of saline water in the borehole during natural as well as pumped conditions. Finally, EC of fracture-specific water was measured for a selection of fractures.

Sammanfattning

Differensflödesloggning är en snabb metod för bestämning av transmissivitet och hydraulisk tryckhöjd i borrhålssektioner och sprickor/sprickzoner i kärnborrhål. Denna rapport presenterar huvudprinciperna för metoden och resultat av mätningar utförda i borrhål KFM03A i Forsmark, Sverige, i augusti 2003 (mätkampanj 1) och maj 2004 (mätkampanj 2) med Posiva flödesloggningsmetod. Det primära syftet med mätningarna var att bestämma läget och flödet för vattenförande sprickor i borrhål KFM03A.

Syftet med mätkampanj 2 var att, som en kontroll, upprepa mätningen av sprickspecifik EC i utvalda sprickor eftersom en tidigare jämförelse av EC-mätningarna från mätkampanj 1 med EC-mätningar utförda med SKB:s mätutrustning för hydrokemisk karakterisering ej givit entydiga resultat. Dessutom upprepades den detaljerade överlappande differensflödes loggningen i borrhålsintervallet ca 100–400 m eftersom dessa mätningar var något osäkra vid den första mätkampanjen.

Flödet till eller från en 5 m lång testsektion mättes mellan 100–1 000 m borrhålslängd under såväl naturliga (icke-pumpade) som pumpade förhållanden. Flödesmätningarna upprepades vid lägena för de detekterade flödesanomalierna med en 1 m lång testsektion som förflyttades successivt med 0,1 m.

Längdkalibrering gjordes baserad på längdmärkena som frästs in i borrhålsväggen vid noggrant bestämda positioner längs borrhålet. Längdmärkena detekterades med caliper- och punktresistansmätningar med hjälp av sensorer anslutna på flödesloggningssonden.

En högupplösande absoluttryckgivare användes för att mäta det absoluta totala trycket längs borrhålet. Dessa mätningar utfördes tillsammans med flödesmätningarna.

Elektrisk konduktivitet och temperatur på borrhålsvattnet mättes också. EC-mätningarna användes för att studera förekomsten av saltvatten i borrhålet under såväl naturliga som pumpade förhållanden. Slutligen mättes EC på vattnet från ett antal utvalda sprickor.

Contents

1 Introduction

The difference flow logging in the core drilled borehole KFM03A at Forsmark was conducted between August 12–26, 2003 and May 4–11, 2004. KFM03A is the third core drilled borehole in the Forsmark candidate area. The borehole is sub-vertical and c 1,000 m deep. The borehole is performed with telescopic drilling technique, where the interval 0–100 m is percussion drilled with the diameter 196 mm and the remaining interval, 100–1,000 m, is core drilled with the diameter 77.3 mm. The borehole is cased only through the soil layer (artificial filling) and a few metres into solid rock. The major part of the percussion drilled interval 0–100 m is therefore uncased, in contrast to boreholes KFM01A and KFM02A, which are both cased to 100 m. The location of borehole KFM03A at drilling site DS3 within the Forsmark area is shown in Figure 1-1.

The field work and the subsequent interpretation were conducted by PRG-Tec Oy. The Posiva Flow Log/Difference Flow method has previously been employed in Posiva's site characterisation programme in Finland as well as at the Äspö Hard Rock Laboratory at Simpevarp, Sweden. The commissions at the latter site included measurements in the 1,700 m long cored borehole KLX02 at Laxemar together with a methodology study /Ludvigson et al. 2002/.

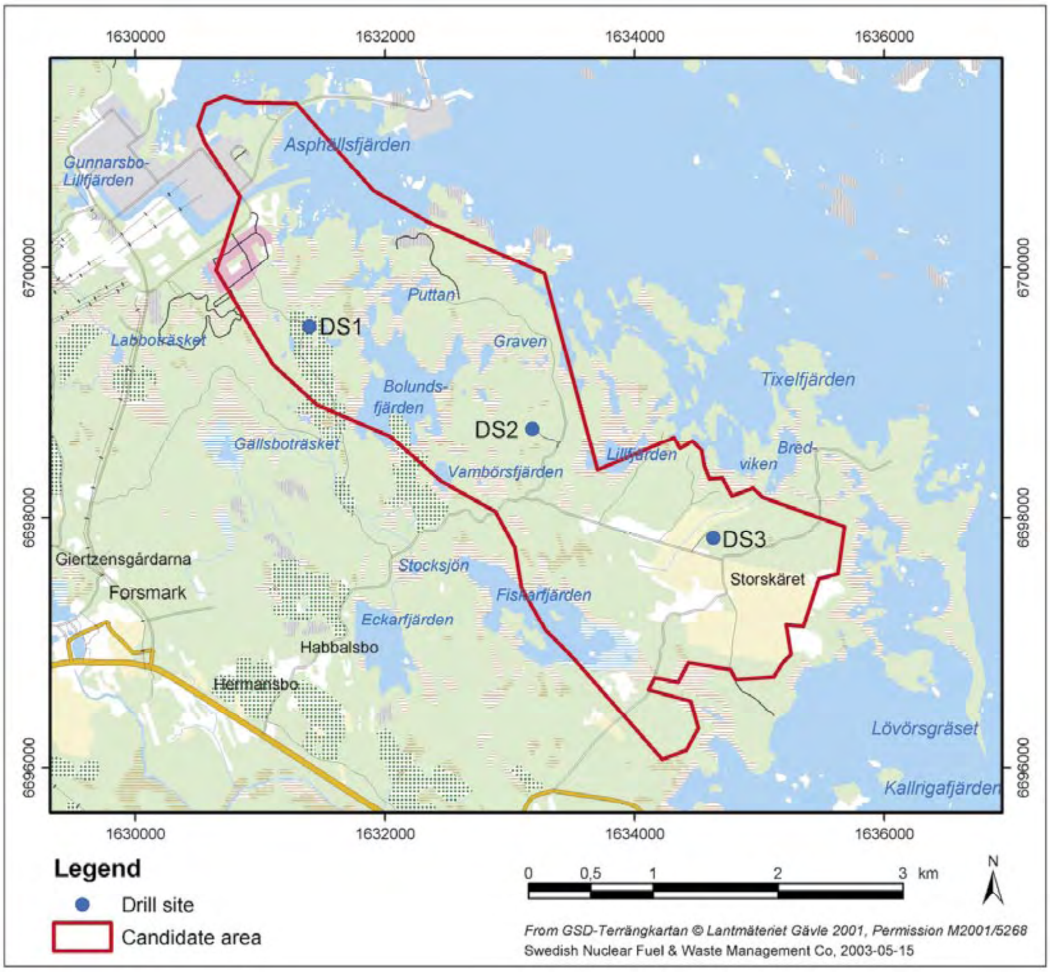


***Figure 1-1.** Locations of drilling sites DS1-3 at Forsmark. Borehole KFM03A is situated at DS3.*

This document reports the results gained by the Difference flow logging in borehole KFM03A. The activity is performed within the Forsmak site investigation. The work was carried out in accordance with the SKB internal controlling documents AP PF 400-03-24 and AP PF 400-04-41. Data and results were delivered to the SKB site characterization database SICADA with Field note number: Forsmark 165 and Forsmark 296.

2 Objective and scope

The main objective of the difference flow logging in KFM03A was to identify water-conductive sections/fractures suitable for subsequent hydro-geochemical characterisation. Secondly, the measurements aimed at a hydrogeological characterisation, including the prevailing water flow balance in the borehole and the hydraulic properties (transmissivity and undisturbed hydraulic head) of the tested sections. Based on the results of these investigations, a more detailed characterisation of flow anomalies along the hole, e.g. an estimate of the conductive fracture frequency (CFF), may be obtained.

Besides the difference flow logging, the measurement programme also included supporting measurements, performed for a better understanding of the overall hydrogeochemical conditions. These measurements included electric conductivity and temperature of the borehole fluid as well as single-point resistance of the borehole wall. The electric conductivity was also measured for a number of selected high-transmissive fractures in the borehole. Furthermore, the recovery of the groundwater level after pumping was registered and interpreted hydraulically.

A high-resolution absolute pressure sensor was used to measure the total pressure along the borehole. These measurements were carried out together with the flow measurements. The results are used for calculation of hydraulic head along the borehole.

Single point resistance measurements were also combined with caliper (borehole diameter) measurements for detection of length marks milled into the borehole wall at accurately determined positions along the borehole. This procedure was applied for length calibration of all measurements.

3 Principles of measurement and interpretation

3.1 Measurements

Unlike traditional types of borehole flowmeters, the Difference flowmeter method measures the flow rate into or out of limited sections of the borehole, instead of measuring the total cumulative flow rate along the borehole. The advantage of measuring the flow rate in isolated sections is a better detection of the incremental changes of flow along the borehole, which are generally very small and can easily be missed using traditional types of flowmeters.

Rubber disks at both ends of the downhole tool are used to isolate the flow in the test section from that in the rest of the borehole, see Figure 3-1. The flow along the borehole outside the isolated test section passes through the test section by means of a bypass pipe and is discharged at the upper end of the downhole tool.

The Difference flowmeter can be used in two modes, a sequential mode and an overlapping mode. In the sequential mode, the measurement increment is as long as the section length. It is used for determining the transmissivity and the hydraulic head /Öhberg and Rouhiainen, 2000/. In the overlapping mode, the measurement increment is shorter than the section length. It is mostly used to determine the location of hydraulically conductive fractures and to classify them with regard to their flow rates.

The Difference flowmeter measures the flow rate into or out of the test section by means of thermistors, which track both the dilution (cooling) of a thermal pulse and transfer of thermal pulse with moving water. In the sequential mode, both methods are used, whereas in the overlapping mode, only the thermal dilution method is applied because it operates faster than thermal pulse method.

Besides incremental changes of flow, the downhole tool of the Difference flowmeter can be used to measure:

- The electric conductivity (EC) of the borehole water and fracture-specific water. The electrode for the EC measurements is placed on the top of the flow sensor, Figure 3-1.
- The single point resistance (SPR) of the borehole wall (grounding resistance). The electrode of the Single point resistance tool is located in between the uppermost rubber disks, see Figure 3-1. This method is used for high-resolution depth/length determination of fractures and geological structures.
- The diameter of the borehole (caliper). The caliper tool, combined with SPR, is used for detection of the depth/length marks milled into the borehole wall. This enables an accurate depth/length calibration of the flow measurements.
- The prevailing water pressure profile in the borehole. The pressure sensor is located inside the electronics tube and connected via another tube to the borehole water, Figure 3-2.
- Temperature of the borehole water. The temperature sensor is placed in the flow sensor, Figure 3-1.

All of the above measurements were performed in KFM03A.

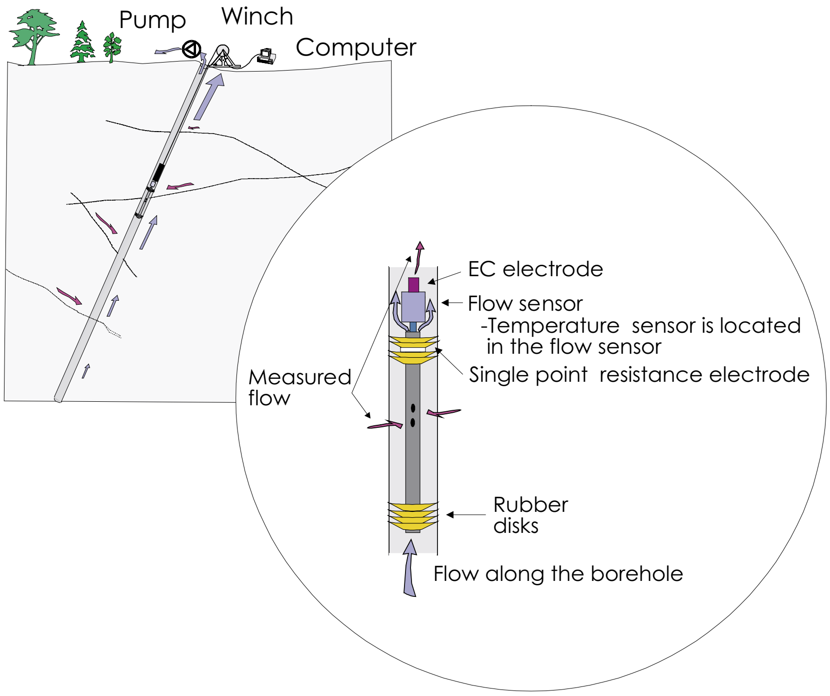


Figure 3-1. *Schematic presentation of the downhole equipment used in the Difference flowmeter.*

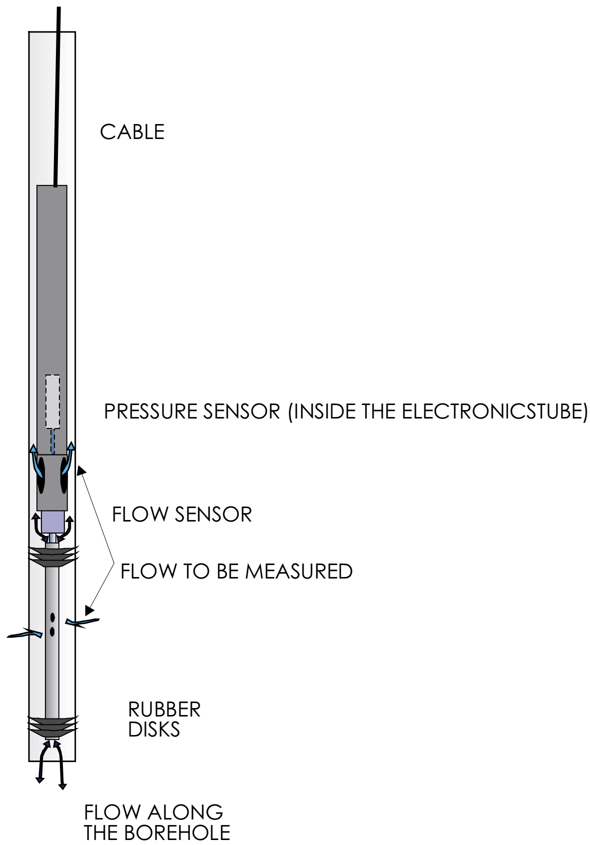


Figure 3-2. *The absolute pressure sensor is located inside the electronics tube and connected via another tube to the borehole water.*

The principles of difference flow measurements are described in Figures 3-3 and 3-4. The flow sensor consists of three thermistors, see Figure 3-3a. The central thermistor, A, is used both as a heating element and for the thermal pulse method and for registration of temperature changes in the thermal dilution method, Figures 3-3b and c. The side thermistors, B1 and B2, serve to detect the moving thermal pulse, Figure 3-3d, caused by the constant power heating in A, Figure 3-3b.

Flow rate is measured during the constant power heating (Figure 3-3b). If the flow rate exceeds 600 mL/h, the constant power heating is increased, Figure 3-4a, and the thermal dilution method is applied.

If the flow rate during the constant power heating (Figure 3-3b) falls below 600 mL/h, the measurement continues with monitoring of transient thermal dilution and thermal pulse response (Figure 3-3d). When applying the thermal pulse method, also thermal dilution is always measured. The same heat pulse is used for both methods.

Flow is measured when the tool is at rest. After transfer to a new position, there is a waiting time (the duration can be adjusted according to the prevailing circumstances) before the heat pulse (Figure 3-3b) is launched. The waiting time after the constant power thermal pulse can also be adjusted, but is normally 10 s long for thermal dilution and 300 s long for thermal pulse. The measuring range of each method is given in Table 3-1.

The lower end limits of the thermal dilution and the thermal pulse methods in Table 3-1 correspond to the theoretical lowest measurable values. Depending on the borehole conditions, these limits may not always prevail. Examples of disturbing conditions are floating drilling debris in the borehole water, gas bubbles in the water and high flow rates (above about 30 L/min) along the borehole. If disturbing conditions are significant, a practical measurement limit is calculated for each set of data.

Table 3-1. Ranges of flow measurements.

Method	Range of measurement (mL/h)
Thermal dilution P1	30–6,000
Thermal dilution P2	600–300,000
Thermal pulse	6–600

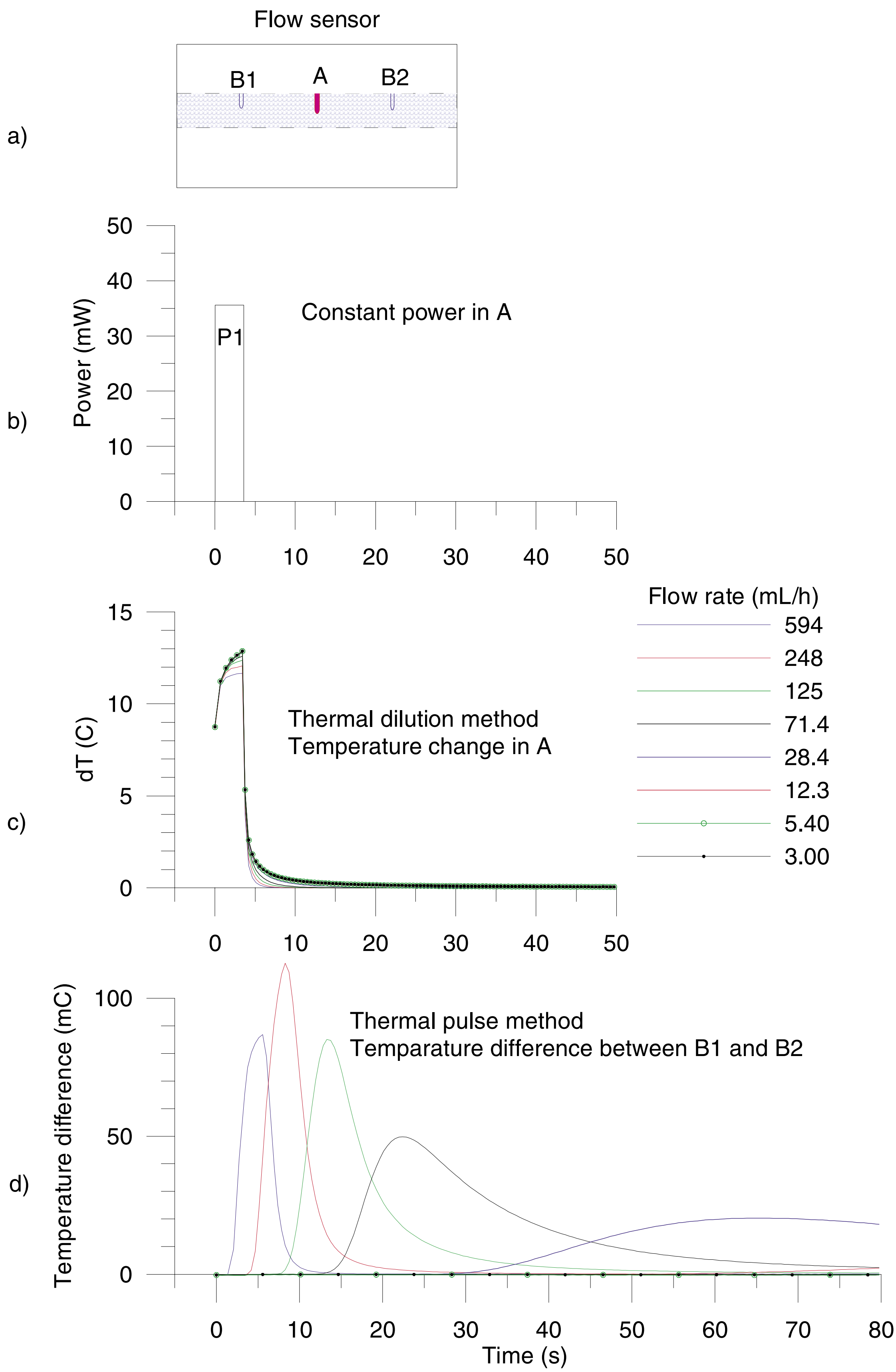


Figure 3-3. *Flow measurement, flow rate < 600 mL/h.*

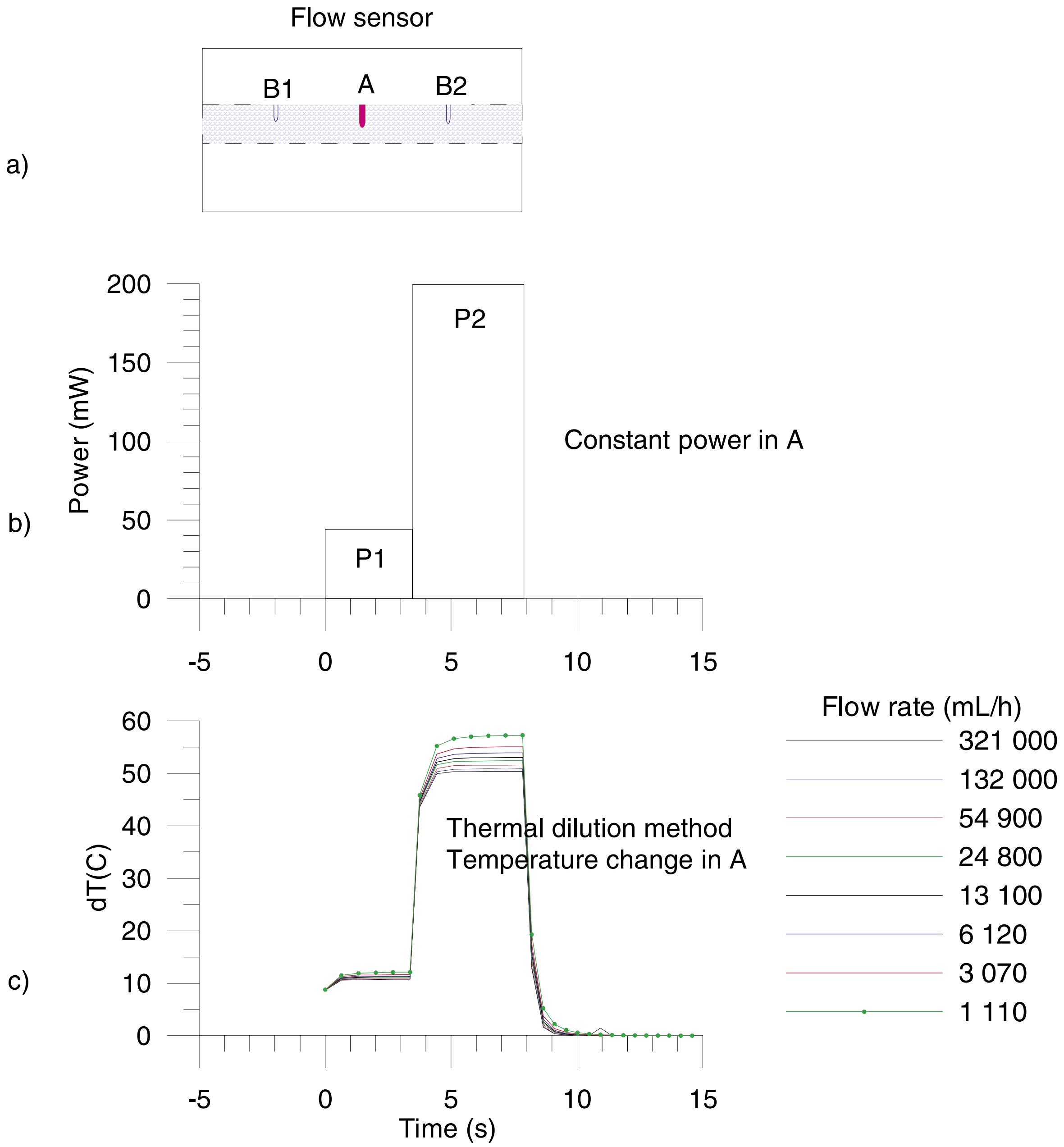


Figure 3-4. *Flow measurement, flow rate > 600 mL/h.*

3.2 Interpretation

The interpretation is based on Thiems or Dupuits formula that describes a steady state and two-dimensional radial flow into the borehole /Marsily, 1986/:

$$h_s - h = Q / (T \cdot a) \qquad 3\text{-}1$$

where

h is hydraulic head in the vicinity of the borehole and $h = h_s$ at the radius of influence (R),

Q is the flow rate into the borehole,

T is the transmissivity of the test section,

a is a constant depending on the assumed flow geometry. For cylindrical flow, the constant a is:

$$a = 2 \cdot \pi / \ln(R/r_0) \qquad 3\text{-}2$$

where

r_0 is the radius of the well and

R is the radius of influence, i.e. the zone inside which the effect of the pumping is felt.

If flow rate measurements are carried out using two levels of hydraulic heads in the borehole, i.e. natural or pump-induced hydraulic heads, then the undisturbed (natural) hydraulic head and transmissivity of the tested borehole sections can be calculated. Two equations can be written directly from equation 3-1:

$$Q_{s1} = T_s \cdot a \cdot (h_s - h_1) \qquad 3\text{-}3$$

$$Q_{s2} = T_s \cdot a \cdot (h_s - h_2) \qquad 3\text{-}4$$

where

h_1 and h_2 are the hydraulic heads in the borehole at the test level,

Q_{s1} and Q_{s2} are the measured flow rates in the test section,

T_s is the transmissivity of the test section and

h_s is the undisturbed hydraulic head of the tested zone far from the borehole.

Since, in general, very little is known of the flow geometry, cylindrical flow without skin zones is assumed. Cylindrical flow geometry is also justified because the borehole is at a constant head and there are no strong pressure gradients along the borehole, except at its ends.

The radial distance R to the undisturbed hydraulic head h_s is not known and must be assumed. Here a value of 500 is selected for the quotient R/r_0.

The hydraulic head and the test section transmissivity can be deduced from the two measurements:

$$h_s = (h_1 - b \cdot h_2)/(1 - b) \qquad 3\text{-}5$$

$$T_s = (1/a)\,(Q_{s1} - Q_{s2})/(h_2 - h_1) \qquad 3\text{-}6$$

where
$b = Q_{s1}/Q_{s2}$

Transmissivity (T_f) and hydraulic head (h_f) of individual fractures can be calculated, provided that the flow rates of individual fractures are known. Similar assumptions as above have to be used (a steady state cylindrical flow regime without skin zones).

$$h_f = (h_1 – b\ h_2)/(1 – b) \qquad 3\text{-}7$$

$$T_f = (1/a)\ (Q_{f1} – Q_{f2})/(h_2 – h_1) \qquad 3\text{-}8$$

where

Q_{f1} and Q_{f2} are the flow rates at a fracture and

h_f and T_f are the hydraulic head (far away from borehole) and the transmissivity of a fracture, respectively.

Since the actual flow geometry and the skin effects are unknown, transmissivity values should be taken as indicating orders of magnitude. As the calculated hydraulic heads do not depend on geometrical properties but only on the ratio of the flows measured at different heads in the borehole, they should be less sensitive to unknown fracture geometry. A discussion of potential uncertainties in the calculation of transmissivity and hydraulic head is provided in /Ludvigson et al. 2002/.

4 Equipment specifications

The Posiva Flow Log/Difference flowmeter monitors the flow of groundwater into or out from a borehole by means of a flow guide (rubber discs). The flow guide thereby defines the test section to be measured without altering the hydraulic head. Groundwater flowing into or out from the test section is guided to the flow sensor. Flow is measured using the thermal pulse and/or thermal dilution methods. Measured values are transferred in digital form to the PC computer.

Type of instrument:	Posiva Flow Log/Difference Flowmeter.
Borehole diameters:	56 mm, 66 mm and 76–77 mm.
Length of test section:	A variable length flow guide is used.
Method of flow measurement:	Thermal pulse and/or thermal dilution.
Range and accuracy of measurement:	Table 4-1.
Additional measurements:	Temperature, Single point resistance, Electric conductivity of water, Caliper, Water pressure
Winch:	Mount Sopris Wna 10, 0.55 kW, 220V/50Hz. Steel wire cable 1,500 m, four conductors, Gerhard-Owen cable head.
Length determination:	Based on the marked cable and on the digital length counter.
Logging computer:	PC, Windows 2000.
Software:	Based on MS Visual Basic.
Total power consumption:	1.5–2.5 kW depending on the pumps.
Calibrated:	April 2004.
Calibration of cable length:	Using length marks in the borehole.

Range and accuracy of sensors is presented in Table 4-1.

Table 4-1. Range and accuracy of sensors.

Sensor	Range	Accuracy
Flow	6 – 300,000 mL/h	+/– 10% curr.value
Temperature (middle thermistor)	0 – 50°C	0.1°C
Temperature difference (between outer thermistors)	–2 – +2°C	0.0001°C
Electric conductivity of water (EC)	0.02 – 11 S/m	+/– 5% curr.value
Single point resistance	5 – 500,000 Ω	+/– 10% curr.value
Groundwater level sensor	0 – 0.1 MPa	+/– 1% full scale
Absolute pressure sensor	0 – 20 MPa	+/– 0.01% full scale

5 Performance

The first Commission was performed according to Activity Plan AP PF 400-03-24 following the SKB Method Description 322.010, Version 1.0 (Method description for difference flow logging). The second Commission was performed in compliance with Activity Plan AP PF 400-04-41, Version 1.0. All the documents are SKB internal controlling document. Prior to the measurements, the downhole tool and the measurement cable were disinfected. Time was synchronized with local Swedish time. The activity schedules of the borehole measurements is presented in Table 5-1 (the first campaign) and Table 5-2 (the second campaign). The items and activities in Table 5-1 and Table 5-2 are the same as in the Activity Plans.

Logging cables, wires, and pipe strings are exposed to stretching when lowered into a vertical or sub-vertical borehole. This will introduce a certain error in defining the position of a test tool connected to the end of e.g. a logging cable. Immediately after completion of the drilling operations in borehole KFM03A, length marks were milled into the borehole wall at certain intervals to be used for length calibration of various logging tools. By using the known positions of the length marks, logging cables etc can be calibrated in order to obtain an accurate length correction of the testing tool.

Each depth mark includes two 20 mm wide tracks in the borehole wall. The distance between the marks is 100 mm. The upper track represents the reference level. An inevitable condition for a successful depth calibration is that all depth marks, or at least the major part of them, are detectable. The Difference flow metre system uses caliper measurements in combination with single point resistance measurement (SPR) for this purpose, and these measurements were the first to be performed in borehole KFM03A (Item 7 in Table 5-1). These methods also reveal parts of the borehole widened for other reasons (fracture zones, breakouts etc).

The caliper- and SPR-measurements were preceded by measurements of electric conductivity (EC) of the borehole water (Item 8 in Table 5-1) during natural (un-pumped) conditions.

The combined sequential/overlapping flow logging (Item 9 in Table 5-1) was carried out in the borehole interval 100–1,000 m. The section length was 5 m, and the length increment (step length) 5 m for the thermal pulse method, respectively 0.5 m for the thermal dilution method. The measurements were performed during natural (un-pumped) conditions.

Pumping was started on August 17. After 25 hours waiting time, the combined sequential/overlapping flow logging (Item 10 in Table 5-1) was repeated in the same interval, 100–1,000 m using the same section and step lengths as before.

The overlapping flow logging was then continued in the way that previously measured flow anomalies were re-measured with 1 m section length and 0.1 m step length (Item 11 in Table 5-1). At the same time, fracture specific EC was measured on water from some selected fractures (Item 13 in Table 5-1).

Still during pumped conditions, EC of the borehole water (Item 12 in Table 5-1) was measured. After this, the pump was stopped and the recovery of groundwater level was monitored (Item 14).

Table 5-1. Flow logging and testing in KFM03A. Activity schedule, first campaign.

Item	Activity	Explanation	Date
7	Length calibration of the down-hole tool	Dummy logging (SKB Caliper and SPR). Logging without the lower rubber discs, no pumping	2003-08-13 2003-08-14
8	EC- and temp-logging of the borehole fluid	Logging without the lower rubber discs, no pumping	2003-08-14 2003-08-15
9	Combined sequential and overlapping flow logging	Section length L_w=5 m. Step length dL=0.5 m. Pulse measurement every 10th point, no pumping	2003-08-15 2003-08-17
10	Combined sequential and overlapping flow logging	Section length L_w=5 m. Step length dL=0.5 m. Pulse measurement every 10th point, at pumping (includes 1 day waiting after start of pumping) (entire borehole applying a high pumping rate)	2003-08-17 2003-08-20
10	Combined sequential and overlapping flow logging	Section length L_w=5 m. Step length dL=0.5 m. Pulse measurement every 10th point, at pumping (upper part of borehole with reduced pumping rate)	2003-08-20 2003-08-21
11	Overlapping flow logging	Section length L_w=1 m. Step length dL=0.1 m, at pumping (only in conductive borehole intervals) (upper part of borehole with low pumping rate)	2003-08-21 2003-08-22
11	Overlapping flow logging	Section length L_w=1 m. Step length dL=0.1 m, at pumping (only in conductive borehole intervals) (lower part of borehole with a high pumping rate)	2003-08-22 2003-08-25
12	EC- and temp-logging of the borehole fluid	Logging without the lower rubber discs, at pumping	2003-08-25
13	Fracture-specific EC measurement	Section length L_w=1 m, at pumping (in a selection of fractures)	2003-08-21 2003-08-25
14	Recovery transient	Measurement of water level in the borehole after stop of pumping	2003-08-25 2003-08-26
11 extra	Flow measurements at the depth of 388.6 m	Section length L_w=1 m (only borehole interval 388.14–389.14 m), without pumping and with three different pumping rates	2003-08-26

A high transmissive fracture was encountered at 388.6 m. The fracture water yield was so high that the upper part of the borehole had to be measured applying a reduced pumping rate. (Item 10 and Item 11 in Table 5-1). This fracture was also re-measured after groundwater recovery without pumping and with three different pumping rates (Appendix 4).

The fracture-EC values measured in conjunction with the initial difference flow logging campaign (Table 5-1) in KFM03A were found to deviate from the fracture EC-values measured in conjunction with the subsequent hydrochemical characterisation (HCC) in the same borehole /Berg and Nilsson, 2003/. The deviations were observed in several borehole sections. Furthermore, the quality of the measured flow rates during pumped conditions in the initial difference flow logging campaign of borehole KFM03A was somewhat uncertain in the borehole interval c 100–400 m due to the large inflow to the borehole from the high-conductivity fracture at c 388 m.

In order to investigate the reason for the observed differences in fracture-EC as well as the uncertainty in the flow rate measurements, it was proposed to re-measure fracture-EC in a few selected fractures and re-measure the flow distribution in the interval c 100–400 m (Table 5-2).

As before, the tools and the measurement cable were disinfected and time was synchronized with local Swedish time.

The caliper- and SPR-measurements (Item 5 in Table 5-2) were preceded by measurements of electric conductivity (EC) of the borehole water (Item 6 in Table 5-2) during natural (un-pumped) conditions. Fracture-specific EC was measured at several fractures (Items 7–12 in Table 5-2) and EC of the borehole water was re-measured (Item 13 in Table 5-2) at pumping. Pumping rate was then decreased and flow rate was measured in the upper part of the borehole (Items 14 and 15 in Table 5-2).

Table 5-2. Flow logging and testing in KFM03A. Activity schedule, second campaign.

Item	Activity	Explanation	Date
5	Length calibration of the down-hole tool	Dummy logging (SKB Caliper and SPR) Logging without the lower rubber discs, no pumping	2004-05-04 2004-05-05
6	EC- and temp-logging of the borehole fluid	Logging without the lower rubber discs, no pumping	2004-05-05 2004-05-06
7	Standard fracture-specific EC measurement in the fracture at 643.9 m	Section length L_w=1 m, at pumping	2004-05-06 2004-05-07
8	Fracture-specific EC measurement series in the fracture at 944.2 m	Section length L_w=1 m, at pumping	2004-05-07
9	Fracture-specific EC measurement in the fracture at 986.2 m	Section length L_w=1 m, at pumping	2004-05-07
10	Fracture-specific EC measurement series in the fracture at 643.9 m	Section length L_w=1 m, at pumping	2004-05-07 2004-05-08
11	Standard fracture-specific EC measurement in the fracture at 451.3 m	Section length L_w=1 m, at pumping	2004-05-08
12	Standard fracture-specific EC measurement in the fracture at 388.6 m	Section length L_w=1 m, at pumping	2004-05-08
13	Repeated EC- and temp-logging together with pressure logging along the borehole	Logging without the lower rubber discs, at pumping	2004-05-08 2004-05-09
14	Change of pumping rate and stabilization		2004-05-09
15	Overlapping flow logging and pressure logging	Section length L_w=1 m, Step length dL=0.1 m, at pumping, the borehole interval c 100-400 m	2004-05-09 2004-05-10
16	Demobilisation		2004-05-11

6 Results

6.1 Length calibration

6.1.1 Caliper and SPR measurement

Accurate length measurements are difficult to perform in long boreholes. The main cause of inaccuracy is stretching of the logging cable. The stretching depends on the tension of the cable, the magnitude of wich in turn depends, among other things, on the inclination of the borehole and on the friction against the borehole wall. The cable tension is larger when the borehole is measured upwards. The cables, especially new cables, may also stretch out permanently. In KFM03A, the stretching of the cable was larger in the second campaign since the measurements were performed from the bottom of the borehole in the upward direction. The cable probably also suffered permanent stretching in the second campaign, see Appendix 1.38.

Length marks on the borehole wall can be used to minimise the length errors. The length marks are detected with the SKB caliper tool. The length scale is firstly corrected according to the length marks. Single point resistance is recorded simultaneously with the caliper logging. All flow measurement sequences can then be length corrected by synchronising the SPR results (SPR is recorded during all measurements) with the original caliper/SPR measurement.

The procedure of length correction was the following:

- The Caliper + SPR measurements (Item 7 in Table 5-1) were initially length corrected in relation to the known length marks, Appendix 1.38, black curve. Corrections between the length marks were obtained for each length mark by linear interpolation.
- The SPR curve of Item 7 was then compared with the SPR curves of other measurements to obtain relative length errors of these measurement sequences.
- All SPR curves could then be synchronized, as can be seen in Appendices 1.2–1.37.

The results of the caliper and single point resistance measurements from all measurements in the entire borehole are presented in Appendix 1.1. Eight SPR-curves are plotted together with caliper-data.

Resistance of the SPR measurements in general showed a lower level in the second campaign than in the first campaign. The resistance level depends on a combination of the resistivity of rock and the resistivity of borehole water. However, the measured resistance is qualitative. SPR is only used for detection of fracture anomalies for depth correlation. The measured resistance strongly depends on secondary effects, such as stiffness of the rubber disks. Therefore quantitative conclusions of the resistivity of the bedrock cannot be drawn on the basis of the SPR results.

Zoomed results of caliper and SPR are presented in Appendices 1.2–1.37. The depth marks were detected at 110 m, 150 m, 200 m, 250 m, 300 m, 350 m, 403 m, 453 m, 500 m, 550 m, 600 m, 650 m, 700 m, 750 m, 800 m, 850 m, and at 900 m. In other words, every mark was detected. They can be seen also in the SPR results. However, the anomaly is complicated due to the four rubber disks used at the upper end of the section, two at the each side of the resistance electrode. A selection of depth intervals where SPR-anomalies were found, are plotted as well.

The aim of the plots in Appendices 1.2–1.37 is to verify the accuracy of the depth correction. The curves in these plots represent already depth corrected results. The same depth correction was applied to the flow- and EC results.

The length calibration of the borehole EC measurements is not as accurate as those of the other measurements because SPR is not registered during the borehole EC measurements. The length correction of caliper measurements was applied to the borehole EC measurements, black curve in Appendix 1.37.

The magnitude of the length correction is presented in Appendix 1.38. The error is negative, due to the fact that the stretching extends the logging cable (i.e. the cable is longer than the nominal length marked on the cable). The stretching is larger in the second campaign, especially in the caliper measurement that was carried out from the bottom upwards, see Appendix 1.38. The upper part of the borehole was measured in the downward direction (see Chapter 6.4) in both campaigns. Stretching is larger in the re-measurement. This is probably due to permanent stretching of the cable.

6.1.2 Estimated error in location of detected fractures

In spite of the length correction described above, there are still length errors due to following reasons:

1. The point interval in flow measurements is 0.1 m in overlapping mode. This could cause an error of +/– 0.05 m.
2. The length of the test section is not exact. The specified section length denotes the distance between the nearest upper and lower rubber disks. Effectively, the section length can be larger. At the upper end of the test section there are four rubber disks. The distance between these is 5 cm. This will cause rounded flow anomalies, and flow may be detected already when a fracture is situated between the upper rubber disks. These phenomena can only be seen with the short step length (0.1 m). This could cause an error of +/– 0.05 m.
3. Corrections between the length marks can be other than linear. This could cause an error of +/– 0.1 m in the caliper/SPR measurement.
4. SPR curves may be imperfectly synchronized. This could cause error +/– 0.1 m

In the worst case, the errors of points 1, 2, 3 and 4 are summed up. Then the total estimated error between the length marks would be +/– 0.3 m.

Near the length marks the situation is slightly better. In the worst case, the errors of points 1, 2, and 4 are accumulated. Then the total estimated error near the length marks would be +/– 0.2 m.

Accurate location is important when different measurements are compared, for instance flow logging and borehole TV. In that case, the situation may not be as severe as the worst case above, since parts of the length errors are systematic and the length error is nearly constant for fractures near each other. However, the error of point 1 is of random type.

Fractures nearly parallel with the borehole may also be problematic. Fracture location may be difficult to accurately define in such cases.

6.2 Electric conductivity and temperature

6.2.1 Electric conductivity and temperature of borehole water

The electric conductivity of the borehole water (EC) was initially measured when the borehole was at rest, i.e. at natural, un-pumped conditions. The measurements were performed in both directions, downwards and upwards, during both the first and the second campaign, see Appendix 2.1.

The EC measurements were repeated at pumping in both campaigns (after a pumping period of several days), see Appendix 2.1

The electric conductivity of the borehole water was lower in the second campaign when the borehole was at rest. In the first campaign, EC did not change below 100 m when the borehole was pumped. In the second campaign, pumping increased EC below 650 m and in the upper part of the borehole. EC still remained at the lower level than in the first campaign at pumping.

Temperature of borehole water was measured simultaneously with the EC-measurements. The EC-values are temperature corrected to 25°C to make them more comparable with other EC measurements /Heikkonen et al. 2002/. The temperature results in Appendix 2.2 correspond to the EC results in Appendix 2.1. Pumping changed temperature profiles above the length of 380 m; high flow rate is an apparent reason to this. The temperature profiles in both campaigns are almost the same.

6.2.2 EC of fracture-specific water

The flow direction is always from the fractures into the borehole if the borehole is pumped with a sufficiently large drawdown. This enables the determination of electric conductivity from fracture-specific water. Both electric conductivity and temperature of flowing water from the fractures were measured.

The flow measurement makes it possible to identify the fractures for the EC measurement. The tool is moved so that the fracture to be tested will be located within the test section (L = 1 m). The EC measurements are commenced if the flow rate exceeds a predetermined limit. The tool is kept on the selected fracture. The measurement is continued at the given length of time, allowing the fracture-specific water to enter the section. The necessary waiting time for the EC measurement can be automatically calculated from the measured flow rate. The aim is to flush the water volume within the test section well enough. The measuring computer is programmed to exchange the water volume within the test section about three times. The water volume in a one metre long test section was 3.6 L. In this case, waiting times were selected to be much longer than the calculated times.

Electric conductivity of fracture-specific water is presented on a time scale, see Appendix 10.1–10.6. The results of the first campaign are presented in Appendices 10.1–10.3 and the corresponding results of the second campaign in Appendices 10.4–10.6. The blue symbol represents the value when the tool was moved (one metre point interval) and the red symbol means that the tool was stopped on a fracture for a fracture specific EC measurement. The same fracture specific EC measurements are also presented on a zoomed time scale, see Appendices 10.2–10. 3 and Appendices 10.5–10.6.

Borehole lengths at the upper and lower ends of the section, fracture locations as well as the final EC values are listed in Table 6-1 (Campaign 1) and in Table 6.2 (Campaign 2). In the second campaign, the fracture at 643.9 m was measured twice, see Appendix 10.4 and Table 6-2.

Table 6-1. Fracture-specific EC, Campaign 1.

Upper end of section (m)	Lower end of section (m)	Fractures measured (m)	EC (S/m) at 25°C
388.2	389.2	388.6	2.34
450.9	451.9	451.3	2.28
643.5	644.5	643.9	2.28
943.9	944.9	944.2	3.29
985.9	986.9	986.2, 986.5	3.84

Table 6-2. Fracture-specific EC, Campaign 2.

Upper end of section (m)	Lower end of section (m)	Fractures measured (m)	EC (S/m) at 25°C
388.0	389.0	388.6	1.65
450.8	451.8	451.3	1.63
643.4	644.4	643.9	1.62, 1.61
943.7	944.7	944.2	2.31
985.9	986.9	986.2, 986.5	2.89

The electric conductivity of fracture-specific water had decreased 29% from the first campaign to the second campaign at 388.6 m, 451.3 m, 643.9 m, and 944.2 m and 25% at 986.2 m (986.5 m). This fact is most likely due to upconing effects of saline water along the sub-vertical fractures in the bottom of the borehole during pumping activities prior to (and during) the first difference flow logging campaign. No significant pumping activities had occurred prior to the re-measurements and thus, no upconing effects. The results of the EC-measurements in the second campaign are consistent with the measured EC in these fractures during the hydro-geochemical characterization in KFM03A.

6.3 Pressure measurements

The absolute pressure was registered together with the other measurements in the borehole, cf Tables 5-1 and 5-2. The pressure sensor measures the sum of hydrostatic pressure in the borehole and air pressure. Air pressure was also registered, Appendices 11.1 and 11.5. Hydraulic head along the borehole at natural and pumped conditions respectively is determined in the following way. Firstly, the monitored air pressure at the site is subtracted from the measured absolute pressure by the pressure sensor. The hydraulic head (h) at a certain elevation z is then calculated according to the following expression /Nordqvist, 2001/:

$$h = (p_{abs} - p_b)/\rho_{fw}\, g + z \qquad 6\text{-}1$$

where

h is the hydraulic head (masl) according to the RHB 70 reference system,

Pabs is the absolute pressure (Pa),

p_b is the barometric (air) pressure (Pa),

ρ_{fw} is the unit density 1,000 kg/m^3

g is the standard gravity 9.80065 m/s^2 and z is the reference point for measurement, i.e. top of casing (masl) according to the RHB 70 reference system.

An offset of 2.46 kPa was subtracted from all absolute pressure results.

The calculated head results are presented in Appendix 5. An exact z-coordinate is important in the head calculation. A 10 cm error in the z-coordinate means 10 cm error in the head.

The high-yielding fracture at 388.6 m caused problems in the measurements when the borehole was pumped. Pumping rate was about 100 L/min. A high flow rate along the borehole caused friction losses when the tool was above the fracture at 388.6 m and the groundwater level in the borehole went down about 30 cm. This can bee seen in head curves between 100 m and 388 m, Appendix 5. The borehole has a larger diameter above 100 m, and no friction losses are visible there. The same changes in water level can be seen in Appendices 11.2 and 11.6 at pumping. The problem of friction is discussed in Chapter 6.4.6.

6.4 Flow logging

6.4.1 General comments on results

The measuring program contains several flow logging sequences. They are presented on the same plots as the single point resistance (right hand side) and caliper plot (in the middle), see Appendices 3.1–3.45. Single point resistance usually shows a low resistance value for a fracture where flow is detected. There are also many other resistance anomalies from other fractures and geological features. The electrode of the single point resistance tool is located within the upper rubber disks. Thus, the locations of the resistance anomalies of the leaky fractures fit with the lower end of the flow anomalies.

The caliper tool shows low voltages when the borehole diameter is below 77 mm and high voltage when the borehole diameter exceeds 77 mm.

The flow logging was firstly performed with a 5 m section length and with 0.5 m length increments, see Appendices 3.1–3.45 (green curve with pumping, dark blue curve without pumping). The method (overlapping flow logging) gives the length and the thickness of conductive zones with a length resolution of 0.5 m. To obtain quick results, only the thermal dilution method was initially used for flow determination.

Under natural conditions every tenth flow measurement was carried out using the thermal pulse method (sequential flow logging). This method is slower but has the advantage of rendering measurements of very small flow rates possible, as well as of their flow directions (into the borehole or out of it). The pulse method was used only without pumping.

The test section length determines the width of a flow anomaly of a single fracture in the plots. If the distance between flow yielding fractures is less than the section length, the anomalies will be overlapped, resulting in a stepwise flow anomaly. The overlapping flow logging was therefore repeated in the vicinity of identified flow anomalies using a 1 m long test section and 0.1 m length increments. The upper part of the borehole (above 390 m) was measured using a smaller drawdown during the first campaign. The noise level in flow was high, and this interval was re-measured also during the second campaign using a 1 m long test section.

The flow rate was above the measurement limit in the fracture at 388.9 m. It was separately re-measured using several small drawdowns, Appendix 4.

Detected fractures are shown on the caliper scale together with their positions (borehole length). They are interpreted on the basis of the flow curves and therefore represent flowing fractures. A long line represents the location of a leaky fracture; short line denotes that the existence of a leaky fracture is uncertain. A short line is used if the flow rate is less than 30 mL/h or if the flow anomalies are overlapping.

6.4.2 Transmissivity and hydraulic head of borehole sections

The entire borehole between 100 m and 1,000 m was flow logged with a 5 m section length and with 0.5 m length increments. The major part of the flow logging results presented in this report is derived from measurements with the thermal dilution method. However, every tenth flow measurement without pumping was carried out using the thermal pulse method (sequential flow logging without pumping), which enables measurements of smaller flow rates than 600 mL/h, above which limit thermal pulse results were used only for detection of the flow direction.

The results of the sequential measurements with a 5 m section length are presented in tables, see Appendix 6. Only the results with 5 m length increments are used, all borehole sections are shown in Appendices 3.1–3.45. Secup1 and Secup2 presented in Appendices 6.1–6.6 are calculated as the distance along the borehole from the reference level (top of the casing tube) to the upper end of the test section. Secup1 refers to the measurements at natural, i.e. un-pumped conditions, and Secup2 to measurements during pumping. They are not identical, due to a minor difference of the cable stretching between the two sequences.

Pressure was measured and calculated as described in Chapter 6.3. Borehole Head1 and Borehole Head2 in Appendices 6.1–6.6 represent heads determined without respectively with pumping. Head in the borehole and calculated heads of borehole sections are given in RHB 70 scale.

The flow results presented in Appendices 6.1–6.6 (Flow1 and Flow2), representing flow rates derived from measurements during un-pumped respectively pumped conditions, are presented side by side to make comparison easier. Flow rates are positive if the flow is directed from the bedrock into the borehole and vice versa. With the borehole at rest, 13 sections were detected as flow yielding, of which 11 had a flow direction from the borehole into the bedrock (negative flow). During pumping, all 27 detected flows were directed towards the borehole.

The measurable flow ranges were exceeded in the section with Secup 385.96 m when the borehole was pumped (even with the smaller pumping), see Appendix 6.2. The actual flow rate and transmissivity are larger than in Appendix 6.2 at 385.96 m. Fracture head is not accurate here, because there were friction losses when the flow guide was situated on the fracture. The fracture was later measured separately.

The flow data is presented as a plot, see Appendix 7.1. The left hand side of each diagram represents flow from the borehole into the bedrock for the respective test sections, whereas the right hand side represents the opposite. If the measured flow was zero (below the measurement limit), it is not visible in the logarithmic scale of the appendices.

In the plots (Appendix 7.1) and in the tables (Appendix 6), also the lower and upper measurement limits of flow are presented. There are theoretical and practical lower limits of flow rate, see Chapter 6.4.4.

Hydraulic head and transmissivity (T_S) of borehole sections can be calculated from flow data using the method described in Chapter 3. Hydraulic head of sections is presented in the plots if none of the two flow values at the same length is equal to zero. Transmissivity is presented if none or just one of the flows is equal to zero, see Appendix 7.2. The measurement limits of transmissivity are also shown in Appendix 7.2 and in Appendix 6. All the measurement limit values of transmissivity are based on the actual pressure difference in the borehole (Borehole Head1 and Borehole Head2 in Appendix 6).

The sum of detected flows without pumping (Flow1) was 9,808 mL/h. This sum should normally be zero if all the flows in the borehole are correctly measured, the borehole is not pumped, the water level is constant, the salinity distribution in the borehole is stabilized and the fractures are at steady state pressure. More flows were measured into the borehole than away from it. In this case the upper part of the borehole is uncased. Therefore it is probable that there are natural outflows above 100 m.

6.4.3 Transmissivity and hydraulic head of fractures

An attempt was made to evaluate the magnitude of fracture-specific flow rates. The results for a 1 m section length and for 0.1 m length increments were used for this purpose. The first step in this procedure is to identify the locations of individual flowing fractures and then to evaluate their flow rates.

In cases where the fracture distance is less than one metre, it may be difficult to evaluate the flow rate. Such cases are illustrated for instance in Appendix 3.14. Increase or decrease of a flow anomaly at the fracture location (marked with the lines in Appendix 3) is used for determination of flow rate.

Since sections with 1 m length were not used at un-pumped conditions, the results for a 5 m section length were used instead. The fracture locations, which are important when evaluating flow rate at un-pumped conditions, are known on the basis of the measurements for a 1 m section length. An increase or decrease of a flow anomaly at the fracture location determines the flow rate. The measurements for a 5 m section length at un-pumped conditions are used for the corresponding fracture flow rates. The flow direction is evaluated as well. The results of the evaluation are plotted in Appendix 3, blue filled triangle.

The total amount of detected flowing fractures is 52, but only 6 of these were observed without pumping. These 6 fractures could be used for head estimations and all 52 were used for transmissivity estimations. Transmissivity and hydraulic head of fractures are presented in Appendices 8.1–8.2.

Some fracture-specific results were rated to be "uncertain", see Appendix 8.1. The criterion of "uncertain" was in most cases a minor flow rate (< 30 mL/h). In some cases fracture anomalies were unclear, since the distance between them was less than one metre.

The upper part of the borehole, 100–400 m was re-measured in the second campaign, because the noise level in flow was very high during the first campaign. It was assumed that the increased noise was caused by the high flow rate along the borehole. For the second campaign, the number of lower rubbers was increased. The noise level was lower and thus, new fractures were detected in the upper part of the borehole. The results in Appendices 8.1 and 8.2 for the borehole interval c 100–400 m are taken from the second campaign, whereas the results from the interval c 400–1,000 m are from the first campaign.

Fracture-specific transmissivities were compared with transmissivities of borehole sections in Appendix 9. All fracture-specific transmissivities within each 5 m interval were first summed up to make them comparable with measurements with a 5 m section length.

6.4.4 Transmissivity and head of the fracture at 388.6 m

The measured flow rate at the depth of 388.6 m exceeded the limit of the measurable flow rate even during the smaller drawdown. This depth was measured again after groundwater recovery in the first campaign. Very small drawdowns had to be used to keep the flow rate within measurable limits. Pumping rate, hydraulic head by the absolute pressure sensor in the flowmeter, and the measured flow rate from the fracture are presented in Appendix 4.

Electric conductivity of fracture-specific water was also measured, see Appendix 4. It shows a slowly decreasing trend, see Appendix 4, and the final EC value is smaller than in the other fracture-specific measurement made four days earlier with higher pumping rate (Appendix 9.2). A decreasing fracture-specific EC is probably an indication of a still existing recovery state. Pumping tends to lift saline water and the original state recovers only slowly after pumping (or during smaller pumping as in this case).

A still existing recovery of the water level is also visible in Appendix 11.3. The original water level was near zero (RHB70 scale) on August 17. During this separate test on August 26, the water level without pumping was about –0.22 m. It is also possible that the water level has a long term natural variation.

Water level becomes important when choosing the hydraulic heads in the borehole at the test level (h_1 and h_2 in equations 3-7 and 3-8). To calculate transmissivity, it may be more correct to take both head values from the test in Appendix 4 than to take one head from the test and the other one from measurement about ten days earlier (without pumping).

Transmissivity and fracture head can be calculated from several sets using only the test results in Appendix 4. All possible combinations are presented in Table 6.3.

Friction losses in the flow sensor occur especially for flow rates of 149 L/h and 84 L/h. Therefore, the actual transmissivity of the fracture is higher than that presented in Table 6-3. Fracture head is erroneous as well, due to friction losses and because of the still continuing recovery state.

The fracture at 388.6 m was re-measured during the second campaign. Pumping rate was much larger than in the experiment described here and the calculated transmissivity was $9.2 \cdot 10^{-5}$ m/s, see Appendix 8.1. The results in Table 6-3 are considered to be more reliable, because the friction losses were smaller. The results at this location in Appendices 6 and 7 are taken from Table 6-3.

Table 6-3. Transmissivity and head of fracture at 388.6 m.

Pumping rate 1 (L/min)	Borehole head 1 (masl)	Flow 1 (mL/h)	Pumping rate 2 (L/min)	Borehole head 2 (masl)	Flow 2 (mL/h)	Transmissivity (m²/s)	Fracture head (masl)
0	2.73	10,000	3.8	2.48	149,000	1.5E–04	2.75
0.8	2.68	40,000	3.8	2.48	149,000	1.5E–04	2.75
2	2.61	84,000	3.8	2.48	149,000	1.4E–04	2.78
0	2.73	10,000	2	2.61	84,000	1.7E–04	2.75
0.8	2.68	40,000	2	2.61	84,000	1.7E–04	2.74
0	2.73	10,000	0.8	2.68	40,000	1.7E–04	2.75

6.4.5 Theoretical and practical measurement limits of flow and transmissivity

The theoretical minimum of measurable flow rate in the overlapping results (thermal dilution method only) is about 30 mL/h. The thermal pulse method was also used when the borehole was not pumped. Its theoretical lower limit is about 6 mL/h. The upper limit of the flow measurement is 300,000 mL/h. These limits are determined on the basis of flow calibration. It is assumed that flow can be reliably detected between the upper and lower theoretical limits during favourable borehole conditions.

The minimum measurable flow rate may however be much higher in practice. Borehole conditions may have an influence in the base level of flow (noise level). The noise level can be evaluated on borehole intervals without flowing fractures or other structures. The noise level may vary along the borehole.

There are several known reasons for increased noise level in flow:

1) Rough borehole wall.
2) Solid particles in the borehole water such as clay or drilling debris.
3) Gas bubbles in water.
4) High flow rate along the borehole.

A rough borehole wall always causes a high noise, not only in flow but also in single point resistance results. The flow curve and SPR curves are typically spiky when the borehole wall is rough.

Drilling debris usually increases the noise level. Typically, this kind of noise is seen both without pumping and with pumping.

Pumping causes a pressure drop in the borehole water and in water in fractures near the borehole. This may lead to a release of gas from dissolved form to gas bubbles. Some fractures may produce more gas than other. Sometimes an increased noise level is obtained just above certain fractures (when the borehole is measured in the upward direction). The reason is assumed to be gas bubbles. Bubbles may cause a decrease of the average density of the water and therefore also decrease of the measured head in the borehole.

The effect of a high flow rate along the borehole can often be seen above highly flow yielding fractures. Any minor leak at the lower rubber disks is directly measured as an increased noise level in flow.

A high noise level in flow masks the "real" flow, smaller than the noise. Real flows are totally invisible if they are about ten times smaller than the noise. Real flows are registered correctly if they are about ten times larger than the noise. By experience, real flows between 1/10 times noise and 10 times noise are summed up with noise. Therefore the noise level could be subtracted from the measured flow to get the real flow. This correction, has not been done so far because it is not clear whether it is applicable in every case.

The noise level was a problem in the upper part of borehole KFM03A, see Chapter 6.4.6. The practical minimum level of flow rate is evaluated and presented in Appendices 3.1–3.45 using a grey dashed line (Lower limit of flow rate). Below this line there may be fractures or structures that remain undetected.

In some boreholes, the upper limit of flow measurement (300,000 mL/h) may be exceeded. Such fractures or structures hardly remain undetected (as the fractures below the lower limit). Highly water yielding fractures can be measured separately at smaller drawdowns.

The practical minimum of measurable flow rate is also presented in Appendix 6 (Q-lower limit Practical). It is taken from the plotted curve in Appendix 3 (Lower limit of flow rate). The practical minimum of measurable transmissivity can be evaluated using Q-lower limit and the actual head difference at each measurement, see Appendix 6. The theoretical minimum measurable transmissivity can also be evaluated using the Q value of 6 mL/h (minimum theoretical flow rate with the thermal pulse method) instead of Q-lower limit Practical.

The upper measurement limit of transmissivity can be evaluated using the maximum flow rate (300,000 mL/h) at the actual head difference as above, see Appendix 6 (T_s-Upper Limit).

All three flow limits are also plotted with measured flow rates, see Appendix 7.1. Theoretical minimum and maximum values are 6 mL/h and 300,000 mL/h, respectively.

The three transmissivity limits are also presented graphically, see Appendix 7.2. The upper measurement limit T is not even, but shows steps upwards. At these locations, a smaller pumping rate (smaller head difference) was used, because there are highly water yielding fractures occur at these locations.

Similar flow and transmissivity limits are not given for the fracture-specific results, Appendices 8.1–8.2. However, approximately the same limits would be valid also for these results. The limits for fracture-specific results are though more difficult to define. For instance, it may be difficult to observe a small flow rate near (< 1 m) a high flowing fracture. The situation is similar for the upper flow limit. If there are several highly water yielding fractures nearer each other than one metre, the upper flow limit depends on the sum of flows which must be below 300,000 mL/h.

The practical lower flow limit in the upper part of the borehole (100–400 m) is based on the results of the first campaign. In the second campaign much smaller flow rates could be detected. They are presented in Appendix 8.

6.4.6 Friction losses

The biggest problem in this borehole was the high noise level in flow above 388 m during the first campaign. The noise level or minimum measurable flow rate in the overlapping results was high only when the borehole was pumped but normal when the borehole was at rest, blue curve Appendices 3.1–3.15.

It can be evaluated from the test illustrated in Appendix 4 that at least 65% of the pumped water comes from the single fracture at 388.6 m. It has earlier been revealed that a high flow rate along the borehole may increase the noise in flow. A high flow rate may cause friction in the flow guide. In such case even small leaks at the lower rubber disks can increase the flow through the flow sensor.

By experience, a high flow rate along borehole can cause an increased noise level if the flow rate along the borehole is larger than 30–50 L/min. In these cases the borehole has been measured upward and the rubber disks are bended downwards. In this position they may more effectively resist an overpressure from below. Borehole KFM03A was measured downwards causing the rubber disks to leak more easily. The result could have been better if the borehole had been measured upwards. An increased number of rubber disks at the lower end of the section can also help in avoiding noise. This latter method was successfully applied in the second campaign.

The exceptionally high pumping rate caused friction losses in the flowmeter. The consequences are already discussed above. Friction losses may occur at two parts of the equipment:

- in the bypass tubing and
- in the flow sensor.

Friction loss caused by the bypass tubing can be seen in the borehole head curves, see Appendix 5 head curve from August 18–20, 2003. A similar feature can bee seen with a high pumping rate in August 25, 2003, and during the second campaign in May 8–9, 2004 (borehole EC measurements).

The absolute pressure sensor is located above the bypass tubing (above the flow guide). Therefore it measured a lower pressure between 100 and 388 m, i.e. as long as the flow-meter was above the highly yielding fracture. Above 100 m, the borehole diameter is large and a pressure drop due to friction losses cannot be seen.

It can be estimated that with a pumping rate of about 100 L/min, the flow rate along the borehole was > 65 L/min between 100 m and 388 m. This caused a 20–30 cm pressure drop in the bypass tubing.

The flow guide is designed for 56 mm boreholes. It is therefore possible to increase the diameter bypass tubing for 76 mm boreholes.

The inside diameter of the flow sensor is much smaller than the inside diameter of the bypass tubing. At the flow rate of 1 L/min, the pressure drop through the flow sensor is about 0.1 m. Depending on used drawdown, a pressure drop through the flow sensor may have consequences for calculated transmissivity and head, as discussed in Chapter 6.4.4.

Borehole head anomalies in August 20–21 and August 21–22, 2003 were partially caused by the friction loss in the flow sensor, see Appendix 5 at the depth of 388 m. When the lower rubber disks passed the fracture, the pump stopped. It was re-started by the operator (August 21, 2003). The same thing happened again in August 22. In the latter case, no representative of the measurement crew was present and the pump remained stopped. The pump apparently stopped because it took air.

It is not possible to increase the inside diameter of the flow sensor without loosing its sensitivity. However, it is possible to design one flow sensor for small flow rate and another for large flow rate.

6.5 Groundwater level and pumping rate

The level of the groundwater table in the borehole during the measurements is presented in Appendix 11.2 (the first campaign) and in Appendix 11.6 (the second campaign). The borehole was pumped between August 17 and 25, 2003, with a drawdown of about eight metres, except between August 20 and 22 when, the drawdown was only 2.3 m. The borehole was pumped also in August 26 a short time with three different very small drawdowns, see Appendix 4.

The groundwater recovery was measured after the pumping period in the first campaign, August 25–26, 2003, Appendix 11.3. The recovery was measured with two methods, using the water level sensor (pressure sensor for monitoring water level) as well as the absolute pressure sensor at the depth 986.02 m.

During the second campaign, the borehole was pumped between May 6 and 9, 2004, with a drawdown of about seven metres. During the measurement of the upper part of the borehole, the drawdown was about four metres between May 9 and 11, Appendix 11.6.

Finally, the pumping rate was also recorded, see Appendix 11.4 (the first campaign) and in Appendix 11.7 (the second campaign).

Data from the flow- and recovery period of the pumping during the difference flow logging was utilized to calculate the total borehole transmissivity, see Appendix 12.

7 Summary

In this study, the Posiva Flow Log/Difference Flow method has been used to determine the location and flow rate of flowing fractures or structures in borehole KFM03A at Forsmark. Measurements were carried out both when the borehole was at rest and during pumping. A 5 m section length with 0.5 m length increments was initially used. The measurements were repeated using 1 m section length with 0.1 m length increments over the flow anomalies.

Length calibration was made using the length marks on the borehole wall. The length marks were detected by caliper and in single point resistance logging. The latter method was also performed simultaneously with the flow measurements, and thus all flow results could be length calibrated by synchronising the single point resistance logs.

The distribution of saline water along the borehole was logged by electric conductivity and temperature measurements of the borehole water. In addition, electric conductivity was measured in selected flowing fractures.

The borehole was re-measured almost one year after the first campaign to determine possible changes in electric conductivity of deep fracture-specific water. An attempt was also made to improve the practical lower limit of measurable flow rate in the upper part (c 100–400 m) of the borehole. Eleven "new" flowing fractures were found in this borehole interval which remained undetected in the first campaign. However, the noise level of the measured flow in this interval was still high, most likely due to the large inflow from the highly water yielding fracture at 388.6 m during pumping, causing a high flow rate along the borehole above this fracture. This flow also caused friction losses in the bypass tubing and in the flow sensor of the flow guide.

The re-measurements of EC in selected fractures resulted in significantly lower EC-values, most likely due to upconing effects of saline water along the sub-vertical fractures in the bottom of the borehole during pumping activities prior to (and during) the first difference flow logging campaign. No significant pumping activities had occurred prior to the re-measurements and thus, no upconing effects.

The total amount of detected flowing fractures was 52. Transmissivity and hydraulic head were calculated for borehole sections and fractures. The highest transmissivity ($1.7 \cdot 10^{-4}$ m^2/s) was detected in a fracture at the borehole length of 388.6 m. This fracture had to be measured separately using a small drawdown. It also caused problems in flow measurements above it during the first campaign.

The fieldwork went smoothly, at least from the contactors point of view. An important reason to this is that the site was well organized. The measurements, which were going on round the clock, including weekends, were carried out in a relatively short time.

The final, representative results from the two difference flow logging campaigns in borehole KFM03A, stored in the Sicada database, are presented in Appendix 13.

8 References

Berg C, Nilsson A-C, 2003. Hydrochemical logging in KFM03A. Forsmark site investigation. SKB P-03-96, Svensk Kärnbränslehantering AB.

Heikkonen J, Heikkinen E, Mäntynen M, 2002. Mathematical modelling of temperature adjustment algorithm for groundwater electrical conductivity on basis of synthetic water sample analysis. Helsinki, Posiva Oy. Working report 2002-10 (in Finnish).

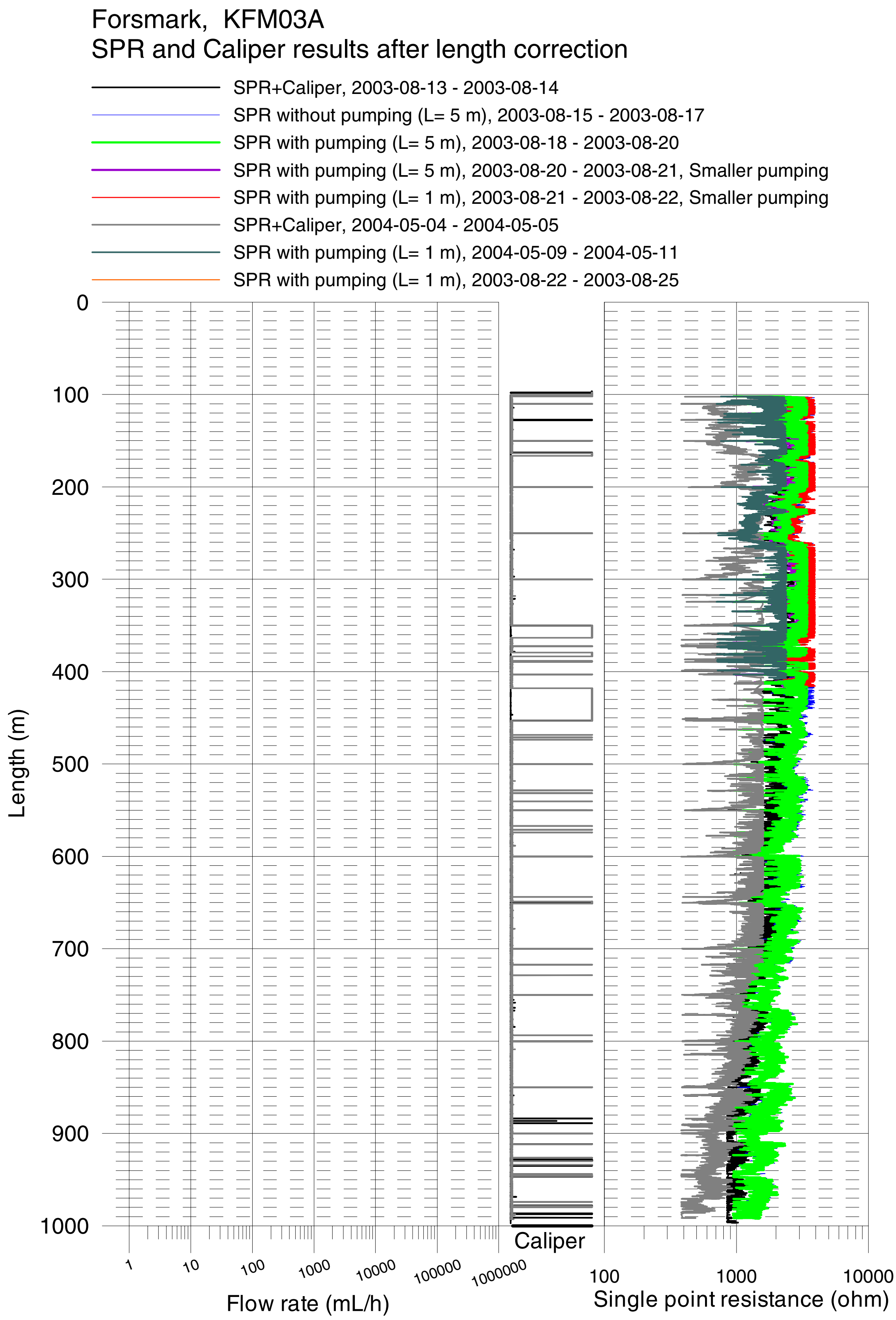
Ludvigson J-E, Hansson K. Rouhiainen P, 2002. Methodology study of Posiva difference flow metre in borehole KLX02 at Laxemar. SKB R-01-52, Svensk Kärnbränslehantering AB.

Marsily G, 1986. Quantitive Hydrology, Groundwater Hydrology for Engineers. Academic Press, Inc, London

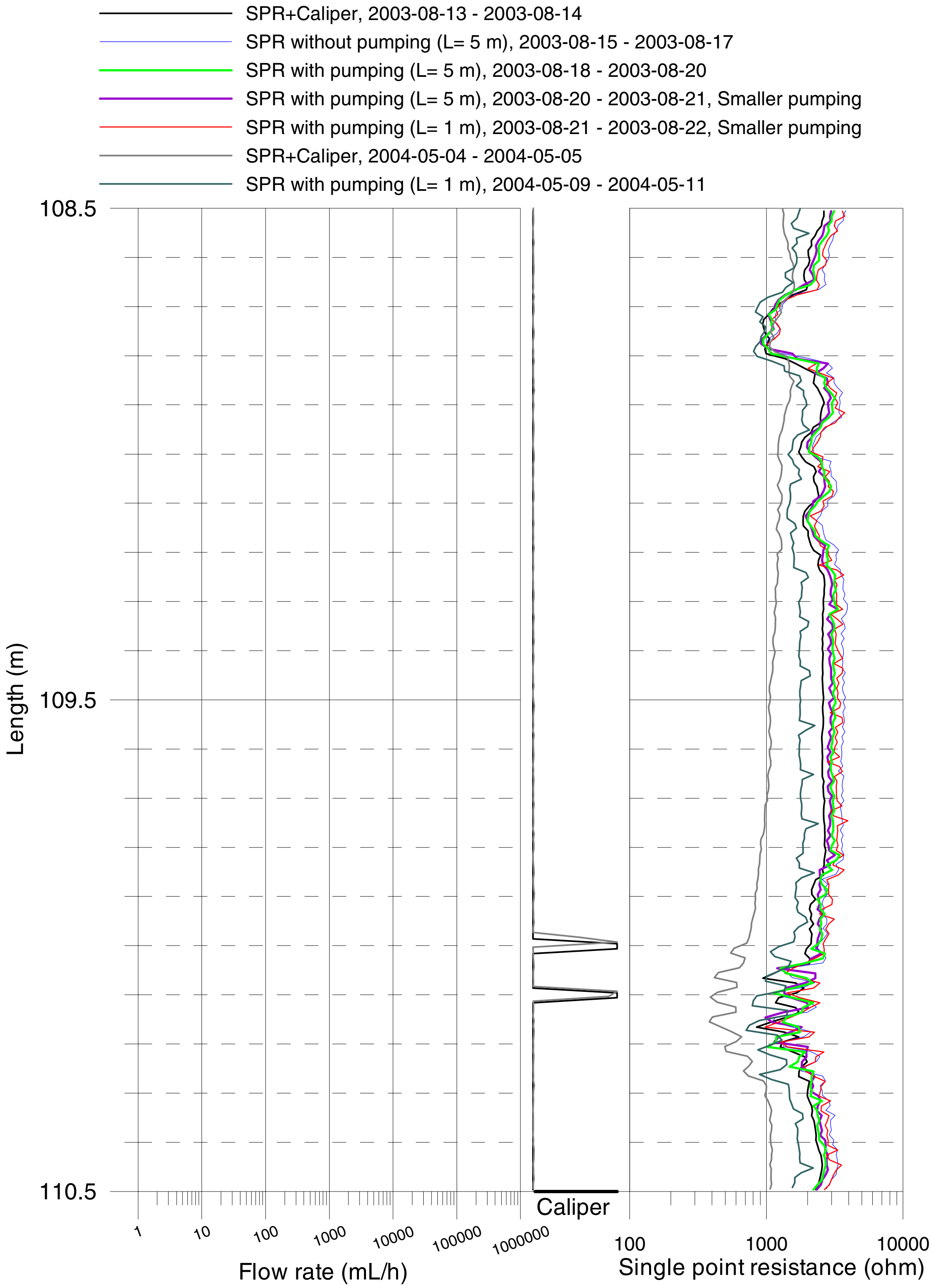
Nordqvist R, 2001. Grundvattentryck – Inventering och utarbetande av rekommendationer för det geovetenskapliga undersökningsprogrammet. Djupförvarsteknik. SKB TD-03-01, Svensk Kärnbränslehantering AB.

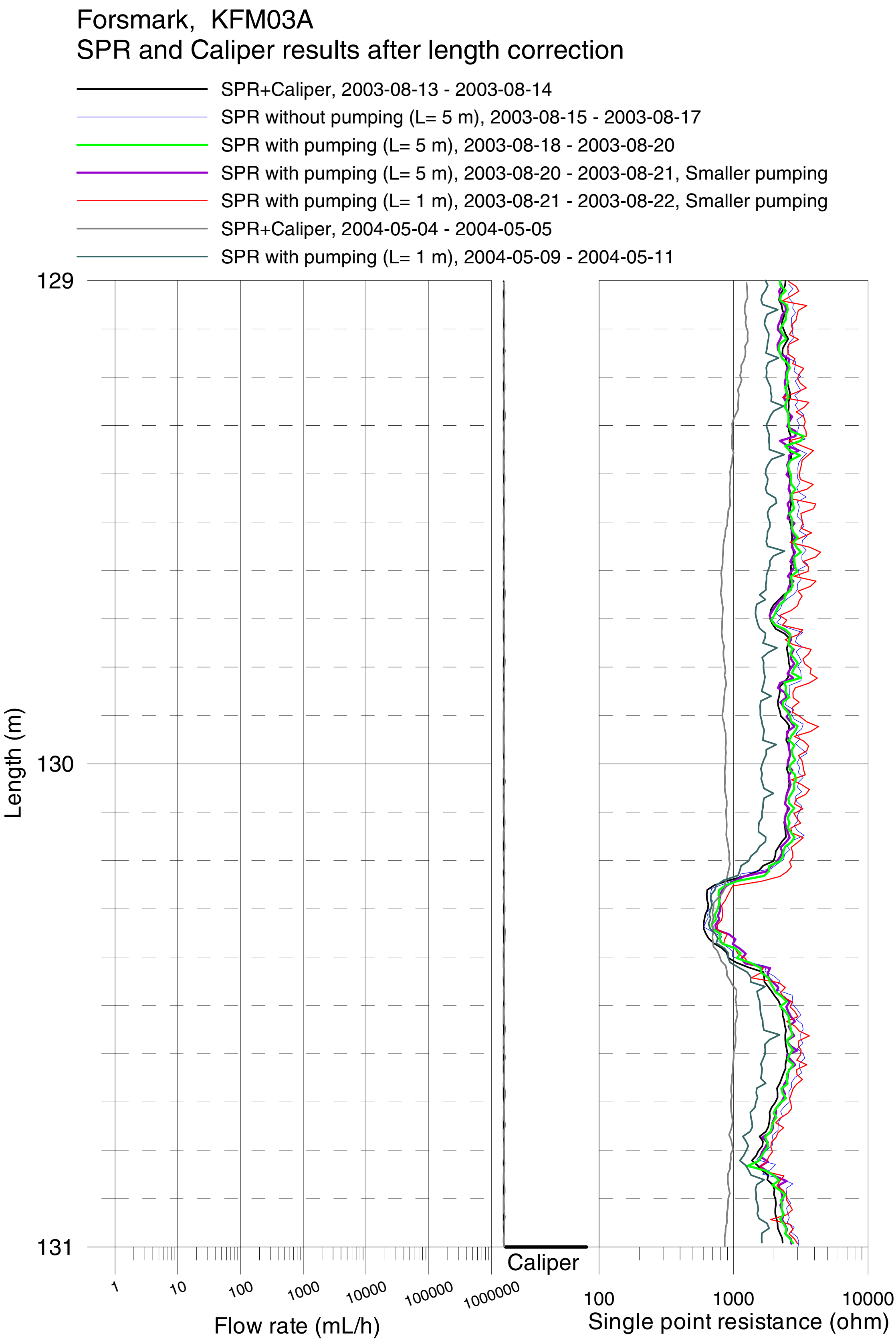
Öhberg A, Rouhiainen P, 2000. Posiva groundwater flow measuring techniques. Helsinki, Posiva Oy. Report POSIVA 2000-12.

9 Appendices

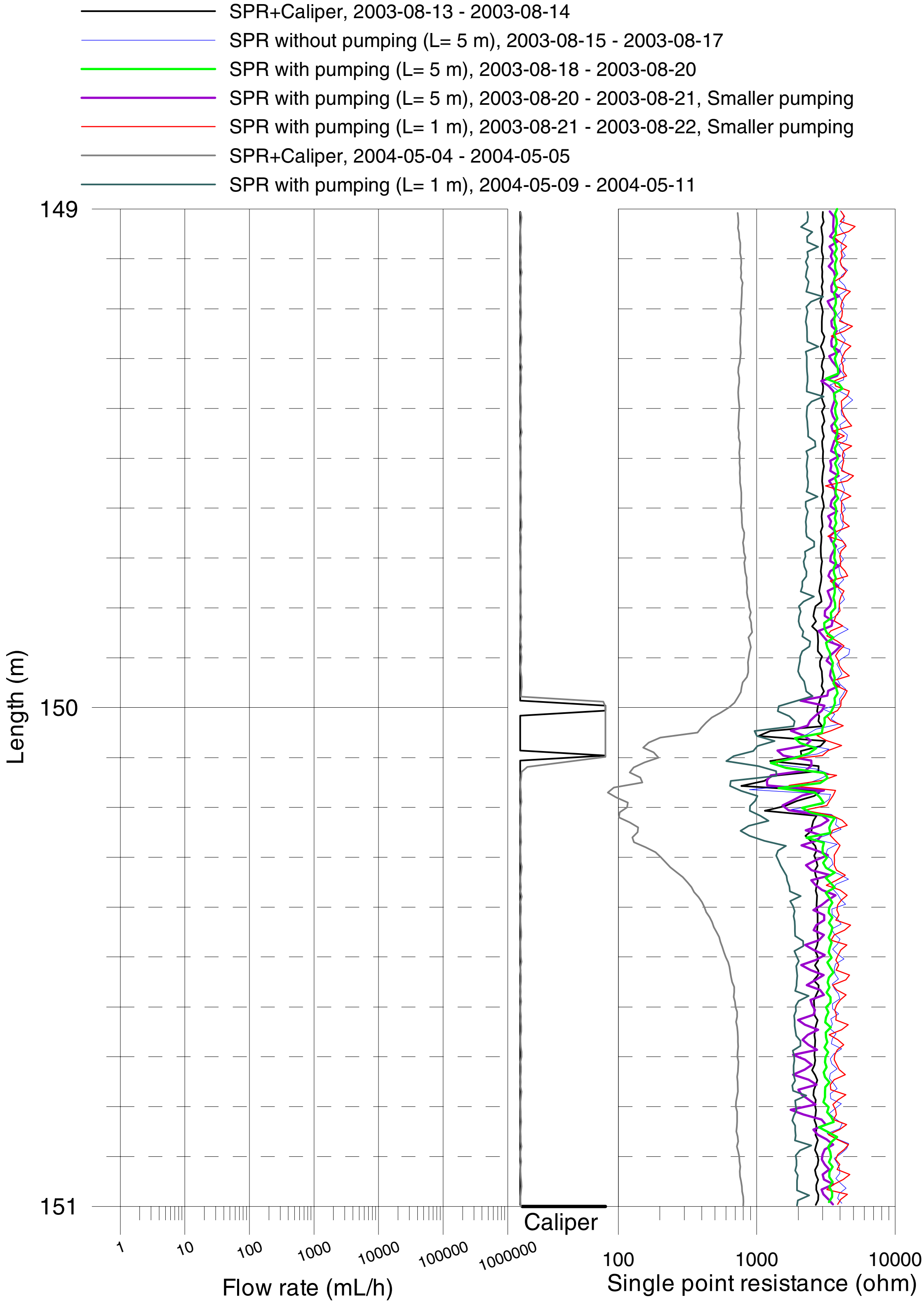

Forsmark, KFM03A
SPR and Caliper results after length correction
SPR+Caliper, 2003-08-13 - 2003-08-14
SPR without pumping (L= 5 m), 2003-08-15 - 2003-08-17
SPR with pumping (L= 5 m), 2003-08-18 - 2003-08-20
SPR with pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
SPR with pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
SPR+Caliper, 2004-05-04 - 2004-05-05
SPR with pumping (L= 1 m), 2004-05-09 - 2004-05-11
SPR with pumping (L= 1 m), 2003-08-22 - 2003-08-25
Length (m)
0
100
200
300
400
500
600
700
800
900
1000
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
Single point resistance (ohm)

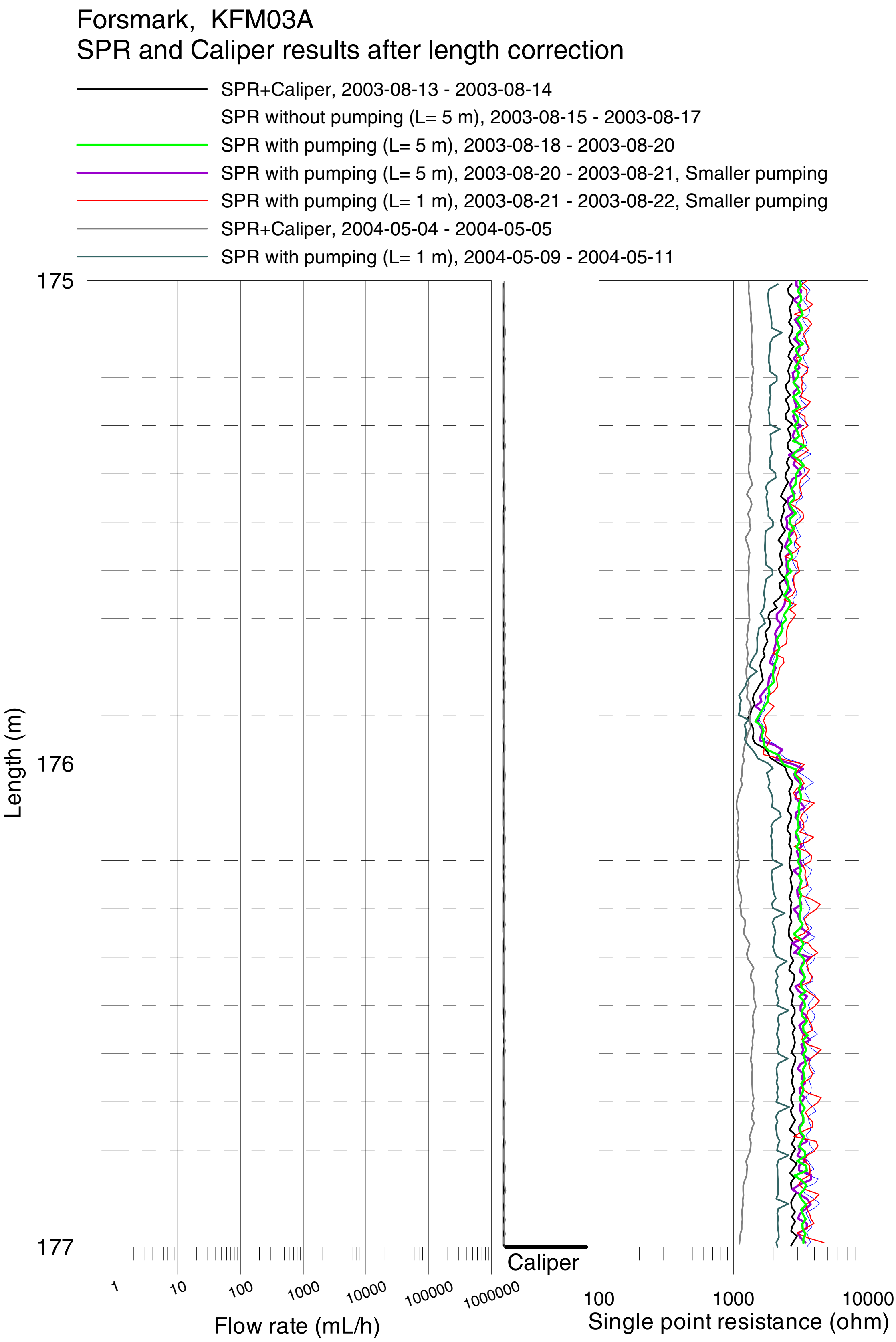
Forsmark, KFM03A
SPR and Caliper results after length correction




Forsmark, KFM03A
SPR and Caliper results after length correction
SPR+Caliper, 2003-08-13 - 2003-08-14
SPR without pumping (L= 5 m), 2003-08-15 - 2003-08-17
SPR with pumping (L= 5 m), 2003-08-18 - 2003-08-20
SPR with pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
SPR with pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
SPR+Caliper, 2004-05-04 - 2004-05-05
SPR with pumping (L= 1 m), 2004-05-09 - 2004-05-11
Length (m)
129
130
131
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
Single point resistance (ohm)

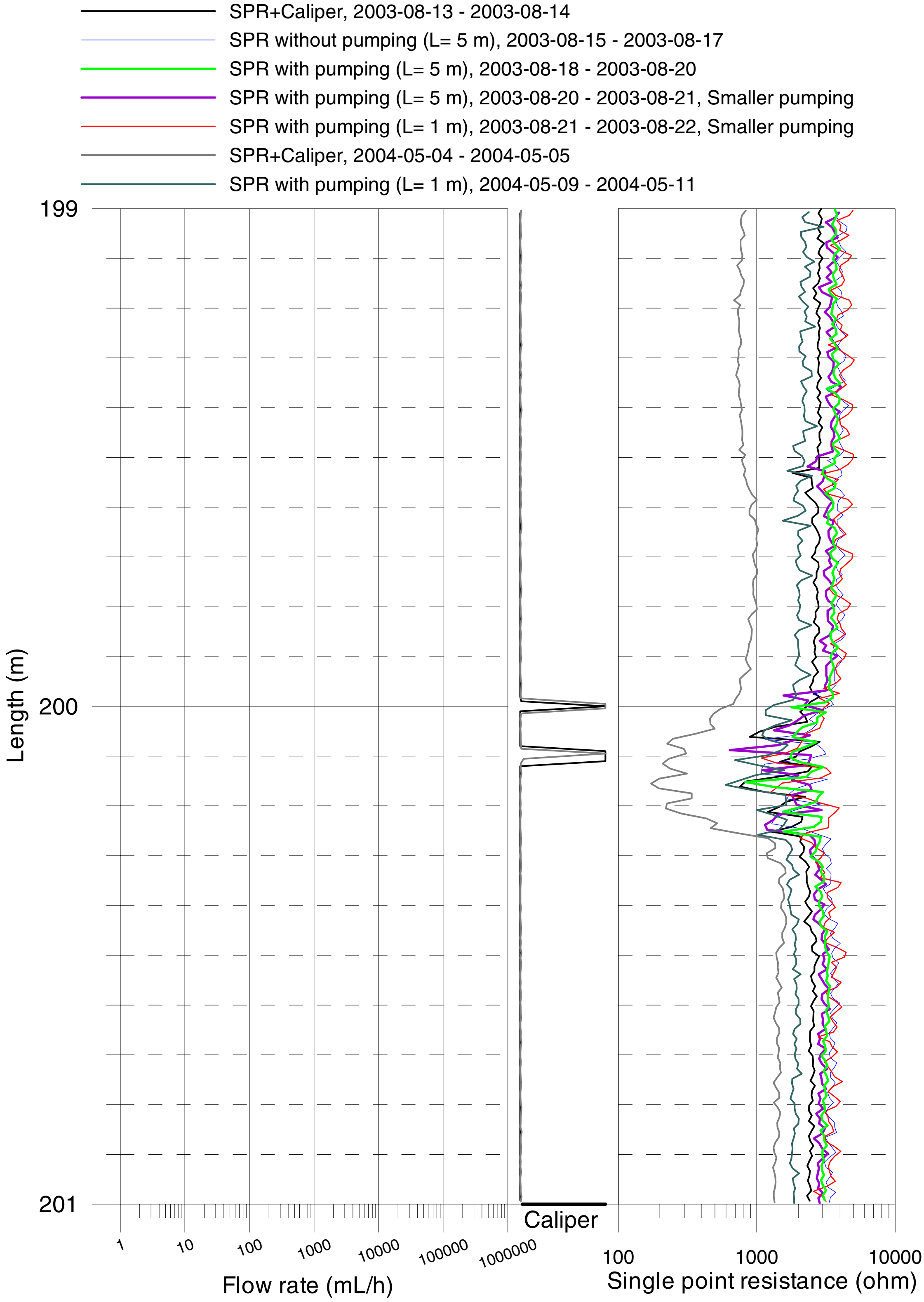
Forsmark, KFM03A
SPR and Caliper results after length correction



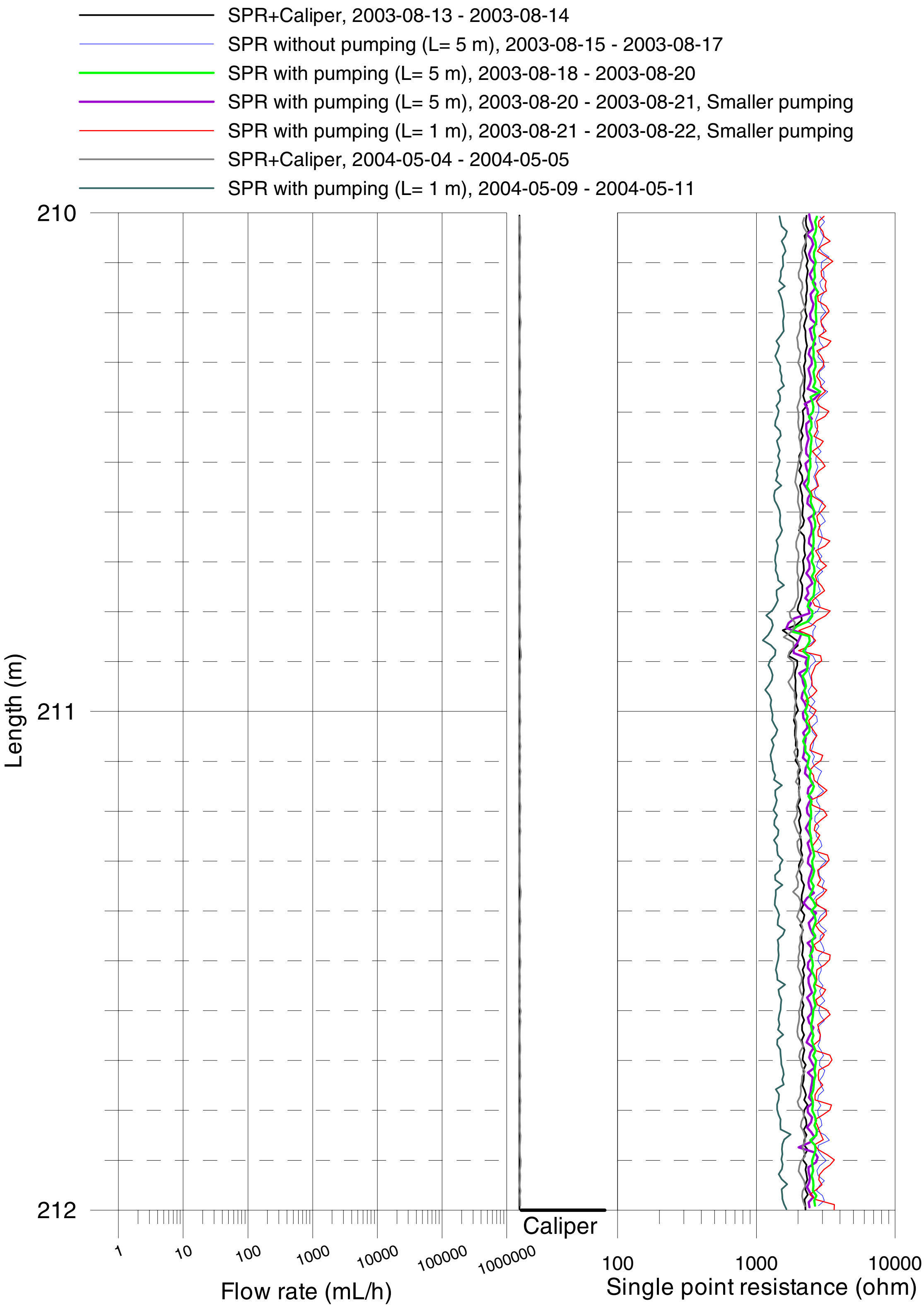

Forsmark, KFM03A
SPR and Caliper results after length correction
SPR+Caliper, 2003-08-13 - 2003-08-14
SPR without pumping (L= 5 m), 2003-08-15 - 2003-08-17
SPR with pumping (L= 5 m), 2003-08-18 - 2003-08-20
SPR with pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
SPR with pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
SPR+Caliper, 2004-05-04 - 2004-05-05
SPR with pumping (L= 1 m), 2004-05-09 - 2004-05-11
175
176
177
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

Appendix 1.6

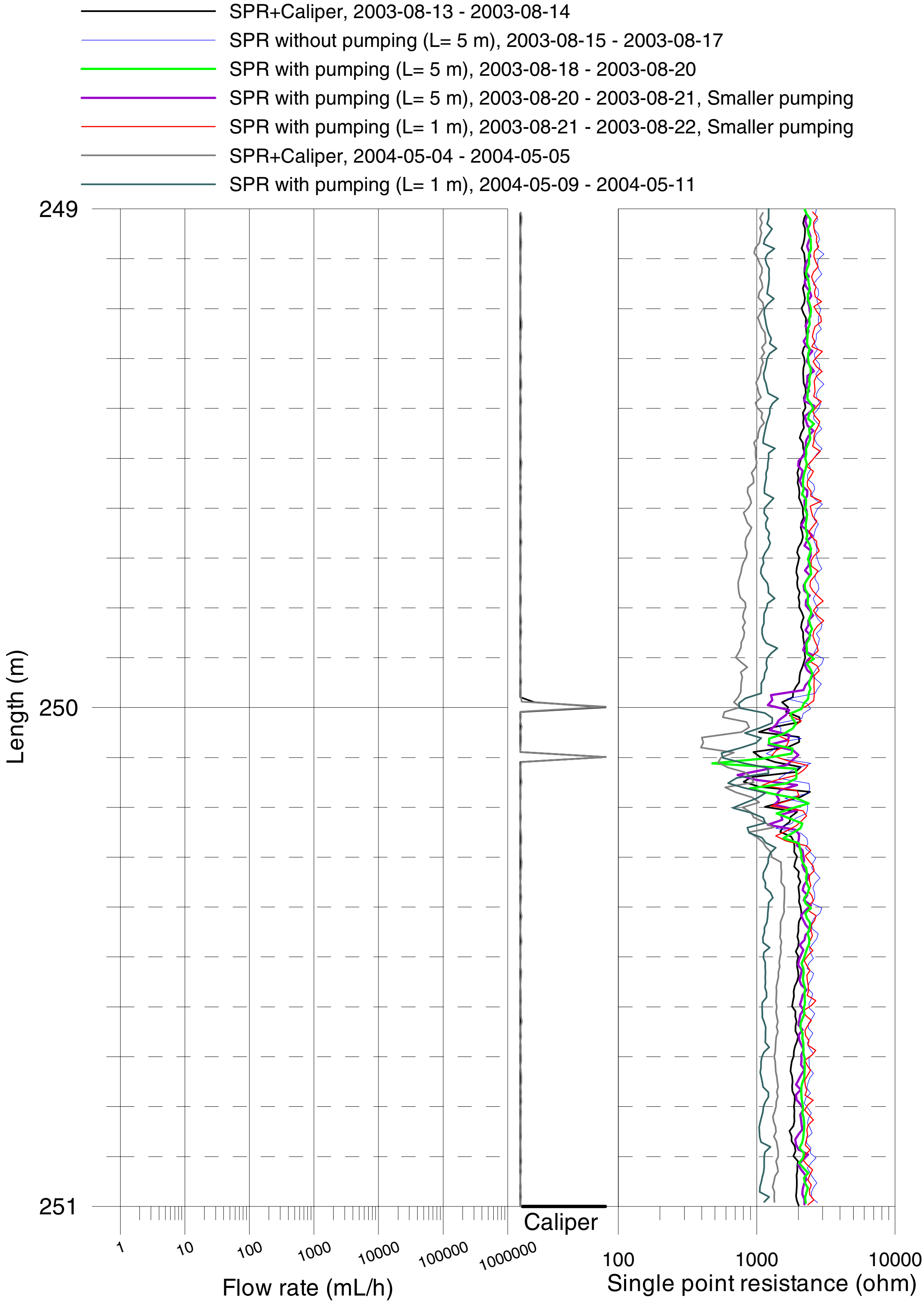
Forsmark, KFM03A
SPR and Caliper results after length correction



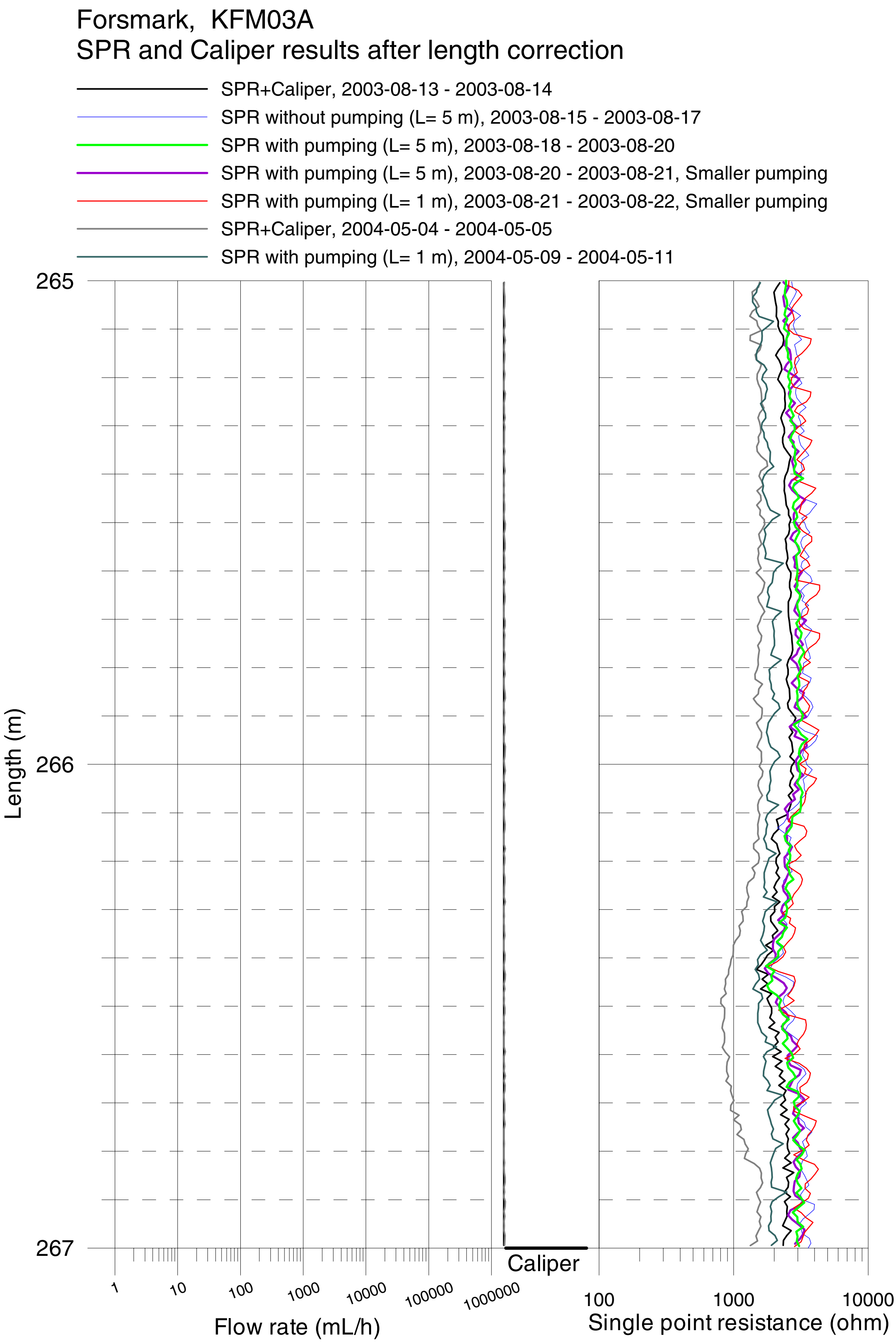
Forsmark, KFM03A
SPR and Caliper results after length correction



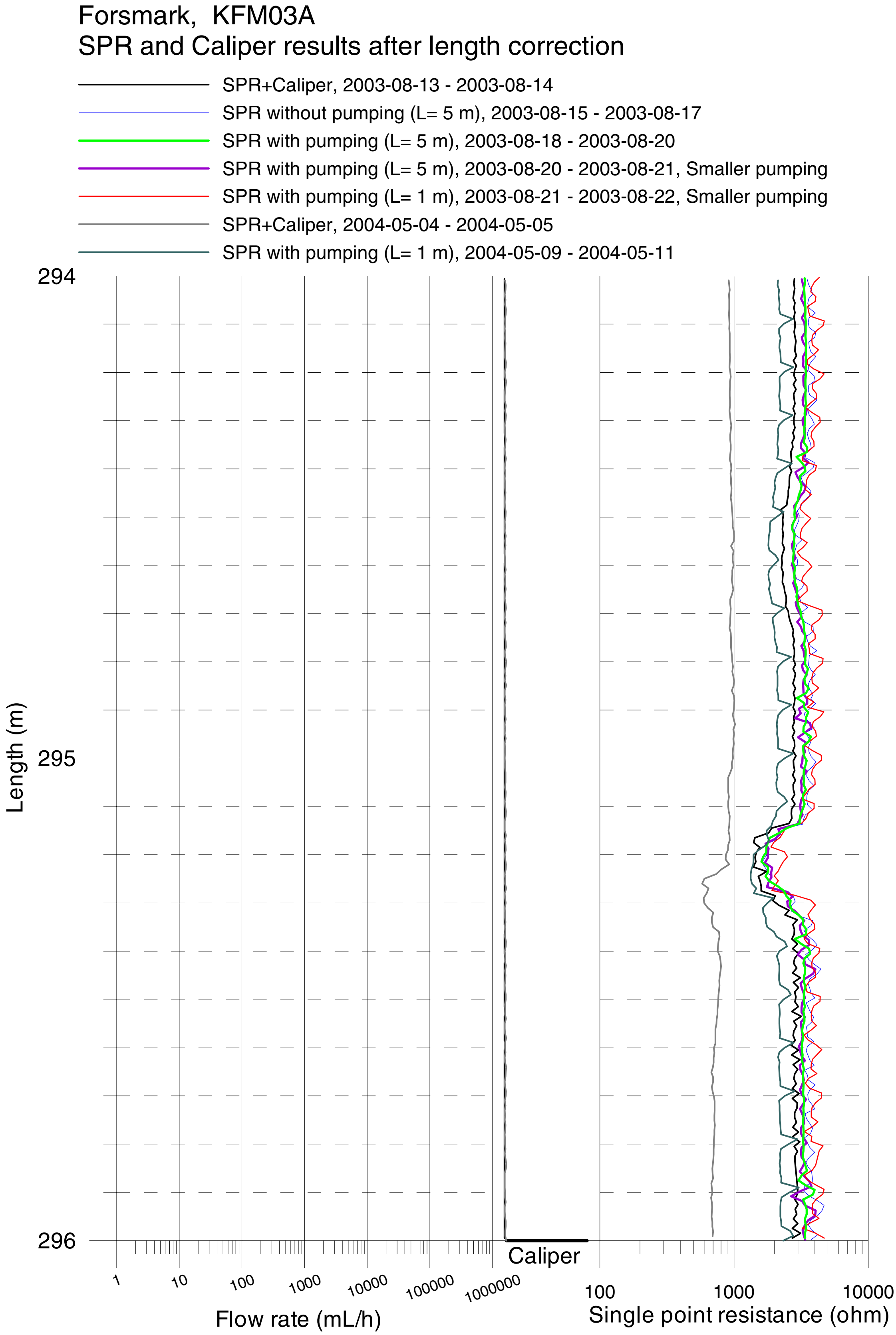
Forsmark, KFM03A
SPR and Caliper results after length correction



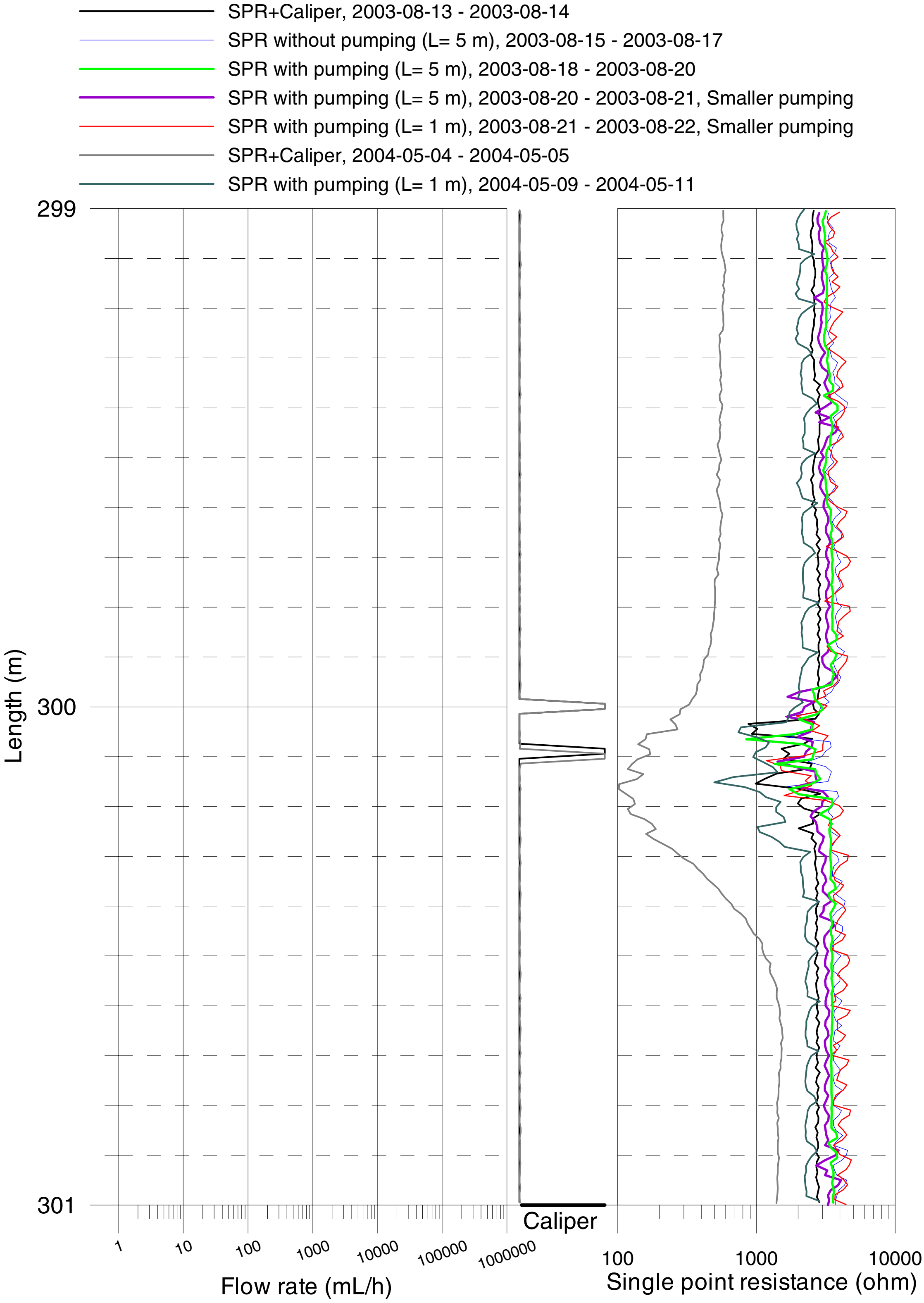
Appendix 1.9



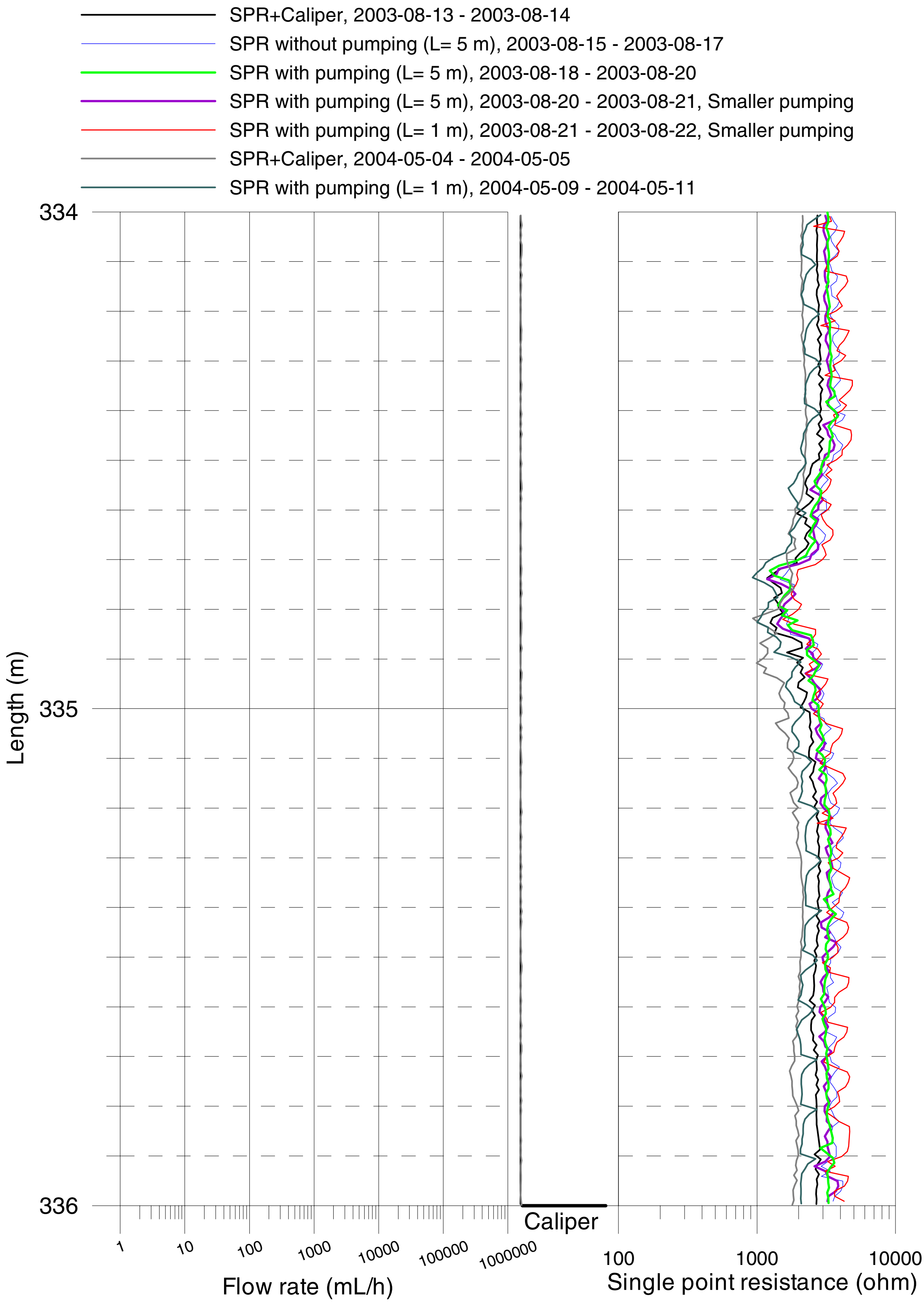
Forsmark, KFM03A
SPR and Caliper results after length correction
SPR+Caliper, 2003-08-13 - 2003-08-14
SPR without pumping (L= 5 m), 2003-08-15 - 2003-08-17
SPR with pumping (L= 5 m), 2003-08-18 - 2003-08-20
SPR with pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
SPR with pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
SPR+Caliper, 2004-05-04 - 2004-05-05
SPR with pumping (L= 1 m), 2004-05-09 - 2004-05-11
265
266
267
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

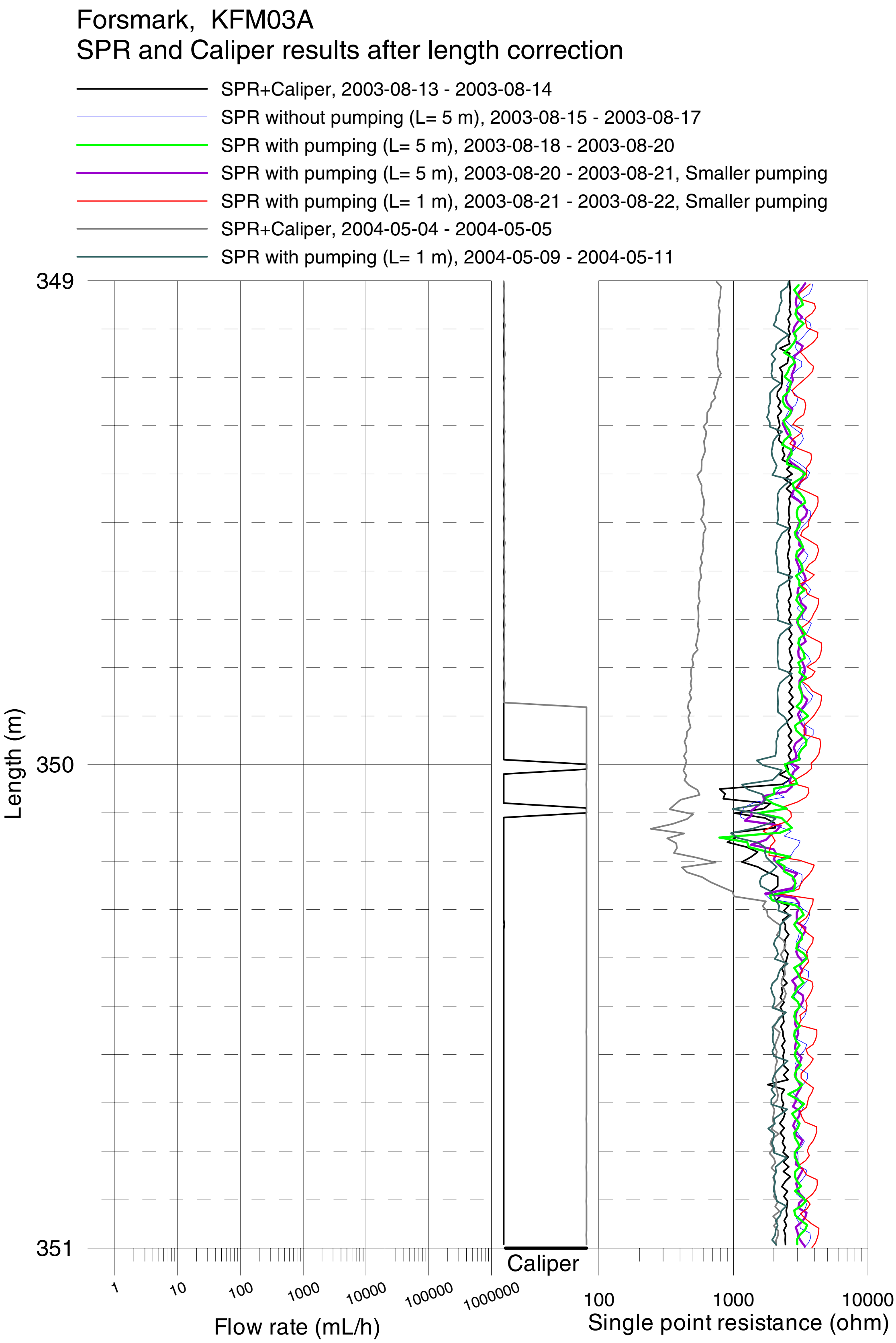

Forsmark, KFM03A
SPR and Caliper results after length correction
SPR+Caliper, 2003-08-13 - 2003-08-14
SPR without pumping (L= 5 m), 2003-08-15 - 2003-08-17
SPR with pumping (L= 5 m), 2003-08-18 - 2003-08-20
SPR with pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
SPR with pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
SPR+Caliper, 2004-05-04 - 2004-05-05
SPR with pumping (L= 1 m), 2004-05-09 - 2004-05-11
Length (m)
294
295
296
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

Forsmark, KFM03A
SPR and Caliper results after length correction

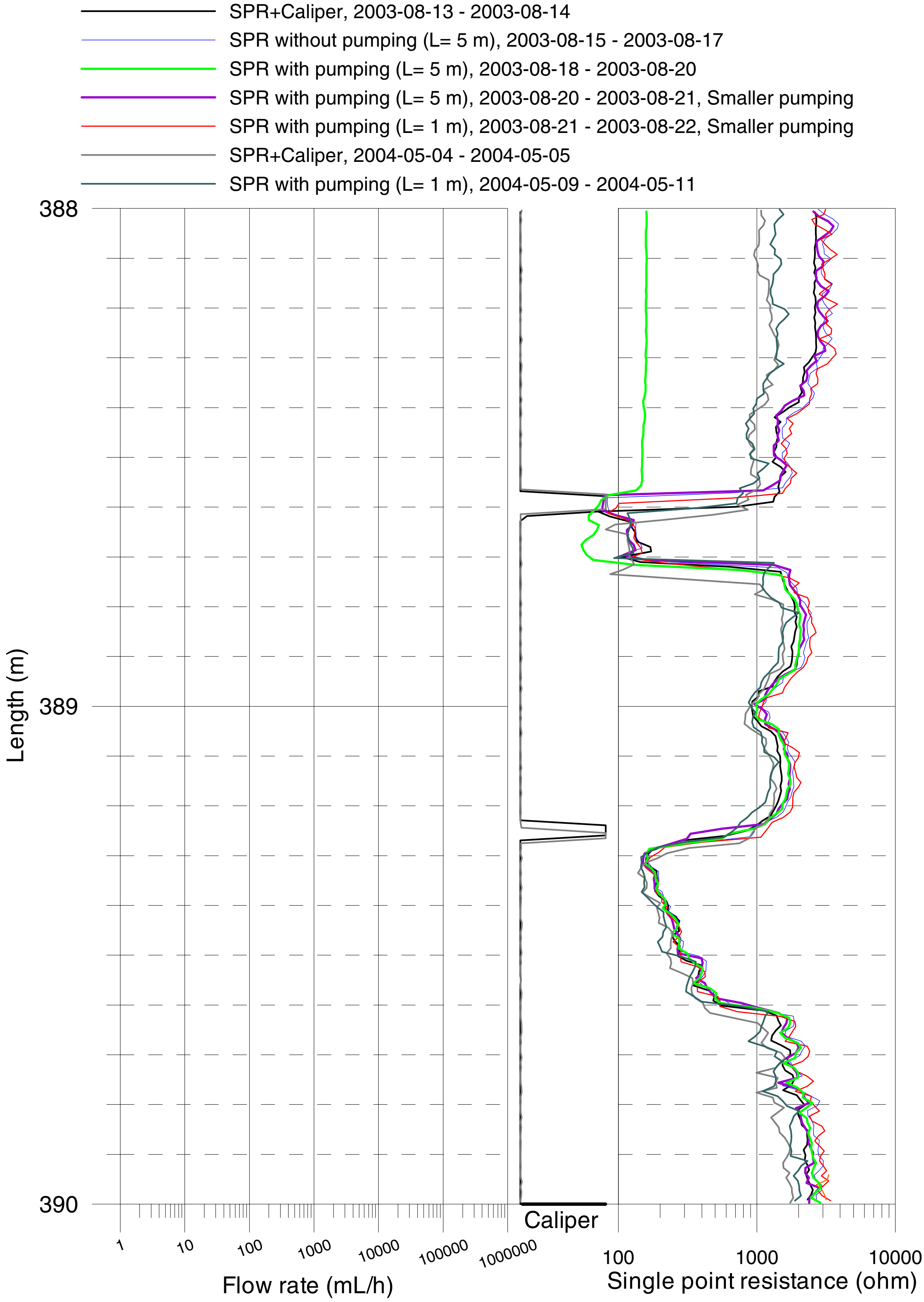


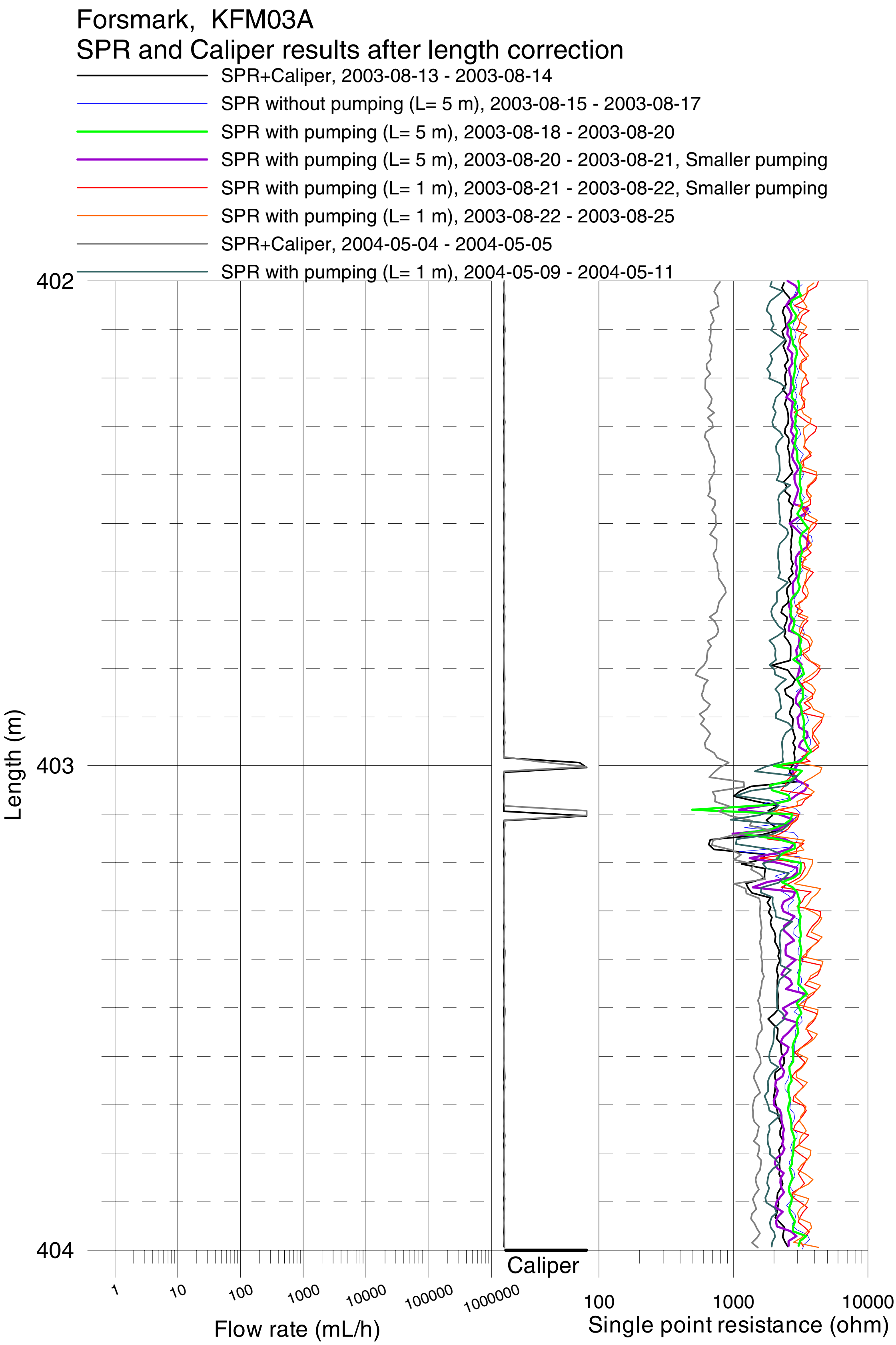
Forsmark, KFM03A
SPR and Caliper results after length correction



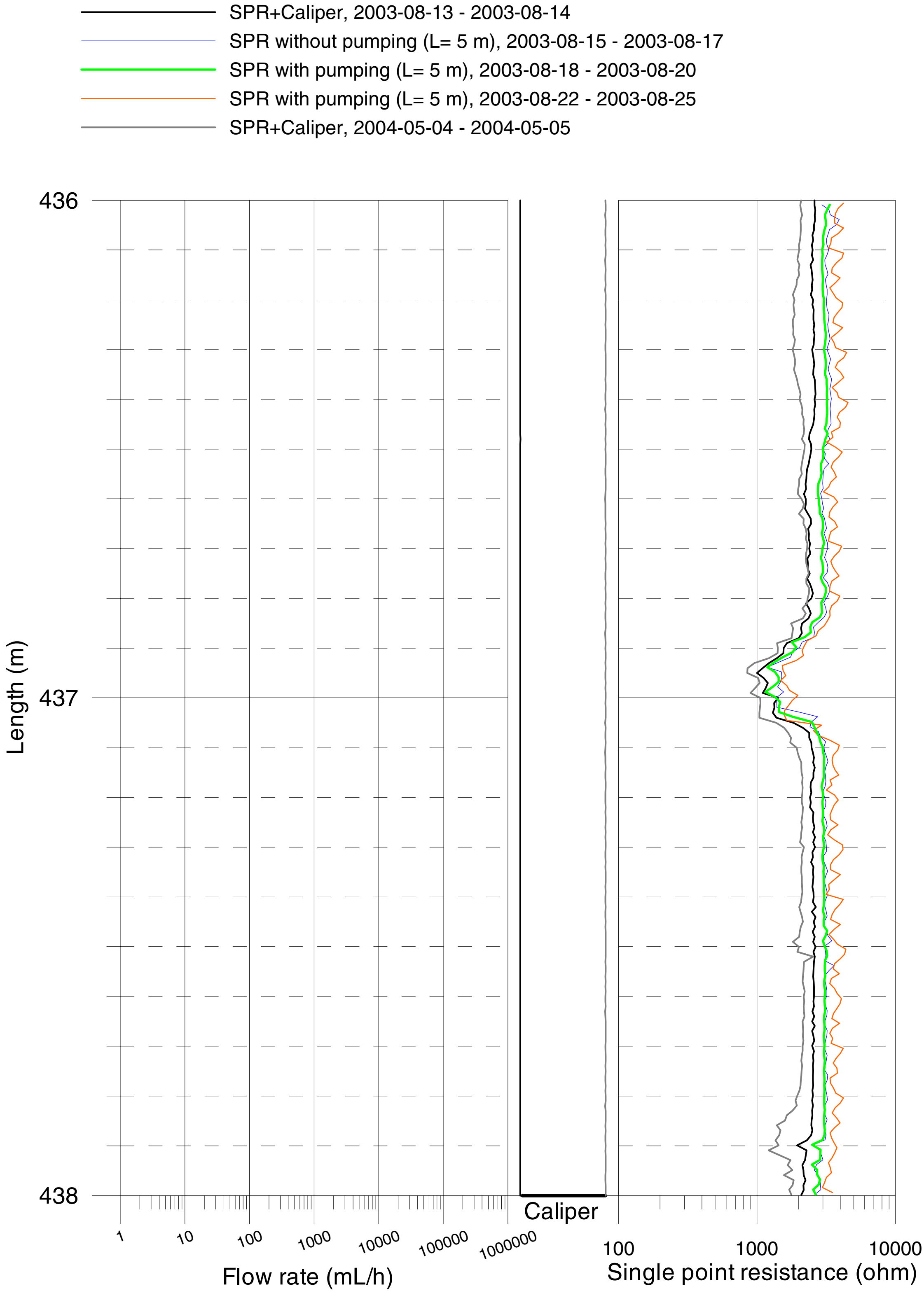

Forsmark, KFM03A
SPR and Caliper results after length correction
SPR+Caliper, 2003-08-13 - 2003-08-14
SPR without pumping (L= 5 m), 2003-08-15 - 2003-08-17
SPR with pumping (L= 5 m), 2003-08-18 - 2003-08-20
SPR with pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
SPR with pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
SPR+Caliper, 2004-05-04 - 2004-05-05
SPR with pumping (L= 1 m), 2004-05-09 - 2004-05-11
349
350
351
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
Single point resistance (ohm)

Forsmark, KFM03A
SPR and Caliper results after length correction

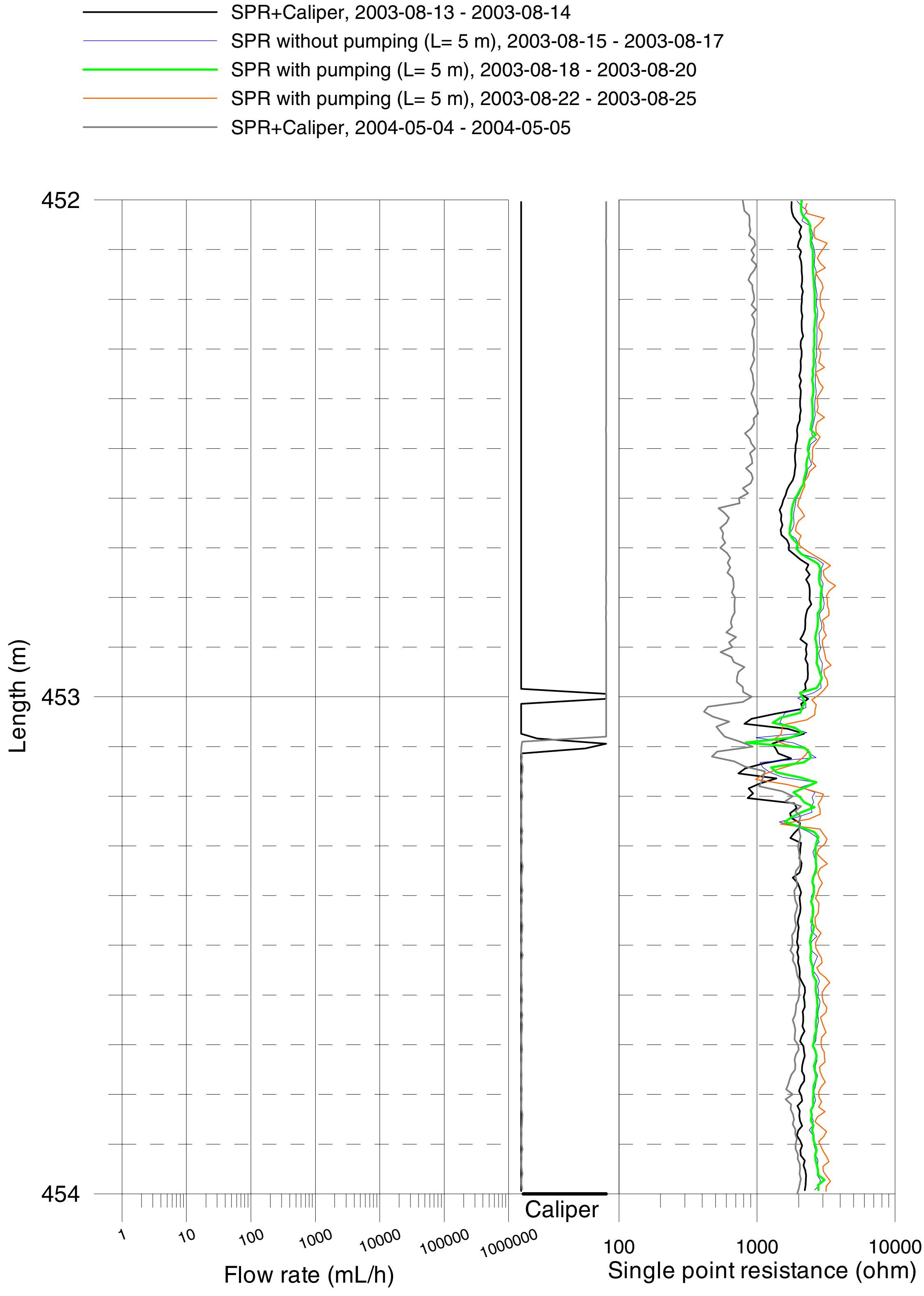



Forsmark, KFM03A
SPR and Caliper results after length correction
SPR+Caliper, 2003-08-13 - 2003-08-14
SPR without pumping (L= 5 m), 2003-08-15 - 2003-08-17
SPR with pumping (L= 5 m), 2003-08-18 - 2003-08-20
SPR with pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
SPR with pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
SPR with pumping (L= 1 m), 2003-08-22 - 2003-08-25
SPR+Caliper, 2004-05-04 - 2004-05-05
SPR with pumping (L= 1 m), 2004-05-09 - 2004-05-11
402
403
404
Length (m)
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
Single point resistance (ohm)

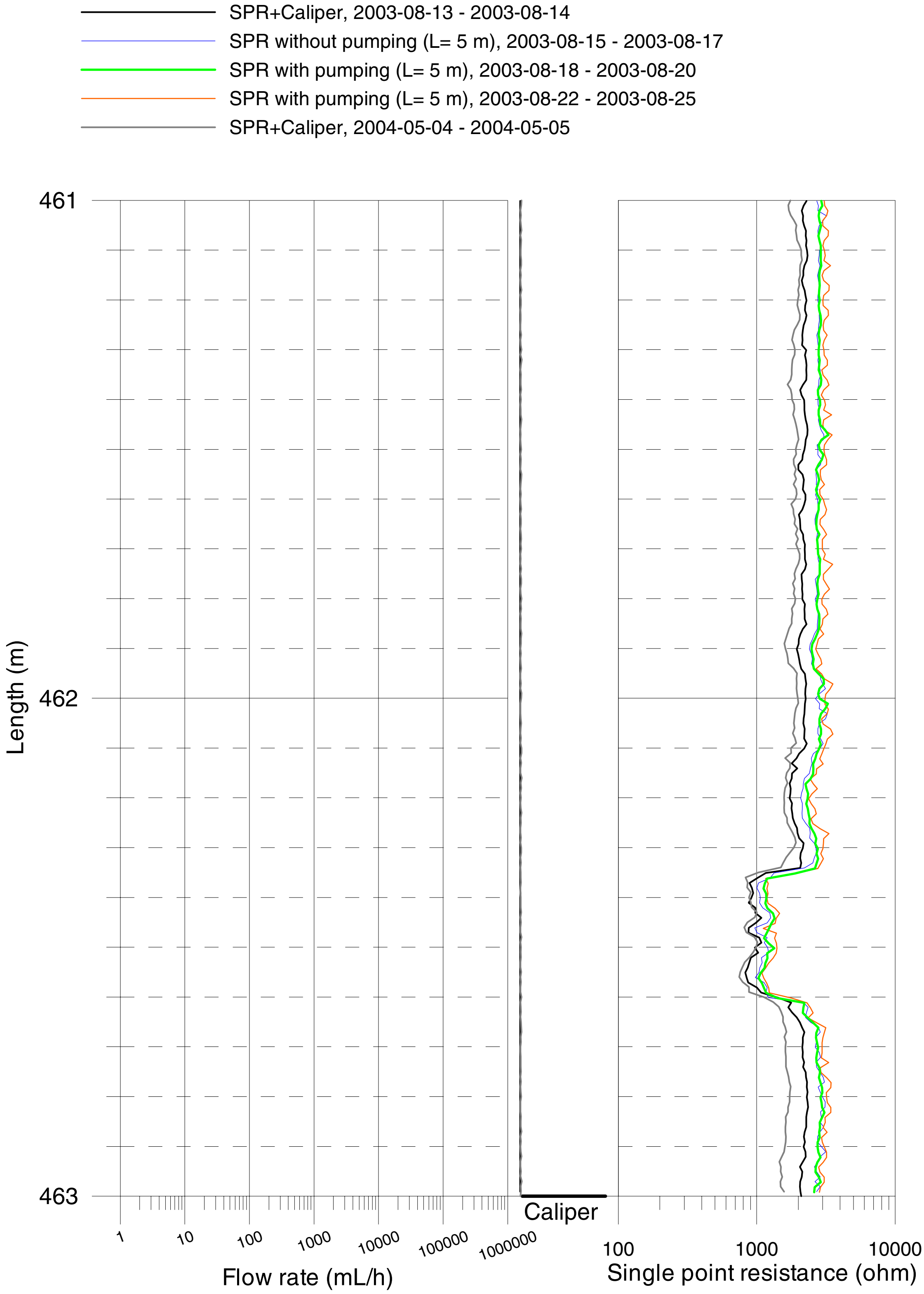
Forsmark, KFM03A
SPR and Caliper results after length correction



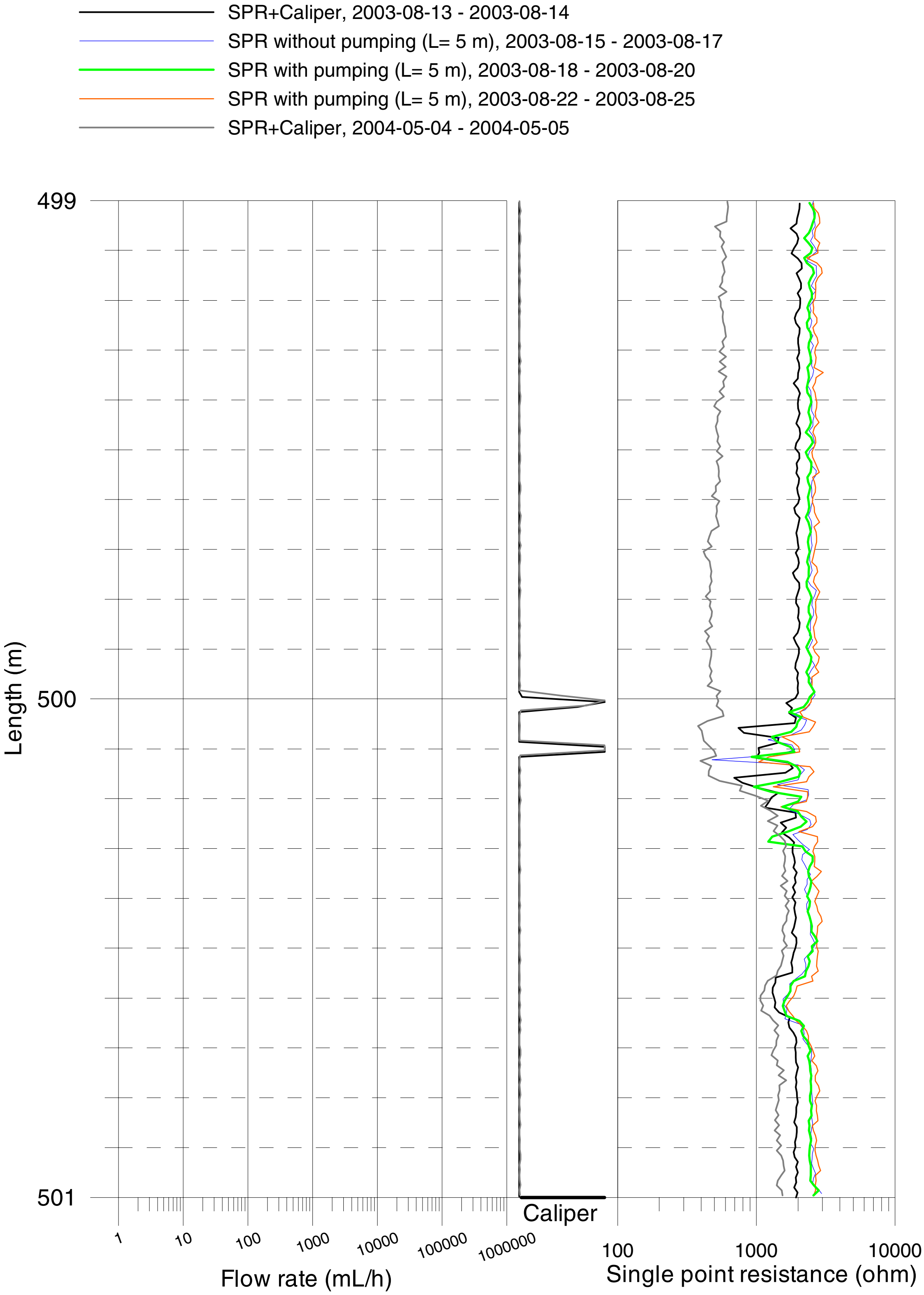
Forsmark, KFM03A
SPR and Caliper results after length correction



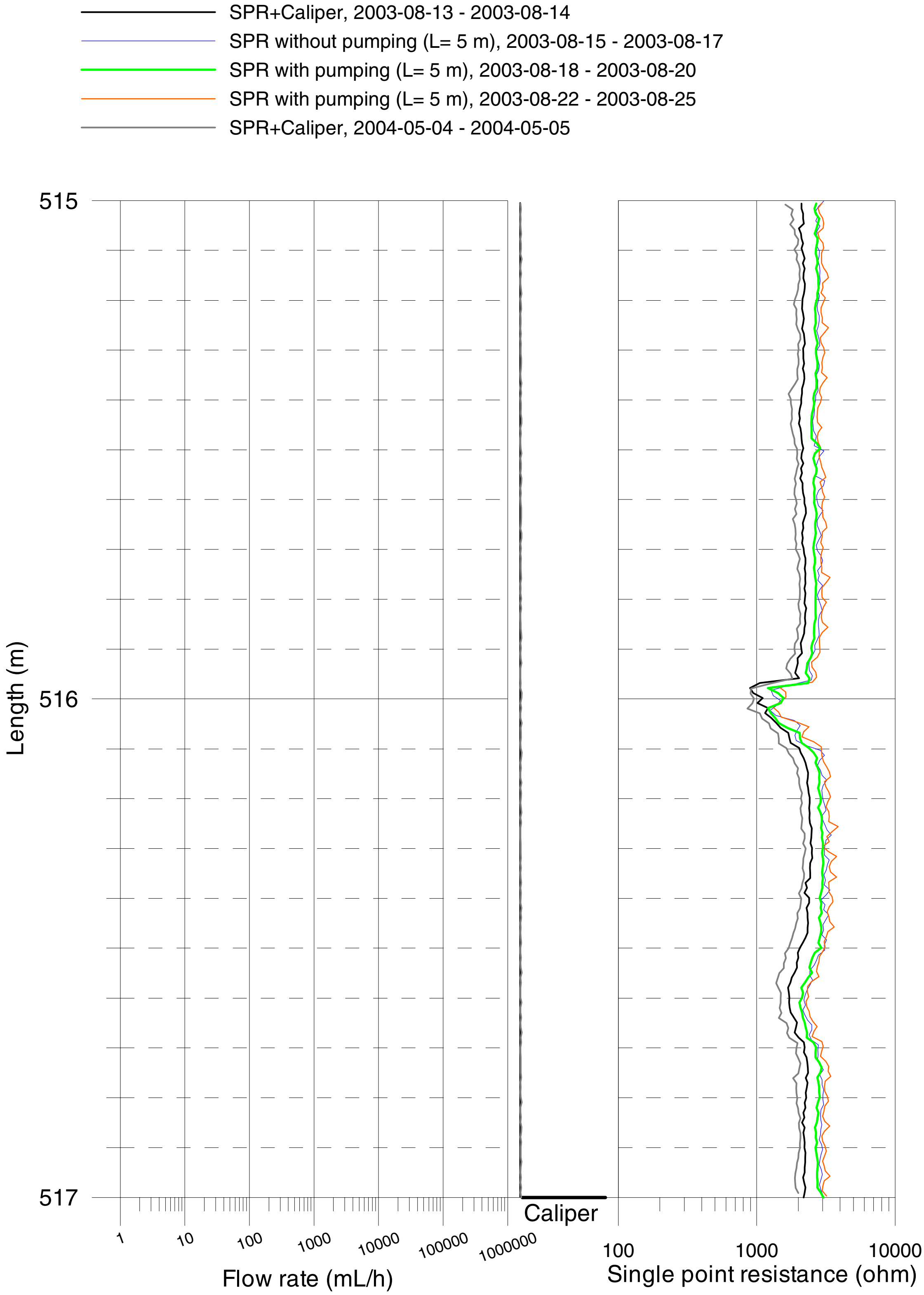
Forsmark, KFM03A
SPR and Caliper results after length correction



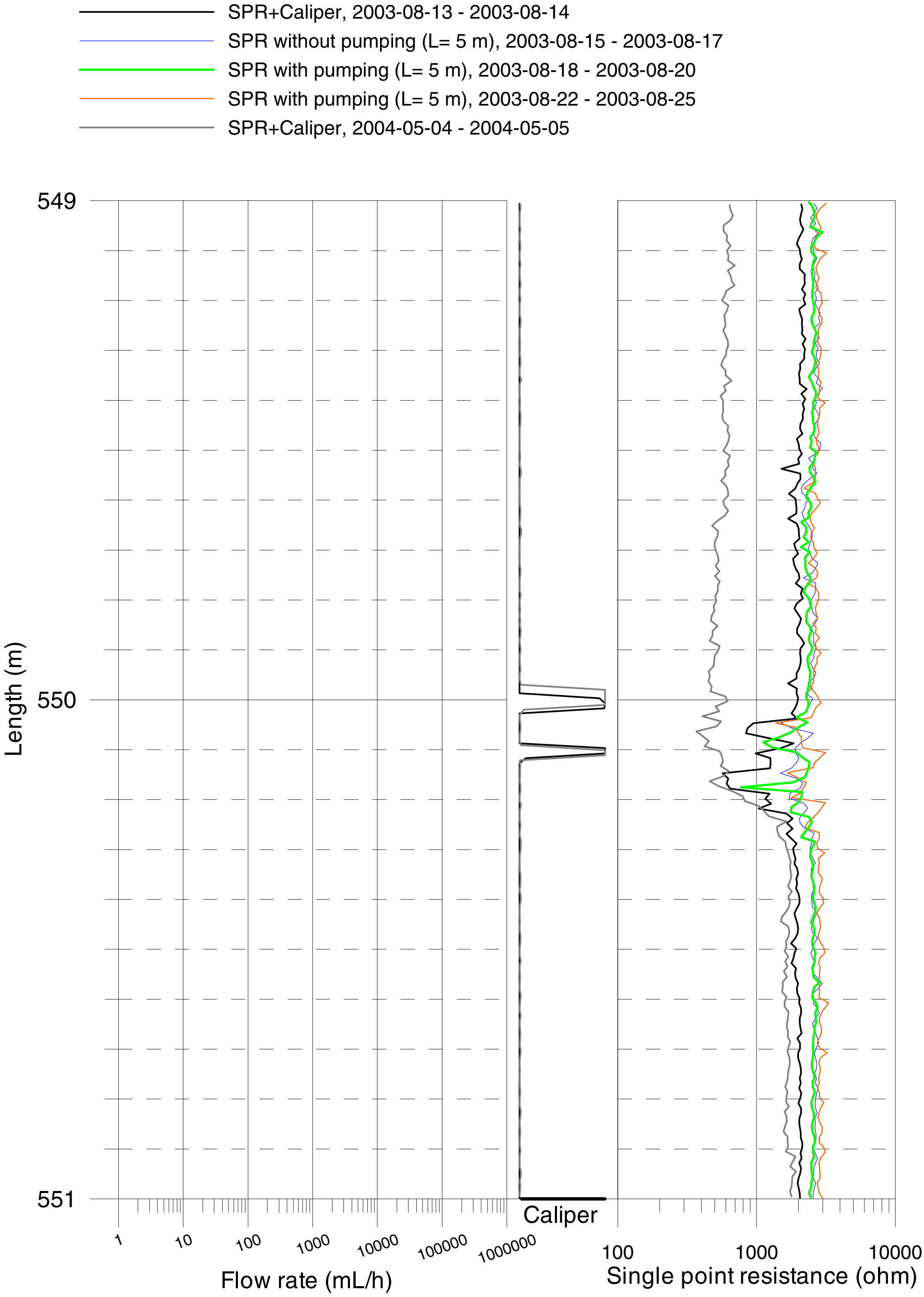
Forsmark, KFM03A
SPR and Caliper results after length correction



Forsmark, KFM03A
SPR and Caliper results after length correction

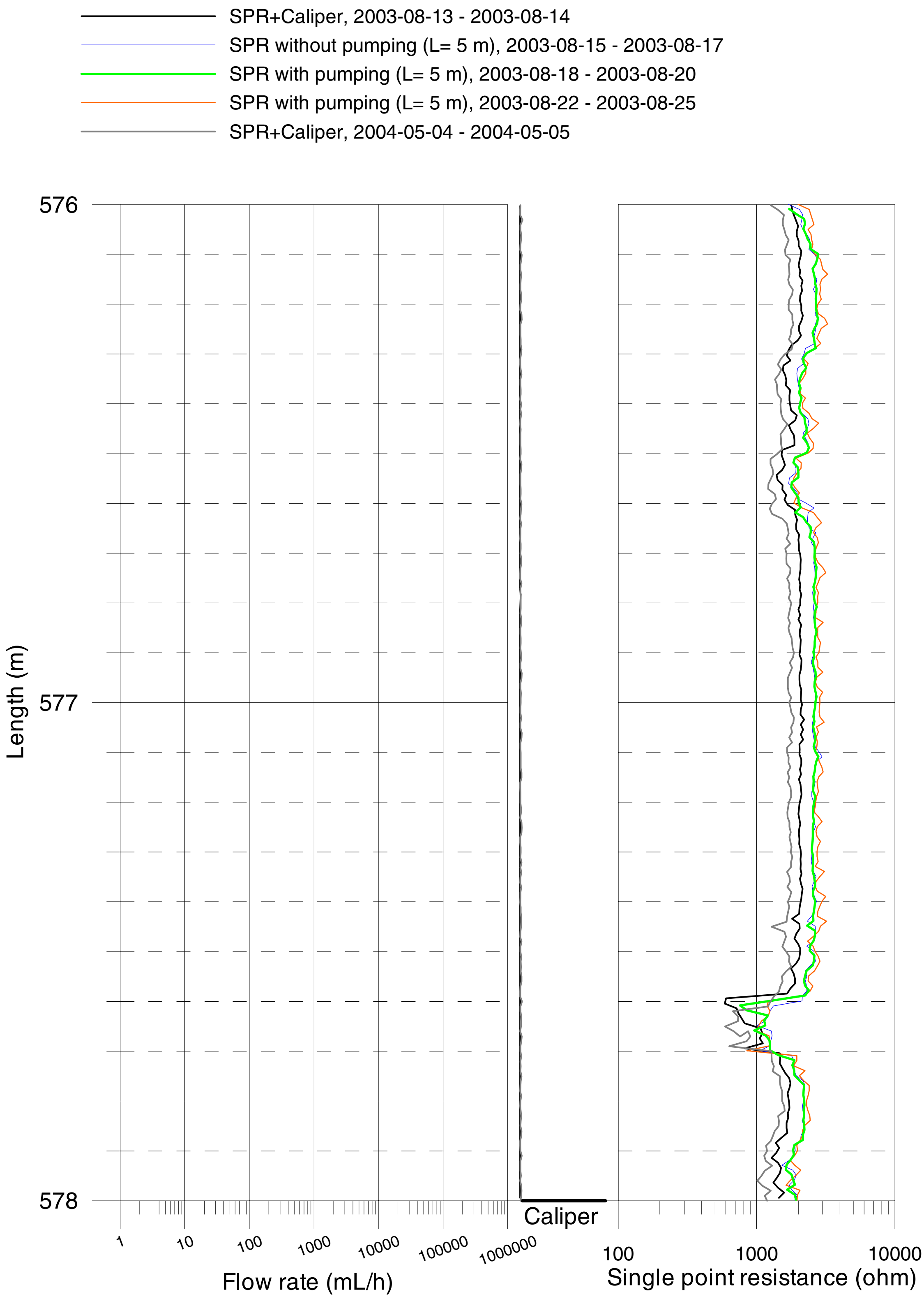


Forsmark, KFM03A
SPR and Caliper results after length correction

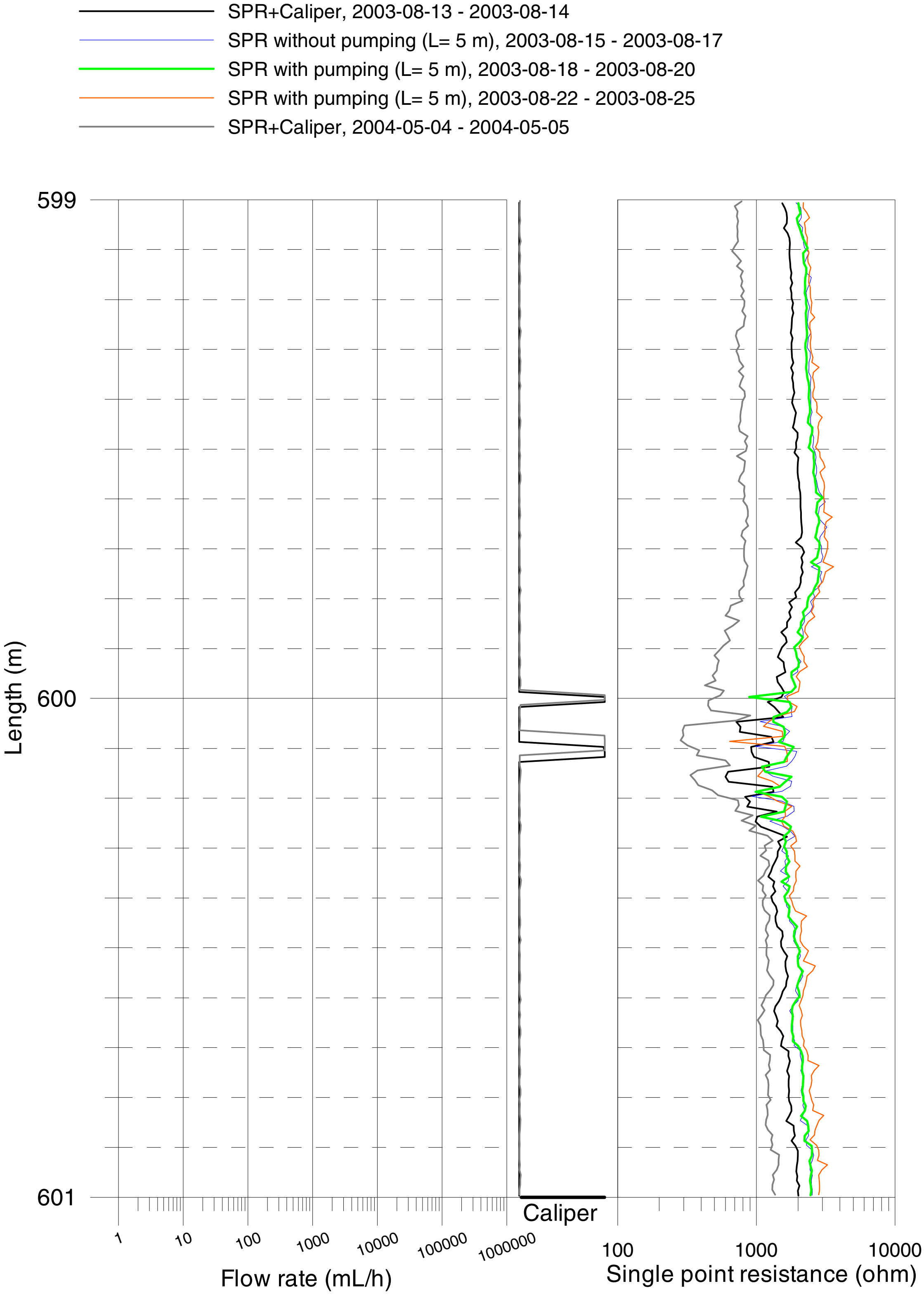


Appendix 1.22

Forsmark, KFM03A
SPR and Caliper results after length correction

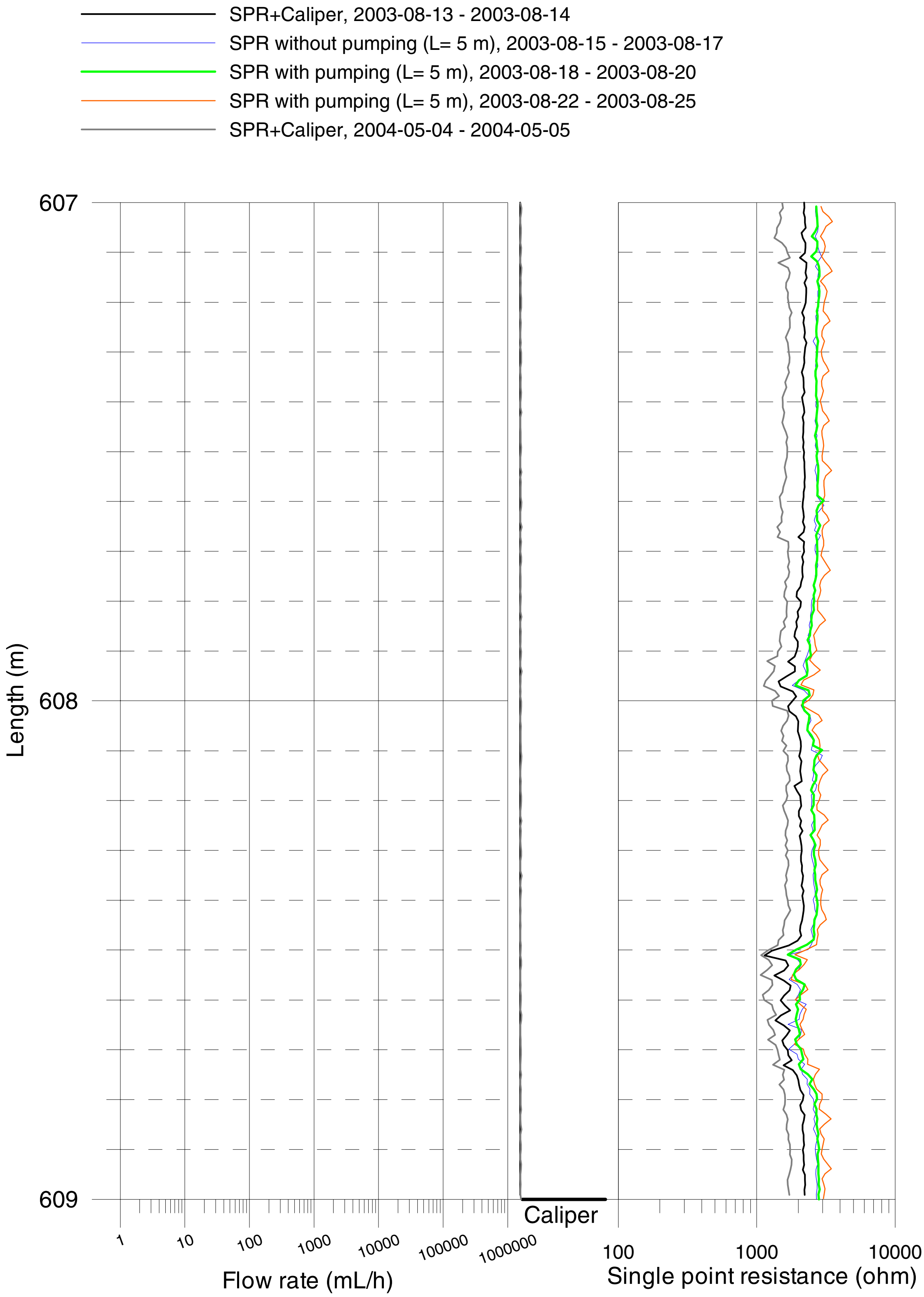


Forsmark, KFM03A
SPR and Caliper results after length correction

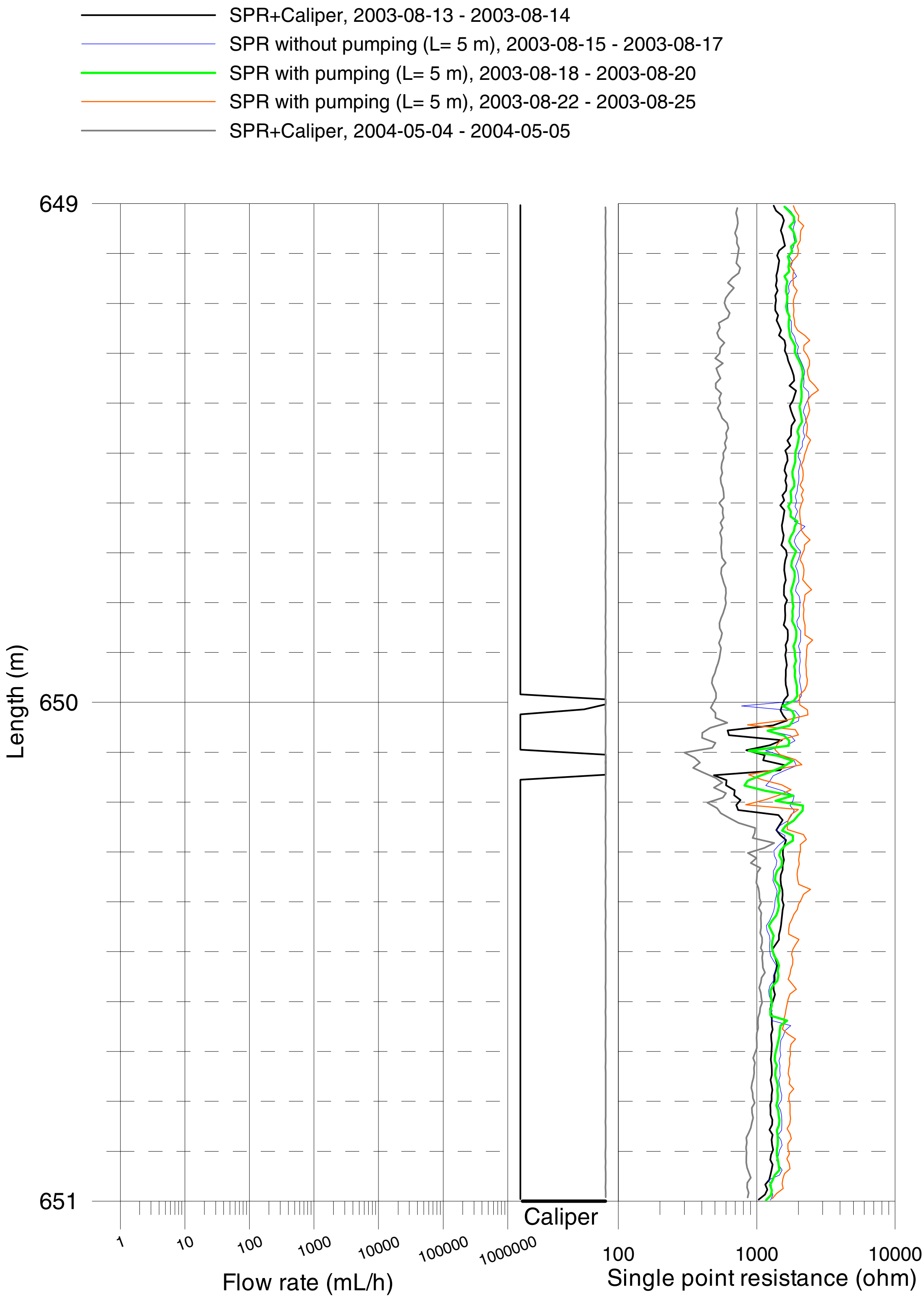


Appendix 1.24

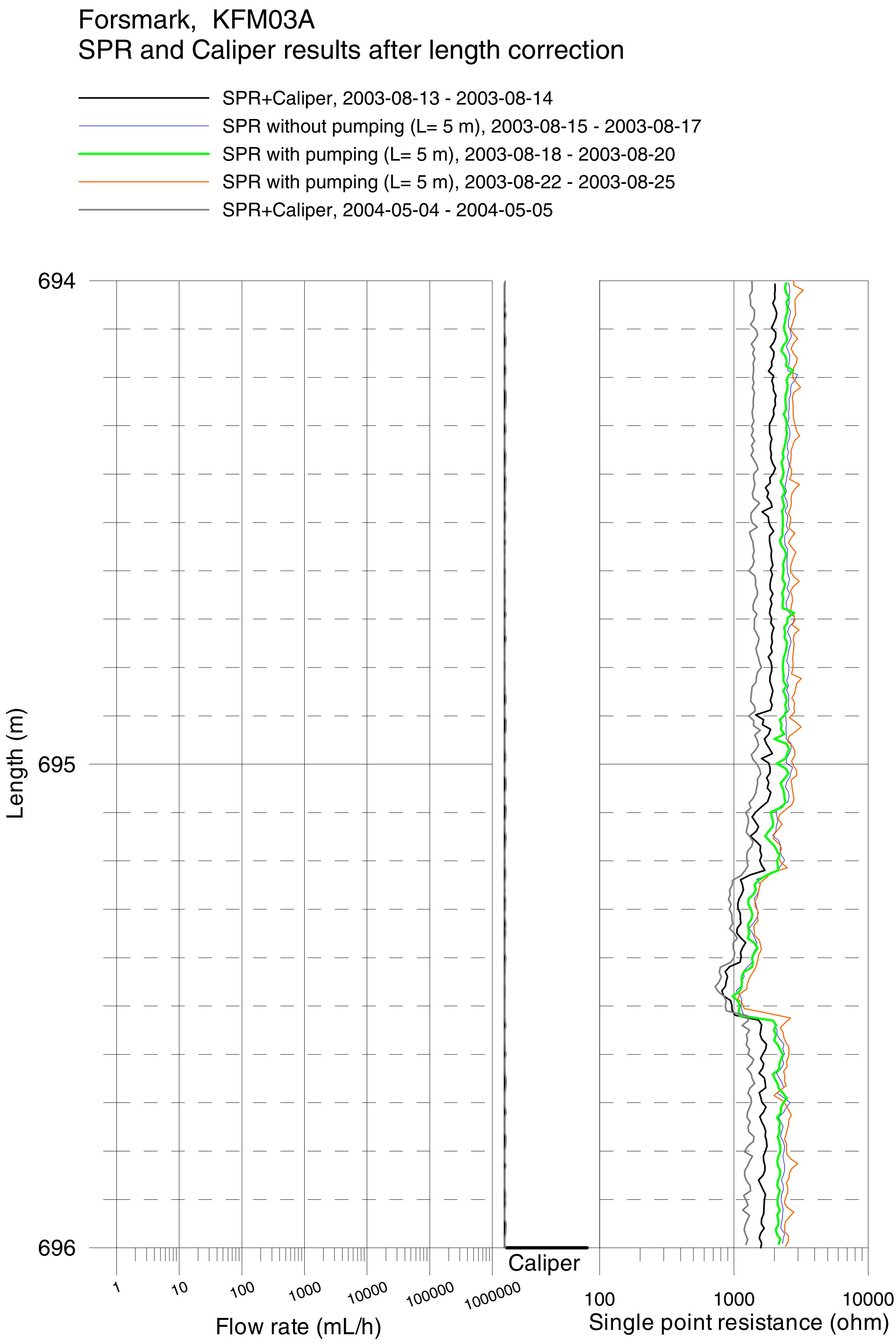
Forsmark, KFM03A
SPR and Caliper results after length correction



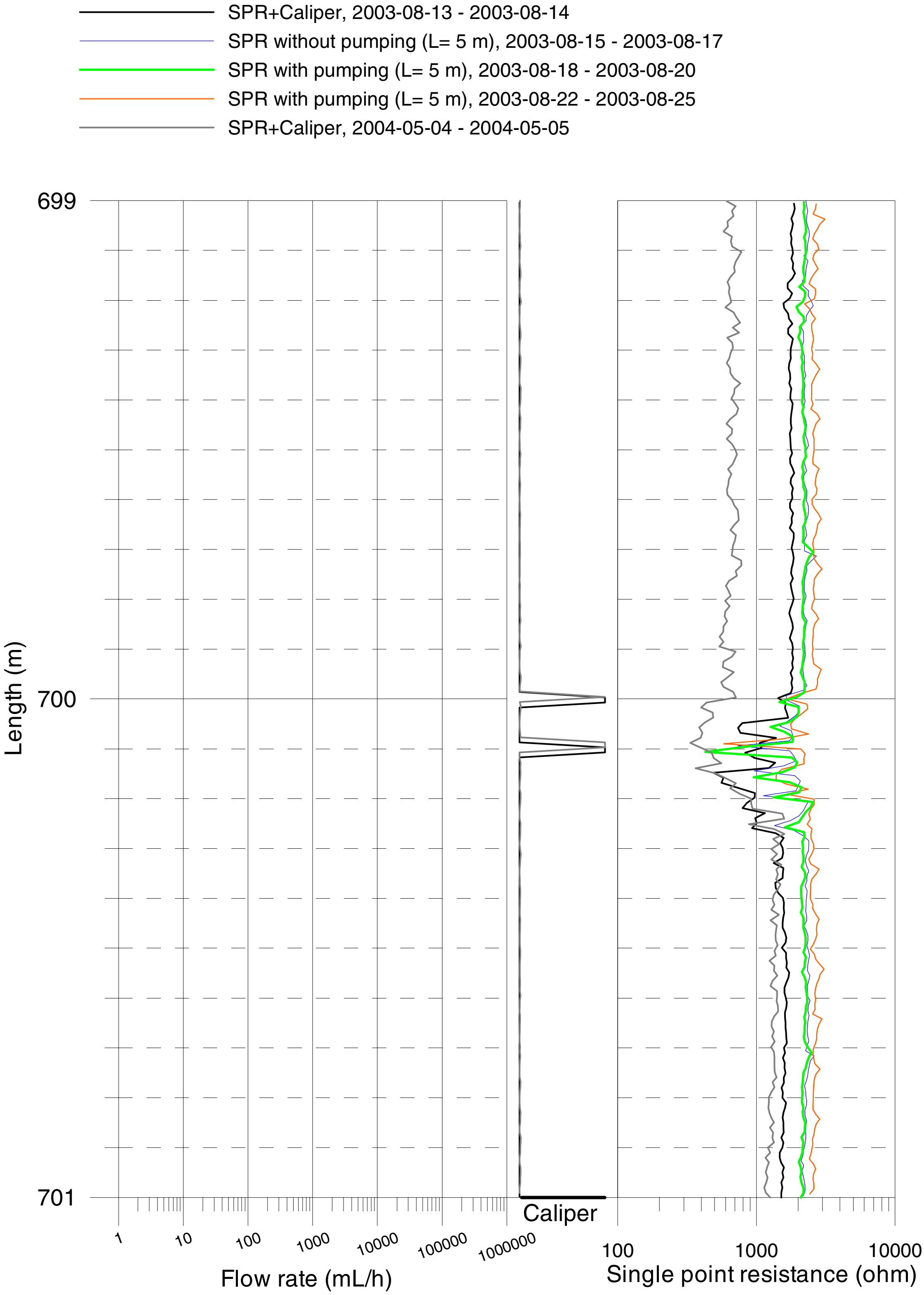
Forsmark, KFM03A
SPR and Caliper results after length correction



Appendix 1.26

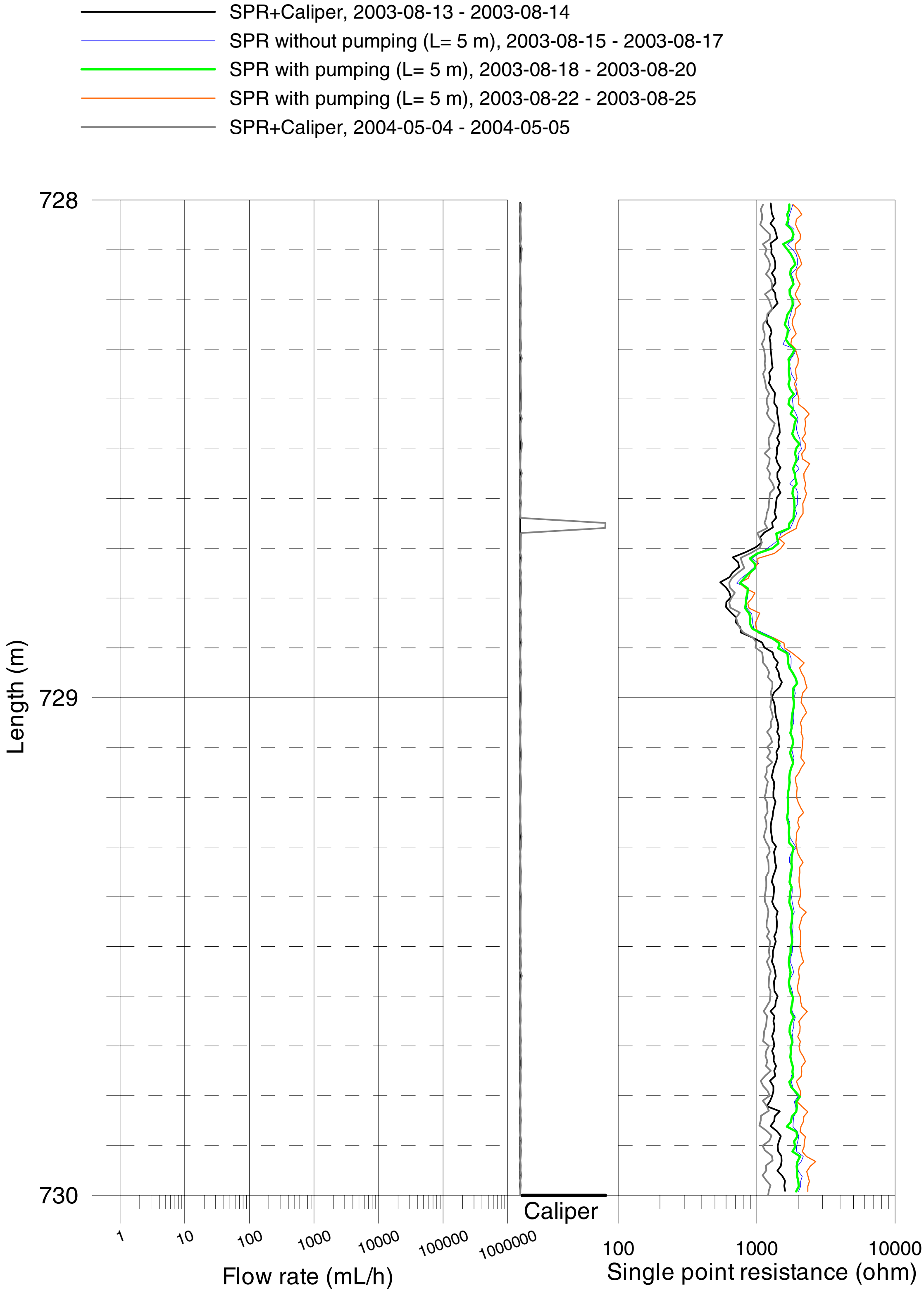


Forsmark, KFM03A
SPR and Caliper results after length correction

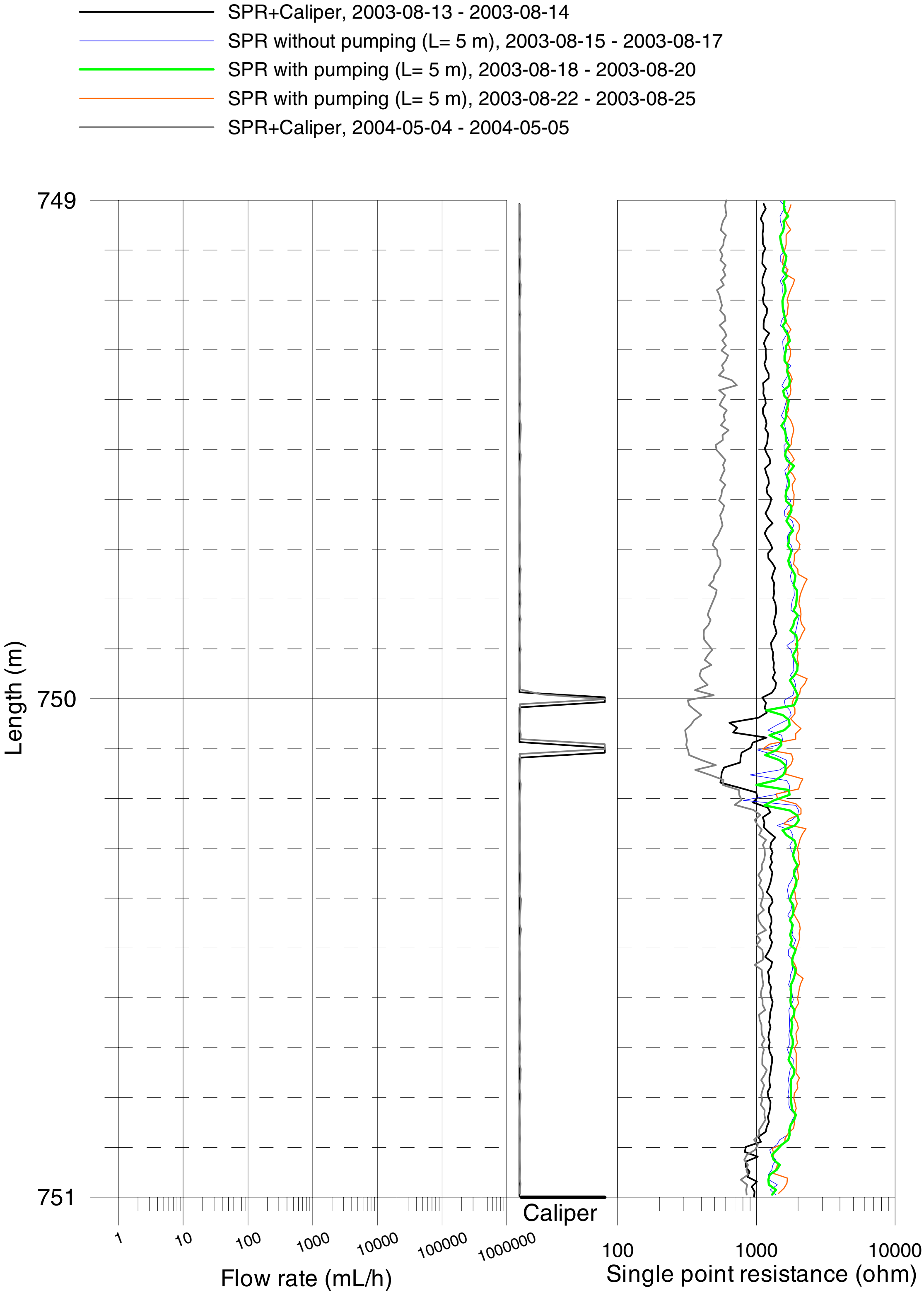


Appendix 1.28

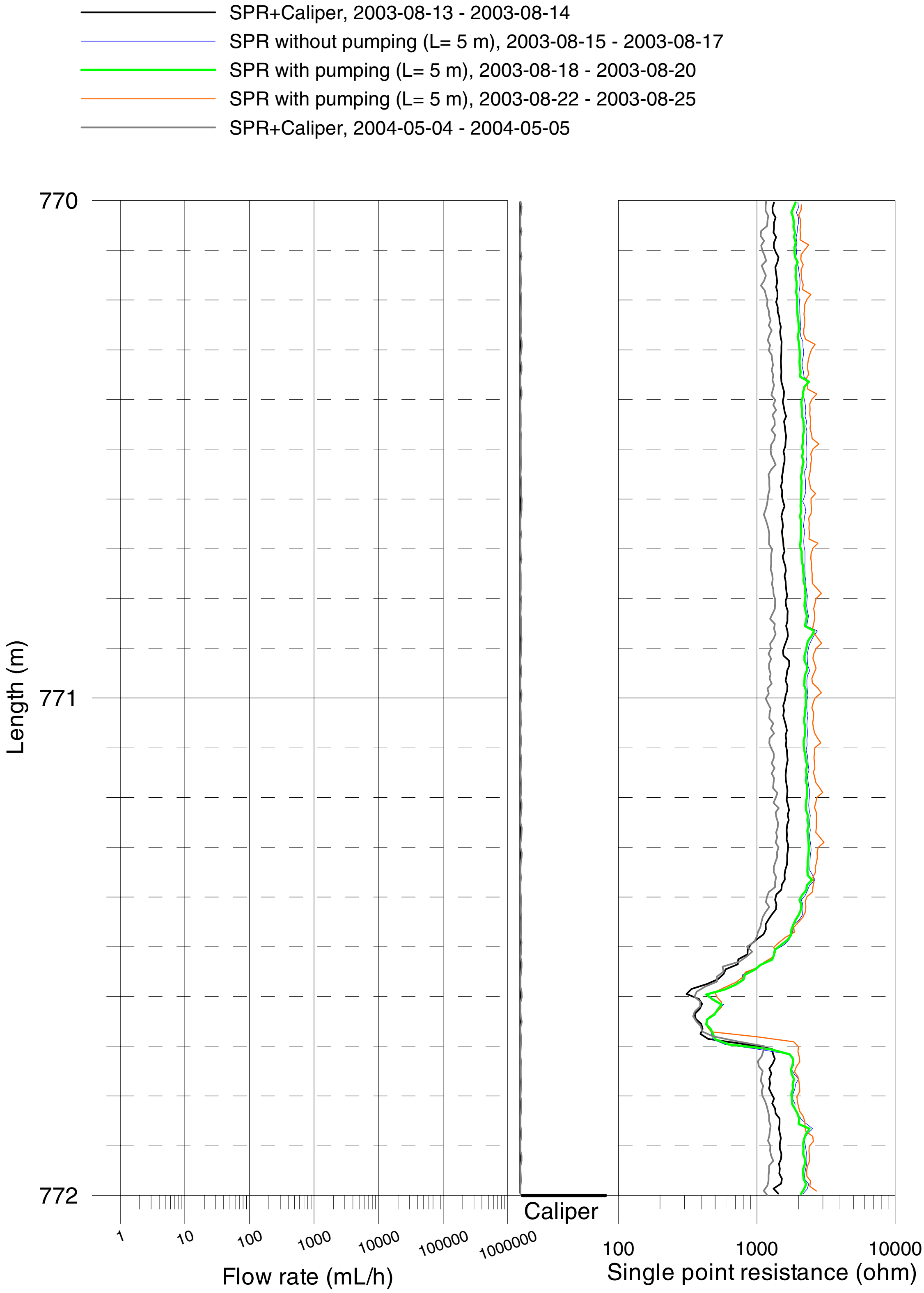
Forsmark, KFM03A
SPR and Caliper results after length correction

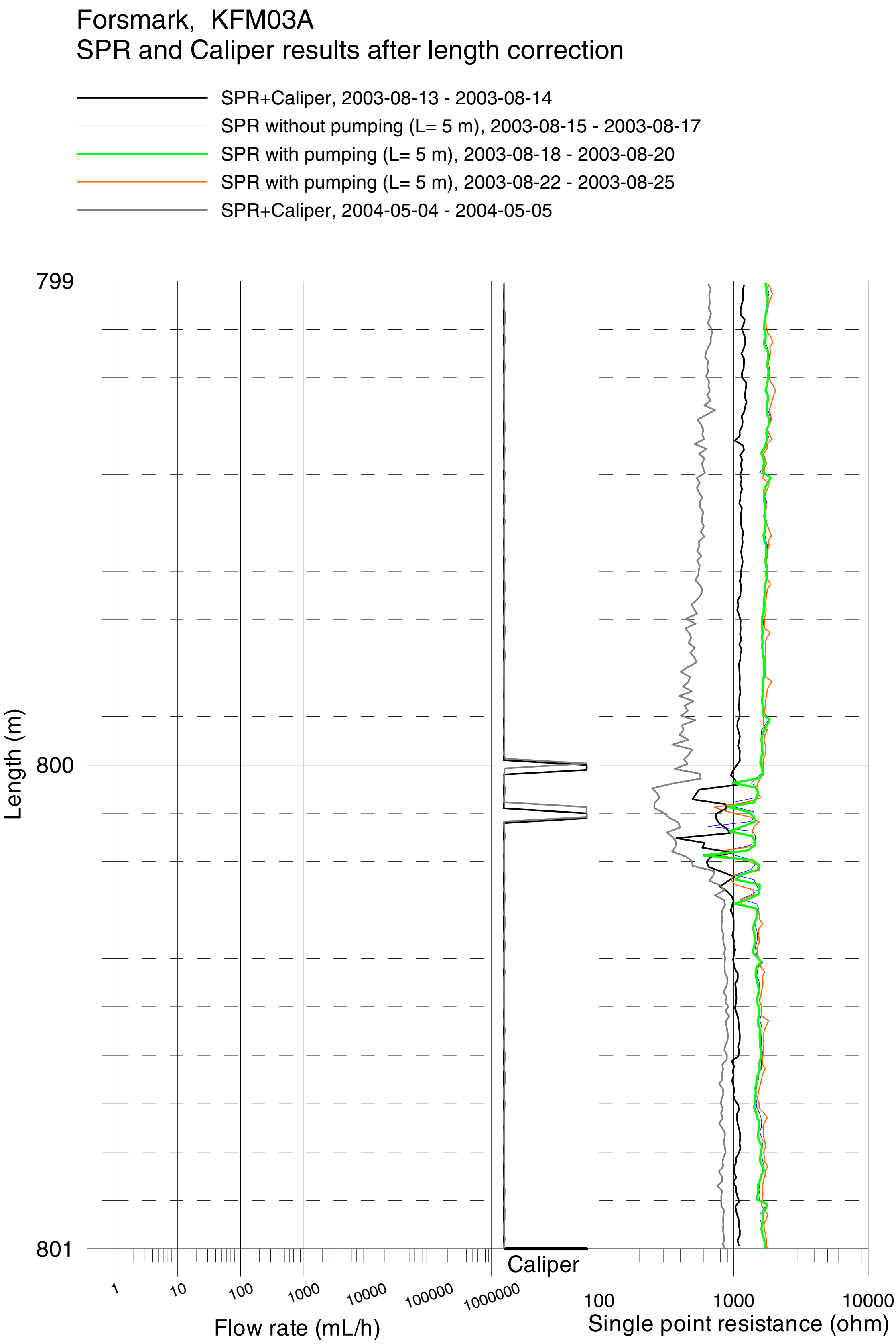


Forsmark, KFM03A
SPR and Caliper results after length correction

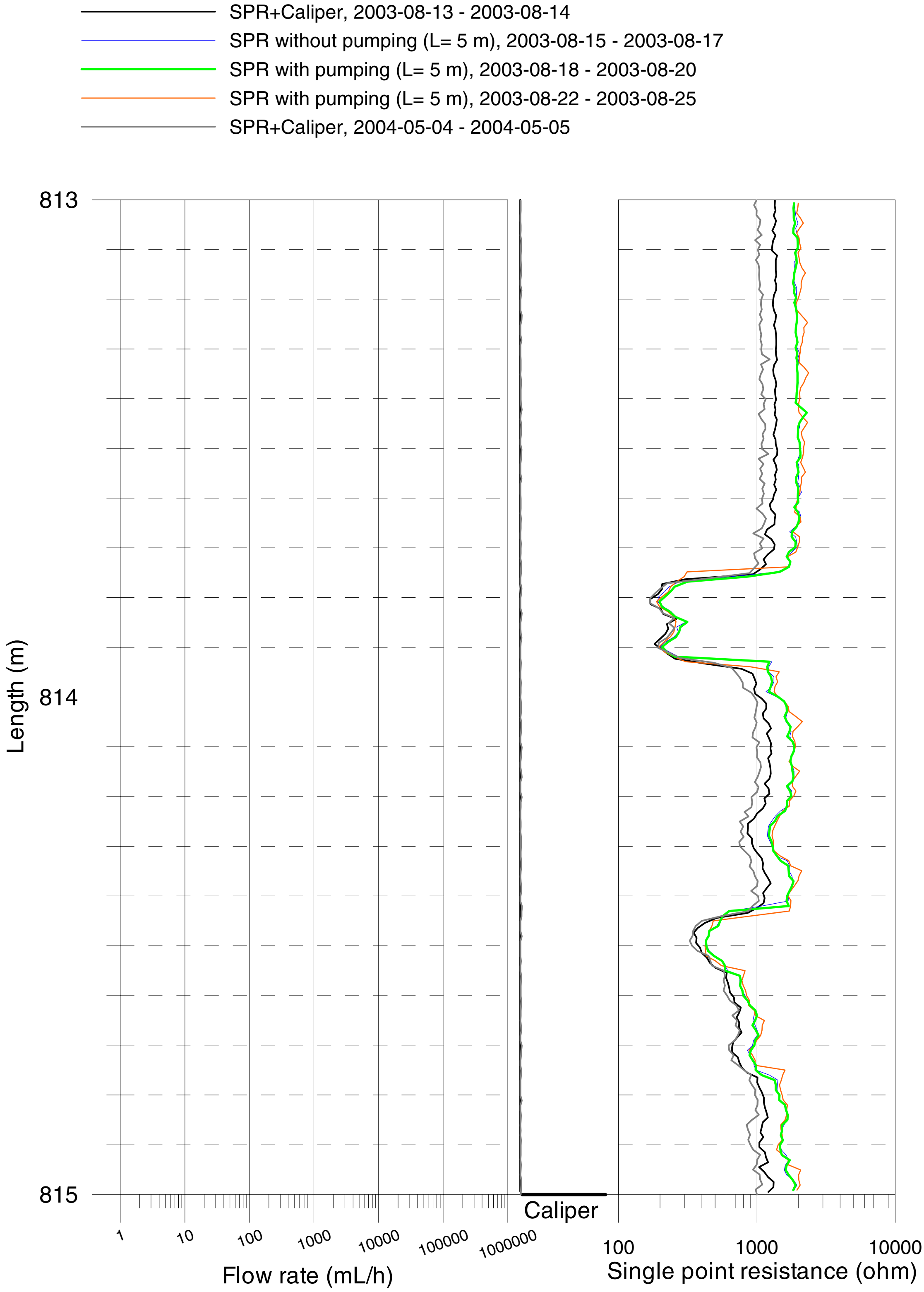


Forsmark, KFM03A
SPR and Caliper results after length correction

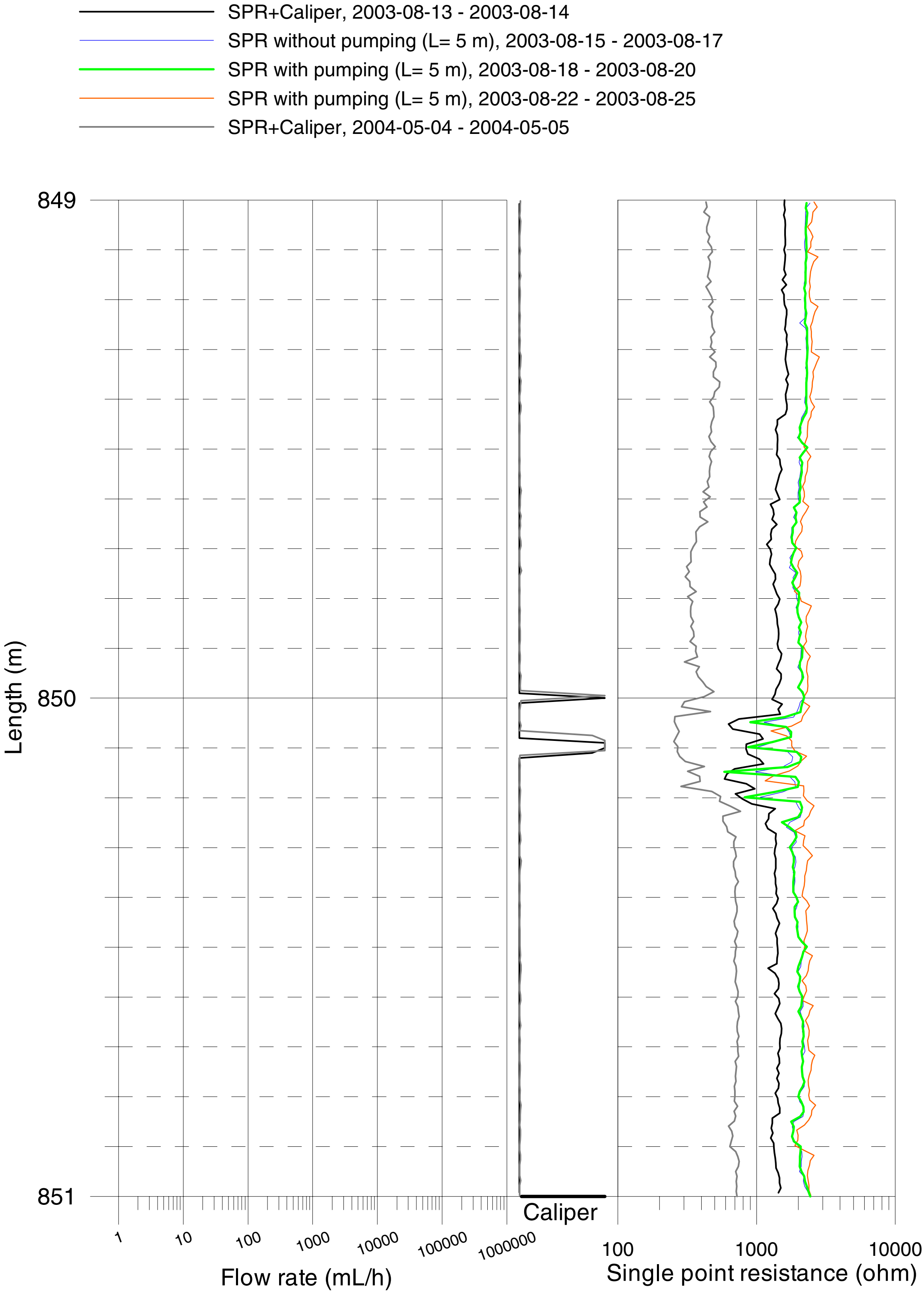



Forsmark, KFM03A
SPR and Caliper results after length correction
SPR+Caliper, 2003-08-13 - 2003-08-14
SPR without pumping (L= 5 m), 2003-08-15 - 2003-08-17
SPR with pumping (L= 5 m), 2003-08-18 - 2003-08-20
SPR with pumping (L= 5 m), 2003-08-22 - 2003-08-25
SPR+Caliper, 2004-05-04 - 2004-05-05
Length (m)
799
800
801
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
Single point resistance (ohm)

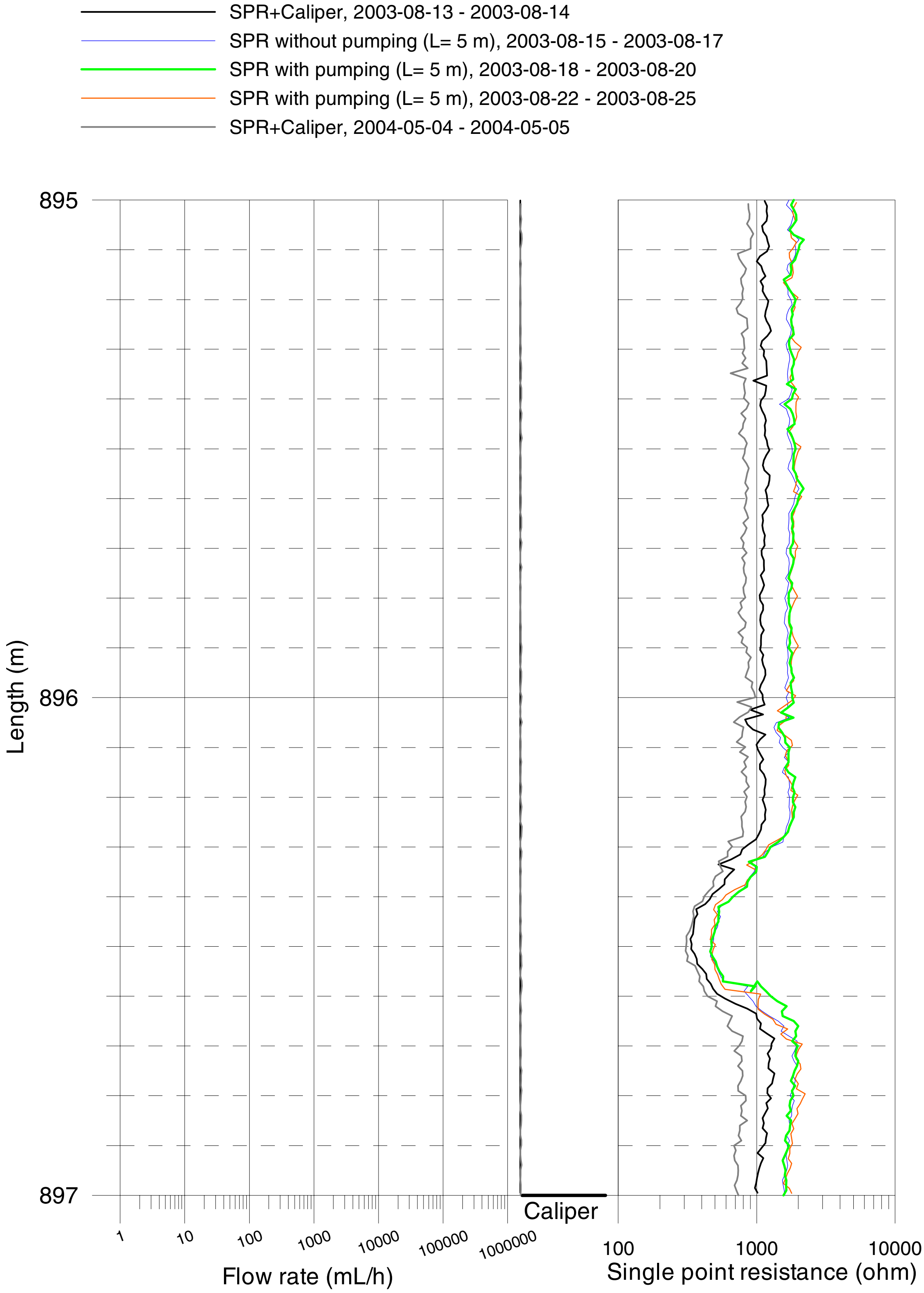
Forsmark, KFM03A
SPR and Caliper results after length correction



Forsmark, KFM03A
SPR and Caliper results after length correction

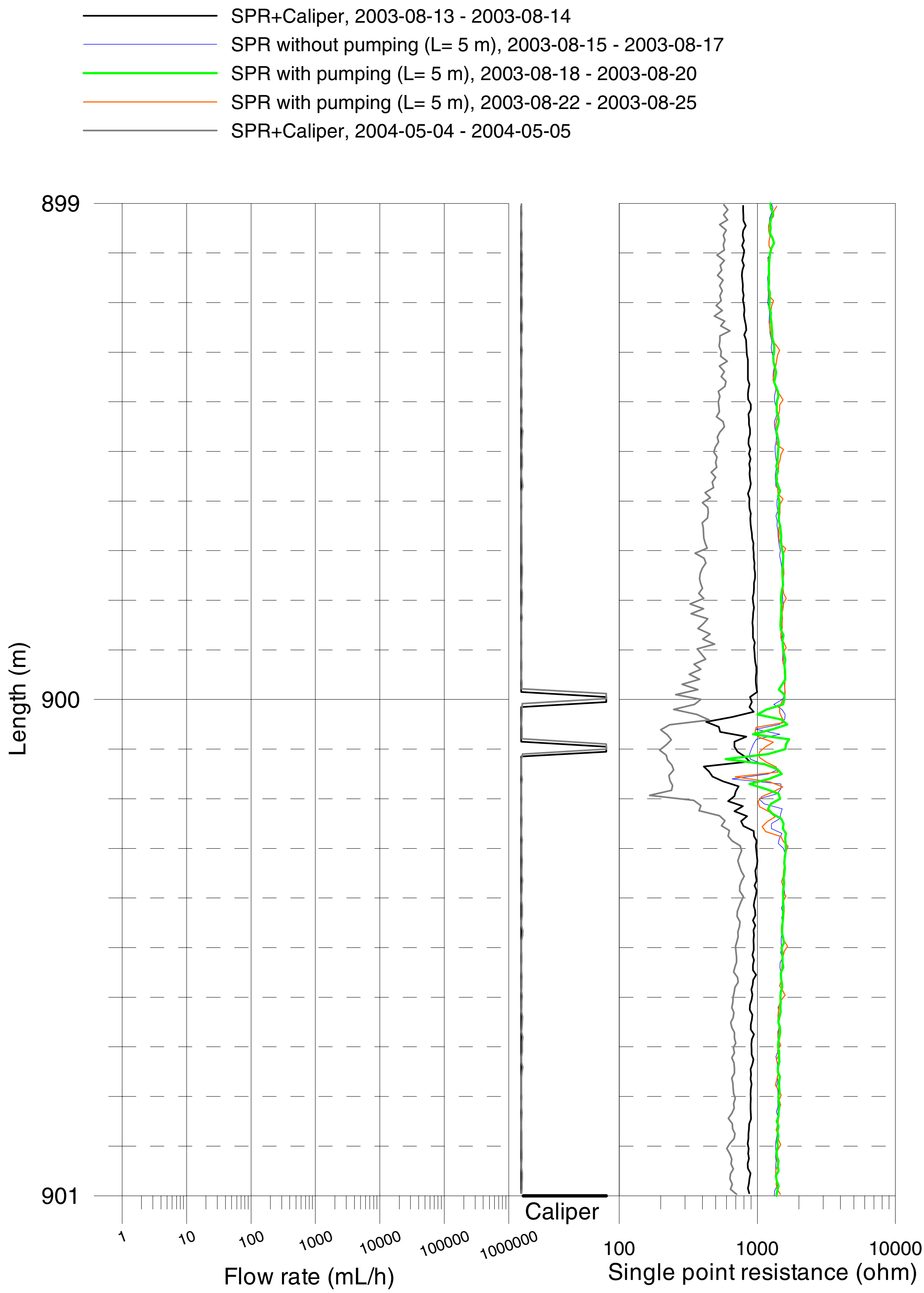


Forsmark, KFM03A
SPR and Caliper results after length correction



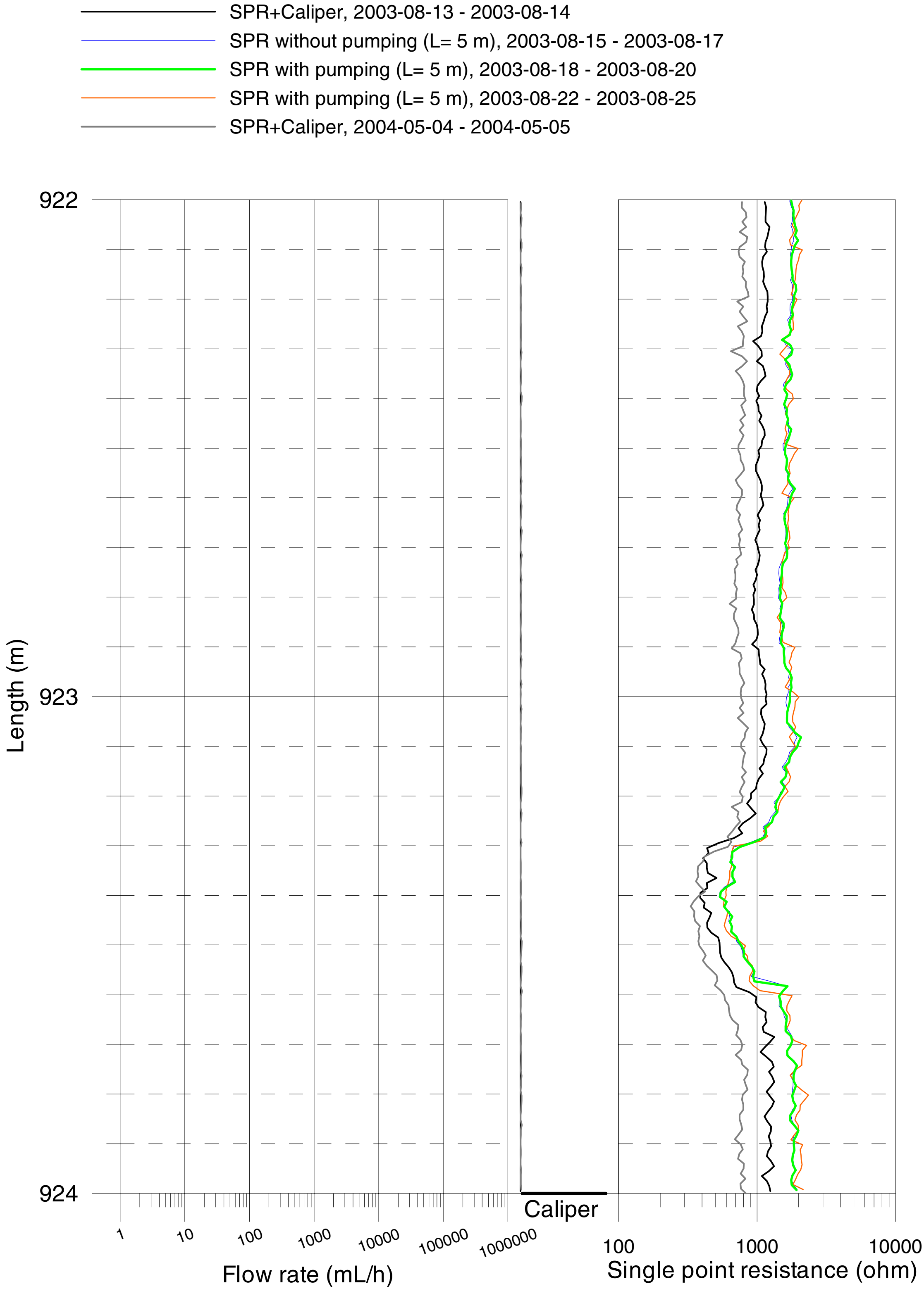
Appendix 1.35

Forsmark, KFM03A
SPR and Caliper results after length correction

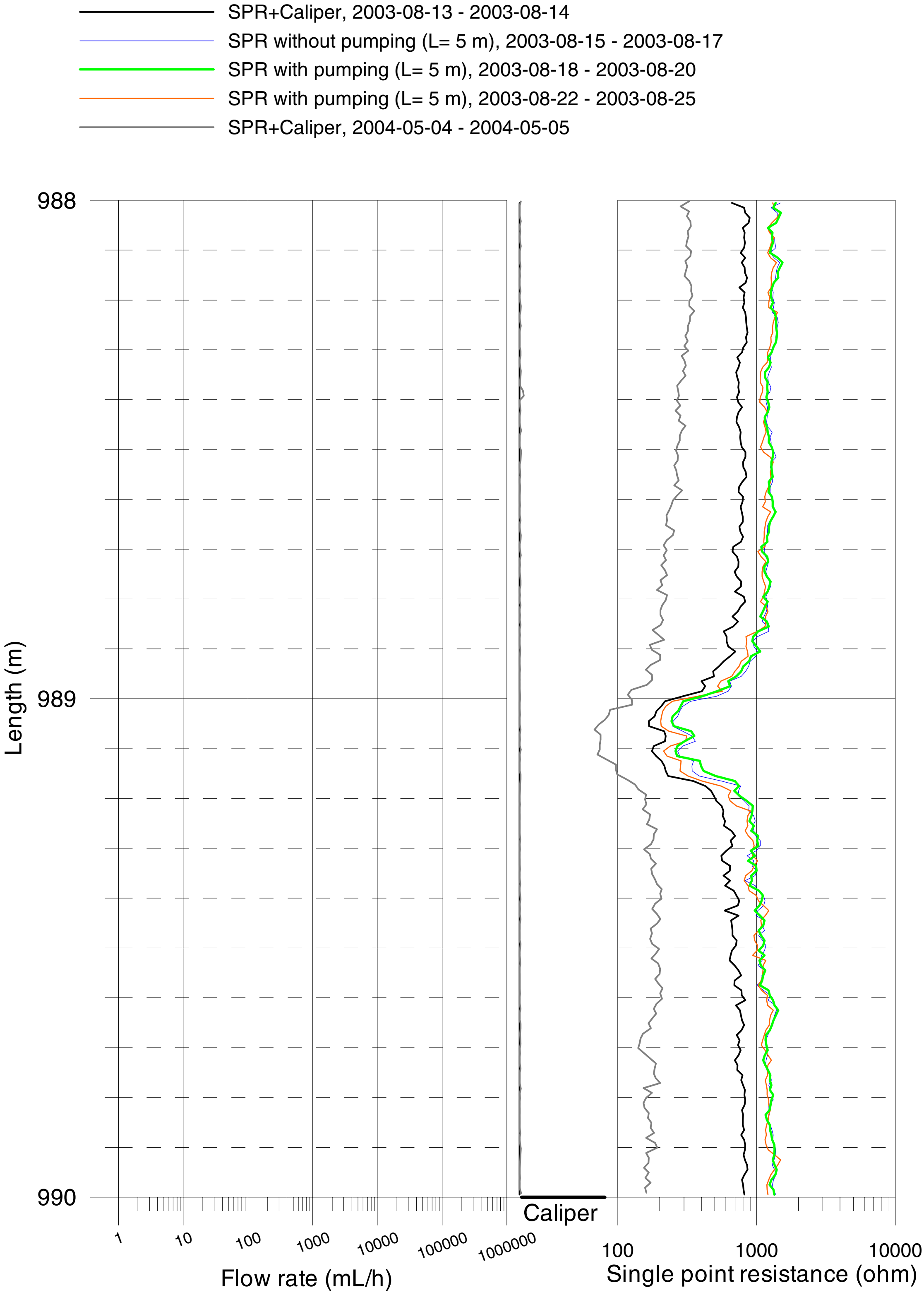


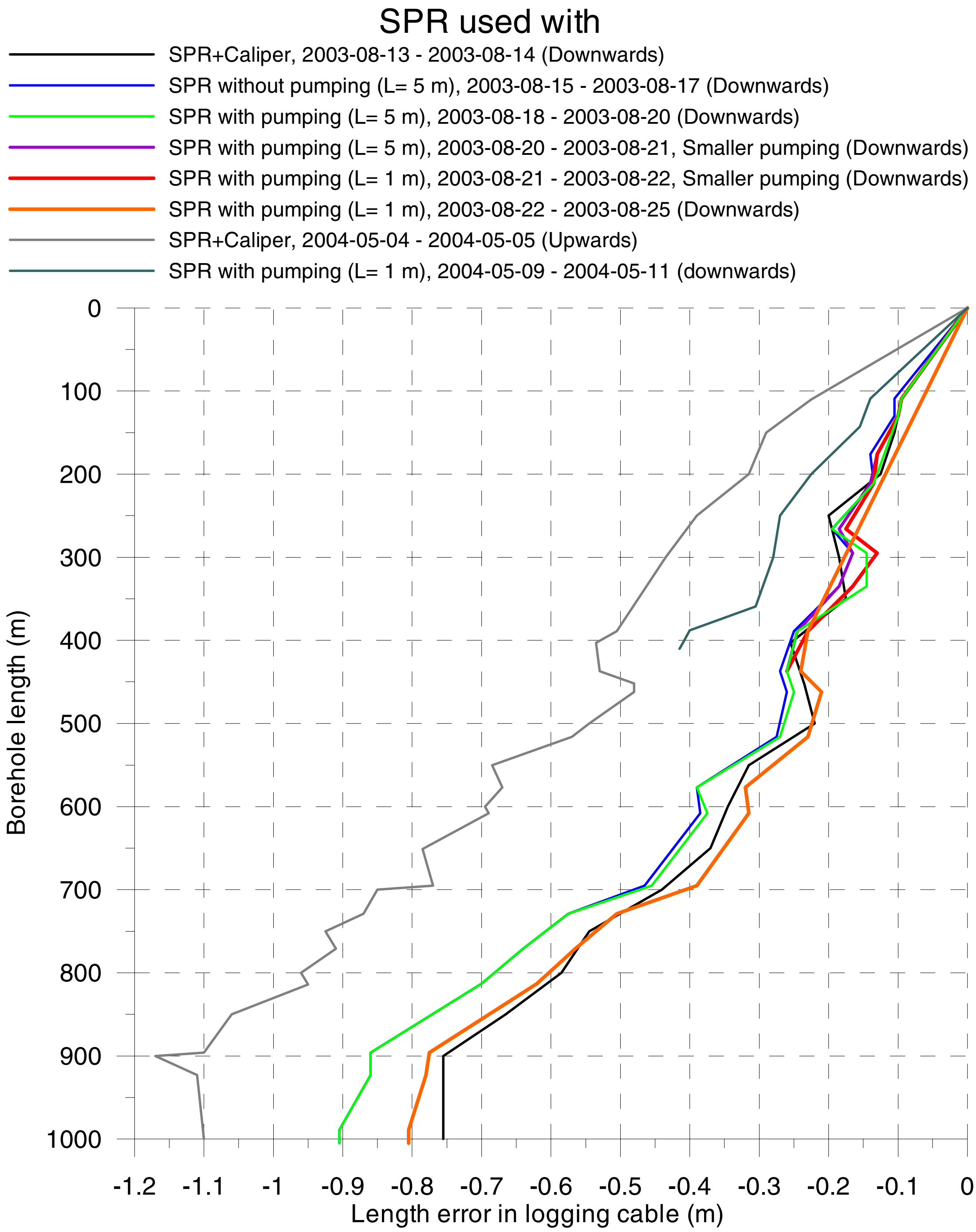
Appendix 1.36

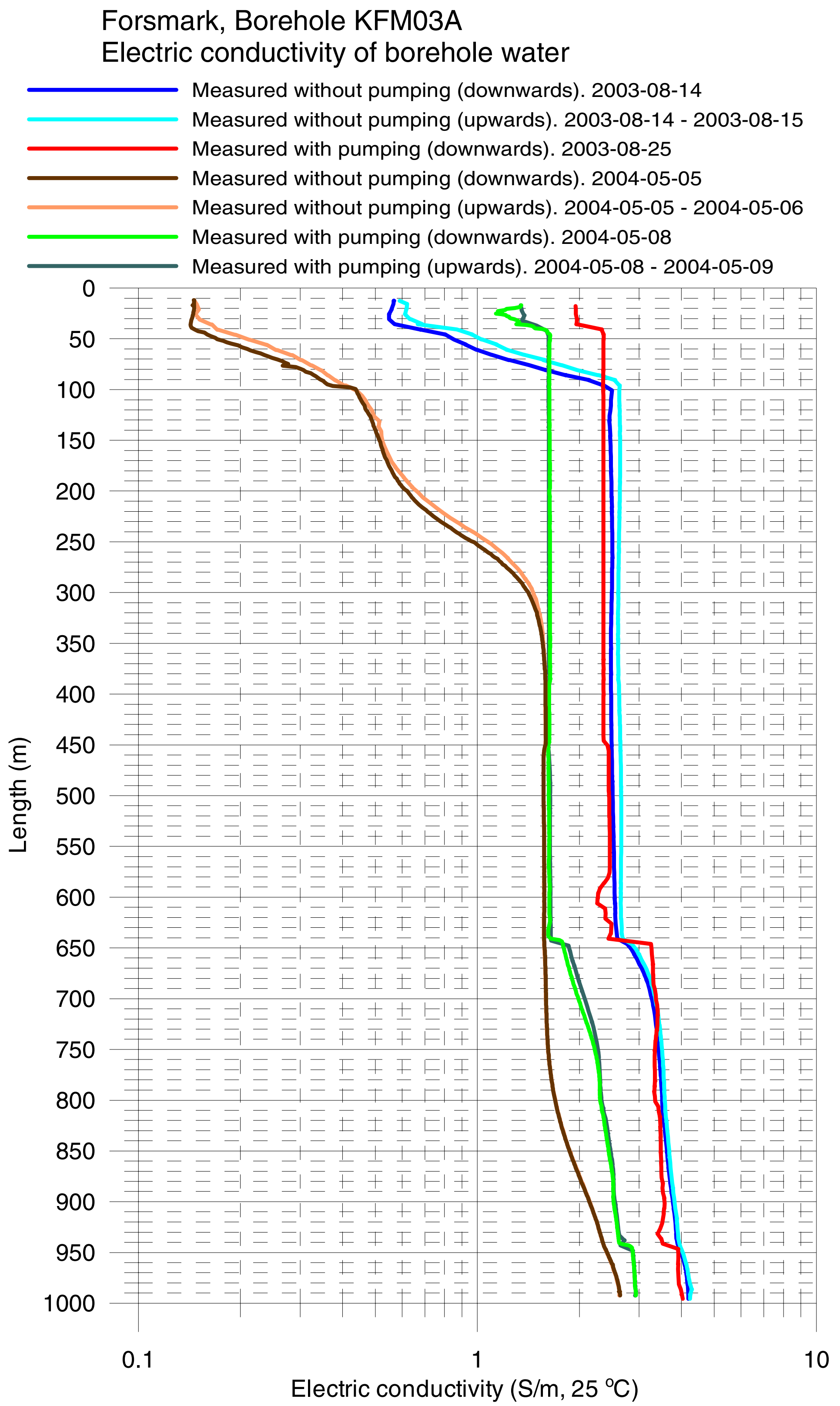
Forsmark, KFM03A
SPR and Caliper results after length correction

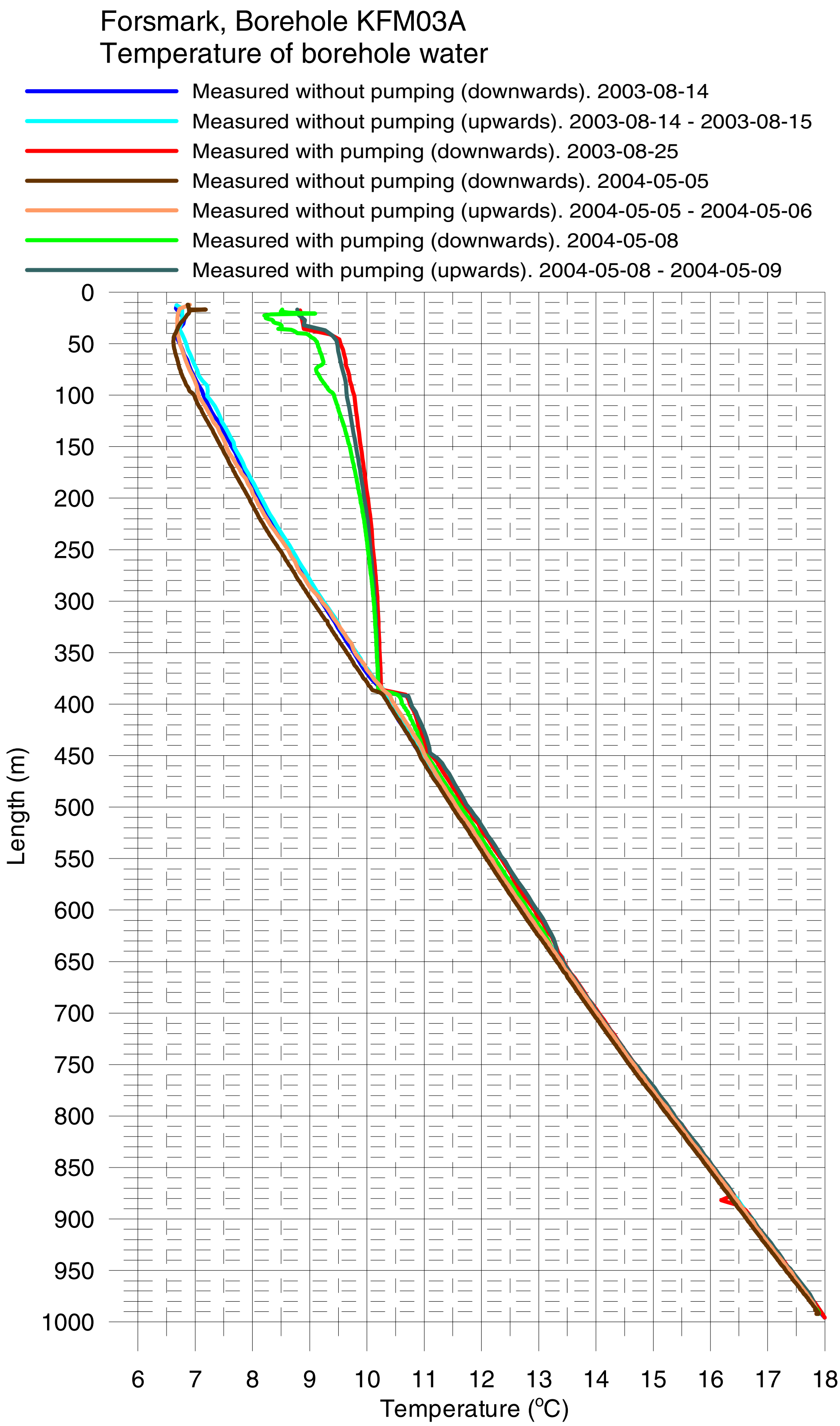


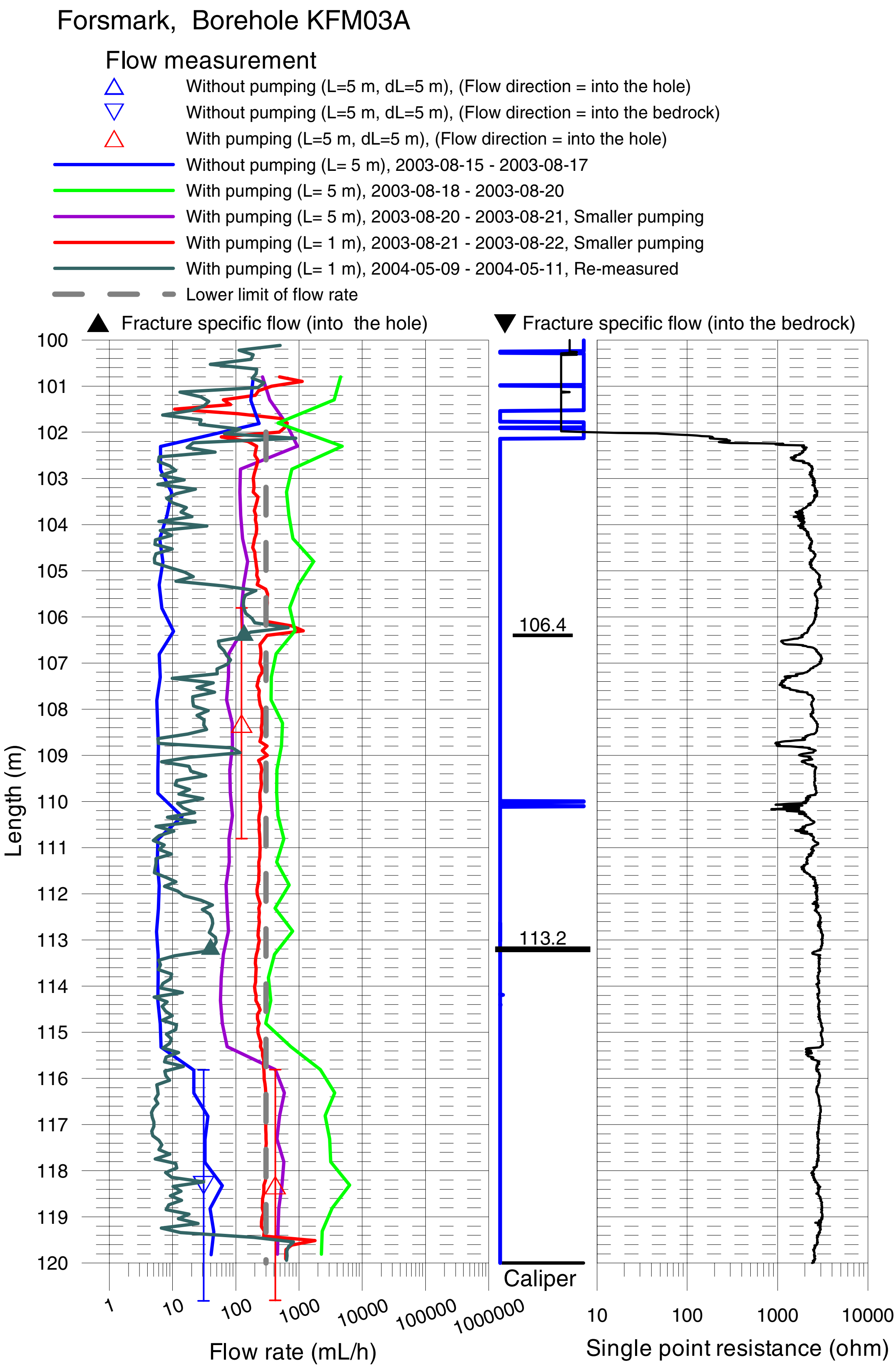
Forsmark, KFM03A
SPR and Caliper results after length correction



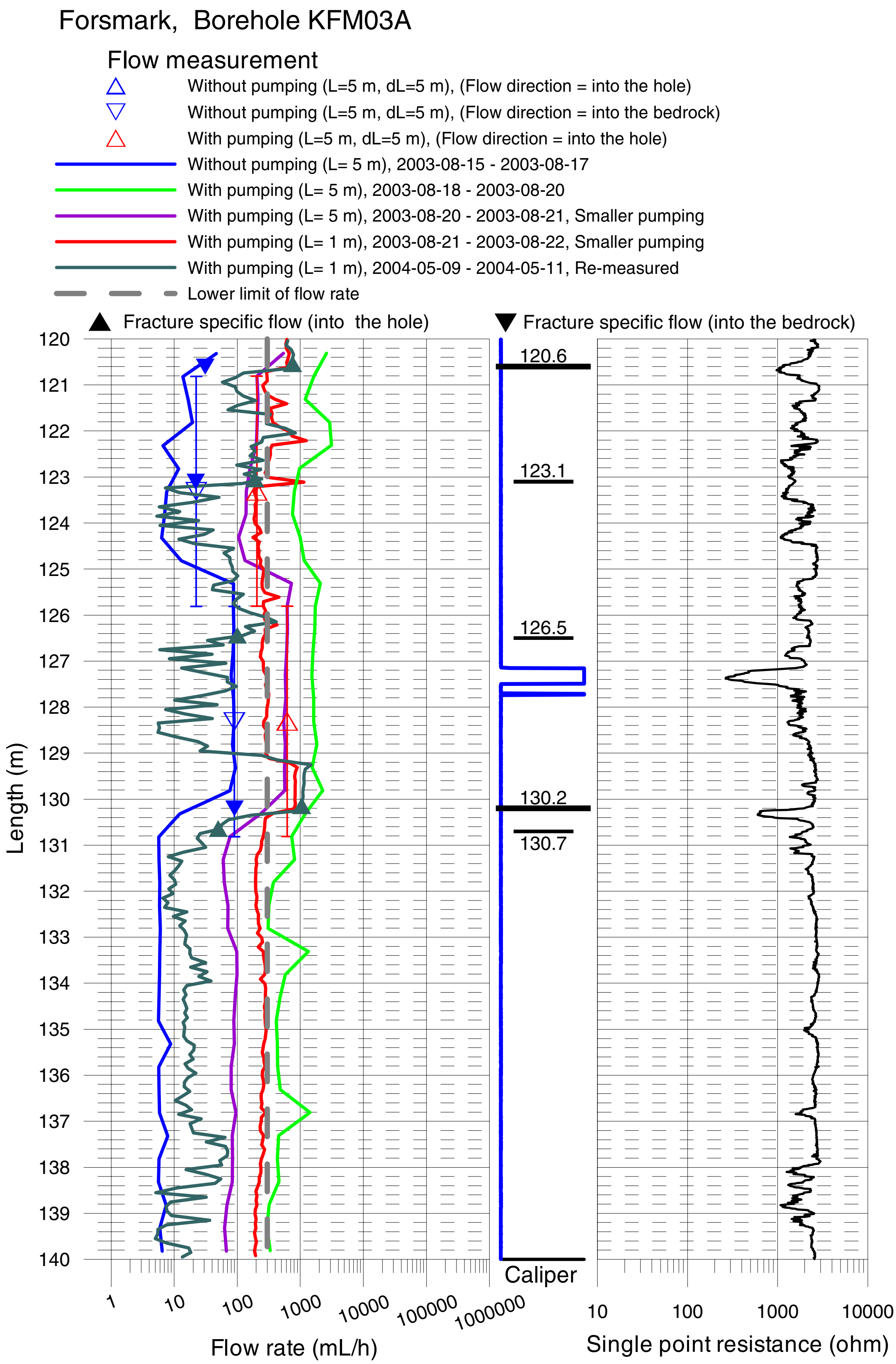

SPR used with
SPR+Caliper, 2003-08-13 - 2003-08-14 (Downwards)
SPR without pumping (L= 5 m), 2003-08-15 - 2003-08-17 (Downwards)
SPR with pumping (L= 5 m), 2003-08-18 - 2003-08-20 (Downwards)
SPR with pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping (Downwards)
SPR with pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping (Downwards)
SPR with pumping (L= 1 m), 2003-08-22 - 2003-08-25 (Downwards)
SPR+Caliper, 2004-05-04 - 2004-05-05 (Upwards)
SPR with pumping (L= 1 m), 2004-05-09 - 2004-05-11 (downwards)
Borehole length (m)
0
100
200
300
400
500
600
700
800
900
1000
-1.2
-1.1
-1
-0.9
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
Length error in logging cable (m)

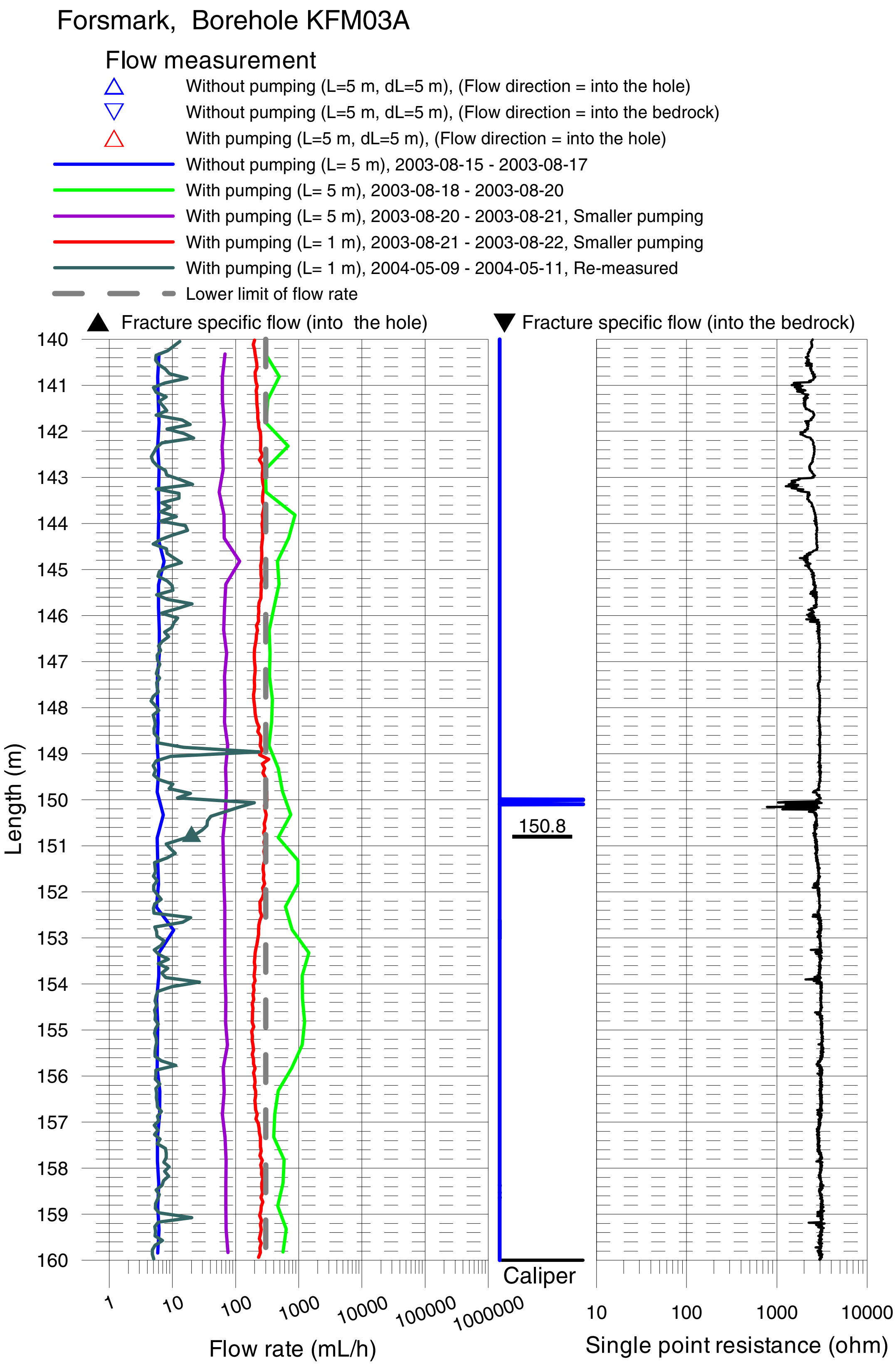

Forsmark, Borehole KFM03A
Electric conductivity of borehole water
Measured without pumping (downwards). 2003-08-14
Measured without pumping (upwards). 2003-08-14 - 2003-08-15
Measured with pumping (downwards). 2003-08-25
Measured without pumping (downwards). 2004-05-05
Measured without pumping (upwards). 2004-05-05 - 2004-05-06
Measured with pumping (downwards). 2004-05-08
Measured with pumping (upwards). 2004-05-08 - 2004-05-09
Length (m)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
0.1
1
10
Electric conductivity (S/m, 25 °C)

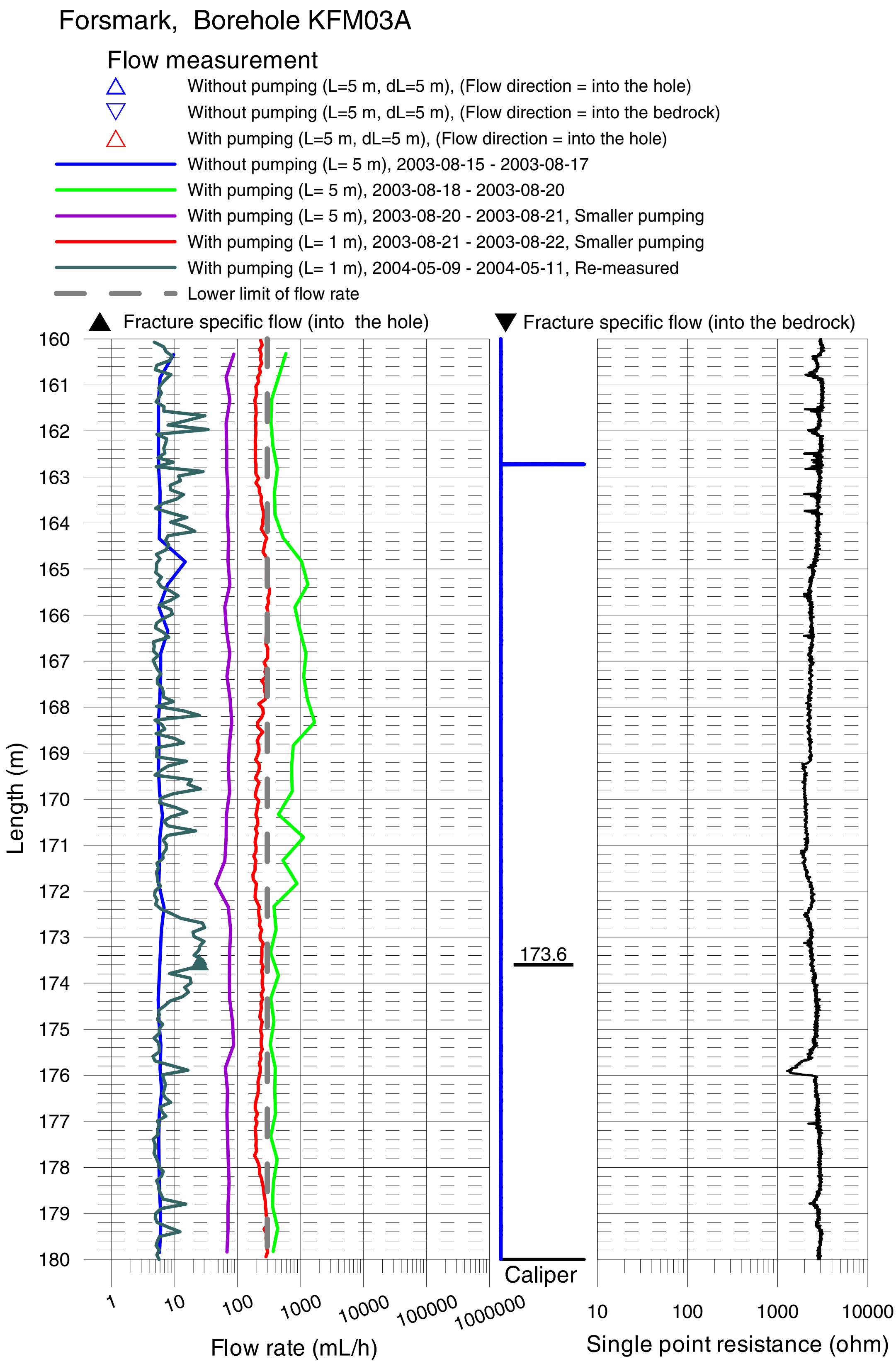

Forsmark, Borehole KFM03A
Temperature of borehole water
Measured without pumping (downwards). 2003-08-14
Measured without pumping (upwards). 2003-08-14 - 2003-08-15
Measured with pumping (downwards). 2003-08-25
Measured without pumping (downwards). 2004-05-05
Measured without pumping (upwards). 2004-05-05 - 2004-05-06
Measured with pumping (downwards). 2004-05-08
Measured with pumping (upwards). 2004-05-08 - 2004-05-09
Length (m)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
6
7
8
9
10
11
12
13
14
15
16
17
18
Temperature (°C)

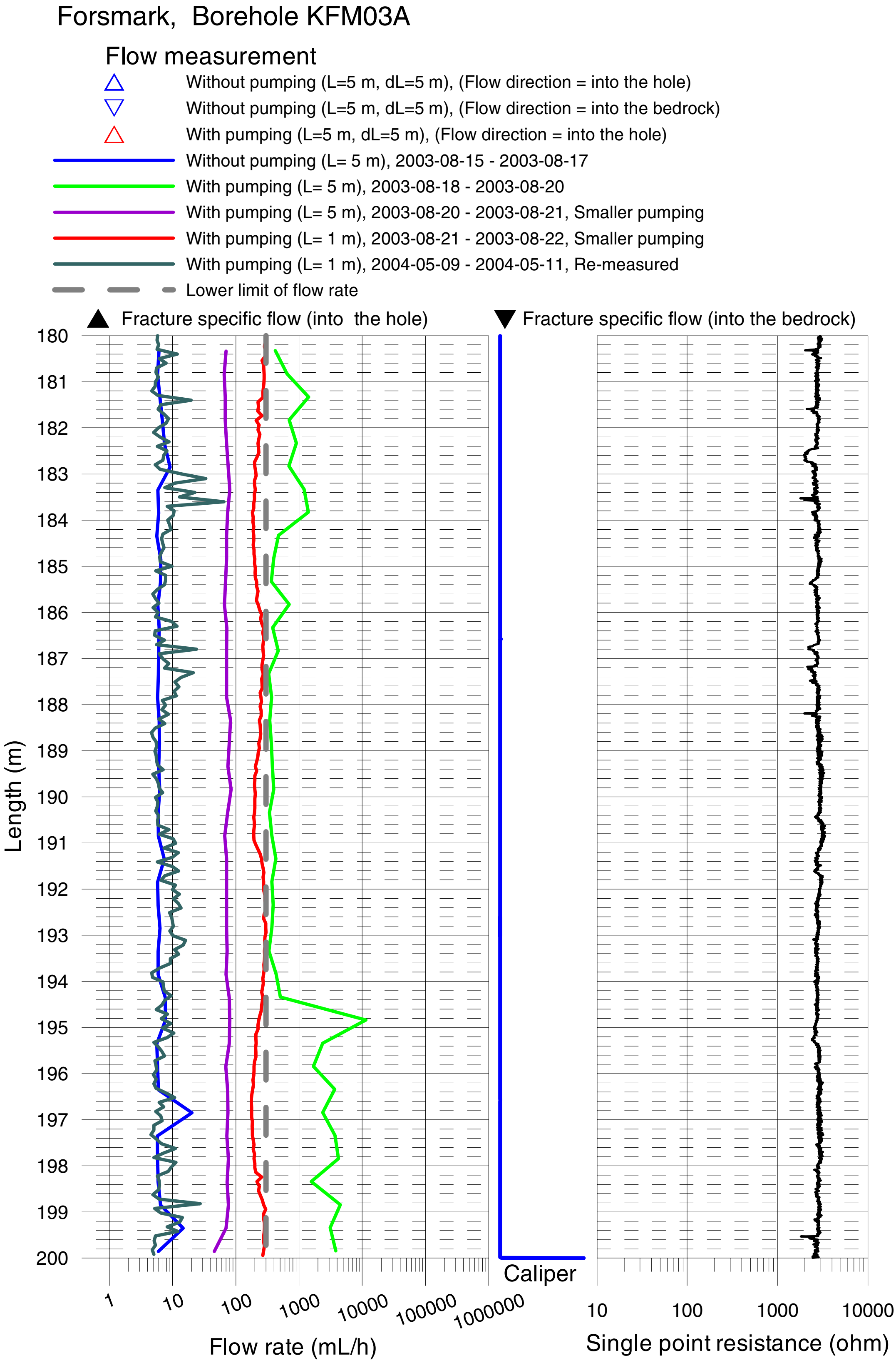


Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
With pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
With pumping (L= 1 m), 2004-05-09 - 2004-05-11, Re-measured
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
106.4
113.2
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

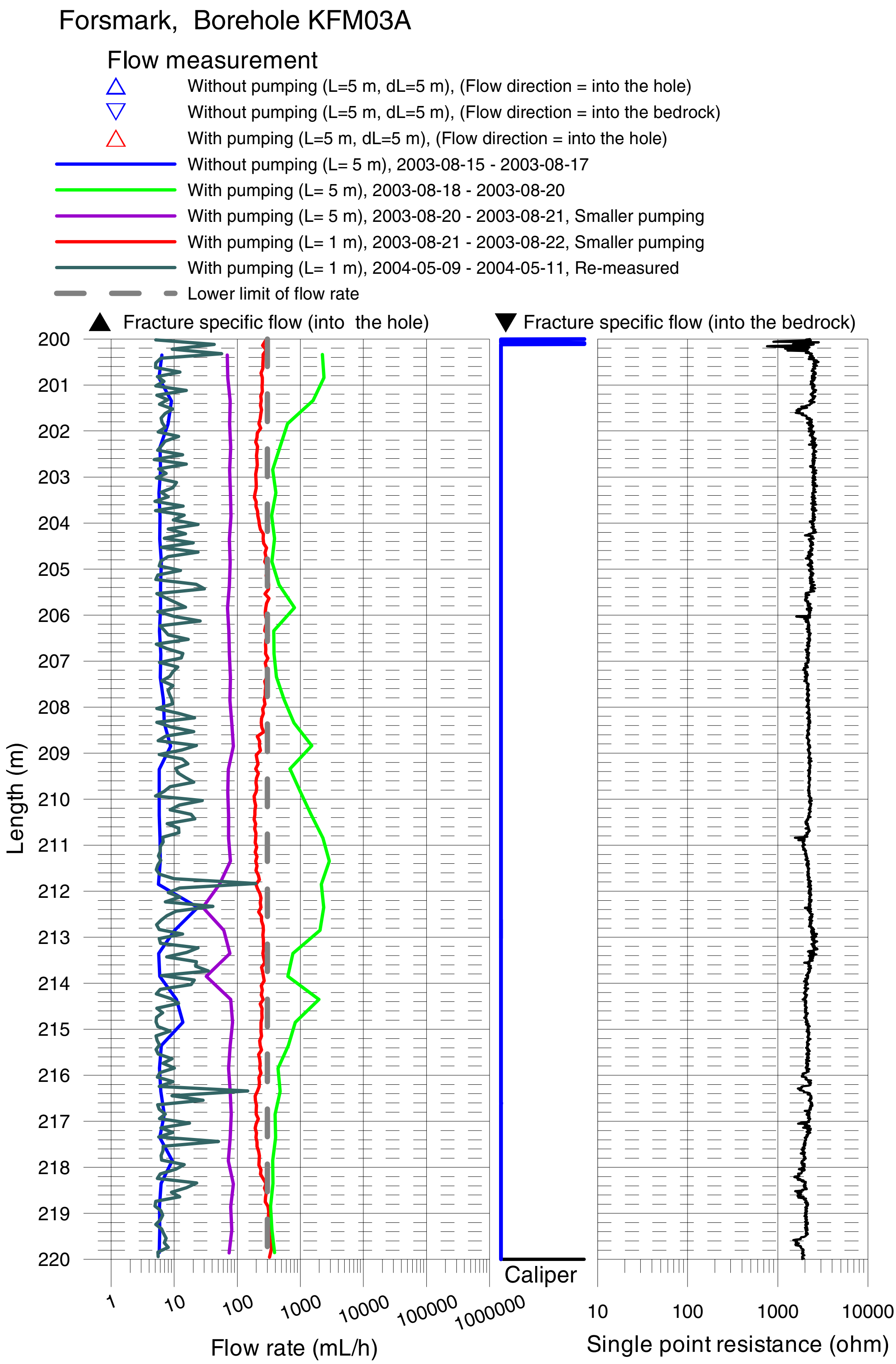

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
With pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
With pumping (L= 1 m), 2004-05-09 - 2004-05-11, Re-measured
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
120.6
123.1
126.5
130.2
130.7
Length (m)
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)


Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
With pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
With pumping (L= 1 m), 2004-05-09 - 2004-05-11, Re-measured
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
150.8
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

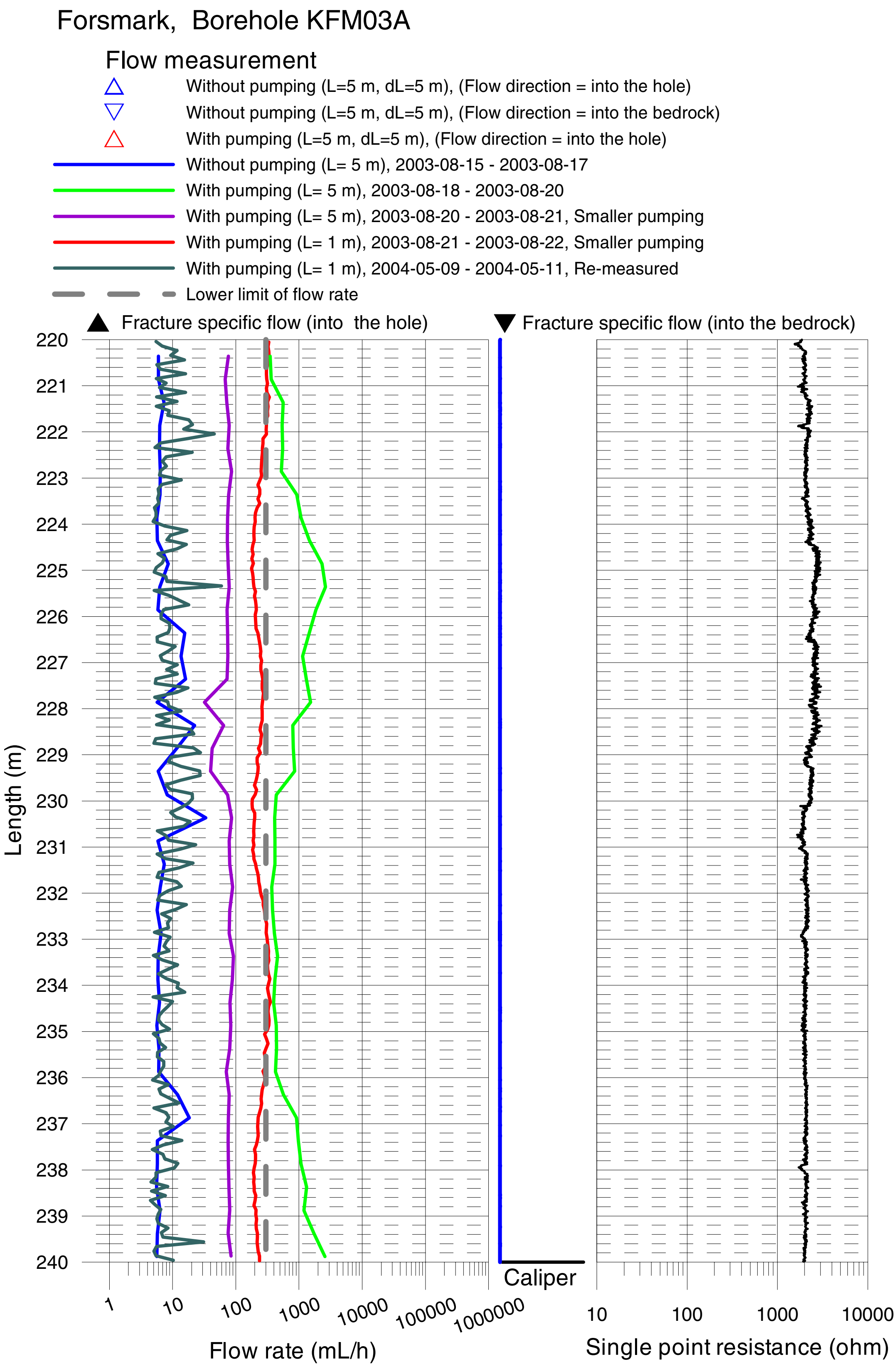

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
With pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
With pumping (L= 1 m), 2004-05-09 - 2004-05-11, Re-measured
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
173.6
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

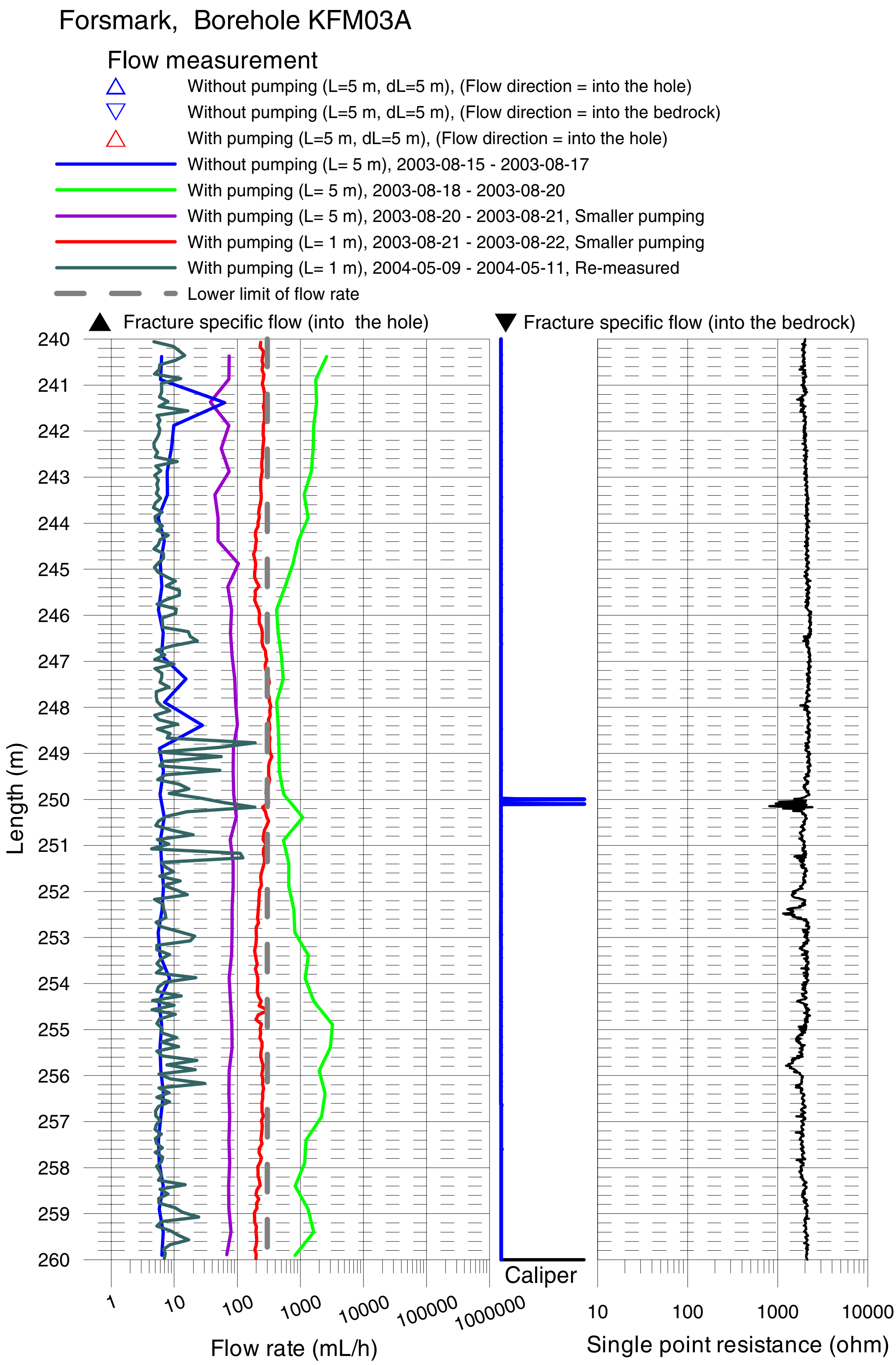

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
With pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
With pumping (L= 1 m), 2004-05-09 - 2004-05-11, Re-measured
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

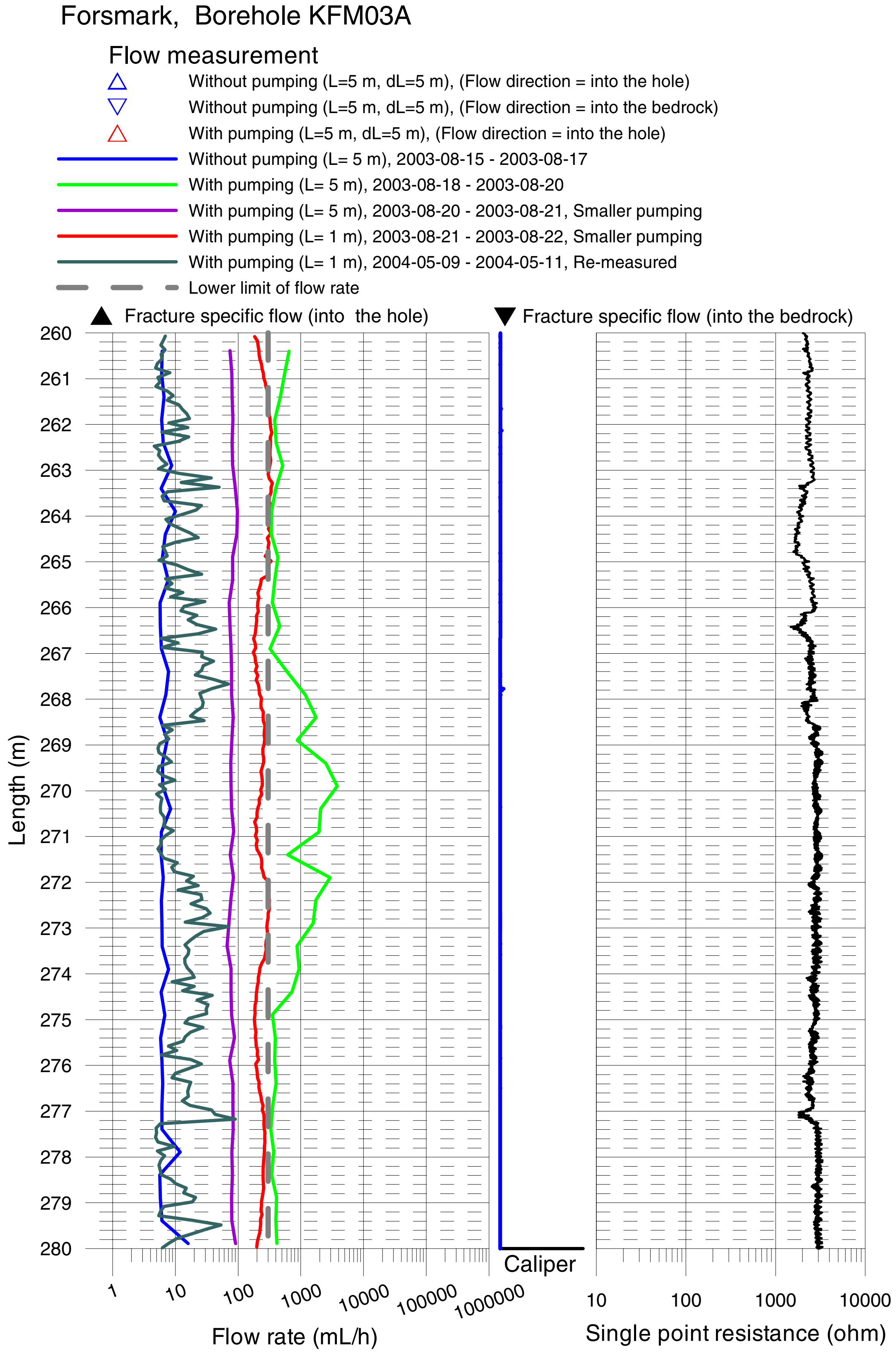
Appendix 3.6



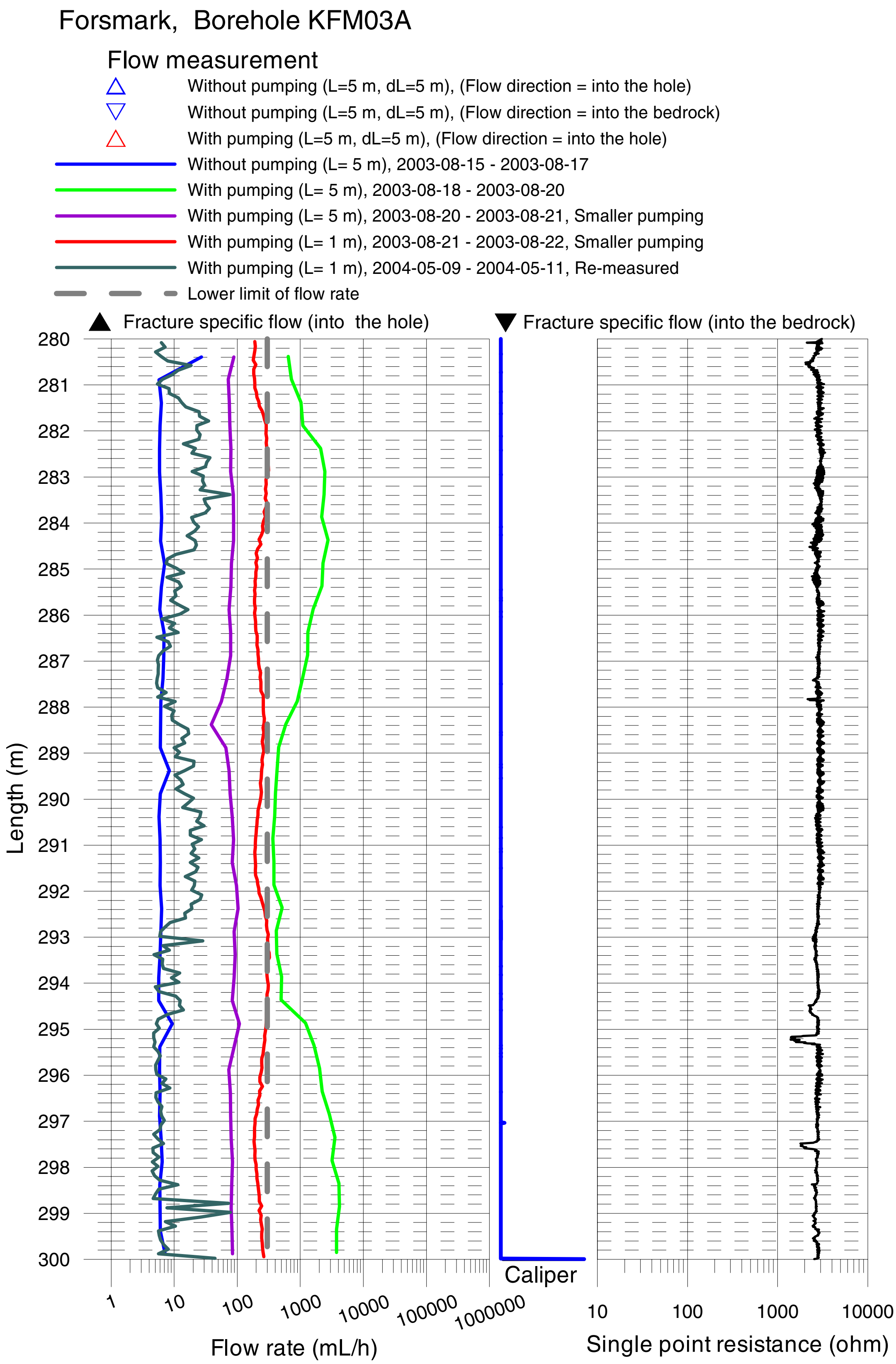
Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
With pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
With pumping (L= 1 m), 2004-05-09 - 2004-05-11, Re-measured
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)


Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
With pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
With pumping (L= 1 m), 2004-05-09 - 2004-05-11, Re-measured
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

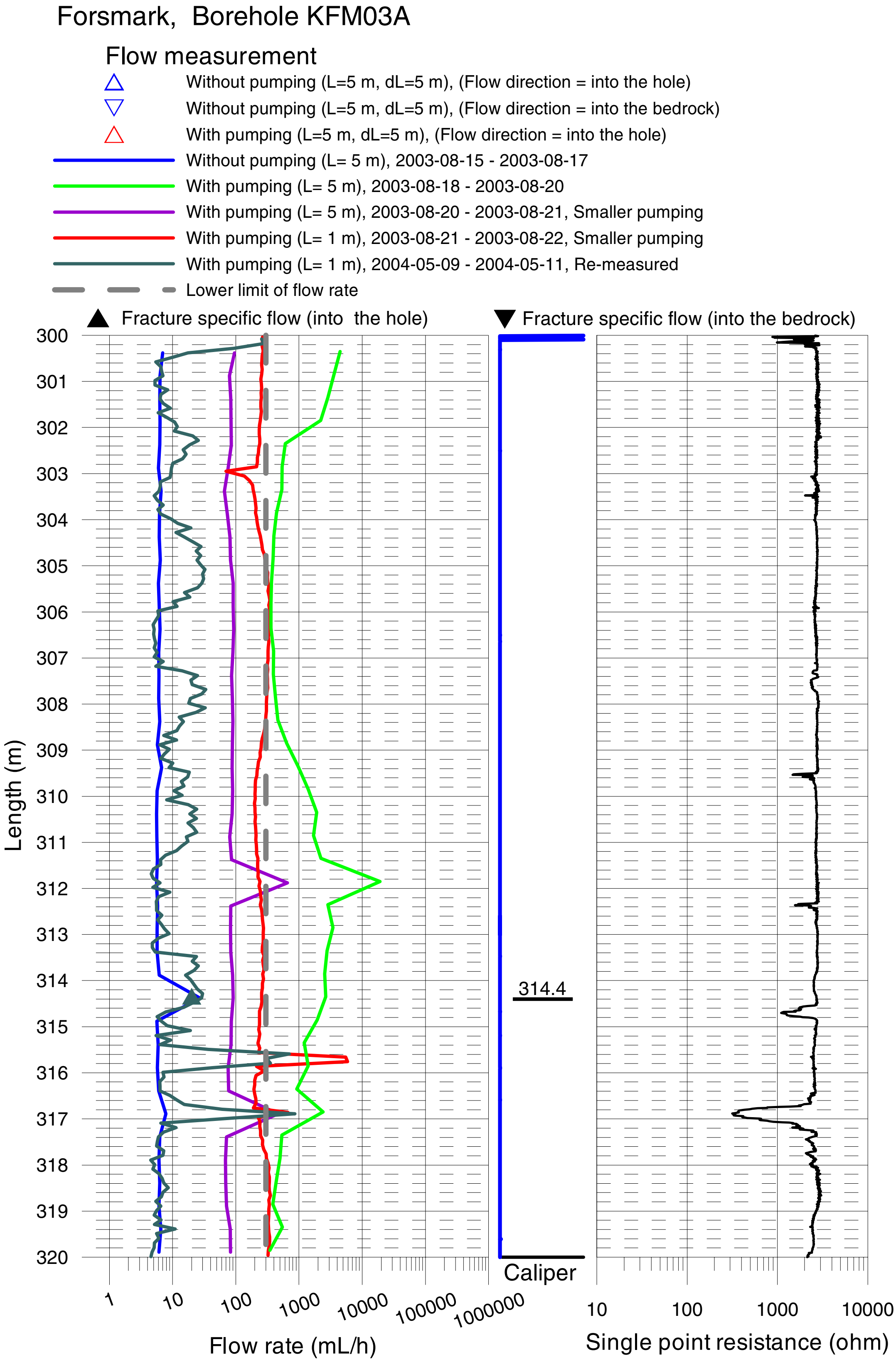

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
With pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
With pumping (L= 1 m), 2004-05-09 - 2004-05-11, Re-measured
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)



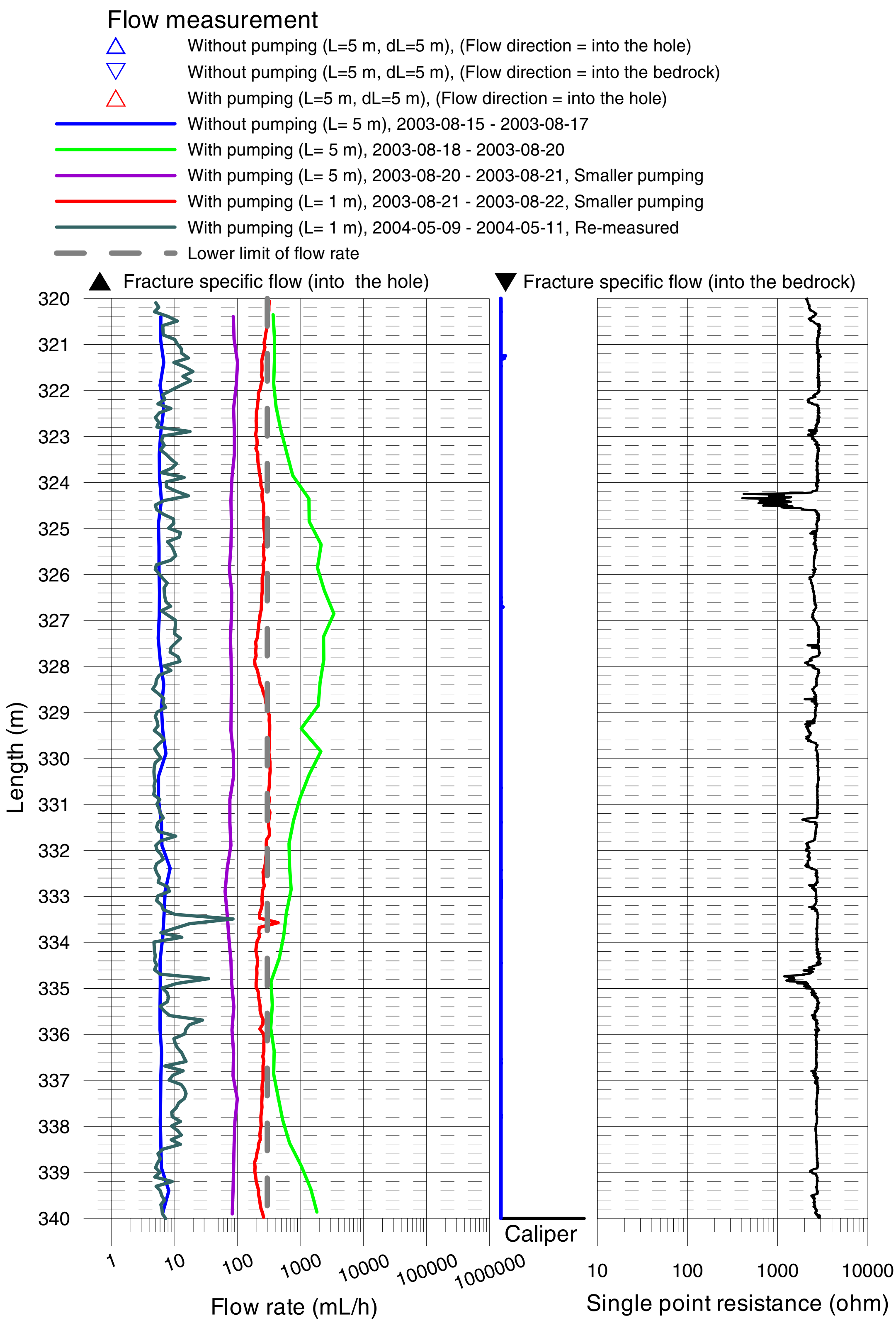
Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
With pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
With pumping (L= 1 m), 2004-05-09 - 2004-05-11, Re-measured
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

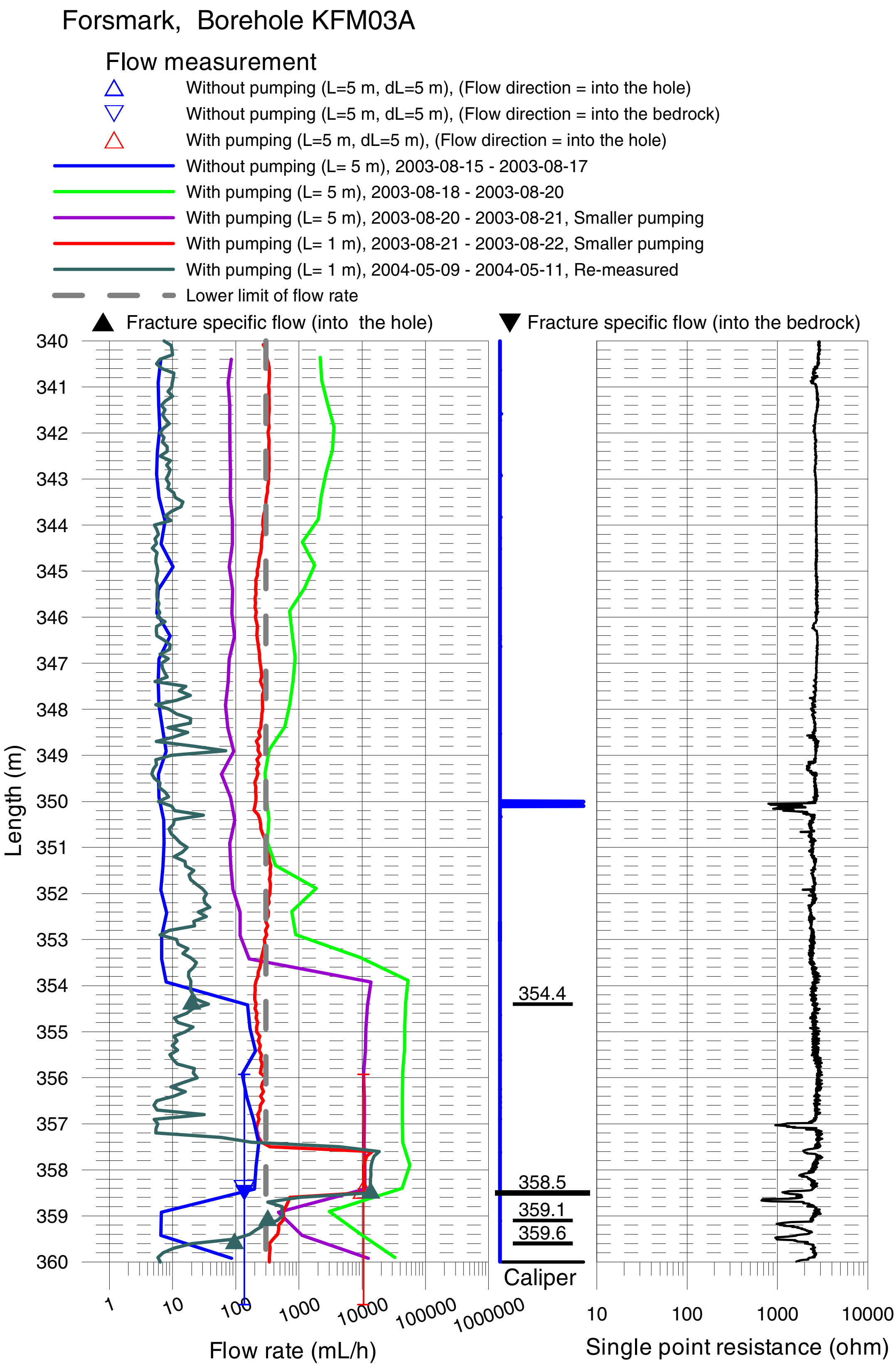


Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
With pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
With pumping (L= 1 m), 2004-05-09 - 2004-05-11, Re-measured
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

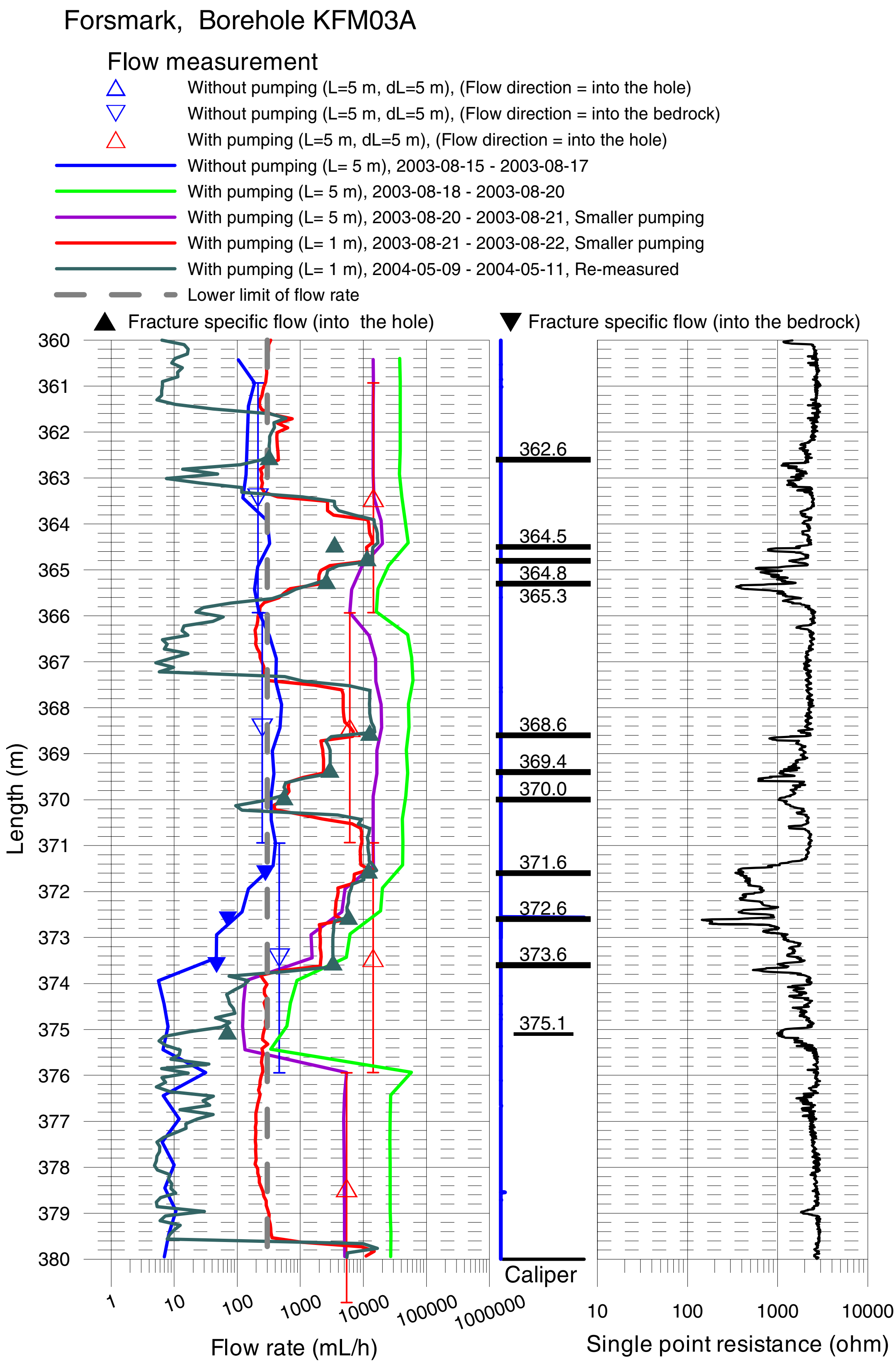

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
With pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
With pumping (L= 1 m), 2004-05-09 - 2004-05-11, Re-measured
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
314.4
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

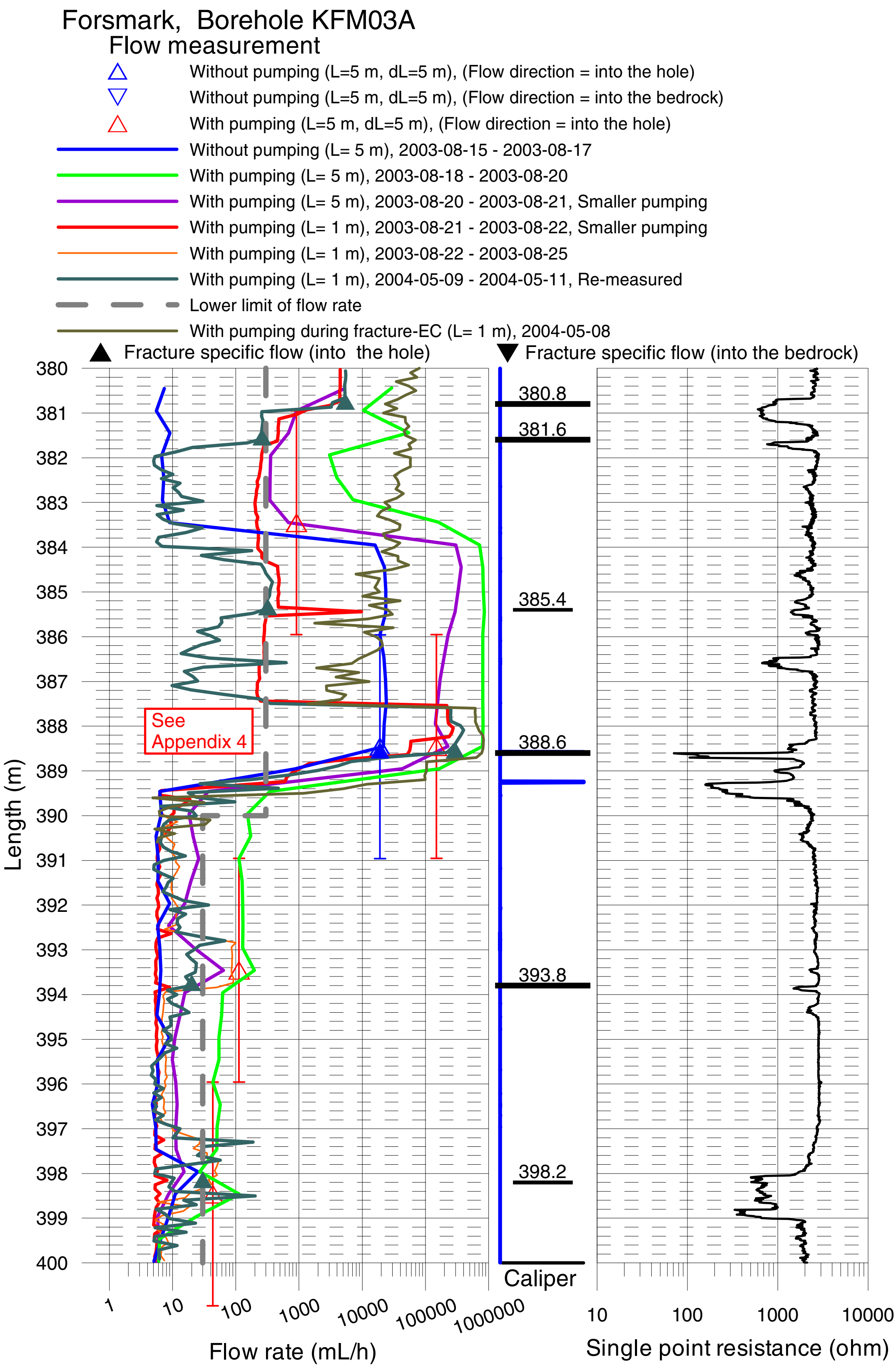
Forsmark, Borehole KFM03A





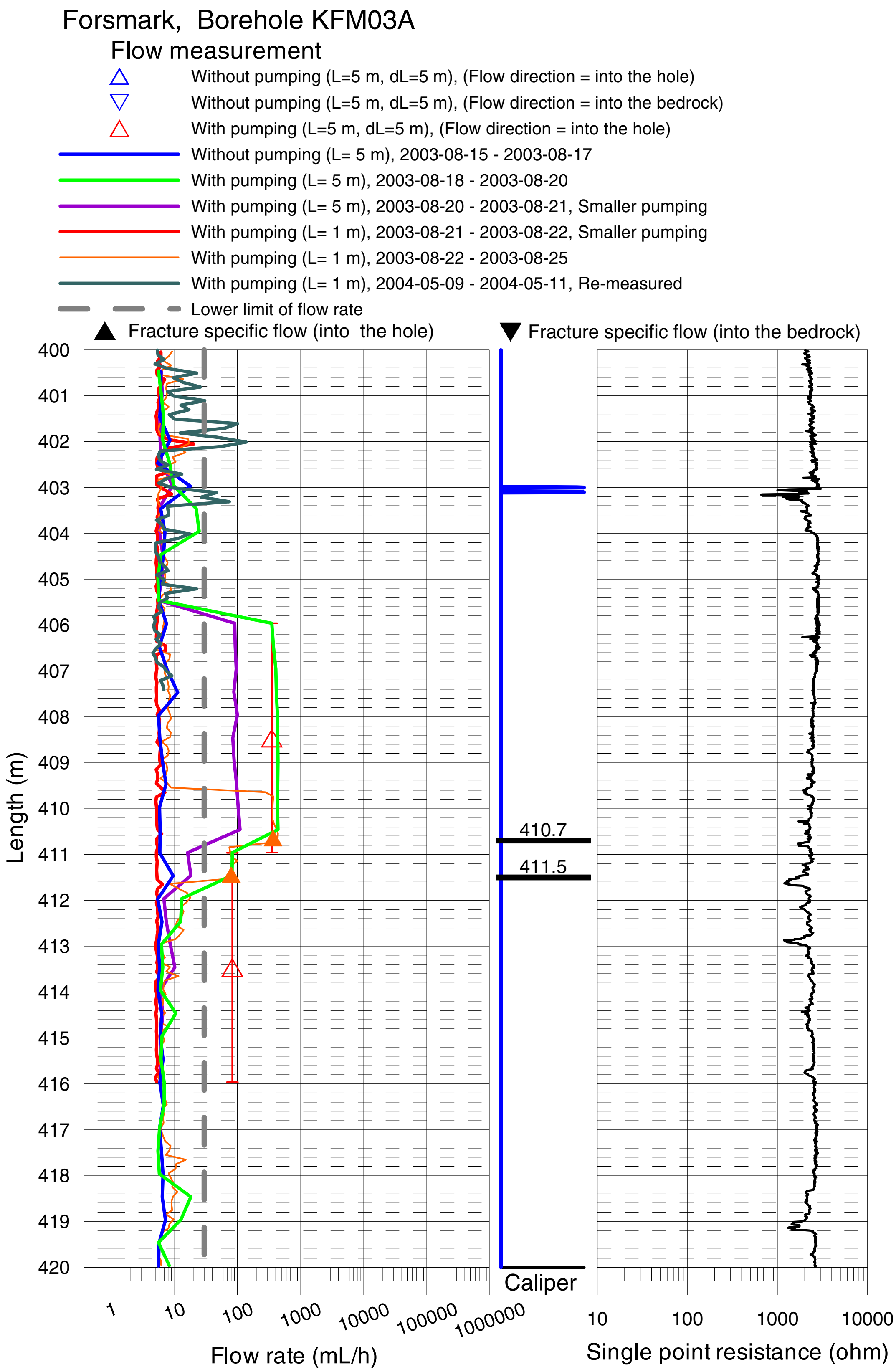
Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
With pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
With pumping (L= 1 m), 2004-05-09 - 2004-05-11, Re-measured
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
354.4
358.5
359.1
359.6
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

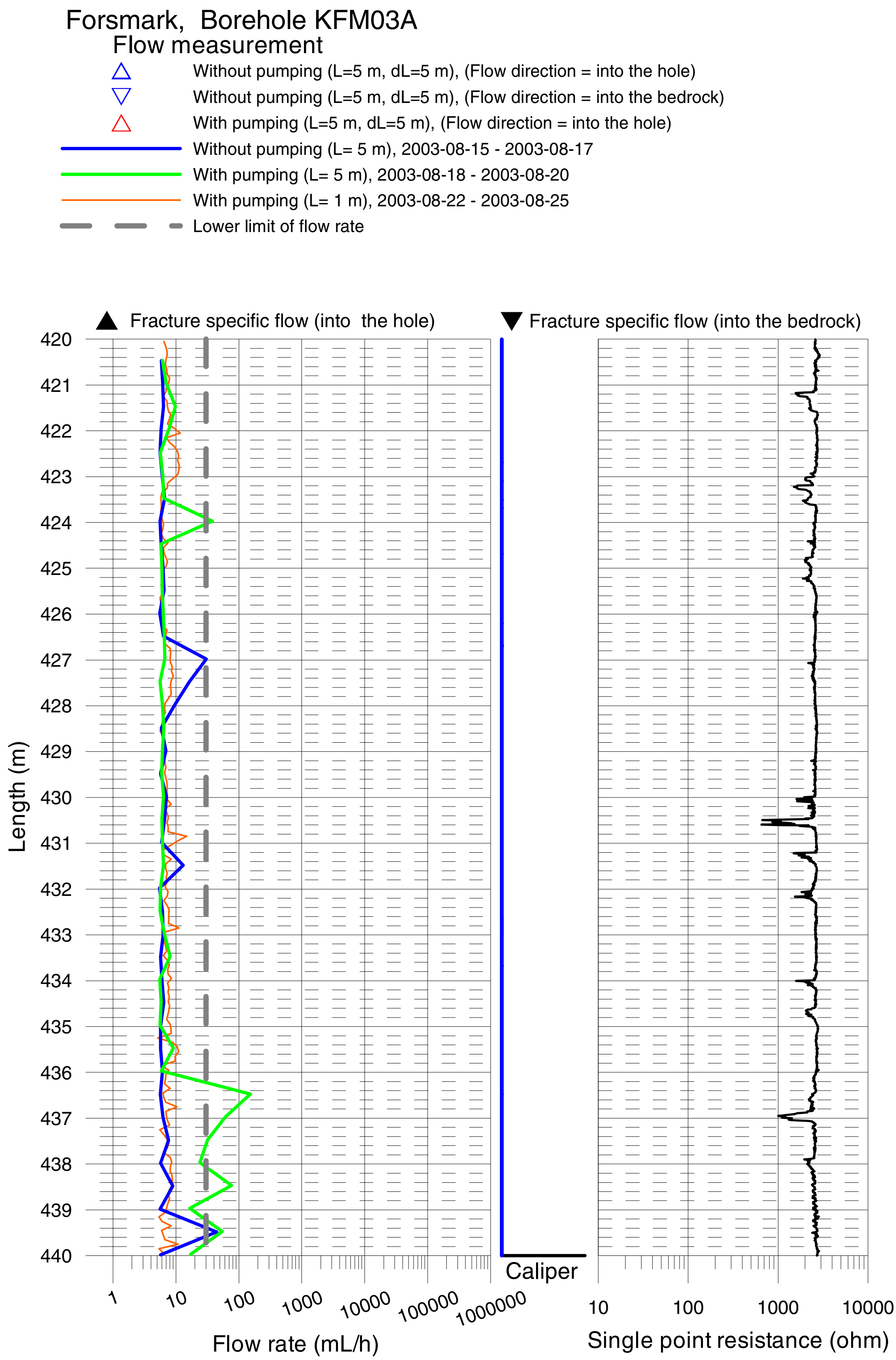

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
With pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
With pumping (L= 1 m), 2004-05-09 - 2004-05-11, Re-measured
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
362.6
364.5
364.8
365.3
368.6
369.4
370.0
371.6
372.6
373.6
375.1
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)



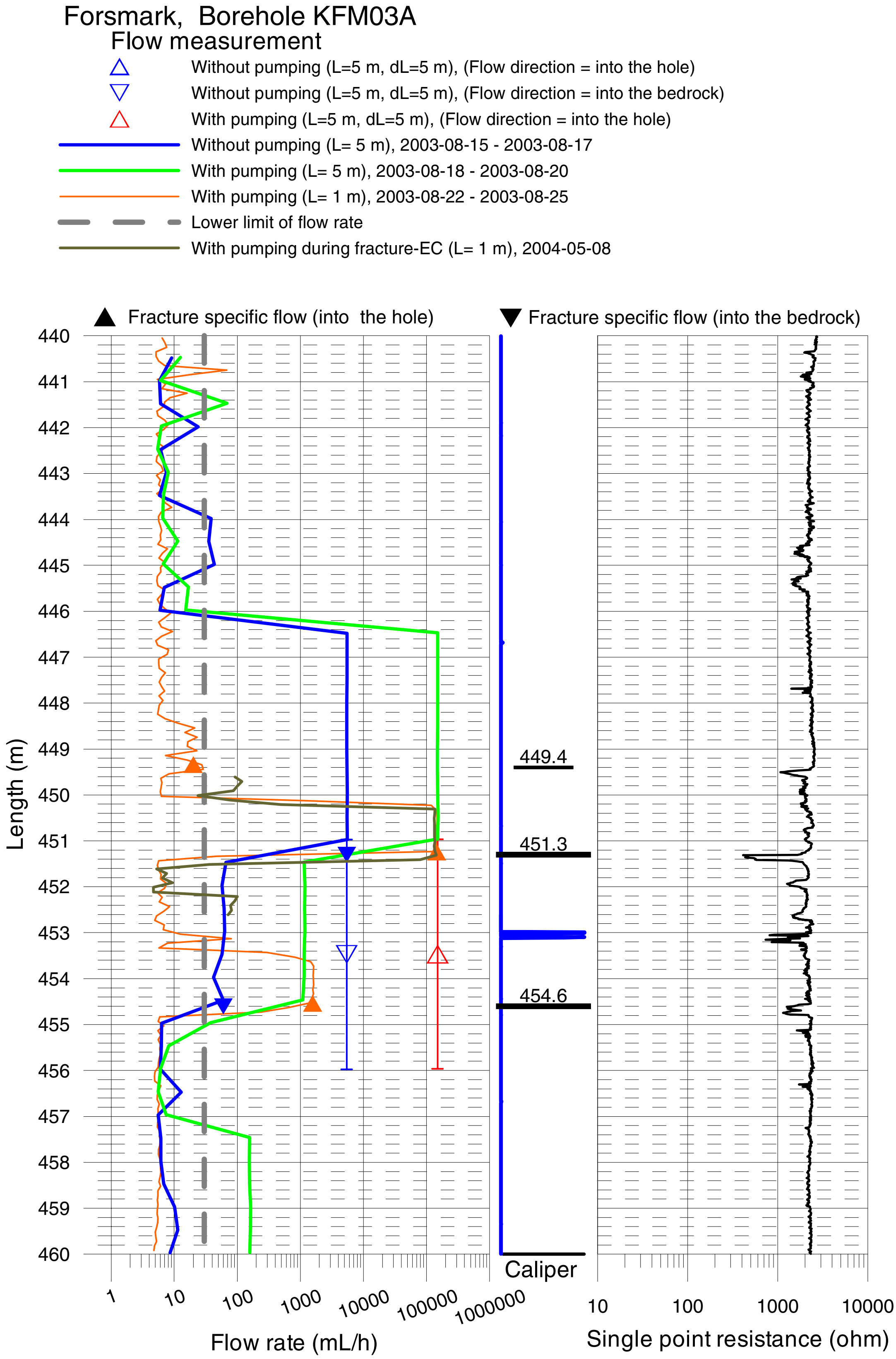
Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 5 m), 2003-08-20 - 2003-08-21, Smaller pumping
With pumping (L= 1 m), 2003-08-21 - 2003-08-22, Smaller pumping
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
With pumping (L= 1 m), 2004-05-09 - 2004-05-11, Re-measured
Lower limit of flow rate
With pumping during fracture-EC (L= 1 m), 2004-05-08
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
See Appendix 4
380.8
381.6
385.4
388.6
393.8
398.2
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

Appendix 3.16



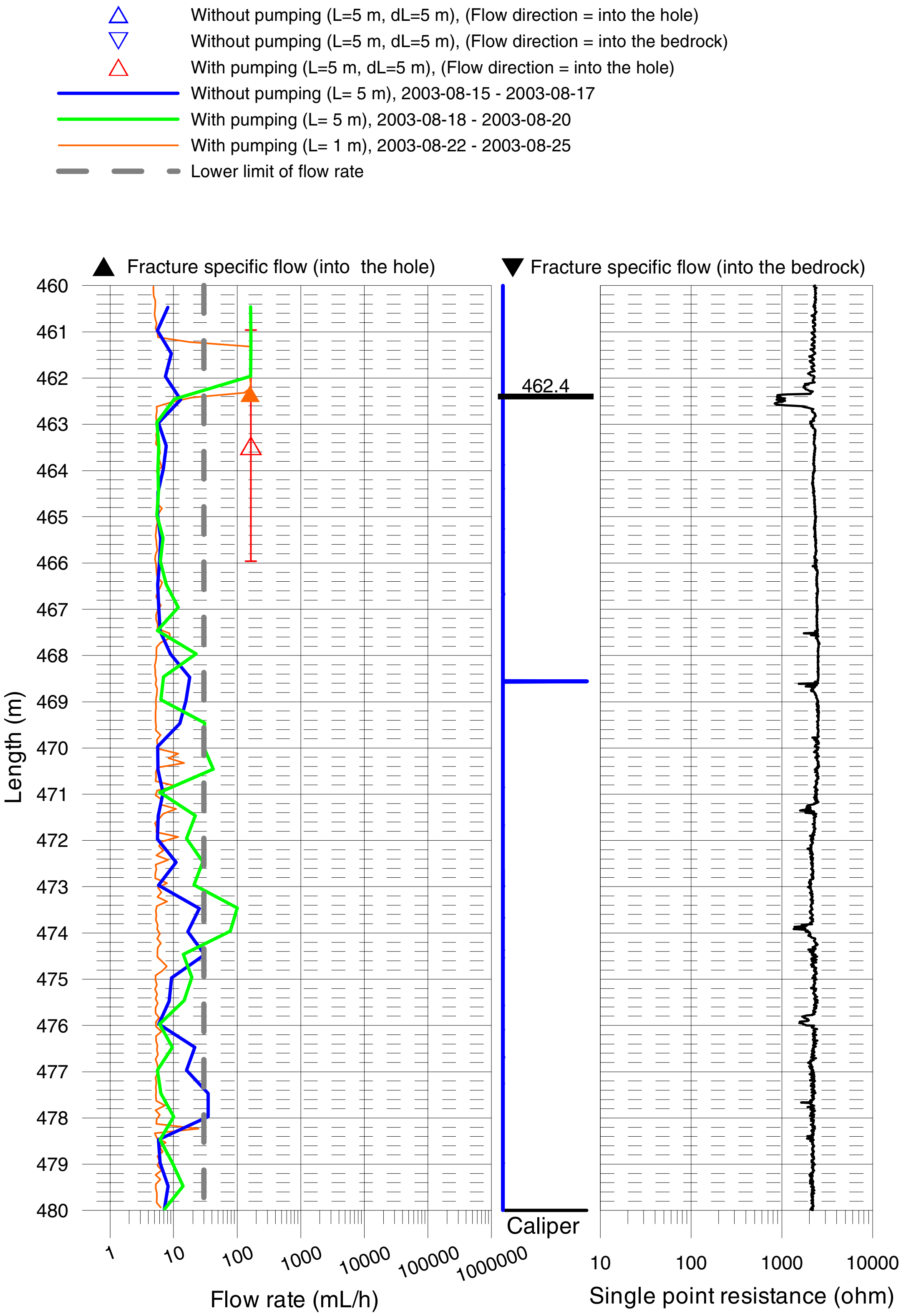

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

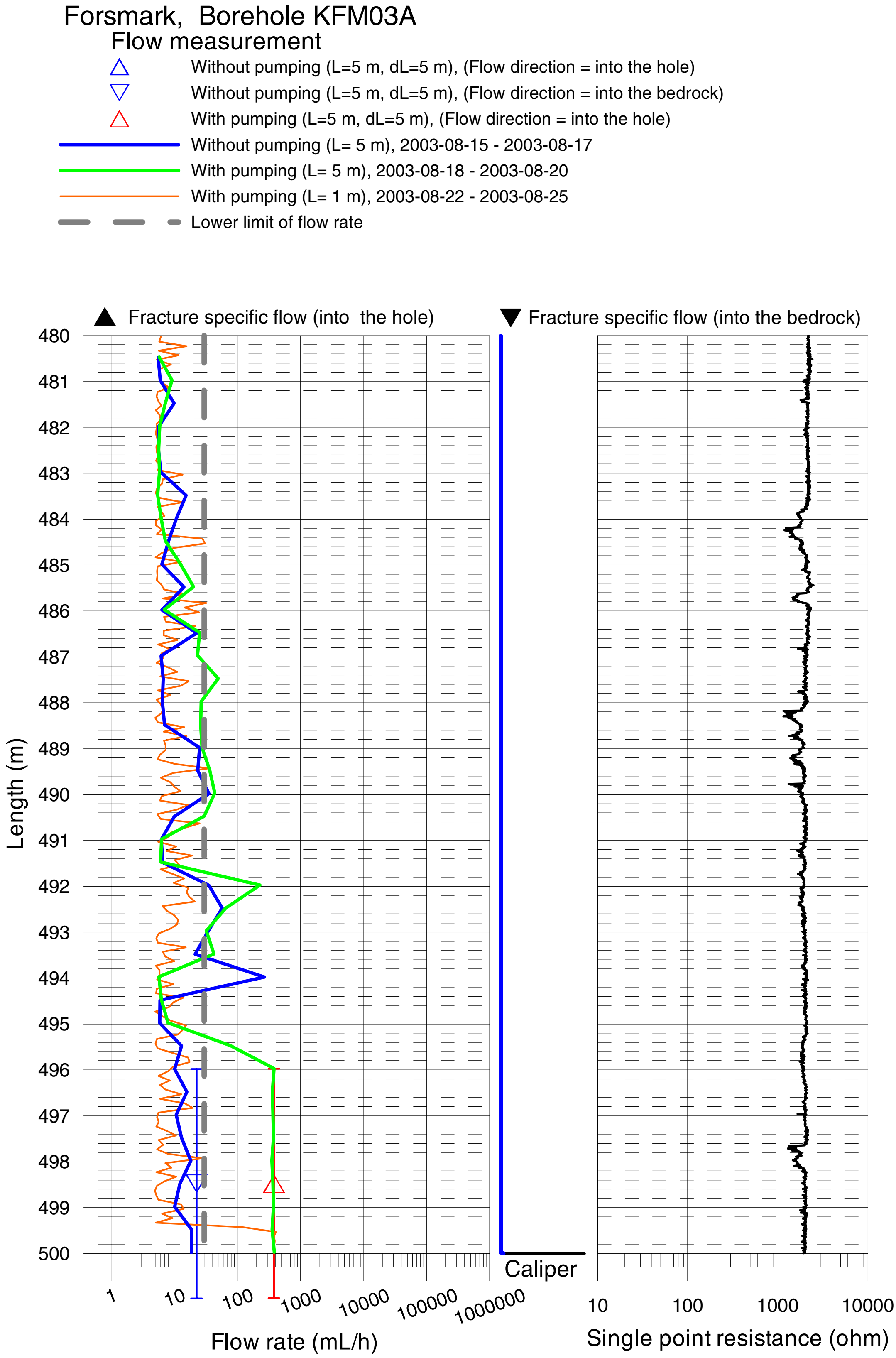
Appendix 3.18

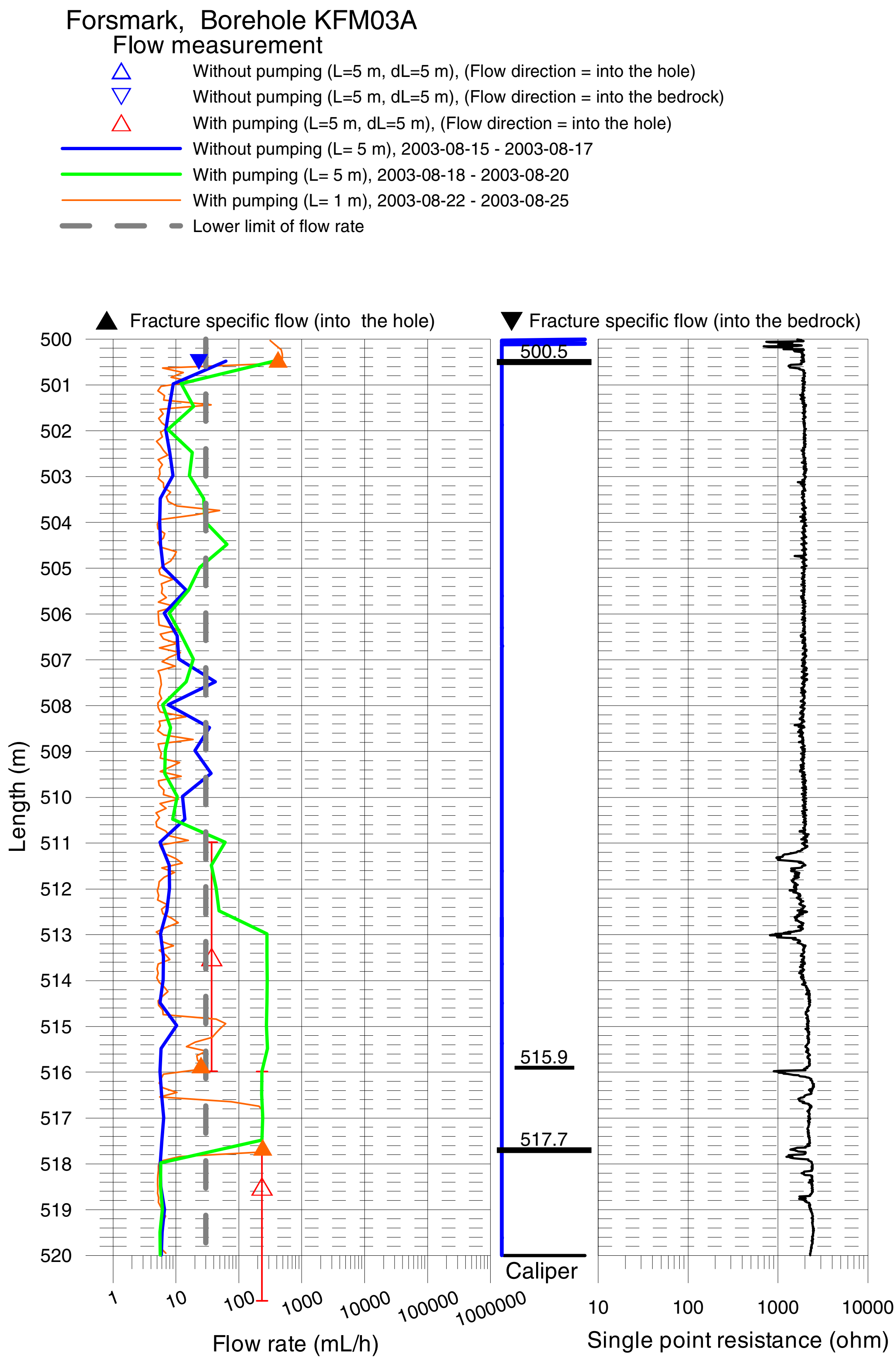


Forsmark, Borehole KFM03A

Flow measurement

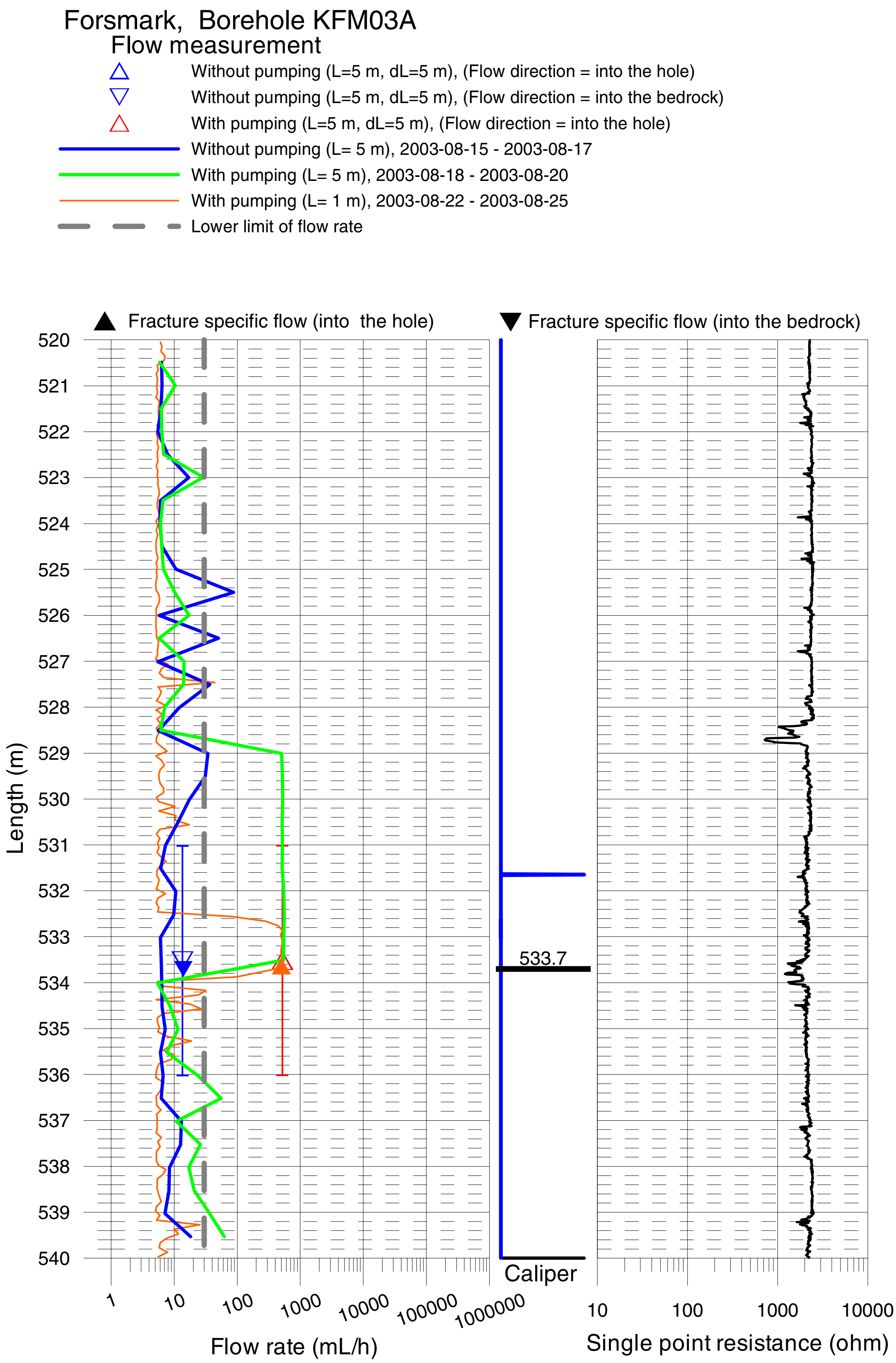


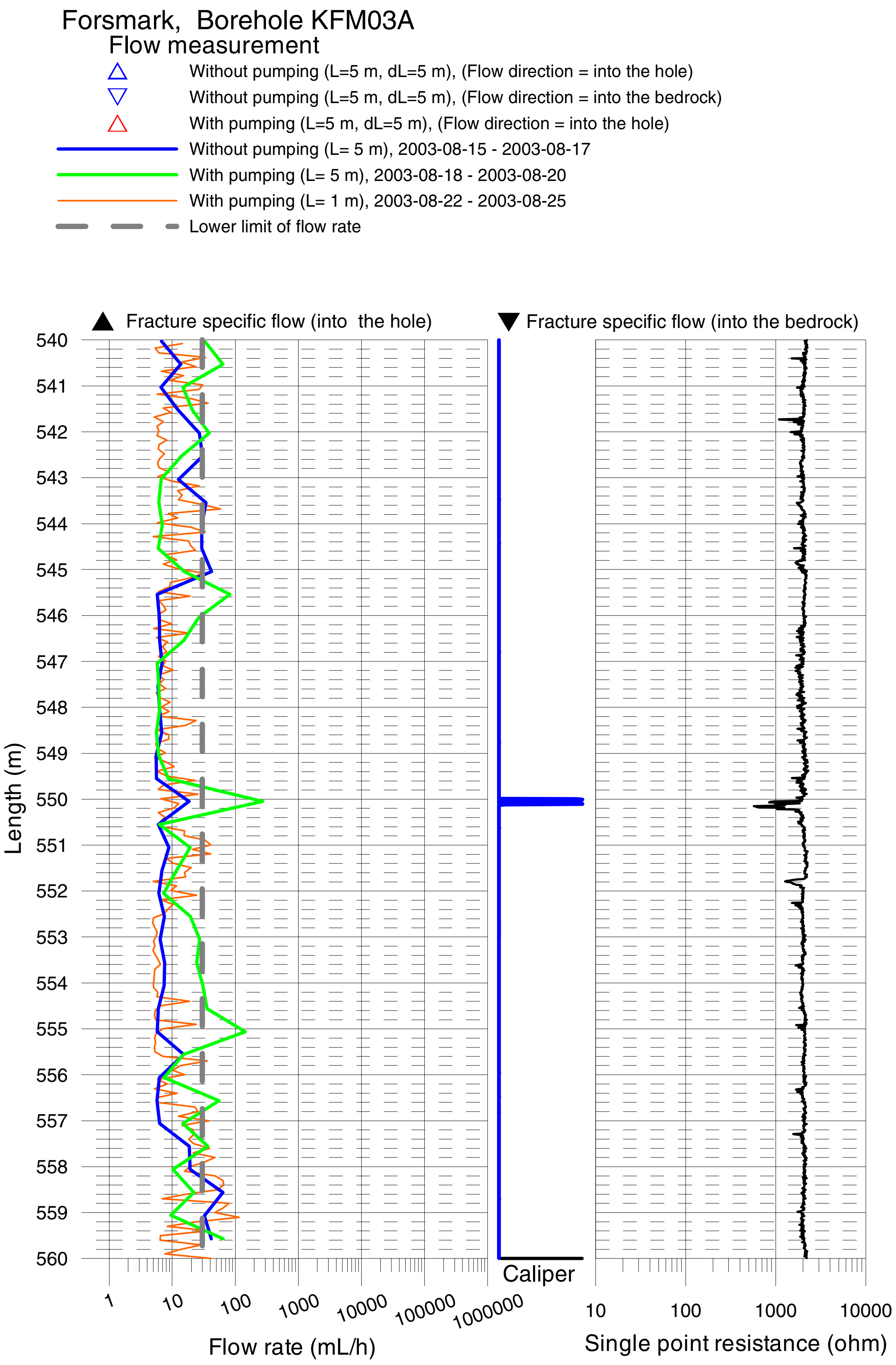

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

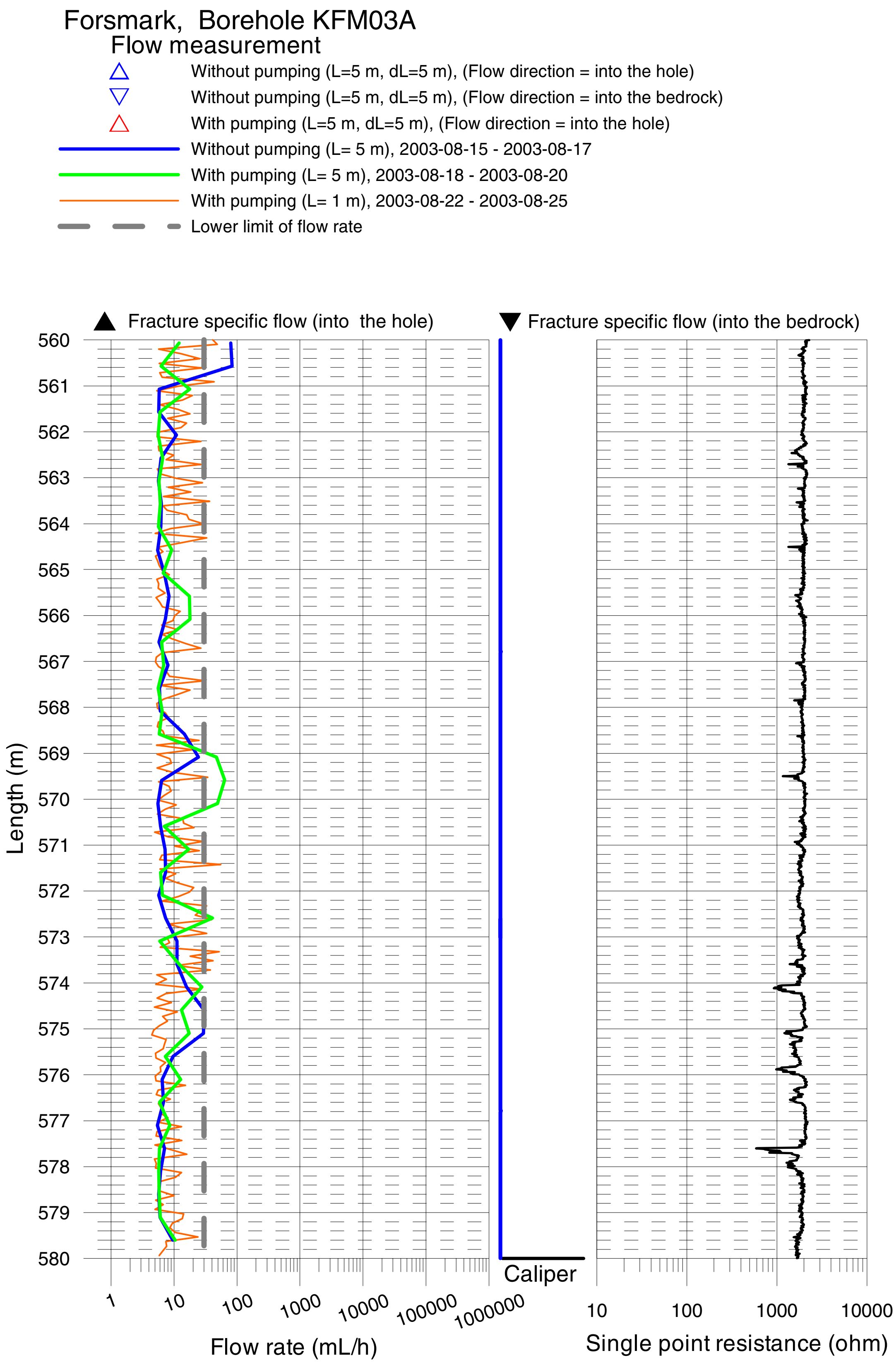


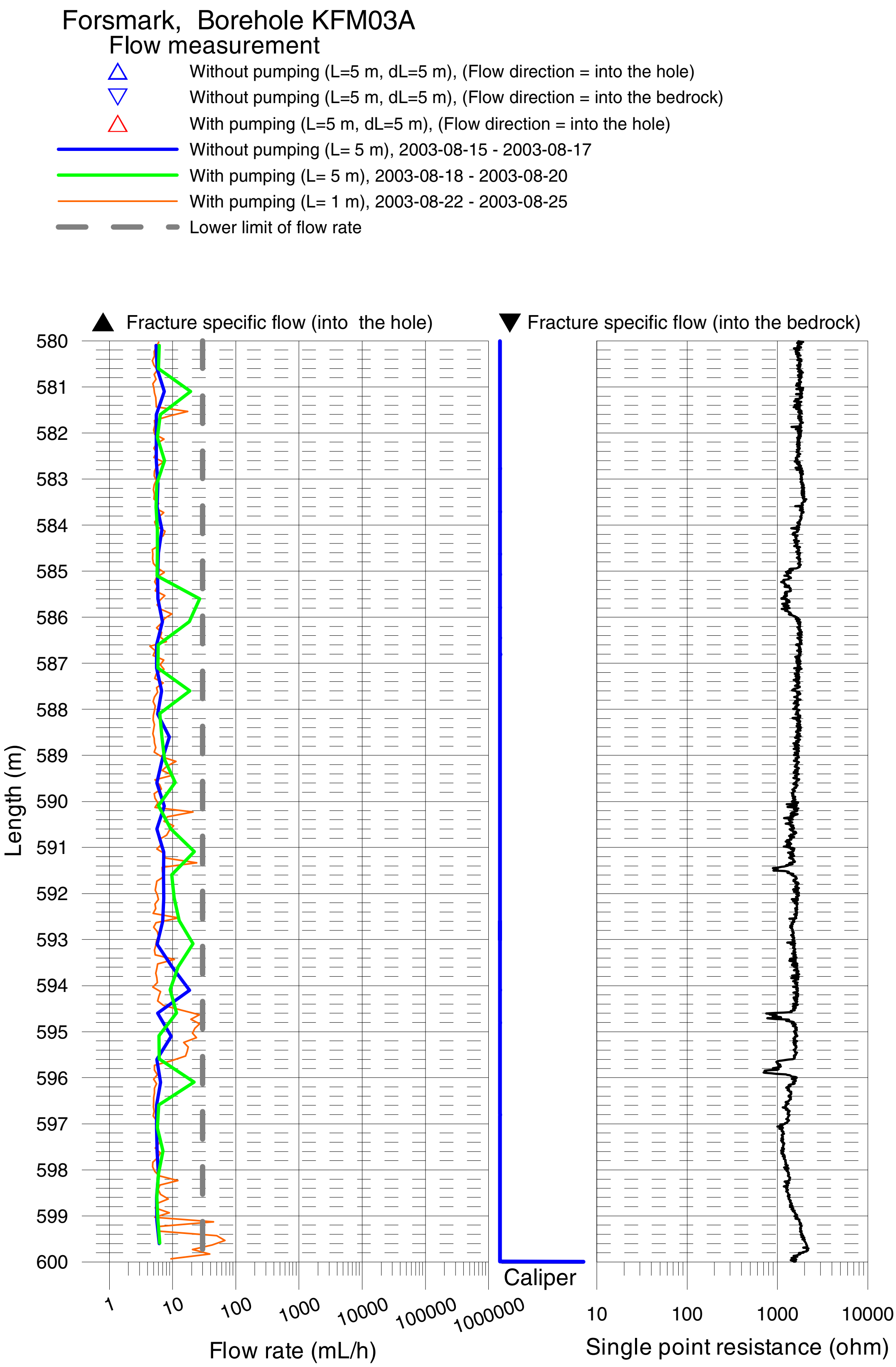
Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
500.5
515.9
517.7
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

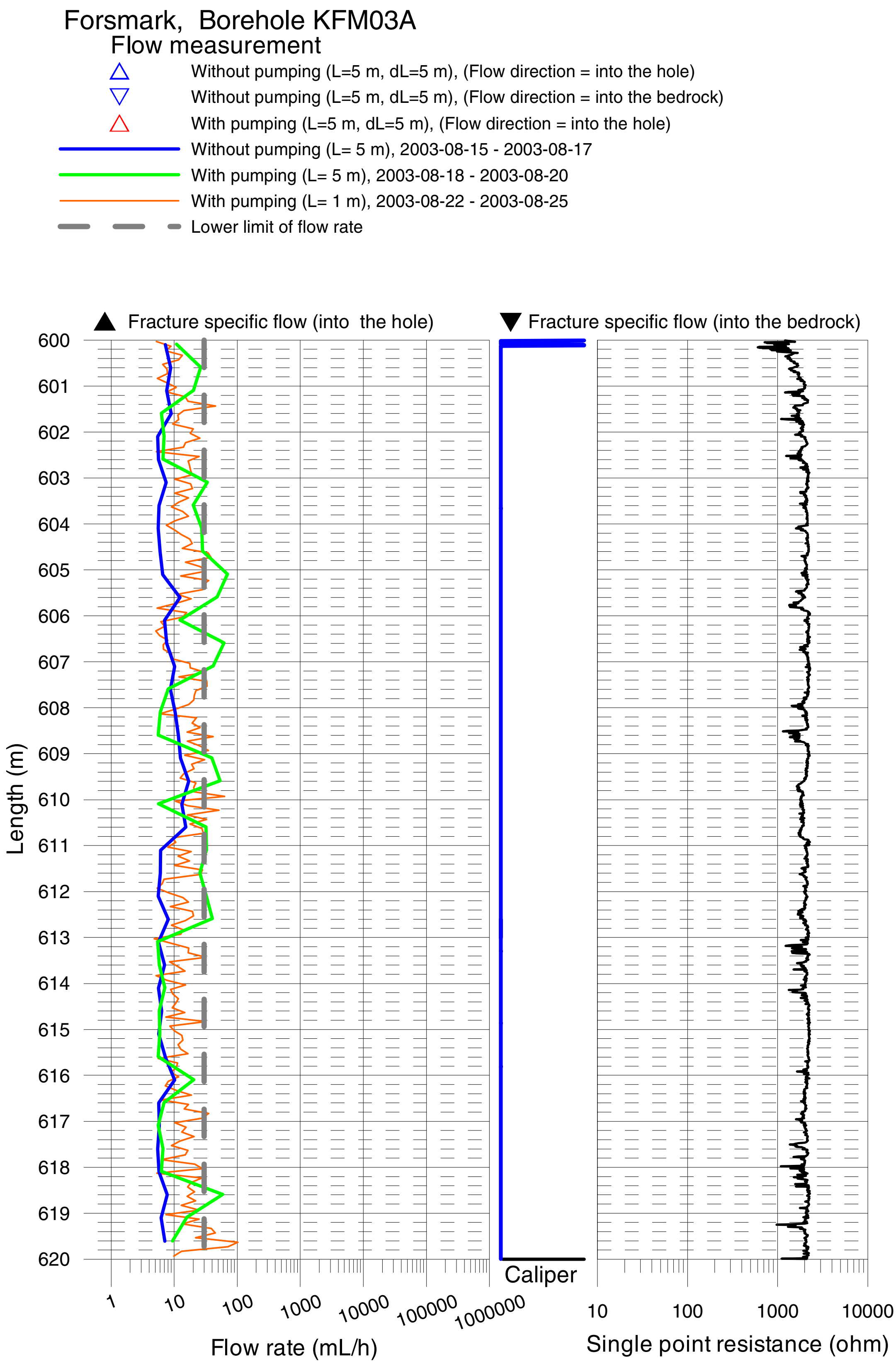
Appendix 3.22

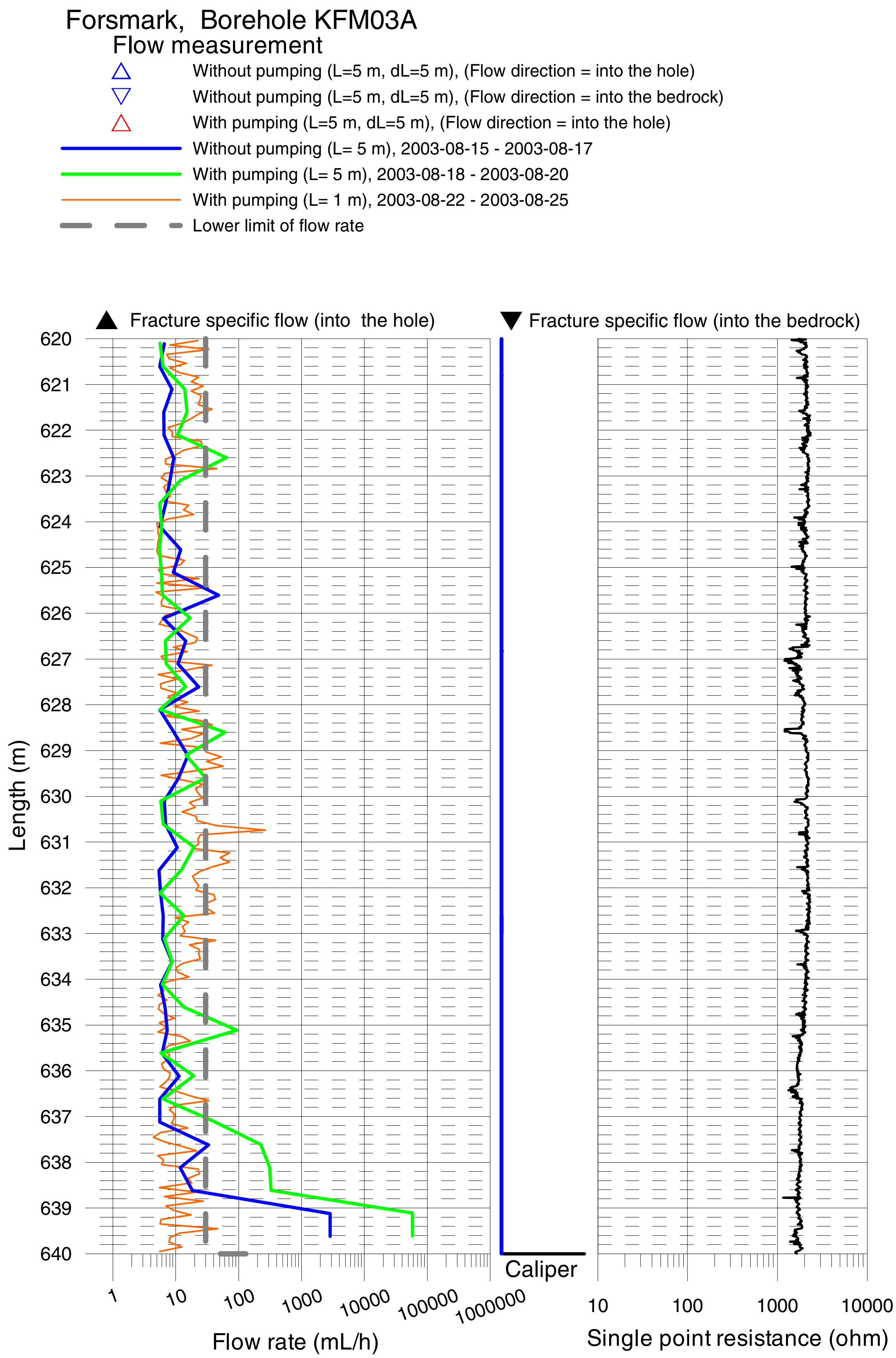



Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

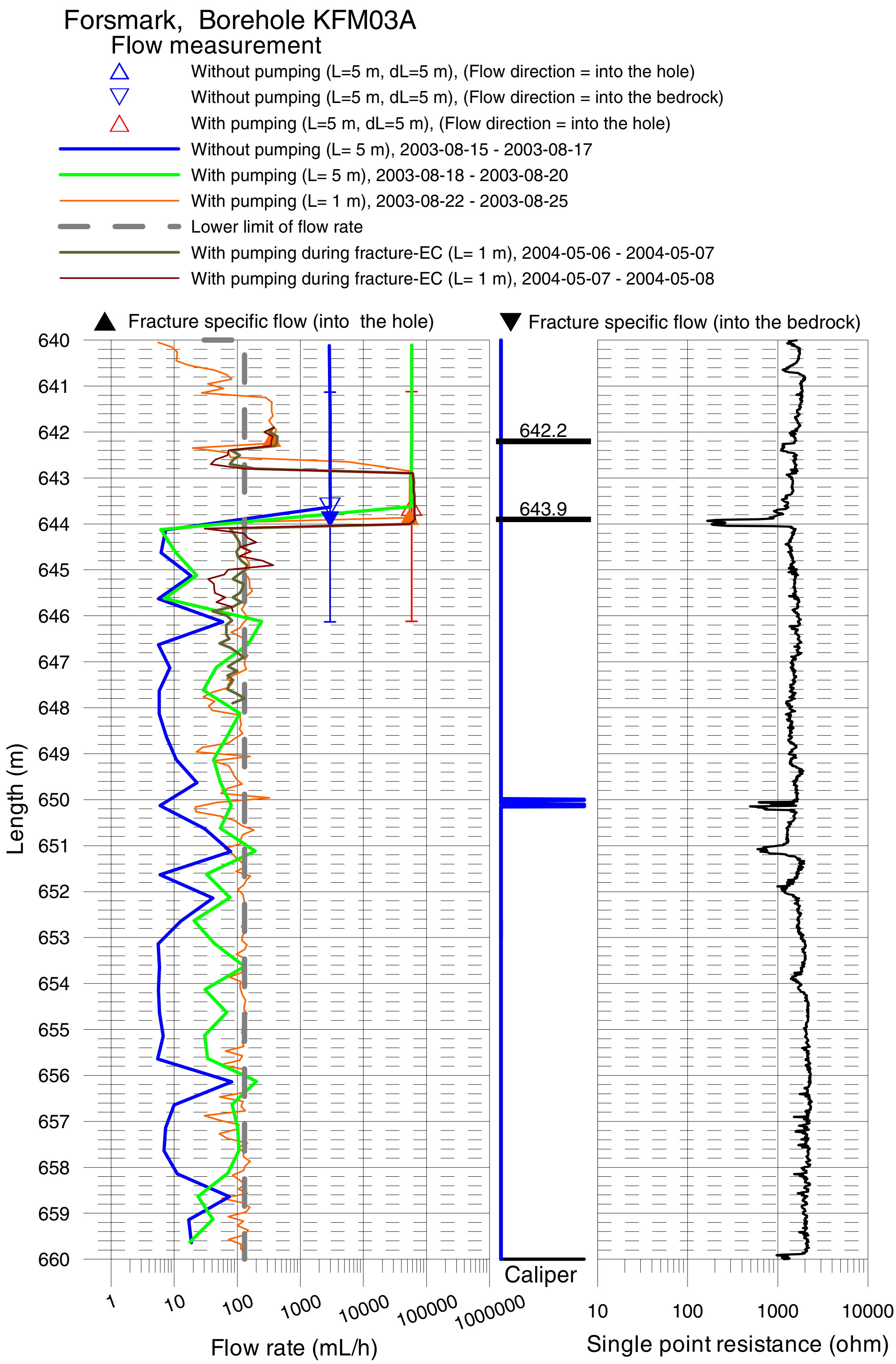

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)


Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

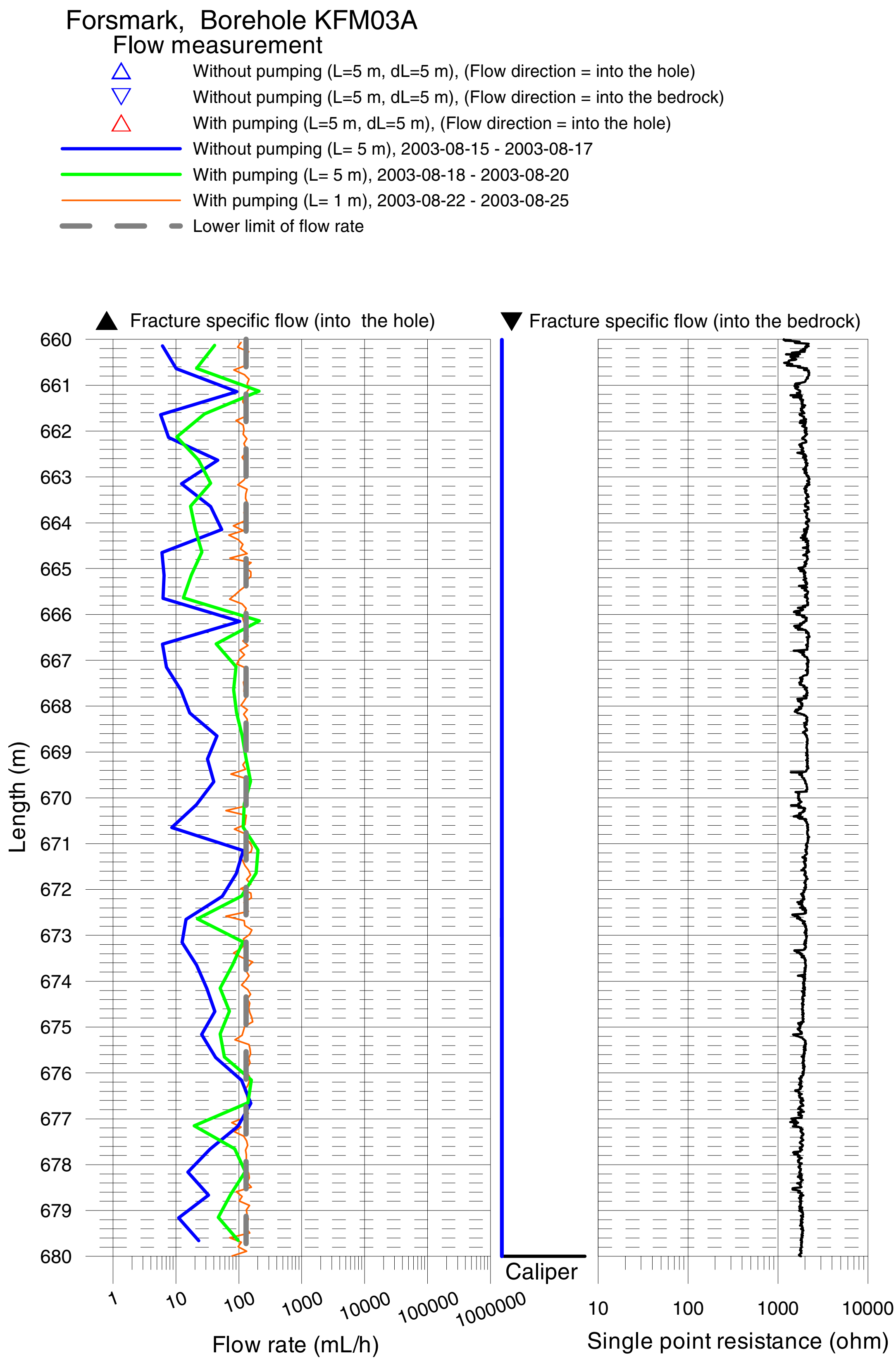

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

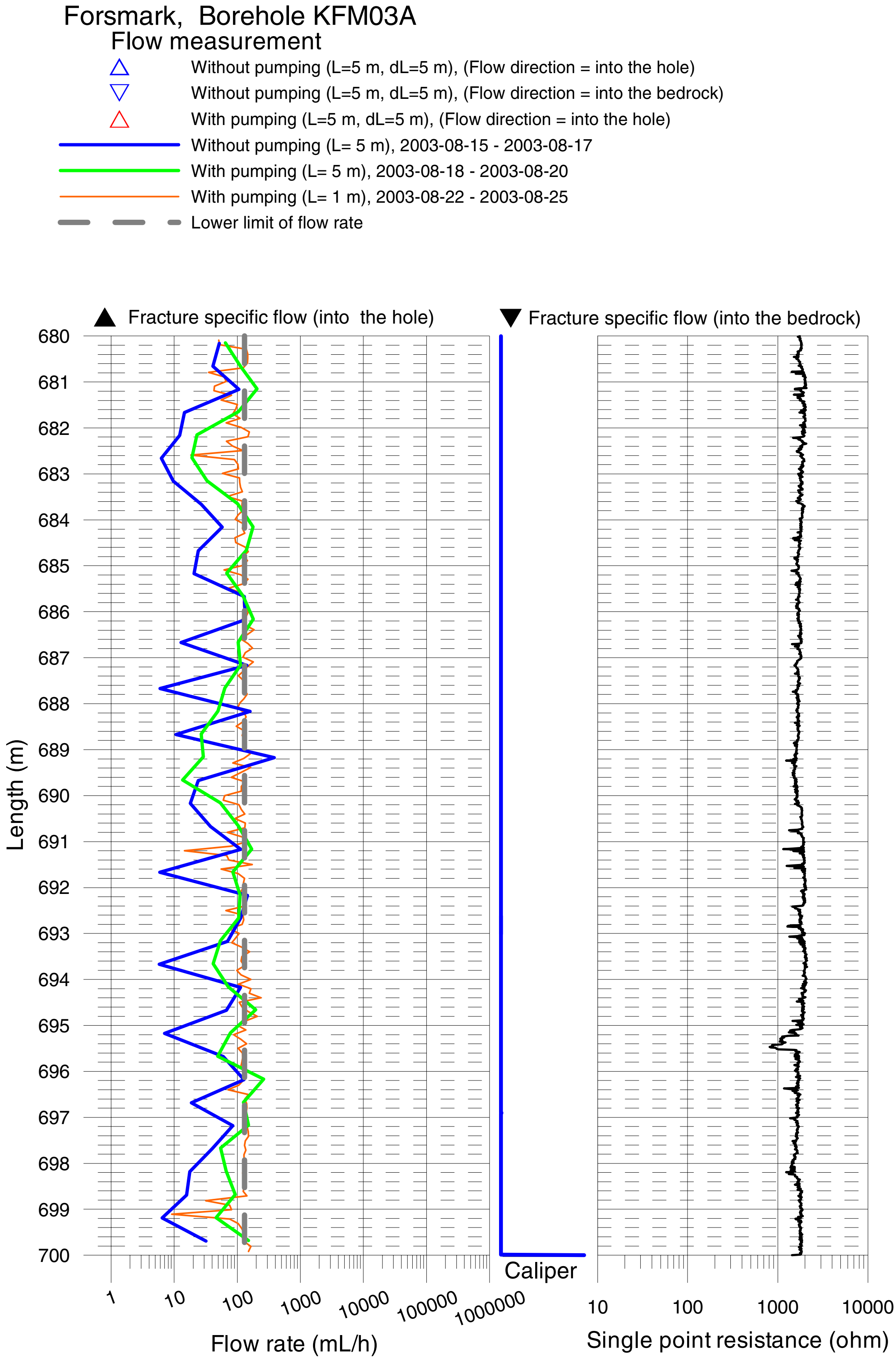


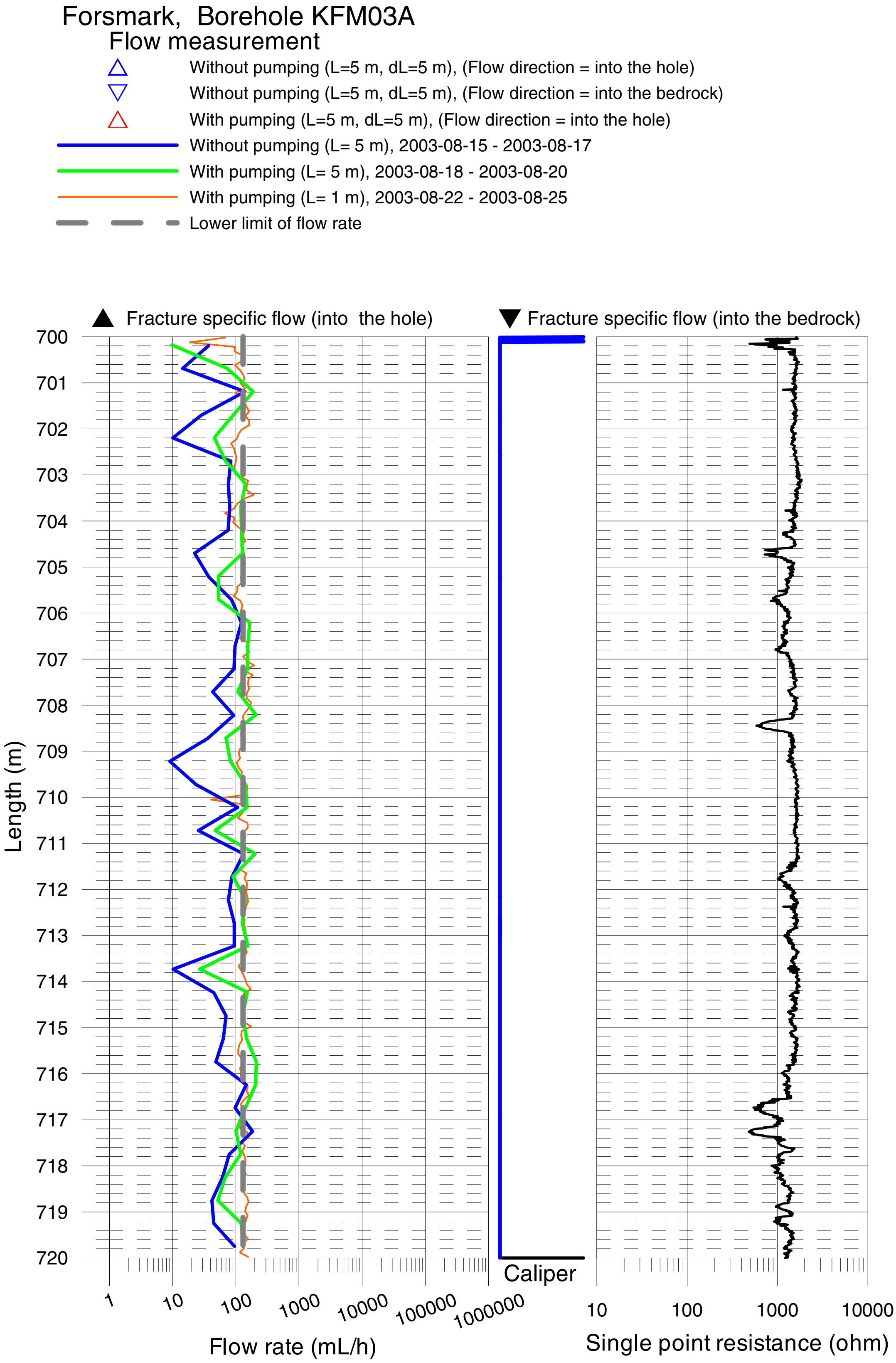
Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)



Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
With pumping during fracture-EC (L= 1 m), 2004-05-06 - 2004-05-07
With pumping during fracture-EC (L= 1 m), 2004-05-07 - 2004-05-08
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
642.2
643.9
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

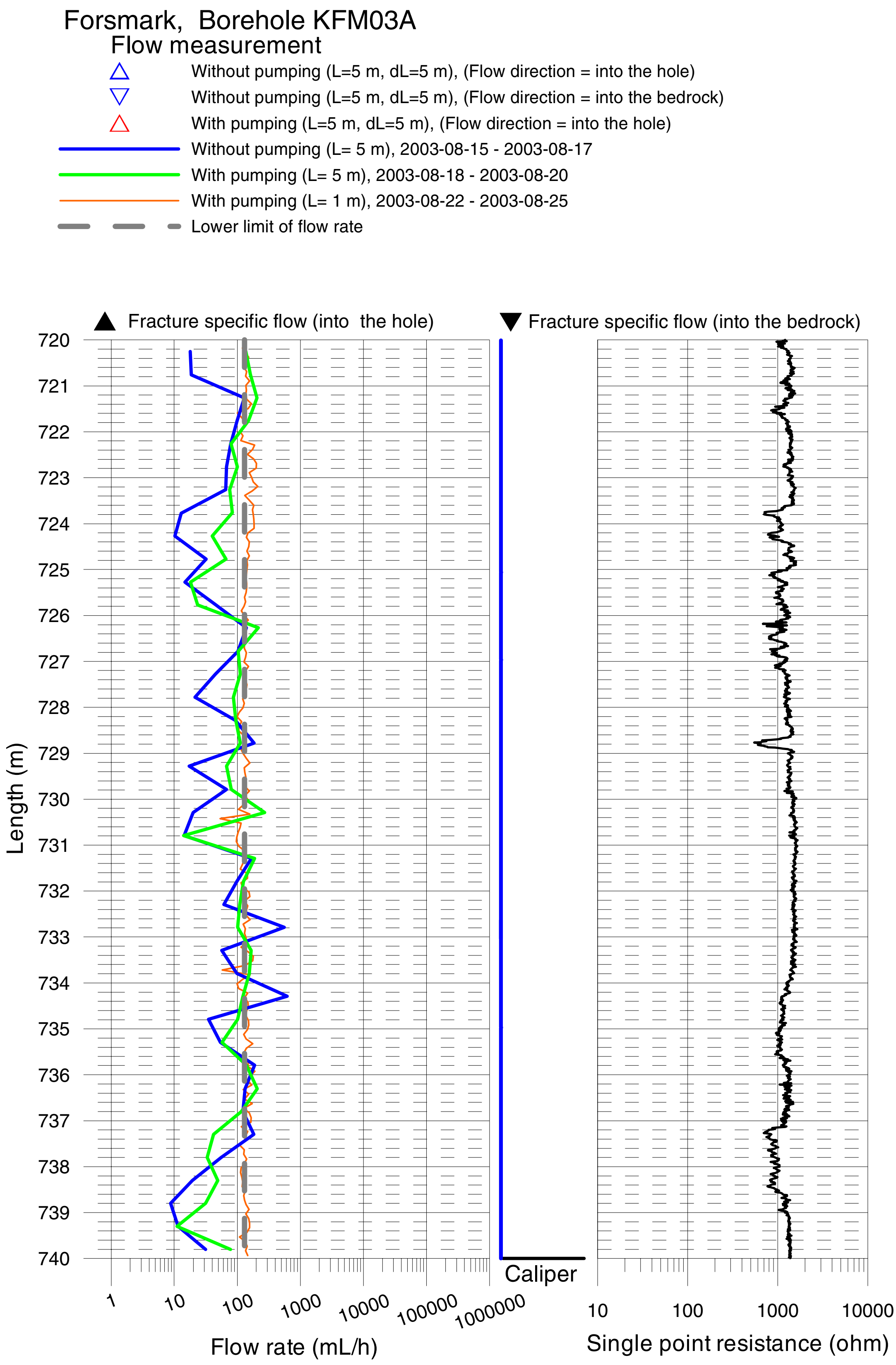

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
Length (m)
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

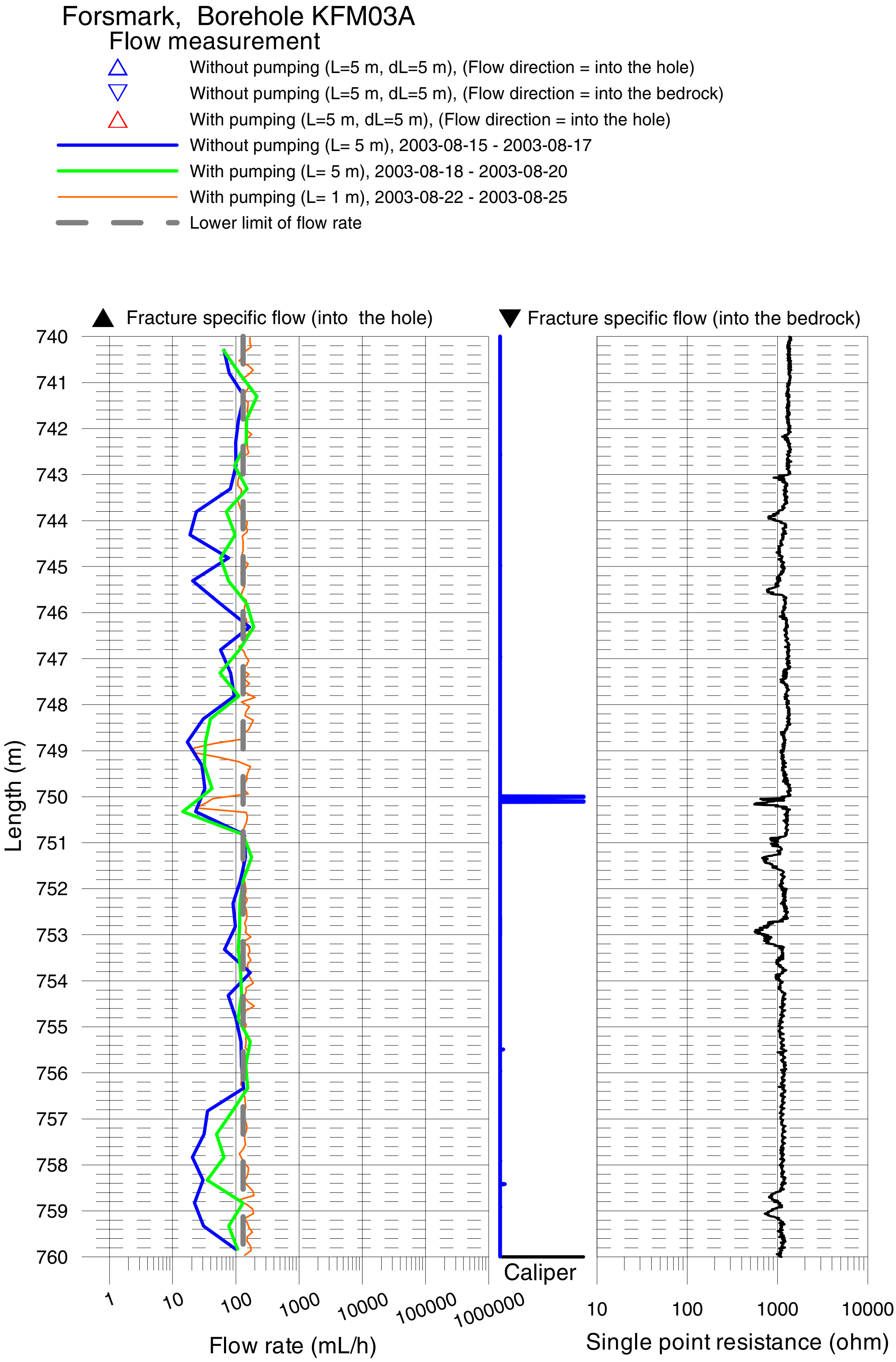

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

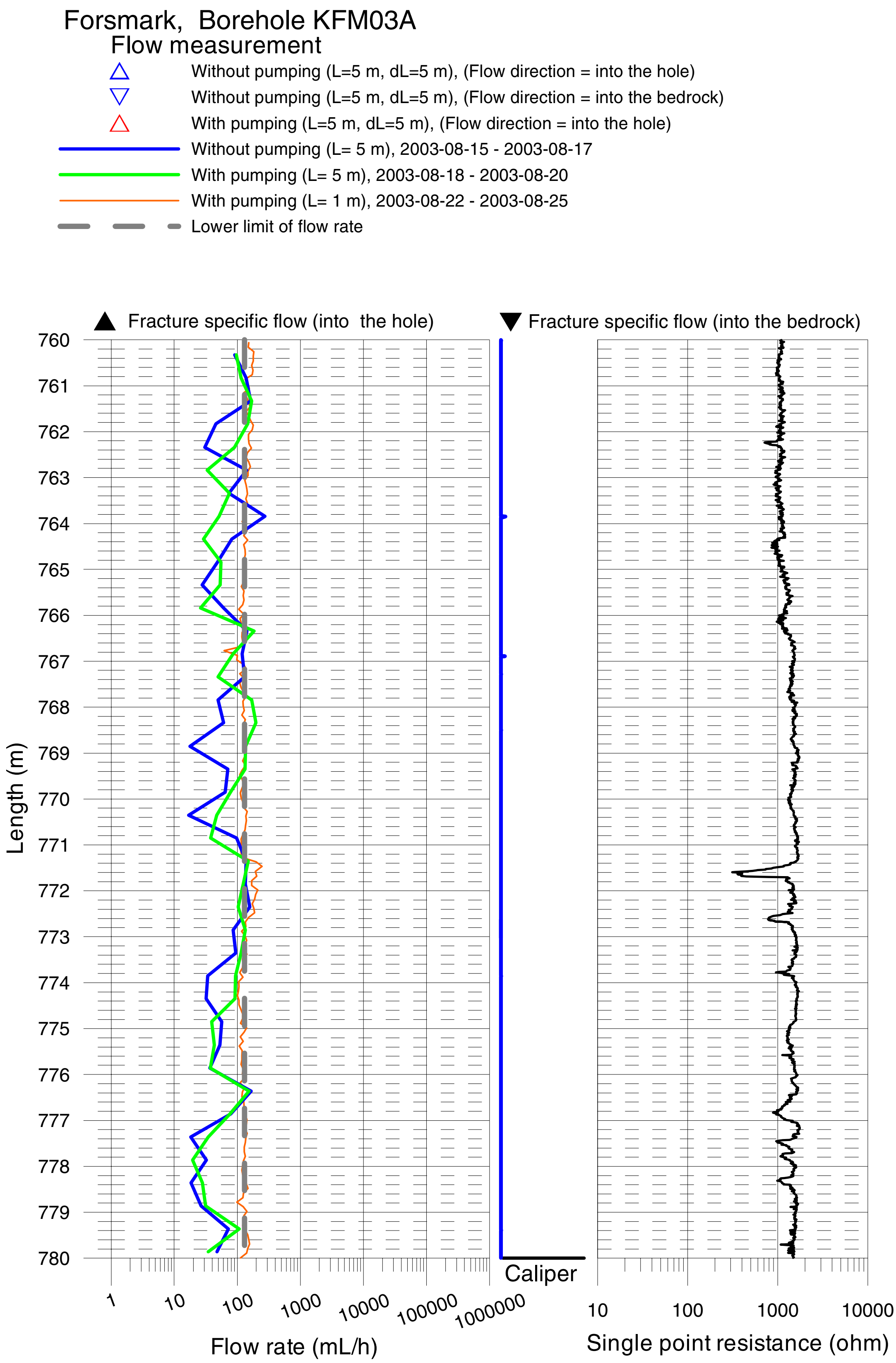


Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

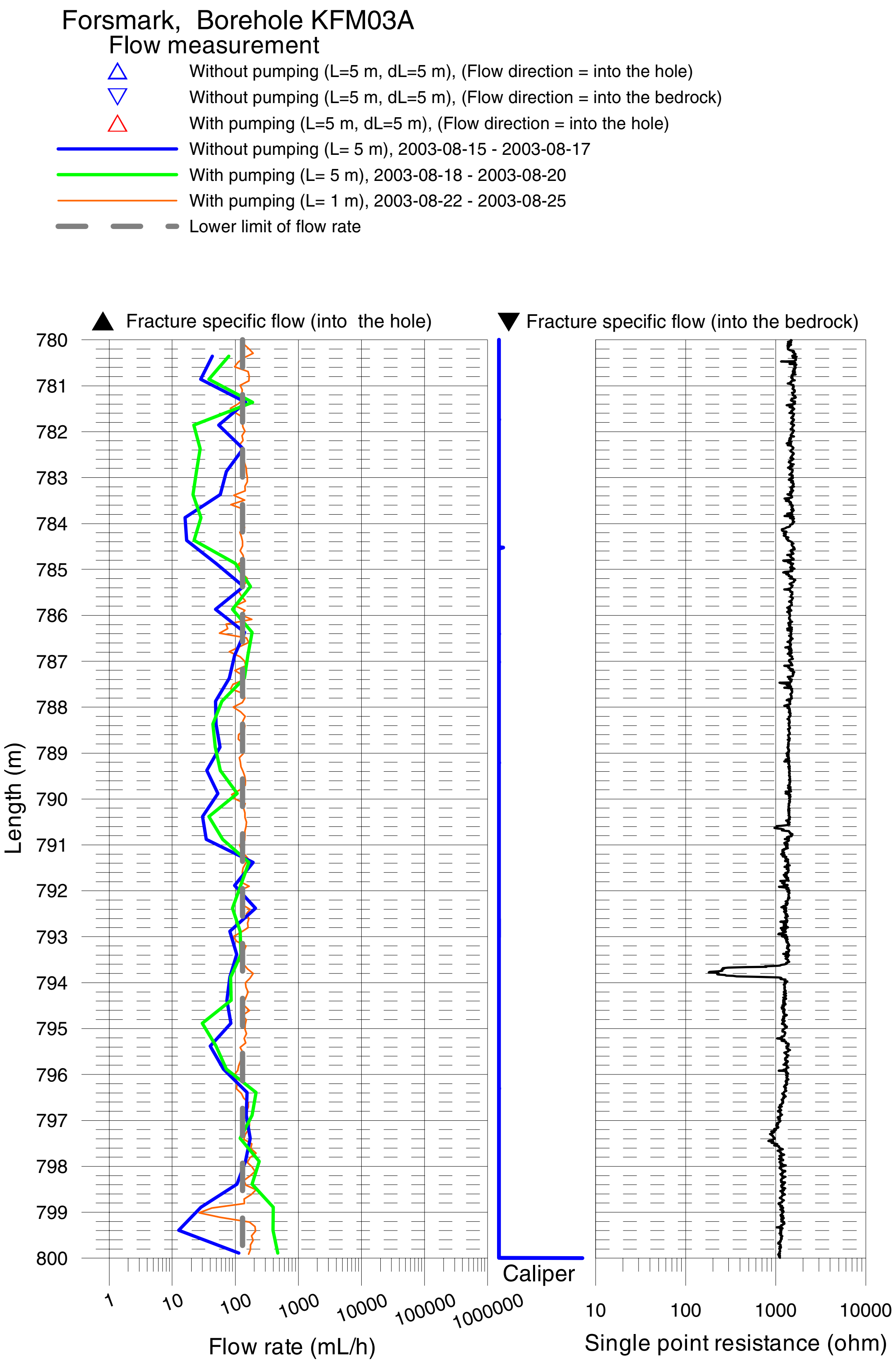
Appendix 3.32




Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

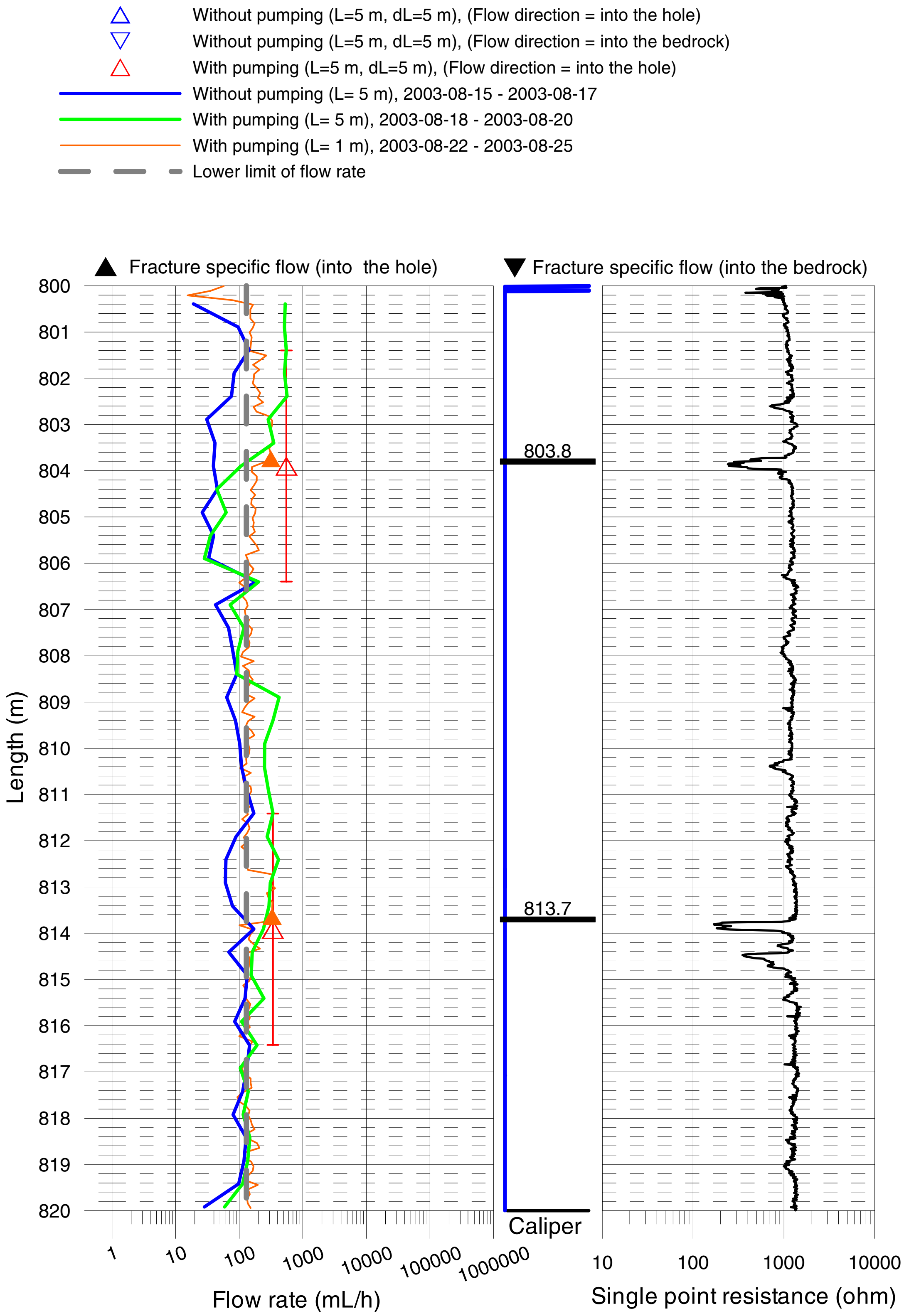


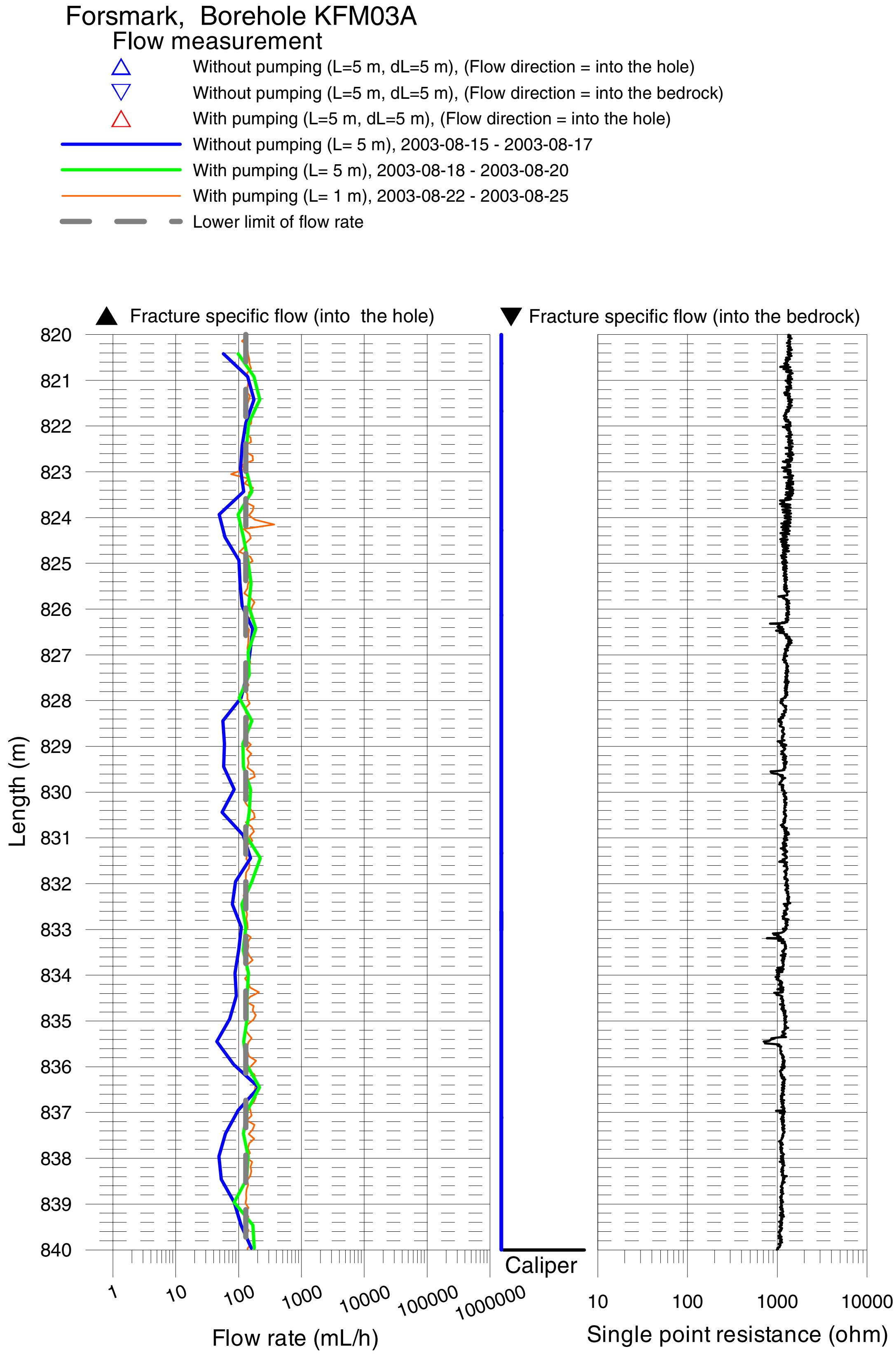
Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

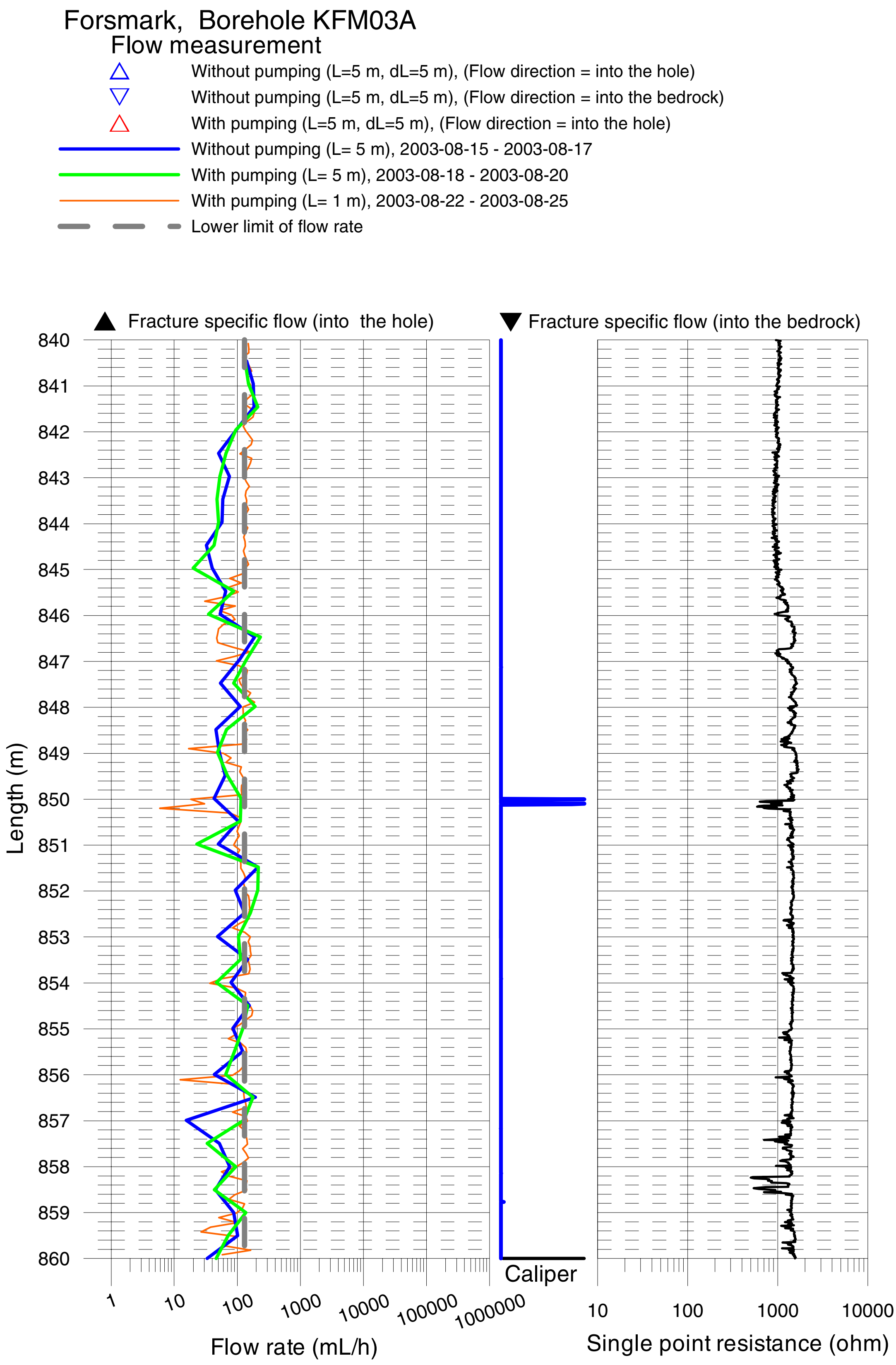

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

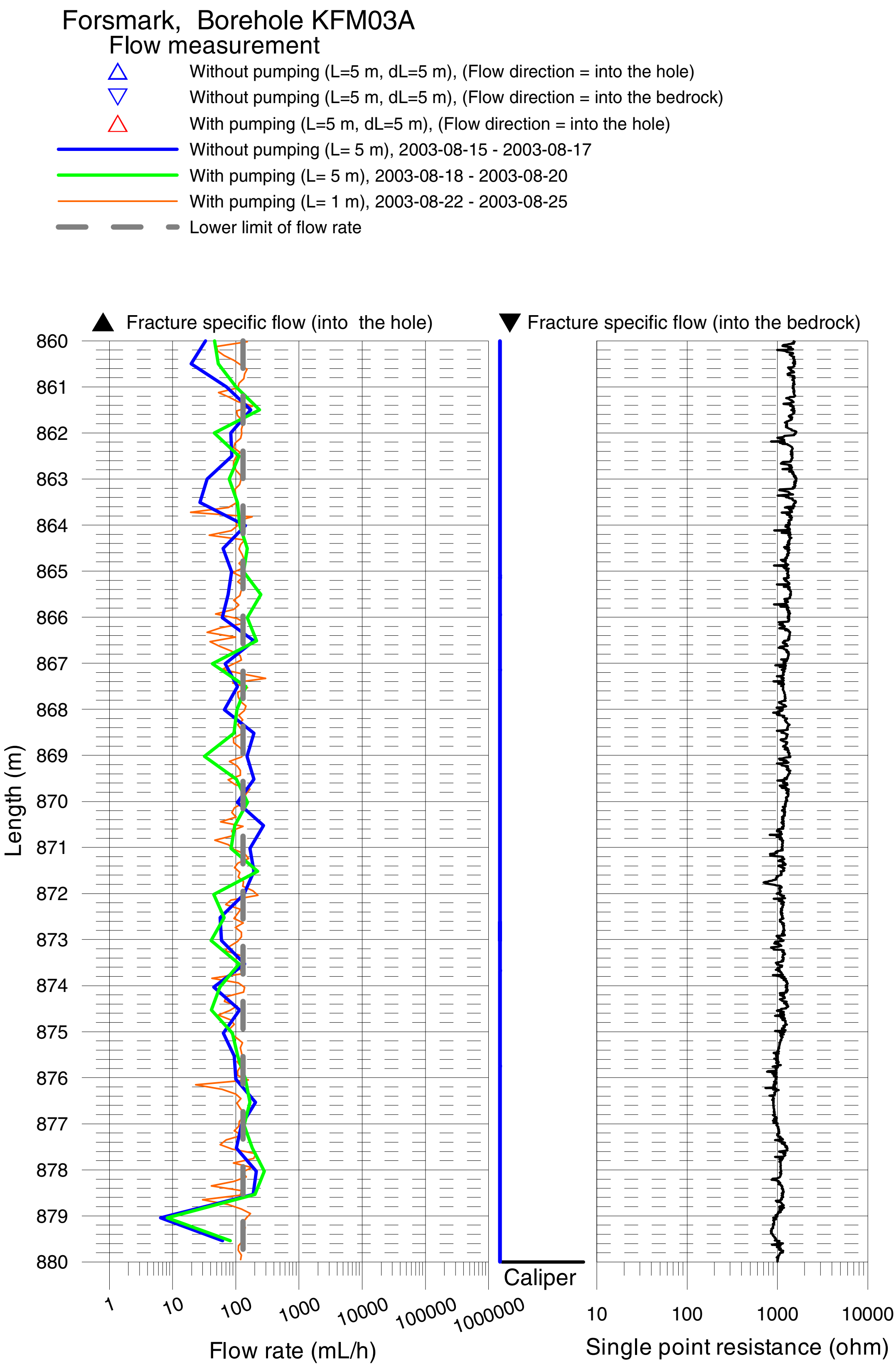
Forsmark, Borehole KFM03A

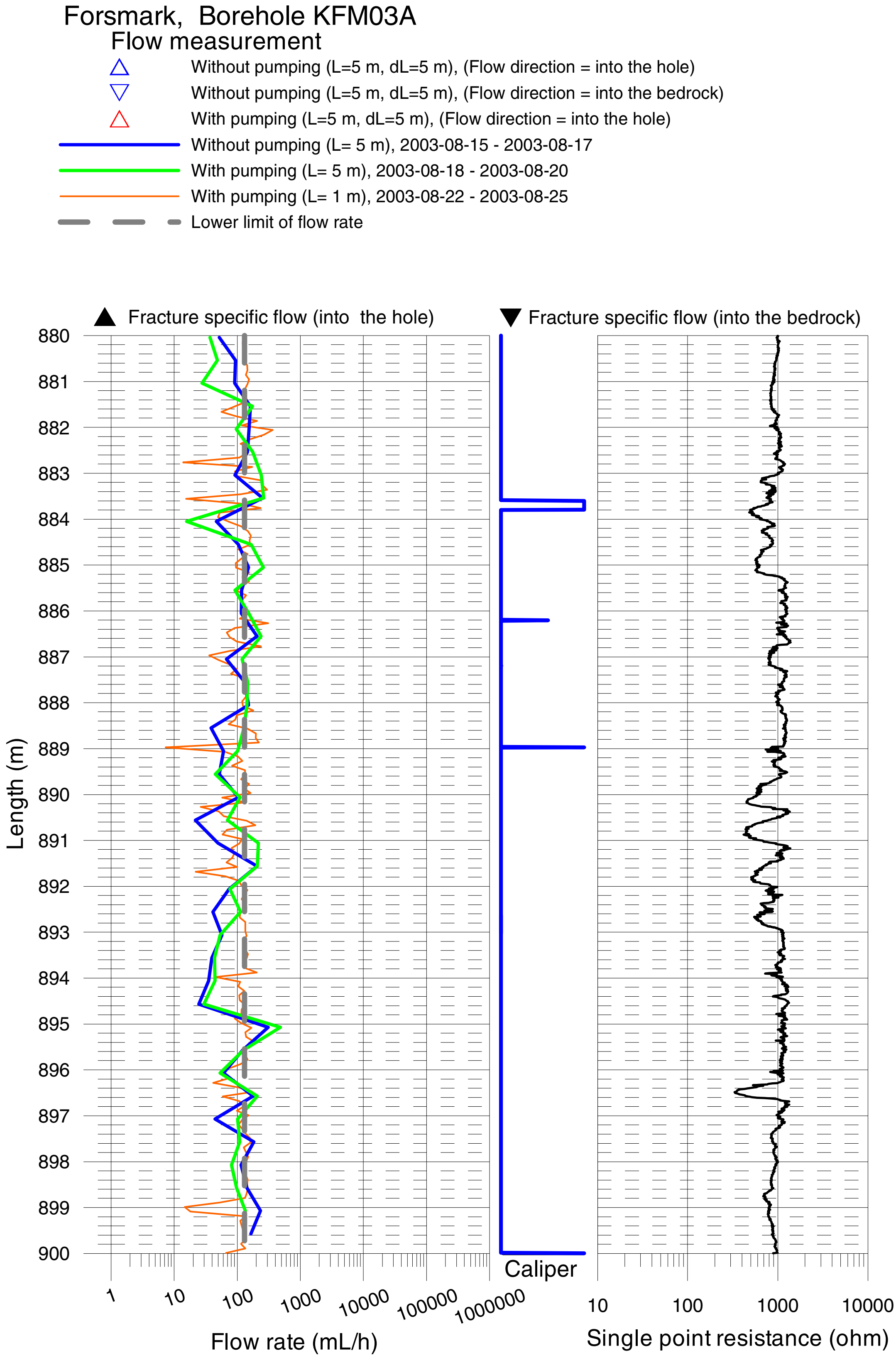
Flow measurement

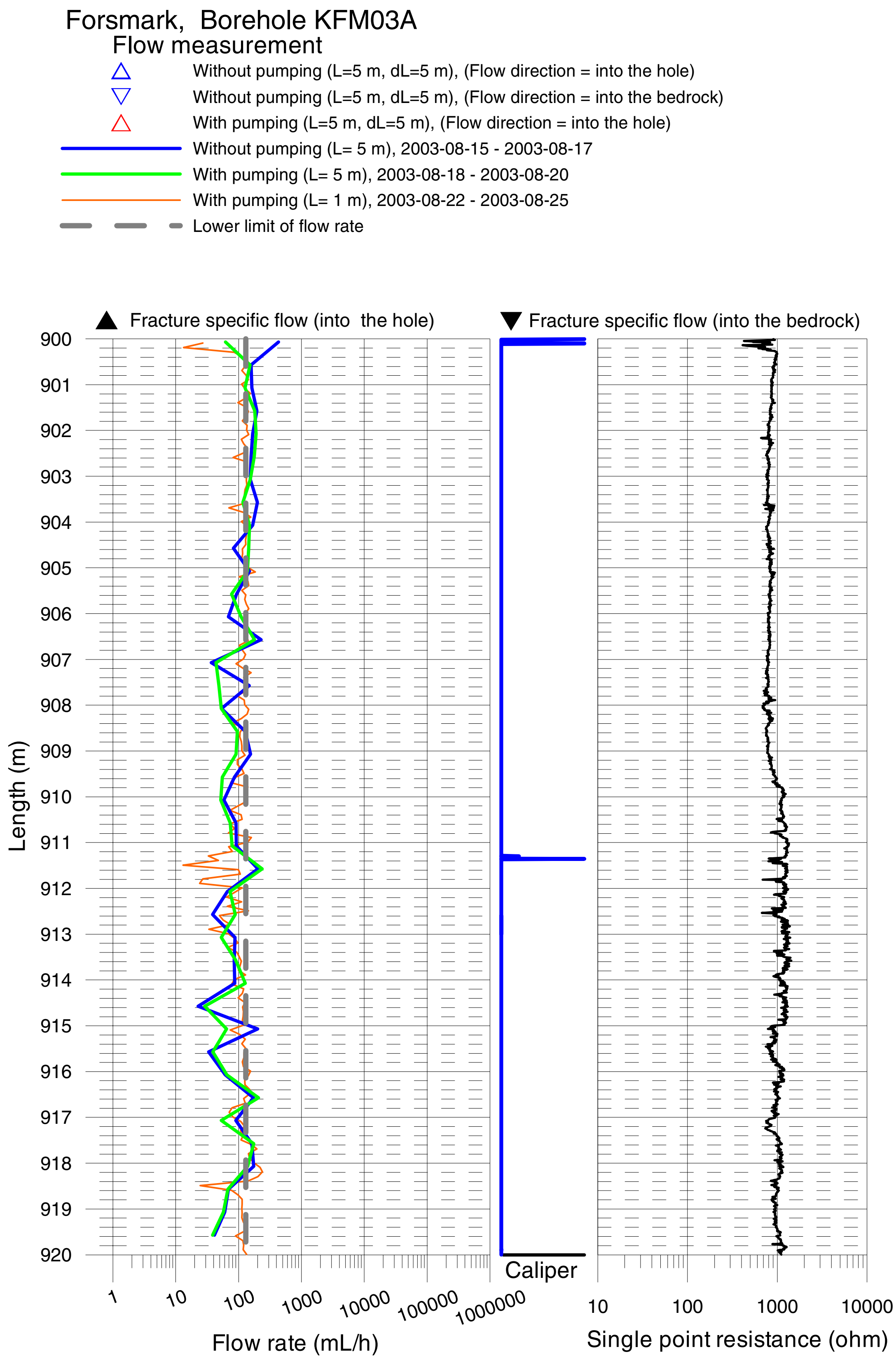


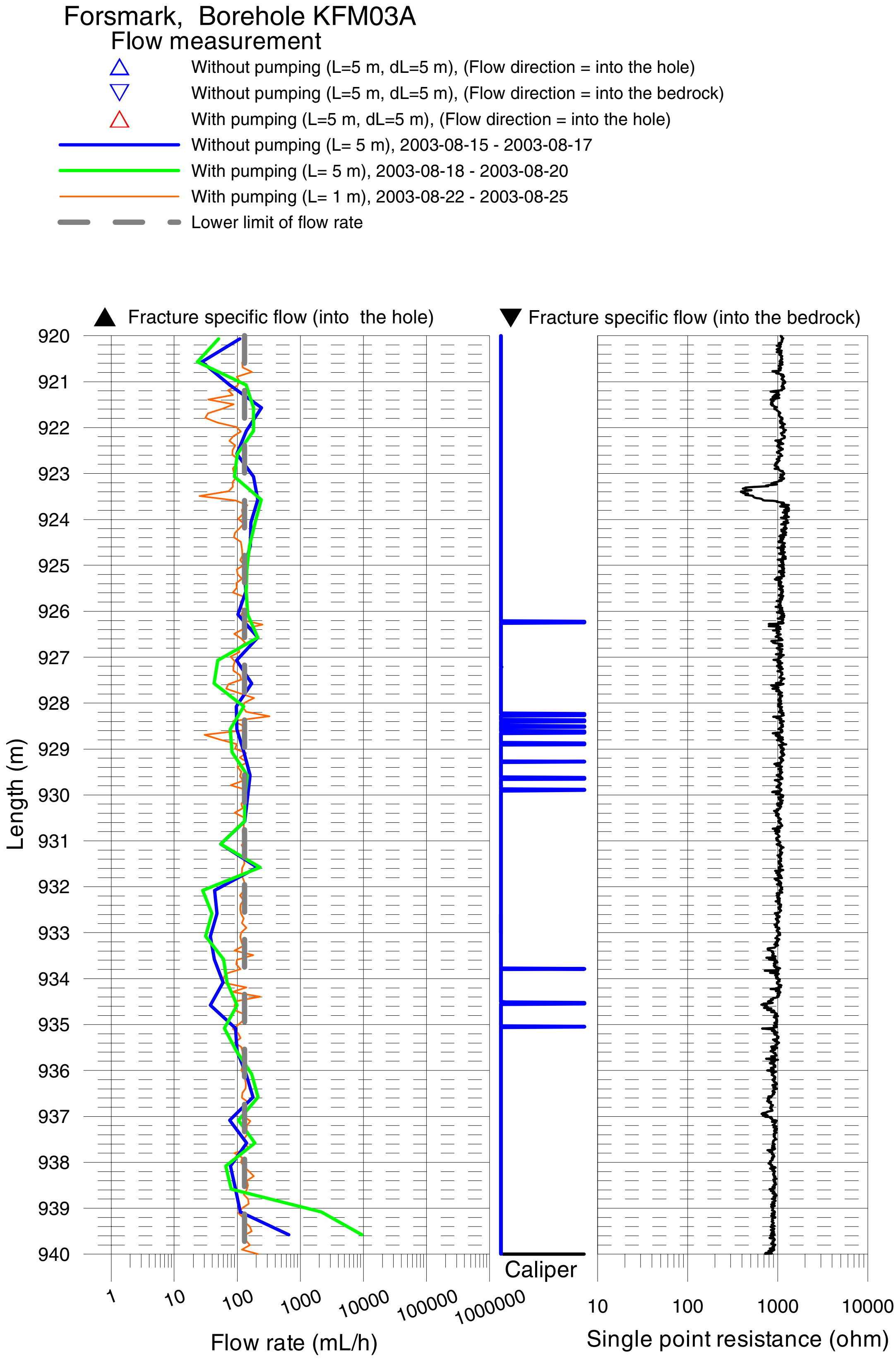

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

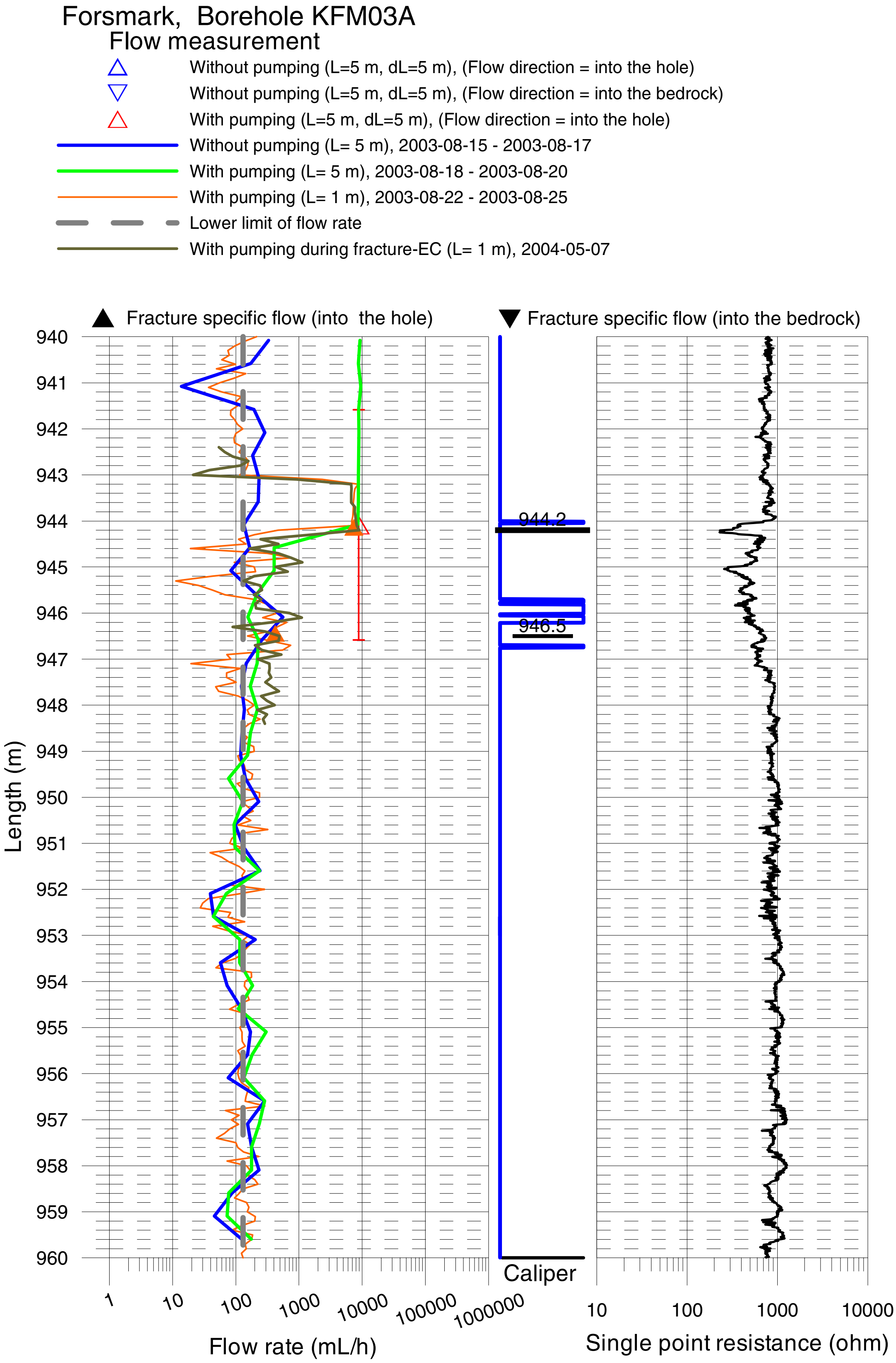

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)


Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

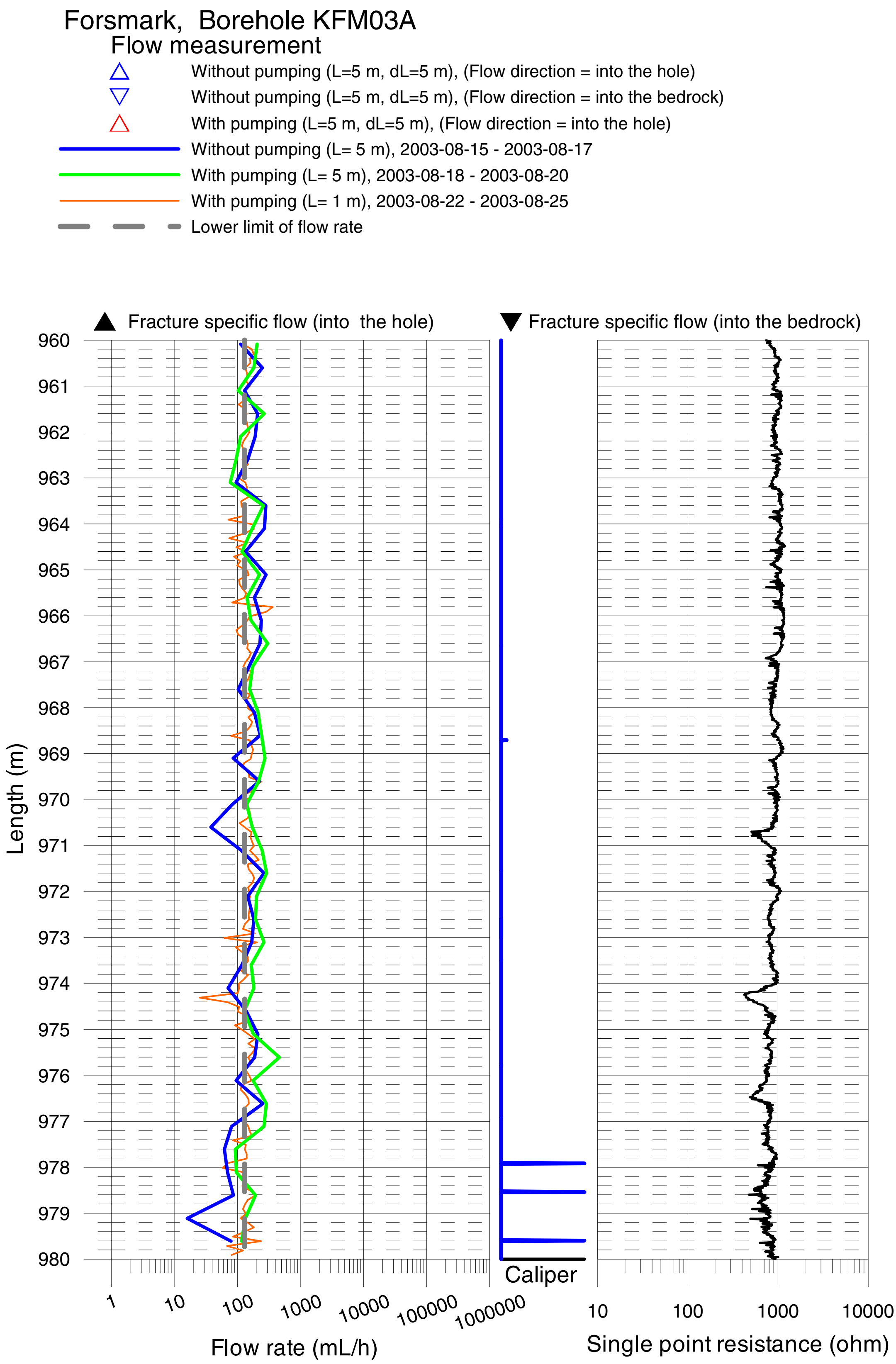

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)


Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

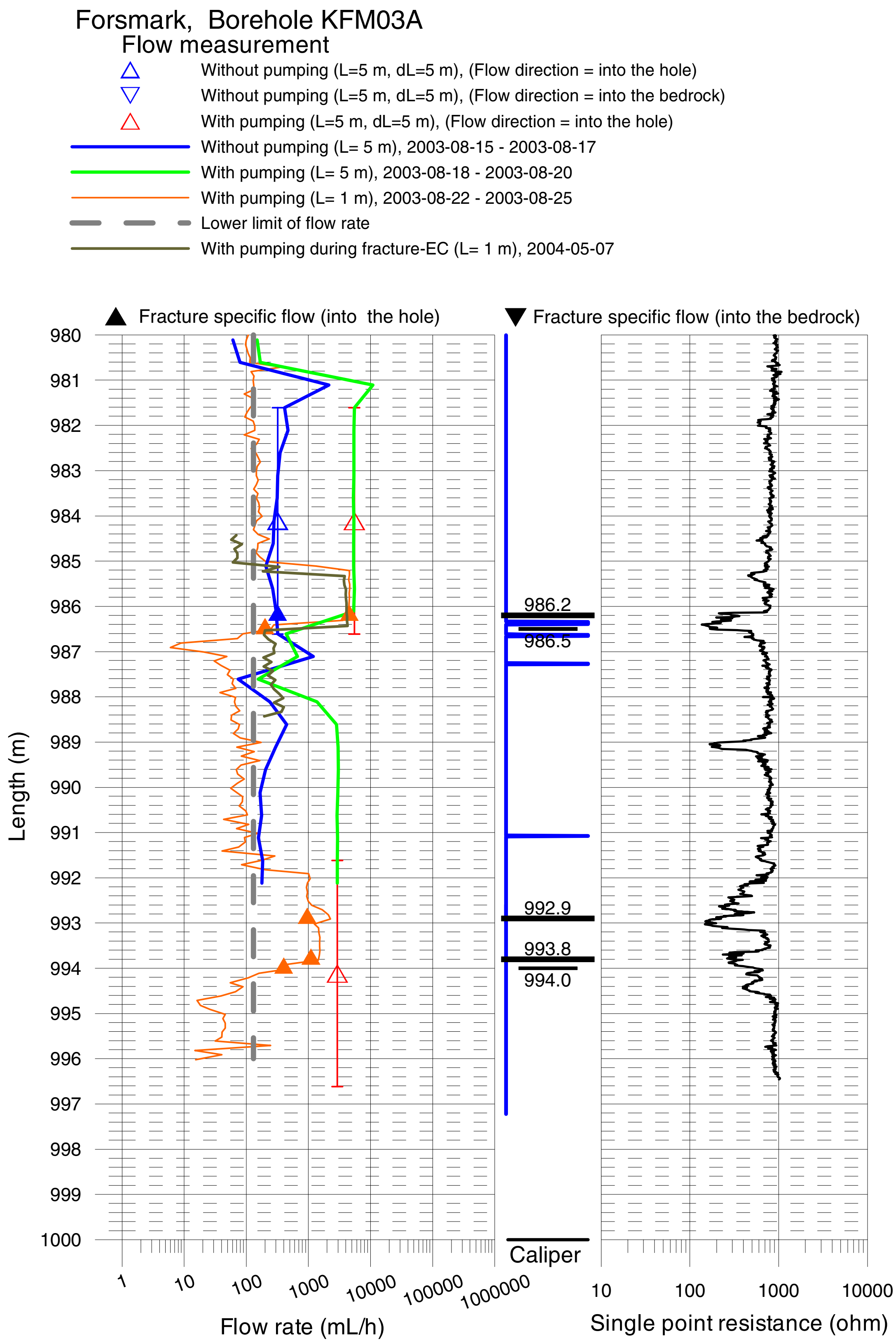

Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)



Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
With pumping during fracture-EC (L= 1 m), 2004-05-07
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
944.2
946.5
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

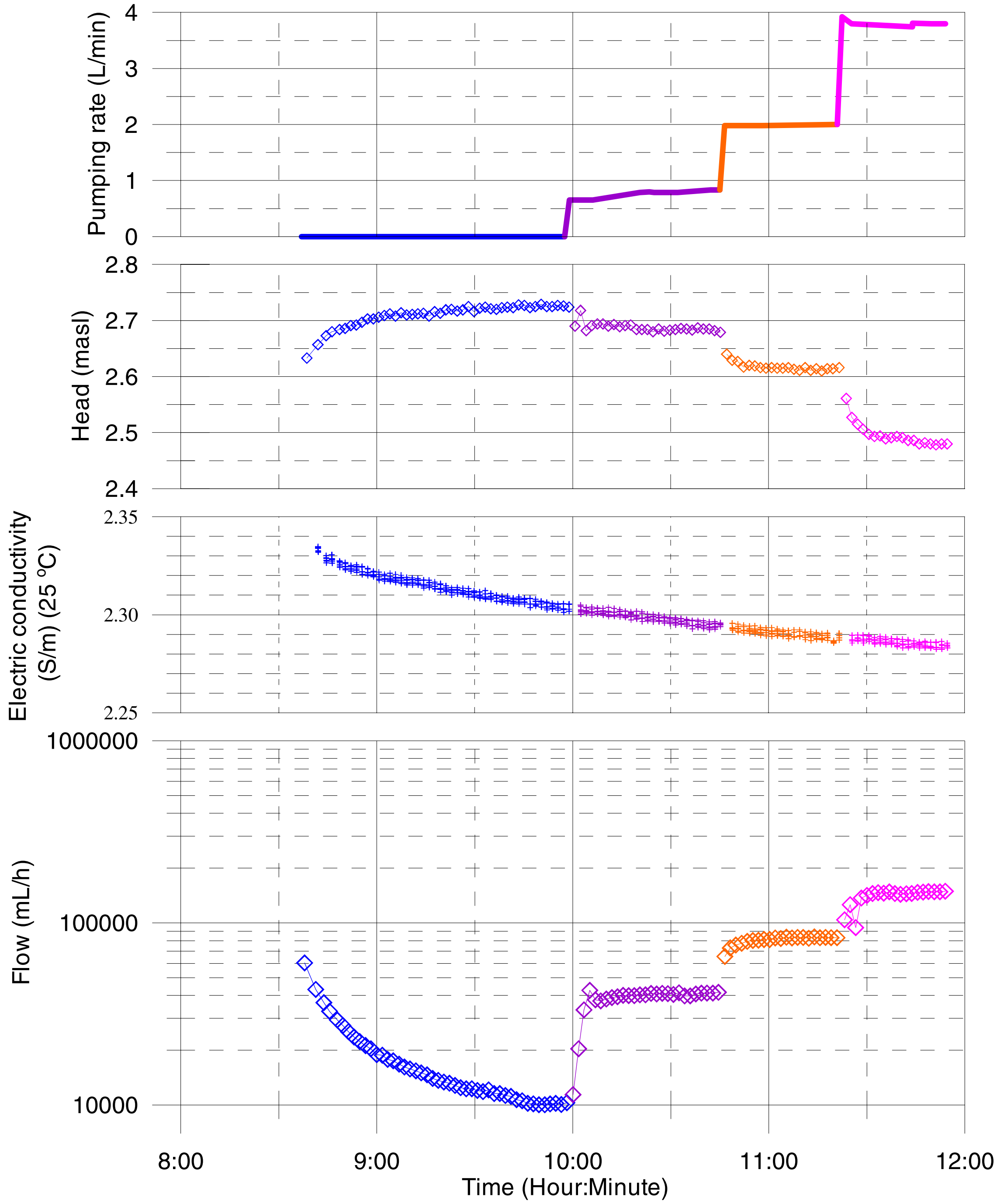


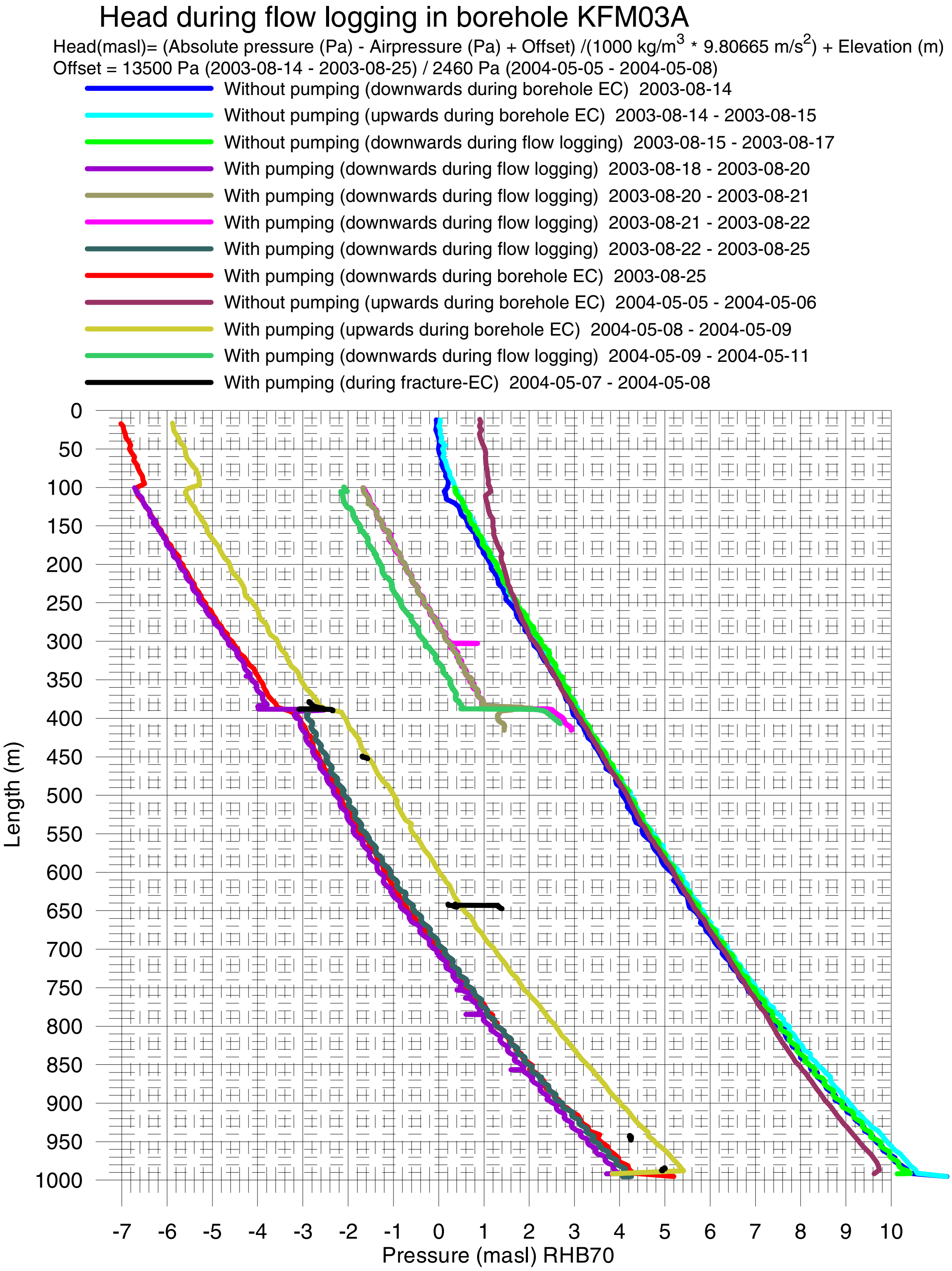
Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)



Forsmark, Borehole KFM03A
Flow measurement
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L= 5 m), 2003-08-15 - 2003-08-17
With pumping (L= 5 m), 2003-08-18 - 2003-08-20
With pumping (L= 1 m), 2003-08-22 - 2003-08-25
Lower limit of flow rate
With pumping during fracture-EC (L= 1 m), 2004-05-07
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
986.2
986.5
992.9
993.8
994.0
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

Forsmark KFM03A
Flow measurements at depth interval 388.14 - 389.14 m
2003-08-26




Head during flow logging in borehole KFM03A
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m3 * 9.80665 m/s2) + Elevation (m)
Offset = 13500 Pa (2003-08-14 - 2003-08-25) / 2460 Pa (2004-05-05 - 2004-05-08)
Without pumping (downwards during borehole EC) 2003-08-14
Without pumping (upwards during borehole EC) 2003-08-14 - 2003-08-15
Without pumping (downwards during flow logging) 2003-08-15 - 2003-08-17
With pumping (downwards during flow logging) 2003-08-18 - 2003-08-20
With pumping (downwards during flow logging) 2003-08-20 - 2003-08-21
With pumping (downwards during flow logging) 2003-08-21 - 2003-08-22
With pumping (downwards during flow logging) 2003-08-22 - 2003-08-25
With pumping (downwards during borehole EC) 2003-08-25
Without pumping (upwards during borehole EC) 2004-05-05 - 2004-05-06
With pumping (upwards during borehole EC) 2004-05-08 - 2004-05-09
With pumping (downwards during flow logging) 2004-05-09 - 2004-05-11
With pumping (during fracture-EC) 2004-05-07 - 2004-05-08
Length (m)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
10
Pressure (masl) RHB70

Appendix 6.1

Secup1 (m)	Borehole Head1 (masl)	Flow1 (mL/h)	Secup2 (m)	Borehole Head2 (masl)	Flow2 (mL/h)	Section Head (masl)	T_s (m^2/s)	Q-lower limit Practical (mL/h)	T_s-Lower Limit Theoretical (m^2/s)	T_s-Lower Limit Practical (m^2/s)	T_s-Upper Limit (m^2/s)
100.81	0.36	0	100.80	-1.67	0	-	-	300	8.13E-10	4.06E-08	4.06E-05
105.82	0.40	0	105.81	-1.62	123	-	1.68E-08	300	8.18E-10	4.09E-08	4.09E-05
110.82	0.46	0	110.81	-1.56	0	-	-	300	8.15E-10	4.08E-08	4.08E-05
115.82	0.52	-31	115.81	-1.52	420	0.38	6.05E-08	300	8.06E-10	4.03E-08	4.03E-05
120.82	0.55	-22	120.81	-1.48	204	0.35	3.06E-08	300	8.10E-10	4.05E-08	4.05E-05
125.82	0.60	-90	125.81	-1.42	620	0.34	9.70E-08	300	8.19E-10	4.10E-08	4.10E-05
130.82	0.65	0	130.81	-1.38	0	-	-	300	8.14E-10	4.07E-08	4.07E-05
135.82	0.68	0	135.82	-1.34	0	-	-	300	8.15E-10	4.07E-08	4.07E-05
140.83	0.71	0	140.82	-1.29	0	-	-	300	8.28E-10	4.14E-08	4.14E-05
145.83	0.76	0	145.82	-1.25	0	-	-	300	8.18E-10	4.09E-08	4.09E-05
150.83	0.81	0	150.83	-1.20	0	-	-	300	8.19E-10	4.09E-08	4.09E-05
155.84	0.86	0	155.83	-1.13	0	-	-	300	8.30E-10	4.15E-08	4.15E-05
160.84	0.92	0	160.83	-1.10	0	-	-	300	8.17E-10	4.09E-08	4.09E-05
165.85	0.95	0	165.84	-1.05	0	-	-	300	8.22E-10	4.11E-08	4.11E-05
170.85	0.98	0	170.84	-1.01	0	-	-	300	8.31E-10	4.15E-08	4.15E-05
175.85	1.05	0	175.84	-0.97	0	-	-	300	8.19E-10	4.10E-08	4.10E-05
180.85	1.11	0	180.84	-0.90	0	-	-	300	8.21E-10	4.10E-08	4.10E-05
185.85	1.15	0	185.84	-0.86	0	-	-	300	8.20E-10	4.10E-08	4.10E-05
190.85	1.21	0	190.85	-0.83	0	-	-	300	8.07E-10	4.04E-08	4.04E-05
195.85	1.27	0	195.85	-0.77	0	-	-	300	8.08E-10	4.04E-08	4.04E-05
200.85	1.29	0	200.85	-0.74	0	-	-	300	8.12E-10	4.06E-08	4.06E-05
205.85	1.34	0	205.85	-0.70	0	-	-	300	8.12E-10	4.06E-08	4.06E-05
210.85	1.39	0	210.85	-0.63	0	-	-	300	8.15E-10	4.08E-08	4.08E-05
215.86	1.43	0	215.86	-0.59	0	-	-	300	8.16E-10	4.08E-08	4.08E-05
220.86	1.46	0	220.86	-0.56	0	-	-	300	8.16E-10	4.08E-08	4.08E-05
225.87	1.53	0	225.87	-0.50	0	-	-	300	8.13E-10	4.07E-08	4.07E-05
230.87	1.57	0	230.87	-0.46	0	-	-	300	8.10E-10	4.05E-08	4.05E-05
235.88	1.61	0	235.87	-0.43	0	-	-	300	8.11E-10	4.06E-08	4.06E-05
240.88	1.67	0	240.88	-0.36	0	-	-	300	8.14E-10	4.07E-08	4.07E-05
245.89	1.73	0	245.88	-0.32	0	-	-	300	8.07E-10	4.04E-08	4.04E-05

Secup1 (m)	Borehole Head1 (masl)	Flow1 (mL/h)	Secup2 (m)	Borehole Head2 (masl)	Flow2 (mL/h)	Section Head (masl)	T_s (m^2/s)	Q-lower limit Practical (mL/h)	T_s-Lower Limit Theoretical (m^2/s)	T_s-Lower Limit Practical (m^2/s)	T_s-Upper Limit (m^2/s)	Comments
250.89	1.76	0	250.89	-0.29	0	-	-	300	8.06E-10	4.03E-08	4.03E-05	
255.90	1.82	0	255.89	-0.22	0	-	-	300	8.11E-10	4.06E-08	4.06E-05	
260.90	1.88	0	260.89	-0.16	0	-	-	300	8.07E-10	4.04E-08	4.04E-05	
265.90	1.93	0	265.89	-0.13	0	-	-	300	8.01E-10	4.01E-08	4.01E-05	
270.90	1.96	0	270.89	-0.06	0	-	-	300	8.15E-10	4.07E-08	4.07E-05	
275.89	2.04	0	275.89	-0.02	0	-	-	300	8.03E-10	4.01E-08	4.01E-05	
280.89	2.09	0	280.88	0.03	0	-	-	300	8.01E-10	4.01E-08	4.01E-05	
285.88	2.13	0	285.88	0.10	0	-	-	300	8.12E-10	4.06E-08	4.06E-05	
290.88	2.19	0	290.88	0.13	0	-	-	300	8.02E-10	4.01E-08	4.01E-05	
295.88	2.25	0	295.88	0.18	0	-	-	300	7.97E-10	3.99E-08	3.99E-05	
300.88	2.28	0	300.88	0.24	0	-	-	300	8.08E-10	4.04E-08	4.04E-05	
305.88	2.35	0	305.88	0.29	0	-	-	300	8.01E-10	4.01E-08	4.01E-05	
310.89	2.42	0	310.89	0.35	0	-	-	300	7.94E-10	3.97E-08	3.97E-05	
315.89	2.45	0	315.89	0.41	0	-	-	300	8.10E-10	4.05E-08	4.05E-05	
320.89	2.48	0	320.89	0.44	0	-	-	300	8.08E-10	4.04E-08	4.04E-05	
325.89	2.54	0	325.89	0.48	0	-	-	300	8.01E-10	4.01E-08	4.01E-05	
330.90	2.57	0	330.90	0.54	0	-	-	300	8.15E-10	4.07E-08	4.07E-05	
335.90	2.60	0	335.90	0.57	0	-	-	300	8.14E-10	4.07E-08	4.07E-05	
340.91	2.67	0	340.91	0.62	0	-	-	300	8.04E-10	4.02E-08	4.02E-05	
345.91	2.72	0	345.91	0.70	0	-	-	300	8.16E-10	4.08E-08	4.08E-05	
350.92	2.74	0	350.92	0.73	0	-	-	300	8.23E-10	4.11E-08	4.11E-05	
355.93	2.80	-136	355.92	0.78	10446	2.78	1.44E-06	300	8.14E-10	4.07E-08	4.07E-05	
360.93	2.85	-213	360.93	0.82	14375	2.82	1.98E-06	300	8.13E-10	4.07E-08	4.07E-05	
365.94	2.87	-249	365.93	0.85	6096	2.79	8.65E-07	300	8.17E-10	4.08E-08	4.08E-05	
370.94	2.93	-462	370.94	0.91	14325	2.87	2.01E-06	300	8.16E-10	4.08E-08	4.08E-05	
375.95	3.00	0	375.95	0.98	5415	-	7.35E-07	300	8.15E-10	4.07E-08	4.07E-05	
380.96	3.02	0	380.95	1.05	912	-	1.28E-07	300	8.38E-10	4.19E-08	4.19E-05	
385.96	2.73	10000	385.96	2.61	84000	2.75	1.74E-04	300	8.38E-10	4.19E-08	6.87E-04	From App 4
390.96	3.14	0	390.96	-3.13	112	-	4.93E-09	30	2.63E-10	1.31E-09	1.31E-05	
395.97	3.19	0	395.96	-3.13	43	-	1.87E-09	30	2.61E-10	1.30E-09	1.30E-05	

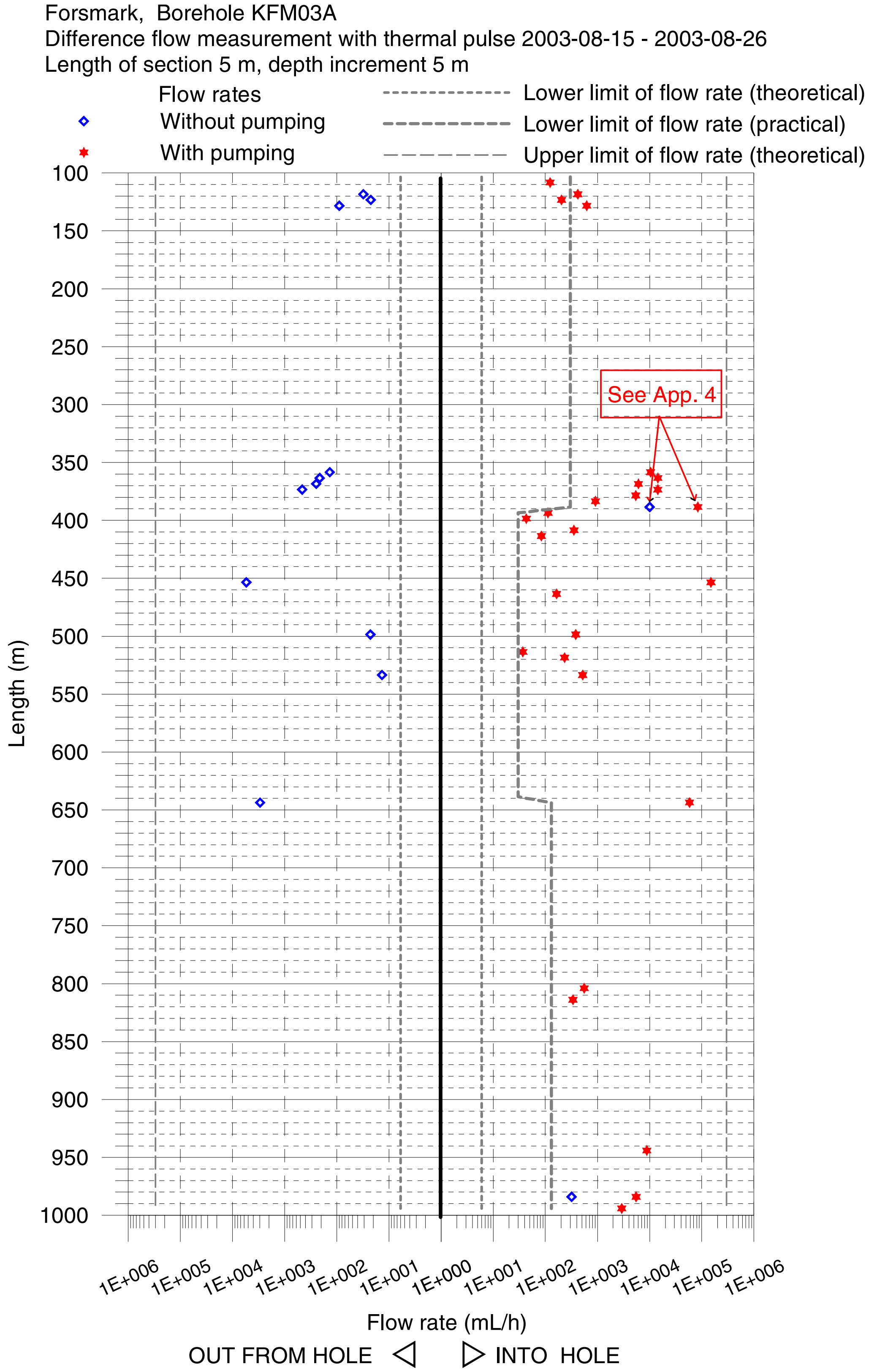
Appendix 6.3

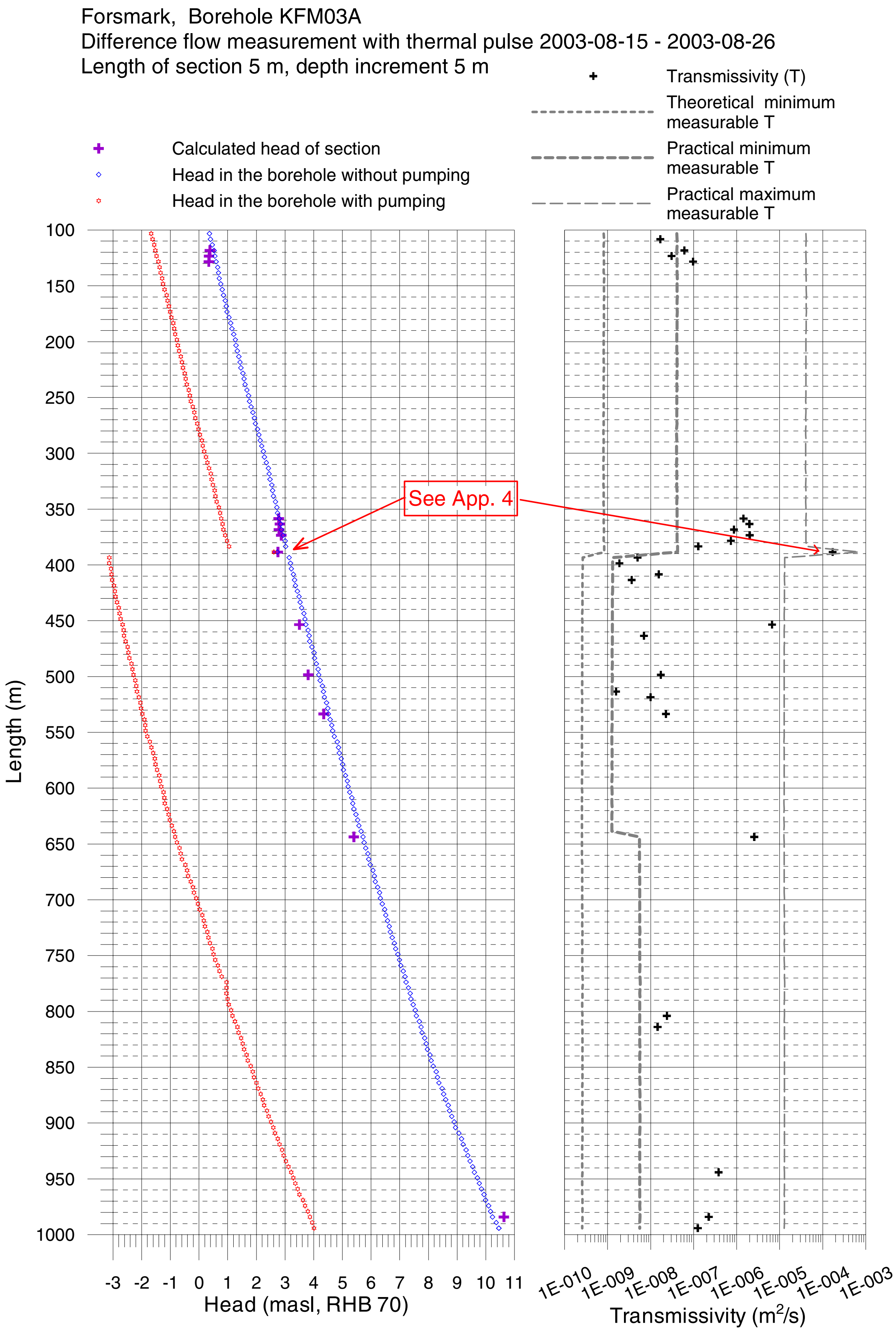
Secup1 (m)	Borehole Head1 (masl)	Flow1 (mL/h)	Secup2 (m)	Borehole Head2 (masl)	Flow2 (mL/h)	Section Head (masl)	T_s (m^2/s)	Q-lower limit Practical (mL/h)	T_s-Lower Limit Theoretical (m^2/s)	T_s-Lower Limit Practical (m^2/s)	T_s-Upper Limit (m^2/s)
400.97	3.22	0	400.96	-3.07	0	-	-	30	2.62E-10	1.31E-09	1.31E-05
405.97	3.29	0	405.96	-3.05	354	-	1.54E-08	30	2.60E-10	1.30E-09	1.30E-05
410.97	3.33	0	410.96	-3.03	84	-	3.62E-09	30	2.59E-10	1.30E-09	1.30E-05
415.97	3.36	0	415.97	-2.97	0	-	-	30	2.60E-10	1.30E-09	1.30E-05
420.98	3.43	0	420.97	-2.93	0	-	-	30	2.59E-10	1.30E-09	1.30E-05
425.98	3.49	0	425.97	-2.91	0	-	-	30	2.58E-10	1.29E-09	1.29E-05
430.98	3.52	0	430.97	-2.86	0	-	-	30	2.58E-10	1.29E-09	1.29E-05
435.98	3.58	0	435.97	-2.80	0	-	-	30	2.59E-10	1.29E-09	1.29E-05
440.98	3.66	0	440.97	-2.77	0	-	-	30	2.56E-10	1.28E-09	1.28E-05
445.98	3.70	0	445.97	-2.74	0	-	-	30	2.56E-10	1.28E-09	1.28E-05
450.97	3.73	-5436	450.96	-2.67	149711	3.50	6.65E-06	30	2.58E-10	1.29E-09	1.29E-05
455.97	3.80	0	455.96	-2.63	0	-	-	30	2.56E-10	1.28E-09	1.28E-05
460.97	3.84	0	460.96	-2.62	164	-	7.00E-09	30	2.55E-10	1.28E-09	1.28E-05
465.97	3.86	0	465.96	-2.56	0	-	-	30	2.57E-10	1.28E-09	1.28E-05
470.97	3.94	0	470.97	-2.49	0	-	-	30	2.56E-10	1.28E-09	1.28E-05
475.98	4.01	0	475.97	-2.46	0	-	-	30	2.55E-10	1.27E-09	1.27E-05
480.98	4.03	0	480.97	-2.43	0	-	-	30	2.55E-10	1.28E-09	1.28E-05
485.98	4.09	0	485.97	-2.36	0	-	-	30	2.56E-10	1.28E-09	1.28E-05
490.98	4.16	0	490.97	-2.32	0	-	-	30	2.55E-10	1.27E-09	1.27E-05
495.98	4.18	-23	495.97	-2.29	382	3.81	1.72E-08	30	2.55E-10	1.28E-09	1.28E-05
500.98	4.23	0	500.98	-2.22	0	-	-	30	2.56E-10	1.28E-09	1.28E-05
505.98	4.31	0	505.98	-2.19	0	-	-	30	2.54E-10	1.27E-09	1.27E-05
510.99	4.34	0	510.98	-2.16	37	-	1.57E-09	30	2.53E-10	1.27E-09	1.27E-05
515.99	4.37	0	515.99	-2.10	234	-	9.95E-09	30	2.55E-10	1.27E-09	1.27E-05
521.00	4.45	0	521.00	-2.04	0	-	-	30	2.54E-10	1.27E-09	1.27E-05
526.01	4.49	0	526.01	-2.02	0	-	-	30	2.53E-10	1.27E-09	1.27E-05
531.02	4.51	-14	531.02	-1.98	519	4.35	2.26E-08	30	2.54E-10	1.27E-09	1.27E-05
536.03	4.57	0	536.03	-1.90	0	-	-	30	2.55E-10	1.27E-09	1.27E-05
541.04	4.63	0	541.04	-1.88	0	-	-	30	2.53E-10	1.27E-09	1.27E-05
546.05	4.66	0	546.05	-1.86	0	-	-	30	2.53E-10	1.26E-09	1.26E-05

Secup1 (m)	Borehole Head1 (masl)	Flow1 (mL/h)	Secup2 (m)	Borehole Head2 (masl)	Flow2 (mL/h)	Section Head (masl)	T_s (m^2/s)	Q-lower limit Practical (mL/h)	T_s-Lower Limit Theoretical (m^2/s)	T_s-Lower Limit Practical (m^2/s)	T_s-Upper Limit (m^2/s)
551.06	4.72	0	551.06	-1.80	0	-	-	30	2.53E-10	1.26E-09	1.26E-05
556.07	4.82	0	556.07	-1.71	0	-	-	30	2.52E-10	1.26E-09	1.26E-05
561.08	4.86	0	561.08	-1.66	0	-	-	30	2.53E-10	1.26E-09	1.26E-05
566.09	4.89	0	566.09	-1.60	0	-	-	30	2.54E-10	1.27E-09	1.27E-05
571.10	4.96	0	571.10	-1.54	0	-	-	30	2.54E-10	1.27E-09	1.27E-05
576.10	5.01	0	576.10	-1.52	0	-	-	30	2.53E-10	1.26E-09	1.26E-05
581.10	5.03	0	581.10	-1.46	0	-	-	30	2.54E-10	1.27E-09	1.27E-05
586.10	5.11	0	586.09	-1.39	0	-	-	30	2.54E-10	1.27E-09	1.27E-05
591.10	5.17	0	591.09	-1.36	0	-	-	30	2.53E-10	1.26E-09	1.26E-05
596.10	5.20	0	596.09	-1.32	0	-	-	30	2.53E-10	1.26E-09	1.26E-05
601.10	5.26	0	601.09	-1.24	0	-	-	30	2.54E-10	1.27E-09	1.27E-05
606.10	5.33	0	606.09	-1.21	0	-	-	30	2.52E-10	1.26E-09	1.26E-05
611.10	5.36	0	611.09	-1.19	0	-	-	30	2.51E-10	1.26E-09	1.26E-05
616.11	5.40	0	616.10	-1.11	0	-	-	30	2.53E-10	1.27E-09	1.27E-05
621.11	5.48	0	621.10	-1.06	0	-	-	30	2.52E-10	1.26E-09	1.26E-05
626.12	5.53	0	626.11	-1.02	0	-	-	30	2.52E-10	1.26E-09	1.26E-05
631.12	5.58	0	631.11	-0.95	0	-	-	30	2.53E-10	1.26E-09	1.26E-05
636.12	5.65	0	636.11	-0.88	0	-	-	30	2.52E-10	1.26E-09	1.26E-05
641.13	5.72	-2950	641.12	-0.83	58014	5.40	2.56E-06	130	2.52E-10	5.45E-09	1.26E-05
646.13	5.76	0	646.12	-0.77	0	-	-	130	2.53E-10	5.47E-09	1.26E-05
651.14	5.81	0	651.13	-0.68	0	-	-	130	2.54E-10	5.50E-09	1.27E-05
656.14	5.89	0	656.13	-0.64	0	-	-	130	2.53E-10	5.47E-09	1.26E-05
661.15	5.92	0	661.14	-0.60	0	-	-	130	2.53E-10	5.48E-09	1.27E-05
666.15	5.97	0	666.14	-0.47	0	-	-	130	2.56E-10	5.54E-09	1.28E-05
671.16	6.07	0	671.15	-0.41	0	-	-	130	2.54E-10	5.51E-09	1.27E-05
676.16	6.12	0	676.15	-0.38	0	-	-	130	2.54E-10	5.50E-09	1.27E-05
681.17	6.15	0	681.16	-0.29	0	-	-	130	2.56E-10	5.55E-09	1.28E-05
686.17	6.23	0	686.16	-0.21	0	-	-	130	2.56E-10	5.55E-09	1.28E-05
691.18	6.30	0	691.17	-0.18	0	-	-	130	2.55E-10	5.52E-09	1.27E-05
696.19	6.32	0	696.18	-0.10	0	-	-	130	2.57E-10	5.56E-09	1.28E-05

Secup1 (m)	Borehole Head1 (masl)	Flow1 (mL/h)	Secup2 (m)	Borehole Head2 (masl)	Flow2 (mL/h)	Section Head (masl)	T_s (m^2/s)	Q-lower limit Practical (mL/h)	T_s-Lower Limit Theoretical (m^2/s)	T_s-Lower Limit Practical (m^2/s)	T_s-Upper Limit (m^2/s)
701.21	6.39	0	701.20	-0.04	0	-	-	130	2.56E-10	5.56E-09	1.28E-05
706.22	6.47	0	706.22	0.02	0	-	-	130	2.55E-10	5.54E-09	1.28E-05
711.24	6.51	0	711.24	0.11	0	-	-	130	2.58E-10	5.58E-09	1.29E-05
716.26	6.57	0	716.25	0.17	0	-	-	130	2.57E-10	5.57E-09	1.29E-05
721.27	6.63	0	721.27	0.21	0	-	-	130	2.56E-10	5.56E-09	1.28E-05
726.29	6.67	0	726.29	0.29	0	-	-	130	2.59E-10	5.60E-09	1.29E-05
731.29	6.74	0	731.29	0.33	0	-	-	130	2.57E-10	5.57E-09	1.29E-05
736.30	6.81	0	736.30	0.38	0	-	-	130	2.56E-10	5.55E-09	1.28E-05
741.31	6.86	0	741.31	0.47	0	-	-	130	2.58E-10	5.59E-09	1.29E-05
746.32	6.94	0	746.32	0.50	0	-	-	130	2.56E-10	5.55E-09	1.28E-05
751.33	6.99	0	751.33	0.56	0	-	-	130	2.56E-10	5.56E-09	1.28E-05
756.33	7.04	0	756.33	0.66	0	-	-	130	2.58E-10	5.60E-09	1.29E-05
761.34	7.12	0	761.34	0.71	0	-	-	130	2.57E-10	5.57E-09	1.29E-05
766.35	7.19	0	766.35	0.79	0	-	-	130	2.58E-10	5.59E-09	1.29E-05
771.36	7.22	0	771.36	0.96	0	-	-	130	2.63E-10	5.70E-09	1.32E-05
776.36	7.30	0	776.36	0.96	0	-	-	130	2.60E-10	5.63E-09	1.30E-05
781.37	7.37	0	781.37	0.96	0	-	-	130	2.57E-10	5.58E-09	1.29E-05
786.38	7.39	0	786.38	1.00	0	-	-	130	2.58E-10	5.59E-09	1.29E-05
791.38	7.47	0	791.38	1.04	0	-	-	130	2.56E-10	5.55E-09	1.28E-05
796.39	7.54	0	796.39	1.12	0	-	-	130	2.57E-10	5.56E-09	1.28E-05
801.40	7.58	0	801.40	1.17	555	-	2.38E-08	130	2.57E-10	5.57E-09	1.29E-05
806.41	7.68	0	806.41	1.26	0	-	-	130	2.57E-10	5.56E-09	1.28E-05
811.41	7.74	0	811.41	1.34	338	-	1.45E-08	130	2.58E-10	5.58E-09	1.29E-05
816.42	7.78	0	816.42	1.38	0	-	-	130	2.58E-10	5.58E-09	1.29E-05
821.43	7.87	0	821.43	1.47	0	-	-	130	2.58E-10	5.58E-09	1.29E-05
826.44	7.92	0	826.44	1.52	0	-	-	130	2.58E-10	5.58E-09	1.29E-05
831.45	7.96	0	831.45	1.57	0	-	-	130	2.58E-10	5.59E-09	1.29E-05
836.46	8.05	0	836.46	1.66	0	-	-	130	2.58E-10	5.58E-09	1.29E-05
841.47	8.10	0	841.47	1.70	0	-	-	130	2.58E-10	5.58E-09	1.29E-05
846.48	8.17	0	846.48	1.80	0	-	-	130	2.59E-10	5.61E-09	1.30E-05

Secup1 (m)	Borehole Head1 (masl)	Flow1 (mL/h)	Secup2 (m)	Borehole Head2 (masl)	Flow2 (mL/h)	Section Head (masl)	T_s (m^2/s)	Q-lower limit Practical (mL/h)	T_s-Lower Limit Theoretical (m^2/s)	T_s-Lower Limit Practical (m^2/s)	T_s-Upper Limit (m^2/s)
851.49	8.28	0	851.49	1.87	0	-	-	130	2.57E-10	5.58E-09	1.29E-05
856.50	8.32	0	856.50	1.91	0	-	-	130	2.57E-10	5.58E-09	1.29E-05
861.51	8.37	0	861.51	2.00	0	-	-	130	2.59E-10	5.61E-09	1.29E-05
866.52	8.48	0	866.52	2.06	0	-	-	130	2.57E-10	5.57E-09	1.28E-05
871.53	8.53	0	871.53	2.15	0	-	-	130	2.58E-10	5.60E-09	1.29E-05
876.54	8.60	0	876.54	2.23	0	-	-	130	2.59E-10	5.60E-09	1.29E-05
881.55	8.69	0	881.55	2.27	0	-	-	130	2.57E-10	5.56E-09	1.28E-05
886.56	8.74	0	886.56	2.37	0	-	-	130	2.59E-10	5.61E-09	1.29E-05
891.57	8.81	0	891.57	2.43	0	-	-	130	2.58E-10	5.59E-09	1.29E-05
896.57	8.90	0	896.57	2.51	0	-	-	130	2.58E-10	5.59E-09	1.29E-05
901.57	8.94	0	901.57	2.59	0	-	-	130	2.60E-10	5.62E-09	1.30E-05
906.57	9.06	0	906.57	2.65	0	-	-	130	2.57E-10	5.57E-09	1.29E-05
911.57	9.15	0	911.57	2.75	0	-	-	130	2.57E-10	5.57E-09	1.29E-05
916.57	9.21	0	916.57	2.81	0	-	-	130	2.57E-10	5.58E-09	1.29E-05
921.57	9.32	0	921.57	2.90	0	-	-	130	2.57E-10	5.57E-09	1.28E-05
926.58	9.37	0	926.58	2.95	0	-	-	130	2.57E-10	5.56E-09	1.28E-05
931.58	9.45	0	931.58	3.03	0	-	-	130	2.57E-10	5.56E-09	1.28E-05
936.58	9.54	0	936.58	3.12	0	-	-	130	2.57E-10	5.56E-09	1.28E-05
941.59	9.60	0	941.59	3.21	8815	-	3.79E-07	130	2.58E-10	5.59E-09	1.29E-05
946.59	9.71	0	946.59	3.29	0	-	-	130	2.57E-10	5.56E-09	1.28E-05
951.59	9.78	0	951.59	3.36	0	-	-	130	2.57E-10	5.56E-09	1.28E-05
956.60	9.85	0	956.60	3.44	0	-	-	130	2.57E-10	5.57E-09	1.29E-05
961.60	9.94	0	961.60	3.50	0	-	-	130	2.56E-10	5.54E-09	1.28E-05
966.60	10.00	0	966.60	3.62	0	-	-	130	2.59E-10	5.61E-09	1.29E-05
971.61	10.10	0	971.61	3.70	0	-	-	130	2.58E-10	5.58E-09	1.29E-05
976.61	10.17	0	976.61	3.80	0	-	-	130	2.59E-10	5.61E-09	1.29E-05
981.61	10.23	319	981.61	3.87	5495	10.63	2.24E-07	130	2.59E-10	5.61E-09	1.30E-05
986.62	10.36	0	986.62	3.95	0	-	-	130	2.57E-10	5.57E-09	1.28E-05
991.62	10.46	0	991.62	4.01	2919	-	1.25E-07	130	2.56E-10	5.54E-09	1.28E-05

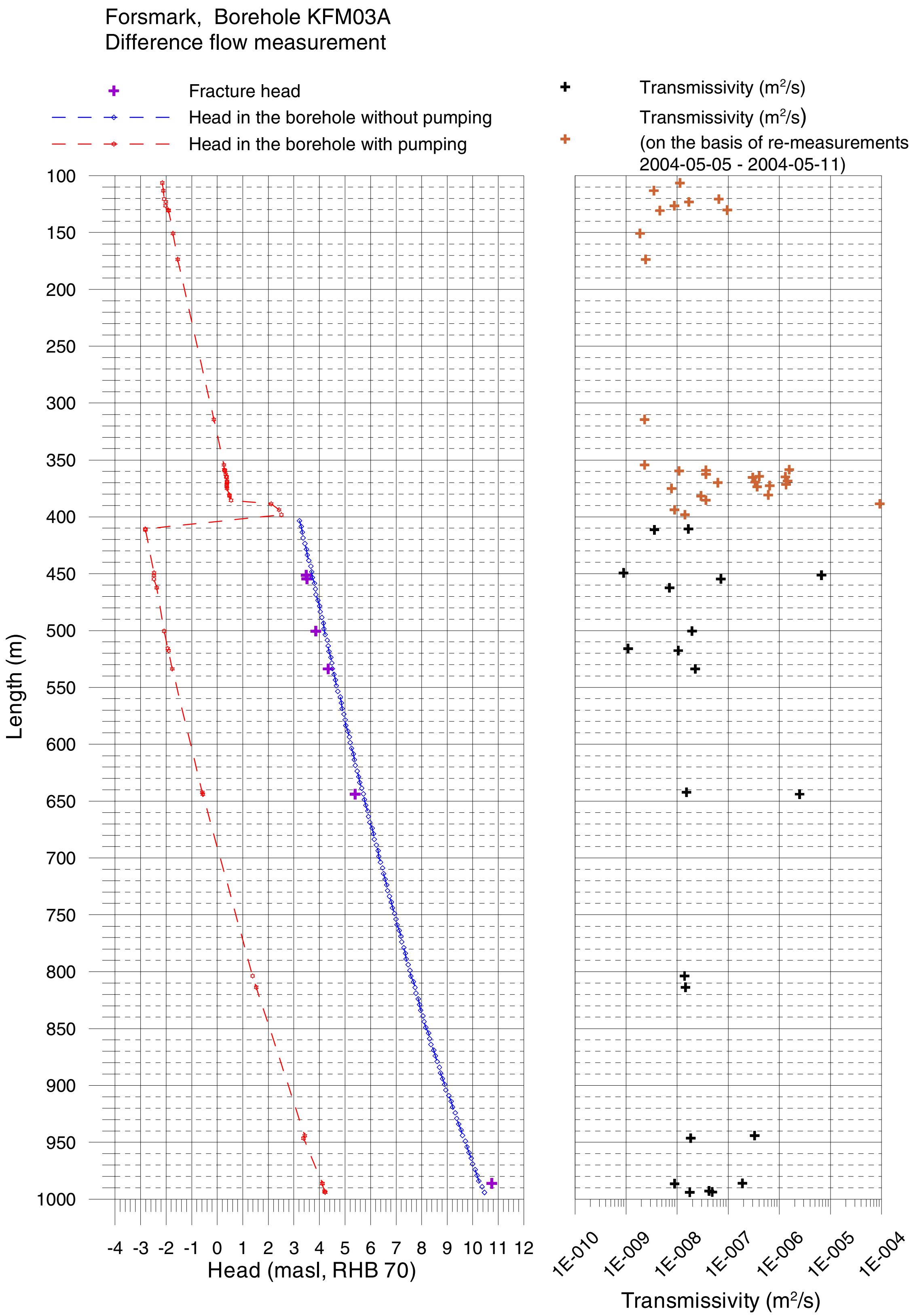

Forsmark, Borehole KFM03A
Difference flow measurement with thermal pulse 2003-08-15 - 2003-08-26
Length of section 5 m, depth increment 5 m
Flow rates
Without pumping
With pumping
Lower limit of flow rate (theoretical)
Lower limit of flow rate (practical)
Upper limit of flow rate (theoretical)
See App. 4
Length (m)
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1E+006
1E+005
1E+004
1E+003
1E+002
1E+001
1E+000
1E+001
1E+002
1E+003
1E+004
1E+005
1E+006
Flow rate (mL/h)
OUT FROM HOLE
INTO HOLE


Forsmark, Borehole KFM03A
Difference flow measurement with thermal pulse 2003-08-15 - 2003-08-26
Length of section 5 m, depth increment 5 m
Calculated head of section
Head in the borehole without pumping
Head in the borehole with pumping
Transmissivity (T)
Theoretical minimum measurable T
Practical minimum measurable T
Practical maximum measurable T
See App. 4
Length (m)
Head (masl, RHB 70)
Transmissivity (m2/s)
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
-3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11
1E-010 1E-009 1E-008 1E-007 1E-006 1E-005 1E-004 1E-003

Appendix 8.1

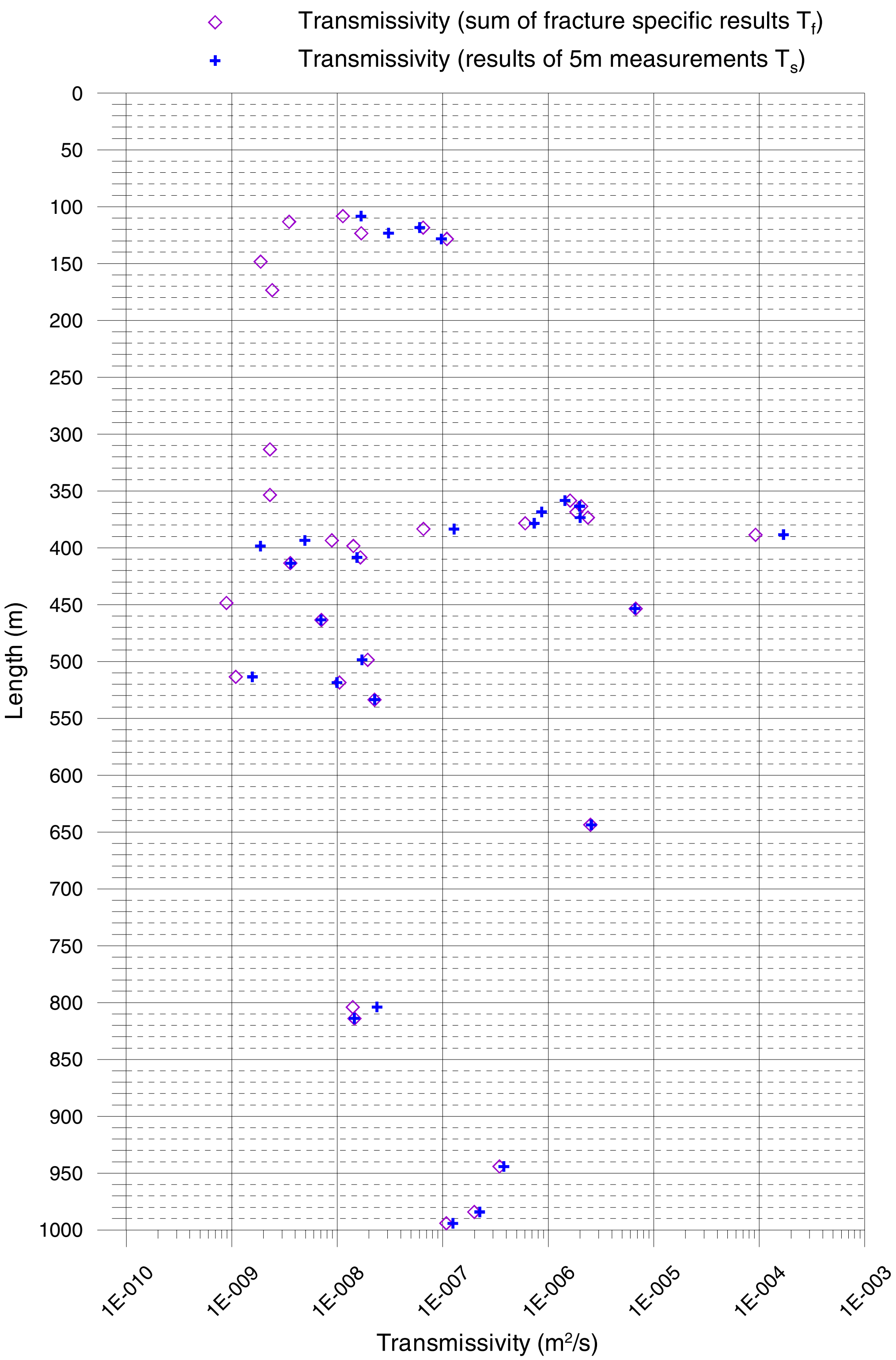
Length to fracture (m)	Borehole head1 (masl)	Flow1 (mL/h)	Borehole head2 (masl)	Flow2 (mL/h)	T_f (m^2/s)	Fracture head (masl)	Comments)		
106.4	1.12	-	-2.15	135	1.13E-08	-	*		***
113.2	1.04	-	-2.11	40	3.49E-09	-	*	**	
120.6	1.08	-	-2.08	750	6.52E-08	-	*		
123.1	1.08	-	-2.01	190	1.69E-08	-	*		***
126.5	1.09	-	-2.02	100	8.83E-09	-	*	**	***
130.2	1.11	-	-1.91	1050	9.55E-08	-	*		
130.7	1.11	-	-1.9	50	4.56E-09	-	*	**	***
150.8	1.20	-	-1.73	20	1.88E-09	-	*	**	***
173.6	1.29	-	-1.55	25	2.42E-09	-	*	**	***
314.4	2.26	-	-0.13	20	2.30E-09	-	*	**	***
354.4	2.65	-	0.26	20	2.30E-09	-	*	**	***
358.5	2.68	-	0.27	13650	1.56E-06	-	*		
359.1	2.69	-	0.29	320	3.66E-08	-	*	**	***
359.6	2.69	-	0.3	95	1.09E-08	-	*	**	***
362.6	2.73	-	0.33	320	3.66E-08	-	*		
364.5	2.74	-	0.36	3500	4.04E-07	-	*		
364.8	2.74	-	0.35	11400	1.31E-06	-	*		
365.3	2.75	-	0.37	2600	3.00E-07	-	*		
368.6	2.78	-	0.38	12600	1.44E-06	-	*		
369.4	2.80	-	0.38	2950	3.35E-07	-	*		
370	2.81	-	0.38	550	6.22E-08	-	*	**	
371.6	2.82	-	0.37	12000	1.35E-06	-	*		
372.6	2.83	-	0.37	5800	6.48E-07	-	*		
373.6	2.84	-	0.37	3300	3.67E-07	-	*		
375.1	2.86	-	0.38	70	7.75E-09	-	*	**	***
380.8	2.92	-	0.47	5400	6.06E-07	-	*		
381.6	2.93	-	0.48	260	2.92E-08	-	*		
385.4	2.96	-	0.54	320	3.63E-08	-	*		***
388.6	2.99	-	2.11	295000	9.21E-05	-	*		
393.8	3.04	-	2.42	20	8.86E-09	-	*		
398.2	3.09	-	2.51	30	1.42E-08	-	*		***
410.7	3.33	0	-2.82	370	1.65E-08	-			
411.5	3.33	0	-2.81	80	3.58E-09	-			
449.4	3.70	0	-2.47	20	8.90E-10	-			***
451.3	3.71	-5430	-2.48	144300	6.65E-06	3.48			
454.6	3.74	-60	-2.48	1560	7.16E-08	3.51			
462.4	3.84	0	-2.37	160	7.08E-09	-			
500.5	4.18	-23	-2.08	420	1.94E-08	3.86			
515.9	4.35	0	-1.94	25	1.09E-09	-			***
517.7	4.36	0	-1.90	240	1.05E-08	-			
533.7	4.51	-14	-1.76	500	2.25E-08	4.34			
642.2	5.71	0	-0.59	350	1.53E-08	-			
643.9	5.72	-2950	-0.57	53900	2.48E-06	5.40			
803.8	7.58	0	1.38	315	1.40E-08	-			
813.7	7.74	0	1.53	330	1.46E-08	-			
944.2	9.60	0	3.42	7370	3.28E-07	-			
946.5	9.64	0	3.38	420	1.84E-08	-			***
986.2	10.28	320	4.11	4550	1.89E-07	10.74			
986.5	10.29	0	4.11	200	8.90E-09	-			***
992.9	10.44	0	4.19	960	4.22E-08	-			
993.8	10.45	0	4.22	1100	4.85E-08	-			
994.0	10.45	0	4.23	400	1.76E-08	-			***

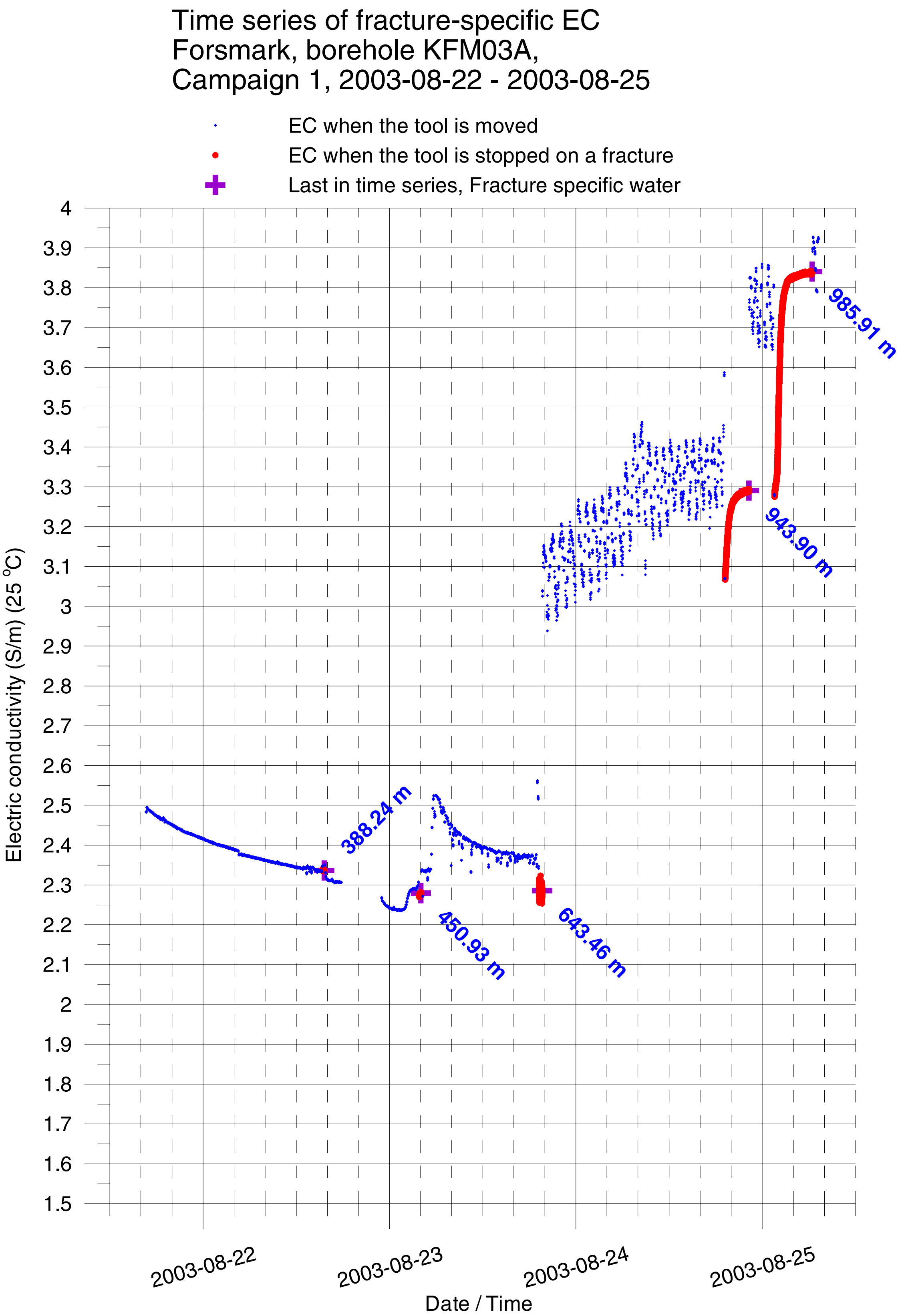
* Re-measurements 2004-05-09 – 2004-05-11
** Not detected during the first campaign
*** Uncertain



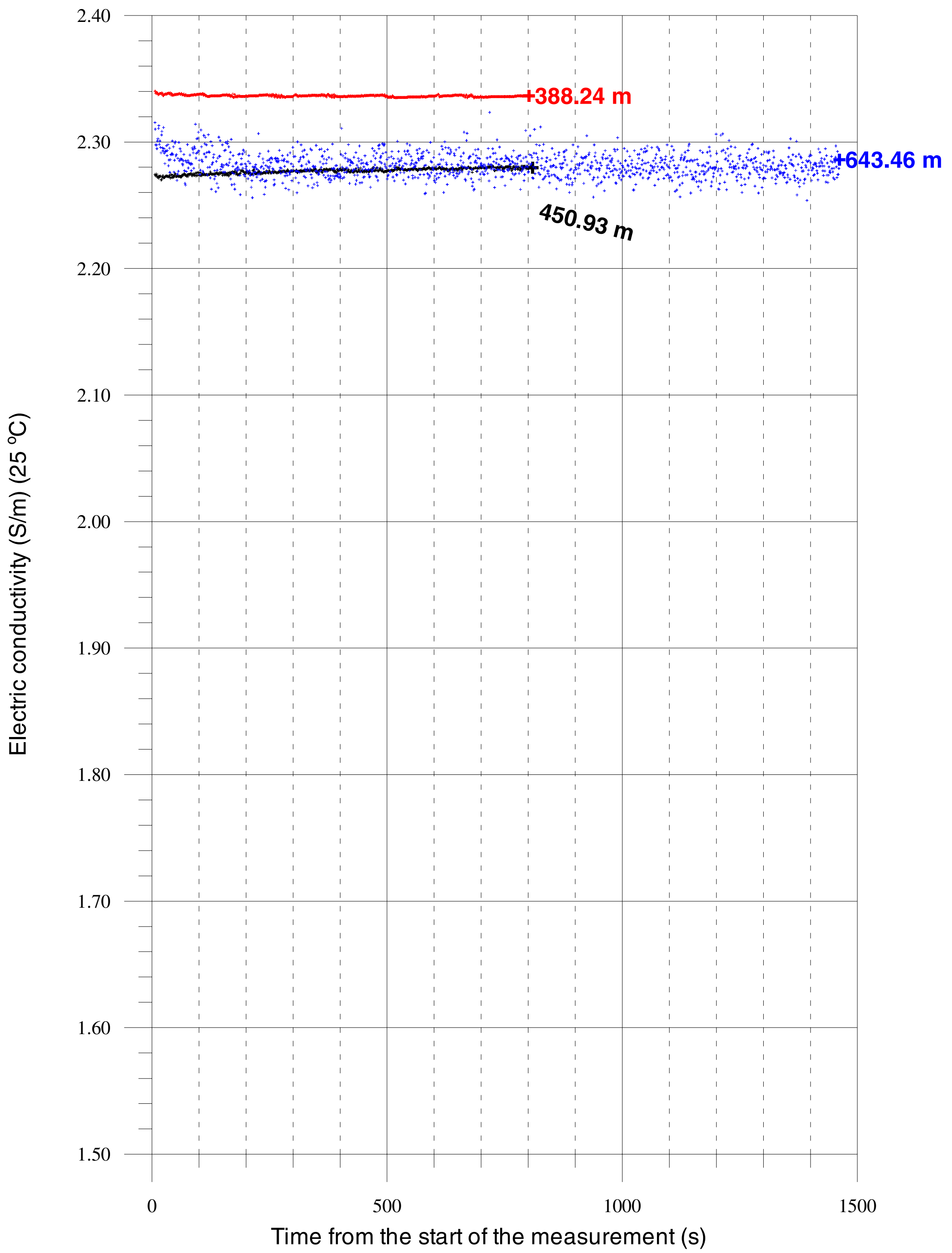
Forsmark, Borehole KFM03A
Difference flow measurement
Fracture head
Head in the borehole without pumping
Head in the borehole with pumping
Transmissivity (m²/s)
Transmissivity (m²/s)
(on the basis of re-measurements
2004-05-05 - 2004-05-11)
Length (m)
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
-4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12
Head (masl, RHB 70)
1E-010
1E-009
1E-008
1E-007
1E-006
1E-005
1E-004
Transmissivity (m²/s)

Forsmark, Borehole KFM03A
Comparison of transmissivity of borehole sections (5m) and fracture transmissivities

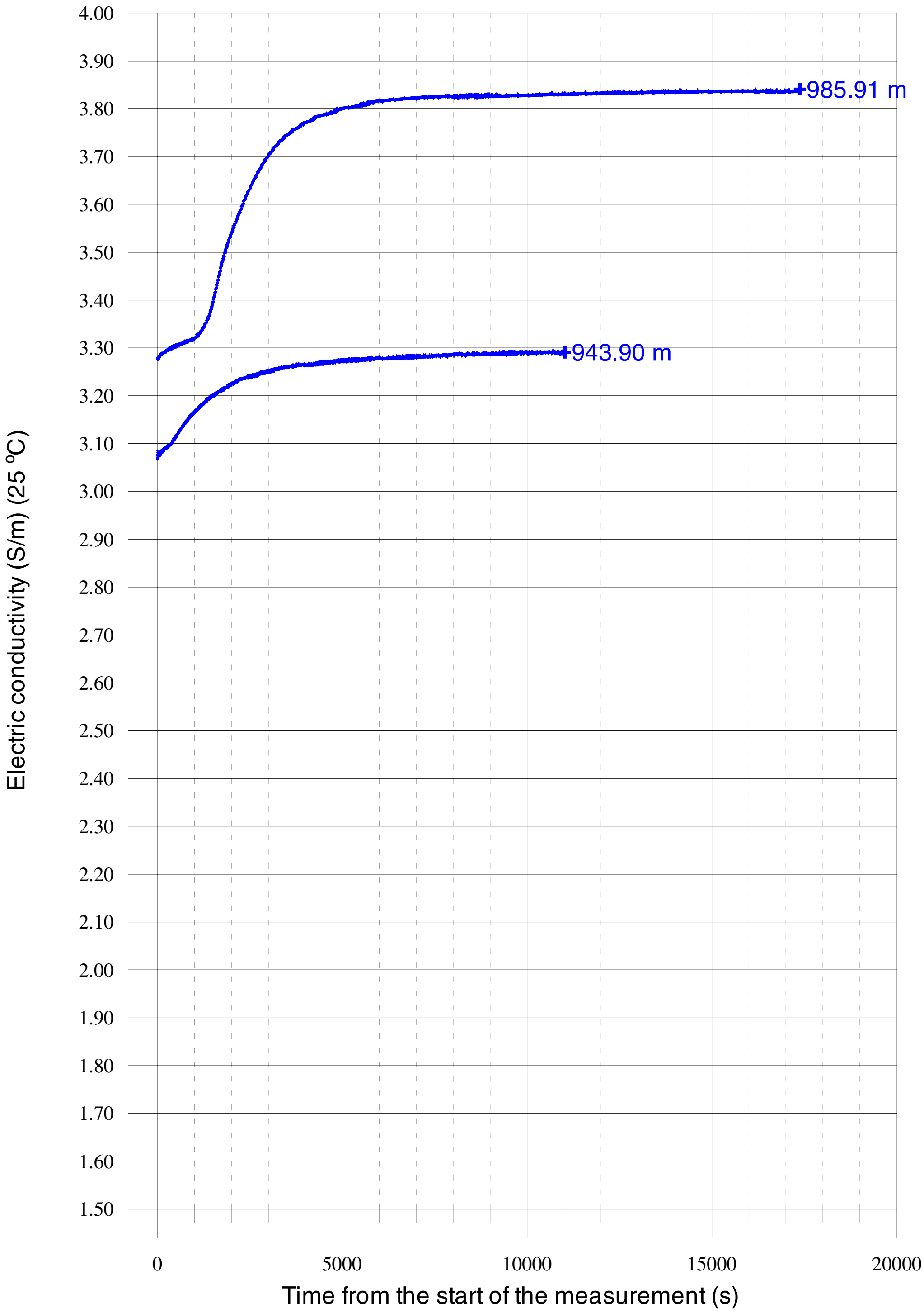


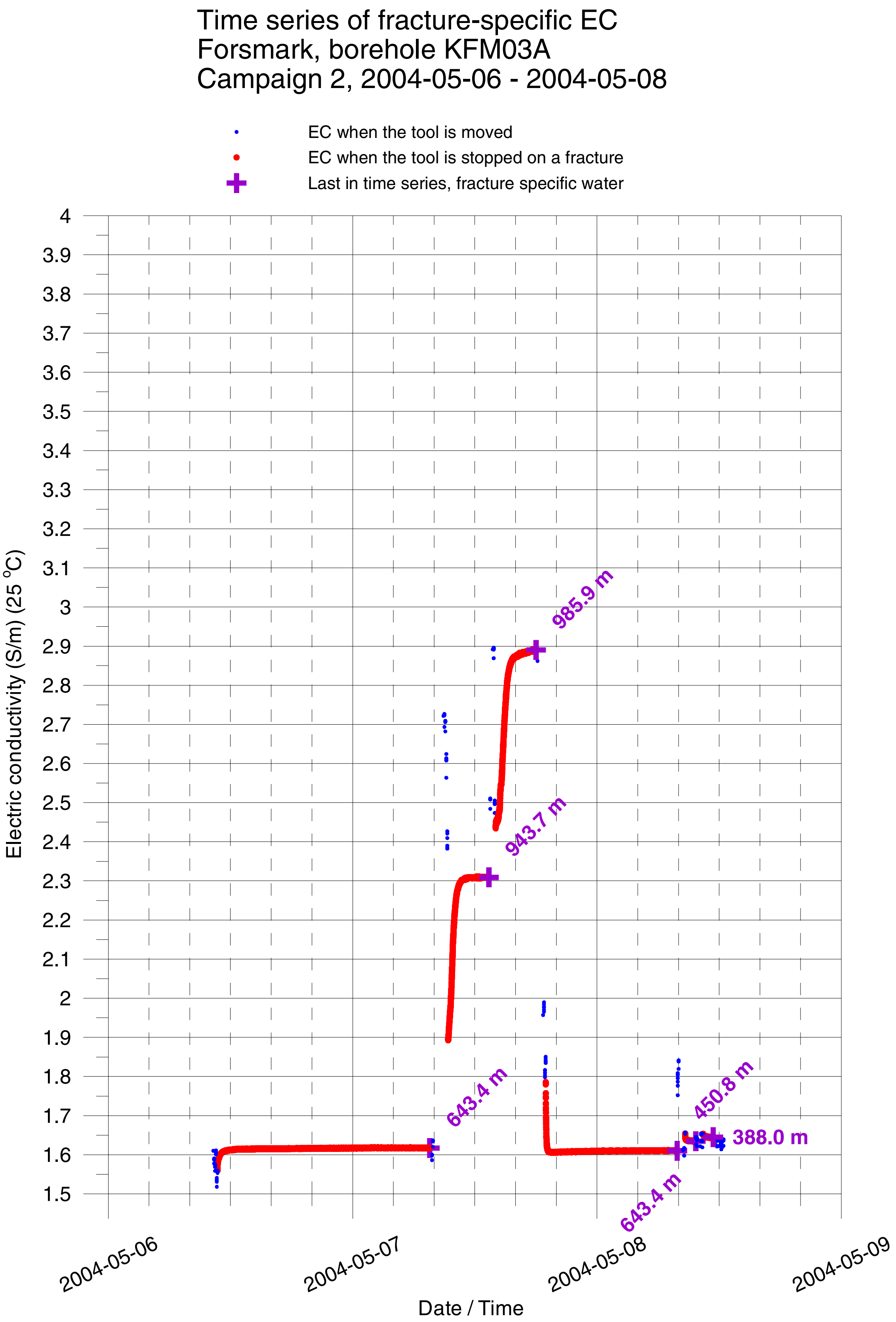

Time series of fracture-specific EC
Forsmark, borehole KFM03A,
Campaign 1, 2003-08-22 - 2003-08-25
EC when the tool is moved
EC when the tool is stopped on a fracture
Last in time series, Fracture specific water
Electric conductivity (S/m) (25 °C)
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
388.24 m
450.93 m
643.46 m
943.90 m
985.91 m
2003-08-22
2003-08-23
2003-08-24
2003-08-25
Date / Time

Time series of fracture-specific EC
Forsmark, borehole KFM03A
Campaign 1, 2003-08-22 - 2003-08-25

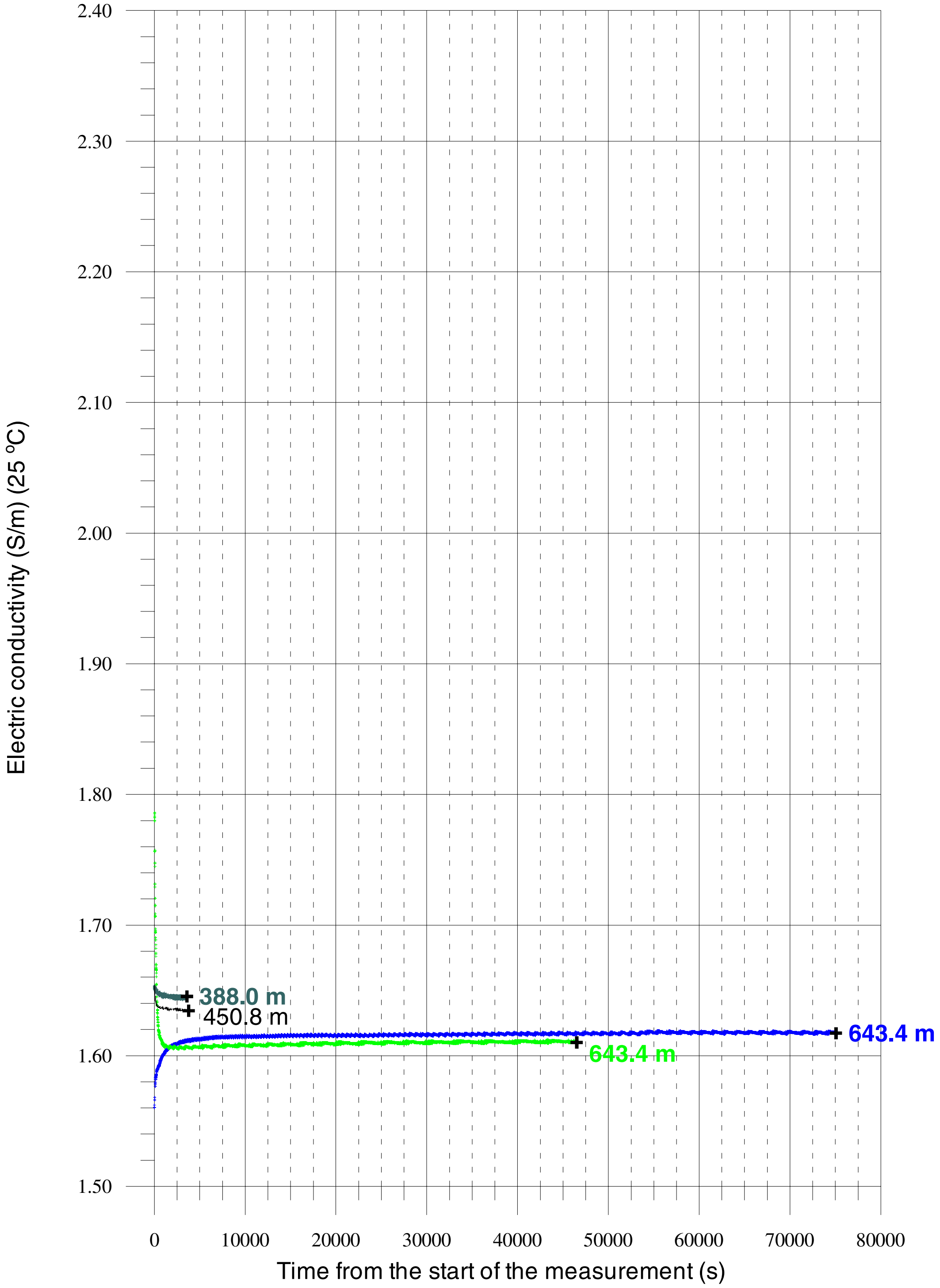


Time series of fracture-specific EC
Forsmark, borehole KFM03A
Campaign 1, 2003-08-22 - 2003-08-25

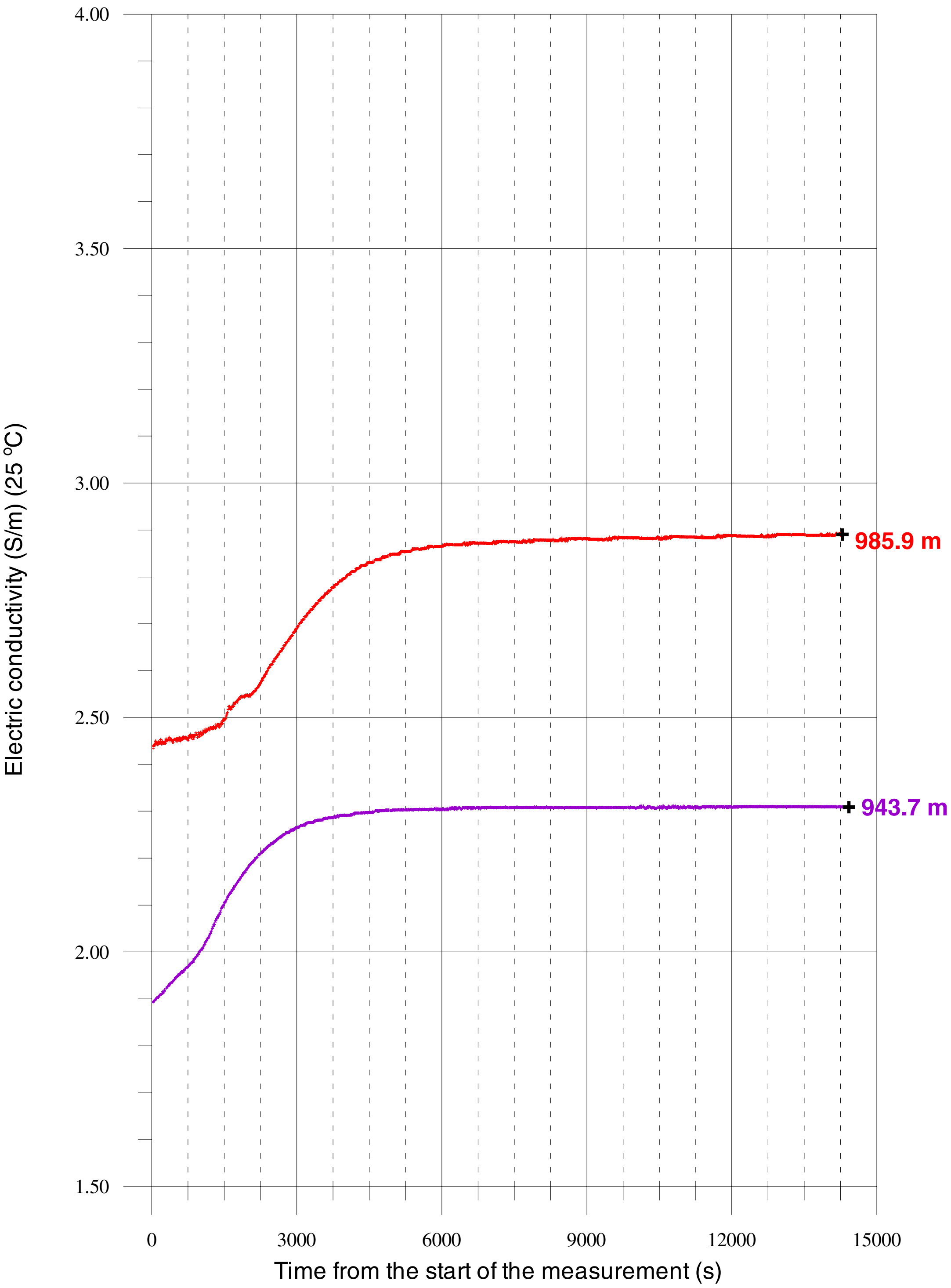


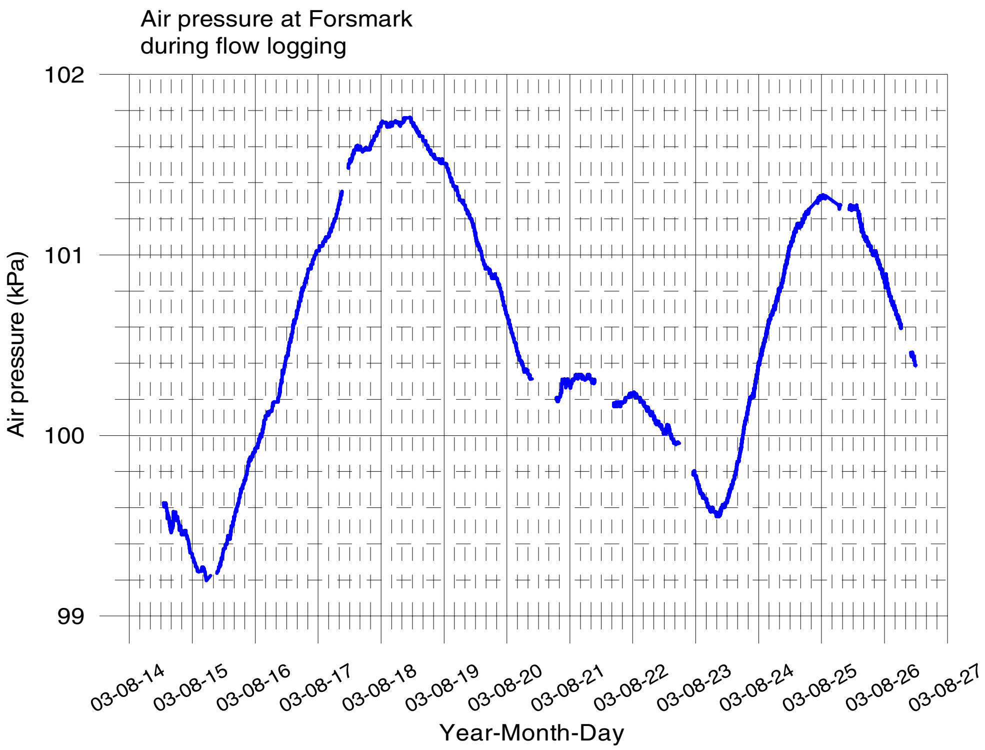

Time series of fracture-specific EC
Forsmark, borehole KFM03A
Campaign 2, 2004-05-06 - 2004-05-08
EC when the tool is moved
EC when the tool is stopped on a fracture
Last in time series, fracture specific water
Electric conductivity (S/m) (25 °C)
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
985.9 m
943.7 m
643.4 m
450.8 m
388.0 m
643.4 m
2004-05-06
2004-05-07
2004-05-08
2004-05-09
Date / Time

Time series of fracture-specific EC
Forsmark, borehole KFM03A
Campaign 2, 2004-05-06 - 2004-05-08

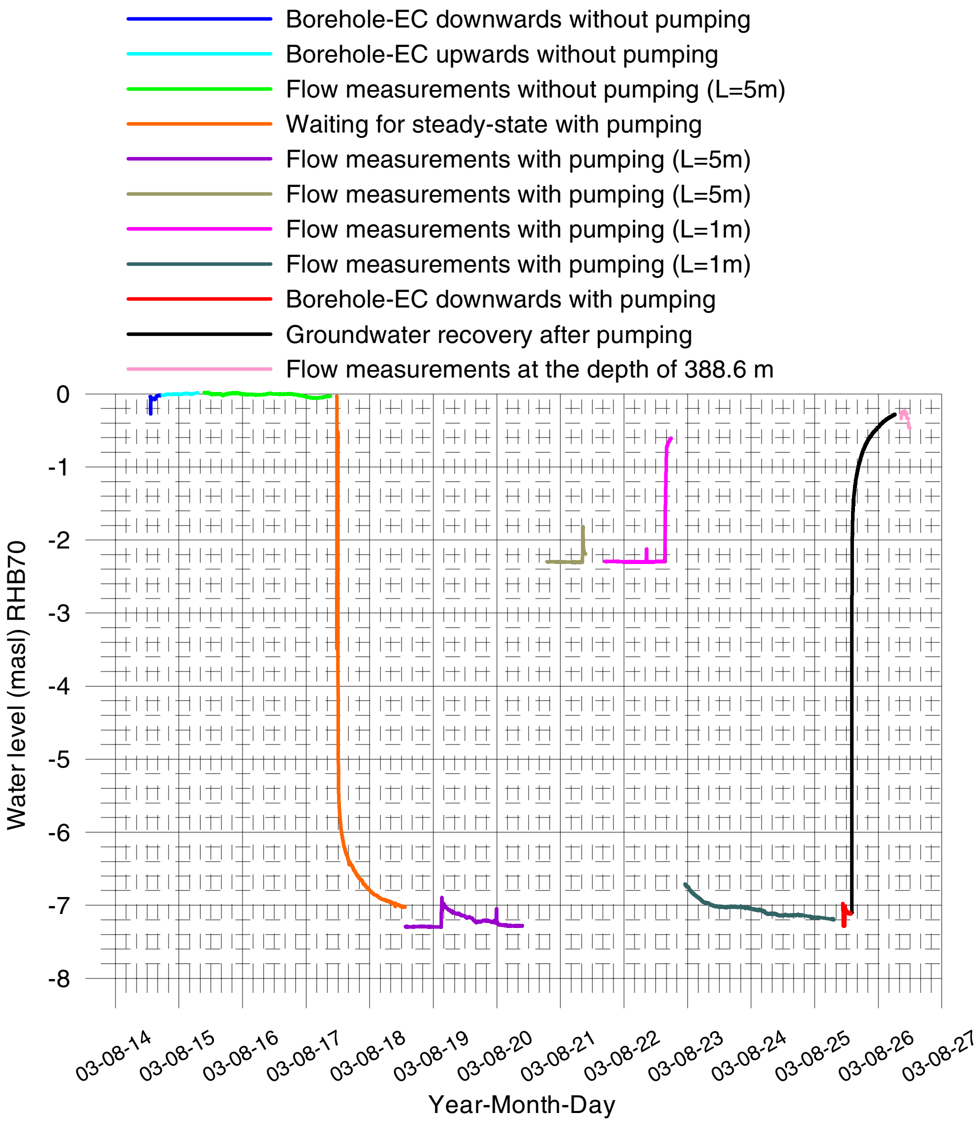


Time series of fracture-specific EC
Forsmark, borehole KFM03A
Campaign 2, 2004-05-06 - 2004-05-08

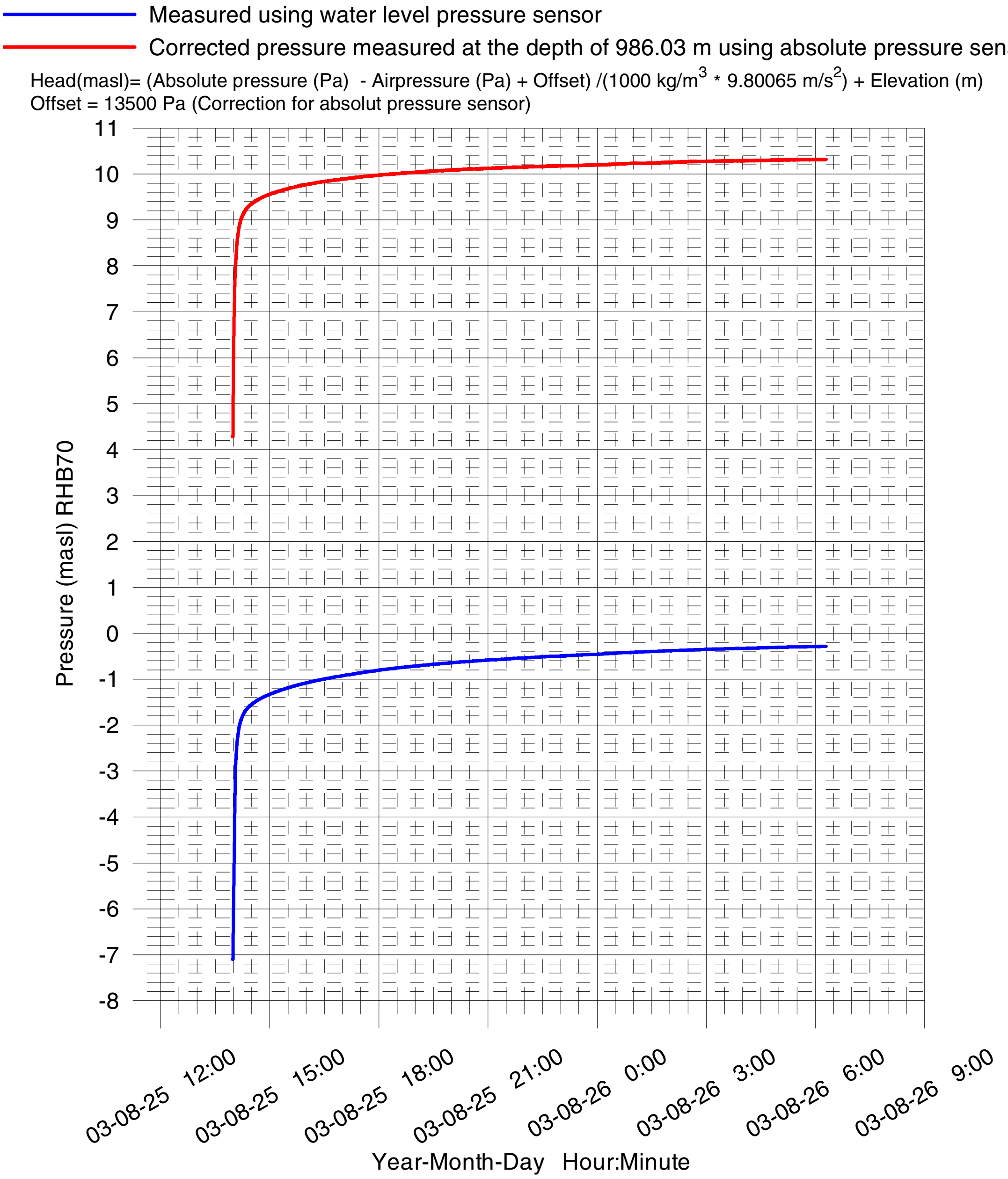



Air pressure at Forsmark
during flow logging
102
101
100
99
Air pressure (kPa)
03-08-14
03-08-15
03-08-16
03-08-17
03-08-18
03-08-19
03-08-20
03-08-21
03-08-22
03-08-23
03-08-24
03-08-25
03-08-26
03-08-27
Year-Month-Day

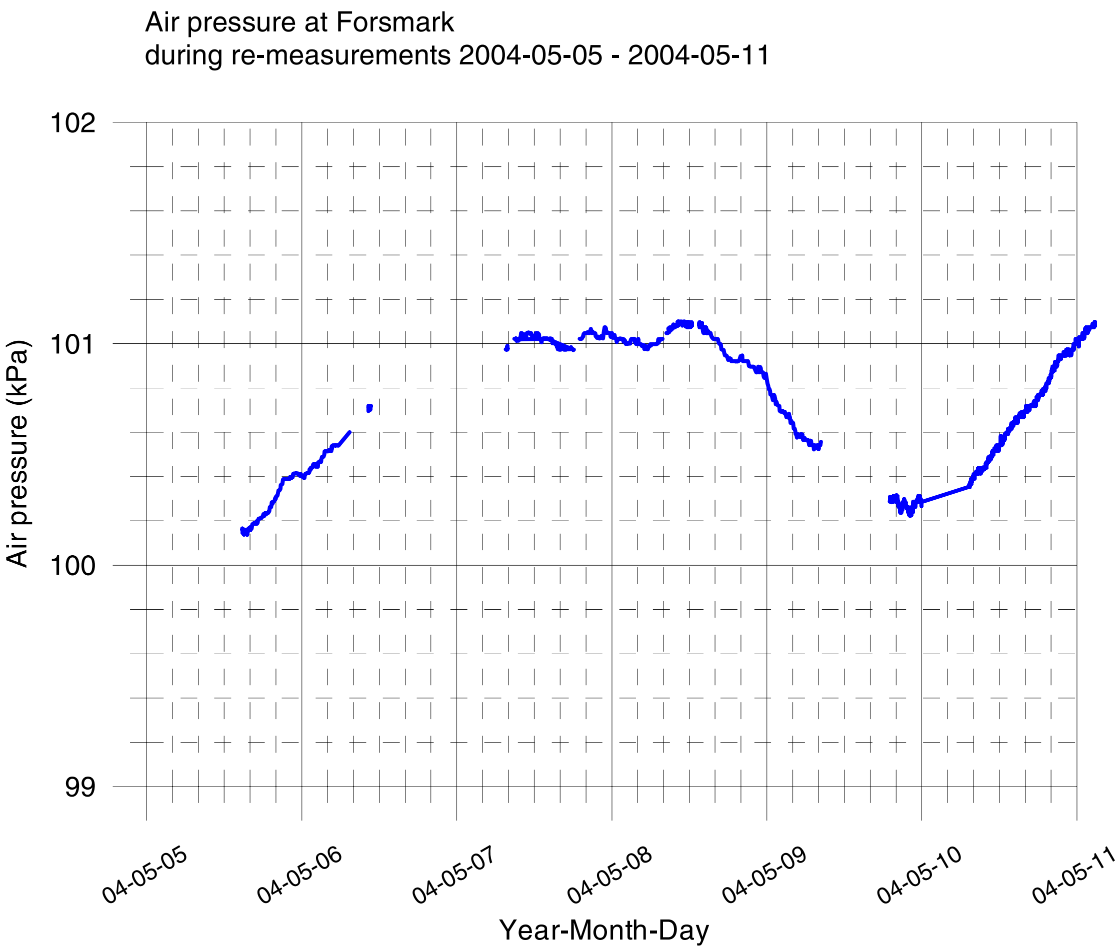
Water level during difference flow measurements
Borehole KFM03A, Forsmark



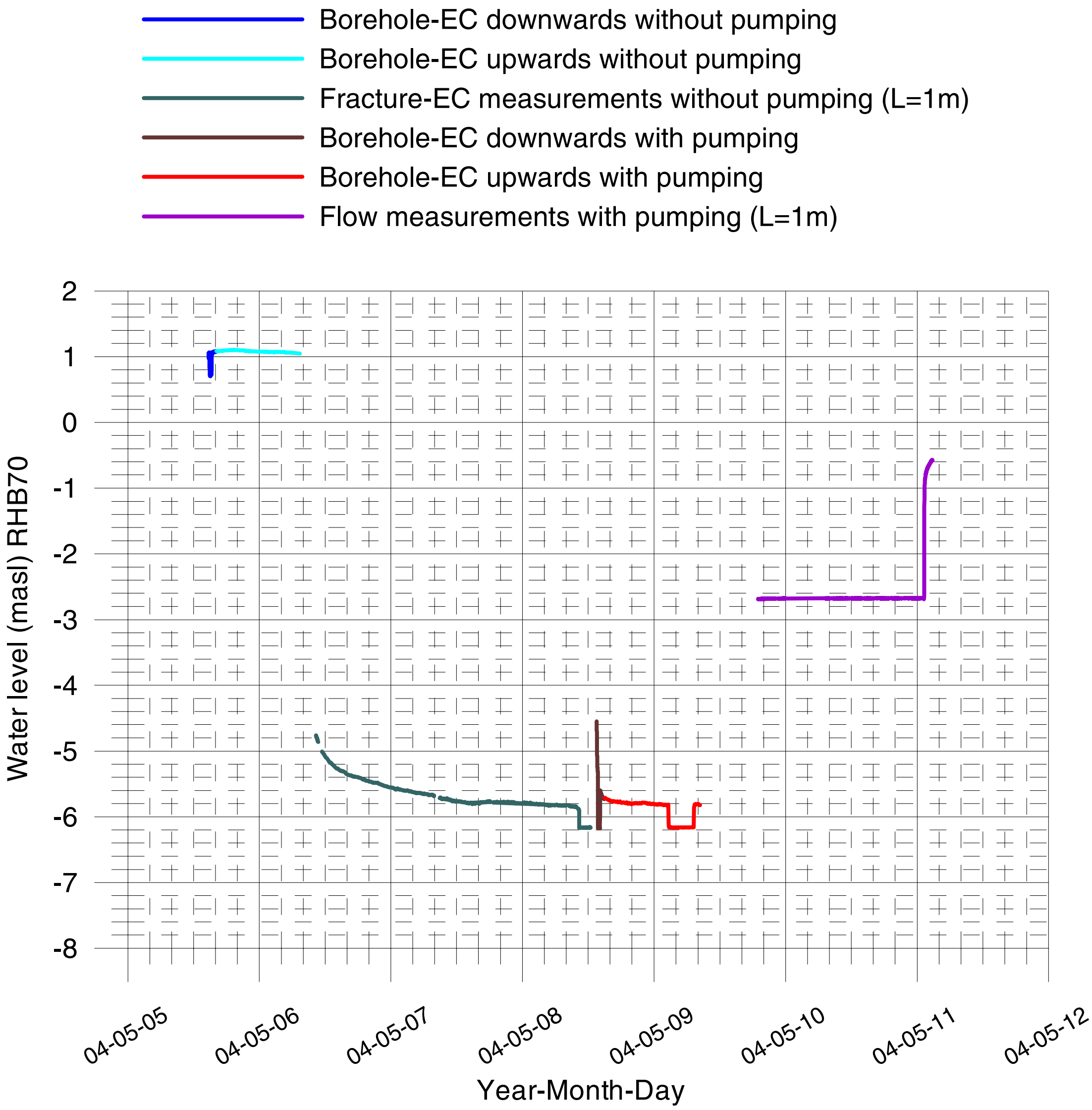
Groundwater recovery after pumping



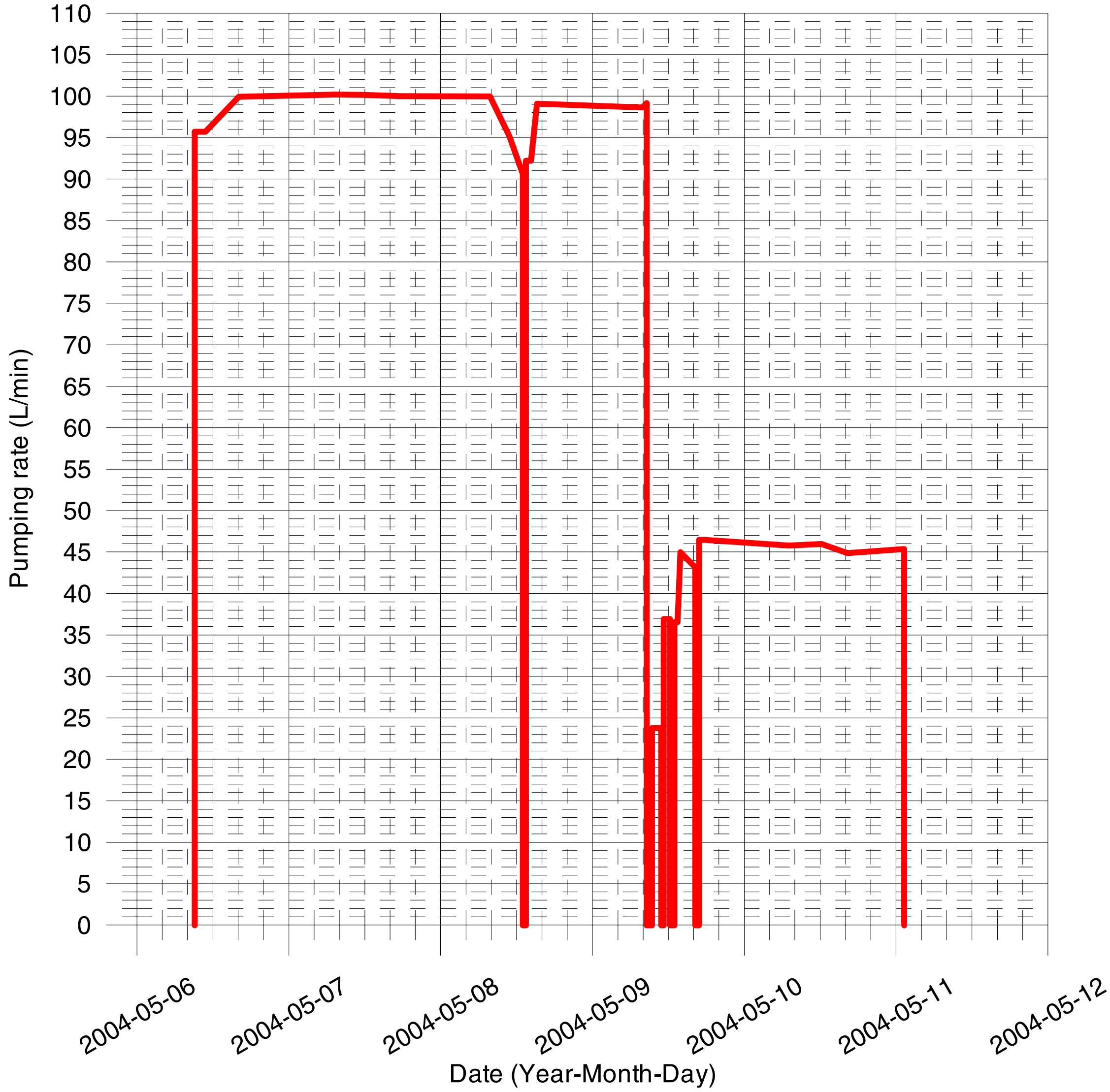
Pumping during flow logging
Forsmark, borehole KFM03A
Pumping rate (L/min)
Cumulative pumping (m3)
0
10
20
30
40
50
60
70
80
90
100
110
120
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
2003-08-17
2003-08-18
2003-08-19
2003-08-20
2003-08-21
2003-08-22
2003-08-23
2003-08-24
2003-08-25
2003-08-26
Date (Year-Month-Day)


Air pressure at Forsmark
during re-measurements 2004-05-05 - 2004-05-11
102
101
100
99
Air pressure (kPa)
04-05-05
04-05-06
04-05-07
04-05-08
04-05-09
04-05-10
04-05-11
Year-Month-Day

Water level during re-measurements 2004-05-05 - 2004-05-11
Borehole KFM03A, Forsmark



Pumping rate during re-measurements 2004-05-05 - 2004-05-11
Forsmark, borehole KFM03A



Appendix 12

Pumping test during difference flow logging in borehole KFM03A

Jan-Erik Ludvigson

Geosigma AB

November 2003

Key words: Forsmark, hydrogeology, pumping test, hydraulic parameters, transmissivity, hydraulic conductivity, AP PF 400-03-24, Field Note No: Forsmark 165.

Abstract

The pressure responses during the flow- and recovery period of the c. 8 days long open-hole pumping test during difference flow logging in borehole KFM03A were utilized to calculate the total transmissivity of the open borehole interval. In addition, possible effects of outer hydraulic boundaries of the rock volume tested were studied. During the first phase of the flow period, before the flow logging commenced, the flow rate was relatively constant during c. 1 day in order to achieve approximately steady-state conditions during the flow logging. During the different sequences of the flow logging, a constant drawdown at an appropriate water level in the borehole was maintained.

After stop of pumping the recovery of the water level in the borehole was recorded during c. 16 h. In addition, the pressure recovery was also measured at the bottom of the hole by a high-resolution absolute pressure sensor. The pressure responses during both the flow- and the recovery period were evaluated by transient methods. The flow rate was measured manually during the flow periods.

The total transmissivity of the entire open borehole interval (c. 12-1000 m) was calculated both from the first part of the flow period with nearly constant flow rate and from the recovery period. The total transmissivity of borehole KFM03A was calculated to $5 \cdot 10^{-4}$ m^2/s. The main inflow to the borehole is assumed to occur from a narrow fracture zone at c. 388 m. In addition, is a relatively large flow anomaly at c. 66 m previously identified.

No significant effects of outer hydraulic boundaries, e.g. no-flow boundaries, could be observed, neither from the responses during the relatively long total flow period, nor during the recovery period. This fact may indicate that the assumed fracture zones intersecting the borehole have a large lateral extent.

Sammanfattning

Tryckresponserna under flödes- och återhämtningsperioden av den ca 8 dygn långa pumptesten i öppet hål under differensflödesloggningen i borrhål KFM03A användes för att beräkna den totala transmissiviteten av dess öppna intervall. Dessutom studerades förekomsten av eventuella hydrauliska gränser inom den testade bergvolymen. Under den första delen av pumpningen, innan flödesloggningen påbörjades, var pumpflödet från borrhålet relativt konstant för att uppnå approximativt stationära förhållanden under flödesloggningen. Under de olika flödesloggningssekvenserna hölls en konstant avsänkning på lämplig vattennivå i borrhålet.

Efter avslutad pumpning registrerades återhämtningen av vattennivån i borrhålet under ca 16 timmar. Dessutom mättes tryckåterhämtningen även i botten av hålet med en tryckgivare med hög upplösning. Tryckresponserna under såväl flödes- som återhämtningsperioden utvärderades med transienta metoder. Pumpflödet mättes manuellt under flödesperioderna.

Den totala transmissiviteten av borrhålets öppna del (ca 12-1000 m) beräknades dels från den första delen av flödesperioden med nästan konstant flöde och dels från återhämtningsperioden. Borrhål KFM03As totala transmissivitet beräknades till $5 \cdot 10^{-4}$ m^2/s. Det huvudsakliga inflödet till borrhålet antas ske från en smal sprickzon vid ca 388 m. Dessutom är ett relativt stort inflöde vid ca 66 m känt sedan tidigare.

Inga tydliga effekter av yttre hydrauliska gränser, t.ex. negativa gränser, kunde observeras, varken under den relativt långa totala flödesperioden eller under återhämtningsperioden. Detta kan tyda på att de förmodade sprickzonerna som skär borrhålet har stor lateral utbredning.

Contents

1 Introduction

The water level in the open borehole was registered by a superficial pressure sensor during both the flow- and recovery period of the pumping test in conjunction with difference flow logging in borehole KFM03A. In addition, the pressure recovery was registered by a high-resolution absolute pressure sensor located at the bottom of the borehole. A relatively low pumping flow rate (c. 29 L/min) was maintained during the flow logging in the upper part of the borehole (c. 100-400 m) whereas a high pumping flow rate (c. 108 L/min) was applied by the logging in the lower part (c. 400-1000 m).

Manual readings of the pumping flow rate were made from a mechanical flow meter during the flow periods. No flow logging was performed in the uncased percussion-drilled part of the borehole above 100 m. A relatively large inflow has been observed in this interval at c. 66 m from previous investigations.

2 Objective

The main purposes of the analysis of the pumping test during difference flow logging in borehole KFM03A were to estimate the total transmissivity of the entire uncased borehole interval (c. 12-1000 m) and to deduce information on possible hydraulic outer hydraulic boundaries during the test.

Since a significant inflow is assumed from the zone at c. 66 m, the calculated total borehole transmissivity from the pumping test will not be equal to the estimated cumulative transmissivity from the flow logging in the cored borehole interval of KFM03A.

3 Scope

3.1 Borehole

Selected main technical data for borehole KFM03A are shown in Table 3-1. The borehole is cased to c. 12 m with a diameter of 0.2 m. This casing is gap injected. The percussion-drilled borehole interval from c. 12-97.2 m is uncased with a diameter of 196 mm. The interval 97.20-101.85 m is cased with smaller casing diameters. More detailed data are available from SICADA. The reference point in the borehole is the top of casing (ToC). The reference coordinate system for the X-Y-coordinates is RT90 and RHB70 for the elevation data. The starting point coordinates (at ToC) of the borehole are:

Northing (m): 6697852.096 RT90 2,5 gon V 0:-15

Easting (m): 1634630.733 RT90 2,5 gon V 0:-15

Table 3-1. Selected main technical data of borehole KFM03A. (From SICADA).

Borehole KFM03A							
ID	**Elevation of top of casing (ToC) (m.a.s.l.)**	**Borehole interval from ToC (m)**	**Casing/ Bh-diam. (m)**	**Inclination- top of bh (from horizontal plane) (º)**	**Dip-direction- top of borehole (from local N) (º)**	**Remarks**	**Drilling finished Date (YYYY-MM-DD)**
KFM03A	8.285	0.0-11.96	0.200	-85.747	271.523	Casing ID	
”		11.96-100.29*	0.196			Open hole**	
”		102.05-1001.19***	0.077			Open hole***	2003-06-23

* percussion borehole
** the interval 97.20-101.85 m is cased with decreasing casing diameters
*** cored borehole interval

3.2 Tests performed

The registration of the water level and flow rate together with the pressure recovery during the difference flow logging campaign in borehole KFM03A was mainly performed according to the Activity Plan AP PF 400-03-24 and the methodology description for difference flow logging (SKB MD 322.010, Version 1.0), both SKB internal controlling documents. Due to the high inflow from the narrow fracture (zone) at c. 388 m, the pumping rate was decreased during flow logging of the upper part (c. 100-400 m) of the borehole. This fracture zone was later tested separately by a stepwise increase of drawdown while measuring the inflow rate from the zone by the flow logging probe fixed across the fracture. Pertinent data of the pumping test during the difference flow logging campaign in KFM03A are shown in Table 3-2.

Table 3-2. Pertinent data of the pumping test sequence during difference flow logging in borehole KFM03A.

Pumping Bh ID	Pumped section (open hole) (m)	Test type[1]	Test no	Test start date and time (YYYY-MM-DD hh::mm)	Test stop date and time (YYYY-MM-DD hh::mm)
KFM03A	11.96-1001.19[2)]	1B	1	2003-08-17 11:55	2003-08-26 06:18

1) 1B: Pumping test with submersible pump with subsequent recovery
2) The interval 97.20-101.85 m is cased with decreasing casing diameters. This casing is not gap injected.

3.3 Equipment check

An equipment check was performed at the site as a simple and fast test to establish the operating status of sensors and other equipment. In addition, calibration constants were implemented and checked.

4 Equipment

4.1 Description of equipment

The pumping test was carried out with the standard equipment in the Posiva difference flow logging system including the following parts:

- submersible pump and hose to the ground surface
- winch and steel wire
- flow rate control valve at the surface
- vessel in the borehole to maintain a constant water level
- superficial pressure transducer
- high-resolution absolute pressure sensor
- data logger
- logging computer

The high-resolution pressure sensor, implemented in the flow logging probe, was used to measure the pressure recovery at the bottom of the borehole, see Table 4.2. Finally, a pressure sensor for registration of the barometric pressure was used.

4.2 Sensors

Technical specifications of the sensor for barometric pressure together with the superficial- and high resolution absolute pressure transducers (P1 and P_{abs}) used for registration of the water level and bottom-hole pressure, respectively, are listed in Table 4-1, cf. Chapter 4 in the main report.

Table 4-1. Technical specification of the pressure sensors used for registration of the barometric pressure, water level and bottom-hole pressure in borehole KFM03A. FS=Full Scale.

Technical specification of pressure sensors*				
Sensor	**Parameter**	**Unit**	**Value/range**	**Comments**
Barometric pressure	Output signal Meas. Range Resolution Accuracy	VDC kPa kPa kPa	0 – 5 80-106 0.01 ±0.03	at +20 °C
Superficial pressure P1 (groundwater level)	Output signal Meas. Range Resolution Accuracy	mA kPa kPa kPa	4 – 20 0 – 100 0.1 ±1% of FS	
Absolute Pressure P_{abs}	Output signal Meas. Range Resolution Accuracy	digital kPa kPa kPa	 0 – 20000 0.0001 % of FS ±0.01% of FS	

* according to the manufacturers

Table 4-2 illustrates the position of pressure sensors (P1 and P_{abs}) together with the (lower) level of the submersible pump (Pump) is shown. Positions are given in borehole length from top of casing (ToC). Equipment affecting wellbore storage is given in terms of diameter of the submerged parts. The volume of the submerged pump (~a few dm^3) is in most cases of minor importance regarding wellbore storage.

Table 4-2. Position along the borehole (from ToC) of sensors and equipment affecting wellbore storage in the pumping borehole KFM03A.

Borehole information			Sensors		Equipment affecting wellbore storage (WBS)		
ID	Test section (m)	Test no	Type	Position (m b. ToC)	Position[1)]	Function	Outer diameter (mm)
KFM03A	11.96-1001.19[2)]	1	Pump vessel (lower level) P (P1) P_{abs}	16.04 16.04 986.025	In open borehole	Pump hose Signal cable Pump cable wire	18 6 11.5 3

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

[2)] The interval 97.20-101.85 m is cased with decreasing casing diameters

5 Execution

5.1 Performance of the test

5.1.1 Test principle

During the first part of the flow period before the difference flow logging started the flow rate was almost constant, see flow rate history in Figure 12.2-1 in Appendix 12.2. The water level in the borehole was then kept constant at different levels during the various flow logging sequences. The flow periods were followed by a pressure recovery period.

5.1.2 Test procedure

The maximum flow rate (c. 108 L/min) with the actual pump was maintained rather constant during the first c. 24 h of the pumping test causing a drawdown of the water level of c. 7 m, cf. Figure 6-4 in the main report. The difference flow logging started after c. 1 day of pumping at a constant drawdown (c. 7.3 m). The drawdown was then decreased to c. 2.3 m at a pumping flow rate of c. 29 L/min during flow logging in the upper part (c. 100-400 m) due to a high-conductivity fracture at c. 388 m. During the last flow logging sequence of the lower part of the borehole (c. 400-1000 m) the pumping flow rate was again increased to c. 108 L/min. The total duration of the flow periods during the difference flow logging campaign in KFM03A was c. 8 days, followed by a recovery period of c. 16 h.

The pumped flow was discharged at the ground surface sloping downhill from the pumping borehole. The flow rate was measured manually c. 5-6 times/day by a mechanical flow meter.

The changes of the water level were registered by the superficial pressure sensor throughout the entire logging campaign. In addition, the pressure recovery was measured at the bottom of the borehole by the absolute pressure transducer, located at c. 986 m. The sampling frequency of the registration of the water level in the borehole was c. 1 min during the flow periods. During the recovery period, the sampling frequency was according to Table 5-1, both for the water level- and the absolute pressure sensor.

Table 5-1. Sampling frequency for pressure registration during the recovery period of the pumping test in borehole KFM03A.

Time interval (min) from stop of pumping	Sampling frequency (s)
0.0-160	2
160-1002	11

5.2 Data handling

A list of the data files of pressure versus time from the recovery phase from the data logger is shown in Appendix 12.1. Files in mio-format of the entire test sequence and recovery period, respectively, further processed by the program PUMPKONV, were created through macro-editing of the original logger files in the text editor UltraEdit.

By the preparation of the pressure recovery data from the absolute pressure sensor, the barometric pressure was firstly subtracted from the measured pressure data. However, no such corrections were made on the measured water level data from the superficial transducer (gauge pressure).

The *.mio-files with pressure versus time data were converted to drawdown- and recovery files by the code PUMPKONV and plotted in selected diagrams by the code SKB-plot in accordance with the Method Instruction SKB MD 320.004, Version 1.0 (Instruktion för analys av injektions- och enhålspumptester)(SKB internal controlling document) In addition, a linear diagram of the pressure- and flow rate history during the entire flow logging campaign was prepared.

By the calculation of the pressure derivatives during the flow- and recovery period, different values were applied on the filter coefficient (step length) to study its effect on the derivative to achieve maximal smoothing of the derivative without altering the original shape of the data.

5.3 Analyses and interpretation

The main transient evaluation was made on data from the first part (c. 24 h) of the flow period with almost constant flow rate together with the recovery period. From the flow period, data from the water level sensor were used whereas data from the absolute pressure sensor were used for analysis of the recovery period.

Firstly, a qualitative evaluation was performed to identify the actual flow regimes during both the flow- and recovery period (e.g. wellbore storage, pseudo-radial flow etc.) and possible outer hydraulic boundary conditions. The qualitative analysis was mainly made from the pressure responses together with the corresponding pressure derivatives versus time in the log-log diagrams. The pressure recovery was plotted versus equivalent time dt_e after stop of pumping since there was a slightly increasing drawdown trend at the end of the flow period before stop of pumping.

The quantitative, transient interpretation of hydraulic parameters from the pumping borehole (e.g. transmissivity and skin factor) was based on the identified pseudo-radial flow regimes in the lin-log diagrams according to methods described in /1/ and the Instruction mentioned above for tests in an equivalent porous medium. In addition, the wellbore storage coefficient was estimated from the initial phase of the recovery period.

Both responses from the flow- and recovery period were analysed with methods for constant flow rate tests described in /1/. In addition, a steady-state analysis (Moye's formula) was made from the flow period.

6 Results

6.1 Nomenclature and symbols

The nomenclature and symbols used for the results of the pumping test are according to SKB MD 320.004. Additional symbols used are explained in the text.

6.2 Single-hole pumping test

General test data from the pumping borehole KFM03A are presented in Table 6-1. The atmospheric pressure during the difference flow logging campaign in KFM03A is shown in Appendix 11.1 in the main report of the difference flow logging.

Since no data from observation boreholes were available, a value on the storativity must be assumed by the calculation of the skin factor. In this case the value $S^{*}=5 \cdot 10^{-5}$, obtained from interference tests between HFM01 and HFM02 /2/, was used. A summary of the results of the single-hole pumping test in KFM03A is presented in Section 6.3. Test diagrams are shown in Appendix 12.2.

Table 6-1. General test data from the pumping borehole KFM03A.

General test data			
Testtype[1]	Constant flow rate and recovery test		
Test section (open borehole/packed-off section):	open borehole		
Test No	1		
Field crew	J. Pöllänen and P. Heikkinen, PRG Tec-Oy		
Test equipment system	Posiva difference flow logging system		
General comment	Single-hole test		
	Nomen-clature	**Unit**	**Value**
Borehole length	L	m	1001.19
Casing length	L_c	m	11.96 (ID 0.200 m)
Test section- secup	Secup	m	11.96
Test section- seclow	Seclow	m	1001.19
Test section length	L_w	m	989.23*
Test section diameter	$2 \cdot r_w$	mm	77
Test start (start of pressure registration)		yymmdd hh:mm	20030817 11:55
Packer expanded		yymmdd hh:mm:ss	-
Start of flow period		yymmdd hh:mm:ss	20030817 11:58:04
Stop of flow period		yymmdd hh:mm:ss	20030825 13:59:18
Test stop (stop of pressure registration)		yymmdd hh:mm	20030826 06:17:55
Total flow time	t_p	min	11641
Total recovery time	t_F	min	1002

*the interval 97.20-101.85 m is cased with decreasing casing diameters

Groundwater level data

Groundwater level data in pumping borehole KFM03A	Nomen-clature	Unit	Value (m.a.s.l)
Level in borehole before start of flow period	h_i	m	0.02
Level in borehole before stop of flow period	h_p	m	-7.20
Level in borehole at stop of recovery period	h_F	m	-0.28
Maximal drawdown in borehole during flow period	s_p	m	7.22

Manual water level measurements in pumping borehole KFM03A				
Date YYYY-MM-DD	**Time tt:mm:ss**	**Time (min)**	**GW level (m b. ToC)**	**GW level (m a s l)**
2003-08-14	13:04:00		8.72	-0.41

Flow data

Flow data in pumping borehole KFM03A	Nomen-clature	Unit	Value
Flow rate from test section just before stop of pumping	Q_p	m^3/s	$1.76 \cdot 10^{-3}$
Mean (arithmetic) flow rate during flow period	Q_m	m^3/s	$1.42 \cdot 10^{-3}$
Total volume discharged during flow period	V_p	m^3	993.5

Interpreted flow regimes

Selected test diagrams are presented in Appendix 12.2. Figure 12.2-2 shows that a well-defined period with pseudo-radial flow occurred during intermediate times of the first part (c. 24 h) of the flow period at constant flow rate. No evidences of outer hydraulic boundaries were seen during the entire flow period.

During the recovery period, wellbore storage effects (WBS) were observed only during the first c. 0.5 min in the (open) pumping borehole. After a transition period, a well-defined period with pseudo-radial flow occurred. By the end of the recovery period, some variations in pressure occurred as displayed in the pressure derivative plot (Figure 12.2-4). No effects of hydraulic boundaries were seen during the recovery period.

Interpreted parameters

The transient analyses of the flow-and recovery periods according to the methods described in Section 5-3, based on the identified periods with pseudo-radial flow, are shown in Figures 12.2-5 in Appendix 12.2. The results are presented in Table 6-3 and in the Test Summary Sheets.

6.3 Summary of test data

Test data from the single-hole pumping test in conjunction with difference flow logging in borehole KFM03A are summarized in Table 6-2. The calculated hydraulic parameters together with the estimated measurement limits are presented in Table 6-3 and in the Test Summary Sheet below. The calculated hydraulic parameters represent the entire open borehole interval 11.96-1001.19 m (except the cased interval 97.20-101.85 m) in KFM03A. The main inflow zones to this interval are located at c. 388.6 m as identified from the difference flow logging and from an assumed fracture zone at c. 66 m from previous investigations.

The parameter file of the results from the pumping test for storage in the SICADA data base under Field Note Number: Forsmark 165, is presented in Appendix 12.3 below.

Table 6-2. Summary of test data of the single-hole pumping test during the difference flow logging in the open borehole KFM03A.

Borehole ID	Interval (m)	Test type[1)]	h_i (m a s l)	h_p (m a s l)	h_F (m a s l)	Q_p (m^3/s)	V_p (m^3)	Q_m (m^3/s)
KFM03A	11.96-1001.19*	1B	0.02	-7.20	-0.28	$1.76 \cdot 10^{-3}$	993.5	$1.76 \cdot 10^{-3}$

1) 1B: Pumping test-submersible pump followed by a recovery test

*the interval 97.20-101.85 m is cased with decreasing casing diameters

Table 6-3. Summary of calculated hydraulic parameters from the pumping test in conjunction with difference flow logging in borehole KFM03A.

Borehole ID	Test period	Phase of evaluation	Q/s (m^2/s)	T_M (m^2/s)	T (m^2/s)	S* (-)	ζ (-)	C (m^3/Pa)
KFM03A	flow	first 24 h	$2.55 \cdot 10^{-4}$	$4.24 \cdot 10^{-4}$	$3.84 \cdot 10^{-4}$	$5 \cdot 10^{-5}$	0.10	
KFM03A	recovery	Entire period			$4.66 \cdot 10^{-4}$	$5 \cdot 10^{-5}$	0.87	$5.03 \cdot 10^{-6}$

Q/s= specific flow
T_M= steady-state transmissivity from Moye´s formula
T = calculated transmissivity from transient evaluation of the test
S^*= assumed value on the storativity
ζ = skin factor
C = wellbore storage coefficient

6.4 Conclusions

The total transmissivity of the interval 11.96-1001.19 m in borehole KFM03A was calculated to c. $4 \cdot 10^{-4}$ m^2/s from the pumping test during difference flow logging. As identified from the latter logging, the dominant inflow in the cored interval of KFM03A occurred at c. 388.6 m. The transmissivity of this zone was estimated at c. $2 \cdot 10^{-4}$ m^2/s from separate flow measurements in a 1 m section located across the fracture zone using the difference flow logging probe, see Section 6.4.4 in the main report. A relatively large inflow to the borehole has previously also been observed from the assumed fracture zone at c. 66 m.

The pumping test showed no significant effects of outer hydraulic boundaries, e.g. no-flow boundaries, during the rather long (c. 8 days) flow period. This fact may indicate that the assumed fracture zones at c. 388.6 m and c. 66 m are extensive in the lateral direction.

The calculated transmissivity from the pumping test cannot in this case be directly compared with the results of the difference flow logging in this case since the entire open borehole interval was not flow-logged (i.e. the interval above c. 100 m). However, the cumulative transmissivities from the sequential flow logging in 5 m sections ($\sum T_D$) and from the overlapping logging of the flow anomalies ($\sum T_{Df}$), using the above estimate of the transmissivity of the zone at c. 388.6 m, are listed in Table 6-4 together with the estimated total transmissivity T_T from the recovery period of the pumping test.

The difference between the calculated transmissivity from the pumping test and difference flow logging in Table 6-4 is assumed to reflect the transmissivity of the zone at c. 66 m. From the difference, the transmissivity of the zone at c. 66 m is in the order of $1\text{-}3\cdot10^{-4}$ m^2/s, but this estimate is regarded as uncertain and only an-order-of magnitude estimate.

Table 6-4. Comparison of total transmissivity of the open part of the borehole and cumulative transmissivity from the difference flow logging in the interval 101.85-1001.19 m in borehole KFM03A.

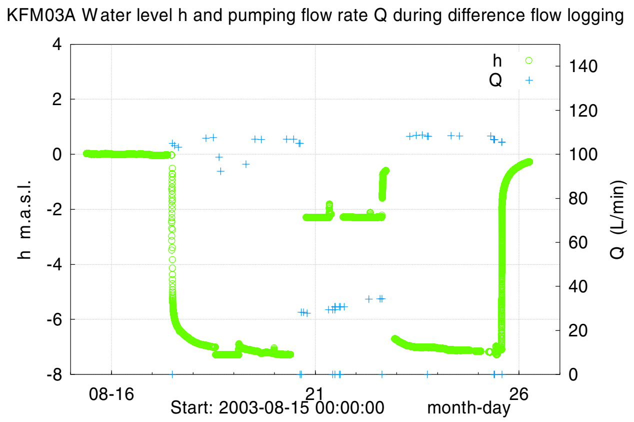
Borehole ID	Test method	Measured interval (m)	T_T (m^2/s)	$\sum T_D$ (m^2/s)	$\sum T_{Df}$ (m^2/s)
KFM03A	Pumping test	11.96-1001.19*	$4.66\cdot10^{-4}$		
	Difference flow logging	101.85-996.62		$1.87\cdot10^{-4}$	$1.88\cdot10^{-4}$

*the interval 97.20-101.85 m is cased with decreasing casing diameters

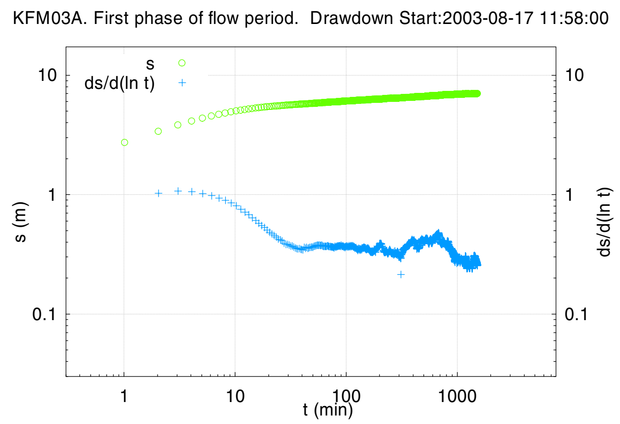
Test Summary Sheet – Pumping borehole KFM03A

Project:	PLU	Test type:	1B
Area:	Forsmark	Test no:	1
Borehole ID:	KFM03A	Test start:	2003-08-17 11:58
Test section (m):	11.96-1001.19	Responsible for test performance:	P. Rouhiainen, PRG-Tec Oy
Section diameter, $2 \cdot r_w$ (m):	0.077	Responsible for test evaluation:	GEOSIGMA AB J-E Ludvigson

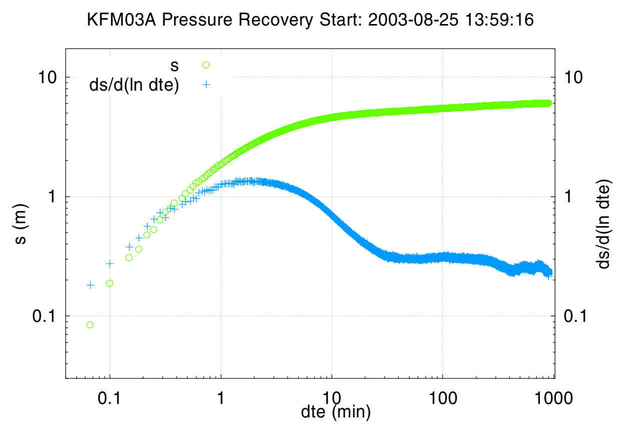
Lin-Lin plot – Entire test period



Log-Log plot incl. derivative- flow period



Log-Log plot incl. derivative- recovery period



Flow period		**Recovery period**	
Indata		**Indata**	
h_0 (m.a.s.l.)	0.02		
h_i (m.a.s.l.)	0.02		
h_p (m.a.s.l.)	-7.20	h_F (m.a.s.l.)	-0.28
Q_p (m^3/s)	$1.76 \cdot 10^{-3}$		
tp (min)	11641	t_F (min)	978
S^*	$5 \cdot 10^{-5}$	S^*	$5 \cdot 10^{-5}$
EC_w (mS/m)	-		
Te_w(deg C)	-		
Derivative fact.	0.3	Derivative fact.	0.3
Results		**Results**	
Q/s (m^2/s)	$2.55 \cdot 10^{-4}$		
T_M (m^2/s)	$4.24 \cdot 10^{-4}$		
Flow regime:	PRF	Flow regime:	PRF
t_1 (min)	30	t_1 (min)	30
t_2 (min)	600	t_2 (min)	300
T_w (m^2/s)	$3.84 \cdot 10^{-4}$	T_w (m^2/s)	$4.66 \cdot 10^{-4}$
S_w (-)	-	S_w (-)	-
K_{sw} (m/s)	-	K_{sw} (m/s)	-
S_{sw} (1/m)	-	S_{sw} (1/m)	-
C (m^3/Pa)	-	C (m^3/Pa)	-
C_D (-)	-	C_D (-)	-
ξ (-)	0.10	ξ (-)	0.87
T_{GRF}(m^2/s)		T_{GRF}(m^2/s)	
S_{GRF}(-)		S_{GRF}(-)	
D_{GRF} (-)		D_{GRF} (-)	

Interpreted formation and well parameters.

Flow regime:	PRF	C (m^3/Pa)	$5.03 \cdot 10^{-6}$
t_1 (min)	30	C_D (-)	-
t_2 (min)	300	ξ (-)	0.87
T_T (m^2/s)	$4.66 \cdot 10^{-4}$		
S (-)	-		
K_s (m/s)	-		
S_s (1/m)	-		

Comments: After initial wellbore storage- and skin effects, pseudo-radial flow occurred during both the recovery period and the first phase of the flow period during the difference flow logging campaign in KFM03A.

7 References

1 **Almén K-E, et al. 1986.**Hydraulic testing in crystalline rock. A comparative study of single-hole test methods. Technical Report 86-27, Svensk Kärnbränslehantering AB.

2 **Ludvigson J-E and Jönsson S, 2003.** Forsmark Site Investigation - Hydraulic interference tests. Boreholes HFM01, HFM02 and HFM03. Report P-03-35, Svensk Kärnbränslehantering AB.

8 Appendices

Appendix 12.1: Test data files

Appendix 12.2: Test data diagrams

Appendix 12.3: Parameter file to SICADA

APPENDIX 12.1 – TEST DATA FILES

Bh ID	Test section (m)	Test type[1]	Test start Date, time YYYY-MM-DD hh:mm	Test stop Date, time YYYY-MM-DD hh:mm	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	Selected Parameters measured	Comments
KFM03A	11.96-1001.19[2]	1B	2003-08-17 11:55	2003-08-26 06:18	2003-08-17 11:35	2003-08-25 13:59	FOF03APU16E050T105.DAT	Q	Entire flow period (Item 10-12 in AP)
KFM03A	11.96-1001.19[2]	1B	2003-08-17 11:55	2003-08-26 06:18	2003-08-17 11:31:29	2003-08-18 09:32:55	FOF03AGL18E050D105.CSV	P1	Item 10 in AP
KFM03A	11.96-1001.19[2]	1B	2003-08-17 11:55	2003-08-26 06:18	2003-08-18 10:36:43	2003-08-18 13:18:20	FOF03AGL16E050D105.CSV	P1	Item 10 in AP Cont.
KFM03A	11.96-1001.19[2]	1B	2003-08-17 11:55	2003-08-26 06:18	2003-08-18 13:31:55	2003-08-20 09:38:29	FOF03AGW16E050D105.CSV	P1	Item 10 in AP Cont.
KFM03A	11.96-1001.19[2]	1B	2003-08-17 11:55	2003-08-26 06:18	2003-08-20 18:52:19	2003-08-21 09:30:13	FOF03AGW11E050D205.CSV	P1	Item 10 in AP Cont.
KFM03A	11.96-1001.19[2]	1B	2003-08-17 11:55	2003-08-26 06:18	2003-08-21 16:40:29	2003-08-22 17:47:19	FOF03AGW11E010D105.CSV	P1	Item 11 in AP
KFM03A	11.96-1001.19[2]	1B	2003-08-17 11:55	2003-08-26 06:18	2003-08-22 23:00:21	2003-08-25 07:14:41	FOF03AGW16E010D105.CSV	P1	Item 11 in AP Cont.
KFM03A	11.96-1001.19[2]	1B	2003-08-17 11:55	2003-08-26 06:18	2003-08-25 10:33:33	2003-08-25 13:35:19	FOF03APR16D005D105.CSV	P1	Item 12 in AP
KFM03A	11.96-1001.19[2]	1B	2003-08-17 11:55	2003-08-26 06:18	2003-08-25 13:58:12	2003-08-26 06:17:55	FOF03AGL16R005D105.CSV	P1, P_{abs}	Recovery period

1: 1B: Pumping test-submersible pump
2: Entire uncased borehole interval (interval 97.20-101.85 m is cased with decreasing casing diameters)

APPENDIX 12.2 TEST DATA DIAGRAMS

Entire test sequence

Flow period

Recovery period

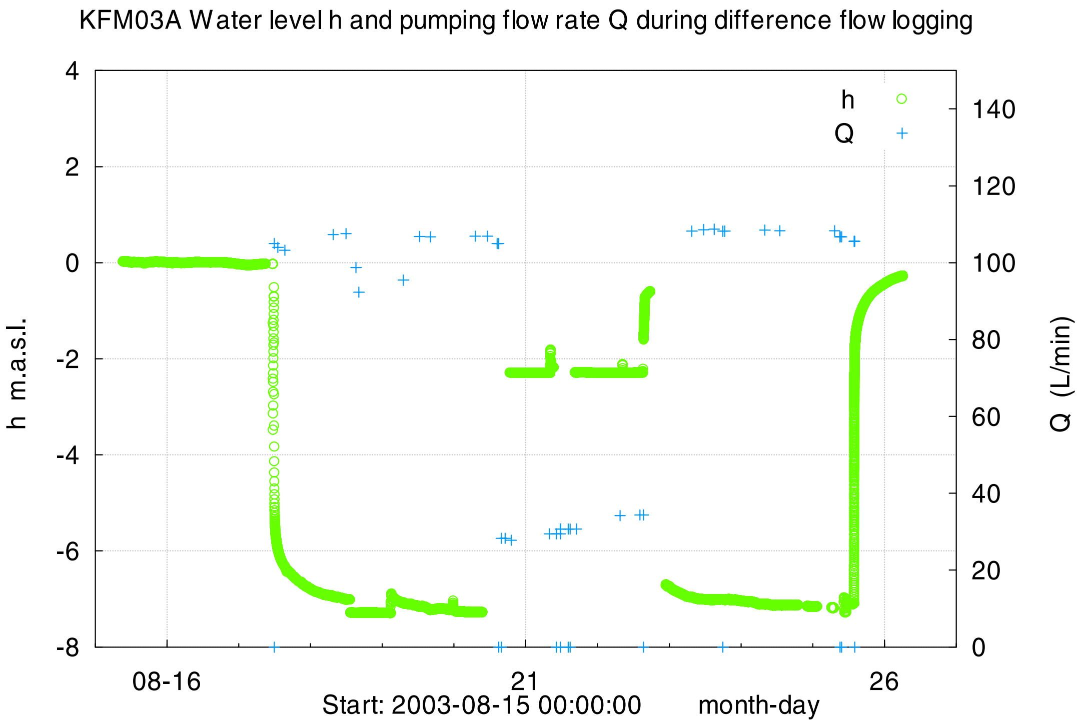


Figure 12.2-1. *Linear plot of groundwater level (h) and flow rate (Q) versus time during the pumping test in conjunction with difference flow logging in borehole KFM03A.*

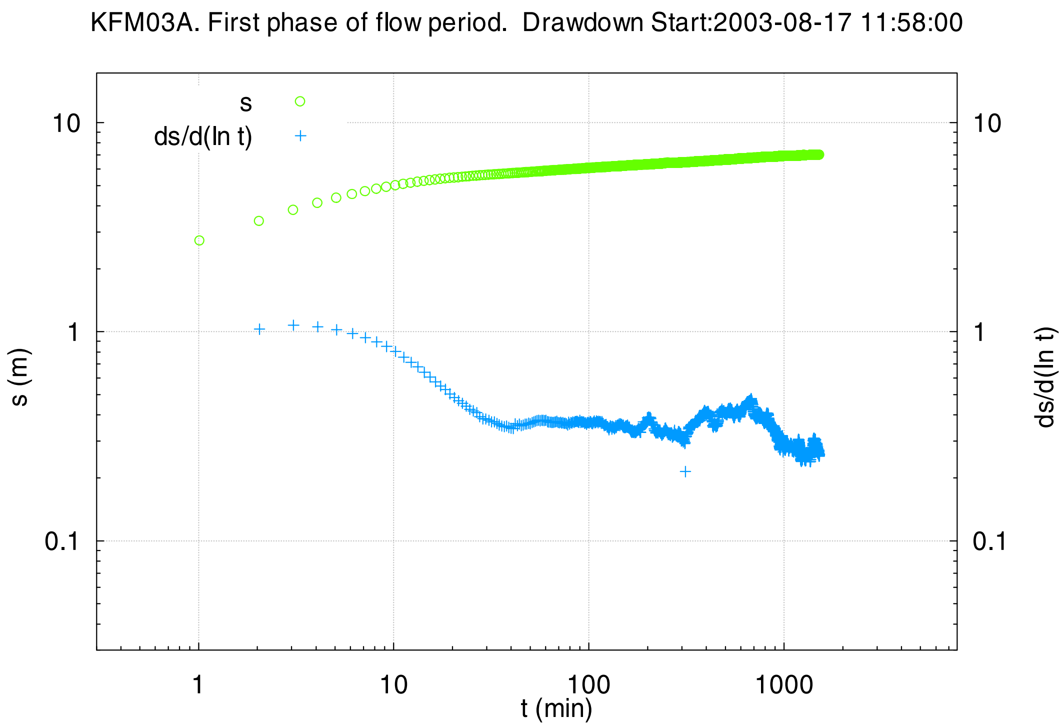


Figure 12.2-2. Log-log plot of drawdown (s) and - derivative, ds/d(ln t) versus time (t) during the first phase of the flow period in borehole KFM03A.

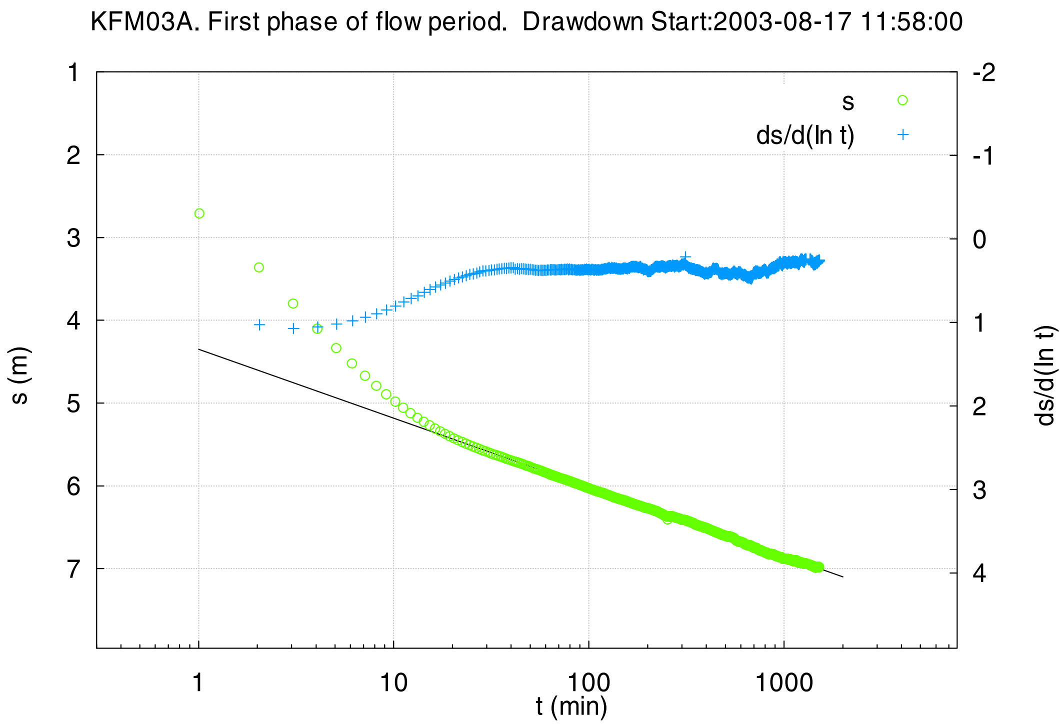


Figure 12.2-3. Lin-log plot of drawdown (s) and - derivative, ds/d(ln t) versus time (t) during the first phase of the flow period in borehole KFM03A.

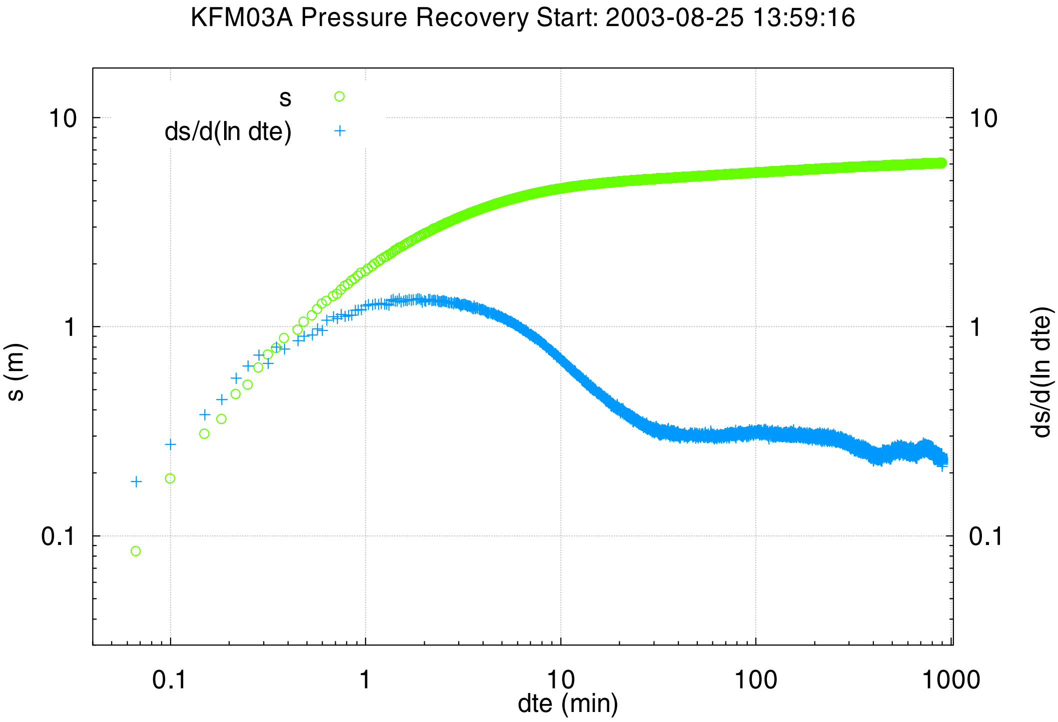


Figure 12.2-4. *Log-log plot of pressure recovery (s) and - derivative, ds/d(ln dte) versus equivalent time (dt_e) during the pumping test in borehole KFM03A.*

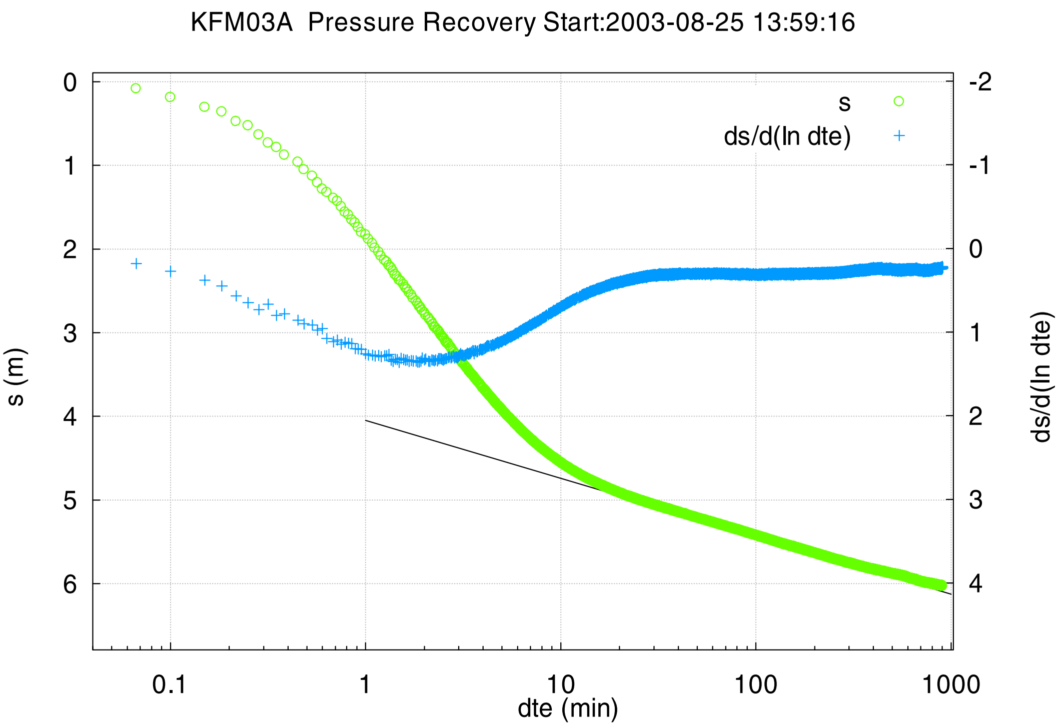


Figure 12.2-5. *Lin-log plot of pressure recovery (s) and - derivative, ds/d(ln dte) versus equivalent time (dt_e) during the pumping test in borehole KFM03A.*

APPENDIX 12.3 PARAMETER FILE TO SICADA

Result Tables for Single-hole pumping- and injection tests

Parameter file of results from single-hole pumping test in borehole KFM03A during difference flow logging.

SINGLEHOLE TESTS, Pumping and injection, s_hole_test_d; General information

Borehole	Borehole secup (m)	Borehole seclow (m)	Test type (1-7)	Formation type (-)	Date and time for test, start YYYYMMDD hh:mm	Date and time for test, stop YYYYMMDD hh:mm	Date and time of flow/ injection, start YYYYMMDD hh:mm:ss	Date and time of flow/ injection, stop YYYYMMDD hh:mm:ss	Q_p (m**3/s)	Value type-Q_p (-1,0,1)	Q-measl-L (m**3)/s	Q-measl-U (m**3)/s
KFM03A	11.96	1001.19	1B	1	2003-08-17 11:55	2003-08-26 06:18	2003-08-17 11:55	2003-08-25 13:59	1.76E-03	0		

cont.

V_p (m**3)	Q_m (m**3/s)	tp (s)	t_F (s)	h_i (m a sl)	h_p (m a sl)	h_F (m a sl)	p_i (kPa)	p_p (kPa)	p_F (kPa)	Te_w (°C)	EC_w (mS/m)	TDS_w (mg/ L)	TDS_{wm} (mg/ L)	Reference	Comments (-)
993.5		698460	58680	0.02	-7.20	-0.28								P-03-xx	

SINGLEHOLE TESTS, Pumping and injection, s_hole_test_ed1; Basic evaluation

Borehole	Borehole secup (m)	Borehole seclow (m)	Date and time for test, start YYYYMMDD hh:mm	Q/s (m^2/ s)	Value type-Q/s (-1, 0, 1)	T_Q (m^2/ s)	T_M (m^2/ s)	b (m)	B (m)	TB (1D) (m^3/ s)	TB-measl-L (1D) (m^3/ s)	TB-measl-U (1D) (m^3/ s)	SB (1D) (m)	SB* (1D) (m)	L_f (1D) (m)	T_T (2D) (m^2/ s)	Value type-T_T (-1, 0, 1)
KFM03A	11.96	1001.19	2003-08-17 11:55	2.55E-04	0		4.24E-04	989.23								4.66E-04	0

cont.

Q/s-measl-L (m^2/ s)	Q/s-measl-U (m^2/ s)	S (2D) (-)	S* (2D) (-)	K´/b´ (2D) (1/s)	K_S (3D) (m/s)	K_S-measl-L (3D) (m/s)	K_S-measl-U (3D) (m/s)	S_S (3D) (1/m)	S_S* (3D) (1/m)	L_p (m)	C (m**3/Pa)	C_D (-)	ξ (2D) (-)	ω (-)	λ (-)	t_1 (s)	t_2 (s)	Comments (-)
2.00E-08	2.00E-03		5.00E-05								5.03E-06		0.87			1800	18000	

Appendix 12

Header	Unit	Explanation
Borehole		ID for borehole
Borehole secup	m	Length coordinate along the borehole for the upper limit of the test section
Borehole seclow	m	Length coordinate along the borehole for the lower limit of the test section
Test type (1- 7)	(-)	1A: Pumping test - wireline eq., 1B:Pumping test-submersible pump, 1C: Pumpingtest-airlift pumping, 2: Interference test, 3: Injection test, 4: Slug test, 5A: Difference flow logging-PFL-DIFF-sequential, 5B: Difference flow logging-PFL-DIFF-overlapping, 6:Flow logging_Impeller,7:Grain size analysis
Date for test start		Date for the start of the pumping or injection test (YYYYMMDD hh:mm)
Start flow / injection		Date and time for the start of the pumping or injection period (YYMMDD hh:mm:ss)
Start flow / injection		Date and time for the end of the pumping or injection period (YYMMDD hh:mm:ss)
Q_m	m^3/s	Arithmetic mean flow rate of the pumping/injection period.
Q_p	m^3/s	Flow rate at the end of the pumping/injection period.
Value type	-	Code for Q_p-value; -1 means Q_p<lower measurement limit, 0 means measured value, 1 means Q_p> upper measurement value of flowrate
Q-measl_L	m^3/s	Estimated lower measurement limit for flow rate
Q-measl_U	m^3/s	Estimated upper measurement limit for flow rate
V_p	m^3	Total volume pumped (positive) or injected (negative) water during the flow period.
t_p	s	Time for the flowing phase of the test
t_F	s	Time for the recovery phase of the test
h_i	m	Initial formation hydraulic head. Measured as water level in open stand pipes from borehole section with reference level in the local coordinates system with z=0 m.
h_p	m	Final hydraulic head at the end of the pumping/injection period. Measured as water level in open stand pipes from borehole section with reference level in the local coordinates system with z=0 m.
h_F	m	Final hydraulic head at the end of the recovery period. Measured as water level in open stand pipes from borehole section with reference level in the local coordinates system with z=0 m.
p_i	kPa	Initial formation pressure.
p_p	kPa	Final pressure at the end of the pumping/injection period.
p_F	kPa	Final pressure at the end of the recovery period.
Te_w	gr C	Fluid temperature in the test section representative for the evaluated parameters
EC_w	mS/m	Electrical conductivity of the fluid in the test section representative for the evaluated parameters
TDS_w	mg/L	Total salinity of the fluid in formation at test section based on EC.
TDS_{wn}	mg/L	Total salinity of the fluid in formation at test section based on water sampling and chemical analysis.
Sec.type,	(-)	Test section (pumping or injection) is labeled 1 and all observation sections are labeled 2
Q/s	m2/s	Specific capacity, based on Qp and s=abs(pi-pp). Only given for test section (label 1) in interference test.
T_Q	m2/s	Steady-state transmissivity based on specific capacity and a function for T=f(Q/s). The function used should be referred in "Comments"
T_M	m2/s	Steady-state transmissivity based on Moye (1967)
b	m	Interpreted formation thickness representative for evaluated T or TB.
B	m	Interpreted width of a formation with evaluated TB
TB	m3/s	1D model for evaluation of formation properties. T=transmissivity, B=width of formation
TB-measl-L	m2/s	Estimated measurement limit for evaluated TB. If estimated TB equals TB-measlim in the table actual TB is considered to be equal or less than TB-measlim
TB-measl-L	m2/s	Estimated measurement limit for evaluated TB. If estimated TB equals TB-measlim in the table actual TB is considered to be equal or greater than TB-measlim
SB	m	1D model for evaluation of formation properties. S= Storativity, B=width of formation
SB*	m	1D model for evaluation of formation properties. Assumed SB. S= Storativity, B=width of formation

Appendix 12

Header	Unit	Explanation
L_f	m	1D model for evaluation of Leakage factor
T_T	m2/s	2D model for transient evaluation of formation properties. T=transmissivity
T-measl-L	m2/s	Estimated measurement limit for evaluated T (TT, TQ, TM). If estimated T equals T-measlim in the table actual T is considered to be equal or less than T-measlim
T-measl-U	m2/s	Estimated measurement limit for evaluated T (TT, TQ, TM). If estimated T equals T-measlim in the table actual T is considered to be equal or grater than T-measlim
S	(-)	2D model for evaluation of formation properties. S= Storativity
S*	(-)	2D model for evaluation of formation properties. Assumed S. S= Storativity
K´/b´	(1/s)	2D model for evaluation of leakage coefficient. K´= hydraulic conductivity in direction of leaking flow for the aquitard, b´= Saturated thickness of aquitard (leaking formation)
K_S	m/s	3D model for evaluation of formation properties. K=Hydraulic conductivity
K_S-measl-L	m/s	Estimated measurement limit for evaluated KS. If estimated KS equals KS-measlim in the table actual KS is considered to be equal or less than KS-measlim
K_S-measl-U	m/s	Estimated measurement limit for evaluated KS. If estimated KS equals KS-measlim in the table actual KS is considered to be equal or greater than KS-measlim
S_S	1/m	3D model for evaluation of formation properties. Ss=Specific Storage
S_S*	1/m	3D model for evaluation of formation properties. Assumed Ss. Ss=Specific Storage
L_p	m	Hydraulic point of application, based on hydraulic conductivity distribution (if available) or the midpoint of the borehole test section
C	(m3/Pa)	Wellbore storage coefficient
C_D	(-)	Dimensionless wellbore storage coefficient
ξ	(-)	Skin factor
ω	(-)	Storativity ratio
λ	(-)	Interporosity flow coefficient
t_1	s	Estimated start time after pump/injection start OR recovery start, for the period used for the evaluated parameter
t_2	s	Estimated stop time after pump/injection start OR recovery start, for the period used for the evaluated parameter
References		SKB report No for reports describing data and evaluation
Index w		Active borehole or borehole section

PFL-DIFFERENCE FLOW LOGGING - Sequential flow logging

Bore-hole	Date and time of test, start	Logged interval from (m)	Logged interval to (m)	Secup (m)	Seclow (m)	b (m)	Test type	Q_0 (m3/s)	Value type-Q_0	Q_1 (m3/s)	Value type-Q_1	Q_2 (m3/s)	Value type-Q_2	Q-measl-L-practical (m3/s)	h_{0f} (m.a.s.l.)	h_{1f} (m.a.s.l.)	h_{2f} (m.a.s.l.)	T_D (m^2/s)	Value type-T_D	T_D-measl-L-practical (m^2/s)	T_D-measl-U (m^2/s)	h_i (masl)	Value type-h_i	Te_w (°C)	Comments
KFM03A	2003-08-15	101,85	996,62	100,81	105,81	5	5A		-1					8,3E-8	0,361				-1	4,1E-8	4,1E-5		-1		Upper discs in casing
KFM03A	2003-08-15	101,85	996,62	105,82	110,82	5	5A		-1					8,3E-8	0,397			1,68E-08	0	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	110,82	115,82	5	5A		-1					8,3E-8	0,46				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	115,82	120,82	5	5A	-8,6E-9	0					8,3E-8	0,521			6,05E-08	0	4,0E-8	4,0E-5	0,38	0		
KFM03A	2003-08-15	101,85	996,62	120,82	125,82	5	5A	-6,2E-9	0					8,3E-8	0,553			3,06E-08	0	4,1E-8	4,1E-5	0,35	0		
KFM03A	2003-08-15	101,85	996,62	125,82	130,82	5	5A	-2,5E-8	0					8,3E-8	0,597			9,70E-08	0	4,1E-8	4,1E-5	0,34	0		
KFM03A	2003-08-15	101,85	996,62	130,82	135,82	5	5A		-1					8,3E-8	0,649				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	135,82	140,82	5	5A		-1					8,3E-8	0,682				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	140,83	145,83	5	5A		-1					8,3E-8	0,706				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	145,83	150,83	5	5A		-1					8,3E-8	0,761				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	150,83	155,83	5	5A		-1					8,3E-8	0,812				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	155,84	160,84	5	5A		-1					8,3E-8	0,857				-1	4,2E-8	4,2E-5		-1		
KFM03A	2003-08-15	101,85	996,62	160,84	165,84	5	5A		-1					8,3E-8	0,917				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	165,85	170,85	5	5A		-1					8,3E-8	0,954				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	170,85	175,85	5	5A		-1					8,3E-8	0,977				-1	4,2E-8	4,2E-5		-1		
KFM03A	2003-08-15	101,85	996,62	175,85	180,85	5	5A		-1					8,3E-8	1,047				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	180,85	185,85	5	5A		-1					8,3E-8	1,107				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	185,85	190,85	5	5A		-1					8,3E-8	1,147				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	190,85	195,85	5	5A		-1					8,3E-8	1,209				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	195,85	200,85	5	5A		-1					8,3E-8	1,268				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	200,85	205,85	5	5A		-1					8,3E-8	1,292				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	205,85	210,85	5	5A		-1					8,3E-8	1,335				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	210,85	215,85	5	5A		-1					8,3E-8	1,391				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	215,86	220,86	5	5A		-1					8,3E-8	1,429				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	220,86	225,86	5	5A		-1					8,3E-8	1,462				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	225,87	230,87	5	5A		-1					8,3E-8	1,531				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	230,87	235,87	5	5A		-1					8,3E-8	1,571				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	235,88	240,88	5	5A		-1					8,3E-8	1,606				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	240,88	245,88	5	5A		-1					8,3E-8	1,669				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	245,89	250,89	5	5A		-1					8,3E-8	1,725				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	250,89	255,89	5	5A		-1					8,3E-8	1,76				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	255,90	260,90	5	5A		-1					8,3E-8	1,816				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	260,90	265,90	5	5A		-1					8,3E-8	1,879				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	265,90	270,90	5	5A		-1					8,3E-8	1,931				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	270,90	275,90	5	5A		-1					8,3E-8	1,964				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	275,89	280,89	5	5A		-1					8,3E-8	2,037				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	280,89	285,89	5	5A		-1					8,3E-8	2,091				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	285,88	290,88	5	5A		-1					8,3E-8	2,131				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	290,88	295,88	5	5A		-1					8,3E-8	2,185				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	295,88	300,88	5	5A		-1					8,3E-8	2,248				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	300,88	305,88	5	5A		-1					8,3E-8	2,282				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	305,88	310,88	5	5A		-1					8,3E-8	2,349				-1	4,0E-8	4,0E-5		-1		

PFL-DIFFERENCE FLOW LOGGING - Sequential flow logging

Bore-hole	Date and time of test, start	Logged interval from (m)	Logged interval to (m)	Secup (m)	Seclow (m)	b (m)	Test type	Q_0 (m3/s)	Value type-Q_0	Q_1 (m3/s)	Value type-Q_1	Q_2 (m3/s)	Value type-Q_2	Q-measl-L-practical (m3/s)	h_{0f} (m.a.s.l.)	h_{1f} (m.a.s.l.)	h_{2f} (m.a.s.l.)	T_D (m^2/s)	Value type-T_D	T_D-measl-L-practical (m^2/s)	T_D-measl-U (m^2/s)	h_i (masl)	Value type-h_i	Te_w (°C)	Comments
KFM03A	2003-08-15	101,85	996,62	310,89	315,89	5	5A		-1					8,3E-8	2,422				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	315,89	320,89	5	5A		-1					8,3E-8	2,447				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	320,89	325,89	5	5A		-1					8,3E-8	2,478				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	325,89	330,89	5	5A		-1					8,3E-8	2,54				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	330,90	335,90	5	5A		-1					8,3E-8	2,566				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	335,90	340,90	5	5A		-1					8,3E-8	2,596				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	340,91	345,91	5	5A		-1					8,3E-8	2,667				-1	4,0E-8	4,0E-5		-1		
KFM03A	2003-08-15	101,85	996,62	345,91	350,91	5	5A		-1					8,3E-8	2,715				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	350,92	355,92	5	5A		-1					8,3E-8	2,738				-1	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	355,93	360,93	5	5A	-3,8E-8	0					8,3E-8	2,802			1,44E-06	0	4,1E-8	4,1E-5	2,78	0		
KFM03A	2003-08-15	101,85	996,62	360,93	365,93	5	5A	-5,9E-8	0					8,3E-8	2,851			1,98E-06	0	4,1E-8	4,1E-5	2,82	0		
KFM03A	2003-08-15	101,85	996,62	365,94	370,94	5	5A	-6,9E-8	0					8,3E-8	2,871			8,65E-07	0	4,1E-8	4,1E-5	2,79	0		
KFM03A	2003-08-15	101,85	996,62	370,94	375,94	5	5A	-1,3E-7	0					8,3E-8	2,934			2,01E-06	0	4,1E-8	4,1E-5	2,87	0		
KFM03A	2003-08-15	101,85	996,62	375,95	380,95	5	5A		-1					8,3E-8	3,003			7,35E-07	0	4,1E-8	4,1E-5		-1		
KFM03A	2003-08-15	101,85	996,62	380,96	385,96	5	5A		-1					8,3E-8	3,018			1,28E-07	0	4,2E-8	4,2E-5		-1		
KFM03A	2003-08-26	101,85	996,62	385,96	390,96	5	5C	2,8E-6	0					8,3E-8	2,73			1,74E-04	0	4,2E-8	6,9E-4	2,75	0		From PFL-DIFF Step flow test
KFM03A	2003-08-15	101,85	996,62	390,96	395,96	5	5A		-1					8,3E-9	3,142			4,93E-09	0	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	395,97	400,97	5	5A		-1					8,3E-9	3,187			1,87E-09	0	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	400,97	405,97	5	5A		-1					8,3E-9	3,22				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	405,97	410,97	5	5A		-1					8,3E-9	3,291			1,54E-08	0	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	410,97	415,97	5	5A		-1					8,3E-9	3,33			3,62E-09	0	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	415,97	420,97	5	5A		-1					8,3E-9	3,362				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	420,98	425,98	5	5A		-1					8,3E-9	3,427				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	425,98	430,98	5	5A		-1					8,3E-9	3,487				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	430,98	435,98	5	5A		-1					8,3E-9	3,523				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	435,98	440,98	5	5A		-1					8,3E-9	3,579				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	440,98	445,98	5	5A		-1					8,3E-9	3,661				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	445,98	450,98	5	5A		-1					8,3E-9	3,697				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	450,97	455,97	5	5A	-1,5E-6	0					8,3E-9	3,725			6,65E-06	0	1,3E-9	1,3E-5	3,5	0		
KFM03A	2003-08-15	101,85	996,62	455,97	460,97	5	5A		-1					8,3E-9	3,804				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	460,97	465,97	5	5A		-1					8,3E-9	3,841			7,00E-09	0	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	465,97	470,97	5	5A		-1					8,3E-9	3,86				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	470,97	475,97	5	5A		-1					8,3E-9	3,94				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	475,98	480,98	5	5A		-1					8,3E-9	4,009				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	480,98	485,98	5	5A		-1					8,3E-9	4,031				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	485,98	490,98	5	5A		-1					8,3E-9	4,094				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	490,98	495,98	5	5A		-1					8,3E-9	4,155				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	495,98	500,98	5	5A	-6,3E-9	0					8,3E-9	4,176			1,72E-08	0	1,3E-9	1,3E-5	3,81	0		
KFM03A	2003-08-15	101,85	996,62	500,98	505,98	5	5A		-1					8,3E-9	4,225				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	505,98	510,98	5	5A		-1					8,3E-9	4,306				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	510,99	515,99	5	5A		-1					8,3E-9	4,342			1,57E-09	0	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	515,99	520,99	5	5A		-1					8,3E-9	4,372			9,95E-09	0	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	521,00	526,00	5	5A		-1					8,3E-9	4,447				-1	1,3E-9	1,3E-5		-1		

PFL-DIFFERENCE FLOW LOGGING - Sequential flow logging

Bore-hole	Date and time of test, start	Logged interval from (m)	Logged interval to (m)	Secup (m)	Seclow (m)	b (m)	Test type	Q_0 (m3/s)	Value type-Q_0	Q_1 (m3/s)	Value type-Q_1	Q_2 (m3/s)	Value type-Q_2	Q-measl-L-practical (m3/s)	h_{0f} (m.a.s.l.)	h_{1f} (m.a.s.l.)	h_{2f} (m.a.s.l.)	T_D (m^2/s)	Value type-T_D	T_D-measl-L-practical (m^2/s)	T_D-measl-U (m^2/s)	h_i (masl)	Value type-h_i	Te_w (°C)	Comments
KFM03A	2003-08-15	101,85	996,62	526,01	531,01	5	5A		-1					8,3E-9	4,489				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	531,02	536,02	5	5A	-3,8E-9	0					8,3E-9	4,51			2,26E-08	0	1,3E-9	1,3E-5	4,35	0		
KFM03A	2003-08-15	101,85	996,62	536,03	541,03	5	5A		-1					8,3E-9	4,572				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	541,04	546,04	5	5A		-1					8,3E-9	4,628				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	546,05	551,05	5	5A		-1					8,3E-9	4,662				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	551,06	556,06	5	5A		-1					8,3E-9	4,717				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	556,07	561,07	5	5A		-1					8,3E-9	4,818				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	561,08	566,08	5	5A		-1					8,3E-9	4,863				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	566,09	571,09	5	5A		-1					8,3E-9	4,889				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	571,10	576,10	5	5A		-1					8,3E-9	4,959				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	576,10	581,10	5	5A		-1					8,3E-9	5,006				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	581,10	586,10	5	5A		-1					8,3E-9	5,032				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	586,10	591,10	5	5A		-1					8,3E-9	5,108				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	591,10	596,10	5	5A		-1					8,3E-9	5,17				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	596,10	601,10	5	5A		-1					8,3E-9	5,202				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	601,10	606,10	5	5A		-1					8,3E-9	5,257				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	606,10	611,10	5	5A		-1					8,3E-9	5,329				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	611,10	616,10	5	5A		-1					8,3E-9	5,363				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	616,11	621,11	5	5A		-1					8,3E-9	5,401				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	621,11	626,11	5	5A		-1					8,3E-9	5,475				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	626,12	631,12	5	5A		-1					8,3E-9	5,533				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	631,12	636,12	5	5A		-1					8,3E-9	5,576				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	636,12	641,12	5	5A		-1					8,3E-9	5,654				-1	1,3E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	641,13	646,13	5	5A	-8,2E-7	0					3,6E-8	5,72			2,56E-06	0	5,5E-9	1,3E-5	5,4	0		
KFM03A	2003-08-15	101,85	996,62	646,13	651,13	5	5A		-1					3,6E-8	5,758				-1	5,5E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	651,14	656,14	5	5A		-1					3,6E-8	5,814				-1	5,5E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	656,14	661,14	5	5A		-1					3,6E-8	5,888				-1	5,5E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	661,15	666,15	5	5A		-1					3,6E-8	5,917				-1	5,5E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	666,15	671,15	5	5A		-1					3,6E-8	5,97				-1	5,5E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	671,16	676,16	5	5A		-1					3,6E-8	6,065				-1	5,5E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	676,16	681,16	5	5A		-1					3,6E-8	6,116				-1	5,5E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	681,17	686,17	5	5A		-1					3,6E-8	6,145				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	686,17	691,17	5	5A		-1					3,6E-8	6,228				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	691,18	696,18	5	5A		-1					3,6E-8	6,296				-1	5,5E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	696,19	701,19	5	5A		-1					3,6E-8	6,323				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	701,21	706,21	5	5A		-1					3,6E-8	6,39				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	706,22	711,22	5	5A		-1					3,6E-8	6,474				-1	5,5E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	711,24	716,24	5	5A		-1					3,6E-8	6,51				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	716,26	721,26	5	5A		-1					3,6E-8	6,574				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	721,27	726,27	5	5A		-1					3,6E-8	6,634				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	726,29	731,29	5	5A		-1					3,6E-8	6,667				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	731,29	736,29	5	5A		-1					3,6E-8	6,739				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	736,30	741,30	5	5A		-1					3,6E-8	6,814				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	741,31	746,31	5	5A		-1					3,6E-8	6,858				-1	5,6E-9	1,3E-5		-1		

PFL-DIFFERENCE FLOW LOGGING - Sequential flow logging

Bore-hole	Date and time of test, start	Logged interval from (m)	Logged interval to (m)	Secup (m)	Seclow (m)	b (m)	Test type	Q_0 (m3/s)	Value type-Q_0	Q_1 (m3/s)	Value type-Q_1	Q_2 (m3/s)	Value type-Q_2	Q-measl-L-practical (m3/s)	h_{0f} (m.a.s.l.)	h_{1f} (m.a.s.l.)	h_{2f} (m.a.s.l.)	T_D (m^2/s)	Value type-T_D	T_D-measl-L-practical (m^2/s)	T_D-measl-U (m^2/s)	h_i (masl)	Value type-h_i	Te_w (°C)	Comments
KFM03A	2003-08-15	101,85	996,62	746,32	751,32	5	5A		-1					3,6E-8	6,937				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	751,33	756,33	5	5A		-1					3,6E-8	6,993				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	756,33	761,33	5	5A		-1					3,6E-8	7,037				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	761,34	766,34	5	5A		-1					3,6E-8	7,123				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	766,35	771,35	5	5A		-1					3,6E-8	7,186				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	771,36	776,36	5	5A		-1					3,6E-8	7,221				-1	5,7E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	776,36	781,36	5	5A		-1					3,6E-8	7,304				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	781,37	786,37	5	5A		-1					3,6E-8	7,365				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	786,38	791,38	5	5A		-1					3,6E-8	7,388				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	791,38	796,38	5	5A		-1					3,6E-8	7,471				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	796,39	801,39	5	5A		-1					3,6E-8	7,542				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	801,40	806,40	5	5A		-1					3,6E-8	7,578			2,38E-08	0	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	806,41	811,41	5	5A		-1					3,6E-8	7,681				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	811,41	816,41	5	5A		-1					3,6E-8	7,742			1,45E-08	0	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	816,42	821,42	5	5A		-1					3,6E-8	7,775				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	821,43	826,43	5	5A		-1					3,6E-8	7,869				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	826,44	831,44	5	5A		-1					3,6E-8	7,92				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	831,45	836,45	5	5A		-1					3,6E-8	7,962				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	836,46	841,46	5	5A		-1					3,6E-8	8,054				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	841,47	846,47	5	5A		-1					3,6E-8	8,097				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	846,48	851,48	5	5A		-1					3,6E-8	8,165				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	851,49	856,49	5	5A		-1					3,6E-8	8,275				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	856,50	861,50	5	5A		-1					3,6E-8	8,317				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	861,51	866,51	5	5A		-1					3,6E-8	8,368				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	866,52	871,52	5	5A		-1					3,6E-8	8,477				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	871,53	876,53	5	5A		-1					3,6E-8	8,531				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	876,54	881,54	5	5A		-1					3,6E-8	8,603				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	881,55	886,55	5	5A		-1					3,6E-8	8,693				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	886,56	891,56	5	5A		-1					3,6E-8	8,737				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	891,57	896,57	5	5A		-1					3,6E-8	8,813				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	896,57	901,57	5	5A		-1					3,6E-8	8,898				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	901,57	906,57	5	5A		-1					3,6E-8	8,943				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	906,57	911,57	5	5A		-1					3,6E-8	9,061				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	911,57	916,57	5	5A		-1					3,6E-8	9,152				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	916,57	921,57	5	5A		-1					3,6E-8	9,21				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	921,57	926,57	5	5A		-1					3,6E-8	9,315				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	926,58	931,58	5	5A		-1					3,6E-8	9,372				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	931,58	936,58	5	5A		-1					3,6E-8	9,449				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	936,58	941,58	5	5A		-1					3,6E-8	9,542				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	941,59	946,59	5	5A		-1					3,6E-8	9,6			3,79E-07	0	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	946,59	951,59	5	5A		-1					3,6E-8	9,711				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	951,59	956,59	5	5A		-1					3,6E-8	9,776				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	956,60	961,60	5	5A		-1					3,6E-8	9,853				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	961,60	966,60	5	5A		-1					3,6E-8	9,942				-1	5,5E-9	1,3E-5		-1		

PFL-DIFFERENCE FLOW LOGGING - Sequential flow logging

Bore-hole	Date and time of test, start	Logged interval from (m)	Logged interval to (m)	Secup (m)	Seclow (m)	b (m)	Test type	Q_0 (m3/s)	Value type-Q_0	Q_1 (m3/s)	Value type-Q_1	Q_2 (m3/s)	Value type-Q_2	Q-measl-L-practical (m3/s)	h_{0f} (m.a.s.l.)	h_{1f} (m.a.s.l.)	h_{2f} (m.a.s.l.)	T_D (m^2/s)	Value type-T_D	T_D-measl-L-practical (m^2/s)	T_D-measl-U (m^2/s)	h_i (masl)	Value type-h_i	Te_w (°C)	Comments
KFM03A	2003-08-15	101,85	996,62	966,60	971,60	5	5A		-1					3,6E-8	9,995				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	971,61	976,61	5	5A		-1					3,6E-8	10,099				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	976,61	981,61	5	5A		-1					3,6E-8	10,166				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	981,61	986,61	5	5A	8,9E-8	0					3,6E-8	10,233			2,24E-07	0	5,6E-9	1,3E-5	10,63	0		
KFM03A	2003-08-15	101,85	996,62	986,62	991,62	5	5A		-1					3,6E-8	10,363				-1	5,6E-9	1,3E-5		-1		
KFM03A	2003-08-15	101,85	996,62	991,62	996,62	5	5A		-1					3,6E-8	10,455			1,25E-07	0	5,5E-9	1,3E-5		-1		
KFM03A	2003-08-18	390,96	996,62	390,96	395,96	5	5A			3,1E-8	0			8,3E-9		-3,128									
KFM03A	2003-08-18	390,96	996,62	395,96	400,96	5	5A			1,2E-8	0			8,3E-9		-3,133									
KFM03A	2003-08-18	390,96	996,62	400,96	405,96	5	5A				-1			8,3E-9		-3,069									
KFM03A	2003-08-18	390,96	996,62	405,96	410,96	5	5A			9,8E-8	0			8,3E-9		-3,051									
KFM03A	2003-08-18	390,96	996,62	410,96	415,96	5	5A			2,3E-8	0			8,3E-9		-3,027									
KFM03A	2003-08-18	390,96	996,62	415,97	420,97	5	5A				-1			8,3E-9		-2,968									
KFM03A	2003-08-18	390,96	996,62	420,97	425,97	5	5A				-1			8,3E-9		-2,934									
KFM03A	2003-08-18	390,96	996,62	425,97	430,97	5	5A				-1			8,3E-9		-2,914									
KFM03A	2003-08-18	390,96	996,62	430,97	435,97	5	5A				-1			8,3E-9		-2,861									
KFM03A	2003-08-18	390,96	996,62	435,97	440,97	5	5A				-1			8,3E-9		-2,797									
KFM03A	2003-08-18	390,96	996,62	440,97	445,97	5	5A				-1			8,3E-9		-2,771									
KFM03A	2003-08-18	390,96	996,62	445,97	450,97	5	5A				-1			8,3E-9		-2,735									
KFM03A	2003-08-18	390,96	996,62	450,96	455,96	5	5A			4,2E-5	0			8,3E-9		-2,666									
KFM03A	2003-08-18	390,96	996,62	455,96	460,96	5	5A				-1			8,3E-9		-2,63									
KFM03A	2003-08-18	390,96	996,62	460,96	465,96	5	5A			4,6E-8	0			8,3E-9		-2,617									
KFM03A	2003-08-18	390,96	996,62	465,96	470,96	5	5A				-1			8,3E-9		-2,561									
KFM03A	2003-08-18	390,96	996,62	470,97	475,97	5	5A				-1			8,3E-9		-2,49									
KFM03A	2003-08-18	390,96	996,62	475,97	480,97	5	5A				-1			8,3E-9		-2,463									
KFM03A	2003-08-18	390,96	996,62	480,97	485,97	5	5A				-1			8,3E-9		-2,431									
KFM03A	2003-08-18	390,96	996,62	485,97	490,97	5	5A				-1			8,3E-9		-2,356									
KFM03A	2003-08-18	390,96	996,62	490,97	495,97	5	5A				-1			8,3E-9		-2,322									
KFM03A	2003-08-18	390,96	996,62	495,97	500,97	5	5A			1,1E-7	0			8,3E-9		-2,286									
KFM03A	2003-08-18	390,96	996,62	500,98	505,98	5	5A				-1			8,3E-9		-2,219									
KFM03A	2003-08-18	390,96	996,62	505,98	510,98	5	5A				-1			8,3E-9		-2,186									
KFM03A	2003-08-18	390,96	996,62	510,98	515,98	5	5A			1,0E-8	0			8,3E-9		-2,162									
KFM03A	2003-08-18	390,96	996,62	515,99	520,99	5	5A			6,5E-8	0			8,3E-9		-2,097									
KFM03A	2003-08-18	390,96	996,62	521,00	526,00	5	5A				-1			8,3E-9		-2,04									
KFM03A	2003-08-18	390,96	996,62	526,01	531,01	5	5A				-1			8,3E-9		-2,019									
KFM03A	2003-08-18	390,96	996,62	531,02	536,02	5	5A			1,4E-7	0			8,3E-9		-1,976									
KFM03A	2003-08-18	390,96	996,62	536,03	541,03	5	5A				-1			8,3E-9		-1,903									
KFM03A	2003-08-18	390,96	996,62	541,04	546,04	5	5A				-1			8,3E-9		-1,875									
KFM03A	2003-08-18	390,96	996,62	546,05	551,05	5	5A				-1			8,3E-9		-1,864									
KFM03A	2003-08-18	390,96	996,62	551,06	556,06	5	5A				-1			8,3E-9		-1,8									
KFM03A	2003-08-18	390,96	996,62	556,07	561,07	5	5A				-1			8,3E-9		-1,711									
KFM03A	2003-08-18	390,96	996,62	561,08	566,08	5	5A				-1			8,3E-9		-1,659									
KFM03A	2003-08-18	390,96	996,62	566,09	571,09	5	5A				-1			8,3E-9		-1,598									
KFM03A	2003-08-18	390,96	996,62	571,10	576,10	5	5A				-1			8,3E-9		-1,541									
KFM03A	2003-08-18	390,96	996,62	576,10	581,10	5	5A				-1			8,3E-9		-1,516									

PFL-DIFFERENCE FLOW LOGGING - Sequential flow logging

Bore-hole	Date and time of test, start	Logged interval from (m)	Logged interval to (m)	Secup (m)	Seclow (m)	b (m)	Test type	Q_0 (m3/s)	Value type-Q_0	Q_1 (m3/s)	Value type-Q_1	Q_2 (m3/s)	Value type-Q_2	Q-measl-L-practical (m3/s)	h_{0f} (m.a.s.l.)	h_{1f} (m.a.s.l.)	h_{2f} (m.a.s.l.)	T_D (m^2/s)	Value type-T_D	T_D-measl-L-practical (m^2/s)	T_D-measl-U (m^2/s)	h_i (masl)	Value type-h_i	Te_w (°C)	Comments
KFM03A	2003-08-18	390,96	996,62	581,10	586,10	5	5A				-1			8,3E-9		-1,463									
KFM03A	2003-08-18	390,96	996,62	586,09	591,09	5	5A				-1			8,3E-9		-1,387									
KFM03A	2003-08-18	390,96	996,62	591,09	596,09	5	5A				-1			8,3E-9		-1,357									
KFM03A	2003-08-18	390,96	996,62	596,09	601,09	5	5A				-1			8,3E-9		-1,318									
KFM03A	2003-08-18	390,96	996,62	601,09	606,09	5	5A				-1			8,3E-9		-1,238									
KFM03A	2003-08-18	390,96	996,62	606,09	611,09	5	5A				-1			8,3E-9		-1,21									
KFM03A	2003-08-18	390,96	996,62	611,09	616,09	5	5A				-1			8,3E-9		-1,192									
KFM03A	2003-08-18	390,96	996,62	616,10	621,10	5	5A				-1			8,3E-9		-1,112									
KFM03A	2003-08-18	390,96	996,62	621,10	626,10	5	5A				-1			8,3E-9		-1,061									
KFM03A	2003-08-18	390,96	996,62	626,11	631,11	5	5A				-1			8,3E-9		-1,021									
KFM03A	2003-08-18	390,96	996,62	631,11	636,11	5	5A				-1			8,3E-9		-0,951									
KFM03A	2003-08-18	390,96	996,62	636,11	641,11	5	5A				-1			8,3E-9		-0,878									
KFM03A	2003-08-18	390,96	996,62	641,12	646,12	5	5A			1,6E-5	0			3,6E-8		-0,834									
KFM03A	2003-08-18	390,96	996,62	646,12	651,12	5	5A				-1			3,6E-8		-0,77									
KFM03A	2003-08-18	390,96	996,62	651,13	656,13	5	5A				-1			3,6E-8		-0,677									
KFM03A	2003-08-18	390,96	996,62	656,13	661,13	5	5A				-1			3,6E-8		-0,637									
KFM03A	2003-08-18	390,96	996,62	661,14	666,14	5	5A				-1			3,6E-8		-0,595									
KFM03A	2003-08-18	390,96	996,62	666,14	671,14	5	5A				-1			3,6E-8		-0,474									
KFM03A	2003-08-18	390,96	996,62	671,15	676,15	5	5A				-1			3,6E-8		-0,414									
KFM03A	2003-08-18	390,96	996,62	676,15	681,15	5	5A				-1			3,6E-8		-0,382									
KFM03A	2003-08-18	390,96	996,62	681,16	686,16	5	5A				-1			3,6E-8		-0,287									
KFM03A	2003-08-18	390,96	996,62	686,16	691,16	5	5A				-1			3,6E-8		-0,212									
KFM03A	2003-08-18	390,96	996,62	691,17	696,17	5	5A				-1			3,6E-8		-0,175									
KFM03A	2003-08-18	390,96	996,62	696,18	701,18	5	5A				-1			3,6E-8		-0,097									
KFM03A	2003-08-18	390,96	996,62	701,20	706,20	5	5A				-1			3,6E-8		-0,038									
KFM03A	2003-08-18	390,96	996,62	706,22	711,22	5	5A				-1			3,6E-8		0,022									
KFM03A	2003-08-18	390,96	996,62	711,24	716,24	5	5A				-1			3,6E-8		0,114									
KFM03A	2003-08-18	390,96	996,62	716,25	721,25	5	5A				-1			3,6E-8		0,165									
KFM03A	2003-08-18	390,96	996,62	721,27	726,27	5	5A				-1			3,6E-8		0,205									
KFM03A	2003-08-18	390,96	996,62	726,29	731,29	5	5A				-1			3,6E-8		0,29									
KFM03A	2003-08-18	390,96	996,62	731,29	736,29	5	5A				-1			3,6E-8		0,329									
KFM03A	2003-08-18	390,96	996,62	736,30	741,30	5	5A				-1			3,6E-8		0,379									
KFM03A	2003-08-18	390,96	996,62	741,31	746,31	5	5A				-1			3,6E-8		0,467									
KFM03A	2003-08-18	390,96	996,62	746,32	751,32	5	5A				-1			3,6E-8		0,504									
KFM03A	2003-08-18	390,96	996,62	751,33	756,33	5	5A				-1			3,6E-8		0,564									
KFM03A	2003-08-18	390,96	996,62	756,33	761,33	5	5A				-1			3,6E-8		0,657									
KFM03A	2003-08-18	390,96	996,62	761,34	766,34	5	5A				-1			3,6E-8		0,714									
KFM03A	2003-08-18	390,96	996,62	766,35	771,35	5	5A				-1			3,6E-8		0,792									
KFM03A	2003-08-18	390,96	996,62	771,36	776,36	5	5A				-1			3,6E-8		0,96									
KFM03A	2003-08-18	390,96	996,62	776,36	781,36	5	5A				-1			3,6E-8		0,96									
KFM03A	2003-08-18	390,96	996,62	781,37	786,37	5	5A				-1			3,6E-8		0,959									
KFM03A	2003-08-18	390,96	996,62	786,38	791,38	5	5A				-1			3,6E-8		0,998									
KFM03A	2003-08-18	390,96	996,62	791,38	796,38	5	5A				-1			3,6E-8		1,036									
KFM03A	2003-08-18	390,96	996,62	796,39	801,39	5	5A				-1			3,6E-8		1,121									

PFL-DIFFERENCE FLOW LOGGING - Sequential flow logging

Bore-hole	Date and time of test, start	Logged interval from (m)	Logged interval to (m)	Secup (m)	Seclow (m)	b (m)	Test type	Q_0 (m3/s)	Value type-Q_0	Q_1 (m3/s)	Value type-Q_1	Q_2 (m3/s)	Value type-Q_2	Q-measl-L-practical (m3/s)	h_{0f} (m.a.s.l.)	h_{1f} (m.a.s.l.)	h_{2f} (m.a.s.l.)	T_D (m^2/s)	Value type-T_D	T_D-measl-L-practical (m^2/s)	T_D-measl-U (m^2/s)	h_i (masl)	Value type-h_i	Te_w (°C)	Comments
KFM03A	2003-08-18	390,96	996,62	801,40	806,40	5	5A			1,5E-7	0			3,6E-8		1,168									
KFM03A	2003-08-18	390,96	996,62	806,41	811,41	5	5A				-1			3,6E-8		1,255									
KFM03A	2003-08-18	390,96	996,62	811,41	816,41	5	5A			9,4E-8	0			3,6E-8		1,341									
KFM03A	2003-08-18	390,96	996,62	816,42	821,42	5	5A				-1			3,6E-8		1,378									
KFM03A	2003-08-18	390,96	996,62	821,43	826,43	5	5A				-1			3,6E-8		1,468									
KFM03A	2003-08-18	390,96	996,62	826,44	831,44	5	5A				-1			3,6E-8		1,524									
KFM03A	2003-08-18	390,96	996,62	831,45	836,45	5	5A				-1			3,6E-8		1,573									
KFM03A	2003-08-18	390,96	996,62	836,46	841,46	5	5A				-1			3,6E-8		1,658									
KFM03A	2003-08-18	390,96	996,62	841,47	846,47	5	5A				-1			3,6E-8		1,699									
KFM03A	2003-08-18	390,96	996,62	846,48	851,48	5	5A				-1			3,6E-8		1,803									
KFM03A	2003-08-18	390,96	996,62	851,49	856,49	5	5A				-1			3,6E-8		1,872									
KFM03A	2003-08-18	390,96	996,62	856,50	861,50	5	5A				-1			3,6E-8		1,914									
KFM03A	2003-08-18	390,96	996,62	861,51	866,51	5	5A				-1			3,6E-8		2									
KFM03A	2003-08-18	390,96	996,62	866,52	871,52	5	5A				-1			3,6E-8		2,062									
KFM03A	2003-08-18	390,96	996,62	871,53	876,53	5	5A				-1			3,6E-8		2,151									
KFM03A	2003-08-18	390,96	996,62	876,54	881,54	5	5A				-1			3,6E-8		2,227									
KFM03A	2003-08-18	390,96	996,62	881,55	886,55	5	5A				-1			3,6E-8		2,273									
KFM03A	2003-08-18	390,96	996,62	886,56	891,56	5	5A				-1			3,6E-8		2,372									
KFM03A	2003-08-18	390,96	996,62	891,57	896,57	5	5A				-1			3,6E-8		2,427									
KFM03A	2003-08-18	390,96	996,62	896,57	901,57	5	5A				-1			3,6E-8		2,512									
KFM03A	2003-08-18	390,96	996,62	901,57	906,57	5	5A				-1			3,6E-8		2,591									
KFM03A	2003-08-18	390,96	996,62	906,57	911,57	5	5A				-1			3,6E-8		2,651									
KFM03A	2003-08-18	390,96	996,62	911,57	916,57	5	5A				-1			3,6E-8		2,745									
KFM03A	2003-08-18	390,96	996,62	916,57	921,57	5	5A				-1			3,6E-8		2,807									
KFM03A	2003-08-18	390,96	996,62	921,57	926,57	5	5A				-1			3,6E-8		2,898									
KFM03A	2003-08-18	390,96	996,62	926,58	931,58	5	5A				-1			3,6E-8		2,951									
KFM03A	2003-08-18	390,96	996,62	931,58	936,58	5	5A				-1			3,6E-8		3,03									
KFM03A	2003-08-18	390,96	996,62	936,58	941,58	5	5A				-1			3,6E-8		3,118									
KFM03A	2003-08-18	390,96	996,62	941,59	946,59	5	5A			2,4E-6	0			3,6E-8		3,214									
KFM03A	2003-08-18	390,96	996,62	946,59	951,59	5	5A				-1			3,6E-8		3,288									
KFM03A	2003-08-18	390,96	996,62	951,59	956,59	5	5A				-1			3,6E-8		3,357									
KFM03A	2003-08-18	390,96	996,62	956,60	961,60	5	5A				-1			3,6E-8		3,44									
KFM03A	2003-08-18	390,96	996,62	961,60	966,60	5	5A				-1			3,6E-8		3,5									
KFM03A	2003-08-18	390,96	996,62	966,60	971,60	5	5A				-1			3,6E-8		3,623									
KFM03A	2003-08-18	390,96	996,62	971,61	976,61	5	5A				-1			3,6E-8		3,699									
KFM03A	2003-08-18	390,96	996,62	976,61	981,61	5	5A				-1			3,6E-8		3,797									
KFM03A	2003-08-18	390,96	996,62	981,61	986,61	5	5A			1,5E-6	0			3,6E-8		3,871									
KFM03A	2003-08-18	390,96	996,62	986,62	991,62	5	5A				-1			3,6E-8		3,947									
KFM03A	2003-08-18	390,96	996,62	991,62	996,62	5	5A			8,1E-7	0			3,6E-8		4,009									
KFM03A	2003-08-20	101,85	390,96	100,80	105,80	5	5A						-1	8,3E-8			-1,667								
KFM03A	2003-08-20	101,85	390,96	105,81	110,81	5	5A					3,4E-8	0	8,3E-8			-1,618								
KFM03A	2003-08-20	101,85	390,96	110,81	115,81	5	5A						-1	8,3E-8			-1,562								
KFM03A	2003-08-20	101,85	390,96	115,81	120,81	5	5A					1,2E-7	0	8,3E-8			-1,524								
KFM03A	2003-08-20	101,85	390,96	120,81	125,81	5	5A					5,7E-8	0	8,3E-8			-1,482								

PFL-DIFFERENCE FLOW LOGGING - Sequential flow logging

Bore-hole	Date and time of test, start	Logged interval from (m)	Logged interval to (m)	Secup (m)	Seclow (m)	b (m)	Test type	Q_0 (m3/s)	Value type-Q_0	Q_1 (m3/s)	Value type-Q_1	Q_2 (m3/s)	Value type-Q_2	Q-measl-L-practical (m3/s)	h_{0f} (m.a.s.l.)	h_{1f} (m.a.s.l.)	h_{2f} (m.a.s.l.)	T_D (m^2/s)	Value type-T_D	T_D-measl-L-practical (m^2/s)	T_D-measl-U (m^2/s)	h_i (masl)	Value type-h_i	Te_w (°C)	Comments
KFM03A	2003-08-20	101,85	390,96	125,81	130,81	5	5A					1,7E-7	0	8,3E-8			-1,415								
KFM03A	2003-08-20	101,85	390,96	130,81	135,81	5	5A						-1	8,3E-8			-1,375								
KFM03A	2003-08-20	101,85	390,96	135,82	140,82	5	5A						-1	8,3E-8			-1,341								
KFM03A	2003-08-20	101,85	390,96	140,82	145,82	5	5A						-1	8,3E-8			-1,286								
KFM03A	2003-08-20	101,85	390,96	145,82	150,82	5	5A						-1	8,3E-8			-1,254								
KFM03A	2003-08-20	101,85	390,96	150,83	155,83	5	5A						-1	8,3E-8			-1,202								
KFM03A	2003-08-20	101,85	390,96	155,83	160,83	5	5A						-1	8,3E-8			-1,129								
KFM03A	2003-08-20	101,85	390,96	160,83	165,83	5	5A						-1	8,3E-8			-1,1								
KFM03A	2003-08-20	101,85	390,96	165,84	170,84	5	5A						-1	8,3E-8			-1,052								
KFM03A	2003-08-20	101,85	390,96	170,84	175,84	5	5A						-1	8,3E-8			-1,007								
KFM03A	2003-08-20	101,85	390,96	175,84	180,84	5	5A						-1	8,3E-8			-0,965								
KFM03A	2003-08-20	101,85	390,96	180,84	185,84	5	5A						-1	8,3E-8			-0,901								
KFM03A	2003-08-20	101,85	390,96	185,84	190,84	5	5A						-1	8,3E-8			-0,863								
KFM03A	2003-08-20	101,85	390,96	190,85	195,85	5	5A						-1	8,3E-8			-0,833								
KFM03A	2003-08-20	101,85	390,96	195,85	200,85	5	5A						-1	8,3E-8			-0,772								
KFM03A	2003-08-20	101,85	390,96	200,85	205,85	5	5A						-1	8,3E-8			-0,737								
KFM03A	2003-08-20	101,85	390,96	205,85	210,85	5	5A						-1	8,3E-8			-0,695								
KFM03A	2003-08-20	101,85	390,96	210,85	215,85	5	5A						-1	8,3E-8			-0,631								
KFM03A	2003-08-20	101,85	390,96	215,86	220,86	5	5A						-1	8,3E-8			-0,592								
KFM03A	2003-08-20	101,85	390,96	220,86	225,86	5	5A						-1	8,3E-8			-0,557								
KFM03A	2003-08-20	101,85	390,96	225,87	230,87	5	5A						-1	8,3E-8			-0,496								
KFM03A	2003-08-20	101,85	390,96	230,87	235,87	5	5A						-1	8,3E-8			-0,463								
KFM03A	2003-08-20	101,85	390,96	235,87	240,87	5	5A						-1	8,3E-8			-0,426								
KFM03A	2003-08-20	101,85	390,96	240,88	245,88	5	5A						-1	8,3E-8			-0,357								
KFM03A	2003-08-20	101,85	390,96	245,88	250,88	5	5A						-1	8,3E-8			-0,317								
KFM03A	2003-08-20	101,85	390,96	250,89	255,89	5	5A						-1	8,3E-8			-0,286								
KFM03A	2003-08-20	101,85	390,96	255,89	260,89	5	5A						-1	8,3E-8			-0,216								
KFM03A	2003-08-20	101,85	390,96	260,89	265,89	5	5A						-1	8,3E-8			-0,163								
KFM03A	2003-08-20	101,85	390,96	265,89	270,89	5	5A						-1	8,3E-8			-0,127								
KFM03A	2003-08-20	101,85	390,96	270,89	275,89	5	5A						-1	8,3E-8			-0,059								
KFM03A	2003-08-20	101,85	390,96	275,89	280,89	5	5A						-1	8,3E-8			-0,017								
KFM03A	2003-08-20	101,85	390,96	280,88	285,88	5	5A						-1	8,3E-8			0,033								
KFM03A	2003-08-20	101,85	390,96	285,88	290,88	5	5A						-1	8,3E-8			0,1								
KFM03A	2003-08-20	101,85	390,96	290,88	295,88	5	5A						-1	8,3E-8			0,13								
KFM03A	2003-08-20	101,85	390,96	295,88	300,88	5	5A						-1	8,3E-8			0,18								
KFM03A	2003-08-20	101,85	390,96	300,88	305,88	5	5A						-1	8,3E-8			0,242								
KFM03A	2003-08-20	101,85	390,96	305,88	310,88	5	5A						-1	8,3E-8			0,292								
KFM03A	2003-08-20	101,85	390,96	310,89	315,89	5	5A						-1	8,3E-8			0,347								
KFM03A	2003-08-20	101,85	390,96	315,89	320,89	5	5A						-1	8,3E-8			0,413								
KFM03A	2003-08-20	101,85	390,96	320,89	325,89	5	5A						-1	8,3E-8			0,437								
KFM03A	2003-08-20	101,85	390,96	325,89	330,89	5	5A						-1	8,3E-8			0,482								
KFM03A	2003-08-20	101,85	390,96	330,90	335,90	5	5A						-1	8,3E-8			0,543								
KFM03A	2003-08-20	101,85	390,96	335,90	340,90	5	5A						-1	8,3E-8			0,572								
KFM03A	2003-08-20	101,85	390,96	340,91	345,91	5	5A						-1	8,3E-8			0,617								

PFL-DIFFERENCE FLOW LOGGING - Sequential flow logging

Bore-hole	Date and time of test, start	Logged interval from (m)	Logged interval to (m)	Secup (m)	Seclow (m)	b (m)	Test type	Q_0 (m3/s)	Value type-Q_0	Q_1 (m3/s)	Value type-Q_1	Q_2 (m3/s)	Value type-Q_2	Q-measl-L-practical (m3/s)	h_{0f} (m.a.s.l.)	h_{1f} (m.a.s.l.)	h_{2f} (m.a.s.l.)	T_D (m^2/s)	Value type-T_D	T_D-measl-L-practical (m^2/s)	T_D-measl-U (m^2/s)	h_i (masl)	Value type-h_i	Te_w (°C)	Comments
KFM03A	2003-08-20	101,85	390,96	345,91	350,91	5	5A						-1	8,3E-8			0,695								
KFM03A	2003-08-20	101,85	390,96	350,92	355,92	5	5A						-1	8,3E-8			0,734								
KFM03A	2003-08-20	101,85	390,96	355,92	360,92	5	5A					2,9E-6	0	8,3E-8			0,776								
KFM03A	2003-08-20	101,85	390,96	360,93	365,93	5	5A					4,0E-6	0	8,3E-8			0,824								
KFM03A	2003-08-20	101,85	390,96	365,93	370,93	5	5A					1,7E-6	0	8,3E-8			0,853								
KFM03A	2003-08-20	101,85	390,96	370,94	375,94	5	5A					4,0E-6	0	8,3E-8			0,914								
KFM03A	2003-08-20	101,85	390,96	375,95	380,95	5	5A					1,5E-6	0	8,3E-8			0,98								
KFM03A	2003-08-20	101,85	390,96	380,95	385,95	5	5A					2,5E-7	0	8,3E-8			1,05								
KFM03A	2003-08-26	101,85	390,96	385,96	390,96	5	5A					2,3E-5	0	8,3E-8			2,61								From PFL-DIFF Step flow test

PFL- DIFFERENCE FLOW LOGGING-Step flow test

Bore-hole	Date and time of test, start	Logged interval from (m)	Logged interval to (m)	Secup (m)	Seclow (m)	b (m)	Test type	Q_0 (mL/h)	Q_0 (m3/s)	Value type-Q_0	Q_1 (m3/s)	Value type-Q_1	Q_2 (m3/s)	Value type-Q_2	Q_3 (m3/s)	Value type-Q_3	h_{0f} (m.a.s.l.)	h_{1f} (m.a.s.l.)	h_{2f} (m.a.s.l.)	h_{3f} (m.a.s.l.)
KFM03A	2003-08-26	388,14	389,14	388,14	389,14	1	5C	10000	2,78E-06	0	1E-05	0	2,3E-05	0	4,2E-05	0	2,73	2,68	2,61	2,48

Cont.

T_D (m^2/s)	Value type-T_D	T_D-measl-L-practical (m^2/s)	T_D-measl-U (m^2/s)	h_i (m.a.s.l.)	Value type-h_i	Te_w (°C)	EC_w (S/m)	Comments
1,74E-04	0	3,3E-07	3,3E-04	2,75	0			Remeasurements at low drawdowns

PFL-OVERLAPPING DIFFERENCE FLOW LOGGING - Inferred flow anomalies and Fracture-specific EC measurements

Borehole	Date and time of test, start	Logged interval from	Logged interval to	b	dL	Test type	L_i	Upper limit	Lower limit	Q_0	Value type -Q_0	Q_1	Q_2	Q-measl-L-practical	h_{0f}	h_{1f}	h_{2f}	b_i	T_D	Value type-T_D	T_D-measl-L-practical	T_D-measl-U	h_i	Value type -h_i	Te_f	EC_f	t_f	Comments
ID	yyyymmdd hhmm	(m)	(m)	(m)	(m)	(1-6)	(m)	L (m)	L (m)	m3/s		m3/s	m3/s	m3/s	(m a s l)	(m a s l)	(m a s l)	(m)	(m^2/s)	(m^2/s)	(m^2/s)	(m^2/s)	(m)		°C	(S/m)	(s)	(-)
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	106,4	106,35	106,45	8,3E-8	-1	3,8E-8		8,3E-8	1,12	-2,15		0,1	1,1E-8	0	2,5E-8	2,5E-5	-	-1	9,23			Uncertain
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	113,2	113,15	113,25	8,3E-8	-1	1,1E-8		8,3E-8	1,04	-2,11		0,1	3,5E-9	0	2,6E-8	2,6E-5	-	-1	9,30			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	120,6	120,55	120,65	8,3E-8	-1	2,1E-7		8,3E-8	1,08	-2,08		0,1	6,5E-8	0	2,6E-8	2,6E-5	-	-1	9,30			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	123,1	123,05	123,15	8,3E-8	-1	5,3E-8		8,3E-8	1,08	-2,01		0,1	1,7E-8	0	2,7E-8	2,7E-5	-	-1	9,35			Uncertain
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	126,5	126,45	126,55	8,3E-8	-1	2,8E-8		8,3E-8	1,09	-2,02		0,1	8,8E-9	0	2,7E-8	2,7E-5	-	-1	9,36			Uncertain
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	130,2	130,15	130,25	8,3E-8	-1	2,9E-7		8,3E-8	1,11	-1,91		0,1	9,6E-8	0	2,7E-8	2,7E-5	-	-1	9,34			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	130,7	130,65	130,75	8,3E-8	-1	1,4E-8		8,3E-8	1,11	-1,9		0,1	4,6E-9	0	2,7E-8	2,7E-5	-	-1	9,42			Uncertain
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	150,8	150,75	150,85	8,3E-8	-1	5,6E-9		8,3E-8	1,20	-1,73		0,1	1,9E-9	0	2,8E-8	2,8E-5	-	-1	9,50			Uncertain
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	173,6	173,55	173,65	8,3E-8	-1	6,9E-9		8,3E-8	1,29	-1,55		0,1	2,4E-9	0	2,9E-8	2,9E-5	-	-1	9,64			Uncertain
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	314,4	314,35	314,45	8,3E-8	-1	5,6E-9		8,3E-8	2,26	-0,13		0,1	2,3E-9	0	3,4E-8	3,4E-5	-	-1	10,12			Uncertain
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	354,4	354,35	354,45	8,3E-8	-1	5,6E-9		8,3E-8	2,65	0,26		0,1	2,3E-9	0	3,4E-8	3,4E-5	-	-1	10,17			Uncertain
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	358,5	358,45	358,55	8,3E-8	-1	3,8E-6		8,3E-8	2,68	0,27		0,1	1,6E-6	0	3,4E-8	3,4E-5	-	-1	10,13			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	359,1	359,05	359,15	8,3E-8	-1	8,9E-8		8,3E-8	2,69	0,29		0,1	3,7E-8	0	3,4E-8	3,4E-5	-	-1	10,17			Uncertain
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	359,6	359,55	359,65	8,3E-8	-1	2,6E-8		8,3E-8	2,69	0,3		0,1	1,1E-8	0	3,4E-8	3,4E-5	-	-1	10,18			Uncertain
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	362,6	362,55	362,65	8,3E-8	-1	8,9E-8		8,3E-8	2,73	0,33		0,1	3,7E-8	0	3,4E-8	3,4E-5	-	-1	10,18			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	364,5	364,45	364,55	8,3E-8	-1	9,7E-7		8,3E-8	2,74	0,36		0,1	4,0E-7	0	3,5E-8	3,5E-5	-	-1	10,14			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	364,8	364,75	364,85	8,3E-8	-1	3,2E-6		8,3E-8	2,74	0,35		0,1	1,3E-6	0	3,4E-8	3,4E-5	-	-1	10,14			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	365,3	365,25	365,35	8,3E-8	-1	7,2E-7		8,3E-8	2,75	0,37		0,1	3,0E-7	0	3,5E-8	3,5E-5	-	-1	10,15			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	368,6	368,55	368,65	8,3E-8	-1	3,5E-6		8,3E-8	2,78	0,38		0,1	1,4E-6	0	3,4E-8	3,4E-5	-	-1	10,13			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	369,4	369,35	369,45	8,3E-8	-1	8,2E-7		8,3E-8	2,80	0,38		0,1	3,3E-7	0	3,4E-8	3,4E-5	-	-1	10,17			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	370	369,95	370,05	8,3E-8	-1	1,5E-7		8,3E-8	2,81	0,38		0,1	6,2E-8	0	3,4E-8	3,4E-5	-	-1	10,19			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	371,6	371,55	371,65	8,3E-8	-1	3,3E-6		8,3E-8	2,82	0,37		0,1	1,3E-6	0	3,4E-8	3,4E-5	-	-1	10,15			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	372,6	372,55	372,65	8,3E-8	-1	1,6E-6		8,3E-8	2,83	0,37		0,1	6,5E-7	0	3,4E-8	3,4E-5	-	-1	10,16			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	373,6	373,55	373,65	8,3E-8	-1	9,2E-7		8,3E-8	2,84	0,37		0,1	3,7E-7	0	3,3E-8	3,3E-5	-	-1	10,18			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	375,1	375,05	375,15	8,3E-8	-1	1,9E-8		8,3E-8	2,86	0,38		0,1	7,8E-9	-1	3,3E-8	3,3E-5	-	-1	10,21			Uncertain
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	380,8	380,75	380,85	8,3E-8	-1	1,5E-6		8,3E-8	2,92	0,47		0,1	6,1E-7	0	3,4E-8	3,4E-5	-	-1	10,19			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	381,6	381,55	381,65	8,3E-8	-1	7,2E-8		8,3E-8	2,93	0,48		0,1	2,9E-8	-1	3,4E-8	3,4E-5	-	-1	10,20			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	385,4	385,35	385,45	8,3E-8	-1	8,9E-8		8,3E-8	2,96	0,54		0,1	3,6E-8	0	3,4E-8	3,4E-5	-	-1	10,21			Uncertain
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	388,6	388,55	388,65	8,3E-8	-1	8,2E-5		8,3E-8	2,99	2,11		0,1	9,2E-5	0	9,4E-8	9,4E-5	-	-1	10,22			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	393,8	393,75	393,85	8,3E-8	-1	5,6E-9		8,3E-8	3,04	2,42		0,1	8,9E-9	-1	1,3E-7	1,3E-4	-	-1	10,49			
KFM03A	2004-05-09 09:25	103	410	1	0,1	5B	398,2	398,15	398,25	8,3E-8	-1	8,3E-9		8,3E-8	3,09	2,51		0,1	1,4E-8	-1	1,4E-7	1,4E-4	-	-1	10,58			Uncertain
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	410,7	410,65	410,75	8,3E-8	-1		1,0E-7	8,3E-9	3,33		-2,82	0,1	1,7E-8	0	1,3E-9	1,3E-5	-	-1	10,62			
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	411,5	411,45	411,55	8,3E-8	-1		2,2E-8	8,3E-9	3,33		-2,81	0,1	3,6E-9	0	1,3E-9	1,3E-5	-	-1	10,64			
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	449,4	449,35	449,45	8,3E-8	-1		5,6E-9	8,3E-9	3,70		-2,47	0,1	8,9E-10	-1	1,3E-9	1,3E-5	-	-1	11,10			Uncertain
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	451,3	451,25	451,35	-1,5E-6	0		4,0E-5	8,3E-9	3,71		-2,48	0,1	6,7E-6	0	1,3E-9	1,3E-5	3,48	0	11,03	2,28	806	
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	454,6	454,55	454,65	-1,7E-8	-1		4,3E-7	8,3E-9	3,74		-2,48	0,1	7,2E-8	0	1,3E-9	1,3E-5	3,51	0	11,20			
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	462,4	462,35	462,45	8,3E-8	-1		4,4E-8	8,3E-9	3,84		-2,37	0,1	7,1E-9	0	1,3E-9	1,3E-5	-	-1	11,31			
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	500,5	500,45	500,55	-6,4E-9	-1		1,2E-7	8,3E-9	4,18		-2,08	0,1	1,9E-8	0	1,3E-9	1,3E-5	3,86	0	11,73			
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	515,9	515,85	515,95	8,3E-8	-1		6,9E-9	8,3E-9	4,35		-1,94	0,1	1,1E-9	-1	1,3E-9	1,3E-5	-	-1	11,94			Uncertain

PFL-OVERLAPPING DIFFERENCE FLOW LOGGING - Inferred flow anomalies and Fracture-specific EC measurements

Borehole	Date and time of test, start	Logged interval from	Logged interval to	b	dL	Test type	L_i	Upper limit	Lower limit	Q_0	Value type -Q_0	Q_1	Q_2	Q-measl-L-practical	h_{0f}	h_{1f}	h_{2f}	b_i	T_D	Value type-T_D	T_D-measl-L-practical	T_D-measl-U	h_i	Value type -h_i	Te_f	EC_f	t_f	Comments
ID	yyyymmdd hhmm	(m)	(m)	(m)	(m)	(1-6)	(m)	L (m)	L (m)	m3/s		m3/s	m3/s	m3/s	(m a s l)	(m a s l)	(m a s l)	(m)	(m^2/s)	(m^2/s)	(m^2/s)	(m^2/s)	(m)		°C	(S/m)	(s)	(-)
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	517,7	517,65	517,75	8,3E-8	-1		6,7E-8	8,3E-9	4,36		-1,90	0,1	1,1E-8	0	1,3E-9	1,3E-5	-	-1	11,95			
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	533,7	533,65	533,75	-3,9E-9	-1		1,4E-7	8,3E-9	4,51		-1,76	0,1	2,3E-8	0	1,3E-9	1,3E-5	4,34	0	12,13			
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	642,2	642,15	642,25	8,3E-8	-1		9,7E-8	3,6E-8	5,71		-0,59	0,1	1,5E-8	0	5,7E-9	1,3E-5	-	-1	13,35			
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	643,9	643,85	643,95	-8,2E-7	0		1,5E-5	3,6E-8	5,72		-0,57	0,1	2,5E-6	0	5,7E-9	1,3E-5	5,40	0	13,35	2,29	1460	
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	803,8	803,75	803,85	8,3E-8	-1		8,8E-8	3,6E-8	7,58		1,38	0,1	1,4E-8	0	5,8E-9	1,3E-5	-	-1	15,42			
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	813,7	813,65	813,75	8,3E-8	-1		9,2E-8	3,6E-8	7,74		1,53	0,1	1,5E-8	0	5,7E-9	1,3E-5	-	-1	15,57			
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	944,2	944,15	944,25	8,3E-8	-1		2,0E-6	3,6E-8	9,60		3,42	0,1	3,3E-7	0	5,8E-9	1,3E-5	-	-1	17,35	3,29	11020	
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	946,8	946,75	946,85	8,3E-8	-1		1,2E-7	3,6E-8	9,64		3,38	0,1	1,8E-8	0	5,7E-9	1,3E-5	-	-1	17,39			Uncertain
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	986,2	986,15	986,25	8,9E-8	0		1,3E-6	3,6E-8	10,28		4,11	0,1	1,9E-7	0	5,8E-9	1,3E-5	10,74	0	17,92	3,84	17377	
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	986,5	986,45	986,55	8,3E-8	-1		5,6E-8	3,6E-8	10,29		4,11	0,1	8,9E-9	0	5,8E-9	1,3E-5	-	-1	17,92			Uncertain
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	992,9	992,85	992,95	8,3E-8	-1		2,7E-7	3,6E-8	10,44		4,19	0,1	4,2E-8	0	5,7E-9	1,3E-5	-	-1	18,00			
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	993,8	993,75	993,85	8,3E-8	-1		3,1E-7	3,6E-8	10,45		4,22	0,1	4,8E-8	0	5,7E-9	1,3E-5	-	-1	18,01			
KFM03A	2003-08-22 18:12	390	996	1	0,1	5B	994,0	993,95	994,05	8,3E-8	-1		1,1E-7	3,6E-8	10,45		4,23	0,1	1,8E-8	0	5,7E-9	1,3E-5	-	-1	18,01			Uncertain
KFM03A	2003-08-22 18:12			1			388,6	388,55	388,65																10,25	2,34	800	Fracture-EC
KFM03A	2004-05-08 10:07			1			388,6	388,55	388,65																10,22	1,65	3580	Fracture-EC
KFM03A	2004-05-08 08:28			1			451,3	451,25	451,35																10,98	1,63	3767	Fracture-EC
KFM03A	2004-05-06 10:18			1			643,9	643,85	643,95																13,25	1,62	75069	Fracture-EC
KFM03A	2004-05-07 18:42			1			643,9	643,85	643,95																13,26	1,61	46506	Fracture-EC
KFM03A	2004-05-07 08:54			1			944,2	944,15	944,25																17,27	2,31	14420	Fracture-EC
KFM03A	2004-05-07 13:45			1			986,2	986,15	986,25																17,86	2,89	14286	Fracture-EC

Header	Unit	Description
Borehole		borehole identification code
Secup	m	Length coordinate along the borehole for the upper limit of the logged section (Based on corrected length L)
Seclow	m	Length coordinate along the borehole for the lower limit of the logged section. (Based on corrected length L)
Test type		1A: Pumping test - wireline eq., 1B:Pumping test-submersible pump, 1C: Pumpingtest-airlift pumping, 2: Interference test, 3: Injection test, 4: Slug test, 5A: Difference flow logging-PFL-DIFF-Sequential, 5B: Difference flow logging-PFL-DIFF-Overlapping,
Formation type		1: Rock, 2: Soil (superficial deposits)
Date and time of test, start		Date for the start of the test (YYYY-MM-DD hh:mm)
Date and time of test, stop		Date for the stop of the test (YYYY-MM-DD hh:mm)
Date and time of flow logging, start		Date and time of flow logging start (YYYY-MM-DD hh:mm:ss)
Date and time of flow logging, stop		Date and time of flow logging stop (YYYY-MM-DD hh:mm:ss)
L_w	m	Section length used in the difference flow logging
dL	m	Step length (increment) used in the difference flow logging
Q-measl-L-theoretical	mL/h	Theoretical lower measurement limit for borehole flow rate in flow logging probe
Q-measl-L-practical	mL/h	Estimated practical lower measurement limit for borehole flow rate in flow logging probe
Q-measl-U	mL/h	Upper measurement limit for borehole flow rate in flowlogging probe
Q_{p1}	m^3/s	Flow rate at surface by the end of the first pumping period of the flow logging
Q_{p2}	m^3/s	Flow rate at surface by the end of the second pumping period of the flow logging
t_{p1}	s	Duration of the first pumping period
t_{p2}	s	Duration of the second pumping period
t_{F1}	s	Duration of the first recovery period
t_{F2}	s	Duration of the second recovery period
h_0	m.a.s.l.	Initial hydraulic head. Measured as water level in open borehole with reference level in the local coordinates system with z=0 m.
h_1	m.a.s.l.	Stabilized hydraulic head during first pumping period. Measured as water level in open borehole with reference level in the local coordinates system with z=0 m.
h_2	m.a.s.l.	Stabilized hydraulic head during second pumping period.Measured as water level in open borehole with reference level in the local coordinates system with z=0 m.
h_F	m.a.s.l.	Stabilized hydraulic head at the end of the recovery period.Measured as water level in open borehole with reference level in the local coordinates system with z=0 m.
s_1	m	Drawdown of the water level in the borehole during first pumping period. Difference between the actual hydraulic head and the initial head ($s_1= h_1-h_0$)
s_2	m	Drawdown of the water level in the borehole during second pumping period. Difference between the actual hydraulic head and the initial head ($s_2=h_2-h_0$)
Upper limit	m	Length along the borehole of the upper limit of the test section or flow anomaly (based on corrected length L)

Header	Unit	Description
Lower limit	m	Length along the borehole of the lower limit of the test section or flow anomaly (based on corrected length L)
b	m	Represenative thickness estimated as section length L_w used in the difference flow logging.
Q_0	mL/h	Measured flow rate through the test section or flow anomaly under natural conditions (no pumping) with $h=h_0$ in the open borehole
Value type-Q_0		Code for Q_0-value; -1 means Q_0< lower measurement limit, 0 means measured value within the meausurement limits, 1 means Q_0>upper measurement limit.
Q_1	mL/h	Measured flow rate through the test section or flow anomaly during the first pumping period
Value type-Q_1		Code for Q_1-value; -1 means Q_1< lower measurement limit, 0 means measured value within the meausurement limits, 1 means Q_1 Q_1>upper measurement limit.
Q_2	m**3/s	Measured flow rate through the test section or flow anomaly during the second pumping period
Value type-Q_2		Code for Q_2-value; -1 means Q_2< lower measurement limit, 0 means measured value within the meausurement limits, 1 means Q_2>upper measurement limit.
h_{0f}	m.a.s.l.	Measured initial hydraulic head distribution along the borehole before pumping
h_{1f}	m.a.s.l.	Measured hydraulic head distribution along the borehole during the first flow period.
h_{2f}	m.a.s.l.	Measured hydraulic head distribution along the borehole during the second flow period.
T_D	m**2/s	Transmissivity of section or flow anomaly based on 2D model for evaluation of formation properties of the test section based on PFL-DIFF.
Value type-T_D		Code for T_D -value; -1 means T_D < lower measurement limit, 0 means evaluated value within the meausurement limits, 1 means T_D >upper measurement limit.
T_D-measl-L-practical	m**2/s	Estimated practical measurement limit for evaluated $T_{D.}$ If the estimated T_D equals T_D-measlim, the actual T_D is considered to be equal or less than T_D-measlim.
T_D-measl-U	m**2/s	Upper measurement limit for evaluated $T_{D.}$ If the estimated T_D equals T_D-measlim, the actual T_D is considered to be equal or grater than T_D-measlim.
h_i	m	Calculated natural freshwater head for test section or flow anomaly (undisturbed conditions)
Value type-h_i		Code for h_i-value; -1 means h_i< lower measurement limit, 0 means measured value within the meausurement limits, 1 means h_i>upper measurement limit.
Te_w	centigrade	Measured borehole fluid temperature in the test section during difference flow logging
EC_w	mS/m, S/m	Measured electric conductivity of the borehole fluid in the test section during difference flow logging
TDS_w	mg/L	Total salinity of the fluid in the test section representative for the evaluated parameters based on EC.
b_i	m	Estimated thickness of flow anomaly or, alternatively the step length used in the overlapping logging
L_i	m	Length along the borehole to inferred flow anomaly during overlapping flow logging
Te_f	ºC	Measured fracture-specific fluid temperature in flow anomaly during difference flow logging
EC_f	mS/m	Measured fracture-specific electric conductivity (EC) of the fluid in flow anomaly during difference flow logging
TDS_f	mg/L	Total salinity of the fluid in the test section representative for the evaluated parameters based on EC.
t_f	s	Duration of fracture-specific EC-measurement in flow anomaly
references		SKB report No for reports describing data and evaluation
comments		Short comment to the evaluated parameters