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Forsmark site investigation

Difference flow logging in borehole KFM07A

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PRG-Tec Oy

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Keywords: Forsmark, Hydrogeology, Hydraulic tests, Difference flow measurements, AP PF 400-04-123

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.

Foreword

The performance and evaluation of the difference flow logging campaign in borehole KFM06A was made by PRG-Tec Oy.

The evaluation of the pumping test in conjunction with the difference flow logging (Section 6.6) was performed by Jan-Erik Ludvigson, Geosigma AB.

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 KFM07A at Forsmark, Sweden, in January 2005, 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 KFM07A prior to groundwater sampling.

The flow rate into or out of 5 m long test sections was measured between 91.98–994.81 m borehole length during natural (un-pumped) conditions and between 91.97–896.23 m borehole length during 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 absolute 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 distribution of saline water in the borehole during natural as well as pumped conditions. EC of fracture-specific water was measured at the same time as the flow measurements (1 m test section) for a selection of fractures.

The total transmissivity of the cored borehole KFM07A was estimated at $4.4 \cdot 10^{-4}$ m^2/s from the groundwater recovery after the pumping test in conjunction with the difference flow logging. This value is somewhat higher than the cumulative transmissivity of the measured 5 m sections and of the flow anomalies identified from the difference flow logging, c $1.1 \cdot 10^{-4}$ m^2/s. No significant effects of hydraulic boundaries were observed during the recovery period.

Sammanfattning

Differensflödesloggning är en snabb metod för bestämning av transmissiviteten och hydraulisk tryckhöjd i borrhålssektioner och sprickor/sprickzoner i kärnborrhål. Denna rapport presenterar huvudprinciperna för metoden och resultat av mätningar utförda i borrhål KFM07A i Forsmark, Sverige, i januari 2005 med Posiva flödesloggnings metod. Det primära syftet med mätningarna var att bestämma läget och flödet för vattenförande sprickor i borrhål KFM07A före grundvattenprovtagning.

Flödet till eller från en 5 m lång testsektion mättes mellan 91,98–994,81 m borrhåls längd under naturliga (icke-pumpade) förhållanden och mellan 91,97–896,23 m borrhålslängd under 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 absoluttrycket längs borrhålet. Dessa mätningar utfördes samtidigt 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. EC på vattnet i ett antal utvalda sprickor mättes samtidigt med flödesmätningarna (1 m lång testsektion).

Den totala transmissiviteten för kärnborrhålet KFM07A skattades till $4{,}4 \cdot 10^{-4}$ m^2/s från tryckåterhämtningsperioden efter pumptesten i anslutning till differensflödesloggningen. Detta värde är något högre än den kumulativa transmissiviteten för 5 m sektioner och för de identifierade flödesanomalierna från differensflödesloggningen (ca $1{,}1 \cdot 10^{-4}$ m^2/s). Inga effekter av hydrauliska gränser observerades under återhämtnings perioden.

Contents

1 Introduction

The difference flow logging in the core drilled borehole KFM07A at Forsmark was conducted between January 17–30, 2005. KFM07A is the seventh deep core drilled borehole in the Forsmark candidate area. The borehole is inclined c 60° from the horizontal direction. The c 1,000 m long borehole is performed with telescopic drilling technique, where the interval c 0–100 m is percussion drilled and cased with the inner diameter 200 mm and the remaining interval, c 100–1,000 m, is core drilled with the diameter c 77 mm. The location of borehole KFM07A at drilling site DS7 within the Forsmark area is shown in Figure 1-1.

The field work and the subsequent interpretations 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/.

This document reports the results gained by the Difference flow logging in borehole KFM07A. The activity is performed within the Forsmark site investigation. The work was carried out in accordance with the SKB internal controlling document AP PF 400-04-123. Data and results were delivered to the SKB site characterization database SICADA.

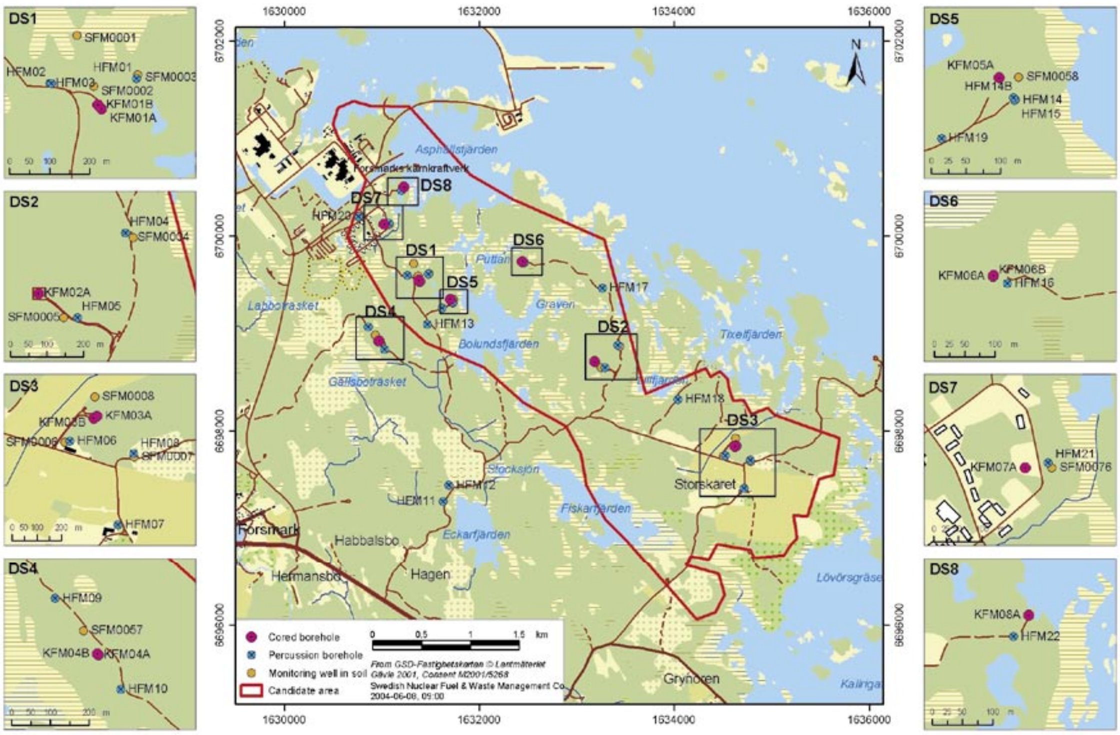

__Figure 1-1.__ Location of drill sites DS1–8 at Forsmark. Detailed maps of all boreholes within the sites are shown.

2 Objective and scope

The main objective of the difference flow logging in KFM07A 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 pressure sensor was used to measure the absolute pressure along the borehole. These measurements were carried out simultaneously 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 depth 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 is conducted 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. This mode 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 the 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 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, see Chapter 2. 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 within the flow sensor, Figure 3-1.

All of the above measurements were performed in KFM07A.

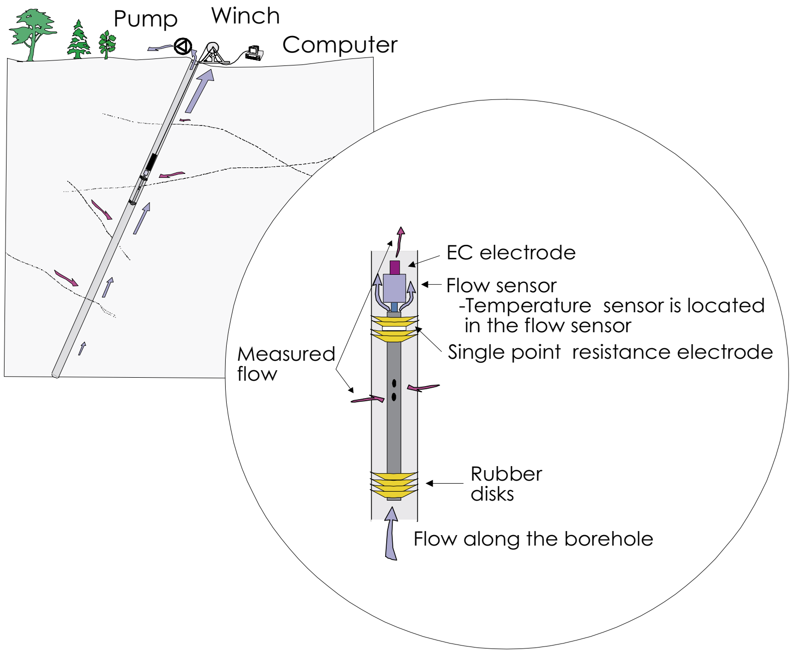

Figure 3-1. *Schematic presentation of the downhole equipment used in the Difference flowmeter.*

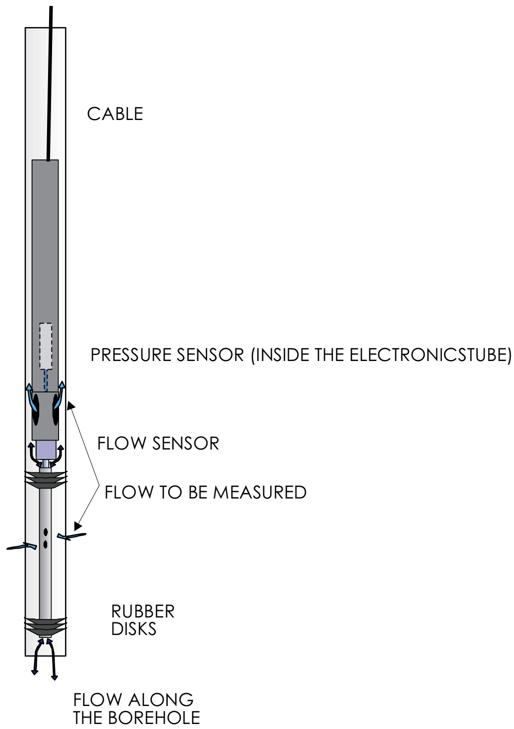

Figure 3-2. *The absolute pressure sensor is located inside the electronics tube and connected via another tube to the borehole water.*

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 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 be valid. 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

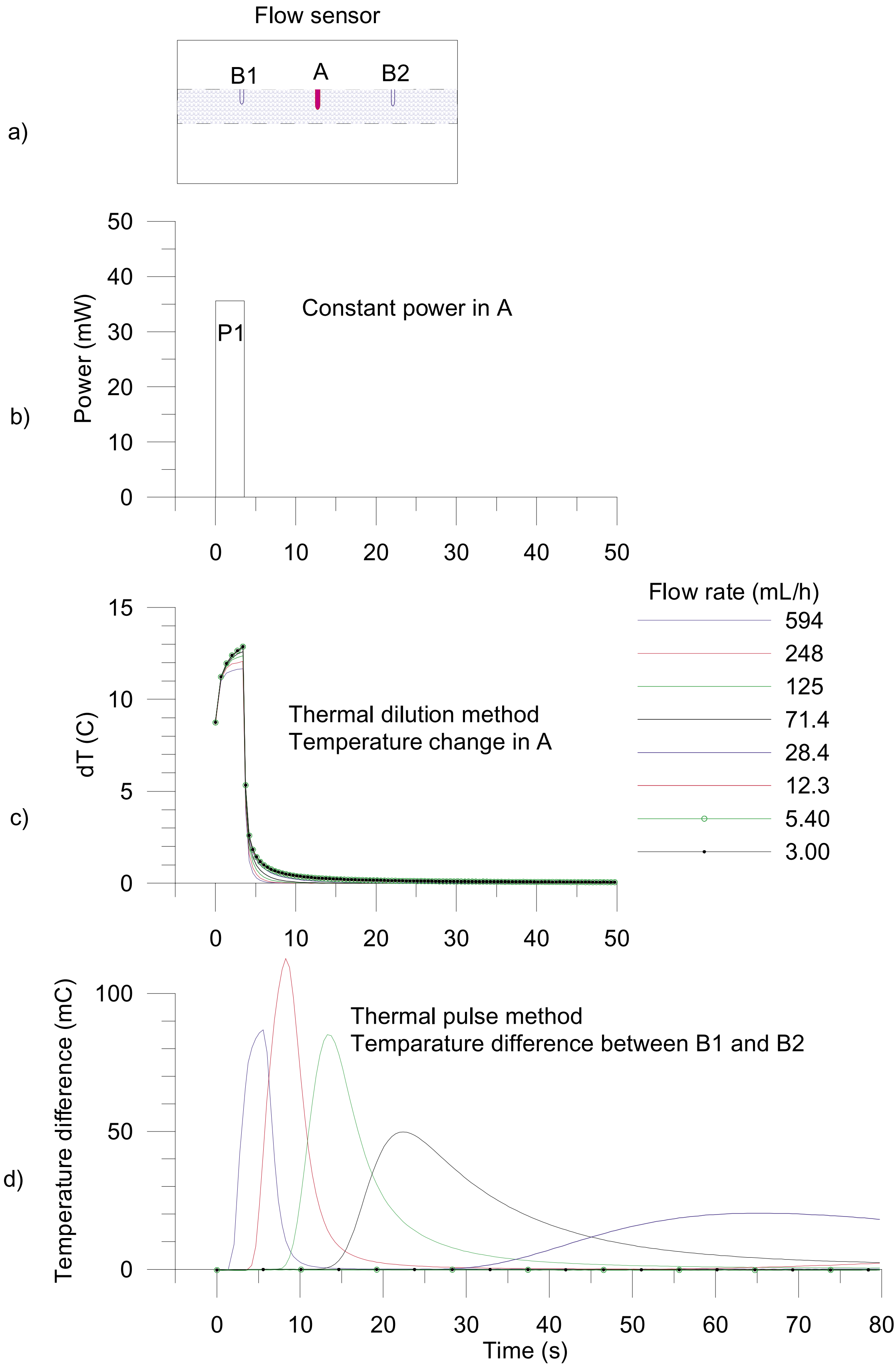

Figure 3-3. *Flow measurement, flow rate < 600 mL/h.*

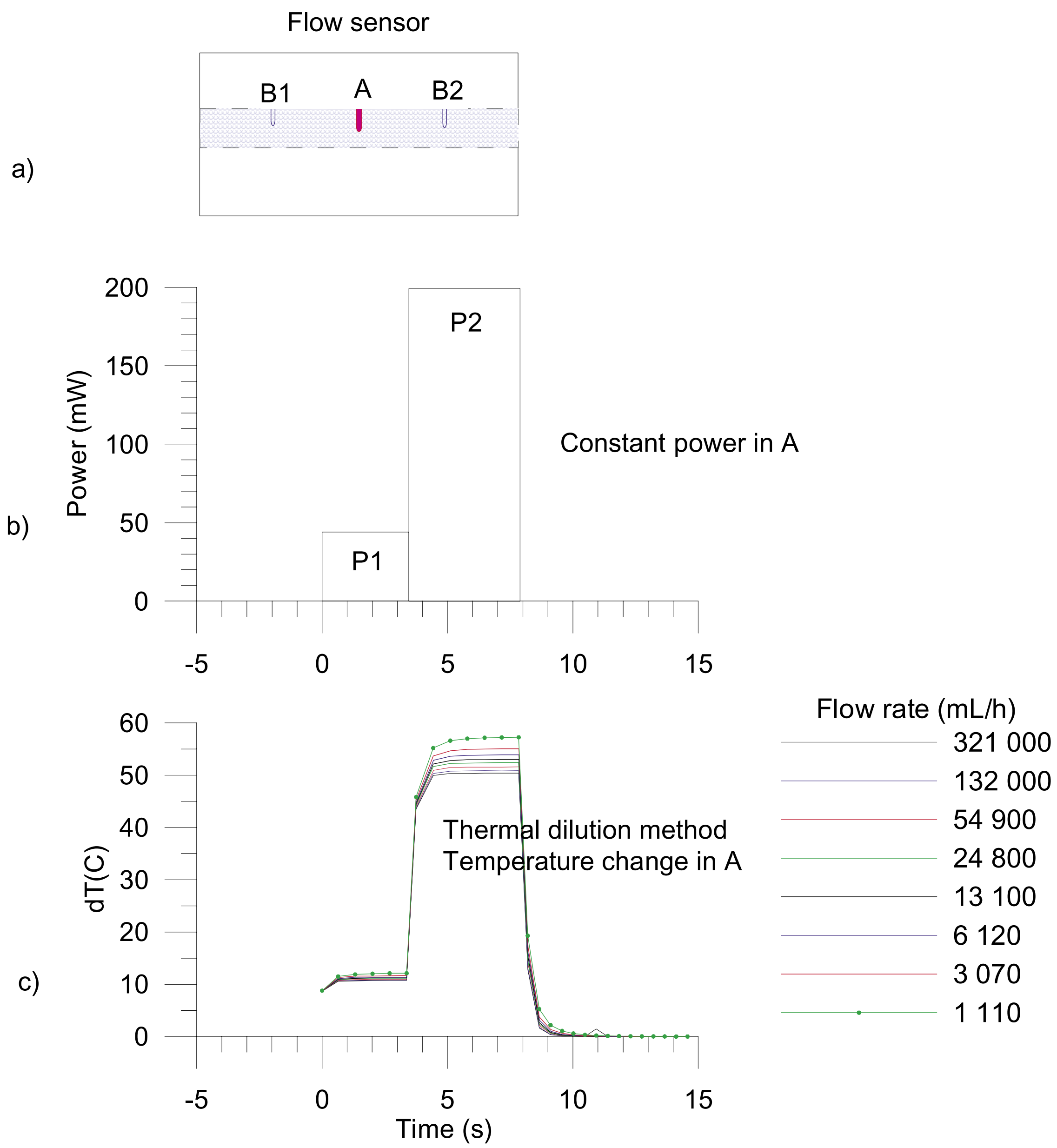

Figure 3-4. *Flow measurement, flow rate > 600 mL/h.*

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:

$$Q_{s0} = T_s \cdot a \cdot (h_s - h_0) \qquad 3\text{-}3$$

$$Q_{s1} = T_s \cdot a \cdot (h_s - h_1) \qquad 3\text{-}4$$

where

h_0 and h_1 are the hydraulic heads in the borehole at the test level,
Q_{s0} and Q_{s1} 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 hs 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:

$h_s = (h_0 - b \cdot h_1)/(1-b)$ 3-5

$T_s = (1/a)\ (Q_{s0} - Q_{s1})/(h_1 - h_0)$ 3-6

where

$b = Q_{s0}/Q_{s1}$

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).

$h_f = (h_0 - b \cdot h_1)/(1-b)$ 3-7

$T_f = (1/a)\ (Q_{f0} - Q_{f1})/(h_1 - h_0)$ 3-8

where

Q_{f0} and Q_{f1} 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/50 Hz. 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 XP.
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% fullscale
Absolute pressure sensor	0–20 MPa	+/– 0.01% fullscale

5 Performance

5.1 Difference flow logging in KFM07A

The Commission was performed according to Activity Plan AP PF 400-04-123 following the SKB Method Description 322.010, Version 1.0 (Method description for difference flow logging). The Activity Plan and the Method Description are both SKB internal controlling documents. Prior to the measurements, the downhole tools and the measurement cable were disinfected. Time was synchronized with local Swedish time. The activity schedule of the borehole measurements is presented in Table 5-1. The items and activities in Table 5-1 are the same as in the Activity Plan.

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 KFM07A, 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.

Table 5-1. Flow logging and testing in KFM07A. Activity schedule.

Item	Activity	Explanation	Date
6	Length calibration of the downhole tool	Dummy logging (SKB Caliper and SPR). Logging without the lower rubber discs, no pumping.	2005-01-17 2005-01-19
7	EC- and temp-logging of the borehole fluid	Logging without the lower rubber discs, no pumping.	2005-01-19
8	Overlapping flow logging	Section length L_w=5 m. Step length dL=0.5 m. No pumping. Problems with flow sensor. The tool was changed (05=>02) 2005-01-21.	2005-01-19 2005-01-22
9	Overlapping flow logging	Section length L_w=5 m. Step length dL=0.5 m at pumping (includes 1 day waiting after beginning of pumping).	2005-01-22 2005-01-25
10	Overlapping flow logging	Section length L_w=1 m. Step length dL=0.1 m, at pumping.	2005-01-25 2005-01-27
11	Fracture-specific EC-measurements in pre-selected fractures	Section length L_w=1 m, at pumping (in pre-selected fractures). These measurements were performed together with Item 10.	2005-01-25 2005-01-27
12	EC- and temp-logging of the borehole fluid	Logging without the lower rubber discs, at pumping.	2005-01-27
13	Recovery transient	Measurement of water level and absolute pressure in the borehole after stop of pumping.	2005-01-27 2005-01-28
10 extra	Overlapping flow logging	Section length L_w=1 m. Step length dL=0.1 m, at smaller pumping. (Spots where flow exceeded measurement limit were re-measured using smaller drawdown).	2005-01-28 2005-01-29

Each length 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 length calibration is that all length marks, or at least the major part of them, are detectable. The Difference flow meter 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 KFM07A (Item 6 in Table 5-1). These methods also reveal parts of the borehole widened for other reason (fracture zones, breakouts etc).

The caliper- and SPR-measurements were preceded by measurements of electric conductivity (EC) of the borehole water (Item 7) during natural (un-pumped) conditions.

The overlapping flow logging (Item 8) was carried out in the borehole interval 91.98–994.81 m. The section length was 5 m and the length increment (step length) 0.5 m. The measurements were performed during natural (un-pumped) conditions. The tool got stuck at c 840 m and problems occurred with the flow sensor. The tool was replaced with another (tool nr 05 was replaced by tool nr 02).

Pumping was started on January 22nd. After c 24 hours waiting time, the overlapping flow logging (Item 9) was measured in the interval 91.97–896.23 m using the same section and step lengths as before. The tool got stuck several times below 850 m, so it was decided not to measure the borehole all the way to the bottom.

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 10). Fracture specific EC on water from some selected fractures (Item 11) was measured together with Item 10.

Still during pumped conditions, the EC of borehole water (Item 12) was measured. After this, the pump was stopped and the recovery of the groundwater level was monitored (Item 13).

The length interval 94–267 m was re-measured using a smaller drawdown, since the flow rate exceeded the measurement limit in several fractures in this interval. A section length of 1 m and a step length of 0.1 m were used here, (Item 10 extra).

5.2 Nonconformities

Only limited measurements were performed below 850 m due to difficulties lowering the tool.

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 which 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 KFM07A the stretching of the cable was relatively low, since the measurements were performed from the top of the borehole in the downward direction (except Caliper+SPR-measurement and first repetition without pumping).

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 6) were initially length corrected in relation to the known length marks, Appendix 1.34, black curve. Corrections between the length marks were obtained by linear interpolation.
- The SPR curve of Item 6 was then compared with the SPR curves of Items 8, 9, 10/11 and 10 extra to obtain relative length errors of these measurement sequences.
- All SPR curves, except first repetition without pumping (see next paragraph), could then be synchronized, as can be seen in Appendices 1.2–1.33.

The results of the caliper and single point resistance measurements from all measurements in the entire borehole are presented in Appendix 1.1. Six SPR-curves are plotted together with caliper-data. These measurements correspond to Items 6, 8, 9, 10/11 and 10 extra in Table 5-1. Because of rough borehole wall and drilling debris in the borehole, the tool was stuck at c 856 m during Caliper+SPR measurement and the measurement was not performed below this. Only the first flow logging without pumping was performed all the way down to the bottom of the borehole. Length correction for this measurement was done according to length correction history from measurements in earlier boreholes.

Zoomed results of caliper and SPR are presented in Appendices 1.2–1.33. The length marks were detected at 150 m, 203 m, 250 m, 300 m, 350 m, 400 m, 450 m, 500 m, 550 m, 600 m, 650 m (only the lower one), 700 m, 750 m, 800 m and at 849 m. In other words, every mark was detected at least partly in the measured interval. They can also be seen 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 each side of the resistance electrode. A selection of length intervals where clear SPR-anomalies were found, are plotted as well.

The aim of the plots in Appendices 1.2–1.33 is to verify the accuracy of the length correction. The curves in these plots represent length corrected results. The same length corrections were applied to the flow- and EC measurements.

The magnitude of the length correction along the borehole is presented in Appendix 1.34. 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).

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 the 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, however, 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. Flow may be detected already when a fracture is situated between the upper rubber disks. These phenomena, which can only be seen with a short step length (0.1 m), 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 (Item 6).
4. SPR curves may be imperfectly synchronized. This could cause an error of +/– 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 for the worst case above, since part 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 measurement was performed in downward direction, see Appendix 2.1, blue curve.

The EC measurement was repeated during pumping (after a pumping period of about five days), see Appendix 2.1, green curve. The results show clear change to less saline water above the lengths of about 120 m and 180 m. These locations coincide with high transmissivities, see Appendices 7 and 8.

Temperature of the 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.

The length calibration of the borehole EC measurements is not as accurate as for the other measurements, because SPR is not registered during the borehole EC measurements. The length correction of the flow measurement without pumping was applied to the borehole EC measurements, dark blue curve in Appendix 1.34.

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 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 is about 3.6 L. In this case, the 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 1 1.1. 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 Appendix 1 1.2.

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.

Table 6-1. Fracture-specific EC.

Upper end of section (m)	Lower end of section (m)	Fractures measured (m)	EC (S/m) at 25°C
133.24	134.24	133.7	1.19
178.11	179.11	178.5	1.44
260.86	261.86	261.4	2.65

6.3 Pressure measurements

The absolute pressure was registered together with the other measurements in Items 7–13 in Table 5-1. The pressure sensor measures the sum of the hydrostatic pressure in the borehole and the air pressure. Air pressure was also registered separately, see Appendix 10.2. 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 calculated according to the following expression /Nordqvist, 2001/:

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

where

h is the hydraulic head (masl) according to the RHB 70 reference system,
p_{abs} 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 elevation of measurement (masl) according to the RHB 70 reference system.

An offset of 2.46 kPa is subtracted from absolute pressure results with sensor 05 and 12.60 kPa with sensor 02.

The calculated head distributions are presented in Appendix 10.1. Exact z-coordinates are important in head calculation. 10 cm error in z-coordinate means 10 cm error in head.

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 diagrams as the single point resistance (right hand side) and caliper plots (in the middle), see Appendices 3.1–3.45. Single point resistance usually shows low resistance values fore fractures where flow is detected. There are also many 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 a low voltages when the borehole diameter is below 78 mm and a high voltage when the borehole diameter exceeds 78 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. The first measurement under natural conditions (REP1, light blue curve) was performed upwards. The tool got stuck at c 840 m and some problems occurred with the flow sensor. The tool was replaced with another tool (tool nr 05 was replaced by tool nr 02) and the logging direction was changed to downward direction. The measurements continued without pumping (REP2, dark blue curve) and then during pumping (red curve). The method (overlapping flow logging) provides 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, flow direction may be into the borehole or out from it. For small flow rates (< 100 mL/h) flow direction cannot be seen in the normal overlapping mode (thermal dilution method). Therefore waiting time was longer for the thermal pulse method to determine flow direction at every 5 m. The thermal pulse method was used only for measuring the flow direction, not for flow rate, which would take even longer time. Longer flow direction measurements are necessary during un-pumped conditions.

The test section length determines the width of a flow anomaly of a single fracture. 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 268 m) was re-measured using a smaller drawdown. The flow rate exceeds the measurement limit in several spots in this interval.

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; a 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 or they are unclear because of noise.

6.4.2 Transmissivity and hydraulic head of borehole sections

The borehole between 96.99 m and 893.15 m was flow logged with a 5 m section length and with 0.5 m length increments both during un-pumped and pumped conditions. All the flow logging results presented in this report are derived from measurements with the thermal dilution method.

The results of the measurements with a 5 m section length are presented in tables, see Appendices 5.1–5.6. Only the results with 5 m length increments are used. All borehole sections are shown in Appendices 3.1–3.45. Secup presented in Appendices 5.1–5.6 is calculated as the distance along the borehole from the reference level (top of the casing tube) to the upper end of the test section, whereas seclow is calculated respectively to the lower end of the test section. Secup and seclow values for the two sequences (measurements at un-pumped and pumped conditions) are not exactly identical, due to a minor difference of the cable stretching. The difference between these two sequences was however small. Secup and seclow given in Appendices 5.1–5.6 are calculated as an average of these two values.

Pressure was measured and calculated as described in Chapter 6.3. dh_0 and dh_1 in Appendices 5.1–5.6 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 in Appendices 5.1–5.6 (Q_0 and Q_1), representing flow rates derived from measurements during un-pumped respectively pumped conditions, are presented side by side to make comparison easier. As can be seen, the measurement with pumping does not cover the lowest part of the borehole. Flow rates are positive if the flow is directed from the bedrock into the borehole and vice versa. With the borehole at rest, 9 sections were detected as flow yielding, of which 5 had a flow direction from the borehole into the bedrock (negative flow). During pumping, all 10 detected flows were directed towards the borehole.

The measurable flow ranges were exceeded at the lengths of 107.00 m, 112.00 m, 117.01 m, 132.04 m and 177.11 m when the borehole was pumped. Flow rates for transmissivity calculations and corresponding borehole heads at these locations (lengths) were taken from the re-measurements with a smaller drawdown (with a section length of 1 m).

Flow data are presented in a plot, see Appendix 6.1. 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 rate was zero (below the measurement limit), it is not visible in the logarithmic scale of the appendices.

In the plots (Appendix 6.1) and in the tables (Appendix 5), also the lower and upper measurement limits of flow are presented. There are both theoretical and practical lower limits of flow, see Chapter 6.4.4.

Hydraulic head and transmissivity (T_D) 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 6.2. The measurement limits of transmissivity are also shown in Appendix 6.2 and in Appendix 5. All the measurement limit values of transmissivity are based on the actual pressure difference in the borehole (dh_0 and dh_1 in Appendix 5).

The sum of detected flows without pumping (Q_0) was $1.32 \cdot 10^{-6}$ m^3/s (4,734 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. In this case the sum is quite far from zero. It is not fully clear which one of the mentioned preconditions that didn't hold in this case. However, when the lowest part of the borehole was measured, the groundwater level was about 0.2 m lower than when the upper part was measured, see Appendix 10.3. The borehole was apparently hydraulically in a changing state.

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 3.1. Increase or decrease of a flow anomaly at the fracture location (marked with the lines in Appendix 3) is used for determination of a flow rate.

Since sections with 1 m length were not used at un-pumped conditions, the results for a 5 m section length were applied 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. It is not a problem to evaluate the flow rate at un-pumped conditions when the distance between flowing fractures is larger than 5 m. The evaluation may though be problematic when the distance between fractures is less than 5 m. In this case an increase or decrease of a flow anomaly at the fracture location determines the flow rate. However, this evaluation is used conservatively, and is applied only in the clearest cases. No flow values are usually evaluated at un-pumped conditions at densely fractured parts of the bedrock. If the flow for a specific fracture can not be determined conclusively, the flow rate is marked with "-" whereas the value 0 is used in transmissivity calculation, see Appendix 8. 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 26, but only 4 could be defined without pumping. Transmissivity and head estimations could not be done for the fractures below 893 m, since the measurement with pumping was not performed below that borehole length. Head estimations could be performed for 3 fractures and transmissivity estimations for a total of 23 fractures. The flow rate exceeded the upper measurement limit for fractures at 120.2 m, 133.7 m and 178.5 m. These fractures were re-measured at a lower drawdown and the results were used for transmissivity and head calculations. Results from the measurement with lower pumping capacity were also applied for the interval 107–122 m. The noise level was better (lower) and flow rate evaluation from these results was more reliable. Transmissivity and hydraulic head of fractures are presented in Appendices 7 and 8.

Some fracture-specific results were rated to be "uncertain", see Appendix 7. 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 the fractures was less than one metre, or since the form of the anomaly was unclear due to noise.

Fracture-specific transmissivities were compared with transmissivities of borehole sections in Appendix 9. All fracture-specific transmisivities within each 5 m interval were first summed up to make them comparable with measurements with a 5 m section length. The results are, in most cases, consistent between the two types of measurements.

6.4.4 Theoretical and practical measurements limits of flow and transmissivity

The theoretical minimum of measurable flow rate in the overlapping measurements (thermal dilution method only) is about 30 mL/h. The thermal pulse method can also be used when the borehole is not pumped. Its theoretical lower limit is about 6 mL/h. In this borehole the thermal pulse method was only used for flow direction, not for flow rate. 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 the 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. The borehole conditions may have an influence on the base level of flow (noise level). The noise level can be evaluated for intervals of the borehole without flowing fractures or other structures. The noise level may vary along the borehole.

There are several known reasons for increased noise 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 level, 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 fracture water near the borehole. This may lead to 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 upwards). The reason is assumed to be gas bubbles. Bubbles may cause a decrease of the average density of the water and therefore also a 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 leakage at the lower rubber disks is directly measured as increased noise level in the flow rate.

A high noise level in flow rate masks a "real" flow rate, smaller than the noise level. Real flows are totally invisible if they are about ten times smaller than the noise level. Real flows are registered correctly if they are about ten times larger than the noise level. By experience, real flow rates between 1/10 times the noise and 10 times the noise are summed up with the 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 small problem in borehole KFM07A. 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.

The noise level in KFM07A was between 10–800 mL/h. In some places it fell below 30 mL/h, i.e. below the theoretical limit of the thermal dilution method. However, the noise line (grey dashed line) was never drawn below 30 mL/h.

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 a smaller drawdown. In KFM07A, the interval c 100–270 m was re-measured using a smaller drawdown.

The practical minimum of measurable flow rate is also presented in Appendix 5 (Q-lower limit P). 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 5 (T_D-measl$_{LP}$). The theoretical minimum measurable transmissivity (T_D-measl$_{LT}$) is evaluated using a Q value of 30 mL/h (minimum theoretical flow rate with the thermal dilution method).

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 5 (T_D-measl$_U$).

All three flow limits are also plotted with measured flow rates, see Appendix 6.1. Theoretical minimum and maximum values are 30 mL/h and 300,000 mL/h, respectively.

The three transmissivity limits are also presented graphically, see Appendix 6.2. 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 highly water yielding fractures occur at these locations.

Similar flow and transmissivity limits are not given for the fracture-specific results, Appendix 7. 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 highly water yielding fracture. The situation is similar for the upper flow limit. If there are several high-yielding fractures nearer each other than one metre, the upper flow limit depends on the sum of flows, which must fall below 300,000 mL/h.

6.5 Groundwater level and pumping rate

The level of the groundwater table in the borehole during the measurement sequences is presented in Appendix 10.3. The borehole was pumped between January 22 and 27 with a drawdown of about 7.1 m. The borehole was pumped also between January 28 and 29 a short time with a smaller drawdown. Pumping rate was recorded, see Appendix 10.5.

The groundwater recovery was measured after the first pumping period, on January 27–28, Appendix 10.4. The recovery was measured with two sensors, using the water level sensor (pressure sensor for monitoring water level) and the absolute pressure sensor located at the borehole length of 786.35 m.

6.6 Evaluation of pumping test

6.6.1 General

The transmissivity of the entire cored borehole interval (c 100–1,000 m) was estimated from the pumping activity in conjunction with the difference flow logging campaign in borehole KFM07A. The borehole transmissivity was estimated from the pressure recovery period using data from both the high-resolution absolute pressure sensor at the bottom of the borehole (786.35 m) and from the water level sensor located in the upper part of the borehole (11.81 m), cf Appendix 10.4. At c 200 s of the recovery period a discontinuity of the pressure is indicated both for the absolute- and superficial sensor.

The borehole transmissivity was also estimated from the first part of the flow period before a constant drawdown of the water level was applied during difference flow logging, cf Appendix 10.3. As for the recovery period, data from both the absolute- and water level sensor were used. The pumping flow rate was decreasing from c 200 L/min to c 182 L/min during the first part of the flow period causing a drawdown of the water level of c 7.1 m, cf Appendix 10.3.

The main purposes of the analysis of the pumping test during the difference flow logging were to estimate the total transmissivity of the cored borehole interval and to deduce information on possible hydraulic outer hydraulic boundaries during the test.

Furthermore, the results of the pumping test should be compared with the results of the difference flow logging in the borehole regarding estimated transmissivities of the measured 5 m sections and flow anomalies identified.

The registration of the water level, flow rate and pressure recovery was performed according to the Activity Plan AP PF 400-04-123 (SKB internal controlling document) and the methodology description for difference flow logging (SKB MD 322.010, Version 1.0). The evaluation of the pumping test was made in accordance with the Method Instruction SKB MD 320.004, Version 1.0 (Instruktion för analys av injektions och enhålspumptester).

By the calculation of the pressure drawdown and -recovery from the absolute pressure sensor at depth, the atmospheric pressure was subtracted from the measured pressure. The variations of the atmospheric pressure during the test period are shown in Appendix 10.2. However, no such corrections were made on the measured (gauge) pressure data from the superficial water level transducer. By the calculation of the pressure derivatives during the flow- and recovery periods, different values were applied on the filter coefficient (step length) to study its effect on the derivative. It is desired to achieve maximum smoothing of the derivative without altering the original shape of the data curve, i.e. the lowest possible step length.

Firstly, a qualitative evaluation was performed to identify the actual flow regimes during the flow- and recovery period (e.g. wellbore storage, pseudo-radial flow etc) and possible outer hydraulic boundary conditions. The qualitative analysis was made from the pressure responses together with the corresponding pressure derivatives versus time, preferably in the log-log diagrams. The pressure recovery was plotted versus real time after stop of pumping since both the pressure and flow rate were rather stable at the end of the flow period, cf Appendix 10.3 and 10.5, respectively, and since the recovery period was rather short compared to the total flow period.

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 using the code AQTESOLV. By the analysis of the flow period, a variable flow rate was applied to account for the decrease in flow rate during the first part of the flow period. In addition, steady-state analysis (Moye's formula) was made from the latter period.

6.6.2 Results

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. The nomenclature applied in the diagrams prepared by the code AQTESOLV is shown in Appendix 12. Since no data from observation boreholes were available, the storativity was assumed at $S^*=5\cdot10^{-5}$ by the calculation of the skin factor. The assumed storativity value was obtained from previous interference tests at Forsmark /Ludvigson and Jönsson, 2003/. A summary of the results of the pumping test in KFM07A is presented in Table 6-2. Selected test diagrams according to the Instruction for analysis of single-hole injection- and pumping tests together with simulated test responses are presented in Appendix 12.

Interpreted flow regimes

The pressure drawdown (measured by the absolute pressure sensor) during the first phase (c 12 h) of the flow period is shown in Figures A12-1 to A12-4 in Appendix 12. As for the recovery period, wellbore storage effects only occurred during the initial phase of the flow period, cf Figure A12-1. A short pseudo-radial flow regime (PRF) with higher transmissivity is indicated between c 500–1,200 s. After a long transition period, a second pseudo-radial flow regime with slightly lower transmissivity is then indicated by the end. The first PRF is less evident during the recovery period and may be distorted by the pressure discontinuity at c 200 s, cf Figure A12-5.

No evidences of outer hydraulic boundaries were seen during the first part of the flow period. The drawdown data from the absolute- respectively superficial pressure sensors were very similar during the first part of the flow period.

Figures A12-5 and A12-6 in Appendix 12 show log-log- respectively lin-log graphs, respectively of the pressure recovery versus time after stop of pumping using data from the absolute pressure sensor. Figure A12-5 illustrates that wellbore storage effects (WBS) were only seen during the initial pressure response in the (open) pumping borehole KFM07A. After c 200 s, a pressure discontinuity is indicated causing a major effect on the pressure derivative. After a long transition period, a nearly pseudo-radial flow regime occurred by the end of the recovery period as indicated by the pressure derivative, cf Figure A12-5.

No significant effects of outer hydraulic boundaries were seen during the recovery period. Although not shown, very similar results were obtained using water level data from the superficial pressure sensor during the recovery period.

Interpreted parameters

The transient analysis of the first part (c 12 h) of the flow period and of the recovery period (c 16 h) was based on the identified periods with pseudo-radial flow according to theories for flow in an equivalent porous medium. Two sets of hydraulic parameters were thus calculated from the flow period. The evaluations based on the first and second PRF are shown in Figures A12-1 and A12-2 respectively A12-3 and A12-4. The first PRF may possibly represent the near-region around the borehole dominated by a fracture zone and the second PRF a larger-scale region with averaged hydraulic properties of the rock and fracture zone. The results from the recovery period are displayed in Figures A12-5 and A12-6 based on the second PRF. The results of the evaluation of the pumping test in KFM07A are presented in Table 6-2.

The results from the flow- and recovery period are very consistent. The interpreted hydraulic parameters from the recovery period are considered as the most representative for the cored borehole interval of KFM07A on a semi-large scale. The high, negative value on the skin factor indicates that major fractures are intersecting the borehole. No representative values on the wellbore storage coefficient C could be calculated due to the high transmissivity of the borehole.

The calculated borehole transmissivity from the pumping test is somewhat higher than the cumulative transmissivity ($T=1.1\cdot10^{-4}$ m^2/s) of the measured 5 m sections and of the fractures identified ($T=1.4\cdot10^{-4}$ m^2/s) during the difference flow logging, cf Appendix 5 and 7, respectively. One of the measured sections (120–125 m) and fractures (120.2 m) from the difference flow logging were close to the upper measurement limit, even at a low drawdown, which possibly resulted in an underestimation of the transmissivity of this fracture.

Table 6-2. Summary of calculated hydraulic parameters from the pumping test in conjunction with difference flow logging in borehole KFM07A.

Test period	Q/s (m^2/s)	T_M (m^2/s)	T_T (m^2/s)	S* (–)	ζ (–)	C (m^3/Pa)
Flow period	$4.27 \cdot 10^{-4}$	$7.06 \cdot 10^{-4}$				
– first PRF			$1.00 \cdot 10^{-3}$	$5 \cdot 10^{-5}$	0.19	–
– second PRF			$3.15 \cdot 10^{-4}$	$5 \cdot 10^{-5}$	–5.81	–
Recovery period						
– second PRF			$4.40 \cdot 10^{-4}$	$5 \cdot 10^{-5}$	–4.93	–

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

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 KFM07A 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 used firstly. The measurements were repeated using 1 m section length with 0.1 m length increments over the flow anomalies. The tool got stuck in the borehole several times during the measurements. To avoid damage, most of the measurements were not carried out at the bottom of the borehole. The measurement programme could not be fully conducted below c 850 m.

Length calibration was made using the length marks on the borehole wall. The length marks were detected by caliper and 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 synchronizing 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 total amount of detected flowing fractures was 26. Transmissivity and hydraulic head were calculated for borehole sections and fractures above 893 m. The highest transmissivity ($7.67 \cdot 10^{-5}$ m^2/s) was detected in a fracture at the borehole length of 120.2 m. High-transmissive fractures were also found at 112.4 m, 133.7 m and 178.5 m. The deepest identified fracture in the borehole was detected from measurements without pumping at 970 m.

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Appendices

Appendices 1.1–1.33	SPR and Caliper results after length correction
Appendix 1.34	Length correction
Appendix 2.1	Electric conductivity of borehole water
Appendix 2.2	Temperature of borehole water
Appendices 3.1–3.45	Measured flow rates, Caliper and Single point resistance
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Appendices 5.1–5.6	Table of transmissivity and head of 5 m sections
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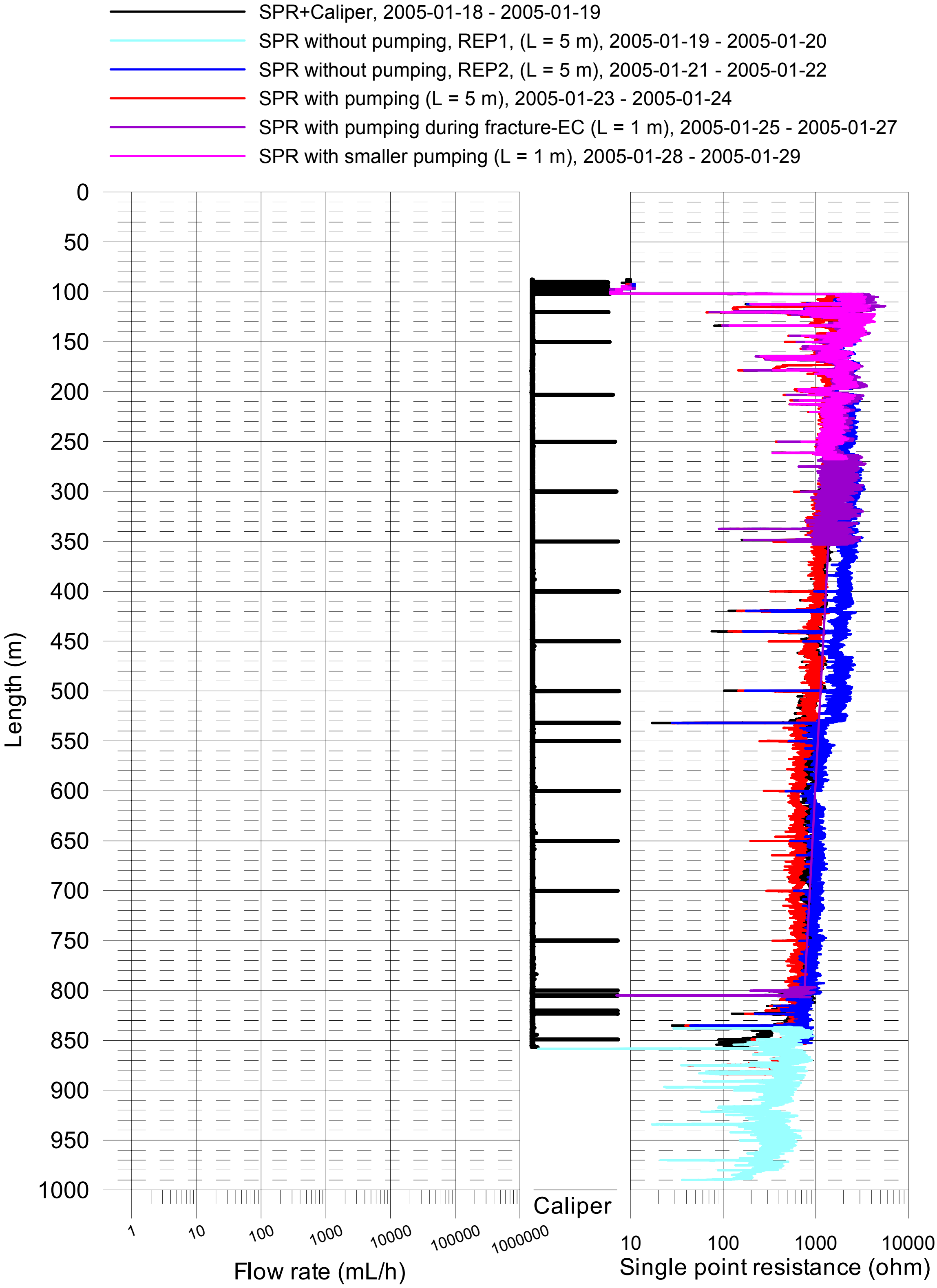
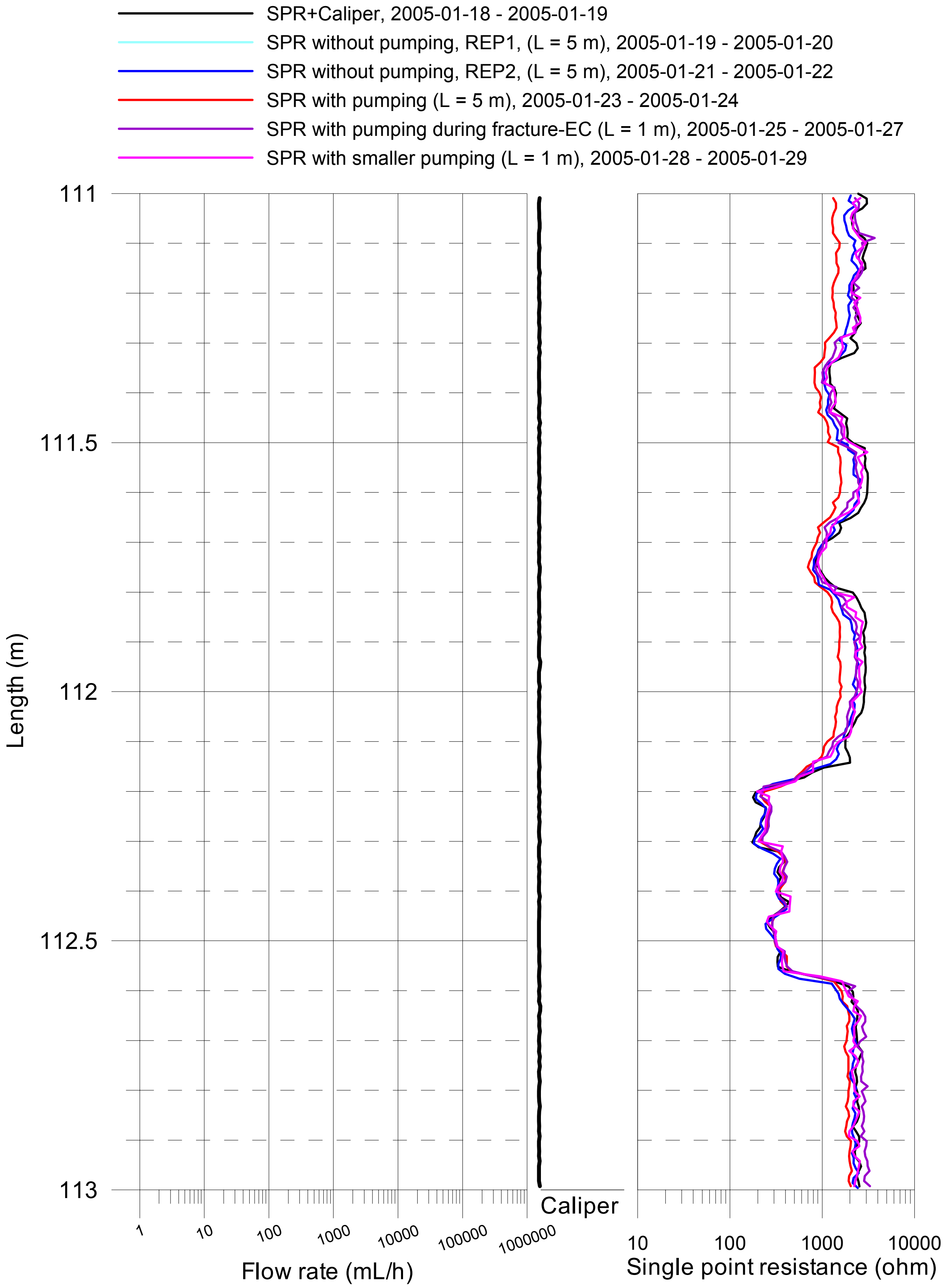
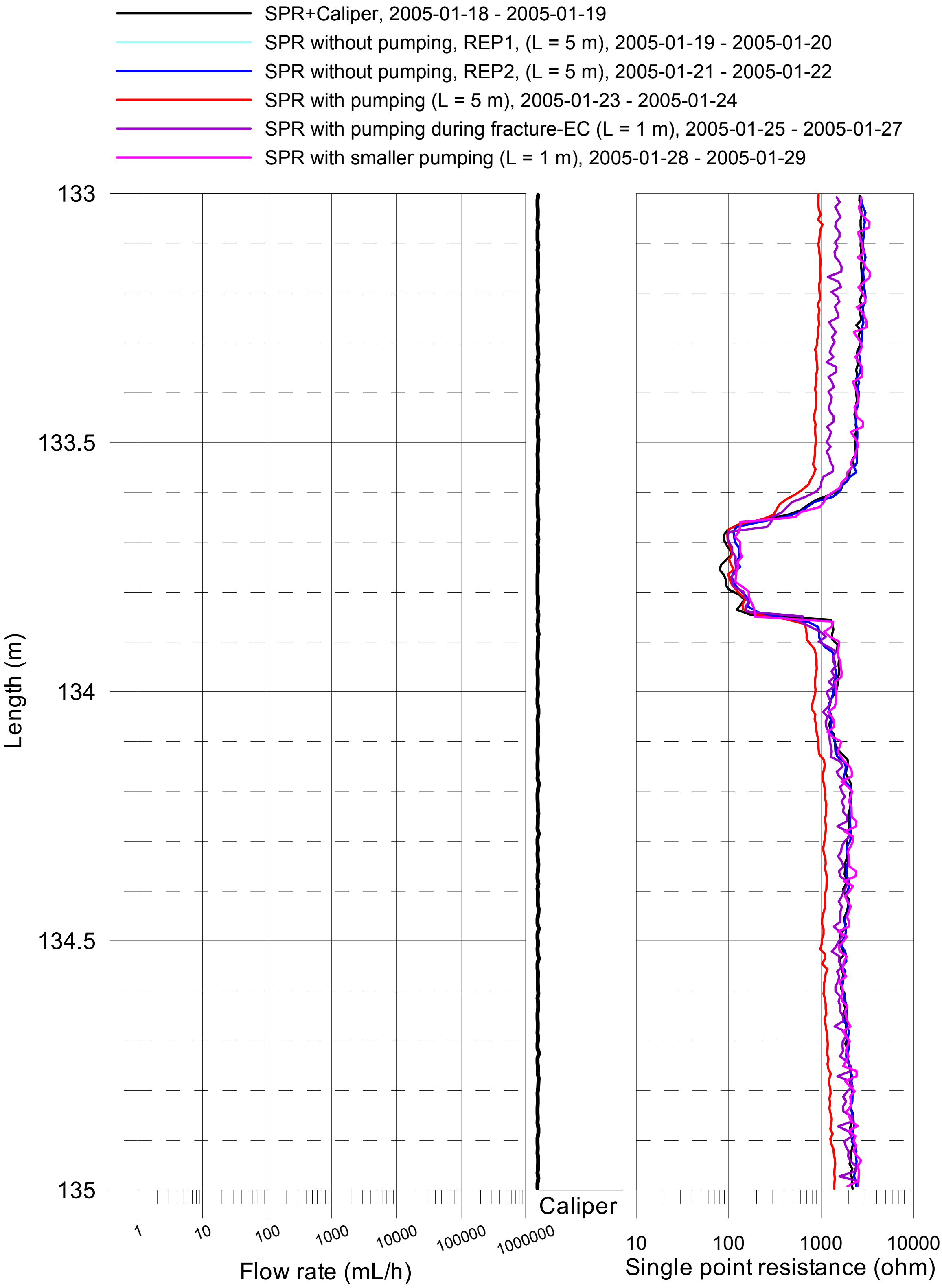
Forsmark, KFM07A
SPR and Caliper results after length correction

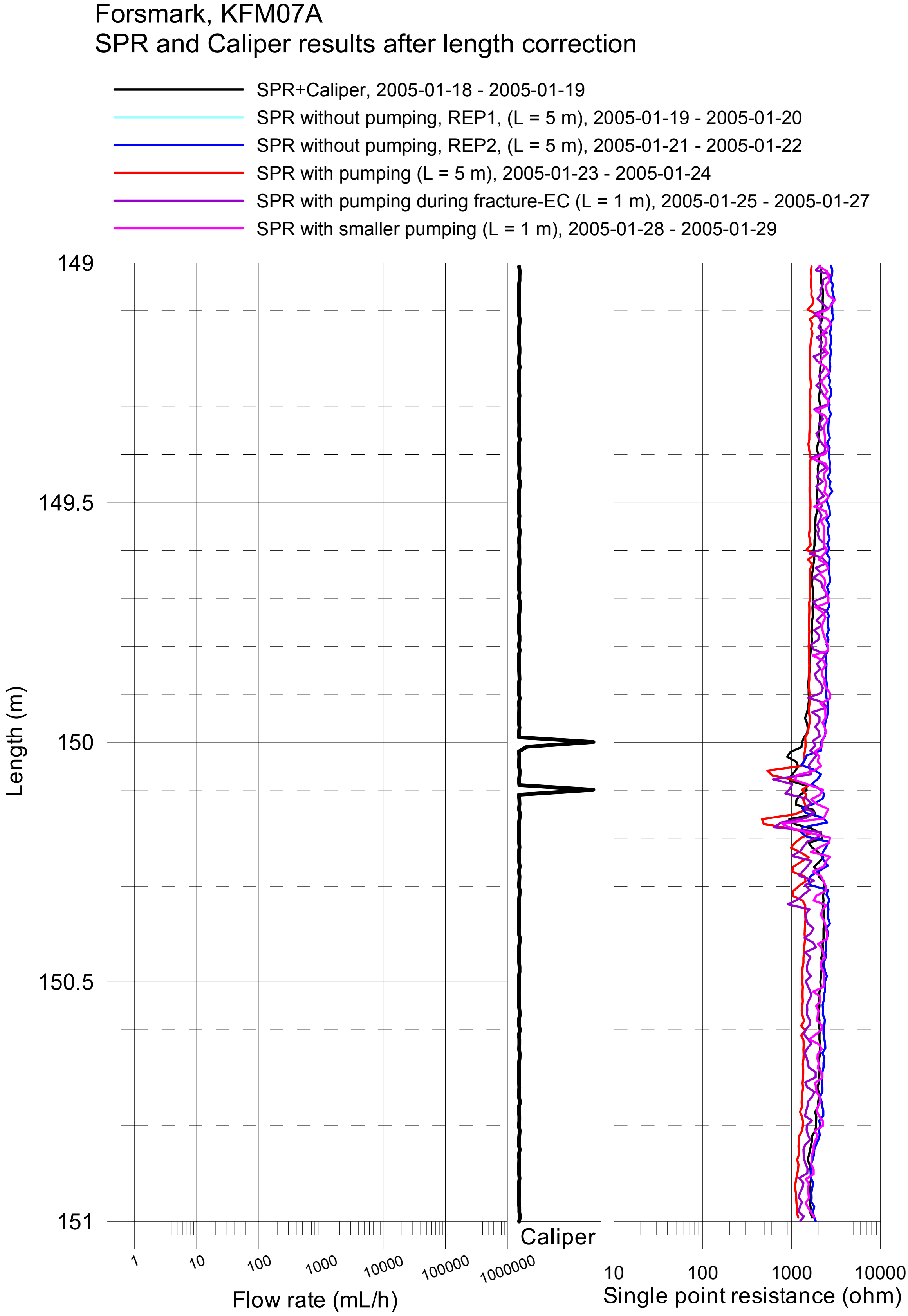


Forsmark, KFM07A
SPR and Caliper results after length correction

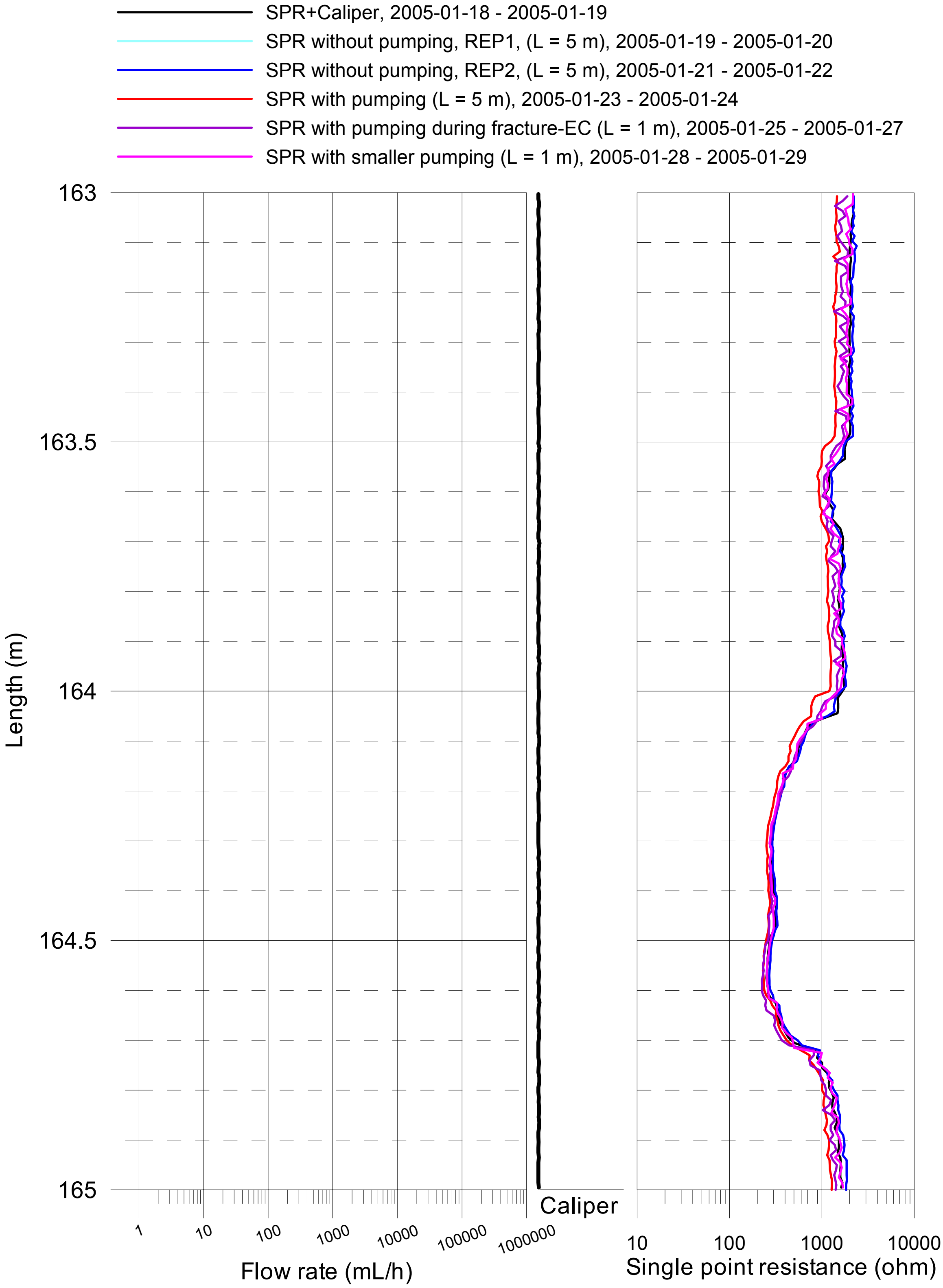


Forsmark, KFM07A
SPR and Caliper results after length correction

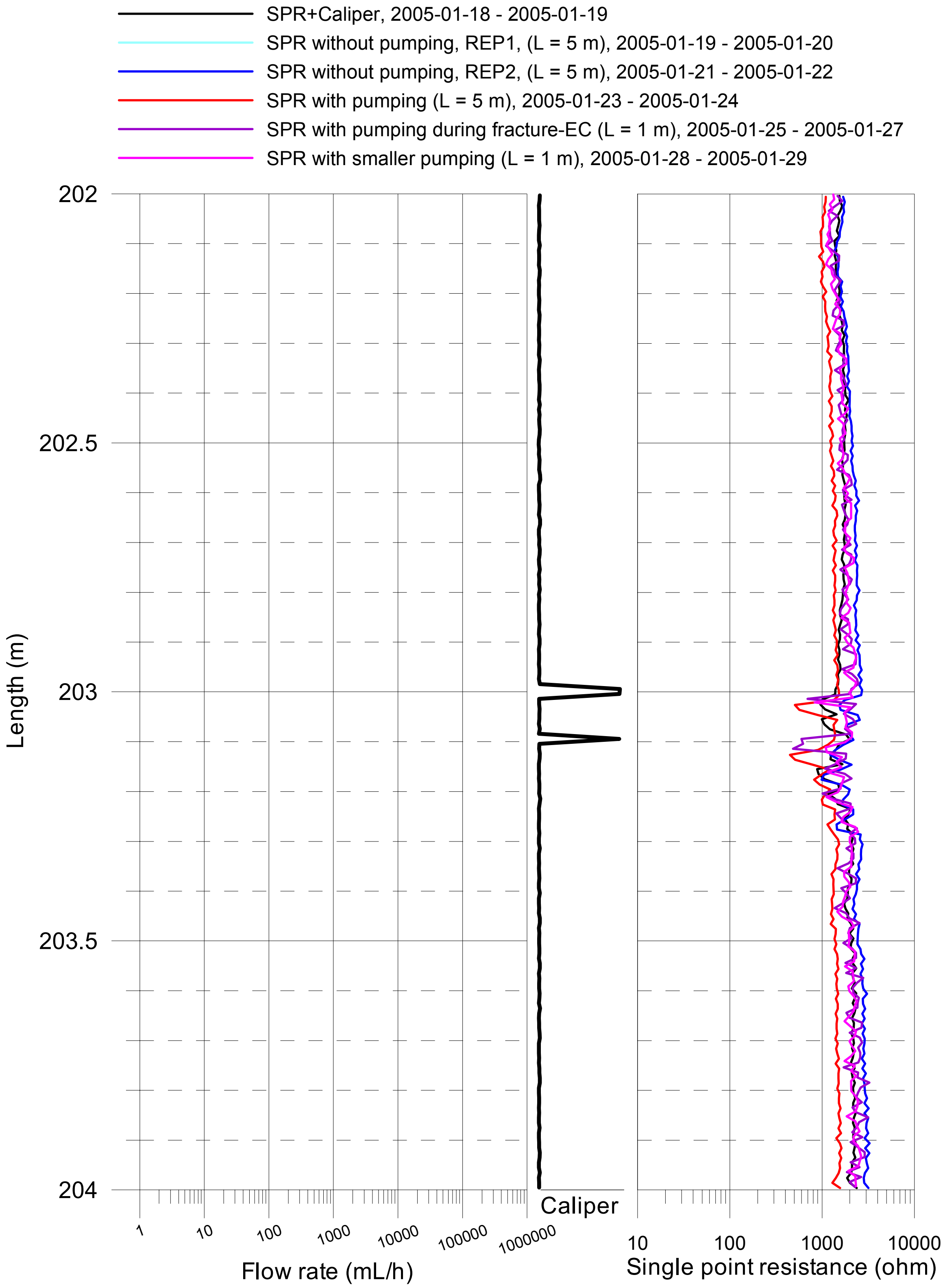


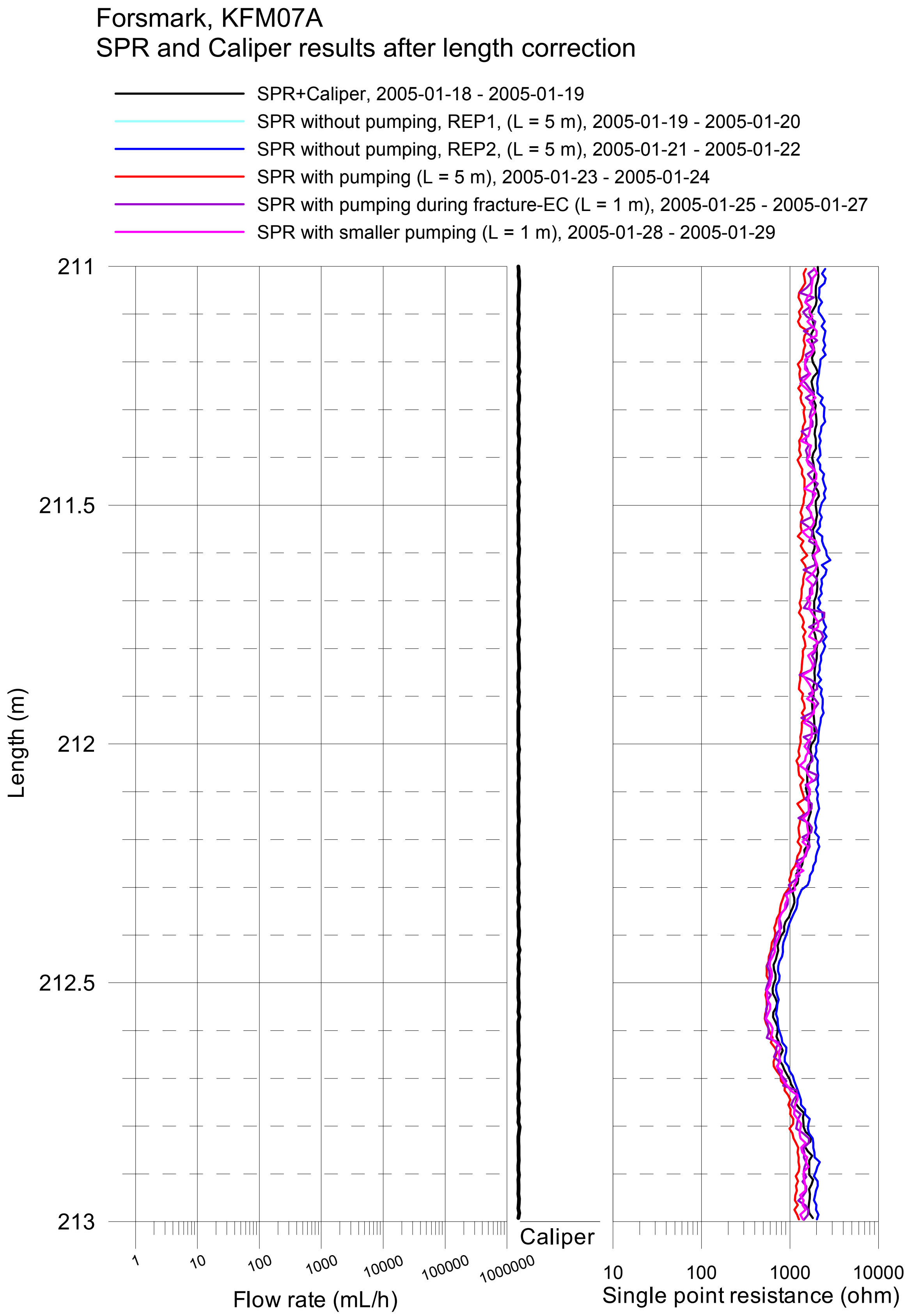

Forsmark, KFM07A
SPR and Caliper results after length correction
SPR+Caliper, 2005-01-18 - 2005-01-19
SPR without pumping, REP1, (L = 5 m), 2005-01-19 - 2005-01-20
SPR without pumping, REP2, (L = 5 m), 2005-01-21 - 2005-01-22
SPR with pumping (L = 5 m), 2005-01-23 - 2005-01-24
SPR with pumping during fracture-EC (L = 1 m), 2005-01-25 - 2005-01-27
SPR with smaller pumping (L = 1 m), 2005-01-28 - 2005-01-29
149
149.5
150
150.5
151
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

Forsmark, KFM07A
SPR and Caliper results after length correction



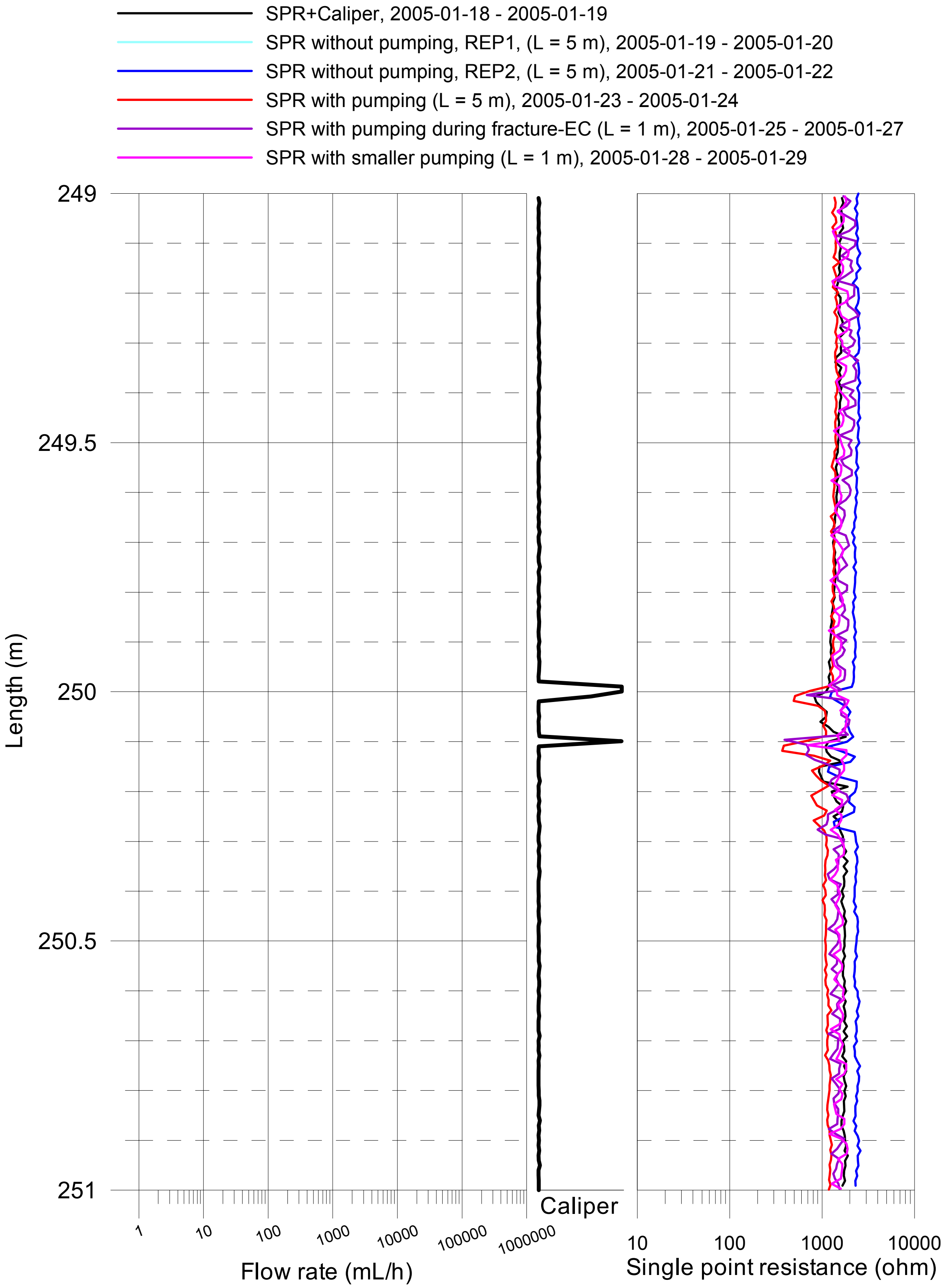
Forsmark, KFM07A
SPR and Caliper results after length correction



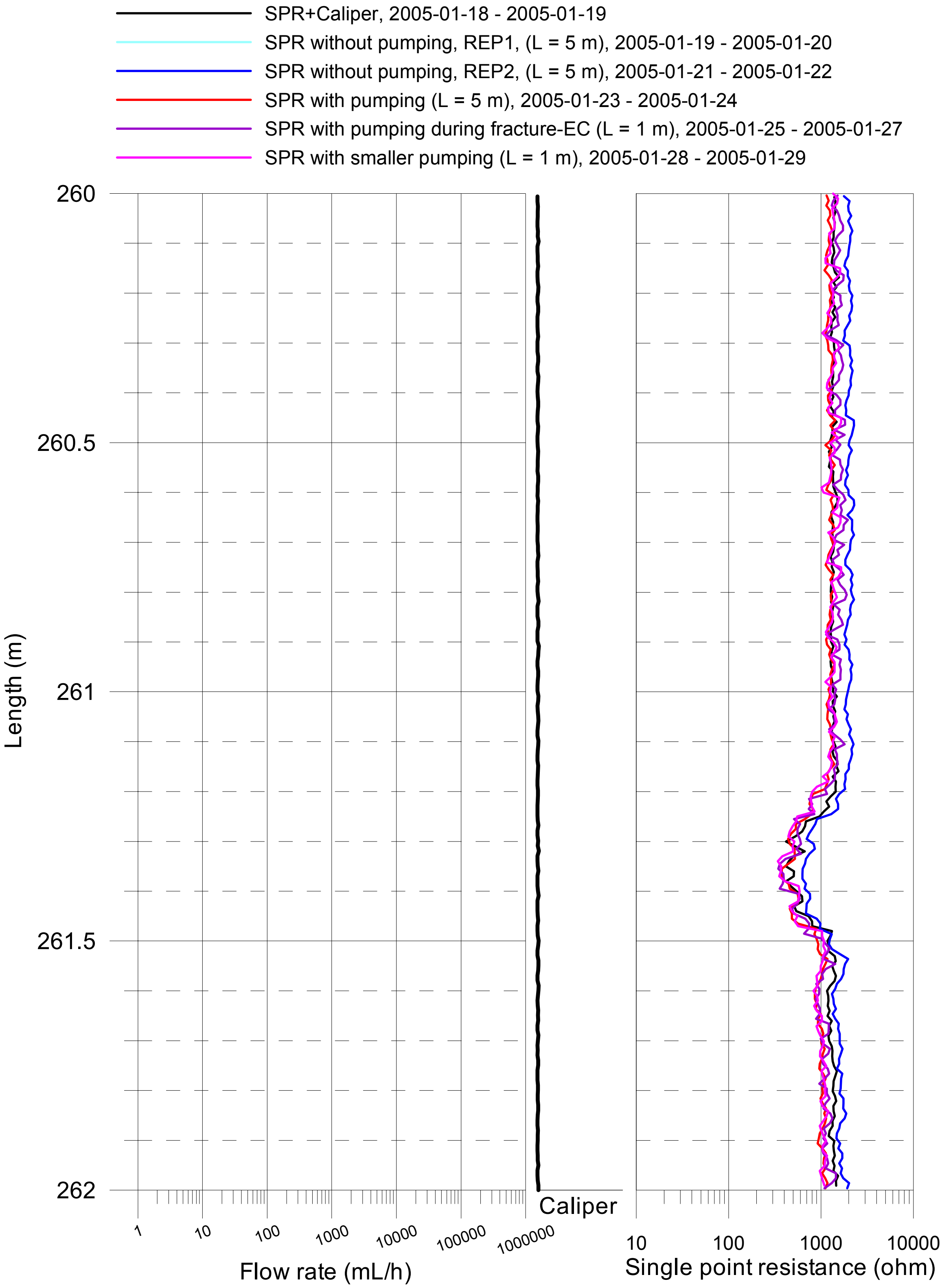


Forsmark, KFM07A
SPR and Caliper results after length correction
SPR+Caliper, 2005-01-18 - 2005-01-19
SPR without pumping, REP1, (L = 5 m), 2005-01-19 - 2005-01-20
SPR without pumping, REP2, (L = 5 m), 2005-01-21 - 2005-01-22
SPR with pumping (L = 5 m), 2005-01-23 - 2005-01-24
SPR with pumping during fracture-EC (L = 1 m), 2005-01-25 - 2005-01-27
SPR with smaller pumping (L = 1 m), 2005-01-28 - 2005-01-29
Length (m)
211
211.5
212
212.5
213
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

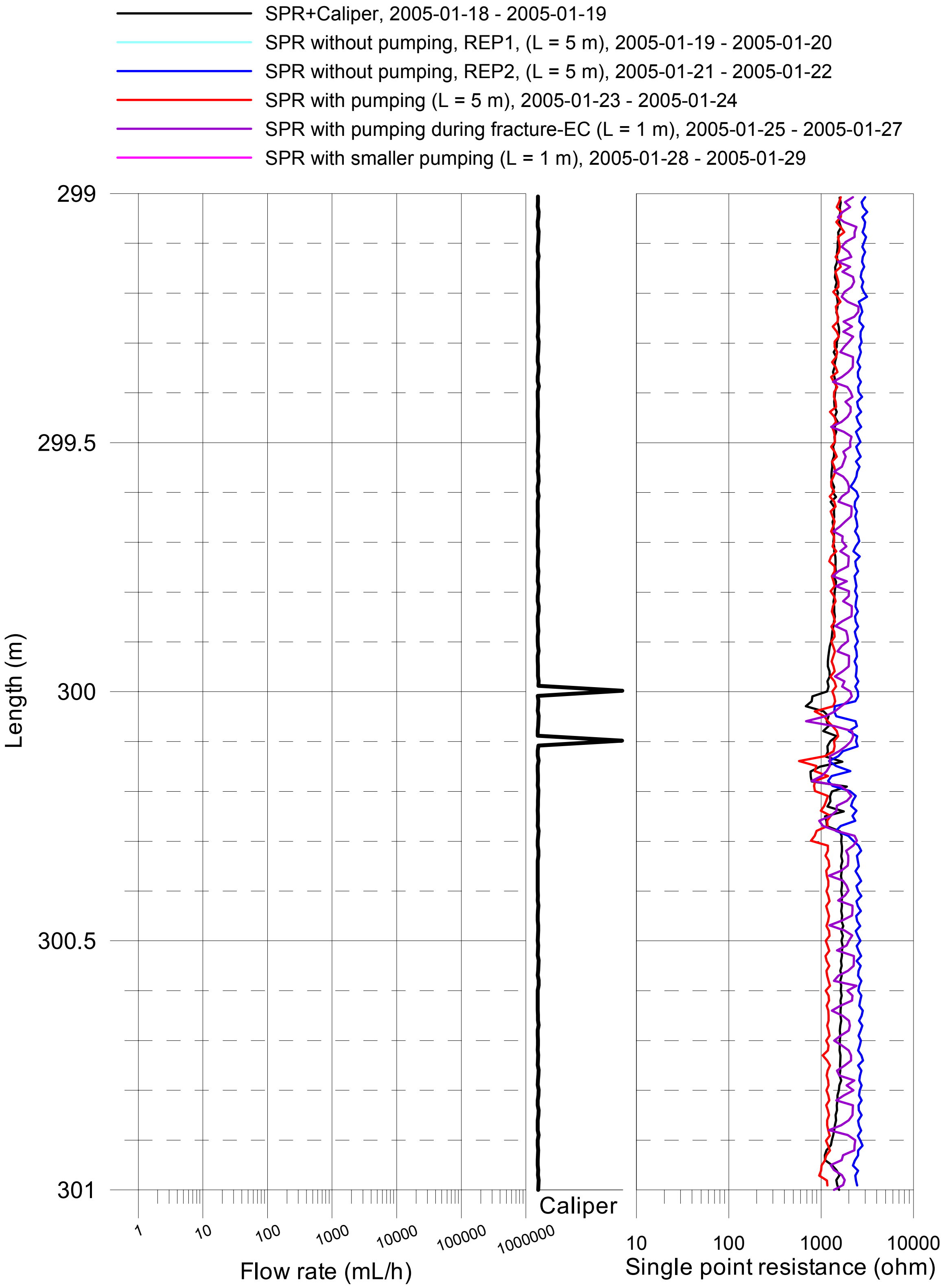
Forsmark, KFM07A
SPR and Caliper results after length correction

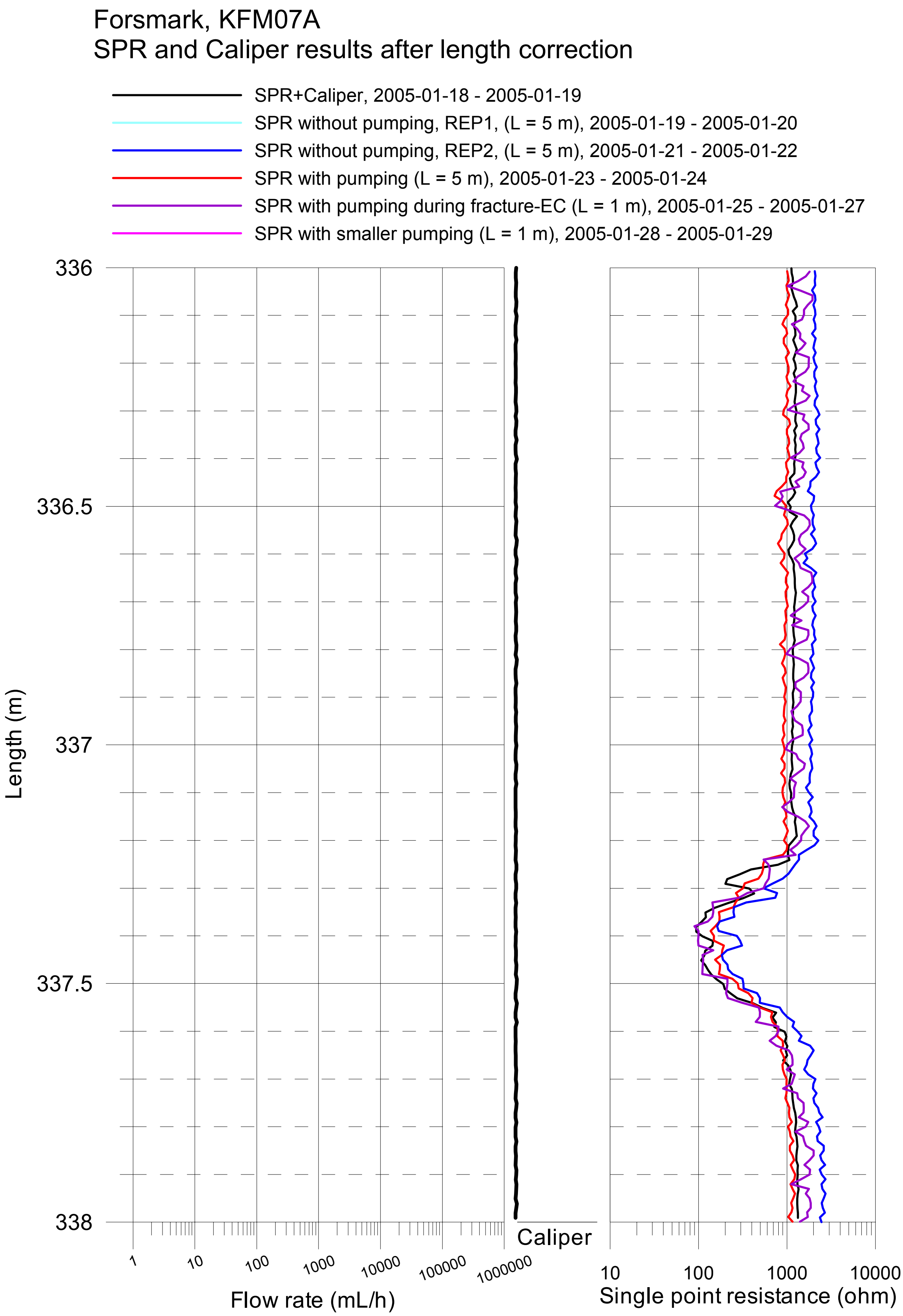


Forsmark, KFM07A
SPR and Caliper results after length correction



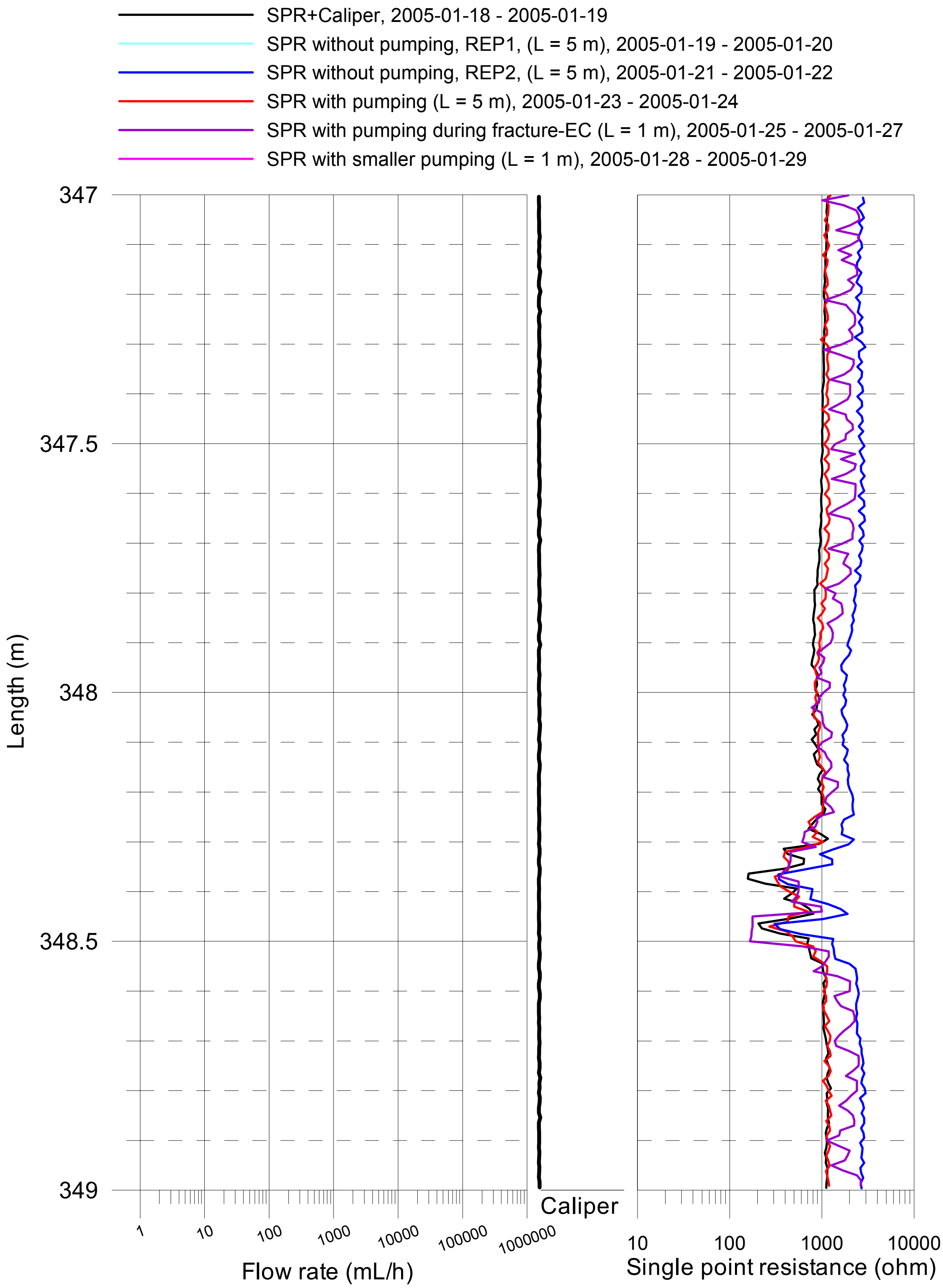
Forsmark, KFM07A
SPR and Caliper results after length correction



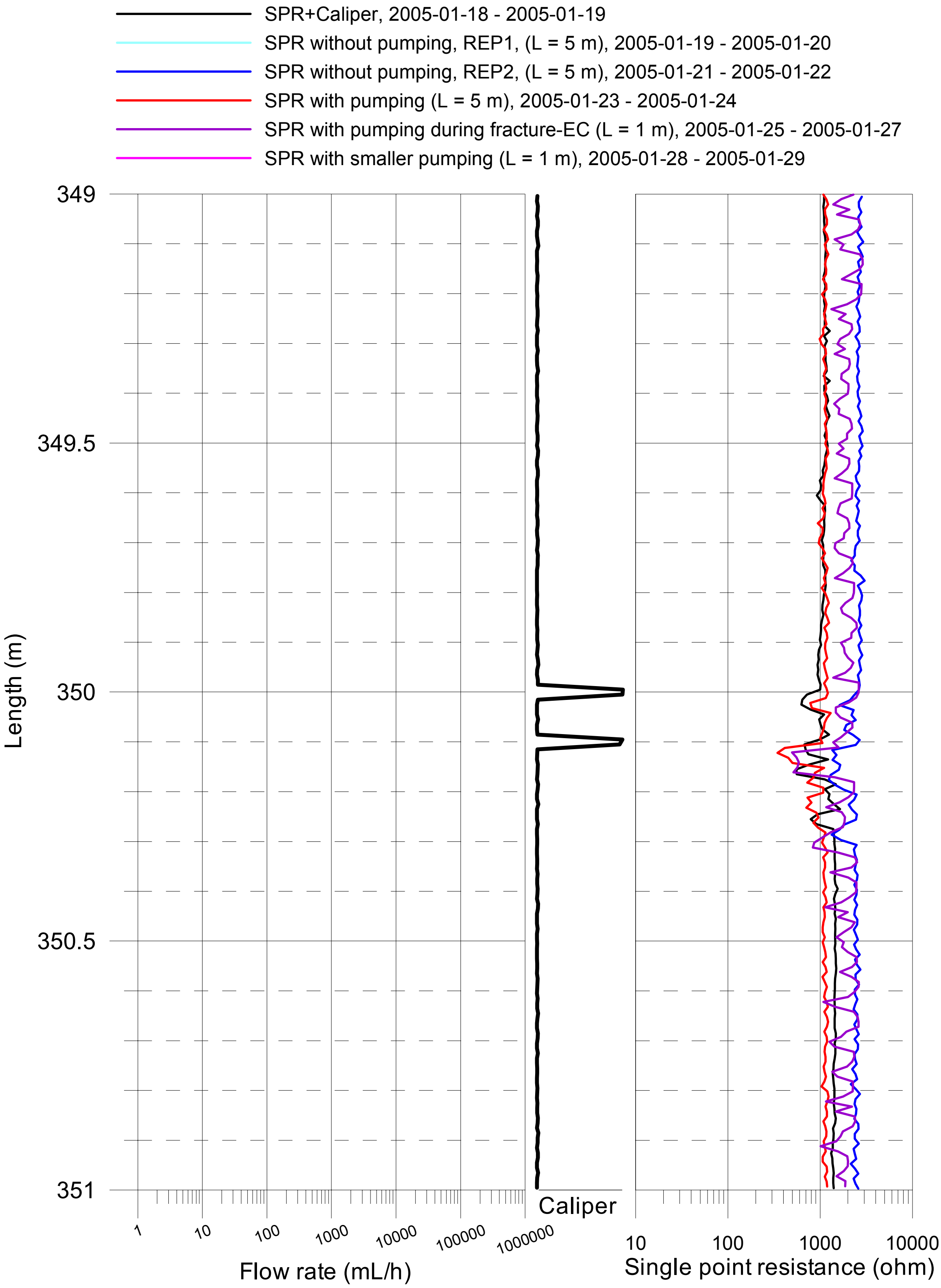


Forsmark, KFM07A
SPR and Caliper results after length correction
SPR+Caliper, 2005-01-18 - 2005-01-19
SPR without pumping, REP1, (L = 5 m), 2005-01-19 - 2005-01-20
SPR without pumping, REP2, (L = 5 m), 2005-01-21 - 2005-01-22
SPR with pumping (L = 5 m), 2005-01-23 - 2005-01-24
SPR with pumping during fracture-EC (L = 1 m), 2005-01-25 - 2005-01-27
SPR with smaller pumping (L = 1 m), 2005-01-28 - 2005-01-29
Length (m)
336
336.5
337
337.5
338
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

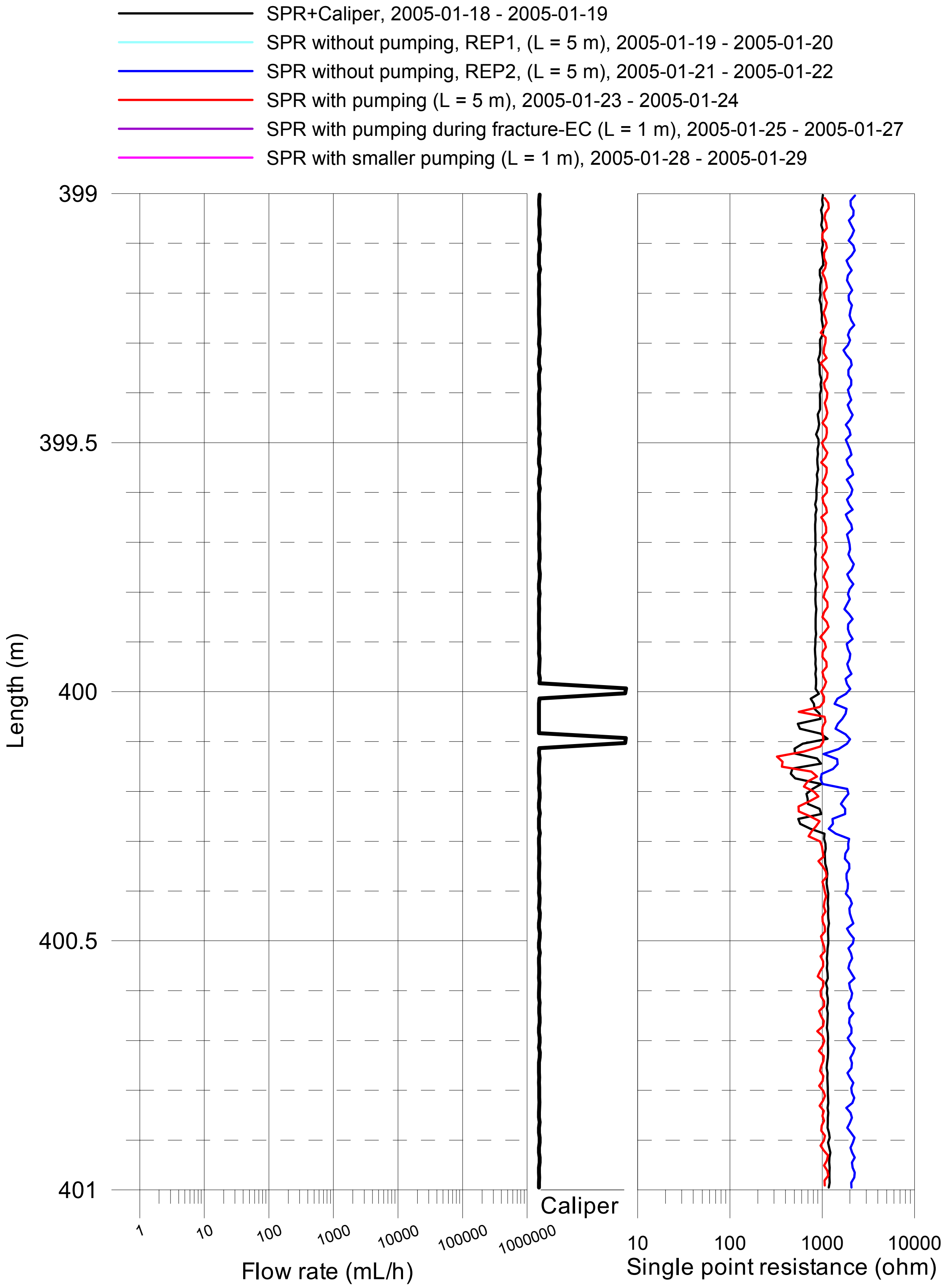
Forsmark, KFM07A
SPR and Caliper results after length correction



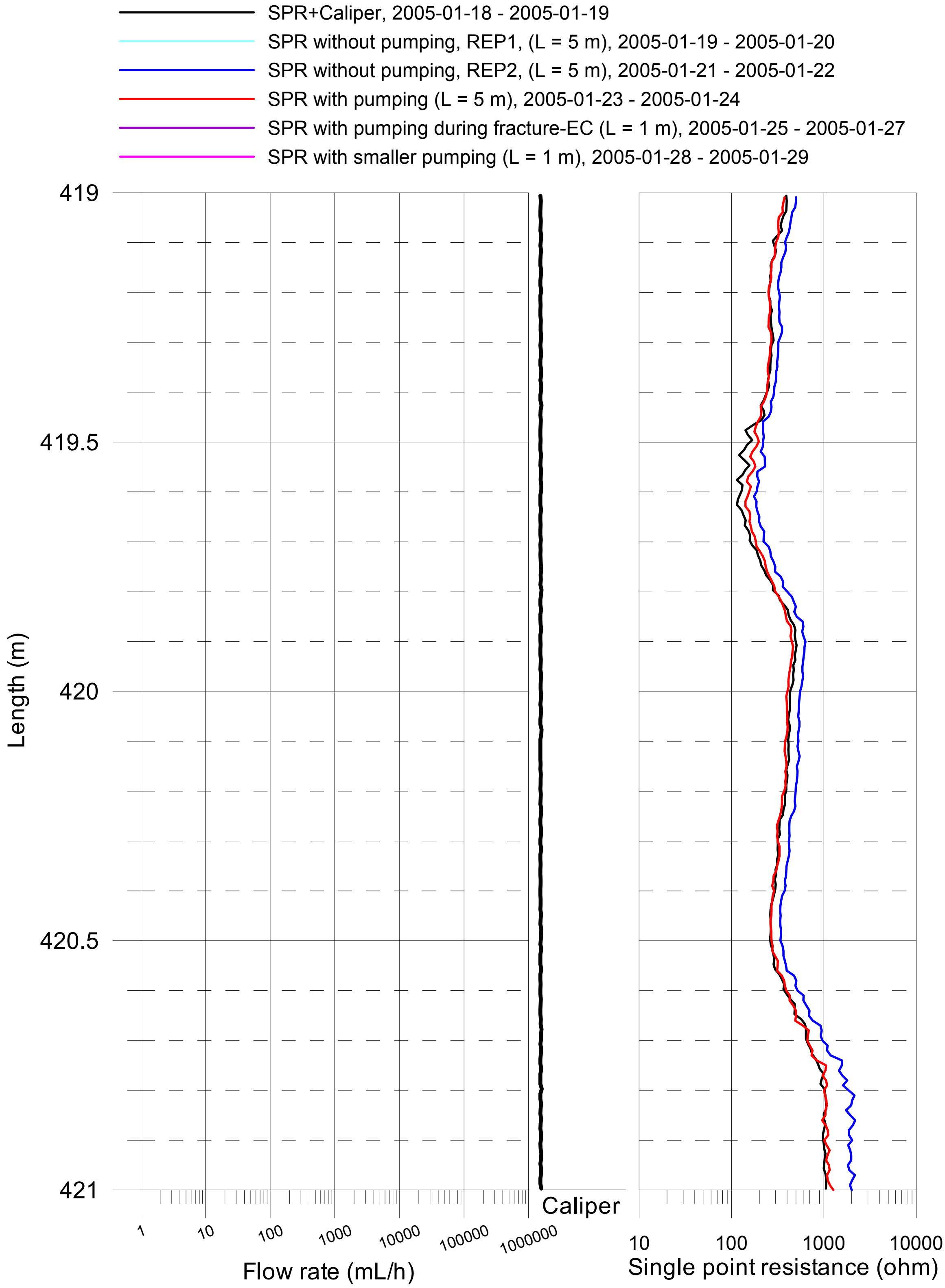
Forsmark, KFM07A
SPR and Caliper results after length correction



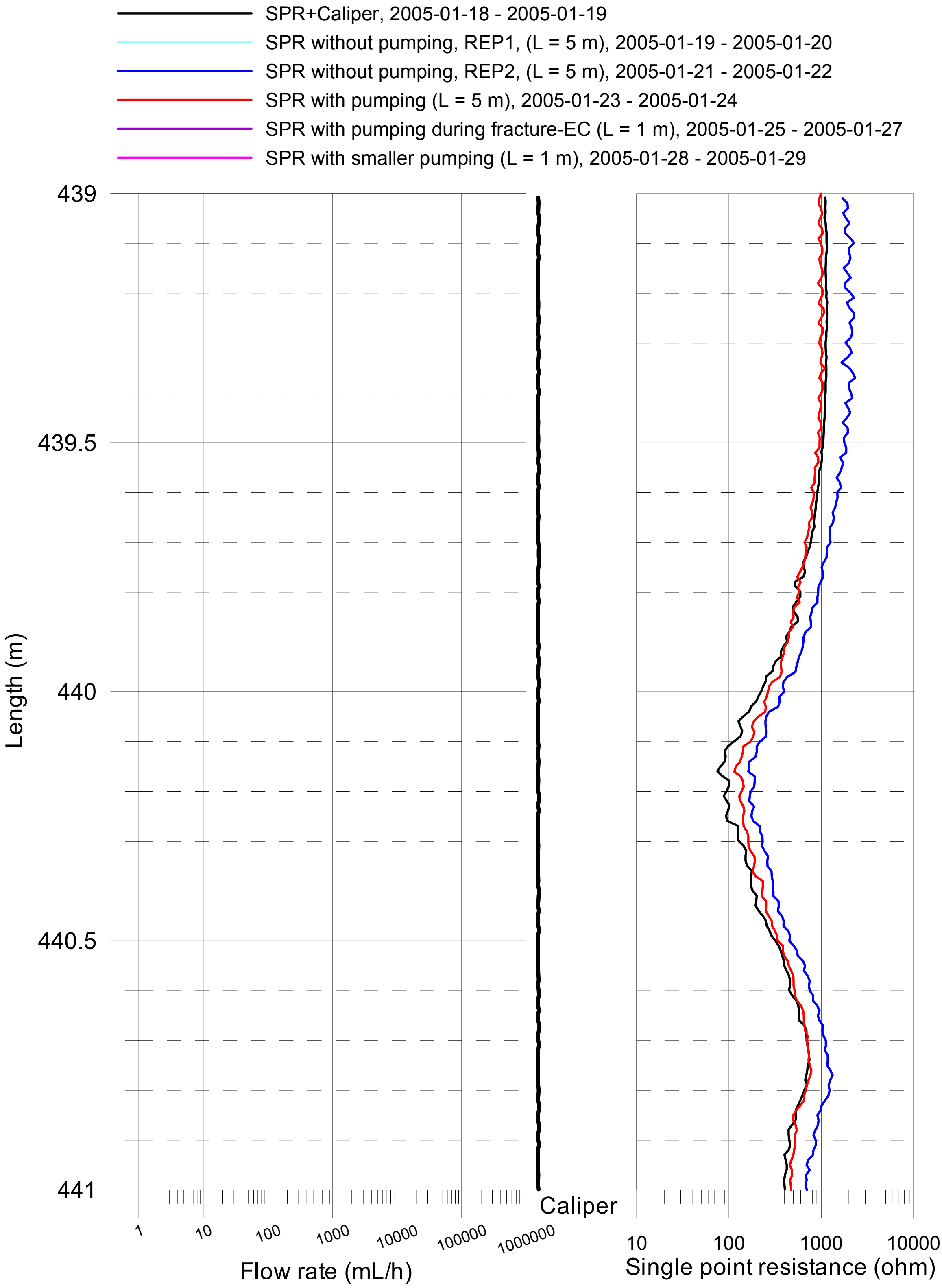
Forsmark, KFM07A
SPR and Caliper results after length correction



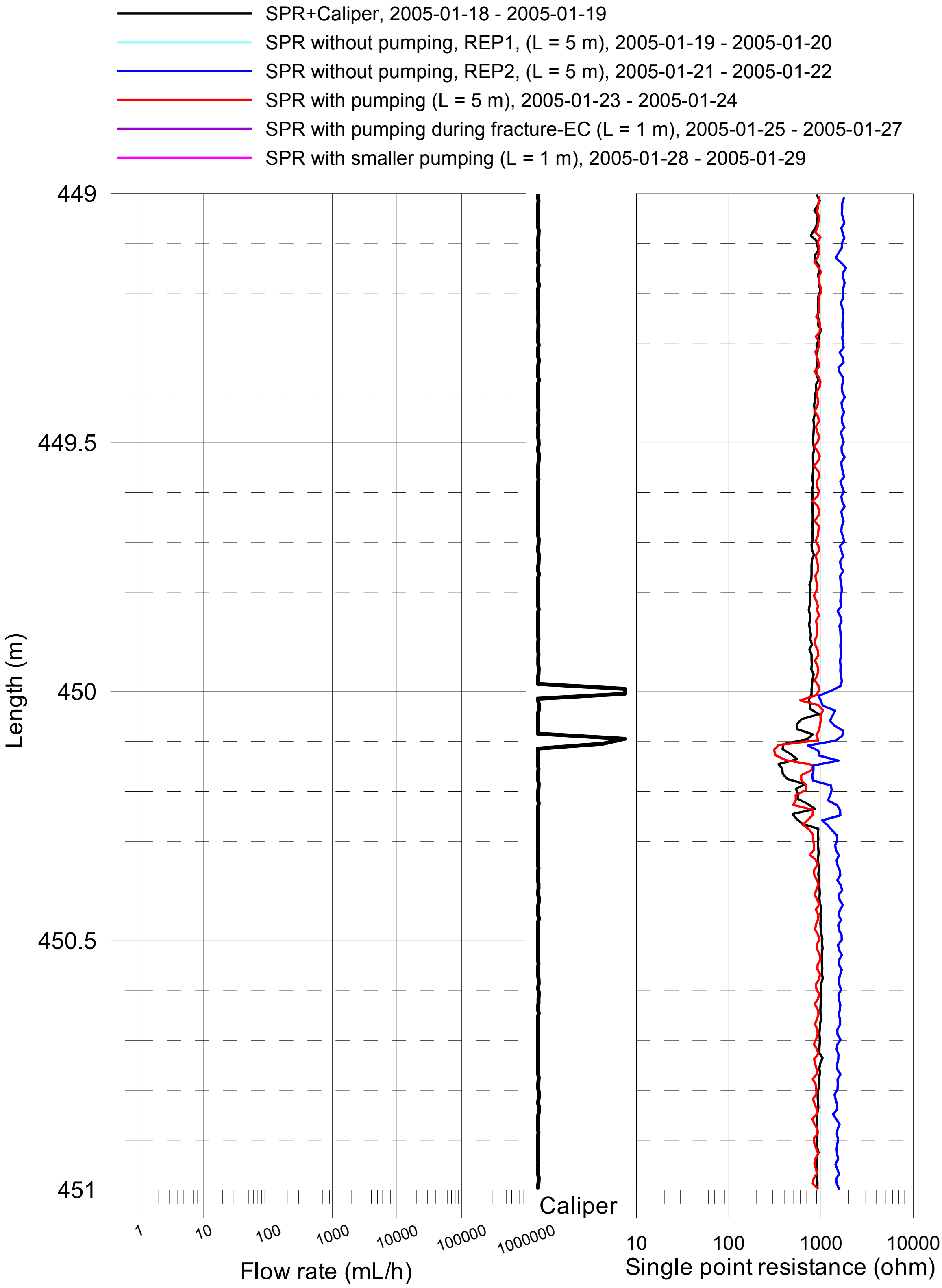
Forsmark, KFM07A
SPR and Caliper results after length correction



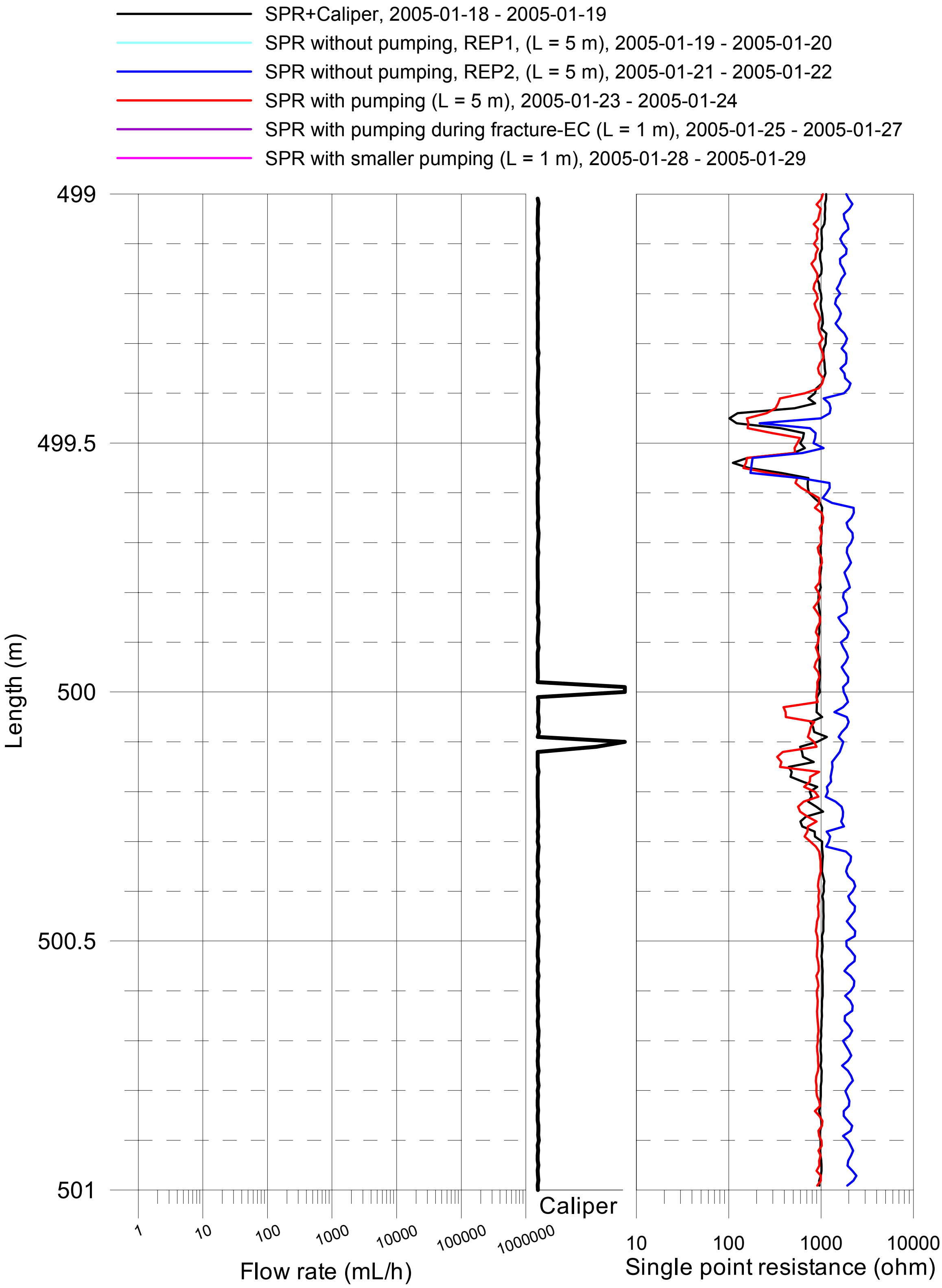
Forsmark, KFM07A
SPR and Caliper results after length correction



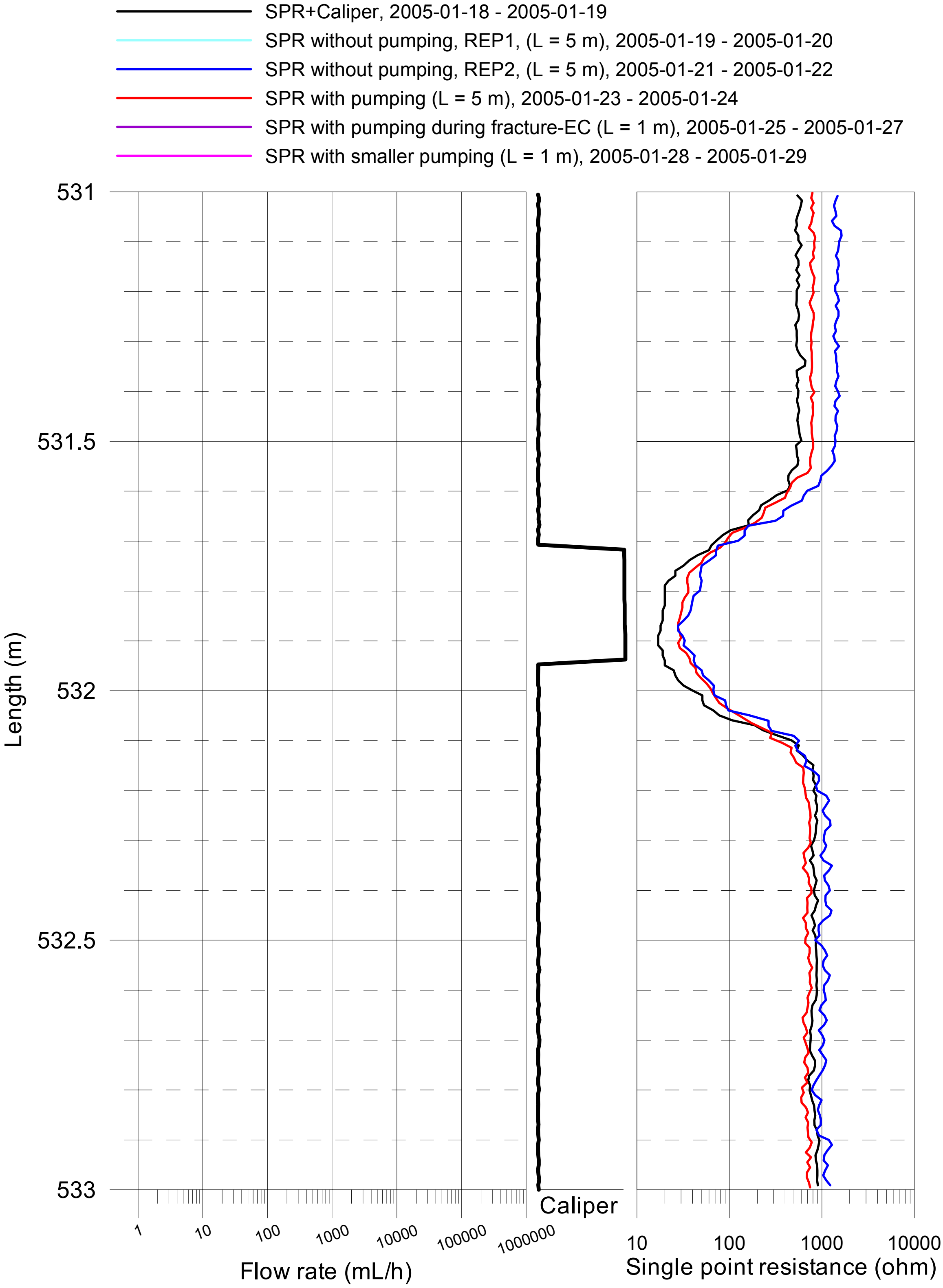
Forsmark, KFM07A
SPR and Caliper results after length correction



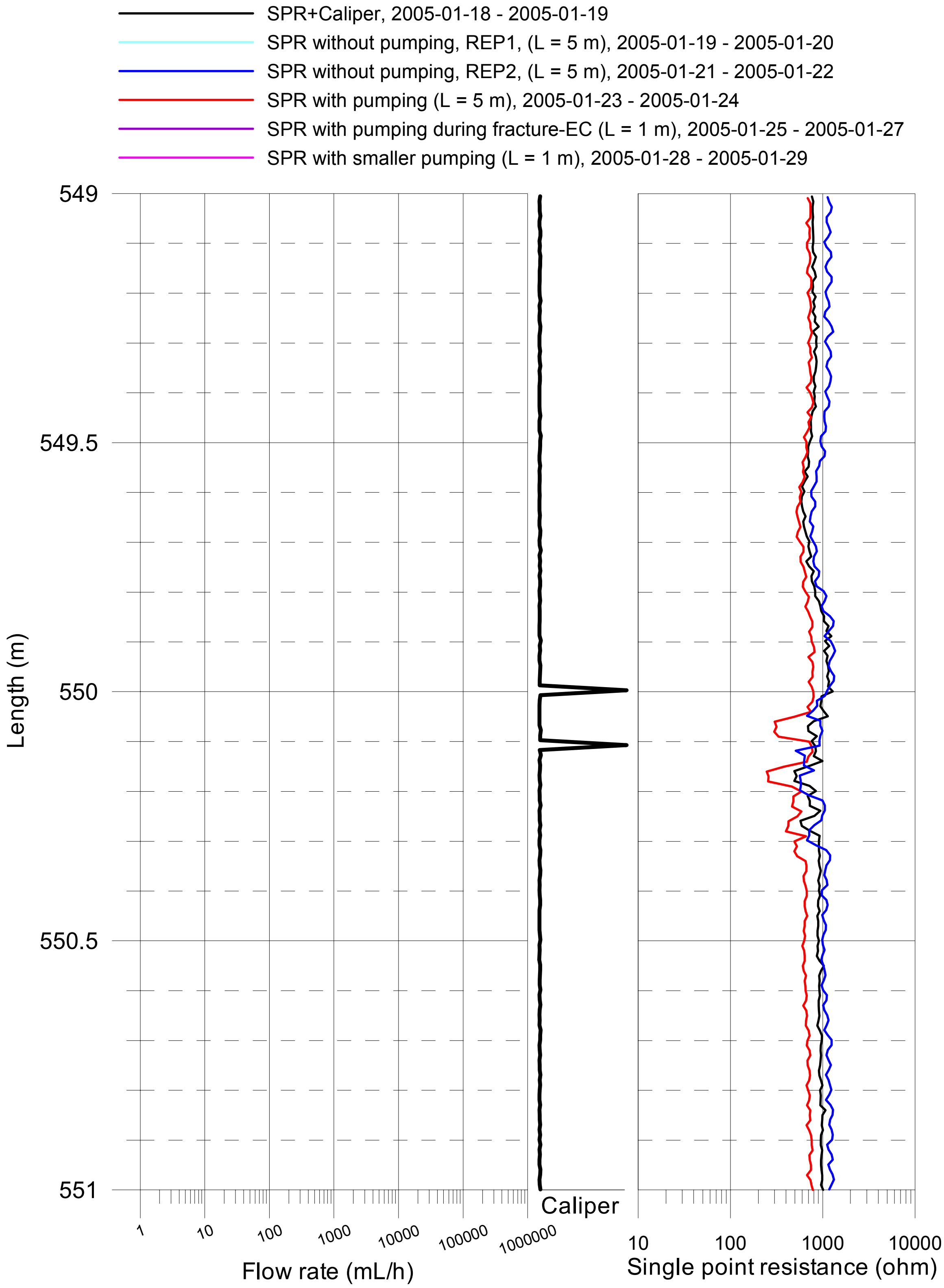
Forsmark, KFM07A
SPR and Caliper results after length correction



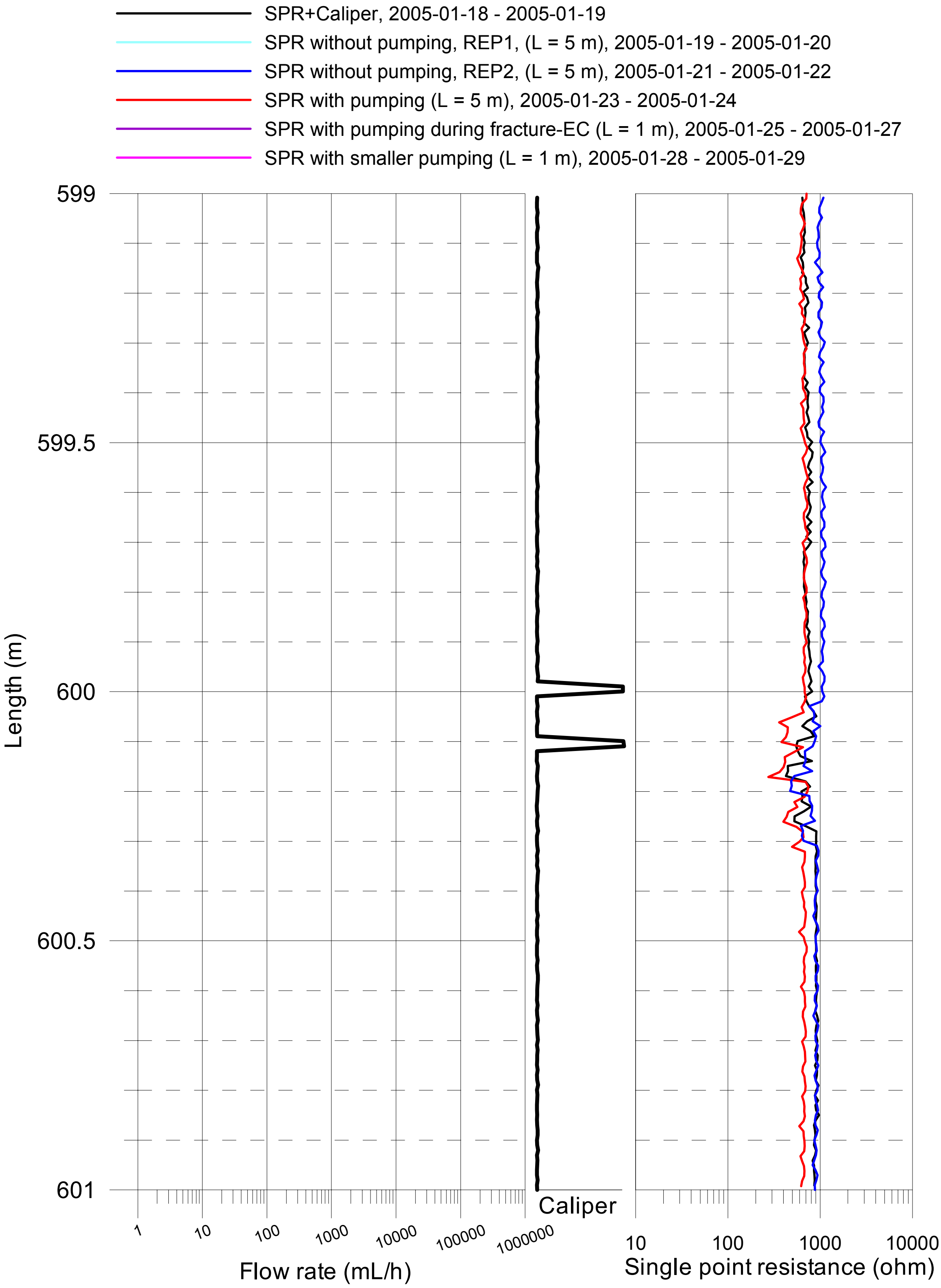
Forsmark, KFM07A
SPR and Caliper results after length correction



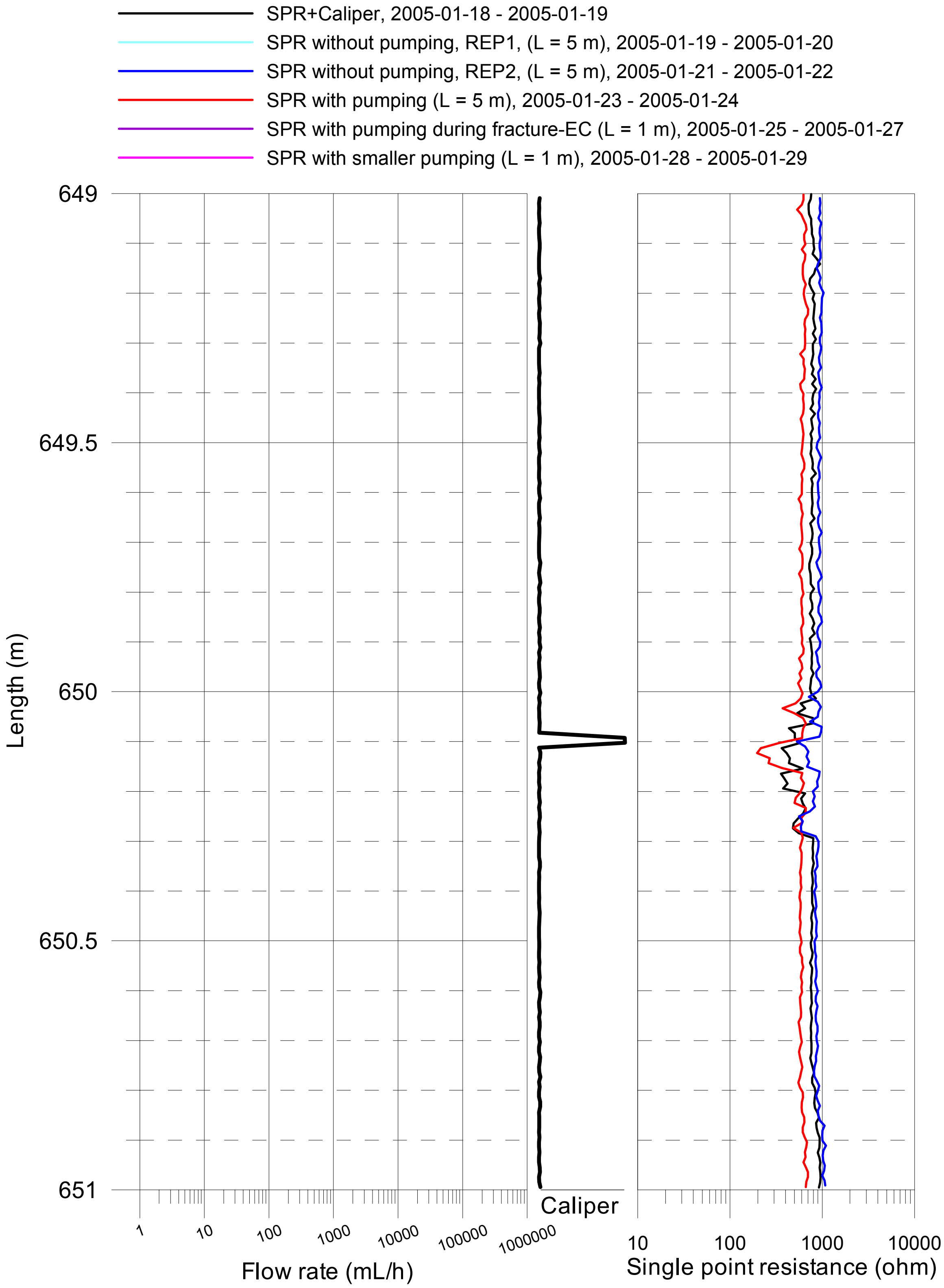
Forsmark, KFM07A
SPR and Caliper results after length correction



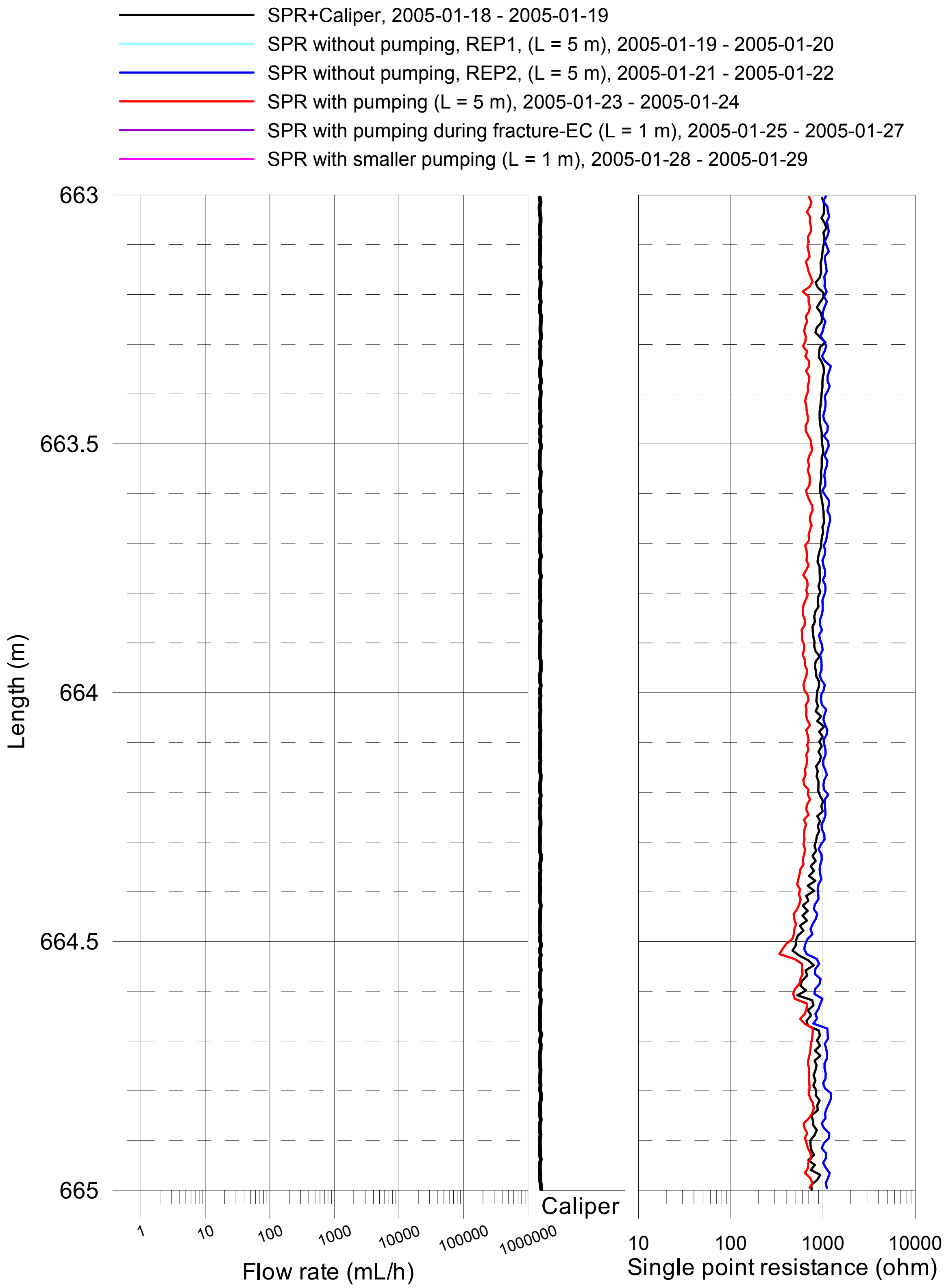
Forsmark, KFM07A
SPR and Caliper results after length correction

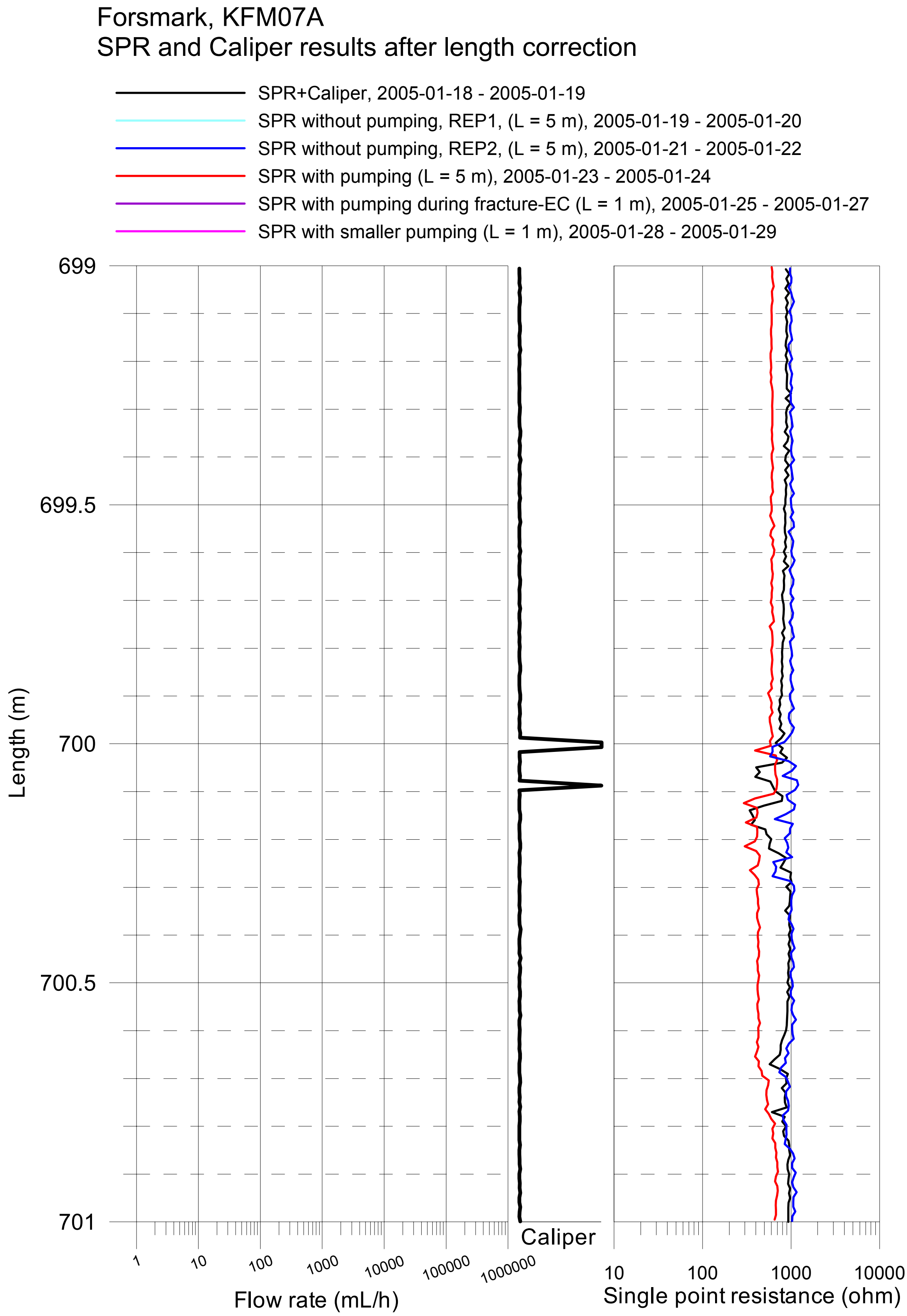


Forsmark, KFM07A
SPR and Caliper results after length correction

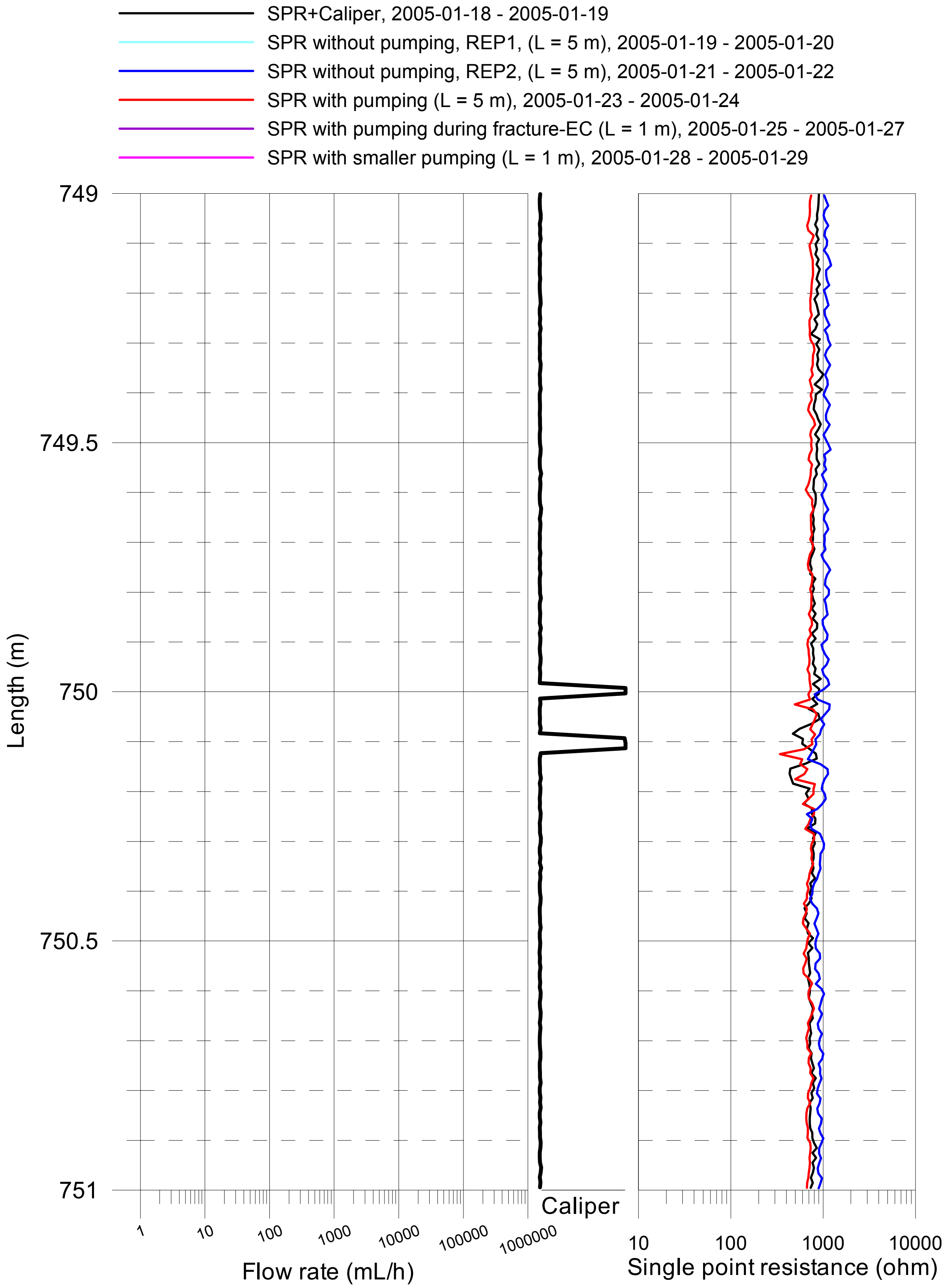


Forsmark, KFM07A
SPR and Caliper results after length correction

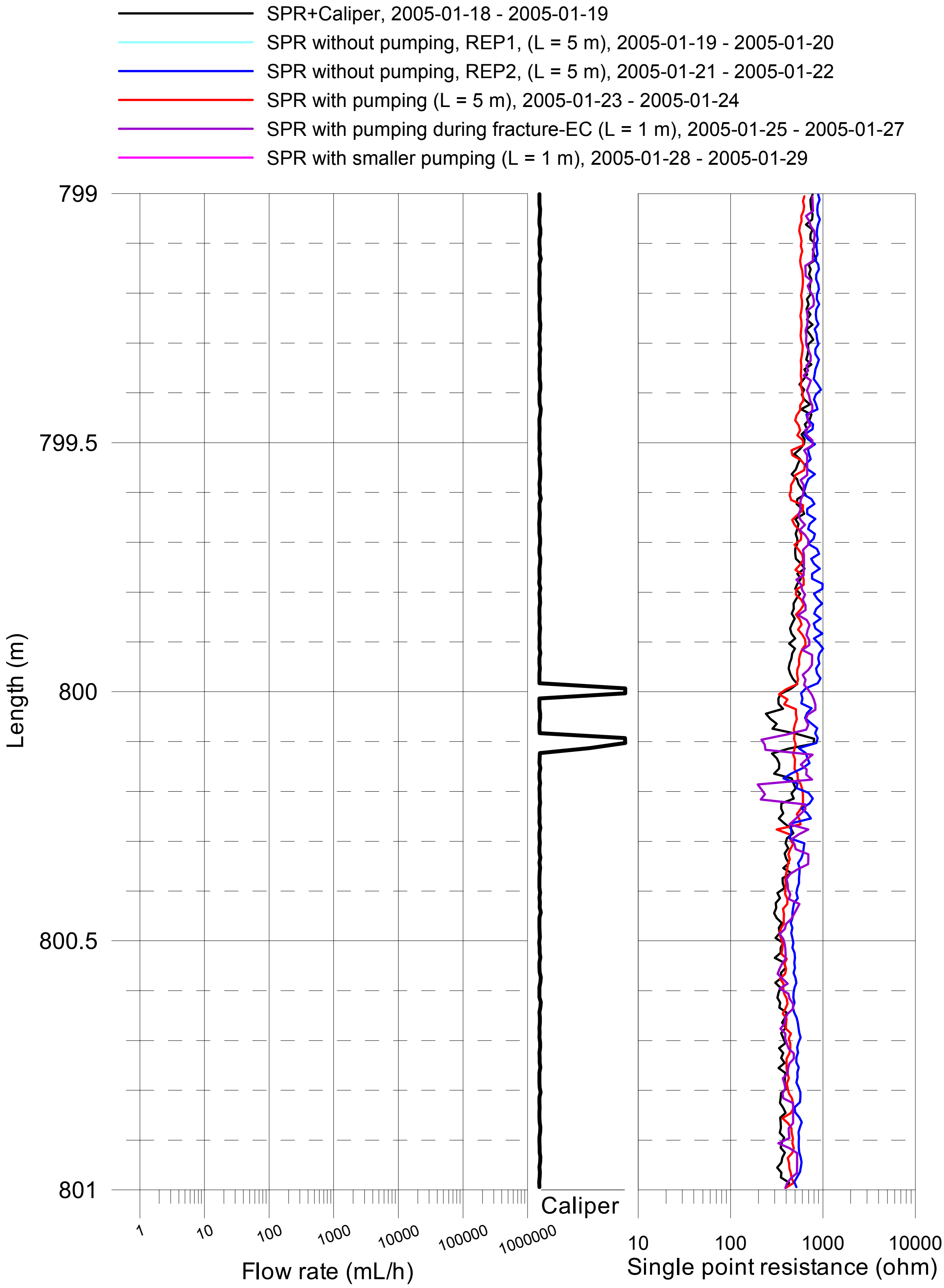



Forsmark, KFM07A
SPR and Caliper results after length correction
SPR+Caliper, 2005-01-18 - 2005-01-19
SPR without pumping, REP1, (L = 5 m), 2005-01-19 - 2005-01-20
SPR without pumping, REP2, (L = 5 m), 2005-01-21 - 2005-01-22
SPR with pumping (L = 5 m), 2005-01-23 - 2005-01-24
SPR with pumping during fracture-EC (L = 1 m), 2005-01-25 - 2005-01-27
SPR with smaller pumping (L = 1 m), 2005-01-28 - 2005-01-29
Length (m)
699
699.5
700
700.5
701
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

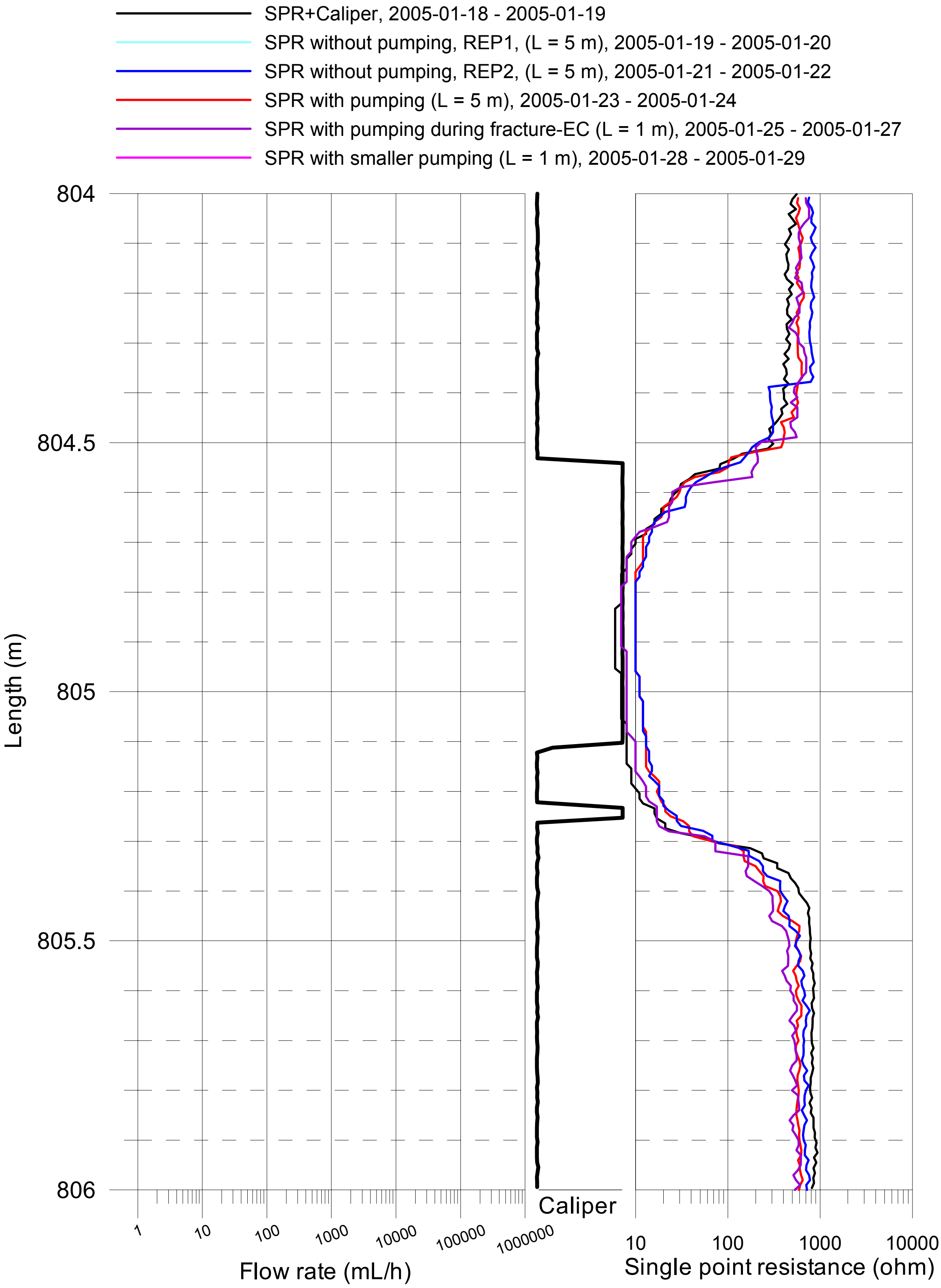
Forsmark, KFM07A
SPR and Caliper results after length correction



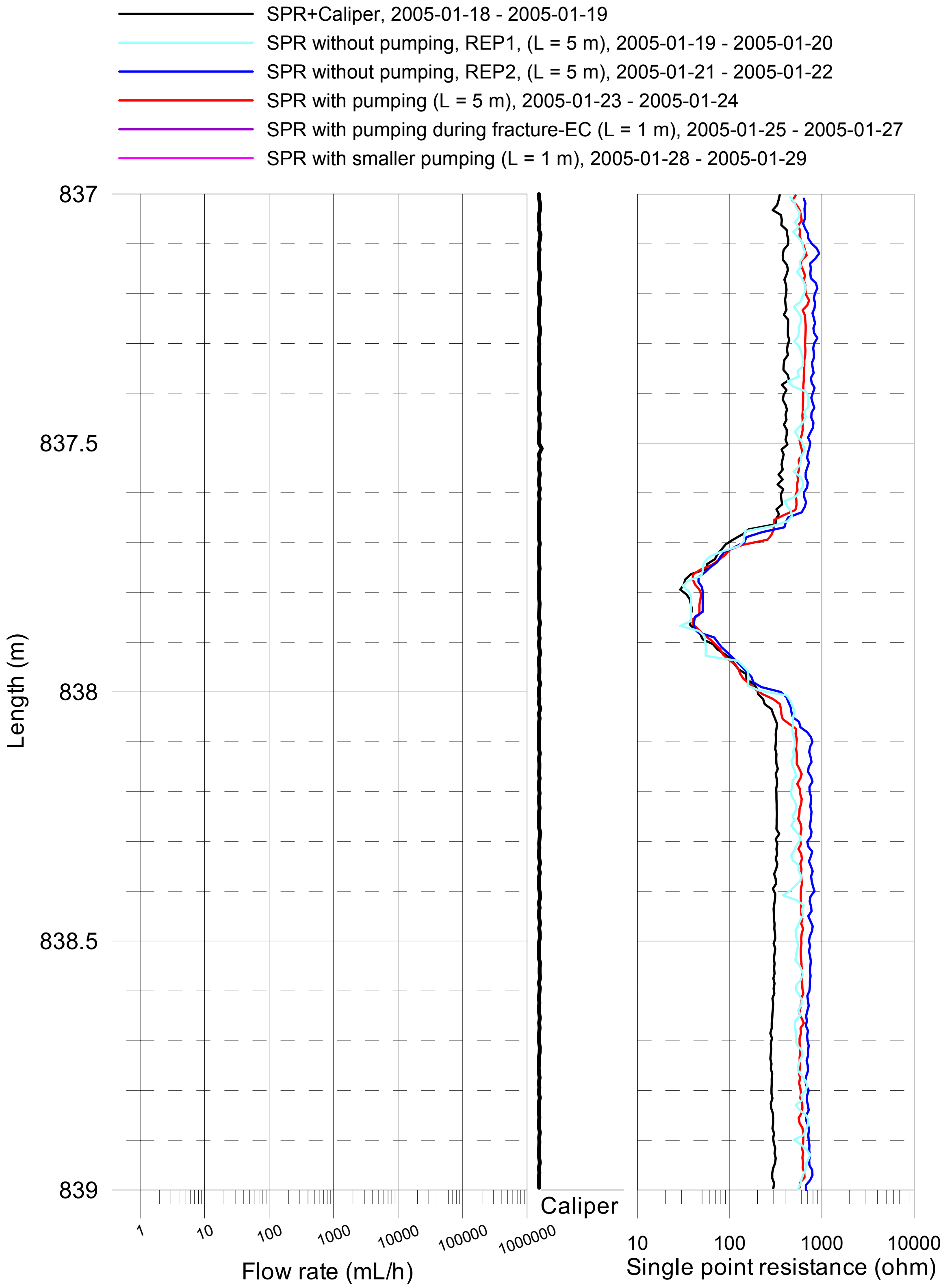
Forsmark, KFM07A
SPR and Caliper results after length correction

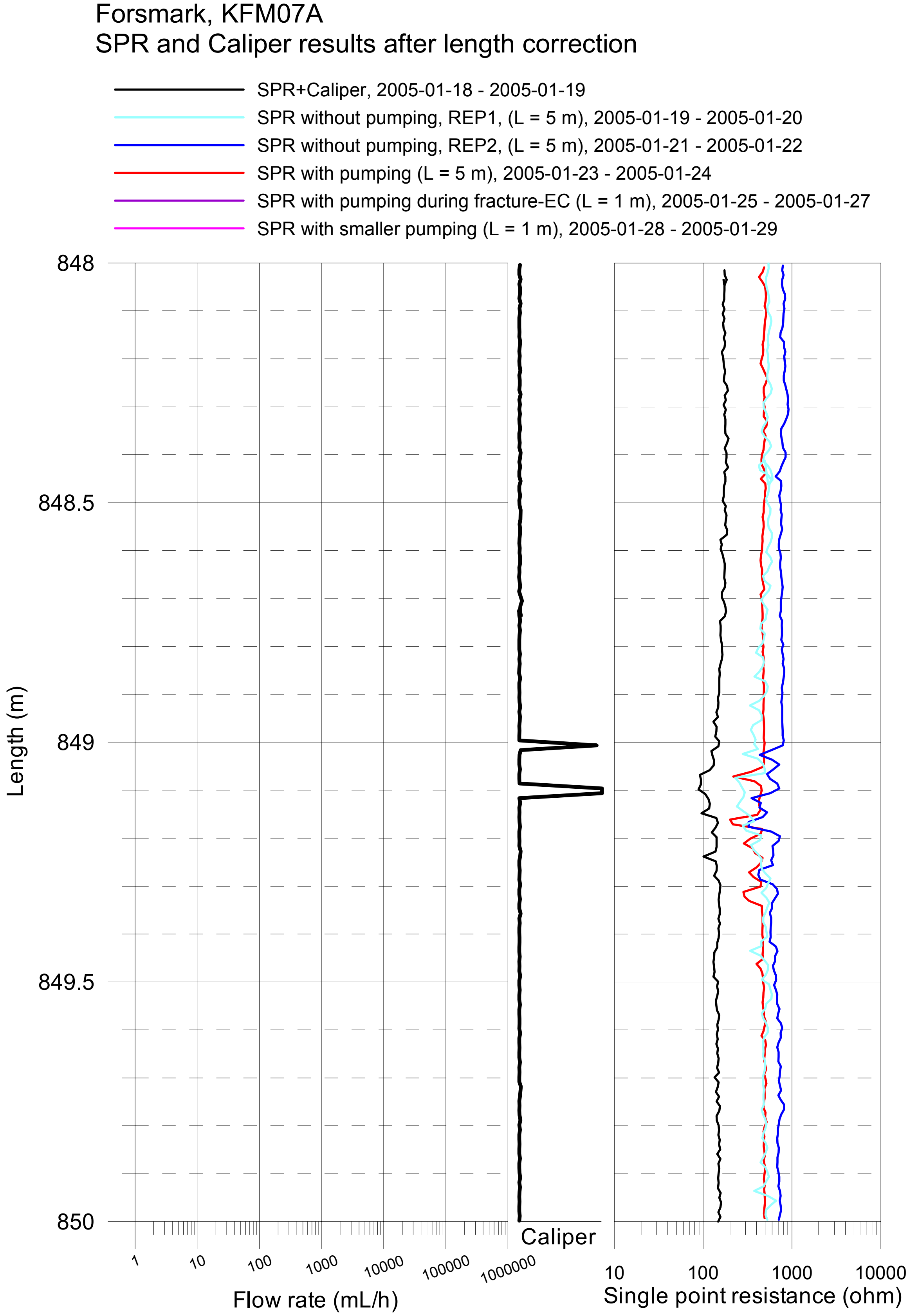


Forsmark, KFM07A
SPR and Caliper results after length correction

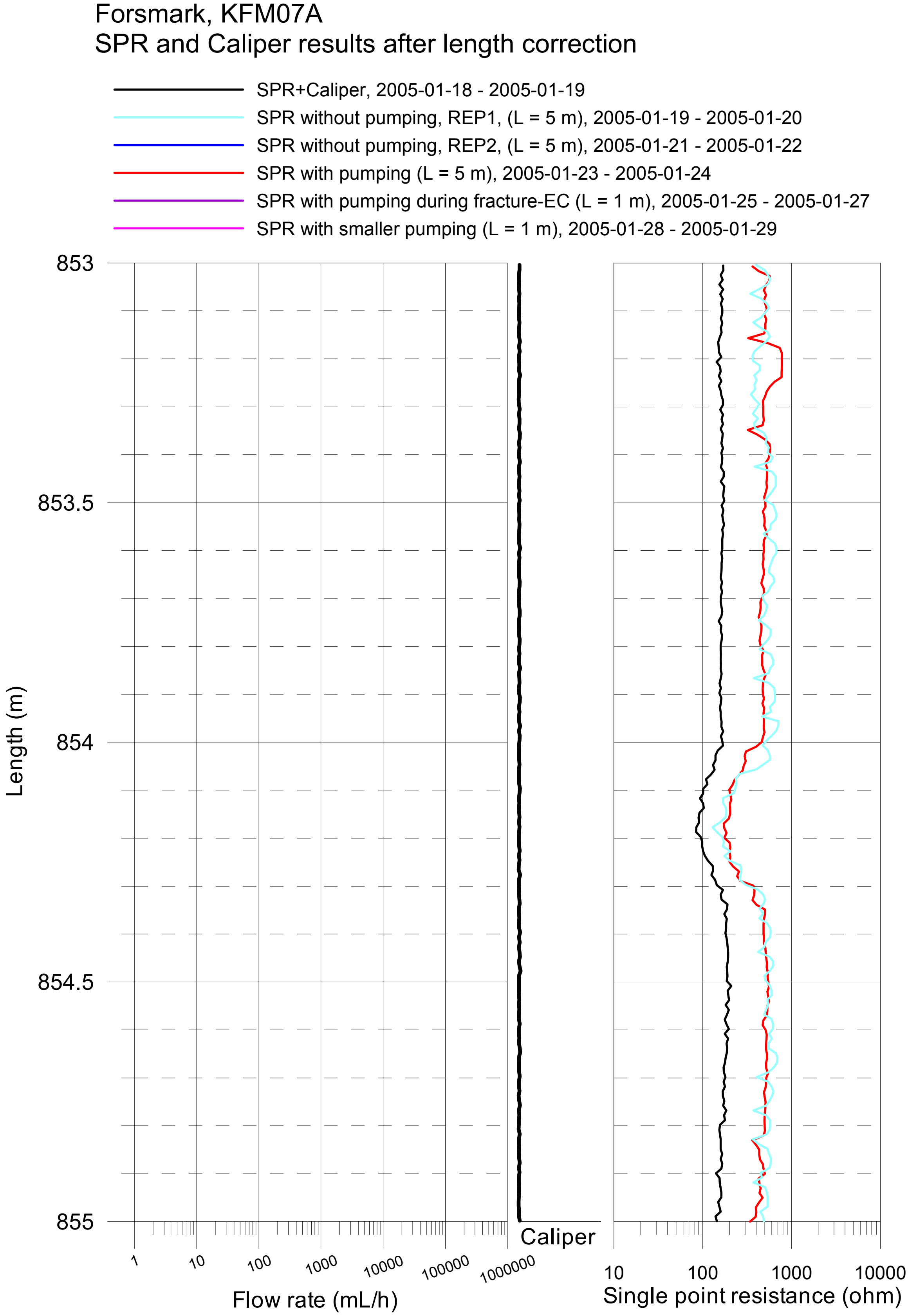


Forsmark, KFM07A
SPR and Caliper results after length correction

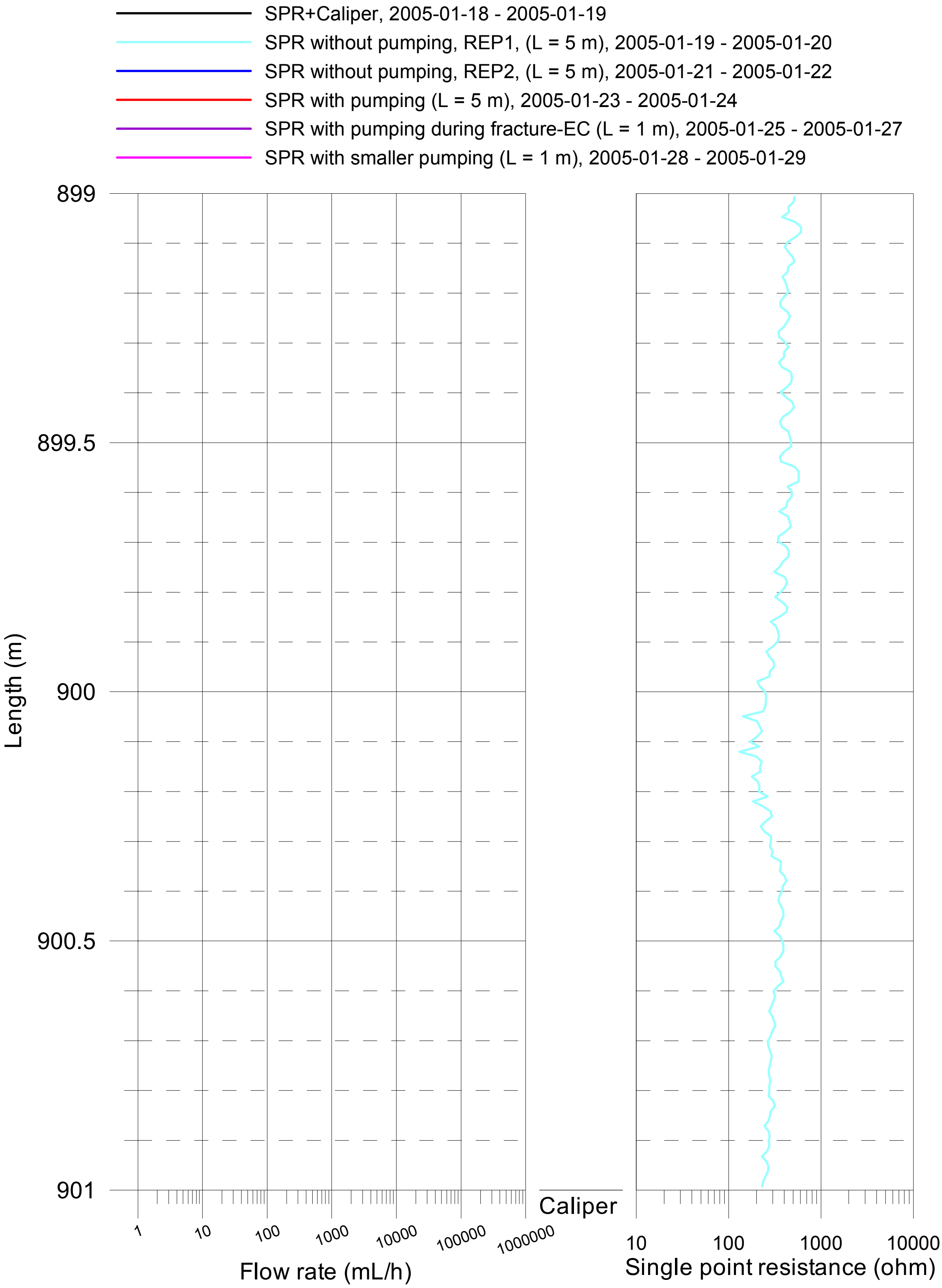


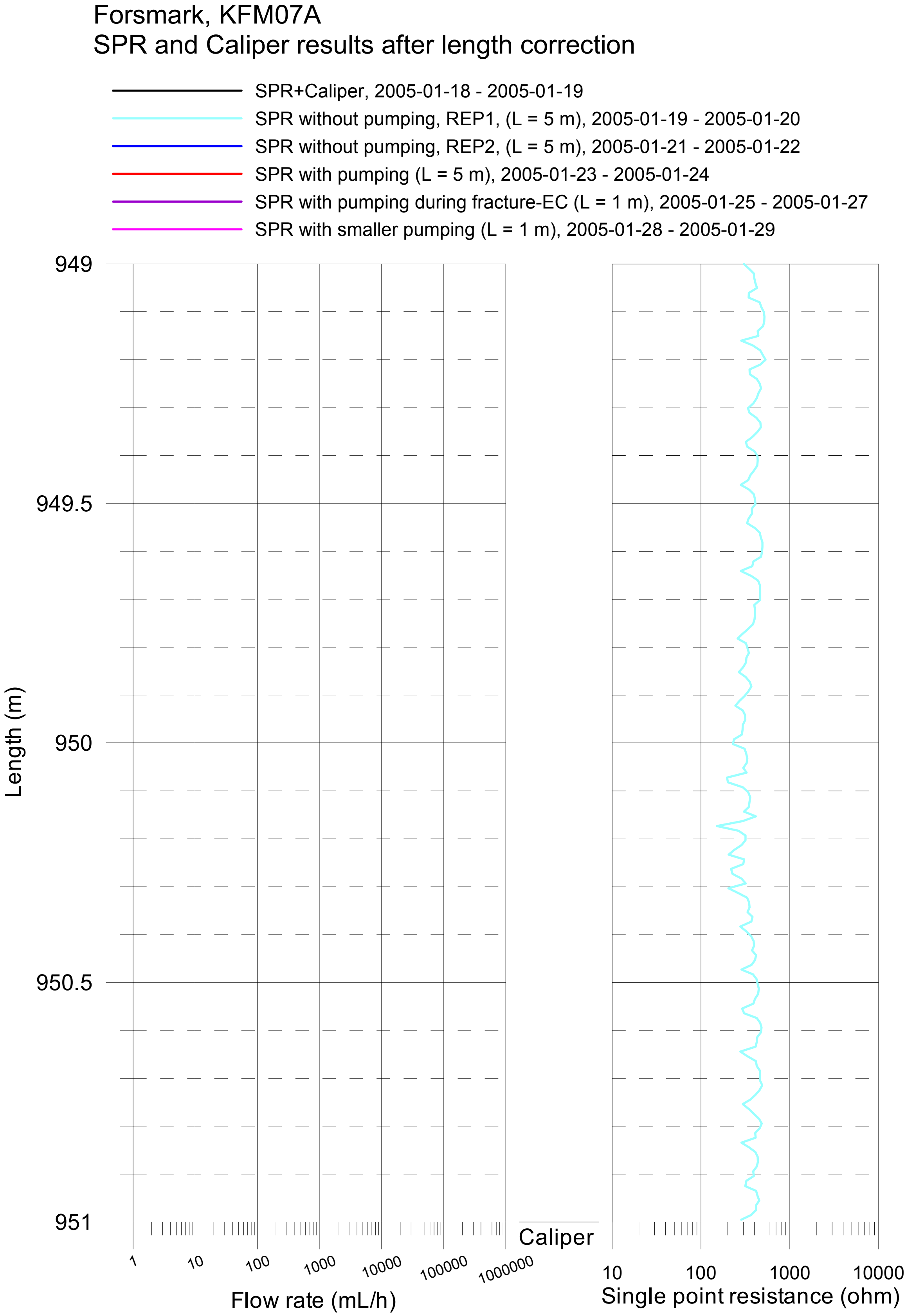


Forsmark, KFM07A
SPR and Caliper results after length correction
SPR+Caliper, 2005-01-18 - 2005-01-19
SPR without pumping, REP1, (L = 5 m), 2005-01-19 - 2005-01-20
SPR without pumping, REP2, (L = 5 m), 2005-01-21 - 2005-01-22
SPR with pumping (L = 5 m), 2005-01-23 - 2005-01-24
SPR with pumping during fracture-EC (L = 1 m), 2005-01-25 - 2005-01-27
SPR with smaller pumping (L = 1 m), 2005-01-28 - 2005-01-29
Length (m)
848
848.5
849
849.5
850
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

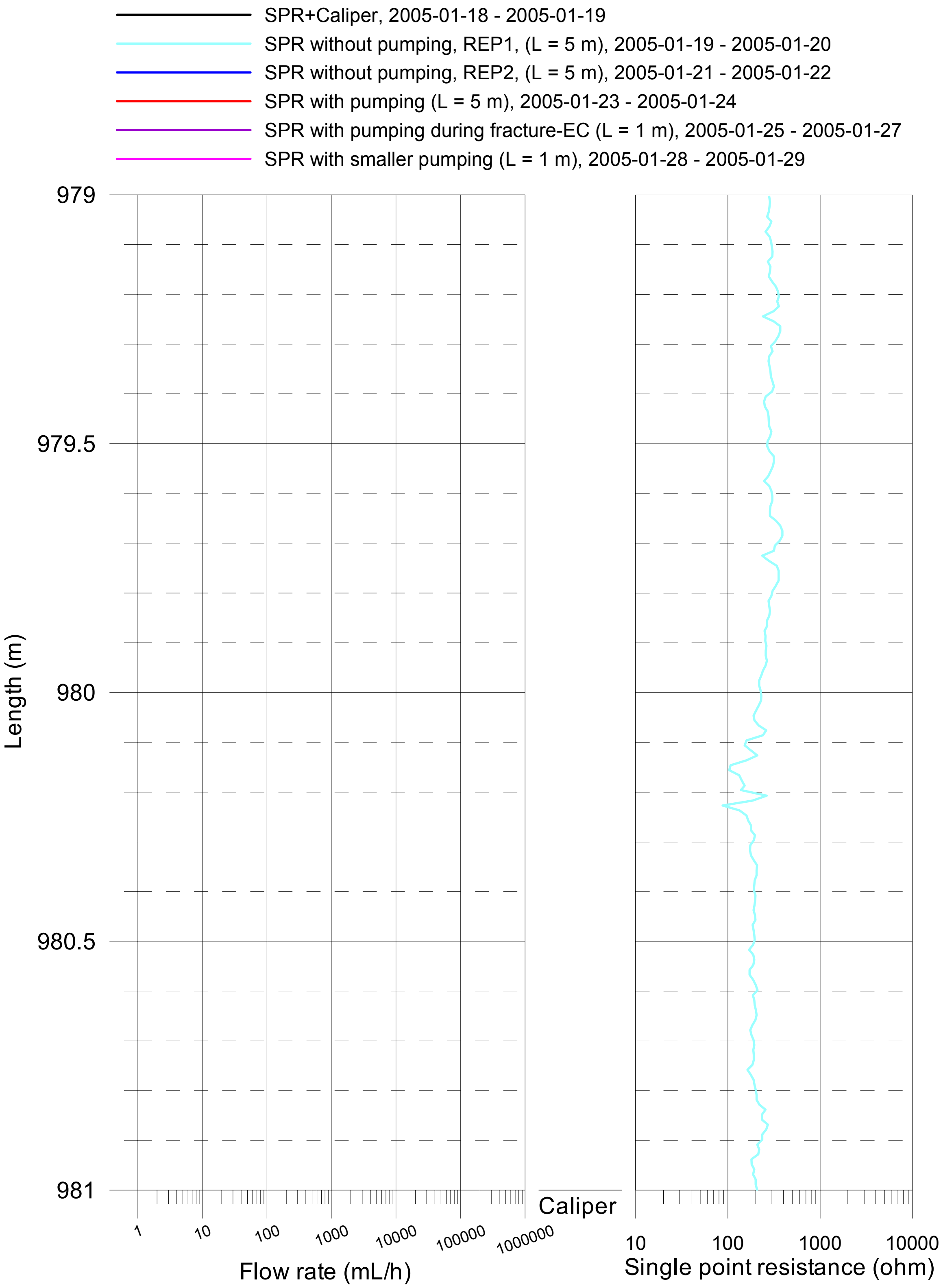

Forsmark, KFM07A
SPR and Caliper results after length correction
SPR+Caliper, 2005-01-18 - 2005-01-19
SPR without pumping, REP1, (L = 5 m), 2005-01-19 - 2005-01-20
SPR without pumping, REP2, (L = 5 m), 2005-01-21 - 2005-01-22
SPR with pumping (L = 5 m), 2005-01-23 - 2005-01-24
SPR with pumping during fracture-EC (L = 1 m), 2005-01-25 - 2005-01-27
SPR with smaller pumping (L = 1 m), 2005-01-28 - 2005-01-29
853
853.5
854
854.5
855
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

Forsmark, KFM07A
SPR and Caliper results after length correction

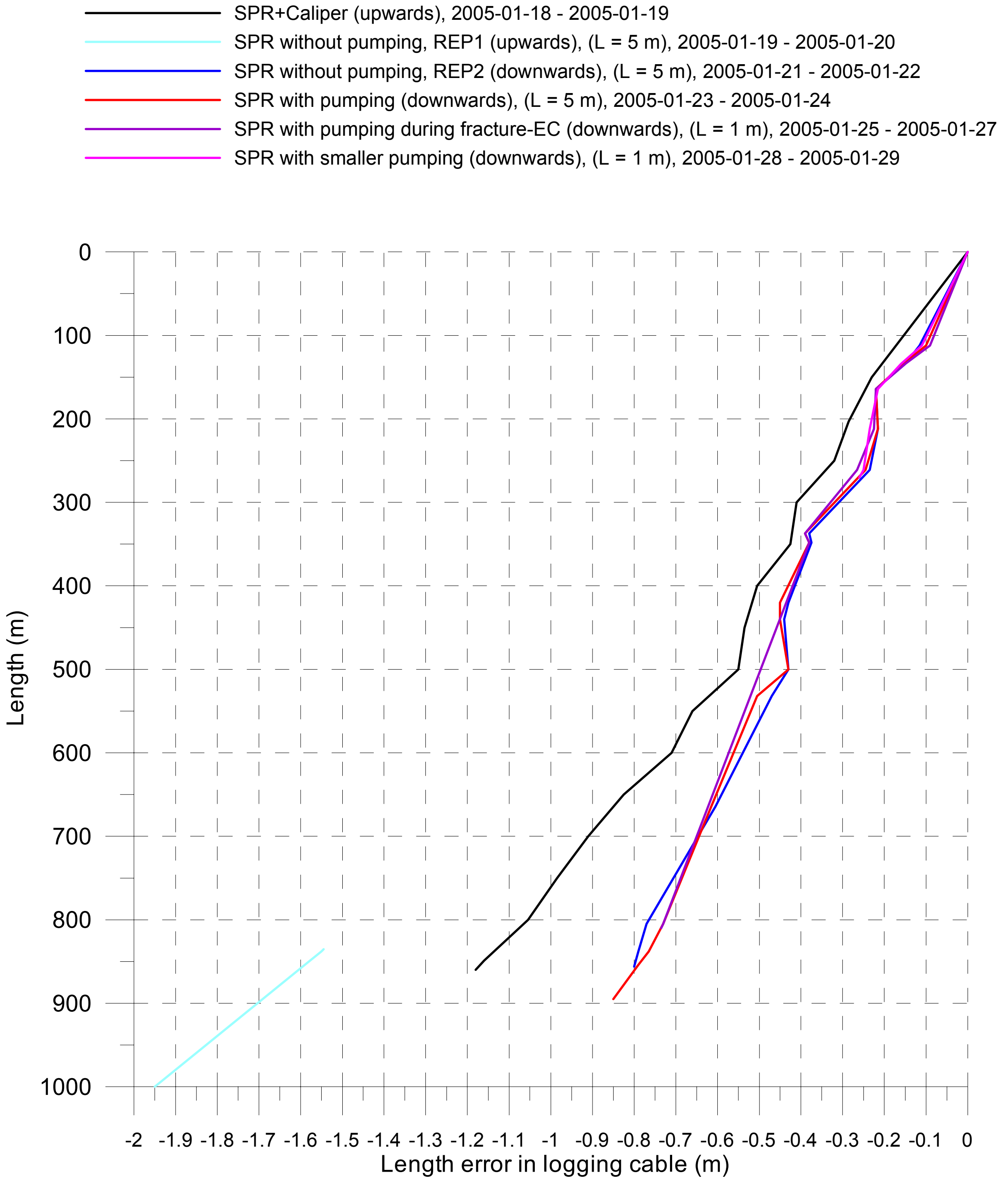



Forsmark, KFM07A
SPR and Caliper results after length correction
SPR+Caliper, 2005-01-18 - 2005-01-19
SPR without pumping, REP1, (L = 5 m), 2005-01-19 - 2005-01-20
SPR without pumping, REP2, (L = 5 m), 2005-01-21 - 2005-01-22
SPR with pumping (L = 5 m), 2005-01-23 - 2005-01-24
SPR with pumping during fracture-EC (L = 1 m), 2005-01-25 - 2005-01-27
SPR with smaller pumping (L = 1 m), 2005-01-28 - 2005-01-29
949
949.5
950
950.5
951
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

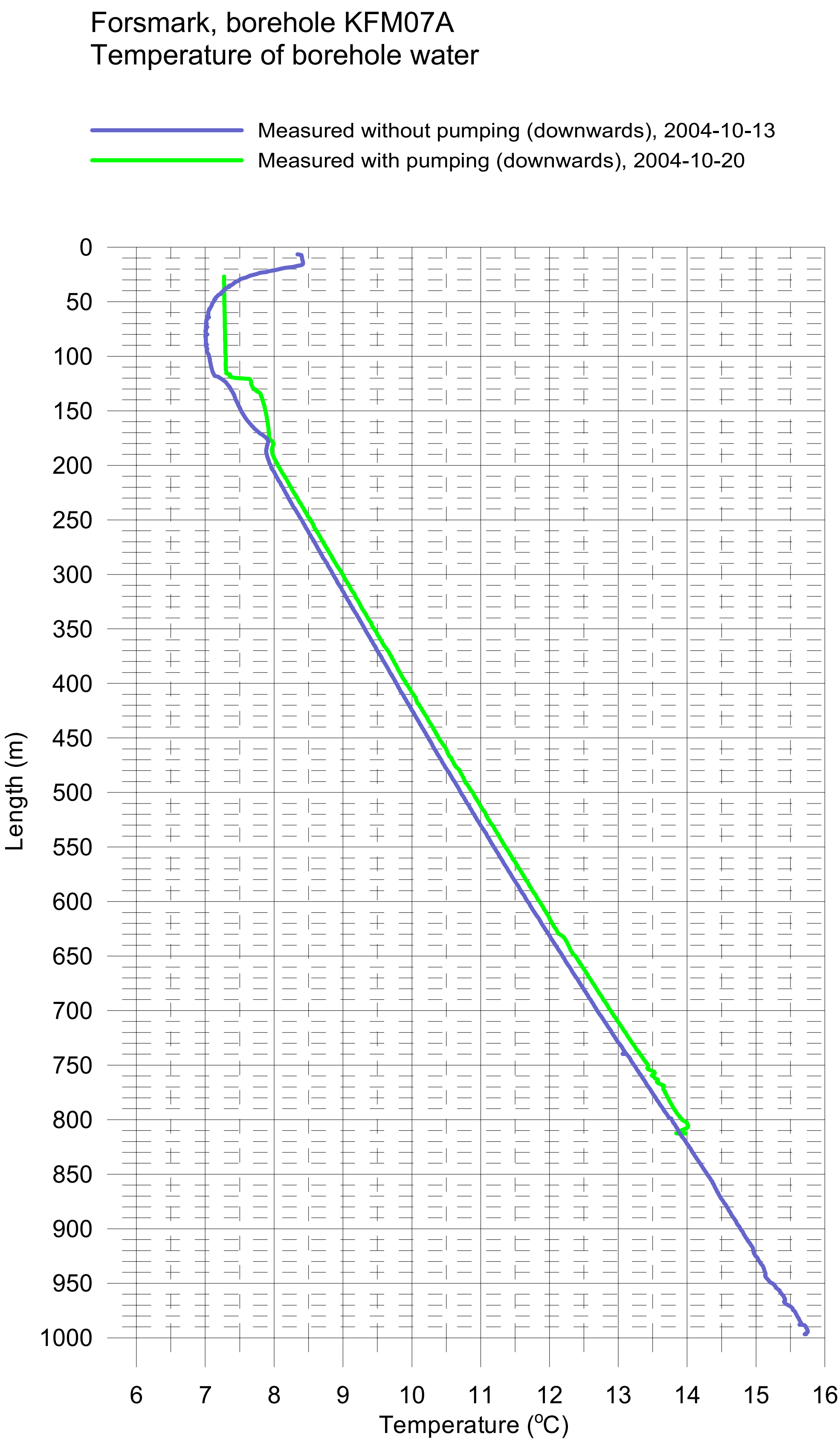
Forsmark, KFM07A
SPR and Caliper results after length correction

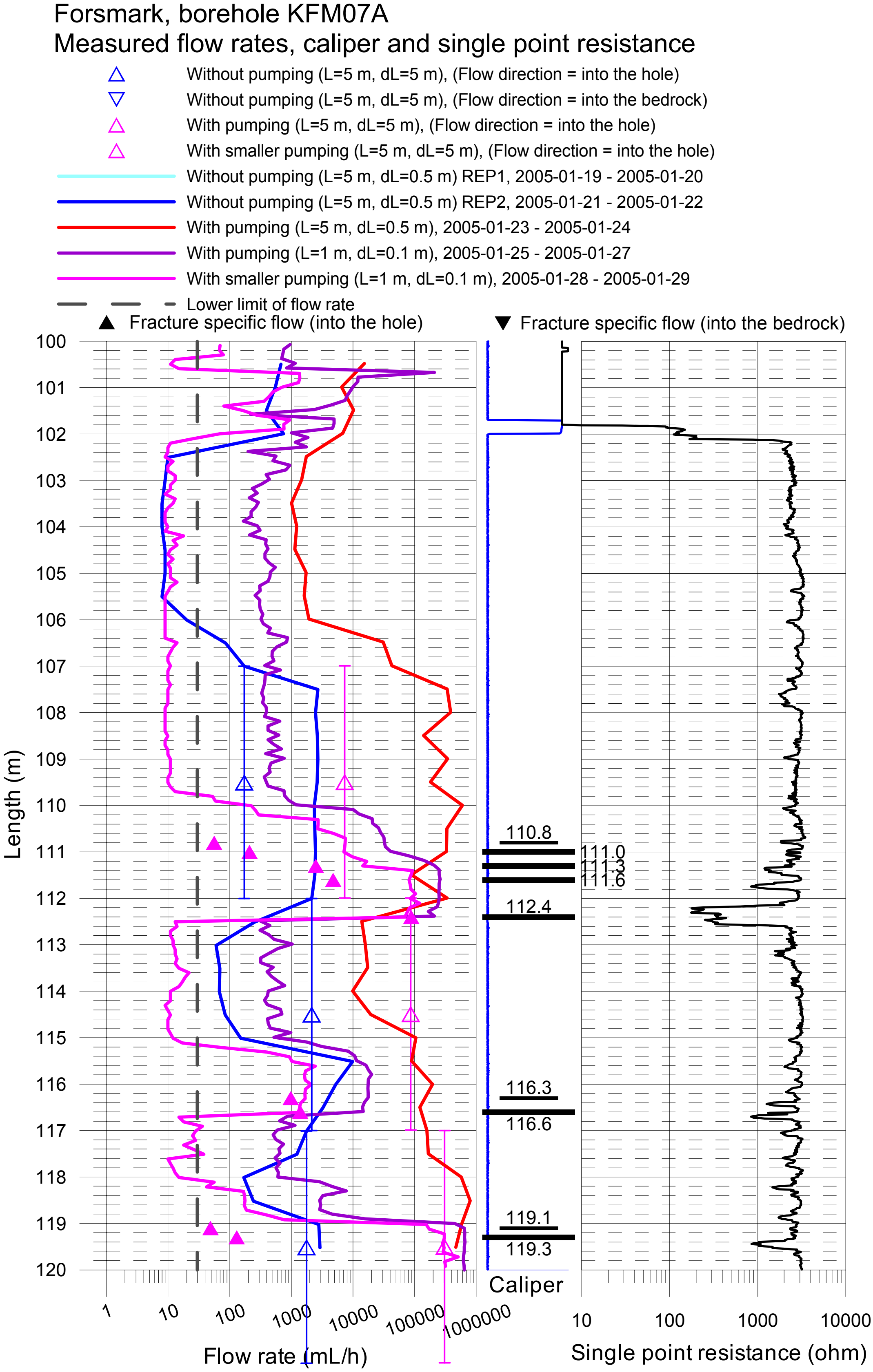


Forsmark, KFM07A
Length correction



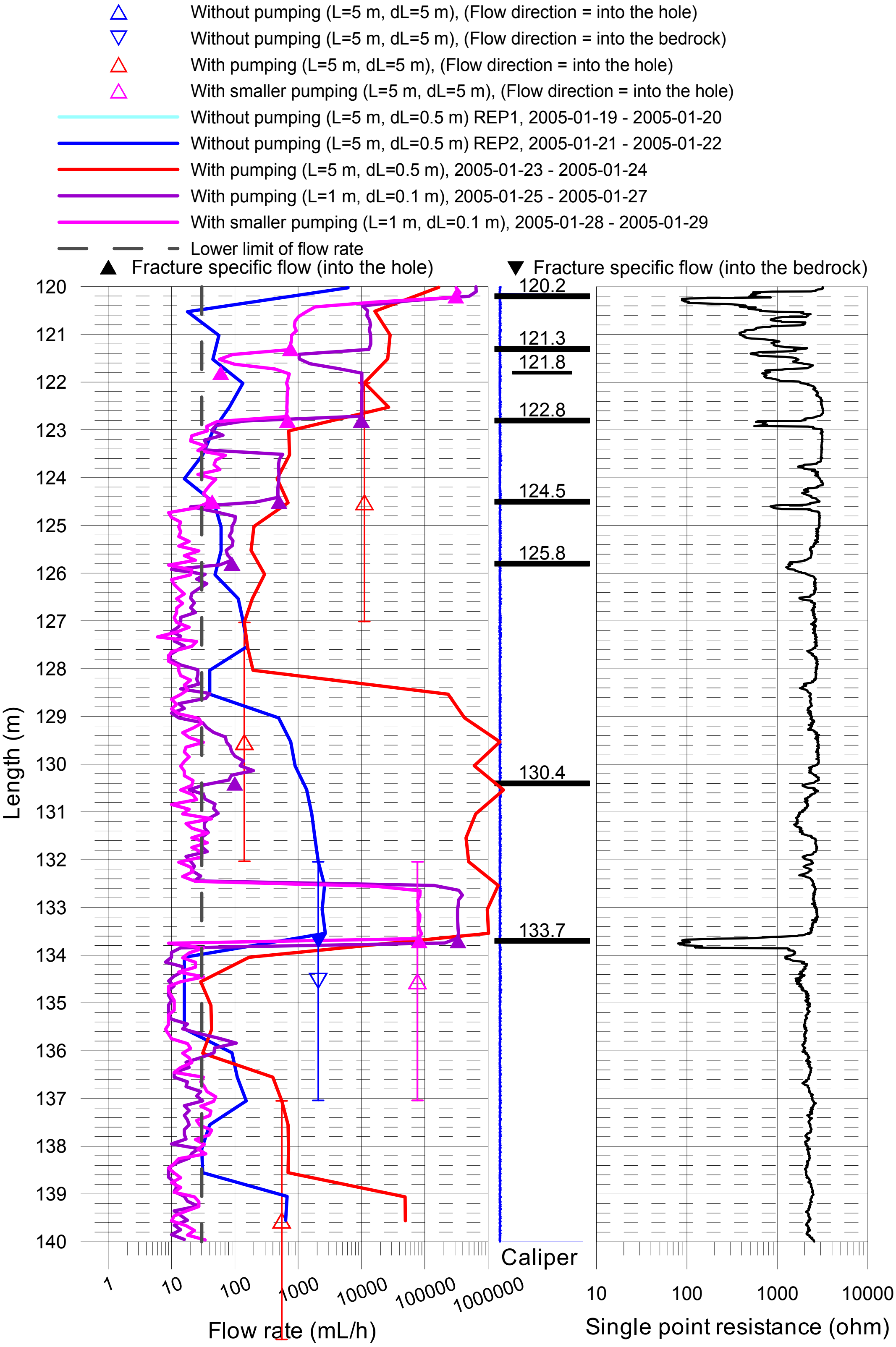

Forsmark, borehole KFM07A
Electric conductivity of borehole water
Measured without pumping (downwards), 2005-01-19
Measured with pumping (downwards), 2005-01-27
Length (m)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
0.8
0.9
1
2
3
4
Electric conductivity (S/m, 25 °C)


Forsmark, borehole KFM07A
Temperature of borehole water
Measured without pumping (downwards), 2004-10-13
Measured with pumping (downwards), 2004-10-20
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
Temperature (ºC)

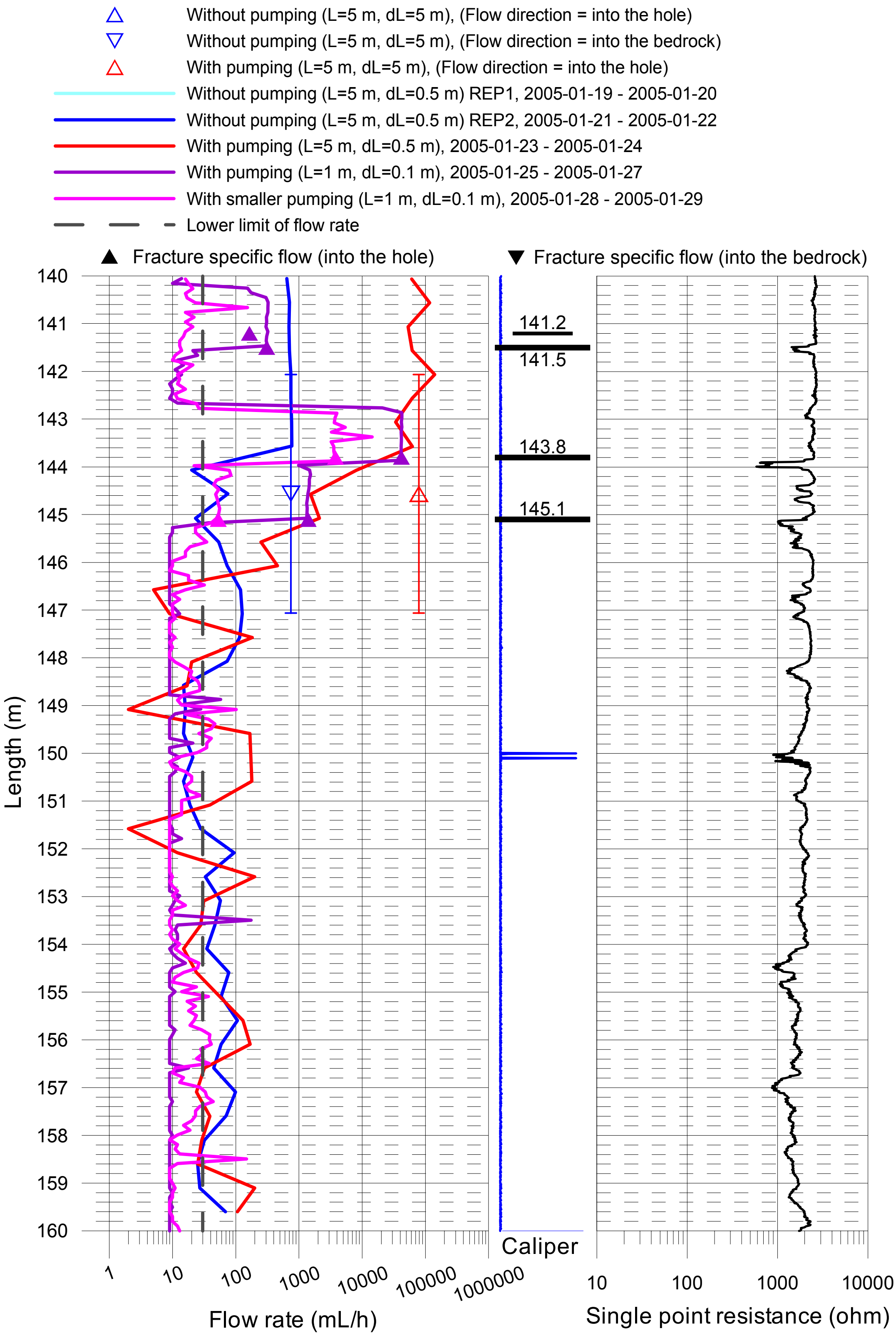


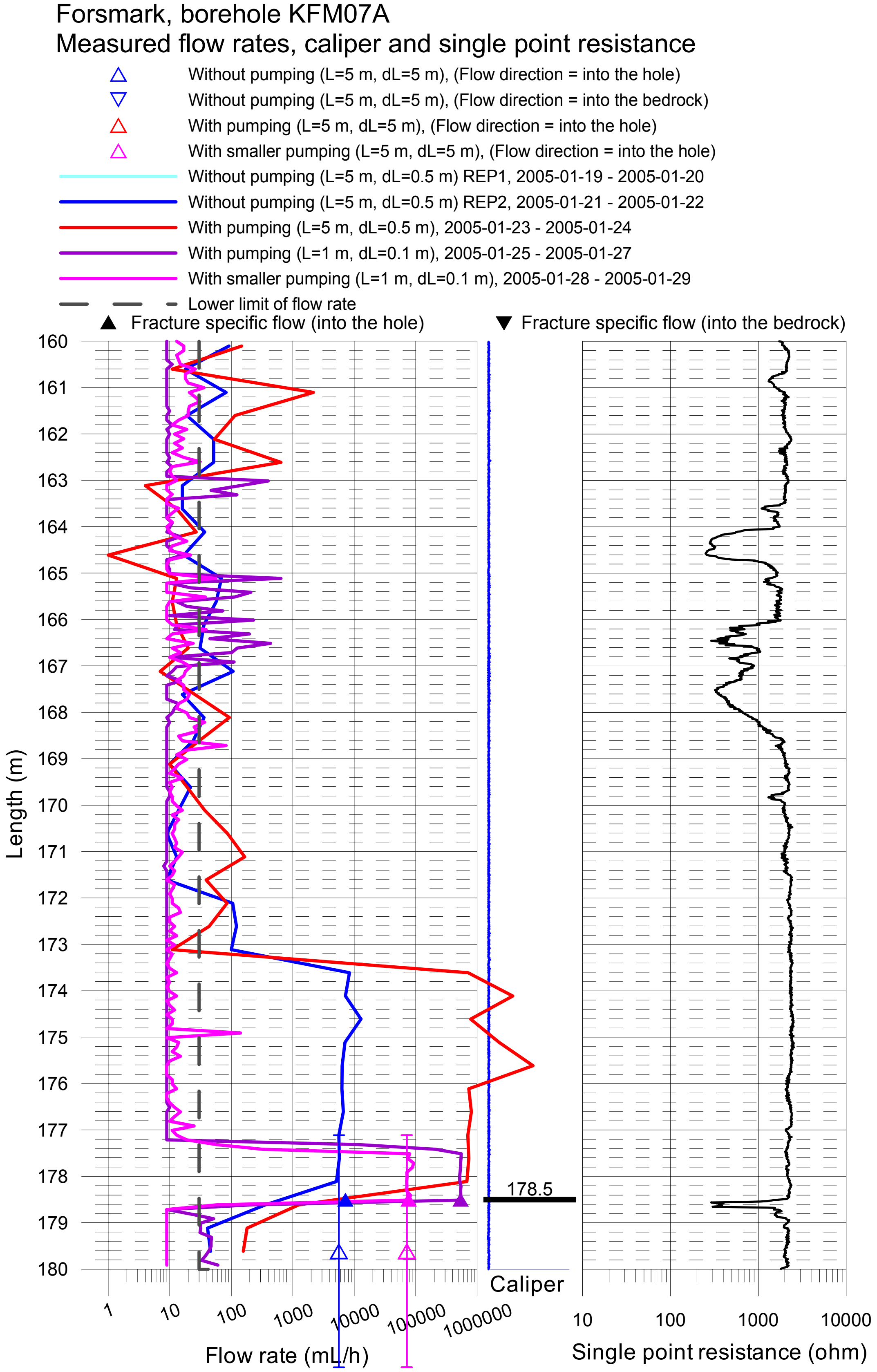
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
With smaller pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m) REP1, 2005-01-19 - 2005-01-20
Without pumping (L=5 m, dL=0.5 m) REP2, 2005-01-21 - 2005-01-22
With pumping (L=5 m, dL=0.5 m), 2005-01-23 - 2005-01-24
With pumping (L=1 m, dL=0.1 m), 2005-01-25 - 2005-01-27
With smaller pumping (L=1 m, dL=0.1 m), 2005-01-28 - 2005-01-29
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
110.8
111.0
111.3
111.6
112.4
116.3
116.6
119.1
119.3
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance

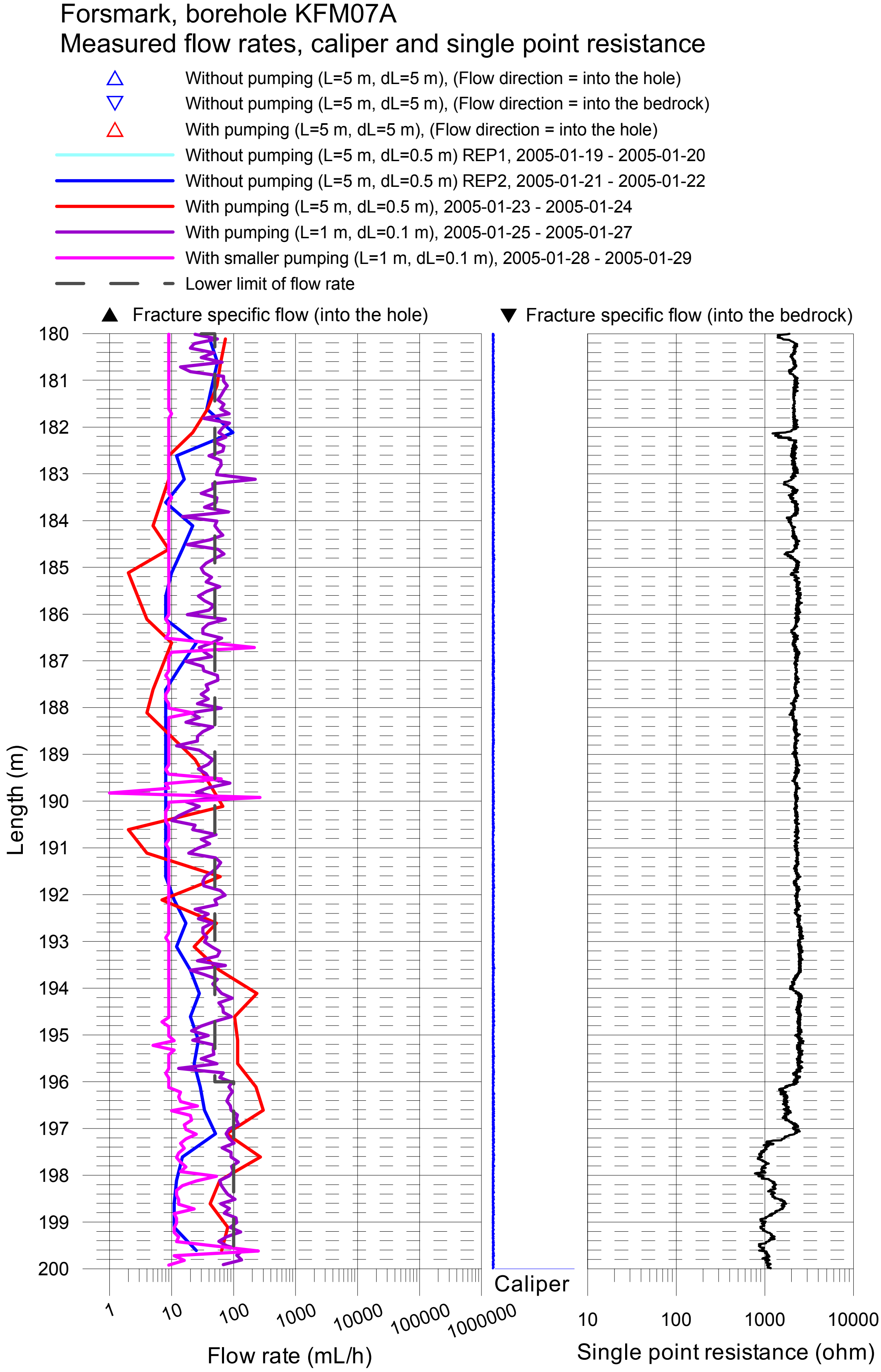


Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance

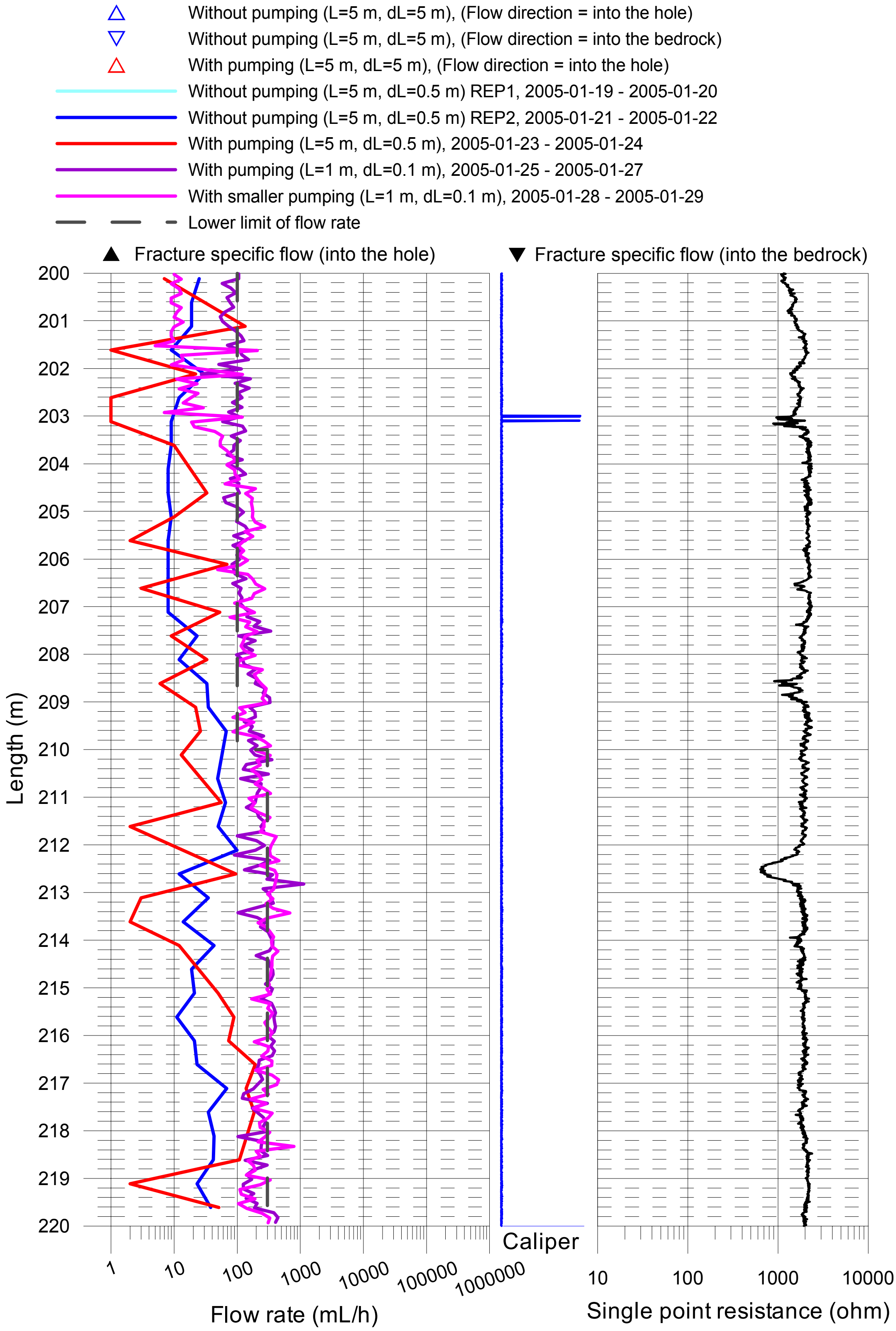


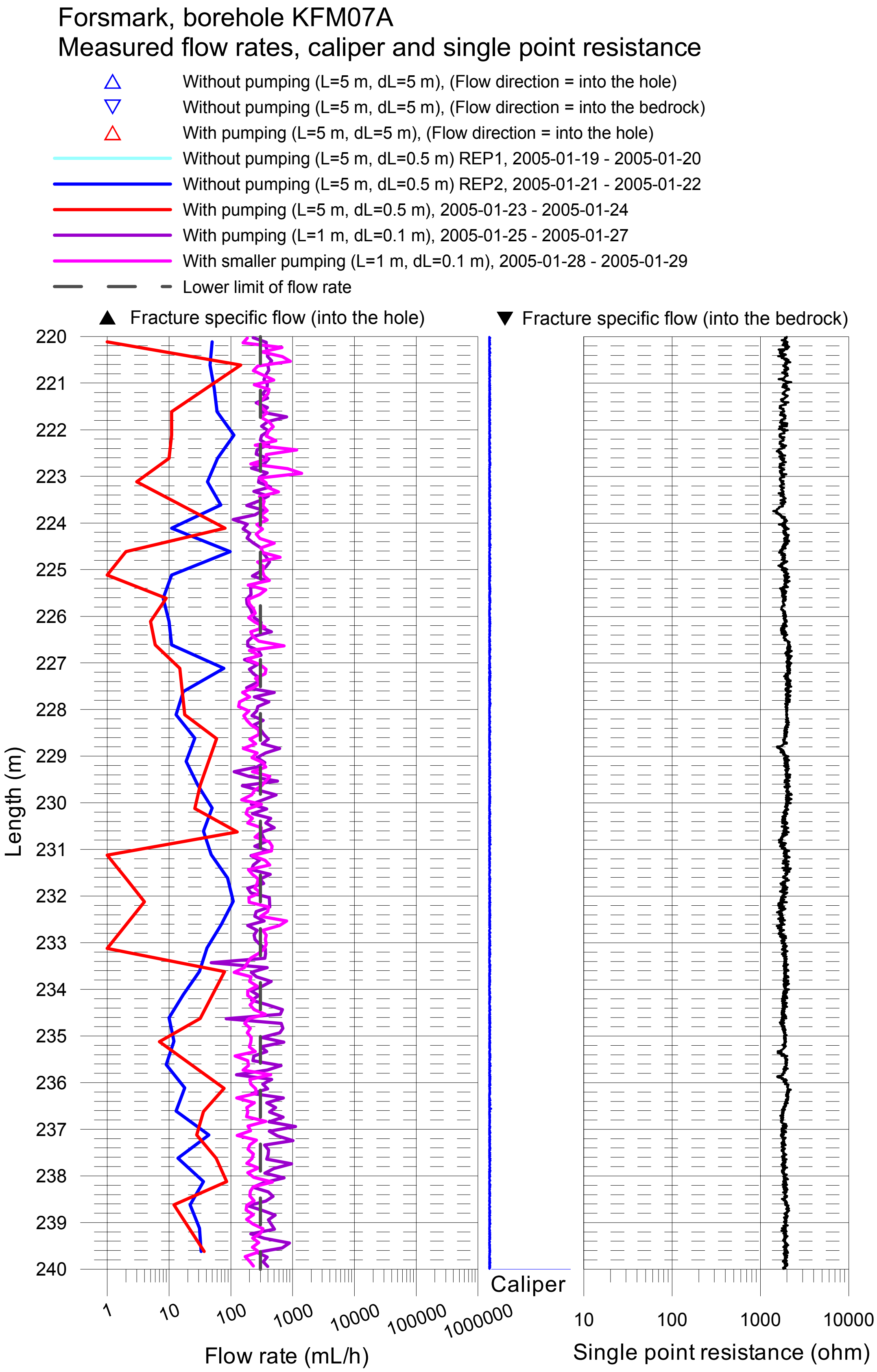


Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
With smaller pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m) REP1, 2005-01-19 - 2005-01-20
Without pumping (L=5 m, dL=0.5 m) REP2, 2005-01-21 - 2005-01-22
With pumping (L=5 m, dL=0.5 m), 2005-01-23 - 2005-01-24
With pumping (L=1 m, dL=0.1 m), 2005-01-25 - 2005-01-27
With smaller pumping (L=1 m, dL=0.1 m), 2005-01-28 - 2005-01-29
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
178.5
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
10
100
1000
10000
Single point resistance (ohm)

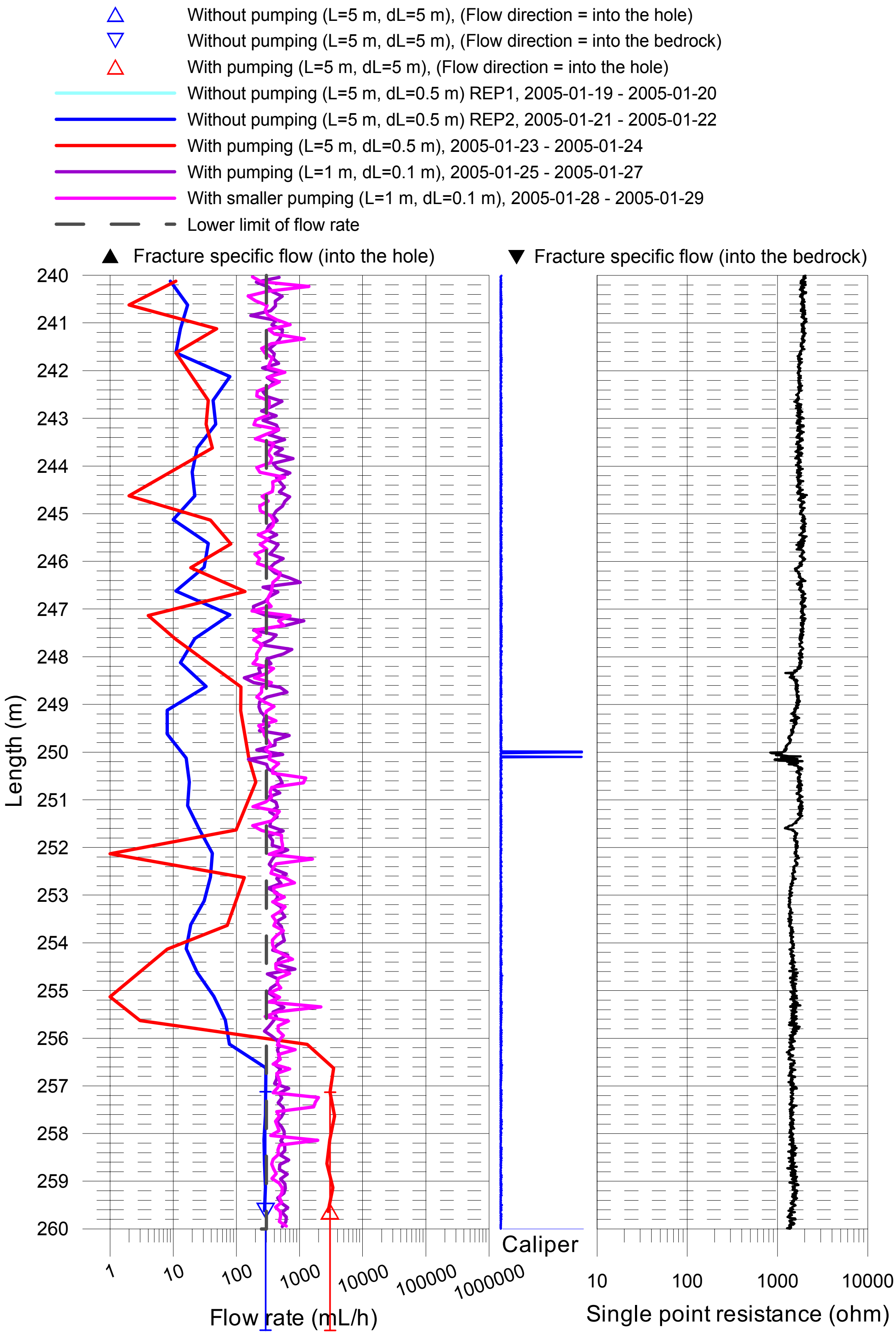

Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m) REP1, 2005-01-19 - 2005-01-20
Without pumping (L=5 m, dL=0.5 m) REP2, 2005-01-21 - 2005-01-22
With pumping (L=5 m, dL=0.5 m), 2005-01-23 - 2005-01-24
With pumping (L=1 m, dL=0.1 m), 2005-01-25 - 2005-01-27
With smaller pumping (L=1 m, dL=0.1 m), 2005-01-28 - 2005-01-29
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)

Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance

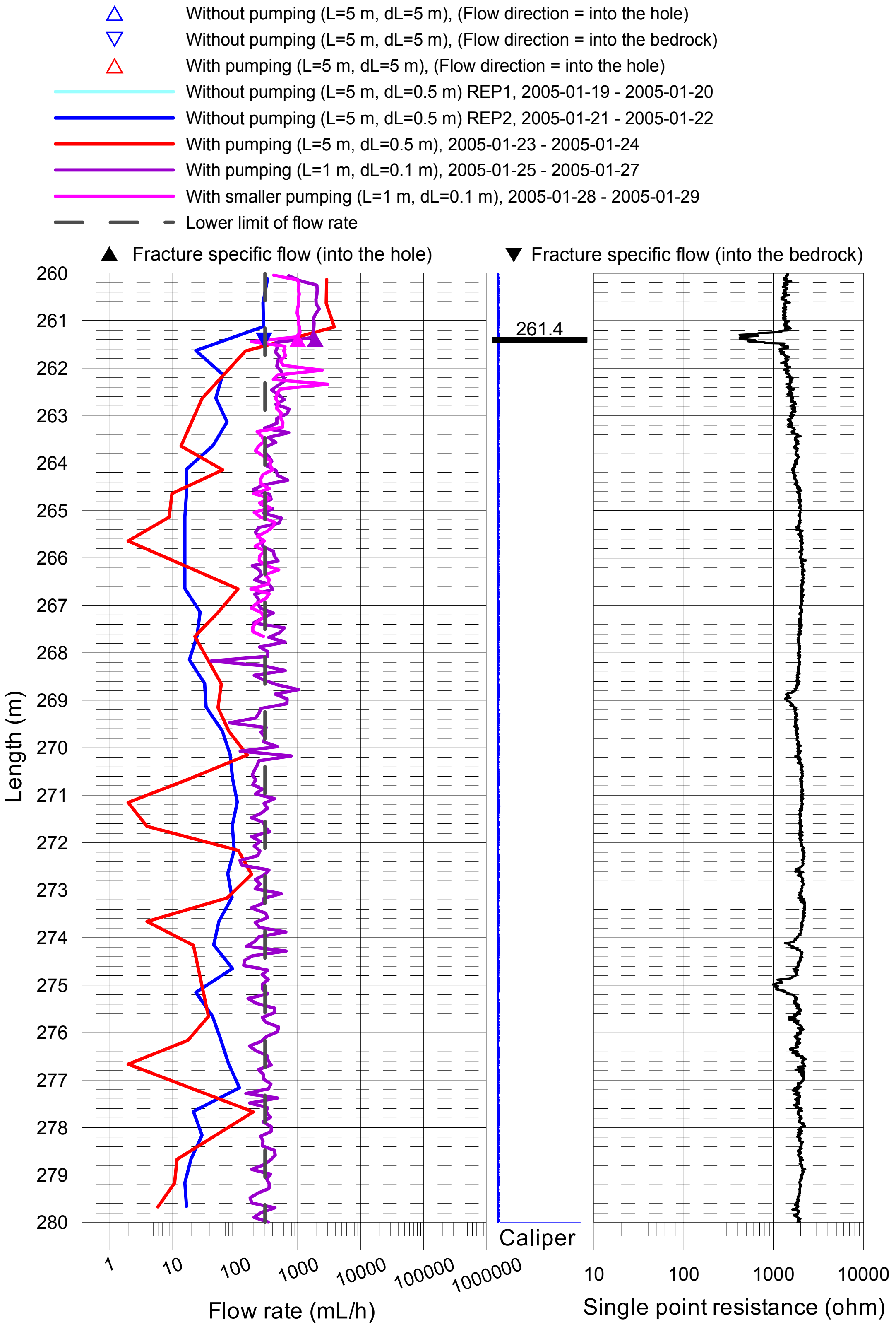



Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m) REP1, 2005-01-19 - 2005-01-20
Without pumping (L=5 m, dL=0.5 m) REP2, 2005-01-21 - 2005-01-22
With pumping (L=5 m, dL=0.5 m), 2005-01-23 - 2005-01-24
With pumping (L=1 m, dL=0.1 m), 2005-01-25 - 2005-01-27
With smaller pumping (L=1 m, dL=0.1 m), 2005-01-28 - 2005-01-29
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)

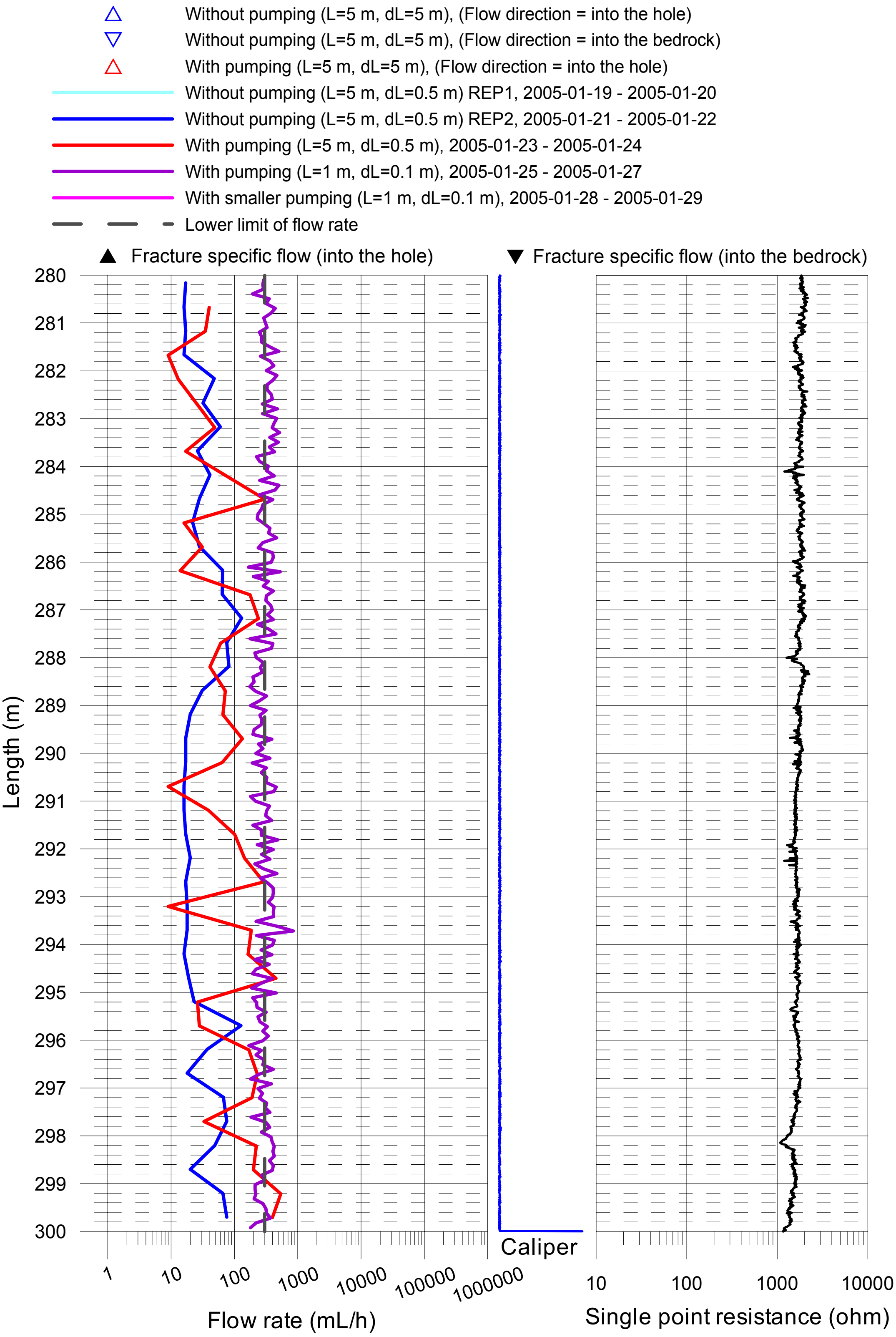
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance

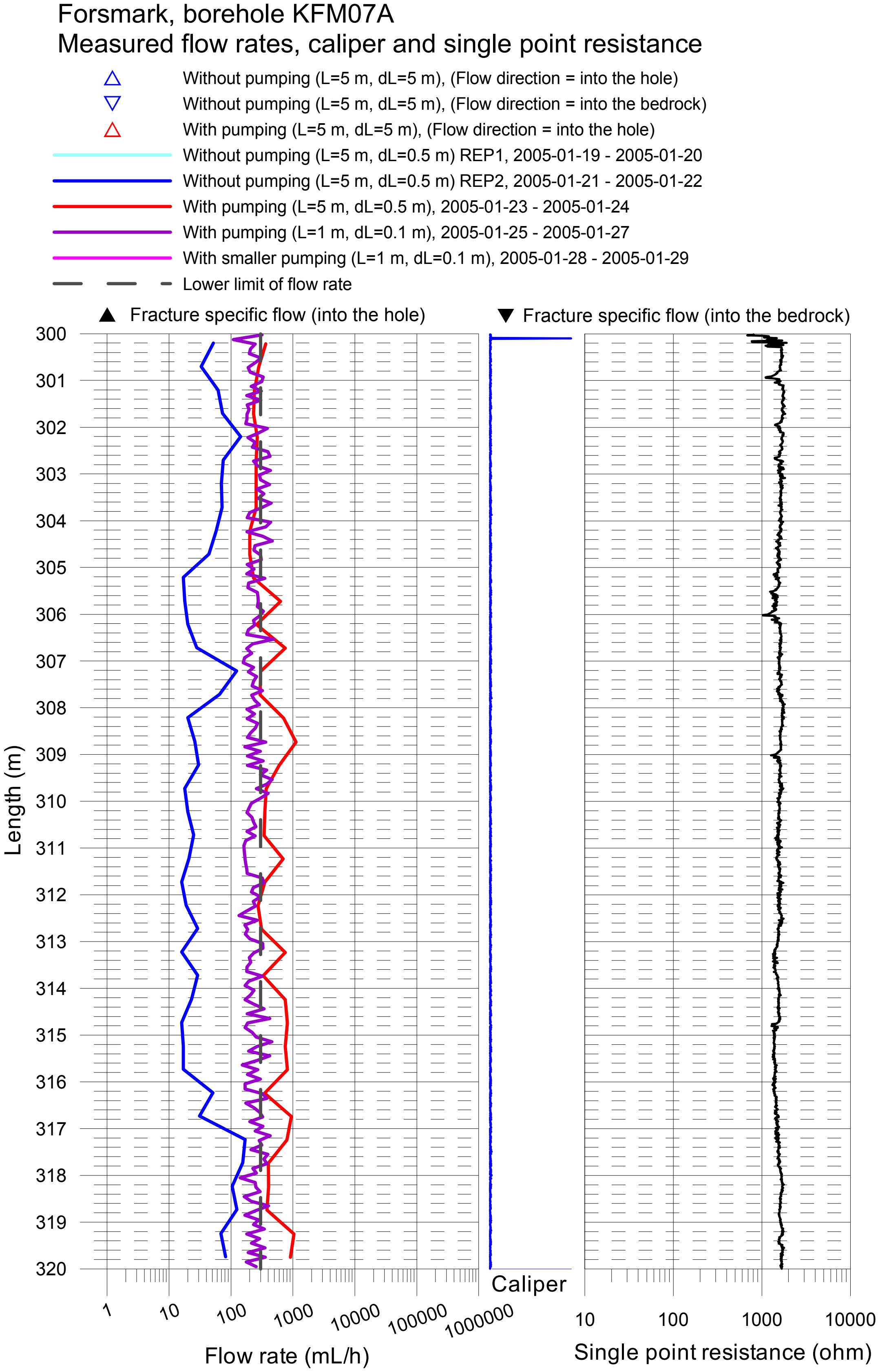


Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance

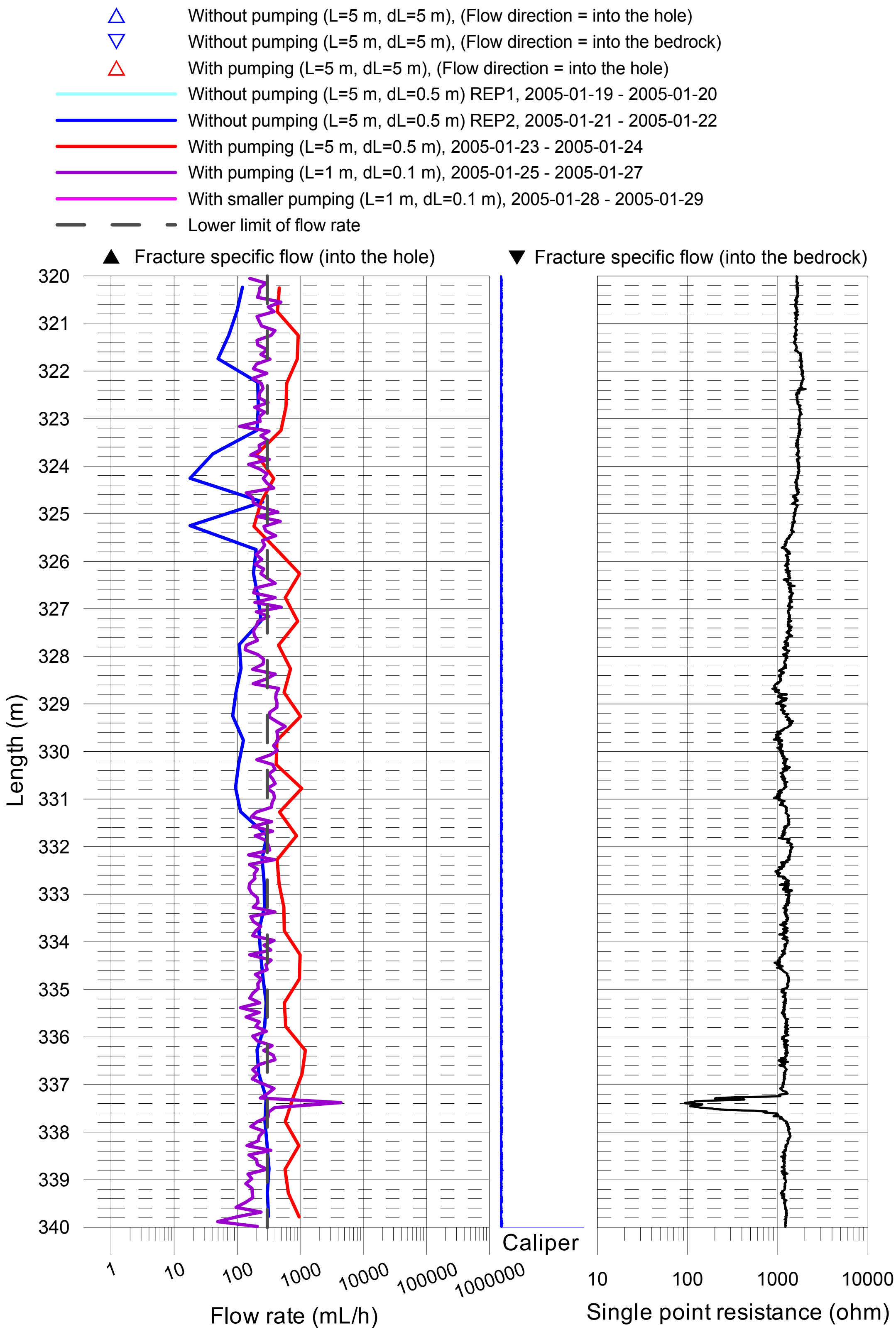


Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance

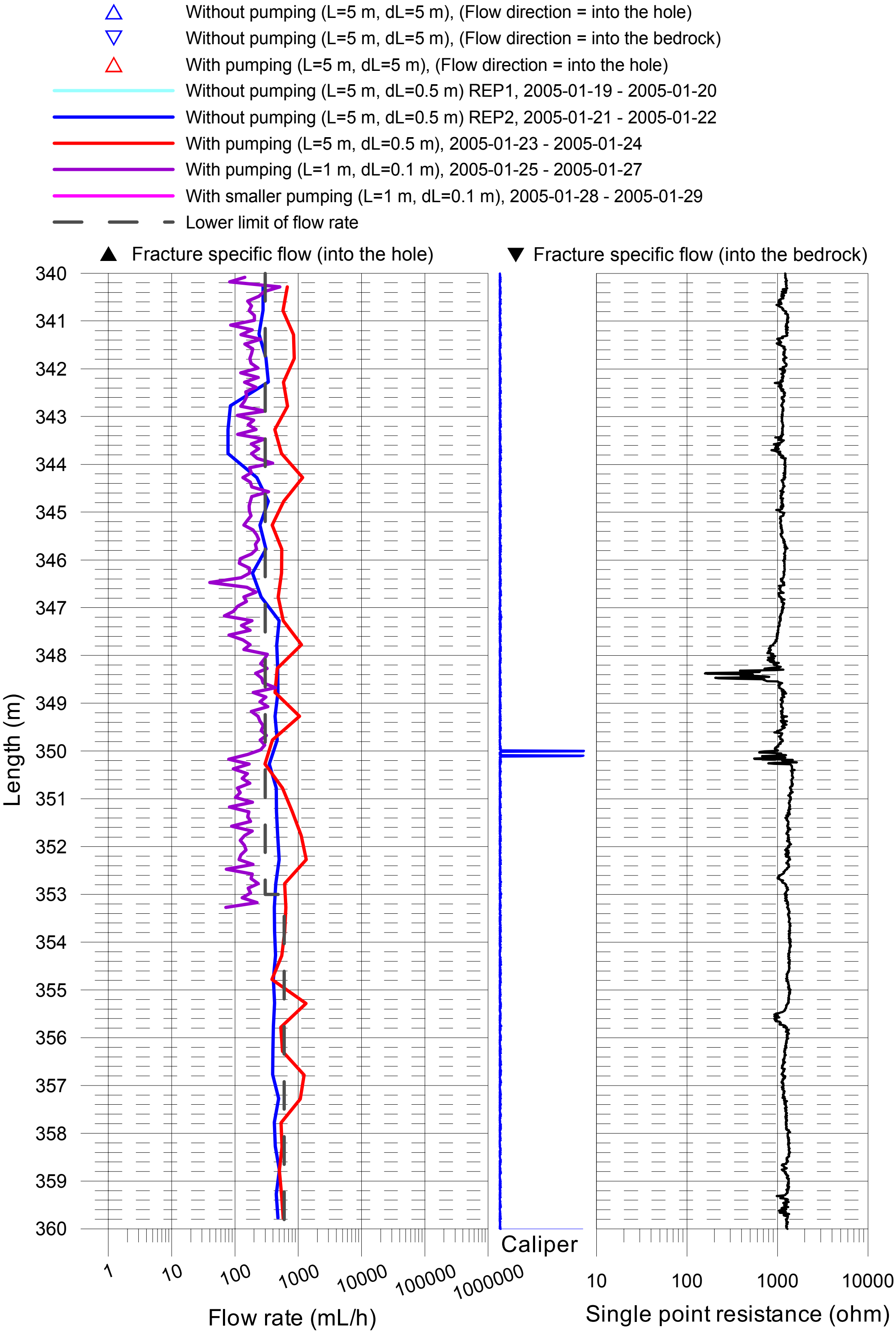



Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m) REP1, 2005-01-19 - 2005-01-20
Without pumping (L=5 m, dL=0.5 m) REP2, 2005-01-21 - 2005-01-22
With pumping (L=5 m, dL=0.5 m), 2005-01-23 - 2005-01-24
With pumping (L=1 m, dL=0.1 m), 2005-01-25 - 2005-01-27
With smaller pumping (L=1 m, dL=0.1 m), 2005-01-28 - 2005-01-29
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
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

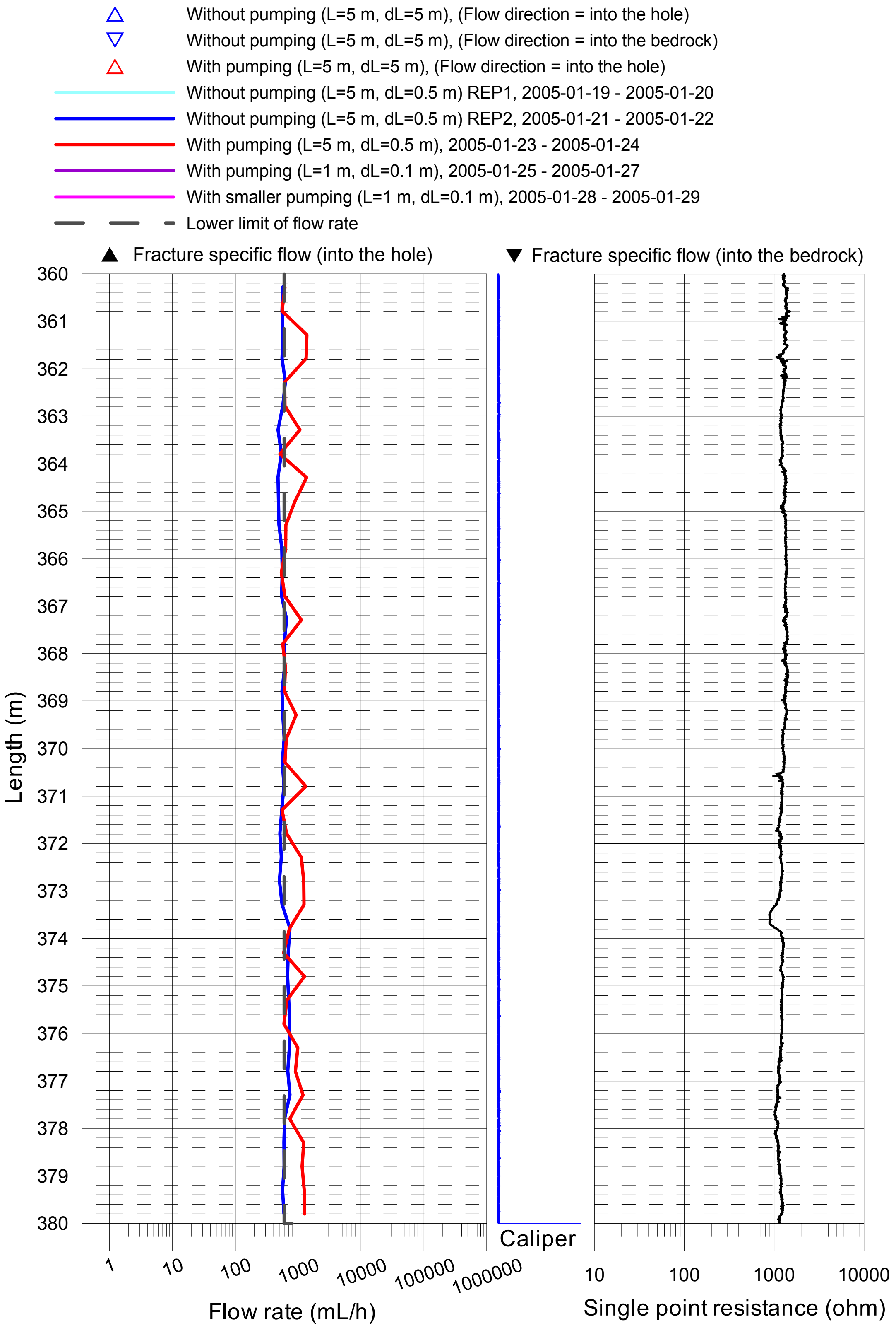
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance

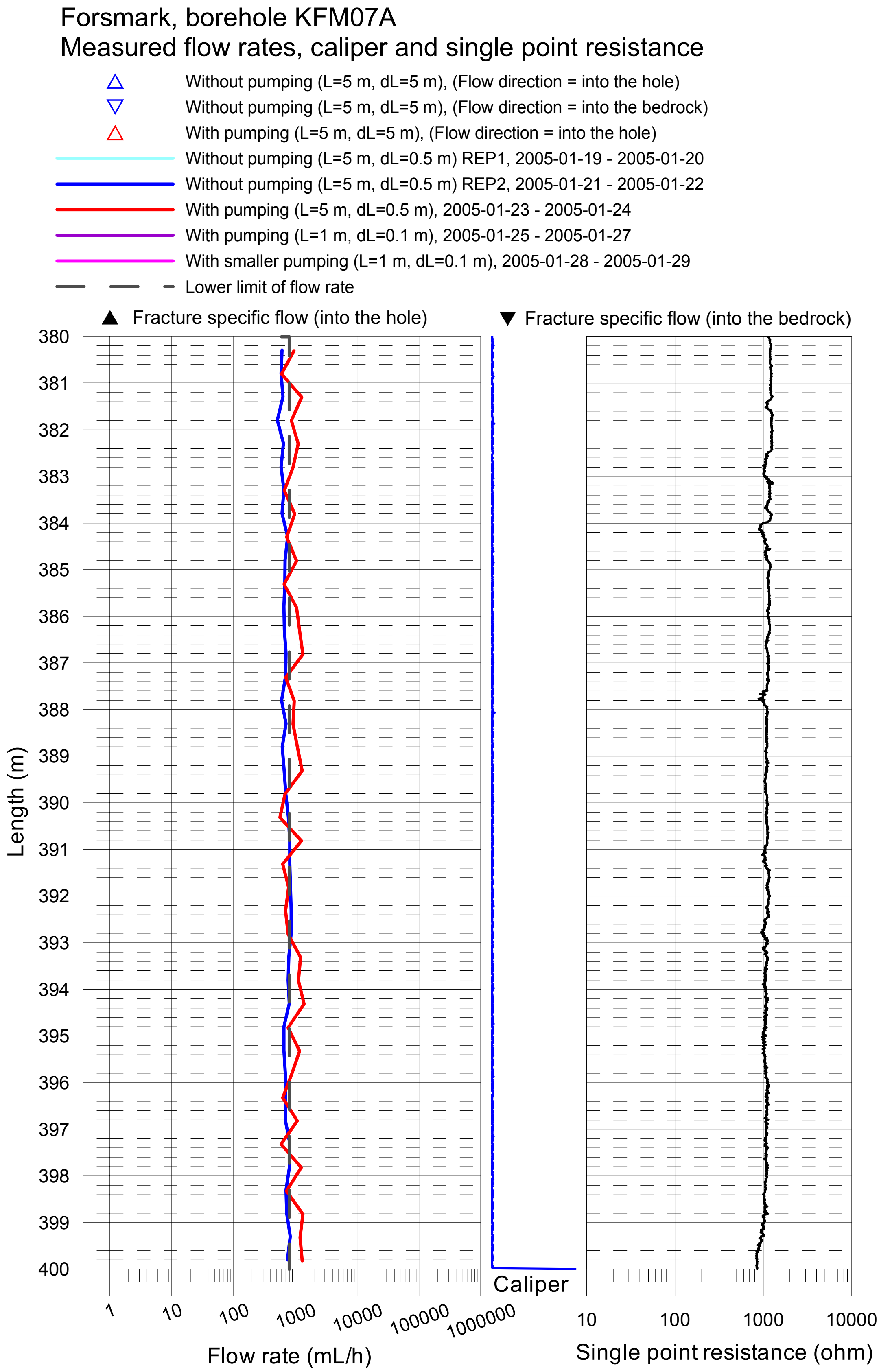


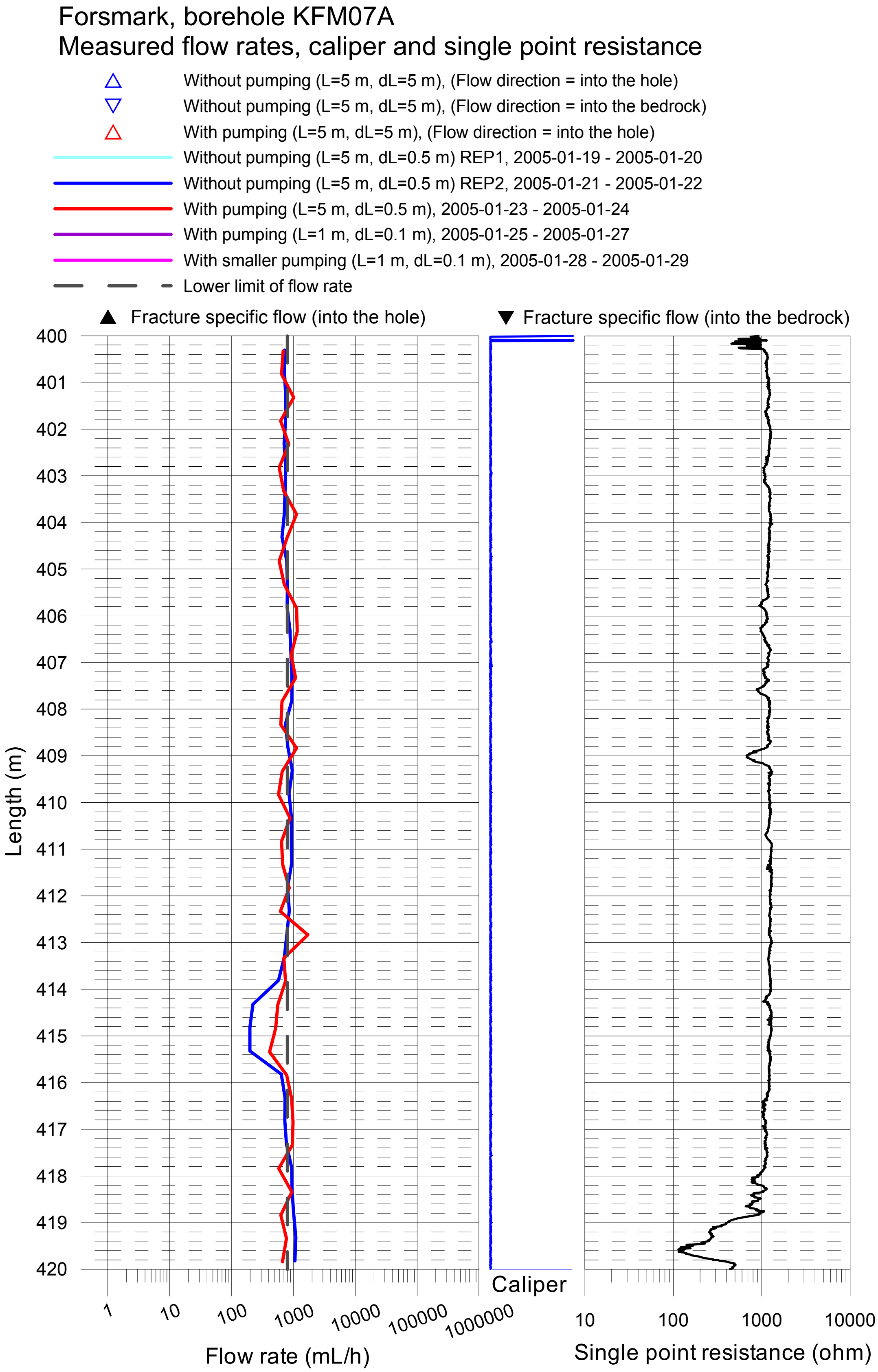
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



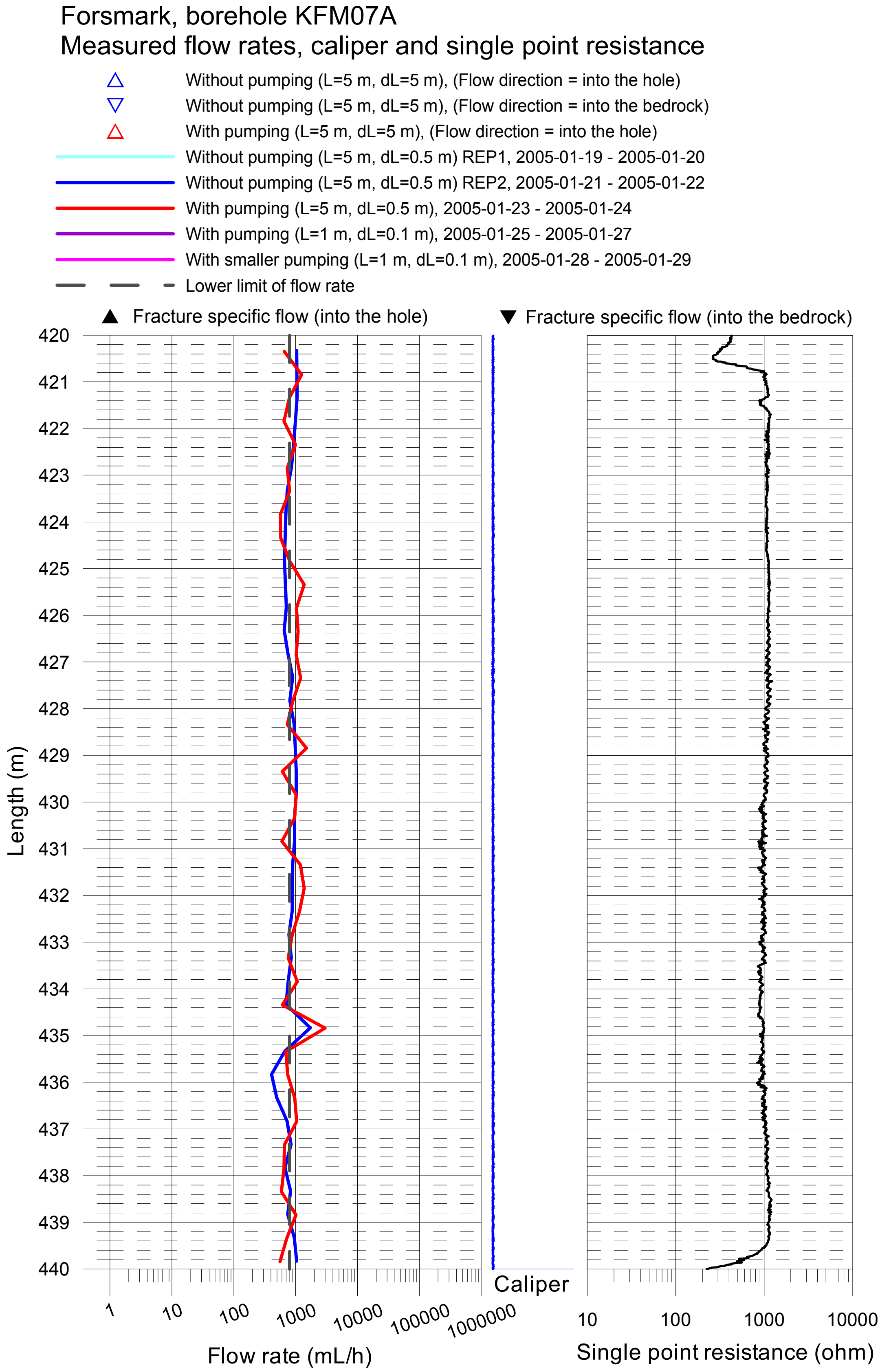
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



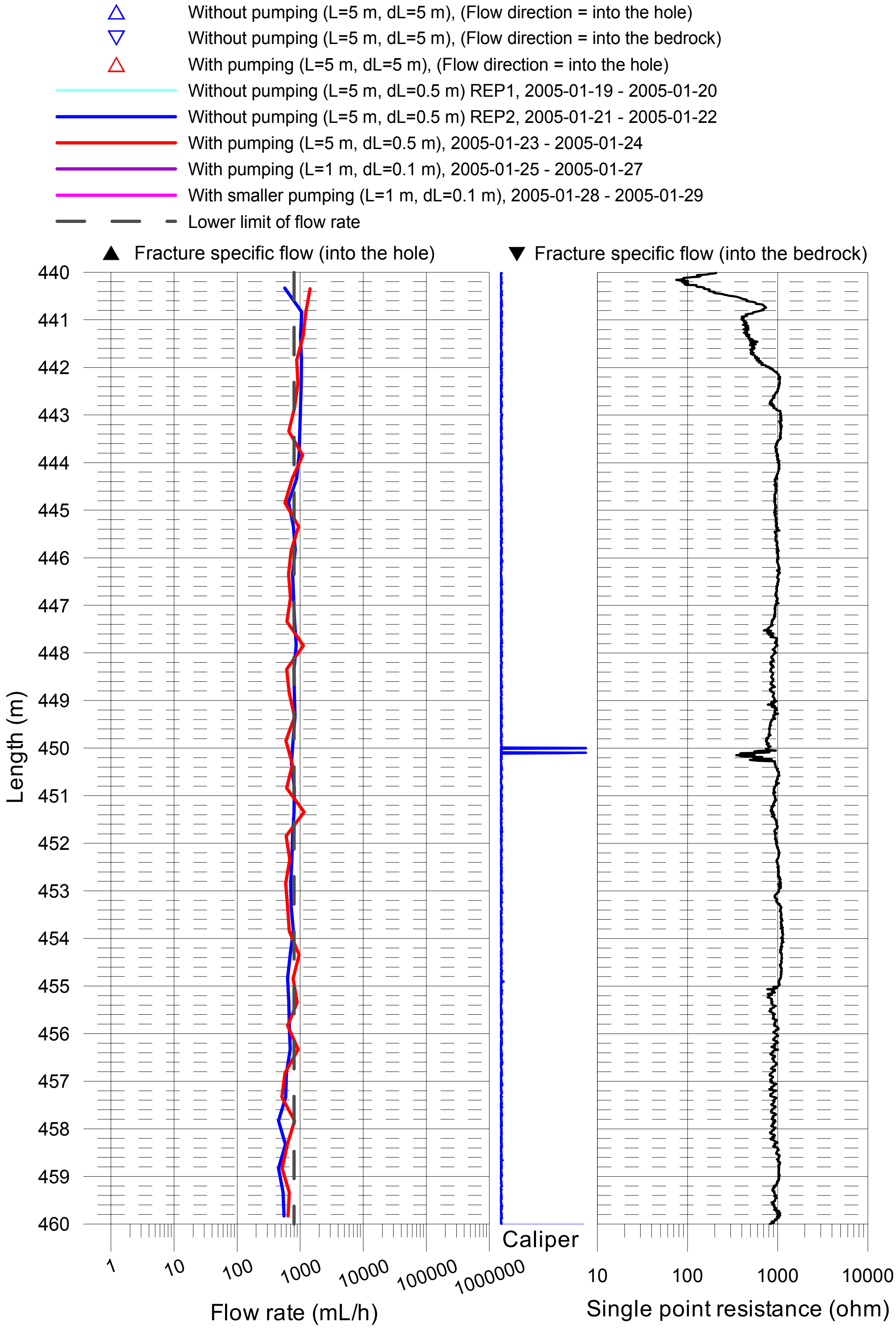

Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m) REP1, 2005-01-19 - 2005-01-20
Without pumping (L=5 m, dL=0.5 m) REP2, 2005-01-21 - 2005-01-22
With pumping (L=5 m, dL=0.5 m), 2005-01-23 - 2005-01-24
With pumping (L=1 m, dL=0.1 m), 2005-01-25 - 2005-01-27
With smaller pumping (L=1 m, dL=0.1 m), 2005-01-28 - 2005-01-29
Lower limit of flow rate
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
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)



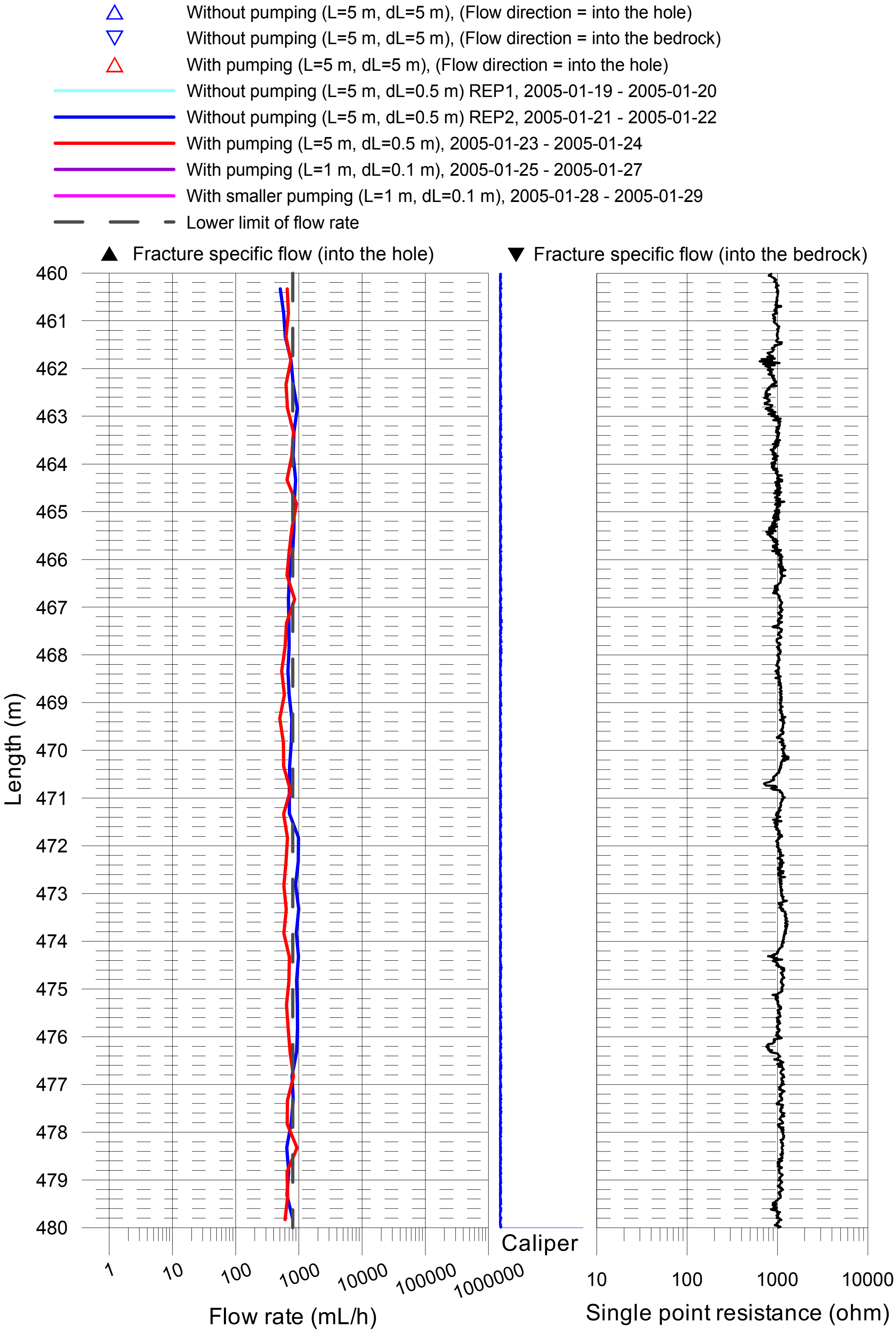
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m) REP1, 2005-01-19 - 2005-01-20
Without pumping (L=5 m, dL=0.5 m) REP2, 2005-01-21 - 2005-01-22
With pumping (L=5 m, dL=0.5 m), 2005-01-23 - 2005-01-24
With pumping (L=1 m, dL=0.1 m), 2005-01-25 - 2005-01-27
With smaller pumping (L=1 m, dL=0.1 m), 2005-01-28 - 2005-01-29
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

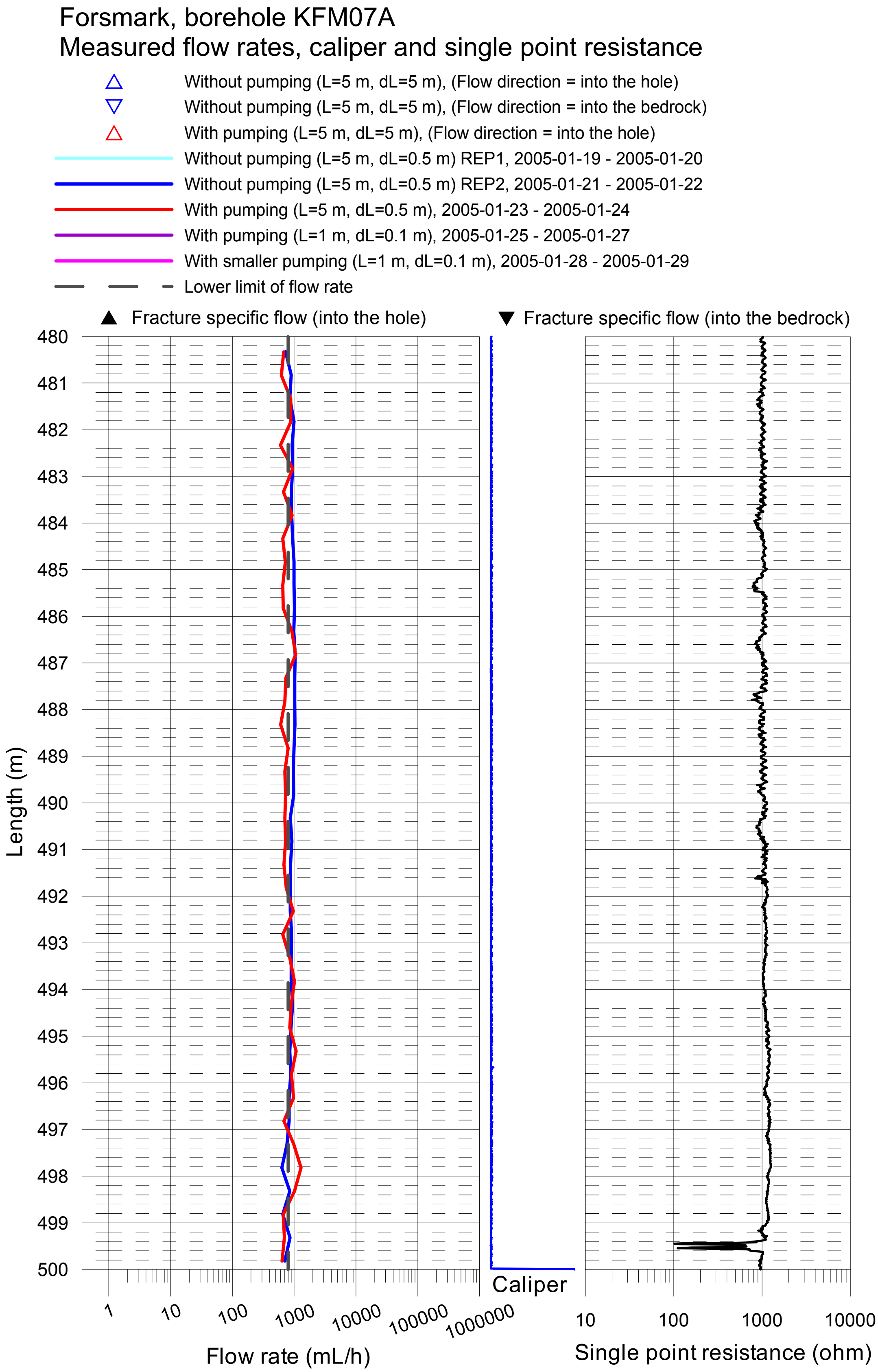

Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m) REP1, 2005-01-19 - 2005-01-20
Without pumping (L=5 m, dL=0.5 m) REP2, 2005-01-21 - 2005-01-22
With pumping (L=5 m, dL=0.5 m), 2005-01-23 - 2005-01-24
With pumping (L=1 m, dL=0.1 m), 2005-01-25 - 2005-01-27
With smaller pumping (L=1 m, dL=0.1 m), 2005-01-28 - 2005-01-29
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
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance

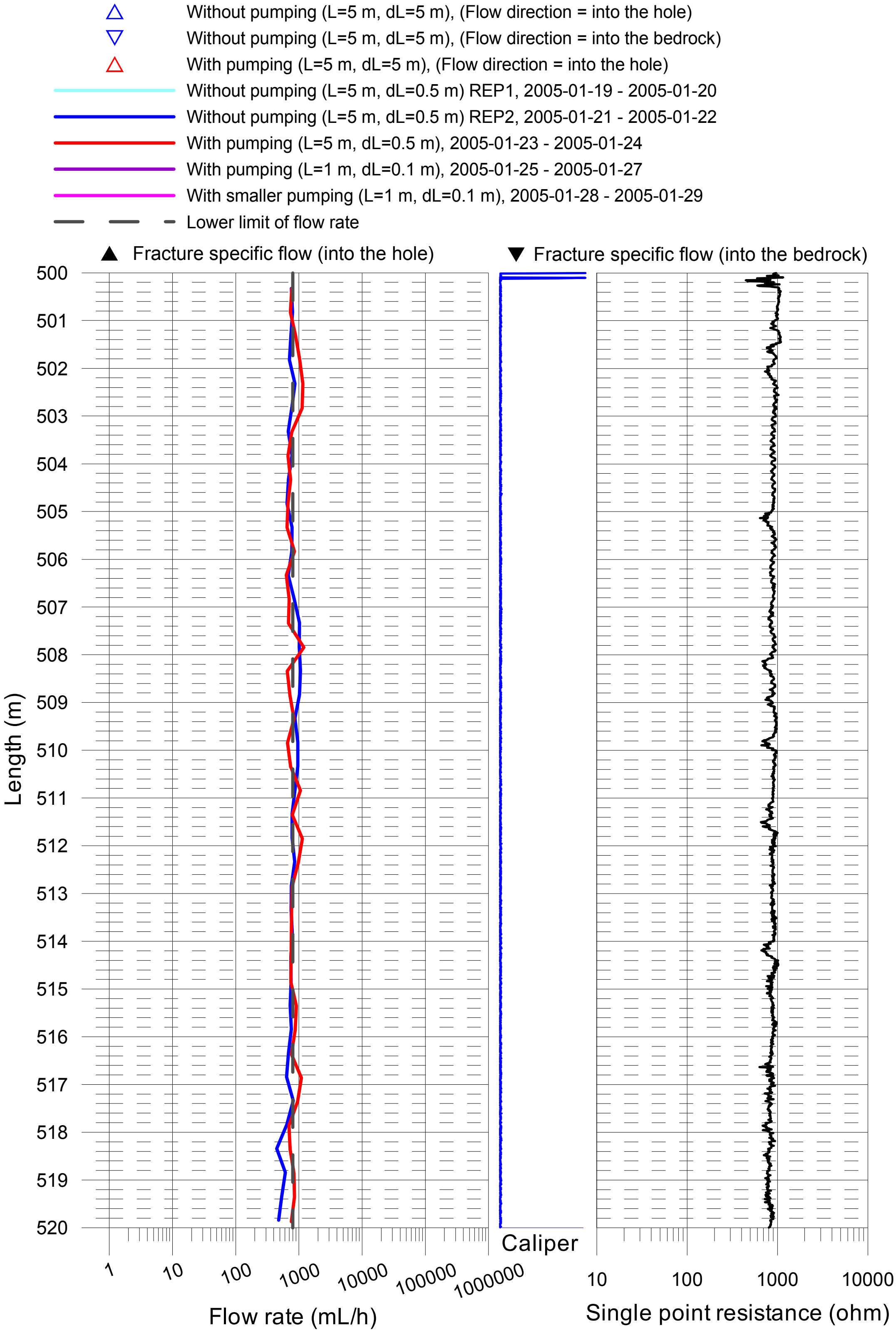


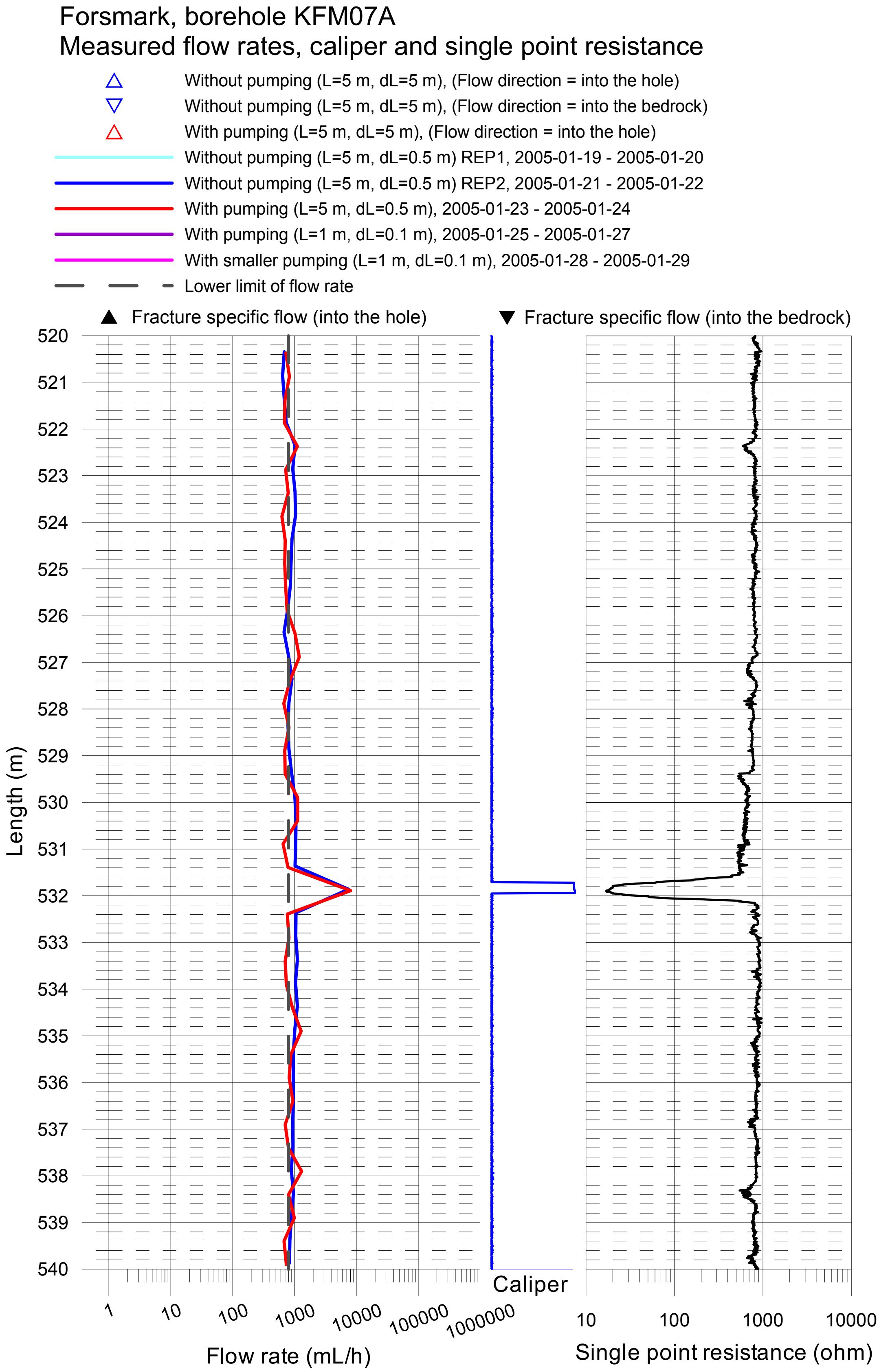
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance

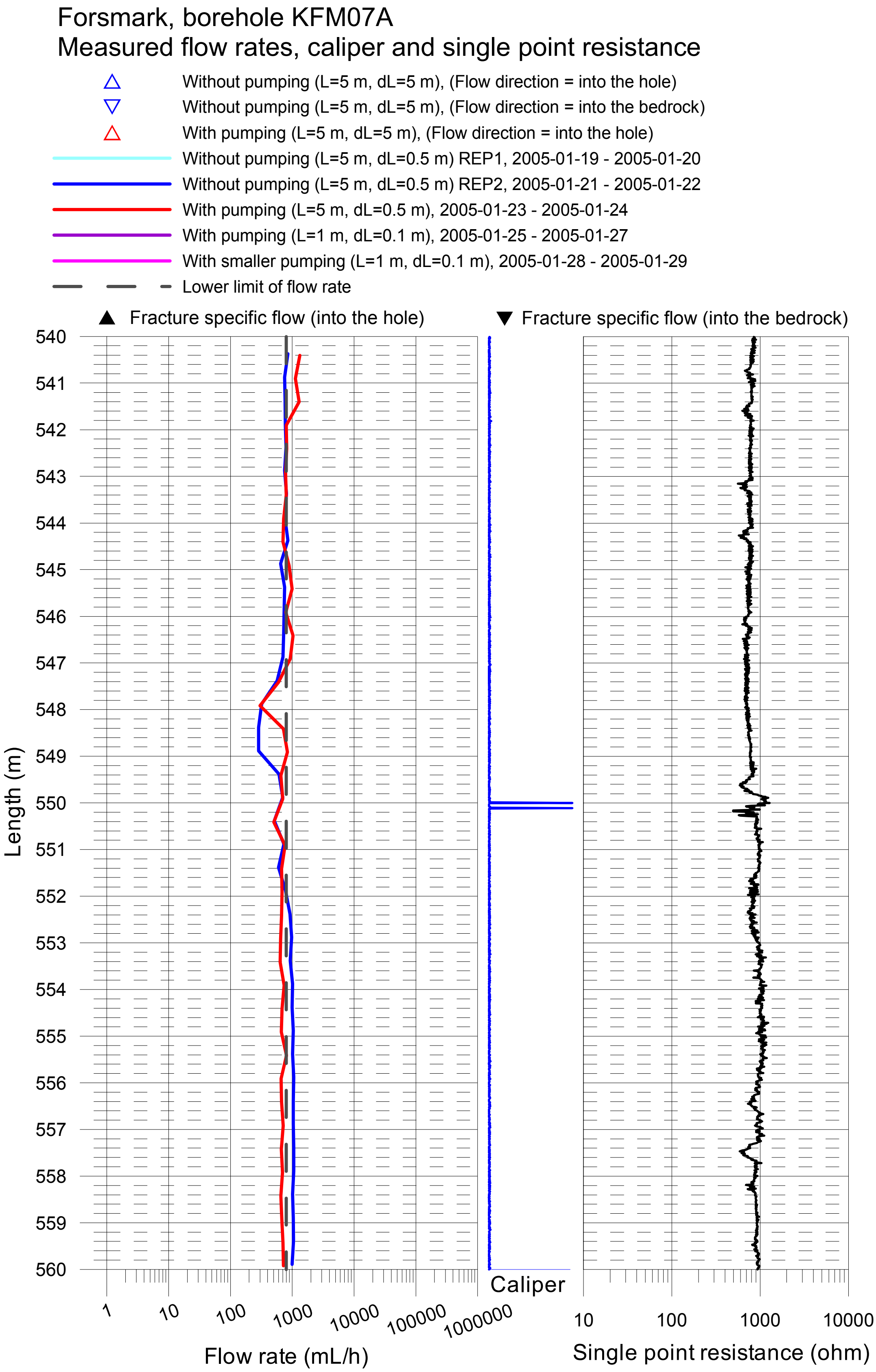


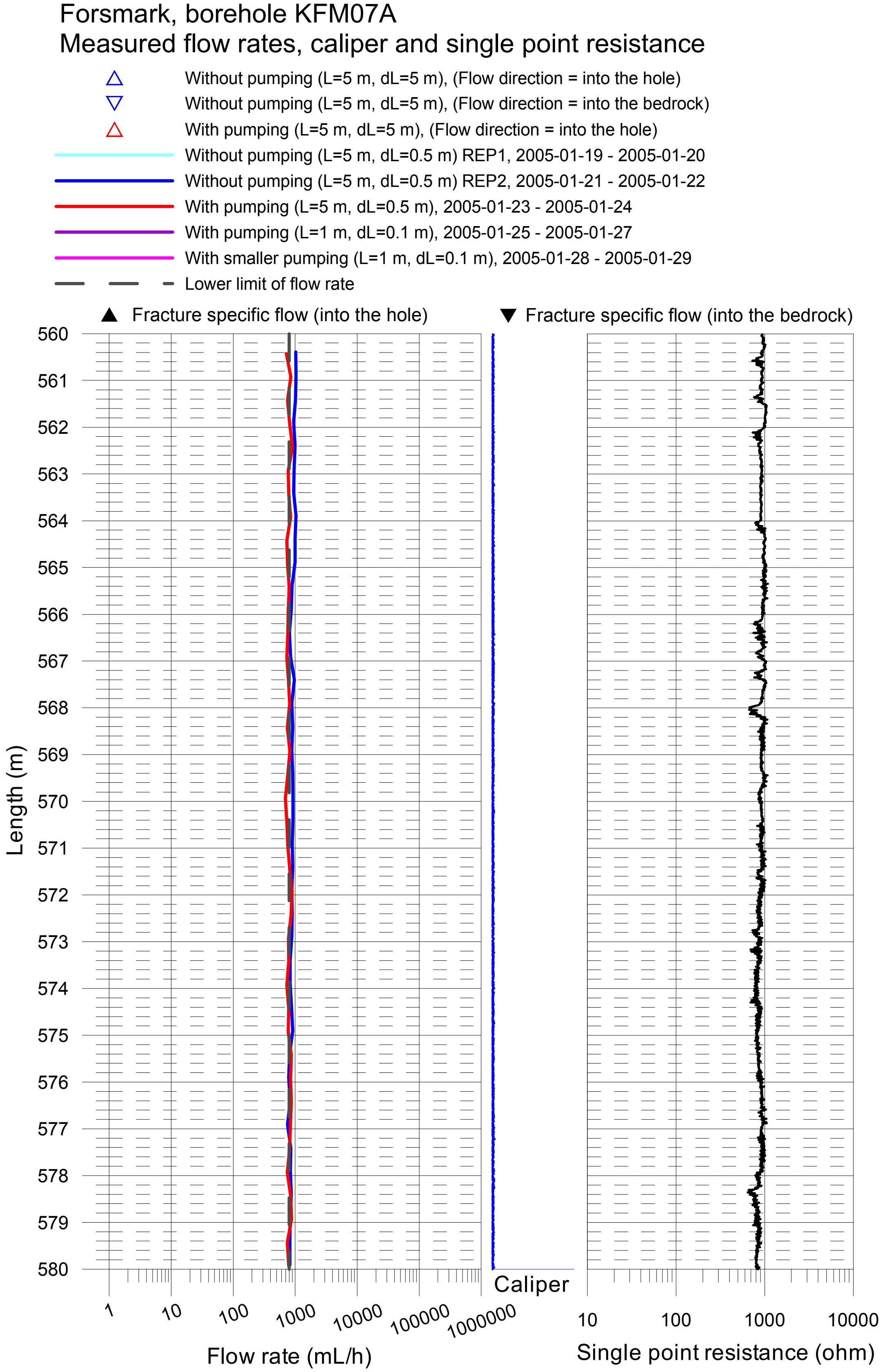

Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m) REP1, 2005-01-19 - 2005-01-20
Without pumping (L=5 m, dL=0.5 m) REP2, 2005-01-21 - 2005-01-22
With pumping (L=5 m, dL=0.5 m), 2005-01-23 - 2005-01-24
With pumping (L=1 m, dL=0.1 m), 2005-01-25 - 2005-01-27
With smaller pumping (L=1 m, dL=0.1 m), 2005-01-28 - 2005-01-29
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 KFM07A
Measured flow rates, caliper and single point resistance



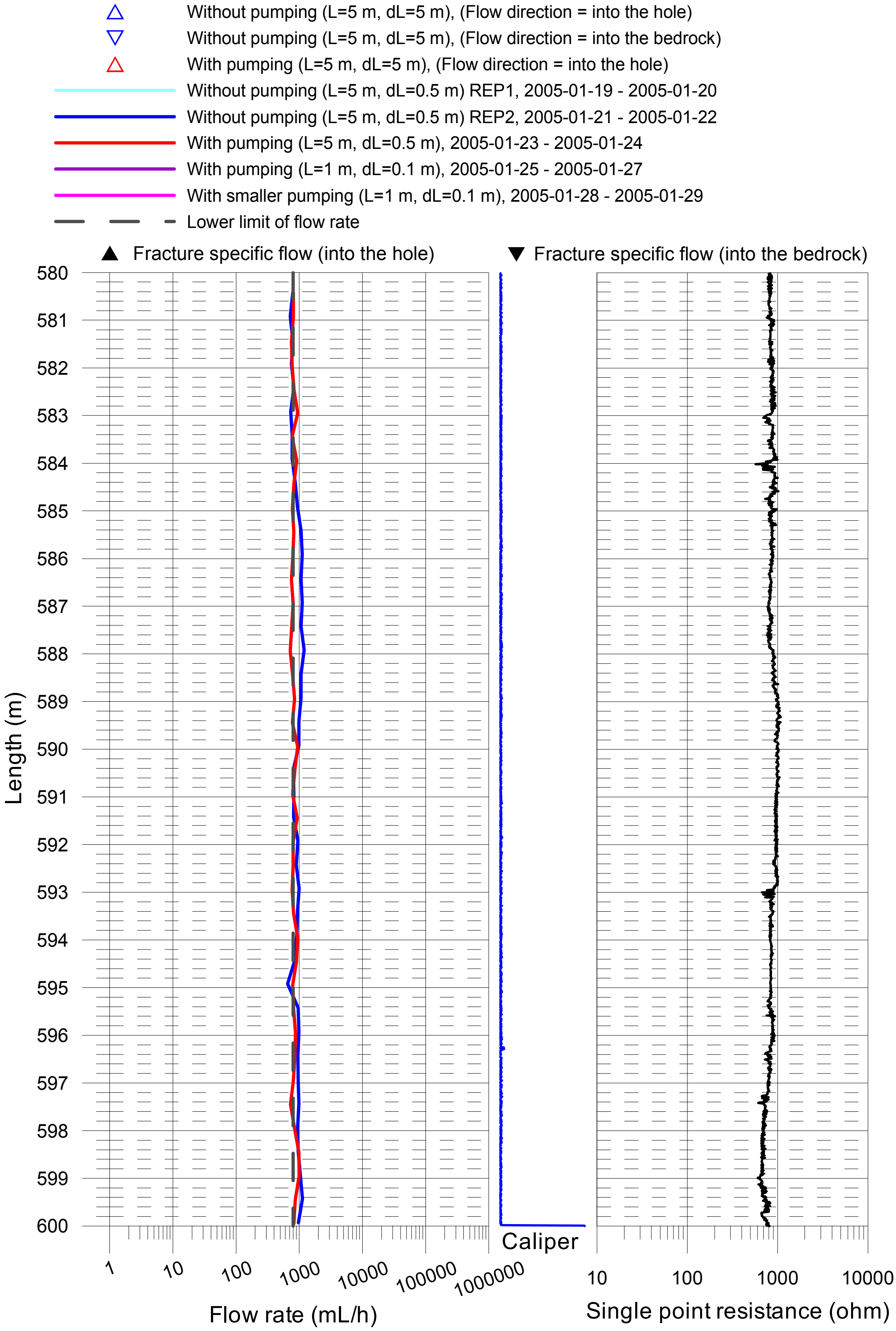

Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m) REP1, 2005-01-19 - 2005-01-20
Without pumping (L=5 m, dL=0.5 m) REP2, 2005-01-21 - 2005-01-22
With pumping (L=5 m, dL=0.5 m), 2005-01-23 - 2005-01-24
With pumping (L=1 m, dL=0.1 m), 2005-01-25 - 2005-01-27
With smaller pumping (L=1 m, dL=0.1 m), 2005-01-28 - 2005-01-29
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

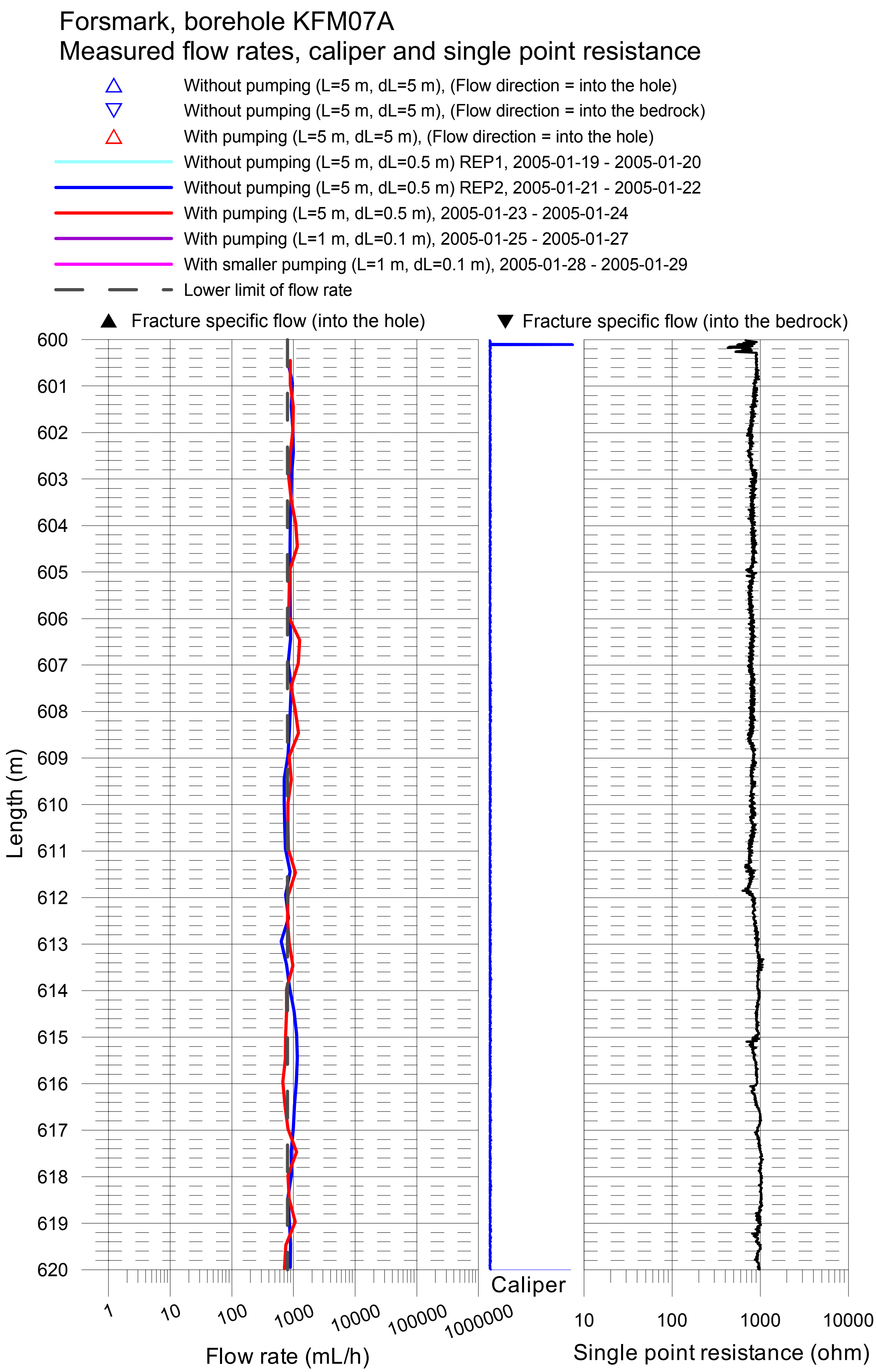

Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m) REP1, 2005-01-19 - 2005-01-20
Without pumping (L=5 m, dL=0.5 m) REP2, 2005-01-21 - 2005-01-22
With pumping (L=5 m, dL=0.5 m), 2005-01-23 - 2005-01-24
With pumping (L=1 m, dL=0.1 m), 2005-01-25 - 2005-01-27
With smaller pumping (L=1 m, dL=0.1 m), 2005-01-28 - 2005-01-29
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)



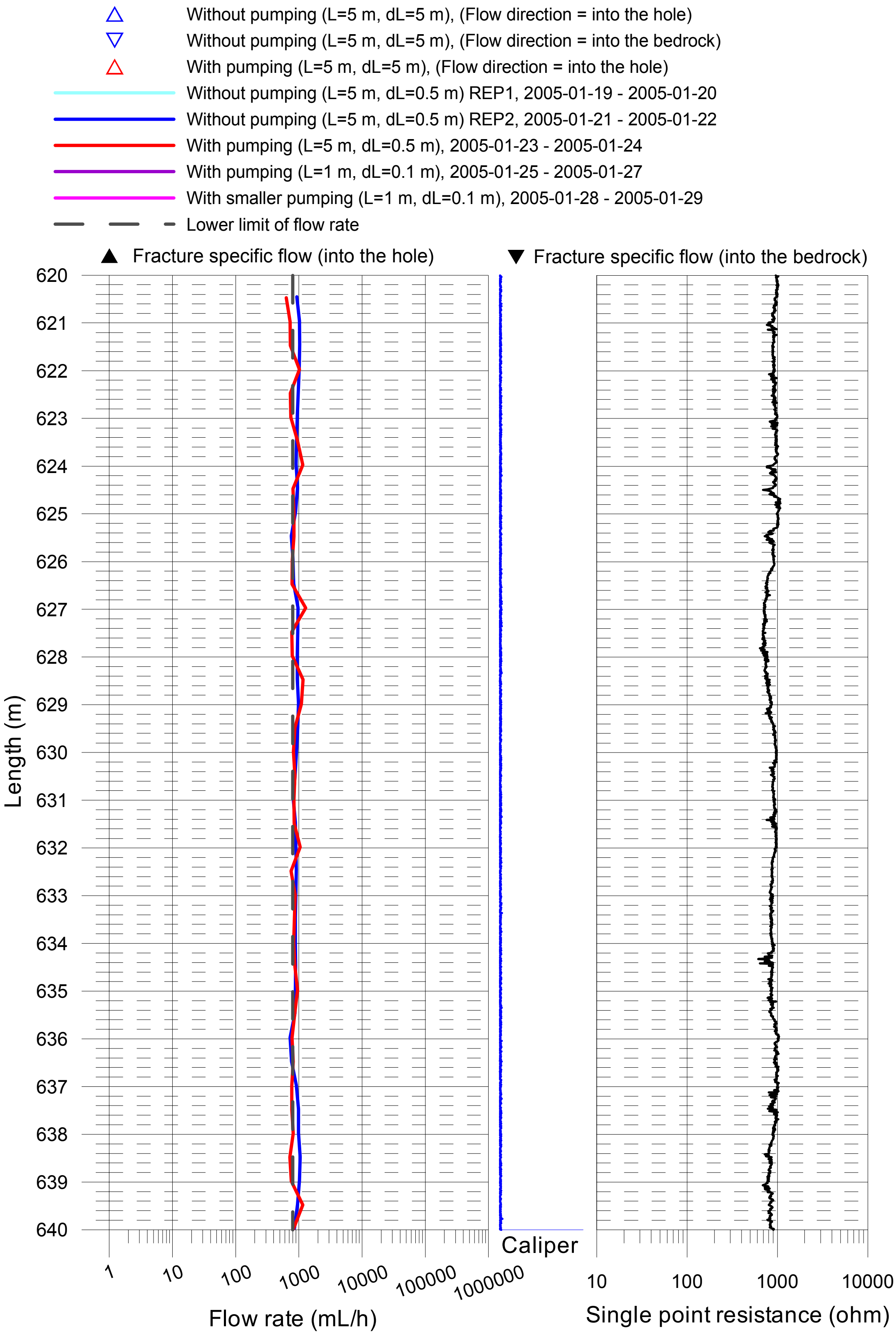
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m) REP1, 2005-01-19 - 2005-01-20
Without pumping (L=5 m, dL=0.5 m) REP2, 2005-01-21 - 2005-01-22
With pumping (L=5 m, dL=0.5 m), 2005-01-23 - 2005-01-24
With pumping (L=1 m, dL=0.1 m), 2005-01-25 - 2005-01-27
With smaller pumping (L=1 m, dL=0.1 m), 2005-01-28 - 2005-01-29
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)

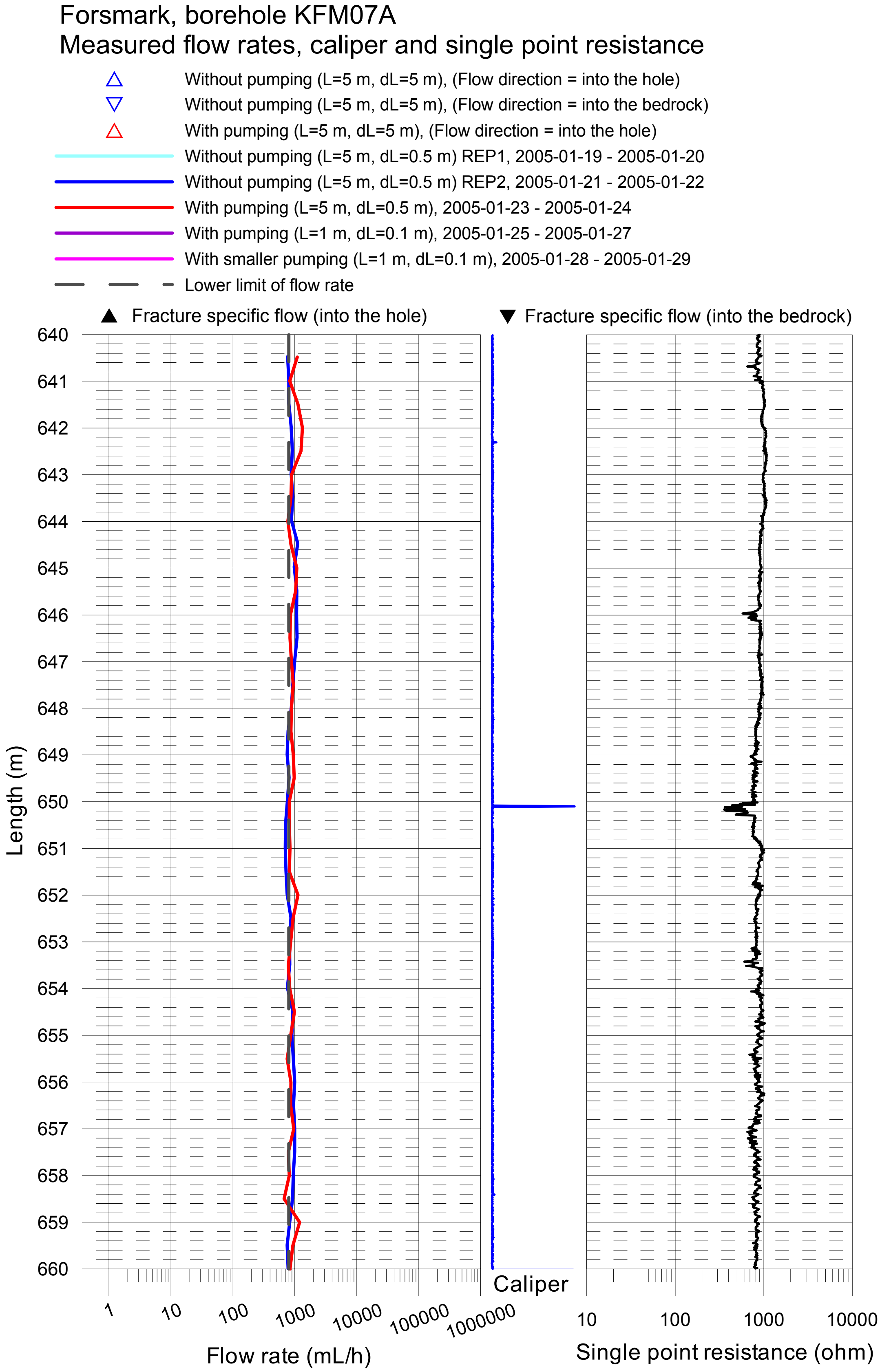
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance




Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance
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, dL=0.5 m) REP1, 2005-01-19 - 2005-01-20
Without pumping (L=5 m, dL=0.5 m) REP2, 2005-01-21 - 2005-01-22
With pumping (L=5 m, dL=0.5 m), 2005-01-23 - 2005-01-24
With pumping (L=1 m, dL=0.1 m), 2005-01-25 - 2005-01-27
With smaller pumping (L=1 m, dL=0.1 m), 2005-01-28 - 2005-01-29
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
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

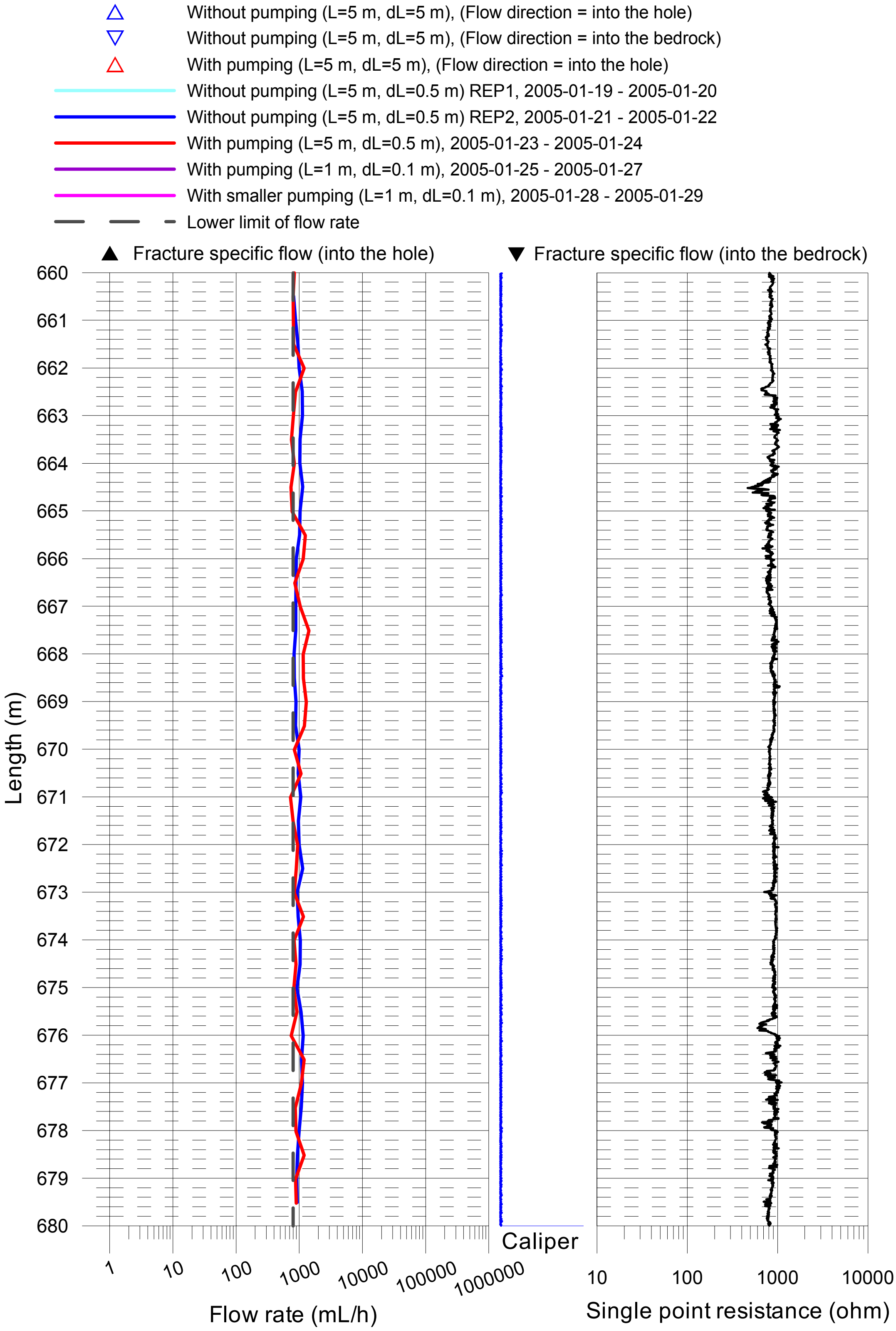
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



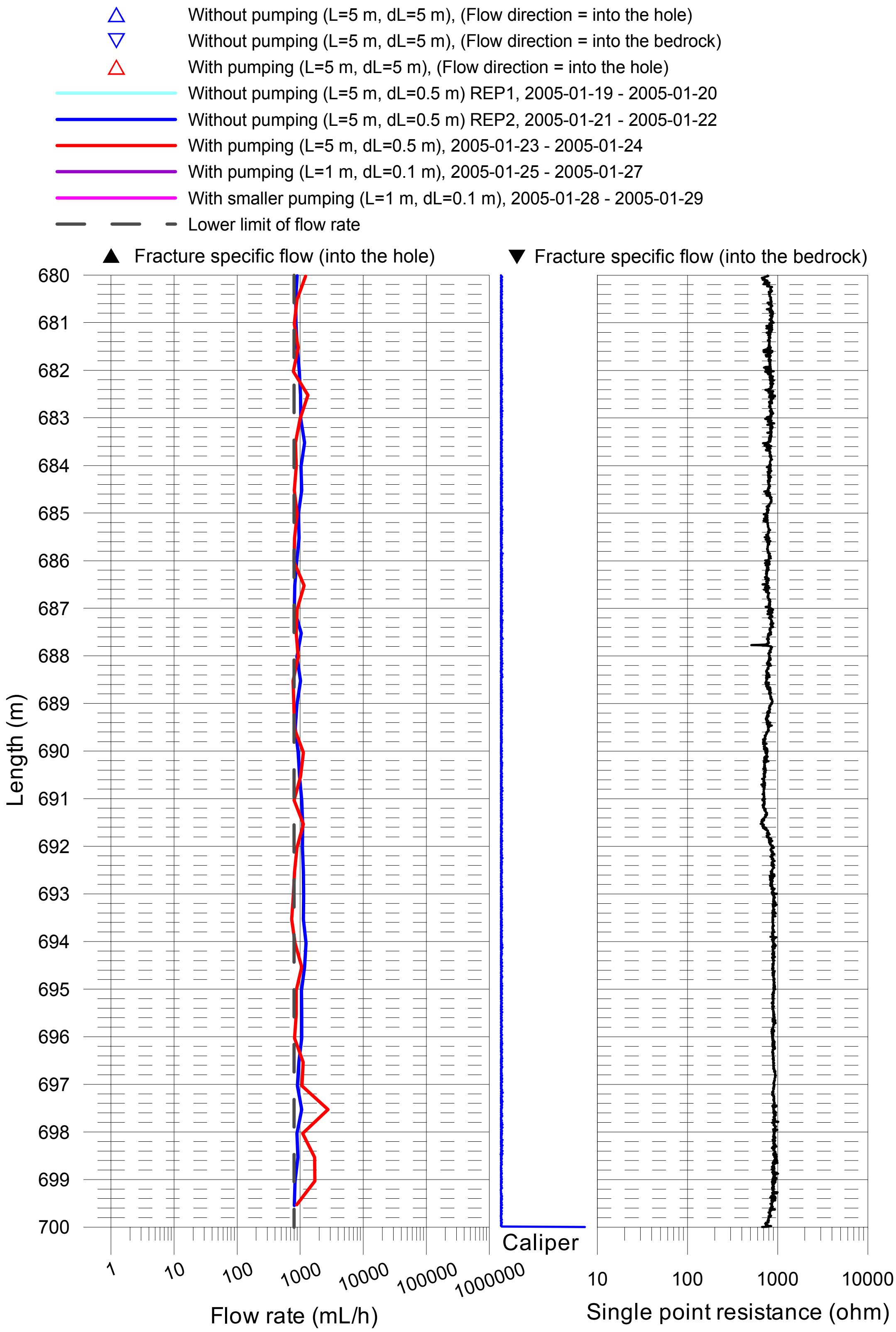


Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m) REP1, 2005-01-19 - 2005-01-20
Without pumping (L=5 m, dL=0.5 m) REP2, 2005-01-21 - 2005-01-22
With pumping (L=5 m, dL=0.5 m), 2005-01-23 - 2005-01-24
With pumping (L=1 m, dL=0.1 m), 2005-01-25 - 2005-01-27
With smaller pumping (L=1 m, dL=0.1 m), 2005-01-28 - 2005-01-29
Lower limit of flow rate
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
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
10
100
1000
10000
Single point resistance (ohm)

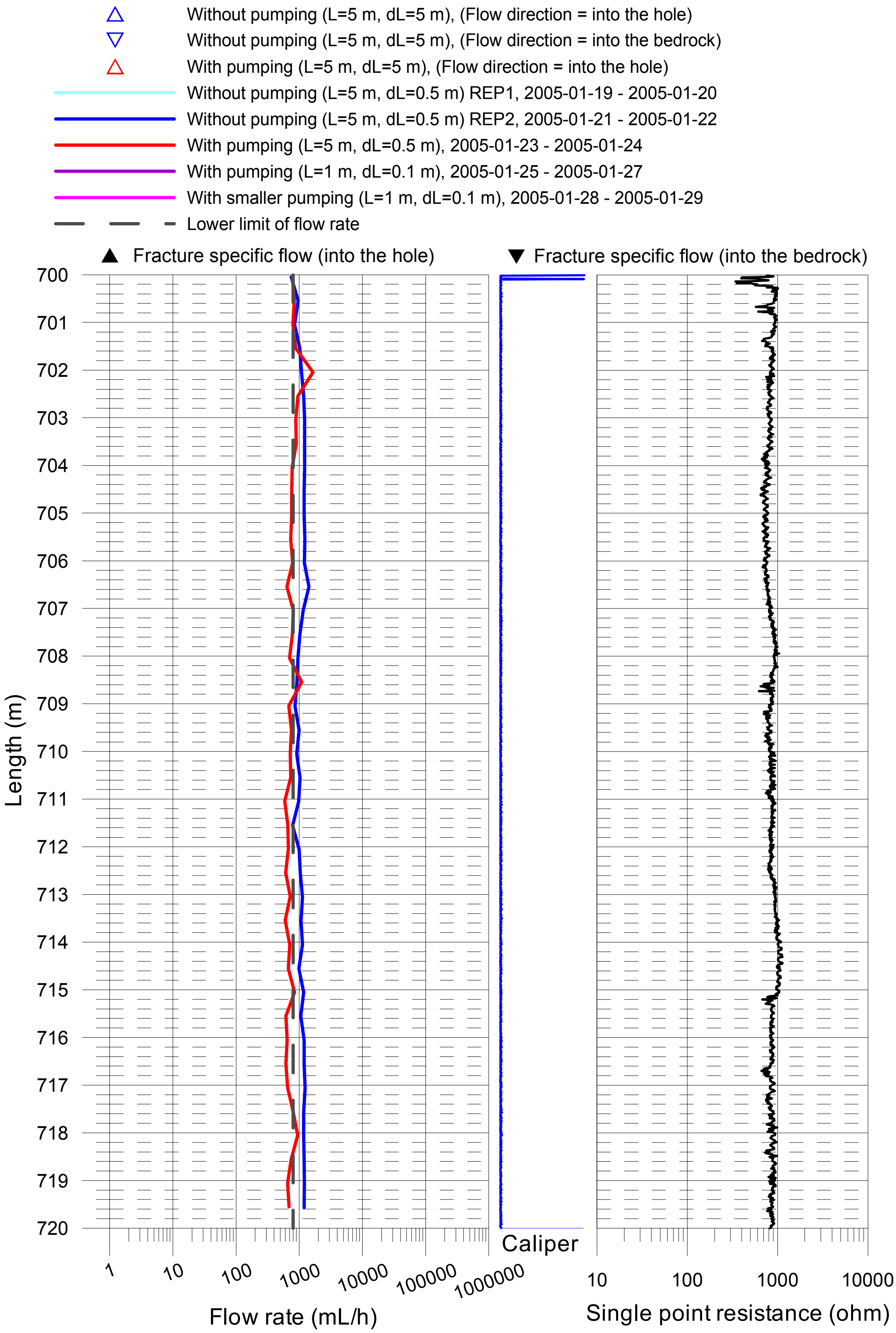
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



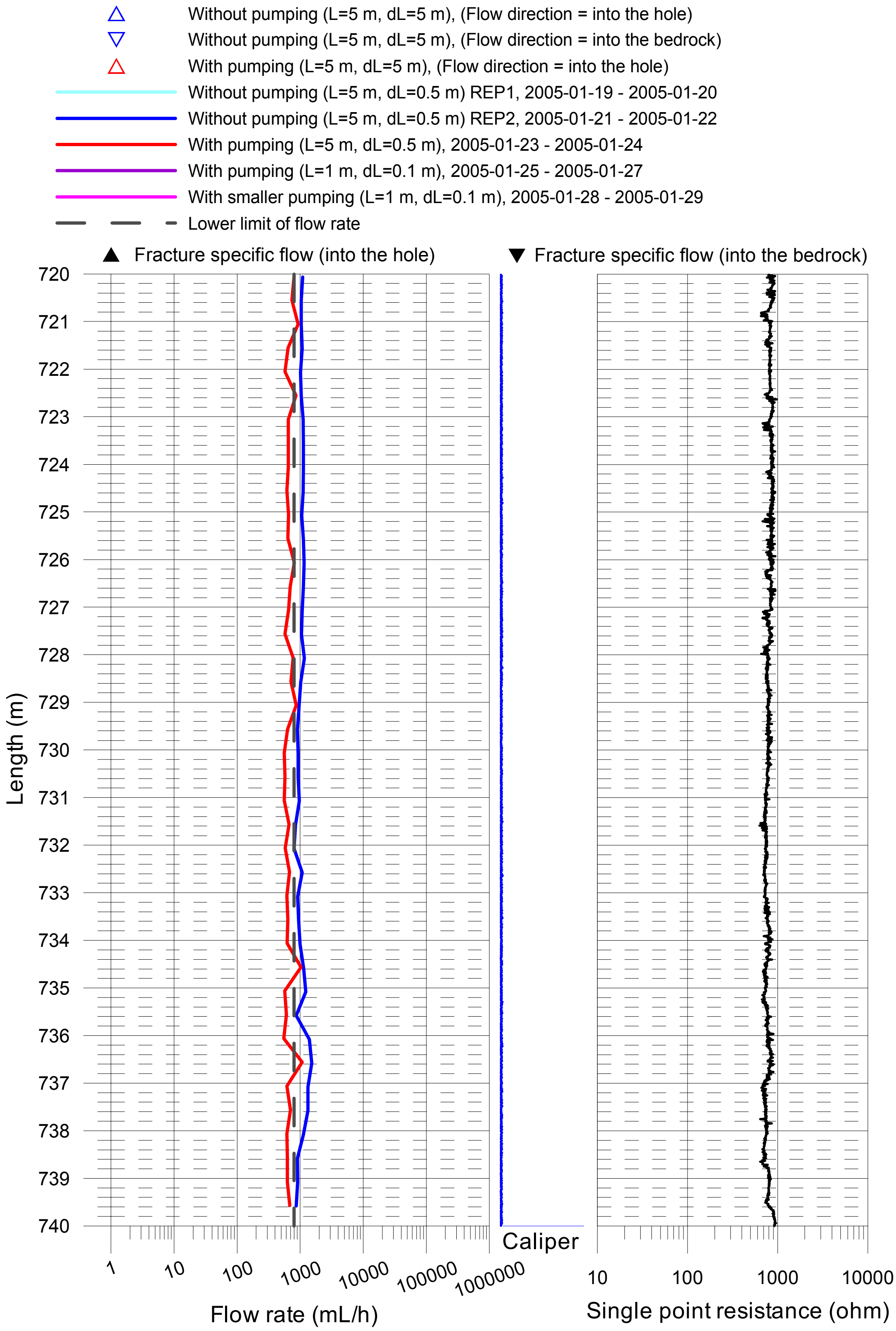
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



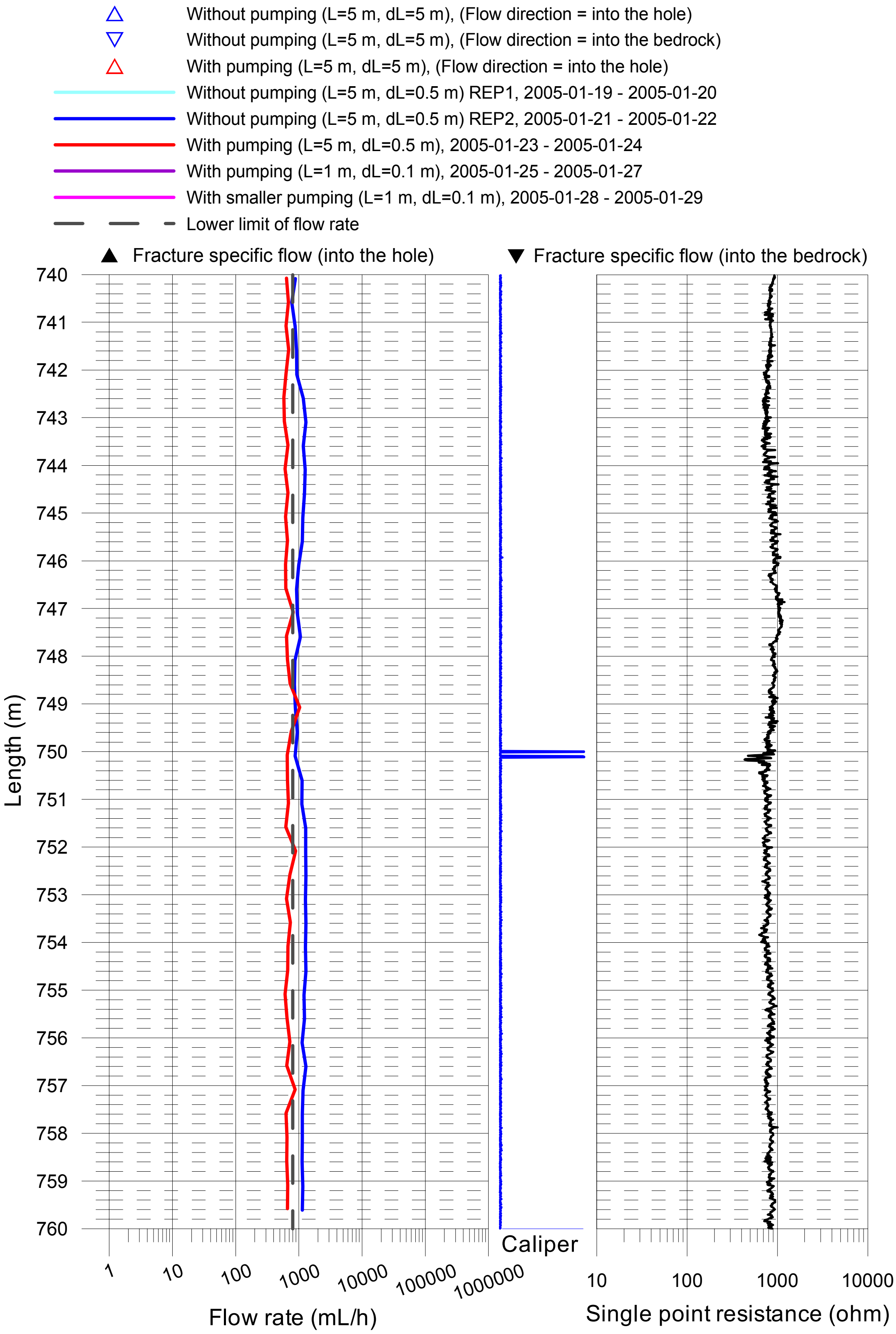
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



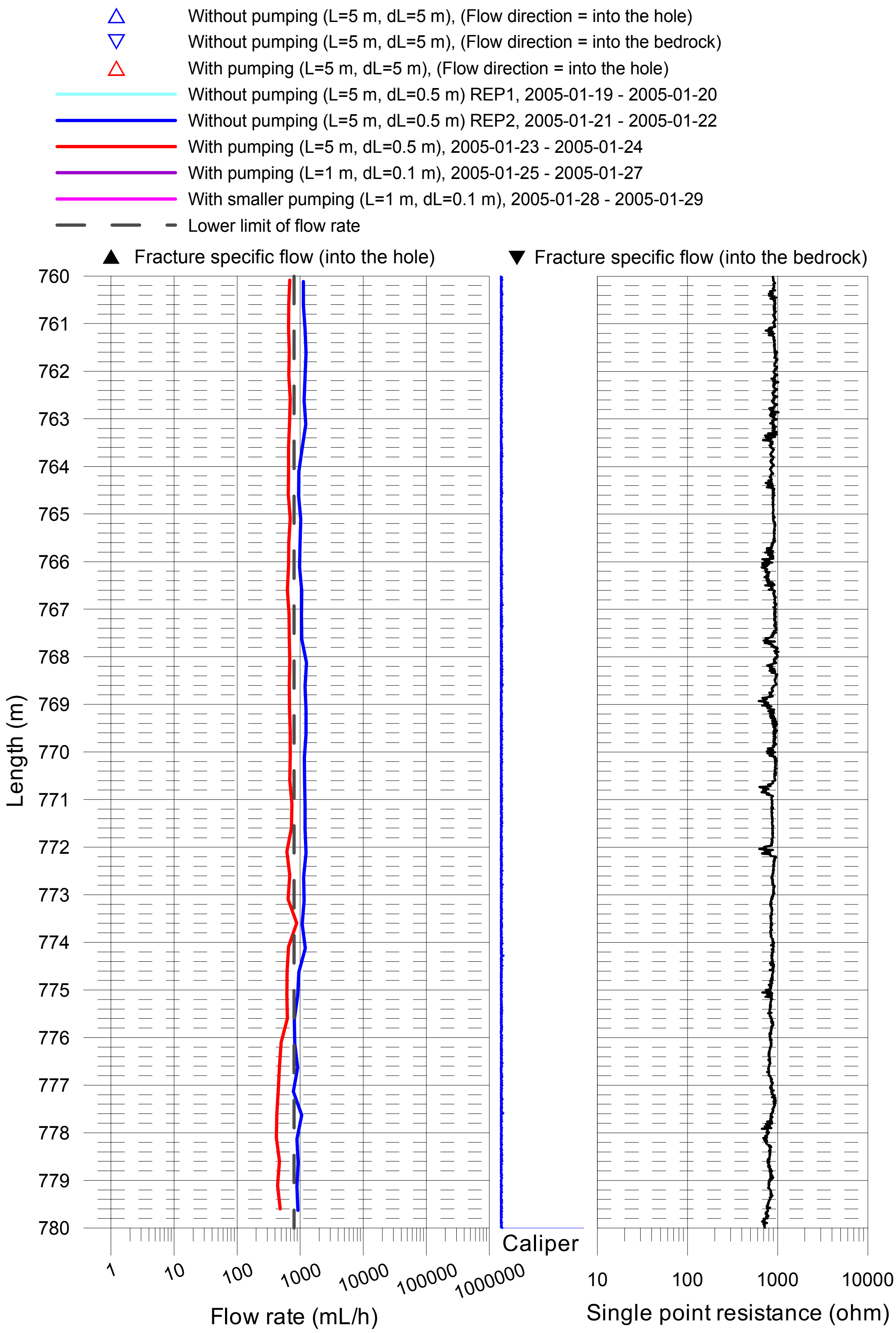
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



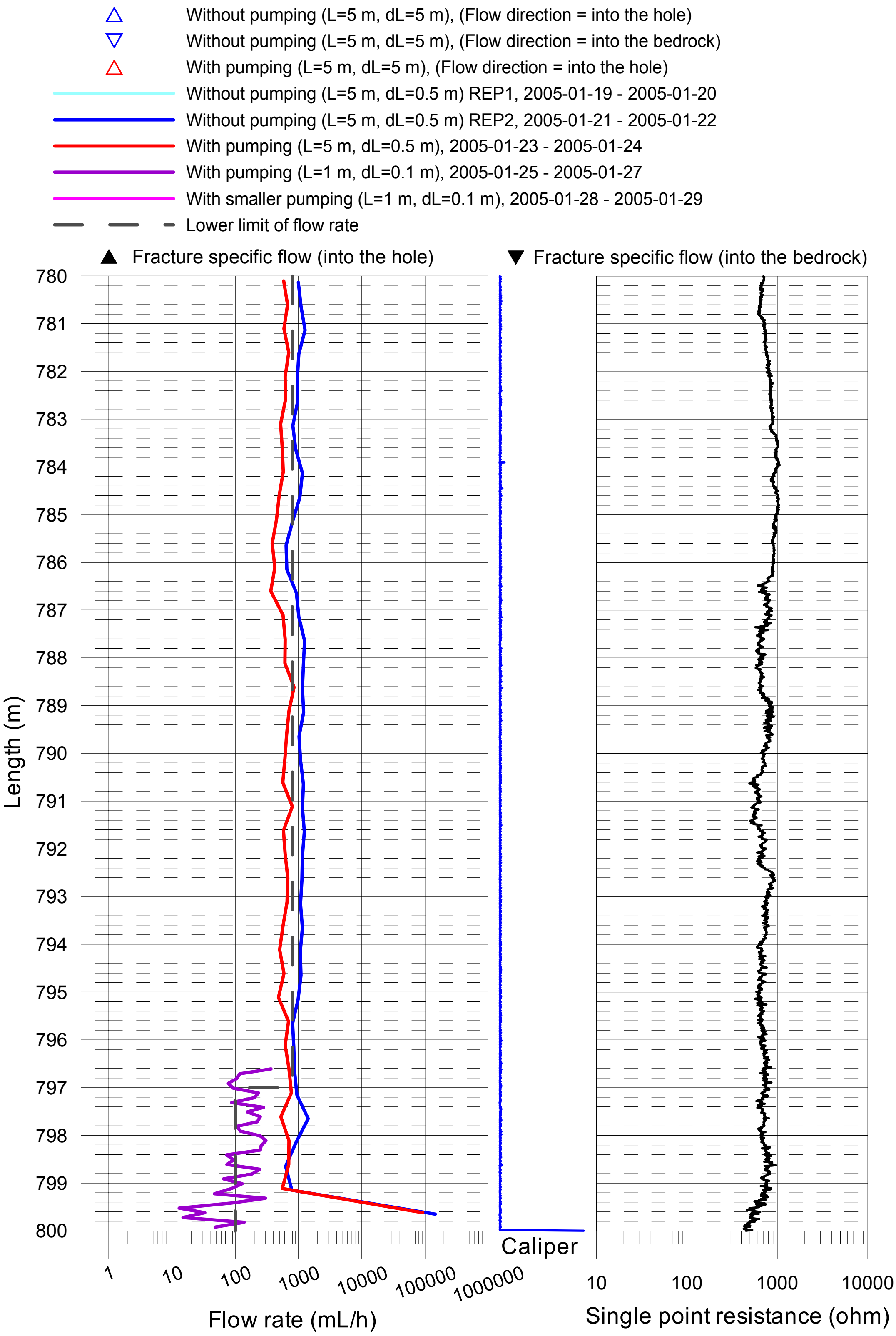
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



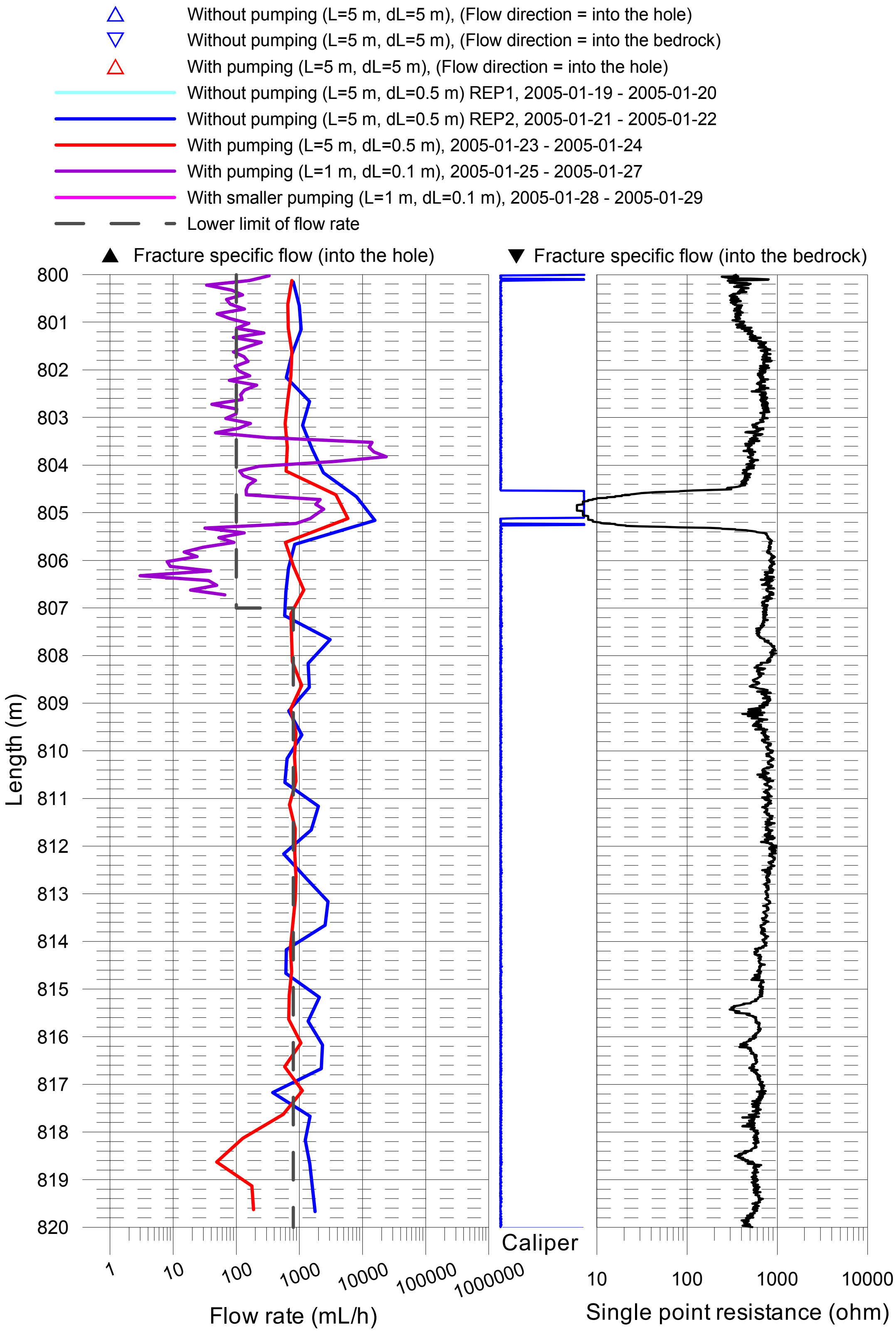
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



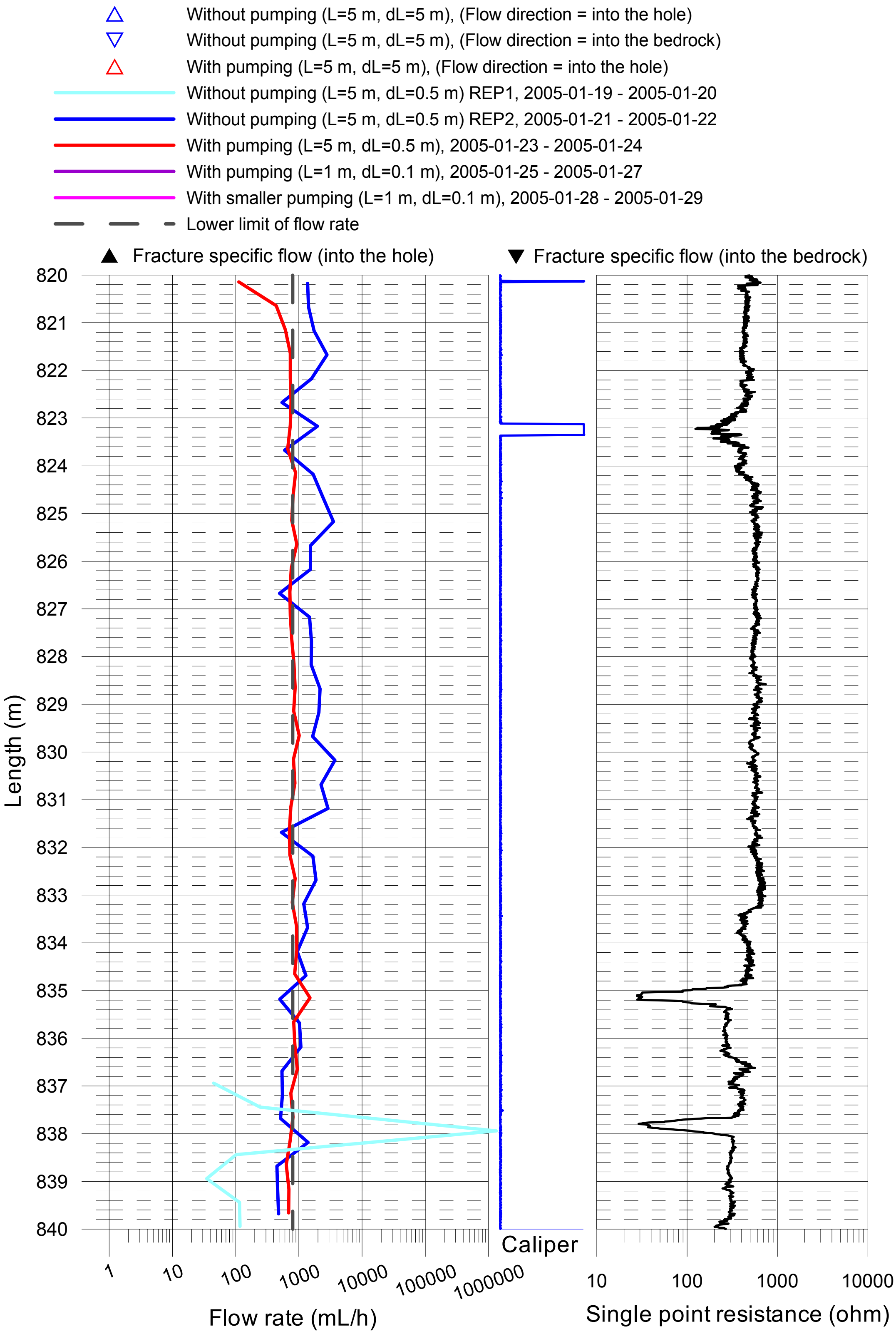
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



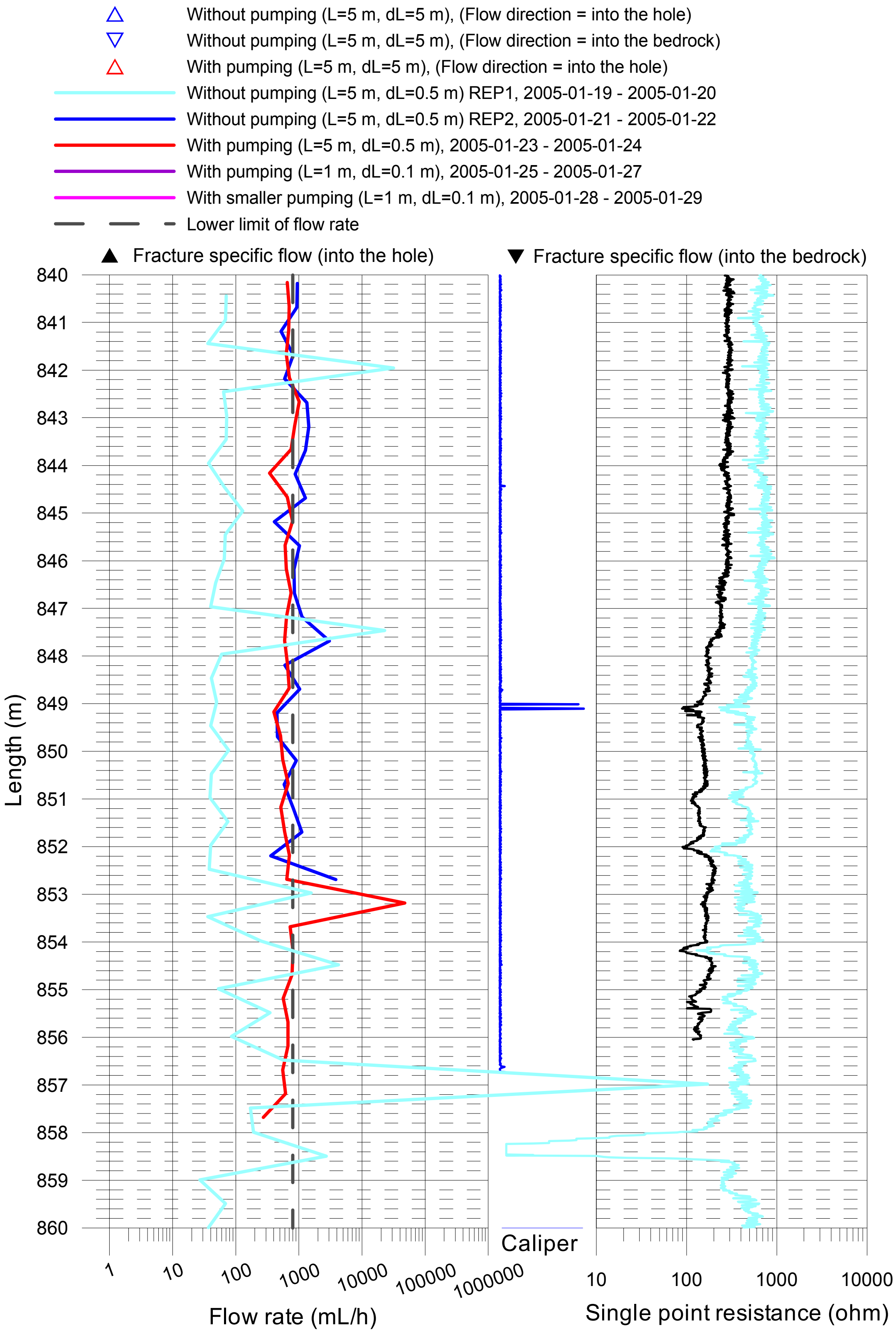
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



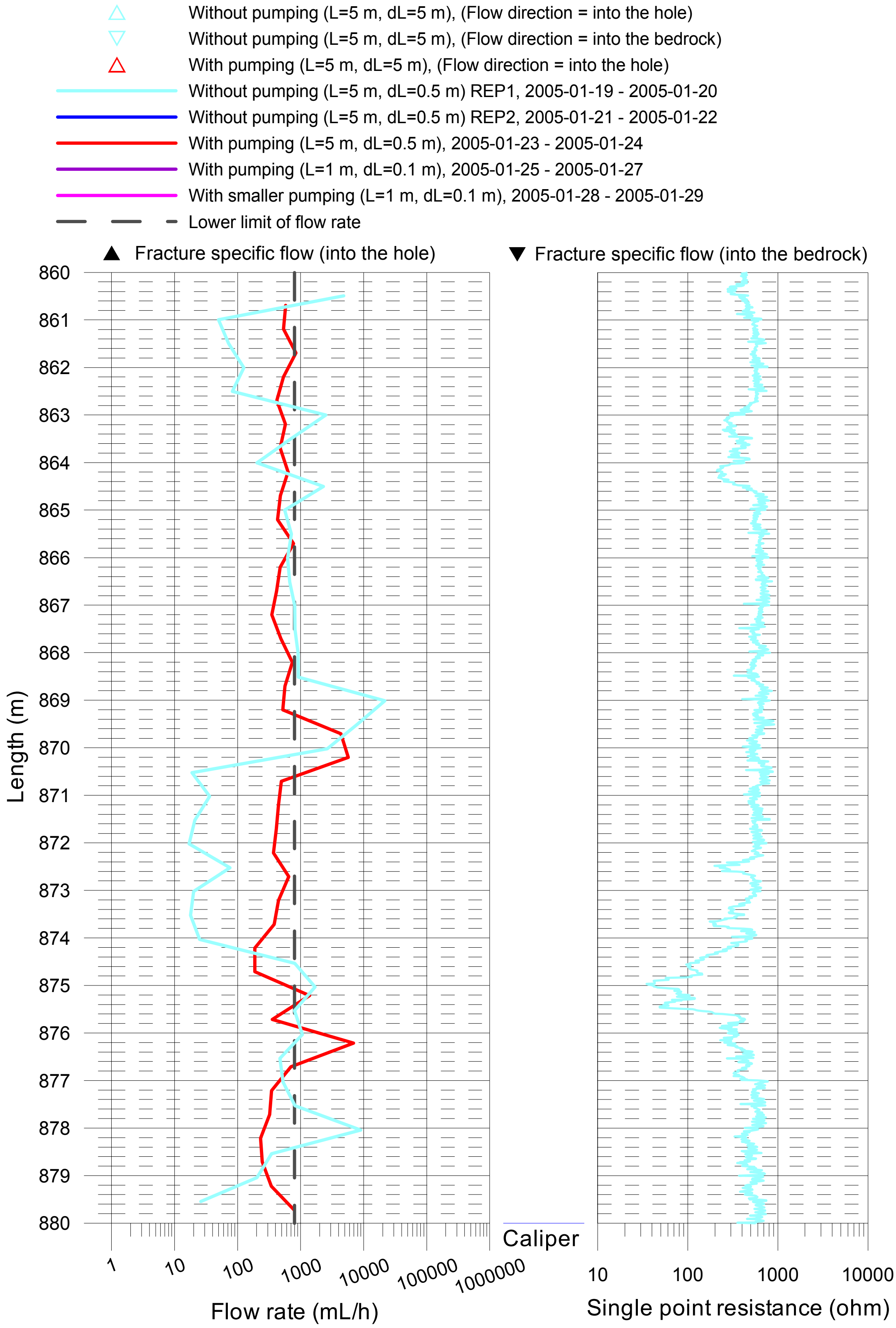
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



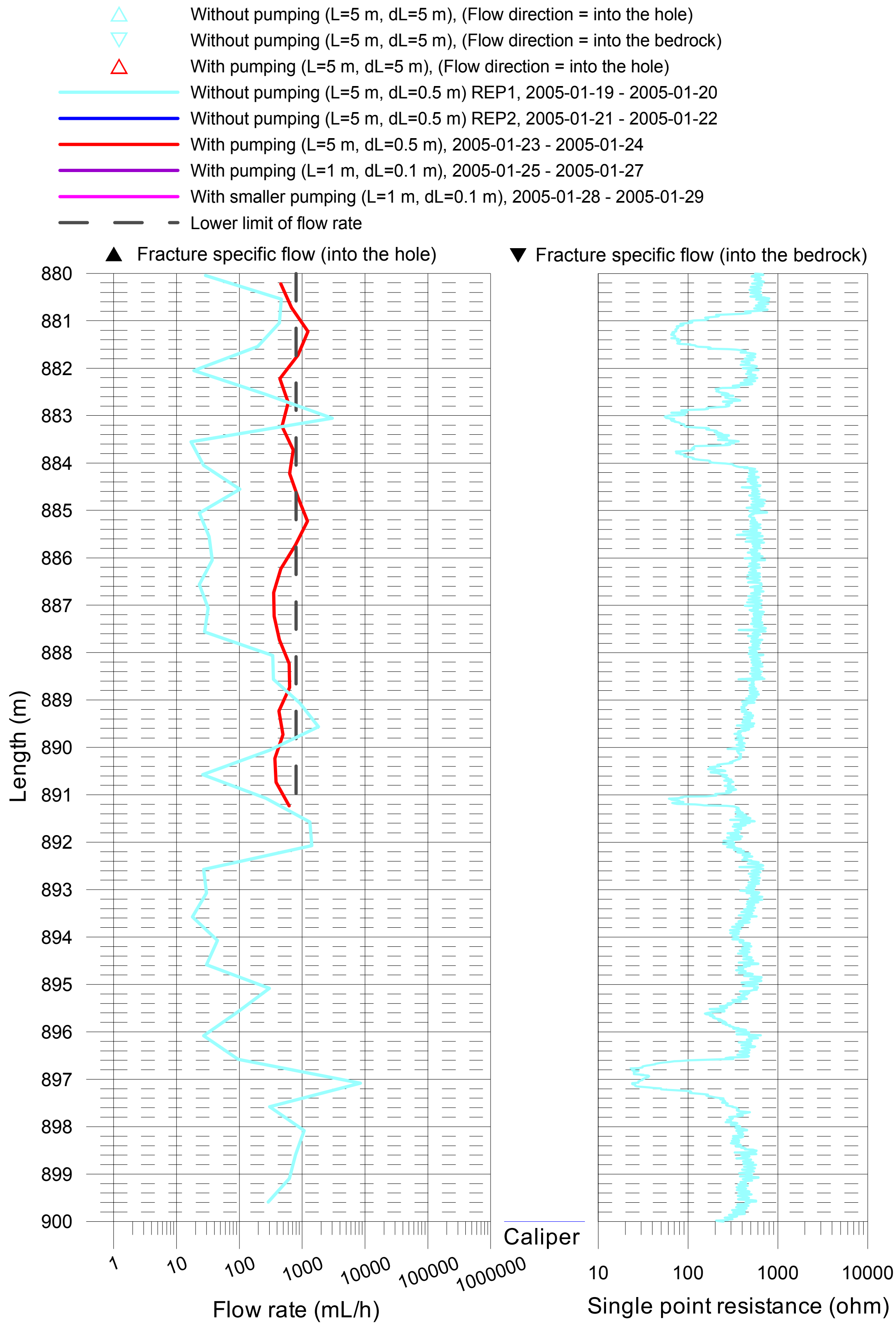
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



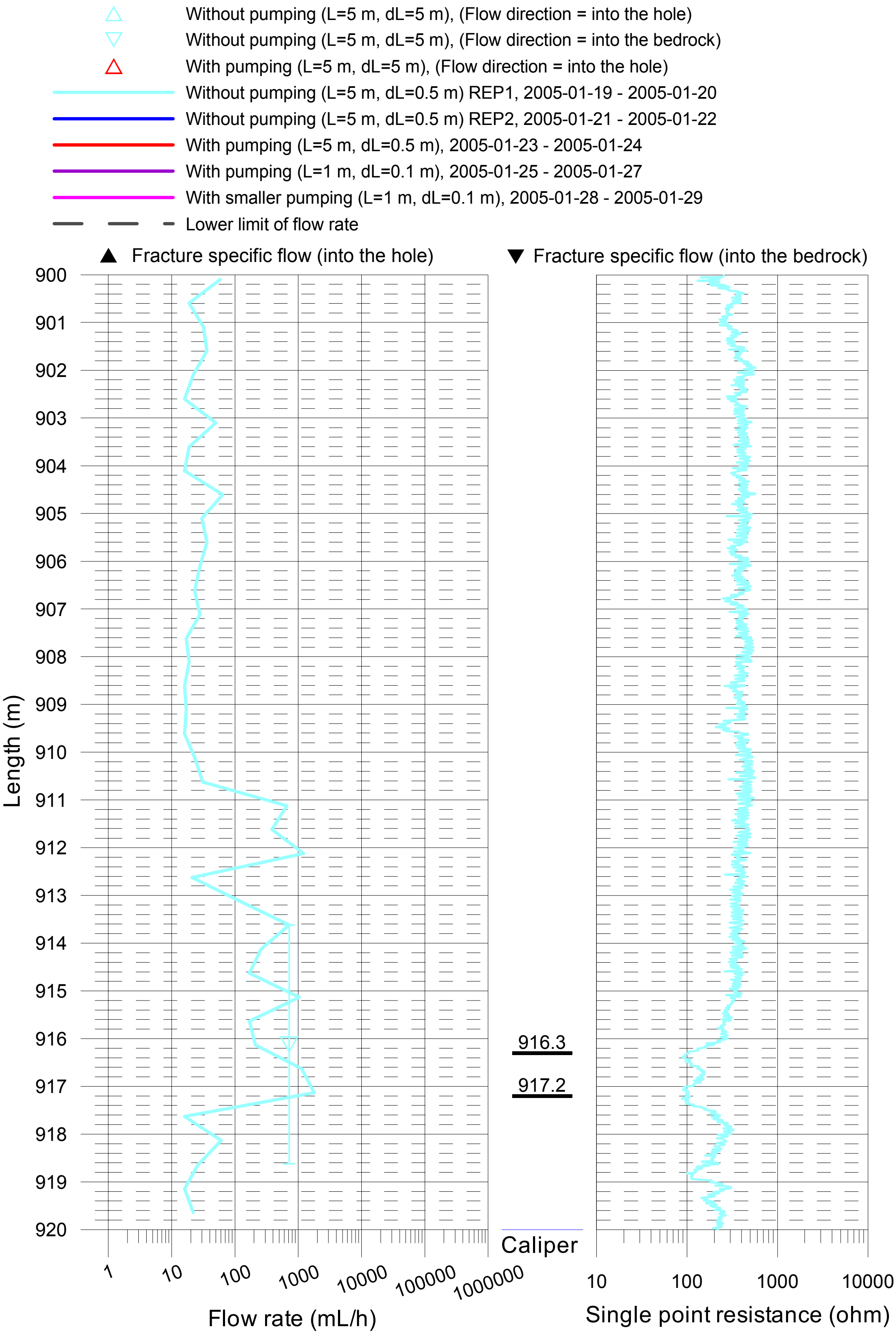
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



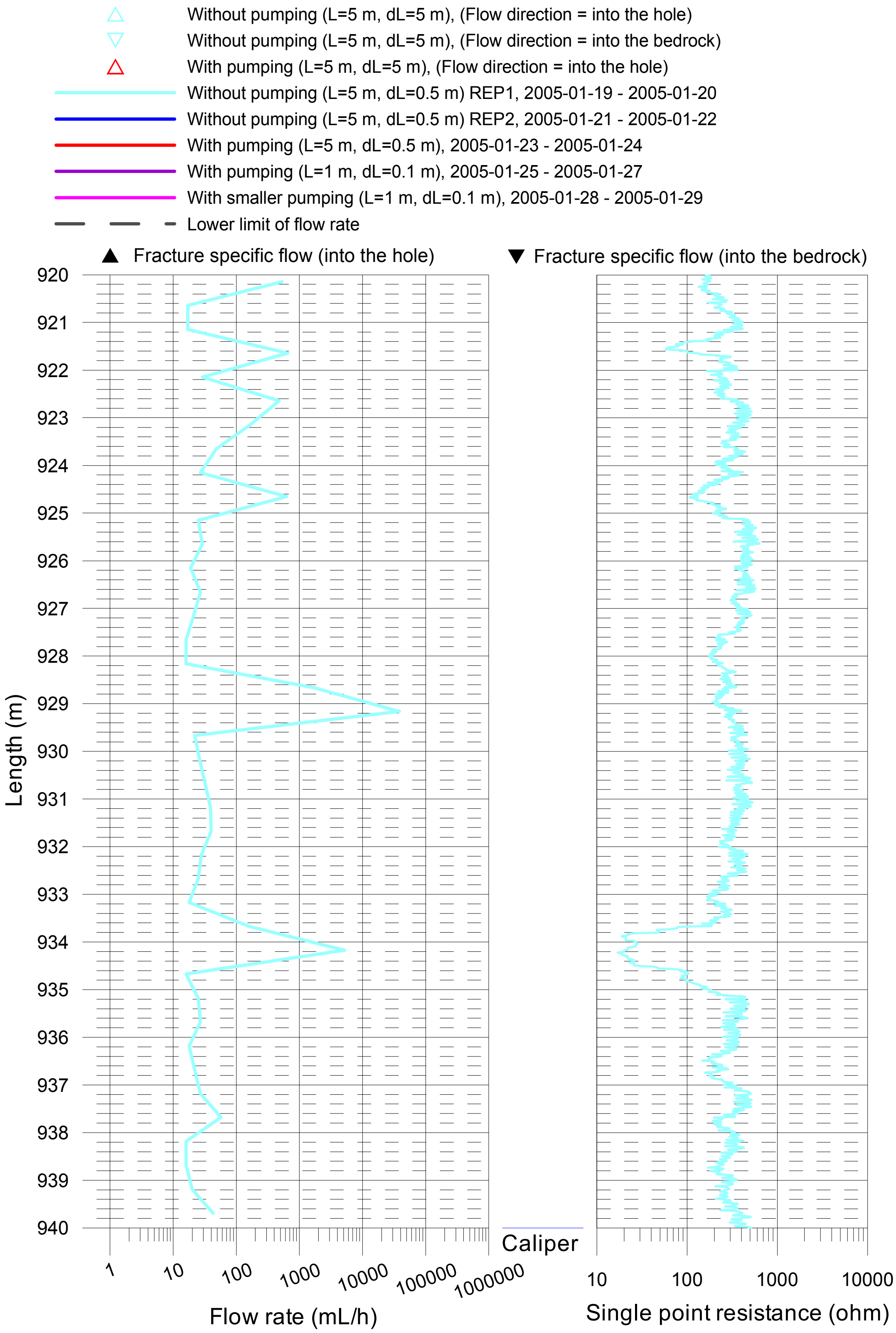
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



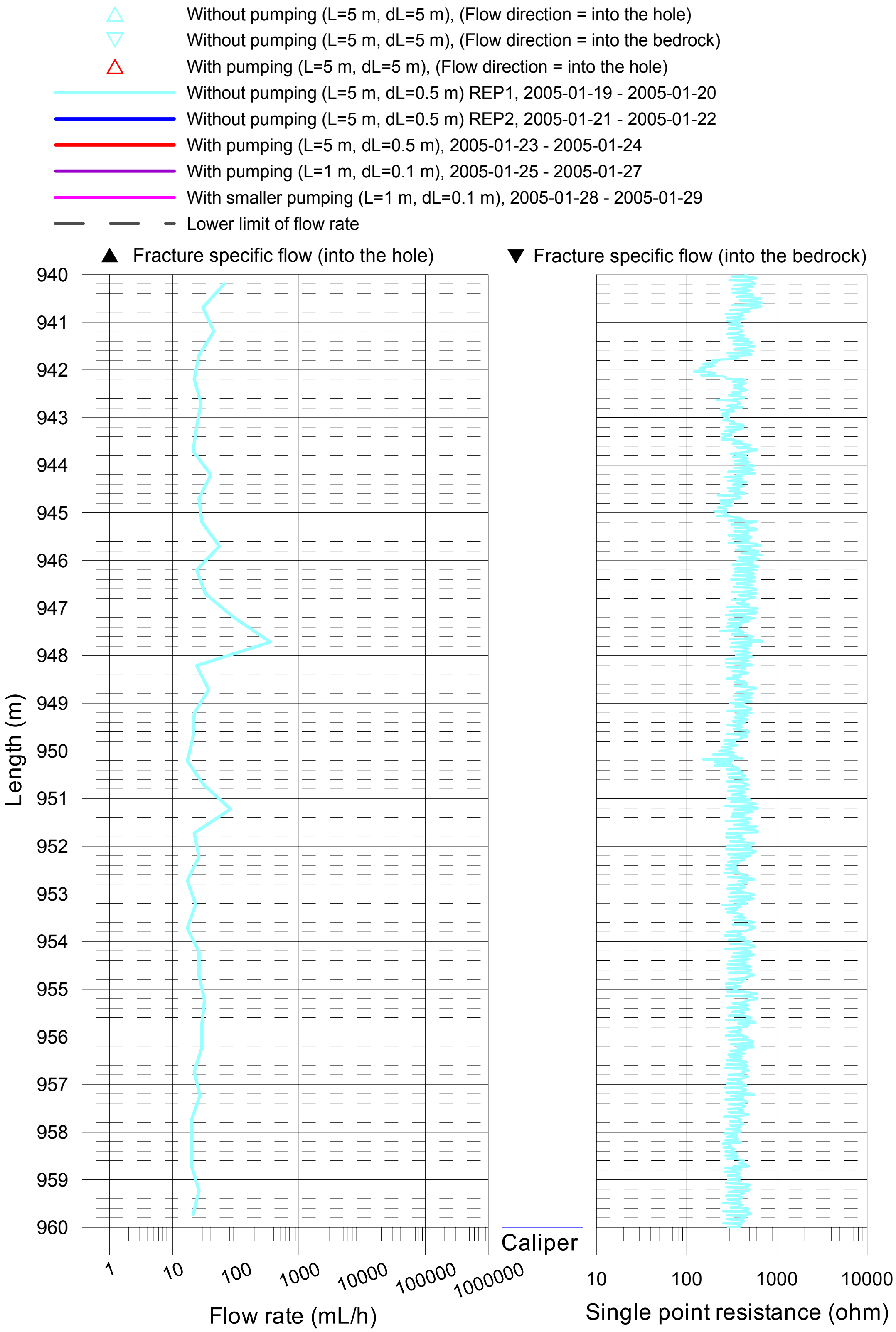
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



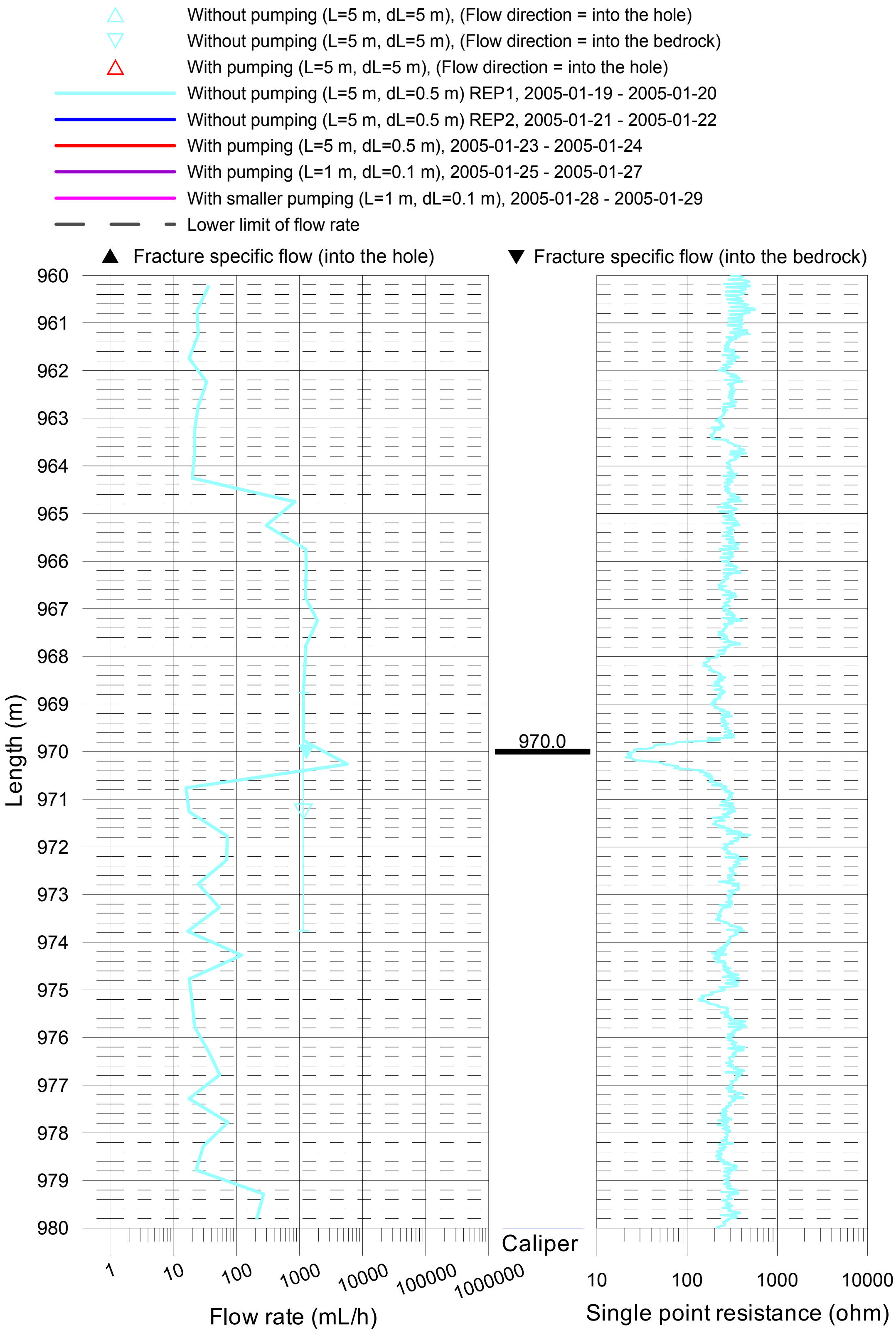
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



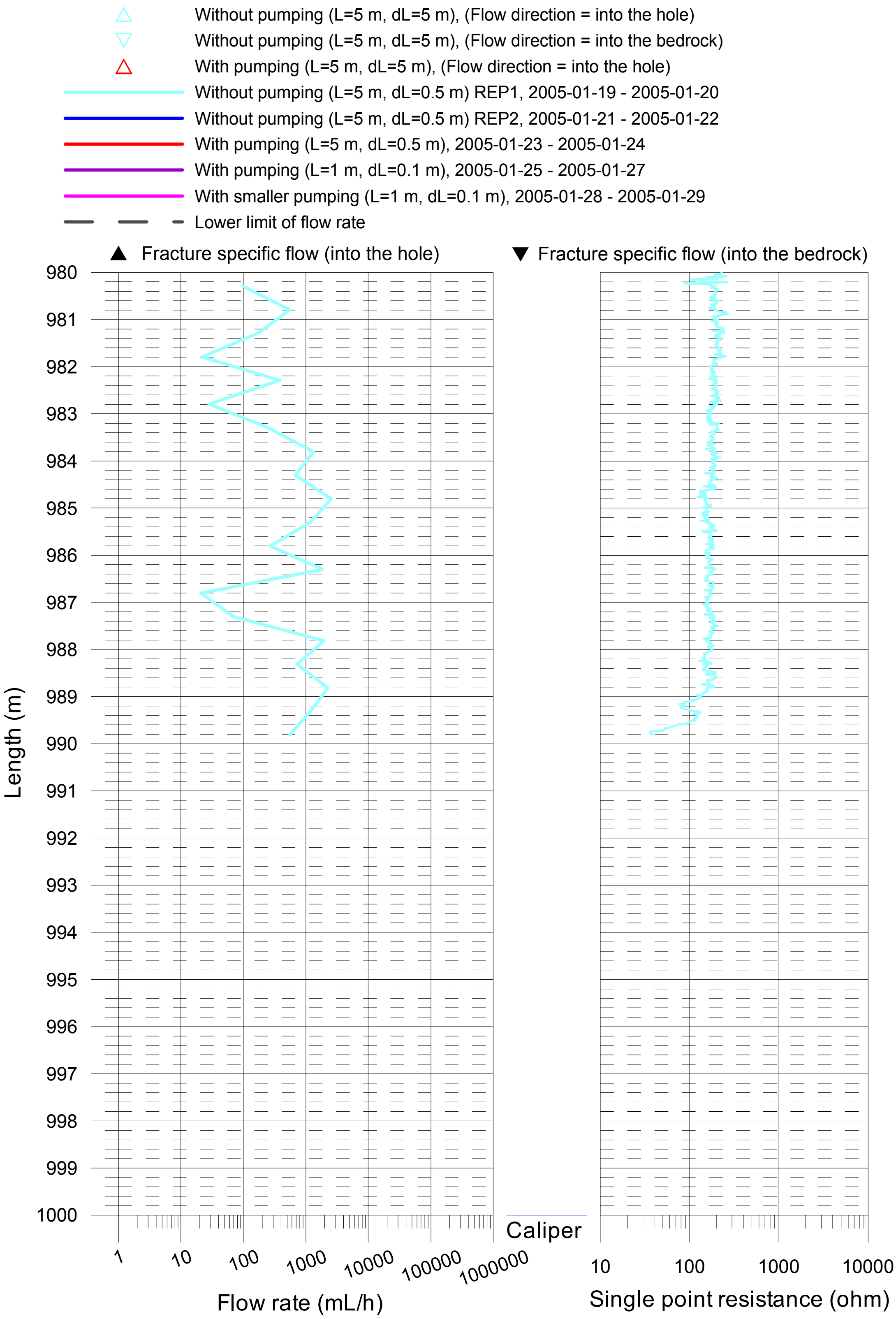
Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



Forsmark, borehole KFM07A
Measured flow rates, caliper and single point resistance



EXPLANATIONS

Header	Unit	Explanations
Borehole		ID for borehole
Secup	m	Length along the borehole for the upper limit of the test section (based on corrected length L)
Seclow	m	Length along the borehole for the lower limit of the test section (based on corrected length L)
L	m	Corrected length along borehole based on SKB procedures for length correction
Length to flow anom	m	Length along the borehole to inferred flow anomaly during overlapping flow logging
Test type (1-6)	(-)	1A: Pumping test – wire-line eq., 1B:Pumping test-submersible pump, 1C: Pumping test-airlift pumping, 2: Interference test, 3: Injection test, 4: Slug test, 5A: Difference flow logging – PFL-DIFF-Sequential, 5B: Difference flow logging – PFL-DIFF-Overlapping, 6: Flow logging-Impeller
Date of test, start	YY-MM-DD	Date for start of pumping
Time of test, start	hh:mm	Time for start of pumping
Date of flowl, start	YY-MM-DD	Date for start of the flow logging
Time of flowl, start	hh:mm	Time for start of the flow loggin
Date of test, stop	YY-MM-DD	Date for stop of the test
Time of test, stop	hh:mm	Time for stop of the test
L_w	m	Section length used in the difference flow logging
dL	m	Step length (increment) used in the difference flow logging
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 before pumping. Elevation of water level in open borehole in the local co-ordinates system with z=0 m
h_1	m a s l	Stabilised hydraulic head during the first pumping period. Elevation of water level in open borehole in the local co-ordinates system with z=0 m
h_2	m a s l	Stabilised hydraulic head during the second pumping period. Elevation of water level in open borehole in the local co-ordinates 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 ($s_2 = h_2 - h_0$)
T	m^2/s	Transmissivity of the entire borehole
Q_0	m^3/s	Measured flow rate through the test section or flow anomaly under natural conditions (no pumping) with $h = h_0$ in the open borehole
Q_1	m^3/s	Measured flow rate through the test section or flow anomaly during the first pumping period
Q_2	m^3/s	Measured flow rate through the test section or flow anomaly during the second pumping period
dh_0	m	Corrected initial hydraulic head difference along the hole due to e.g. varying salinity conditions of the borehole fluid before pumping
dh_1	m	Corrected hydraulic head difference along the hole due to e.g. varying salinity conditions of the borehole fluid during the first pumping period
dh_2	m	Corrected hydraulic head difference along the hole due to e.g. varying salinity conditions of the borehole fluid during the second pumping period
EC_w	S/m	Measured electric conductivity of the borehole fluid in the test section during difference flow logging
Te_w	°C	Measured borehole fluid temperature in the test section during difference flow logging
EC_f	S/m	Measured fracture-specific electric conductivity of the fluid in flow anomaly during difference flow logging
Te_f	°C	Measured fracture-specific fluid temperature in flow anomaly during difference flow logging
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
T-$measl_{LT}$	m^2/s	Estimated theoretical lower 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-$meas_{lLP}$	m^2/s	Estimated practical lower 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-$meas_{lU}$	m^2/s	Estimated 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 less than T_D-measlim
h_i	m	Calculated relative, natural freshwater head for test section or flow anomaly (undisturbed conditions)

Table of transmissivity and head of 5 m sections.

Borehole ID	Secup L (m)	Seclow L (m)	Lw (m)	Q0 (m³/s)	dh0 (m)	Q1 (m³/s)	dh1 (m)	TD (m²/s)	hi (m)	Q-lower limit P (mL/h)	TD-measlLT (m²/s)	TD-measlLP (m²/s)	TD-measlU (m²/s)	ECw0 (S/m)	Tew0 (°C)	ECw1 (S/m)	Tew1 (°C)	Comments
KFM07A	988.81	993.81	5	–	17.14	–	–	–	–	–	–	–	–	3.48	15.52	–	–	
KFM07A	983.80	988.80	5	–	17.04	–	–	–	–	–	–	–	–	3.84	15.49	–	–	
KFM07A	978.78	983.78	5	–	16.95	–	–	–	–	–	–	–	–	3.83	15.45	–	–	
KFM07A	973.77	978.77	5	–	16.87	–	–	–	–	–	–	–	–	3.83	15.40	–	–	
KFM07A	968.76	973.76	5	–3.22E–07	16.75	–	–	–	–	–	–	–	–	3.83	15.34	–	–	
KFM07A	963.75	968.75	5	–	16.67	–	–	–	–	–	–	–	–	3.83	15.31	–	–	
KFM07A	958.73	963.73	5	–	16.59	–	–	–	–	–	–	–	–	3.83	15.25	–	–	
KFM07A	953.72	958.72	5	–	16.47	–	–	–	–	–	–	–	–	3.83	15.21	–	–	
KFM07A	948.71	953.71	5	–	16.39	–	–	–	–	–	–	–	–	3.83	15.14	–	–	
KFM07A	943.70	948.70	5	–	16.33	–	–	–	–	–	–	–	–	3.84	15.11	–	–	
KFM07A	938.68	943.68	5	–	16.26	–	–	–	–	–	–	–	–	3.83	15.04	–	–	
KFM07A	933.67	938.67	5	–	16.13	–	–	–	–	–	–	–	–	3.83	14.98	–	–	
KFM07A	928.66	933.66	5	–	16.06	–	–	–	–	–	–	–	–	3.83	14.93	–	–	
KFM07A	923.65	928.65	5	–	15.96	–	–	–	–	–	–	–	–	3.83	14.90	–	–	
KFM07A	918.64	923.64	5	–	15.84	–	–	–	–	–	–	–	–	3.84	14.83	–	–	
KFM07A	913.62	918.62	5	–2.00E–07	15.74	–	–	–	–	–	–	–	–	3.83	14.77	–	–	
KFM07A	908.61	913.61	5	–	15.65	–	–	–	–	–	–	–	–	3.84	14.71	–	–	
KFM07A	903.60	908.60	5	–	15.54	–	–	–	–	–	–	–	–	3.84	14.68	–	–	
KFM07A	898.59	903.59	5	–	15.47	–	–	–	–	–	–	–	–	3.90	14.61	–	–	
KFM07A	893.57	898.57	5	–	15.37	–	–	–	–	–	–	–	–	3.83	14.57	–	–	
KFM07A	888.15	893.15	5	–	15.25	–	9.65	–	–	800	1.47E–09	1.47E–09	1.47E–05	3.96	14.57	3.58	15.03	
KFM07A	883.14	888.14	5	–	15.15	–	9.55	–	–	800	1.47E–09	1.47E–09	1.47E–05	3.83	14.47	3.62	15.15	
KFM07A	878.13	883.13	5	–	15.05	–	9.43	–	–	800	1.47E–09	2.44E–09	1.47E–05	3.98	14.40	3.59	14.92	
KFM07A	873.12	878.12	5	–	14.96	–	9.27	–	–	800	1.45E–09	2.41E–09	1.45E–05	3.83	14.36	3.62	15.02	
KFM07A	868.11	873.11	5	–	14.89	–	9.18	–	–	800	1.44E–09	2.41E–09	1.44E–05	4.07	14.44	3.77	14.82	
KFM07A	863.10	868.10	5	–	14.80	–	9.08	–	–	800	1.44E–09	2.40E–09	1.44E–05	4.12	14.42	3.58	14.75	
KFM07A	858.09	863.09	5	–	14.71	–	9.04	–	–	800	1.45E–09	2.42E–09	1.45E–05	4.15	14.22	3.40	14.74	
KFM07A	852.69	857.69	5	–	15.02	–	8.91	–	–	800	1.35E–09	2.25E–09	1.35E–05	3.70	15.56	3.50	14.68	
KFM07A	847.68	852.68	5	–	14.92	–	8.72	–	–	800	1.33E–09	2.22E–09	1.33E–05	3.71	15.35	3.78	14.63	
KFM07A	842.67	847.67	5	–	14.80	–	8.60	–	–	800	1.33E–09	2.22E–09	1.33E–05	3.73	15.07	3.79	14.69	

Borehole ID	Secup L (m)	Seclow L (m)	Lw (m)	Q0 (m^3/s)	dh0 (m)	Q1 (m^3/s)	dh1 (m)	TD (m^2/s)	hi (m)	Q-lower limit P (mL/h)	TD-measlLT (m^2/s)	TD- measlLP (m^2/s)	TD- measlU (m^2/s)	ECw0 (S/m)	Tew0 (°C)	ECw1 (S/m)	Tew1 (°C)	Comments
KFM07A	837.67	842.67	5	–	14.71	–	8.49	–	–	800	1.33E–09	3.53E–08	1.33E–05	3.77	14.52	3.80	14.51	
KFM07A	832.67	837.67	5	–	14.60	–	8.43	–	–	800	1.34E–09	3.56E–08	1.34E–05	3.74	14.90	3.79	14.64	
KFM07A	827.66	832.66	5	–	14.51	–	8.37	–	–	800	1.34E–09	3.58E–08	1.34E–05	3.73	14.96	3.78	14.41	
KFM07A	822.66	827.66	5	–	14.41	–	8.27	–	–	800	1.34E–09	3.58E–08	1.34E–05	3.78	14.35	3.79	14.35	
KFM07A	817.65	822.65	5	–	14.32	–	8.16	–	–	800	1.34E–09	3.57E–08	1.34E–05	3.73	14.88	3.79	14.29	
KFM07A	812.65	817.65	5	–	14.22	–	8.07	–	–	800	1.34E–09	3.57E–08	1.34E–05	3.73	14.61	3.81	14.25	
KFM07A	807.64	812.64	5	–	14.13	–	7.99	–	–	800	1.34E–09	3.58E–08	1.34E–05	3.71	14.65	3.89	14.18	
KFM07A	802.64	807.64	5	–	14.02	–	7.99	–	–	100	1.37E–09	4.56E–09	1.37E–05	3.74	14.41	3.87	14.12	
KFM07A	797.63	802.63	5	–	13.93	–	7.91	–	–	100	1.37E–09	4.56E–09	1.37E–05	3.74	14.12	3.77	14.09	
KFM07A	792.63	797.63	5	–	13.84	–	7.84	–	–	800	1.37E–09	3.66E–08	1.37E–05	3.75	14.01	3.78	14.01	
KFM07A	787.63	792.63	5	–	13.73	–	7.75	–	–	800	1.38E–09	3.68E–08	1.38E–05	3.75	13.96	3.76	13.95	
KFM07A	782.62	787.62	5	–	13.62	–	7.64	–	–	800	1.38E–09	3.68E–08	1.38E–05	3.76	13.91	3.79	13.90	
KFM07A	777.62	782.62	5	–	13.52	–	7.53	–	–	800	1.38E–09	3.67E–08	1.38E–05	3.75	13.85	3.79	13.85	
KFM07A	772.61	777.61	5	–	13.45	–	7.43	–	–	800	1.37E–09	3.65E–08	1.37E–05	3.74	13.81	3.77	13.78	
KFM07A	767.61	772.61	5	–	13.33	–	7.32	–	–	800	1.37E–09	3.66E–08	1.37E–05	3.74	13.75	3.76	13.74	
KFM07A	762.60	767.60	5	–	13.22	–	7.22	–	–	800	1.37E–09	3.66E–08	1.37E–05	3.74	13.69	3.75	13.70	
KFM07A	757.59	762.59	5	–	13.12	–	7.10	–	–	800	1.37E–09	3.65E–08	1.37E–05	3.74	13.63	3.75	13.66	
KFM07A	752.59	757.59	5	–	13.01	–	6.99	–	–	800	1.37E–09	3.65E–08	1.37E–05	3.73	13.58	3.76	13.61	
KFM07A	747.58	752.58	5	–	12.94	–	6.90	–	–	800	1.36E–09	3.64E–08	1.36E–05	3.74	13.53	3.76	13.56	
KFM07A	742.58	747.58	5	–	12.82	–	6.80	–	–	800	1.37E–09	3.65E–08	1.37E–05	3.73	13.47	3.76	13.49	
KFM07A	737.57	742.57	5	–	12.72	–	6.69	–	–	800	1.37E–09	3.65E–08	1.37E–05	3.73	13.41	3.75	13.55	
KFM07A	732.57	737.57	5	–	12.59	–	6.59	–	–	800	1.37E–09	3.66E–08	1.37E–05	3.73	13.35	3.77	13.37	
KFM07A	727.57	732.57	5	–	12.50	–	6.47	–	–	800	1.37E–09	3.65E–08	1.37E–05	3.70	13.29	3.74	13.32	
KFM07A	722.56	727.56	5	–	12.39	–	6.36	–	–	800	1.37E–09	3.65E–08	1.37E–05	3.71	13.25	3.74	13.44	
KFM07A	717.56	722.56	5	–	12.30	–	6.25	–	–	800	1.36E–09	3.63E–08	1.36E–05	3.71	13.19	3.74	13.33	
KFM07A	712.55	717.55	5	–	12.22	–	6.15	–	–	800	1.36E–09	3.62E–08	1.36E–05	3.71	13.14	3.76	13.16	
KFM07A	707.55	712.55	5	–	12.11	–	6.05	–	–	800	1.36E–09	3.63E–08	1.36E–05	3.71	13.08	3.75	13.11	
KFM07A	702.54	707.54	5	–	11.98	–	5.96	–	–	800	1.37E–09	3.65E–08	1.37E–05	3.71	13.02	3.67	13.10	
KFM07A	697.53	702.53	5	–	11.88	–	5.78	–	–	800	1.35E–09	3.60E–08	1.35E–05	3.71	12.97	3.63	13.37	
KFM07A	692.53	697.53	5	–	11.80	–	5.66	–	–	800	1.34E–09	3.58E–08	1.34E–05	3.70	12.91	3.63	12.94	
KFM07A	687.52	692.52	5	–	11.71	–	5.55	–	–	800	1.34E–09	3.57E–08	1.34E–05	3.71	12.86	3.65	12.91	

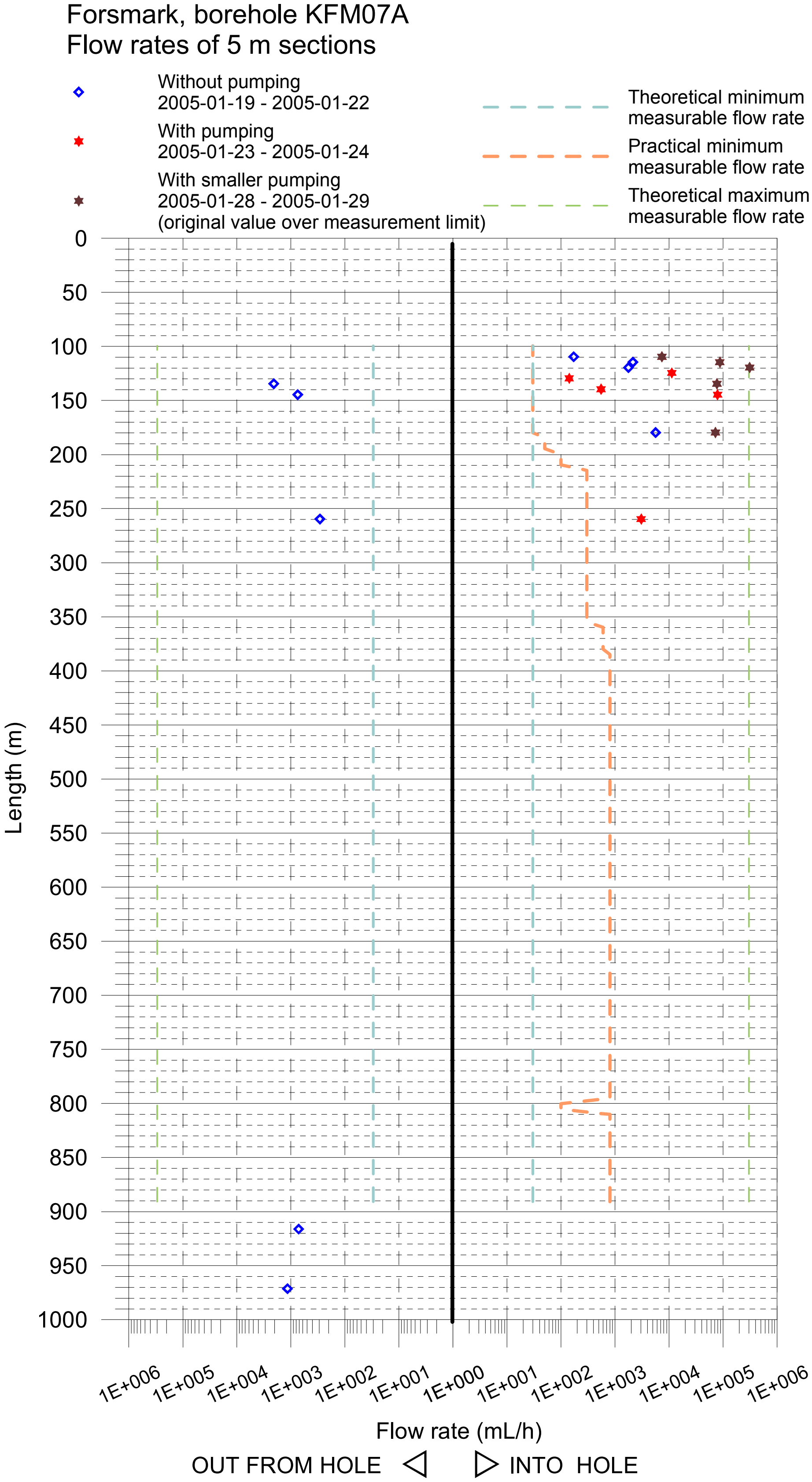
Borehole ID	Secup L (m)	Seclow L (m)	Lw (m)	Q0 (m^3/s)	dh0 (m)	Q1 (m^3/s)	dh1 (m)	TD (m^2/s)	hi (m)	Q-lower limit P (mL/h)	TD-measlLT (m^2/s)	TD- measlLP (m^2/s)	TD- measlU (m^2/s)	ECw0 (S/m)	Tew0 (°C)	ECw1 (S/m)	Tew1 (°C)	Comments
KFM07A	682.52	687.52	5	–	11.57	–	5.45	–	–	800	1.35E–09	3.59E–08	1.35E–05	3.70	12.80	3.61	13.10	
KFM07A	677.52	682.52	5	–	11.47	–	5.32	–	–	800	1.34E–09	3.57E–08	1.34E–05	3.71	12.74	3.58	12.83	
KFM07A	672.51	677.51	5	–	11.39	–	5.24	–	–	800	1.34E–09	3.57E–08	1.34E–05	3.72	12.68	3.60	12.74	
KFM07A	667.51	672.51	5	–	11.28	–	5.11	–	–	800	1.34E–09	3.56E–08	1.34E–05	3.70	12.63	3.58	12.90	
KFM07A	662.50	667.50	5	–	11.16	–	5.00	–	–	800	1.34E–09	3.57E–08	1.34E–05	3.70	12.58	3.58	12.63	
KFM07A	657.50	662.50	5	–	11.05	–	4.92	–	–	800	1.34E–09	3.59E–08	1.34E–05	3.71	12.52	3.57	12.58	
KFM07A	652.49	657.49	5	–	10.95	–	4.80	–	–	800	1.34E–09	3.57E–08	1.34E–05	3.69	12.47	3.56	12.59	
KFM07A	647.49	652.49	5	–	10.87	–	4.69	–	–	800	1.33E–09	3.56E–08	1.33E–05	3.71	12.42	3.53	12.49	
KFM07A	642.48	647.48	5	–	10.76	–	4.55	–	–	800	1.33E–09	3.54E–08	1.33E–05	3.70	12.37	3.54	12.57	
KFM07A	637.48	642.48	5	–	10.64	–	4.46	–	–	800	1.33E–09	3.56E–08	1.33E–05	3.71	12.32	3.52	12.36	
KFM07A	632.47	637.47	5	–	10.55	–	4.34	–	–	800	1.33E–09	3.54E–08	1.33E–05	3.73	12.27	3.54	12.31	
KFM07A	627.47	632.47	5	–	10.46	–	4.25	–	–	800	1.33E–09	3.54E–08	1.33E–05	3.71	12.21	3.54	12.26	
KFM07A	622.46	627.46	5	–	10.36	–	4.14	–	–	800	1.33E–09	3.53E–08	1.33E–05	3.71	12.16	3.47	12.23	
KFM07A	617.46	622.46	5	–	10.26	–	4.05	–	–	800	1.33E–09	3.54E–08	1.33E–05	3.72	12.11	3.48	12.30	
KFM07A	612.45	617.45	5	–	10.15	–	3.92	–	–	800	1.32E–09	3.53E–08	1.32E–05	3.71	12.06	3.53	12.11	
KFM07A	607.45	612.45	5	–	10.04	–	3.81	–	–	800	1.32E–09	3.53E–08	1.32E–05	3.71	12.01	3.48	12.07	
KFM07A	602.44	607.44	5	–	9.96	–	3.73	–	–	800	1.32E–09	3.53E–08	1.32E–05	3.70	11.96	3.47	12.04	
KFM07A	597.44	602.44	5	–	9.85	–	3.61	–	–	800	1.32E–09	3.52E–08	1.32E–05	3.71	11.91	3.43	11.94	
KFM07A	592.43	597.43	5	–	9.74	–	3.50	–	–	800	1.32E–09	3.52E–08	1.32E–05	3.70	11.86	3.46	11.89	
KFM07A	587.43	592.43	5	–	9.65	–	3.40	–	–	800	1.32E–09	3.52E–08	1.32E–05	3.68	11.81	3.40	11.85	
KFM07A	582.43	587.43	5	–	9.55	–	3.30	–	–	800	1.32E–09	3.52E–08	1.32E–05	3.68	11.76	3.49	11.80	
KFM07A	577.42	582.42	5	–	9.48	–	3.20	–	–	800	1.31E–09	3.50E–08	1.31E–05	3.69	11.71	3.46	11.76	
KFM07A	572.42	577.42	5	–	9.37	–	3.10	–	–	800	1.31E–09	3.51E–08	1.31E–05	3.68	11.65	3.45	11.72	
KFM07A	567.41	572.41	5	–	9.29	–	2.99	–	–	800	1.31E–09	3.49E–08	1.31E–05	3.67	11.60	3.43	11.66	
KFM07A	562.41	567.41	5	–	9.13	–	2.85	–	–	800	1.31E–09	3.50E–08	1.31E–05	3.67	11.54	3.40	11.68	
KFM07A	557.41	562.41	5	–	9.05	–	2.74	–	–	800	1.31E–09	3.48E–08	1.31E–05	3.67	11.49	3.37	11.55	
KFM07A	552.40	557.40	5	–	8.96	–	2.65	–	–	800	1.31E–09	3.48E–08	1.31E–05	3.70	11.44	3.39	11.50	
KFM07A	547.40	552.40	5	–	8.87	–	2.55	–	–	800	1.30E–09	3.48E–08	1.30E–05	3.70	11.39	3.41	11.45	
KFM07A	542.39	547.39	5	–	8.79	–	2.46	–	–	800	1.30E–09	3.47E–08	1.30E–05	3.68	11.33	3.38	11.44	
KFM07A	537.39	542.39	5	–	8.67	–	2.35	–	–	800	1.30E–09	3.48E–08	1.30E–05	3.68	11.29	3.33	11.34	
KFM07A	532.38	537.38	5	–	8.57	–	2.25	–	–	800	1.30E–09	3.48E–08	1.30E–05	3.58	11.24	3.21	11.35	

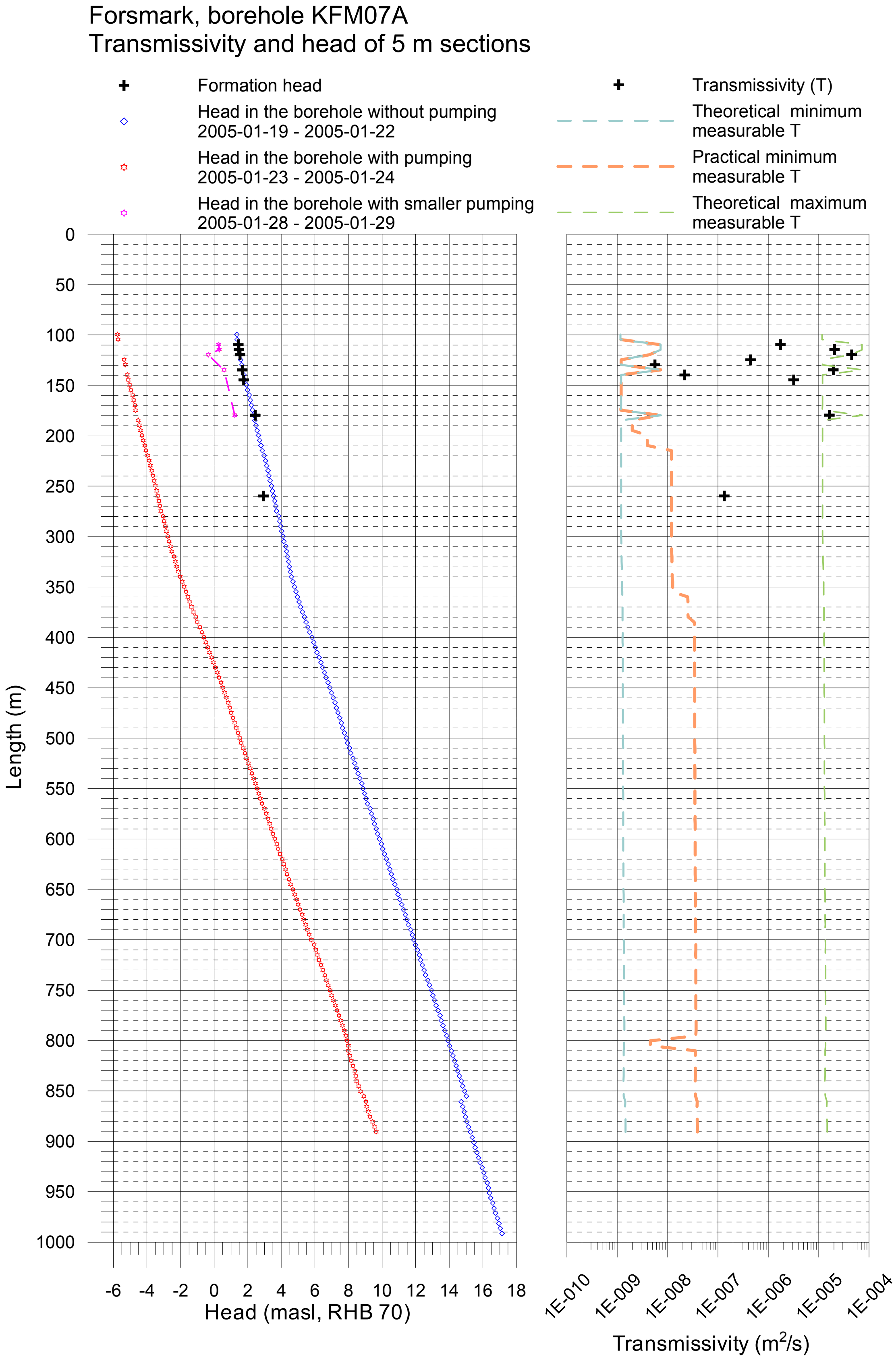
Borehole ID	Secup L (m)	Seclow L (m)	Lw (m)	Q0 (m³/s)	dh0 (m)	Q1 (m³/s)	dh1 (m)	TD (m²/s)	hi (m)	Q-lower limit P (mL/h)	TD-measlLT (m²/s)	TD- measlLP (m²/s)	TD- measlU (m²/s)	ECw0 (S/m)	Tew0 (°C)	ECw1 (S/m)	Tew1 (°C)	Comments
KFM07A	527.37	532.37	5	–	8.47	–	2.15	–	–	800	1.30E–09	3.48E–08	1.30E–05	3.70	11.19	3.29	11.27	
KFM07A	522.36	527.36	5	–	8.37	–	2.04	–	–	800	1.30E–09	3.47E–08	1.30E–05	3.68	11.14	3.18	11.35	
KFM07A	517.35	522.35	5	–	8.27	–	1.93	–	–	800	1.30E–09	3.47E–08	1.30E–05	3.69	11.09	3.27	11.24	
KFM07A	512.34	517.34	5	–	8.14	–	1.84	–	–	800	1.31E–09	3.49E–08	1.31E–05	3.70	11.04	3.24	11.21	
KFM07A	507.34	512.34	5	–	8.05	–	1.74	–	–	800	1.31E–09	3.48E–08	1.31E–05	3.65	10.98	3.14	11.05	
KFM07A	502.32	507.32	5	–	7.95	–	1.61	–	–	800	1.30E–09	3.47E–08	1.30E–05	3.70	10.94	3.20	11.25	
KFM07A	497.32	502.32	5	–	7.87	–	1.52	–	–	800	1.30E–09	3.46E–08	1.30E–05	3.69	10.89	3.21	11.08	
KFM07A	492.32	497.32	5	–	7.76	–	1.42	–	–	800	1.30E–09	3.47E–08	1.30E–05	3.72	10.84	3.21	11.09	
KFM07A	487.32	492.32	5	–	7.65	–	1.32	–	–	800	1.30E–09	3.47E–08	1.30E–05	3.69	10.78	3.09	10.86	
KFM07A	482.33	487.33	5	–	7.57	–	1.22	–	–	800	1.30E–09	3.46E–08	1.30E–05	3.70	10.74	3.15	10.81	
KFM07A	477.33	482.33	5	–	7.48	–	1.12	–	–	800	1.30E–09	3.46E–08	1.30E–05	3.72	10.69	3.21	10.77	
KFM07A	472.33	477.33	5	–	7.37	–	1.01	–	–	800	1.30E–09	3.46E–08	1.30E–05	3.73	10.63	3.06	10.73	
KFM07A	467.33	472.33	5	–	7.28	–	0.93	–	–	800	1.30E–09	3.46E–08	1.30E–05	3.72	10.59	3.20	10.70	
KFM07A	462.33	467.33	5	–	7.20	–	0.84	–	–	800	1.30E–09	3.46E–08	1.30E–05	3.71	10.54	3.15	10.67	
KFM07A	457.33	462.33	5	–	7.09	–	0.73	–	–	800	1.30E–09	3.46E–08	1.30E–05	3.70	10.49	3.18	10.58	
KFM07A	452.34	457.34	5	–	6.99	–	0.62	–	–	800	1.29E–09	3.45E–08	1.29E–05	3.70	10.44	3.15	10.54	
KFM07A	447.34	452.34	5	–	6.88	–	0.51	–	–	800	1.29E–09	3.45E–08	1.29E–05	3.73	10.40	3.13	10.49	
KFM07A	442.34	447.34	5	–	6.78	–	0.41	–	–	800	1.29E–09	3.45E–08	1.29E–05	3.72	10.35	3.02	10.66	
KFM07A	437.34	442.34	5	–	6.66	–	0.29	–	–	800	1.29E–09	3.45E–08	1.29E–05	3.71	10.31	3.12	10.39	
KFM07A	432.34	437.34	5	–	6.57	–	0.19	–	–	800	1.29E–09	3.45E–08	1.29E–05	3.70	10.26	3.09	10.56	
KFM07A	427.33	432.33	5	–	6.46	–	0.06	–	–	800	1.29E–09	3.43E–08	1.29E–05	3.67	10.22	3.04	10.57	
KFM07A	422.33	427.33	5	–	6.36	–	–0.04	–	–	800	1.29E–09	3.43E–08	1.29E–05	3.68	10.18	3.03	10.41	
KFM07A	417.33	422.33	5	–	6.25	–	–0.15	–	–	800	1.29E–09	3.43E–08	1.29E–05	3.64	10.13	3.07	10.40	
KFM07A	412.32	417.32	5	–	6.12	–	–0.28	–	–	800	1.29E–09	3.43E–08	1.29E–05	3.61	10.09	3.05	10.17	
KFM07A	407.32	412.32	5	–	6.02	–	–0.38	–	–	800	1.29E–09	3.43E–08	1.29E–05	3.60	10.04	2.99	10.36	
KFM07A	402.32	407.32	5	–	5.93	–	–0.50	–	–	800	1.28E–09	3.42E–08	1.28E–05	3.60	10.04	3.07	10.19	
KFM07A	397.31	402.31	5	–	5.83	–	–0.61	–	–	800	1.28E–09	3.41E–08	1.28E–05	3.50	9.94	3.02	10.06	
KFM07A	392.31	397.31	5	–	5.69	–	–0.72	–	–	800	1.29E–09	3.43E–08	1.29E–05	3.44	9.89	2.99	9.99	
KFM07A	387.30	392.30	5	–	5.58	–	–0.85	–	–	800	1.28E–09	3.42E–08	1.28E–05	3.34	9.83	3.03	9.95	
KFM07A	382.30	387.30	5	–	5.47	–	–1.01	–	–	800	1.27E–09	3.39E–08	1.27E–05	3.24	9.78	3.07	10.20	
KFM07A	377.30	382.30	5	–	5.37	–	–1.10	–	–	600	1.27E–09	2.55E–08	1.27E–05	3.19	9.73	2.97	10.10	

Borehole ID	Secup L (m)	Seclow L (m)	Lw (m)	Q0 (m³/s)	dh0 (m)	Q1 (m³/s)	dh1 (m)	TD (m²/s)	hi (m)	Q-lower limit P (mL/h)	TD-measlLT (m²/s)	TD- measlLP (m²/s)	TD- measlU (m²/s)	ECw0 (S/m)	Tew0 (°C)	ECw1 (S/m)	Tew1 (°C)	Comments
KFM07A	372.29	377.29	5	–	5.25	–	–1.23	–	–	600	1.27E–09	2.54E–08	1.27E–05	3.08	9.69	3.01	10.15	
KFM07A	367.29	372.29	5	–	5.15	–	–1.35	–	–	600	1.27E–09	2.54E–08	1.27E–05	2.95	9.63	2.91	10.13	
KFM07A	362.28	367.28	5	–	5.06	–	–1.46	–	–	600	1.26E–09	2.53E–08	1.26E–05	2.80	9.58	2.90	9.74	
KFM07A	357.28	362.28	5	–	4.96	–	–1.57	–	–	600	1.26E–09	2.52E–08	1.26E–05	2.65	9.54	2.87	10.02	
KFM07A	352.27	357.27	5	–	4.87	–	–1.68	–	–	300	1.26E–09	8.39E–09	1.26E–05	2.47	9.49	2.80	10.01	
KFM07A	347.27	352.27	5	–	4.79	–	–1.78	–	–	300	1.25E–09	8.36E–09	1.25E–05	2.29	9.44	2.77	9.60	
KFM07A	342.28	347.28	5	–	4.69	–	–1.90	–	–	300	1.25E–09	8.34E–09	1.25E–05	2.11	9.40	2.82	9.56	
KFM07A	337.28	342.28	5	–	4.60	–	–2.03	–	–	300	1.24E–09	8.29E–09	1.24E–05	1.95	9.35	2.72	9.69	
KFM07A	332.27	337.27	5	–	4.54	–	–2.13	–	–	300	1.24E–09	8.24E–09	1.24E–05	1.80	9.29	2.66	9.47	
KFM07A	327.26	332.26	5	–	4.48	–	–2.23	–	–	300	1.23E–09	8.19E–09	1.23E–05	1.71	9.24	2.60	9.79	
KFM07A	322.25	327.25	5	–	4.43	–	–2.31	–	–	300	1.22E–09	8.15E–09	1.22E–05	1.62	9.19	2.44	9.54	
KFM07A	317.24	322.24	5	–	4.37	–	–2.39	–	–	300	1.22E–09	8.13E–09	1.22E–05	1.56	9.14	2.43	9.60	
KFM07A	312.23	317.23	5	–	4.32	–	–2.53	–	–	300	1.20E–09	8.02E–09	1.20E–05	1.51	9.11	2.41	9.28	
KFM07A	307.22	312.22	5	–	4.26	–	–2.60	–	–	300	1.20E–09	8.01E–09	1.20E–05	1.48	9.06	2.29	9.24	
KFM07A	302.21	307.21	5	–	4.15	–	–2.68	–	–	300	1.21E–09	8.05E–09	1.21E–05	1.47	9.01	2.17	9.20	
KFM07A	297.20	302.20	5	–	4.10	–	–2.76	–	–	300	1.20E–09	1.00E–08	1.20E–05	1.47	8.96	1.98	9.13	
KFM07A	292.19	297.19	5	–	4.02	–	–2.84	–	–	300	1.20E–09	1.00E–08	1.20E–05	1.45	8.92	1.94	9.20	
KFM07A	287.18	292.18	5	–	3.96	–	–2.91	–	–	300	1.20E–09	1.00E–08	1.20E–05	1.46	8.86	1.79	9.45	
KFM07A	282.17	287.17	5	–	3.91	–	–2.98	–	–	300	1.20E–09	9.97E–09	1.20E–05	1.45	8.82	1.80	9.00	
KFM07A	277.17	282.17	5	–	3.86	–	–3.04	–	–	300	1.19E–09	9.95E–09	1.19E–05	1.45	8.77	1.70	9.00	
KFM07A	272.16	277.16	5	–	3.72	–	–3.18	–	–	300	1.19E–09	9.95E–09	1.19E–05	1.45	8.72	1.62	9.21	
KFM07A	267.15	272.15	5	–	3.67	–	–3.23	–	–	300	1.19E–09	9.95E–09	1.19E–05	1.44	8.67	1.61	9.11	
KFM07A	262.14	267.14	5	–	3.61	–	–3.29	–	–	300	1.19E–09	9.95E–09	1.19E–05	1.44	8.63	1.57	8.86	
KFM07A	257.13	262.13	5	–8.08E–08	3.54	8.47E–07	–3.36	1.33E–07	2.94	300	1.19E–09	1.19E–08	1.19E–05	1.44	8.58	1.48	8.76	
KFM07A	252.13	257.13	5	–	3.48	–	–3.43	–	–	300	1.19E–09	1.19E–08	1.19E–05	1.44	8.53	1.61	8.80	
KFM07A	247.13	252.13	5	–	3.41	–	–3.50	–	–	300	1.19E–09	1.19E–08	1.19E–05	1.44	8.48	1.60	8.67	
KFM07A	242.12	247.12	5	–	3.33	–	–3.57	–	–	300	1.19E–09	1.19E–08	1.19E–05	1.43	8.44	1.59	8.63	
KFM07A	237.12	242.12	5	–	3.26	–	–3.65	–	–	300	1.19E–09	1.19E–08	1.19E–05	1.43	8.39	1.56	8.73	
KFM07A	232.12	237.12	5	–	3.21	–	–3.72	–	–	300	1.19E–09	1.19E–08	1.19E–05	1.43	8.35	1.54	8.55	
KFM07A	227.11	232.11	5	–	3.12	–	–3.80	–	–	300	1.19E–09	1.19E–08	1.19E–05	1.43	8.30	1.53	8.55	
KFM07A	222.11	227.11	5	–	3.06	–	–3.87	–	–	300	1.19E–09	1.19E–08	1.19E–05	1.43	8.26	1.52	8.44	

Borehole ID	Secup L (m)	Seclow L (m)	Lw (m)	Q0 (m³/s)	dh0 (m)	Q1 (m³/s)	dh1 (m)	TD (m²/s)	hi (m)	Q-lower limit P (mL/h)	TD-measlLT (m²/s)	TD- measlLP (m²/s)	TD- measlU (m²/s)	ECw0 (S/m)	Tew0 (°C)	ECw1 (S/m)	Tew1 (°C)	Comments
KFM07A	217.11	222.11	5	–	2.98	–	–3.96	–	–	300	1.19E–09	1.19E–08	1.19E–05	1.43	8.21	1.50	8.72	
KFM07A	212.11	217.11	5	–	2.87	–	–4.06	–	–	300	1.19E–09	1.19E–08	1.19E–05	1.43	8.16	1.50	8.72	
KFM07A	207.11	212.11	5	–	2.79	–	–4.13	–	–	100	1.19E–09	3.97E–09	1.19E–05	1.43	8.12	1.49	8.55	
KFM07A	202.11	207.11	5	–	2.70	–	–4.22	–	–	100	1.19E–09	3.97E–09	1.19E–05	1.43	8.07	1.49	8.38	
KFM07A	197.11	202.11	5	–	2.64	–	–4.30	–	–	100	1.19E–09	3.96E–09	1.19E–05	1.43	8.03	1.49	8.21	
KFM07A	192.11	197.11	5	–	2.56	–	–4.38	–	–	50	1.19E–09	1.98E–09	1.19E–05	1.42	8.00	1.49	8.18	
KFM07A	187.11	192.11	5	–	2.49	–	–4.45	–	–	50	1.19E–09	1.98E–09	1.19E–05	1.42	7.98	1.49	8.14	
KFM07A	182.11	187.11	5	–	2.42	–	–4.52	–	–	50	1.19E–09	1.98E–09	1.19E–05	1.43	7.99	1.49	8.11	
KFM07A	177.11	182.11	5	1.57E–06	2.35	2.00E–05	1.23	1.63E–05	2.45	30	7.36E–09	7.36E–09	7.36E–05	1.06	7.96	1.48	8.11	**
KFM07A	172.11	177.11	5	–	2.28	–	–4.68	–	–	30	1.18E–09	1.18E–09	1.18E–05	1.40	7.91	1.46	8.35	
KFM07A	167.11	172.11	5	–	2.21	–	–4.72	–	–	30	1.19E–09	1.19E–09	1.19E–05	1.39	7.82	1.45	8.07	
KFM07A	162.11	167.11	5	–	2.15	–	–4.79	–	–	30	1.19E–09	1.19E–09	1.19E–05	1.39	7.76	1.47	8.20	
KFM07A	157.09	162.09	5	–	2.09	–	–4.85	–	–	30	1.19E–09	1.19E–09	1.19E–05	1.39	7.68	1.47	8.11	
KFM07A	152.08	157.08	5	–	1.99	–	–4.96	–	–	30	1.19E–09	1.19E–09	1.19E–05	1.38	7.63	1.47	8.10	
KFM07A	147.07	152.07	5	–	1.92	–	–5.03	–	–	30	1.19E–09	1.19E–09	1.19E–05	1.39	7.58	1.45	8.13	
KFM07A	142.06	147.06	5	–2.08E–07	1.83	2.19E–05	–5.11	3.16E–06	1.76	30	1.19E–09	1.19E–09	1.19E–05	1.38	7.54	1.19	8.02	
KFM07A	137.05	142.05	5	–	1.77	1.53E–07	–5.17	2.19E–08	–	30	1.19E–09	1.19E–09	1.19E–05	1.38	7.49	1.40	8.13	
KFM07A	132.04	137.04	5	–5.78E–07	1.71	2.14E–05	0.59	1.94E–05	1.68	30	7.36E–09	7.36E–09	7.36E–05	1.38	7.46	1.20	7.76	**
KFM07A	127.03	132.03	5	–	1.65	3.94E–08	–5.29	5.62E–09	–	30	1.19E–09	1.19E–09	1.19E–05	1.38	7.38	1.36	7.85	
KFM07A	122.02	127.02	5	–	1.58	3.11E–06	–5.36	4.43E–07	–	30	1.19E–09	1.19E–09	1.19E–05	1.36	7.32	1.03	7.66	
KFM07A	117.01	122.01	5	4.92E–07	1.53	8.61E–05	–0.35	4.50E–05	1.54	30	1.27E–09	1.27E–09	1.27E–05	1.15	7.23	0.86	7.47	**
KFM07A	112.00	117.00	5	5.94E–07	1.44	2.42E–05	0.30	2.05E–05	1.47	30	7.23E–09	7.23E–09	7.23E–05	0.98	7.17	0.73	7.38	**
KFM07A	107.00	112.00	5	4.78E–08	1.41	2.06E–06	0.27	1.74E–06	1.44	30	1.17E–09	1.17E–09	1.17E–05	1.03	7.16	0.89	7.47	**
KFM07A	101.99	106.99	5	–	1.38	–	–5.72	–	–	30	1.16E–09	1.16E–09	1.16E–05	1.02	7.13	0.90	7.44	
KFM07A	96.99	101.99	5	–	1.35	–	–5.76	–	–	30	1.16E–09	1.16E–09	1.16E–05	0.93	7.14	0.90	7.47	

** Values from measurement with decreased drawdown (original pumped flow rate was over the upper measurement limit)


Forsmark, borehole KFM07A
Flow rates of 5 m sections
Without pumping
2005-01-19 - 2005-01-22
With pumping
2005-01-23 - 2005-01-24
With smaller pumping
2005-01-28 - 2005-01-29
(original value over measurement limit)
Theoretical minimum measurable flow rate
Practical minimum measurable flow rate
Theoretical maximum measurable flow rate
Length (m)
0
50
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 KFM07A
Transmissivity and head of 5 m sections
Formation head
Head in the borehole without pumping 2005-01-19 - 2005-01-22
Head in the borehole with pumping 2005-01-23 - 2005-01-24
Head in the borehole with smaller pumping 2005-01-28 - 2005-01-29
Transmissivity (T)
Theoretical minimum measurable T
Practical minimum measurable T
Theoretical maximum measurable T
Length (m)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
-6
-4
-2
0
2
4
6
8
10
12
14
16
18
Head (masl, RHB 70)
1E-010
1E-009
1E-008
1E-007
1E-006
1E-005
1E-004
Transmissivity (m2/s)

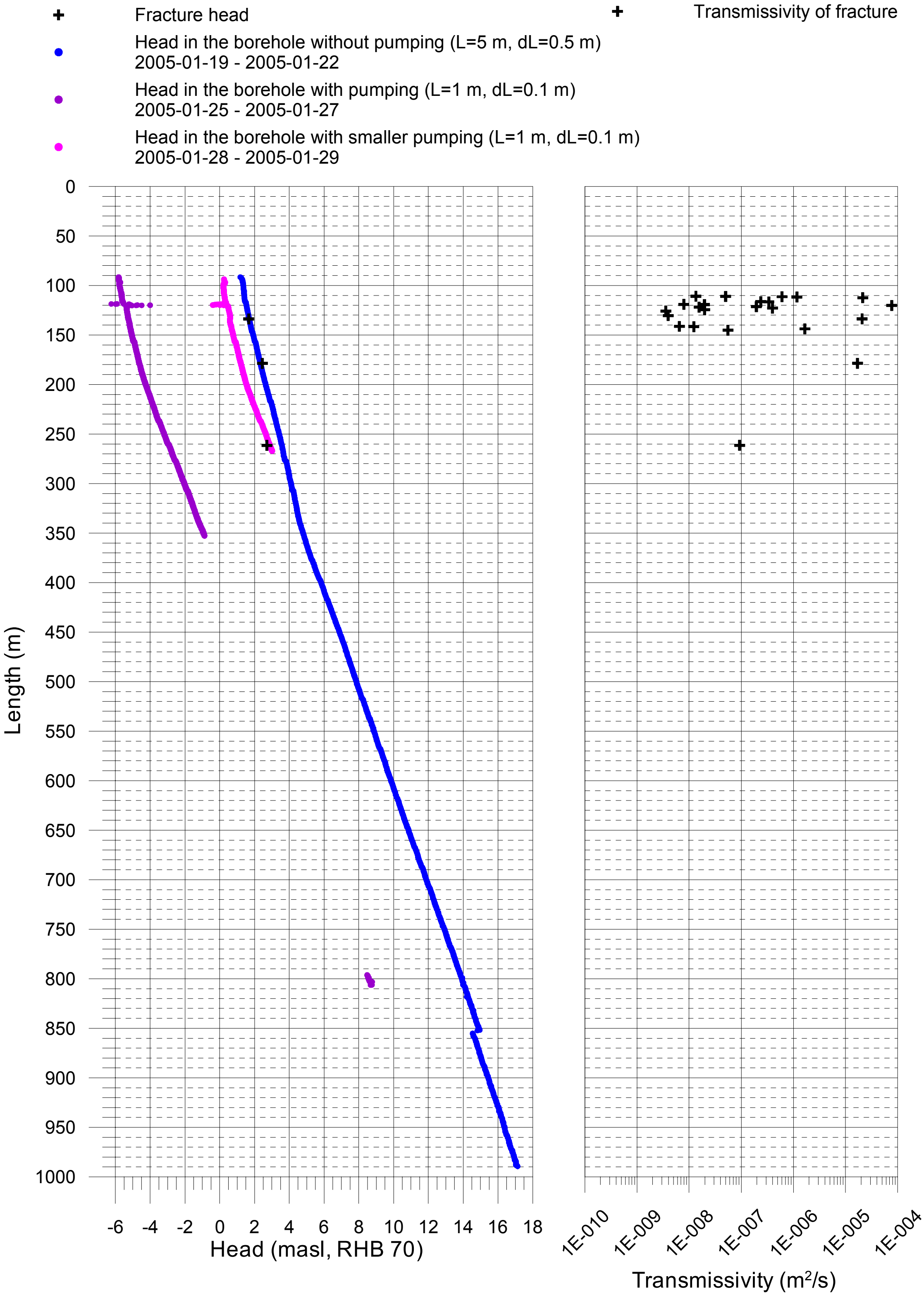
Table of transmissivity and head of detected fractures.

Borehole ID	Length to flow anom. L (m)	Lw (m)	dL (m)	Q0 (m^3/s)	dh0 (m)	Q1 (m^3/s)	dh1 (m)	TD (m^2/s)	hi (m)	Comments
KFM07A	110.8	1.0	0.1	–	1.41	1.56E–08	0.27	1.35E–08	–	*, **
KFM07A	111.0	1.0	0.1	–	1.42	5.83E–08	0.27	5.02E–08	–	**
KFM07A	111.3	1.0	0.1	–	1.42	6.94E–07	0.28	6.03E–07	–	**
KFM07A	111.6	1.0	0.1	–	1.42	1.33E–06	0.29	1.17E–06	–	**
KFM07A	112.4	1.0	0.1	–	1.43	2.47E–05	0.29	2.14E–05	–	**
KFM07A	116.3	1.0	0.1	–	1.45	2.72E–07	0.31	2.36E–07	–	*, **
KFM07A	116.6	1.0	0.1	–	1.46	3.89E–07	0.32	3.37E–07	–	**
KFM07A	119.1	1.0	0.1	–	1.53	1.36E–08	–0.17	7.92E–09	–	*, **
KFM07A	119.3	1.0	0.1	–	1.53	3.61E–08	–0.28	1.97E–08	–	**
KFM07A	120.2	1.0	0.1	–	1.53	8.61E–05	0.42	7.67E–05	–	**
KFM07A	121.3	1.0	0.1	–	1.55	2.11E–07	0.48	1.95E–07	–	**
KFM07A	121.8	1.0	0.1	–	1.55	1.67E–08	0.49	1.56E–08	–	*, **
KFM07A	122.8	1.0	0.1	–	1.57	2.78E–06	–5.36	3.96E–07	–	
KFM07A	124.5	1.0	0.1	–	1.58	1.39E–07	–5.36	1.98E–08	–	
KFM07A	125.8	1.0	0.1	–	1.60	2.50E–08	–5.33	3.57E–09	–	
KFM07A	130.4	1.0	0.1	–	1.65	2.78E–08	–5.29	3.96E–09	–	
KFM07A	133.7	1.0	0.1	–5.83E–07	1.70	2.28E–05	0.59	2.08E–05	1.67	**
KFM07A	141.2	1.0	0.1	–	1.79	4.58E–08	–5.17	6.51E–09	–	*
KFM07A	141.5	1.0	0.1	–	1.79	8.61E–08	–5.16	1.23E–08	–	
KFM07A	143.8	1.0	0.1	–	1.81	1.17E–05	–5.13	1.66E–06	–	
KFM07A	145.1	1.0	0.1	–	1.83	3.89E–07	–5.11	5.54E–08	–	
KFM07A	178.5	1.0	0.1	2.00E–06	2.34	2.14E–05	1.21	1.70E–05	2.46	**
KFM07A	261.4	1.0	0.1	–8.06E–08	3.57	5.28E–07	–2.92	9.27E–08	2.71	
KFM07A	916.3	1.0	0.1	–	15.74	–	–	–	–	*
KFM07A	917.2	1.0	0.1	–	15.76	–	–	–	–	*
KFM07A	970.0	1.0	0.1	–3.61E–07	16.73	–	–	–	–	

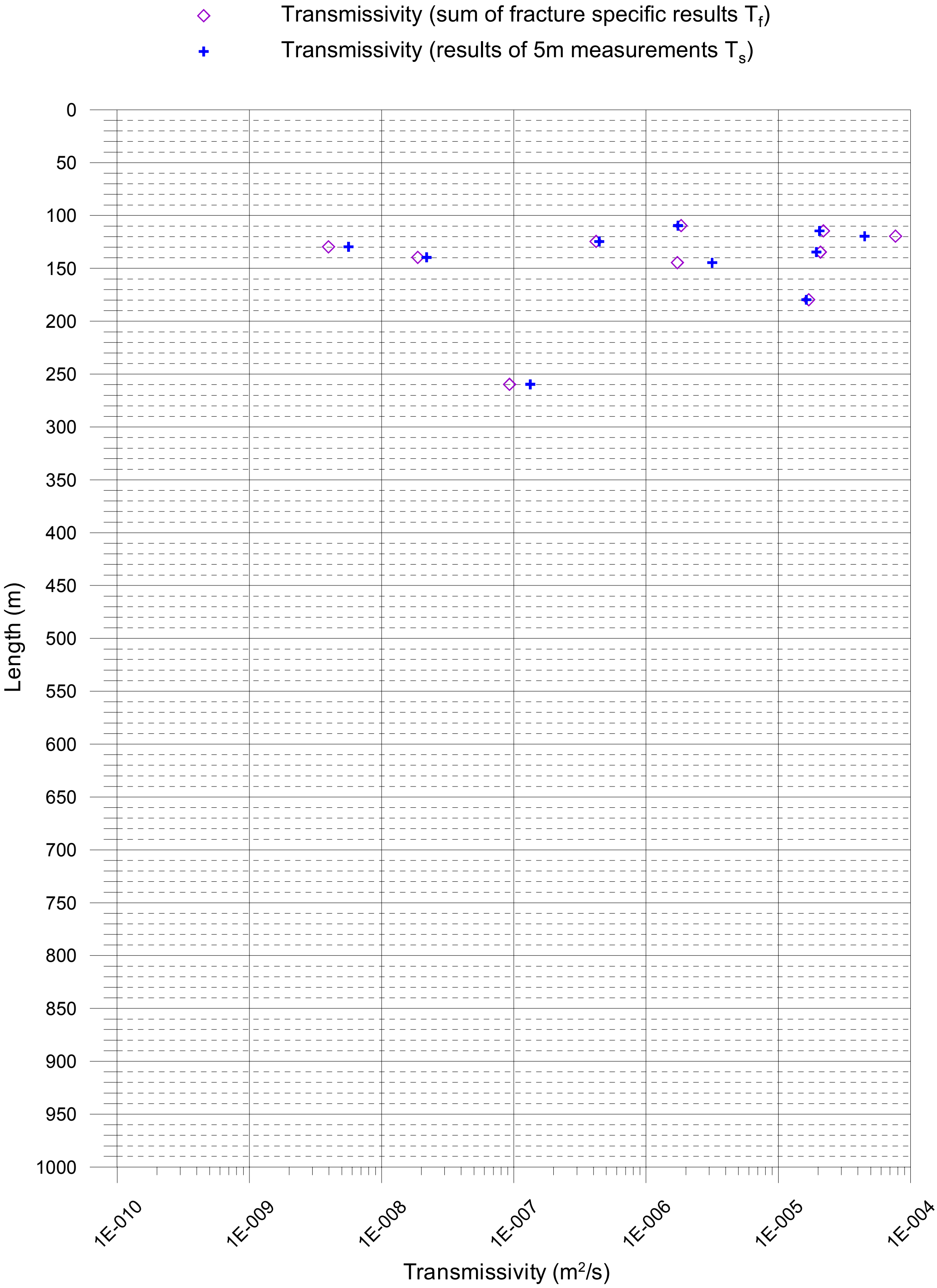
* Uncertain = The flow rate is less than 30 mL/h or the flow anomalies are overlapping or they are unclear because of noise.

** Values from the measurement with smaller pumping (original pumped flow over measurement limit or anomaly unclear because of noise).

Forsmark, borehole KFM07A
Transmissivity and head of detected fractures

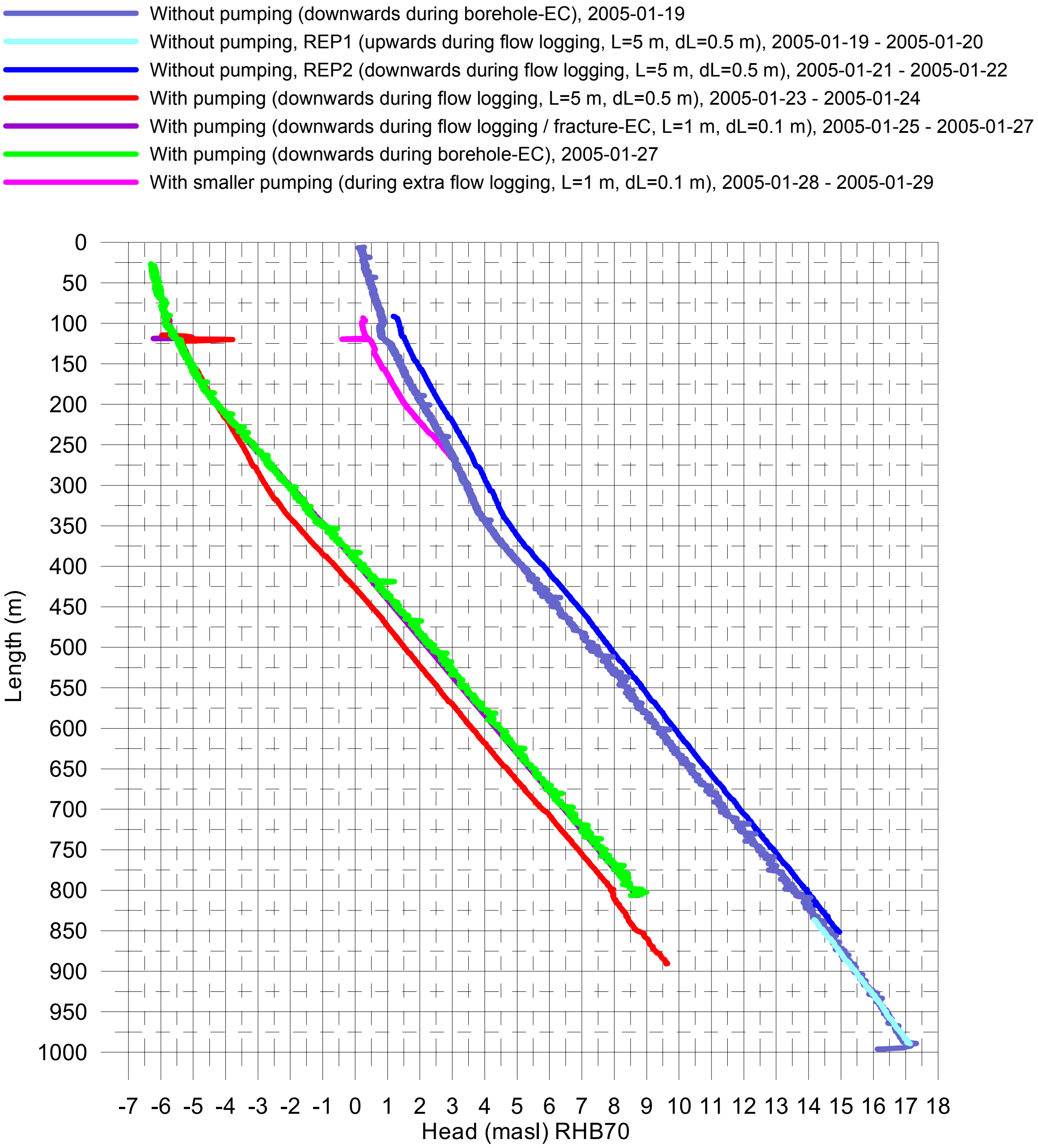


Forsmark, borehole KFM07A
Comparison between section transmissivity and fracture transmissivity

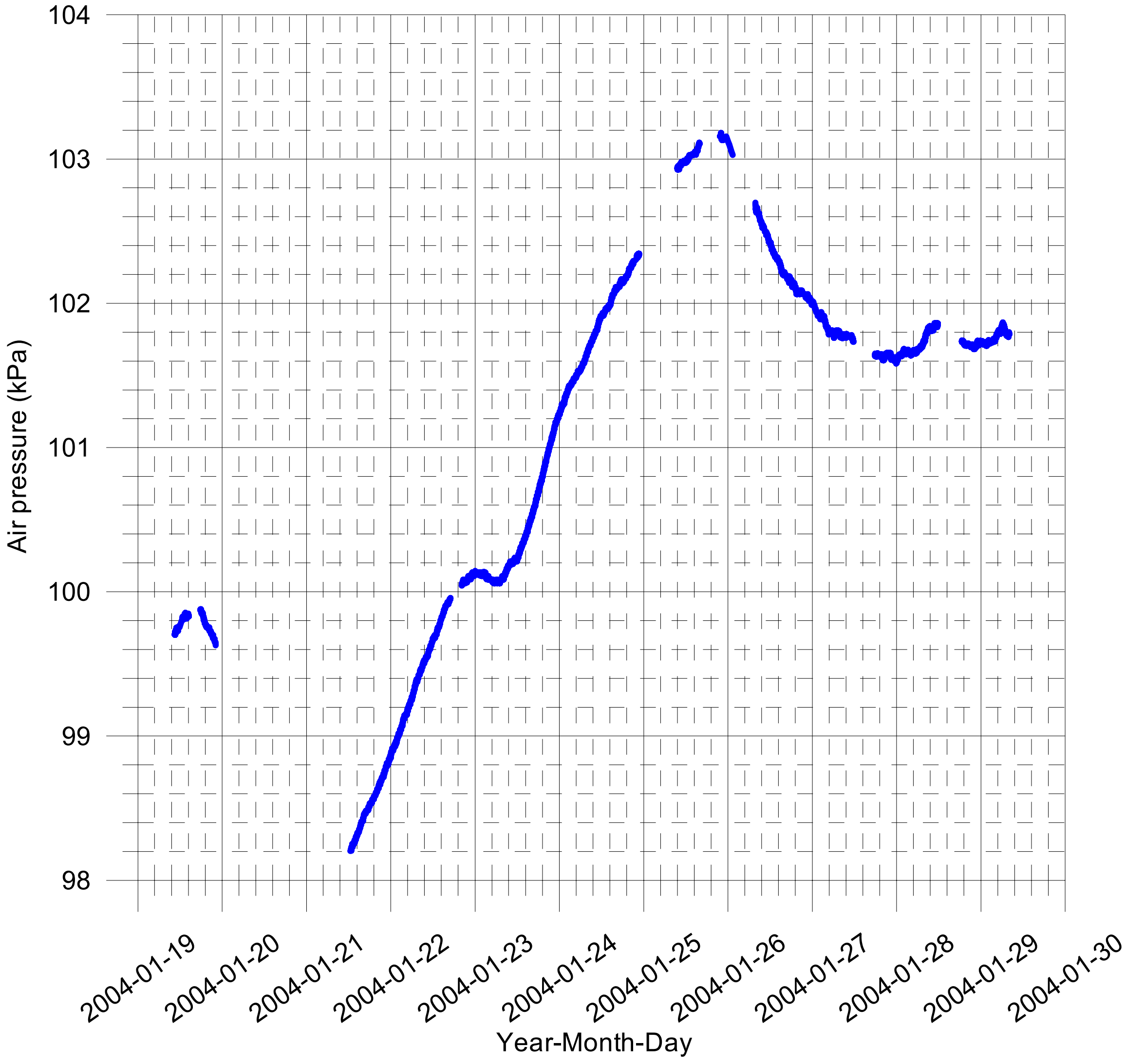


Forsmark, borehole KFM07A
Head in the borehole during flow logging

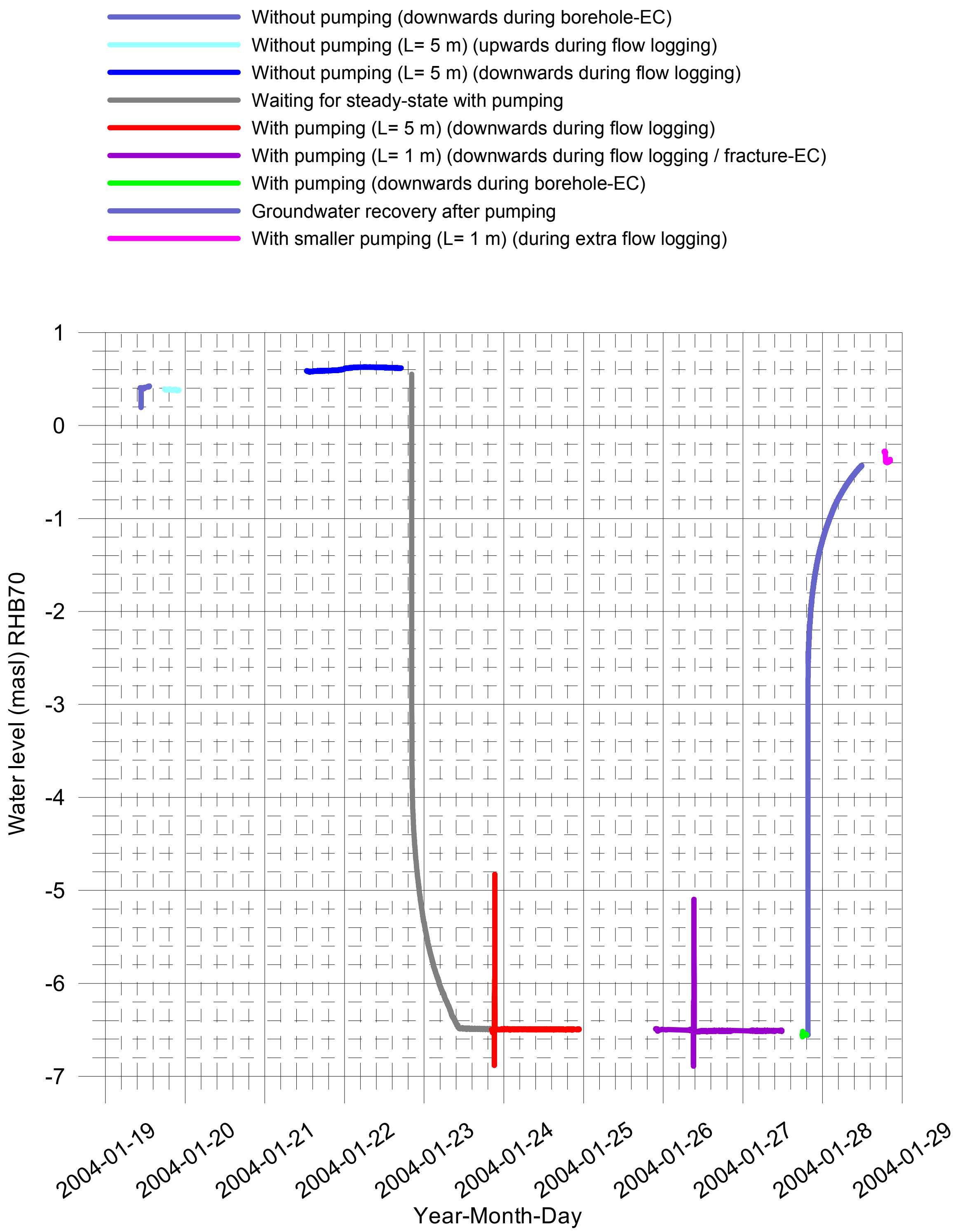
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m^3 * 9.80665 m/s^2) + Elevation (m)
Offset = 2460 Pa (sensor 05) and 12600 Pa (sensor 02) (Correction for absolut pressure sensor)



Forsmark, borehole KFM07A
Air pressure during flow logging
2005-01-19 - 2005-01-29

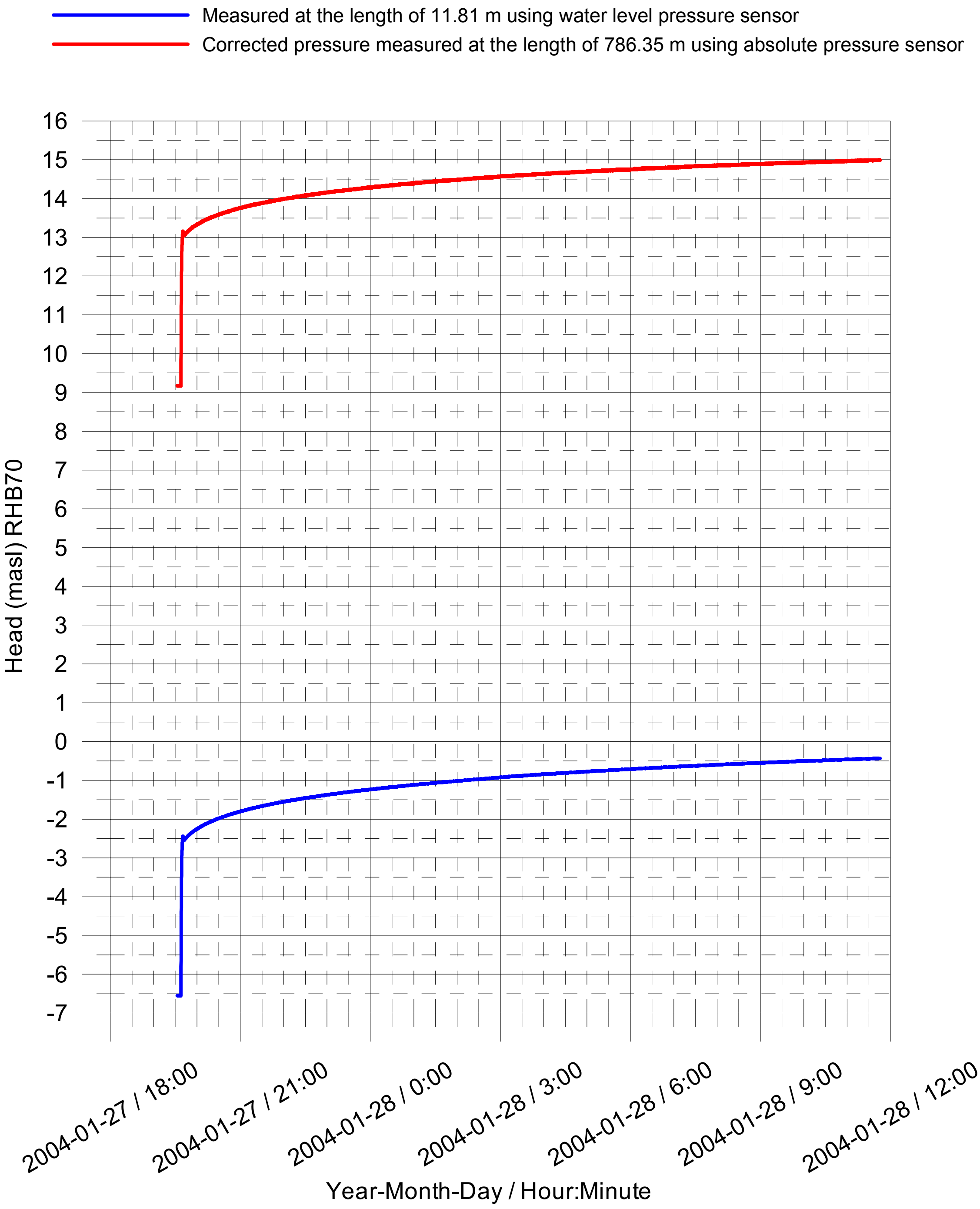


Forsmark, borehole KFM07A
Water level in the borehole during flow logging

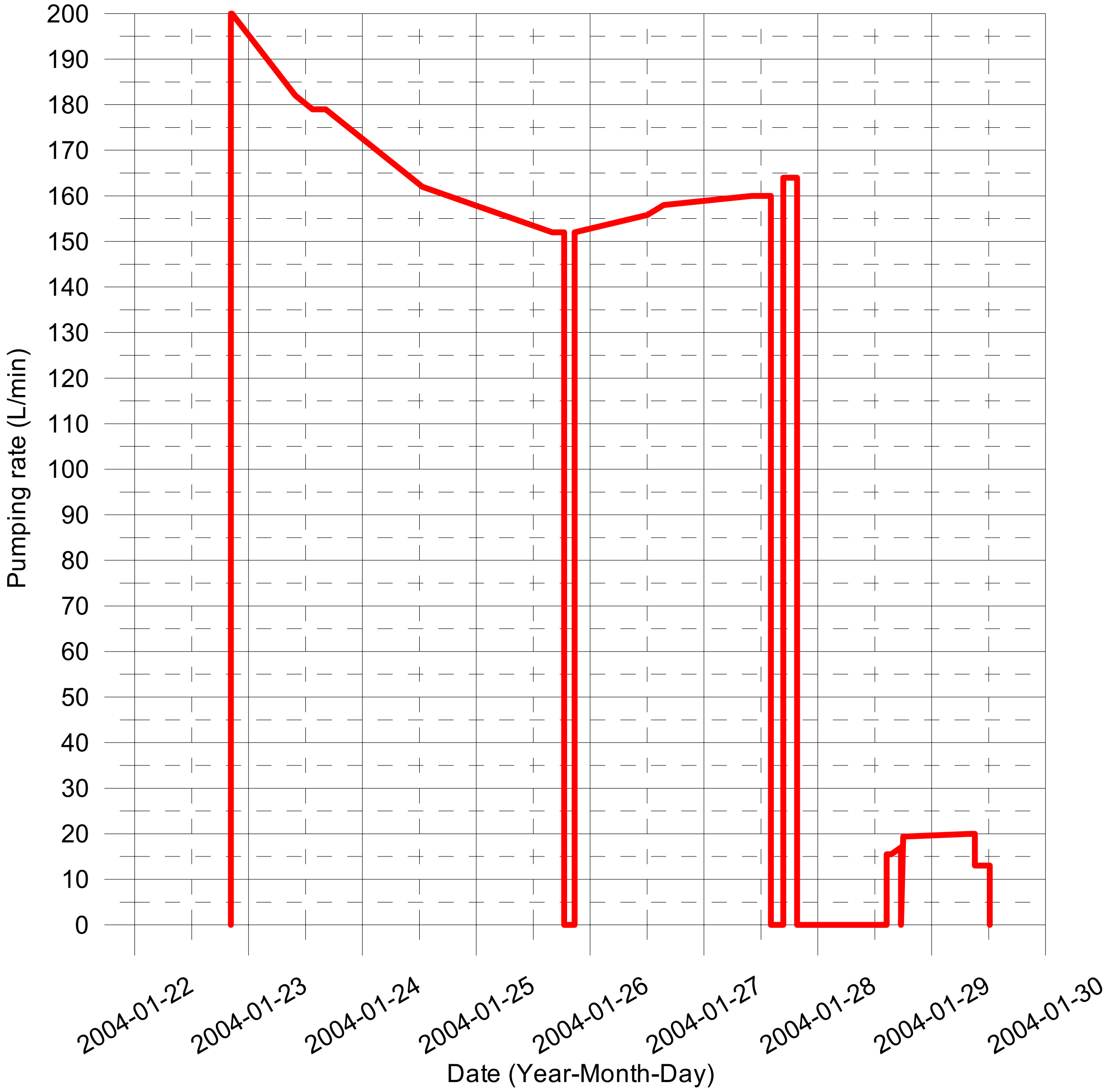


Forsmark, borehole KFM07A
Groundwater recovery after pumping

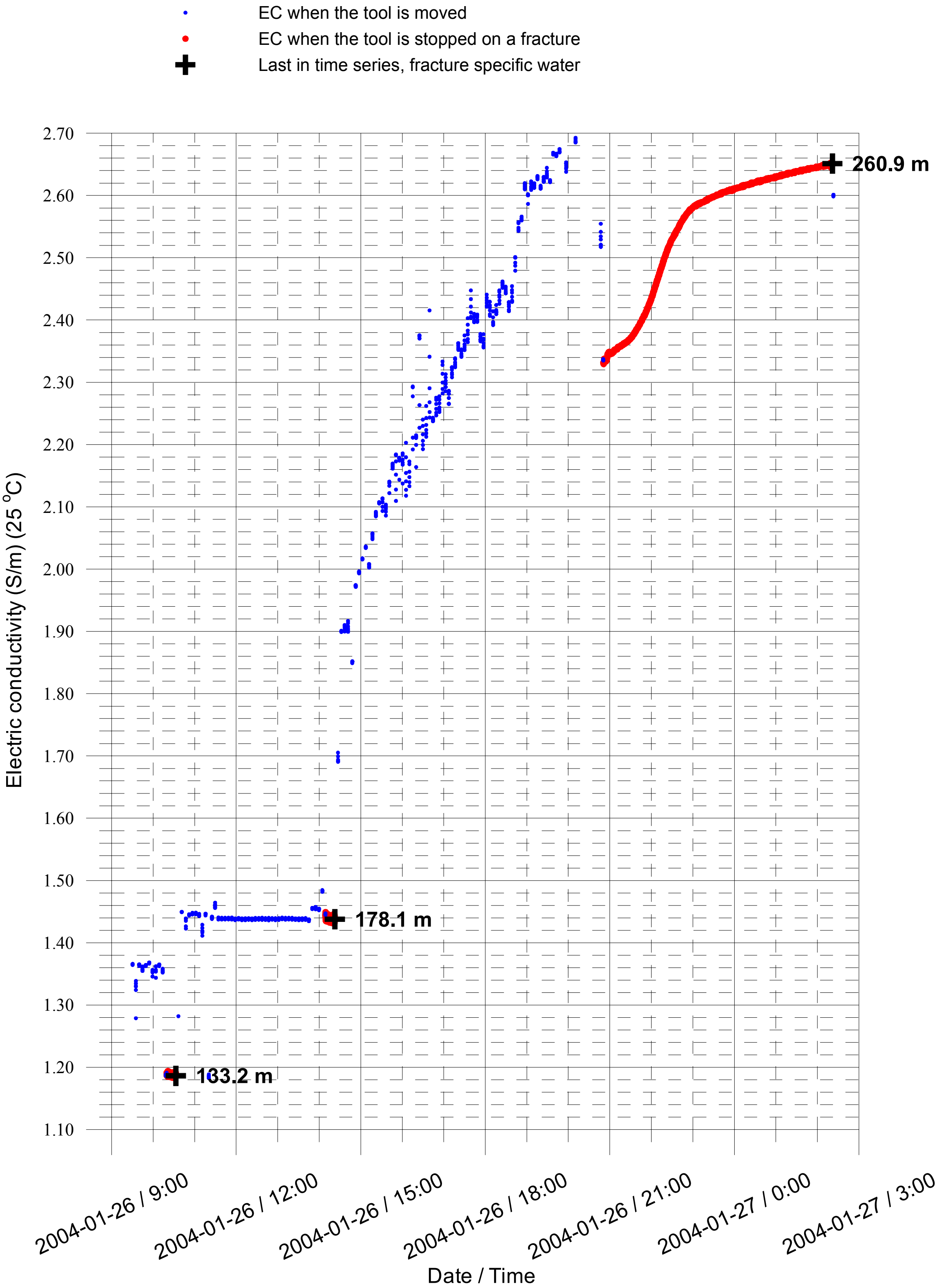
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m^3 * 9.80665 m/s^2) + Elevation (m)
Offset = 2460 Pa (sensor 05) and 12600 Pa (sensor 02) (Correction for absolut pressure sensor)



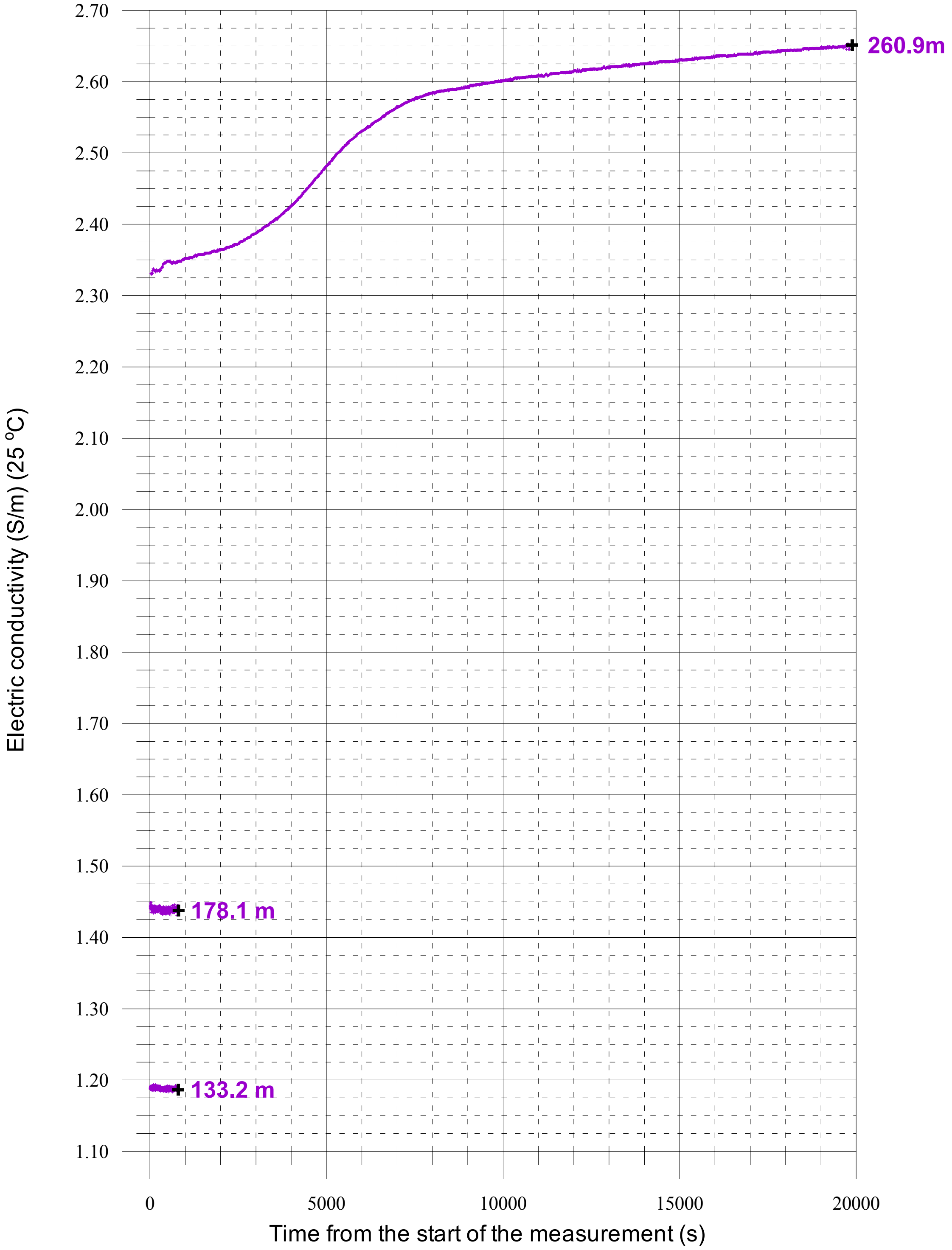
Forsmark, borehole KFM07A
Pumping rate during flow logging



Forsmark, KFM07A
Fracture-specific EC results by date



Forsmark, borehole KFM07A
Time series of fracture-specific EC
2005-01-26 - 2005-01-27



Forsmark, borehole KFM07A

Test data diagrams from pumping test during difference flow logging

Nomenclature used in the test data diagrams from Aqtesolv:

T = transmissivity (m^2/s)

S = storativity (-)

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

S_w = skin factor

r(w) = borehole radius (m)

r(c) = effective casing radius (m)

C = well loss constant (set to 0)

Diagrams presented

Flow period (log-log and lin-log

Recovery period (log-log and lin-log)

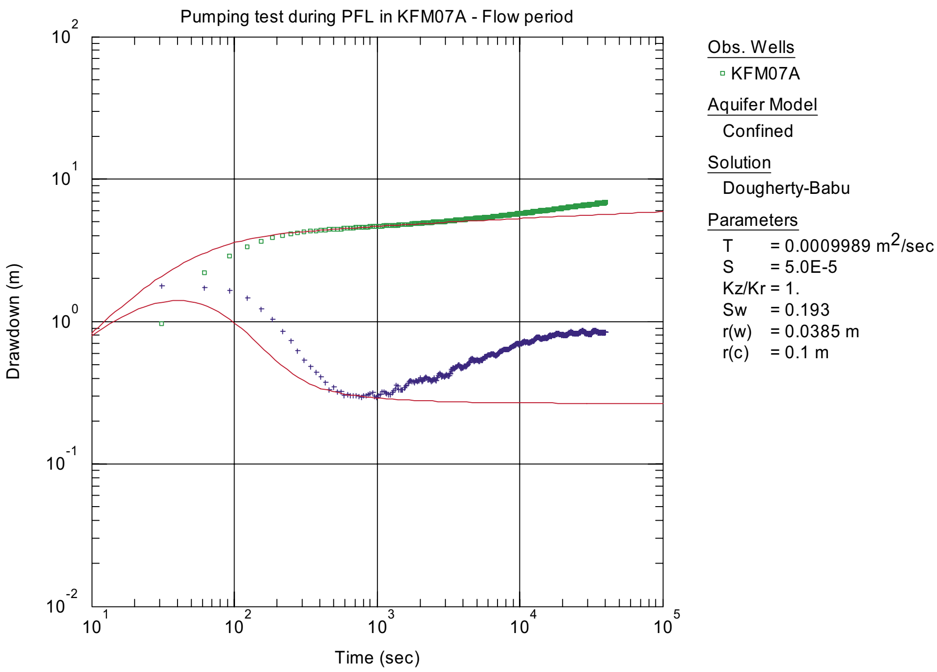


Figure A12-1. *Log-log plot of measured (green) and simulated (red) pressure drawdown and – derivative (blue) versus time during the first phase of the flow period of the pumping test in KFM07A. Evaluation based on the first PRF regime.*

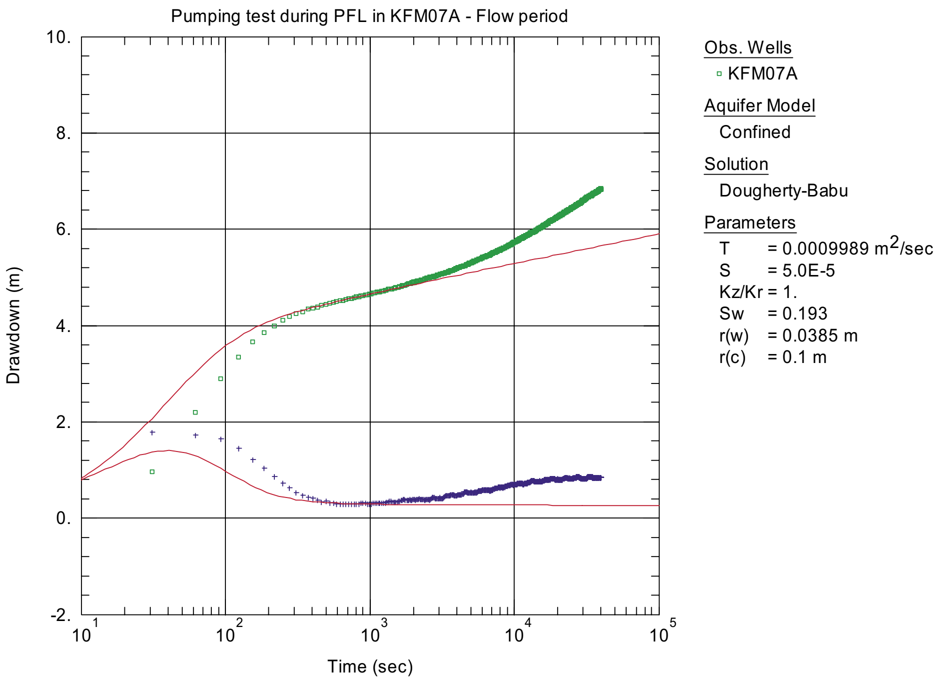


Figure A12-2. *Lin-log plot of measured (green) and simulated (red) pressure drawdown and – derivative (blue) versus time during the first phase of the flow period of the pumping test in KFM07A. Evaluation based on the first PRF regime.*

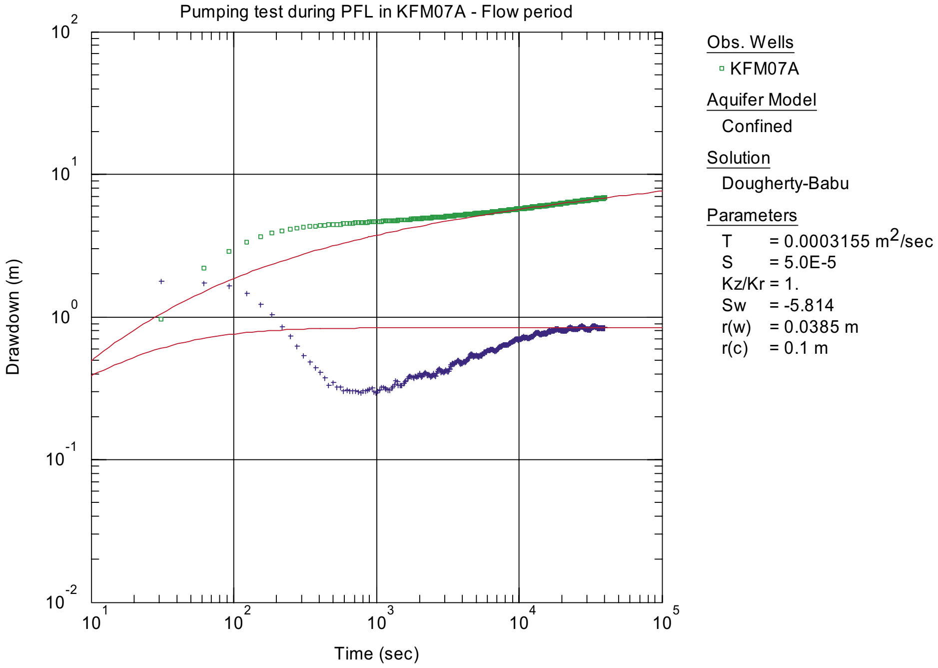


Figure A12-3. *Log-log plot of measured (green) and simulated (red) pressure drawdown and – derivative (blue) versus time during the first phase of the flow period of the pumping test in KFM07A. Evaluation based on the second PRF regime.*

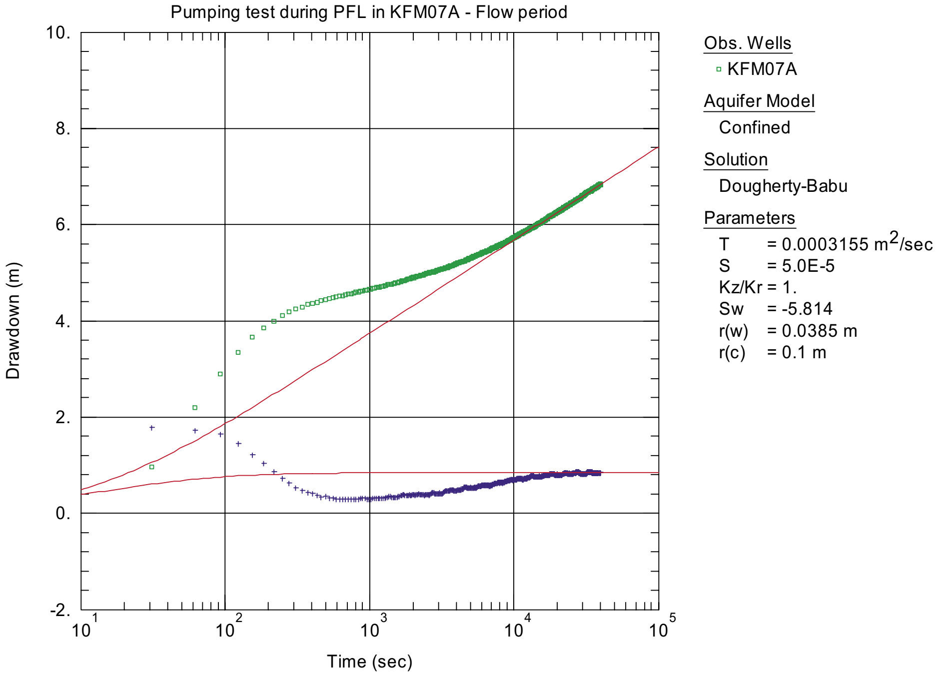


Figure A12-4. *Lin-log plot of measured (green) and simulated (red) pressure drawdown and – derivative (blue) versus time during the first phase of the flow period of the pumping test in KFM07A. Evaluation based on the second PRF regime.*

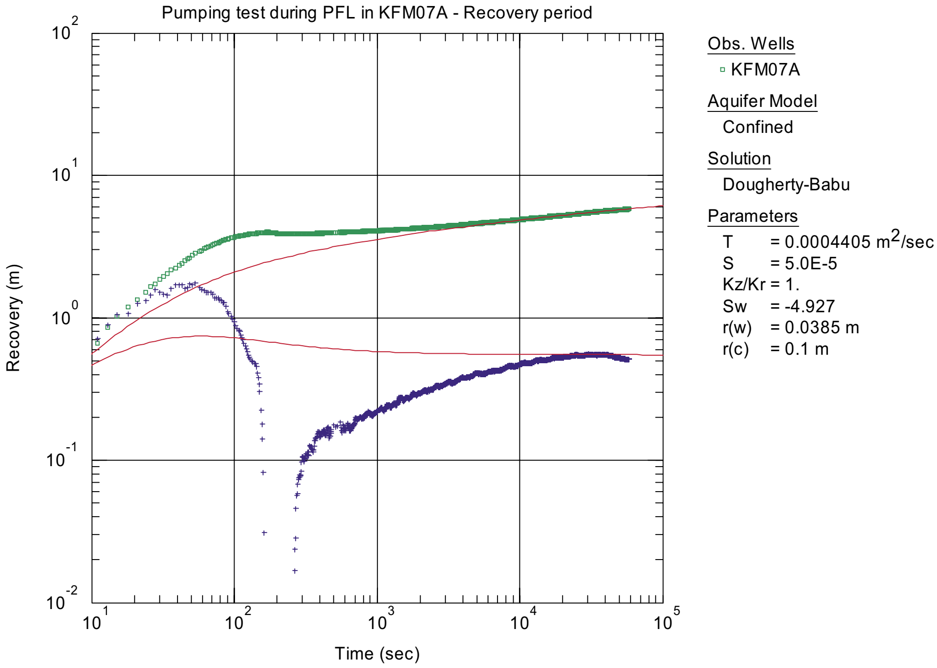


Figure A12-5. *Log-log plot of measured (green) and simulated (red) pressure recovery and – derivative (blue) versus time during the pumping test in borehole KFM07A. Evaluation based on the second PRF regime.*

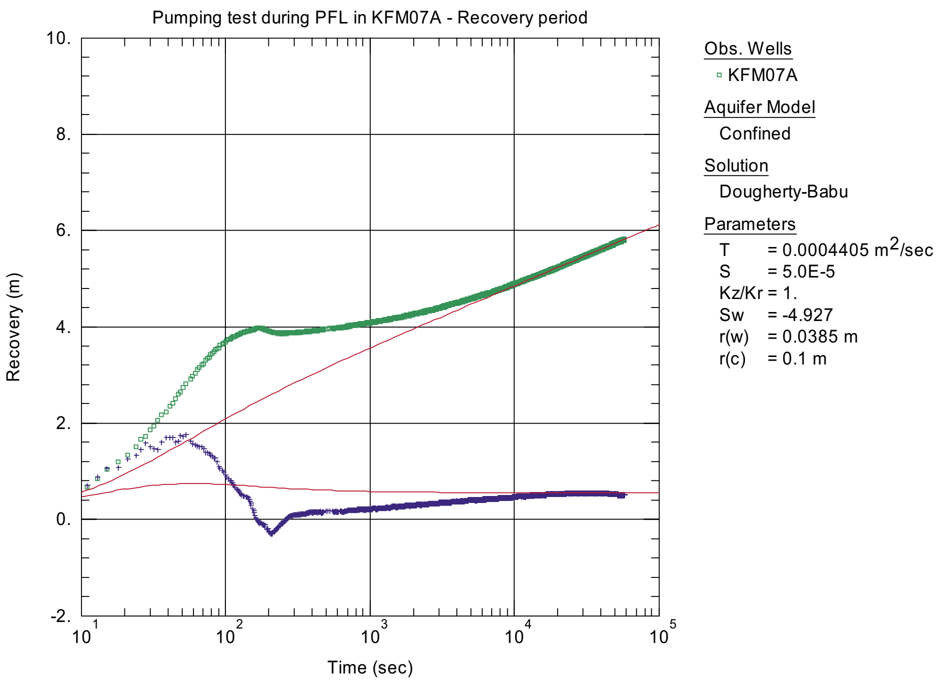


Figure A12-6. *Lin-log plot of measured (green) and simulated (red) pressure recovery and – derivative (blue) versus time during the pumping test in borehole KFM07A. Evaluation based on the second PRF regime.*