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Oskarshamn site investigation

Difference flow logging in borehole KLX06

Subarea Laxemar

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PRG-Tec Oy

April 2005

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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 KLX06 at Oskarshamn, Sweden, in February and March 2005, using Posiva flow log. The primary aim of the measurements was to determine the position and flow rate of flow yielding fractures in borehole KLX06.

The flow rate into or out of a 5 m long test section was measured between 96.33–987.52 m borehole lengths during natural (un-pumped) as well as pumped conditions. The flow measurements were repeated at the location of the detected flow anomalies using a 1 m long test section, successively transferred with an overlapping of 0.1 m.

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

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

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

Sammanfattning

Differensflödesloggning är en snabb metod för bestämning av transmissiviteten och hydraulisk head i borrhålssektioner och sprickor /sprickzoner i kärnborrhål. Denna rapport presenterar huvudprinciperna för metoden och resultat av mätningar utförda i borrhål KLX06 i Oskarshamn, Sverige, i februari och mars 2005 med Posiva flödesloggningsmetod. Det primära syftet med mätningarna var att bestämma läget och flödet för vattenförande sprickor i borrhål KLX06.

Flödet till eller från en 5 m lång testsektion mättes mellan 96,33–987,52 m borrhålslängd under såväl naturliga (icke-pumpade) som pumpade förhållanden. Flödesmätningarna upprepades vid lägena för de detekterade flödesanomalierna med en 1 m lång testsektion som förflyttades successivt med 0,1 m.

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

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

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

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1 Introduction

This document reports the results gained by the difference flow logging, which is one of the activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with activity plan AP PS 400-04-116. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

The difference flow logging in the core drilled borehole KLX06 at Oskarshamn was conducted between February 8–March 1, 2005. The borehole is inclined c. 65° from the horizontal direction, c. 995 m long and performed with a telescopic drilling technique. The interval 0–100.30 m is percussion drilled. The interval 0–9.10 m is cased with the inner diameter 310 mm and the interval 9.10–11.88 is cased with the inner diameter 200 mm. The interval 11.88–100.30 is drilled with the diameter 195 mm. The interval 101.88–994.94 m is core drilled with the diameter 76 mm. The location of borehole KLX06 at the drill site within the Oskarshamn area is shown in Figure 1-1.

The field work and the subsequent interpretation were conducted by PRG-Tec Oy. The Posiva Flow Log/Difference Flow method has previously been employed in Posiva's site characterisation programme in Finland as well as at the Äspö Hard Rock Laboratory at Simpevarp, Sweden.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	**Number**	**Version**
Difference flow logging in borehole KLX06	AP PS 400-04-116	1.0
Method descriptions	**Number**	**Version**
Method description for difference flow logging	SKB MD 322.010	1.0
Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning	SKB MD 600.004	
Instruktion för längdkalibrering vid undersökningar i kärnborrhål	SKB MD 620.010	
Instruktion för analys av injektions- och enhålspump-tester	SKB MD 320.004	

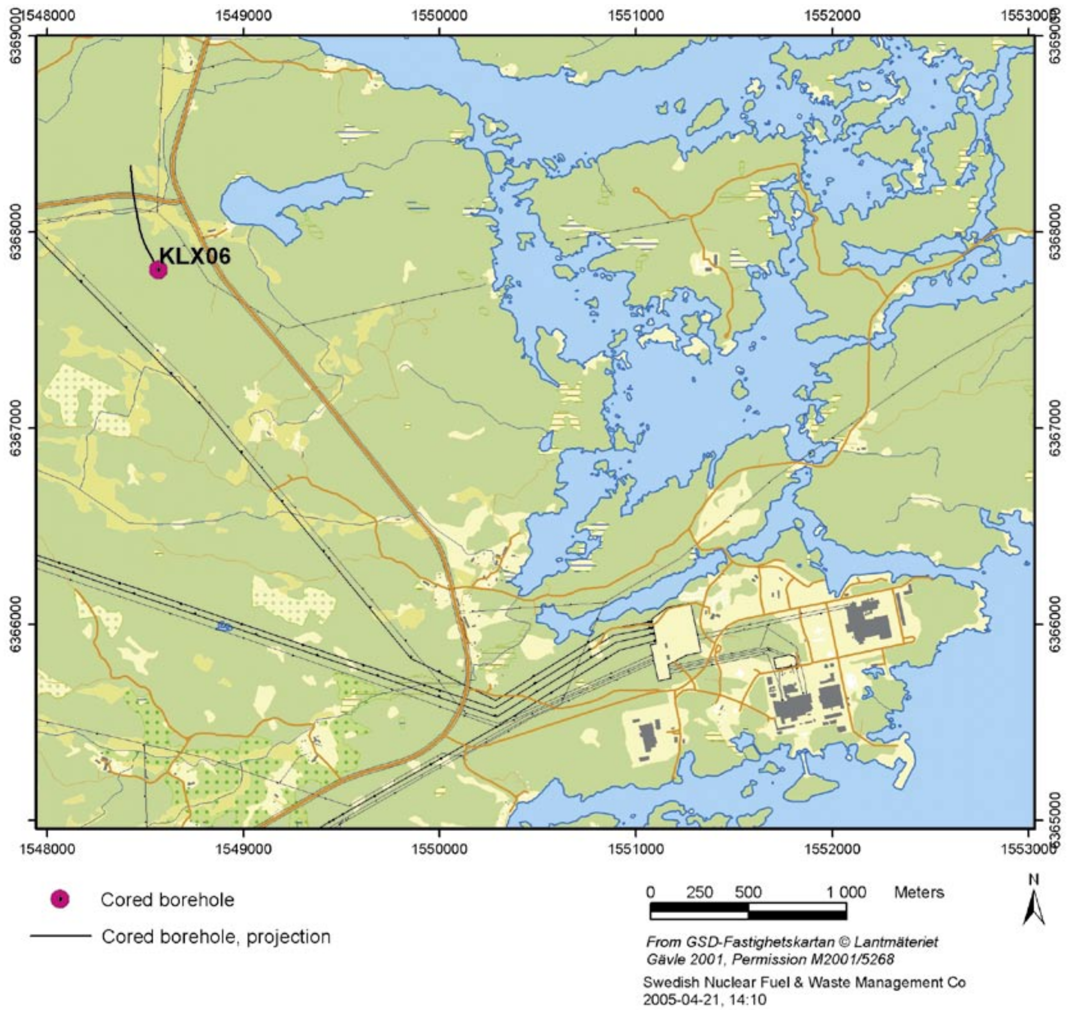


Figure 1-1. *Site map showing the location of borehole KLX06 situated in the subarea of Laxemar.*

2 Objective and scope

The main objective of the difference flow logging in KLX06 was to identify water-conductive sections/fractures, secondly the results are utilised for selecting suitable sections along the borehole for the subsequent water sampling. These aim at a hydrogeological characterisation, including the prevailing water flow balance in the borehole 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 measuring programme also included supporting measurements, performed for a better understanding of the overall hydrogeochemical conditions. These measurements included single-point resistance of the borehole wall and also the electric conductivity was measured for a number of selected high transmissive fractures in the borehole. Furthermore, the recovery of the groundwater level after pumping was registered and interpreted hydraulically.

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

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

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 rate in the test section from the flow rate in the rest of the borehole, see Figure 3-1. The flow rate along the borehole outside the isolated test section passes through the test section by means of a bypass pipe and is discharged at the upper end of the downhole tool.

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

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

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

All of the above measurements were performed in KLX06.

The principles of difference flow measurements are described in Figures 3-3 and 3-4. The flow sensor consists of three thermistors, see Figure 3-3a. The central thermistor, A, is used both as a heating element and for 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 thermal dilution transient 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 the 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 are theoretical lowest measurable values. Depending on the borehole conditions these limits may not always prevail. Examples of disturbing conditions are suspended 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.

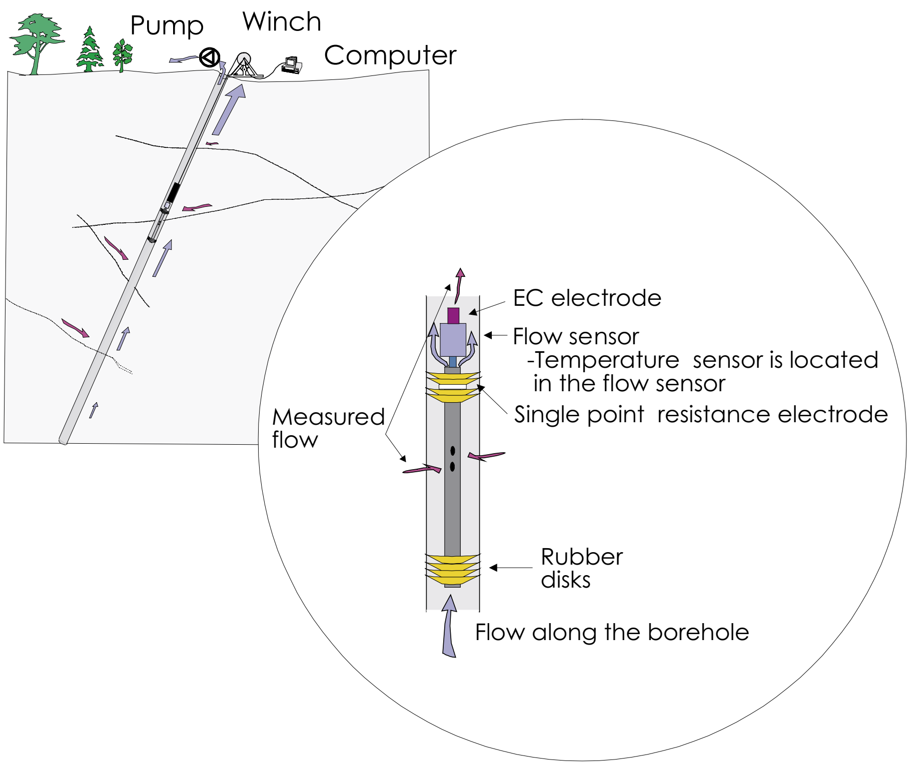


Figure 3-1. *Schematic of the downhole equipment used in the Difference flowmeter.*

Table 3-1. Ranges of flow measurement.

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

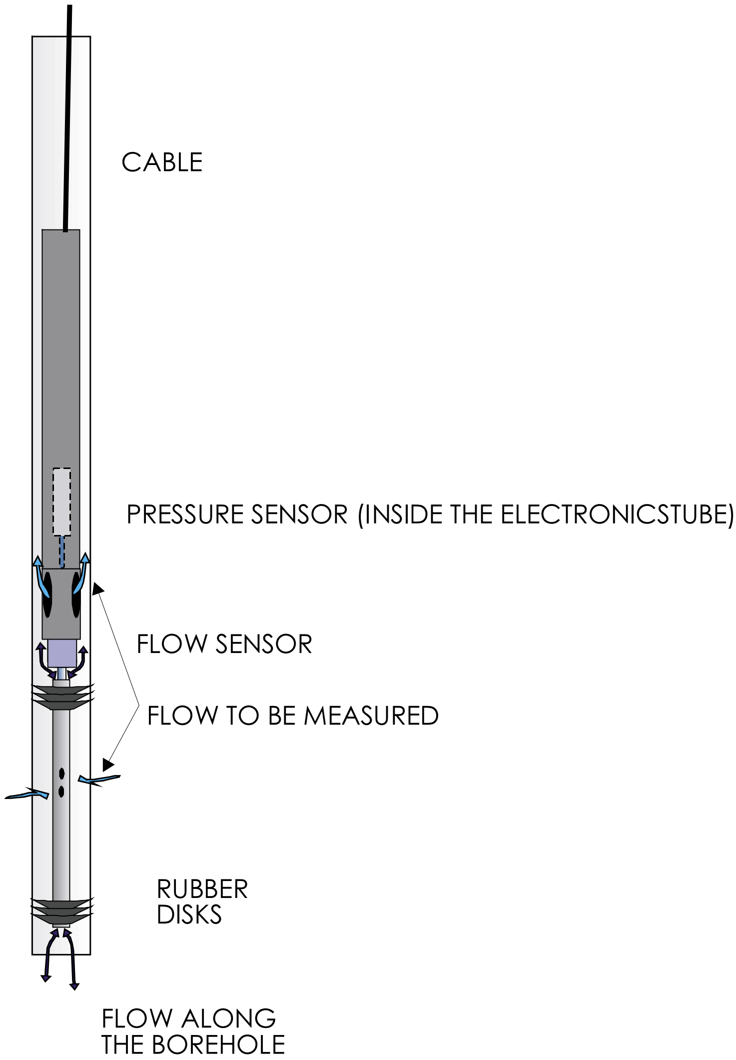


Figure 3-2. *The absolute pressure sensor is located inside the electronics tube and connected through a tube to the borehole water.*

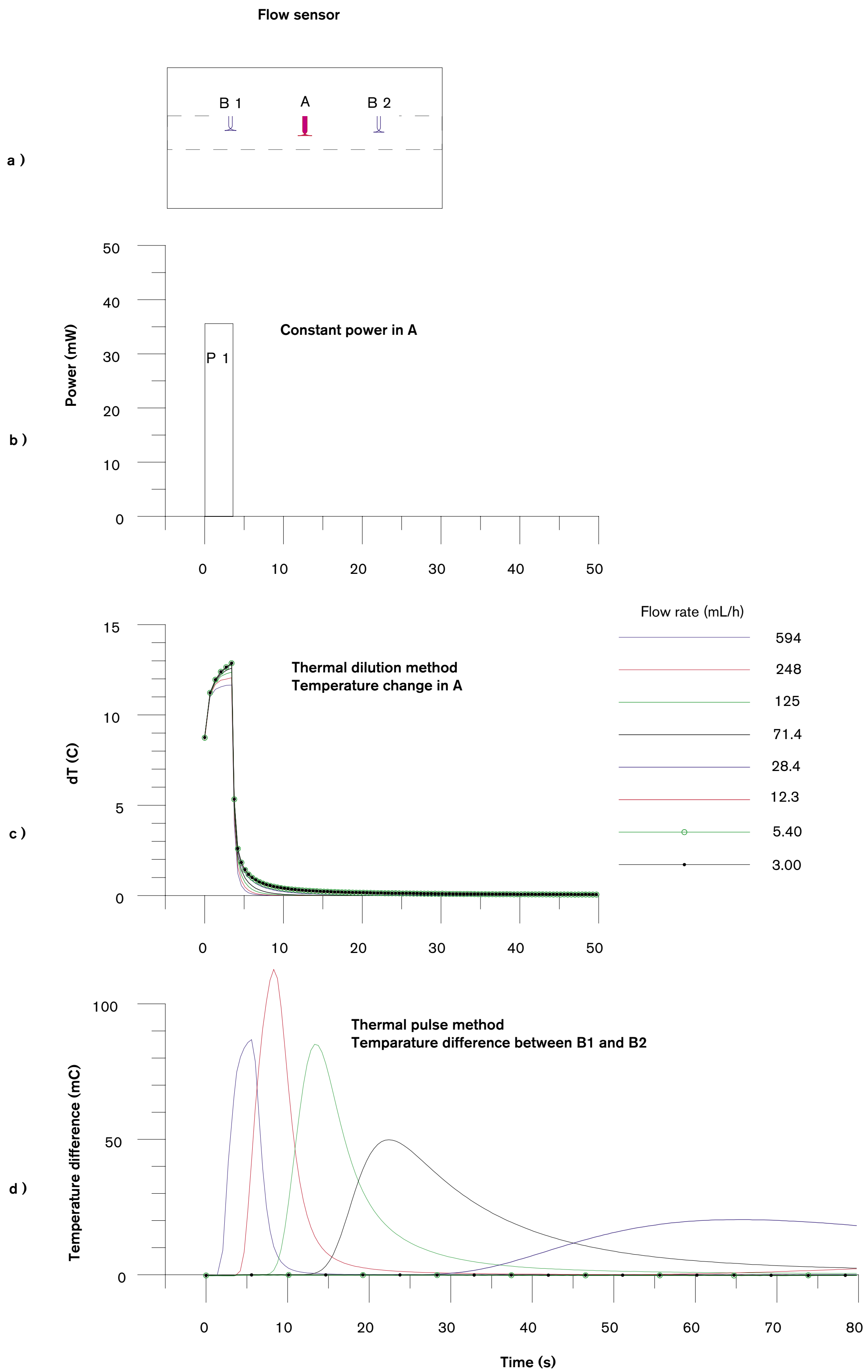


Figure 3-3. *Flow measurement, flow rate < 600 mL/h.*

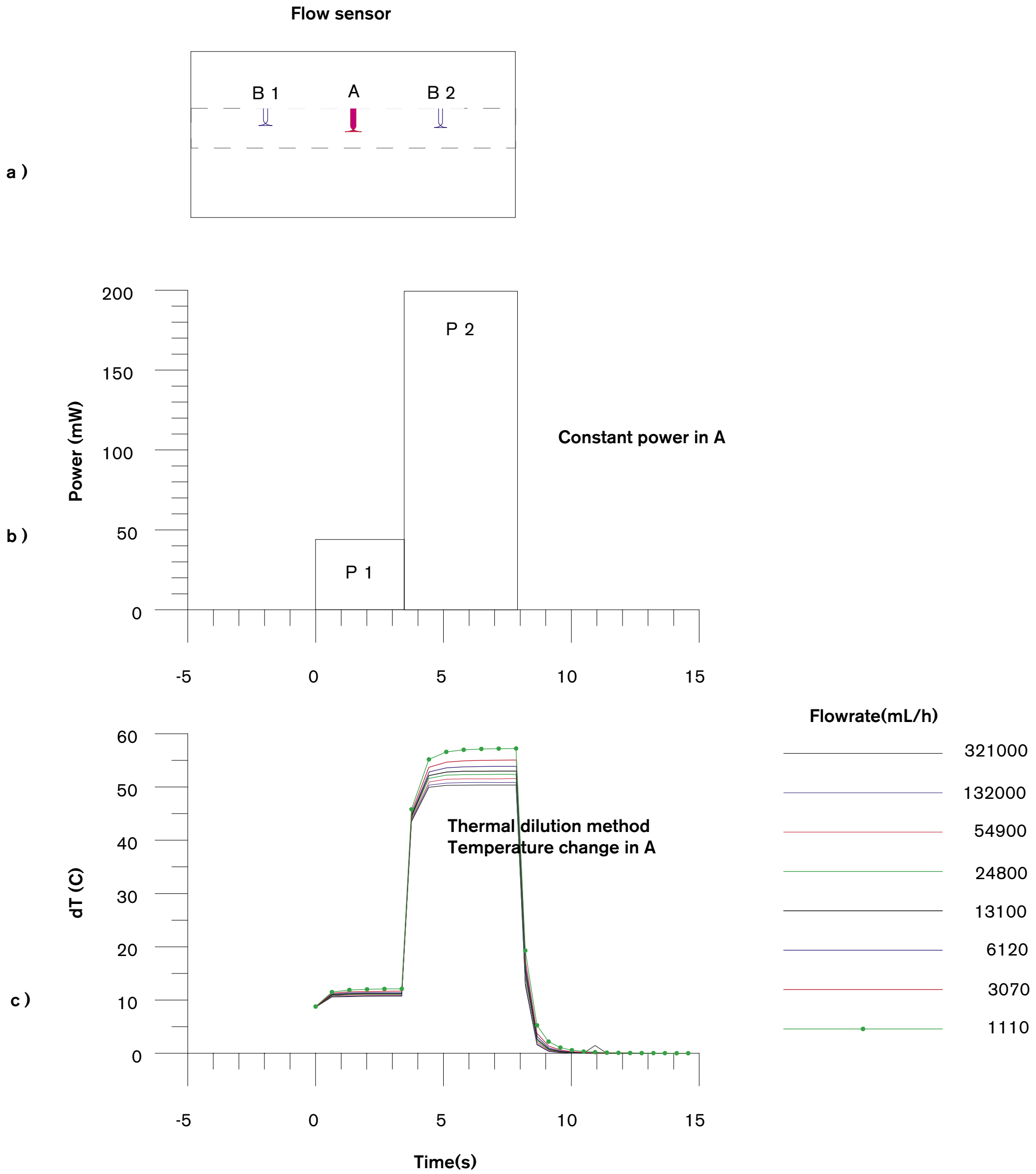


Figure 3-4. *Flow measurement, flow rate > 600 mL/h.*

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:

$$Q_{s_0} = T_s \cdot a \cdot (h_s - h_0) \qquad 3\text{-}3$$

$$Q_{s_1} = T_s \cdot a \cdot (h_s - h_1) \qquad 3\text{-}4$$

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 h_s is not known and must be assumed. Here a value of 500 is selected for the quotient R/r_0.

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

$$h_s = (h_0 - b \cdot h_1)/(1-b) \qquad 3\text{-}5$$

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

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).

$h_f = (h_0\text{-b } h_1)/(1\text{-b})$ 3-7

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

Transmissivity of the entire borehole can be evaluated in several ways using the data of the pumping phase and of the recovery phase. The assumptions above (cylindrical and steady state flow) leads to Dupuits formula /Marsily, 1986/:

$$T = \frac{Q}{s2\pi}\ln\left(\frac{R}{r_0}\right) \qquad 3\text{-}9$$

where

s is drawdown and

Q is the pumping rate at the end of the pumping phase.

In the Moye /Moye, 1967/ formula it is assumed the steady state flow is cylindrical near the borehole (to distance r = L/2, where L is the section under test) and spherical further away:

$$T = \frac{Q}{s2\pi}\cdot\left[1+\ln\left(\frac{L}{2r_0}\right)\right] \qquad 3\text{-}10$$

where

L is length of test section (m), in this case water filled uncased part of the borehole.

The transient recovery phase is evaluated through a Jacob/Horner type of analysis following SKB MD 430.004 (SKB internal controlling document) with the purpose of calculating the transmissivity.

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 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:	See Table 4-1.
Additional measurements:	Temperature, Single point resistance, Electric conductivity of water, Caliper, Water pressure.
Winch:	Mount Sopris Wna 10, 0.55 kW, 220V/50Hz. Steel wire cable 1,500 m, four conductors, Gerhard-Owen cable head.
Length determination:	Based on the marked cable and on the digital length counter.
Logging computer:	PC, Windows 2000.
Software:	Based on MS Visual Basic.
Total power consumption:	1.5–2.5 kW depending on the pumps.
Calibrated:	February 2005.
Calibration of cable length:	Using length marks in the borehole.

Table 4-1. Range and accuracy of sensors.

Sensor	Range	Accuracy
Flow	6–300,000 mL/h	+/– 0% 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

The commission was performed according to Activity Plan AP PS 400-04-116 (SKB internal controlling document) following the SKB Method Description 322.010, Version 1.0 (Method description for difference flow logging). Prior to the measurements, the downhole tools and the measurement cable were disinfected. Time was synchronized to 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 KLX06, length marks were milled into the borehole wall at certain intervals to be used for length calibration of various logging tools. By using the known positions of the length marks, logging cables etc can be calibrated in order to obtain an accurate length correction of the testing tool.

Each 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 flowmeter 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 KLX06 (Item 7 in Table 5-1). These methods also reveal widened parts of the borehole.

The caliper- and SPR-measurements were preceded by measurements of electric conductivity (EC) of the borehole water (Item 9) during natural (un-pumped) conditions.

The combined overlapping/sequential flow logging (Item 8) was carried out in the borehole interval 96.31–988.50 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. Every tenth flow measurement (sequential mode) had a longer measurement time than normally in the overlapping mode. This was done to ensure the direction of the flow (into the borehole or out of it).

Pumping was started on February 18. The pump intake was at level 6.3 m (masl, RHB70), see Appendix 13.2. The groundwater level sensor (pressure transducer) was at 4.72 m (masl, RHB70). After 42 hours waiting time, the overlapping flow logging (Item 10) was carried out in the borehole interval 91.33–988.54 m. The section length was 5 m, and the length increment (step length) 0.5 m.

The overlapping flow logging was then continued in the way that previously measured flow anomalies were re-measured with 1 m section length and 0.1 m step length (Item 11). After that fracture specific EC was measured from some selected fractures (Item 12).

Still during pumped conditions, the EC of borehole water (Item 13) was measured. After this, the pump was stopped and the recovery of the groundwater level was monitored (Item 14).

Re-measurements were done around 108 m, 170 m, 190 m and 265 m using a smaller drawdown since the flow rate was near or over the upper measurement limit at these intervals. A section length of 1 m and a step length of 0.1 m were used here, (Item 11 extra).

Table 5-1. Flow logging and testing in KLX06. Activity schedule.

Item	Activity	Explanation	Date
1	Mobilisation at site	Unpacking the trailer	2005-02-08
7	Length calibration of the downhole tool	Dummy logging (SKB Caliper and SPR). Logging without the lower rubber discs, no pumping	2005-02-14 2005-02-15
9	EC- and temp-logging of the borehole fluid	Logging without the lower rubber discs, no pumping	2005-02-16
8	Combined Overlapping/ Sequential flow logging	Section length L_w=5 m, Step length dL=0.5 m. No pumping	2005-02-16 2005-02-18
10	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)	2005-02-18 2005-02-22
11	Overlapping flow logging	Section length L_w=1 m, Step length dL=0.1 m, at pumping	2005-02-22 2005-02-25
12	Fracture-specific EC-measurements in pre-selected fractures	Section length L_w=0.5 m, at pumping (in pre-selected fractures	2005-02-25 2005-02-26
13	EC- and temp-logging of the borehole fluid	Logging without the lower rubber discs, at pumping	2005-02-26
14	Recovery transient	Measurement of water level and absolute pressure in the borehole after stopping of pumping.	2005-02-26 2005-02-28
11 extra	Overlapping flow logging at smaller pumping	Section length L_w=1 m, Step length dL=0.1 m, at smaller pumping	2005-02-28
15	Delivery and filling of measured data	Delivering Daily logs, logging reports and raw data files for SKB.	2005-02-28 2005-03-01

6 Results

6.1 Length calibration

6.1.1 Caliper and SPR measurement

Accurate length scale of measurements is difficult to achieve in long boreholes. The main cause of inaccuracy is stretching of the logging cable. The stretching depends on the tension of the cable that in turn depends, among other things, on the inclination of the borehole and on friction of the borehole wall. The cable tension is higher when the borehole is measured upwards. The cables, especially new cables, may also stretch out permanently. In KLX06 the stretching of the cable was relatively high since the measurements were performed from the bottom of the borehole in the upward direction.

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:

- Caliper + SPR measurement (Item 7) was initially length corrected in relation to the known length marks, Appendix 1.47 black curve. Corrections between the length marks were obtained for each length mark by linear interpolation.
- The SPR curve of Item 7 was then compared with the SPR curves of Items 8, 10, 11, 12 and 11 extra to obtain relative length errors of these measurement sequences.
- All SPR curves could then be synchronized, as can be seen in Appendices 1.2–1.46.

The results of the caliper and single point resistance measurements from all measurements in the entire borehole are presented in Appendix 1.1. Five SPR-curves are plotted together with the SPR + caliper measurement. These measurements correspond to Items 8, 10, 11, 12 and 11 extra in Table 5-1.

Caliper tool shows low voltage when the borehole diameter is below 77 mm and high voltage when borehole diameter is over 77 mm.

Zoomed results of caliper and SPR are presented in Appendices 1.2–1.46. The length marks were detected at 103 m, 151 m, 200 m, 250 m, 300 m, 350 m, 400 m, 450 m, 500 m, 550 m, 600 m, 700 m (only the lower one), 750 m, 800 m, 850 m (only the upper one), 900 m (only the lower one), 950 m and at 980 m (only the upper one). The length marks were not detected at 650 m with the caliper tool. The length correction was made using the detected length marks, which can also be seen in SPR results. However, the anomaly is complicated due to the four rubber disks used at the upper end of the section, two at the each side of the resistance electrode. A selection of length intervals where clear SPR-anomalies were found, are plotted as well.

The aim of the plots in Appendices 1.2–1.46 is to verify the accuracy of the length correction. The curves in these plots represent length corrected results.

The magnitude of length correction along the borehole is presented in Appendix 1.47. The error is negative, due to 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 following reasons:

1. Point interval in flow measurements is 0.1 m in overlapping mode. This could cause an error +/–0.05 m.
2. The length of the test section is not exact. The specified section length denotes the distance between the nearest upper and lower rubber disks. Effectively, the section length can be larger. At the upper end of the test section there are four rubber disks. The distance between these is 5 cm. This will cause rounded flow anomalies, there may be detected flow already when a fracture is between the upper rubber disks. These phenomena can only be seen with short step length (0.1 m). This could cause an error of +/–0.05 m.
3. Corrections between the length marks can be other than linear. This could cause error +/–0.1 m in the SPR + caliper measurement (Item 7).
4. SPR curves may be imperfectly synchronized. This could cause error +/–0.1 m

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

Near the length marks the situation is slightly better. In the worst case, the errors of points 1, 2, and 4 are summed up. 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 if the flow logging and borehole TV are compared. In that case the situation may not be as severe as the worst case above since part of the length errors are systematic and the length error is nearly constant in 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 results show clear change to less saline water above the length of about 30 m. It indicates, that there is also a high flowing fracture at this location, see Chapter 6.4.1.

The EC measurement was repeated during pumping (after a pumping period of about eight days), see Appendix 2.1, green curve. The results show change to less saline water above the lengths of about 260 m, 370 m and 830 m.

Temperature of borehole water was measured simultaneously with the EC-measurements. The EC-values are temperature corrected to 25°C to make them more comparable with other EC measurements /Heikkonen et al. 2002/. The temperature results in Appendix 2.2 correspond to the EC results in Appendix 2.1.

The length calibration of the borehole EC measurements is not as accurate as of the other measurements because SPR is not registered during the borehole EC measurements. The length correction of the SPR + caliper measurement was applied to the borehole EC measurements, black curve in Appendix 1.47.

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 find 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 = 0.5 m). The EC measurements begin if the flow rate is larger than 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 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 change the water volume within the test section about three times. Also stabilization of measured EC values is monitored to ensure waiting time long enough. The water volume in a half a meter long test section was 1.2 L.

Electric conductivity of fracture-specific water is presented on time scale, see Appendices 14.1–14.2. The blue symbol represents the value when tool was moved (half a meter point interval) and the red symbol means that the tool was stopped on a fracture for a fracture specific EC measurement.

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
195.8	196.3	196.0	0.05
376.7	377.2	376.7, 377.0, 377.2	0.11
562.0	562.5	562.2	0.10
778.8	779.3	779.0	0.13
927.5	928.0	927.7	0.53

6.3 Pressure measurements

Absolute pressure was registered with the other measurements in Items 8, 10, 11, 11 extra, 12 and 14. The pressure sensor measures the sum of hydrostatic pressure in the borehole and air pressure. Air pressure was also registered, Appendix 13.2. Hydraulic head along the borehole is determined in the following way. Firstly, the monitored air pressure at the site is subtracted from the measured absolute pressure by the pressure sensor. The hydraulic head (h) at a certain elevation z is then calculated according to the following expression /SKB, 2002/:

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

where

h is the hydraulic head (masl) according to the RHB70 reference system,
p_{abs} is absolute pressure (Pa),
p_b is barometric (air) pressure (Pa),
ρ_{fw} is unit density 1,000 kg/m^3,
g is standard gravity 9.80065 m/s^2 and
z is the elevation of measurement (masl) according to the RHB70 reference system.

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

Exact z-coordinates are important in head calculation, 10 cm error in z-coordinate means 10 cm error in head. The calculated head results are presented in a graph in Appendix 13.1.

6.4 Flow logging

6.4.1 General comments on results

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

The flow logging was firstly performed with a 5 m section length and with 0.5 m length increments, see Appendices 3.1–3.45 (dark blue curve without pumping, red curve with pumping). The method (overlapping flow logging) gives the length and the thickness of conductive zones with a length resolution of 0.5 m. To obtain quick results, only the thermal dilution method is 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 can not 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 meter (sequential mode). The thermal pulse method was only used for flow direction, not for flow rate which would take even longer time. Longer flow direction measurement has to be done in un-pumped conditions.

The test section length determines the width of a flow anomaly of a single fracture in the plots. If the distance between flow yielding fractures is less than the section length, the anomalies will be overlapped, resulting in a stepwise flow anomaly. The overlapping flow logging was therefore repeated in the vicinity of identified flow anomalies using a 1 m long test section and 0.1 m length increments, see Appendices 3.1–3.45 (violet curve).

Re-measurements with 1 m section length were done around 108 m, 170 m, 190 m and 265 m using a smaller drawdown. The flow rate was above the measurement limit at these spots.

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

The tables in Appendix 10 were used to calculate conductive fracture frequency (CFF). The number of conductive fractures was counted on the same 5 meter sections as in Appendix 7 before. The number of conductive fractures was sorted in six columns depending on their flow rate. The total conductive fracture frequency is presented graphically, see Appendix 11.

6.4.2 Transmissivity and hydraulic head of borehole sections

The entire borehole between 96.33 and 987.52 m was flow logged with a 5 m section length and with 0.5 m length increments. All the flow logging results presented in this report is derived from measurements with the thermal dilution method.

The results of the measurements with a 5 m section length are presented in tables, see Appendix 7. Only the results with a 5 m length increment are used. Secup presented in Appendix 7 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. 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 small. Secup and seclow given in Appendix 7 are calculated as an average of these two values. The same flow rates as in Appendix 7, are also plotted in Appendices 3.1–3.45.

Pressure was measured and calculated as described in Chapter 6.3. Borehole head dh_0 and borehole head dh_1 in Appendix 7 represent heads determined without respectively with pumping. Head in the borehole and calculated heads of borehole sections are given in RHB70 scale.

The flow results presented in Appendix 7 (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. Flow rates are positive if the flow direction is from the bedrock into the borehole and vice versa. With the borehole at rest, 53 sections were detected as flow yielding, of which 12 had a flow direction from the borehole into the bedrock (negative flow). During pumping, all 72 detected flows were directed towards the borehole.

The measurable flow ranges were exceeded at lengths of 106.38 m,166.47 m and 261.64 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).

The flow data is presented as a plot, see Appendix 4.1. The left hand side of each diagram represents flow from the borehole into the bedrock for the respective test sections, whereas the right hand side represents the opposite. If the measured flow was zero (below the measurement limit), it is not visible in the logarithmic scale of the appendices.

In the plots (Appendix 4.1) also the lower and upper measurement limits of flow are presented. There are theoretical and practical lower limits of flow, see Chapter 6.4.4.

Hydraulic head and transmissivity 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 3.2. The measurement limits of transmissivity are also shown in Appendix 4.2 and in Appendix 7. All the measurement limit values of transmissivity are based on the actual pressure difference in the borehole (borehole head dh_0 and borehole head dh_1 in Appendix 7).

The sum of detected flows without pumping (Q_0) was 3.69E–05 m^3/s (133,000 mL/h). This sum should normally be zero if all the flows are measured, they 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 far from zero.

The wider upper part of the borehole, which was not flow logged, is not cased. There is a clear change in EC of the borehole water at the length of c. 30 m (Appendix 2.1). This could indicate flow. Vertical flow along the borehole was measured just below 100 m and the result is in line with the assumption above. The measured flow along the borehole was 2.22E–05 m^3/s (80,000 mL/h), flow direction was upwards along the borehole, see Appendix 13.4. This flow explains most of the unbalance of the flow sum above.

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 fracture distance is less than one meter, it may be difficult to evaluate the flow rate. There are such cases for instance in Appendix 3.1. Increase or decrease of flow anomaly at the fracture location (marked with the lines in Appendix 3) is used for determination of flow rate (filled triangles in Appendix 3).

Some fracture-specific results were rated to be “uncertain” results, see Appendix 8. The criterion of “uncertain” was in part of the cases a minor flow rate (< 30 mL/h). In some cases fracture anomalies were unclear, since the distance between them was less than one meter or since the form of anomaly was unclear because of noise.

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

Total amount of detected flowing fractures was 186, but only 18 could be defined without pumping. These 18 fractures could be used for head estimations and all 186 were used for transmissivity estimations, Appendix 8. Transmissivity and hydraulic head of fractures are plotted in Appendix 5.

Fractures where the flow rate exceeded measurement limit were re-measured at a lower drawdown and these results were used for transmissivity and head calculations. These fractures are marked with "**" in "Comments"-column in Appendix 8.

Fracture-specific transmissivities were compared with transmissivities of borehole sections in Appendix 12. 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 limits of flow measurements and transmissivity

Theoretical minimum of measurable flow rate in the overlapping results (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 flow measurement is 300,000 mL/h. These limits are determined on the basis of flow calibration. It is assumed that flow can be reliably detected between the upper and lower theoretical limits in favourable borehole conditions.

The minimum measurable flow rate may be much higher in practice. Borehole conditions may increase the base level of flow (noise level). The noise level can be evaluated on such intervals of the borehole where there are no 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 water such as clay or drilling mud.
3) Gas bubbles in water.
4) High flow rate along the borehole.

Rough borehole wall always causes high noise not only in flow but also in single point resistance results. Flow curve and SPR curves are typically spiky when borehole wall is rough.

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

Pumping causes pressure drop in borehole water and in water in fractures near the borehole. This may lead to release of gas from dissolved form to gas bubbles. Some fractures may produce more gas than others. Sometimes 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 decrease of average density of water and therefore also decrease of measured head in the borehole.

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

High noise level in flow masks “real” flow that is smaller than the noise. Real flows are totally invisible if they are about ten times smaller than the noise. Real flows are registered correctly if they are about ten times larger than noise. By experience, real flows between 1/10 times noise and 10 times noise are summed up with noise. Therefore 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 each case.

The practical minimum level of measurable flow rate is evaluated and presented in Appendices 3.1–3.45 using grey dashed line (Lower limit of flow rate). The practical minimum level of measurable flow is always evaluated in pumped conditions since this measurement is the most important for transmissivity calculation. The limit is approximate. It is evaluated to get a limit below which there may be fractures or structures that remain undetected.

Noise level in KLX06 was 30 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). High flow fractures can be measured separately at smaller drawdown. In KLX06 there was four different spots which were re-measured using a smaller drawdown.

Practical minimum of measurable flow rate is also presented in Appendix 7 (Q-lower limit P). It is taken from the plotted curve in Appendix 3 (Lower limit of flow rate). Practical minimum of measurable transmissivity can be evaluated using Q-lower limit P and the head difference at each measurement, see Appendix 7 ($TD\text{-}measl_{LP}$). Theoretical minimum measurable transmissivity can also be evaluated using Q value of 30 mL/h (minimum theoretical flow rate with thermal dilution method) instead of Q-lower limit Practical, see Appendix 7 ($TD\text{-}measl_{LT}$). 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 7 ($TD\text{-}measl_{U}$).

All three flow limits are also plotted with measured flow rates, see Appendix 4.1. 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 4.2.

Similar flow and transmissivity limits are not given for the fracture-specific results, Appendices 5 and 8. Approximately the same limits would be valid also for these results. The limits for fracture-specific results are more difficult to define. For instance, it may be difficult to see a small flow rate near (< 1 m) a high flowing fracture. The situation is similar for the upper flow limit. If there are several high flowing fractures nearer each other than one meter, the upper flow limit depends on the sum of flows which must be below 300,000 mL/h.

6.4.5 Transmissivity of the entire borehole

The pumping phase for the logging and its subsequent recovery is utilized to evaluate the transmissivity of the entire borehole. This is done with the two steady state methods and one transient analysis method, described in Chapter 3.

Steady state analysis

For the Dupuit's formula (equation 3-9) R/r_0 is chosen to be 500, Q was 75 L/min and s (drawdown) was 6.93 m. Transmissivity calculated with Dupuit's formula is 1.8 E–04 m^2/s.

In the Moye's formula (equation 3-10) length of test section L is 983.06 m (994.94–11.88 m) and borehole diameter $2r_0$ is 0.076 m. Transmissivity calculated with Moye's formula is 3.0 E–04 m^2/s.

Transient analysis (by M. Morosini, SKB)

A Jacob type of analysis is done on the transient recovery phase following the methodology specified in SKB MD 320.004 (SKB internal controlling document). Briefly it specifies the utilization of the log-log plot and derivative method for the analysis.

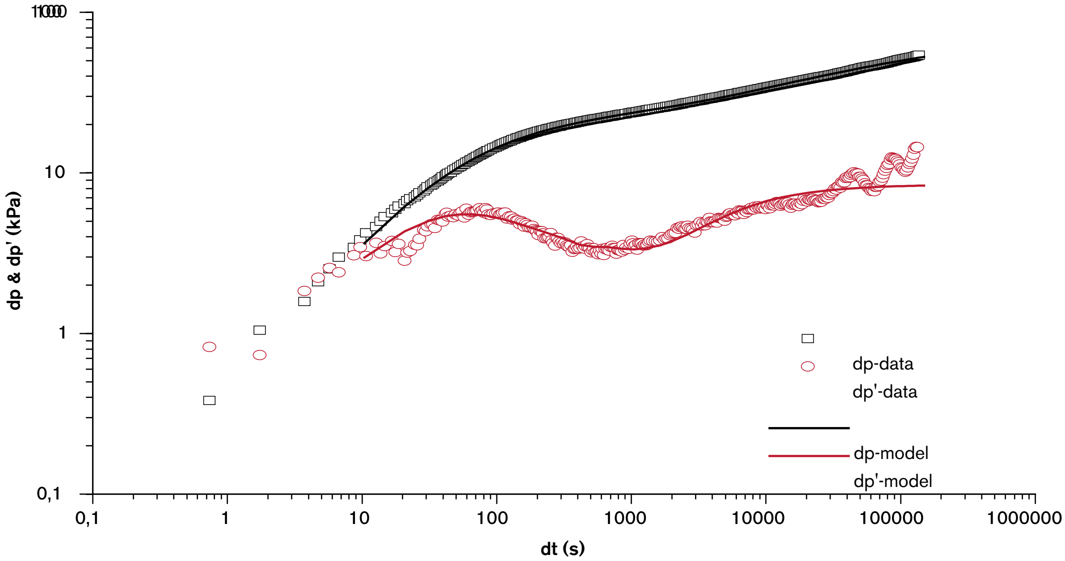
For an assumed storage coefficient S = 9*E–07 the recovery phase was simulated. The best fit simulation yield a transmissivity T = 3*E–04 m^2/s and a skin = –2.6.

Figure 6-1 show the log-log and semi-log plots of the recovery phase, this were utilised to calculate the transmissivity.

The results of the three methods are given in Table 6-2. Basic test data is gathered in Appendix 6.

Table 6-2. Transmissivity of the entire borehole.

Method	Transmissivity (m^2/s)
Dupuit	1.8 E–04
Moye	3.0 E–04
Jacob	3.2 E–04



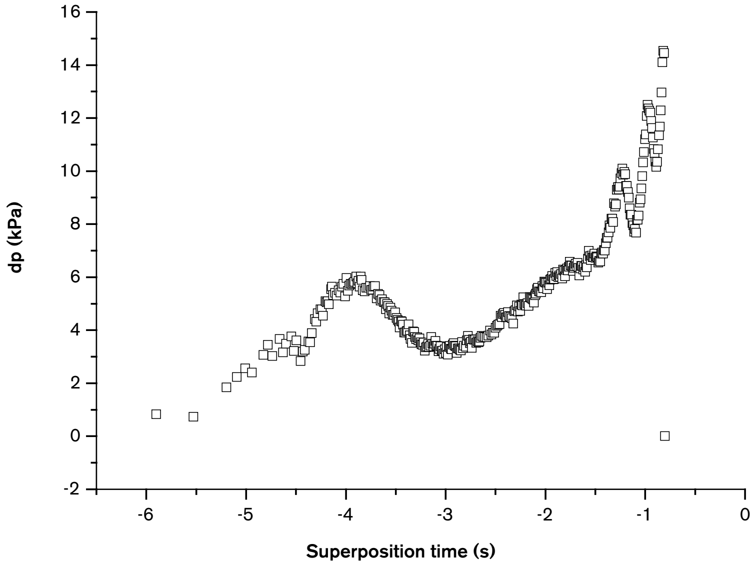


Figure 6-1. *Log-log (top) and semi-log (bottom) plot of recovery phase in KLX06 showing measured pressure dp (□) and pressure derivative dp' (○) along with simulated best fit curves (-) for the log-log plot.*

6.5 Groundwater level and pumping rate

Pumping was started on February 18. The pump intake was at level 6.3 masl (RHB70), see Appendix 13.2. The groundwater level sensor (pressure transducer) was at 4.72 masl (RHB70). The reference level is centerpoint of top of casing (ToC) 17.680 masl (RHB70).

The borehole was pumped between February 18 and 26 with a drawdown of about 6.9 m. The borehole was pumped also February 28 a short time with a smaller drawdown. Pumping rate was recorded, see Appendix 13.2.

The groundwater recovery was measured after the first pumping period, February 26–28, Appendix 13.3. The recovery was measured with two sensors, using the water level sensor and the absolute pressure sensor located in the flowmeter tool at the borehole length of 976.86 m.

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 KLX06 at Oskarshamn. 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.

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

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

The total amount of detected flowing fractures in KLX06 was 186. Transmissivity and hydraulic head were calculated for borehole sections and fractures. The highest transmissivity was detected in a fracture at the length of 108.4 m. High-transmissive fractures were also found at 196.0 m, 264.7 m and 562.5 m. The lowest identified flowing fracture was at the length of 938.8 m.

References

Heikkonen J, Heikkinen E, Mäntynen M, 2001. Mathematical modelling of temperature adjustment algorithm for groundwater electrical conductivity on basis of synthetic water sample analysis. Helsinki, Posiva Oy. Working report 2002-10 (in Finnish).

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

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

SKB, 2002. Hantering av primärdata vid platsundersökningar. Rutin SDP-508, version 1.0, Svensk Kärnbränslehantering AB.

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

Appendices

Appendices	1.1–1.46	SPR and Caliper results after length correction
Appendix	1.47	Length correction
Appendix	2.1	Electric conductivity of borehole water
Appendix	2.2	Temperature of borehole water
Appendices	3.1–3.45	Flow rate, Caliper and Single point resistance
Appendix	4.1	Plotted flow rates of 5 m sections
Appendix	4.2	Plotted transmissivity and head of 5 m sections
Appendix	5	Plotted transmissivity and head of detected fractures
Appendix	6	Basic test data
Appendix	7	Results of sequential flow logging
Appendix	8	Inferred flow anomalies from overlapping flow logging
Appendix	9	Explanations for the tables in Appendices 6–8
Appendix	10	Conductive fracture frequency
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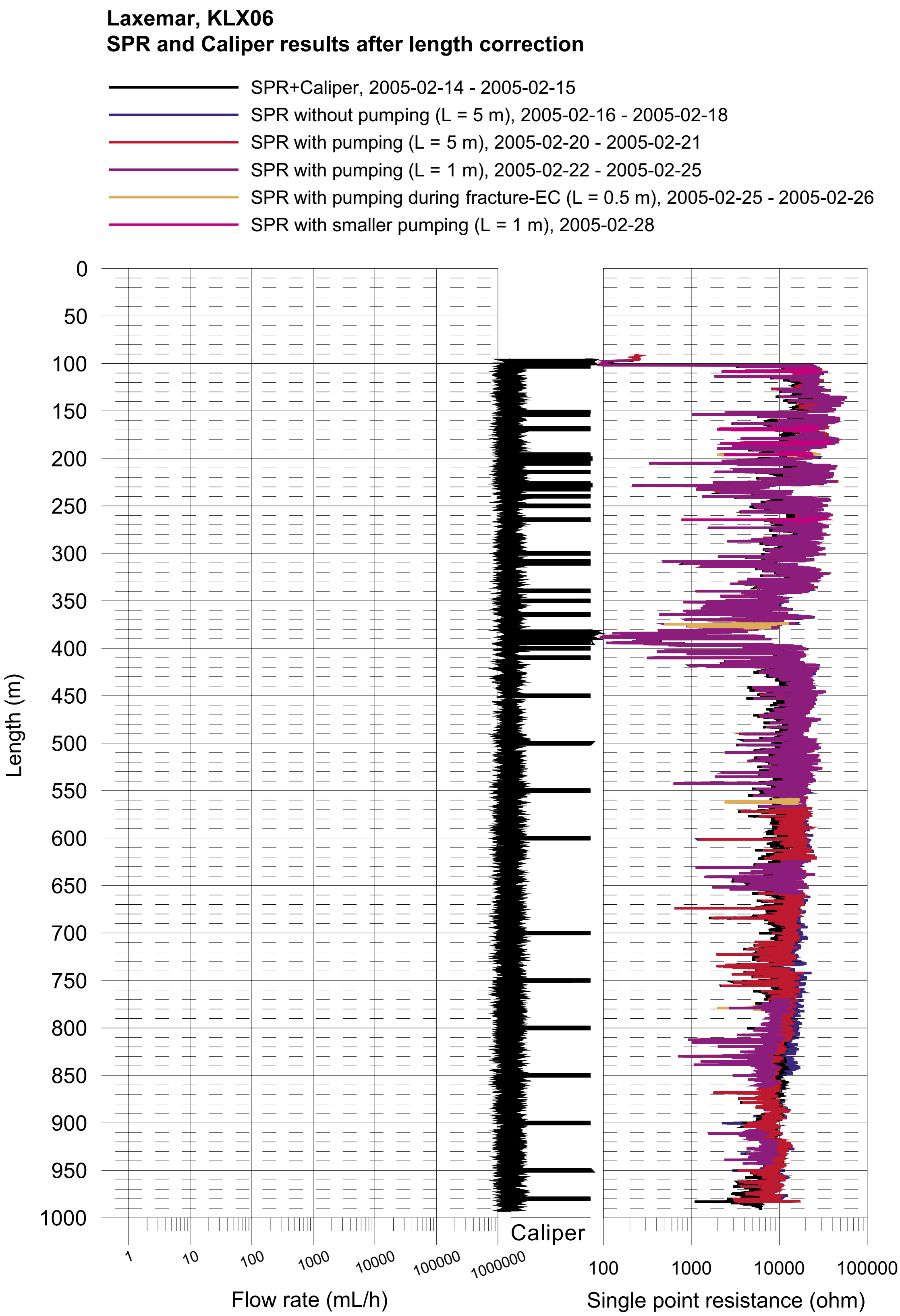
Appendix	12	Comparison between section transmissivity and fracture transmissivity
Appendix	13.1	Head in the borehole during flow logging
Appendix	13.2	Air pressure, water level in the borehole and pumping rate during flow logging
Appendix	13.3	Groundwater recovery after pumping
Appendix	13.4	Vertical flow along the borehole
Appendices	14.1–14.2	Fracture-specific EC results

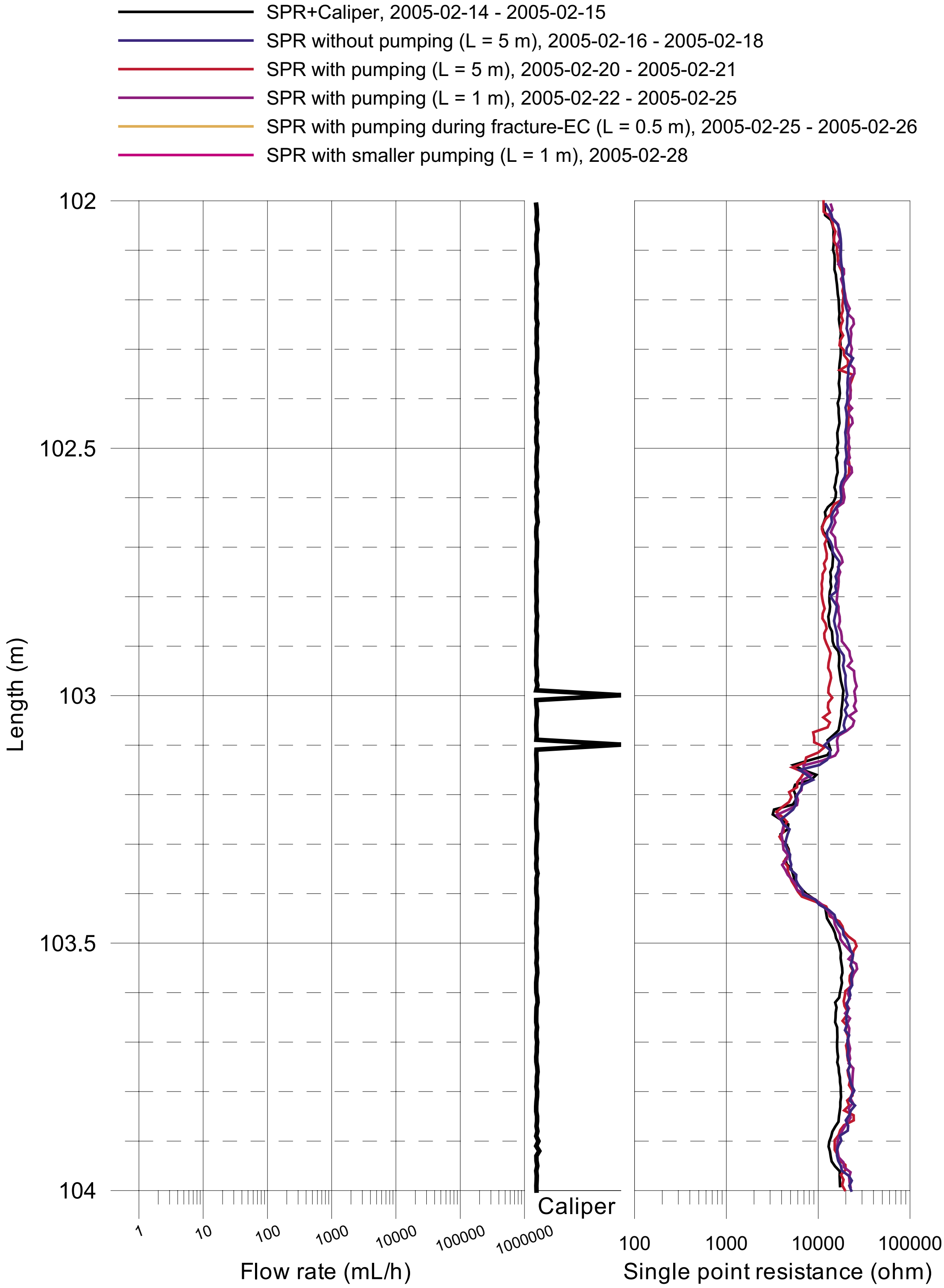
Appendix 1.1



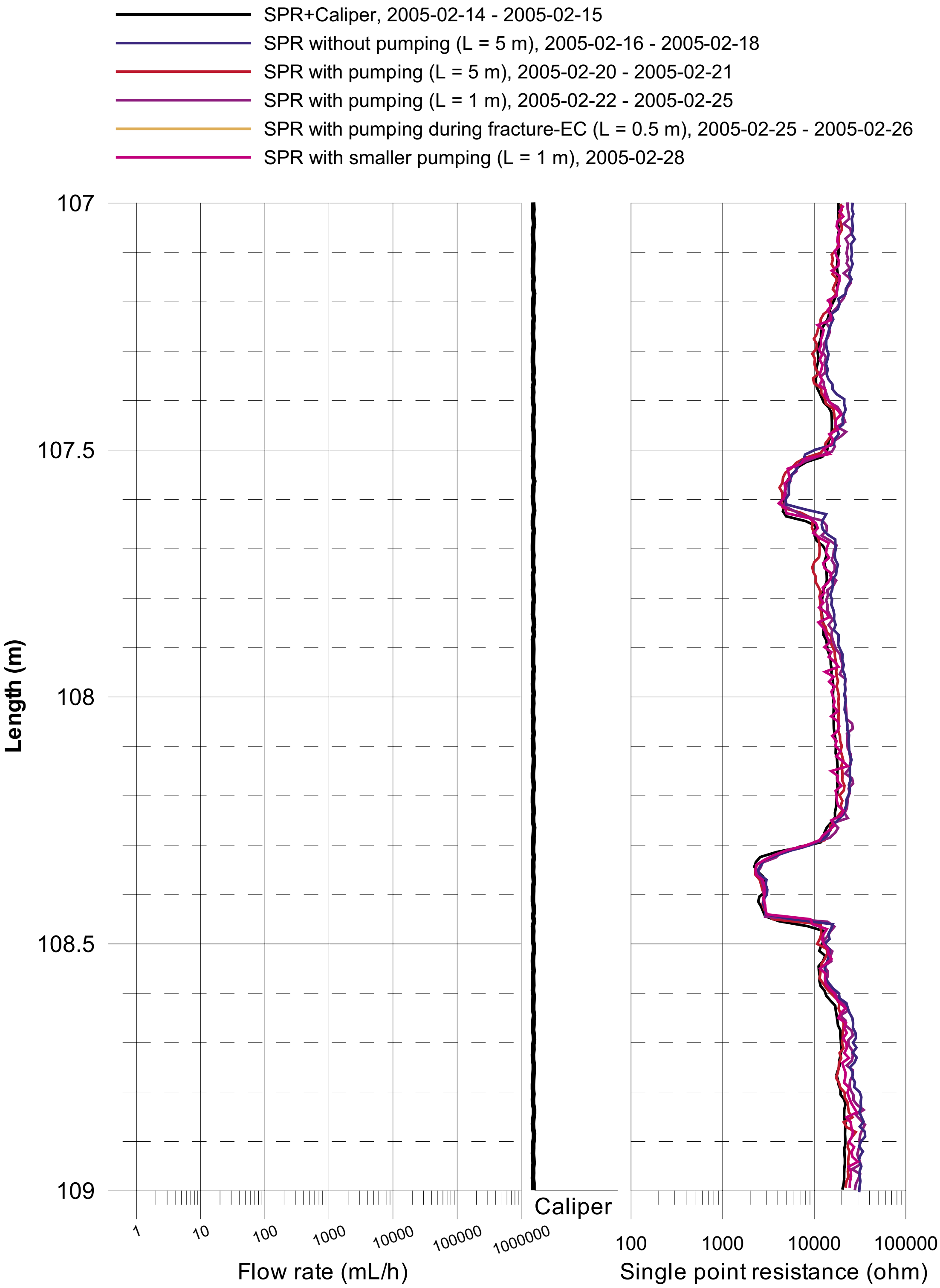
Laxemar, KLX06
SPR and Caliper results after length correction
SPR+Caliper, 2005-02-14 - 2005-02-15
SPR without pumping (L = 5 m), 2005-02-16 - 2005-02-18
SPR with pumping (L = 5 m), 2005-02-20 - 2005-02-21
SPR with pumping (L = 1 m), 2005-02-22 - 2005-02-25
SPR with pumping during fracture-EC (L = 0.5 m), 2005-02-25 - 2005-02-26
SPR with smaller pumping (L = 1 m), 2005-02-28
Length (m)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
100000
Single point resistance (ohm)

Appendix 1.2

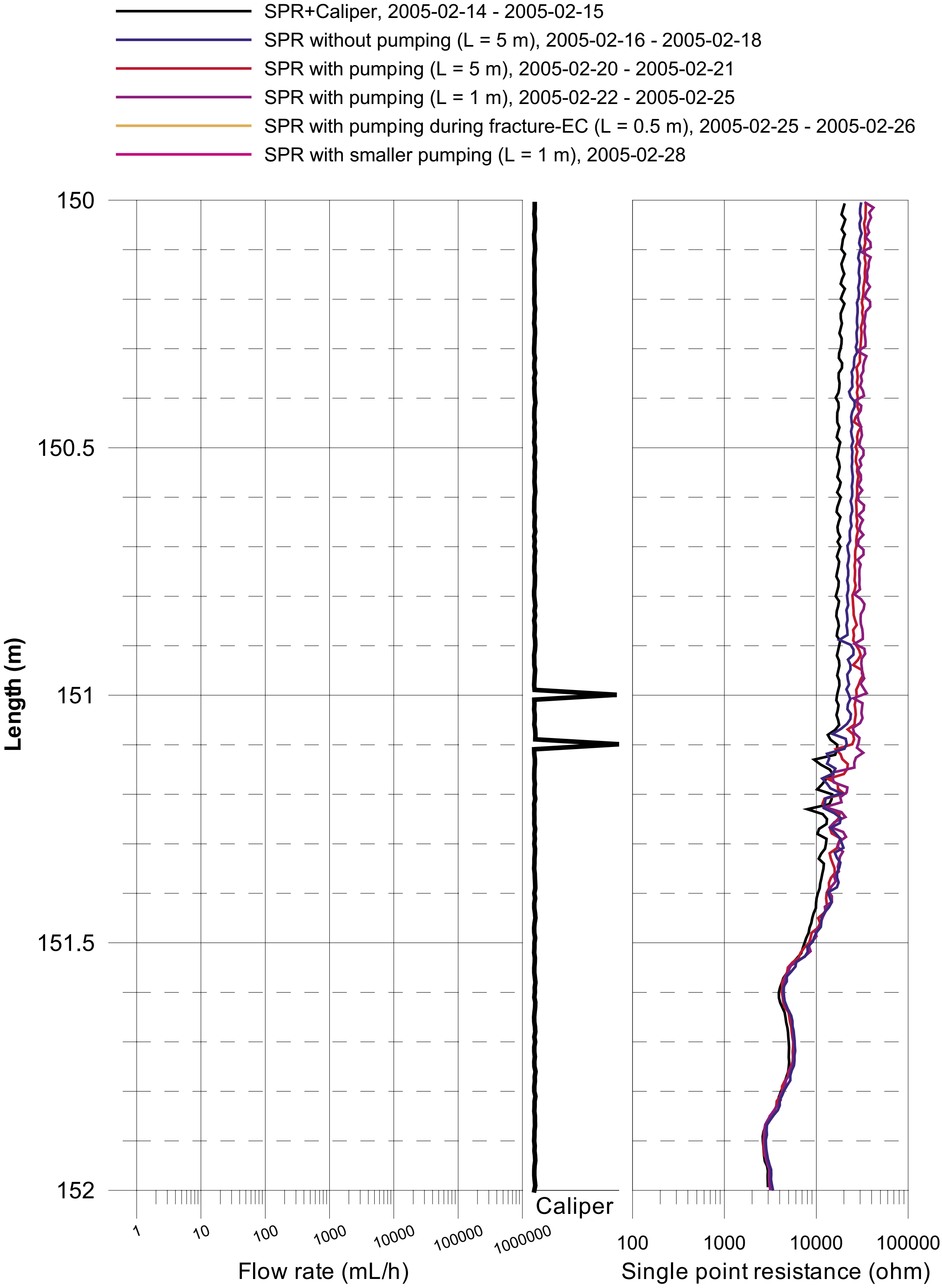
Laxemar, KLX06
SPR and Caliper results after length correction

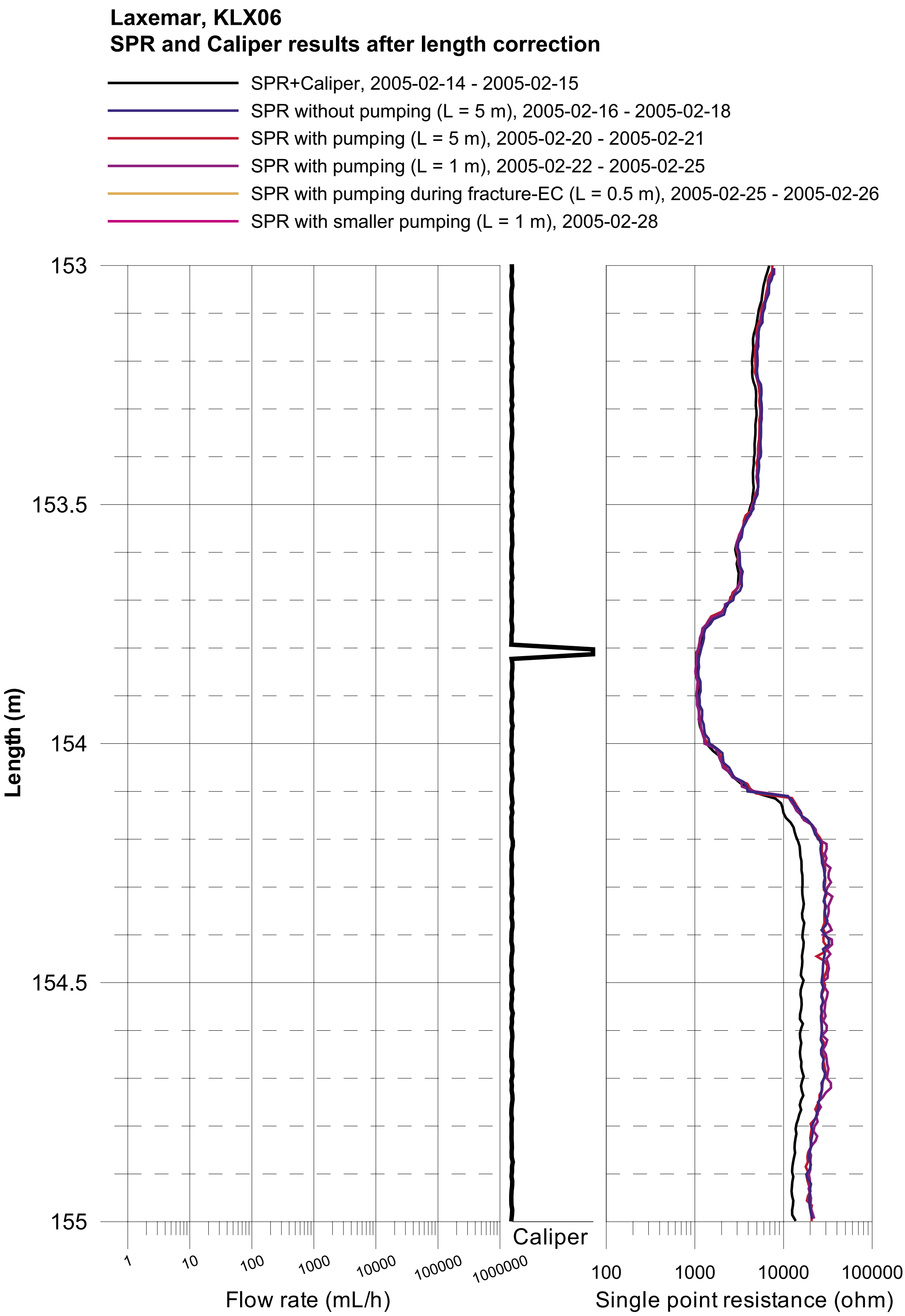


Laxemar, KLX06
SPR and Caliper results after length correction



Laxemar, KLX06
SPR and Caliper results after length correction

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SPR and Caliper results after length correction
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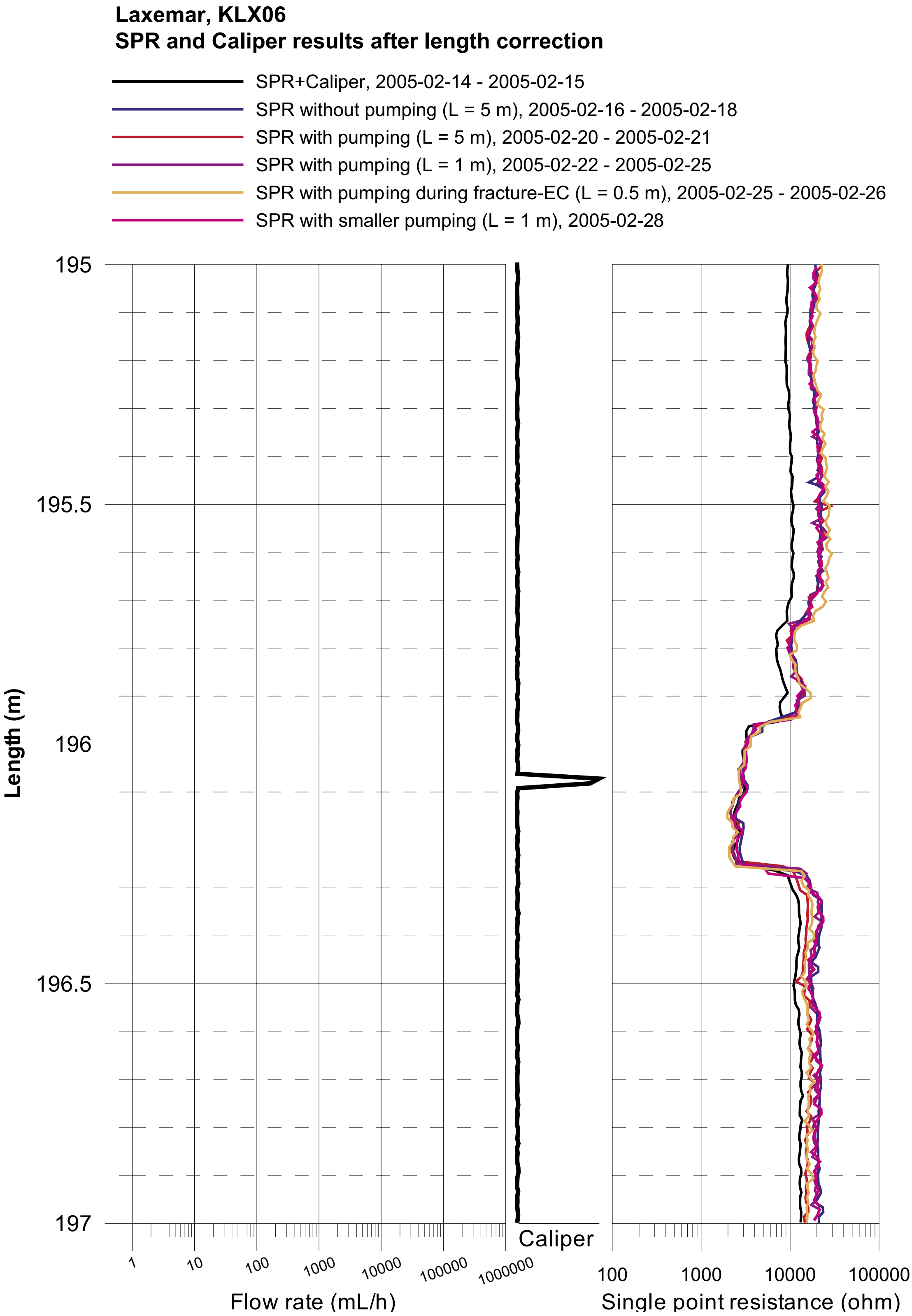
SPR without pumping (L = 5 m), 2005-02-16 - 2005-02-18
SPR with pumping (L = 5 m), 2005-02-20 - 2005-02-21
SPR with pumping (L = 1 m), 2005-02-22 - 2005-02-25
SPR with pumping during fracture-EC (L = 0.5 m), 2005-02-25 - 2005-02-26
SPR with smaller pumping (L = 1 m), 2005-02-28
Length (m)
153
153.5
154
154.5
155
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

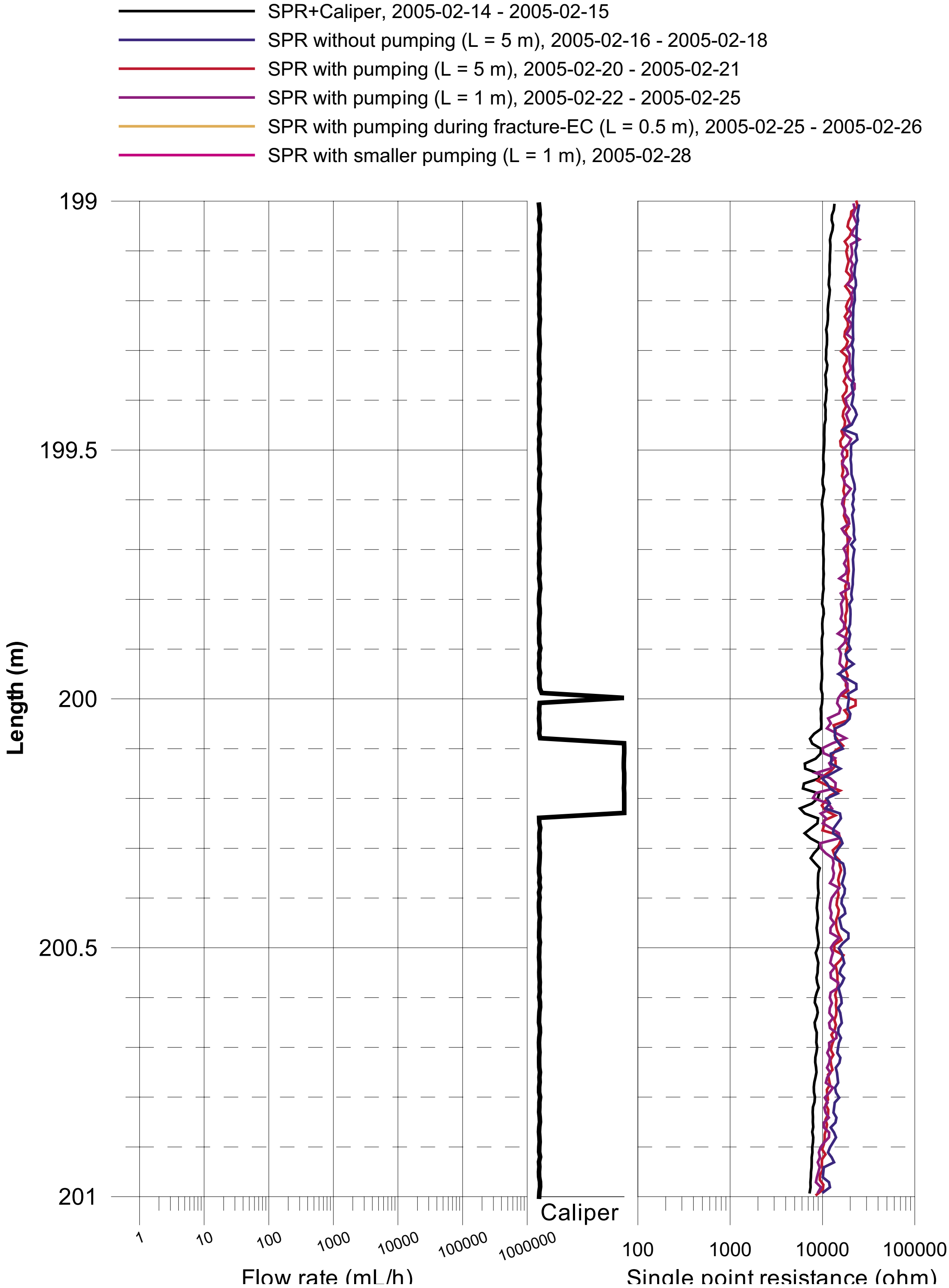
Appendix 1.6



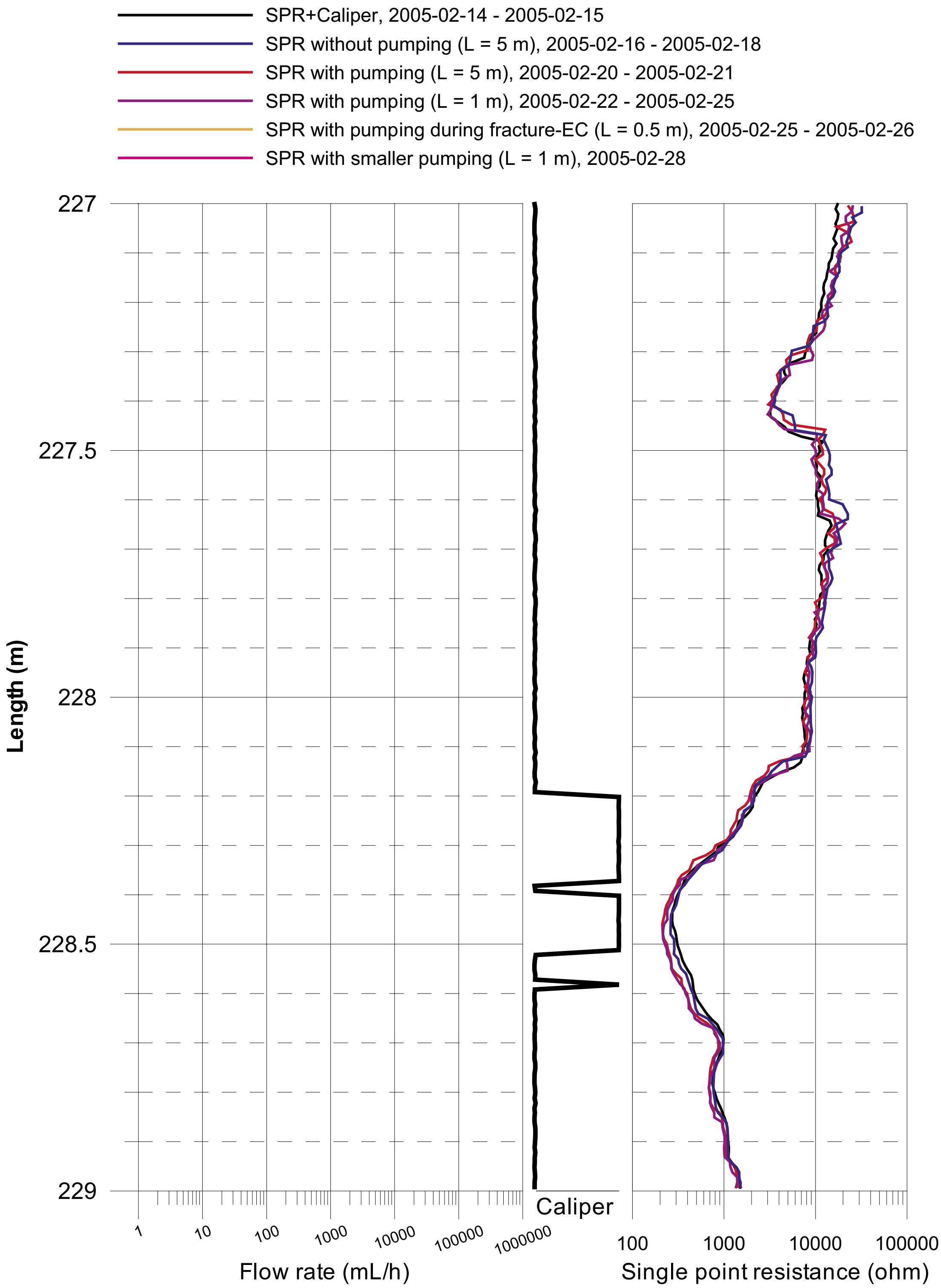
Laxemar, KLX06
SPR and Caliper results after length correction
SPR+Caliper, 2005-02-14 - 2005-02-15
SPR without pumping (L = 5 m), 2005-02-16 - 2005-02-18
SPR with pumping (L = 5 m), 2005-02-20 - 2005-02-21
SPR with pumping (L = 1 m), 2005-02-22 - 2005-02-25
SPR with pumping during fracture-EC (L = 0.5 m), 2005-02-25 - 2005-02-26
SPR with smaller pumping (L = 1 m), 2005-02-28
Length (m)
195
195.5
196
196.5
197
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

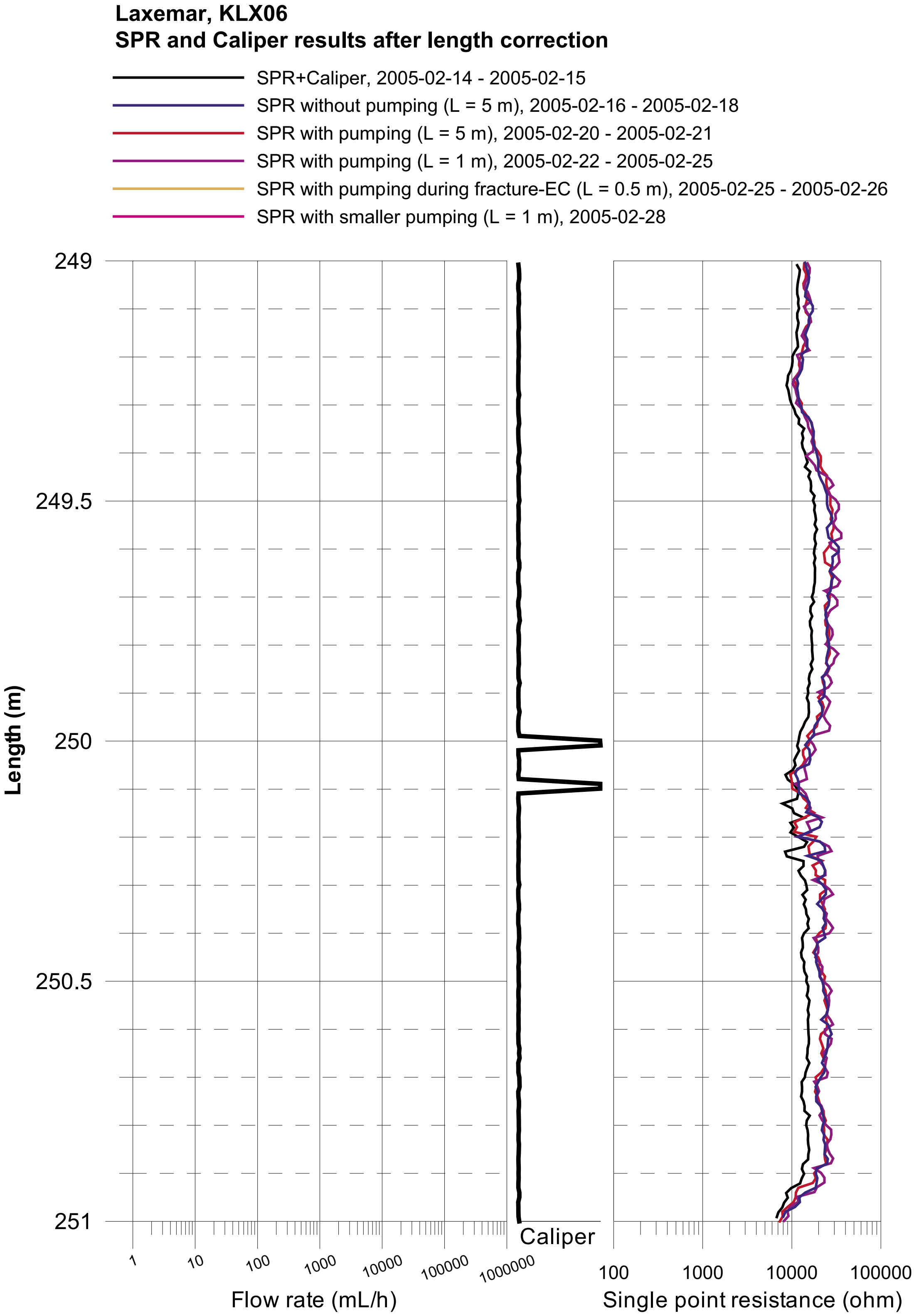
Appendix 1.7

Laxemar, KLX06
SPR and Caliper results after length correction



Laxemar, KLX06
SPR and Caliper results after length correction




Laxemar, KLX06
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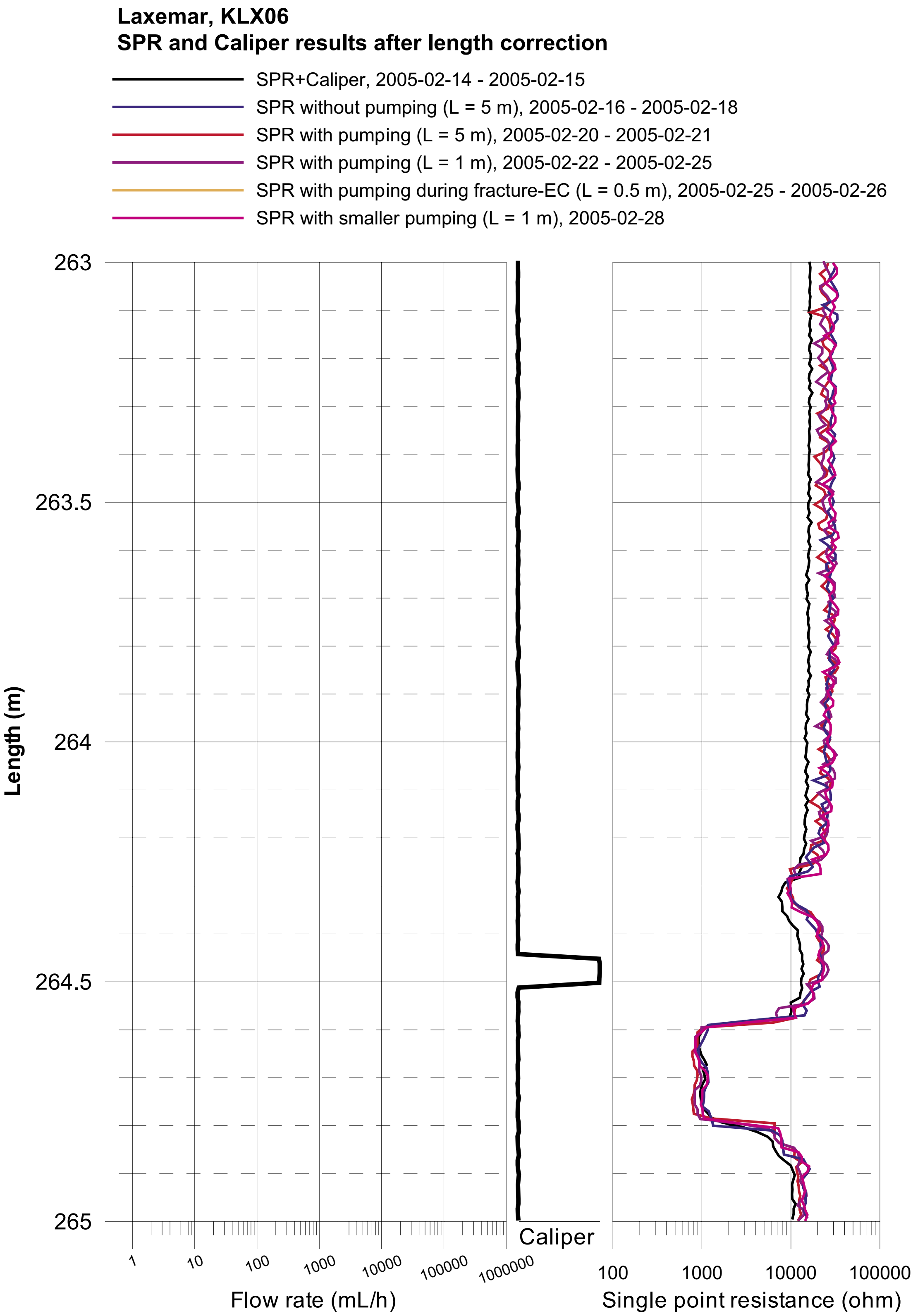
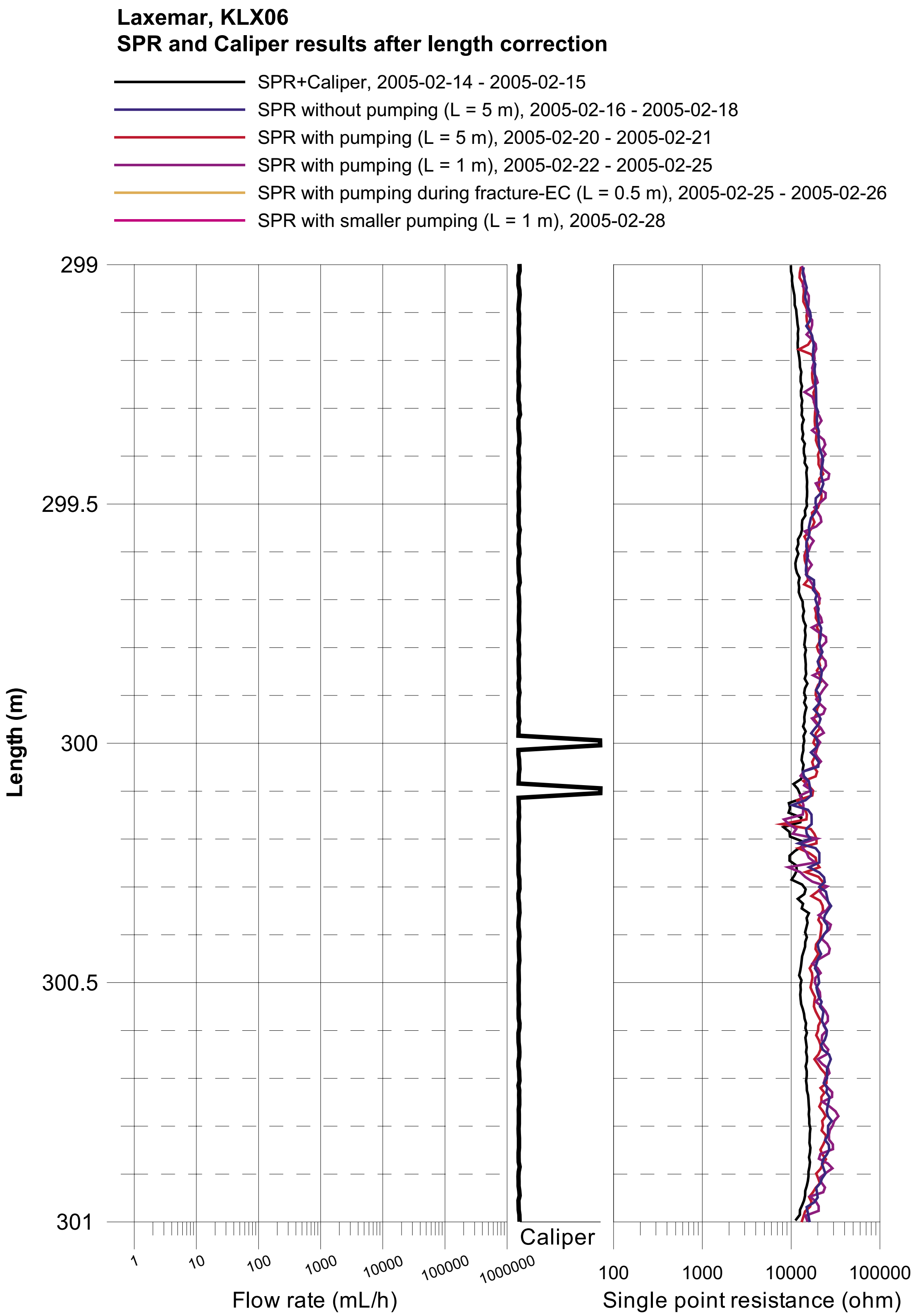
SPR+Caliper, 2005-02-14 - 2005-02-15
SPR without pumping (L = 5 m), 2005-02-16 - 2005-02-18
SPR with pumping (L = 5 m), 2005-02-20 - 2005-02-21
SPR with pumping (L = 1 m), 2005-02-22 - 2005-02-25
SPR with pumping during fracture-EC (L = 0.5 m), 2005-02-25 - 2005-02-26
SPR with smaller pumping (L = 1 m), 2005-02-28
Length (m)
249
249.5
250
250.5
251
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

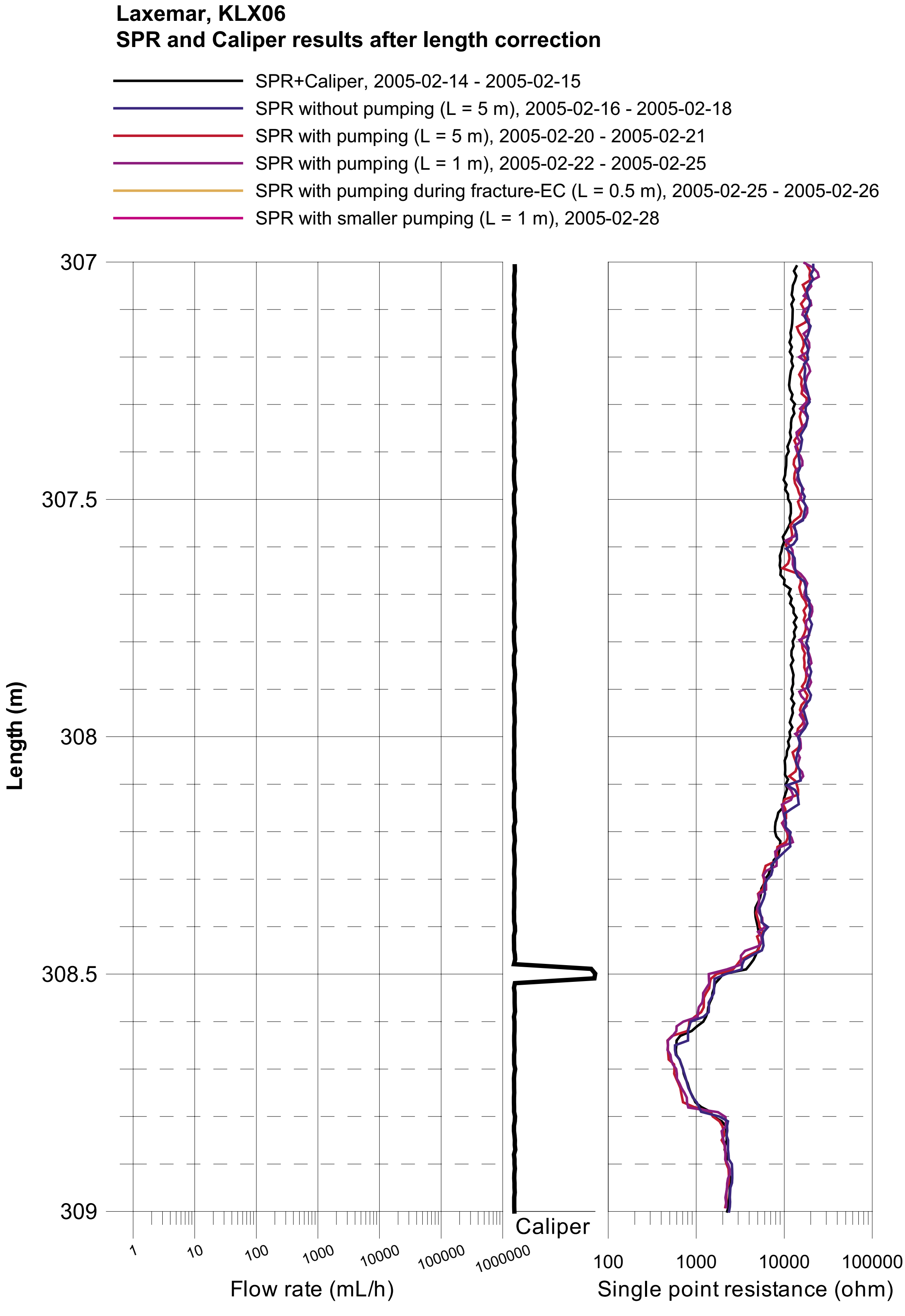
Appendix 1.10



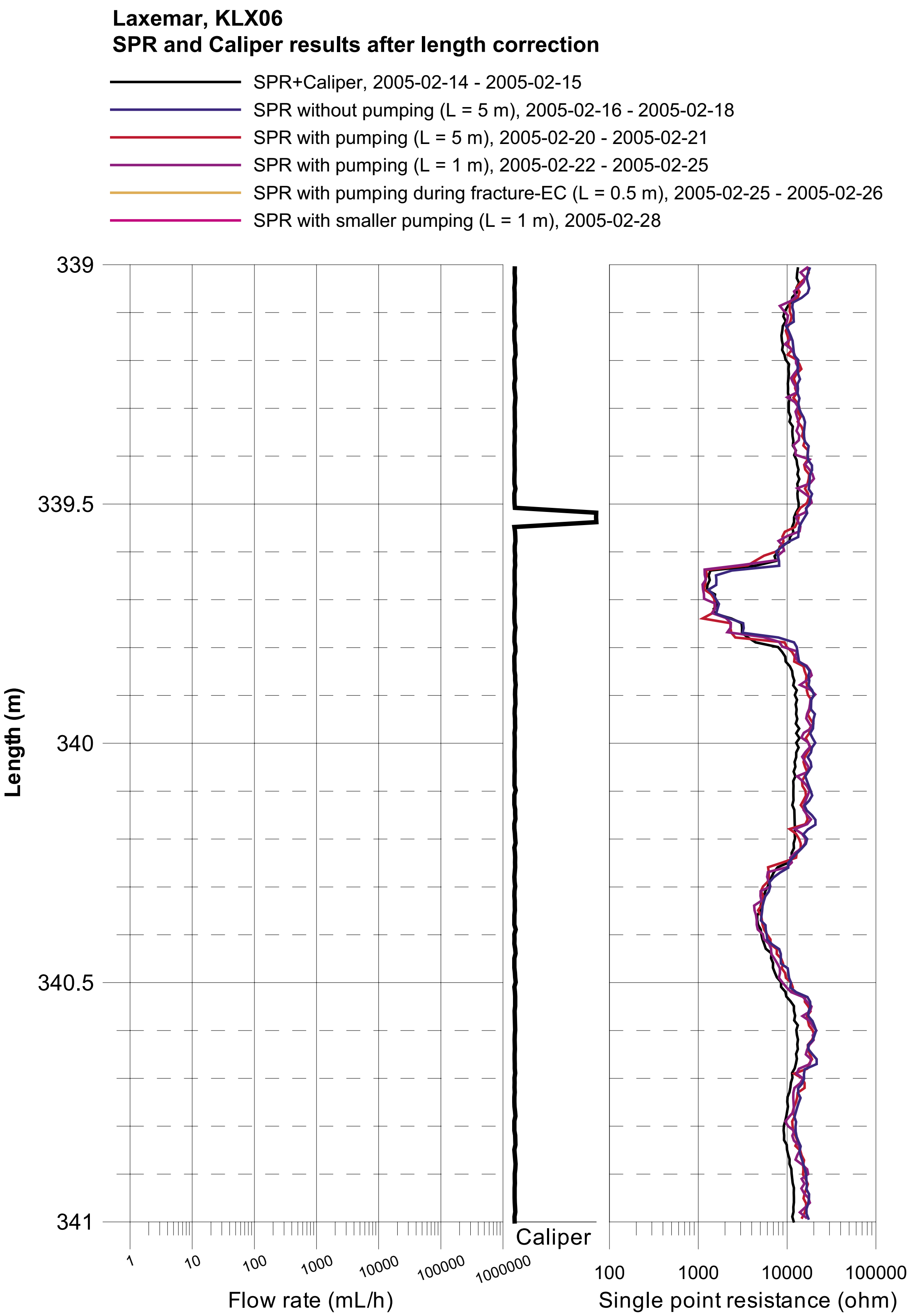
Appendix 1.11



Appendix 1.12

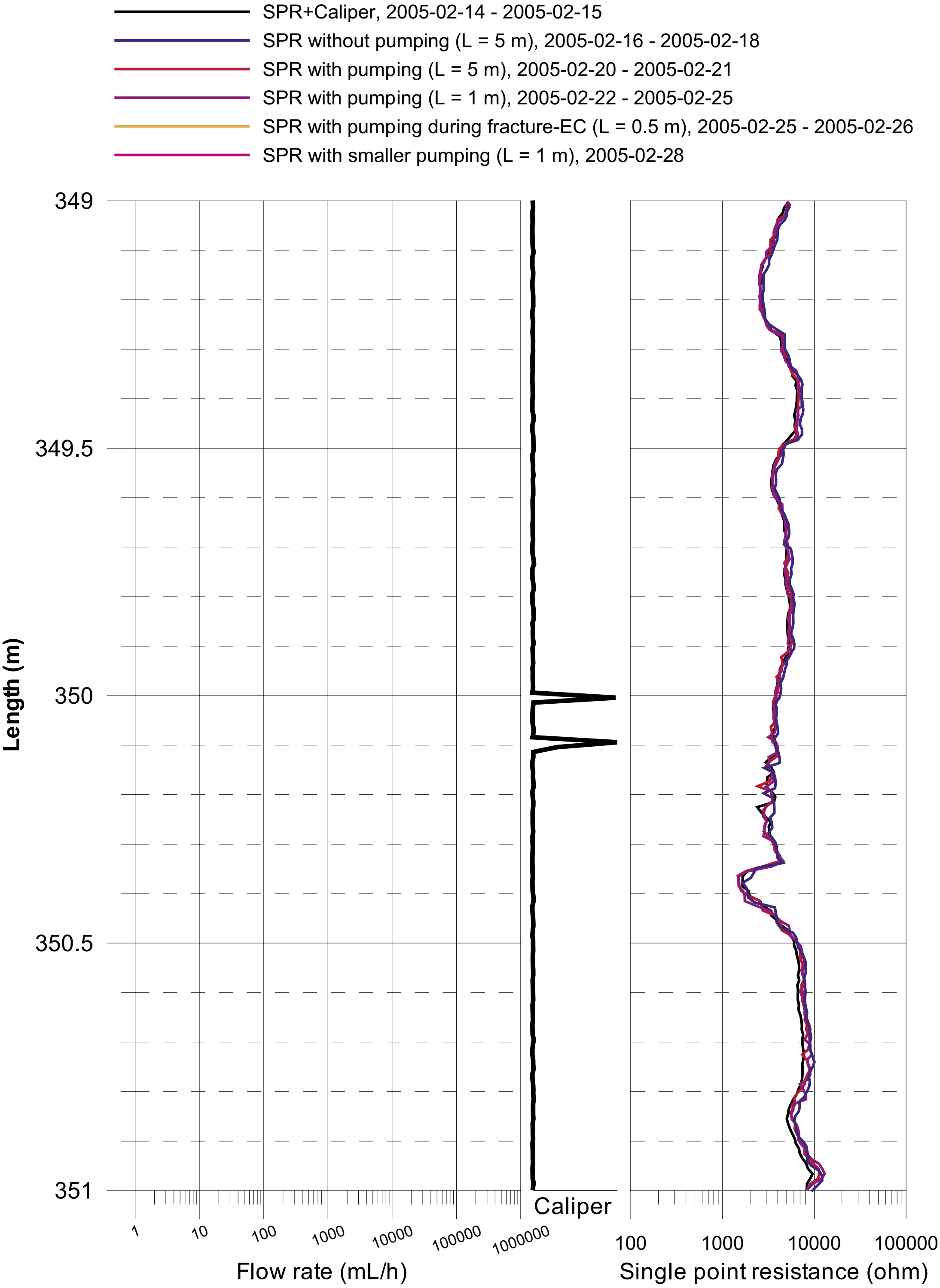


Appendix 1.13

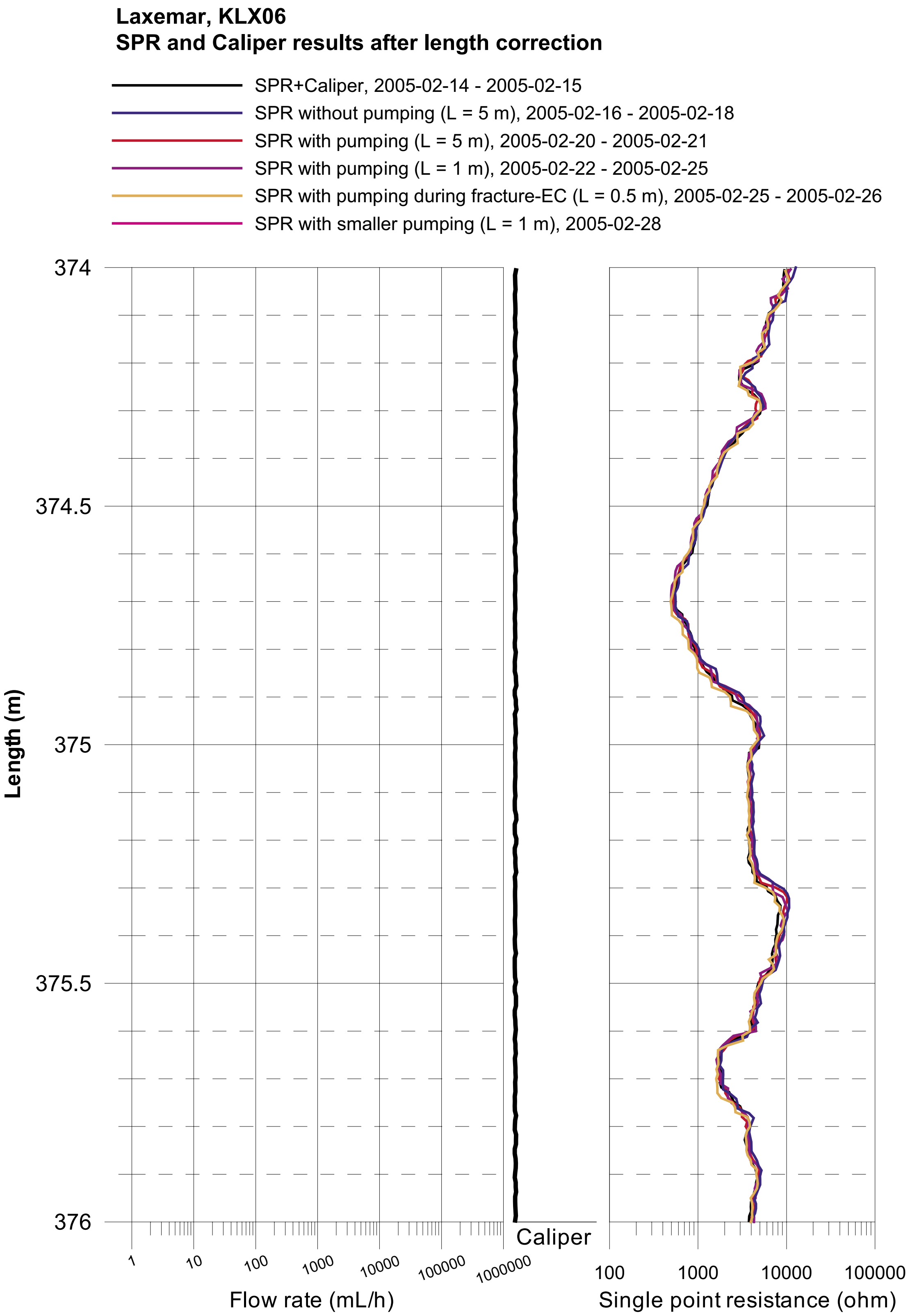


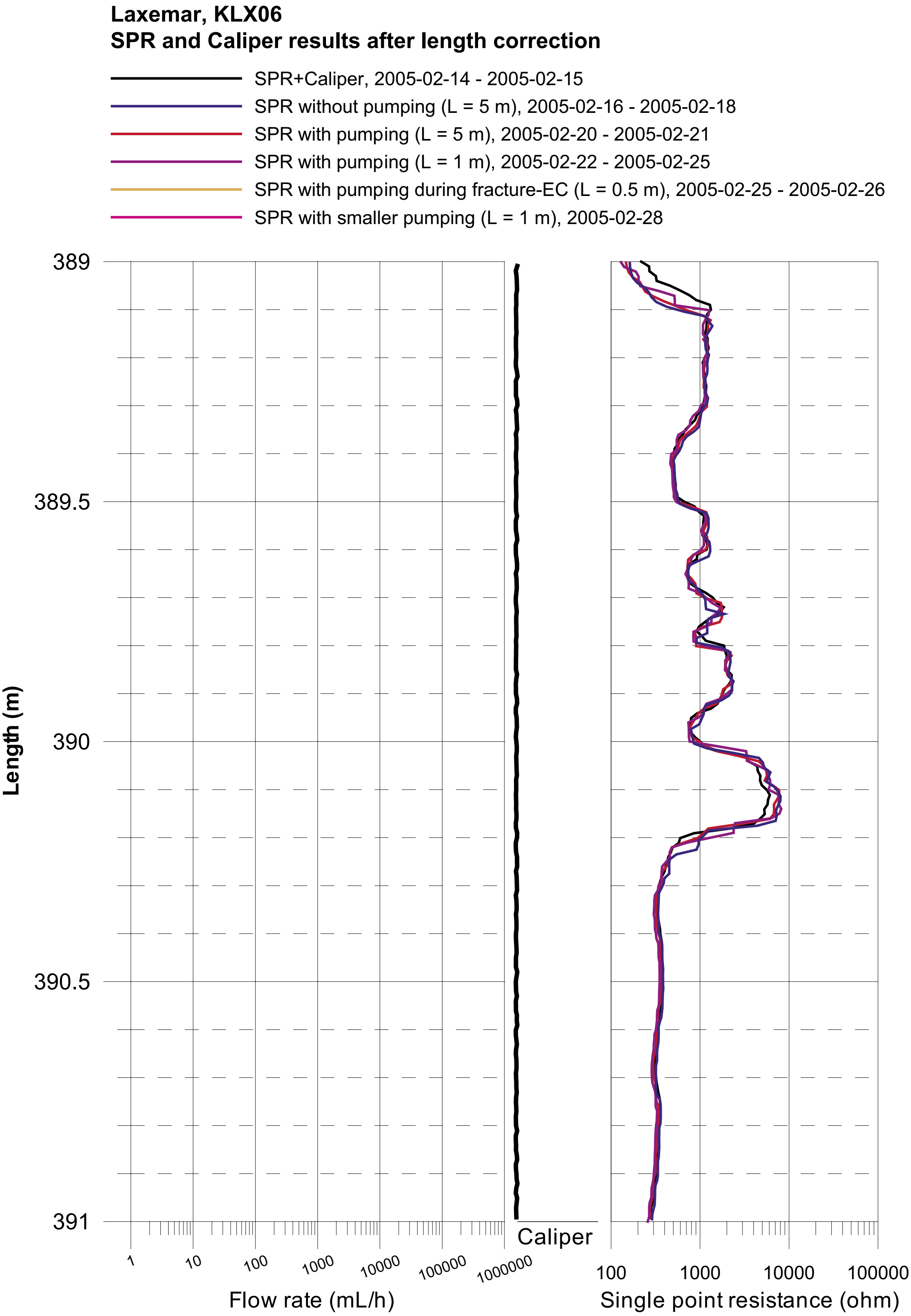
Appendix 1.14

Laxemar, KLX06
SPR and Caliper results after length correction

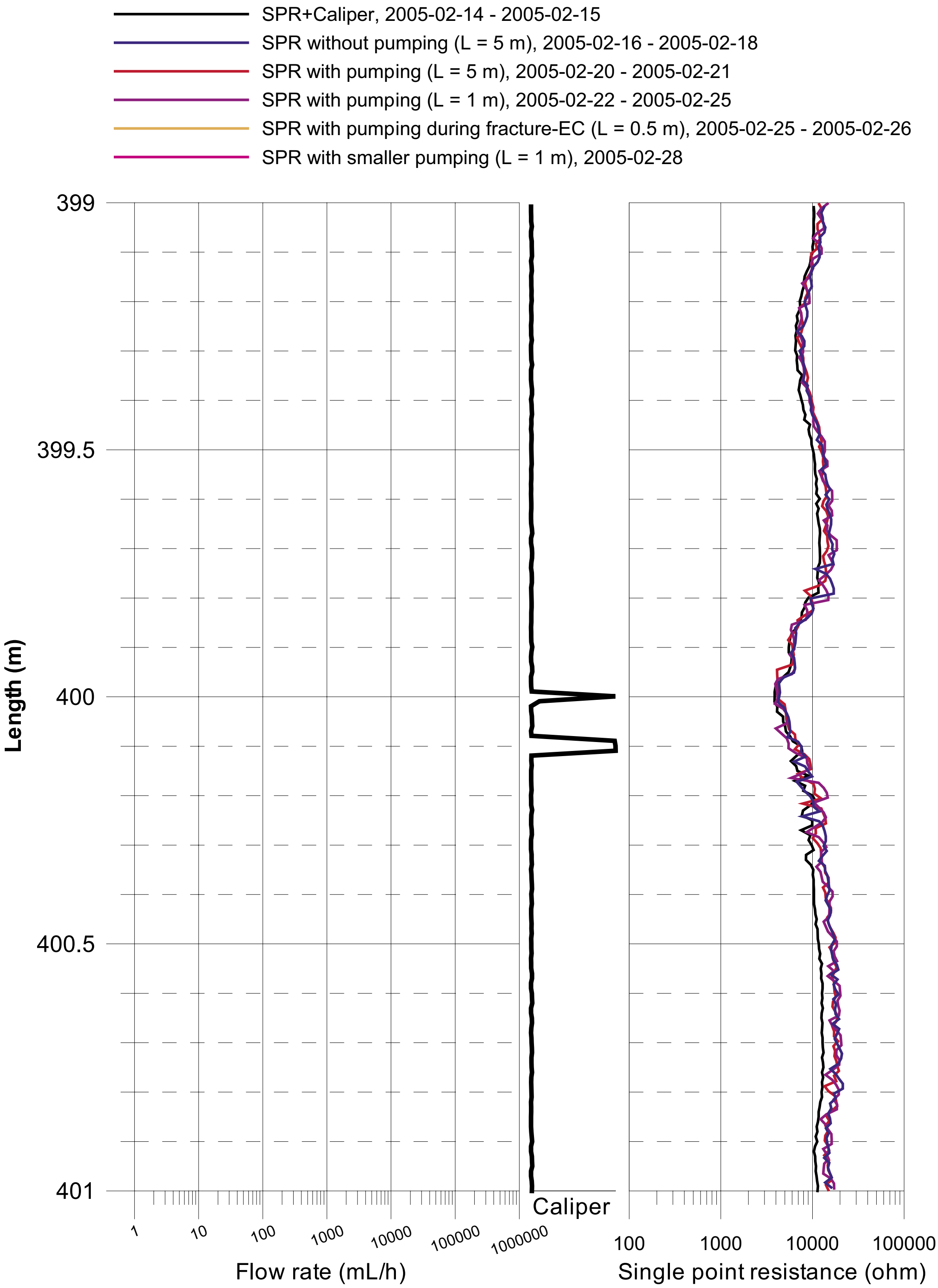


Appendix 1.15

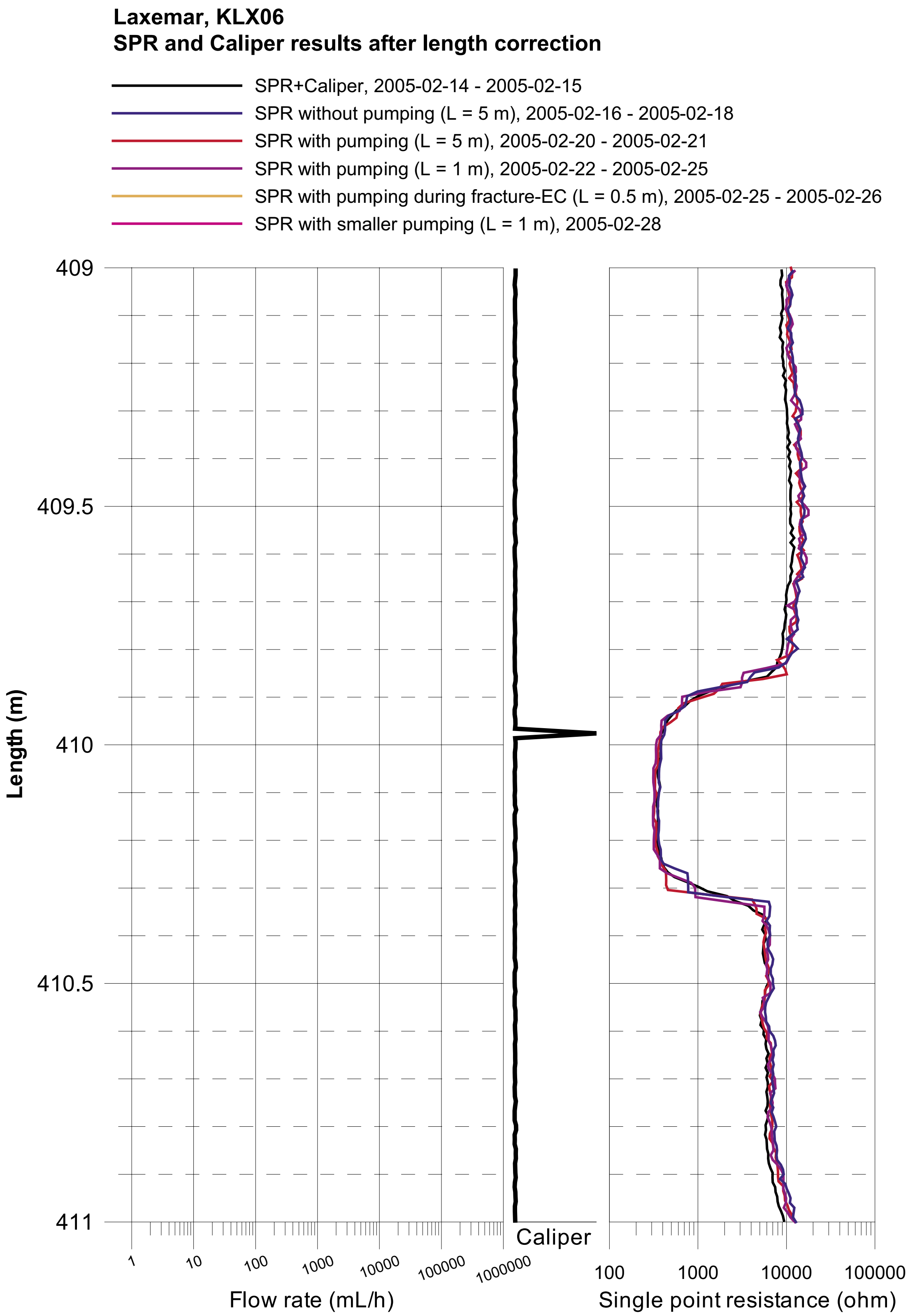



Laxemar, KLX06
SPR and Caliper results after length correction
SPR+Caliper, 2005-02-14 - 2005-02-15
SPR without pumping (L = 5 m), 2005-02-16 - 2005-02-18
SPR with pumping (L = 5 m), 2005-02-20 - 2005-02-21
SPR with pumping (L = 1 m), 2005-02-22 - 2005-02-25
SPR with pumping during fracture-EC (L = 0.5 m), 2005-02-25 - 2005-02-26
SPR with smaller pumping (L = 1 m), 2005-02-28
389
389.5
390
390.5
391
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

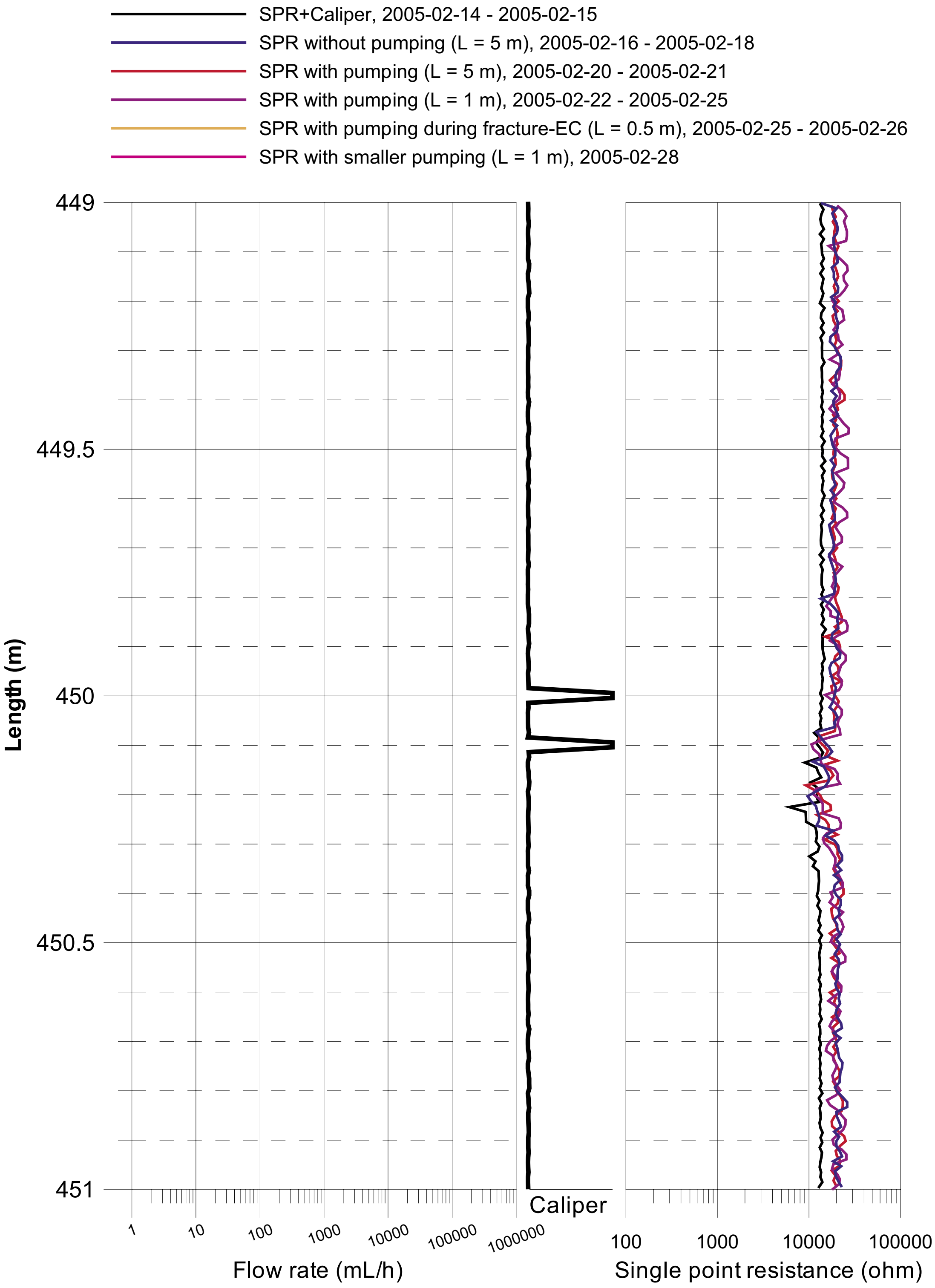
Laxemar, KLX06
SPR and Caliper results after length correction



Appendix 1.18

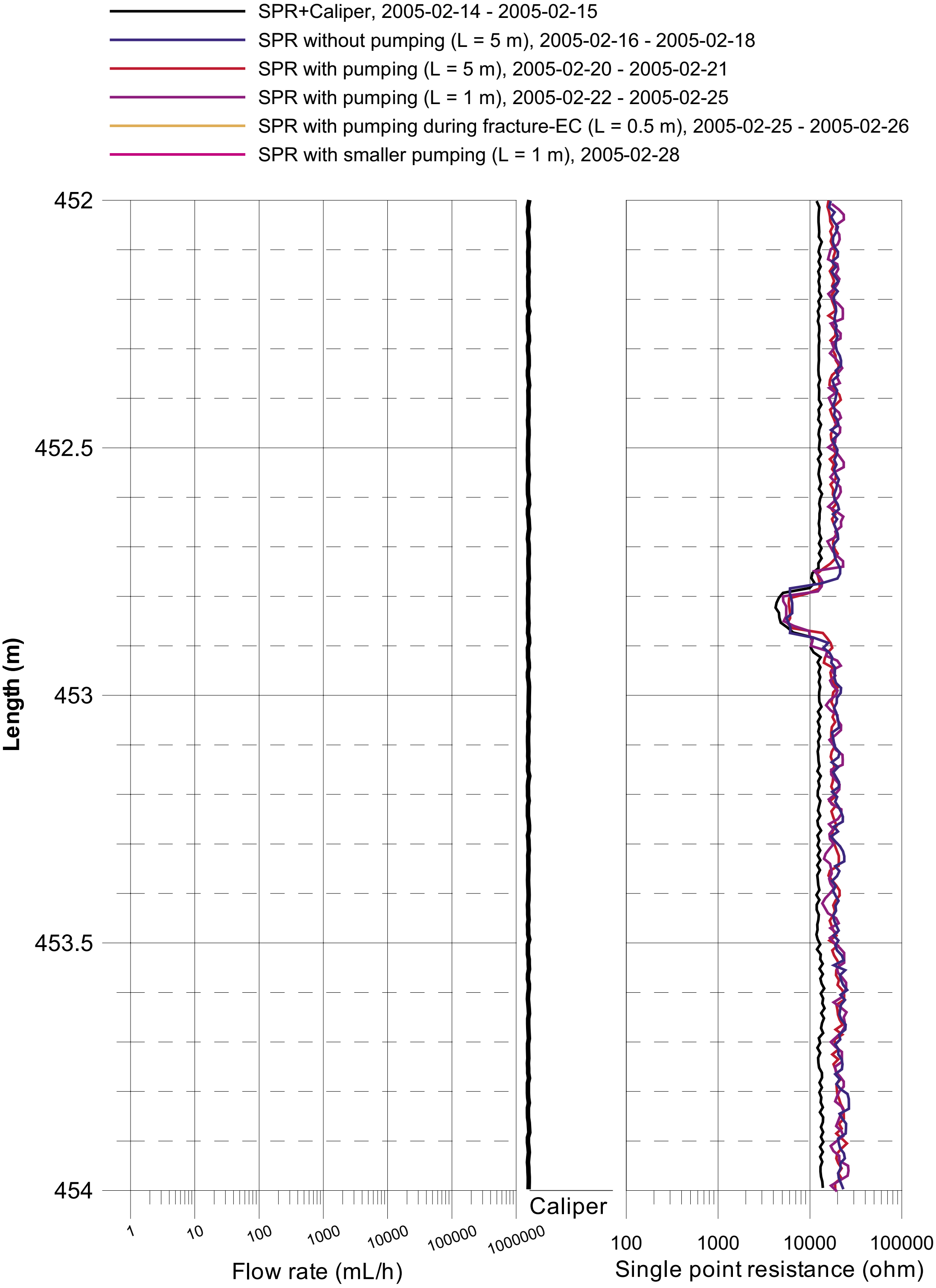


Laxemar, KLX06
SPR and Caliper results after length correction

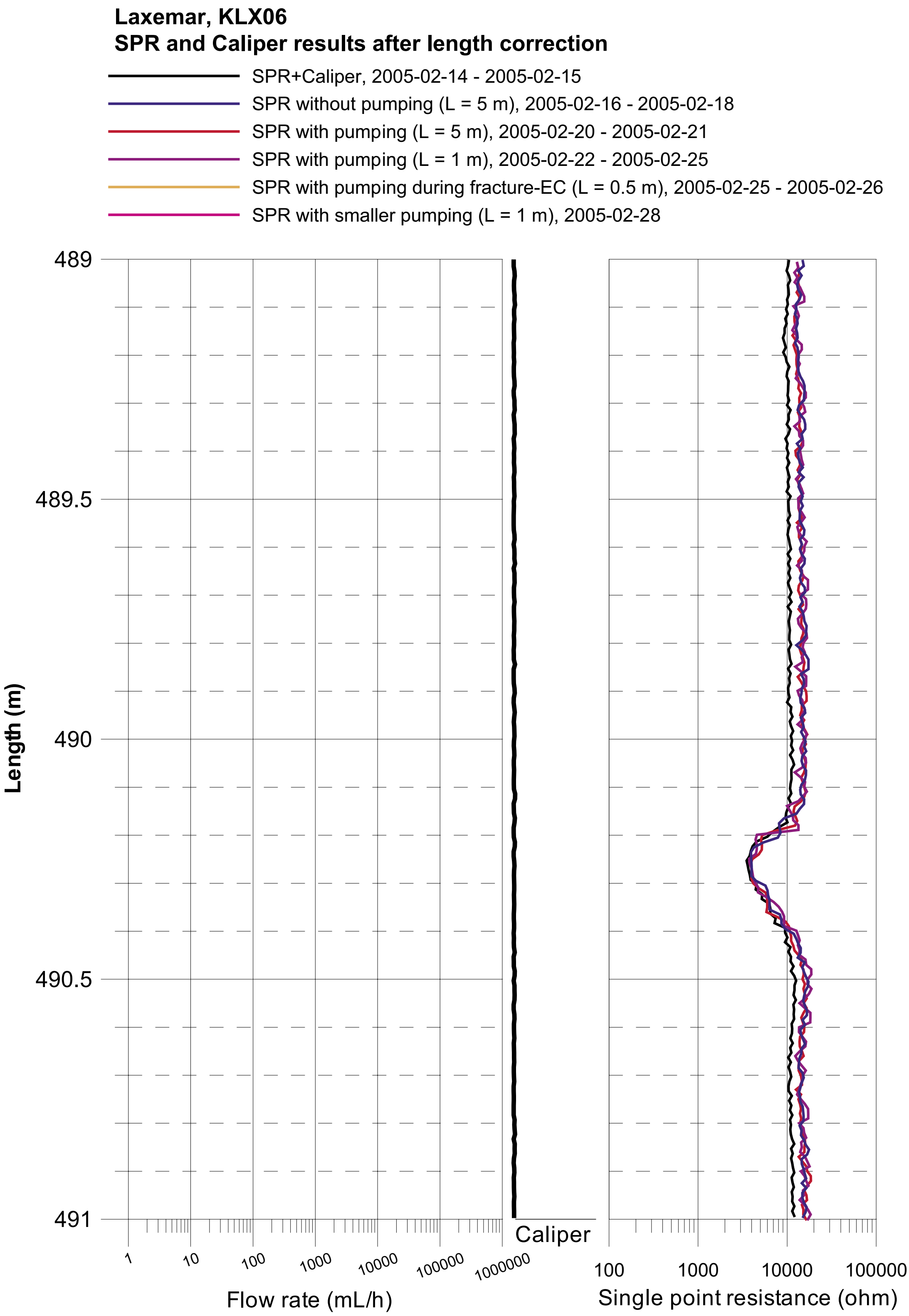


Appendix 1.20

Laxemar, KLX06
SPR and Caliper results after length correction

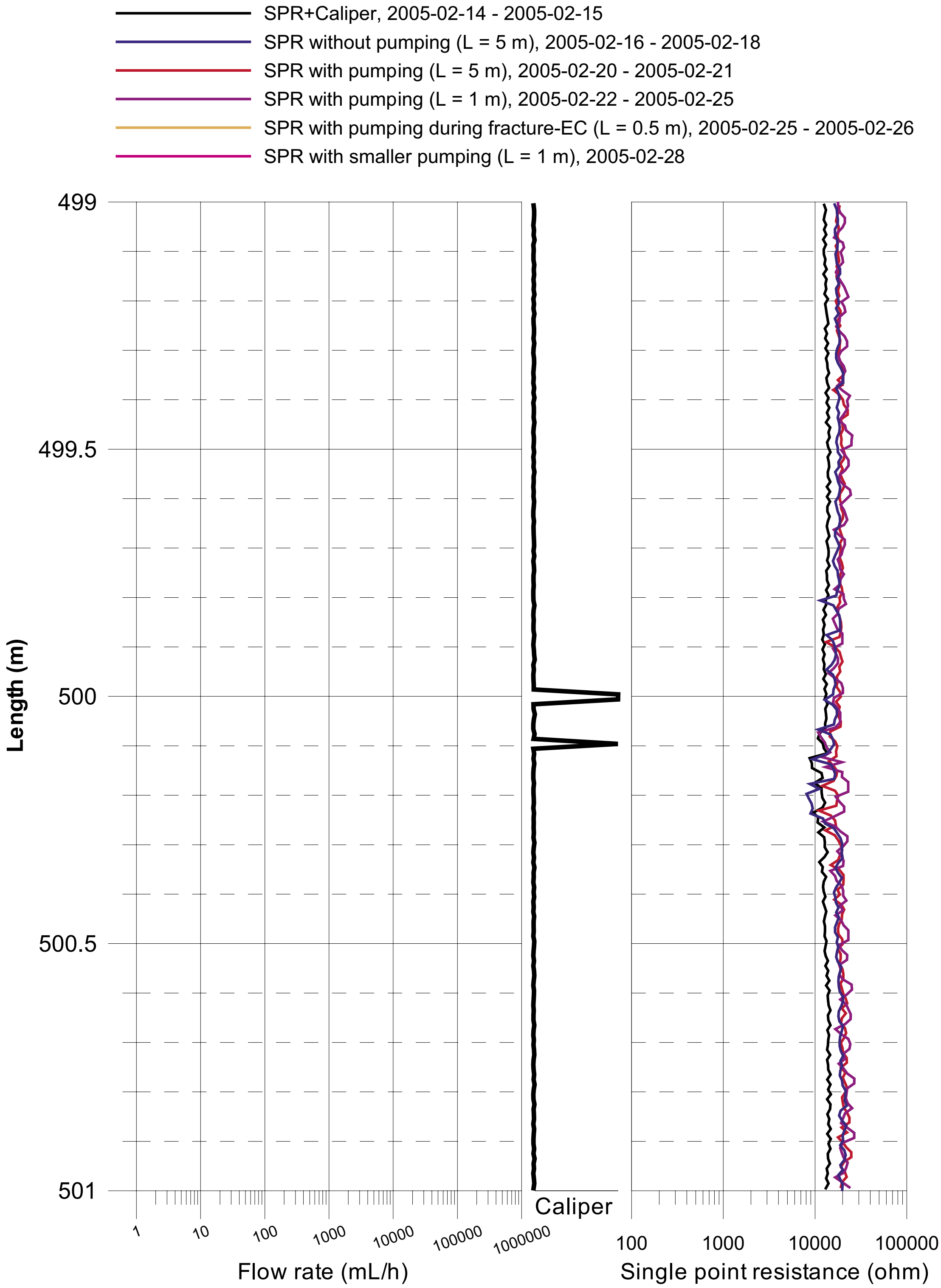


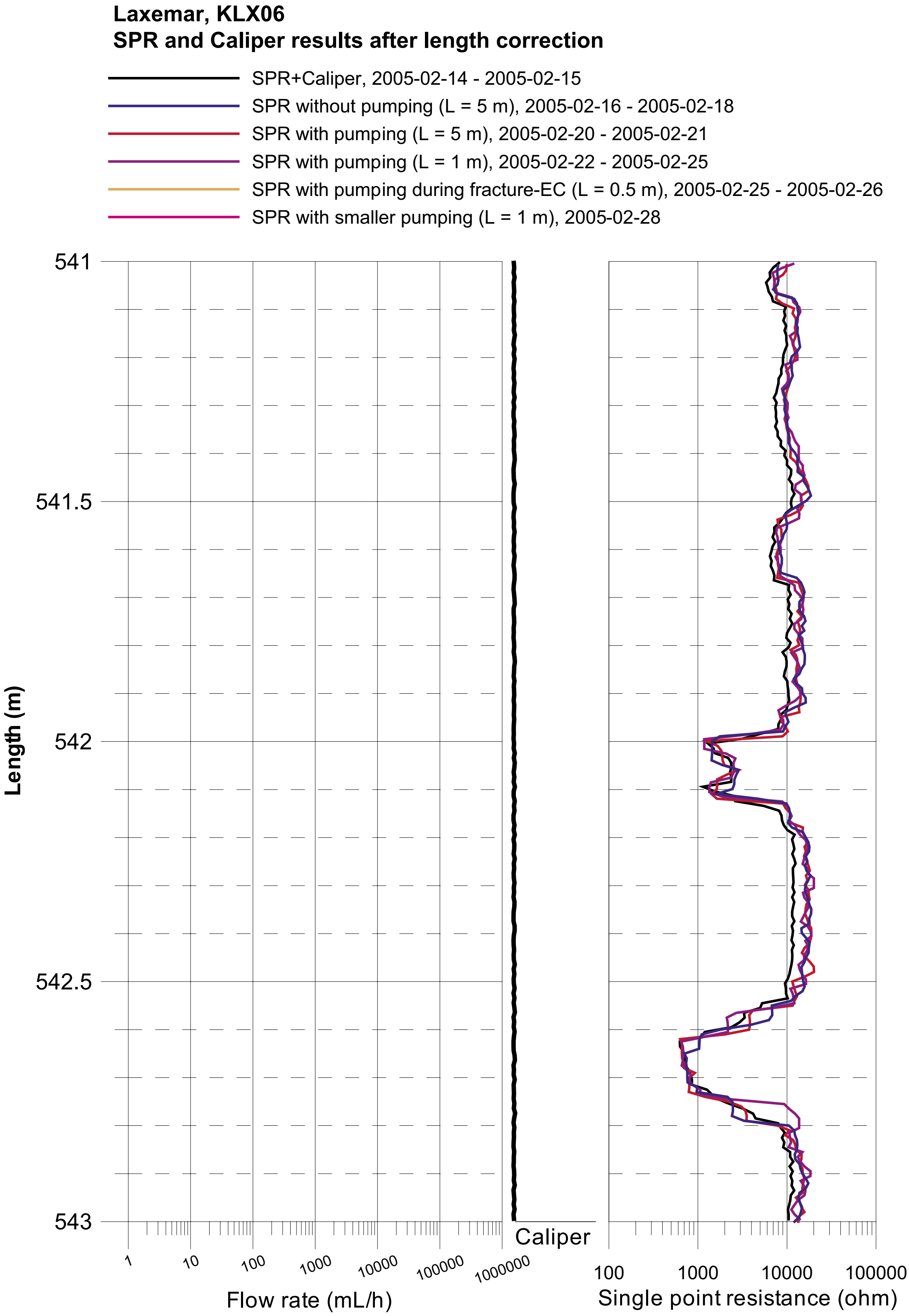
Appendix 1.21



Appendix 1.22

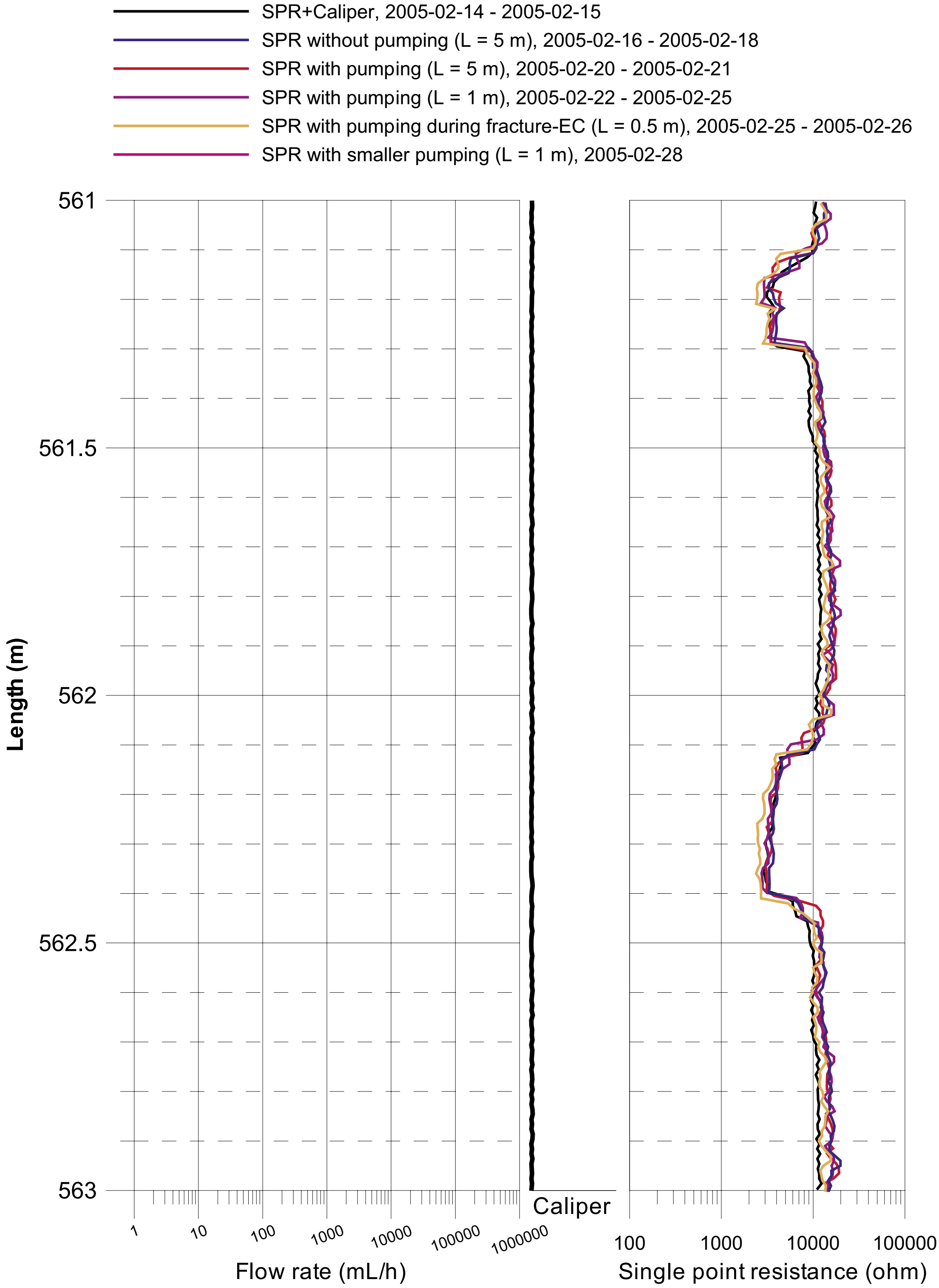
Laxemar, KLX06
SPR and Caliper results after length correction




Laxemar, KLX06
SPR and Caliper results after length correction
SPR+Caliper, 2005-02-14 - 2005-02-15
SPR without pumping (L = 5 m), 2005-02-16 - 2005-02-18
SPR with pumping (L = 5 m), 2005-02-20 - 2005-02-21
SPR with pumping (L = 1 m), 2005-02-22 - 2005-02-25
SPR with pumping during fracture-EC (L = 0.5 m), 2005-02-25 - 2005-02-26
SPR with smaller pumping (L = 1 m), 2005-02-28
Length (m)
541
541.5
542
542.5
543
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

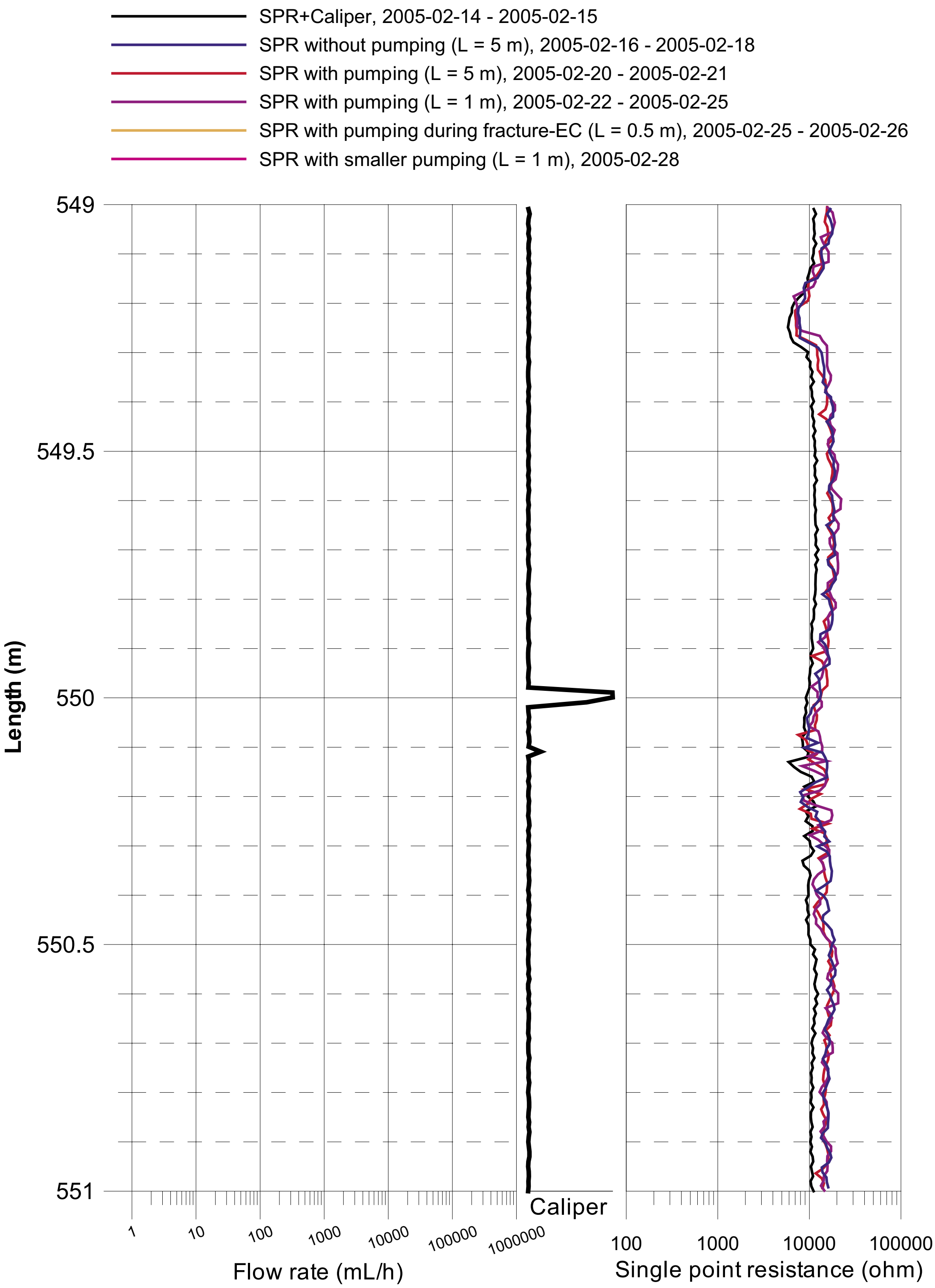
Appendix 1.24

Laxemar, KLX06
SPR and Caliper results after length correction



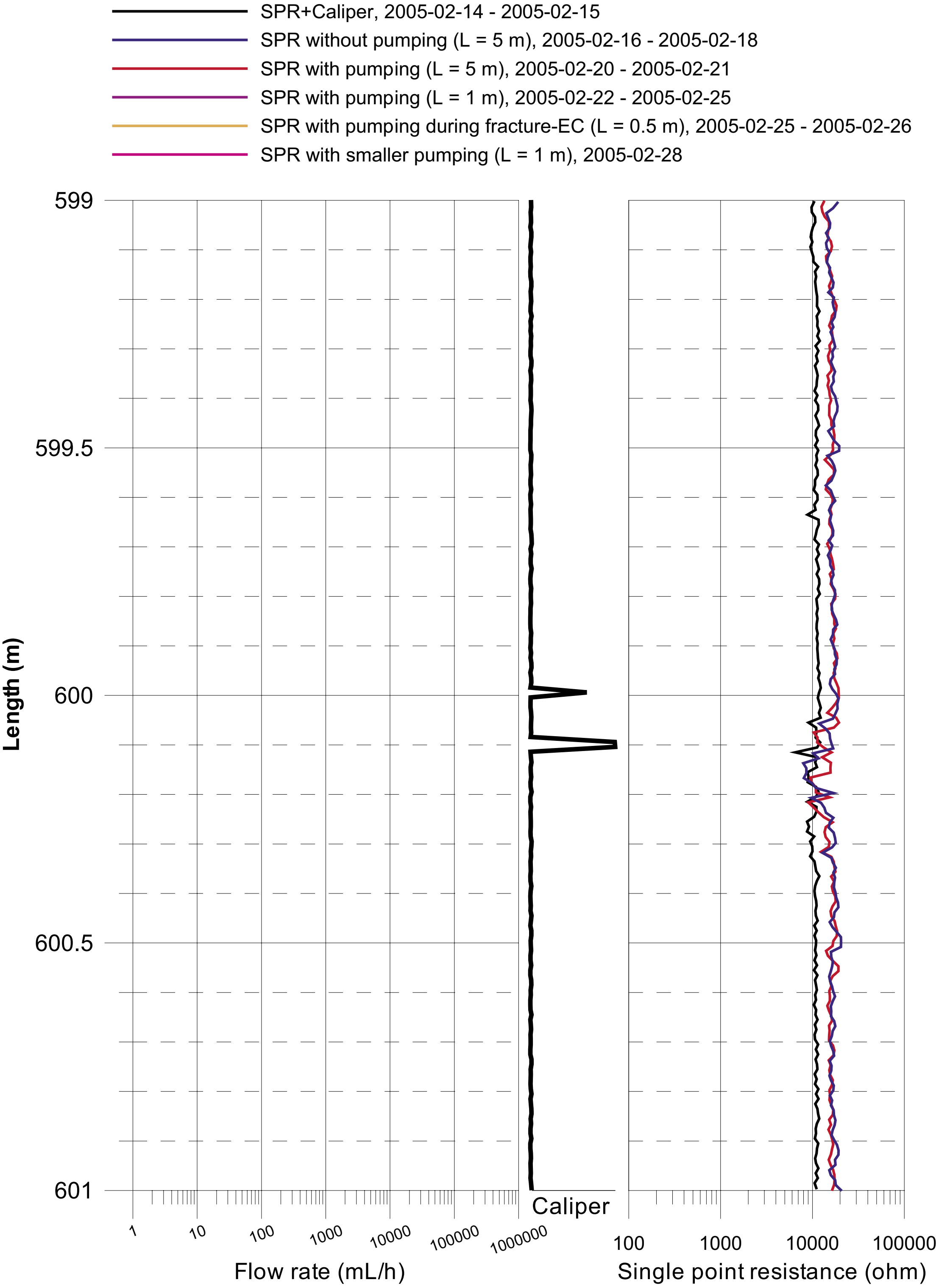
Appendix 1.25

Laxemar, KLX06
SPR and Caliper results after length correction

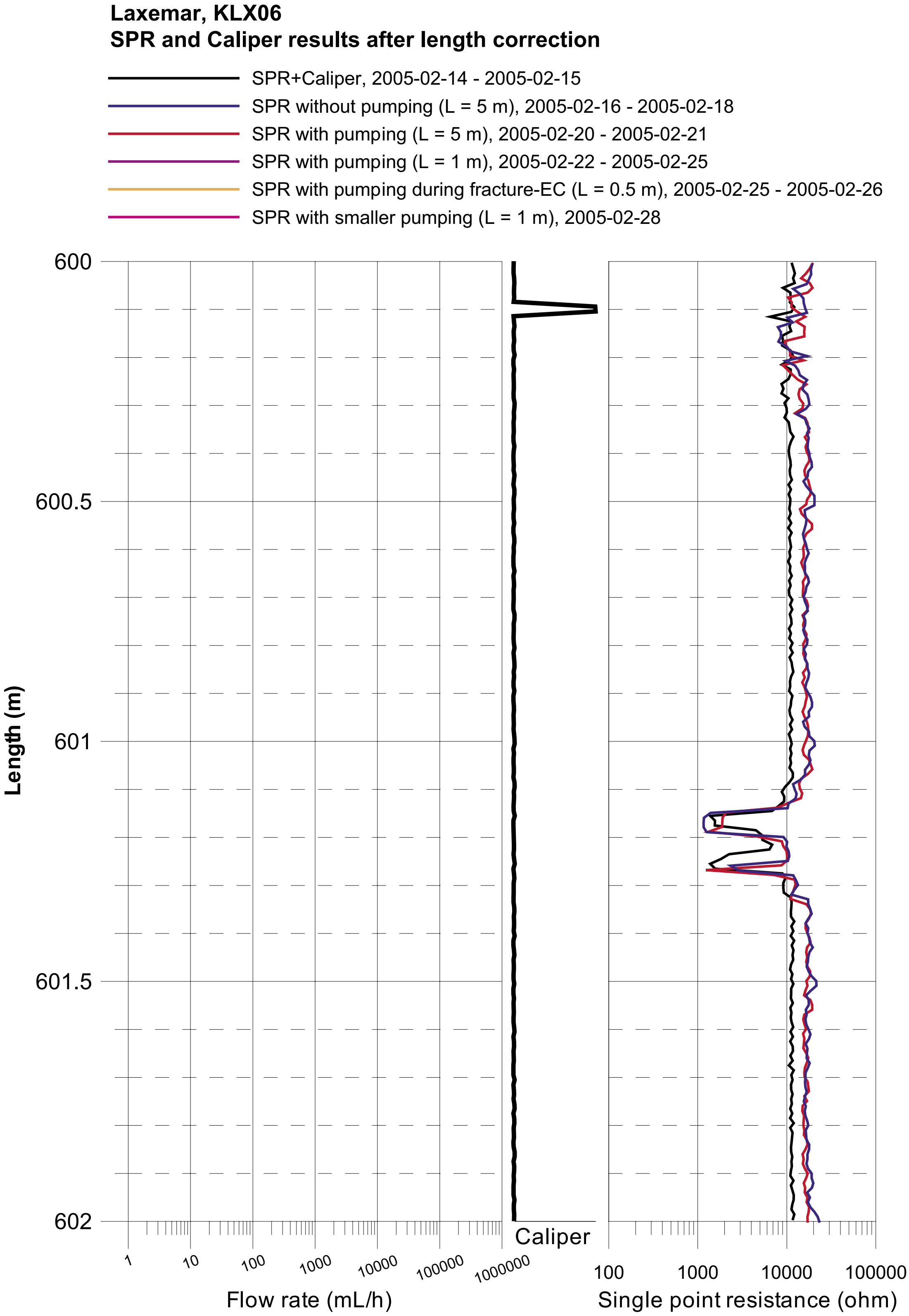


Appendix 1.26

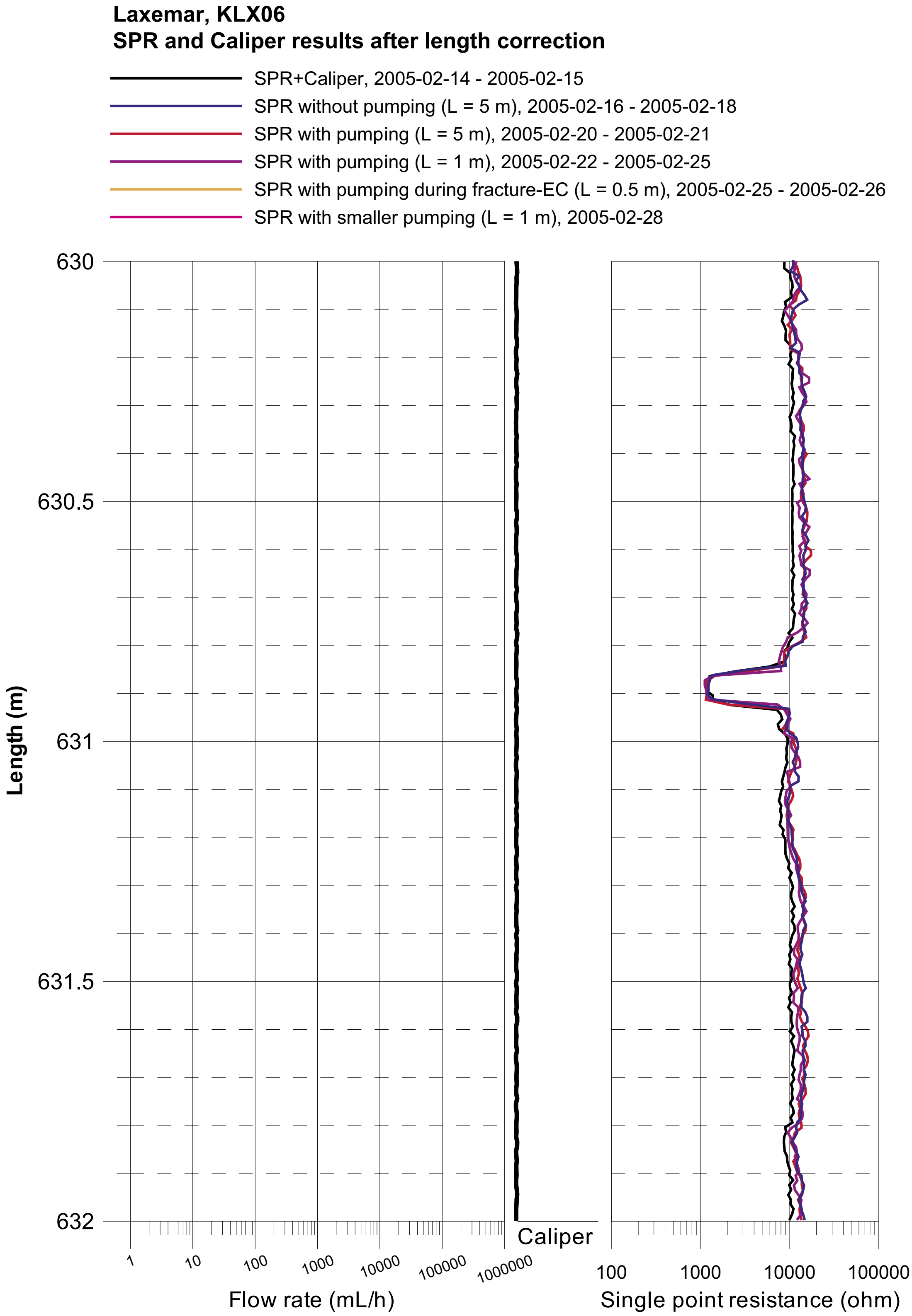
Laxemar, KLX06
SPR and Caliper results after length correction



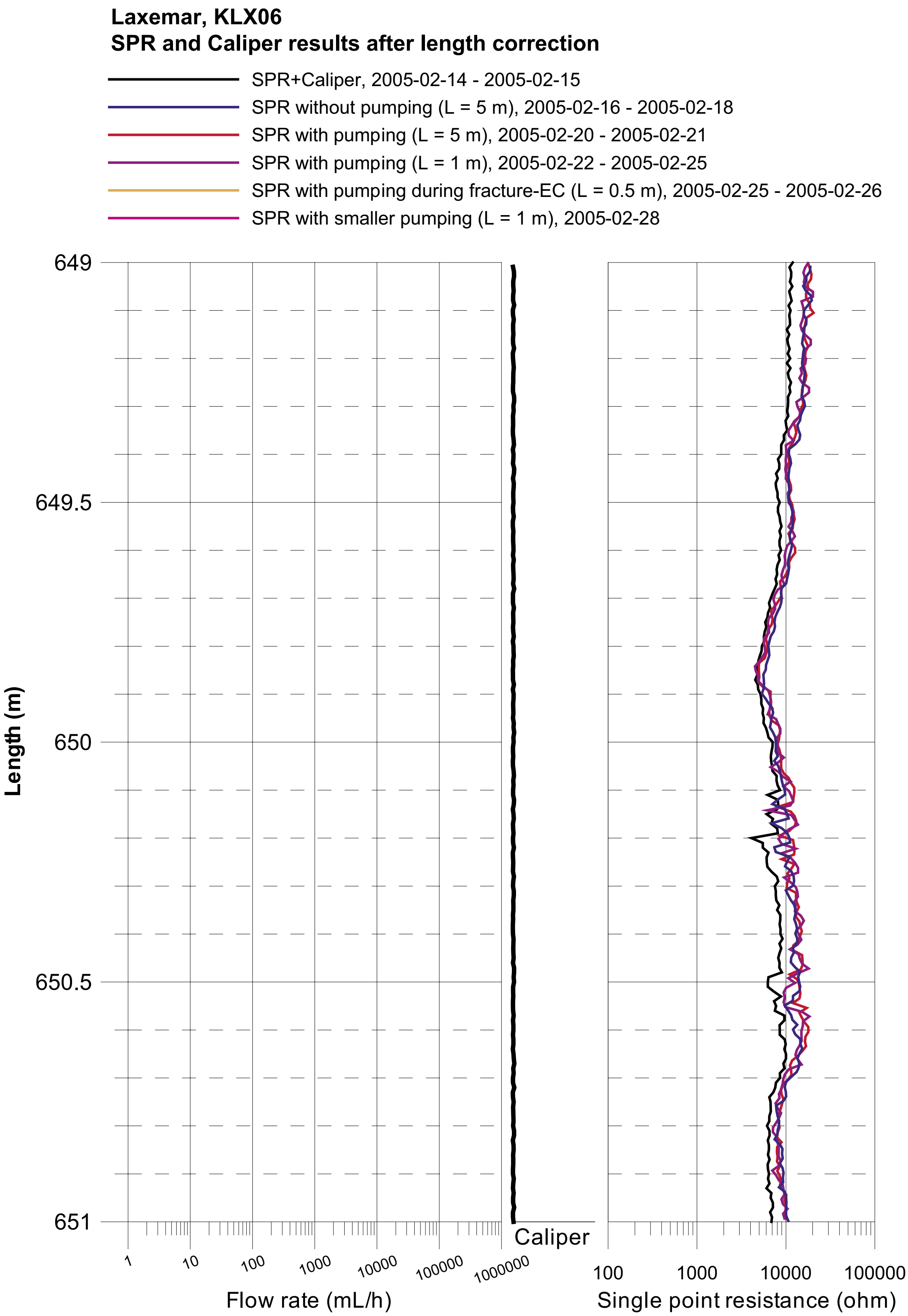
Appendix 1.27



Appendix 1.28

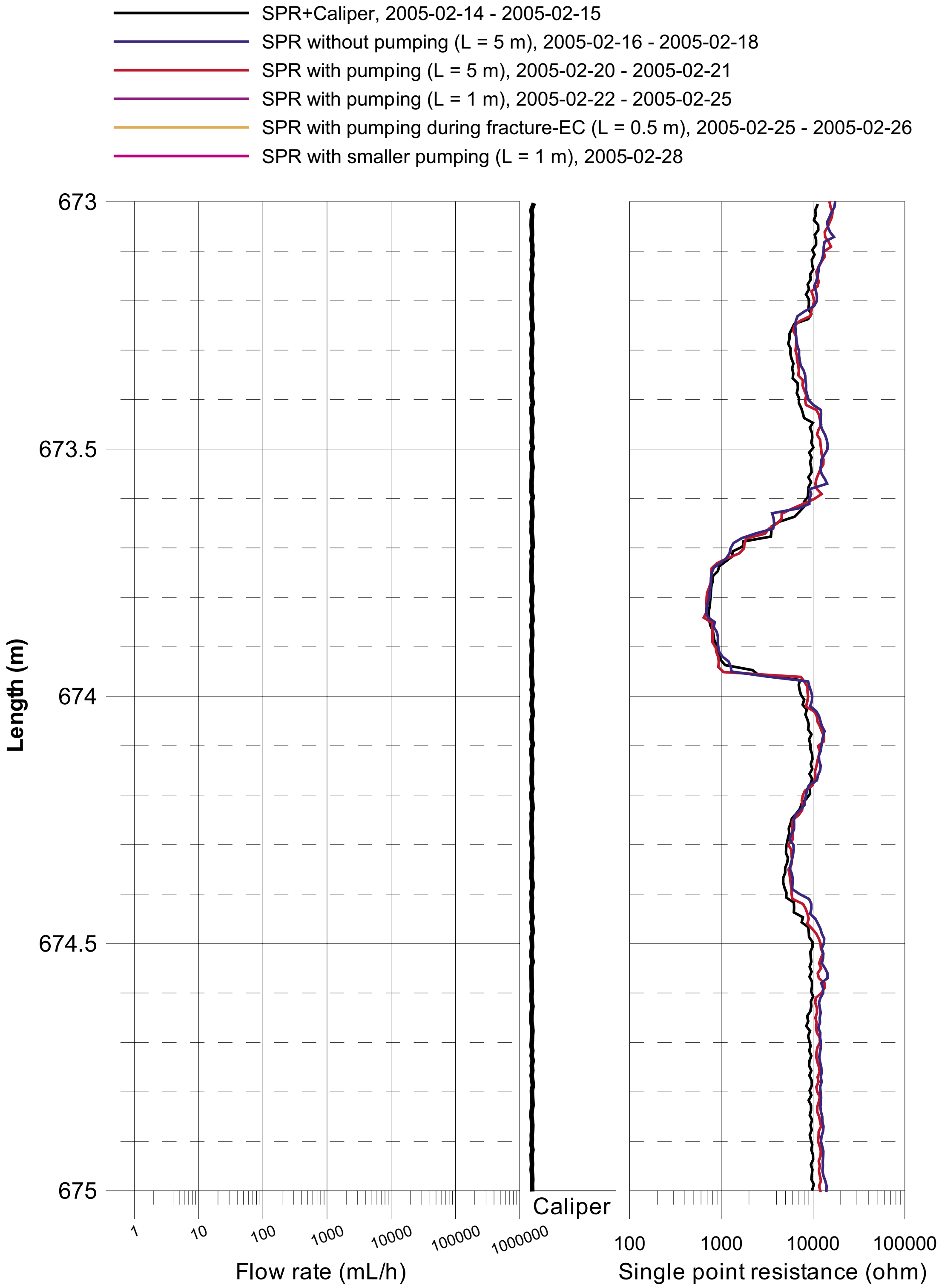


Appendix 1.29



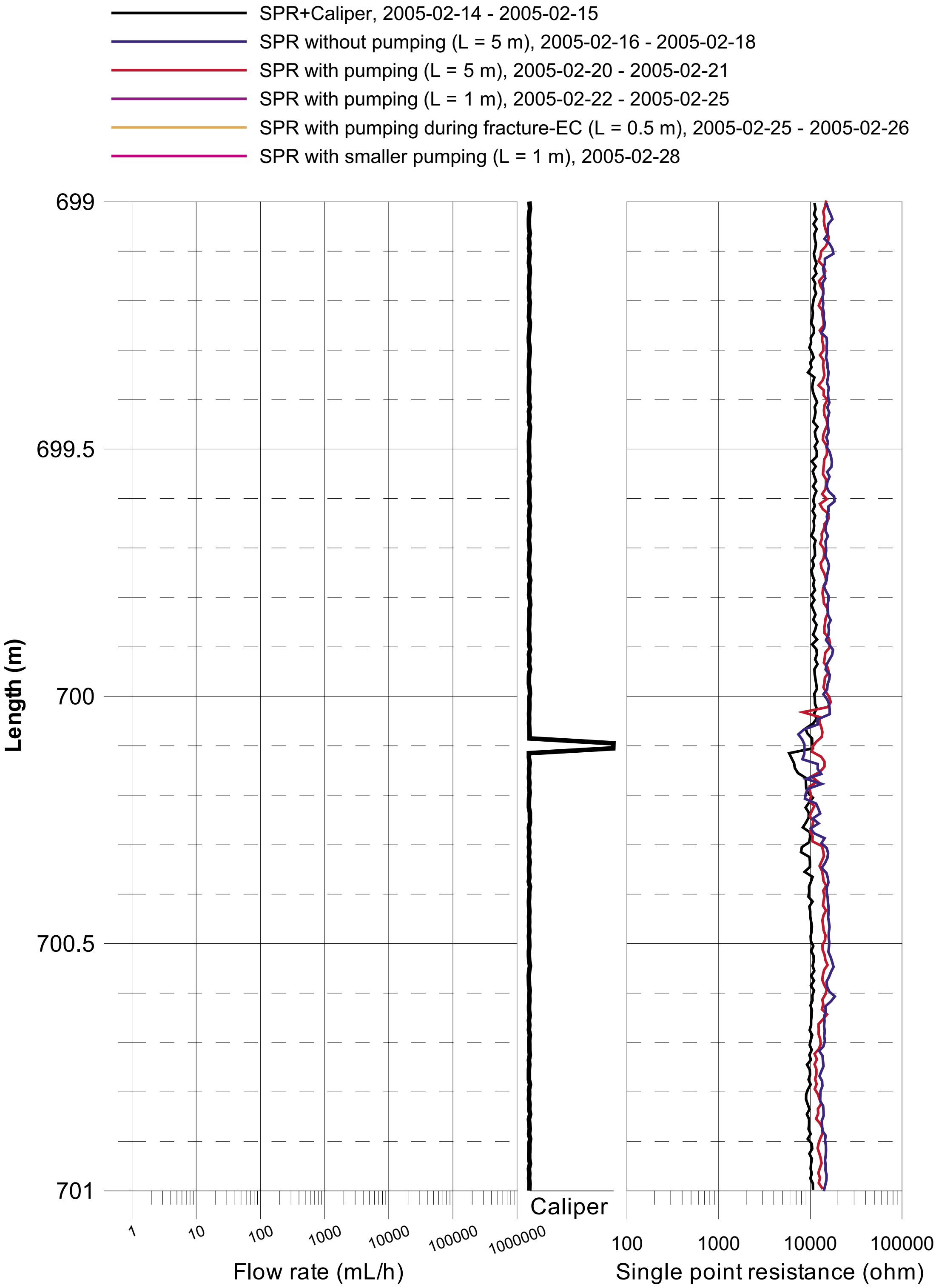
Appendix 1.30

Laxemar, KLX0
SPR and Caliper results after length correction

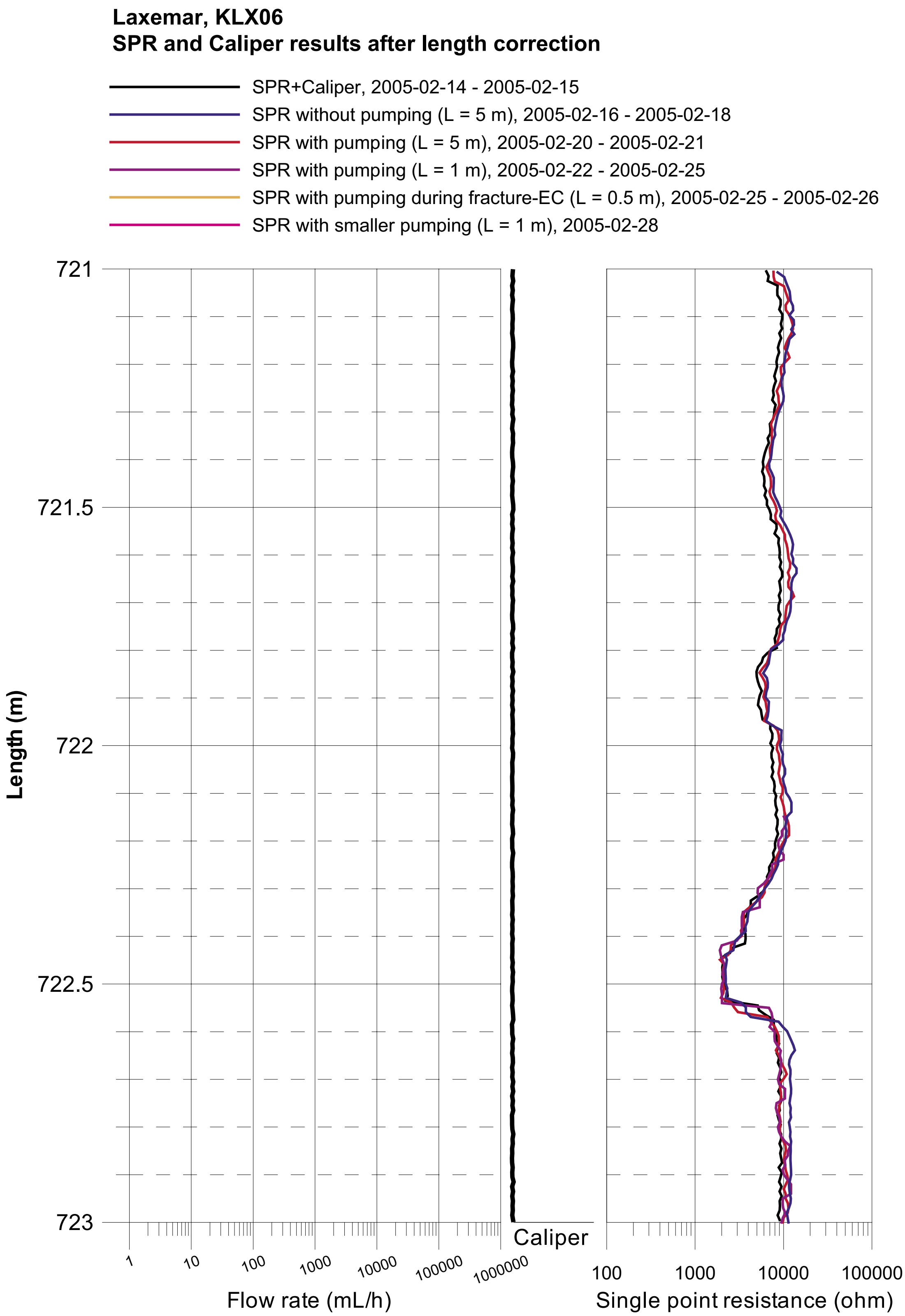


Appendix 1.31

Laxemar, KLX06
SPR and Caliper results after length correction

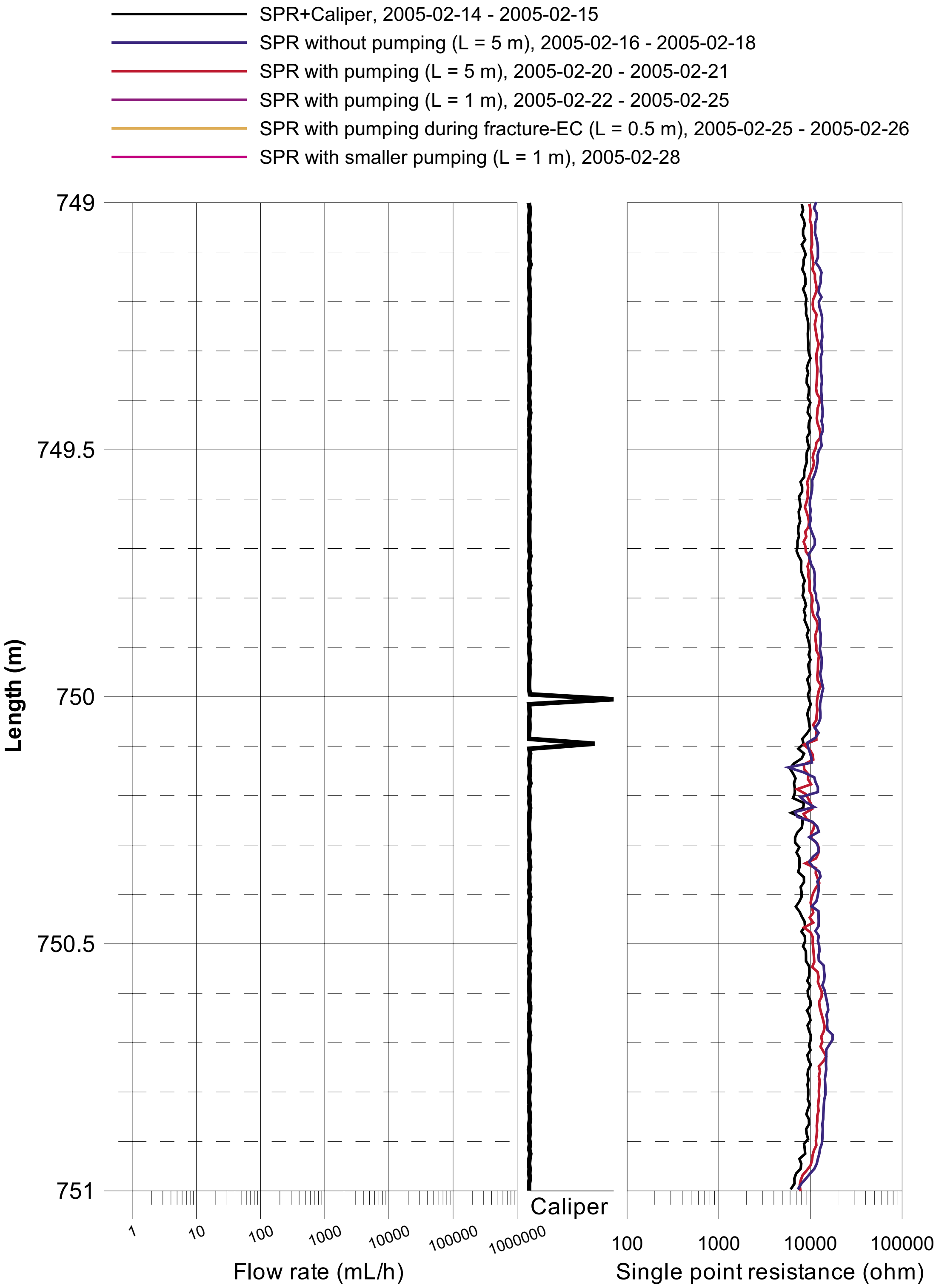


Appendix 1.32



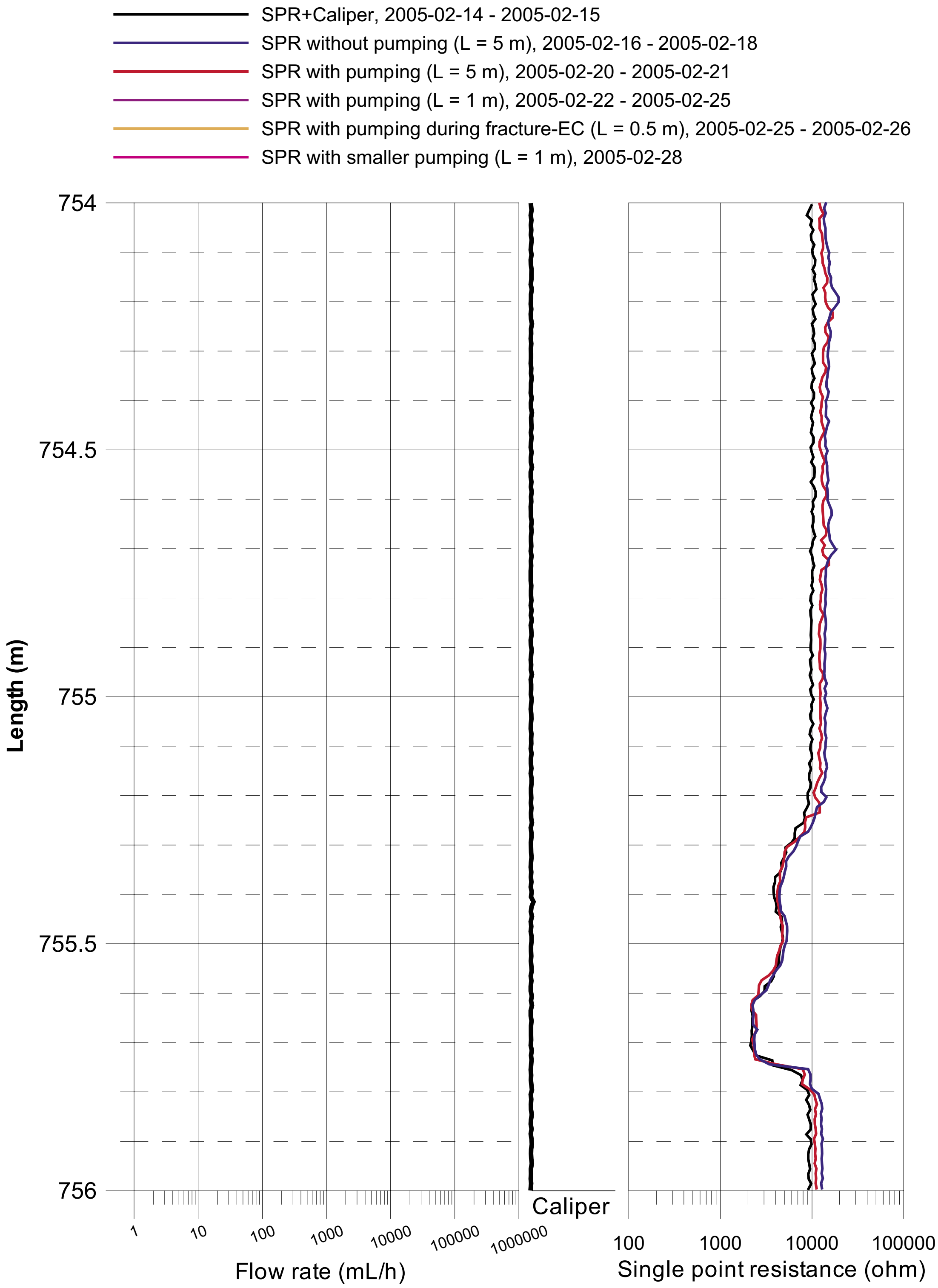
Appendix 1.33

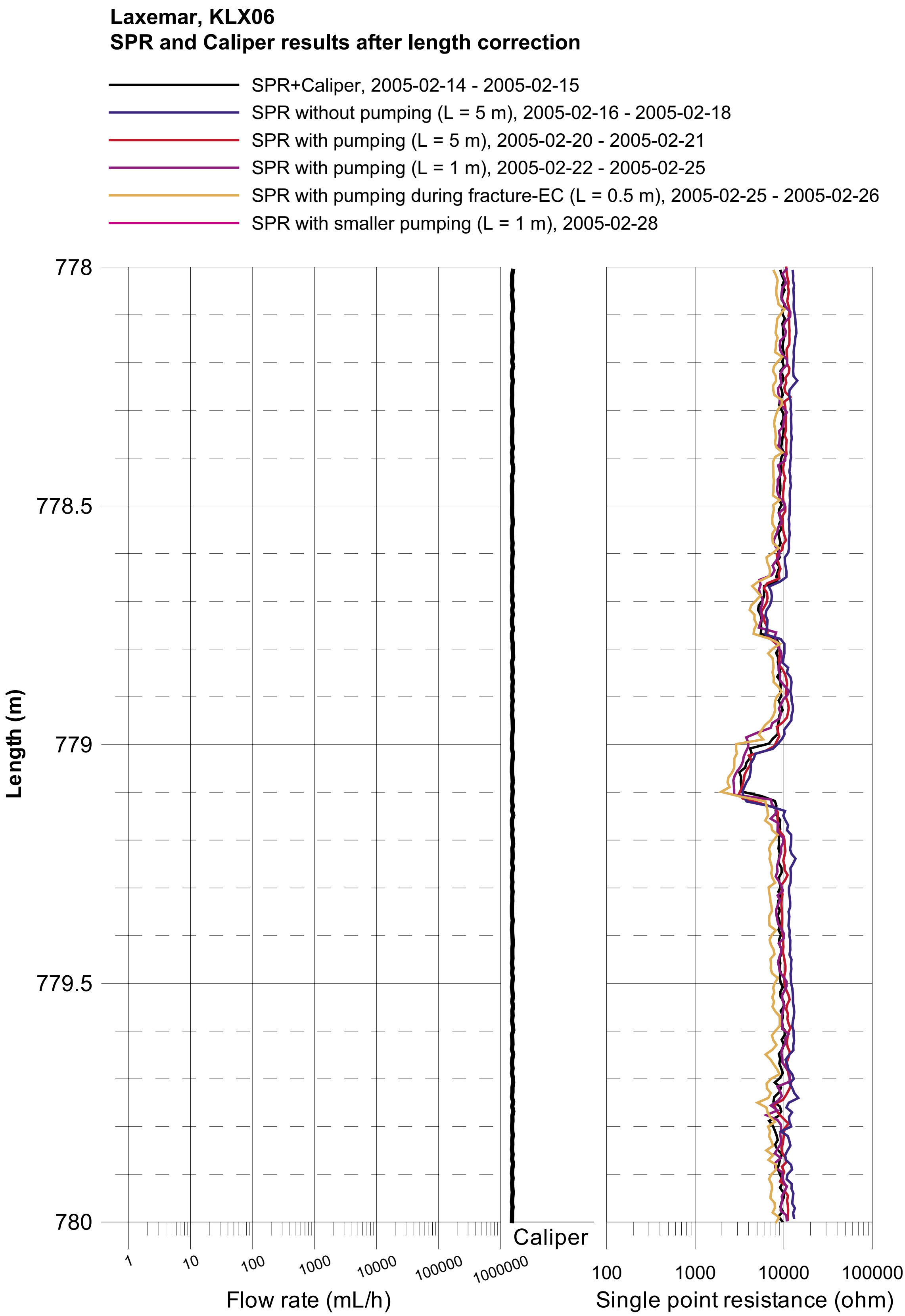
Laxemar, KLX06
SPR and Caliper results after length correction



Appendix 1.34

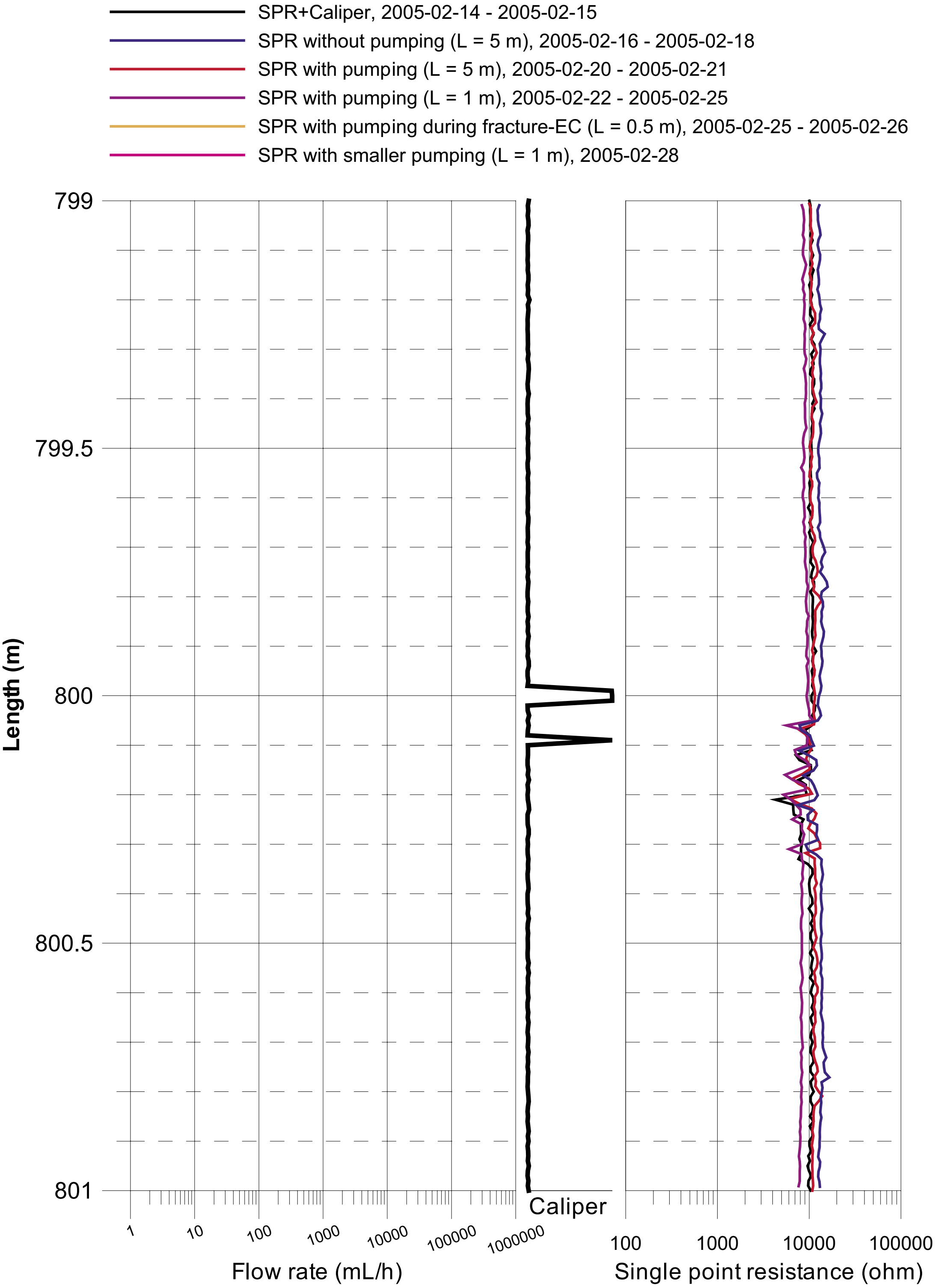
Laxemar, KLX06
SPR and Caliper results after length correction

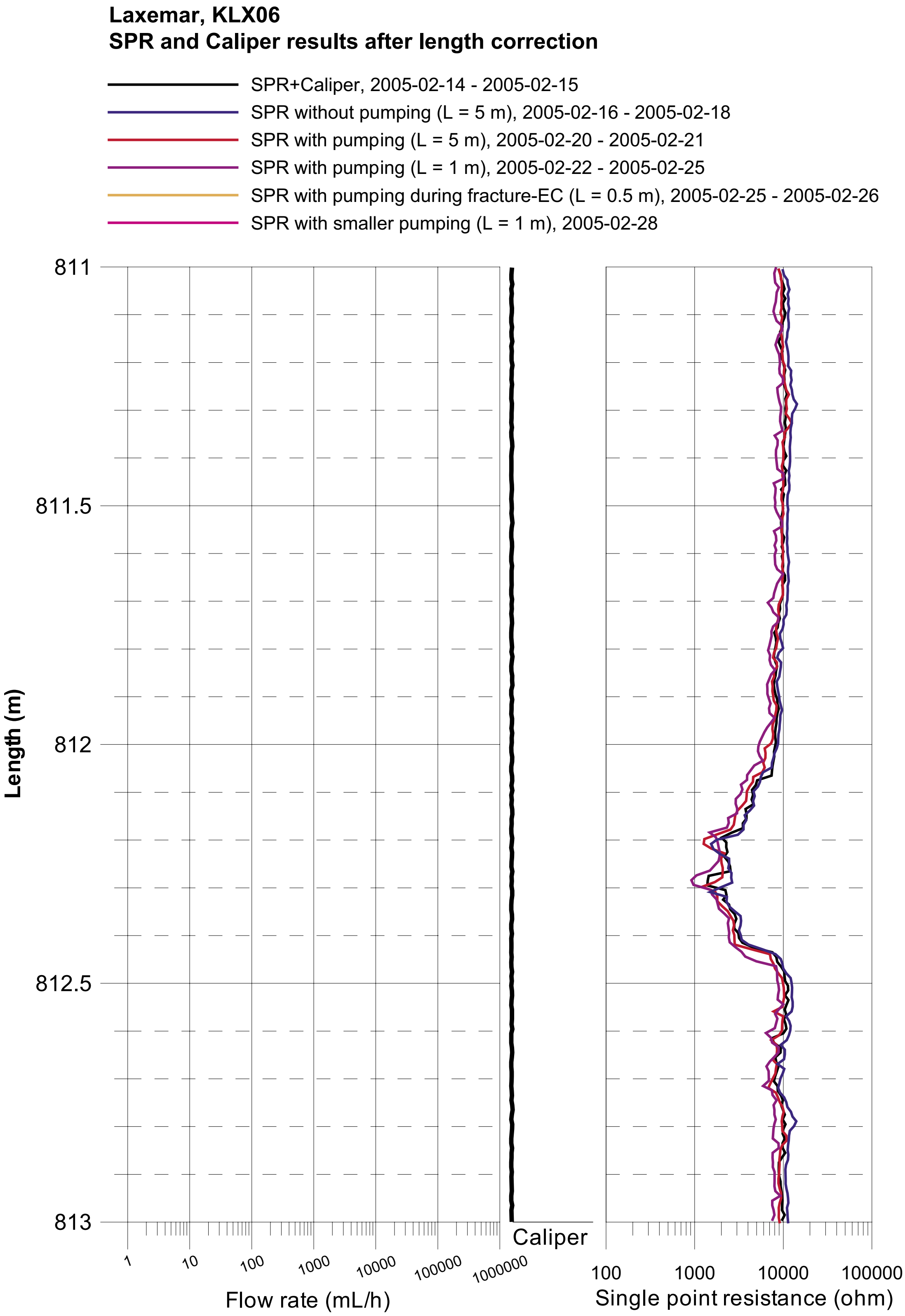



Laxemar, KLX06
SPR and Caliper results after length correction
SPR+Caliper, 2005-02-14 - 2005-02-15
SPR without pumping (L = 5 m), 2005-02-16 - 2005-02-18
SPR with pumping (L = 5 m), 2005-02-20 - 2005-02-21
SPR with pumping (L = 1 m), 2005-02-22 - 2005-02-25
SPR with pumping during fracture-EC (L = 0.5 m), 2005-02-25 - 2005-02-26
SPR with smaller pumping (L = 1 m), 2005-02-28
Length (m)
778
778.5
779
779.5
780
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
100000
Single point resistance (ohm)

Appendix 1.36

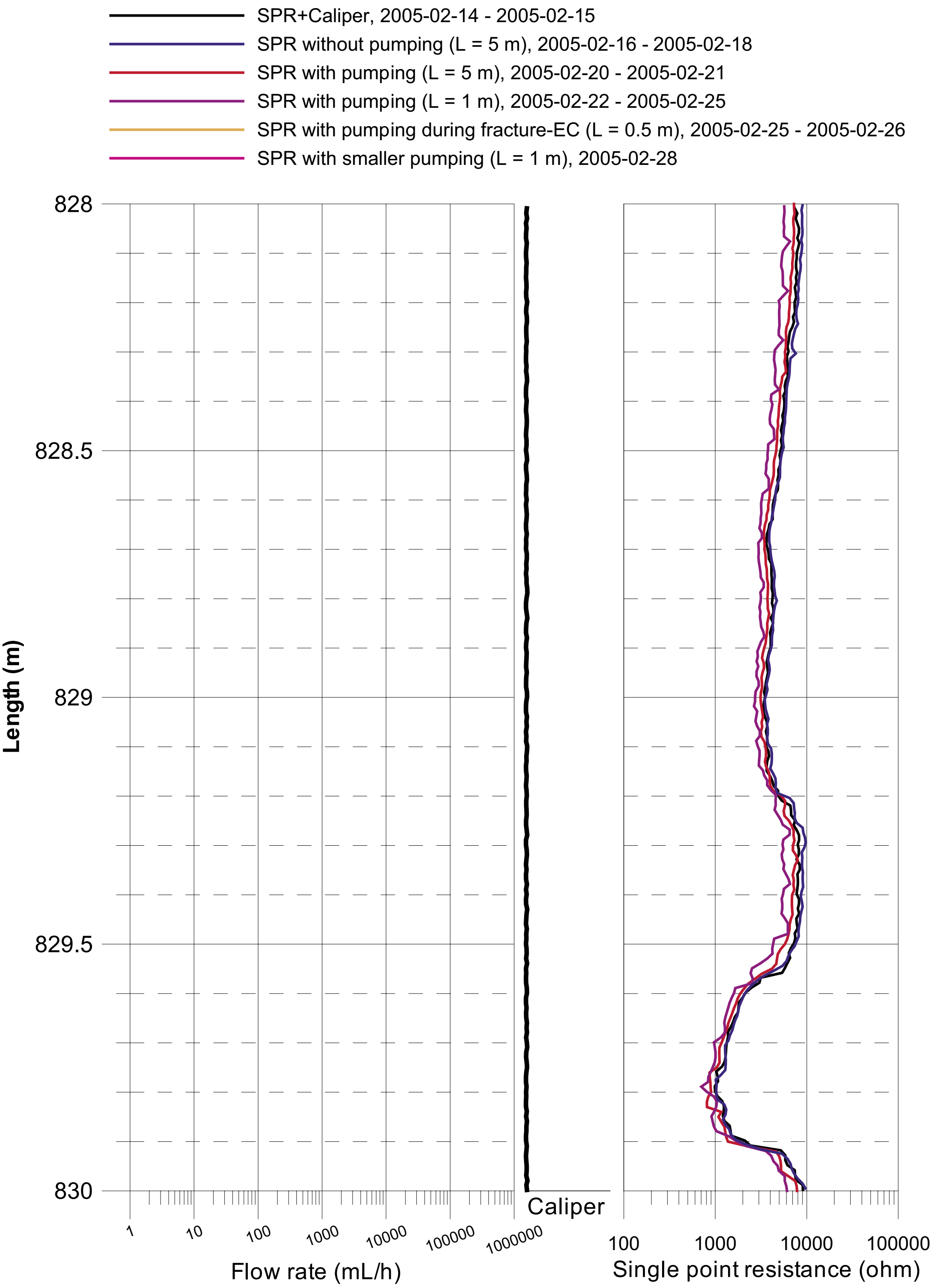
Laxemar, KLX06
SPR and Caliper results after length correction

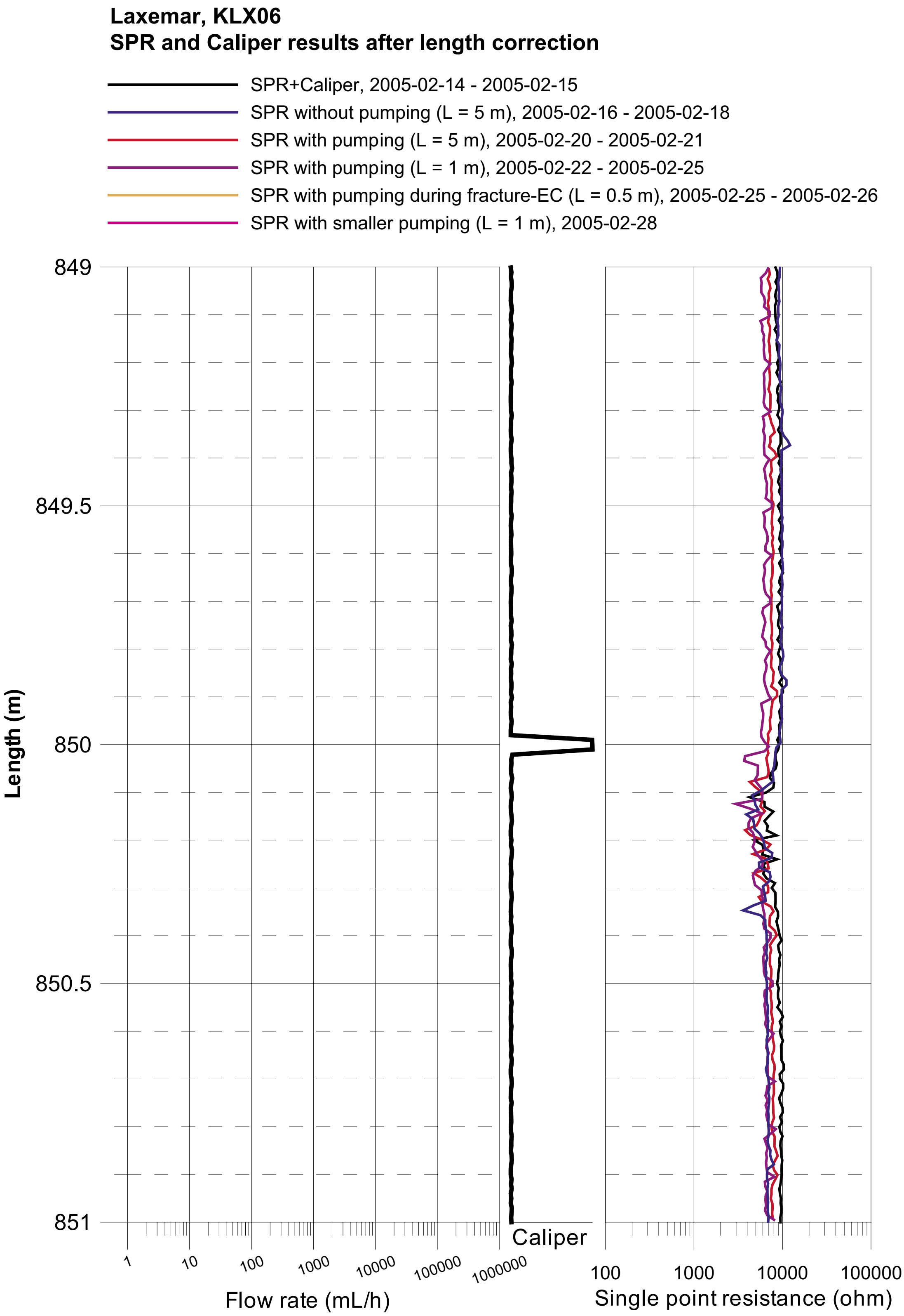



Laxemar, KLX06
SPR and Caliper results after length correction
SPR+Caliper, 2005-02-14 - 2005-02-15
SPR without pumping (L = 5 m), 2005-02-16 - 2005-02-18
SPR with pumping (L = 5 m), 2005-02-20 - 2005-02-21
SPR with pumping (L = 1 m), 2005-02-22 - 2005-02-25
SPR with pumping during fracture-EC (L = 0.5 m), 2005-02-25 - 2005-02-26
SPR with smaller pumping (L = 1 m), 2005-02-28
Length (m)
811
811.5
812
812.5
813
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

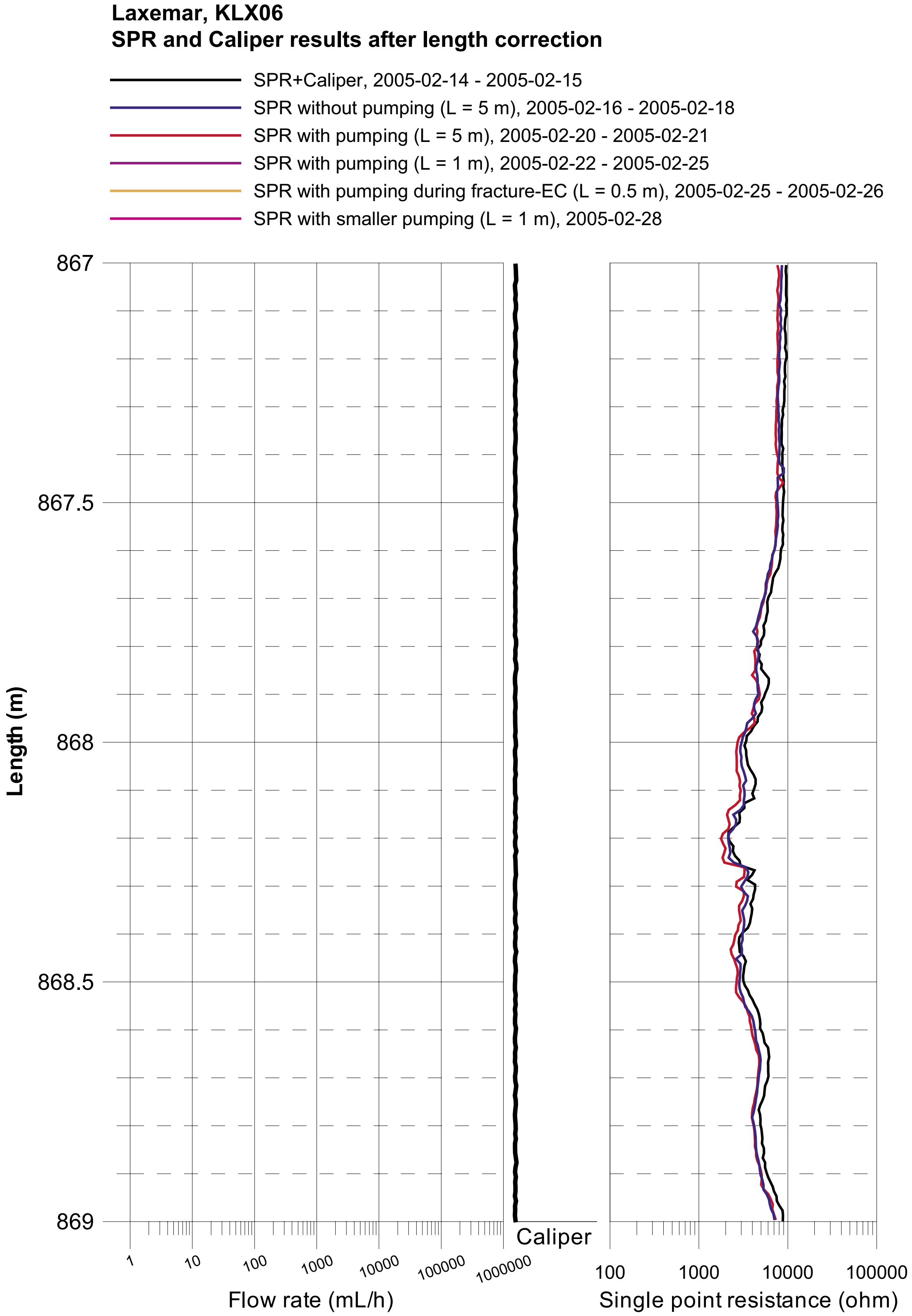
Appendix 1.38

Laxemar, KLX06
SPR and Caliper results after length correction



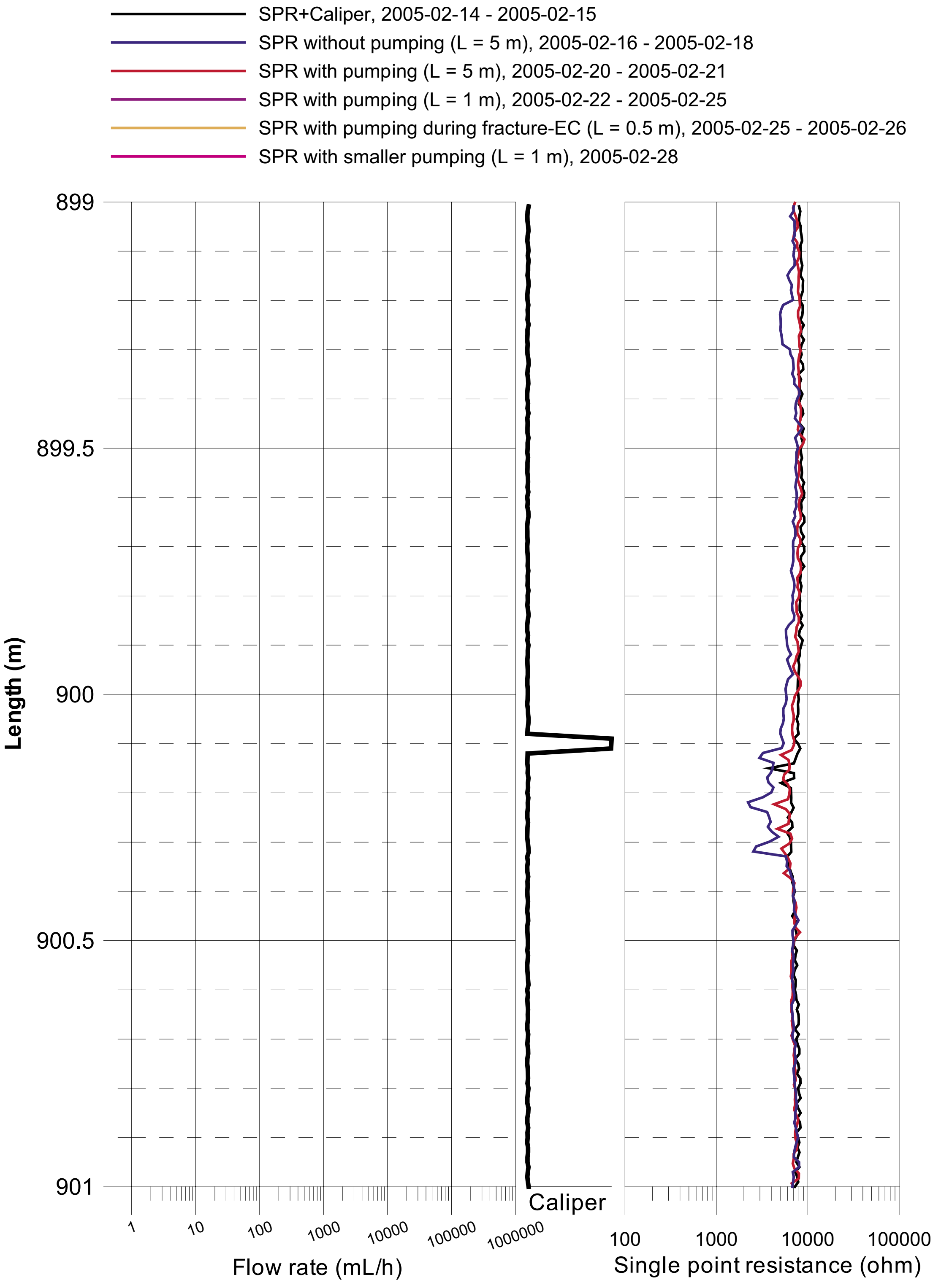

Laxemar, KLX06
SPR and Caliper results after length correction
SPR+Caliper, 2005-02-14 - 2005-02-15
SPR without pumping (L = 5 m), 2005-02-16 - 2005-02-18
SPR with pumping (L = 5 m), 2005-02-20 - 2005-02-21
SPR with pumping (L = 1 m), 2005-02-22 - 2005-02-25
SPR with pumping during fracture-EC (L = 0.5 m), 2005-02-25 - 2005-02-26
SPR with smaller pumping (L = 1 m), 2005-02-28
Length (m)
849
849.5
850
850.5
851
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

Appendix 1.40



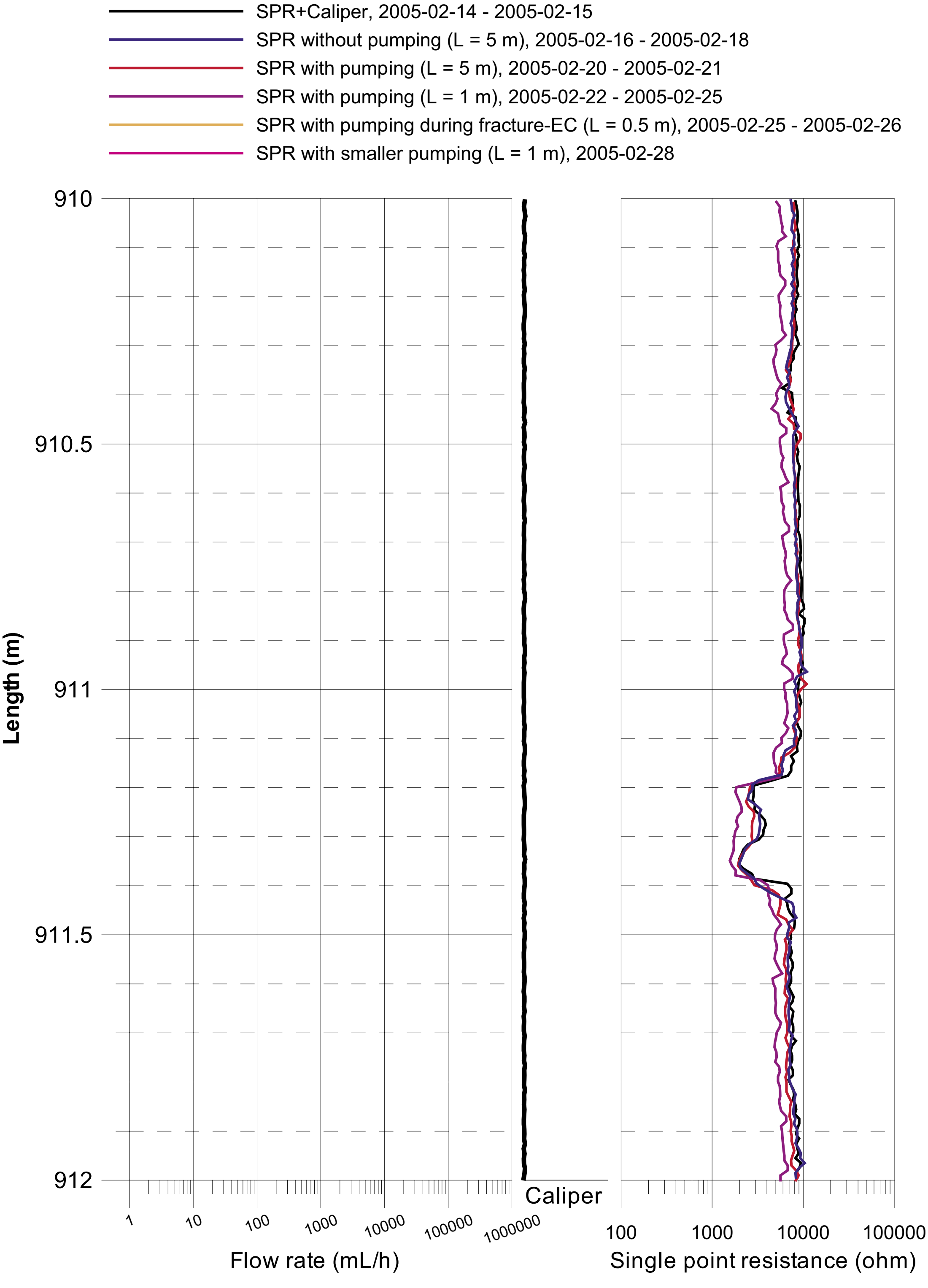
Appendix 1.41

Laxemar, KLX06
SPR and Caliper results after length correction

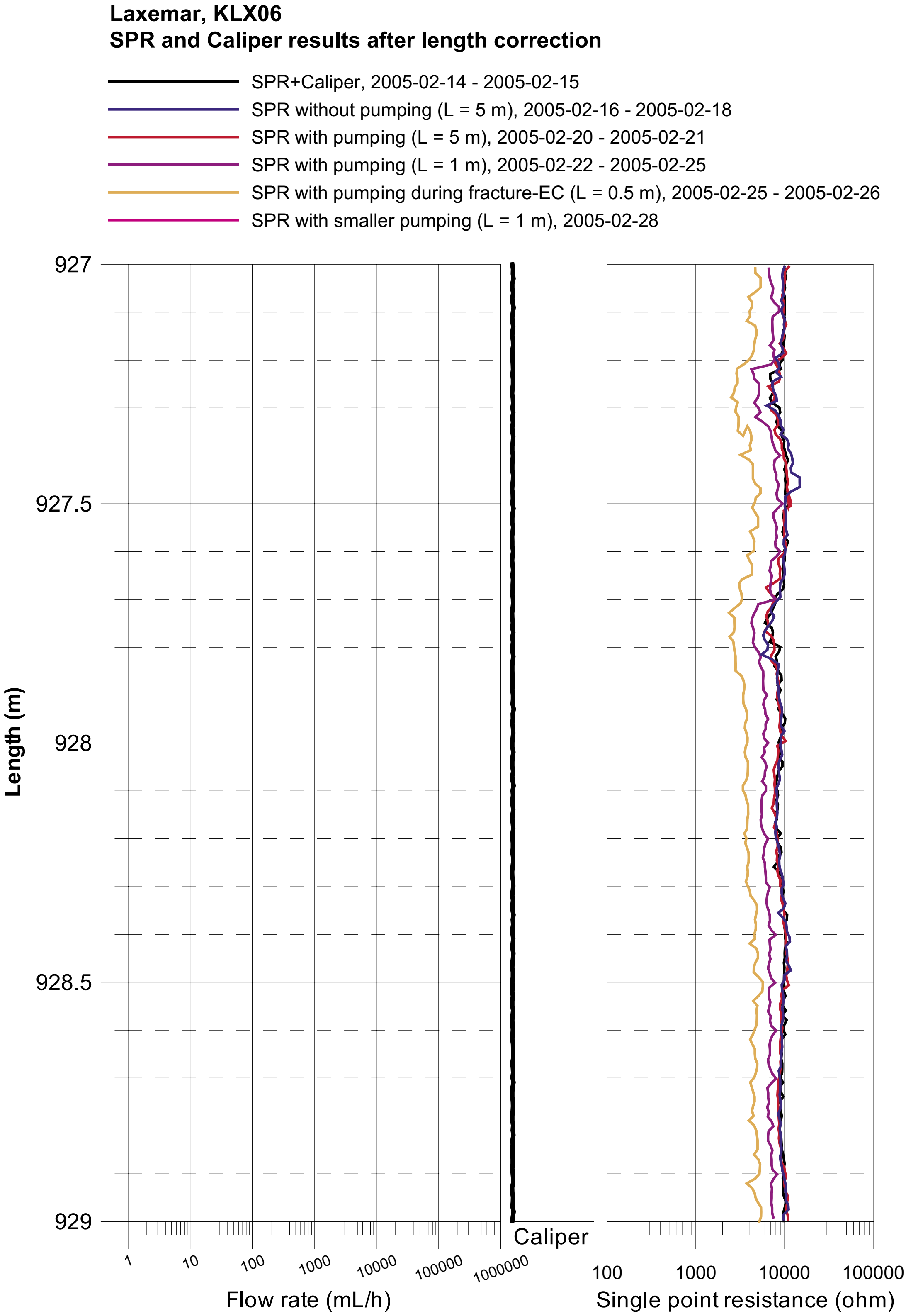


Appendix 1.42

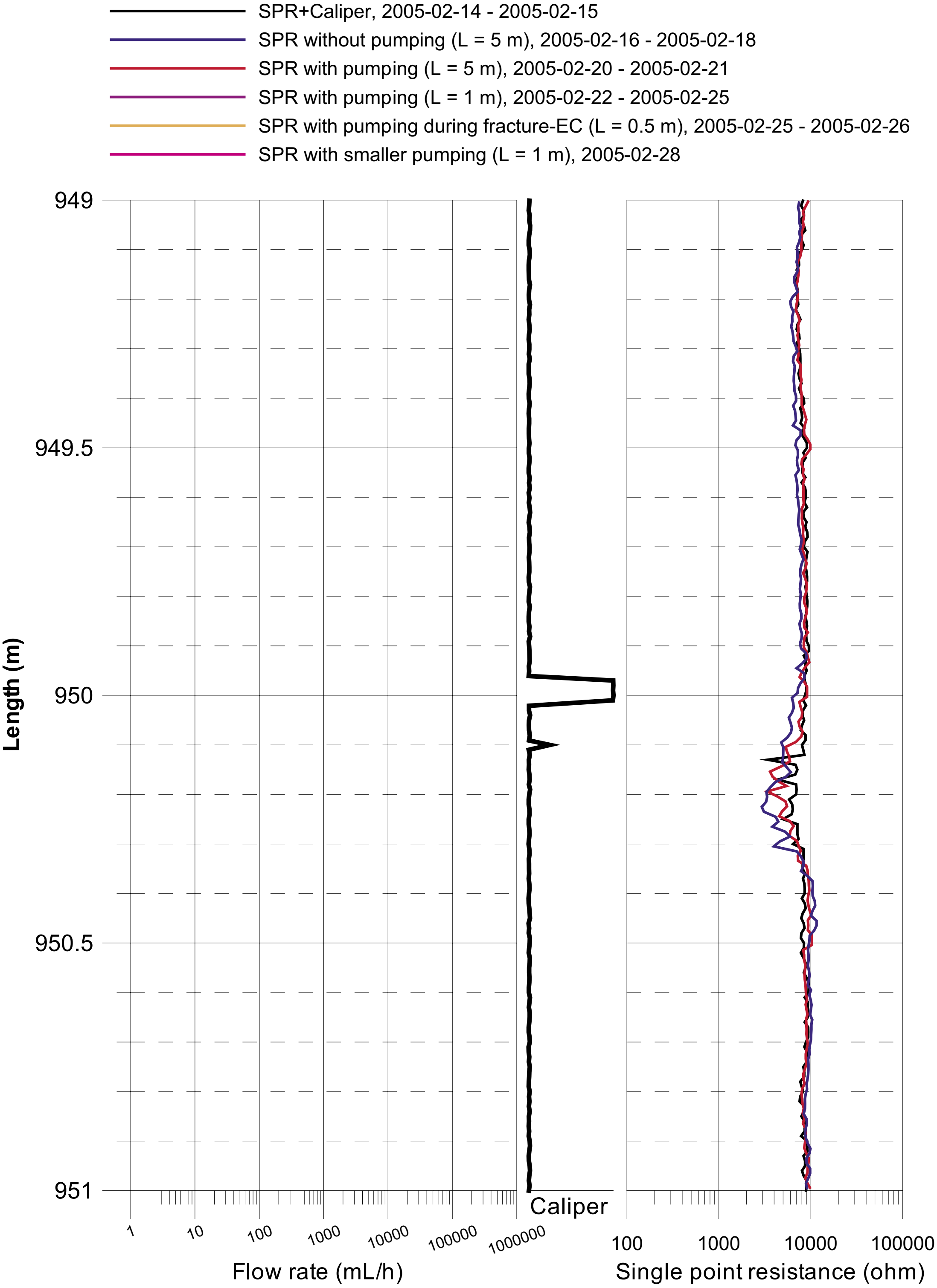
Laxemar, KLX06
SPR and Caliper results after length correction



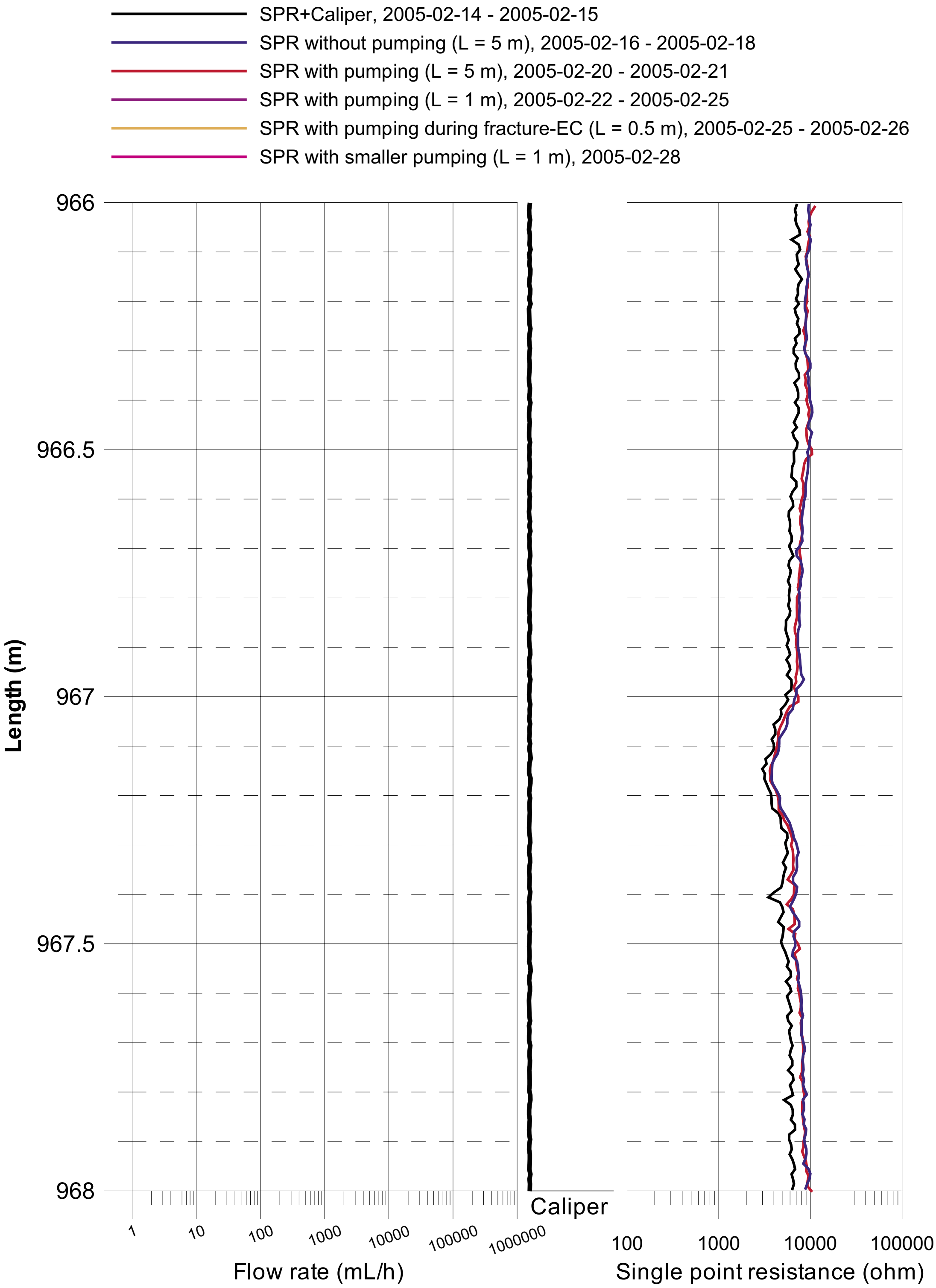
Appendix 1.43



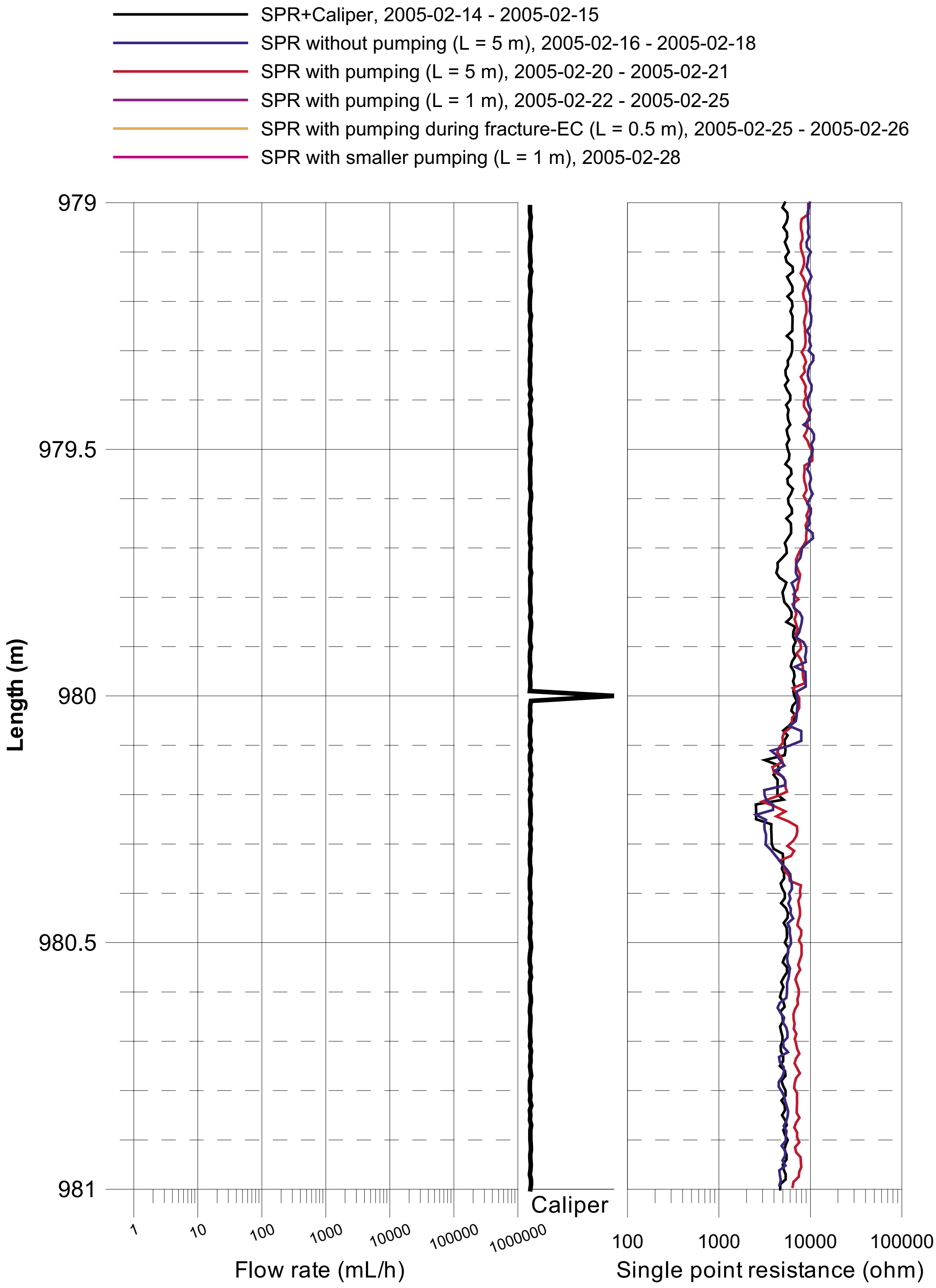
Laxemar, KLX06
SPR and Caliper results after length correction



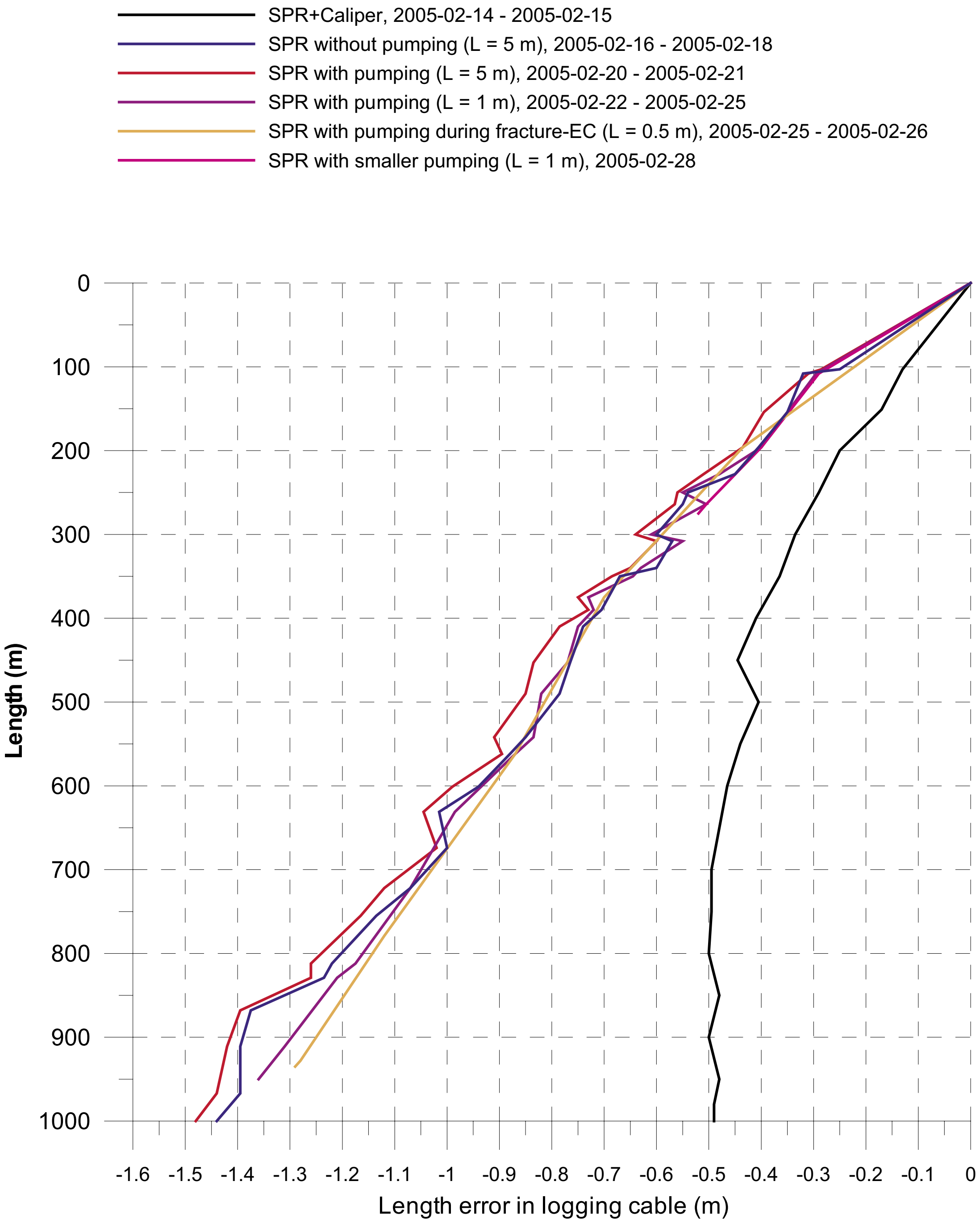
Laxemar, KLX06
SPR and Caliper results after length correction



Laxemar, KLX06
SPR and Caliper results after length correction

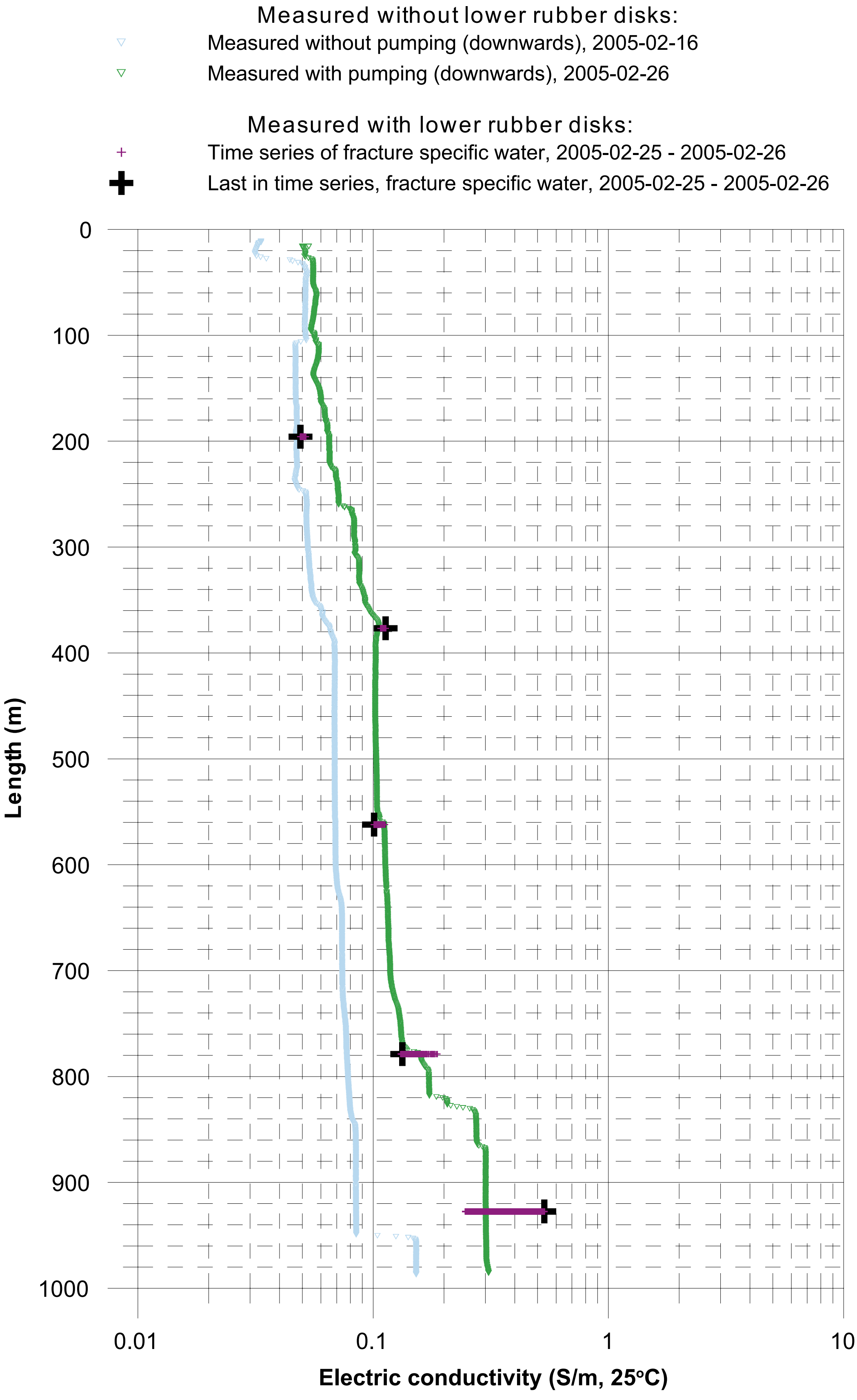


Laxemar, KLX06
Length correction



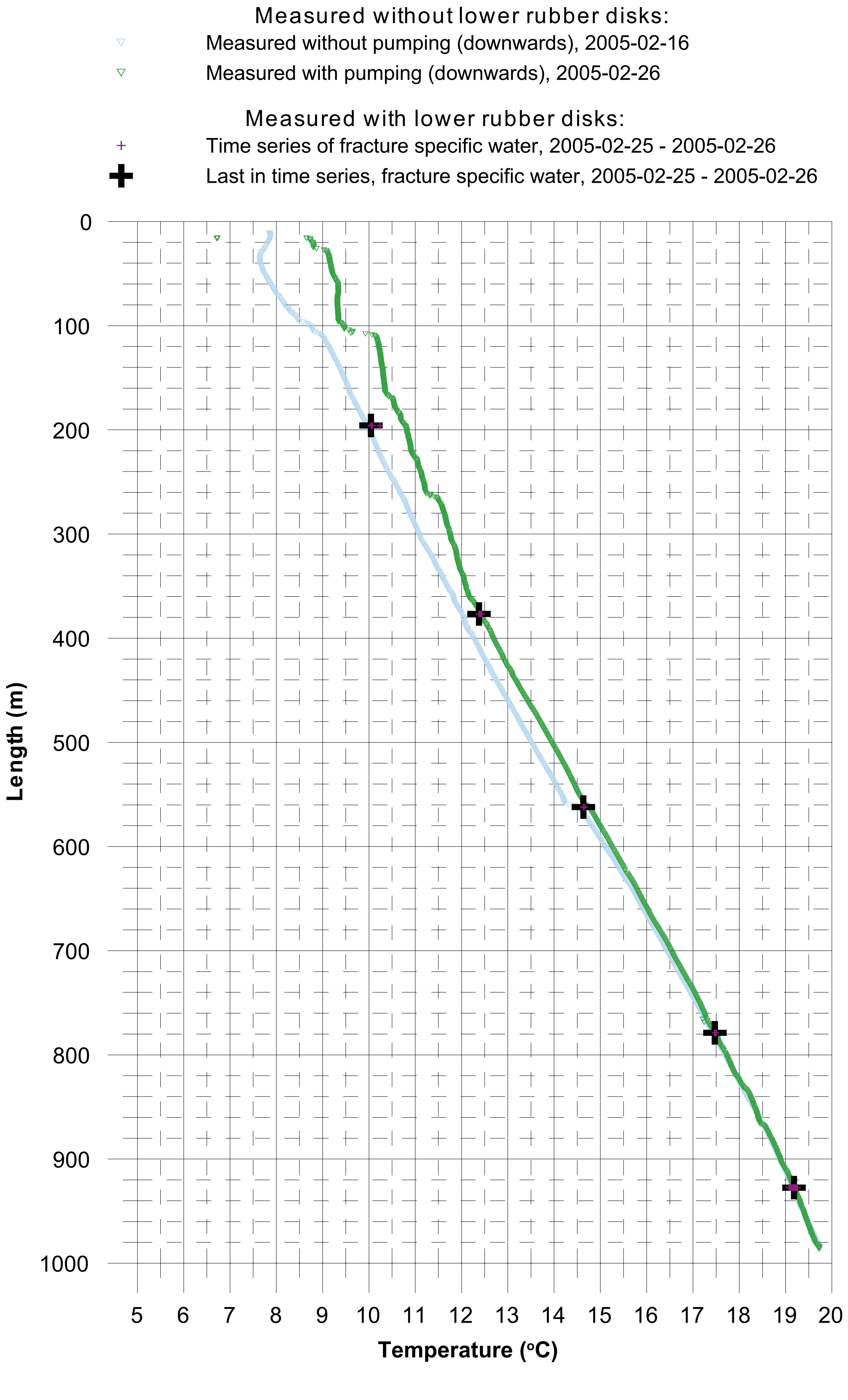
Appendix 2.1

Laxemar, borehole KLX06
Electric conductivity of borehole water

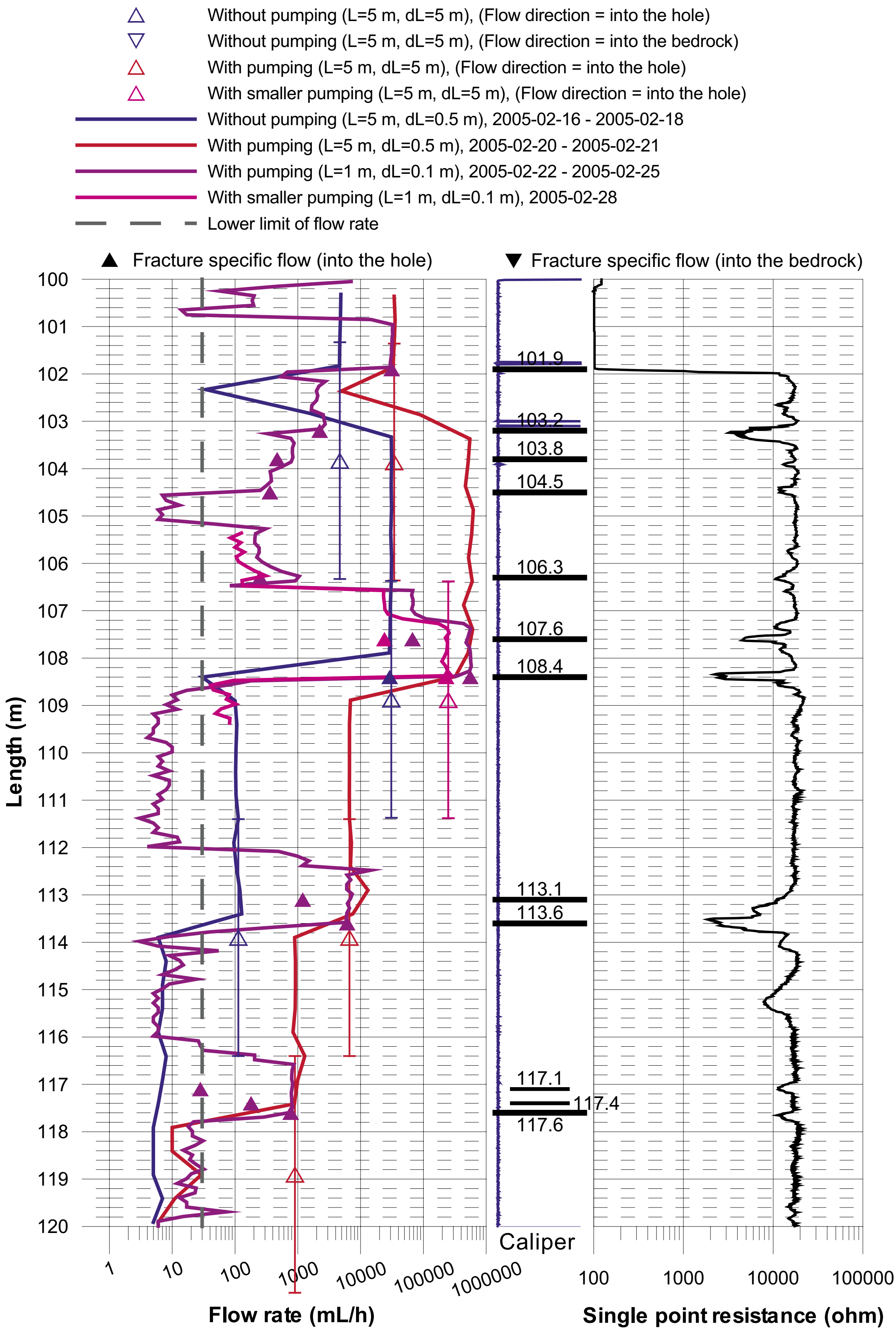


Appendix 2.2

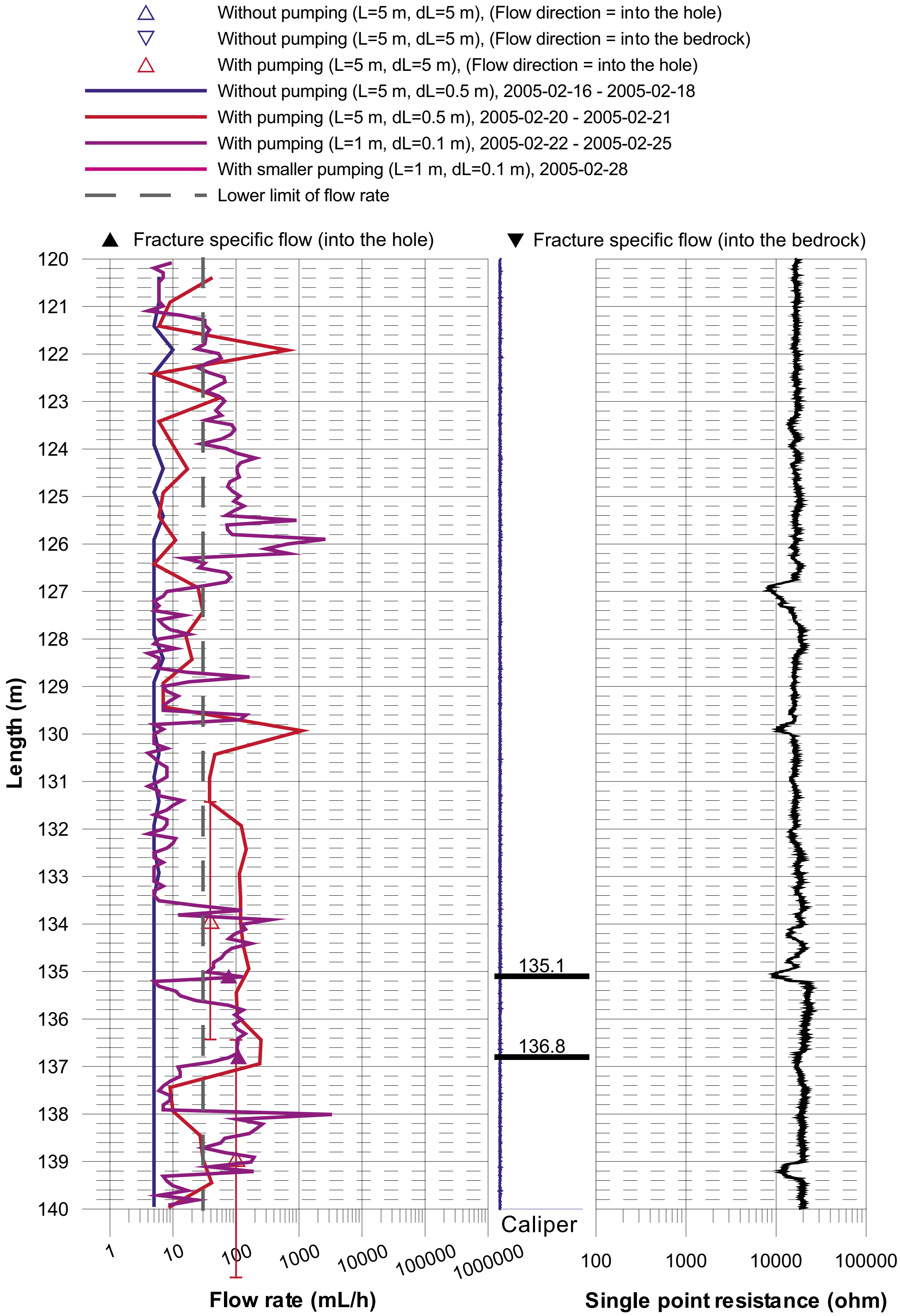
Laxemar, borehole KLX06
Temperature of borehole water



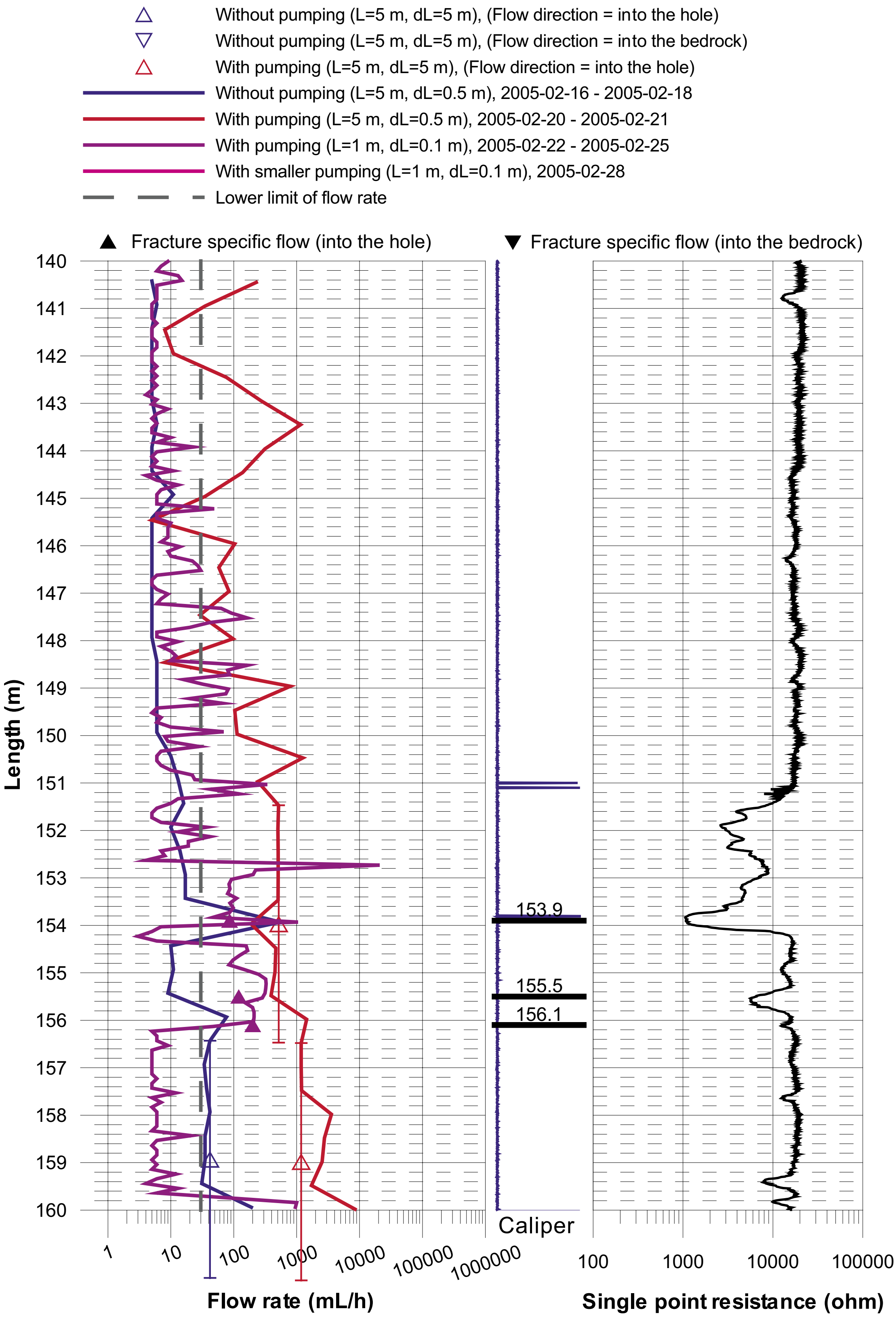
Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



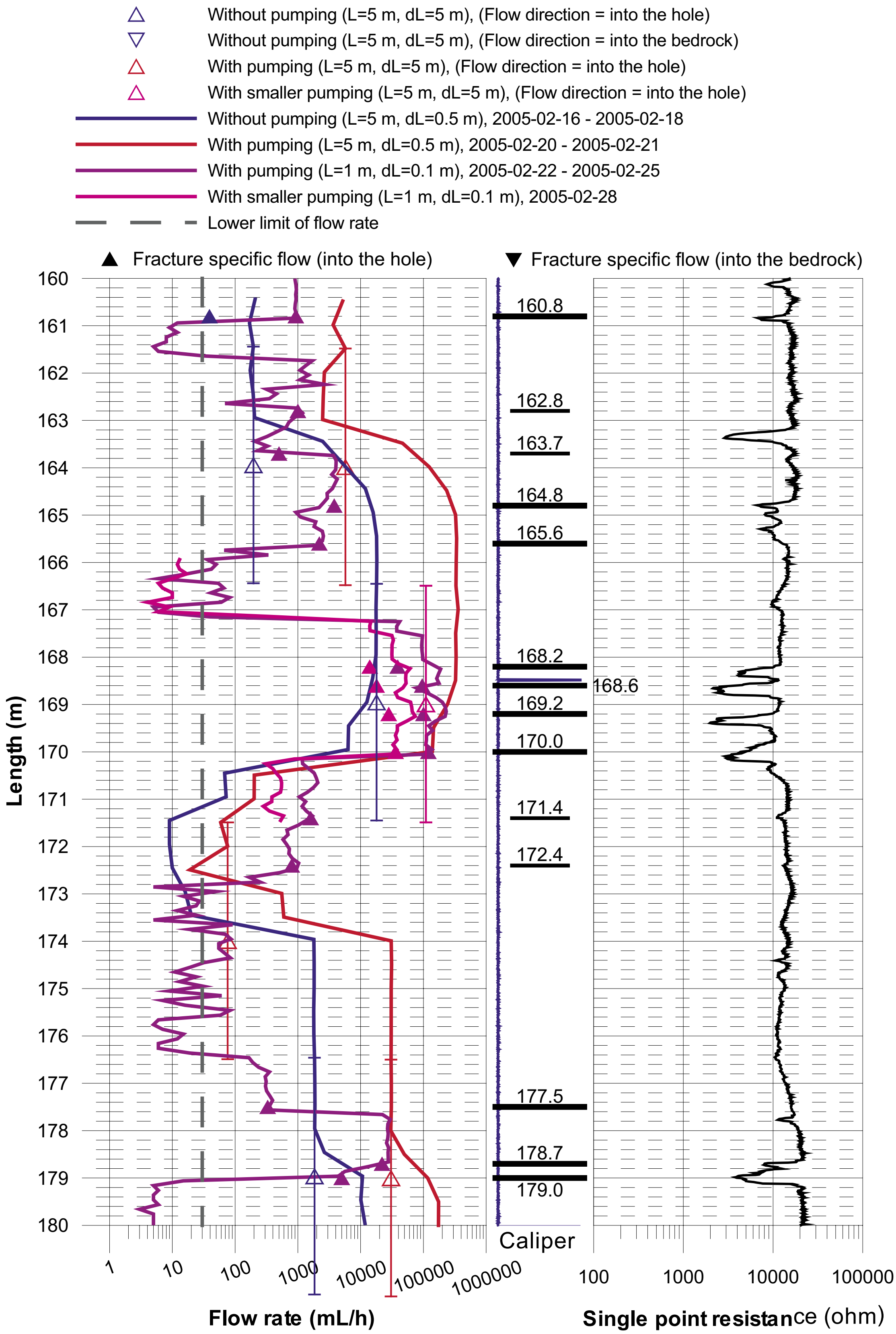
Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

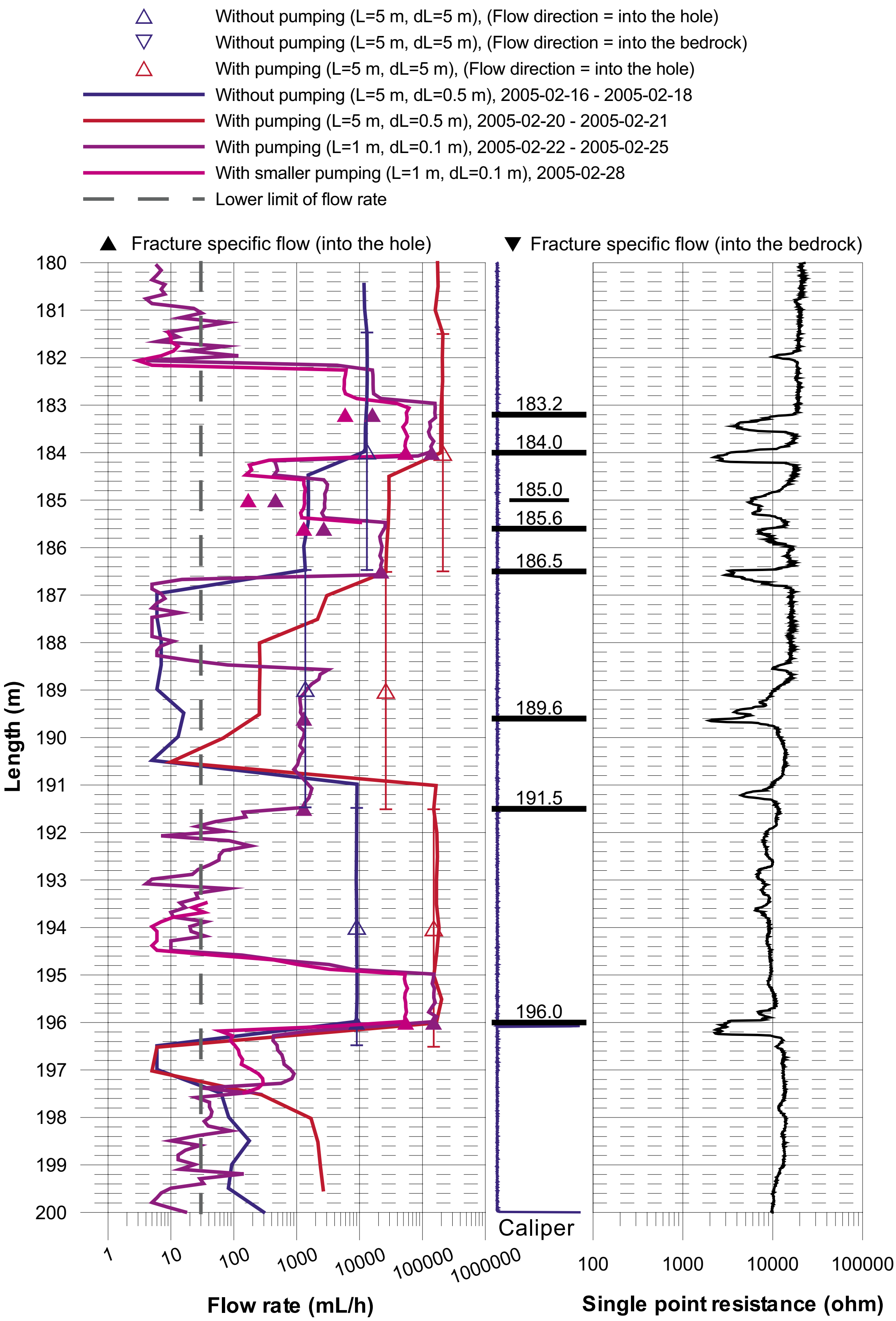


Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

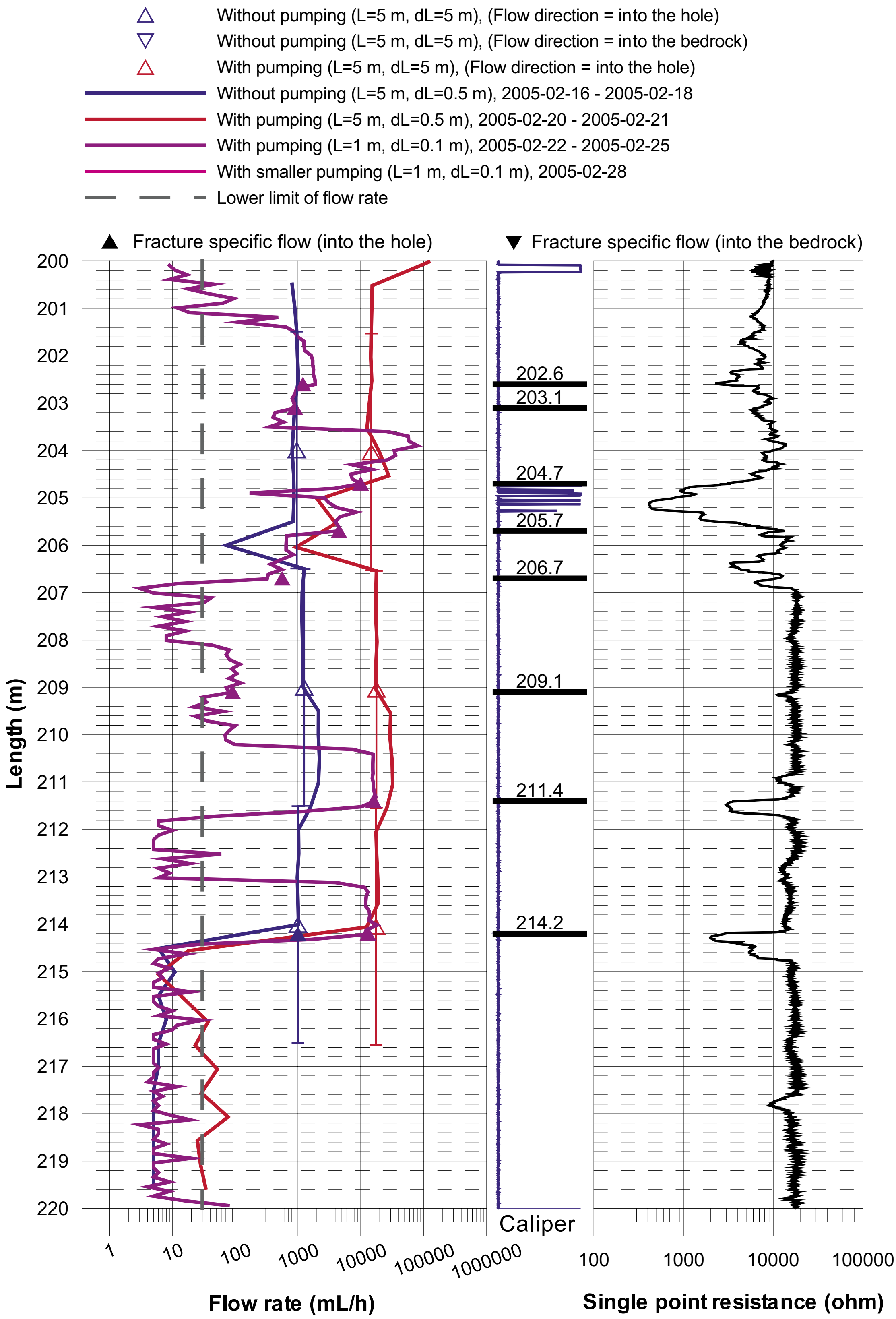


Appendix 3.5

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



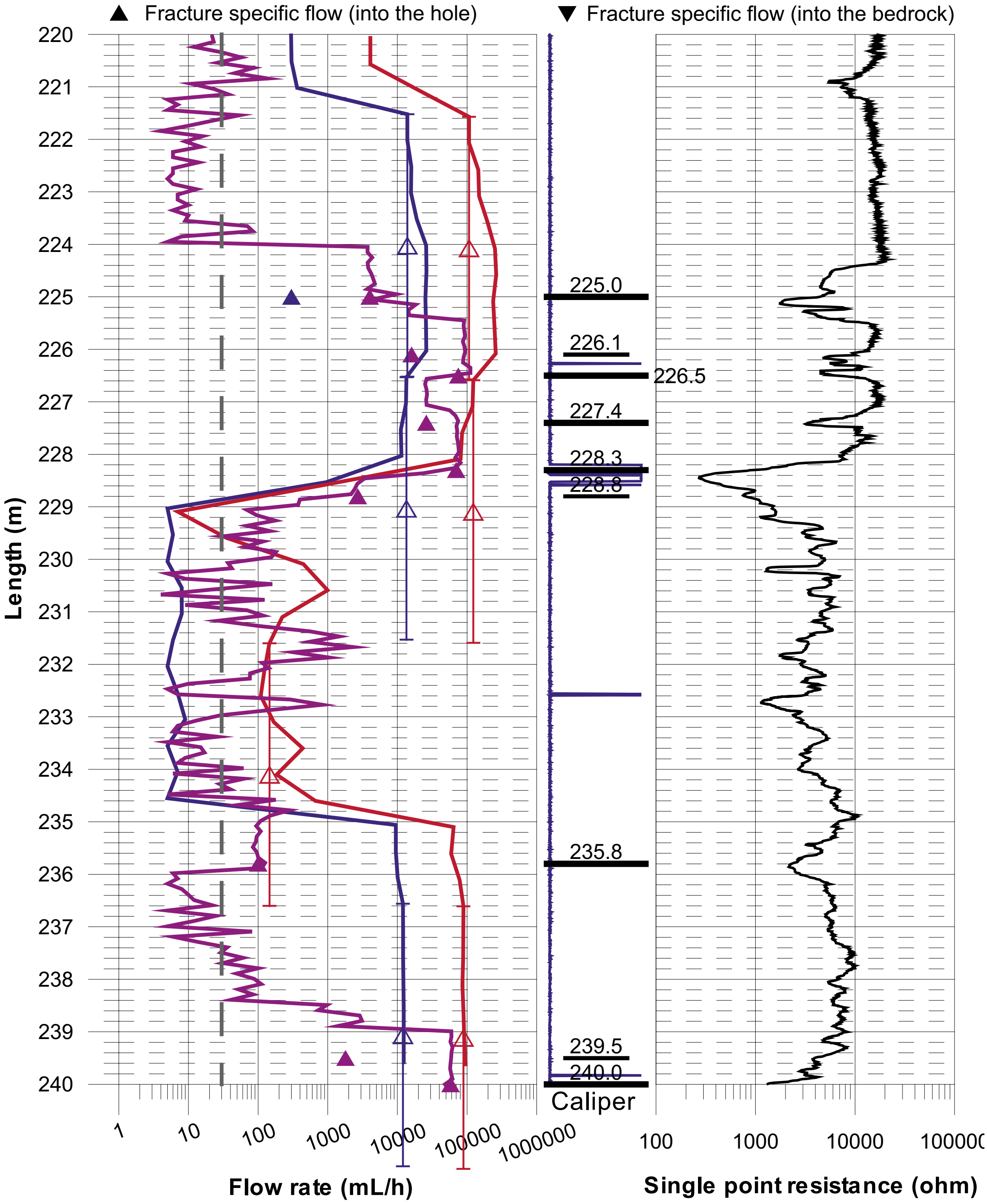
Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



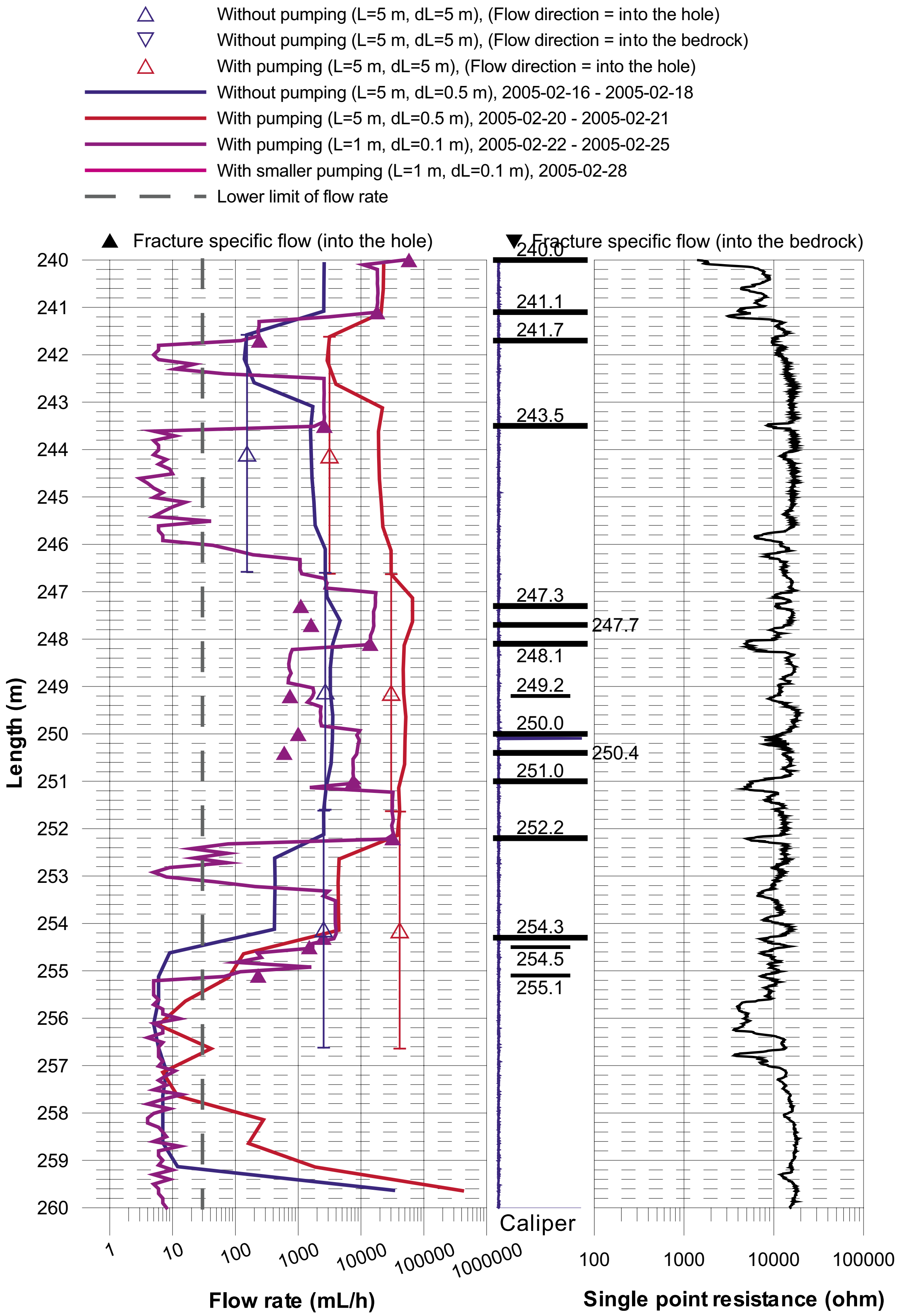
Appendix 3.7

Laxemar, borehole KLX06
Flow rate, 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), 2005-02-16 - 2005-02-18
- With pumping (L=5 m, dL=0.5 m), 2005-02-20 - 2005-02-21
- With pumping (L=1 m, dL=0.1 m), 2005-02-22 - 2005-02-25
- With smaller pumping (L=1 m, dL=0.1 m), 2005-02-28
- Lower limit of flow rate

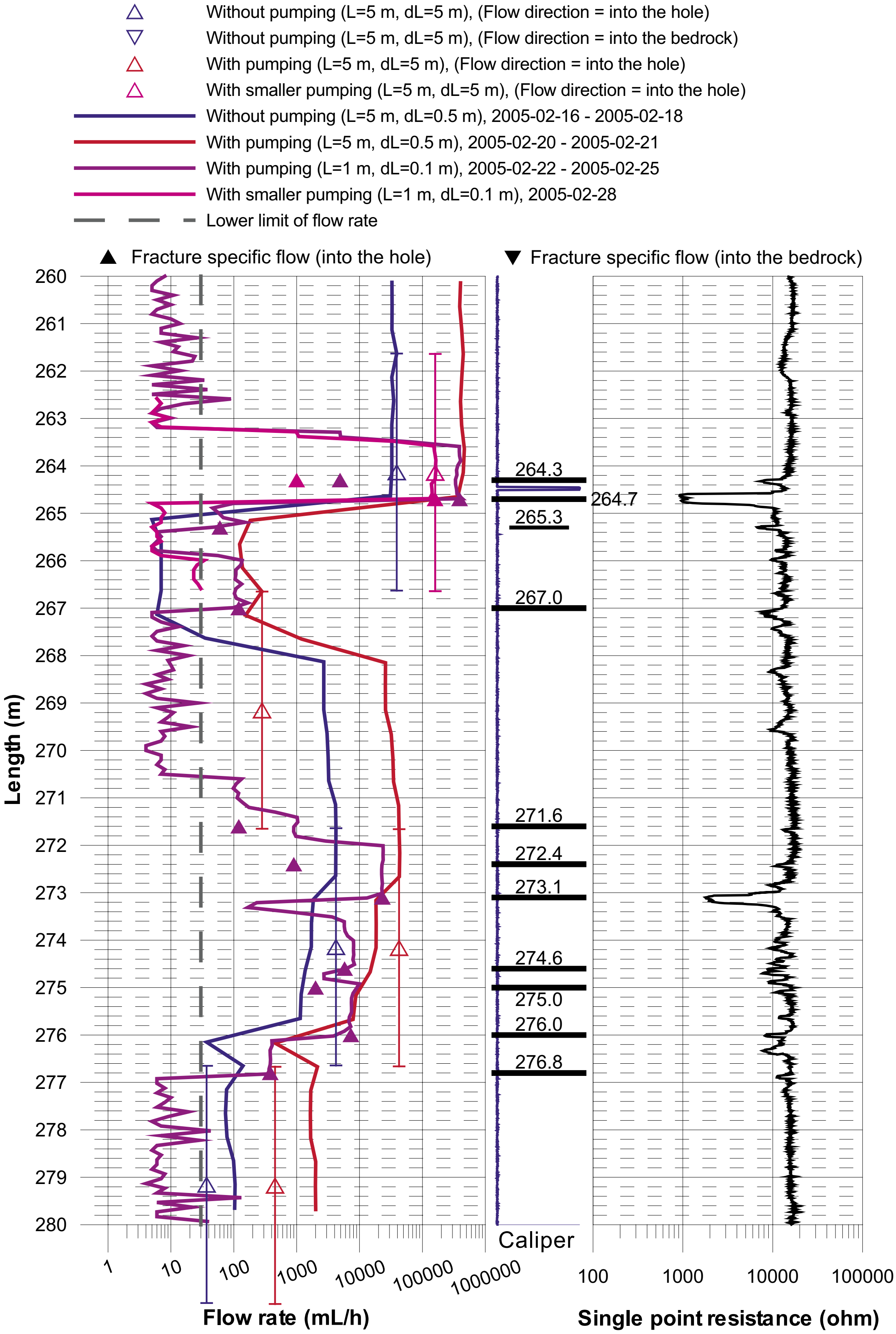


Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



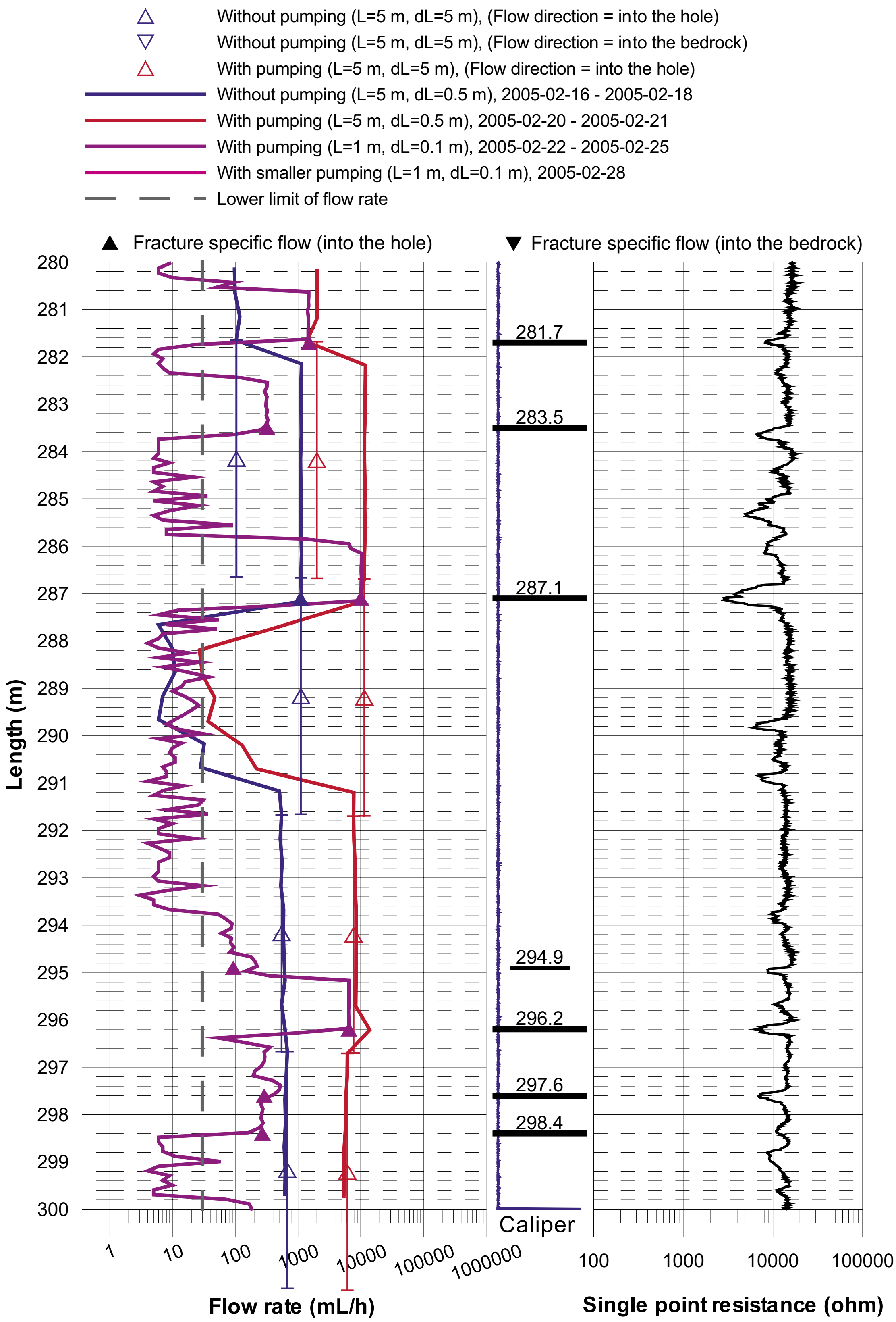
Appendix 3.9

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

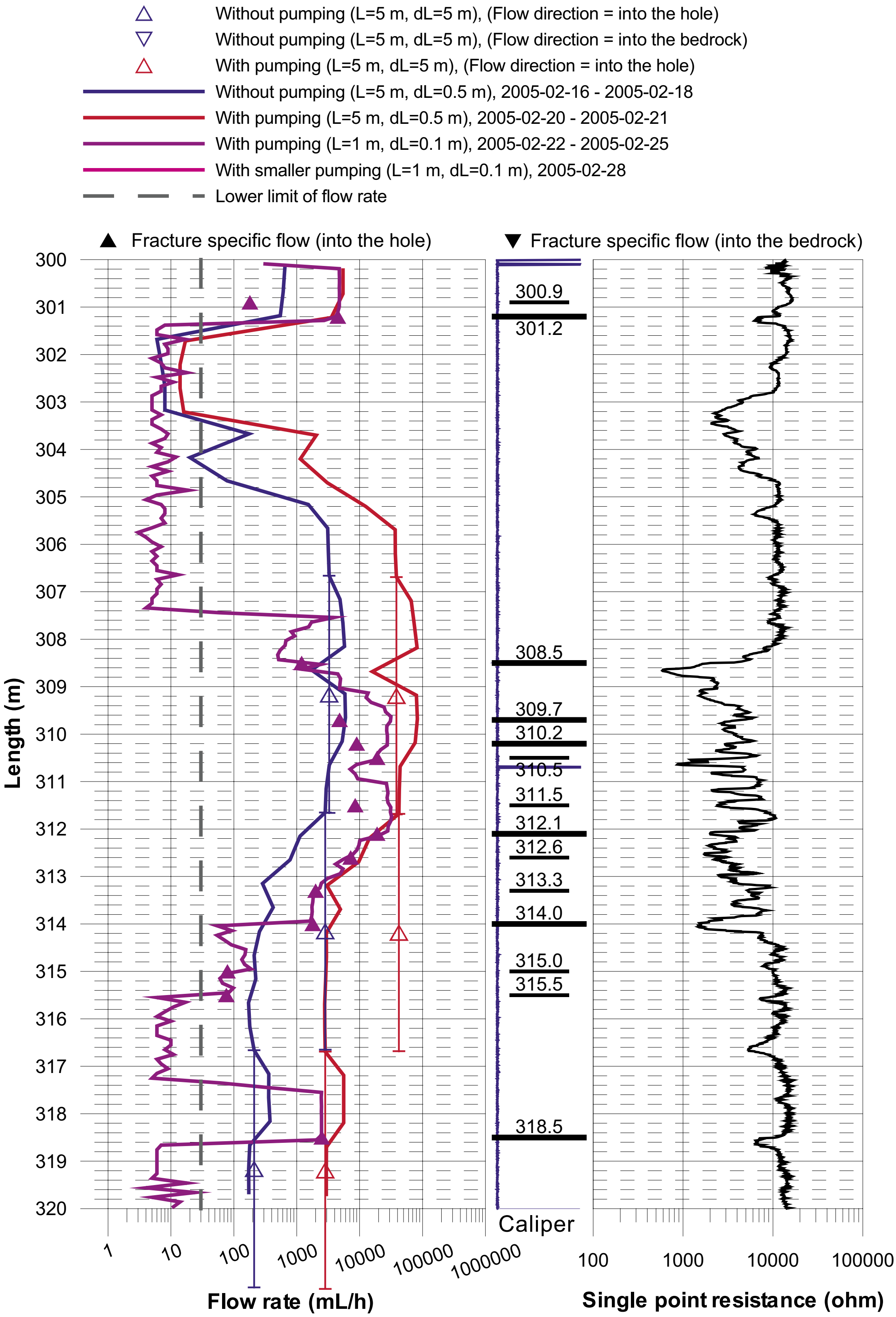


Appendix 3.10

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

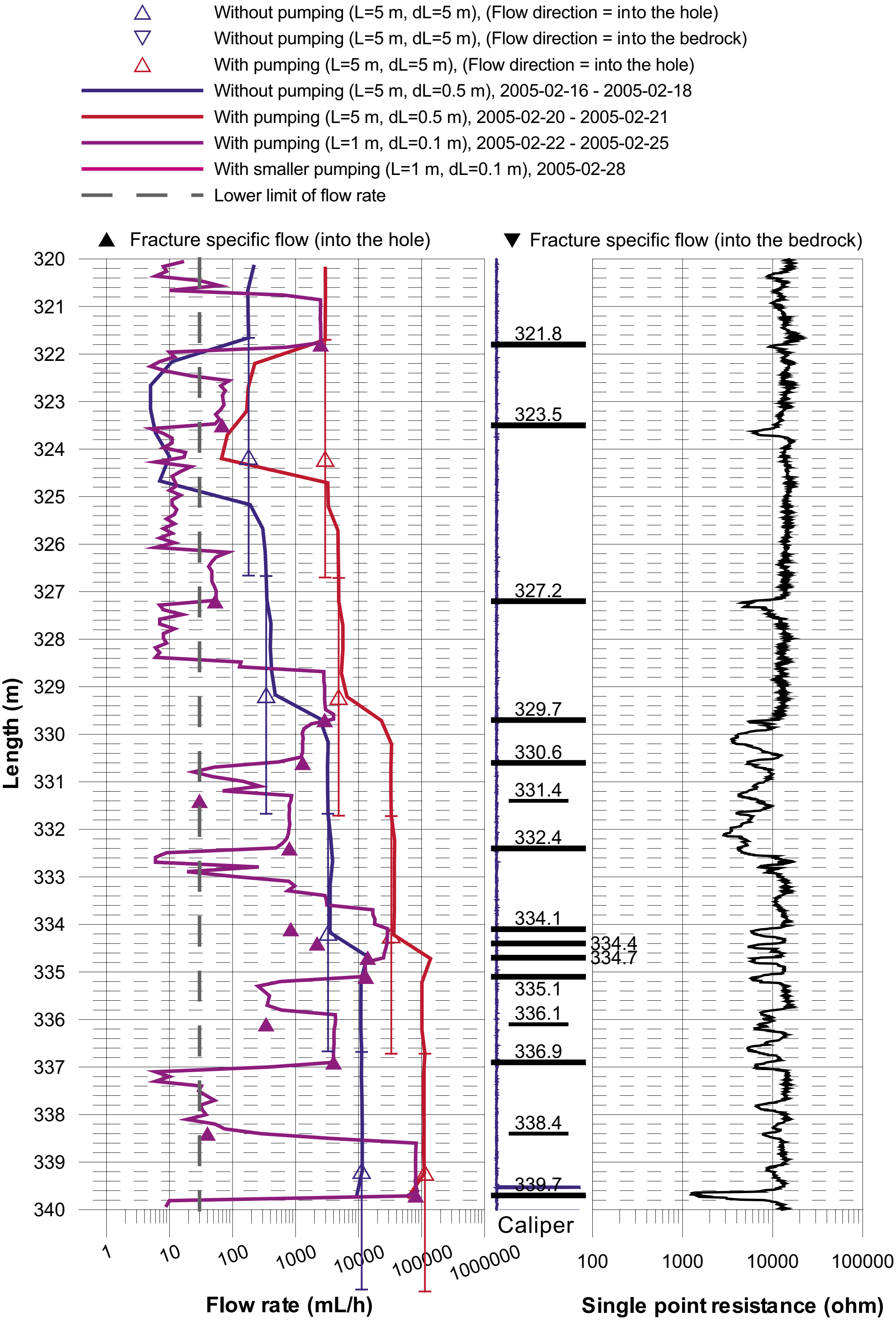


Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

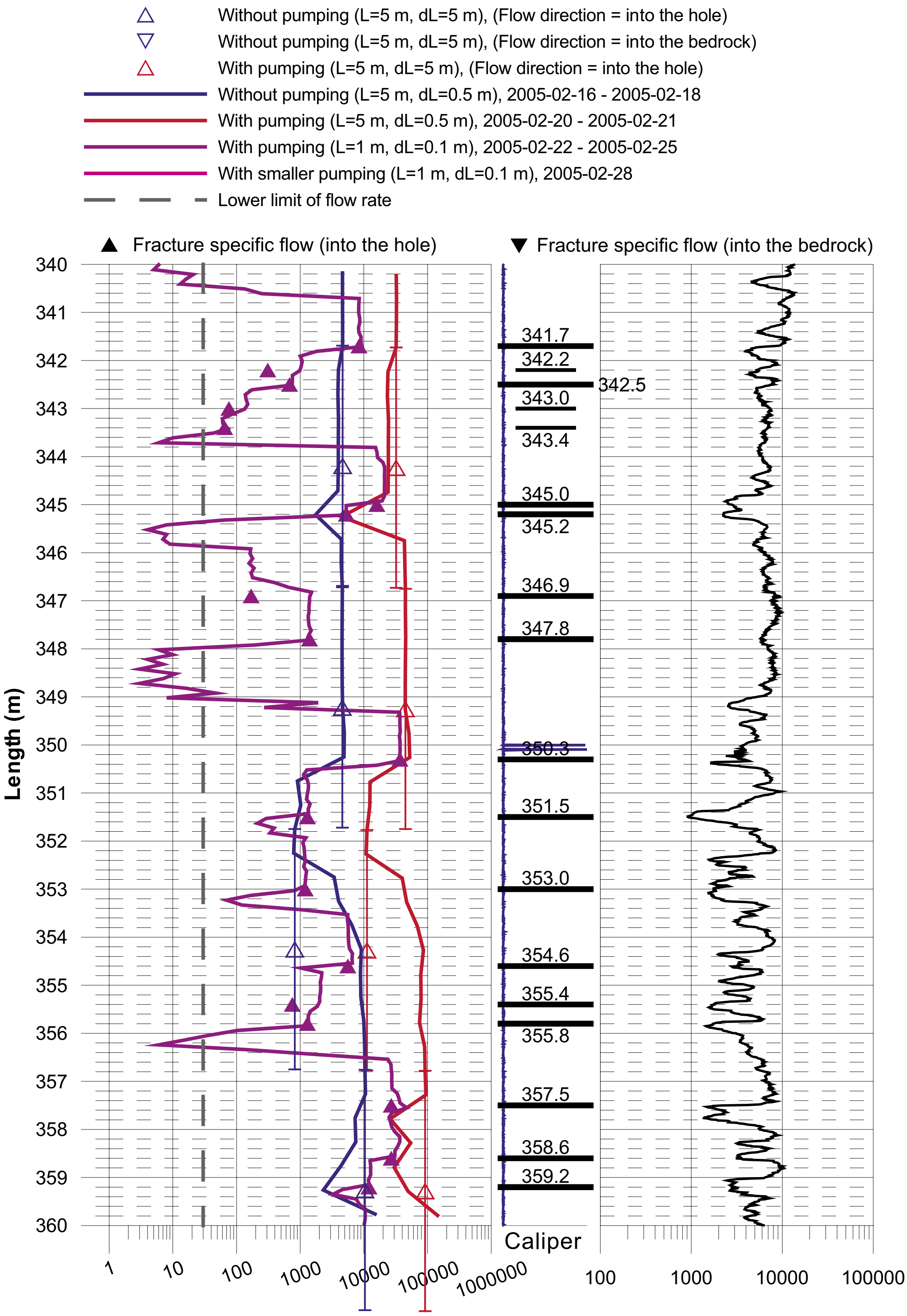


Appendix 3.12

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

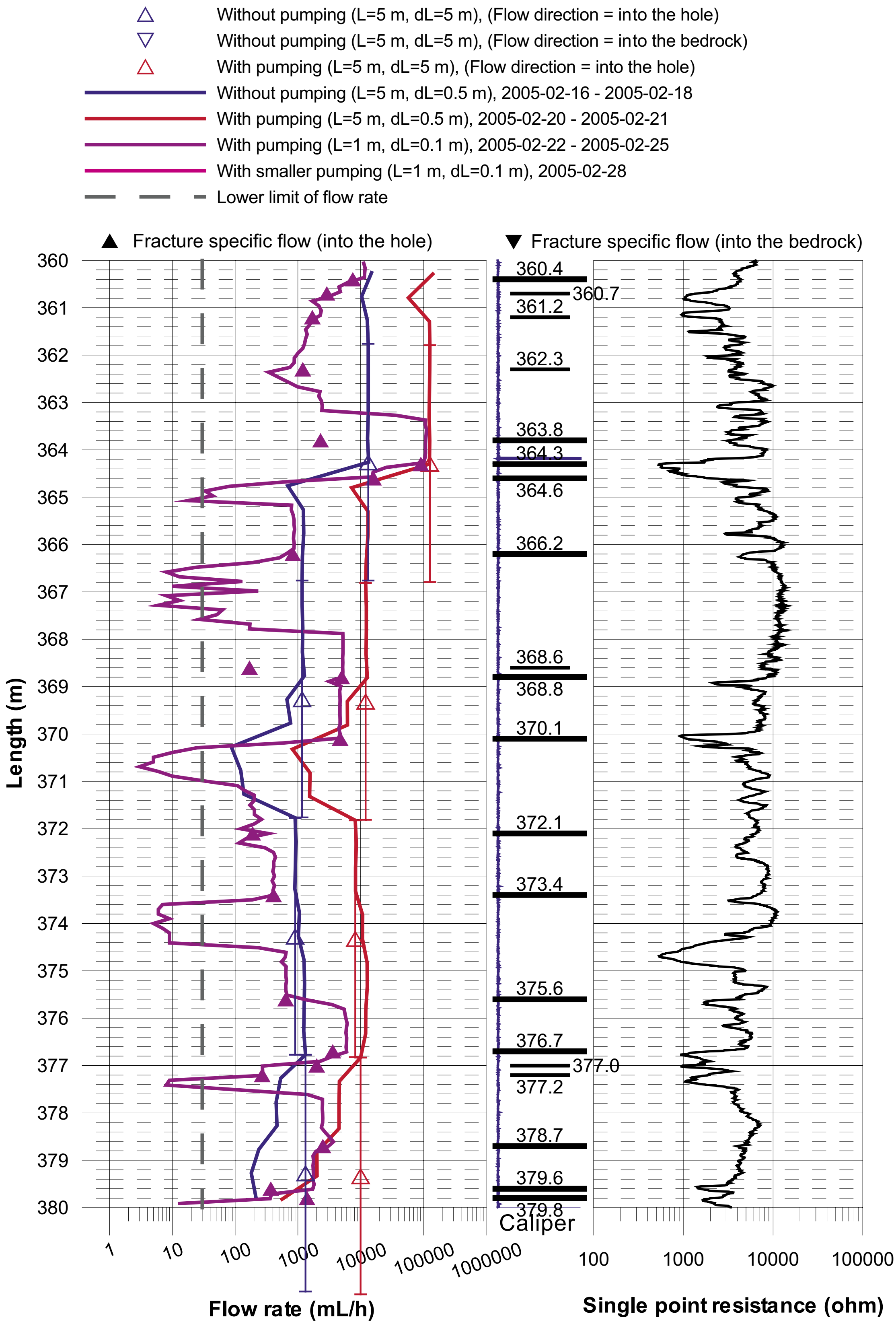


Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



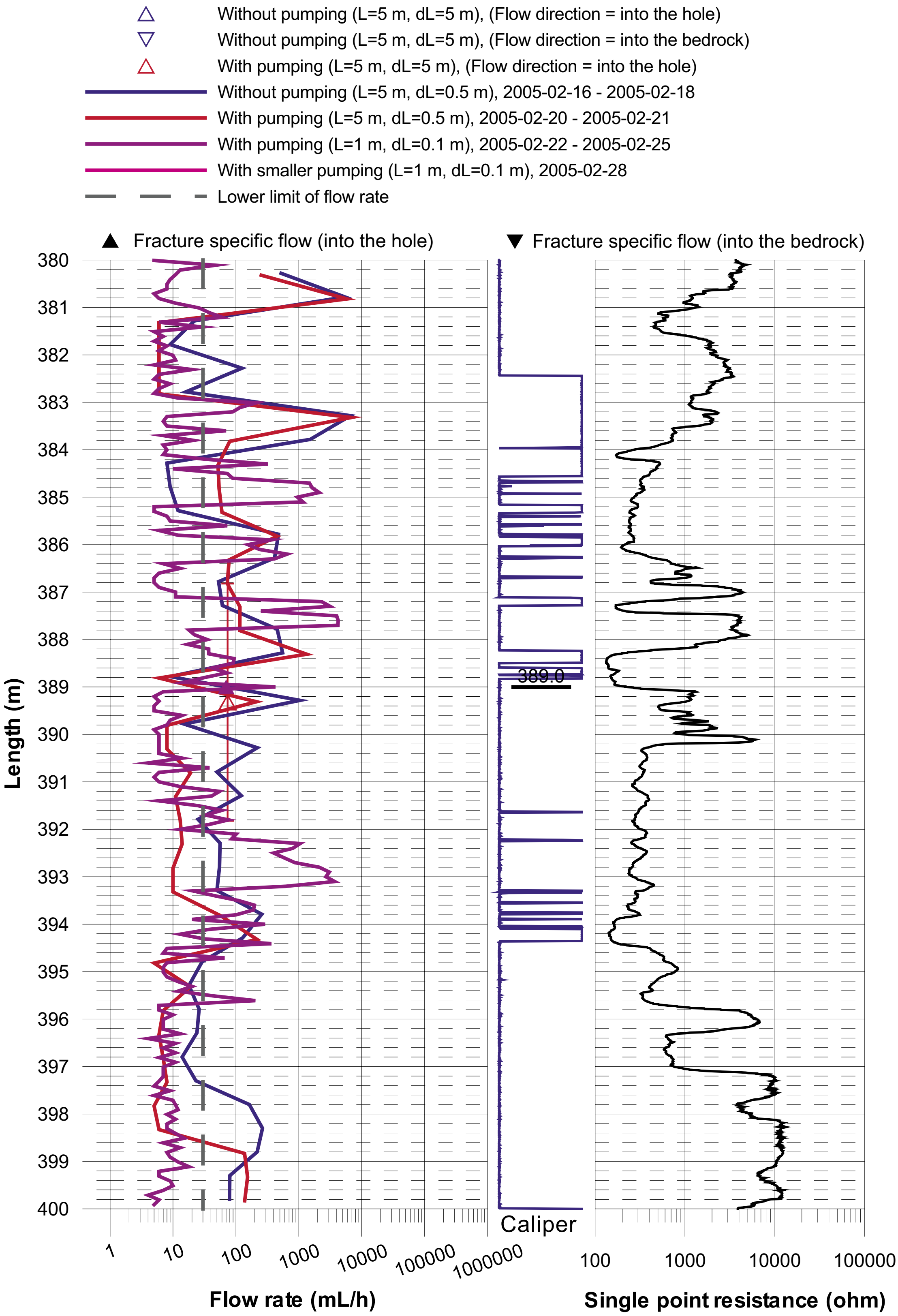
Appendix 3.14

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

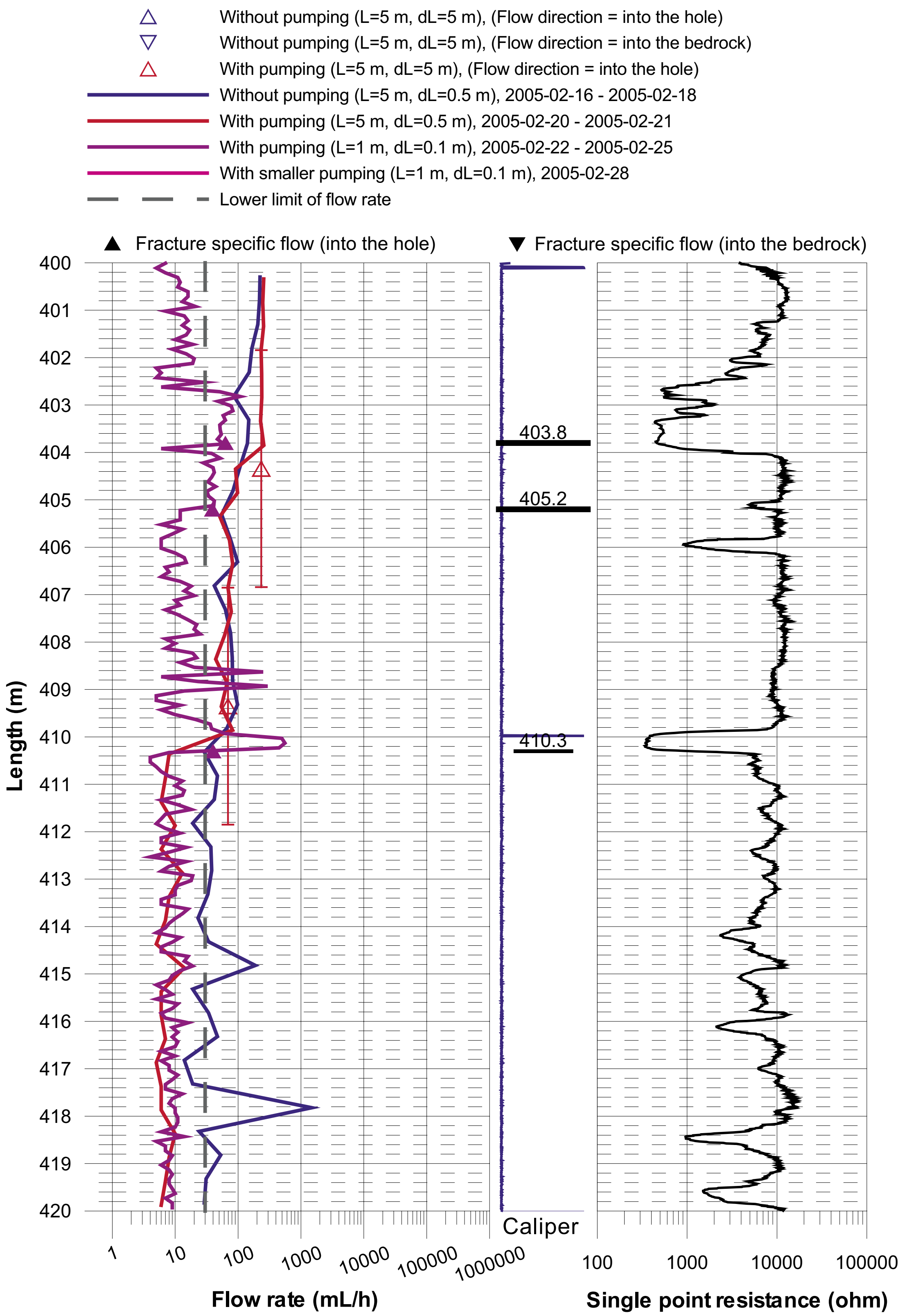


Appendix 3.15

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

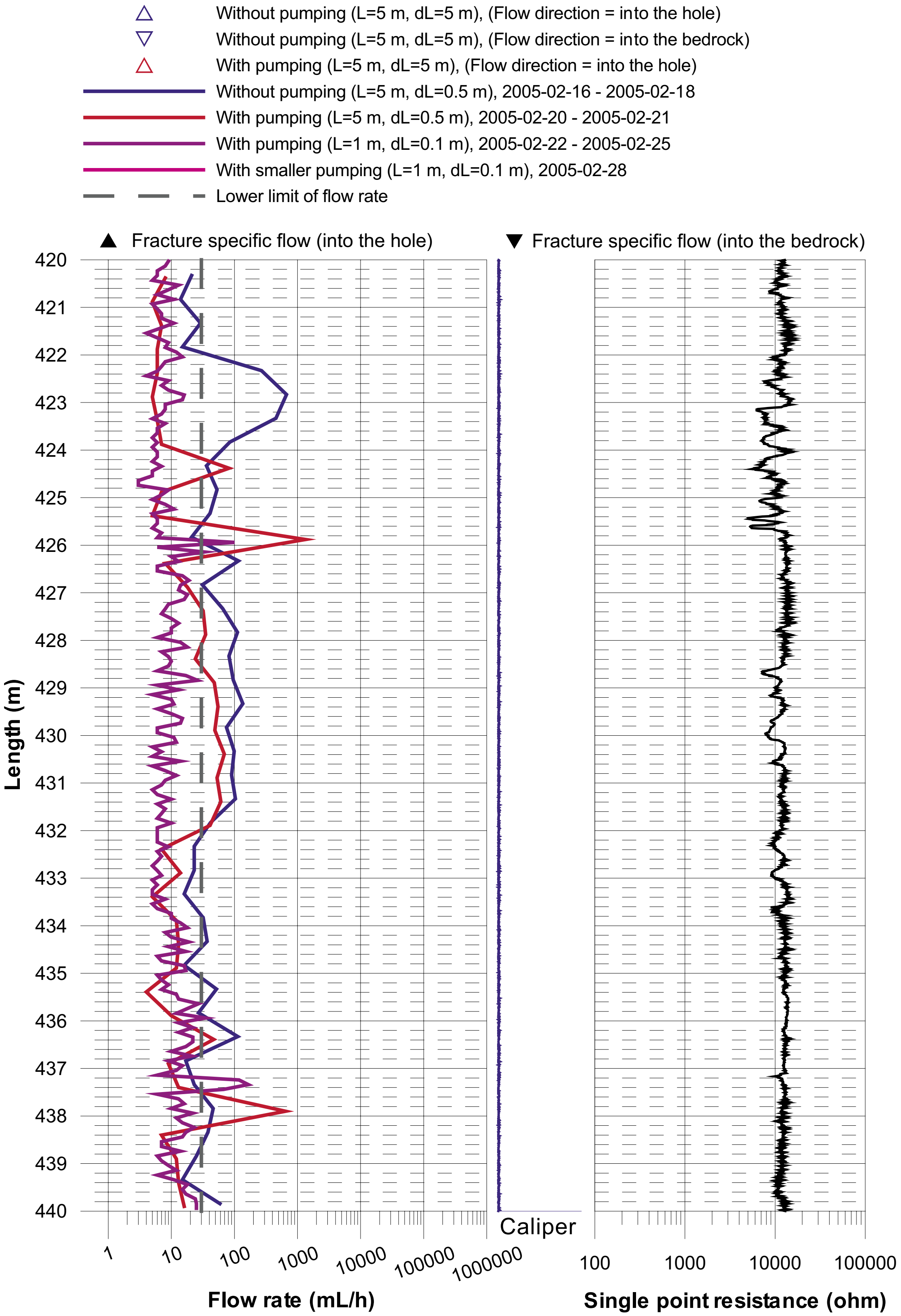


Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



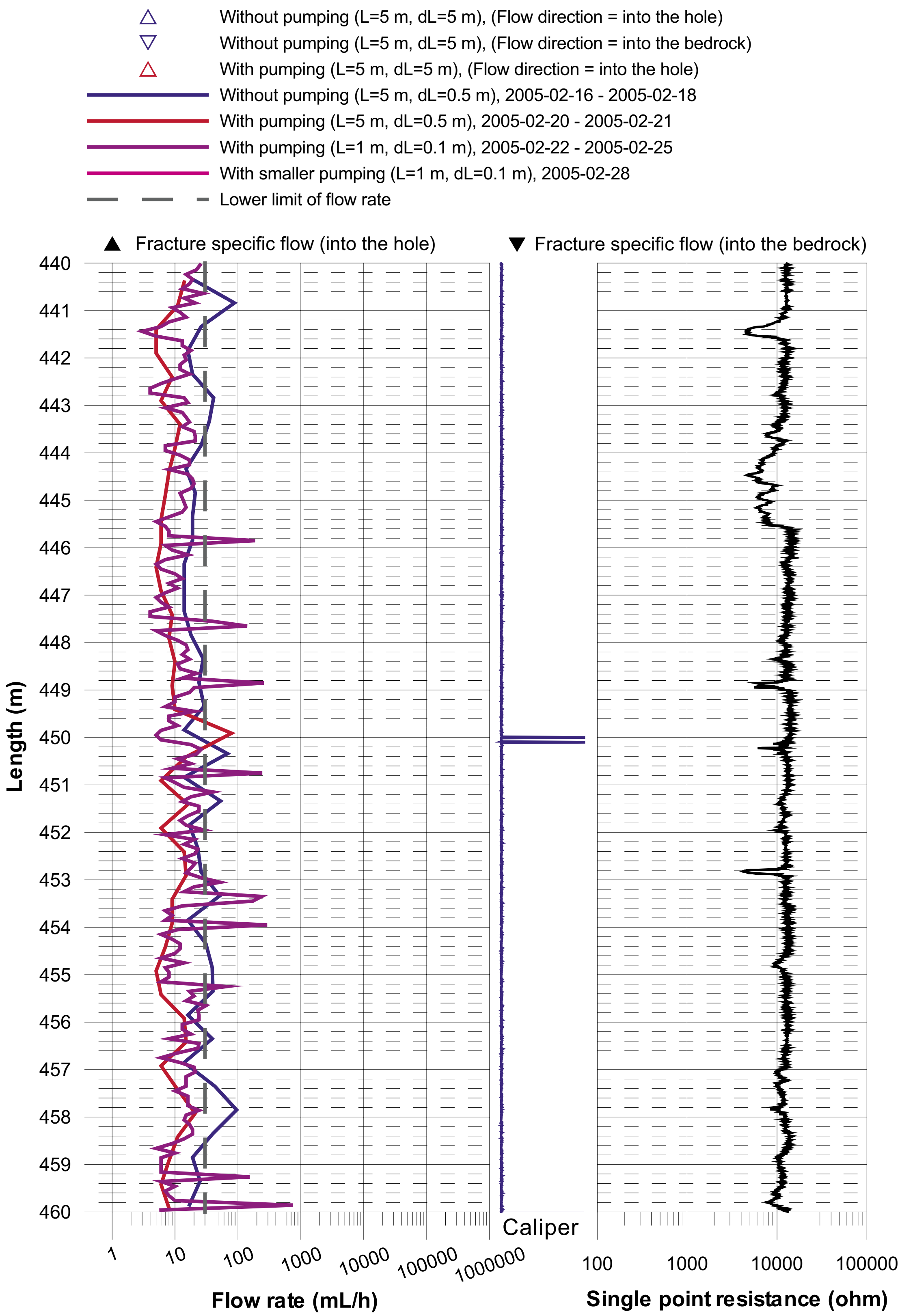
Appendix 3.17

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



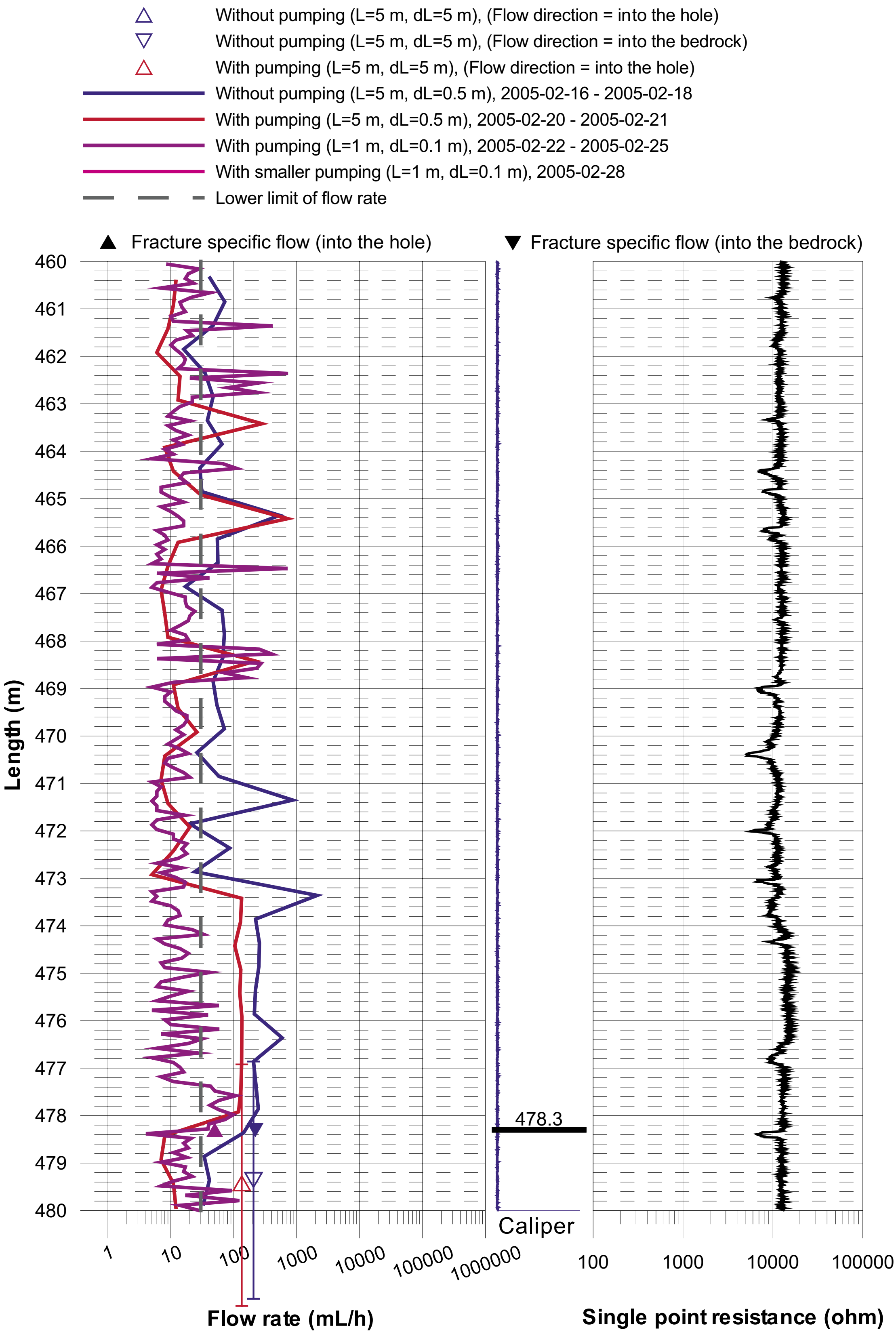
Appendix 3.18

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



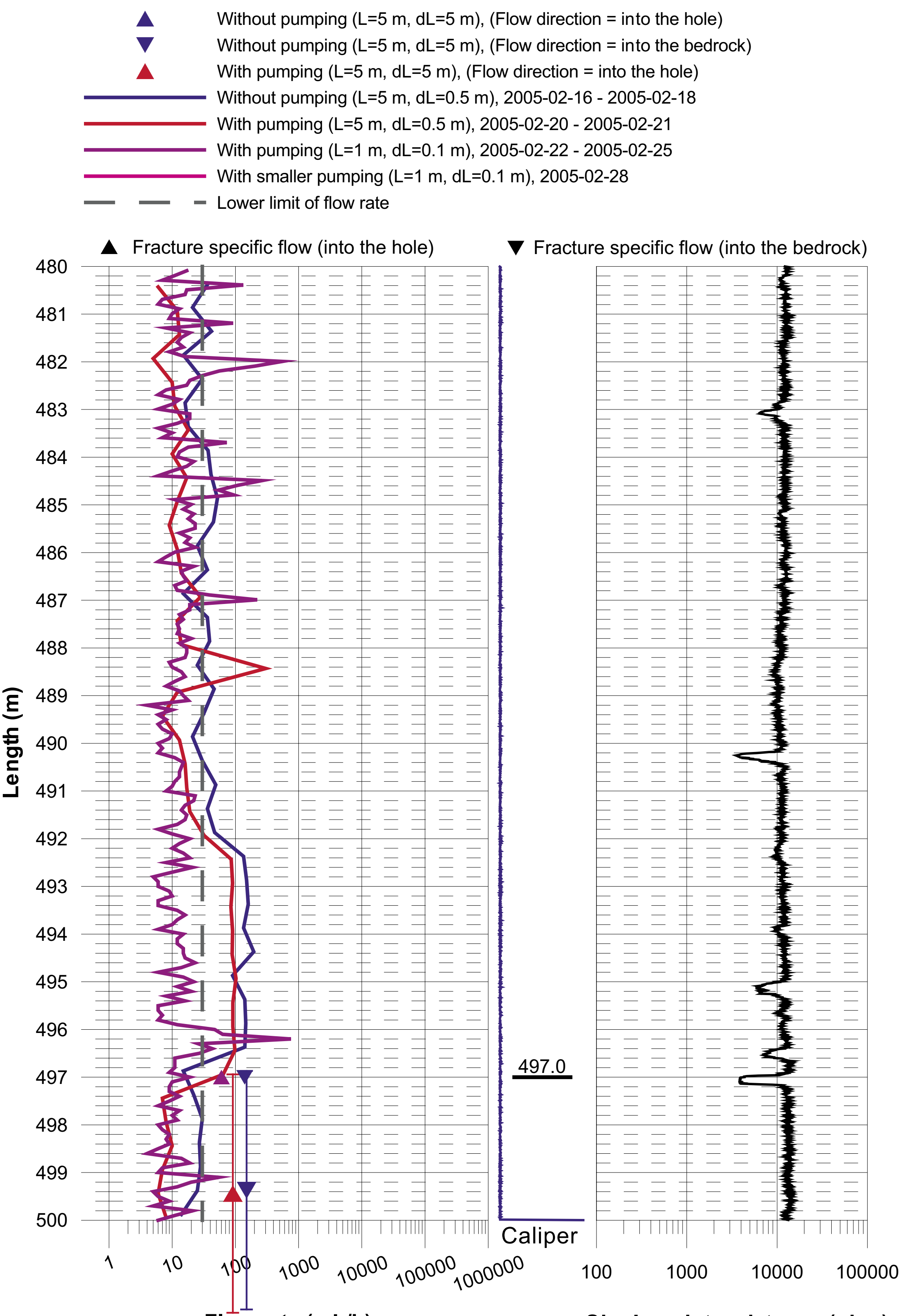
Appendix 3.19

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

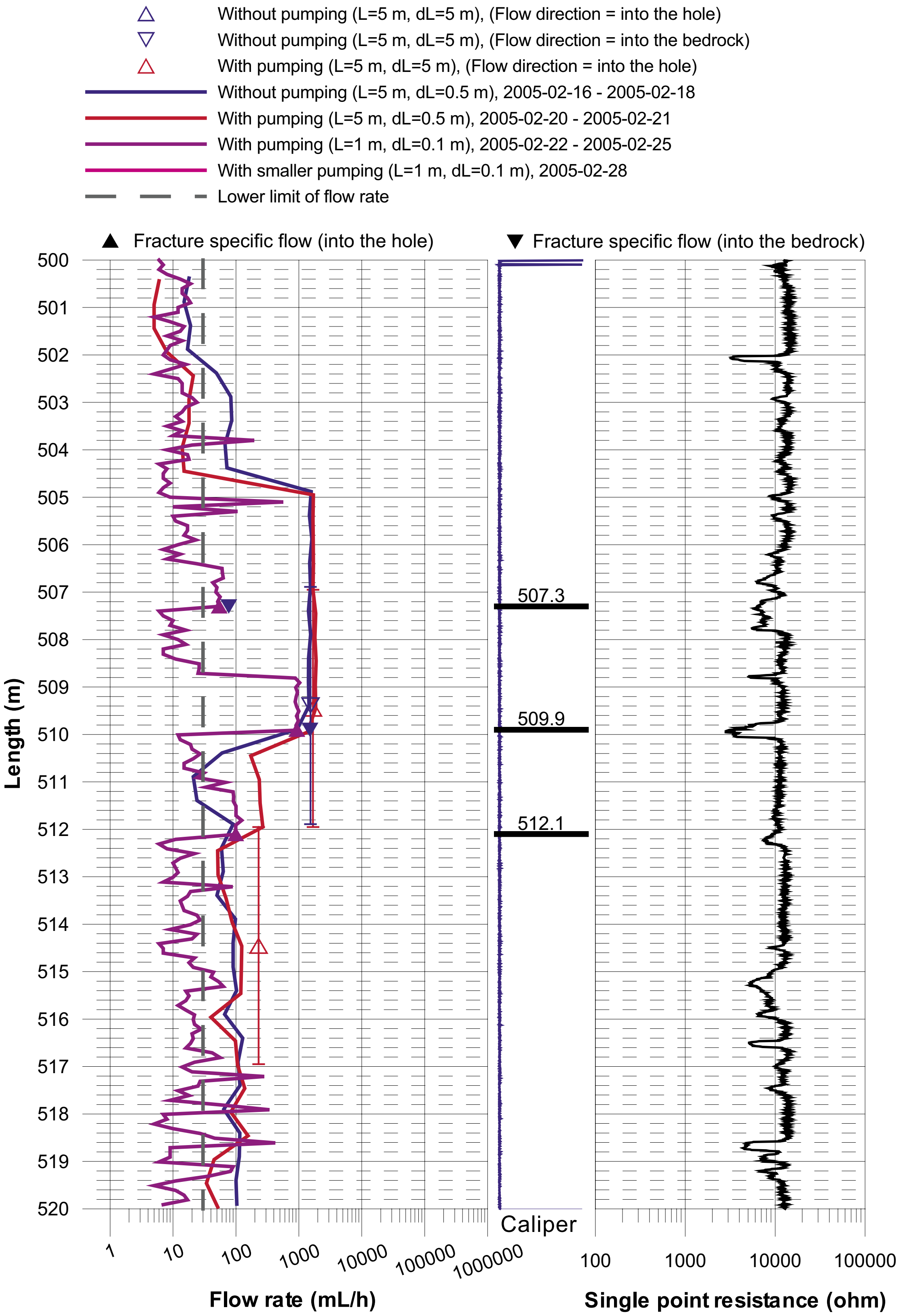


Appendix 3.20

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

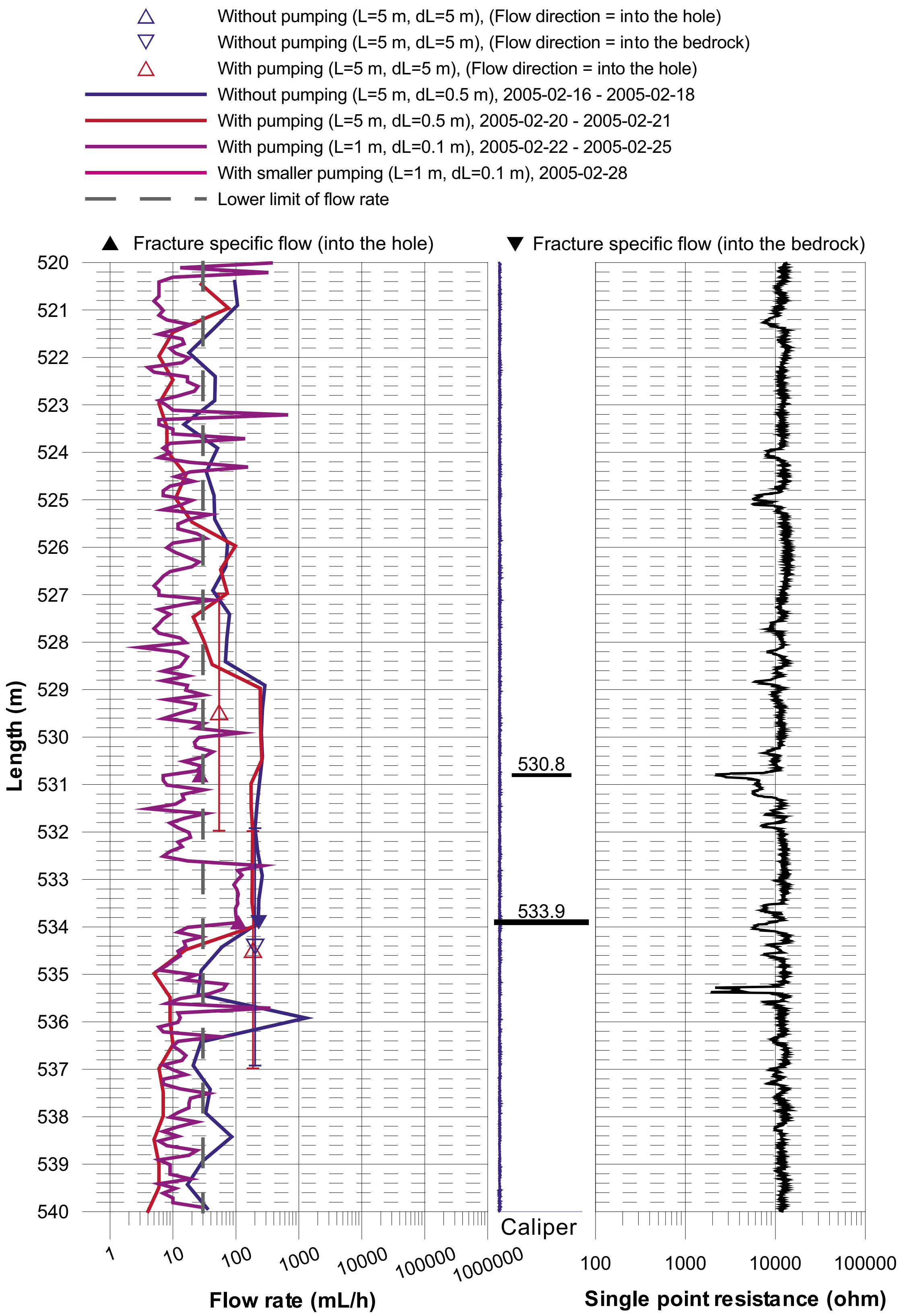


Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



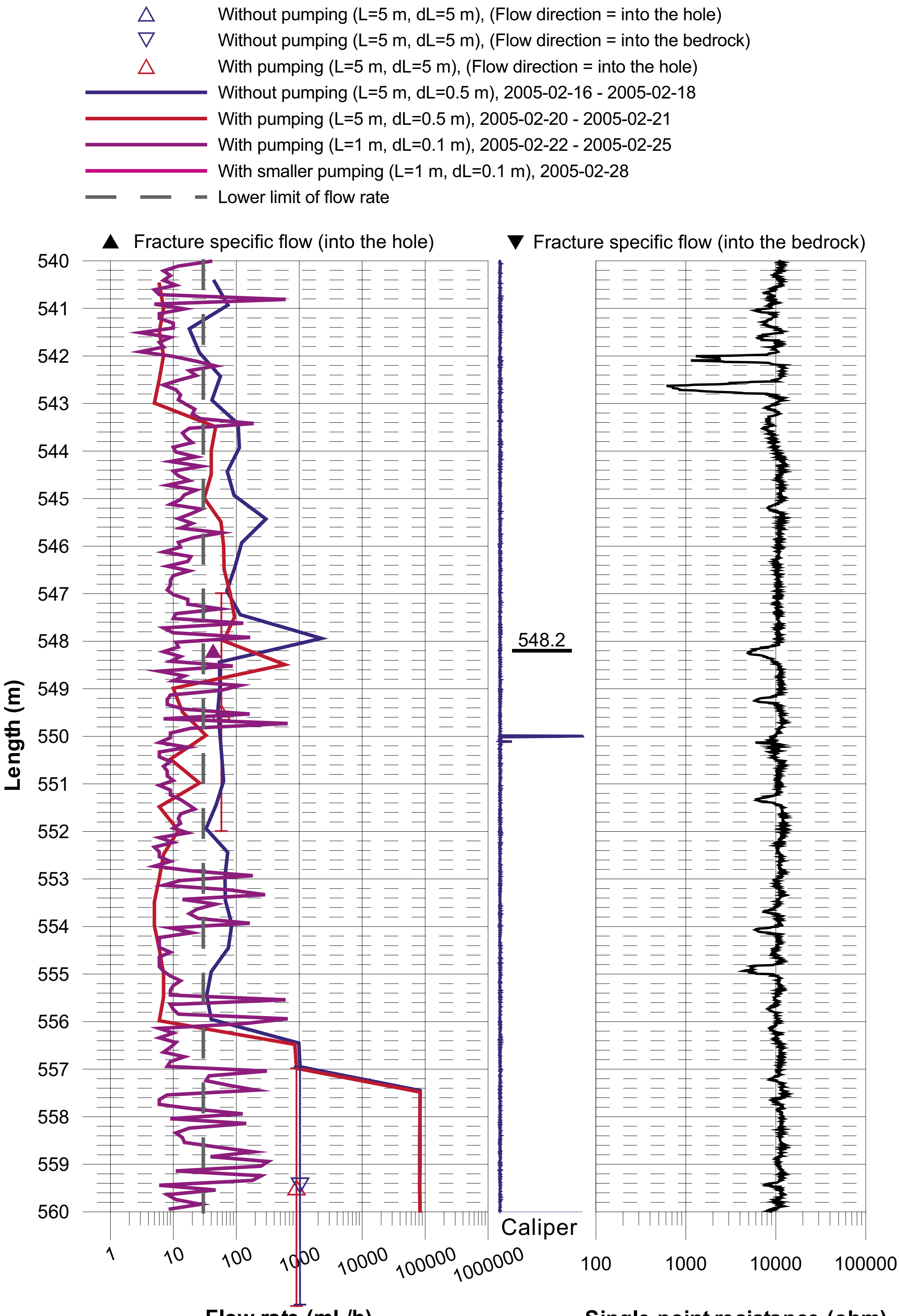
Appendix 3.22

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

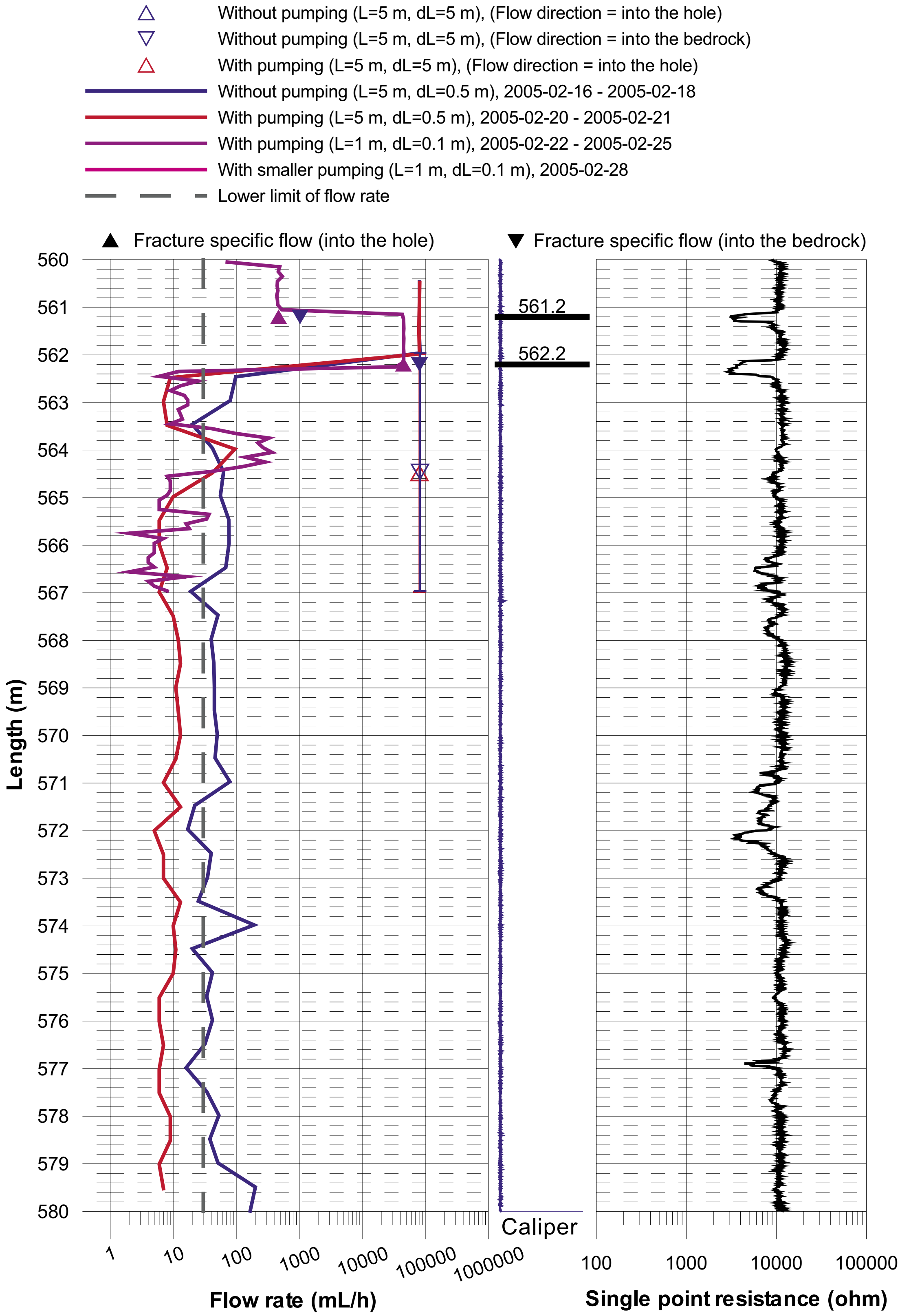


Appendix 3.23

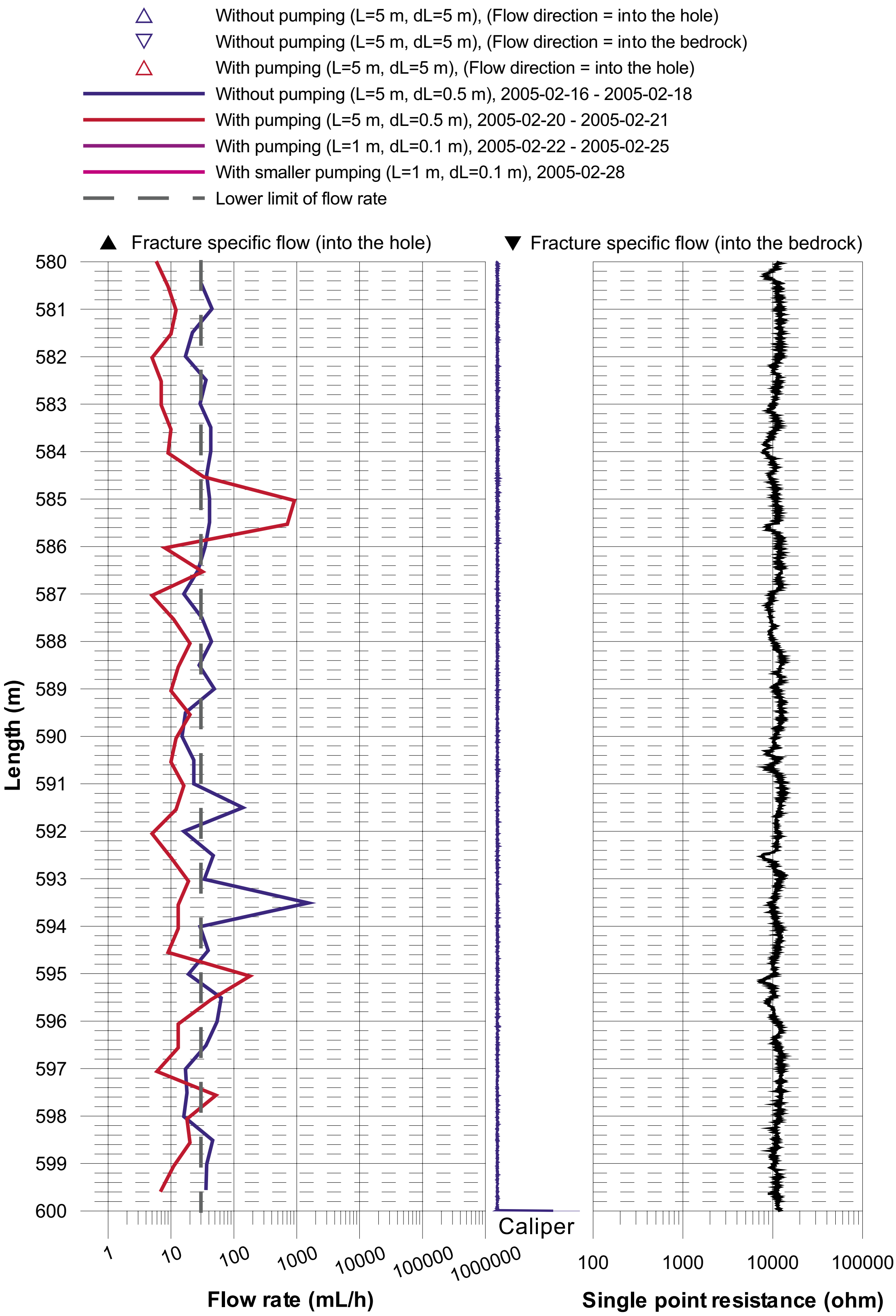
Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



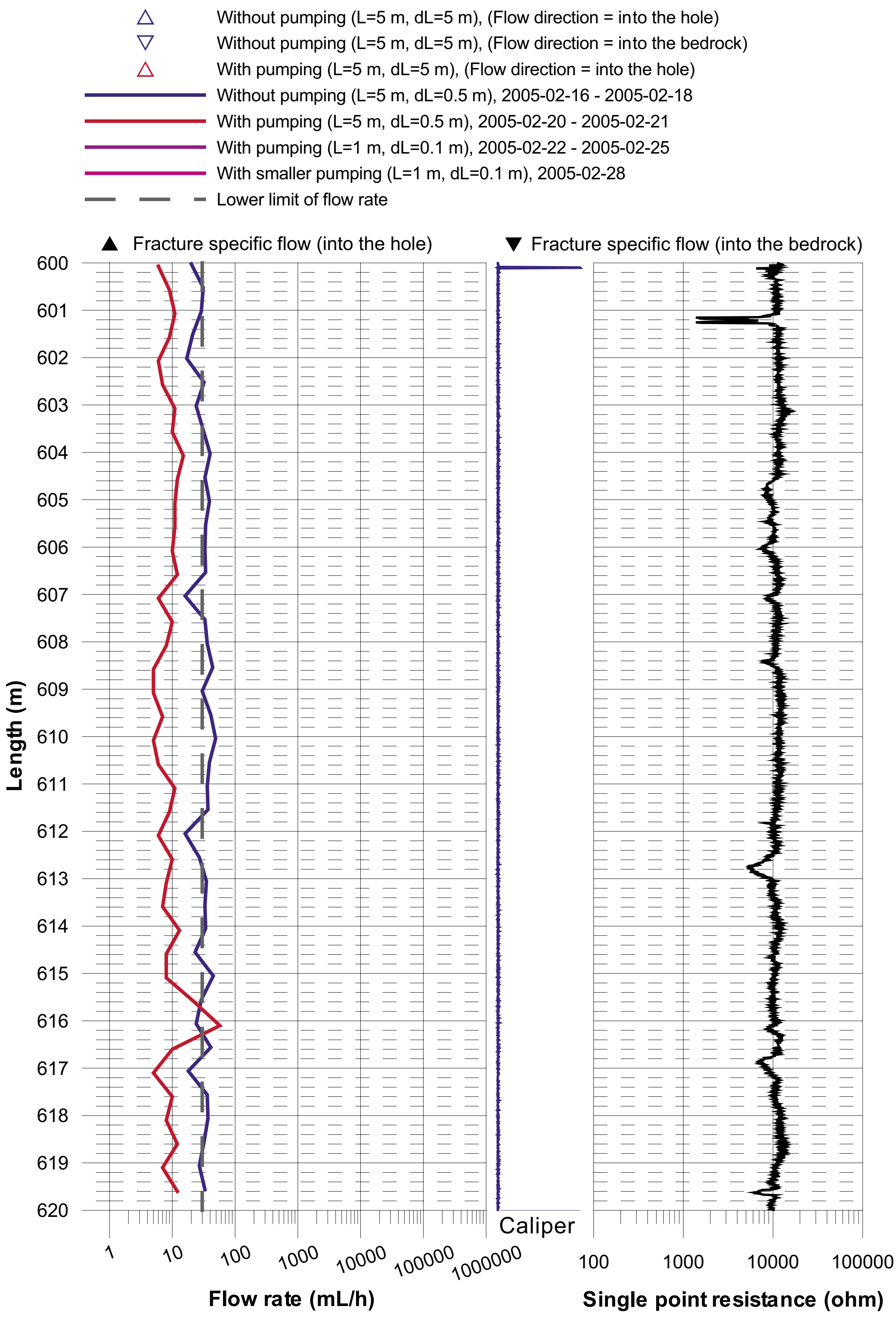
Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

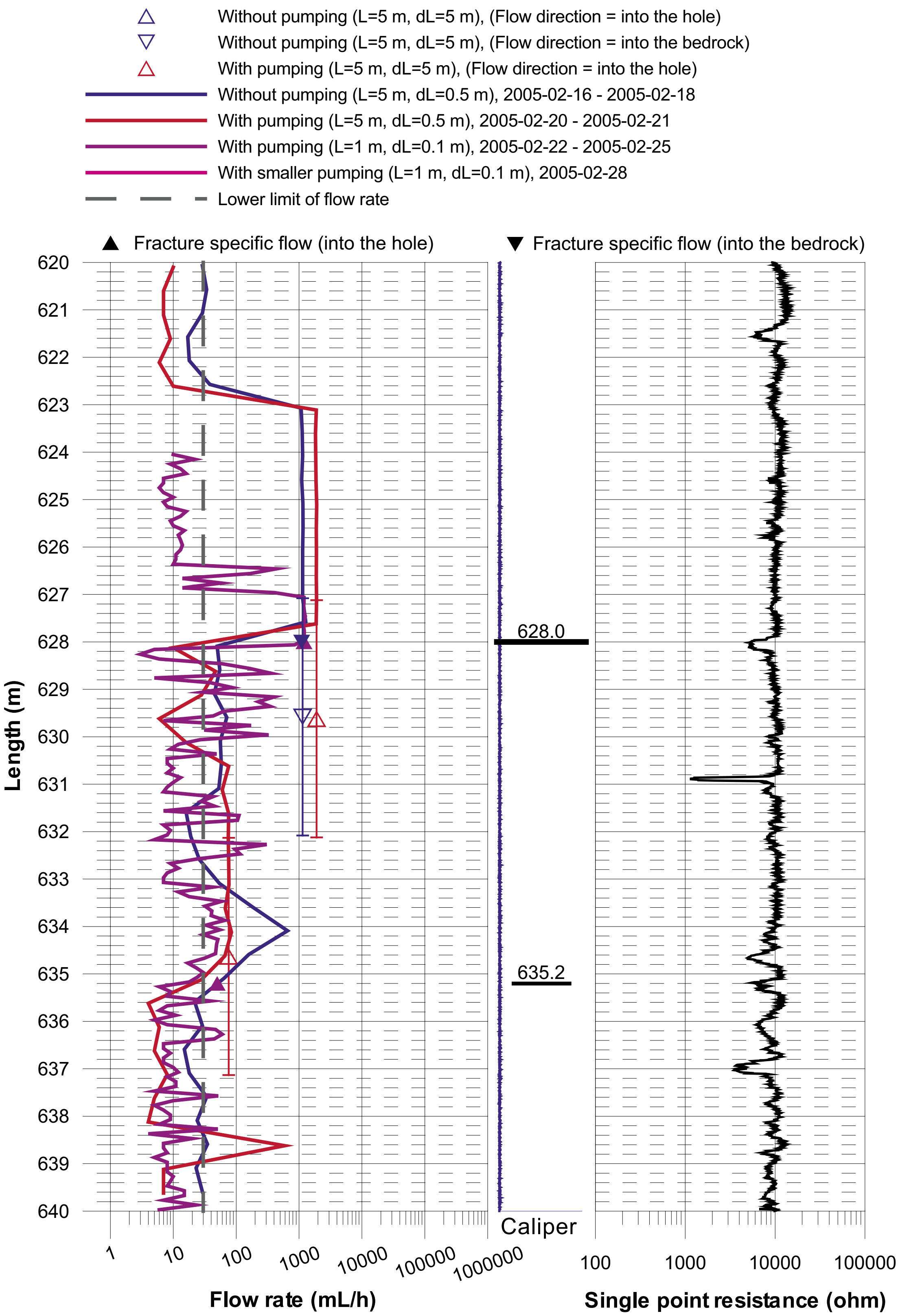


Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

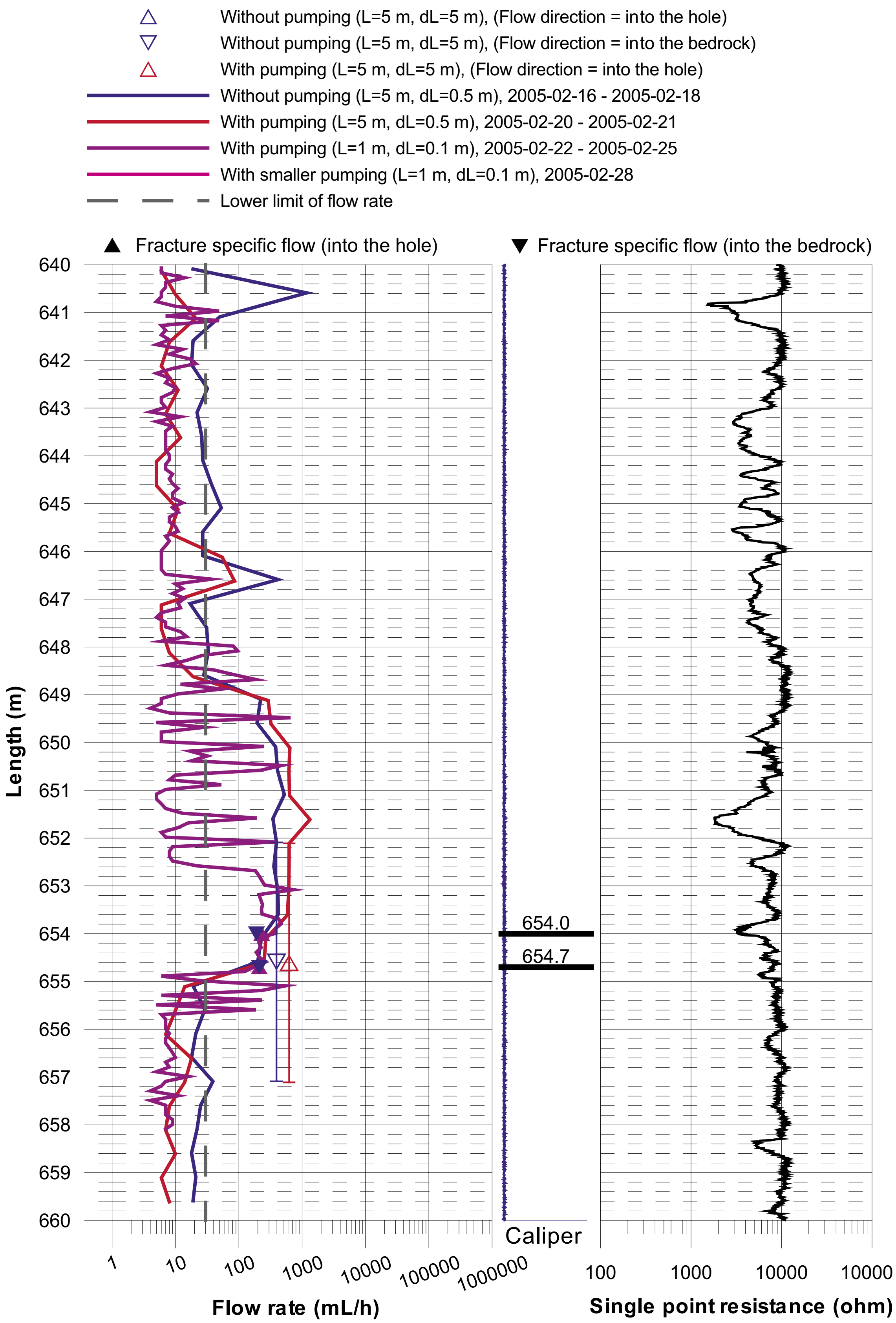


Appendix 3.27

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

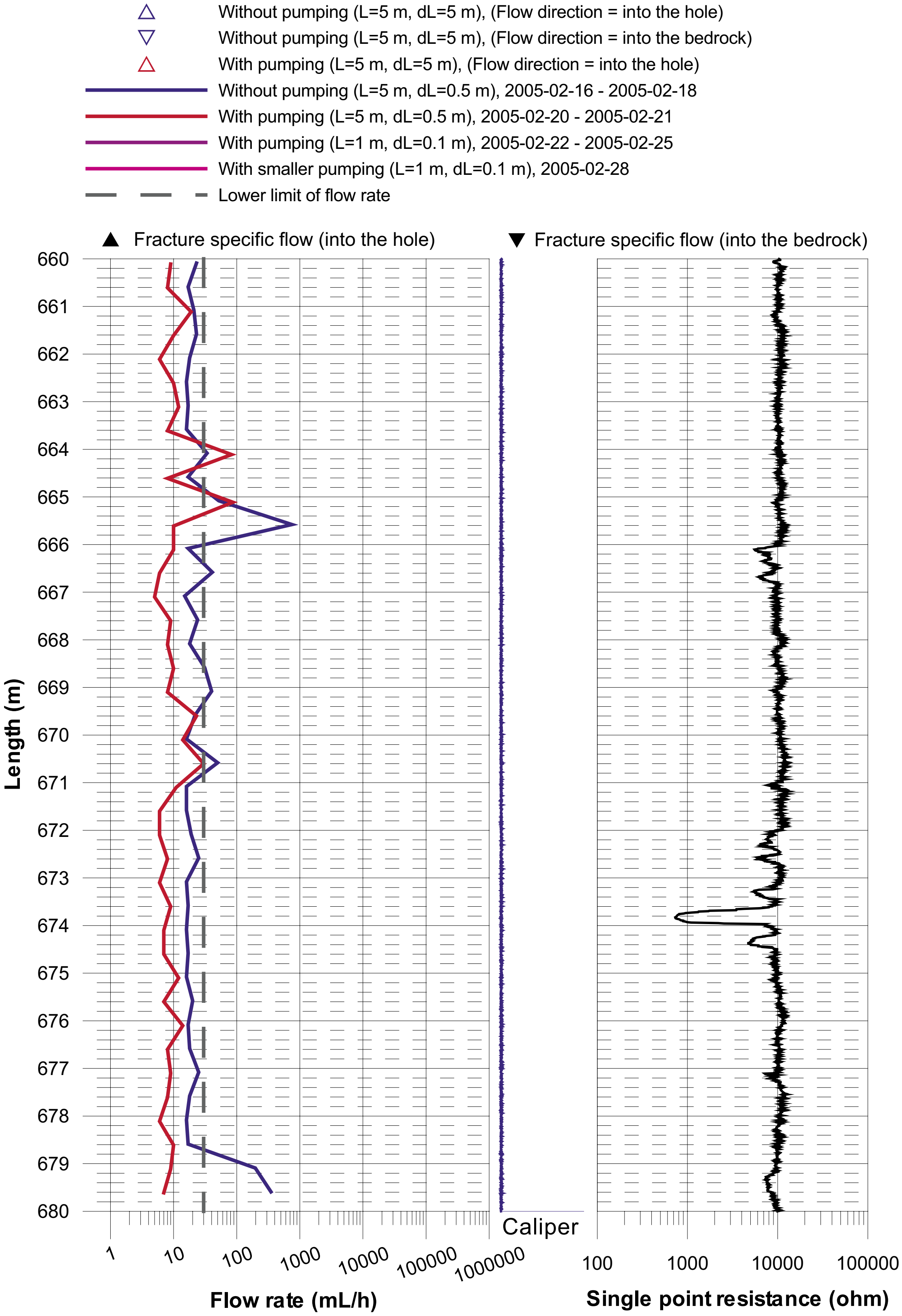


Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

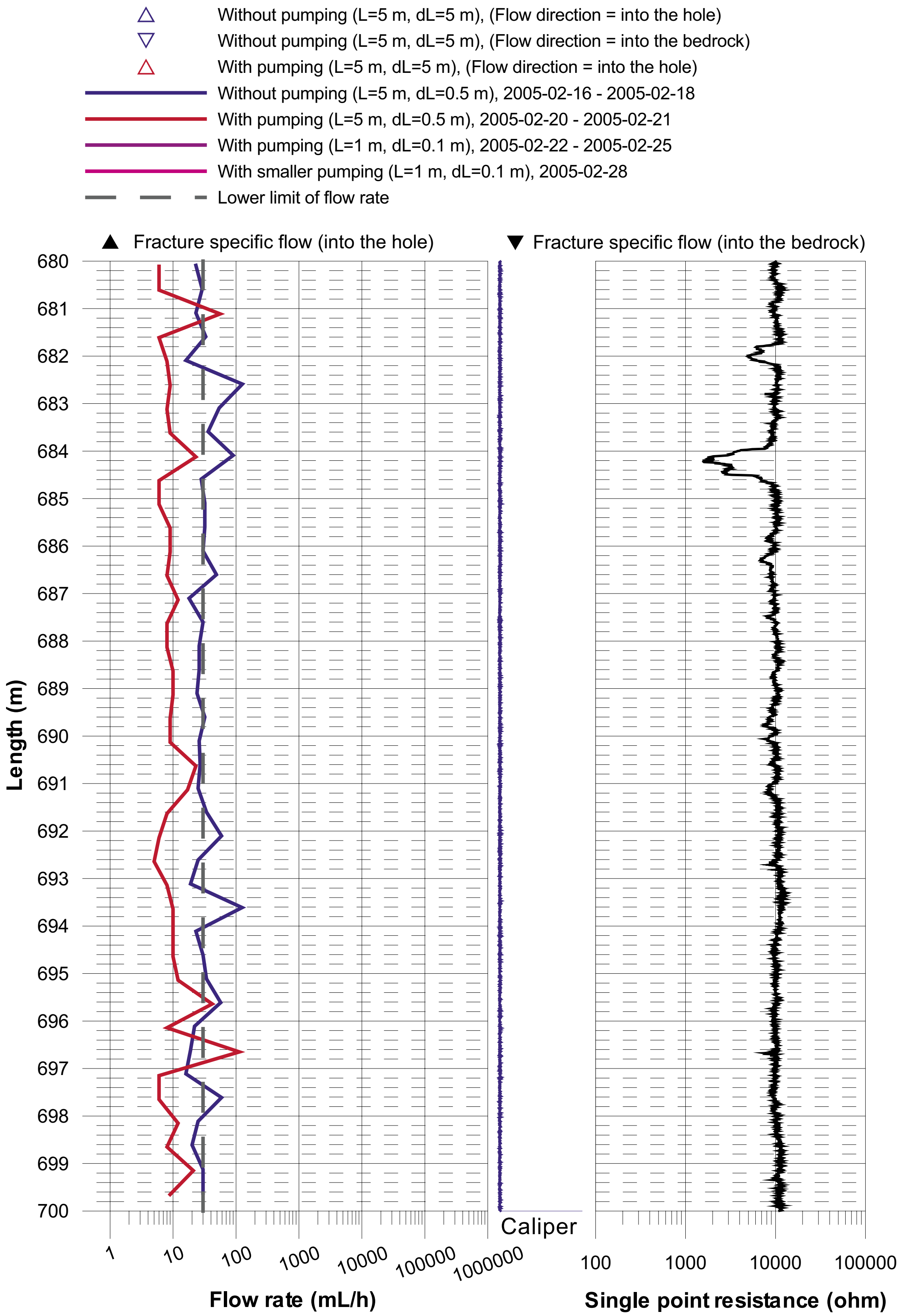


Appendix 3.29

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

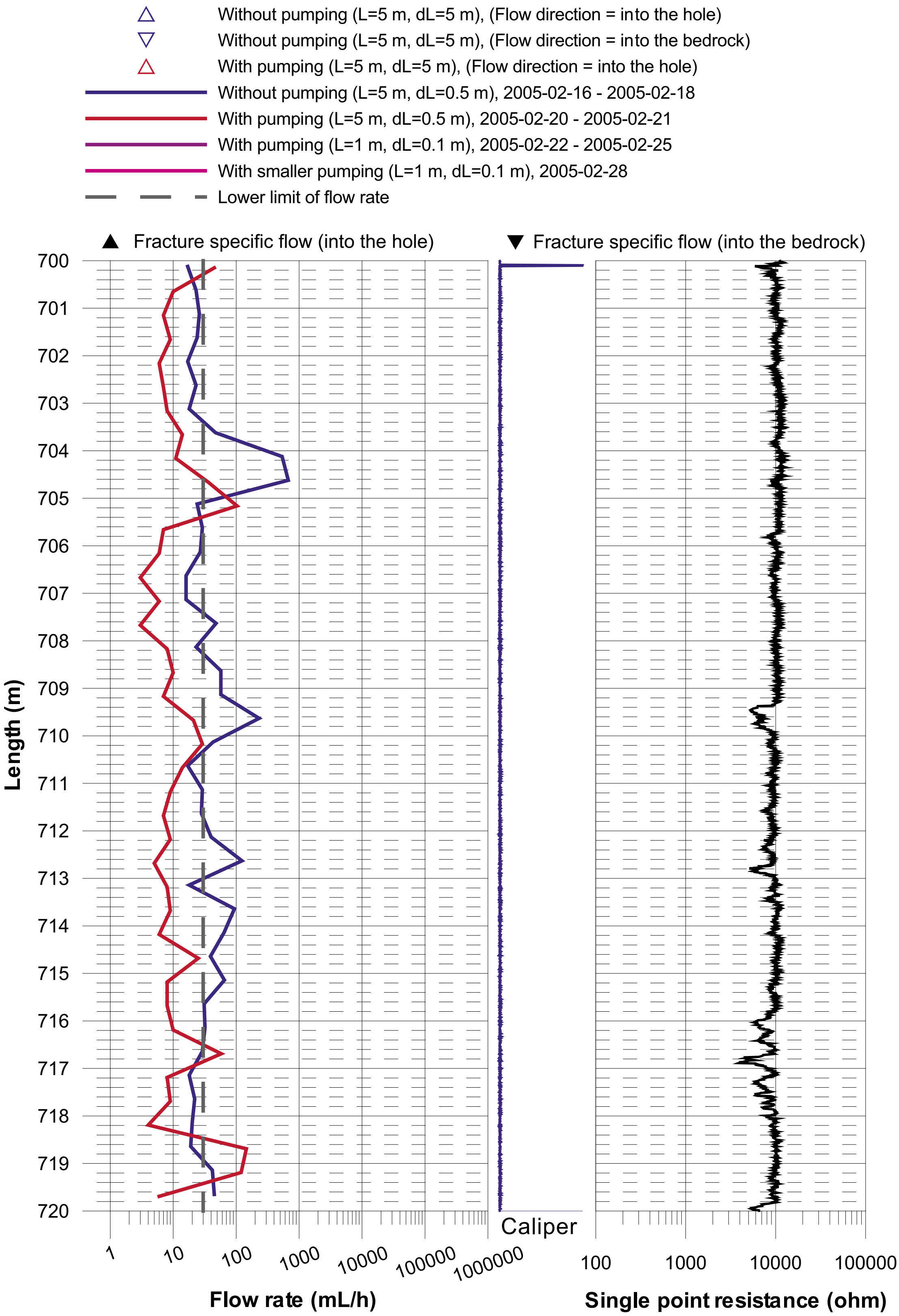


Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



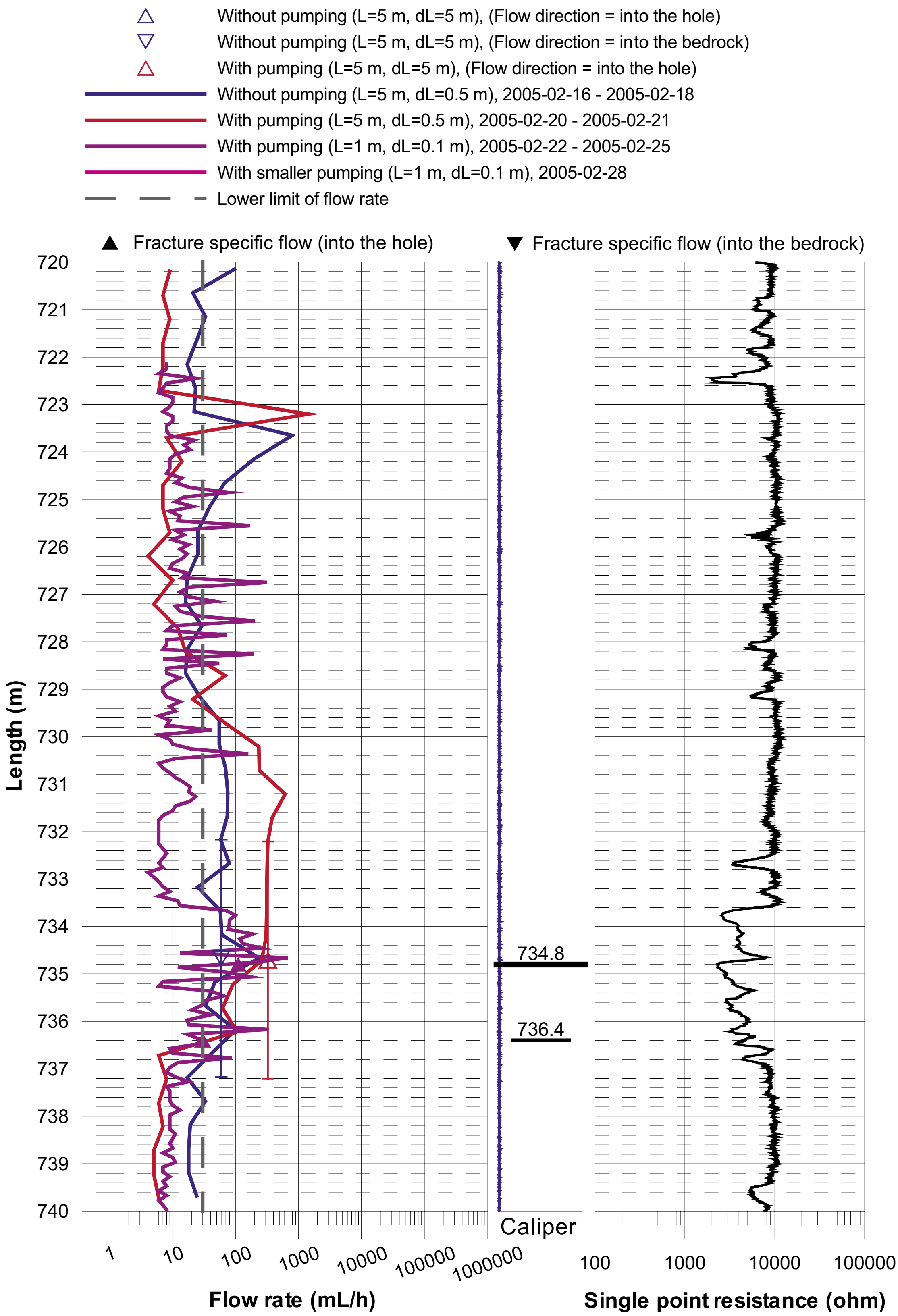
Appendix 3.31

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



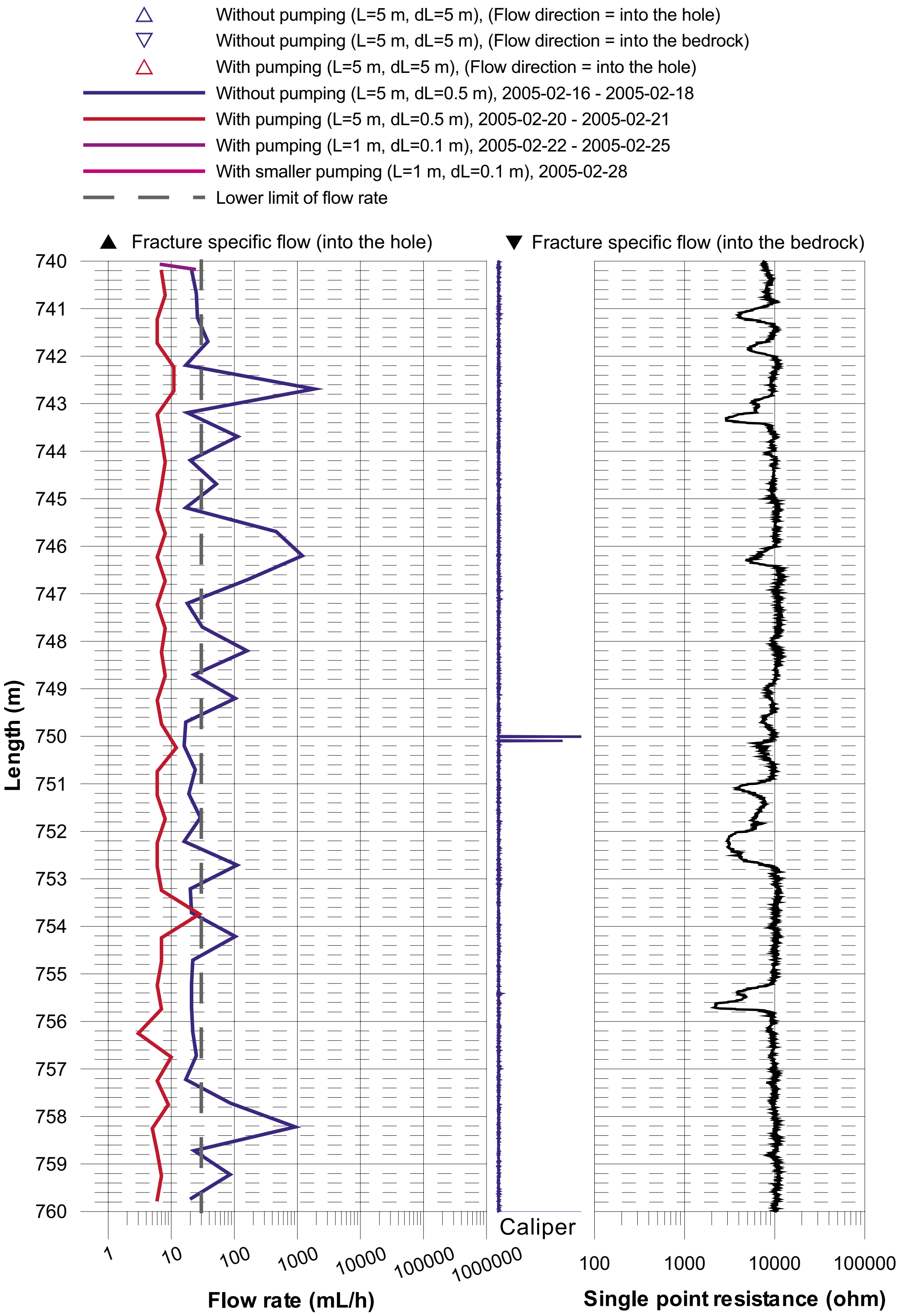
Appendix 3.32

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



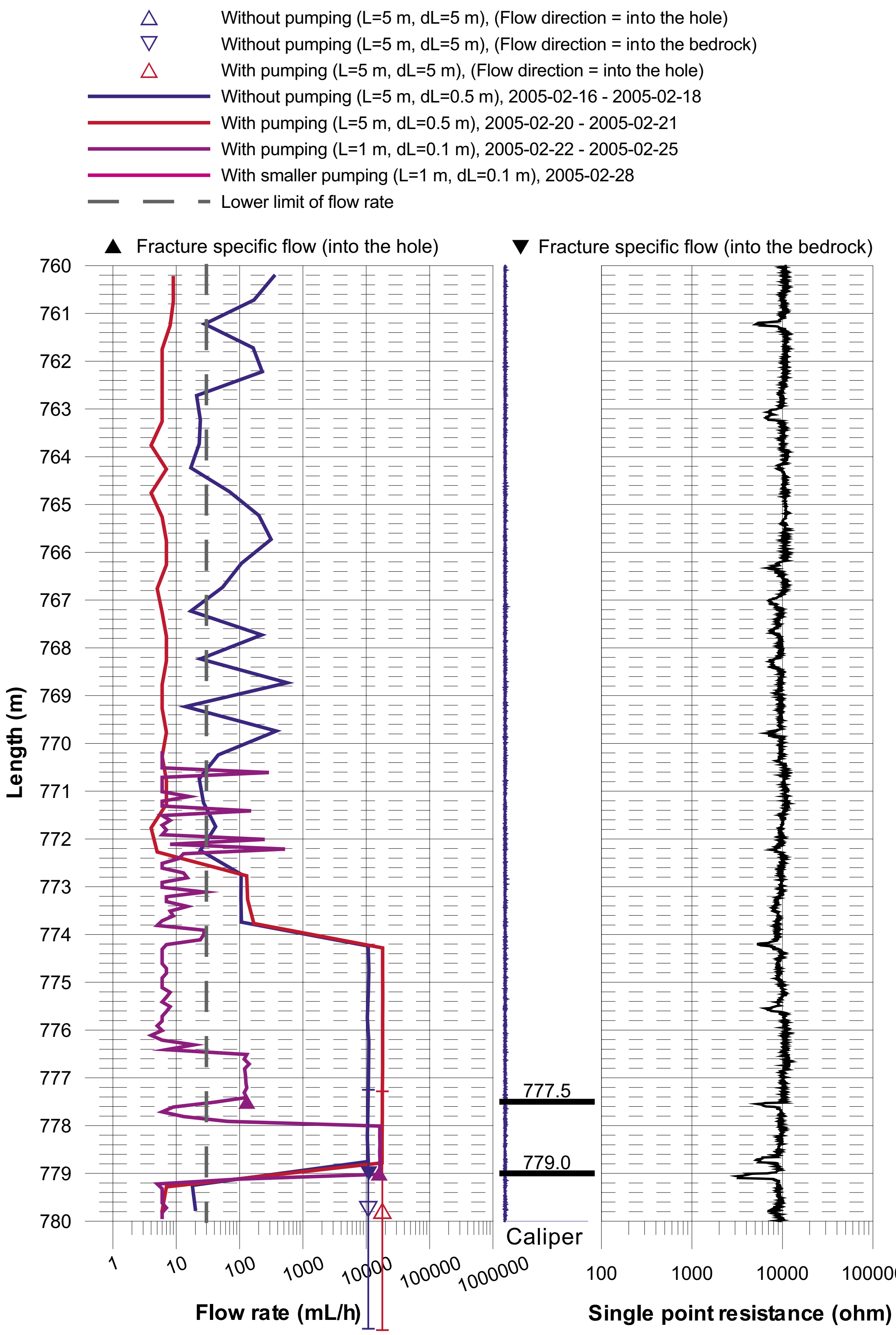
Appendix 3.33

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



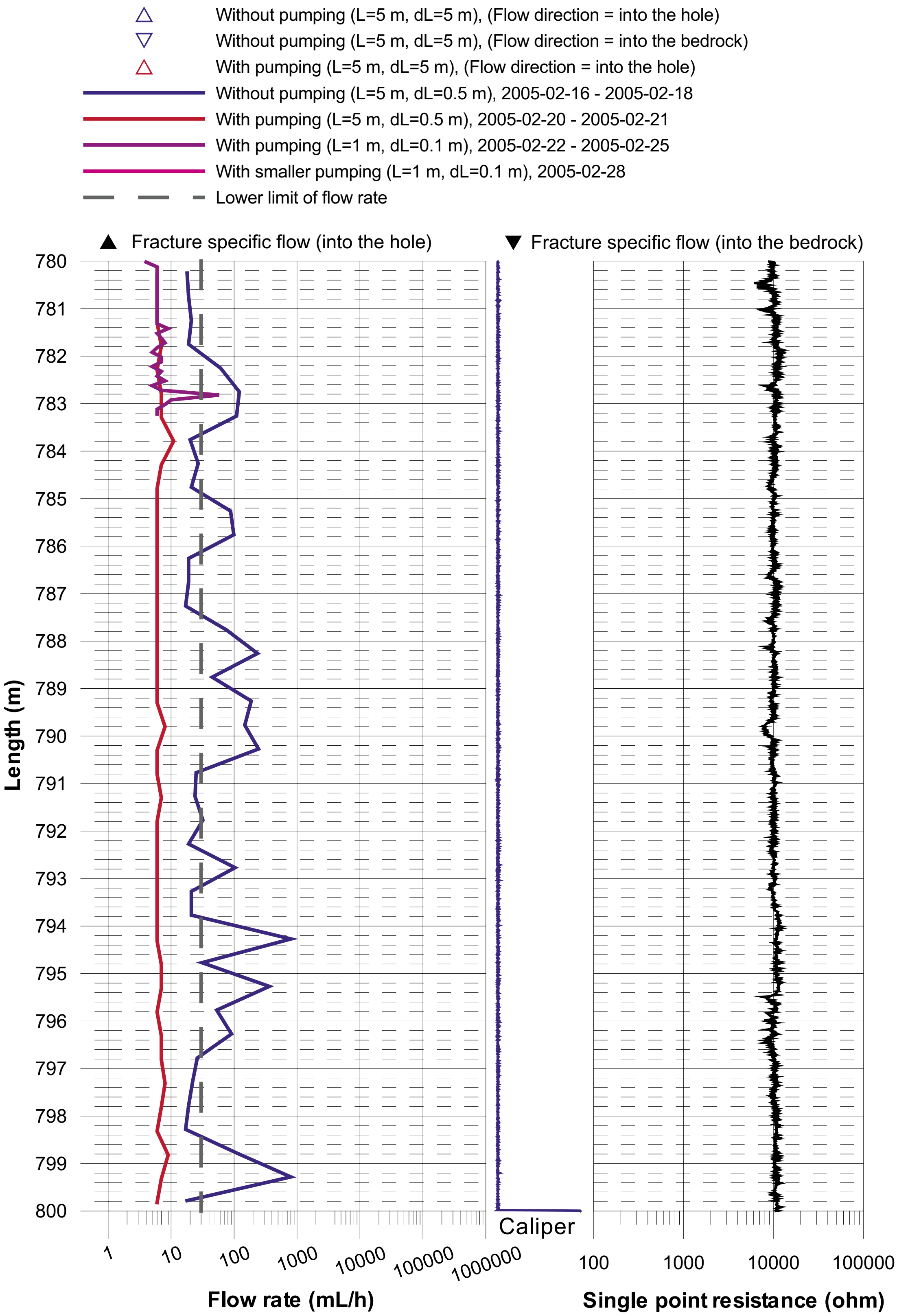
Appendix 3.34

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

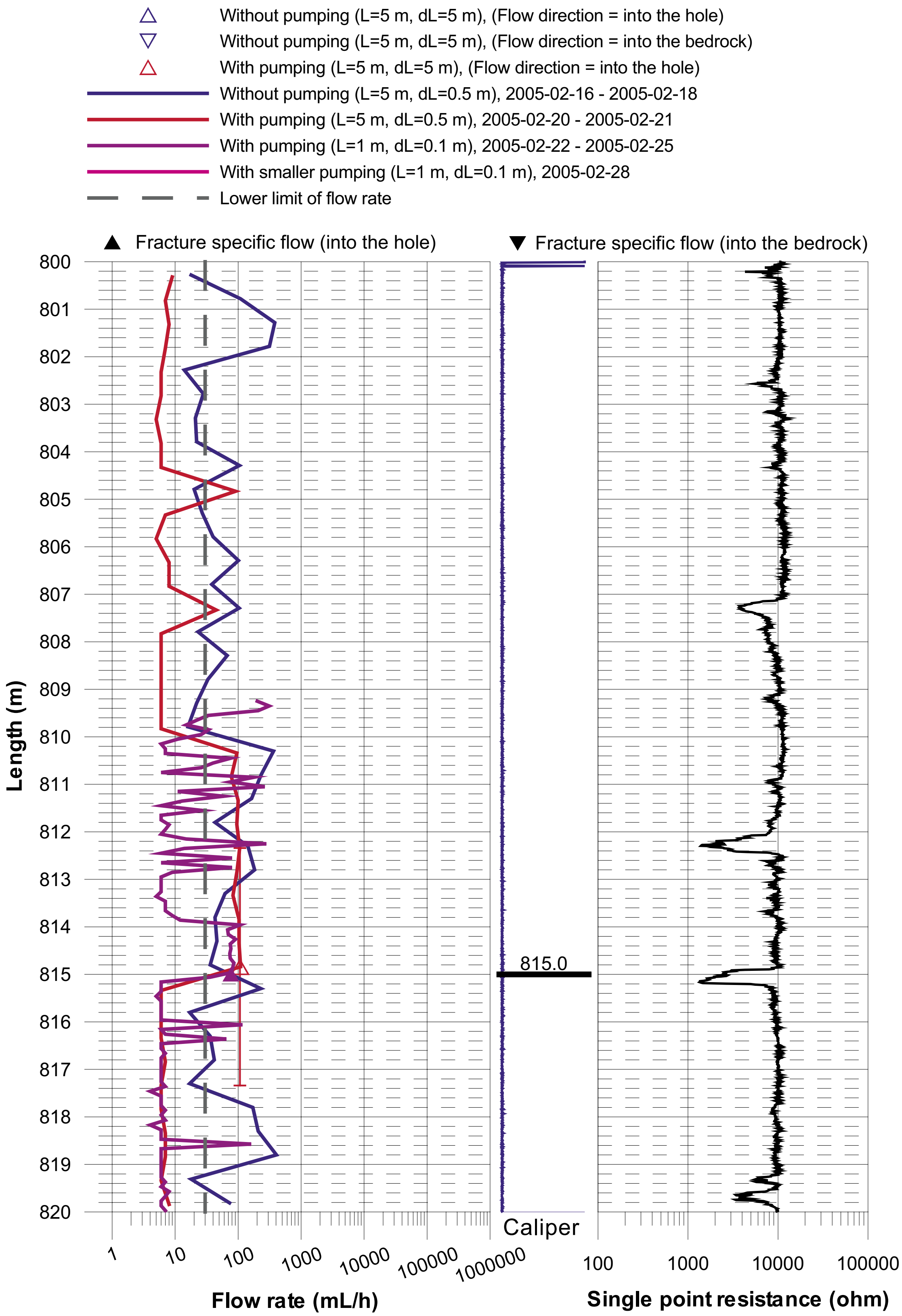


Appendix 3.35

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

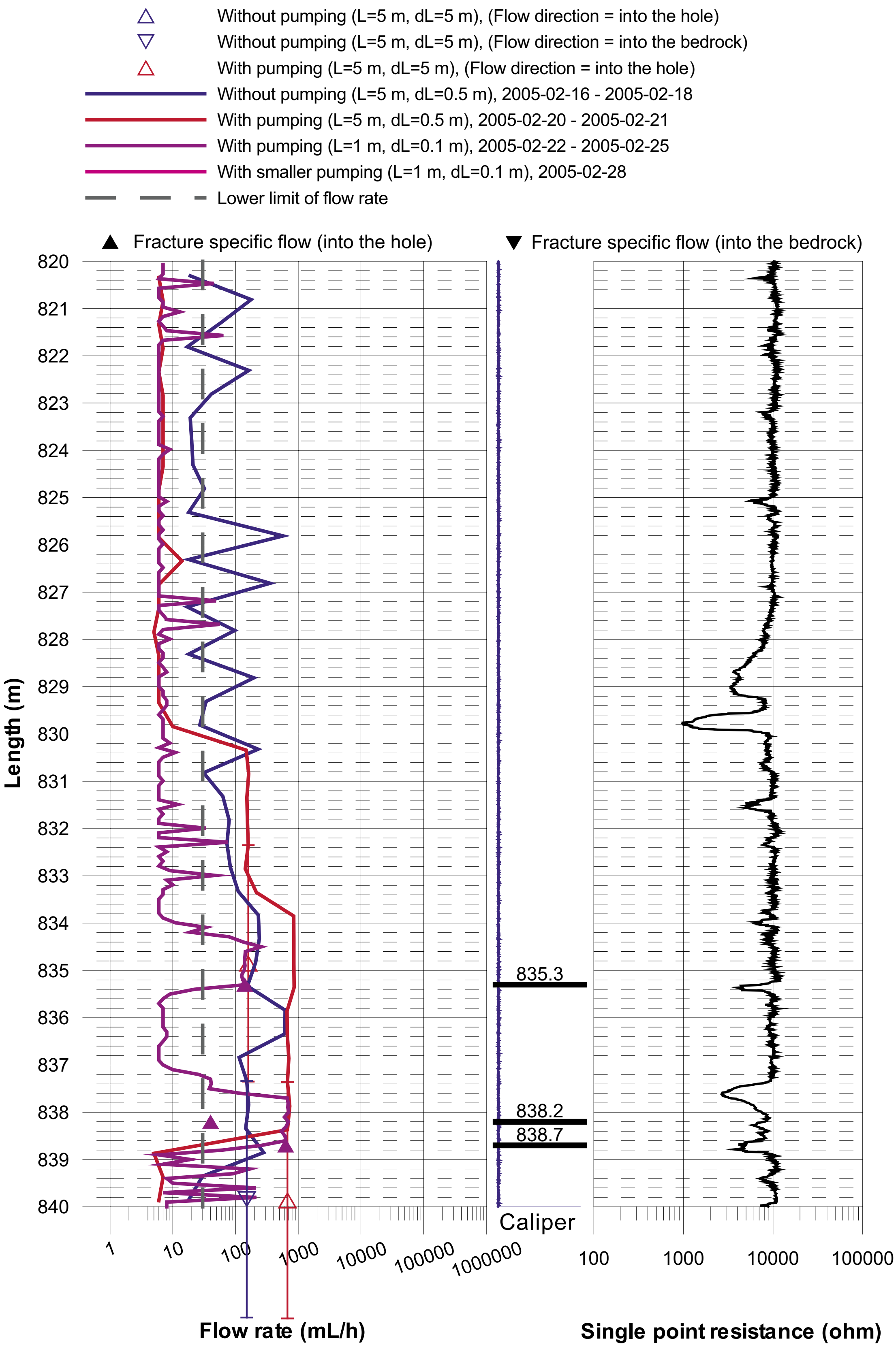


Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



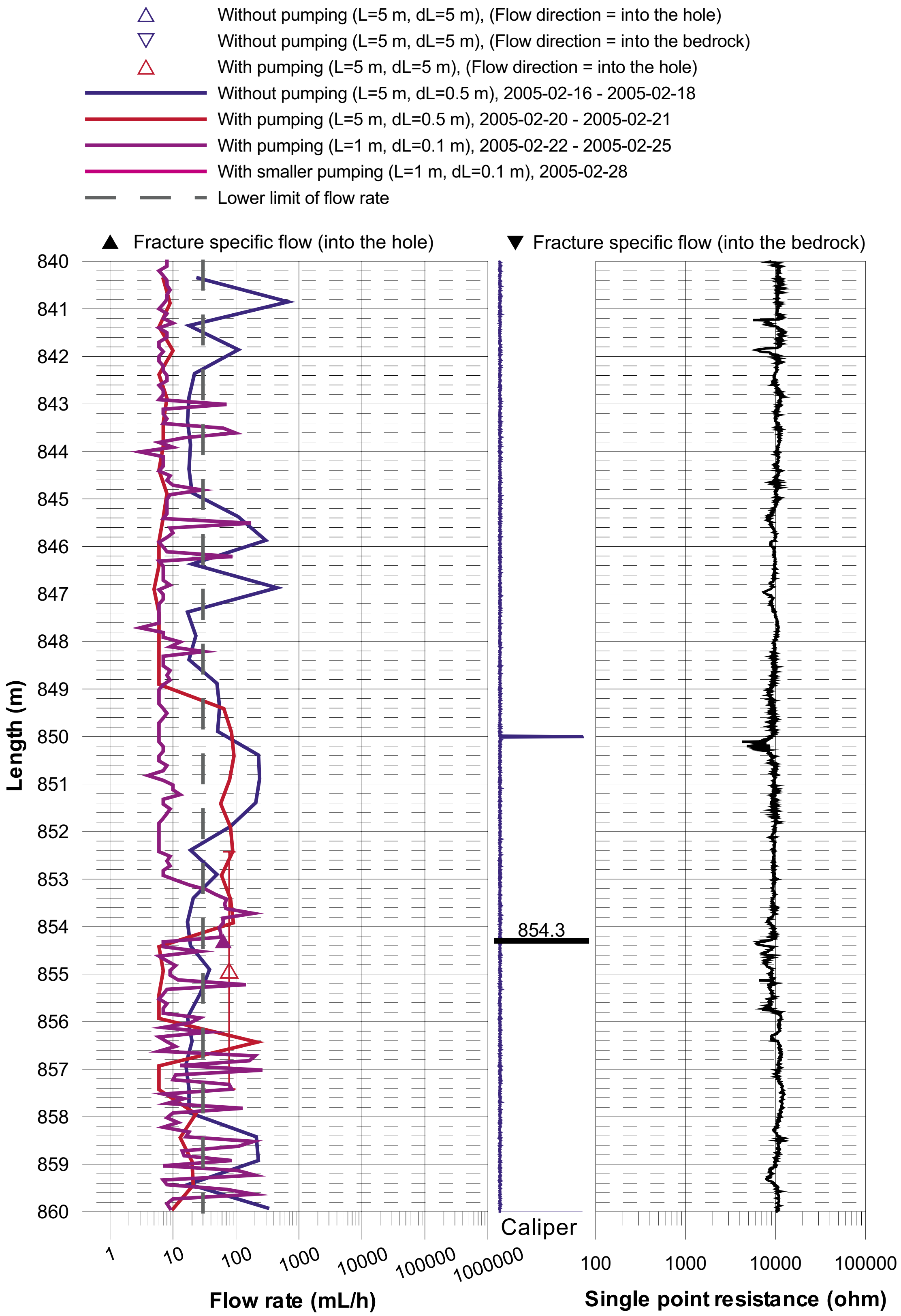
Appendix 3.37

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



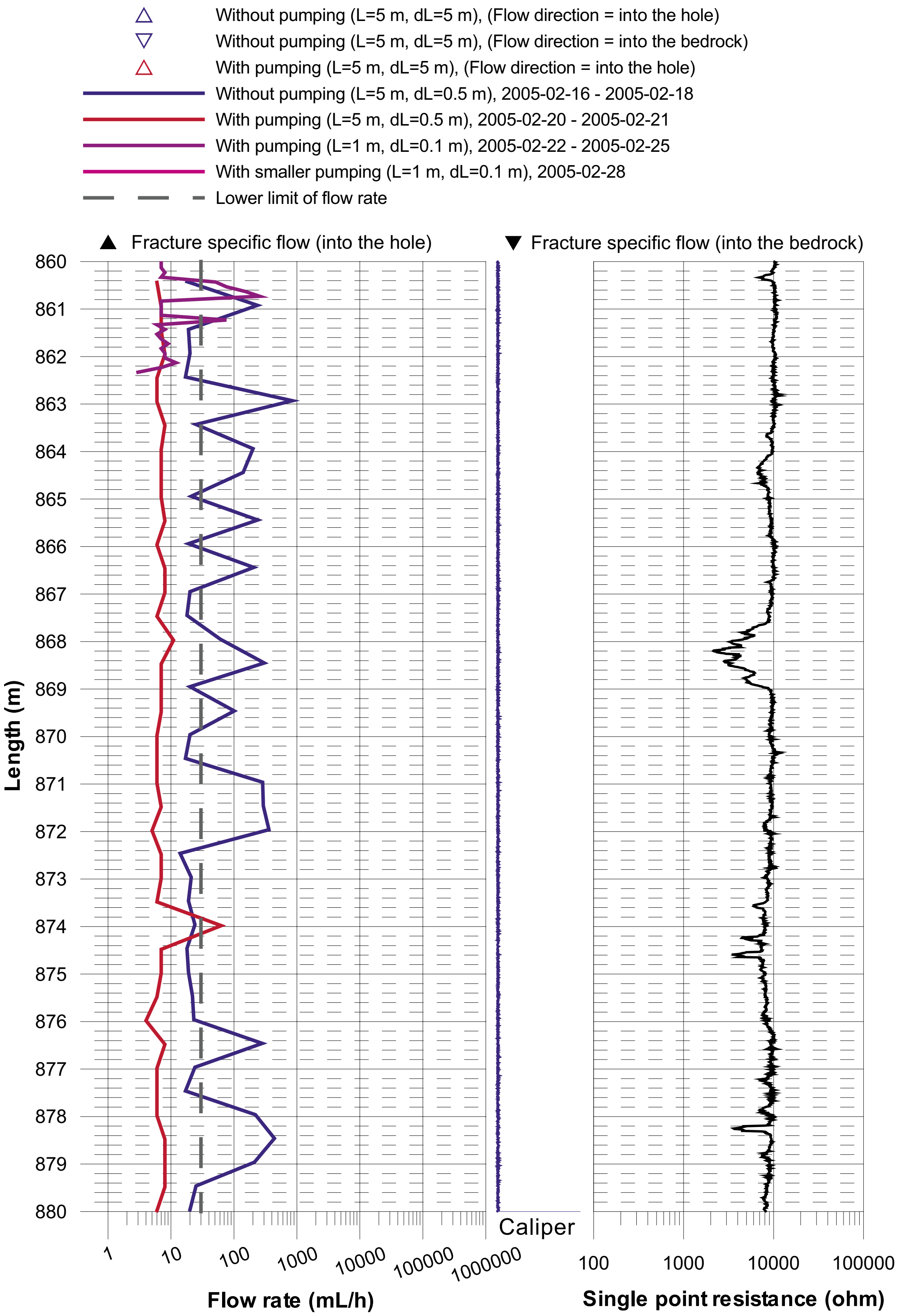
Appendix 3.38

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

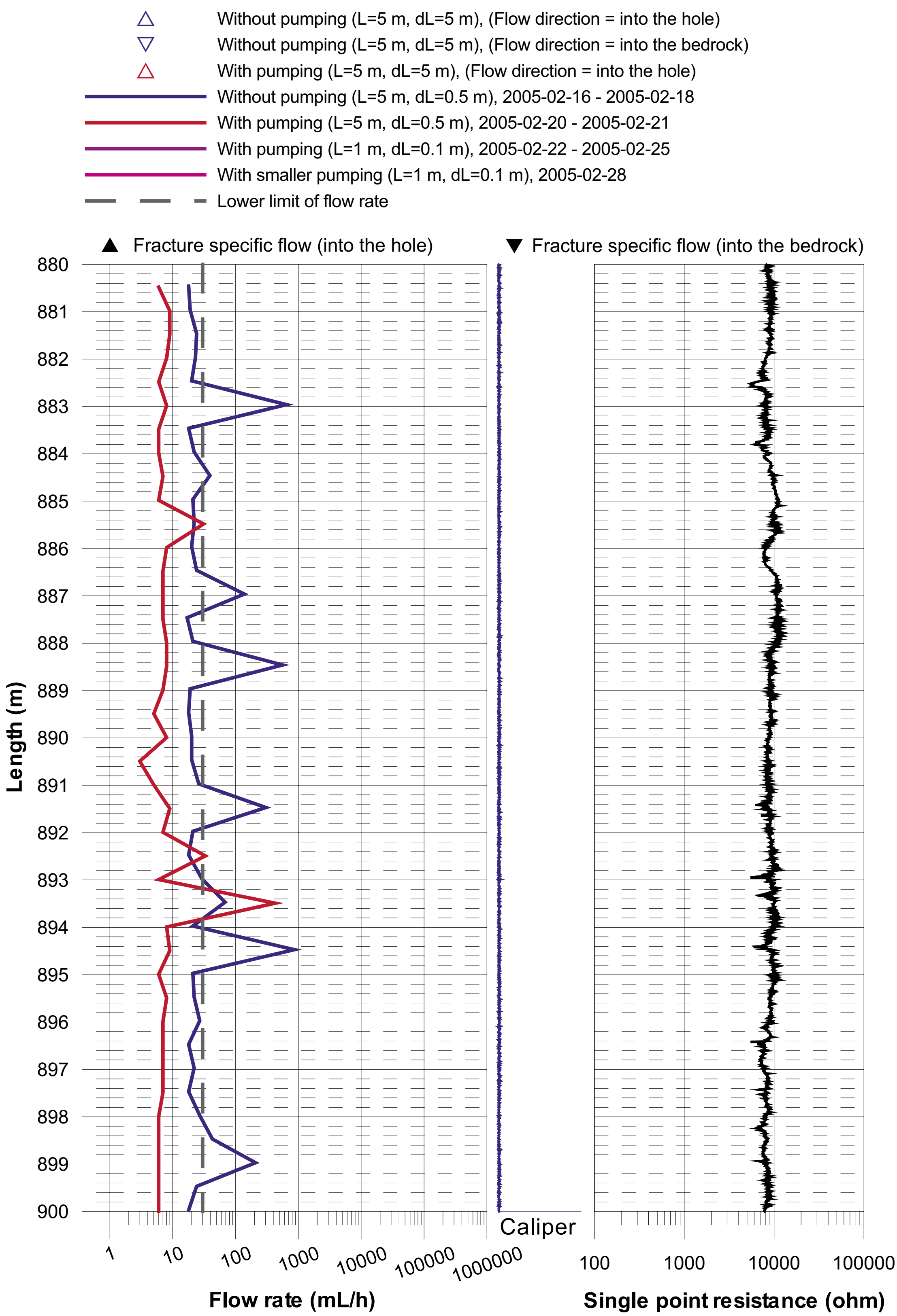


Appendix 3.39

Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

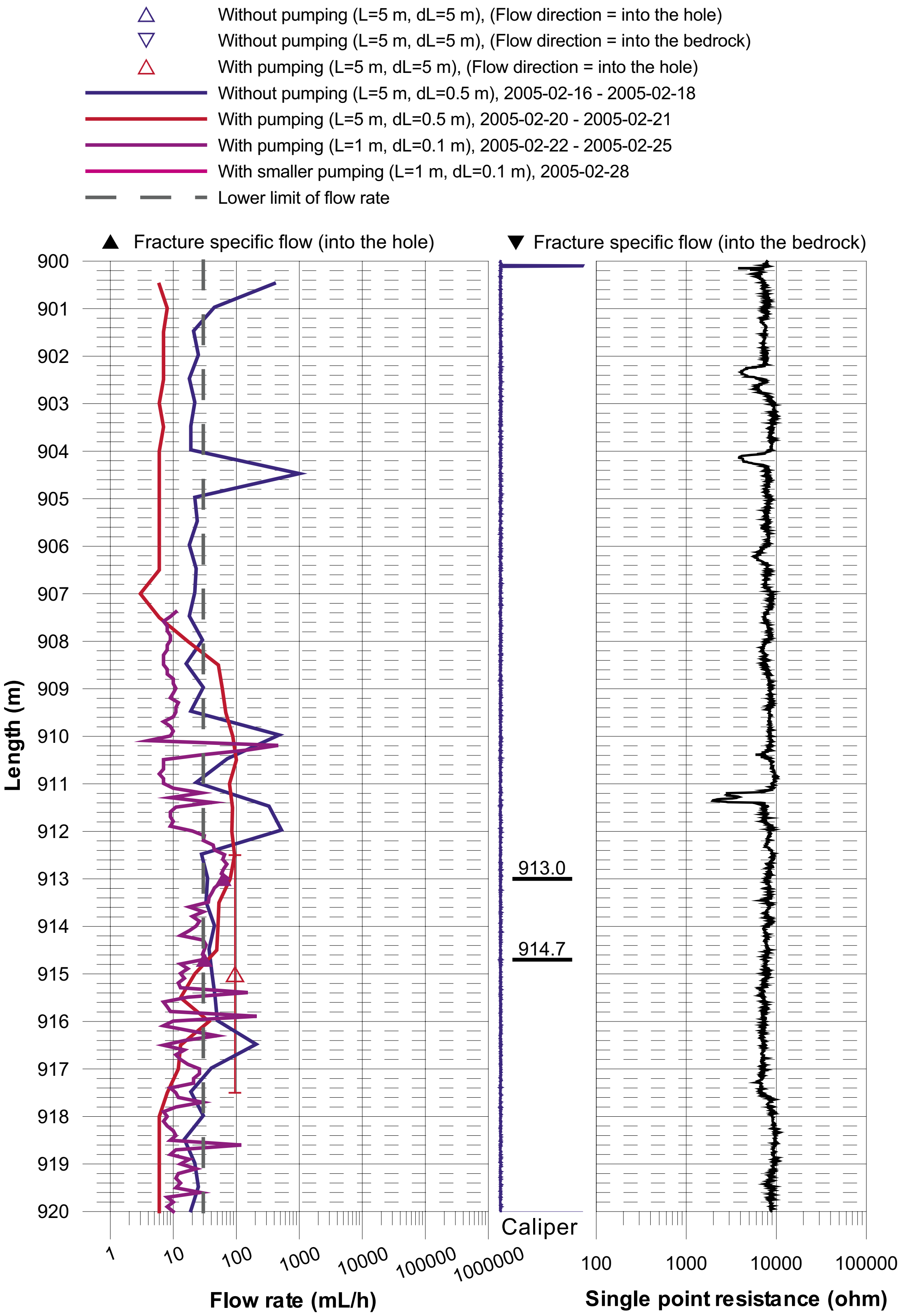


Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

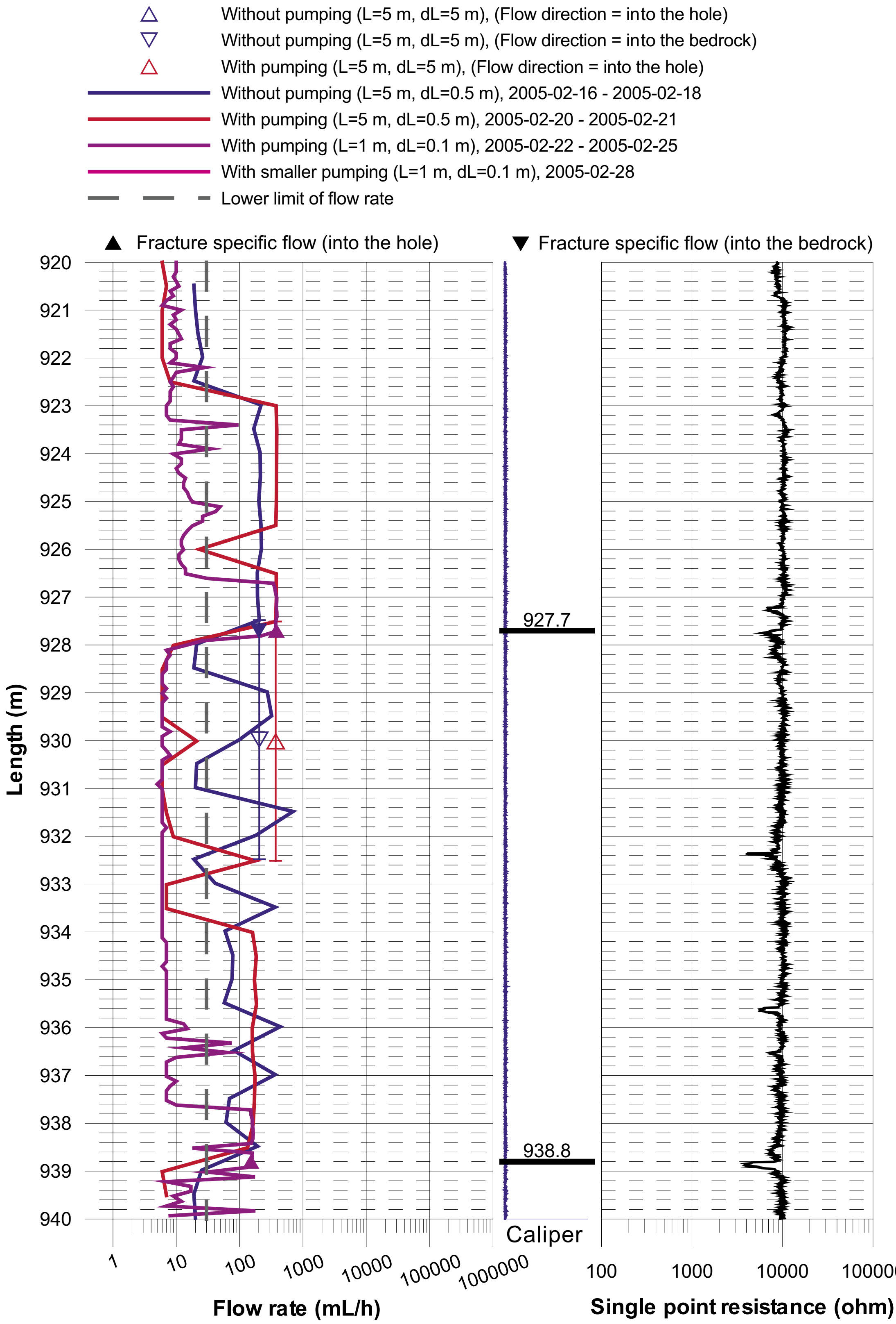


Appendix 3.41

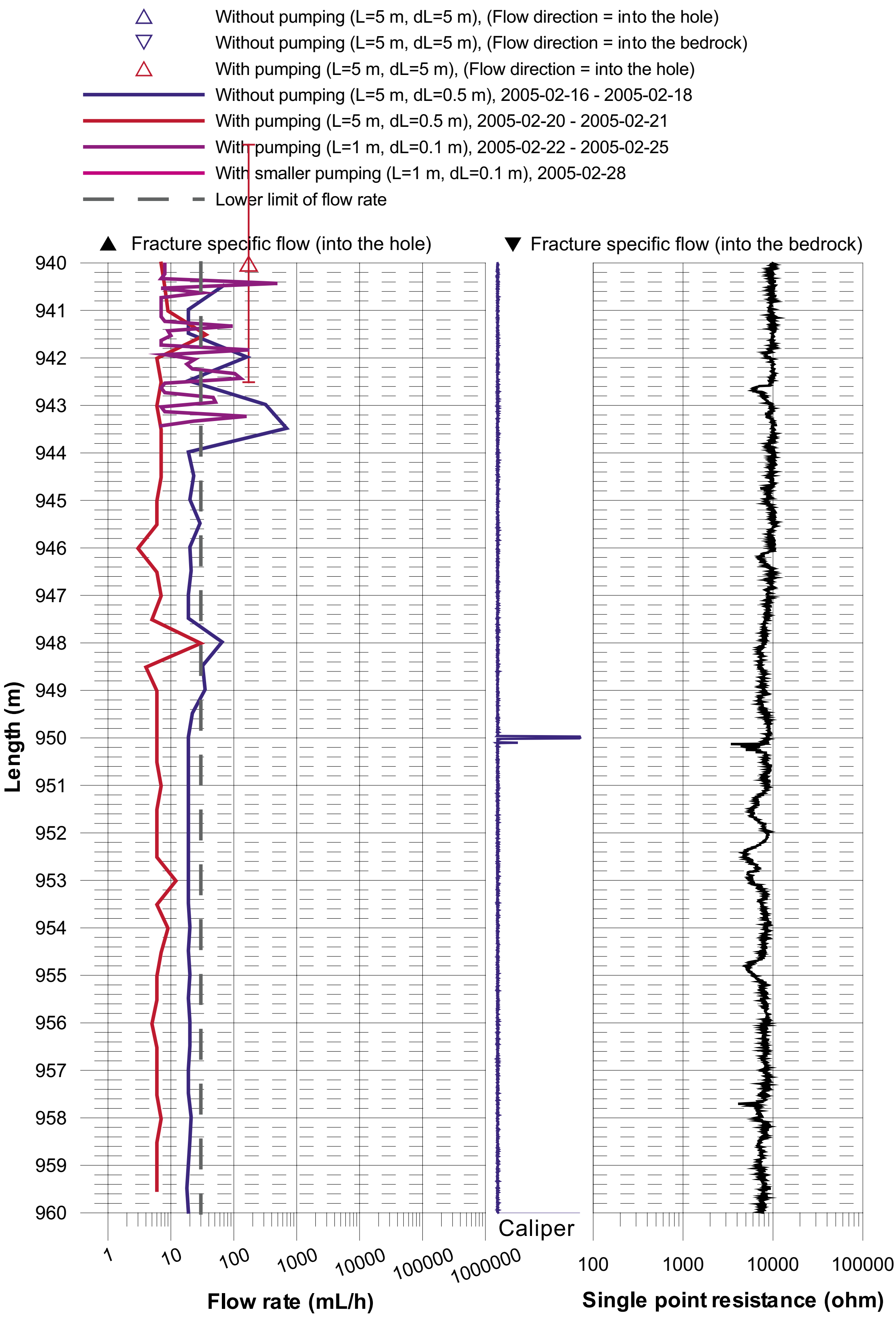
Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

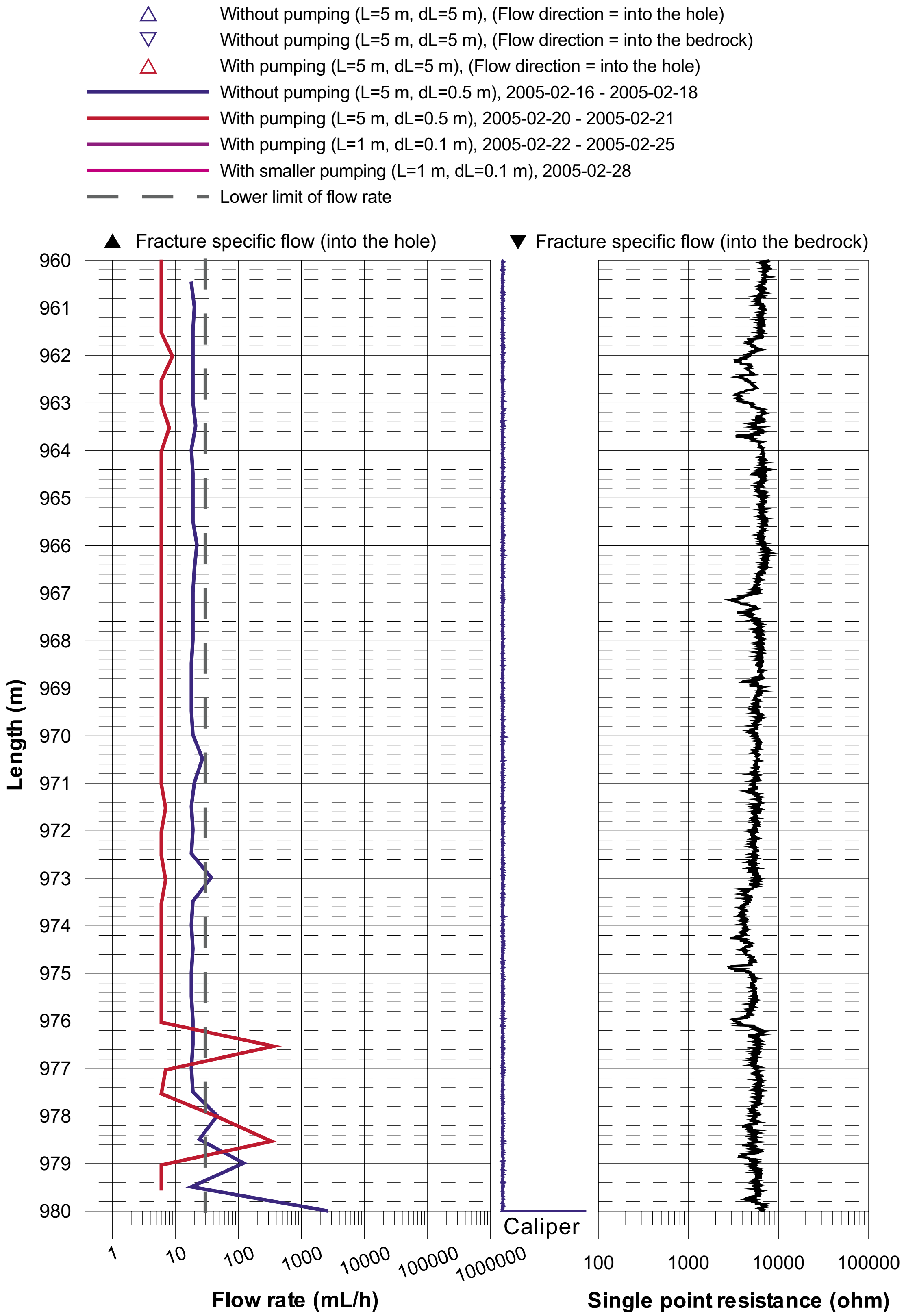


Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

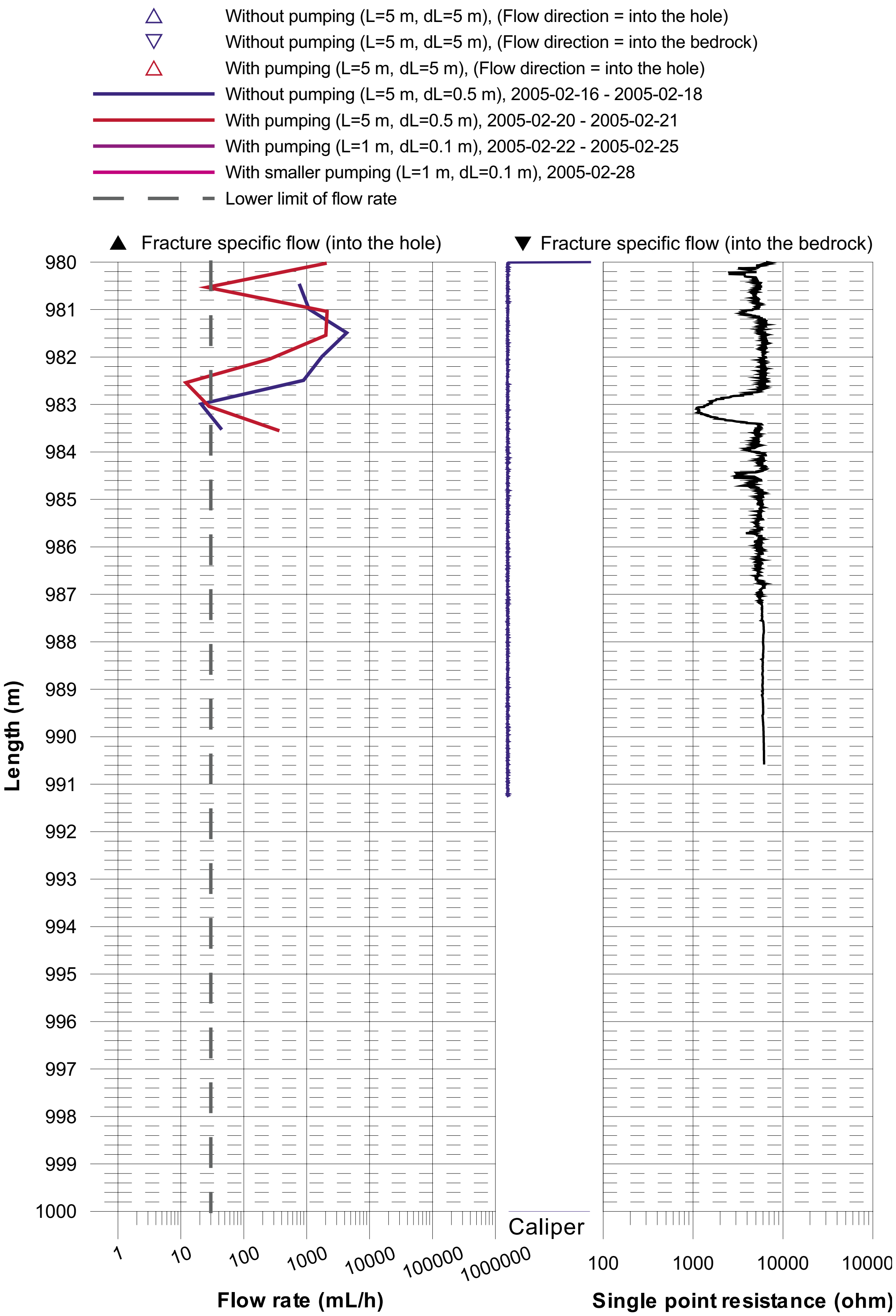


Appendix 3.44

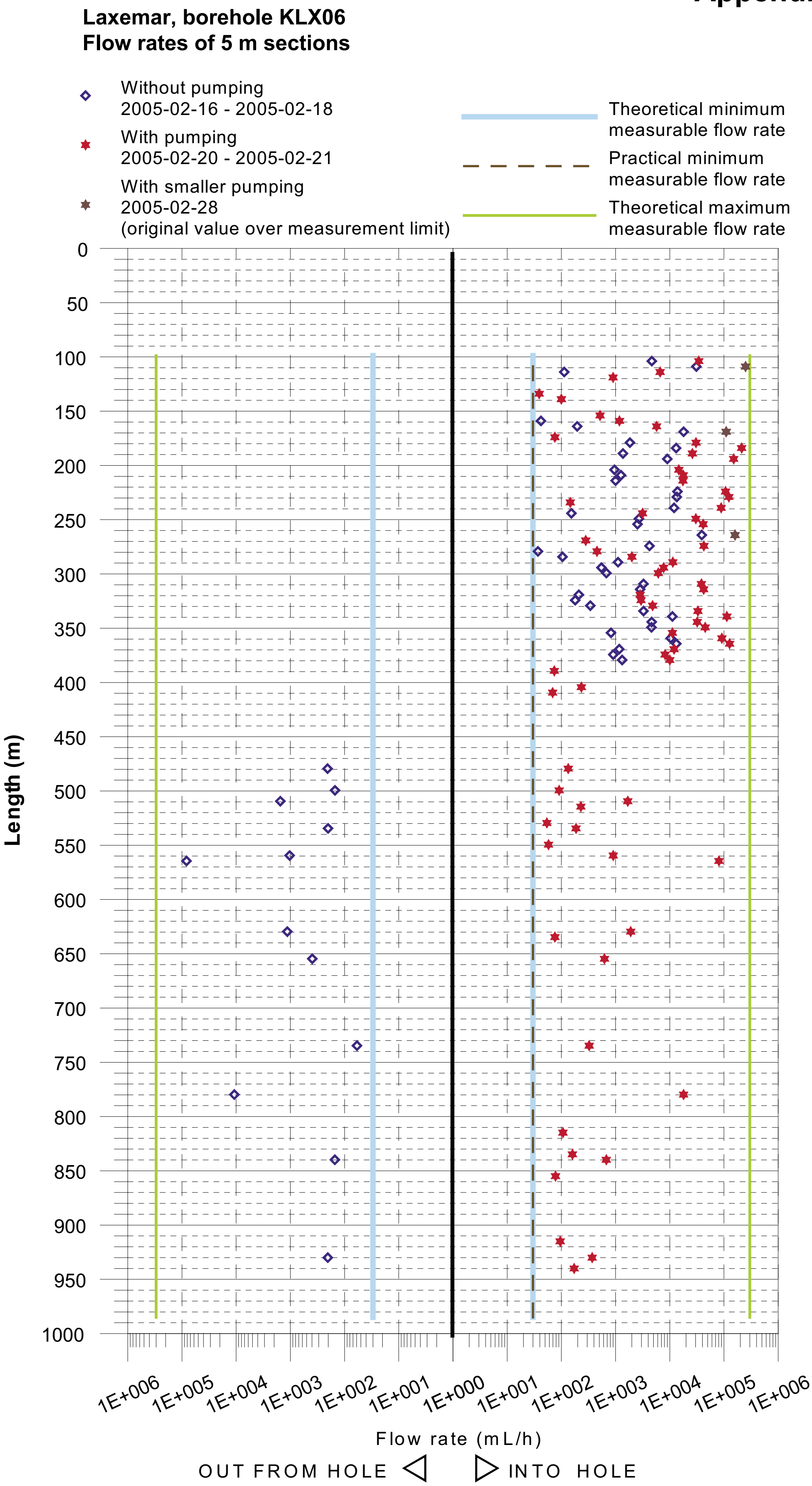
Laxemar, borehole KLX06
Flow rate, caliper and single point resistance



Laxemar, borehole KLX06
Flow rate, caliper and single point resistance

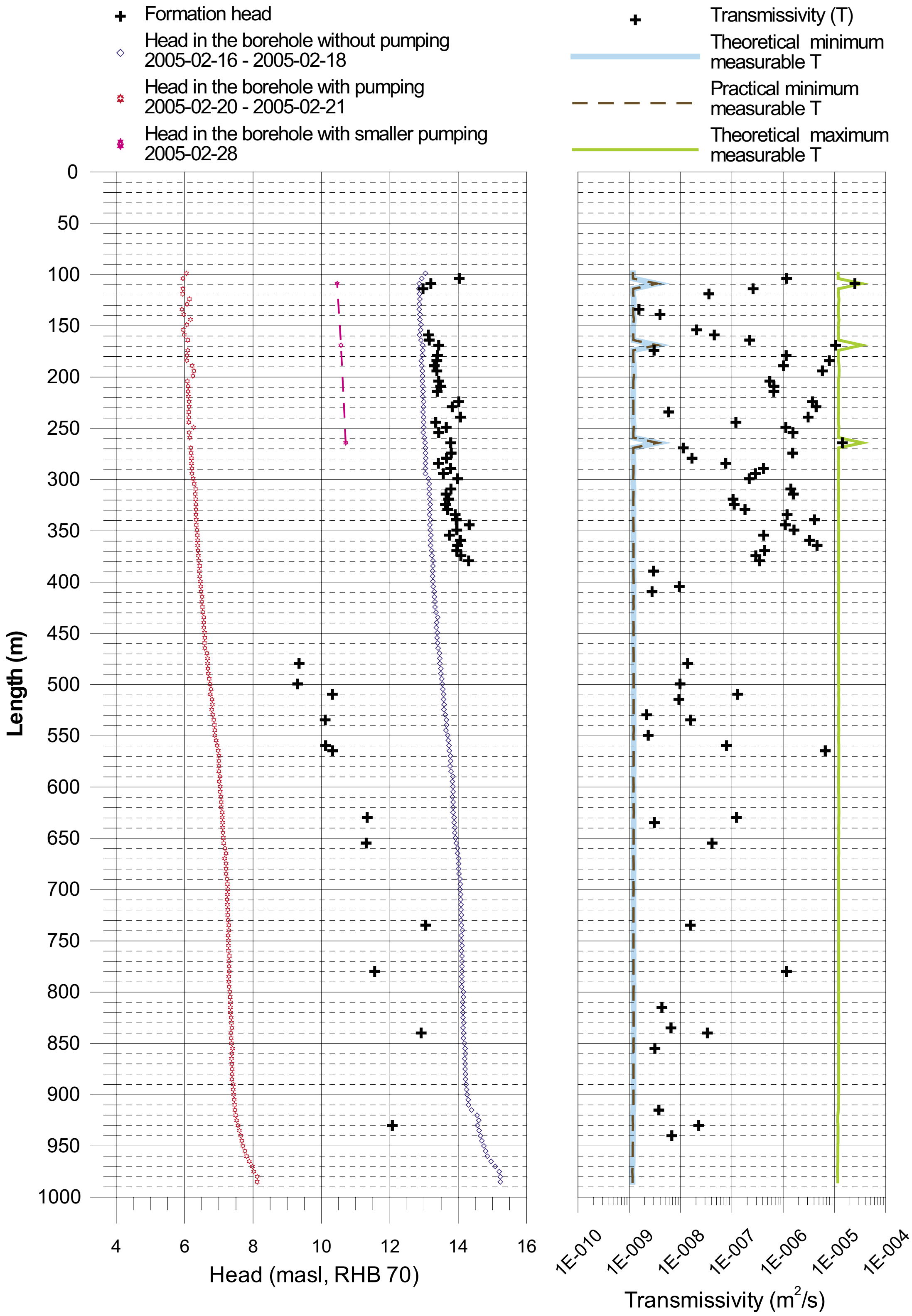


Appendix 4.1



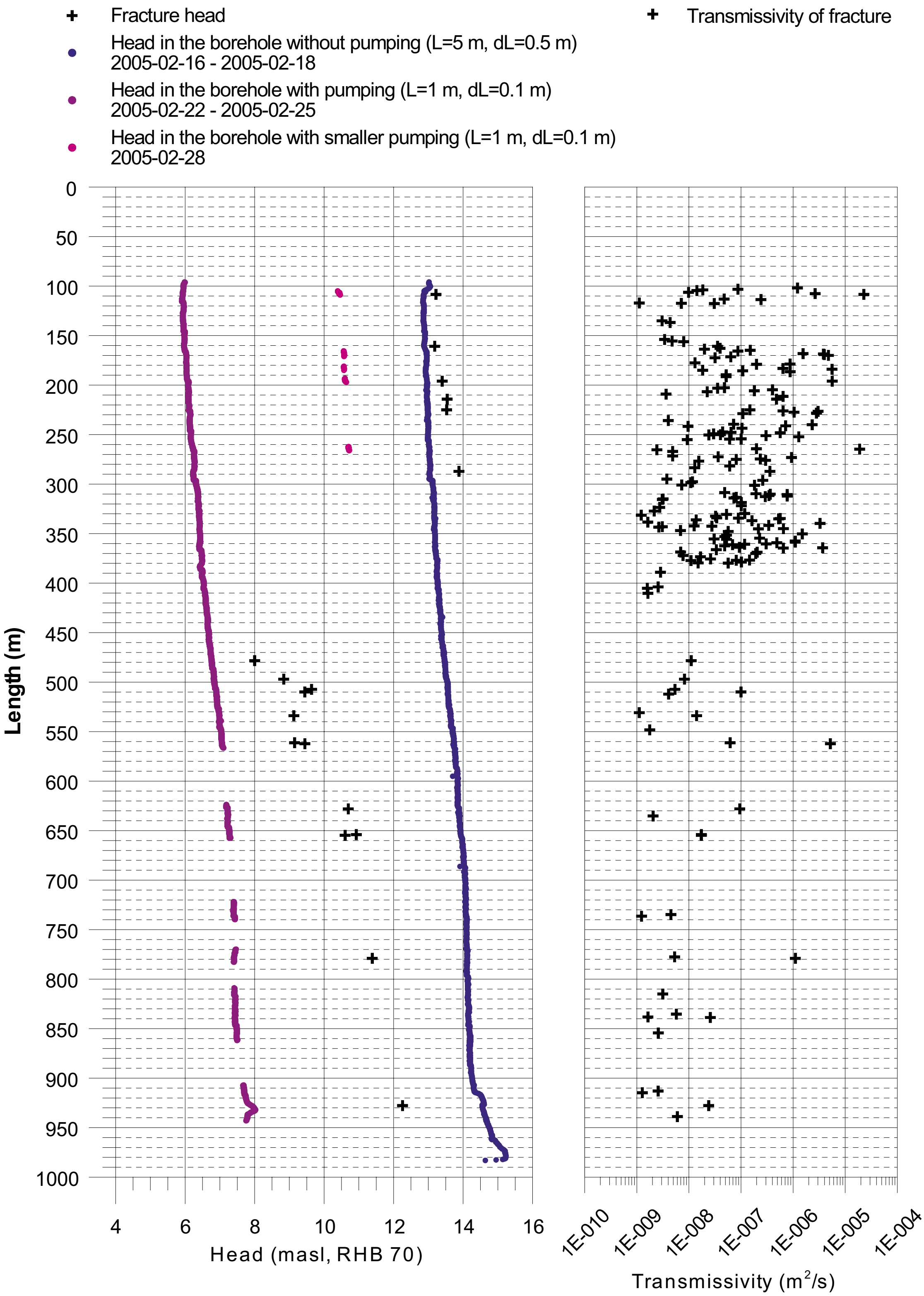
Laxemar, borehole KLX06
Flow rates of 5 m sections
Without pumping
2005-02-16 - 2005-02-18
With pumping
2005-02-20 - 2005-02-21
With smaller pumping
2005-02-28
(original value over measurement limit)
Theoretical minimum measurable flow rate
Practical minimum measurable flow rate
Theoretical maximum measurable 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

Laxemar, borehole KLX06
Transmissivity and head of 5 m sections



Appendix 5

Laxemar, borehole KLX06
Transmissivity and head of detected fractures



Appendix 6

5. PFL-DIFFERENCE FLOW LOGGING -Basic test data

Borehole ID	Logged interval Secup (m)	Seclow m)	Test type (1–6)	Date of test, start YYYYMMDD	Time of test, start hh:mm	Date of flowl. start YYYYMMDD	Time of flowl. start hh:mm	Date of test, stop YYYYMMDD	Time of test, stop hh:mm	L_w (m)	dL (m)	Q_{p1} (m^3/s)	Q_{p2} (m^3/s)
KLX06	**96.33**	**987.52**	**5A**	**20050218**	**16:52**	**20050220**	**10:44**	**20050226**	**16:53**	**5**	**5**	**1.25E-3**	

5. PFL-DIFFERENCE FLOW LOGGING -Basic test data

t_{p1} (s)	t_{p2} (s)	t_{F1} (s)	t_{F2} (s)	h_0 (m)	h_1 (m)	h_2 (m)	s_1 (m)	s_2 (m)	T Entire hole (m^2/s)	Reference (–)	Comments (–)
691,260		**138,900**		**13.16**	**6.23**		**-6.93**		**1.78E-4**		

Appendix 7

DIFFERENCE FLOW LOGGING -Sequential flow loggin

Borehole ID	Secup L(m)	Seclow L(m)	L_w (m)	Q_0 (m^3/s)	dh_0 (m)	Q_1 (m^3/s)	dh_1 (m)	TD (m^2/s)	hi (m)	Q-lower limit P (mL/h)	TD-measl$_{LT}$ (m^2/s)	TD-measl$_{LP}$ (m^2/s)	TD-measl$_U$ (m^2/s)	Comments
KLX06	982.52	987.52	5	–	15.23	–	8.12	–	-	30	1.16E–09	1.16E–09	1.16E–05	
KLX06	977.51	982.51	5	–	15.23	–	8.12	–	-	30	1.16E–09	1.16E–09	1.16E–05	
KLX06	972.50	977.50	5	–	15.20	–	8.02	–	-	30	1.15E–09	1.15E–09	1.15E–05	
KLX06	967.50	972.50	5	–	15.08	–	7.98	–	-	30	1.16E–09	1.16E–09	1.16E–05	
KLX06	962.50	967.50	5	–	14.96	–	7.89	–	-	30	1.17E–09	1.17E–09	1.17E–05	
KLX06	957.50	962.50	5	–	14.85	–	7.81	–	-	30	1.17E–09	1.17E–09	1.17E–05	
KLX06	952.50	957.50	5	–	14.80	–	7.76	–	-	30	1.17E–09	1.17E–09	1.17E–05	
KLX06	947.50	952.50	5	–	14.75	–	7.70	–	-	30	1.17E–09	1.17E–09	1.17E–05	
KLX06	942.50	947.50	5	–	14.69	–	7.67	–	-	30	1.17E–09	1.17E–09	1.17E–05	
KLX06	937.50	942.50	5	–	14.65	4.78E–08	7.64	6.74E–09	-	30	1.18E–09	1.18E–09	1.18E–05	
KLX06	932.50	937.50	5	–	14.61	–	7.60	–	-	30	1.18E–09	1.18E–09	1.18E–05	
KLX06	927.50	932.50	5	–5.67E–08	14.56	1.03E–07	7.56	2.25E–08	12.07	30	1.18E–09	1.18E–09	1.18E–05	
KLX06	922.49	927.49	5	–	14.60	–	7.52	–	-	30	1.16E–09	1.16E–09	1.16E–05	
KLX06	917.49	922.49	5	–	14.55	–	7.49	–	-	30	1.17E–09	1.17E–09	1.17E–05	
KLX06	912.49	917.49	5	–	14.39	2.64E–08	7.47	3.77E–09	-	30	1.19E–09	1.19E–09	1.19E–05	
KLX06	907.49	912.49	5	–	14.30	–	7.46	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	902.48	907.48	5	–	14.29	–	7.45	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	897.48	902.48	5	–	14.26	–	7.43	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	892.48	897.48	5	–	14.24	–	7.42	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	887.48	892.48	5	–	14.23	–	7.42	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	882.47	887.47	5	–	14.21	–	7.38	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	877.47	882.47	5	–	14.21	–	7.39	–	-	30	1.21E–09	1.21E–09	1.21E–05	

Borehole ID	Secup L(m)	Seclow L(m)	L_w (m)	Q_0 (m^3/s)	dh_0 (m)	Q_1 (m^3/s)	dh_1 (m)	TD (m^2/s)	hi (m)	Q-lower limit P (mL/h)	TD-measl$_{LT}$ (m^2/s)	TD-measl$_{LP}$ (m^2/s)	TD-measl$_U$ (m^2/s)	Comments
KLX06	872.47	877.47	5	–	14.20	–	7.39	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	867.46	872.46	5	–	14.20	–	7.38	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	862.44	867.44	5	–	14.19	–	7.37	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	857.42	862.42	5	–	14.21	–	7.38	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	852.41	857.41	5	–	14.20	2.17E–08	7.40	3.15E–09	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	847.39	852.39	5	–	14.18	–	7.37	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	842.37	847.37	5	–	14.15	–	7.36	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	837.35	842.35	5	–4.19E–08	14.16	1.88E–07	7.35	3.33E–08	12.92	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	832.34	837.34	5	–	14.14	4.44E–08	7.38	6.50E–09	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	827.33	832.33	5	–	14.16	–	7.37	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	822.33	827.33	5	–	14.14	–	7.36	–	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	817.32	822.32	5	–	14.14	–	7.34	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	812.32	817.32	5	–	14.14	2.97E–08	7.34	4.32E–09	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	807.31	812.31	5	–	14.13	–	7.34	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	802.30	807.30	5	–	14.15	–	7.33	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	797.30	802.30	5	–	14.15	–	7.32	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	792.29	797.29	5	–	14.10	–	7.30	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	787.28	792.28	5	–	14.11	–	7.29	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	782.27	787.27	5	–	14.10	–	7.29	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	777.27	782.27	5	–3.00E–06	14.11	5.00E–06	7.30	1.16E–06	11.56	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	772.26	777.26	5	–	14.11	–	7.30	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	767.25	772.25	5	–	14.11	–	7.29	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	762.24	767.24	5	–	14.11	–	7.31	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	757.24	762.24	5	–	14.09	–	7.28	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	752.23	757.23	5	–	14.11	–	7.28	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	747.22	752.22	5	–	14.09	–	7.28	–	-	30	1.21E–09	1.21E–09	1.21E–05	

Borehole ID	Secup L(m)	Seclow L(m)	L_w (m)	Q_0 (m^3/s)	dh_0 (m)	Q_1 (m^3/s)	dh_1 (m)	TD (m^2/s)	hi (m)	Q-lower limit P (mL/h)	TD-$measl_{LT}$ (m^2/s)	TD-$measl_{LP}$ (m^2/s)	TD-$measl_U$ (m^2/s)	Comments
KLX06	742.21	747.21	5	–	14.09	–	7.27	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	737.20	742.20	5	–	14.12	–	7.29	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	732.19	737.19	5	–1.64E–08	14.09	9.06E–08	7.29	1.56E–08	13.05	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	727.19	732.19	5	–	14.08	–	7.27	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	722.18	727.18	5	–	14.09	–	7.26	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	717.17	722.17	5	–	14.08	–	7.26	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	712.16	717.16	5	–	14.08	–	7.25	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	707.15	712.15	5	–	14.07	–	7.24	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	702.14	707.14	5	–	14.07	–	7.25	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	697.13	702.13	5	–	14.05	–	7.26	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	692.12	697.12	5	–	14.06	–	7.25	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	687.12	692.12	5	–	14.05	–	7.24	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	682.10	687.10	5	–	14.02	–	7.21	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	677.09	682.09	5	–	14.01	–	7.21	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	672.09	677.09	5	–	14.01	–	7.21	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	667.09	672.09	5	–	14.01	–	7.17	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	662.10	667.10	5	–	13.98	–	7.21	–	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	657.10	662.10	5	–	13.98	–	7.18	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	652.10	657.10	5	–1.09E–07	13.94	1.73E–07	7.14	4.11E–08	11.31	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	647.11	652.11	5	–	13.92	–	7.13	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	642.11	647.11	5	–	13.90	–	7.12	–	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	637.11	642.11	5	–	13.90	–	7.11	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	632.12	637.12	5	–	13.88	2.11E–08	7.11	3.08E–09	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	627.10	632.10	5	–3.17E–07	13.88	5.28E–07	7.10	1.23E–07	11.34	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	622.09	627.09	5	–	13.85	–	7.10	–	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	617.08	622.08	5	–	13.85	–	7.07	–	-	30	1.22E–09	1.22E–09	1.22E–05	

Borehole ID	Secup L(m)	Seclow L(m)	L_w (m)	Q_0 (m^3/s)	dh_0 (m)	Q_1 (m^3/s)	dh_1 (m)	TD (m^2/s)	hi (m)	Q-lower limit P (mL/h)	TD-measl$_{LT}$ (m^2/s)	TD-measl$_{LP}$ (m^2/s)	TD-measl$_U$ (m^2/s)	Comments
KLX06	612.07	617.07	5	–	13.85	–	7.07	–	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	607.06	612.06	5	–	13.83	–	7.06	–	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	602.05	607.05	5	–	13.85	–	7.04	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	597.04	602.04	5	–	13.84	–	7.04	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	592.03	597.03	5	–	13.83	–	7.01	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	587.02	592.02	5	–	13.84	–	7.03	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	582.01	587.01	5	–	13.79	–	7.00	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	577.00	582.00	5	–	13.76	–	7.00	–	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	571.99	576.99	5	–	13.78	–	7.00	–	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	566.98	571.98	5	–	13.77	–	7.00	–	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	561.97	566.97	5	–2.29E–05	13.74	2.24E–05	6.98	6.64E–06	10.32	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	556.97	561.97	5	–2.86E–07	13.73	2.52E–07	6.95	7.85E–08	10.12	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	551.96	556.96	5	–	13.71	–	6.92	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	546.97	551.97	5	–	13.69	1.61E–08	6.88	2.34E–09	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	541.96	546.96	5	–	13.64	–	6.88	–	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	536.95	541.95	5	–	13.66	–	6.87	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	531.95	536.95	5	–5.61E–08	13.65	5.17E–08	6.85	1.57E–08	10.11	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	526.94	531.94	5	–	13.62	1.50E–08	6.82	2.18E–09	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	521.94	526.94	5	–	13.58	–	6.79	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	516.93	521.93	5	–	13.59	–	6.81	–	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	511.92	516.92	5	–	13.57	6.36E–08	6.80	9.29E–09	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	506.92	511.92	5	–4.25E–07	13.57	4.67E–07	6.75	1.29E–07	10.32	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	501.91	506.91	5	–	13.55	–	6.77	–	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	496.91	501.91	5	–4.17E–08	13.53	2.53E–08	6.74	9.75E–09	9.30	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	491.90	496.90	5	–	13.52	–	6.72	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	486.90	491.90	5	–	13.49	–	6.69	–	-	30	1.21E–09	1.21E–09	1.21E–05	

Borehole ID	Secup L(m)	Seclow L(m)	L_w (m)	Q_0 (m^3/s)	dh_0 (m)	Q_1 (m^3/s)	dh_1 (m)	TD (m^2/s)	hi (m)	Q-lower limit P (mL/h)	TD-$measl_{LT}$ (m^2/s)	TD-$measl_{LP}$ (m^2/s)	TD-$measl_U$ (m^2/s)	Comments
KLX06	481.90	486.90	5	–	13.49	–	6.68	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	476.89	481.89	5	–5.72E–08	13.46	3.72E–08	6.67	1.38E–08	9.35	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	471.89	476.89	5	–	13.46	–	6.67	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	466.89	471.89	5	–	13.45	–	6.65	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	461.89	466.89	5	–	13.41	–	6.59	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	456.89	461.89	5	–	13.40	–	6.58	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	451.88	456.88	5	–	13.38	–	6.59	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	446.88	451.88	5	–	13.39	–	6.58	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	441.87	446.87	5	–	13.36	–	6.56	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	436.87	441.87	5	–	13.37	–	6.56	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	431.86	436.86	5	–	13.40	–	6.56	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	426.86	431.86	5	–	13.35	–	6.53	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	421.86	426.86	5	–	13.32	–	6.52	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	416.85	421.85	5	–	13.32	–	6.50	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	411.85	416.85	5	–	13.30	–	6.51	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	406.83	411.83	5	–	13.30	1.92E–08	6.48	2.78E–09	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	401.82	406.82	5	–	13.27	6.50E–08	6.47	9.45E–09	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	396.82	401.82	5	–	13.26	–	6.46	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	391.80	396.80	5	–	13.25	–	6.44	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	386.80	391.80	5	–	13.25	2.06E–08	6.43	2.98E–09	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	381.80	386.80	5	–	13.26	–	6.44	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	376.80	381.80	5	3.67E–07	13.26	2.78E–06	6.41	3.48E–07	14.30	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	371.80	376.80	5	2.52E–07	13.23	2.28E–06	6.40	2.94E–07	14.08	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	366.79	371.79	5	3.25E–07	13.22	3.33E–06	6.39	4.36E–07	13.96	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	361.78	366.78	5	3.67E–06	13.19	3.53E–05	6.38	4.59E–06	13.98	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	356.77	361.77	5	2.89E–06	13.19	2.54E–05	6.38	3.28E–06	14.06	30	1.21E–09	1.21E–09	1.21E–05	

Borehole ID	Secup L(m)	Seclow L(m)	L_w (m)	Q_0 (m^3/s)	dh_0 (m)	Q_1 (m^3/s)	dh_1 (m)	TD (m^2/s)	hi (m)	Q-lower limit P (mL/h)	TD-measl$_{LT}$ (m^2/s)	TD-measl$_{LP}$ (m^2/s)	TD-measl$_U$ (m^2/s)	Comments
KLX06	351.76	356.76	5	2.28E–07	13.20	3.11E–06	6.37	4.17E–07	13.74	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	346.74	351.74	5	1.28E–06	13.18	1.25E–05	6.36	1.63E–06	13.95	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	341.71	346.71	5	1.29E–06	13.17	8.92E–06	6.34	1.11E–06	14.32	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	336.70	341.70	5	3.11E–06	13.19	3.14E–05	6.34	4.08E–06	13.94	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	331.70	336.70	5	9.08E–07	13.16	9.17E–06	6.33	1.20E–06	13.91	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	326.69	331.69	5	9.50E–08	13.17	1.34E–06	6.33	1.80E–07	13.69	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	321.68	326.68	5	5.00E–08	13.18	8.19E–07	6.33	1.11E–07	13.63	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	316.68	321.68	5	5.83E–08	13.17	7.89E–07	6.32	1.05E–07	13.72	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	311.67	316.67	5	7.89E–07	13.15	1.17E–05	6.31	1.58E–06	13.64	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	306.68	311.68	5	9.08E–07	13.15	1.07E–05	6.32	1.41E–06	13.79	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	301.70	306.70	5	–	13.15	–	6.28	–	-	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	296.69	301.69	5	1.88E–07	13.13	1.71E–06	6.25	2.18E–07	13.98	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	291.69	296.69	5	1.52E–07	13.04	2.14E–06	6.21	2.88E–07	13.56	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	286.68	291.68	5	3.08E–07	13.04	3.17E–06	6.21	4.14E–07	13.78	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	281.67	286.67	5	2.92E–08	13.04	5.56E–07	6.20	7.61E–08	13.42	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	276.66	281.66	5	1.03E–08	13.05	1.26E–07	6.20	1.67E–08	13.66	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	271.65	276.65	5	1.17E–06	13.04	1.18E–05	6.19	1.54E–06	13.79	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	266.64	271.64	5	–	13.04	7.83E–08	6.18	1.13E–08	-	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	261.64	266.64	5	1.08E–05	13.03	4.44E–05	10.71	1.43E–05	13.78	30	3.55E–09	3.55E–09	3.55E–05	**
KLX06	256.63	261.63	5	–	13.01	–	6.15	–	-	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	251.63	256.63	5	7.06E–07	12.98	1.15E–05	6.13	1.55E–06	13.43	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	246.62	251.62	5	7.50E–07	12.99	8.42E–06	6.26	1.13E–06	13.65	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	241.60	246.60	5	4.25E–08	12.99	8.75E–07	6.12	1.20E–07	13.34	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	236.59	241.59	5	3.33E–06	12.99	2.47E–05	6.12	3.07E–06	14.06	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	231.57	236.57	5	–	12.97	4.06E–08	6.12	5.86E–09	-	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	226.56	231.56	5	3.75E–06	12.98	3.42E–05	6.13	4.39E–06	13.82	30	1.20E–09	1.20E–09	1.20E–05	

Borehole ID	Secup L(m)	Seclow L(m)	L_w (m)	Q_0 (m^3/s)	dh_0 (m)	Q_1 (m^3/s)	dh_1 (m)	TD (m^2/s)	hi (m)	Q-lower limit P (mL/h)	TD-$measl_{LT}$ (m^2/s)	TD-$measl_{LP}$ (m^2/s)	TD-$measl_U$ (m^2/s)	Comments
KLX06	221.55	226.55	5	3.86E–06	12.99	2.97E–05	6.13	3.73E–06	14.01	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	216.54	221.54	5	–	12.96	–	6.11	–	-	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	211.53	216.53	5	2.78E–07	12.97	4.86E–06	6.10	6.60E–07	13.39	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	206.52	211.52	5	3.50E–07	12.96	4.94E–06	6.10	6.62E–07	13.48	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	201.51	206.51	5	2.65E–07	12.95	4.08E–06	6.08	5.50E–07	13.43	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	196.51	201.51	5	–	12.96	–	6.24	–	-	30	1.23E–09	1.23E–09	1.23E–05	
KLX06	191.50	196.50	5	2.51E–06	12.95	4.19E–05	6.27	5.84E–06	13.37	30	1.23E–09	1.23E–09	1.23E–05	
KLX06	186.49	191.49	5	3.81E–07	12.93	7.28E–06	6.22	1.02E–06	13.30	30	1.23E–09	1.23E–09	1.23E–05	
KLX06	181.49	186.49	5	3.64E–06	12.92	5.89E–05	6.06	7.97E–06	13.37	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	176.48	181.48	5	5.11E–07	12.95	8.47E–06	6.07	1.14E–06	13.39	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	171.47	176.47	5	–	12.96	2.11E–08	6.09	3.04E–09	-	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	166.47	171.47	5	5.00E–06	12.96	3.06E–05	10.57	1.06E–05	13.43	30	3.45E–09	3.45E–09	3.45E–05	**
KLX06	161.46	166.46	5	5.44E–08	12.91	1.59E–06	6.09	2.23E–07	13.15	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	156.46	161.46	5	1.17E–08	12.87	3.28E–07	5.99	4.54E–08	13.12	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	151.45	156.45	5	–	12.90	1.44E–07	5.96	2.05E–08	-	30	1.19E–09	1.19E–09	1.19E–05	
KLX06	146.44	151.44	5	–	12.91	–	6.06	–	-	30	1.20E–09	1.20E–09	1.20E–05	
KLX06	141.44	146.44	5	–	12.88	–	6.17	–	-	30	1.23E–09	1.23E–09	1.23E–05	
KLX06	136.43	141.43	5	–	12.88	2.78E–08	5.97	3.98E–09	-	30	1.19E–09	1.19E–09	1.19E–05	
KLX06	131.43	136.43	5	–	12.86	1.08E–08	5.92	1.54E–09	-	30	1.19E–09	1.19E–09	1.19E–05	
KLX06	126.42	131.42	5	–	12.86	–	6.07	–	-	30	1.21E–09	1.21E–09	1.21E–05	
KLX06	121.41	126.41	5	–	12.88	–	6.14	–	-	30	1.22E–09	1.22E–09	1.22E–05	
KLX06	116.41	121.41	5	–	12.87	2.50E–07	5.94	3.57E–08	-	30	1.19E–09	1.19E–09	1.19E–05	
KLX06	111.40	116.40	5	3.14E–08	12.85	1.84E–06	5.95	2.60E–07	12.97	30	1.19E–09	1.19E–09	1.19E–05	
KLX06	106.38	111.38	5	8.58E–06	12.86	6.94E–05	10.46	2.51E–05	13.20	30	3.43E–09	3.43E–09	3.43E–05	**
KLX06	101.35	106.35	5	1.30E–06	12.93	9.53E–06	5.95	1.17E–06	14.03	30	1.18E–09	1.18E–09	1.18E–05	
KLX06	96.33	101.33	5	–	13.04	–	6.05	–	-	30	1.18E–09	1.18E–09	1.18E–05	

** Values from the measurement with smaller pumping (original flow over measurement limit)

Appendix 8

PFL - DIFFERENCE FLOW LOGGING - Inferred flow anomalies from overlapping flow logging.

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	Q_0 (m^3/s)	dh_0 (m)	Q_1 (m^3/s)	dh_1 (m)	TD (m^2/s)	hi (m)	Comments
KLX06	101.9	1.0	0.1	–	13.03	8.69E–06	5.95	1.21E–06	–	
KLX06	103.2	1.0	0.1	–	12.97	6.19E–07	5.95	8.73E–08	–	
KLX06	103.8	1.0	0.1	–	12.93	1.31E–07	5.94	1.85E–08	–	
KLX06	104.5	1.0	0.1	–	12.90	1.00E–07	5.95	1.42E–08	–	
KLX06	106.3	1.0	0.1	–	12.91	6.94E–08	5.93	9.84E–09	–	
KLX06	107.6	1.0	0.1	–	12.88	1.86E–05	5.93	2.65E–06	–	
KLX06	108.4	1.0	0.1	8.06E–06	12.87	6.39E–05	10.45	2.28E–05	13.22	**
KLX06	113.1	1.0	0.1	–	12.85	3.33E–07	5.91	4.75E–08	–	
KLX06	113.6	1.0	0.1	–	12.85	1.69E–06	5.91	2.41E–07	–	
KLX06	117.1	1.0	0.1	–	12.85	7.78E–09	5.96	1.12E–09	–	*
KLX06	117.4	1.0	0.1	–	12.86	5.00E–08	5.96	7.17E–09	–	*
KLX06	117.6	1.0	0.1	–	12.86	2.14E–07	5.96	3.07E–08	–	
KLX06	135.1	1.0	0.1	–	12.86	2.14E–08	5.93	3.05E–09	–	
KLX06	136.8	1.0	0.1	–	12.86	3.06E–08	5.94	4.37E–09	–	
KLX06	153.9	1.0	0.1	–	12.90	2.39E–08	5.98	3.41E–09	–	
KLX06	155.5	1.0	0.1	–	12.90	3.33E–08	5.98	4.76E–09	–	
KLX06	156.1	1.0	0.1	–	12.89	5.56E–08	5.97	7.94E–09	–	
KLX06	160.8	1.0	0.1	1.08E–08	12.88	2.58E–07	5.97	3.54E–08	13.18	
KLX06	162.8	1.0	0.1	–	12.90	2.78E–07	5.97	3.96E–08	–	*
KLX06	163.7	1.0	0.1	–	12.91	1.39E–07	5.99	1.99E–08	–	*
KLX06	164.8	1.0	0.1	–	12.92	1.06E–06	5.98	1.50E–07	–	
KLX06	165.6	1.0	0.1	–	12.93	6.11E–07	5.99	8.71E–08	–	
KLX06	168.2	1.0	0.1	–	12.94	1.08E–05	6.03	1.55E–06	–	
KLX06	168.6	1.0	0.1	–	12.94	2.67E–05	6.03	3.82E–06	–	
KLX06	169.2	1.0	0.1	–	12.96	2.78E–05	6.03	3.96E–06	–	
KLX06	170.0	1.0	0.1	–	12.95	3.33E–05	6.03	4.76E–06	–	
KLX06	171.4	1.0	0.1	–	12.96	4.44E–07	6.04	6.35E–08	–	*
KLX06	172.4	1.0	0.1	–	12.95	2.22E–07	6.03	3.18E–08	–	*
KLX06	177.5	1.0	0.1	–	12.94	9.17E–08	6.02	1.31E–08	–	
KLX06	178.7	1.0	0.1	–	12.95	6.11E–06	6.04	8.75E–07	–	
KLX06	179.0	1.0	0.1	–	12.95	1.39E–06	6.04	1.99E–07	–	
KLX06	183.2	1.0	0.1	–	12.93	4.44E–06	6.04	6.38E–07	–	
KLX06	184.0	1.0	0.1	–	12.92	3.89E–05	6.04	5.59E–06	–	
KLX06	185.0	1.0	0.1	–	12.92	1.28E–07	6.04	1.84E–08	–	*
KLX06	185.6	1.0	0.1	–	12.92	7.50E–07	6.05	1.08E–07	–	
KLX06	186.5	1.0	0.1	–	12.92	6.11E–06	6.03	8.77E–07	–	
KLX06	189.6	1.0	0.1	–	12.93	3.61E–07	6.04	5.18E–08	–	
KLX06	191.5	1.0	0.1	–	12.94	3.61E–07	6.05	5.18E–08	–	
KLX06	196.0	1.0	0.1	2.50E–06	12.96	4.17E–05	6.09	5.64E–06	13.40	
KLX06	202.6	1.0	0.1	–	12.95	3.33E–07	6.09	4.81E–08	–	
KLX06	203.1	1.0	0.1	–	12.96	2.47E–07	6.09	3.56E–08	–	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	Q_0 (m^3/s)	dh_0 (m)	Q_1 (m^3/s)	dh_1 (m)	TD (m^2/s)	hi (m)	Comments
KLX06	204.7	1.0	0.1	–	12.94	2.78E–06	6.10	4.02E–07	–	
KLX06	205.7	1.0	0.1	–	12.95	1.25E–06	6.10	1.80E–07	–	
KLX06	206.7	1.0	0.1	–	12.97	1.56E–07	6.11	2.24E–08	–	
KLX06	209.1	1.0	0.1	–	12.96	2.53E–08	6.11	3.65E–09	–	
KLX06	211.4	1.0	0.1	–	12.95	4.44E–06	6.10	6.42E–07	–	
KLX06	214.2	1.0	0.1	2.78E–07	12.97	3.61E–06	6.10	4.80E–07	13.54	
KLX06	225.0	1.0	0.1	8.33E–08	12.97	1.11E–06	6.11	1.48E–07	13.53	
KLX06	226.1	1.0	0.1	–	12.99	4.44E–06	6.14	6.42E–07	–	*
KLX06	226.5	1.0	0.1	–	12.99	2.08E–05	6.15	3.01E–06	–	
KLX06	227.4	1.0	0.1	–	12.99	7.22E–06	6.14	1.04E–06	–	
KLX06	228.3	1.0	0.1	–	12.99	1.94E–05	6.14	2.81E–06	–	
KLX06	228.8	1.0	0.1	–	12.99	7.50E–07	6.15	1.08E–07	–	*
KLX06	235.8	1.0	0.1	–	12.97	2.78E–08	6.13	4.02E–09	–	
KLX06	239.5	1.0	0.1	–	12.99	5.00E–07	6.13	7.21E–08	–	*
KLX06	240.0	1.0	0.1	–	13.00	1.61E–05	6.14	2.32E–06	–	
KLX06	241.1	1.0	0.1	–	13.01	5.00E–06	6.14	7.20E–07	–	
KLX06	241.7	1.0	0.1	–	12.99	6.67E–08	6.14	9.63E–09	–	
KLX06	243.5	1.0	0.1	–	13.01	7.22E–07	6.15	1.04E–07	–	
KLX06	247.3	1.0	0.1	–	12.99	3.06E–07	6.16	4.42E–08	–	
KLX06	247.7	1.0	0.1	–	13.00	4.44E–07	6.17	6.44E–08	–	
KLX06	248.1	1.0	0.1	–	12.99	3.89E–06	6.18	5.65E–07	–	
KLX06	249.2	1.0	0.1	–	12.99	2.06E–07	6.17	2.98E–08	–	*
KLX06	250.0	1.0	0.1	–	12.99	2.78E–07	6.17	4.03E–08	–	
KLX06	250.4	1.0	0.1	–	12.99	1.67E–07	6.16	2.41E–08	–	
KLX06	251.0	1.0	0.1	–	13.00	2.08E–06	6.17	3.02E–07	–	
KLX06	252.2	1.0	0.1	–	12.99	8.89E–06	6.15	1.29E–06	–	
KLX06	254.3	1.0	0.1	–	12.98	6.94E–07	6.16	1.01E–07	–	
KLX06	254.5	1.0	0.1	–	12.99	4.17E–07	6.17	6.04E–08	–	*
KLX06	255.1	1.0	0.1	–	12.98	6.39E–08	6.17	9.28E–09	–	*
KLX06	264.3	1.0	0.1	–	13.03	1.36E–06	6.23	1.98E–07	–	
KLX06	264.7	1.0	0.1	–	13.03	4.42E–05	10.72	1.89E–05	–	**
KLX06	265.3	1.0	0.1	–	13.03	1.67E–08	6.23	2.42E–09	–	*
KLX06	267.0	1.0	0.1	–	13.04	3.33E–08	6.27	4.87E–09	–	
KLX06	271.6	1.0	0.1	–	13.02	3.33E–08	6.25	4.87E–09	–	
KLX06	272.4	1.0	0.1	–	13.03	2.50E–07	6.25	3.65E–08	–	
KLX06	273.1	1.0	0.1	–	13.03	6.39E–06	6.25	9.32E–07	–	
KLX06	274.6	1.0	0.1	–	13.04	1.61E–06	6.25	2.35E–07	–	
KLX06	275.0	1.0	0.1	–	13.05	5.56E–07	6.27	8.10E–08	–	
KLX06	276.0	1.0	0.1	–	13.04	2.03E–06	6.28	2.97E–07	–	
KLX06	276.8	1.0	0.1	–	13.04	1.06E–07	6.28	1.54E–08	–	
KLX06	281.7	1.0	0.1	–	13.06	4.17E–07	6.27	6.07E–08	–	
KLX06	283.5	1.0	0.1	–	13.06	8.89E–08	6.27	1.29E–08	–	
KLX06	287.1	1.0	0.1	3.06E–07	13.04	2.78E–06	6.23	3.59E–07	13.88	
KLX06	294.9	1.0	0.1	–	13.03	2.58E–08	6.25	3.77E–09	–	*
KLX06	296.2	1.0	0.1	–	13.12	1.81E–06	6.29	2.61E–07	–	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	Q_0 (m^3/s)	dh_0 (m)	Q_1 (m^3/s)	dh_1 (m)	TD (m^2/s)	hi (m)	Comments
KLX06	297.6	1.0	0.1	–	13.12	8.06E–08	6.31	1.17E–08	–	
KLX06	298.4	1.0	0.1	–	13.12	7.50E–08	6.31	1.09E–08	–	
KLX06	300.9	1.0	0.1	–	13.12	5.00E–08	6.33	7.28E–09	–	*
KLX06	301.2	1.0	0.1	–	13.13	1.25E–06	6.33	1.82E–07	–	
KLX06	308.5	1.0	0.1	–	13.16	3.33E–07	6.36	4.85E–08	–	
KLX06	309.7	1.0	0.1	–	13.16	1.33E–06	6.36	1.94E–07	–	
KLX06	310.2	1.0	0.1	–	13.16	2.50E–06	6.37	3.64E–07	–	
KLX06	310.5	1.0	0.1	–	13.15	5.28E–06	6.37	7.70E–07	–	*
KLX06	311.5	1.0	0.1	–	13.16	2.36E–06	6.38	3.44E–07	–	*
KLX06	312.1	1.0	0.1	–	13.15	5.28E–06	6.38	7.71E–07	–	
KLX06	312.6	1.0	0.1	–	13.14	2.00E–06	6.38	2.93E–07	–	*
KLX06	313.3	1.0	0.1	–	13.15	5.56E–07	6.37	8.10E–08	–	*
KLX06	314.0	1.0	0.1	–	13.14	5.00E–07	6.37	7.30E–08	–	
KLX06	315.0	1.0	0.1	–	13.16	2.19E–08	6.36	3.19E–09	–	*
KLX06	315.5	1.0	0.1	–	13.15	2.11E–08	6.37	3.08E–09	–	*
KLX06	318.5	1.0	0.1	–	13.16	6.94E–07	6.38	1.01E–07	–	
KLX06	321.8	1.0	0.1	–	13.17	6.94E–07	6.39	1.01E–07	–	
KLX06	323.5	1.0	0.1	–	13.17	1.89E–08	6.39	2.76E–09	–	
KLX06	327.2	1.0	0.1	–	13.17	1.47E–08	6.42	2.16E–09	–	
KLX06	329.7	1.0	0.1	–	13.18	8.06E–07	6.41	1.18E–07	–	
KLX06	330.6	1.0	0.1	–	13.17	3.61E–07	6.40	5.28E–08	–	
KLX06	331.4	1.0	0.1	–	13.17	8.33E–09	6.40	1.22E–09	–	*
KLX06	332.4	1.0	0.1	–	13.16	2.22E–07	6.40	3.25E–08	–	
KLX06	334.1	1.0	0.1	–	13.17	2.33E–07	6.41	3.41E–08	–	
KLX06	334.4	1.0	0.1	–	13.18	6.11E–07	6.40	8.92E–08	–	
KLX06	334.7	1.0	0.1	–	13.21	3.89E–06	6.40	5.65E–07	–	
KLX06	335.1	1.0	0.1	–	13.18	3.61E–06	6.41	5.28E–07	–	
KLX06	336.1	1.0	0.1	–	13.17	9.44E–08	6.41	1.38E–08	–	*
KLX06	336.9	1.0	0.1	–	13.19	1.11E–06	6.41	1.62E–07	–	
KLX06	338.4	1.0	0.1	–	13.19	1.11E–08	6.43	1.63E–09	–	*
KLX06	339.7	1.0	0.1	–	13.19	2.25E–05	6.42	3.29E–06	–	
KLX06	341.7	1.0	0.1	–	13.19	2.33E–06	6.41	3.40E–07	–	
KLX06	342.2	1.0	0.1	–	13.18	8.61E–08	6.42	1.26E–08	–	*
KLX06	342.5	1.0	0.1	–	13.18	1.89E–07	6.42	2.76E–08	–	
KLX06	343.0	1.0	0.1	–	13.17	2.11E–08	6.42	3.09E–09	–	*
KLX06	343.4	1.0	0.1	–	13.17	1.81E–08	6.41	2.64E–09	–	*
KLX06	345.0	1.0	0.1	–	13.16	4.44E–06	6.41	6.51E–07	–	
KLX06	345.2	1.0	0.1	–	13.17	1.47E–06	6.42	2.16E–07	–	
KLX06	346.9	1.0	0.1	–	13.18	4.72E–08	6.41	6.90E–09	–	
KLX06	347.8	1.0	0.1	–	13.19	3.89E–07	6.41	5.67E–08	–	
KLX06	350.3	1.0	0.1	–	13.19	1.03E–05	6.43	1.50E–06	–	
KLX06	351.5	1.0	0.1	–	13.20	3.61E–07	6.43	5.28E–08	–	
KLX06	353.0	1.0	0.1	–	13.20	3.33E–07	6.44	4.88E–08	–	
KLX06	354.6	1.0	0.1	–	13.20	1.56E–06	6.44	2.28E–07	–	
KLX06	355.4	1.0	0.1	–	13.19	2.08E–07	6.43	3.05E–08	–	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	Q_0 (m^3/s)	dh_0 (m)	Q_1 (m^3/s)	dh_1 (m)	TD (m^2/s)	hi (m)	Comments
KLX06	355.8	1.0	0.1	–	13.20	3.61E–07	6.43	5.28E–08	–	
KLX06	357.5	1.0	0.1	–	13.19	7.50E–06	6.44	1.10E–06	–	
KLX06	358.6	1.0	0.1	–	13.18	7.50E–06	6.43	1.10E–06	–	
KLX06	359.2	1.0	0.1	–	13.19	3.33E–06	6.42	4.87E–07	–	
KLX06	360.4	1.0	0.1	–	13.19	2.08E–06	6.41	3.04E–07	–	
KLX06	360.7	1.0	0.1	–	13.19	8.06E–07	6.41	1.18E–07	–	*
KLX06	361.2	1.0	0.1	–	13.20	4.72E–07	6.42	6.89E–08	–	*
KLX06	362.3	1.0	0.1	–	13.21	3.33E–07	6.42	4.86E–08	–	*
KLX06	363.8	1.0	0.1	–	13.19	6.39E–07	6.41	9.32E–08	–	
KLX06	364.3	1.0	0.1	–	13.19	2.53E–05	6.41	3.69E–06	–	
KLX06	364.6	1.0	0.1	–	13.19	4.44E–06	6.42	6.49E–07	–	
KLX06	366.2	1.0	0.1	–	13.20	2.31E–07	6.41	3.36E–08	–	
KLX06	368.6	1.0	0.1	–	13.21	4.72E–08	6.47	6.93E–09	–	*
KLX06	368.8	1.0	0.1	–	13.22	1.39E–06	6.48	2.04E–07	–	
KLX06	370.1	1.0	0.1	–	13.22	1.31E–06	6.48	1.92E–07	–	
KLX06	372.1	1.0	0.1	–	13.23	5.28E–08	6.47	7.72E–09	–	
KLX06	373.4	1.0	0.1	–	13.23	1.14E–07	6.48	1.67E–08	–	
KLX06	375.6	1.0	0.1	–	13.24	1.78E–07	6.48	2.60E–08	–	
KLX06	376.7	1.0	0.1	–	13.27	1.00E–06	6.49	1.46E–07	–	
KLX06	377.0	1.0	0.1	–	13.27	5.56E–07	6.50	8.12E–08	–	*
KLX06	377.2	1.0	0.1	–	13.26	7.50E–08	6.48	1.09E–08	–	*
KLX06	378.7	1.0	0.1	–	13.25	6.94E–07	6.49	1.02E–07	–	
KLX06	379.6	1.0	0.1	–	13.25	1.03E–07	6.48	1.50E–08	–	
KLX06	379.8	1.0	0.1	–	13.25	3.89E–07	6.48	5.68E–08	–	
KLX06	389.0	1.0	0.1	–	13.24	1.94E–08	6.50	2.85E–09	–	*
KLX06	403.8	1.0	0.1	–	13.28	1.75E–08	6.53	2.56E–09	–	
KLX06	405.2	1.0	0.1	–	13.26	1.08E–08	6.53	1.59E–09	–	
KLX06	410.3	1.0	0.1	–	13.30	1.11E–08	6.57	1.63E–09	–	*
KLX06	478.3	1.0	0.1	–6.11E–08	13.46	1.39E–08	6.76	1.11E–08	8.00	
KLX06	497.0	1.0	0.1	–3.89E–08	13.52	1.67E–08	6.83	8.21E–09	8.84	*
KLX06	507.3	1.0	0.1	–2.14E–08	13.56	1.50E–08	6.89	5.40E–09	9.64	
KLX06	509.9	1.0	0.1	–4.17E–07	13.56	2.58E–07	6.89	1.00E–07	9.44	
KLX06	512.1	1.0	0.1	–	13.56	2.75E–08	6.90	4.08E–09	–	
KLX06	530.8	1.0	0.1	–	13.63	7.50E–09	6.98	1.12E–09	–	*
KLX06	533.9	1.0	0.1	–6.39E–08	13.62	3.06E–08	6.98	1.41E–08	9.13	
KLX06	548.2	1.0	0.1	–	13.70	1.19E–08	7.02	1.77E–09	–	*
KLX06	561.2	1.0	0.1	–2.86E–07	13.73	1.31E–07	7.06	6.18E–08	9.15	
KLX06	562.2	1.0	0.1	–2.25E–05	13.74	1.25E–05	7.06	5.18E–06	9.45	
KLX06	628.0	1.0	0.1	–3.06E–07	13.88	3.33E–07	7.22	9.49E–08	10.69	
KLX06	635.2	1.0	0.1	–	13.91	1.39E–08	7.23	2.06E–09	–	*
KLX06	654.0	1.0	0.1	–5.28E–08	13.94	6.39E–08	7.28	1.73E–08	10.93	
KLX06	654.7	1.0	0.1	–5.83E–08	13.94	5.83E–08	7.27	1.73E–08	10.61	
KLX06	734.8	1.0	0.1	–	14.09	3.06E–08	7.40	4.52E–09	–	
KLX06	736.4	1.0	0.1	–	14.08	8.33E–09	7.39	1.23E–09	–	*
KLX06	777.5	1.0	0.1	–	14.12	3.61E–08	7.40	5.32E–09	–	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	Q_0 (m^3/s)	dh_0 (m)	Q_1 (m^3/s)	dh_1 (m)	TD (m^2/s)	hi (m)	Comments
KLX06	779.0	1.0	0.1	–3.06E–06	14.12	4.44E–06	7.41	1.11E–06	11.39	
KLX06	815.0	1.0	0.1	–	14.14	2.14E–08	7.42	3.15E–09	–	
KLX06	835.3	1.0	0.1	–	14.14	3.89E–08	7.44	5.74E–09	–	
KLX06	838.2	1.0	0.1	–	14.15	1.11E–08	7.43	1.64E–09	–	
KLX06	838.7	1.0	0.1	–	14.15	1.75E–07	7.43	2.58E–08	–	
KLX06	854.3	1.0	0.1	–	14.18	1.75E–08	7.49	2.59E–09	–	
KLX06	913.0	1.0	0.1	–	14.34	1.72E–08	7.69	2.56E–09	–	*
KLX06	914.7	1.0	0.1	–	14.37	8.61E–09	7.70	1.28E–09	–	*
KLX06	927.7	1.0	0.1	–5.56E–08	14.55	1.06E–07	7.90	2.40E–08	12.26	
KLX06	938.8	1.0	0.1	–	14.64	4.17E–08	7.78	6.01E–09	–	

* 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).

Appendix 9

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 logging.
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	masl	Initial hydraulic head before pumping. Elevation of water level in open borehole in the local co-ordinates system with z=0 m.
h_1	masl	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	masl	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).

Header	Unit	Explanations
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).

Appendix 10

Calculation of conductive fracture frequency.

Borehole ID	SecUp (m)	SecLow (m)	Number of fractures, Total	Number of fractures 10–100 (mL/h)	Number of fractures 100–1,000 (mL/h)	Number of fractures 1,000–10,000 (mL/h)	Number of fractures 10,000–100,000 (mlLh)	Number of fractures 100,000–1,000,000 (mL/h)
KLX06	982.49	987.52	0	0	0	0	0	0
KLX06	977.49	982.51	0	0	0	0	0	0
KLX06	972.48	977.50	0	0	0	0	0	0
KLX06	967.48	972.50	0	0	0	0	0	0
KLX06	962.48	967.50	0	0	0	0	0	0
KLX06	957.48	962.50	0	0	0	0	0	0
KLX06	952.48	957.50	0	0	0	0	0	0
KLX06	947.48	952.50	0	0	0	0	0	0
KLX06	942.48	947.50	0	0	0	0	0	0
KLX06	937.48	942.50	1	0	1	0	0	0
KLX06	932.48	937.50	0	0	0	0	0	0
KLX06	927.48	932.50	1	0	1	0	0	0
KLX06	922.48	927.49	0	0	0	0	0	0
KLX06	917.48	922.49	0	0	0	0	0	0
KLX06	912.48	917.49	2	2	0	0	0	0
KLX06	907.47	912.49	0	0	0	0	0	0
KLX06	902.47	907.48	0	0	0	0	0	0
KLX06	897.47	902.48	0	0	0	0	0	0
KLX06	892.47	897.48	0	0	0	0	0	0
KLX06	887.46	892.48	0	0	0	0	0	0
KLX06	882.46	887.47	0	0	0	0	0	0
KLX06	877.46	882.47	0	0	0	0	0	0
KLX06	872.46	877.47	0	0	0	0	0	0
KLX06	867.45	872.46	0	0	0	0	0	0
KLX06	862.43	867.44	0	0	0	0	0	0
KLX06	857.41	862.42	0	0	0	0	0	0
KLX06	852.39	857.41	1	1	0	0	0	0
KLX06	847.38	852.39	0	0	0	0	0	0
KLX06	842.36	847.37	0	0	0	0	0	0
KLX06	837.34	842.35	2	1	1	0	0	0
KLX06	832.32	837.34	1	0	1	0	0	0
KLX06	827.31	832.33	0	0	0	0	0	0
KLX06	822.31	827.33	0	0	0	0	0	0
KLX06	817.30	822.32	0	0	0	0	0	0
KLX06	812.30	817.32	1	1	0	0	0	0
KLX06	807.29	812.31	0	0	0	0	0	0
KLX06	802.28	807.30	0	0	0	0	0	0
KLX06	797.28	802.30	0	0	0	0	0	0
KLX06	792.27	797.29	0	0	0	0	0	0
KLX06	787.26	792.28	0	0	0	0	0	0
KLX06	782.25	787.27	0	0	0	0	0	0
KLX06	777.25	782.27	2	0	1	0	1	0

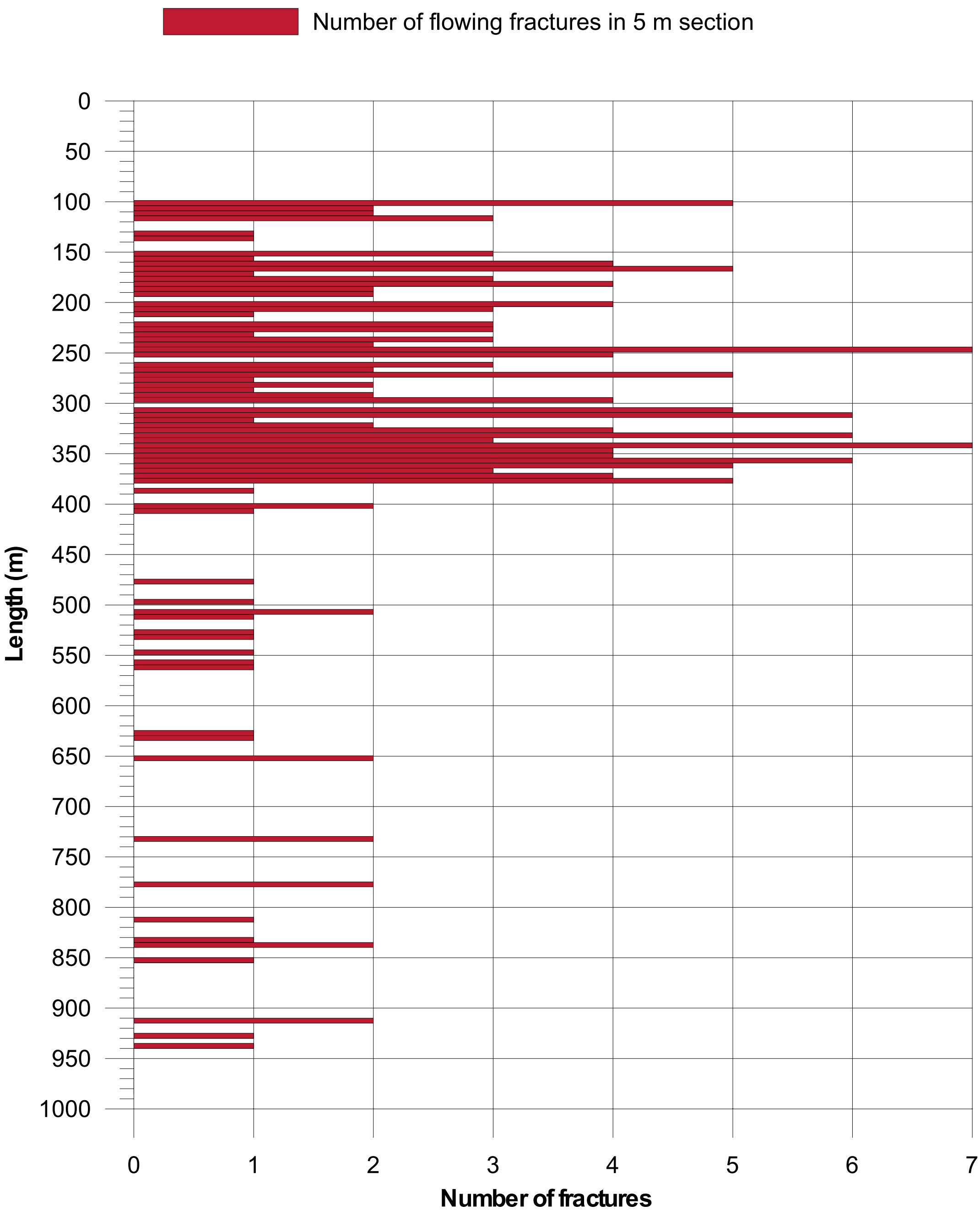
Borehole ID	SecUp (m)	SecLow (m)	Number of fractures, Total	Number of fractures 10–100 (mL/h)	Number of fractures 100–1,000 (mL/h)	Number of fractures 1,000–10,000 (mL/h)	Number of fractures 10,000–100,000 (mlLh)	Number of fractures 100,000–1,000,000 (mL/h)
KLX06	772.24	777.26	0	0	0	0	0	0
KLX06	767.23	772.25	0	0	0	0	0	0
KLX06	762.22	767.24	0	0	0	0	0	0
KLX06	757.22	762.24	0	0	0	0	0	0
KLX06	752.21	757.23	0	0	0	0	0	0
KLX06	747.20	752.22	0	0	0	0	0	0
KLX06	742.19	747.21	0	0	0	0	0	0
KLX06	737.18	742.20	0	0	0	0	0	0
KLX06	732.17	737.19	2	1	1	0	0	0
KLX06	727.16	732.19	0	0	0	0	0	0
KLX06	722.15	727.18	0	0	0	0	0	0
KLX06	717.14	722.17	0	0	0	0	0	0
KLX06	712.13	717.16	0	0	0	0	0	0
KLX06	707.13	712.15	0	0	0	0	0	0
KLX06	702.12	707.14	0	0	0	0	0	0
KLX06	697.11	702.13	0	0	0	0	0	0
KLX06	692.10	697.12	0	0	0	0	0	0
KLX06	687.10	692.12	0	0	0	0	0	0
KLX06	682.09	687.10	0	0	0	0	0	0
KLX06	677.08	682.09	0	0	0	0	0	0
KLX06	672.08	677.09	0	0	0	0	0	0
KLX06	667.08	672.09	0	0	0	0	0	0
KLX06	662.08	667.10	0	0	0	0	0	0
KLX06	657.09	662.10	0	0	0	0	0	0
KLX06	652.09	657.10	2	0	2	0	0	0
KLX06	647.09	652.11	0	0	0	0	0	0
KLX06	642.09	647.11	0	0	0	0	0	0
KLX06	637.09	642.11	0	0	0	0	0	0
KLX06	632.10	637.12	1	1	0	0	0	0
KLX06	627.08	632.10	1	0	0	1	0	0
KLX06	622.07	627.09	0	0	0	0	0	0
KLX06	617.06	622.08	0	0	0	0	0	0
KLX06	612.05	617.07	0	0	0	0	0	0
KLX06	607.03	612.06	0	0	0	0	0	0
KLX06	602.02	607.05	0	0	0	0	0	0
KLX06	597.01	602.04	0	0	0	0	0	0
KLX06	592.00	597.03	0	0	0	0	0	0
KLX06	587.00	592.02	0	0	0	0	0	0
KLX06	581.99	587.01	0	0	0	0	0	0
KLX06	576.98	582.00	0	0	0	0	0	0
KLX06	571.97	576.99	0	0	0	0	0	0
KLX06	566.97	571.98	0	0	0	0	0	0
KLX06	561.96	566.97	1	0	0	0	1	0
KLX06	556.95	561.97	1	0	1	0	0	0
KLX06	551.94	556.96	0	0	0	0	0	0
KLX06	546.94	551.97	1	1	0	0	0	0

Borehole ID	SecUp (m)	SecLow (m)	Number of fractures, Total	Number of fractures 10–100 (mL/h)	Number of fractures 100–1,000 (mL/h)	Number of fractures 1,000–10,000 (mL/h)	Number of fractures 10,000–100,000 (mlLh)	Number of fractures 100,000–1,000,000 (mL/h)
KLX06	541.93	546.96	0	0	0	0	0	0
KLX06	536.92	541.95	0	0	0	0	0	0
KLX06	531.92	536.95	1	0	1	0	0	0
KLX06	526.91	531.94	1	1	0	0	0	0
KLX06	521.90	526.94	0	0	0	0	0	0
KLX06	516.90	521.93	0	0	0	0	0	0
KLX06	511.89	516.92	1	1	0	0	0	0
KLX06	506.89	511.92	2	1	1	0	0	0
KLX06	501.88	506.91	0	0	0	0	0	0
KLX06	496.87	501.91	1	1	0	0	0	0
KLX06	491.87	496.90	0	0	0	0	0	0
KLX06	486.86	491.90	0	0	0	0	0	0
KLX06	481.86	486.90	0	0	0	0	0	0
KLX06	476.86	481.89	1	1	0	0	0	0
KLX06	471.85	476.89	0	0	0	0	0	0
KLX06	466.85	471.89	0	0	0	0	0	0
KLX06	461.85	466.89	0	0	0	0	0	0
KLX06	456.85	461.89	0	0	0	0	0	0
KLX06	451.84	456.88	0	0	0	0	0	0
KLX06	446.84	451.88	0	0	0	0	0	0
KLX06	441.84	446.87	0	0	0	0	0	0
KLX06	436.84	441.87	0	0	0	0	0	0
KLX06	431.83	436.86	0	0	0	0	0	0
KLX06	426.83	431.86	0	0	0	0	0	0
KLX06	421.83	426.86	0	0	0	0	0	0
KLX06	416.82	421.85	0	0	0	0	0	0
KLX06	411.82	416.85	0	0	0	0	0	0
KLX06	406.81	411.83	1	1	0	0	0	0
KLX06	401.80	406.82	2	2	0	0	0	0
KLX06	396.80	401.82	0	0	0	0	0	0
KLX06	391.79	396.80	0	0	0	0	0	0
KLX06	386.78	391.80	1	1	0	0	0	0
KLX06	381.78	386.80	0	0	0	0	0	0
KLX06	376.77	381.80	5	0	2	3	0	0
KLX06	371.77	376.80	4	0	3	1	0	0
KLX06	366.76	371.79	3	0	1	2	0	0
KLX06	361.76	366.78	5	0	1	2	2	0
KLX06	356.76	361.77	6	0	0	3	3	0
KLX06	351.75	356.76	4	0	1	3	0	0
KLX06	346.72	351.74	4	0	1	2	1	0
KLX06	341.69	346.71	7	2	2	2	1	0
KLX06	336.68	341.70	3	1	0	1	1	0
KLX06	331.67	336.70	6	0	3	1	2	0
KLX06	326.67	331.69	4	2	0	2	0	0
KLX06	321.66	326.68	2	1	0	1	0	0
KLX06	316.66	321.68	1	0	0	1	0	0

Borehole ID	SecUp (m)	SecLow (m)	Number of fractures, Total	Number of fractures 10–100 (mL/h)	Number of fractures 100–1,000 (mL/h)	Number of fractures 1,000–10,000 (mL/h)	Number of fractures 10,000–100,000 (mlLh)	Number of fractures 100,000–1,000,000 (mL/h)
KLX06	311.65	316.67	6	2	0	3	1	0
KLX06	306.66	311.68	5	0	0	4	1	0
KLX06	301.68	306.70	0	0	0	0	0	0
KLX06	296.67	301.69	4	0	3	1	0	0
KLX06	291.67	296.69	2	1	0	1	0	0
KLX06	286.66	291.68	1	0	0	1	0	0
KLX06	281.65	286.67	2	0	1	1	0	0
KLX06	276.65	281.66	1	0	1	0	0	0
KLX06	271.64	276.65	5	0	1	3	1	0
KLX06	266.63	271.64	2	0	2	0	0	0
KLX06	261.63	266.64	3	1	0	1	0	1
KLX06	256.62	261.63	0	0	0	0	0	0
KLX06	251.62	256.63	4	0	1	2	1	0
KLX06	246.60	251.62	7	0	3	3	1	0
KLX06	241.58	246.60	2	0	1	1	0	0
KLX06	236.56	241.59	3	0	0	1	2	0
KLX06	231.54	236.57	1	1	0	0	0	0
KLX06	226.53	231.56	3	0	0	1	2	0
KLX06	221.52	226.55	3	0	0	1	2	0
KLX06	216.51	221.54	0	0	0	0	0	0
KLX06	211.51	216.53	1	0	0	0	1	0
KLX06	206.50	211.52	3	1	1	0	1	0
KLX06	201.49	206.51	4	0	1	3	0	0
KLX06	196.49	201.51	0	0	0	0	0	0
KLX06	191.48	196.50	2	0	0	1	0	1
KLX06	186.47	191.49	2	0	0	1	1	0
KLX06	181.47	186.49	4	0	1	1	1	1
KLX06	176.46	181.48	3	0	1	1	1	0
KLX06	171.45	176.47	1	0	1	0	0	0
KLX06	166.45	171.47	5	0	0	1	3	1
KLX06	161.44	166.46	4	0	2	2	0	0
KLX06	156.43	161.46	1	0	1	0	0	0
KLX06	151.43	156.45	3	1	2	0	0	0
KLX06	146.42	151.44	0	0	0	0	0	0
KLX06	141.42	146.44	0	0	0	0	0	0
KLX06	136.42	141.43	1	0	1	0	0	0
KLX06	131.42	136.43	1	1	0	0	0	0
KLX06	126.41	131.42	0	0	0	0	0	0
KLX06	121.41	126.41	0	0	0	0	0	0
KLX06	116.41	121.41	3	1	2	0	0	0
KLX06	111.40	116.40	2	0	0	2	0	0
KLX06	106.37	111.38	2	0	0	0	1	1
KLX06	101.33	106.35	5	0	3	1	1	0
KLX06	96.31	101.33	0	0	0	0	0	0

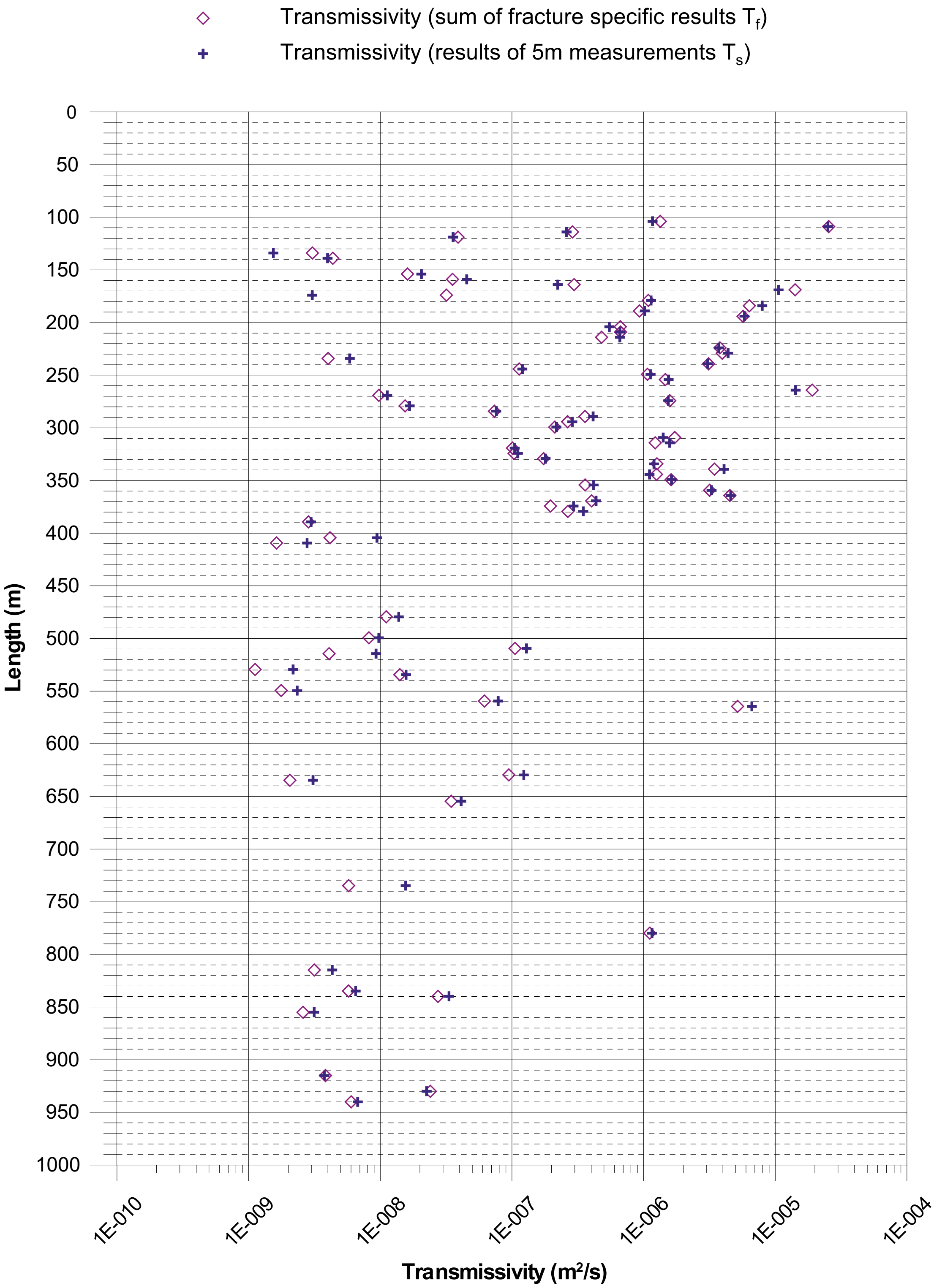
Appendix 11

Laxemar, borehole KLX06
Calculation of conductive fracture frequency



Appendix 12

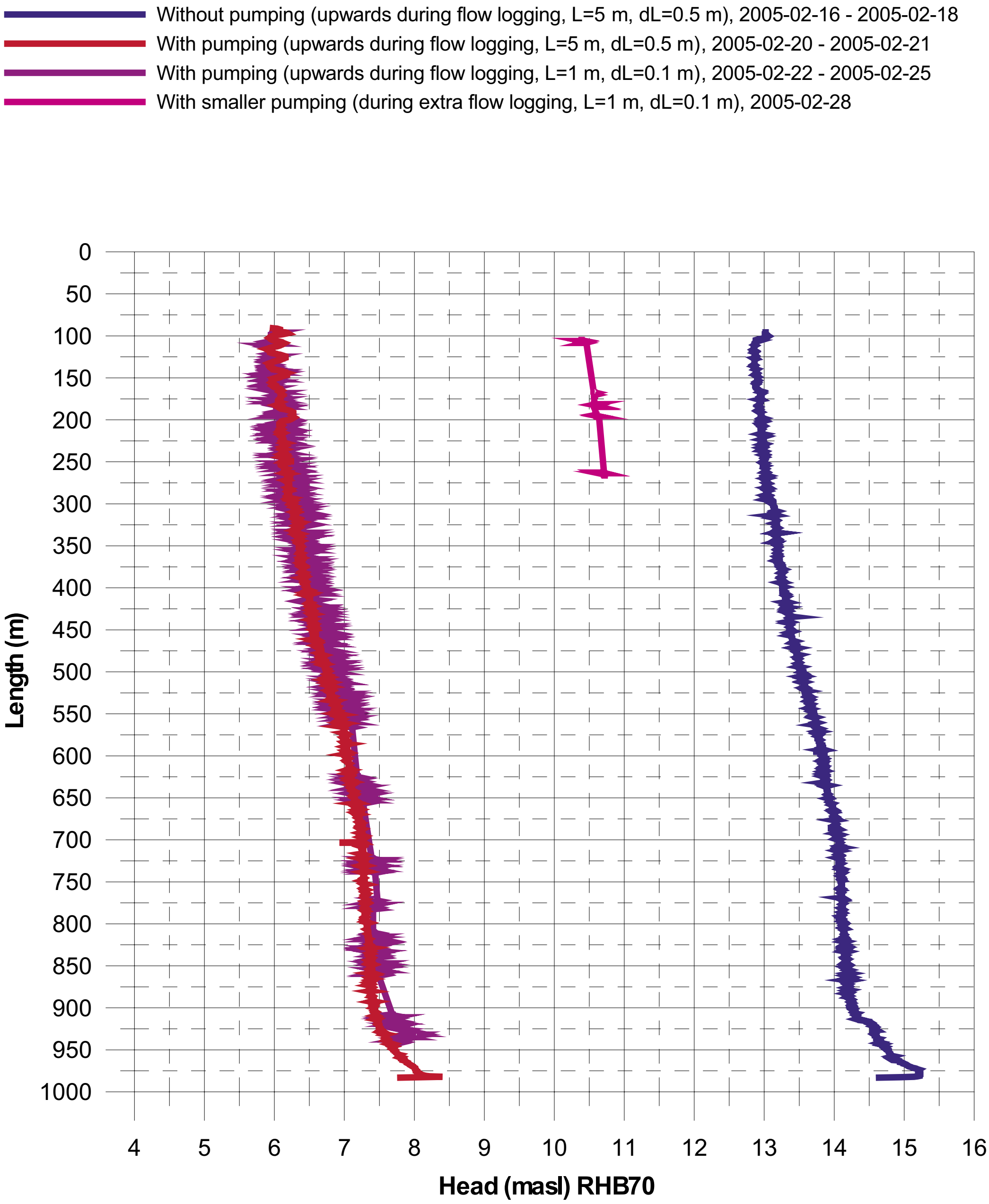
Laxemar, borehole KLX06
Comparison between section transmissivity and fracture transmissivity



Appendix 13

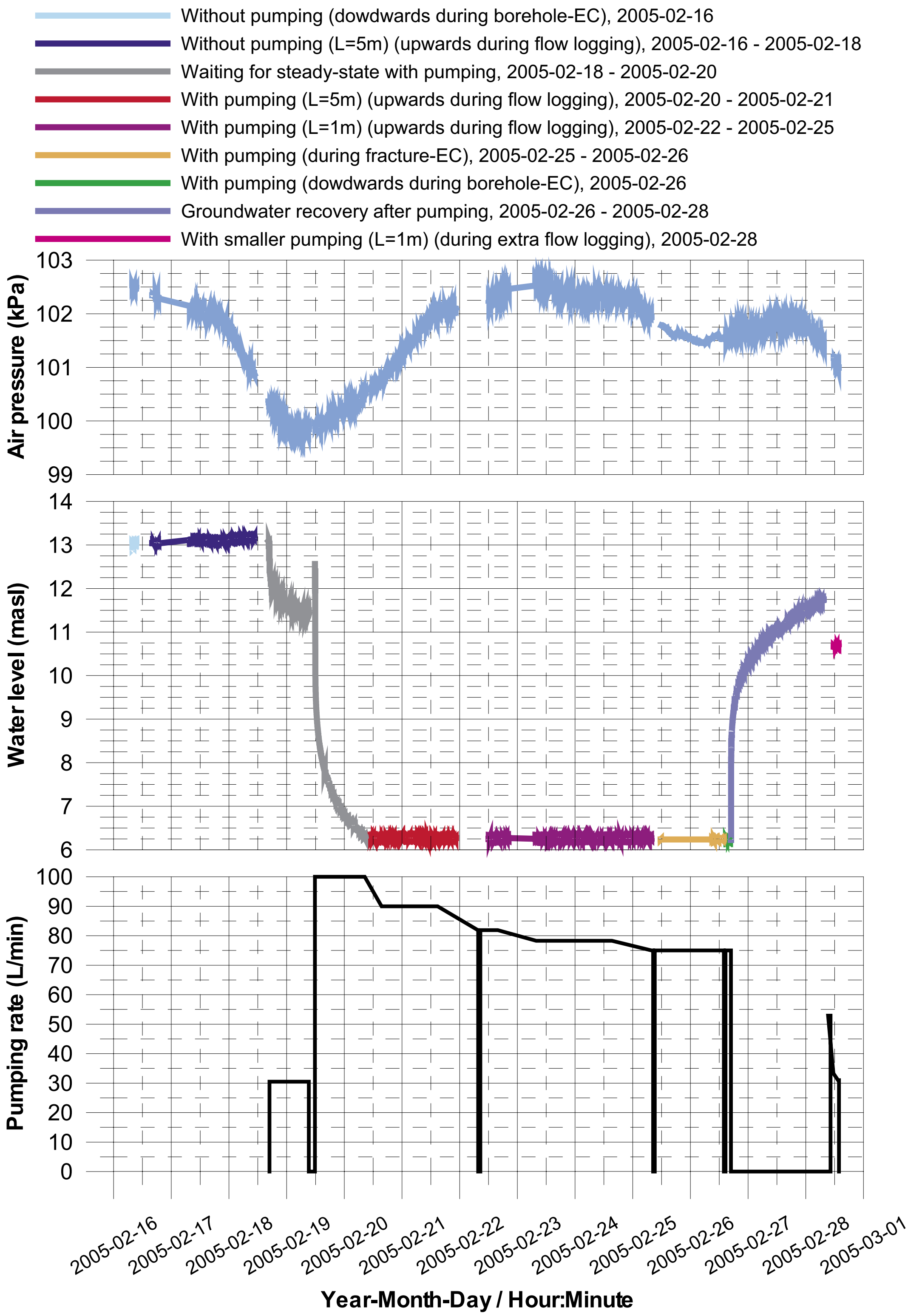
Laxemar, borehole KLX06
Head in the borehole during flow logging

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



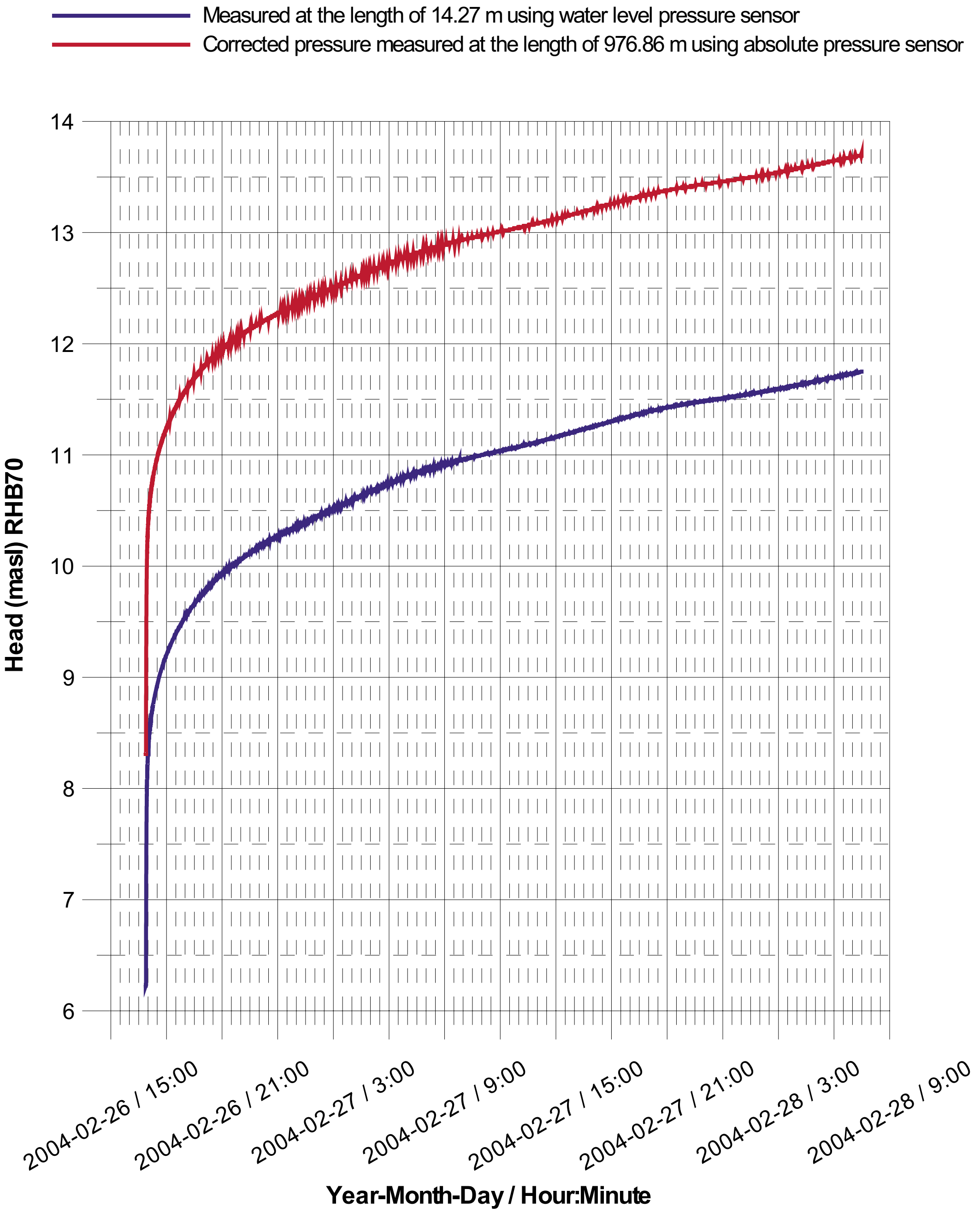
Appendix 13.2

Laxemar, borehole KLX06
Air pressure, water level in the borehole and pumping rate during flow logging

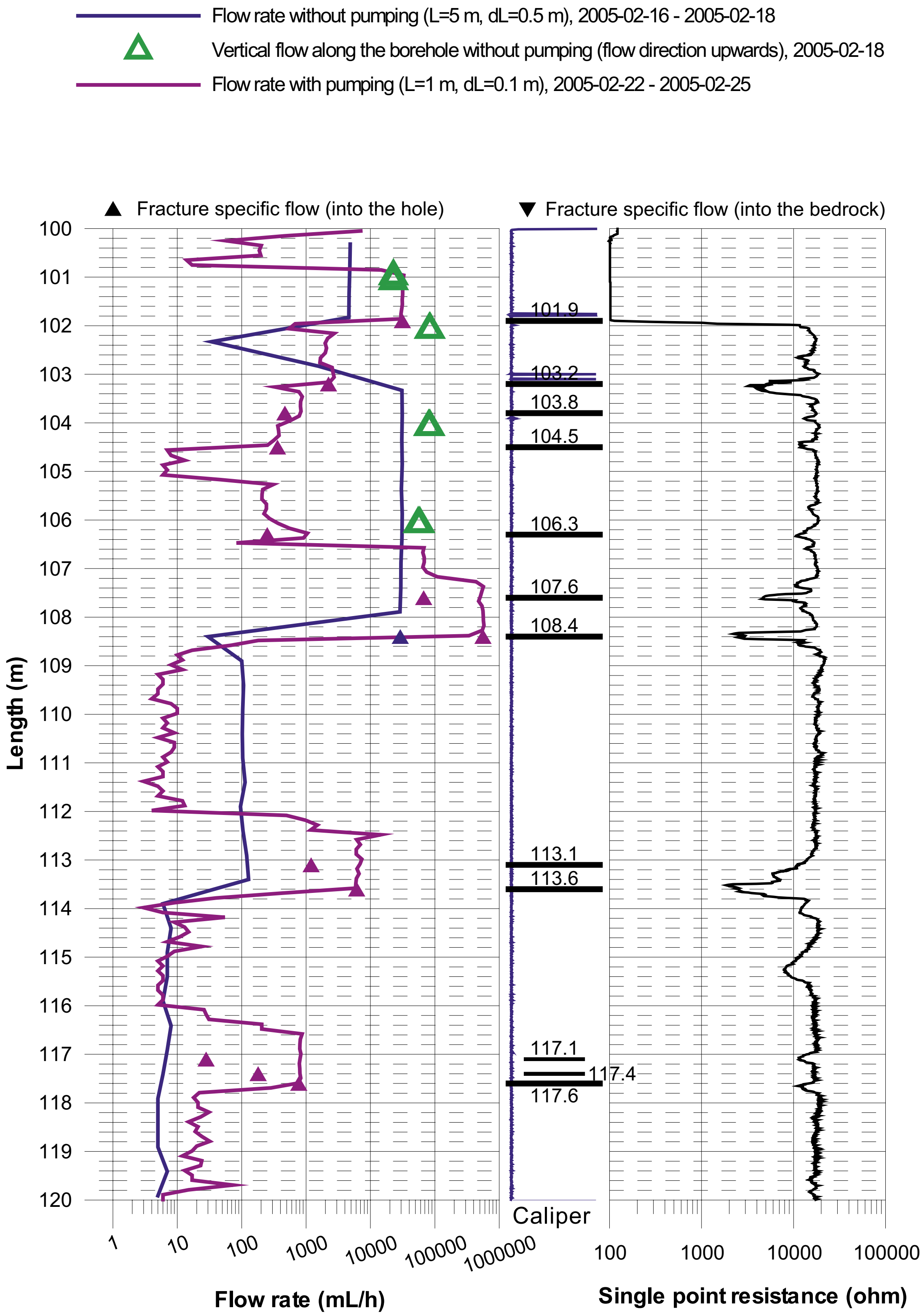


Laxemar, borehole KLX06
Groundwater recovery after pumping

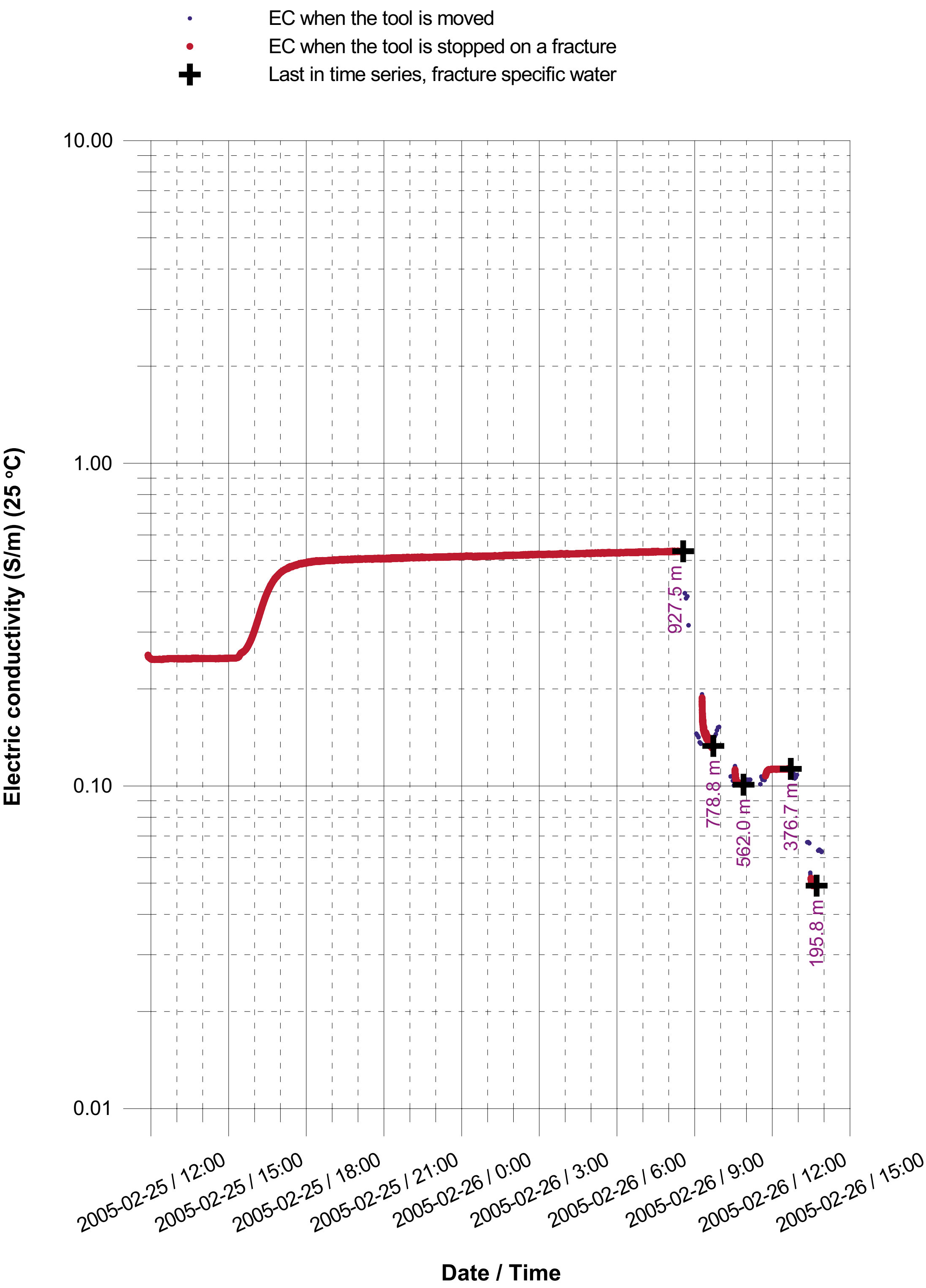
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m^3 * 9.80665 m/s^2) + Elevation (m)
Offset = 2460 Pa (Correction for absolut pressure sensor)



Laxemar, borehole KLX06
Vertical flow along the borehole



Laxemar, borehole KLX06
Fracture-specific EC results by date



Laxemar, borehole KLX06
Fracture-specific EC results by date