P-05-225

Oskarshamn site investigation

Difference flow logging of boreholes KLX07A and KLX07B

Subarea Laxemar

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September 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 boreholes KLX07A and KLX07B at Oskarshamn, Sweden, in June and July 2005, using Posiva flow log. The primary aim of the measurements was to determine the position and flow rate of flow yielding fractures in boreholes KLX07A and KLX07B.

The flow rate into or out of a 5 m long test section in borehole KLX07A was measured between 96.78–827.56 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 (only in KLX07A). 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 (only in KLX07A). 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.

A c 200 m long borehole KLX07B is drilled alongside the borehole KLX07A. The idea of KLX07B is to cover the wider upper part of KLX07A. The flow logging in KLX07B was performed between 22.52–192.75 m borehole lengths under natural (un-pumped) as well as pumped conditions with a 5 m section length and with 0.5 m length increments. The flow measurements were repeated using a 1 m long test section, successively transferred with an overlapping of 0.1 m.

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 KLX07A och KLX07B i Oskarshamn, Sverige, i juni och juli 2005 med Posiva flödesloggningsmetod. Det primära syftet med mätningarna var att bestämma läget och flödet för vattenförande sprickor i borrhål KLX07A och KLX07B.

Flödet till eller från en 5 m lång testsektion mättes i KLX07A mellan 96.78–827.56 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 (endast i KLX07A). Längmärkena detekterades med caliper-mätningar 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 (endast i KLX07A). 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.

Det ca 200 m långa borrhålet KLX07B finns bredvid KLX07A. Intention med KLX07B är att täcka den öppen övre delen av KLX07A. Flödesloggningen under såväl naturliga (icke-pumpade) som pumpade förhållanden mellan 22.52–192.75 m utfördes med en 5 m lång testsektion som förflyttades successivt med 0.5 m. Flödesmätningarna upprepades med en 1 m lång testsektion som förflyttades successivt med 0.1 m.

Contents

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 400-05-042. 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 KLX07A at Oskarshamn was conducted between June 9–29, 2005. The borehole is inclined c 60° from the horizontal direction and drilled to a length of c 845 m. Further details on borehole construction is compiled in Table 1-2 and 1-3. The location of borehole KLX07A at the drill site within the Oskarshamn area is shown in Figure 1-1.

The difference flow logging in the core drilled borehole KLX07B, which is just alongside the borehole KLX07A, was conducted between June 28–July 1, 2005. The borehole is inclined c 85° from the horizontal direction and drilled to a length of c 200 m. Results of measurements carried out in KLX07B are presented in Chapter 7 and in Appendices 15–25.

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 KLX07A and KLX07B.	AP PS 400-05-042	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 enhålspumptester.	SKB MD 320.004	

Table 1-2. Borehole construction KLX07A.

Title	Value				
	Information about cored borehole KLX07A (2005-09-14).				
Old idcode name(s)	KLX07				
Comment	No comment exists.				
Borehole length (m)	844.730				
Reference level	TOC				
Drilling period(s)	From date	To date	Secup (m)	Seclow (m)	Drilling type
	2004-11-23	2004-12-07	0.000	100.460	Percussion drilling
	2005-01-06	2005-05-04	100.460	844.730	Core drilling
Starting point coordinate	Length (m)	Northing (m)	Easting (m)		Elevation coord system
	0.000	6366752.094	1549206.855		18.470 RT90-RHB70
Angles	Length (m)	Bearing	Inclination (– = down)		Coord system
	0.000	174.179	–60.038		RT90-RHB70
Borehole diameter	Secup (m)	Seclow (m)	Hole diam (m)		
	0.000	8.900	0.343		
	8.900	11.800	0.252		
	11.800	100.300	0.198		
	100.300	100.460	0.165		
	100.460	101.980	0.086		
	101.980	844.730	0.076		
Casing diameter	Secup (m)	Seclow (m)	Case in (m)	Case out (m)	
	0.000	11.800	0.200	0.208	
	0.000	8.900	0.310	0.323	
Cone dimensions	Secup (m)	Seclow (m)	Cone in (m)	Cone out (m)	
	97.330	101.980			
Grove milling	Length (m)	Trace detectable			
	110.000	Yes			
	150.000	Yes			
	200.000	Yes			
	250.000	Yes			
	300.000	Yes			
	349.000	Yes			
	400.000	Yes			
	450.000	Yes			
	500.000	Yes			
	550.000	Yes			
	600.000	Yes			
	650.000	Yes			
	700.000	Yes			
	750.000	Yes			
	800.000	Yes			
Installed sections	Section no	Start date	Secup (m)	Seclow (m)	
Section status	Packers are released.				
	End of additional information.				

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Table 1-3. Borehole construction KLX07B.

Title	Value				
	Information about cored borehole KLX07B (2005-11-25).				
Comment:	No comment exists.				
Borehole length (m):	200.130				
Reference level:	TOC				
Drilling Period(s):	From Date	To Date	Secup(m)	Seclow(m)	Drilling Type
	2005-05-23	2005-06-03	0.000	200.130	Core drilling
Starting point coordinate:	Length(m)	Northing(m)	Easting(m)	Elevation	Coord System
	0.000	6366753.135	1549206.758	18.380	RT90-RHB70
Angles:	Length(m)	Bearing	Inclination (- = down)		Coord System
	0.000	174.329	-85.002	RT90-RHB70	
Borehole diameter:	Secup(m)	Seclow(m)	Hole Diam(m)		
	0.000	200.130	0.076		
Core diameter:	Secup(m)	Seclow(m)	Core Diam(m)		
	0.000	200.130	0.050		
Casing diameter:	Secup(m)	Seclow(m)	Case In(m)	Case Out(m)	Comment
	0.000	9.640	0.077	0.089	
Cone dimensions:	Secup(m)	Seclow(m)	Cone In(m)	Cone Out(m)	
Grove milling:	Length(m)	Trace detectable			
	End of additional information.				
Section status	Packers are expanded.				
	End of additional information.				

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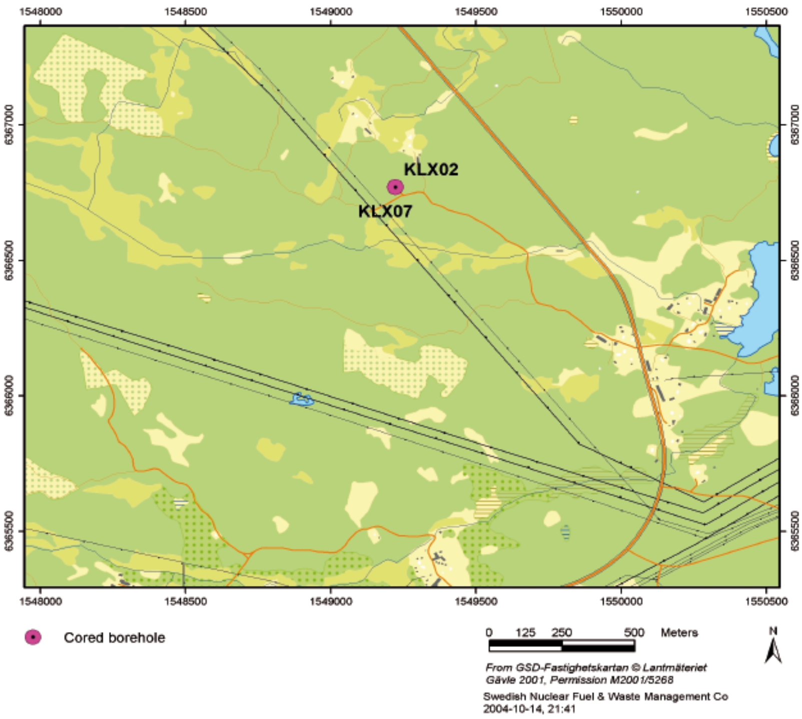

Figure 1-1. *Site map showing the location of borehole KLX07 situated in the subarea of Laxemar, next to KLX02. The drill direction of KLX07A is south and of KLX02 is north.*

2 Objective and scope

The main objective of the difference flow logging in KLX07A and in KLX07B 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 for borehole KLX07A 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.

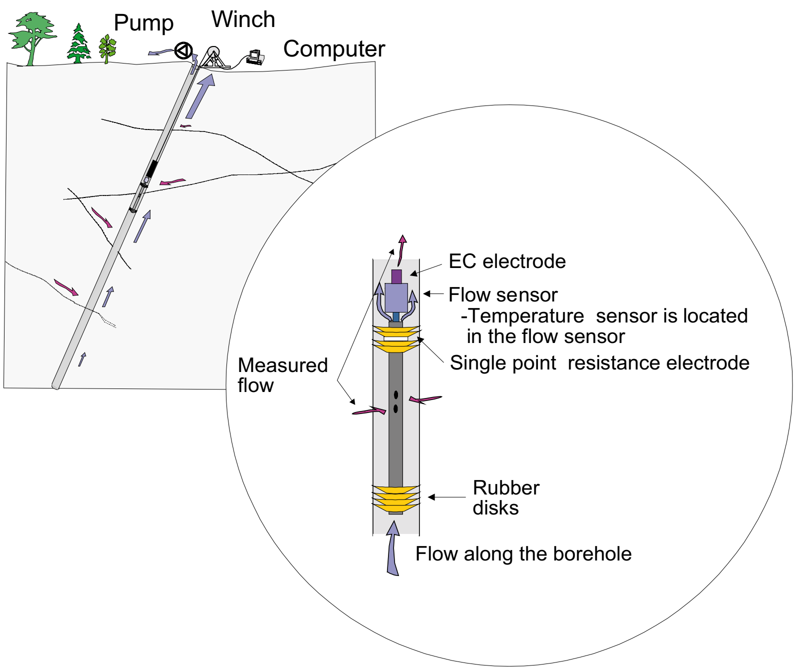

Figure 3-1. *Schematic of the downhole equipment used in the Difference flowmeter.*

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 KLX07A.

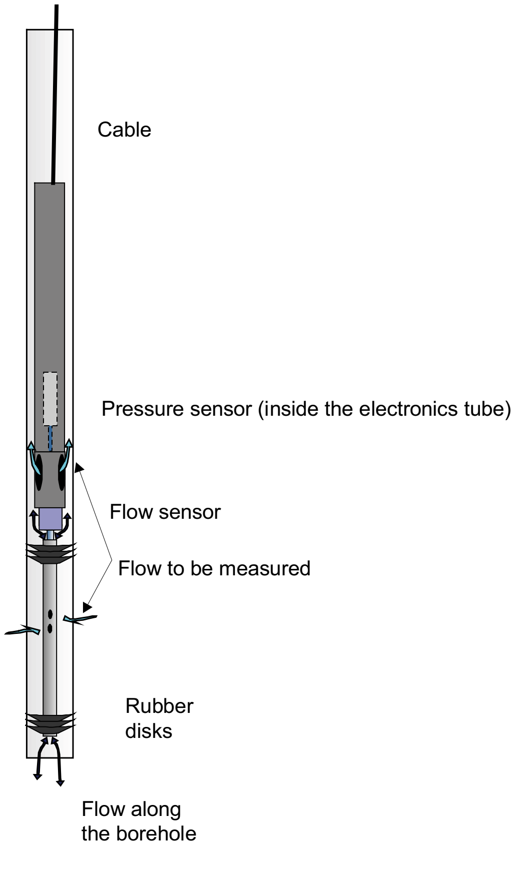

***Figure 3-2.** The absolute pressure sensor is located inside the electronics tube and connected through a tube to the borehole water.*

The principles of difference flow measurements are described in Figures 3-3 and 3-4. The flow sensor consists of three thermistors, see Figure 3-3a. The central thermistor, A, is used both as a heating element and for 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.

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

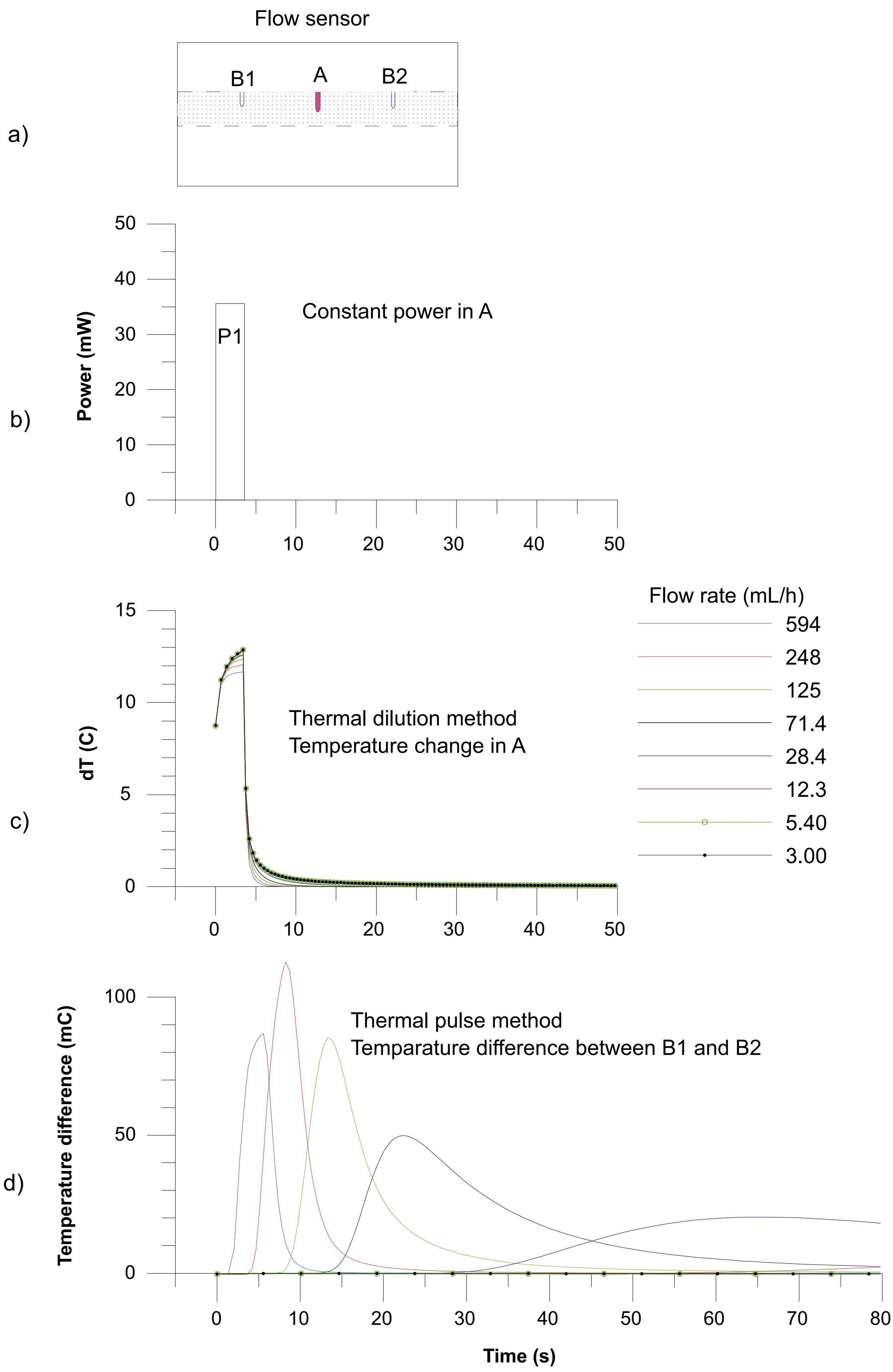

Figure 3-3. *Flow measurement, flow rate < 600 mL/h.*

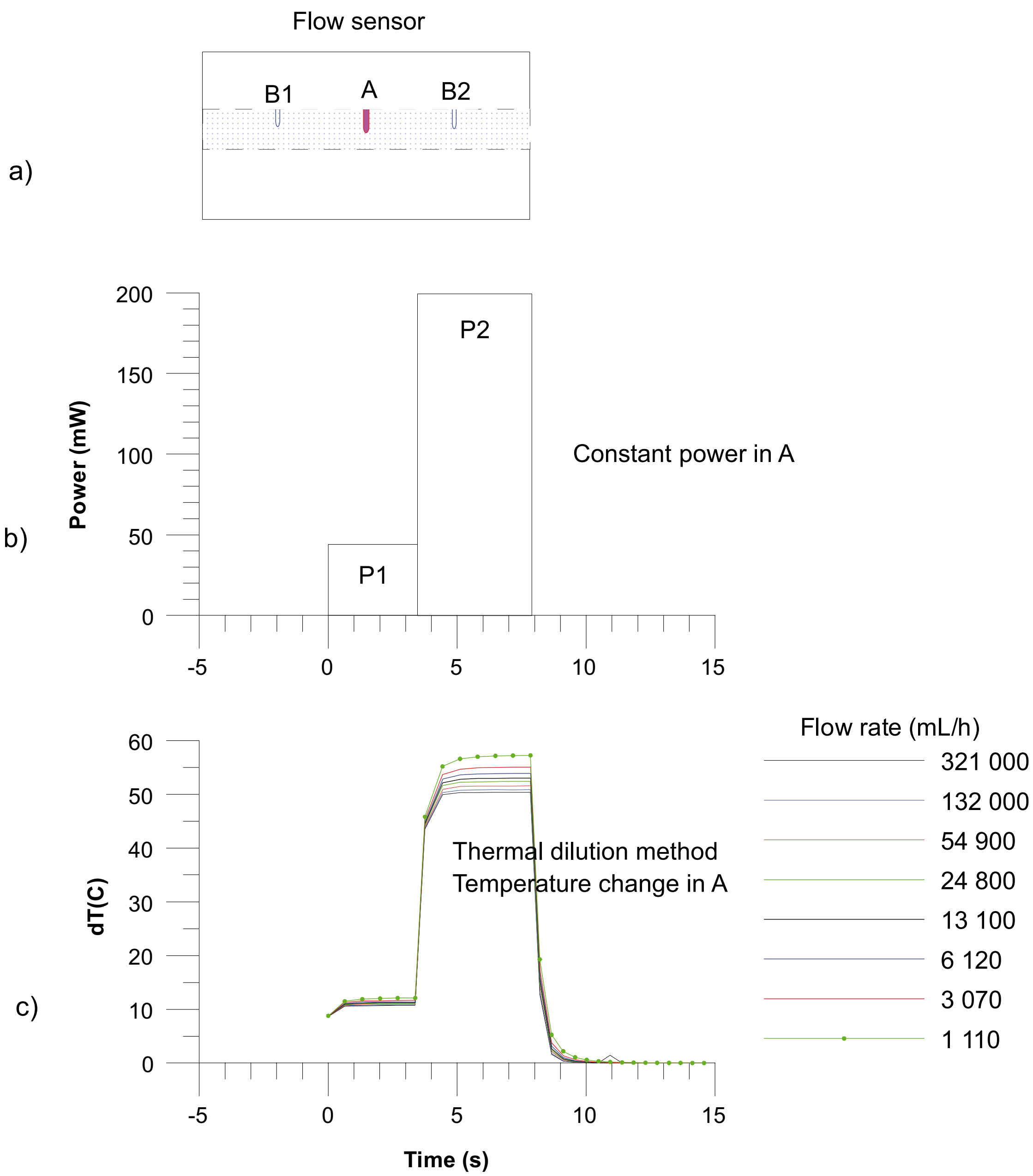

Figure 3-4. *Flow measurement, flow rate > 600 mL/h.*

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/:

$h_s – h = Q/(T \times a)$ 3-1

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:

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

where

r_0 is the radius of the well and

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

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

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

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

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:

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

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

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).

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

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

where

Q_{f0} and Q_{f1} are the flow rates at a fracture and

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

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

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 type of analysis following SKB MD 430.004 (SKB internal controlling document) and a T-value is calculated.

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:	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	June 2005.
Calibration of cable length	Using length marks in the borehole.

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

Table 4-1. Range and accuracy of sensors.

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

5 Performance

5.1 Execution of the field work

The commission was performed according to Activity Plan AP PS 400-05-042 (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 KLX07A, 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 KLX07A (Item 7 in Table 5-1). These methods also reveal widened parts of the borehole.

Table 5-1. Flow logging and testing in KLX07A. Activity schedule.

Item	Activity	Explanation	Date
1	Mobilisation at site	Unpacking the trailer.	2005-06-09 2005-06-10
7	Length calibration of the downhole tool	Dummy logging (SKB Caliper and SPR). Logging without the lower rubber discs, no pumping.	2005-06-10 2005-06-12
9	EC- and temp-logging of the borehole fluid	Logging without the lower rubber discs, no pumping.	2005-06-12
8	Combined Overlapping/ Sequential flow logging	Section length L_w = 5 m, Step length dL = 0.5 m. No pumping.	2005-06-12 2005-06-17
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).	2005-06-17 2005-06-19
11	Overlapping flow logging	Section length L_w = 1 m, Step length dL = 0.1 m, at pumping.	2005-06-19 2005-06-22
12	Fracture-specific EC-measurements in pre-selected fractures	Section length L_w = 1 m, at pumping (in pre-selected fractures.	2005-06-22
13	EC- and temp-logging of the borehole fluid	Logging without the lower rubber discs, at pumping.	2005-06-22
14	Recovery transient	Measurement of water level and absolute pressure in the borehole after stopping of pumping.	2005-06-22 2005-06-28
11 extra	Overlapping flow logging at smaller pumping	Section length L_w = 1 m, Step length dL = 0.1 m, at smaller pumping.	2005-06-28 2005-06-29

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 91.76–830.53 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 June 17. The pump intake was at level 1.9 (masl, RHB70), see Appendix 13.2. The groundwater level sensor (pressure transducer) was at 1.68 (masl, RHB70). After 24 hours waiting time, the overlapping flow logging (Item 10) was carried out in the borehole interval 91.78–830.56 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).

The length interval 102–254 m was re-measured using a smaller drawdown, since the flow rate exceeded the measurement limit in several fractures in this interval. A section length of 1 m and a step length of 0.1 m were used here (Item 11 extra).

The activity schedule of the measurements in borehole KLX07B is presented in Table 5-2. The items and activities in Table 5-2 are the same as in the Activity Plan.

Table 5-2. Flow logging in KLX07B. Activity schedule.

Item	Activity	Explanation	Date
16	Combined Overlapping/ Sequential flow logging	Section length L_w = 5 m, Step length dL = 0.5 m. No pumping.	2005-06-28
17	Overlapping flow logging	Section length L_w = 5 m, Step length dL = 0.5 m at pumping (includes 2 hour waiting after beginning of pumping).	2005-06-29
18	Overlapping flow logging	Section length L_w = 1 m, Step length dL = 0.1 m, at pumping.	2005-06-29 2005-06-30
19	Recovery transient and demobilisation	Measurement of water level and absolute pressure in the borehole after stopping of pumping. Uninstallation of the tool. Packing the trailer.	2005-06-30 2005-07-01
18 extra	Overlapping flow logging at smaller pumping	Section length L_w = 1 m, Step length dL = 0.1 m, at smaller pumping.	2005-06-30 2005-07-01
20	Delivery and filling of measured data	Delivering Daily Logs, logging reports and raw data files for SKB.	2005-07-01

5.2 Nonconformities

No exceptions was made from the Activity Plan.

6 Results, KLX07A

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 KLX07A 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 SPR+caliper measurement.

The procedure of length correction was the following:

- SPR+caliper measurement (Item 7) was initially length corrected in relation to the known length marks, Appendix 1.42 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 1.2–1.41.

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 1.2–1.41. Detection of length marks is listed in Table 6-1. Every mark was detected at least partly with the caliper tool in the measured interval. They can also be seen in the SPR results. However, the SPR-anomaly is complicated due to the four rubber disks used at the upper end of the section, two at each side of the resistance electrode. A selection of length intervals where clear SPR-anomalies were found, are plotted as well.

The aim of the plots in Appendices 1.2–1.40 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 1.41. 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).

Table 6-1. Detected length marks.

Length marks given by SKB (m)	Length marks detected by caliper	Length marks detected by SPR
110	both	yes
150	both	yes
200	both	yes
250	both	yes
300	both	yes
349	both	yes
400	both	yes
450	both	yes
500	both	yes
550	both	yes
600	both	yes
650	both	yes
700	only lower	yes
750	only upper	yes
800	both	yes

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 both in downward and upward direction, see Appendix 2.1, blue coloured curves.

The EC measurements were repeated during pumping (after a pumping period of about five days), see Appendix 2.1, green coloured curves. The results show change to less saline water above the length of about 760 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 1.42.

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 = 1 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 one metre long test section was 3.6 L.

Electric conductivity of fracture-specific water is presented on time scale, see Appendix 14. The blue symbol represents the value when tool was moved (one metre point interval) and the red symbol means that the tool was stopped on a fracture for a fracture specific EC measurement.

Borehole lengths at the upper and lower ends of the section, fracture locations as well as the final EC values are listed in Table 6-2.

Table 6-2. Fracture-specific EC.

Upper end of section (m)	Lower end of section (m)	Fractures measured (m)	EC (S/m) at 25°C
825.17	826.17	825.5	0.86
712.00	713.00	712.4	0.25
635.21	636.21	635.7	0.17
486.99	487.99	487.4	0.48
366.66	367.66	367.4	0.16

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 /Freeze et al. 1979/:

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

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.

A tool-specific offset of 2.46 kPa is subtracted from absolute pressure raw data.

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 Appendix 3. 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 Appendix 3 (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 m (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 Appendix 3 (violet curve).

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 m 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 96.78 and 827.56 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 Appendix 3.

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 RHB 70 scale.

The flow results 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, 79 sections were detected as flow yielding, of which 55 had a flow direction from the borehole into the bedrock (negative flow). During pumping, all 101 detected flows were directed towards the borehole.

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 4.2. 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 -1.0×10^{-04} m^3/s (–370,000 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 partially without a casing tube and can therefore contain flowing fractures. Vertical flow along the borehole was measured at the length of c 102 m. The result is in line with the assumption above. The measured flow along the borehole was c 5.7×10^{-05} m^3/s (200,000 mL/h) and flow direction was downwards along the borehole, see Appendix 13.4. This flow explains most of the unbalance of the flow sum above. The measured flow along the borehole is not as big as the sum above because the measurement tool decelerates the vertical flow. This can be seen as raising water level, see Appendix 13.4.

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 metre, it may be difficult to evaluate the flow rate. There are such cases for instance in Appendix 3.2. 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 metre 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 240, but only 18 could be defined without pumping. These 18 fractures could be used for head estimation and all 240 were used for transmissivity estimations, Appendix 8. Transmissivity and hydraulic head of fractures are plotted in Appendix 5.

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. However below 600 m there is a nearly systematic disparity in the transmissivity results. The flows measured without pumping are significant in this interval and have an effect in transmissivity calculations. Since the flows measured without pumping are better represented in the results of borehole sections, these results can be considered as more correct.

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 Appendix 3 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 KLX07A between 30–100 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 KLX07A interval c 102 m–254 m was 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 metre, 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 85 L/min and s (drawdown) was 5.37 m. Transmissivity calculated with Dupuit's formula is 2.6×10^{-04} m²/s.

In the Moye's formula (equation 3-10) length of test section L is 985.16m (11.80–844.73 m) and borehole diameter $2r_0$ is 0.076 m. Transmissivity calculated with Moye's formula is 4.3×10^{-04} m²/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.

Furthermore, for an assumed storage coefficient S = $1.6.0\times10^{-6}$ the recovery phase was simulated. The best fit simulation yield a transmissivity T = 4.9×10^{-4} m²/s and a skin = –0.5. Further away from the borehole a region of about half of this transmissivity is suggested by the log-log diagnostic plot.

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

The results of the three methods are given in Table 6-2 where for the steady-state analyses method of Dupuit and Moye, the flow was set to Q = 85 L/min and drawdown s = 5.37 m (Appendix 13.2). Basic test data is in Appendix 6.

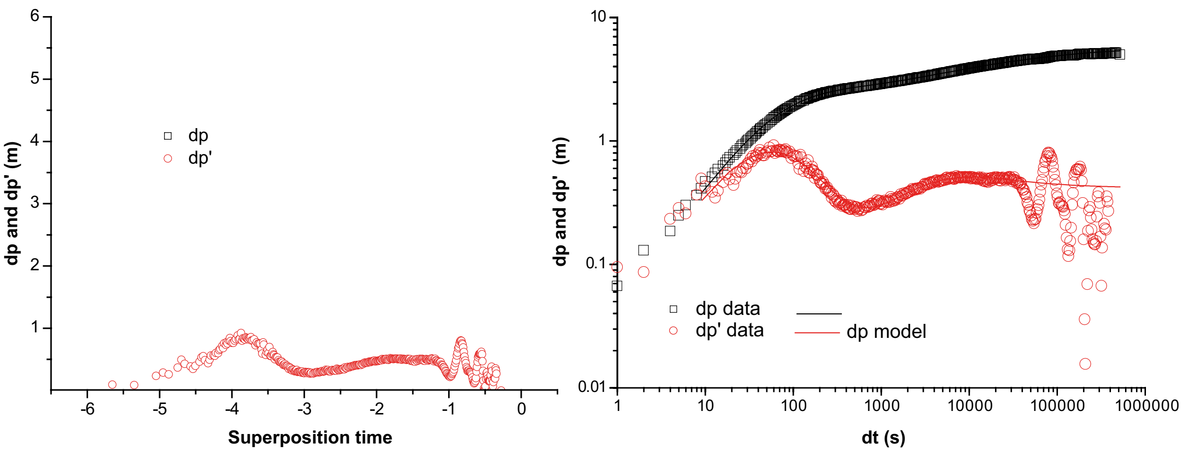

Figure 6-1. *Semi-log and log-log plot of recovery phase in KLX07A showing measured pressure difference dp (■) and pressure difference derivative dp' (o) along with simulated best fit curves (–) in the log-log plot.*

Table 6-2. Transmissivity of the entire borehole KLX07A.

Method	Transmissivity (m^2/s)
Dupuit	2.6×10^{-04}
Moye	4.3×10^{-04}
Jacob	4.9×10^{-04}

6.5 Groundwater level and pumping rate

Pumping was started on June 17. The pump intake was at level 1.9 (masl, RHB70), see Appendix 13.2. The groundwater level sensor (pressure transducer) was at 1.68 (masl, RHB70). The reference level is centerpoint of top of casing (ToC) 18.470 (masl, RHB70).

The borehole was pumped between June 17 and 22 with a drawdown of about 5.4 m. The borehole was pumped also between June 28 and 29 a short time with a smaller drawdown. Pumping rate was recorded, see Appendix 13.2.

The groundwater recovery was measured after the pumping period, June 22–28, 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 21.22 m.

7 Results, KLX07B

The flow logging in borehole KLX07B was firstly performed with a 5 m section length and with 0.5 m length increments, see Appendices 16.1–16.10 (dark blue curve without pumping, red curve with pumping). Flow logging was then repeated using a 1 m long test section and 0.1 m length increments (violet curve). The flow rate exceeded the measurement limit in several fractures, so the borehole was finally re-measured with a 1 m section length and 0.1 m length increments using a smaller drawdown. The measurements were performed in entire borehole between c 19–195 m.

All the flow measurements, except the measurement without pumping (dark blue curve), were length corrected linearly, so that correction is 0 at 0 m and –0.24 at 200 m, see Appendix 15.12. The correction is an average of corrections done in KLX07A. The measurement without pumping was corrected according to the other flow measurements. There are no caliper marks in KLX07B.

Flow rates derived from measurements during un-pumped respectively pumped conditions are presented in Appendix 20 (Q_0 and Q_1). Flow rates are positive if the flow direction is from the bedrock into the borehole and vice versa. With the borehole at rest, 20 sections were detected as flow yielding, of which 11 had a flow direction from the borehole into the bedrock (negative flow). During pumping, all 28 detected flows were directed towards the borehole. The sum of detected flows without pumping (Q_0) was -1.3×10^{-07} m^3/s (–470 mL/h).

Noise level in KLX07B was between 30–100 mL/h. Mostly it was even below 30 mL/h, i.e. below the theoretical limit of thermal dilution method. However, the noise line (grey dashed line, Appendix 16) was never drawn below 30 mL/h.

Hydraulic head and transmissivity of borehole sections are presented in Appendices 17.2 and 20.

Total amount of detected flowing fractures was 80. None of them could be defined without pumping, so no head estimations were done. All 80 fractures were used for transmissivity estimations, Appendix 18 and 21.

Transmissivity of the entire borehole is evaluated with the three methods described in Chapter 3. The results of the three methods are given in Table 7-2, where for the steady-state analyses method of Dupuit and Moye, the flow was set to Q = 24 L/min and drawdown s = 5.86 m. Basic test data is in Appendix 19.

Steady state analysis

For the Dupuit's formula (equation 3-9) R/r_0 is chosen to be 500.

In the Moye's formula (equation 3-10) length of test section L is 200 m and borehole diameter $2r_0$ is 0.076 m.

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.

Furthermore, for an assumed storage coefficient S = $1.5.0\times10^{-5}$ the recovery phase was simulated. The best fit simulation yield a transmissivity T = 1.8×10^{-4} m^2/s and a skin = 5.7. Further away from the borehole a region of about half of this transmissivity is suggested by the log-log diagnostic plot.

Figure 7-1 show the semi-log and log-log plot of the recovery phase, this was utilised to calculate the transmissivity.

Pumping was started on June 29. The pump intake was at level 1.7 (masl, RHB70), see Appendix 25.2. The groundwater level sensor (pressure transducer) was at 1.46 (masl, RHB70). The reference level is centerpoint of top of casing (ToC) 18.470 (masl, RHB70).

The borehole was pumped between June 29–30 with a drawdown of about 5.9 m. The borehole was pumped also between June 30–July 1 a short time with a smaller drawdown. Pumping rate and air pressure was recorded, see Appendix 25.2.

The groundwater recovery was measured after the pumping period, June 30, Appendix 25.3. 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 172.07 m.

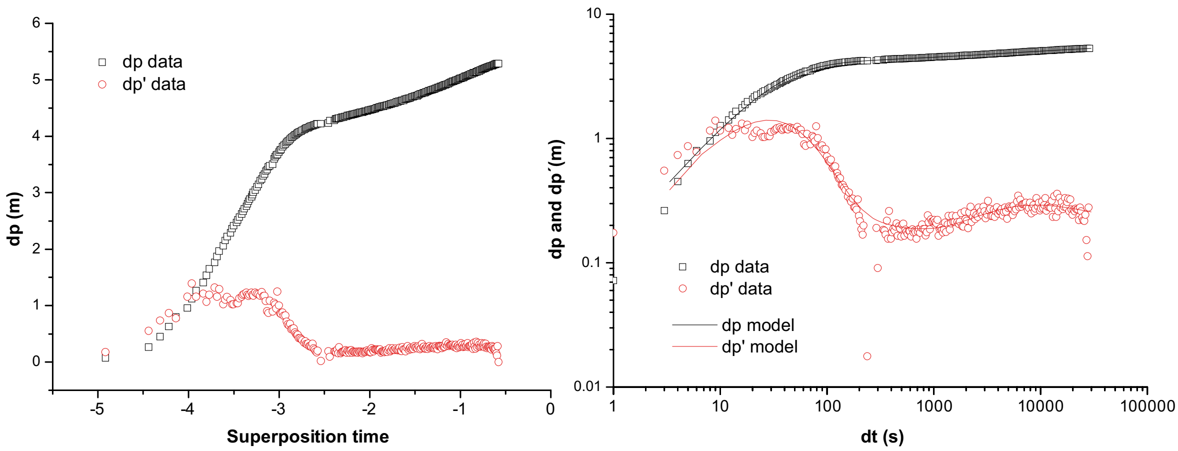

Figure 7-1. *Semi-log and log-log plot of recovery phase in KLX07B showing measured pressure difference dp (■) and pressure difference derivative dp' (o) along with simulated best fit curves (–) in the log-log plot.*

Table 7-2. Transmissivity of the entire borehole KLX07B.

Method	Transmissivity (m^2/s)
Dupuit	6.8×10^{-05}
Moye	9.6×10^{-05}
Jacob	1.8×10^{-04}

8 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 boreholes KLX07A and KLX07B at Oskarshamn. Measurements were carried out both when the boreholes were 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 in KLX07A 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. Because of short length of the borehole, no length marks are milled in KLX07B.

The distribution of saline water along the borehole KLX07A 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 KLX07A was 240. Transmissivity and hydraulic head were calculated for borehole sections and fractures. The highest transmissivity was detected in a fracture at the length of 155.3 m. High-transmissive fractures were also found at 168.1 m, 208.9 m, 228.4 m and 252.6 m. The lowest identified flowing fracture was at the length of 825.5 m.

The total amount of detected flowing fractures in KLX07B was 80. Transmissivity and hydraulic head were calculated for borehole sections and fractures. The highest transmissivity was detected in a fracture at the length of 109.6 m.

Transmissivity of entire borehole KLX07B was smaller than entire borehole KLX07A.

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Appendices

KLX07A

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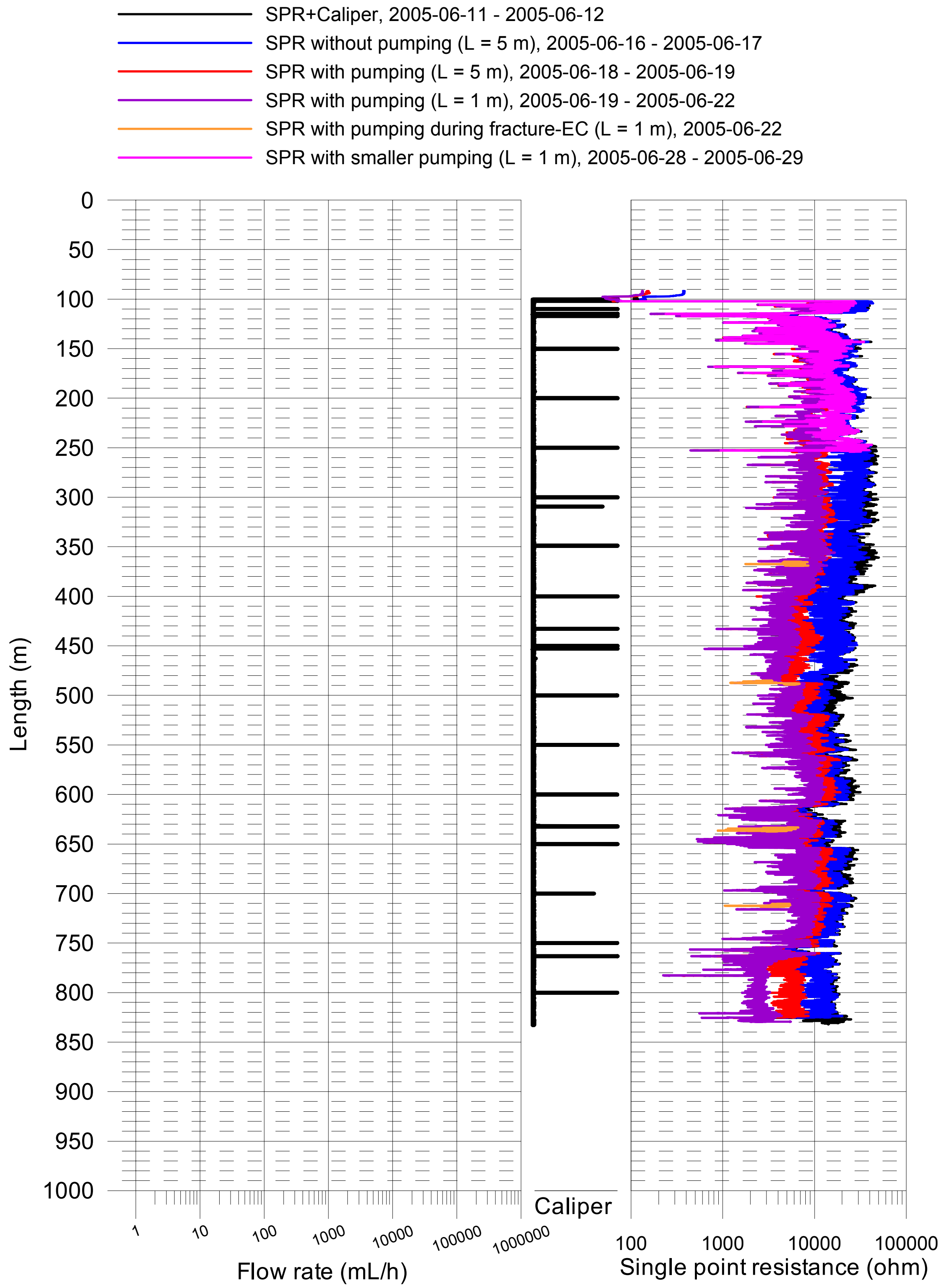
KLX07B

Appendices 15.1–15.11	SPR results after length correction
Appendix 15.12	Length correction
Appendix 16	Flow rate and Single point resistance
Appendix 17.1	Plotted flow rates of 5 m sections

Laxemar, KLX07A
SPR and Caliper results after length correction



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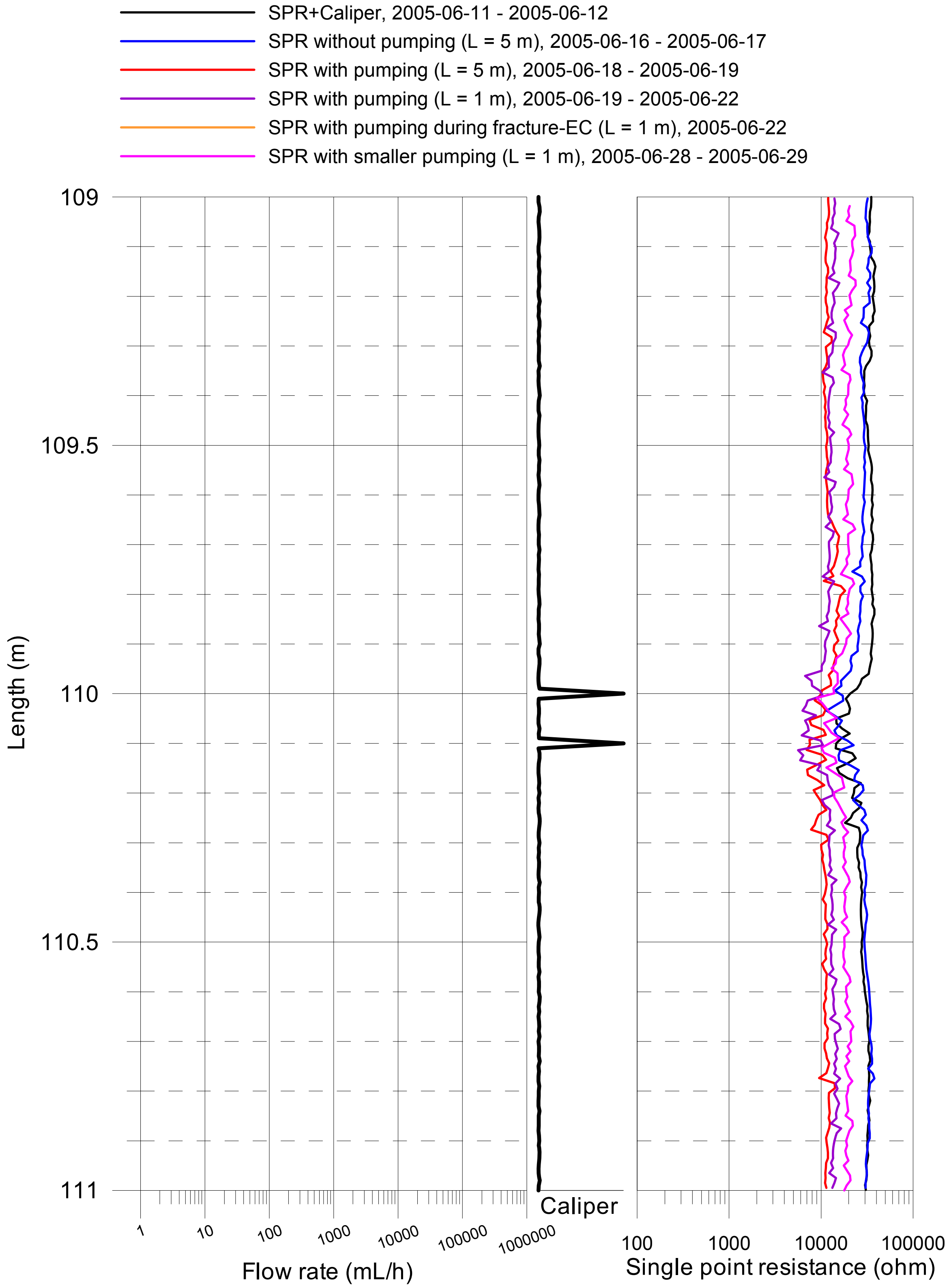

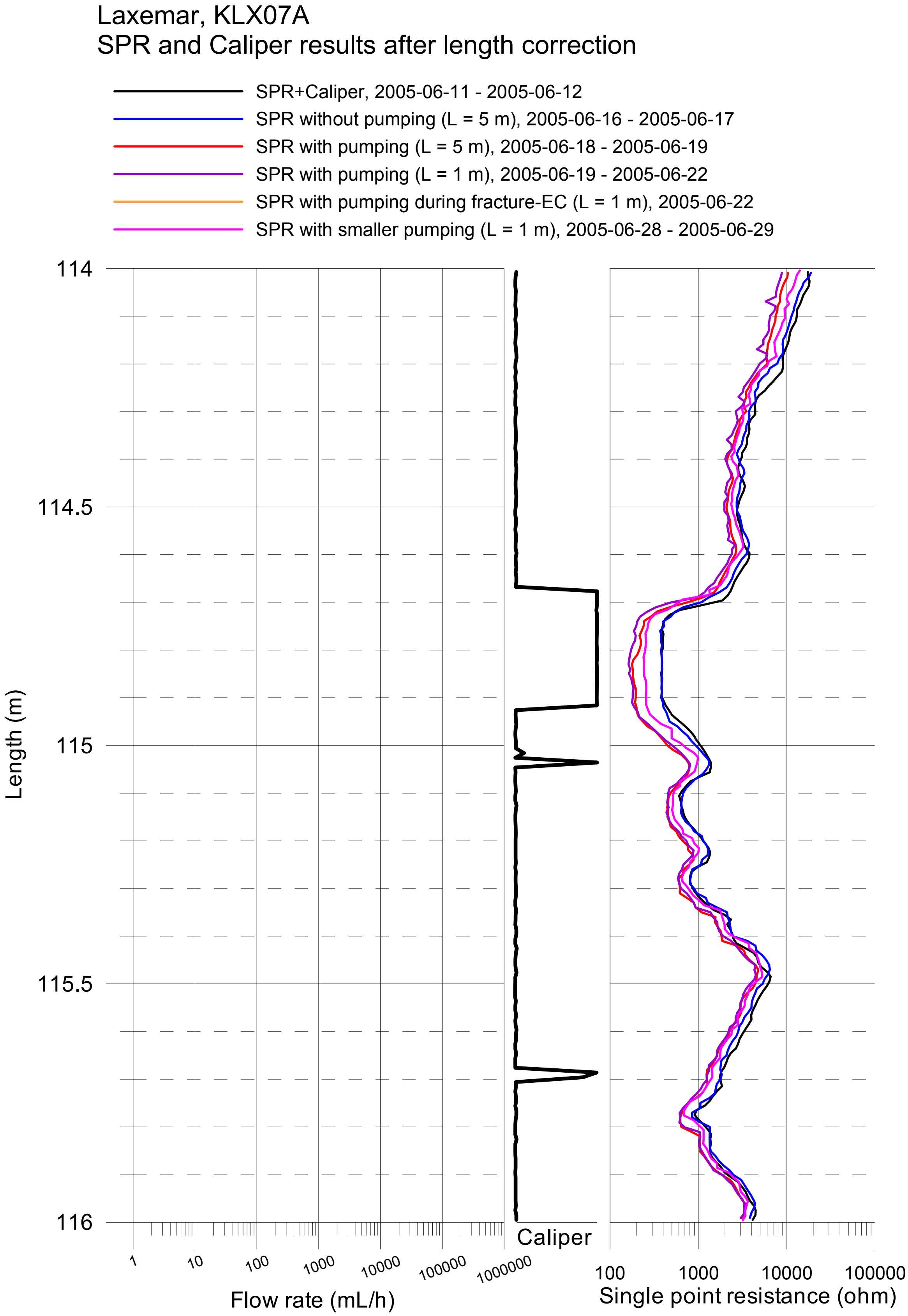
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SPR and Caliper results after length correction
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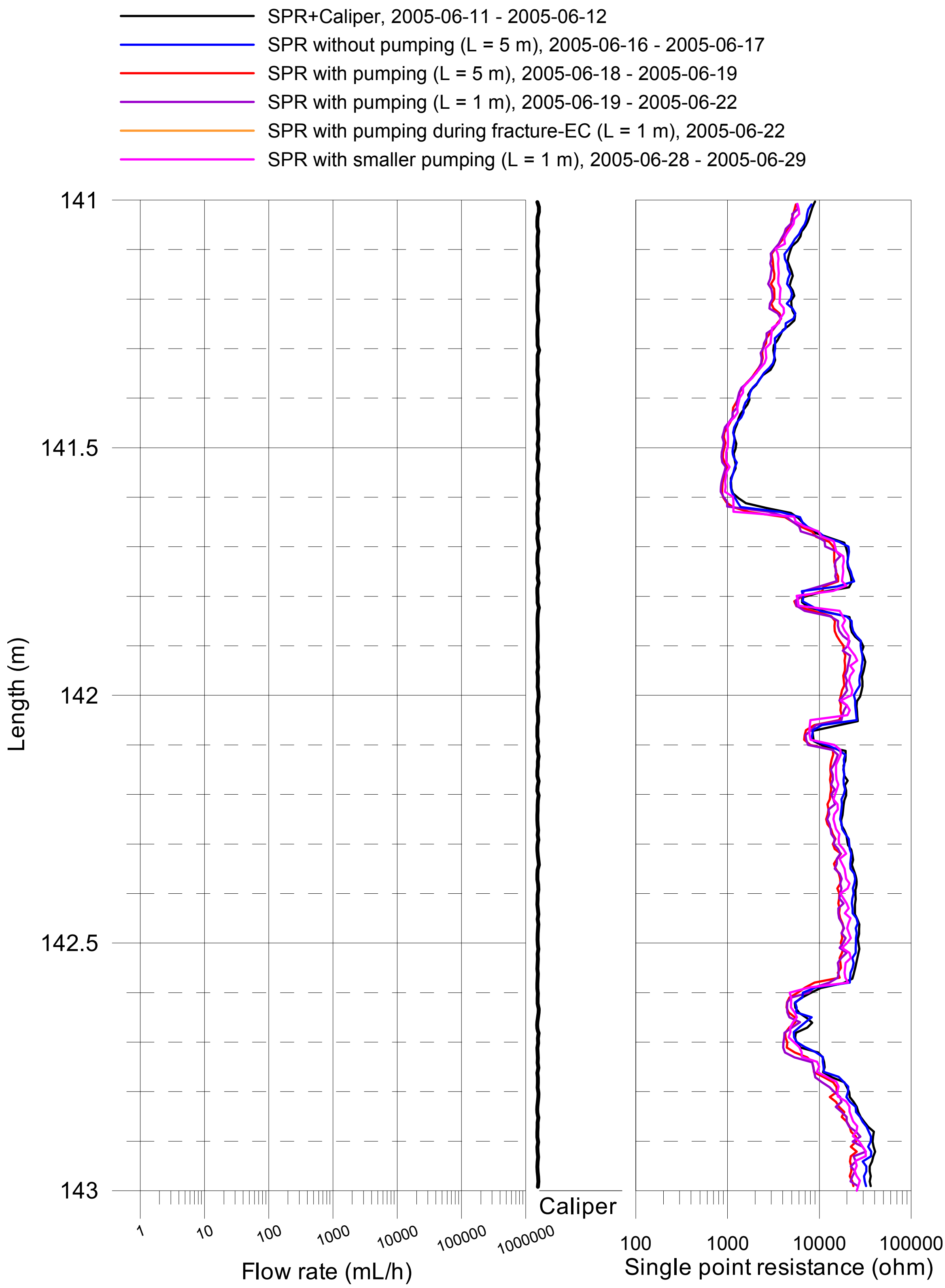
SPR with pumping (L = 5 m), 2005-06-18 - 2005-06-19
SPR with pumping (L = 1 m), 2005-06-19 - 2005-06-22
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
114
114.5
115
115.5
116
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

Laxemar, KLX07A
SPR and Caliper results after length correction



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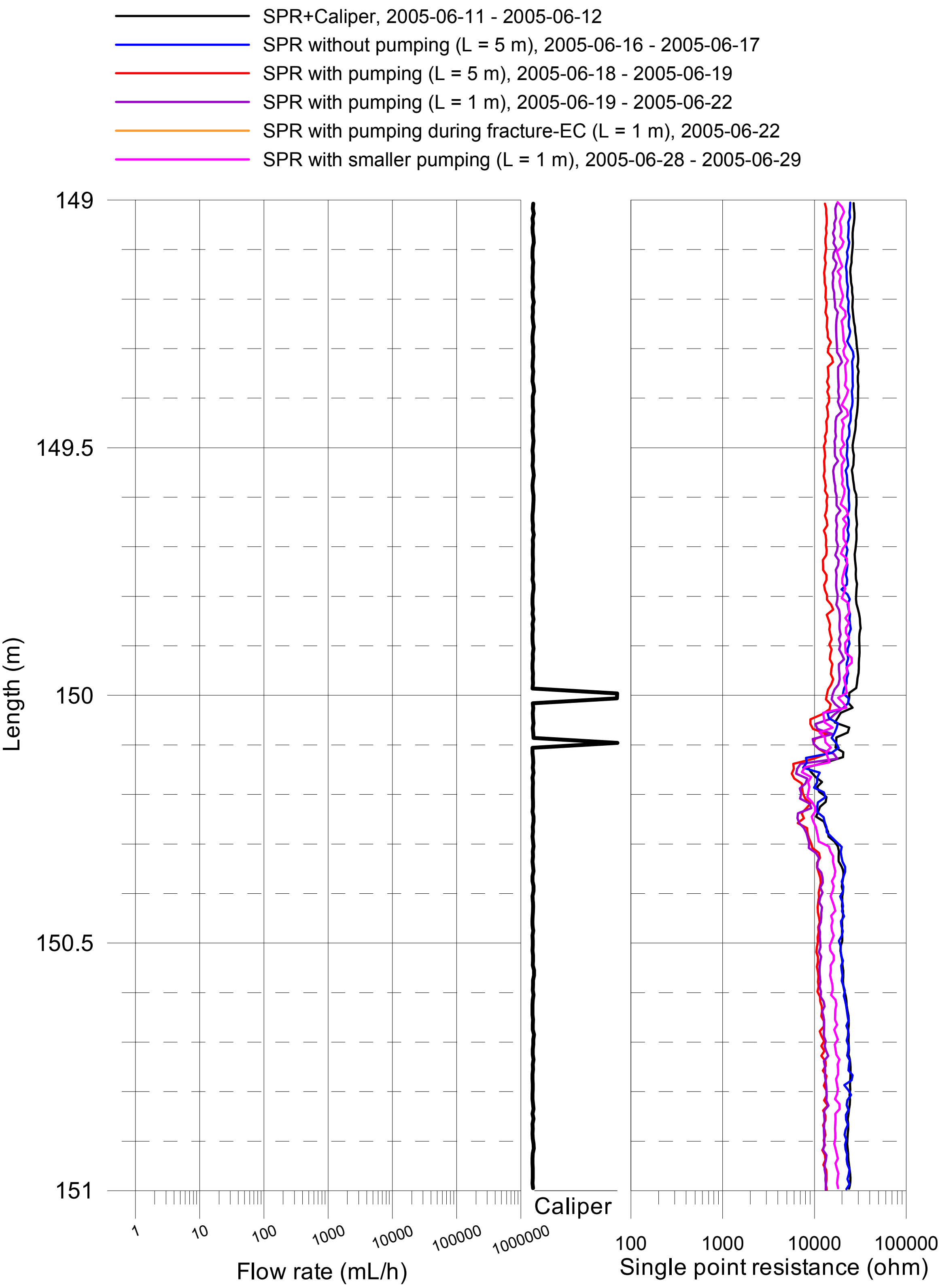

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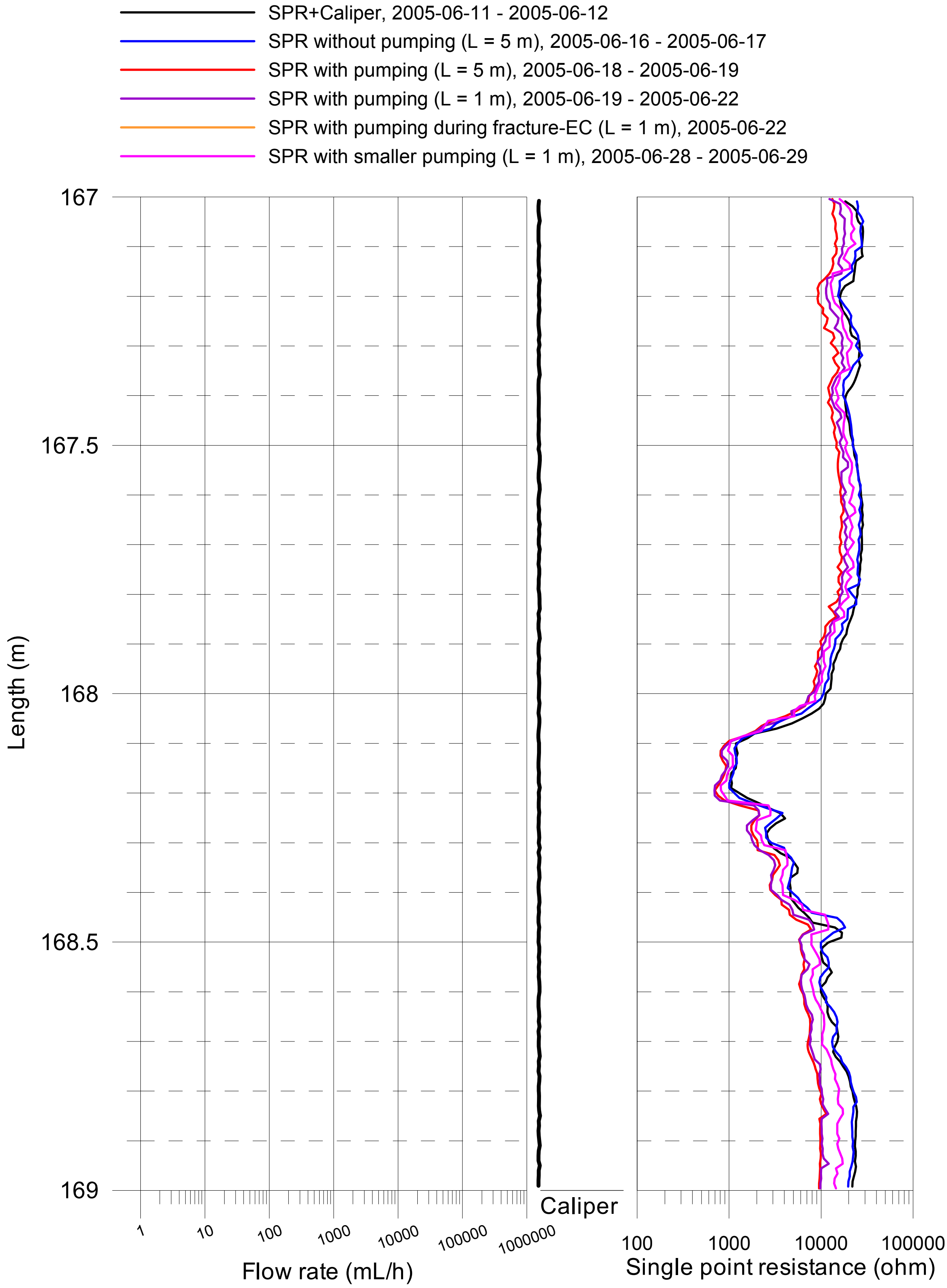

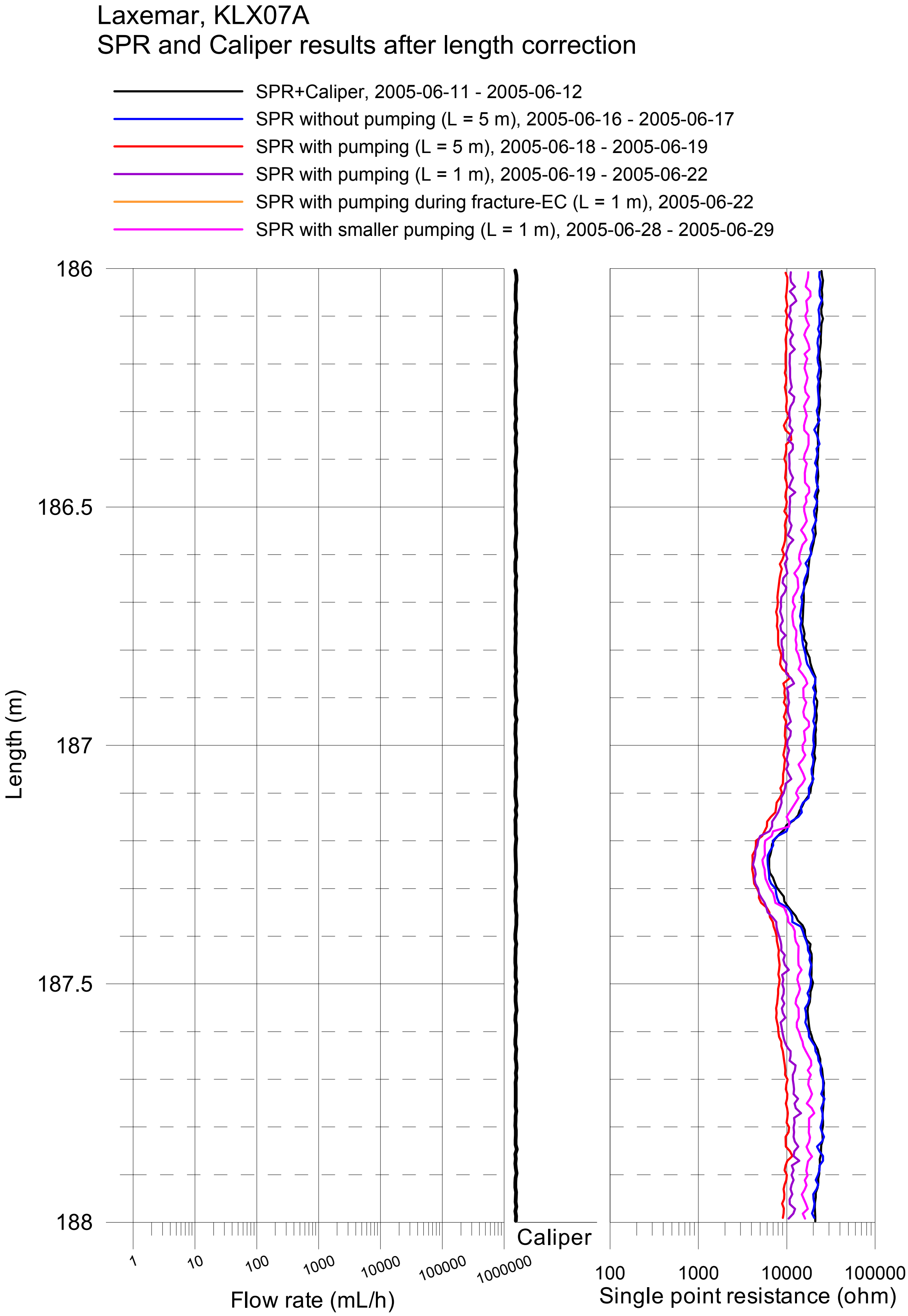
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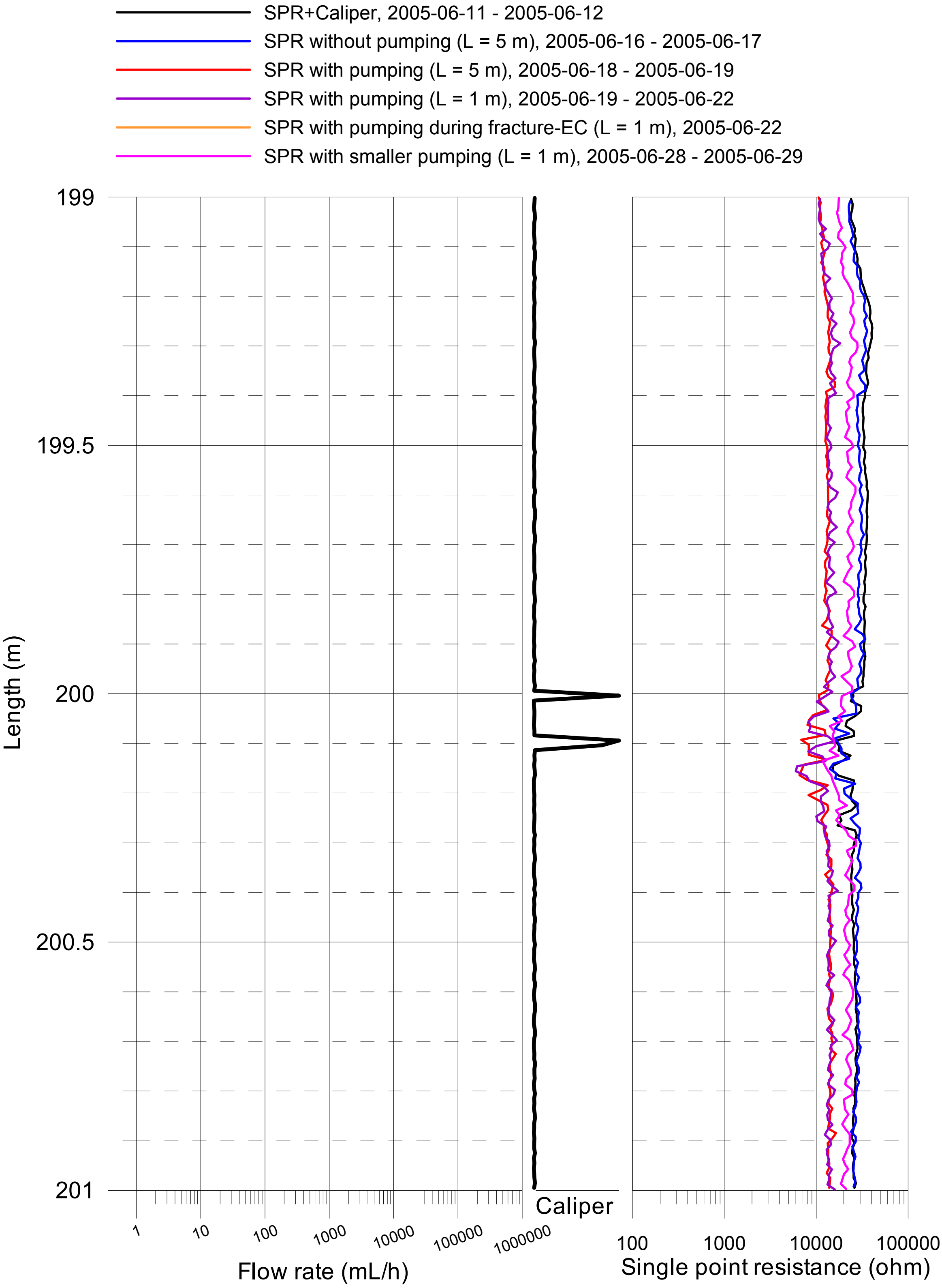
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
186
186.5
187
187.5
188
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

Laxemar, KLX07A
SPR and Caliper results after length correction



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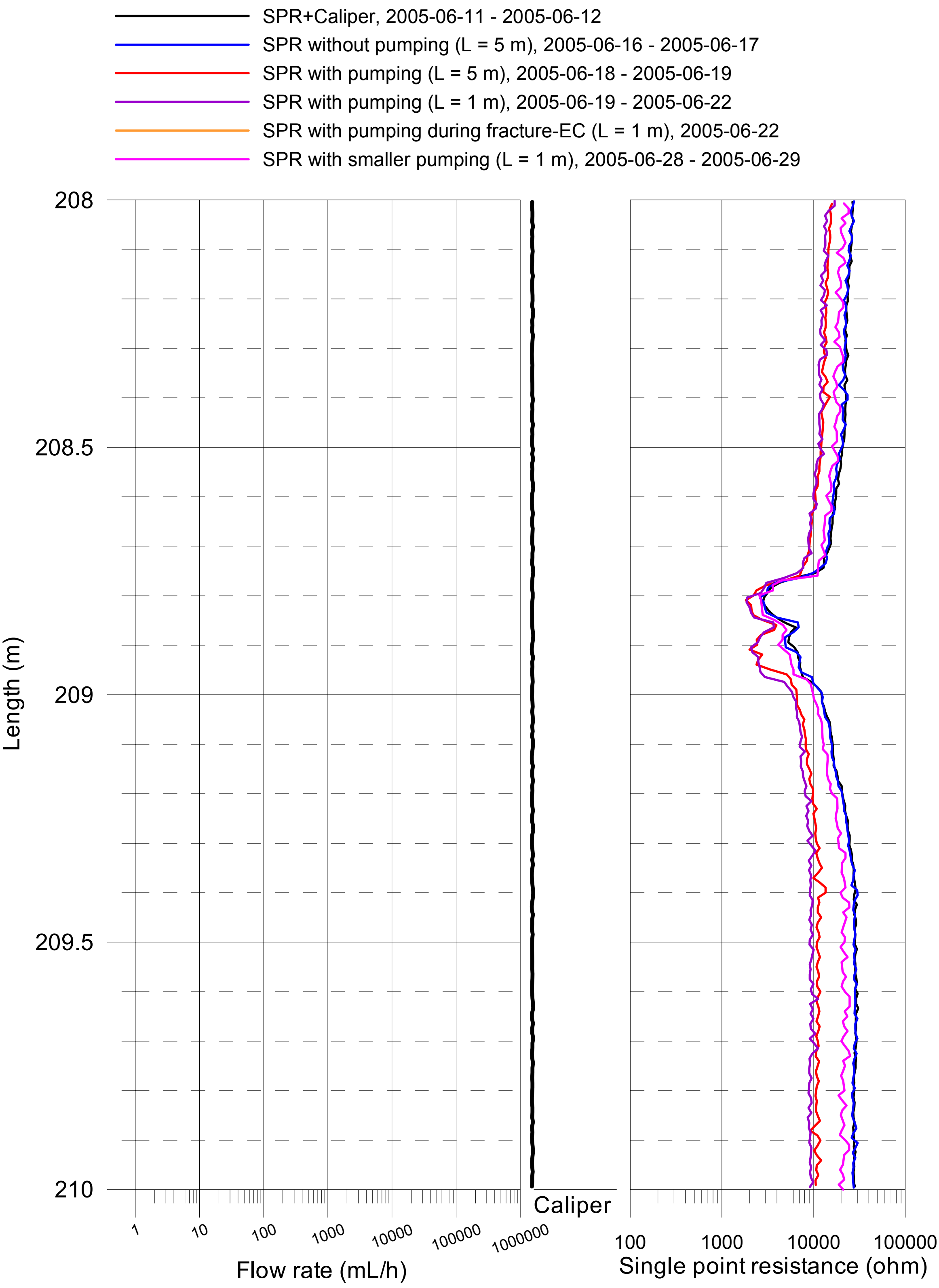

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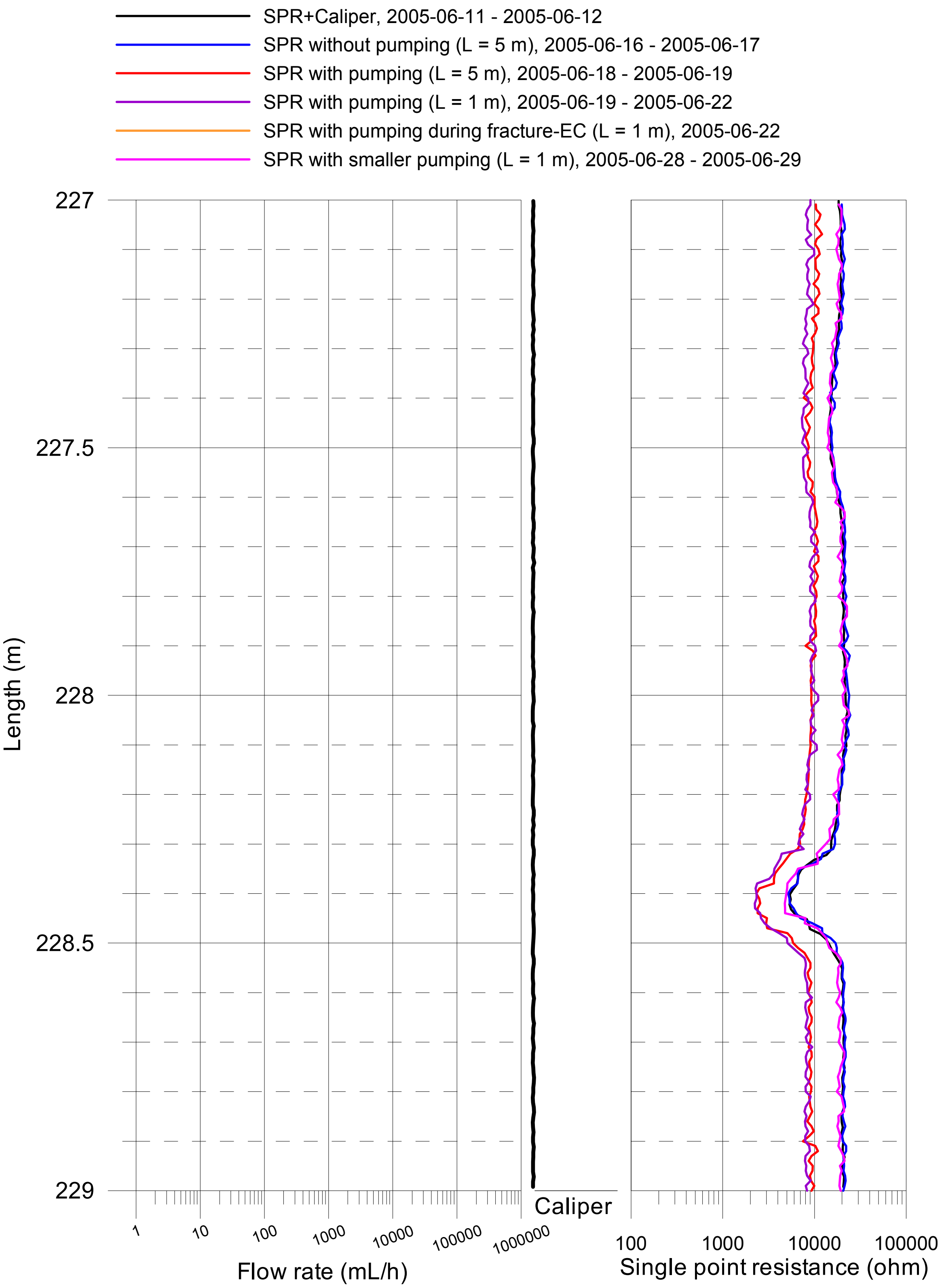

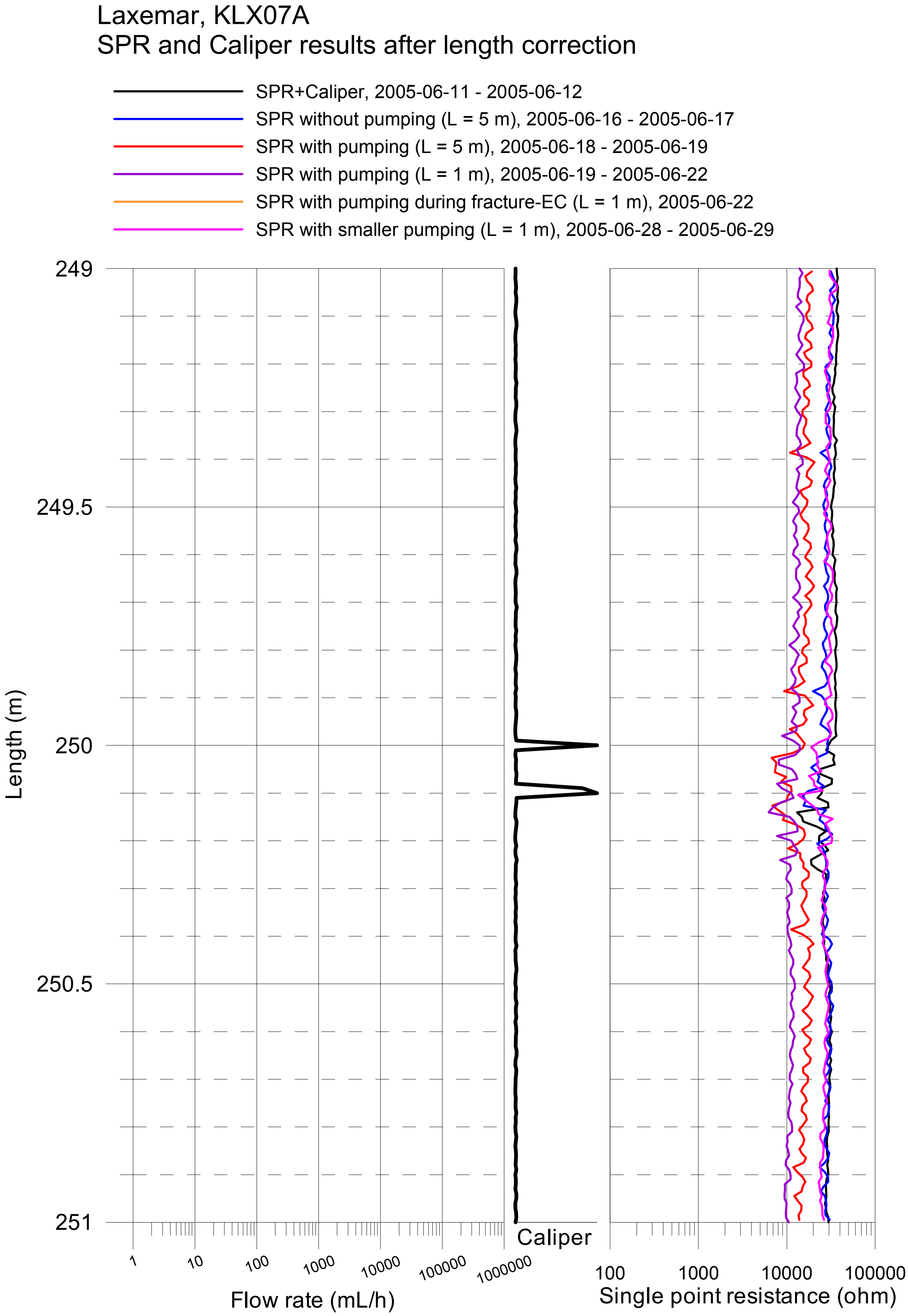
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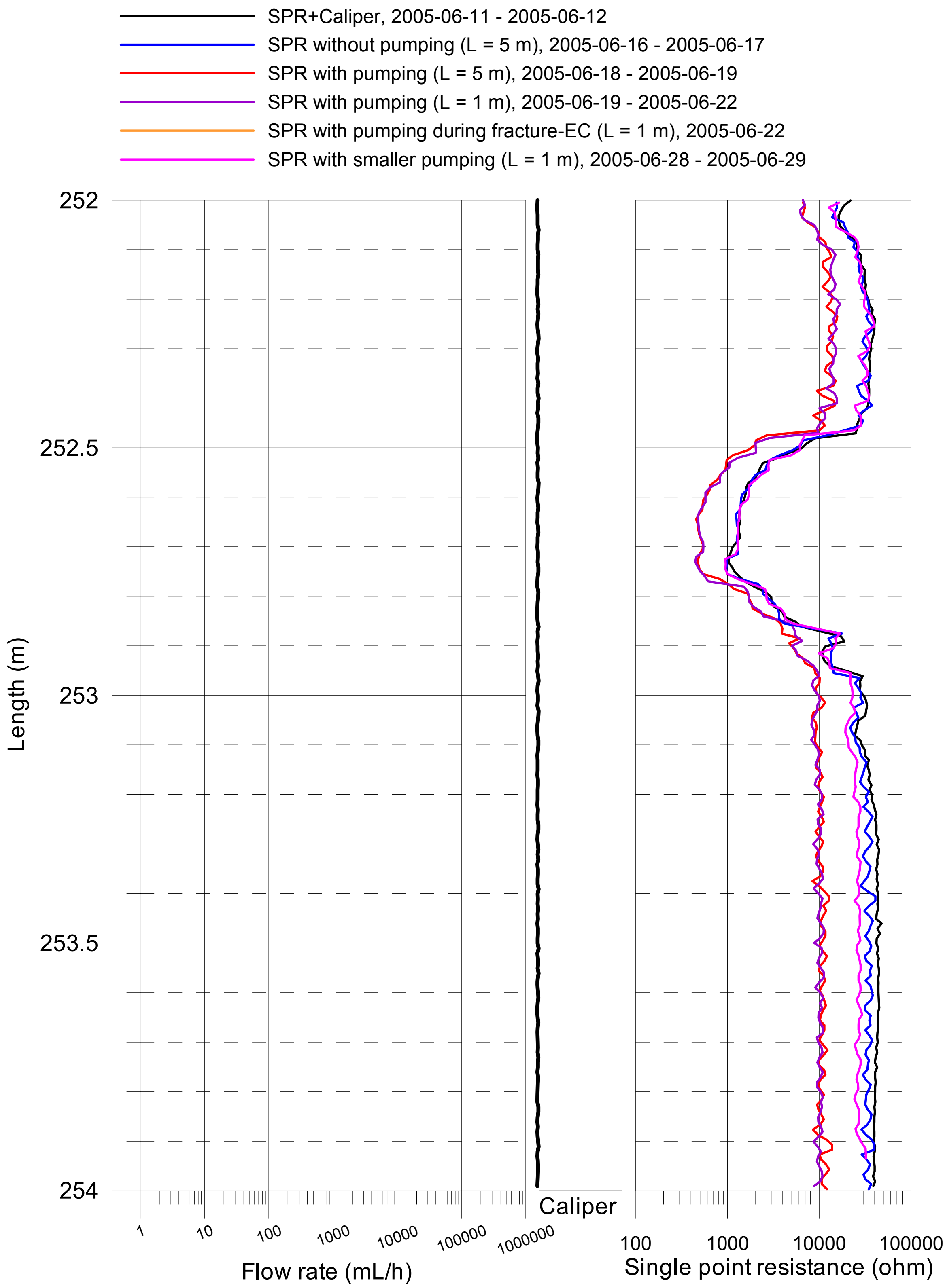
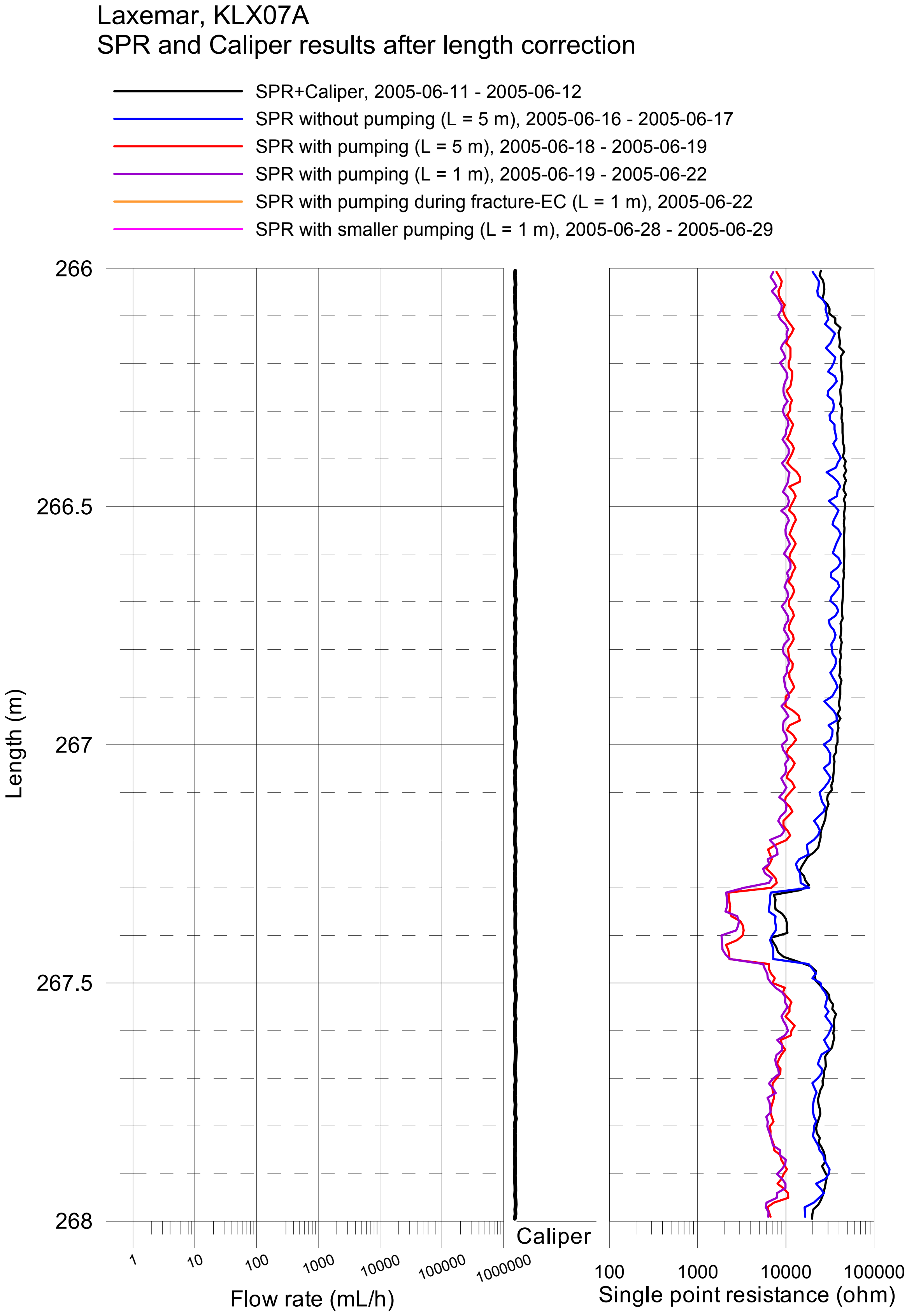
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
Length (m)
249
249.5
250
250.5
251
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

Laxemar, KLX07A
SPR and Caliper results after length correction





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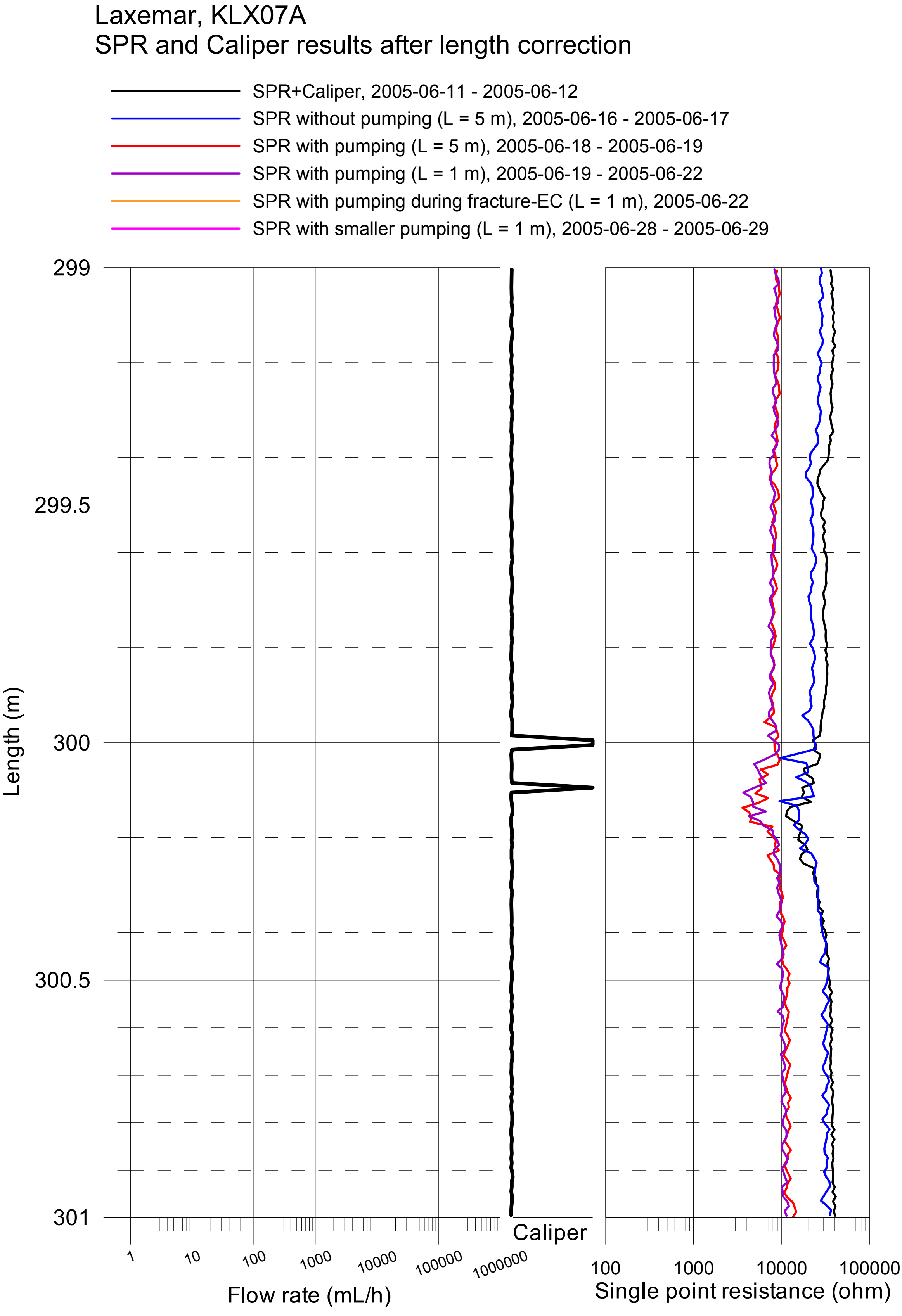
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
Length (m)
266
266.5
267
267.5
268
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)



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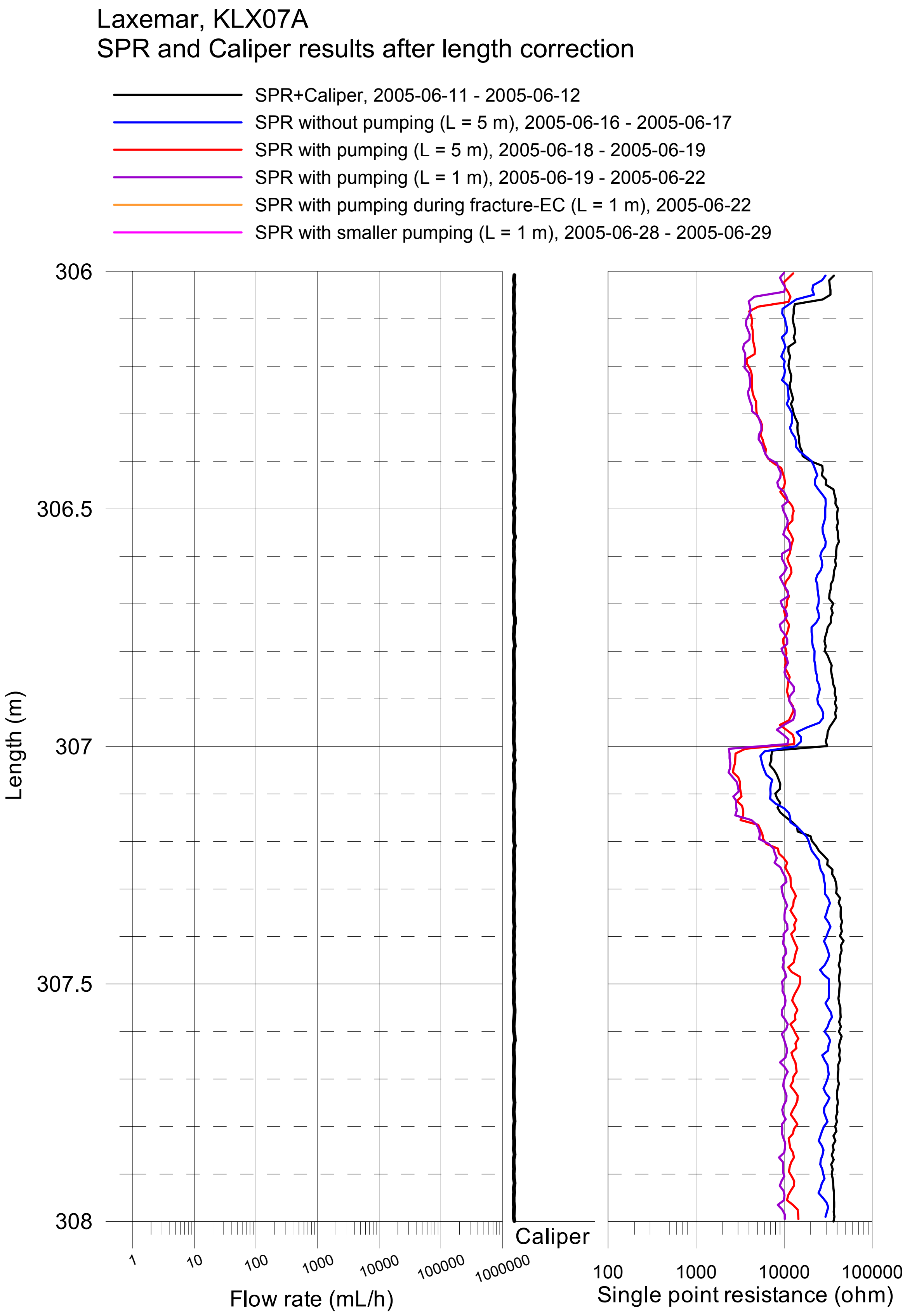
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
Length (m)
299
299.5
300
300.5
301
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)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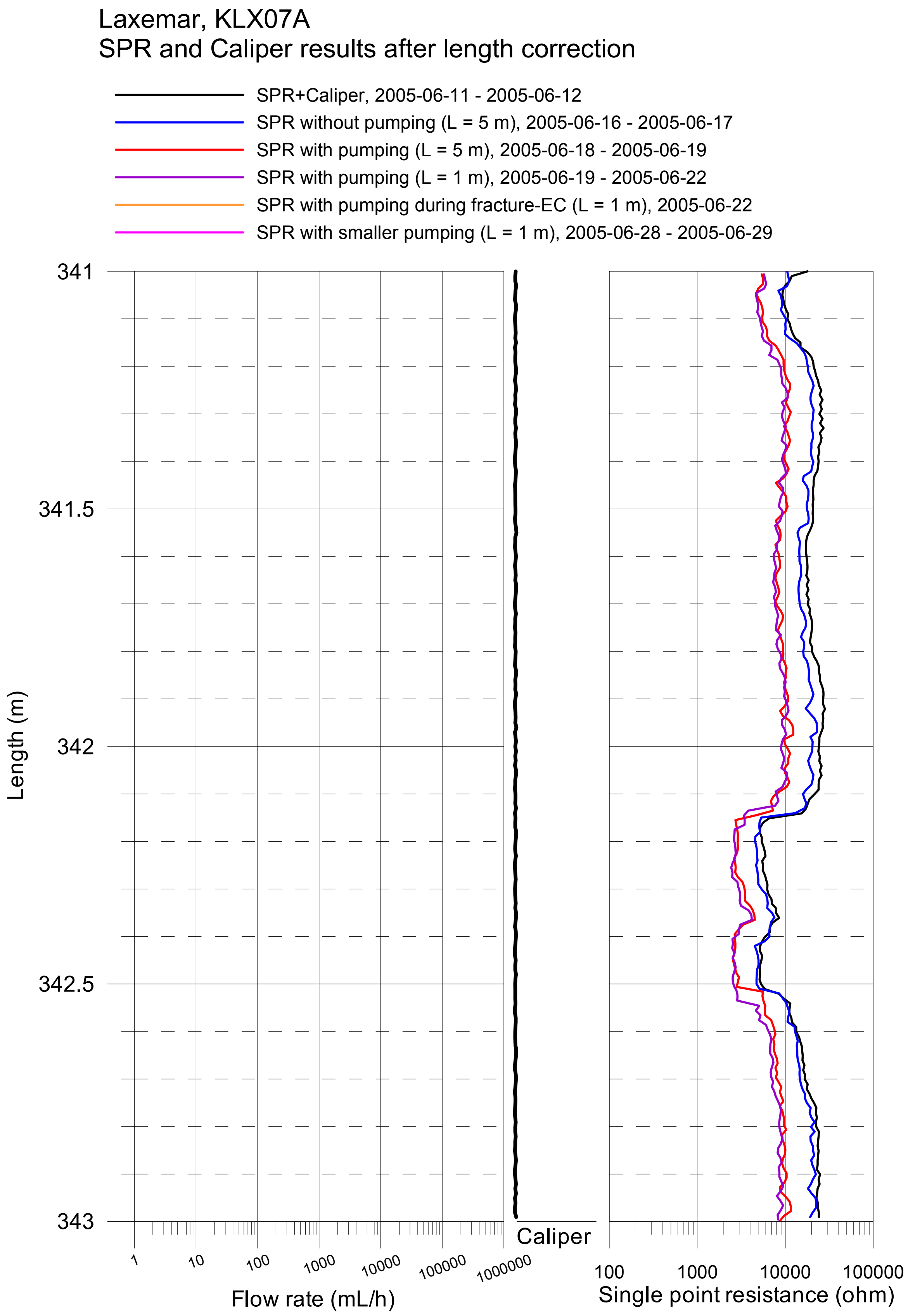
SPR with pumping (L = 1 m), 2005-06-19 - 2005-06-22
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
306
306.5
307
307.5
308
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)



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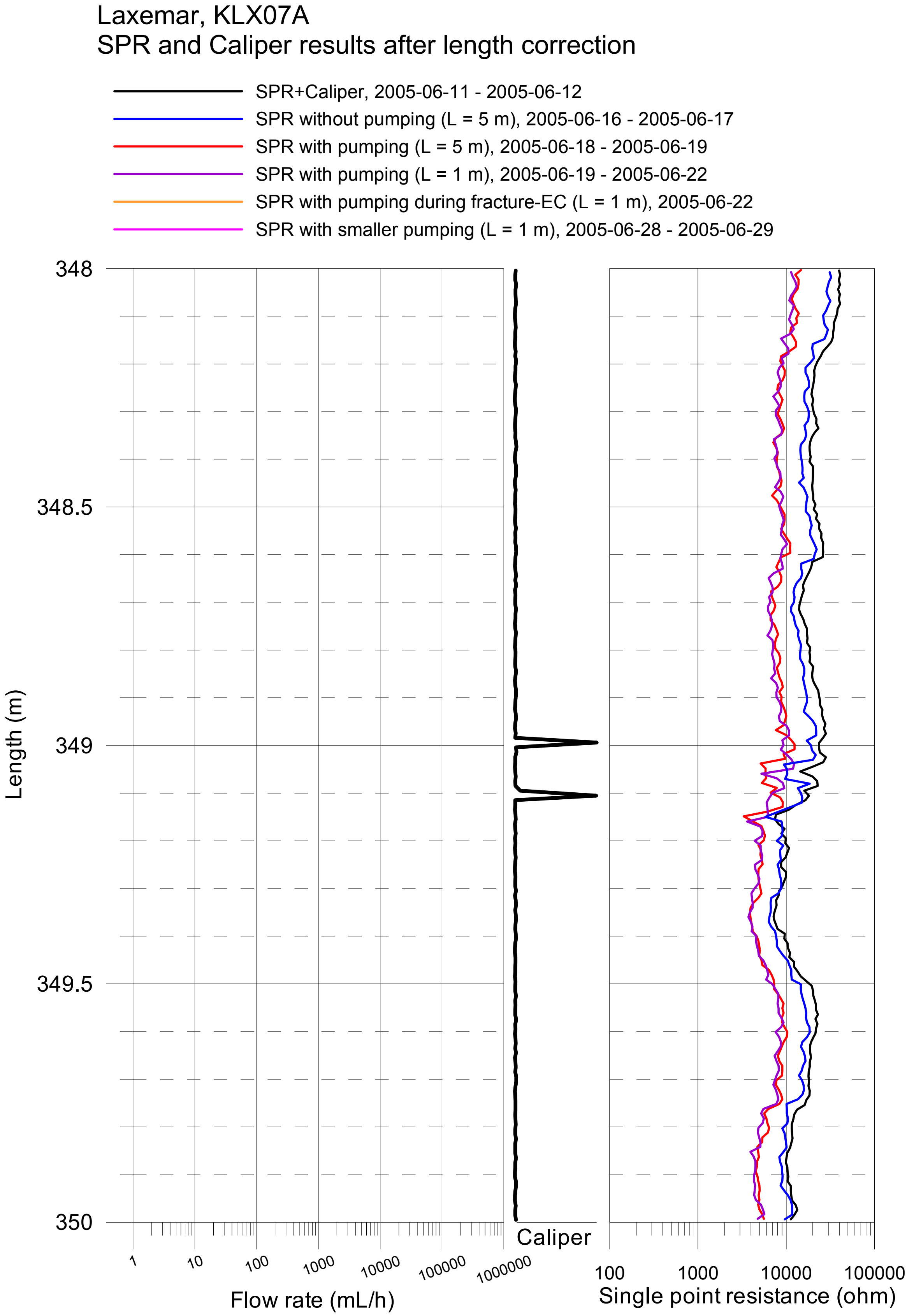
SPR with pumping (L = 1 m), 2005-06-19 - 2005-06-22
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
Length (m)
341
341.5
342
342.5
343
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)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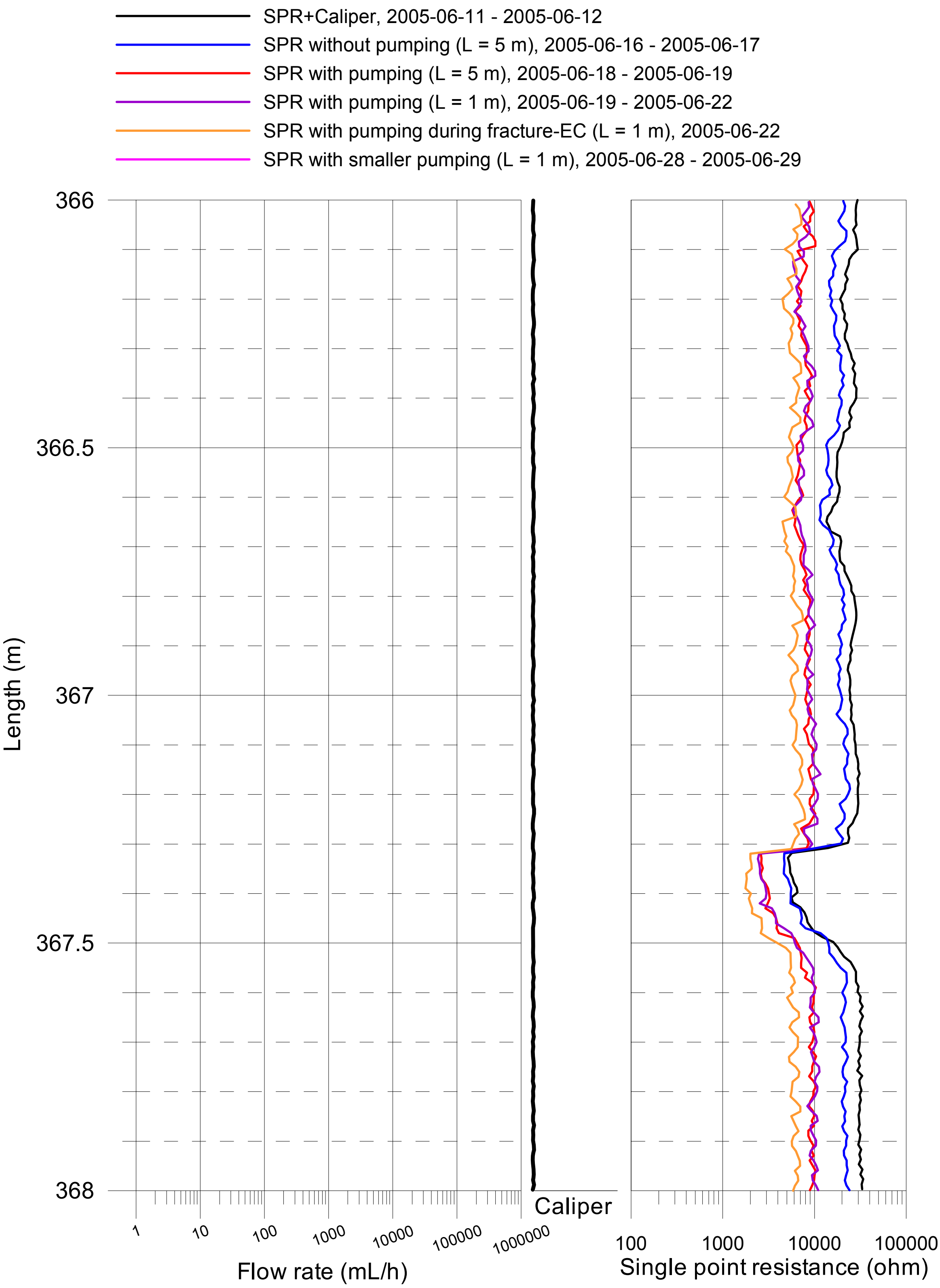
SPR with pumping (L = 1 m), 2005-06-19 - 2005-06-22
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
Length (m)
348
348.5
349
349.5
350
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

Laxemar, KLX07A
SPR and Caliper results after length correction



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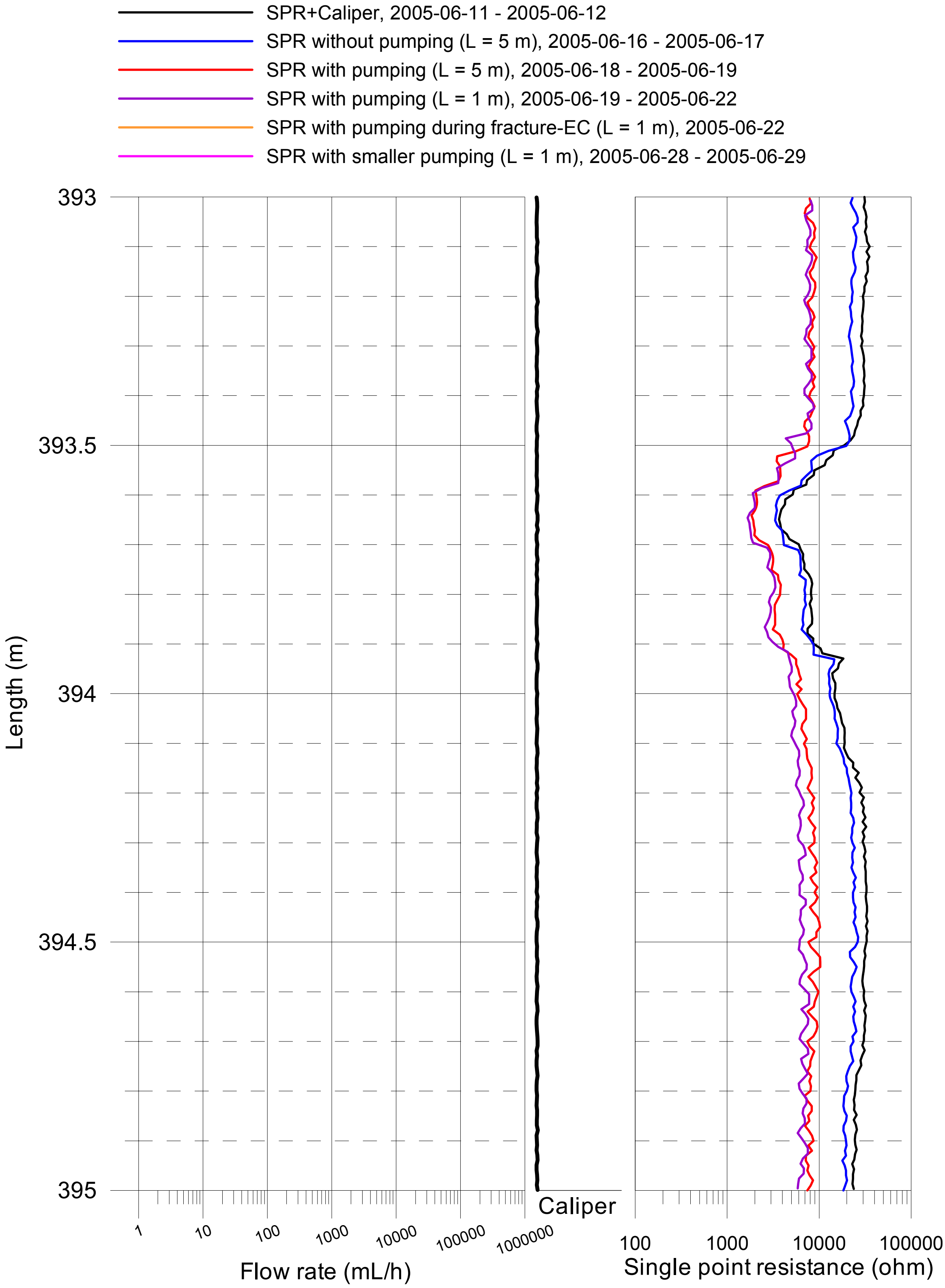

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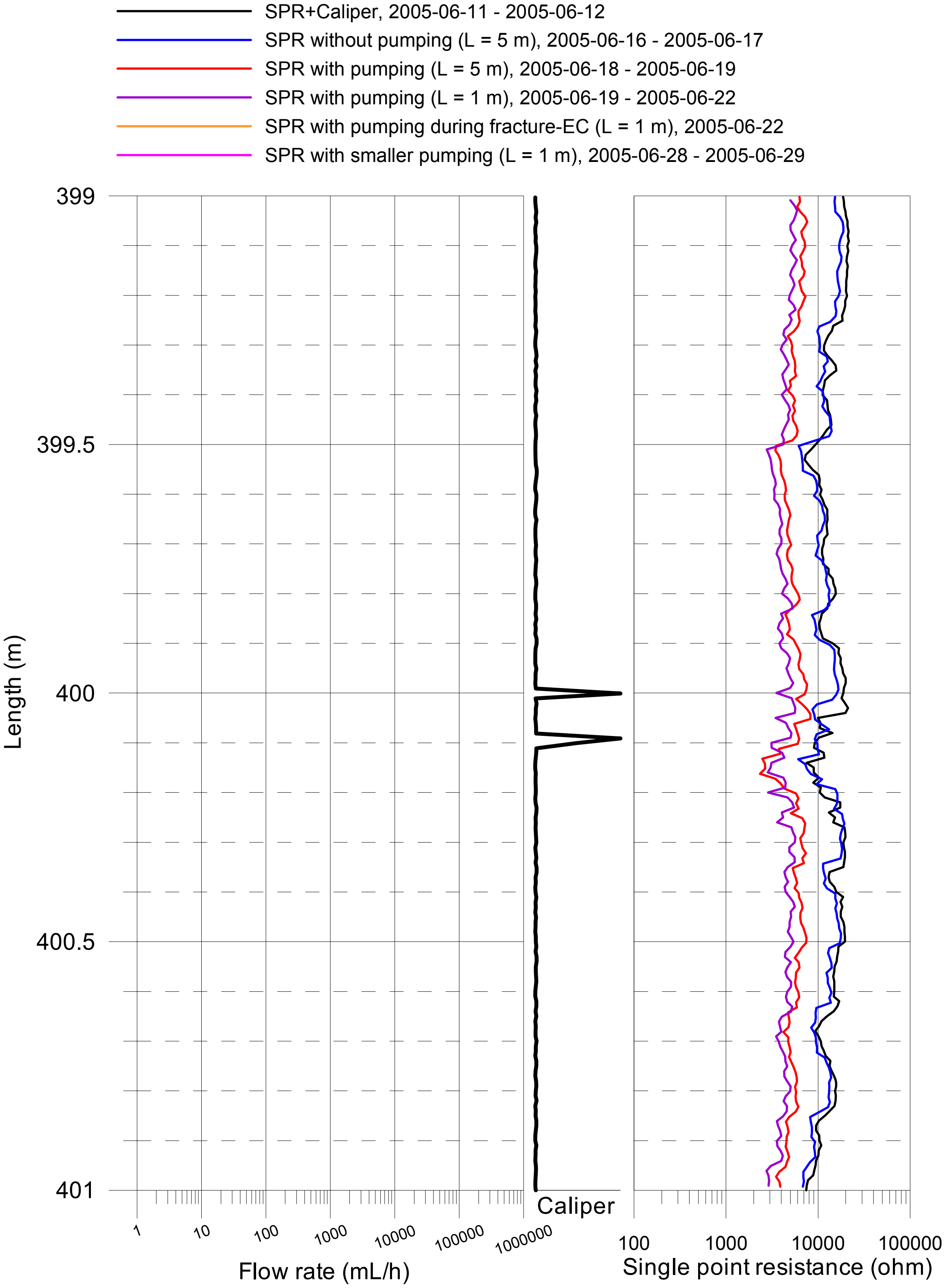

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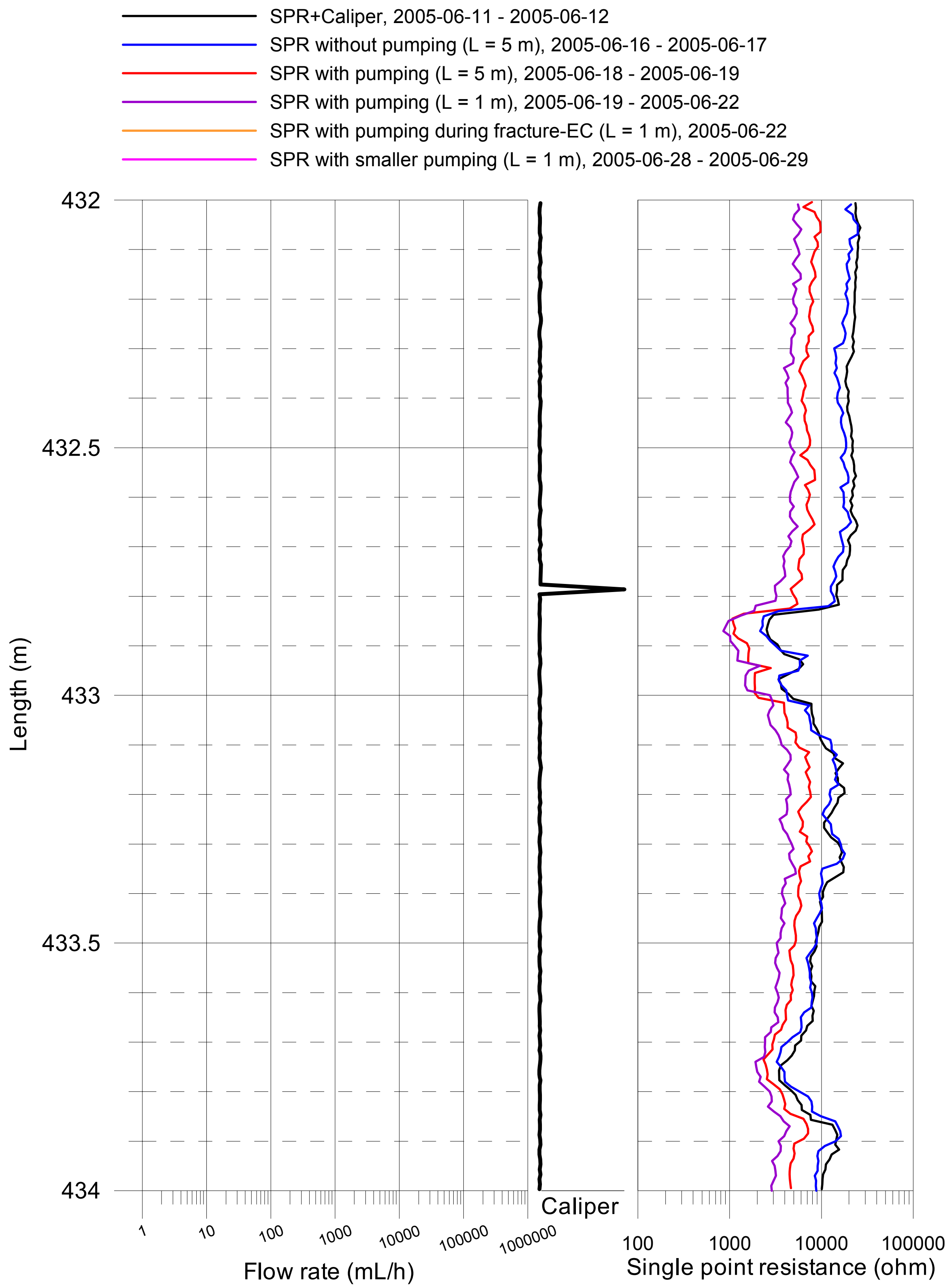

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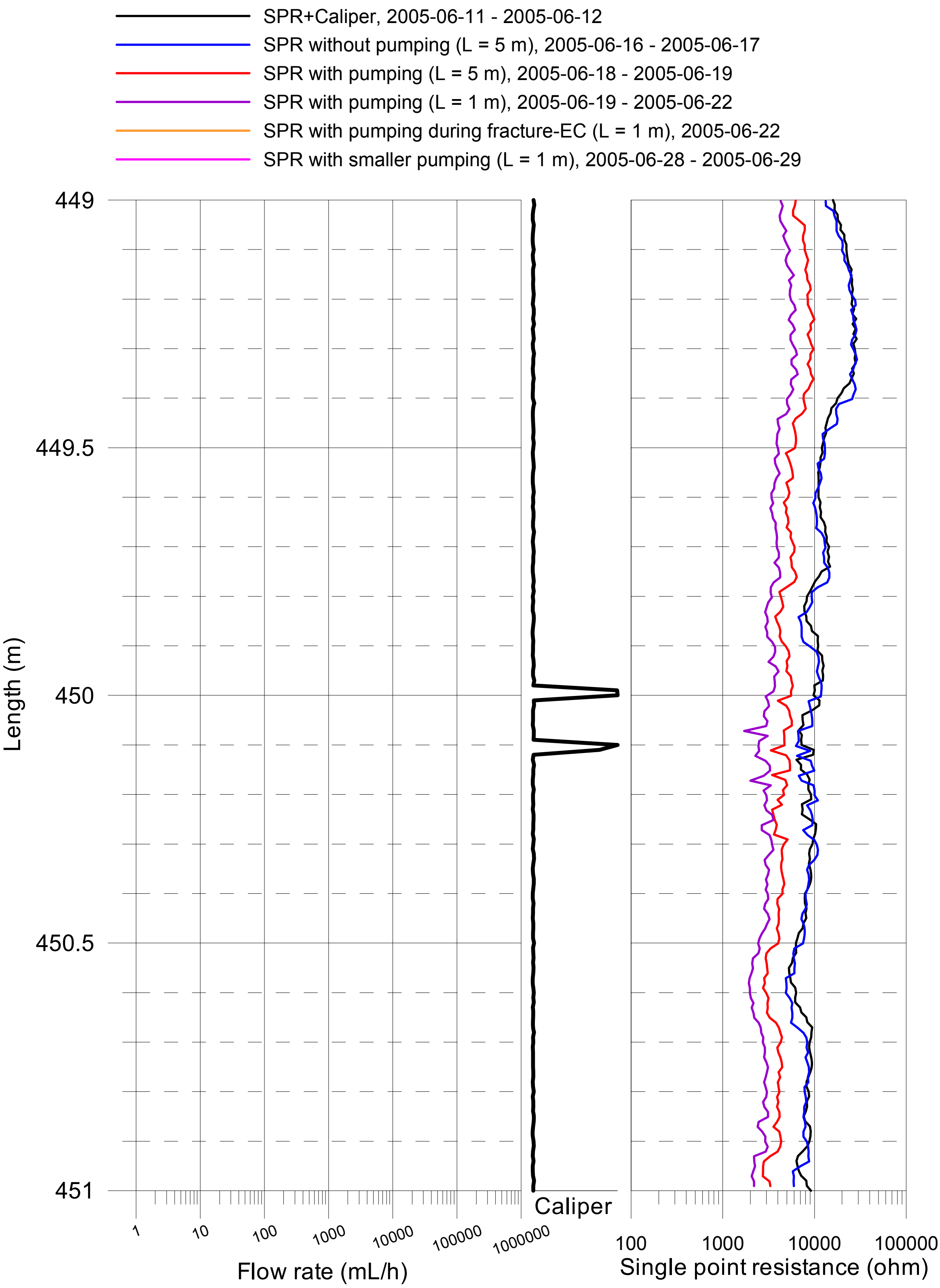

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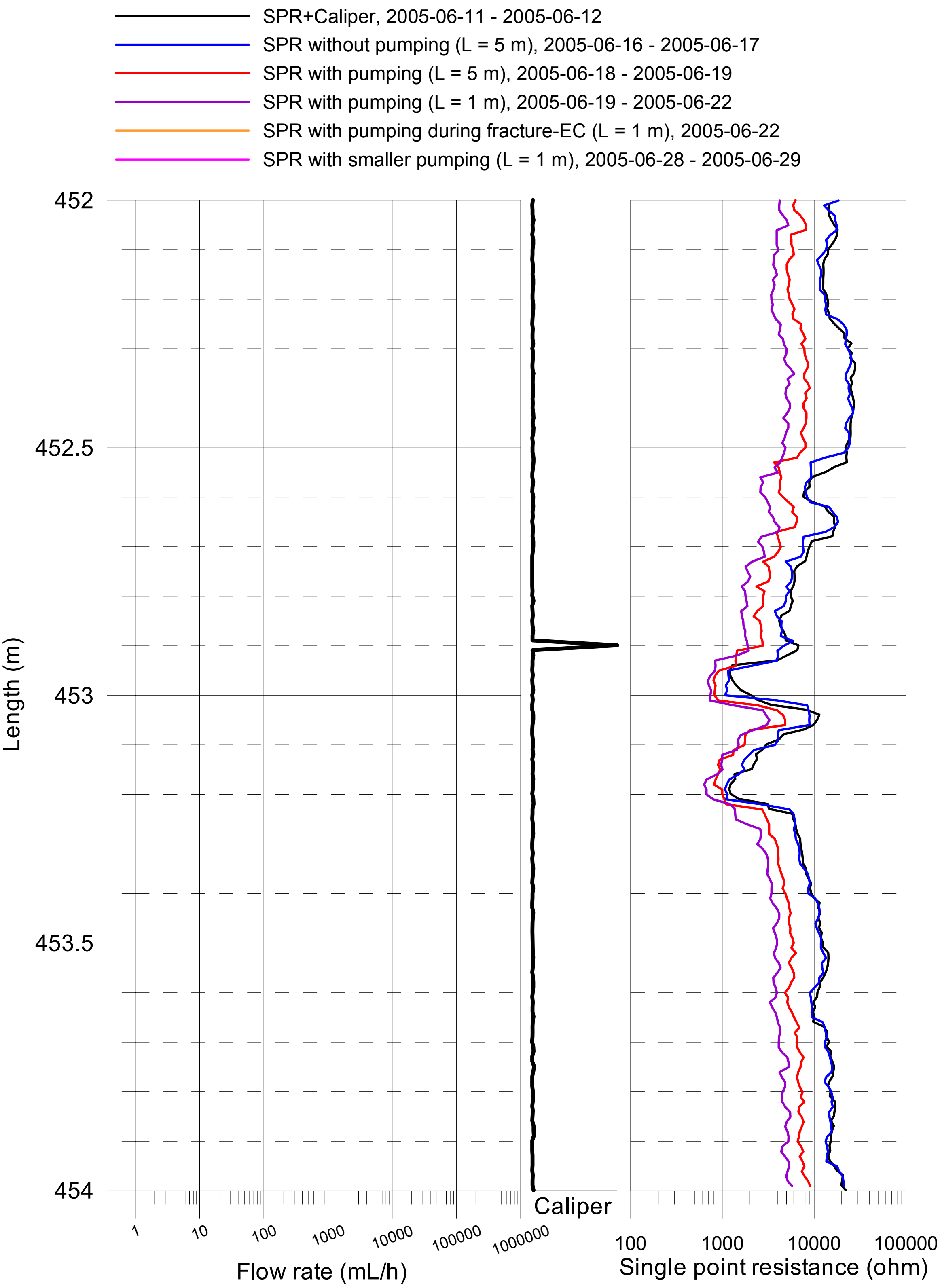

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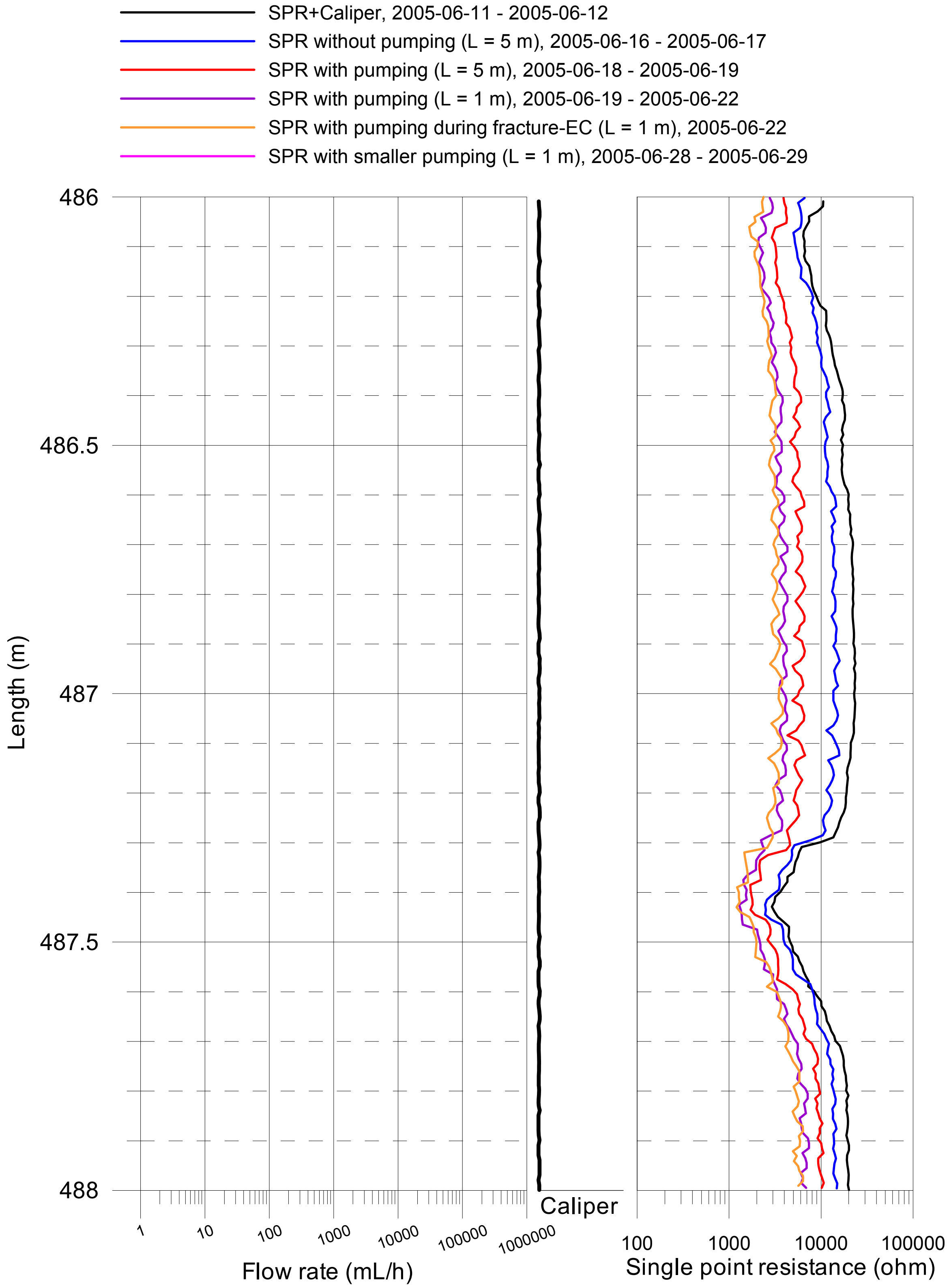

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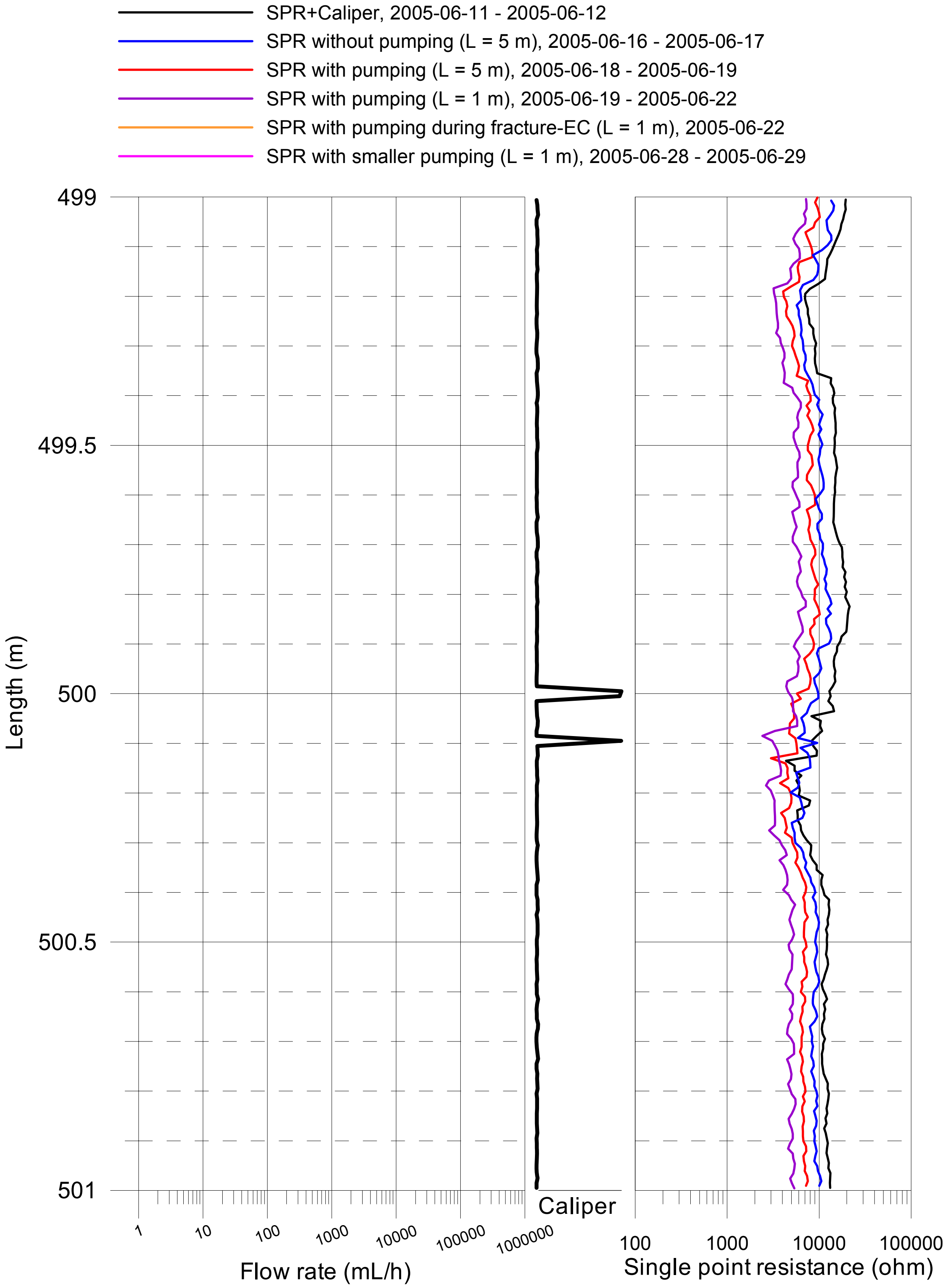

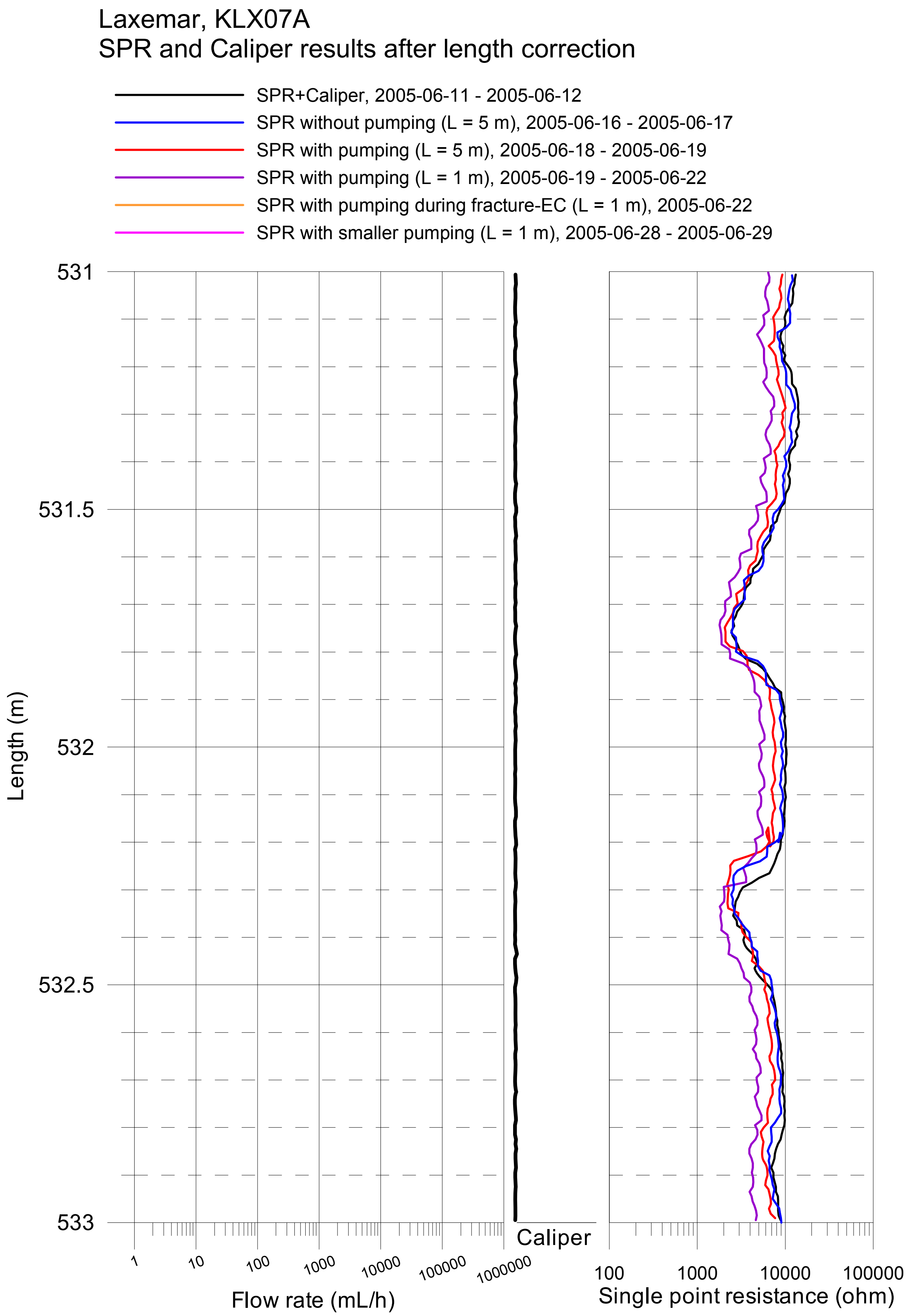
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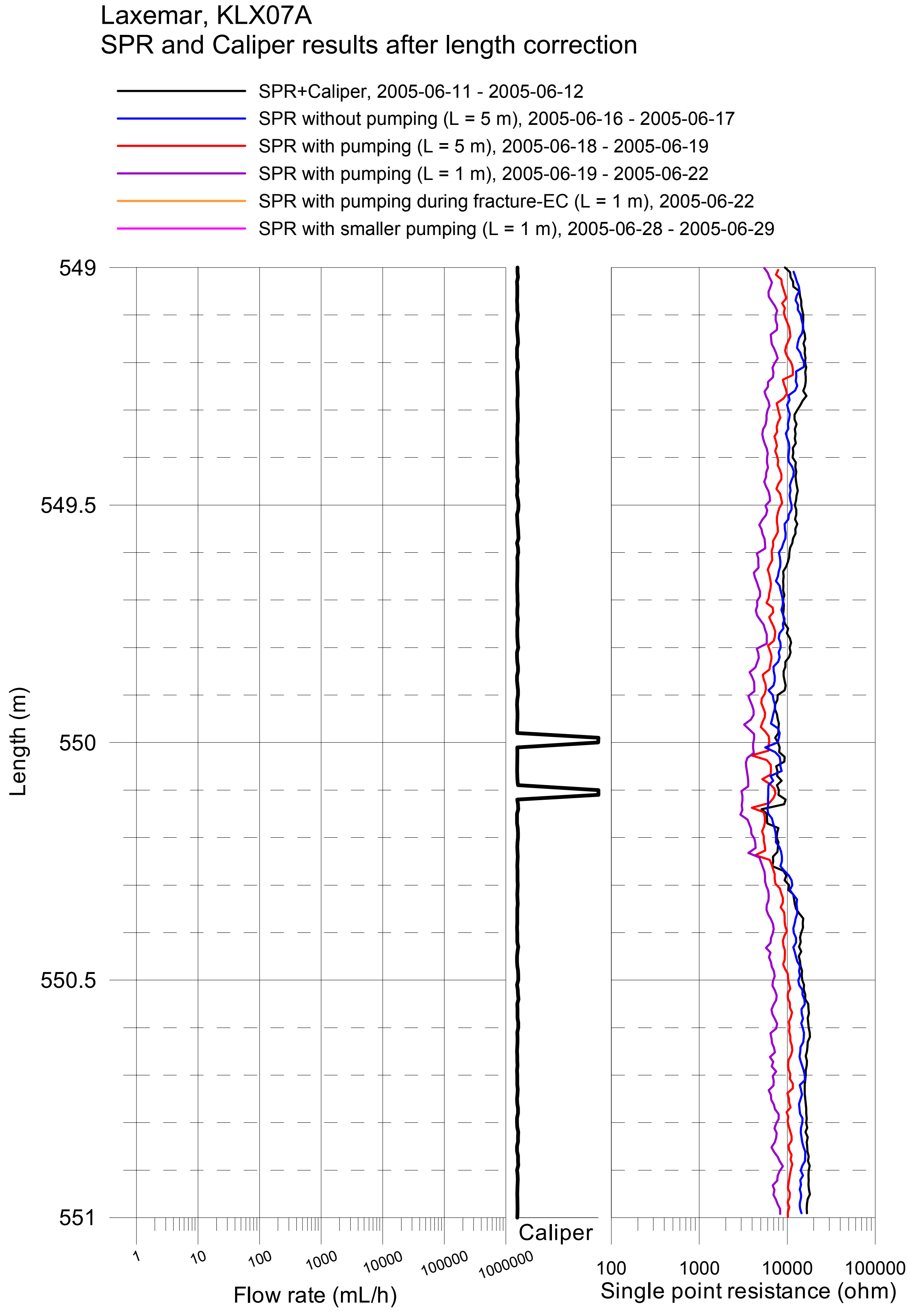
SPR with pumping (L = 1 m), 2005-06-19 - 2005-06-22
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
531
531.5
532
532.5
533
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)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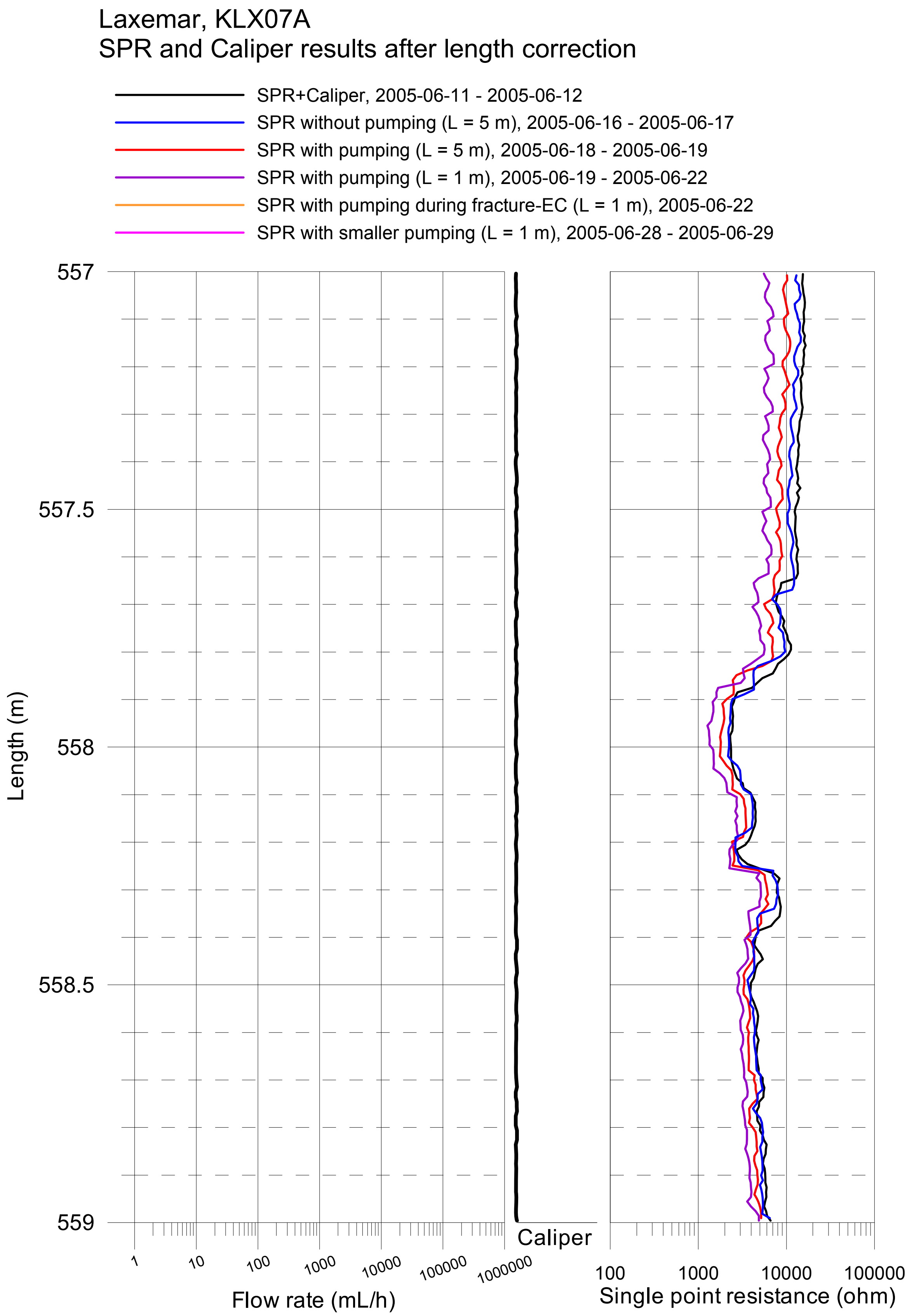
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
549
549.5
550
550.5
551
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)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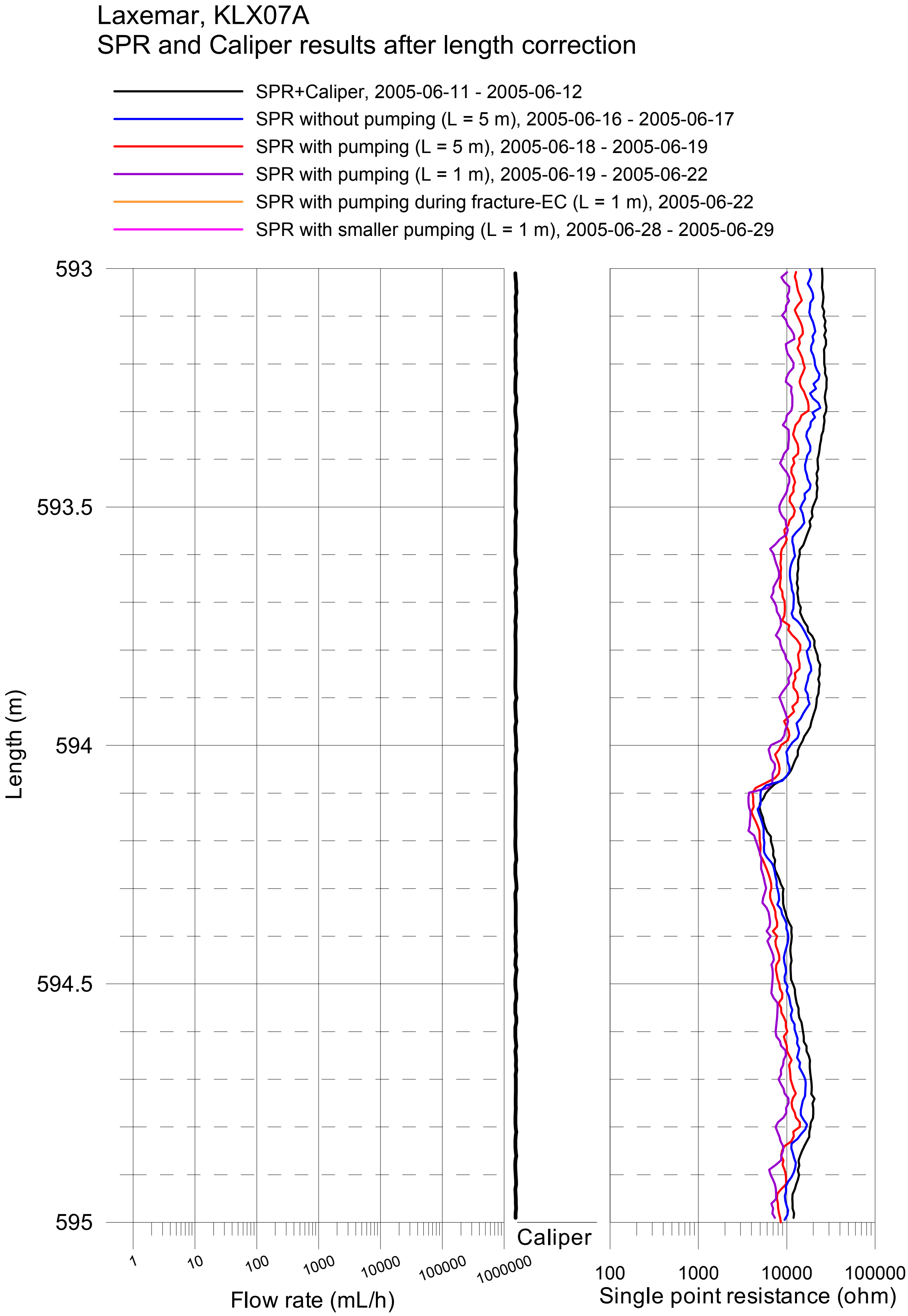
SPR with pumping (L = 1 m), 2005-06-19 - 2005-06-22
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
557
557.5
558
558.5
559
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)



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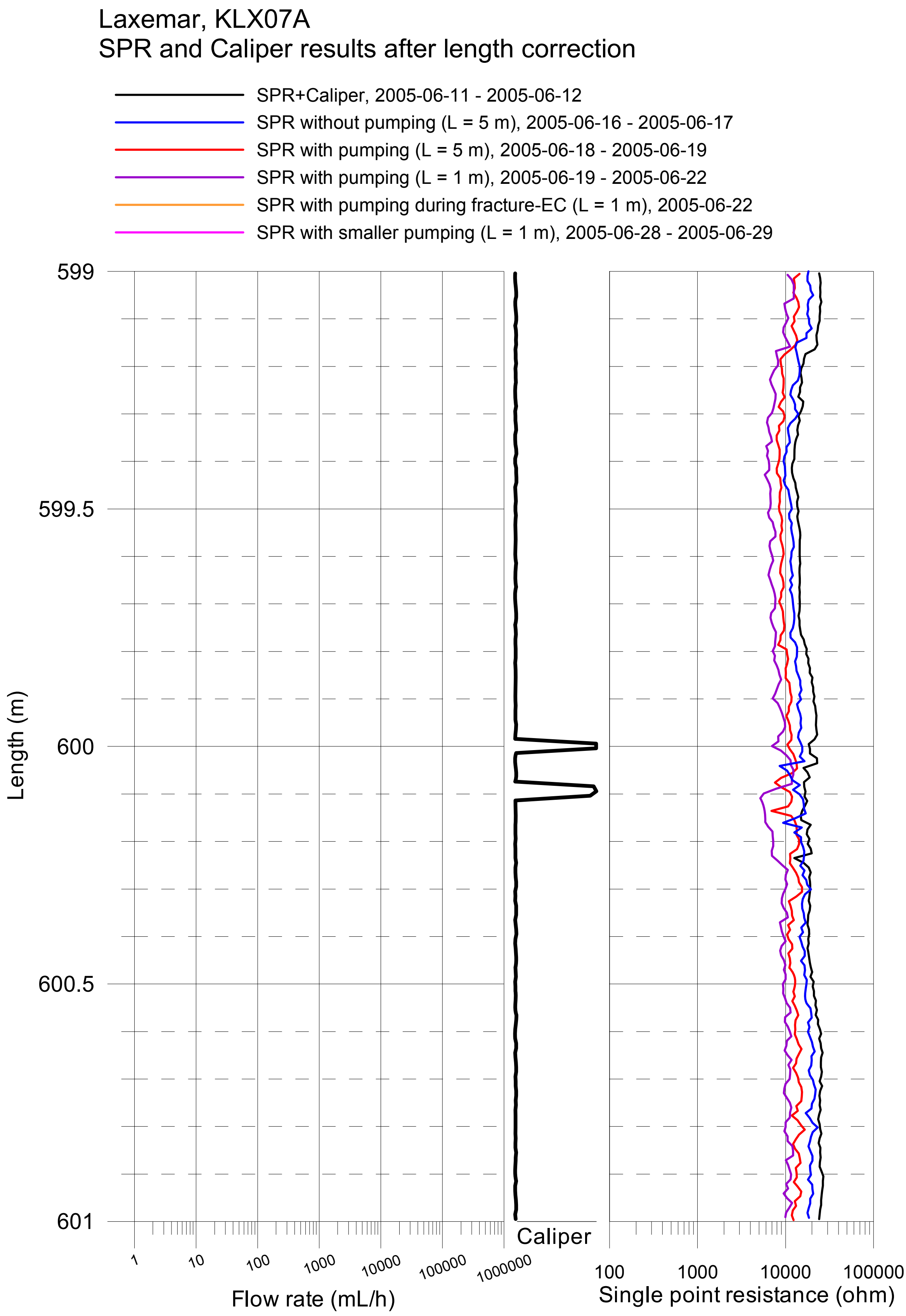
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
593
593.5
594
594.5
595
Length (m)
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)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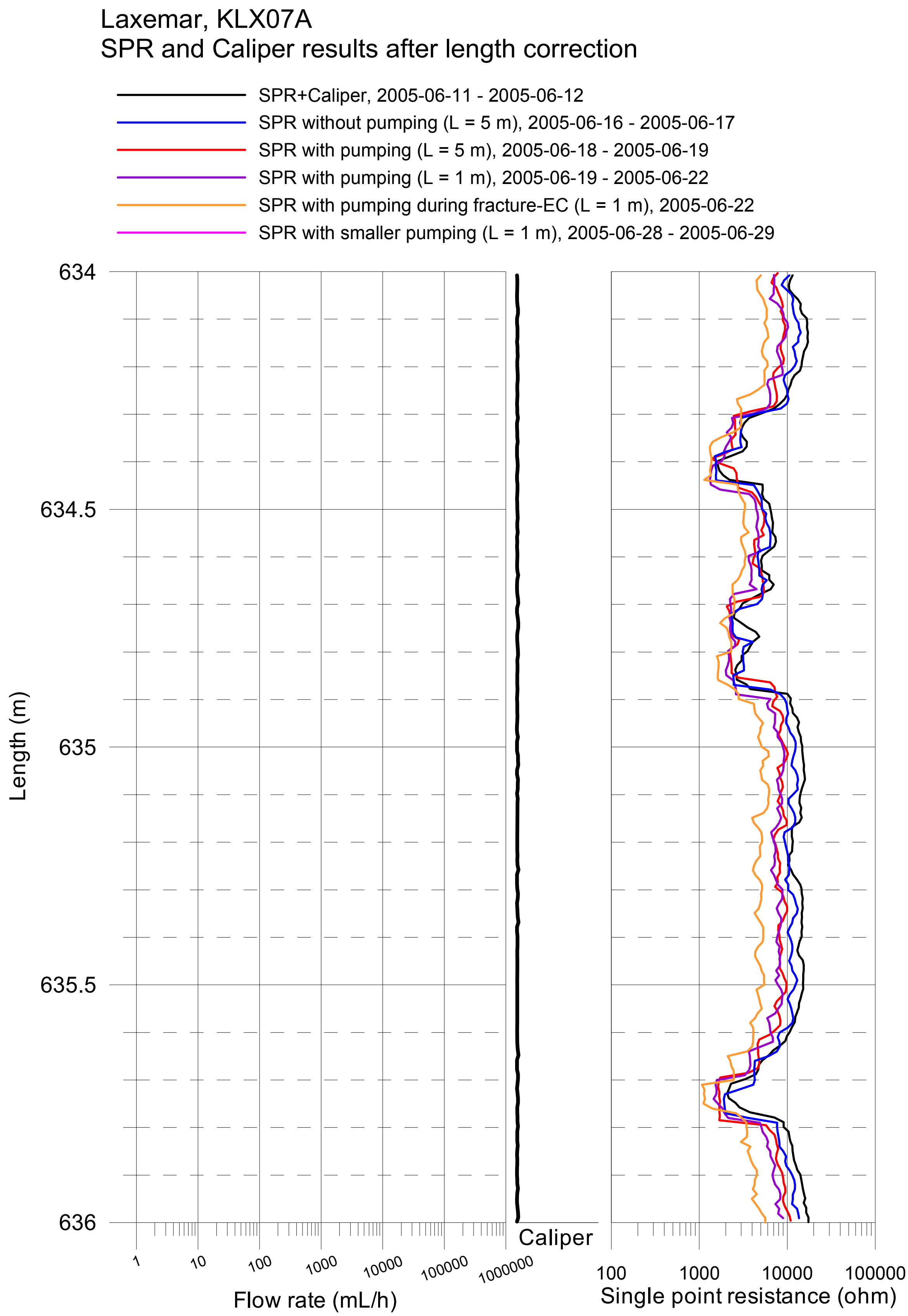
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
Length (m)
599
599.5
600
600.5
601
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)



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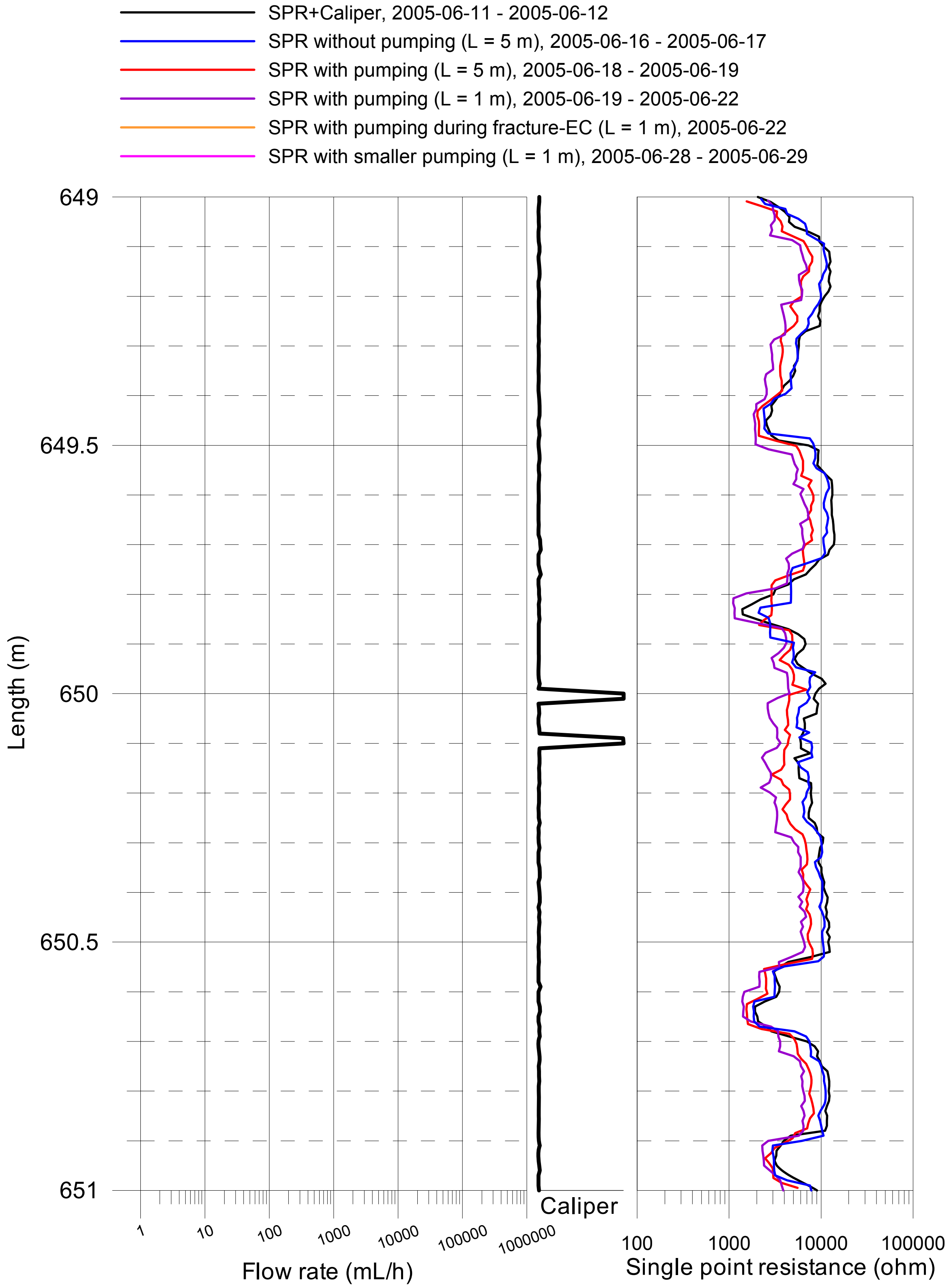
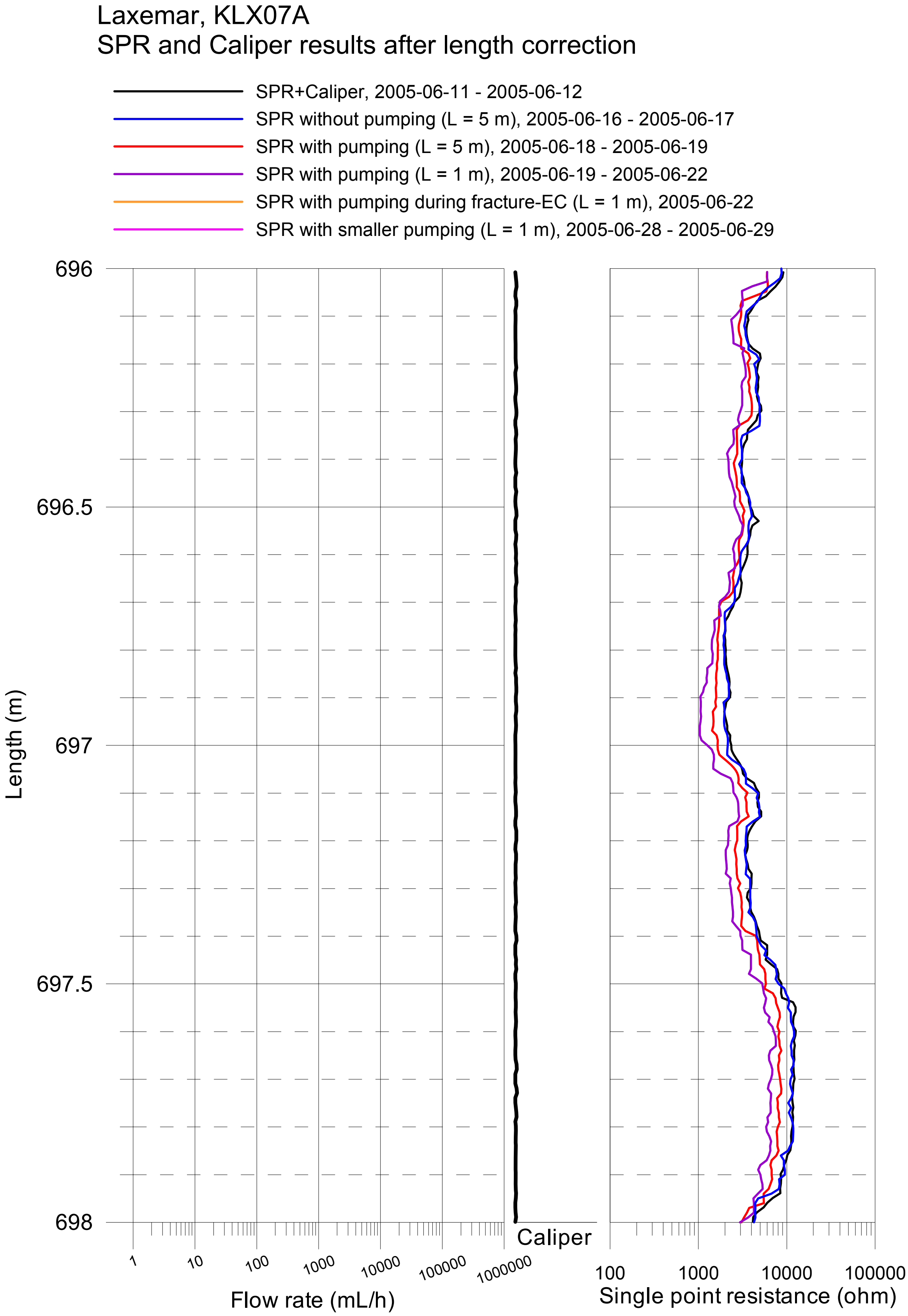
SPR with pumping (L = 1 m), 2005-06-19 - 2005-06-22
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
Length (m)
634
634.5
635
635.5
636
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

Laxemar, KLX07A
SPR and Caliper results after length correction

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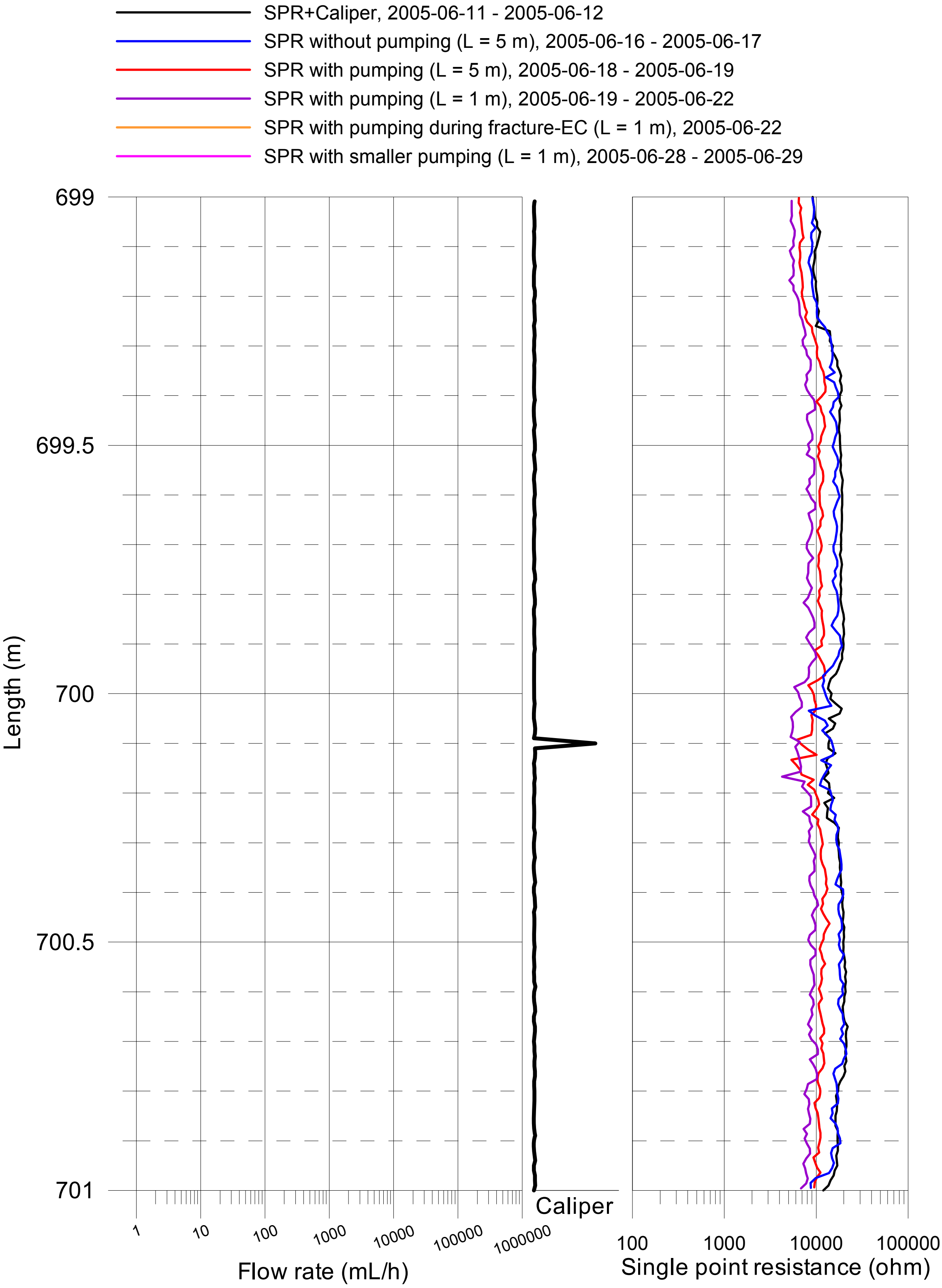
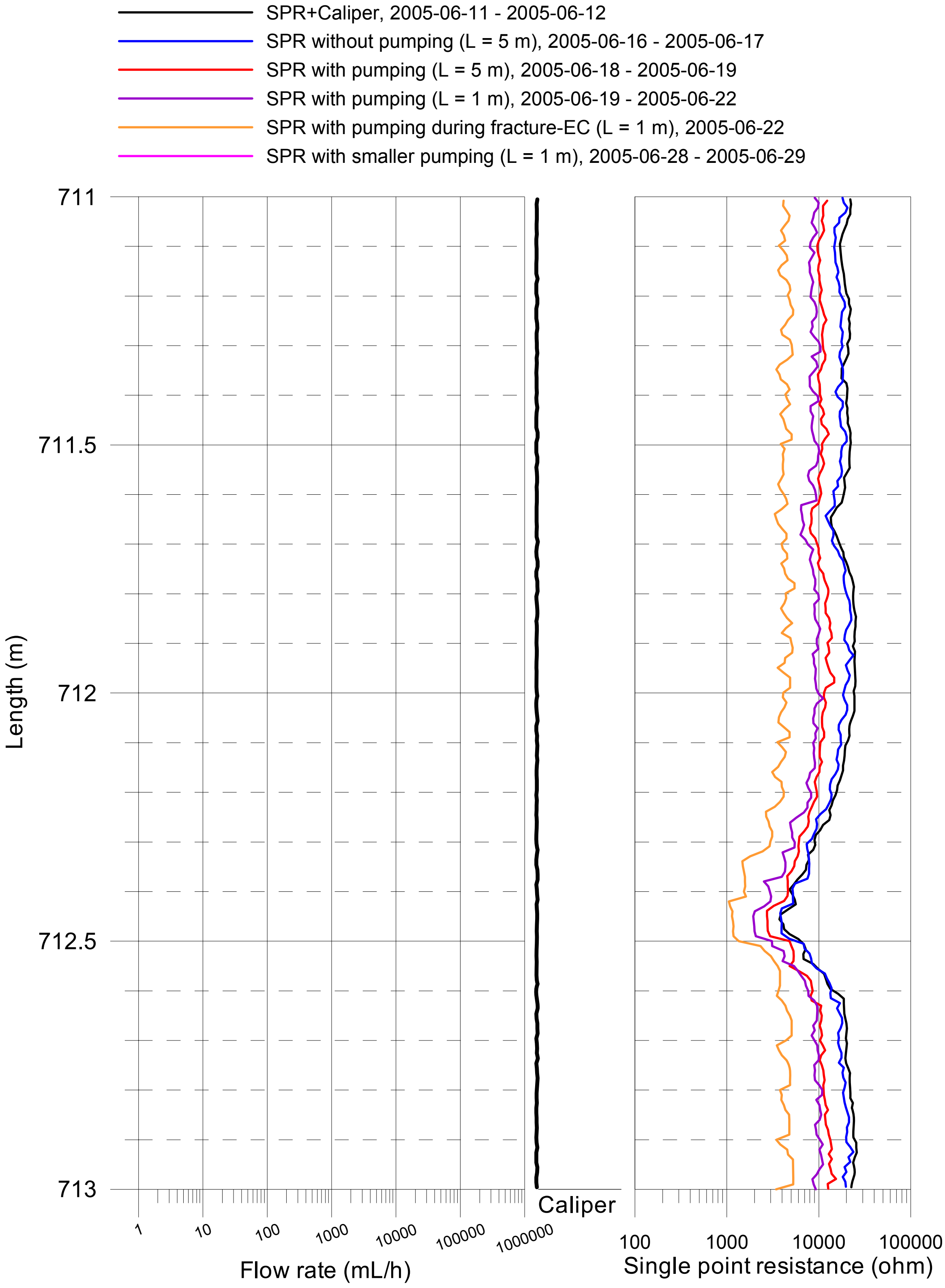
SPR and Caliper results after length correction
SPR+Caliper, 2005-06-11 - 2005-06-12
SPR without pumping (L = 5 m), 2005-06-16 - 2005-06-17
SPR with pumping (L = 5 m), 2005-06-18 - 2005-06-19
SPR with pumping (L = 1 m), 2005-06-19 - 2005-06-22
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
Length (m)
696
696.5
697
697.5
698
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

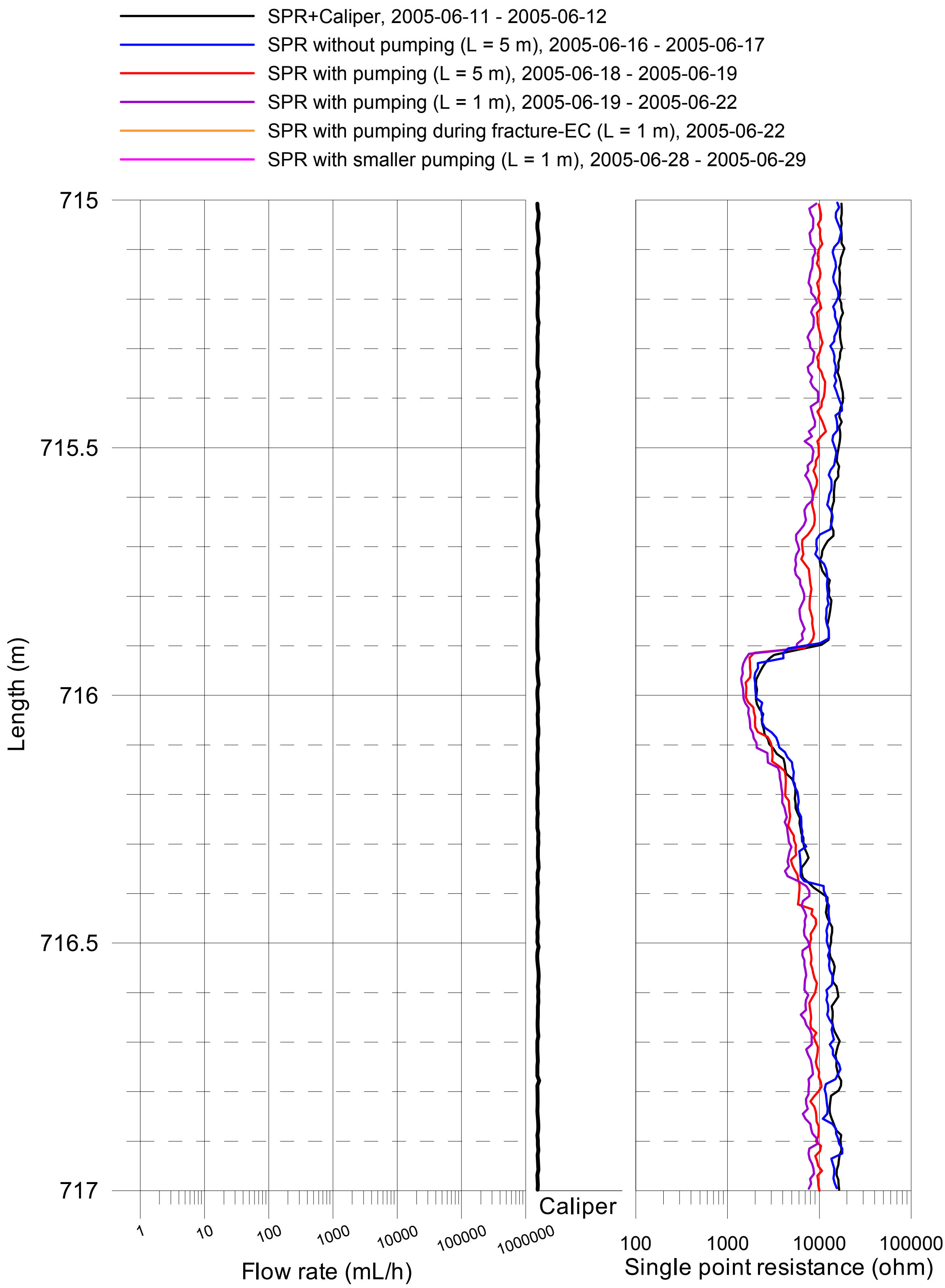
Laxemar, KLX07A
SPR and Caliper results after length correction

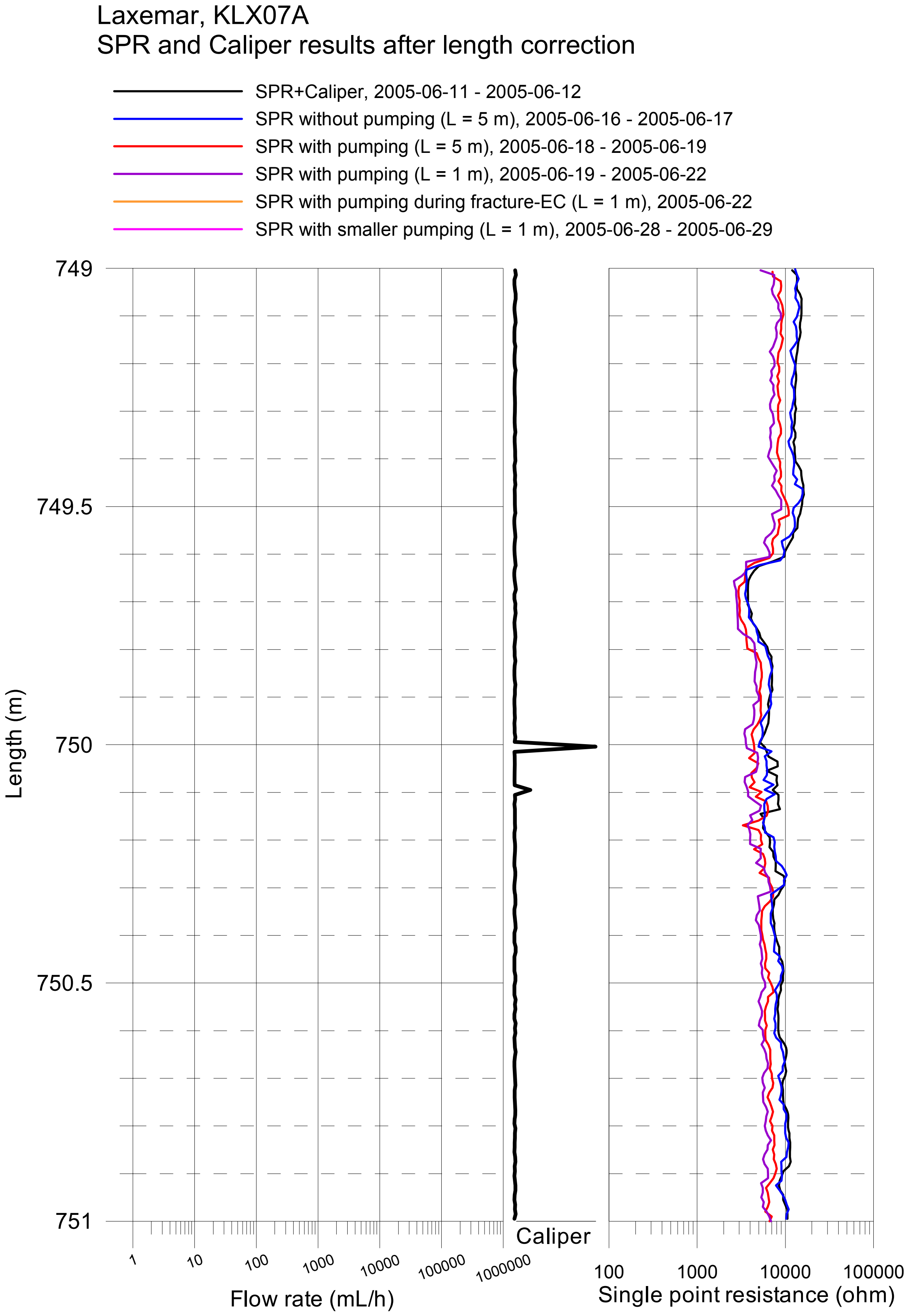


Laxemar, KLX07A
SPR and Caliper results after length correction

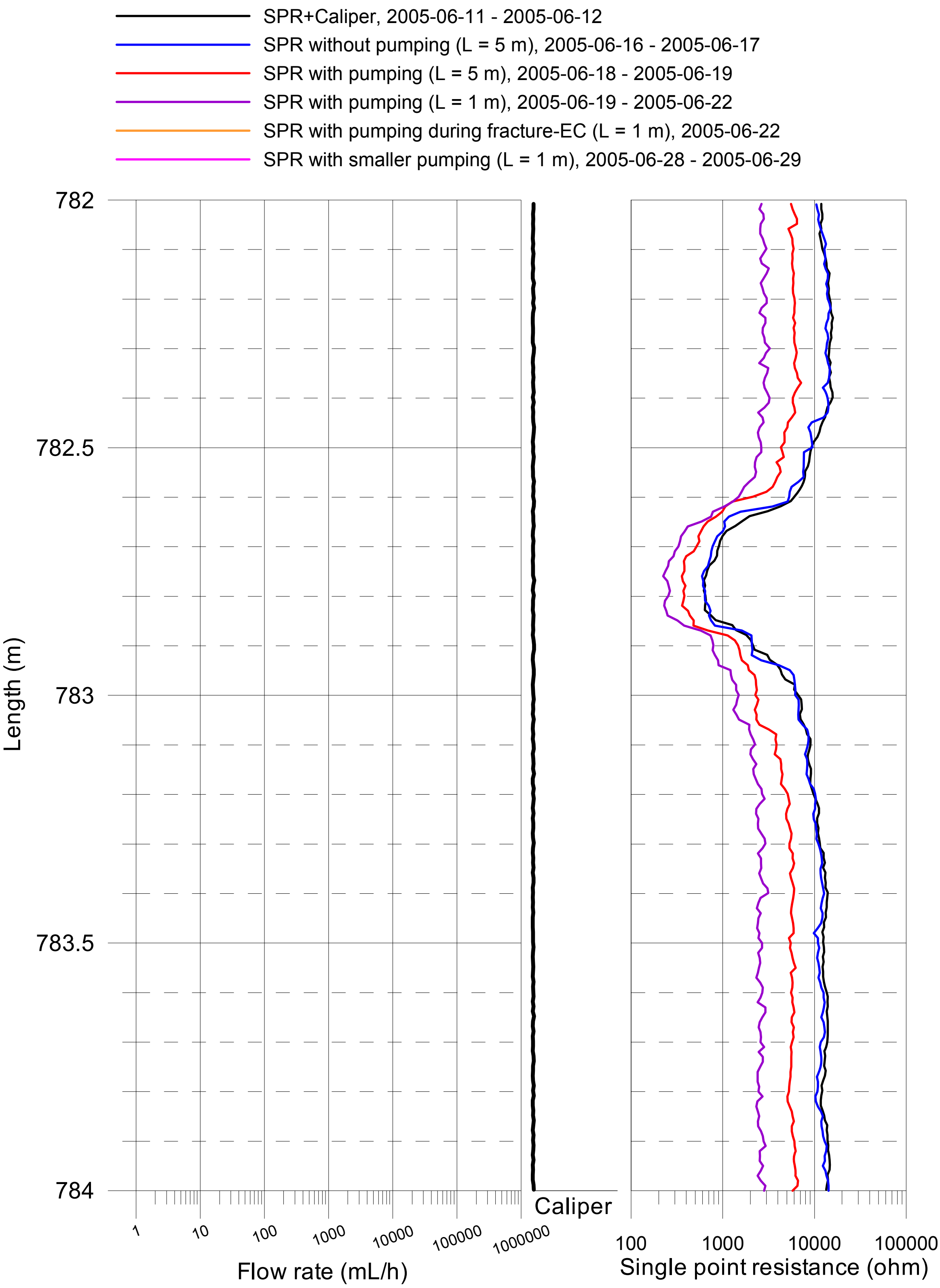


Laxemar, KLX07A
SPR and Caliper results after length correction

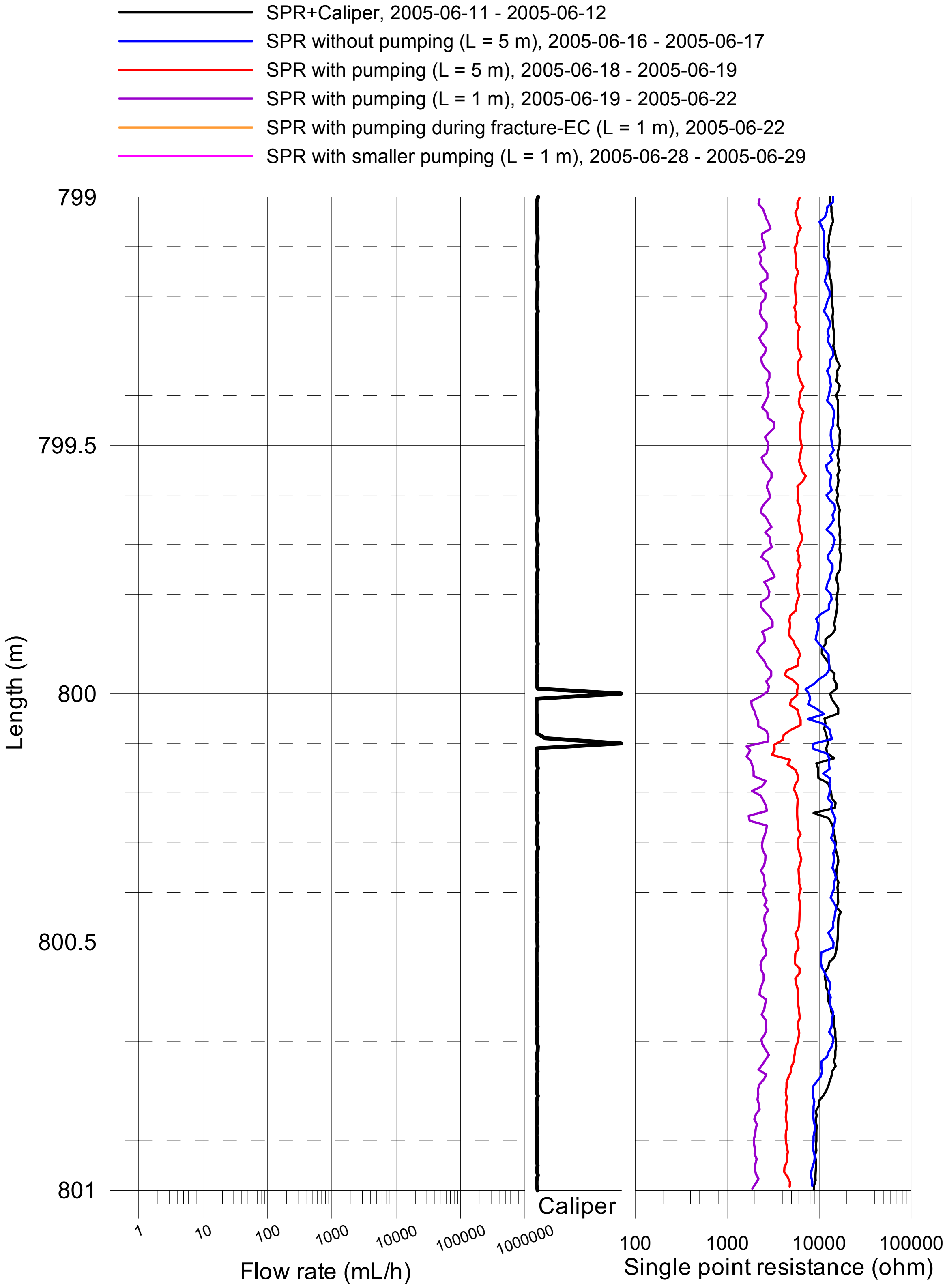



Laxemar, KLX07A
SPR and Caliper results after length correction
SPR+Caliper, 2005-06-11 - 2005-06-12
SPR without pumping (L = 5 m), 2005-06-16 - 2005-06-17
SPR with pumping (L = 5 m), 2005-06-18 - 2005-06-19
SPR with pumping (L = 1 m), 2005-06-19 - 2005-06-22
SPR with pumping during fracture-EC (L = 1 m), 2005-06-22
SPR with smaller pumping (L = 1 m), 2005-06-28 - 2005-06-29
Length (m)
749
749.5
750
750.5
751
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
Caliper
100
1000
10000
100000
Single point resistance (ohm)

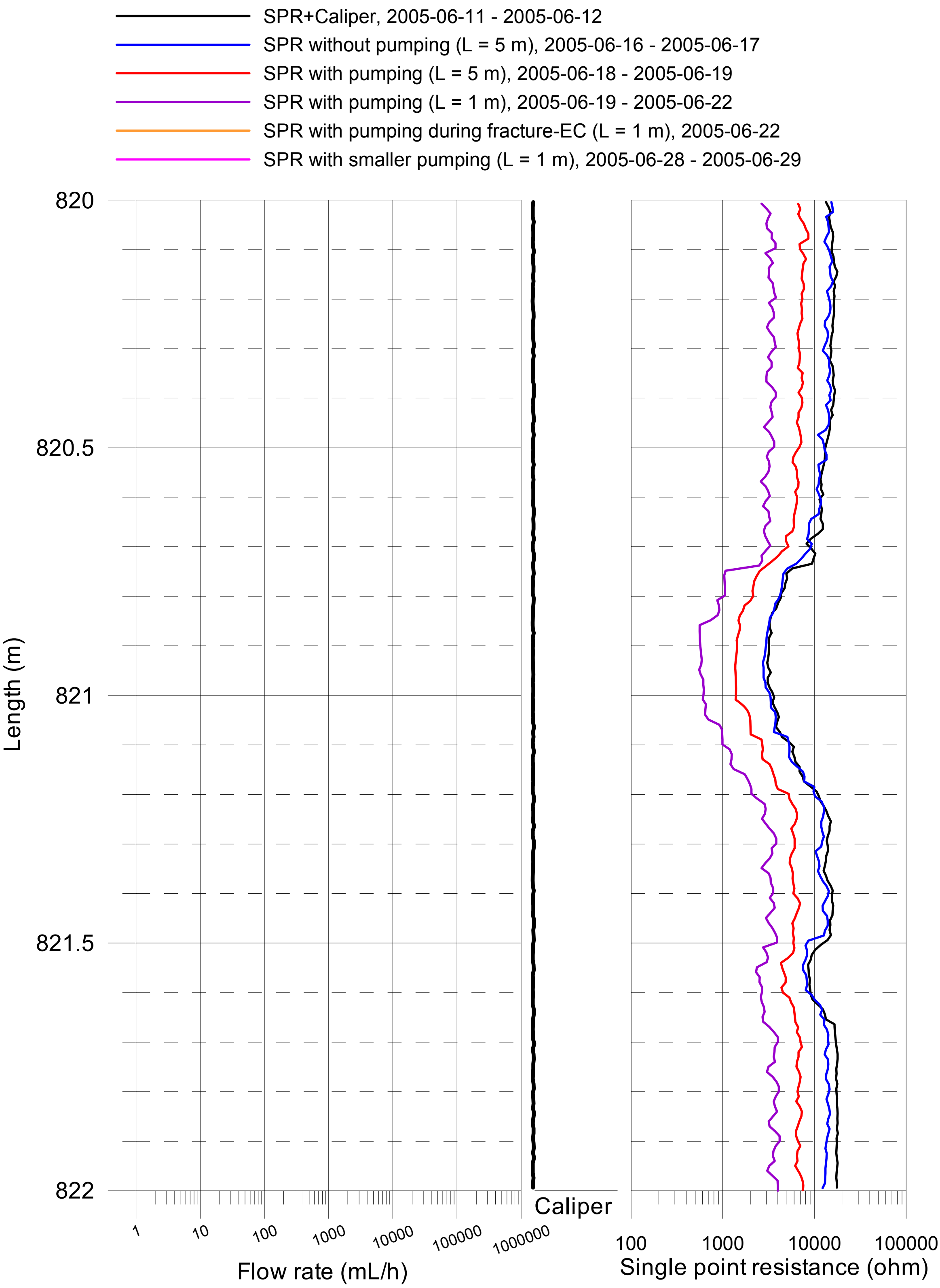
Laxemar, KLX07A
SPR and Caliper results after length correction



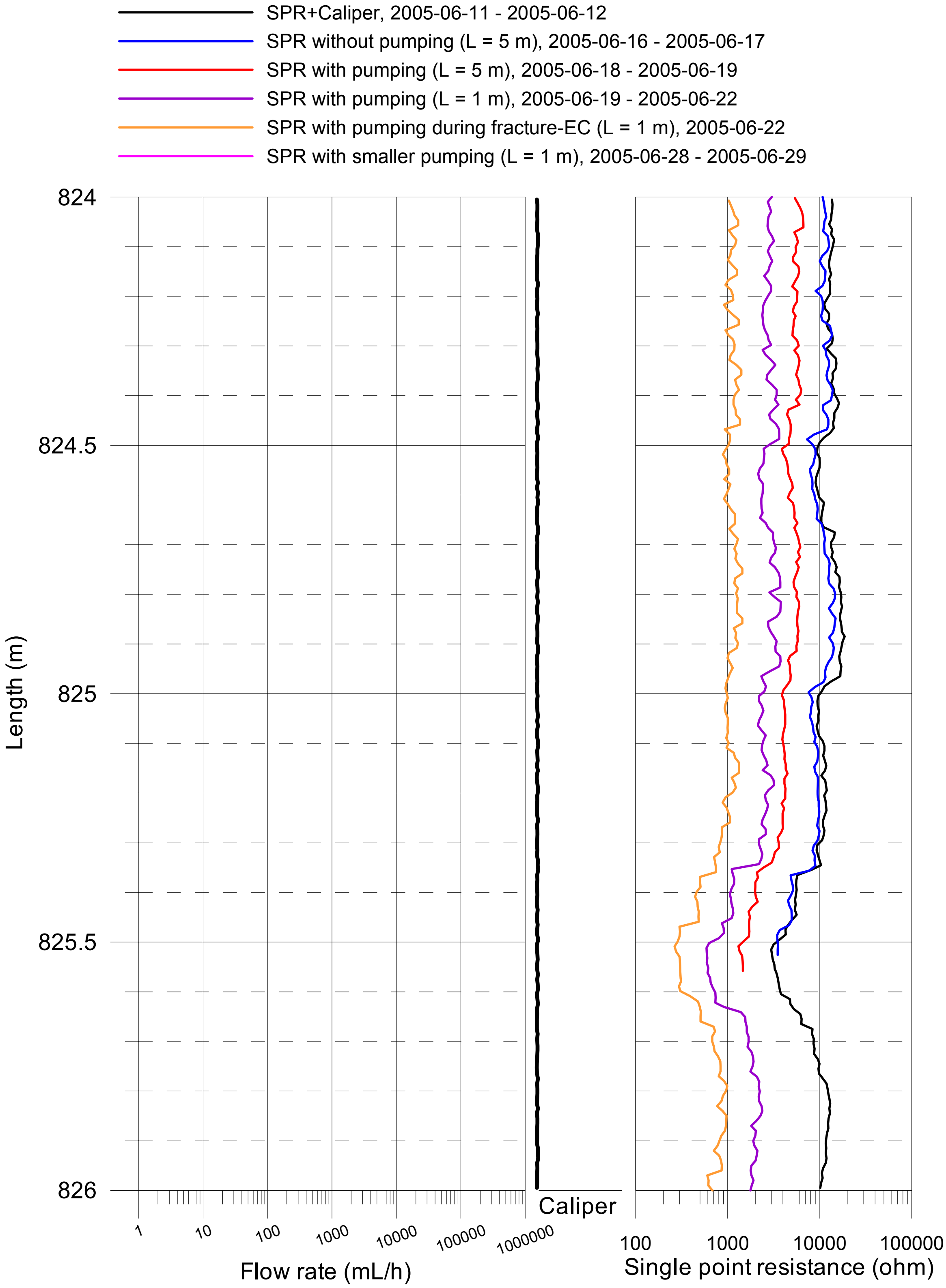
Laxemar, KLX07A
SPR and Caliper results after length correction



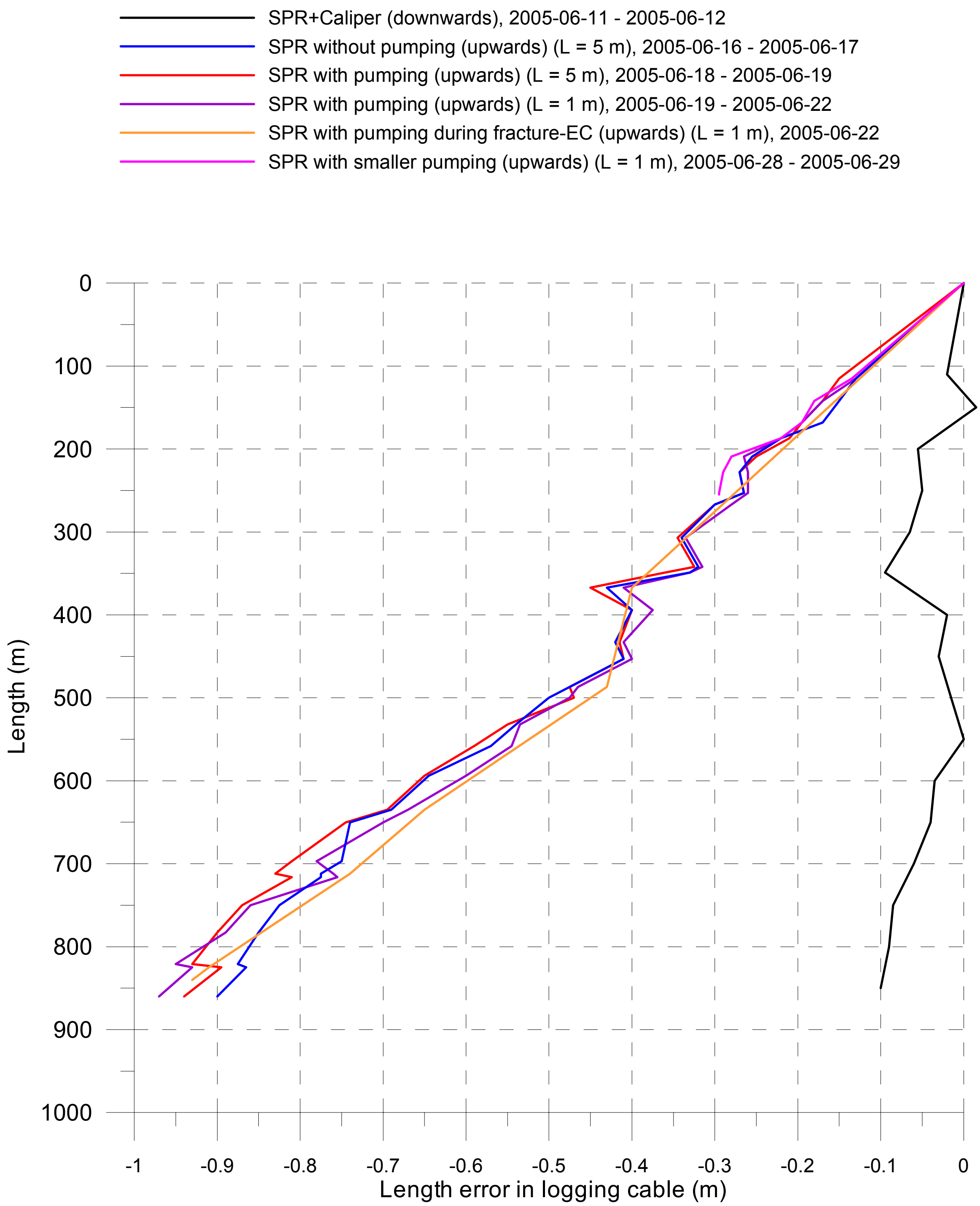
Laxemar, KLX07A
SPR and Caliper results after length correction

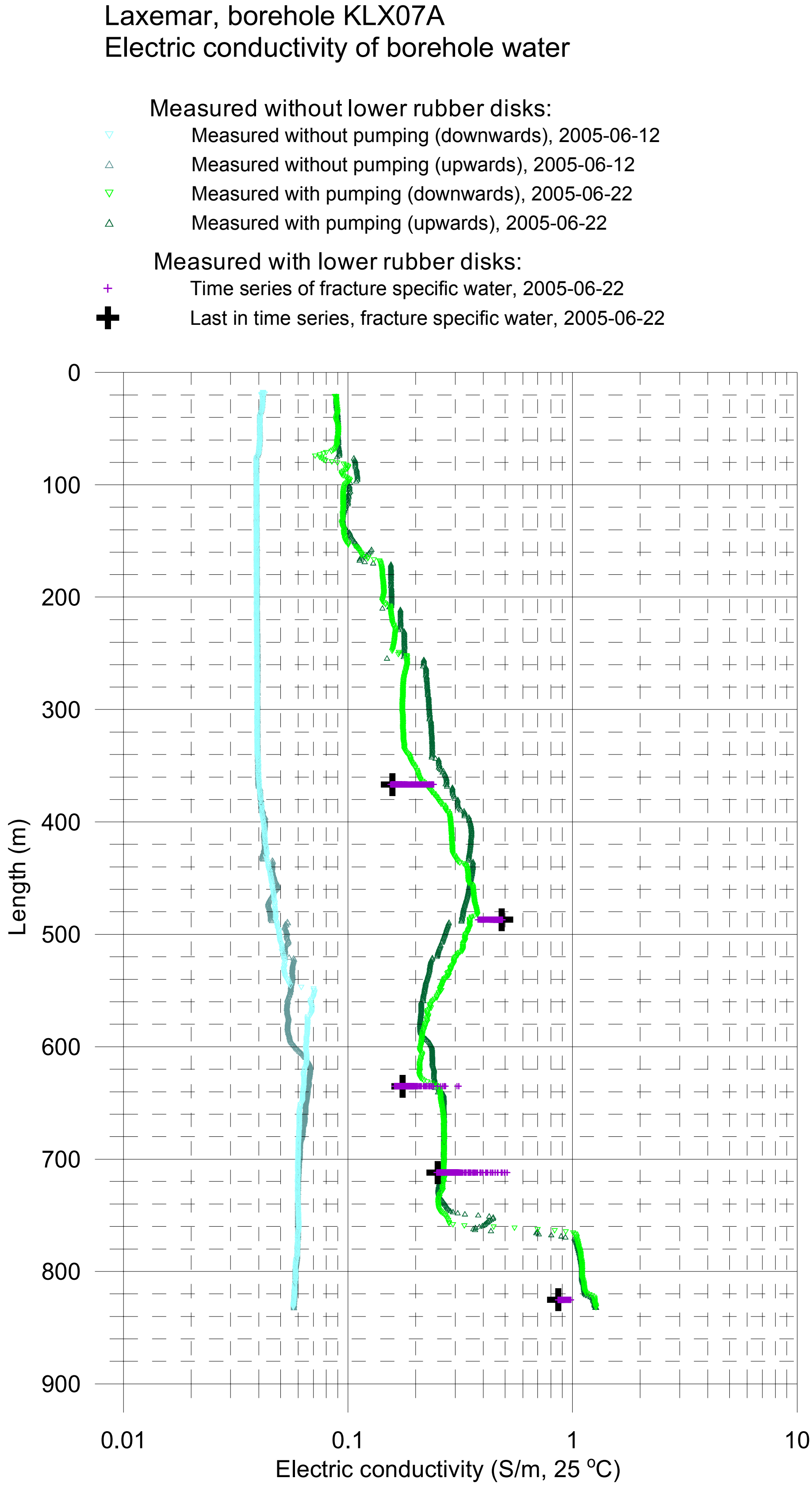


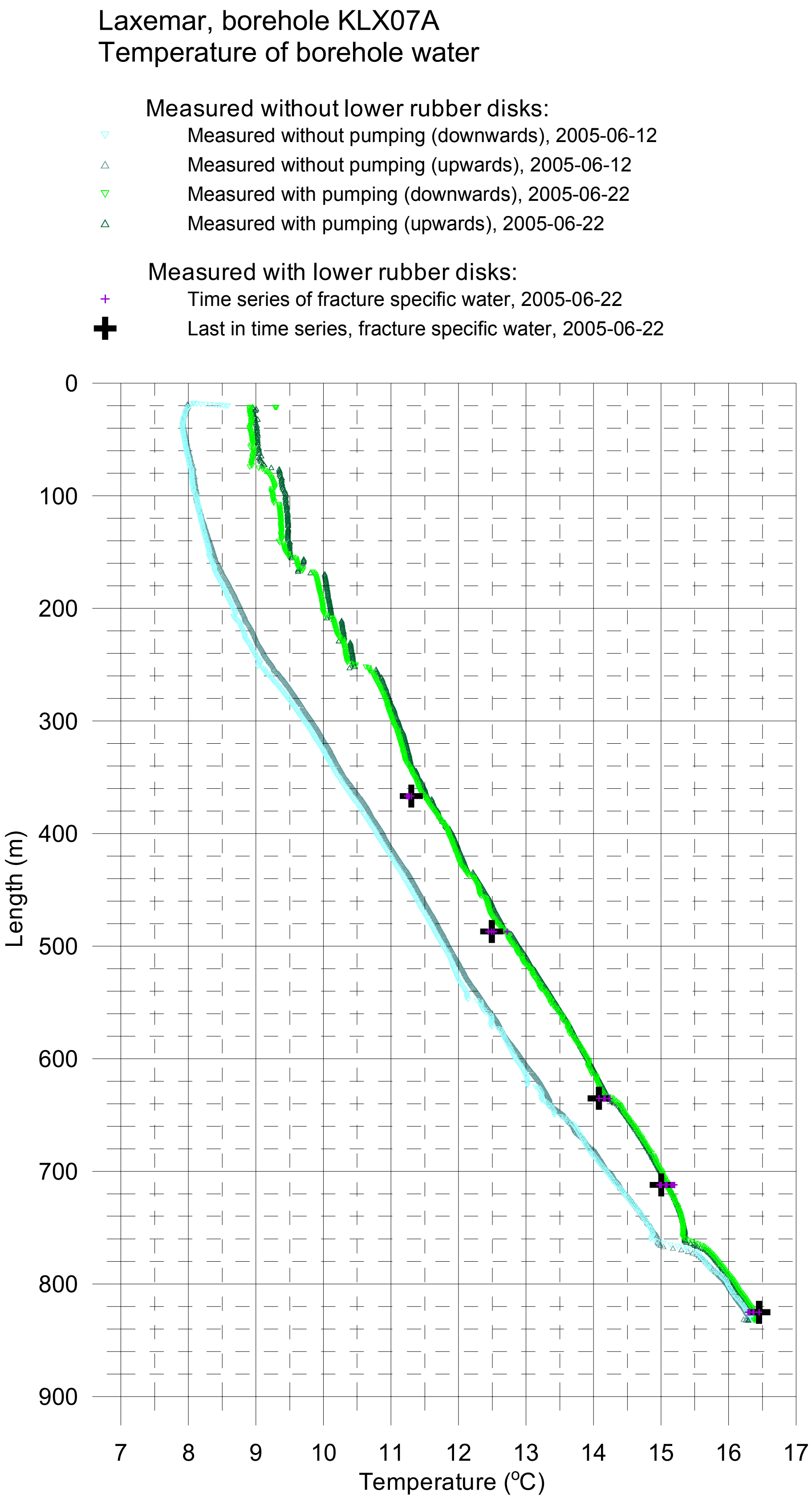
Laxemar, KLX07A
SPR and Caliper results after length correction



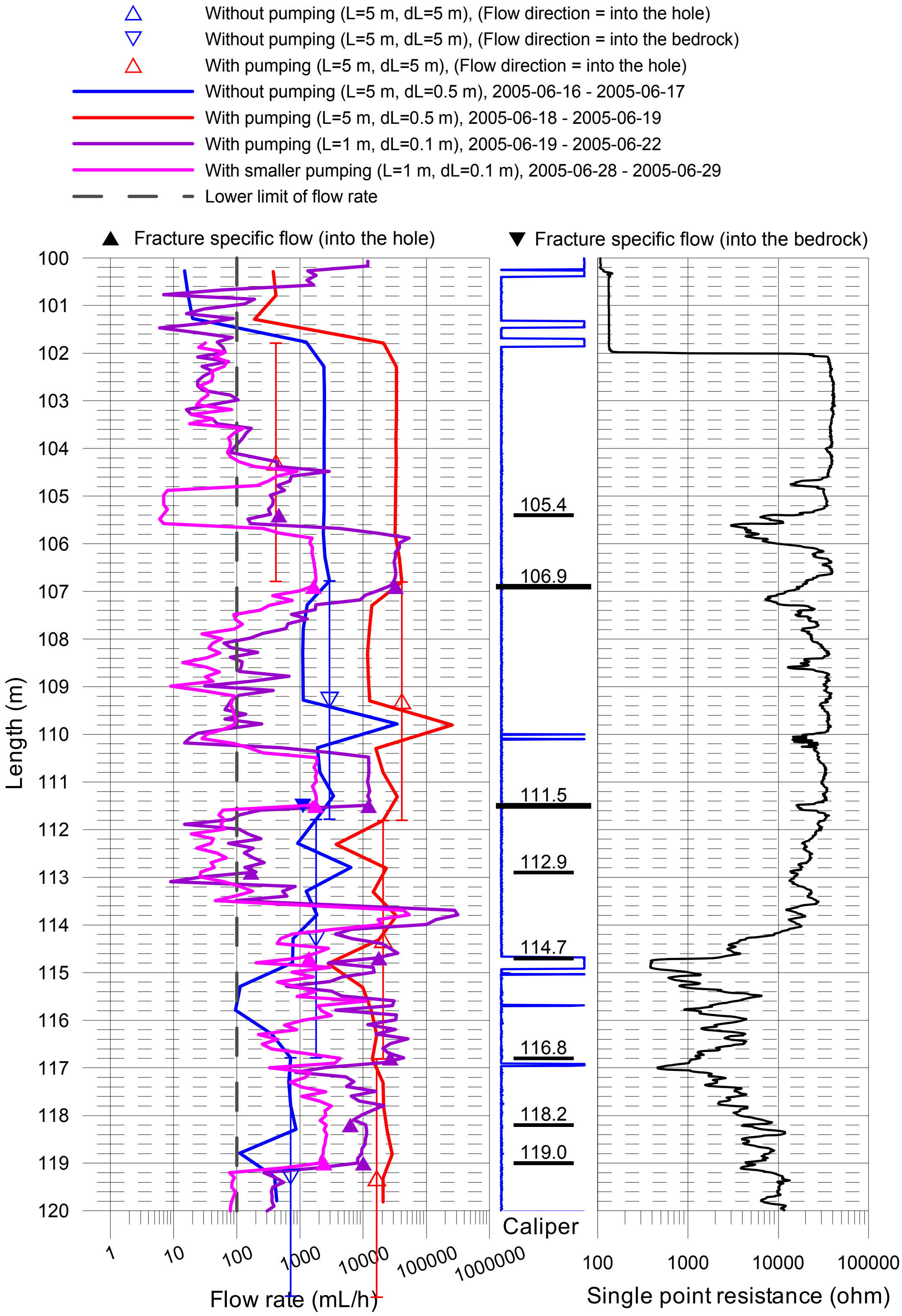
Laxemar, KLX07A
Length correction



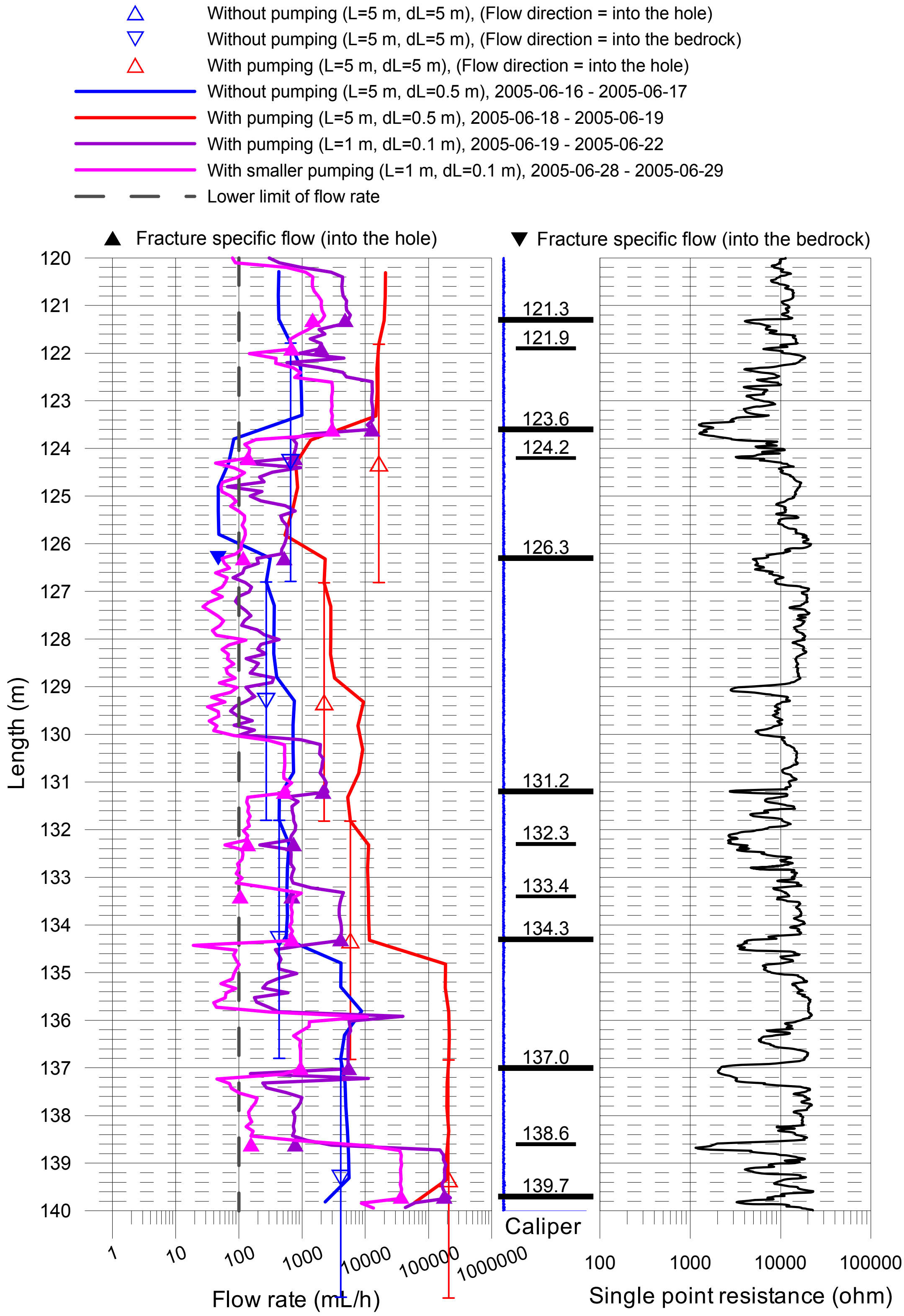

Laxemar, borehole KLX07A
Electric conductivity of borehole water
Measured without lower rubber disks:
Measured without pumping (downwards), 2005-06-12
Measured without pumping (upwards), 2005-06-12
Measured with pumping (downwards), 2005-06-22
Measured with pumping (upwards), 2005-06-22
Measured with lower rubber disks:
Time series of fracture specific water, 2005-06-22
Last in time series, fracture specific water, 2005-06-22
0
100
200
300
400
500
600
700
800
900
Length (m)
0.01
0.1
1
10
Electric conductivity (S/m, 25 °C)


Laxemar, borehole KLX07A
Temperature of borehole water
Measured without lower rubber disks:
Measured without pumping (downwards), 2005-06-12
Measured without pumping (upwards), 2005-06-12
Measured with pumping (downwards), 2005-06-22
Measured with pumping (upwards), 2005-06-22
Measured with lower rubber disks:
Time series of fracture specific water, 2005-06-22
Last in time series, fracture specific water, 2005-06-22
0
100
200
300
400
500
600
700
800
900
Length (m)
7
8
9
10
11
12
13
14
15
16
17
Temperature (°C)

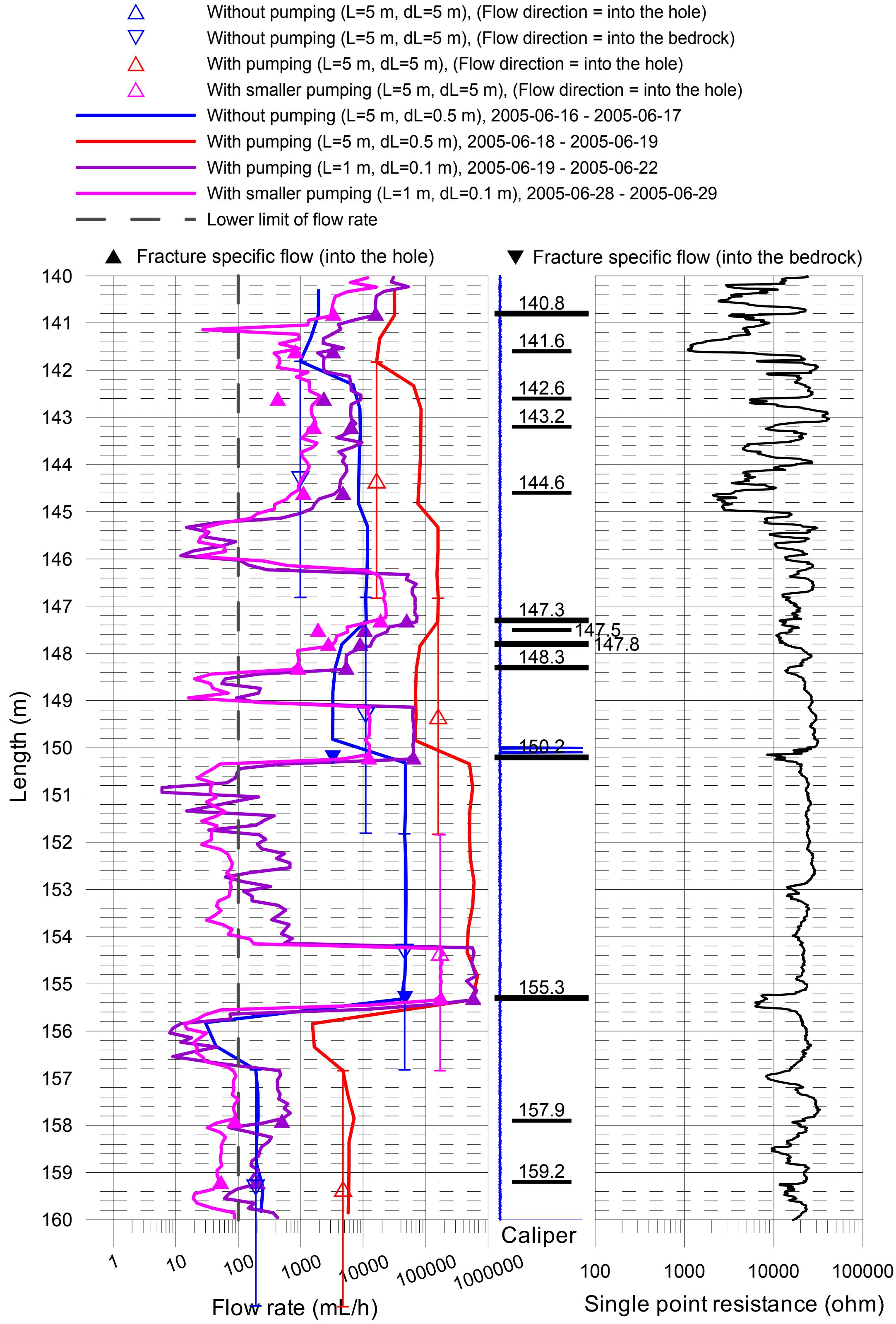
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



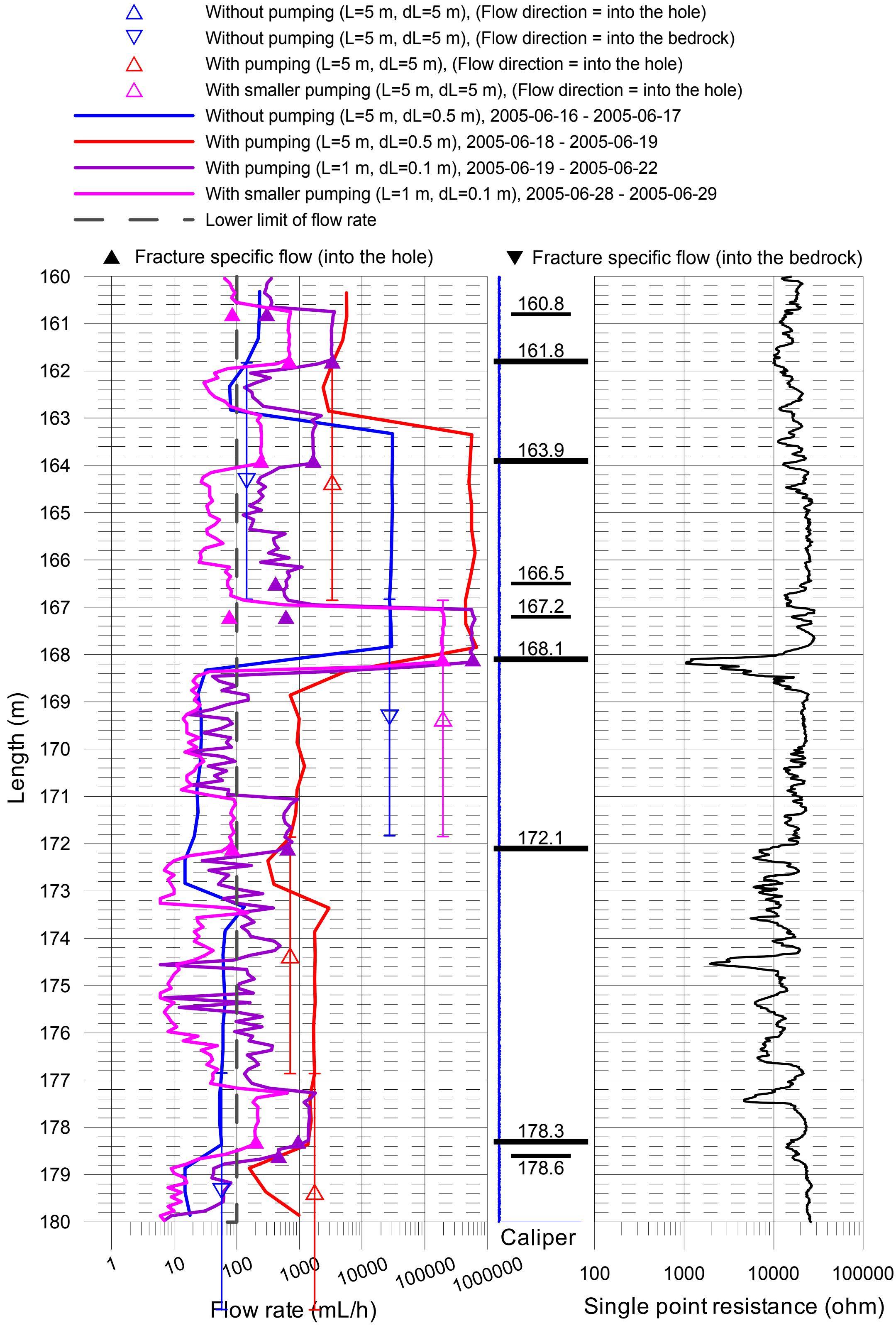
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



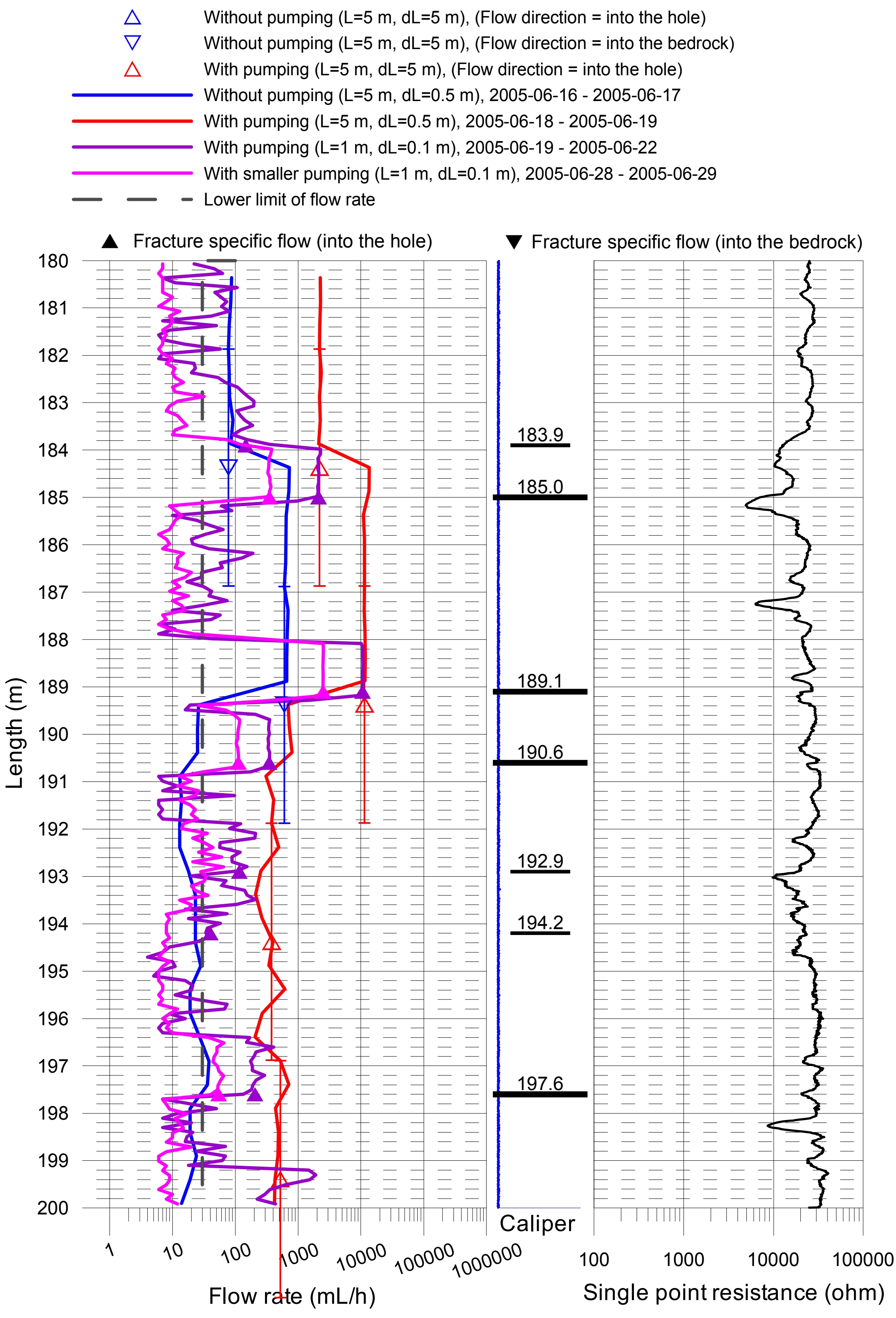
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



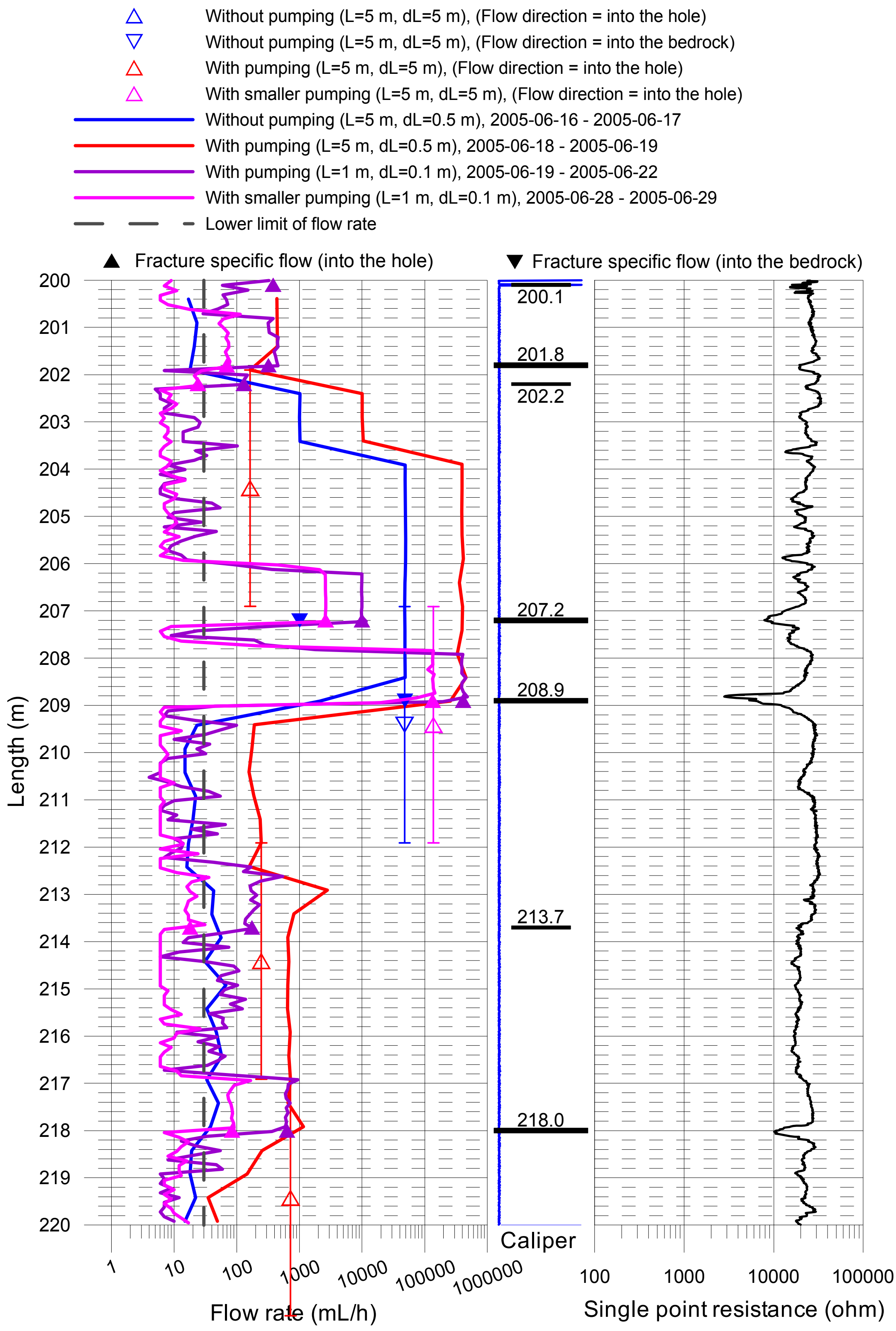
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



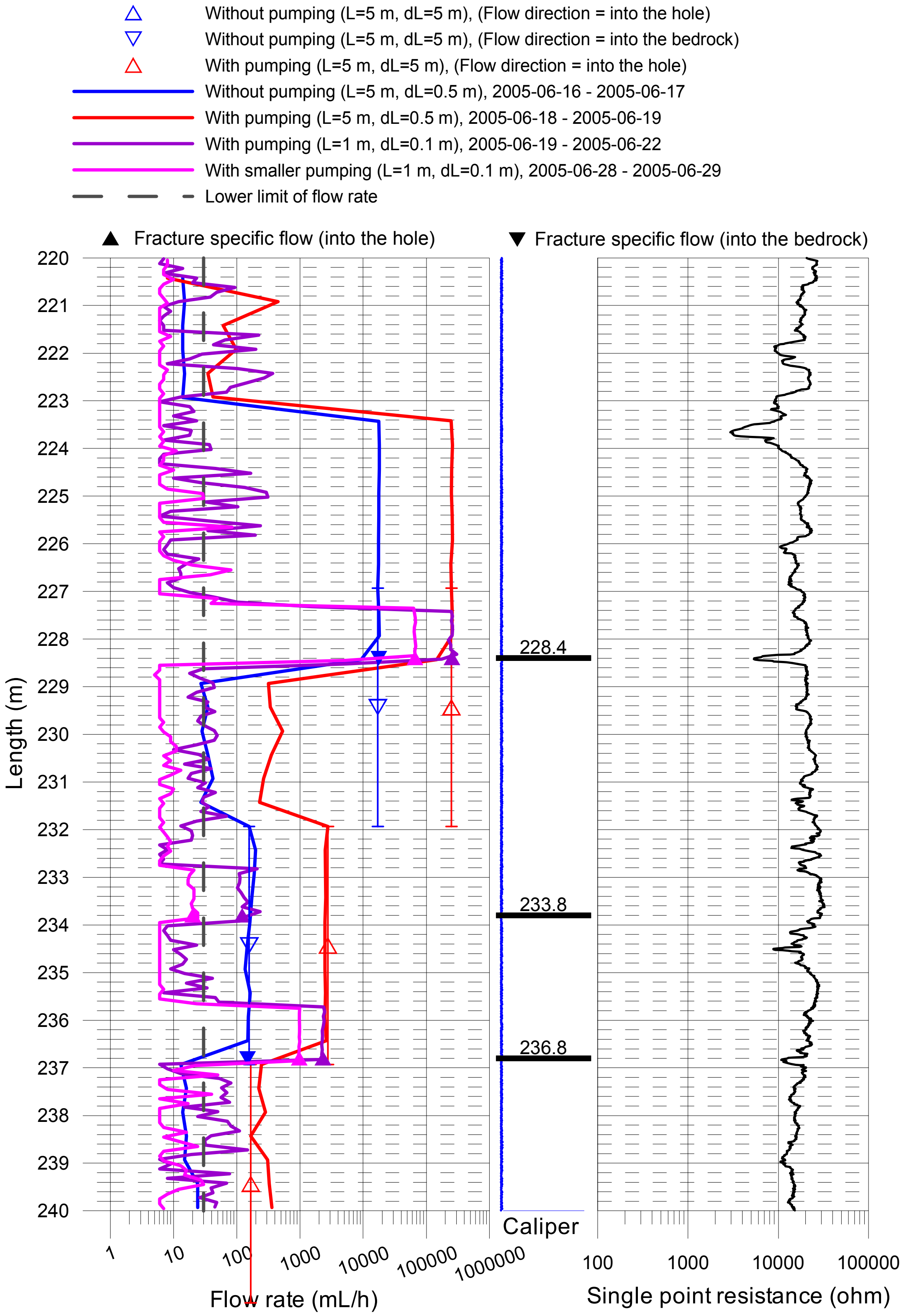
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



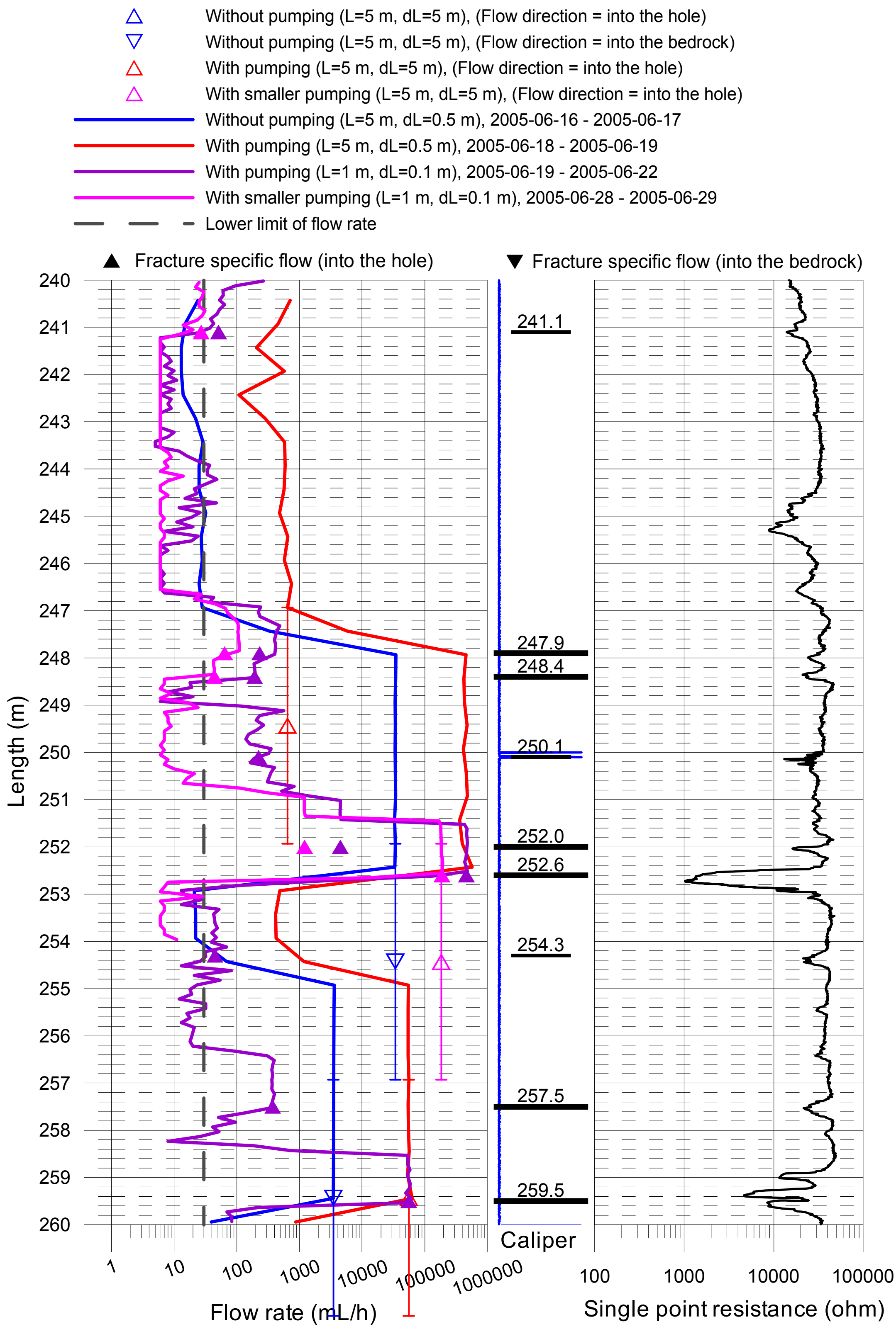
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



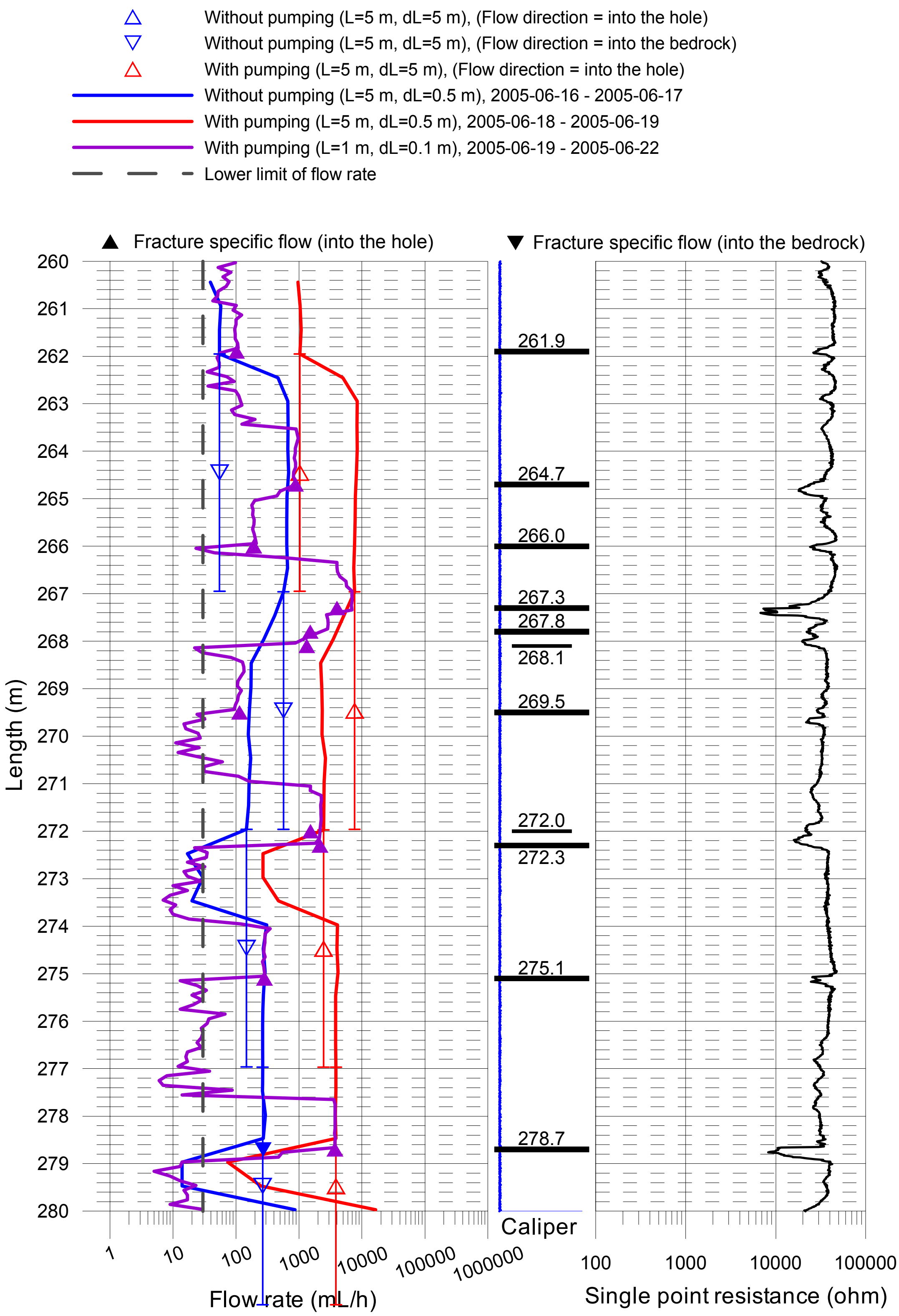
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



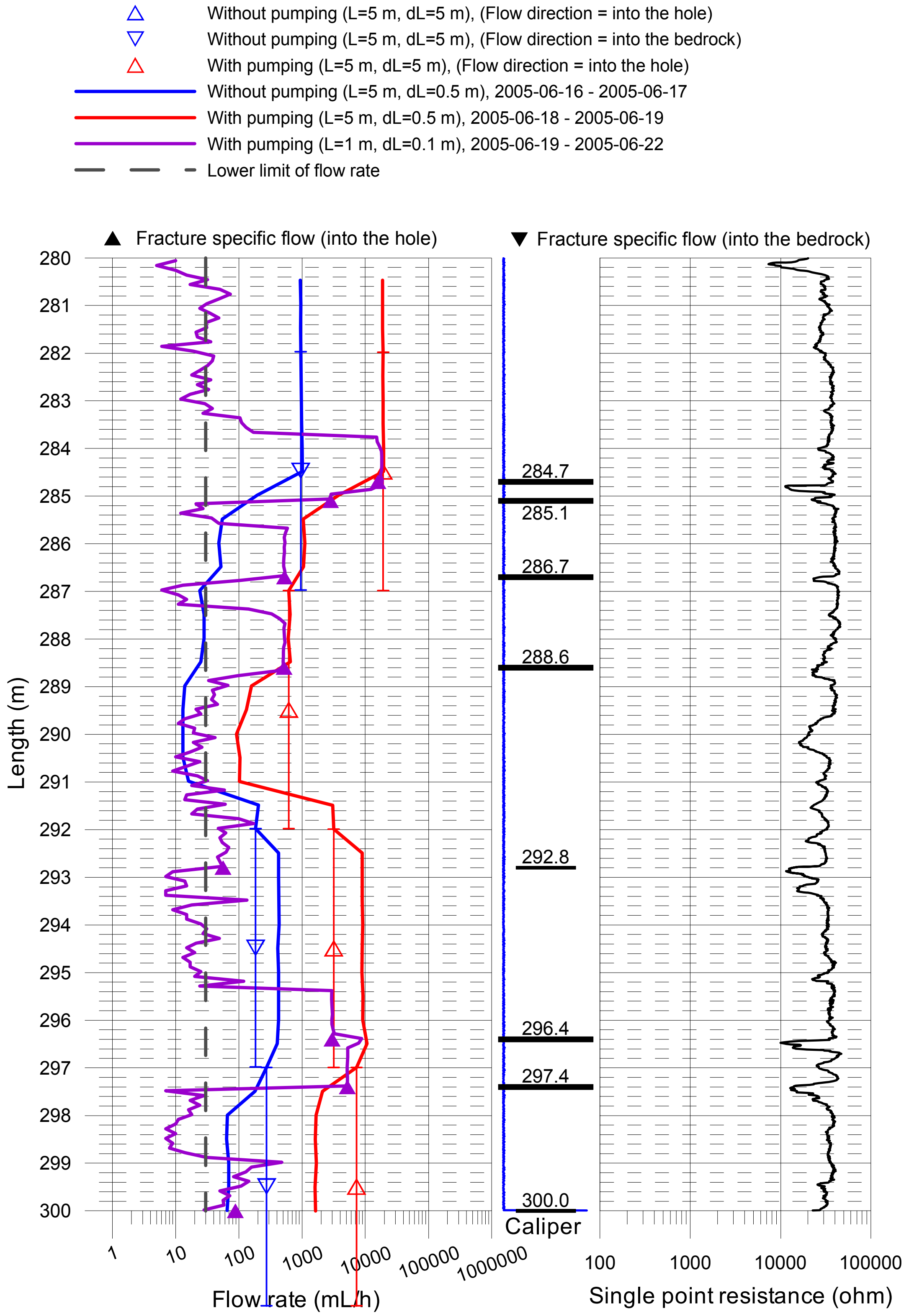
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



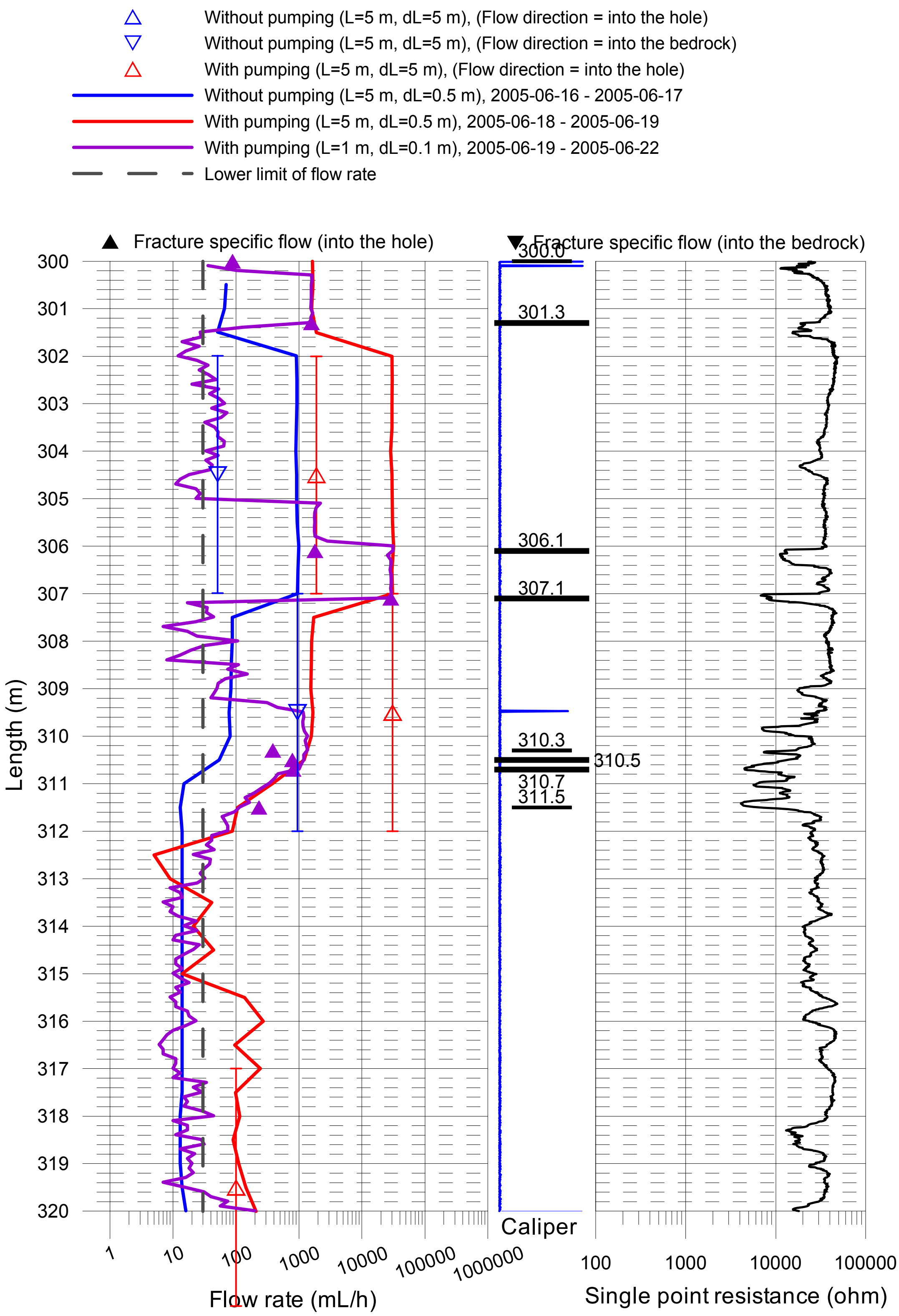
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



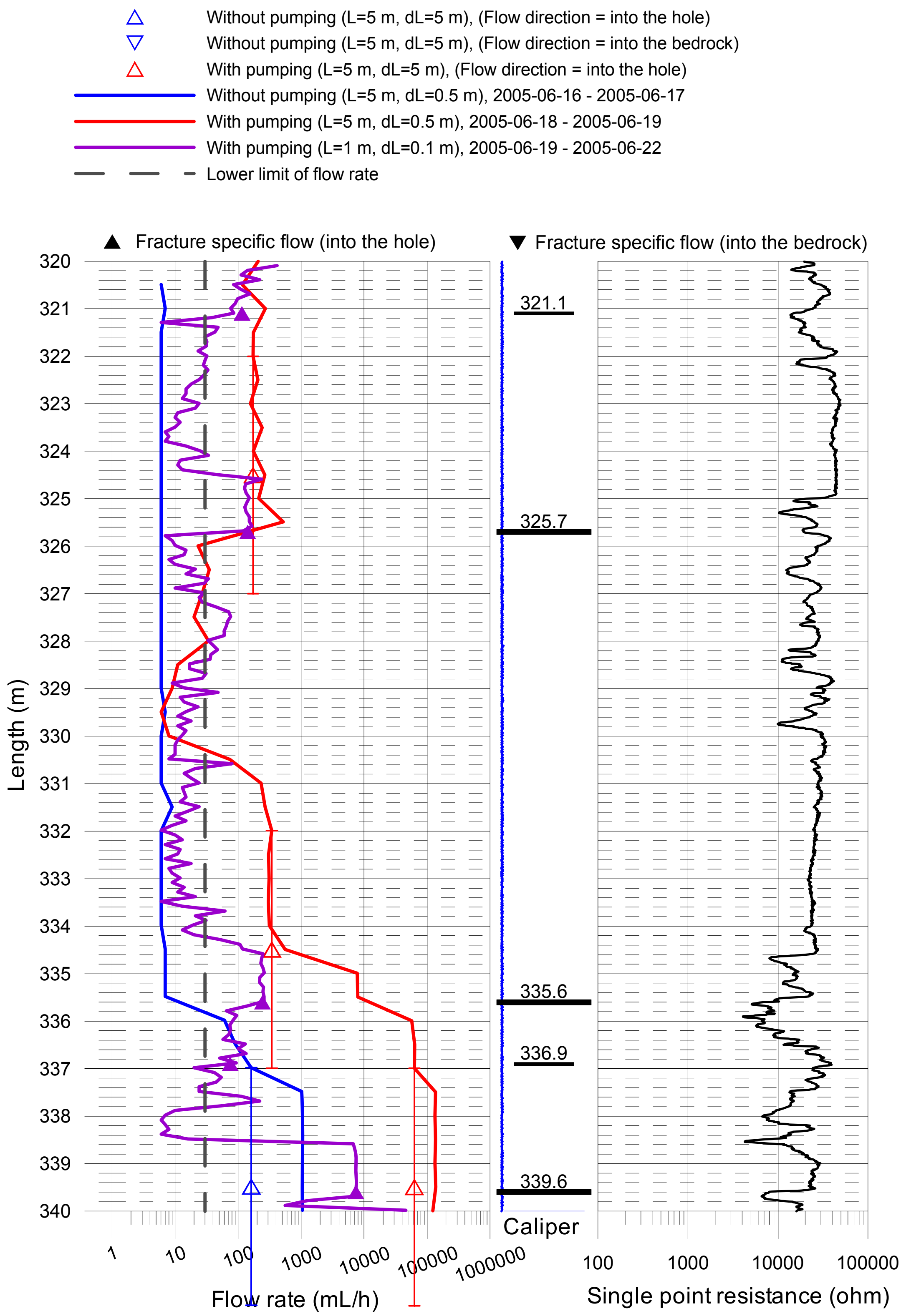
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



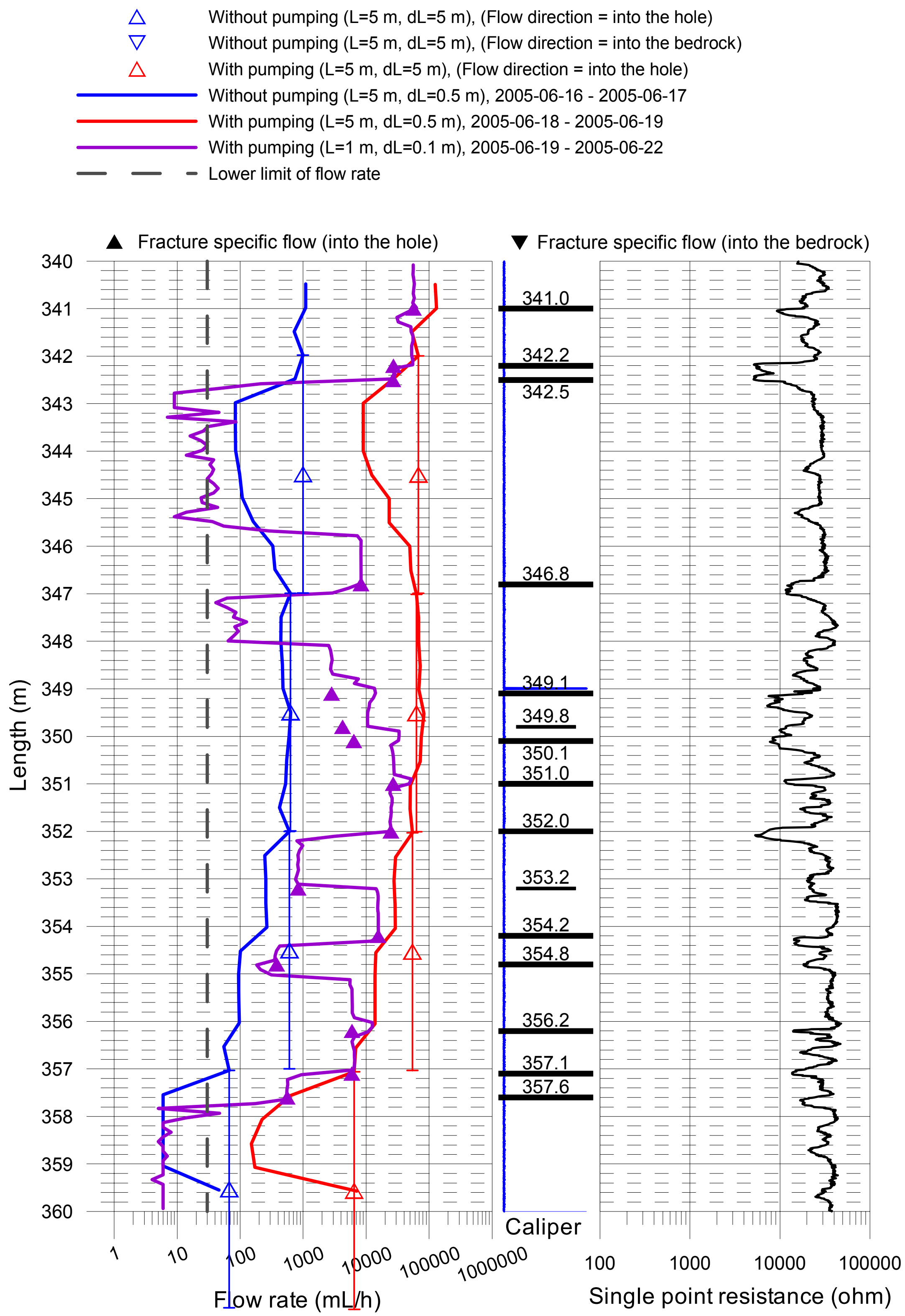
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



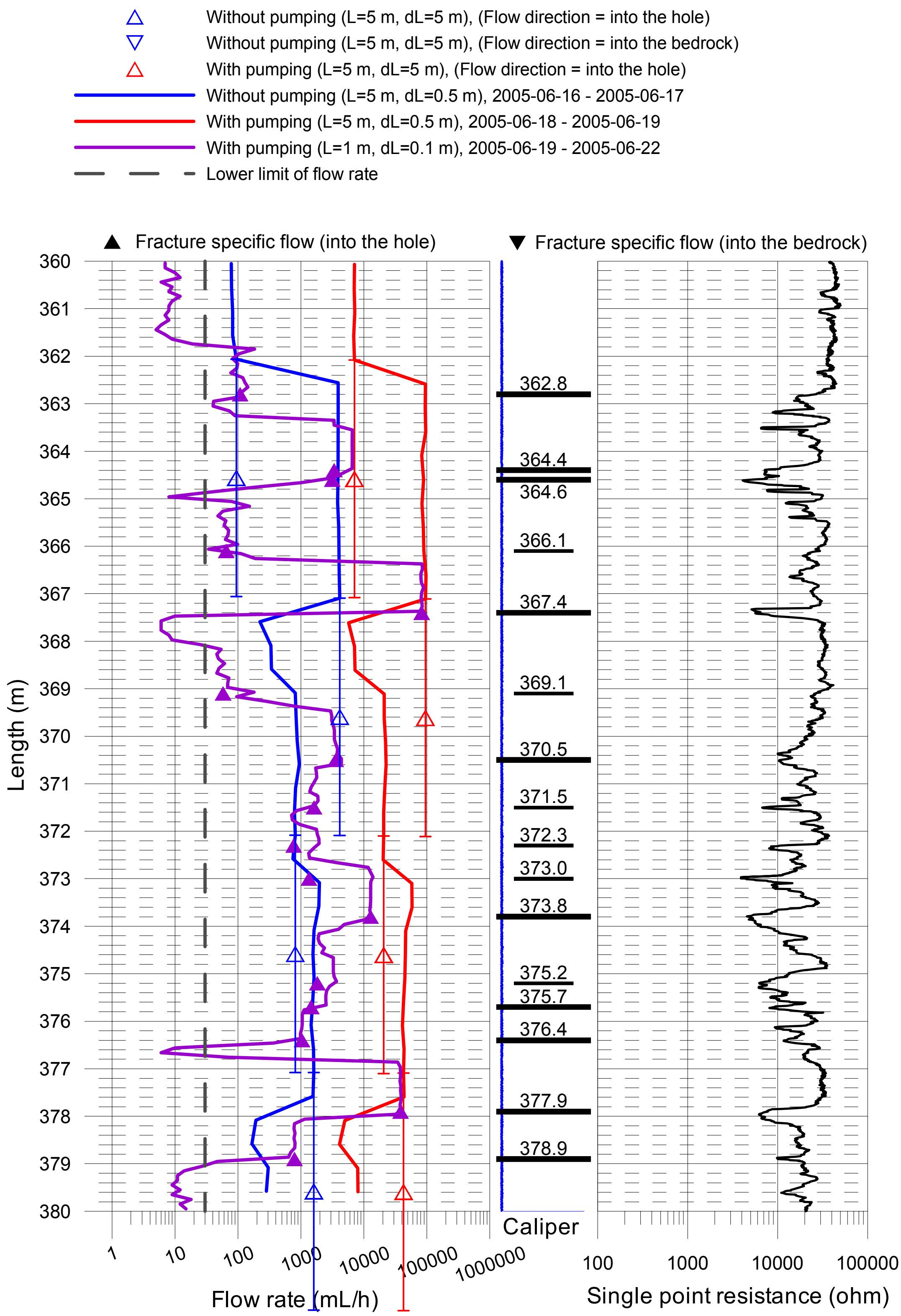
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



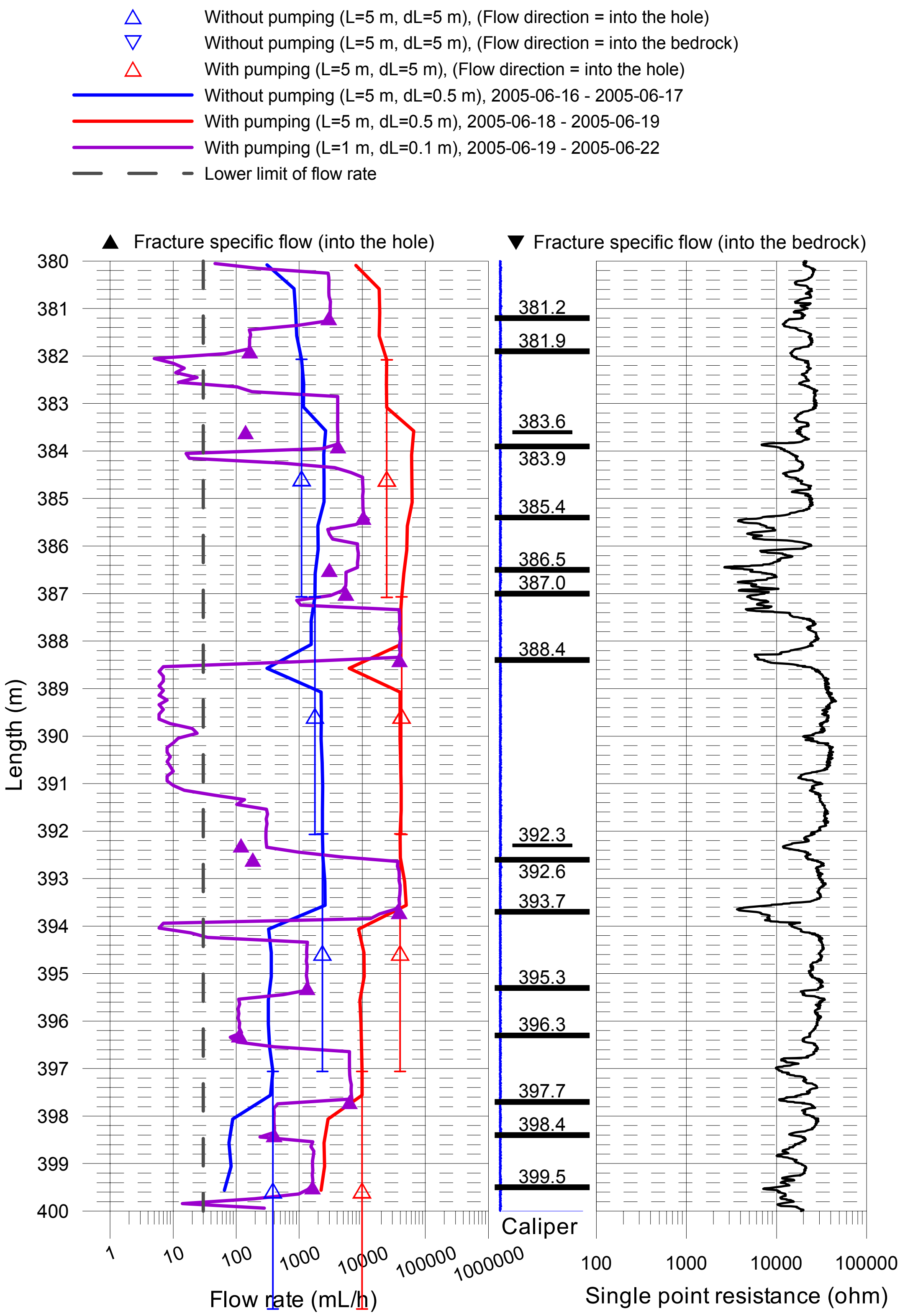
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



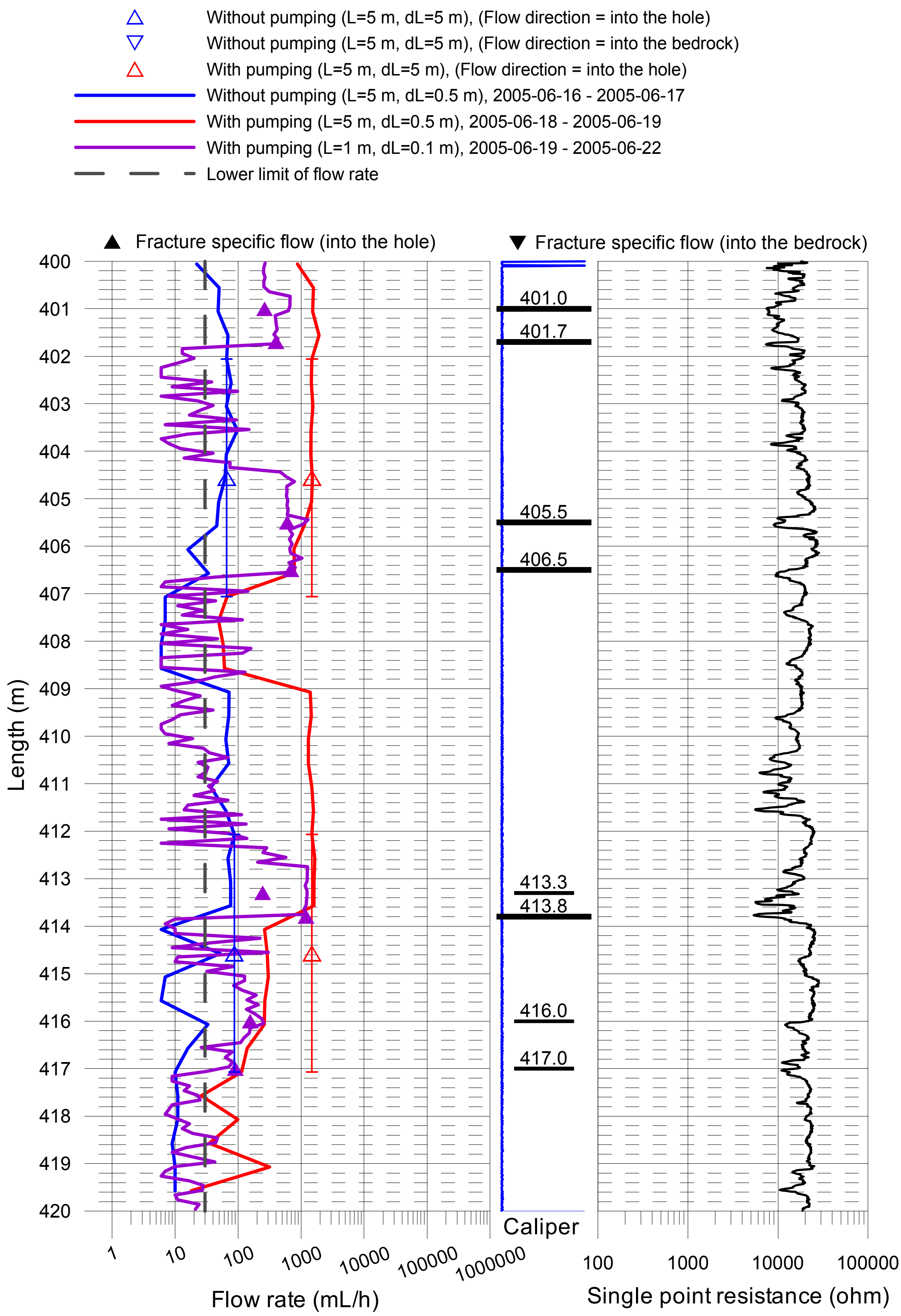
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance

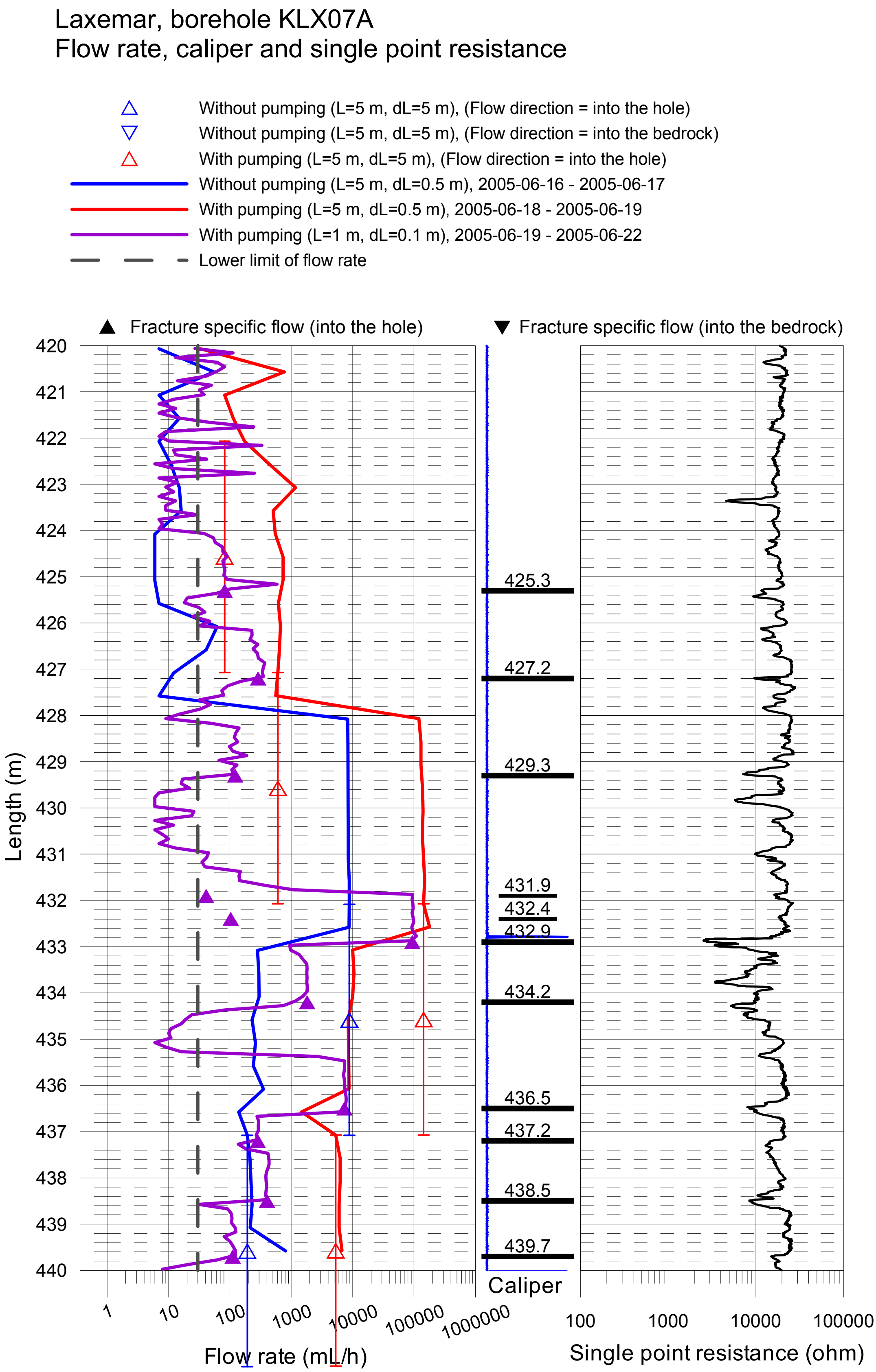


Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



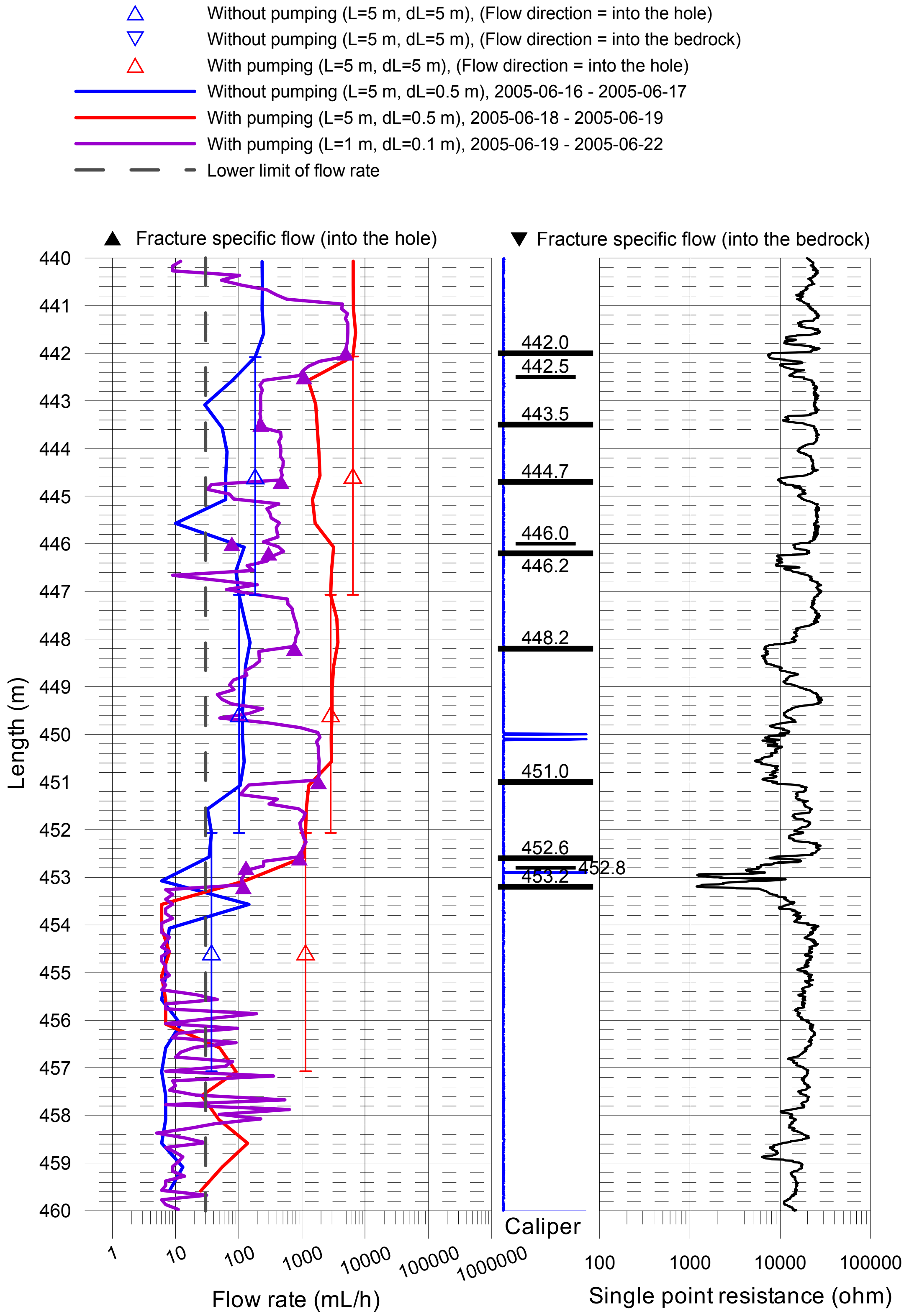
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



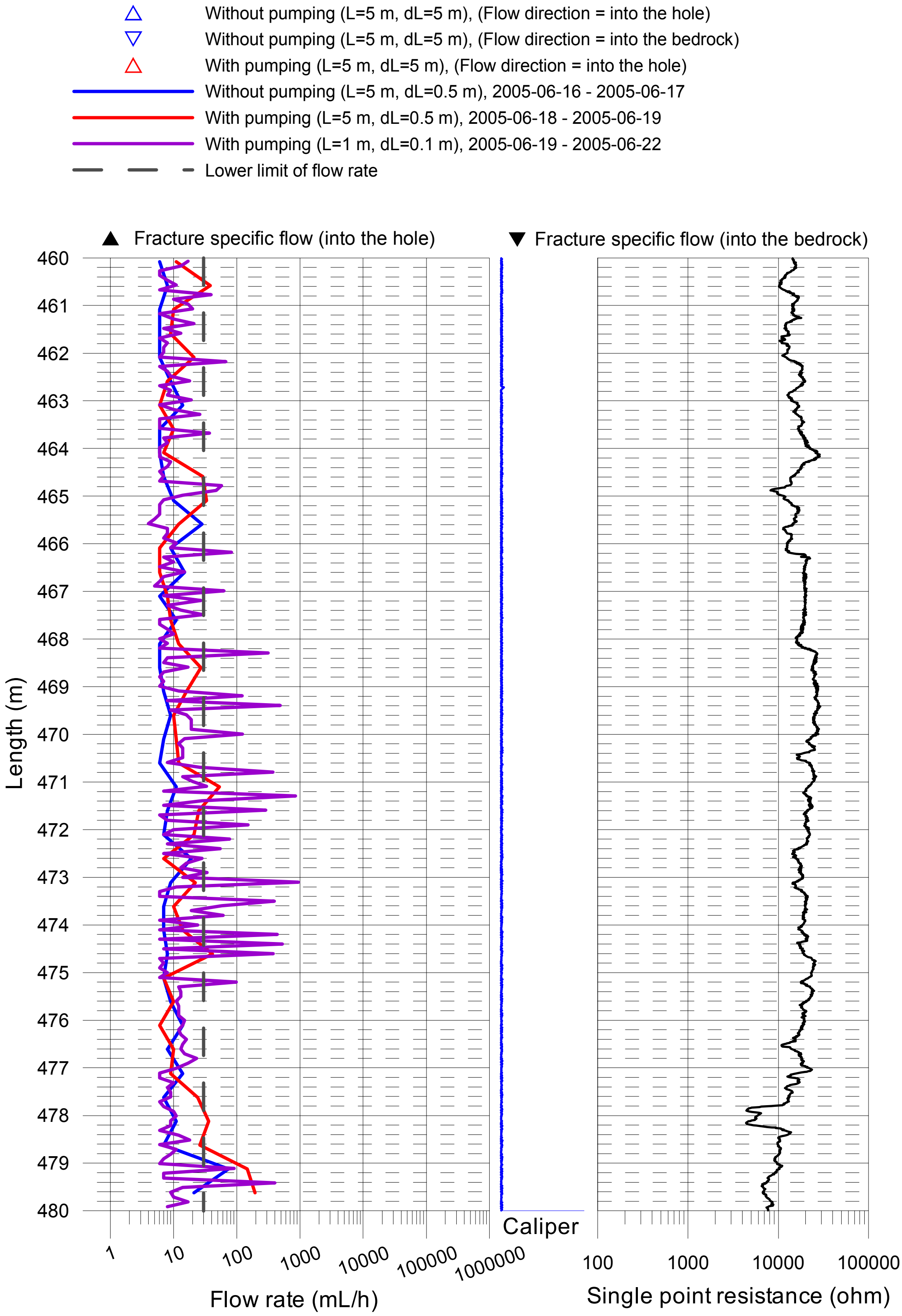


Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2005-06-16 - 2005-06-17
With pumping (L=5 m, dL=0.5 m), 2005-06-18 - 2005-06-19
With pumping (L=1 m, dL=0.1 m), 2005-06-19 - 2005-06-22
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
425.3
427.2
429.3
431.9
432.4
432.9
434.2
436.5
437.2
438.5
439.7
Caliper
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
100000
Single point resistance (ohm)

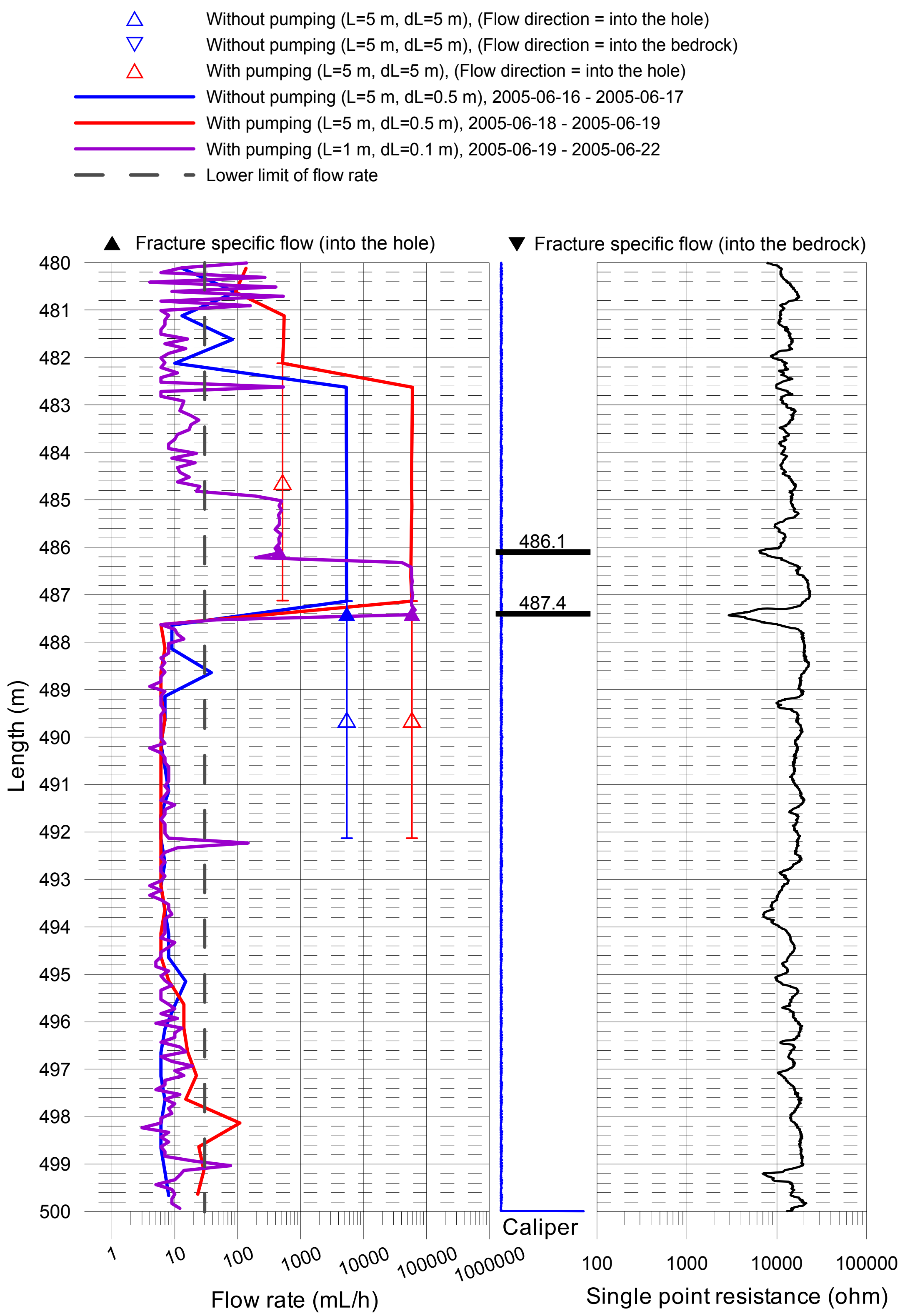
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



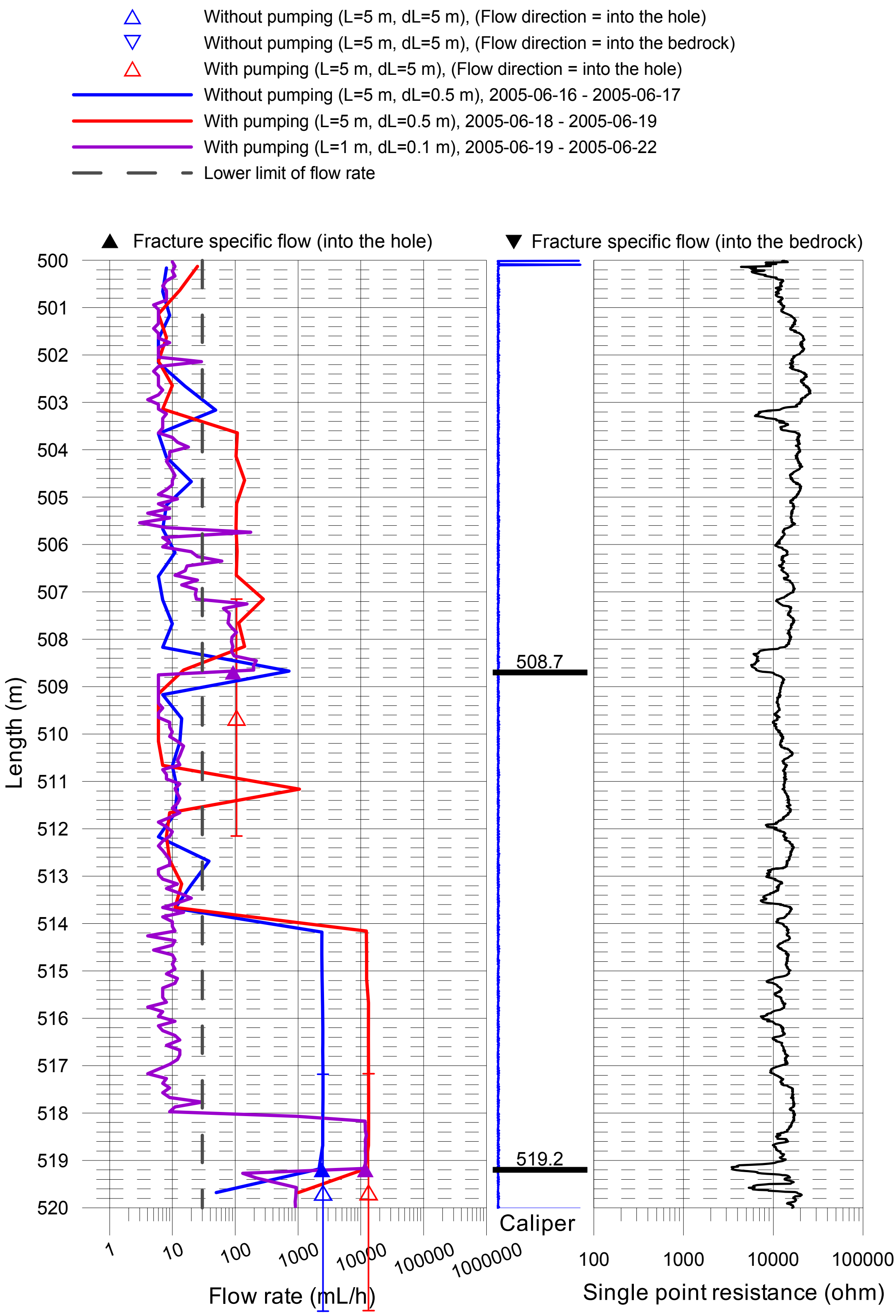
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



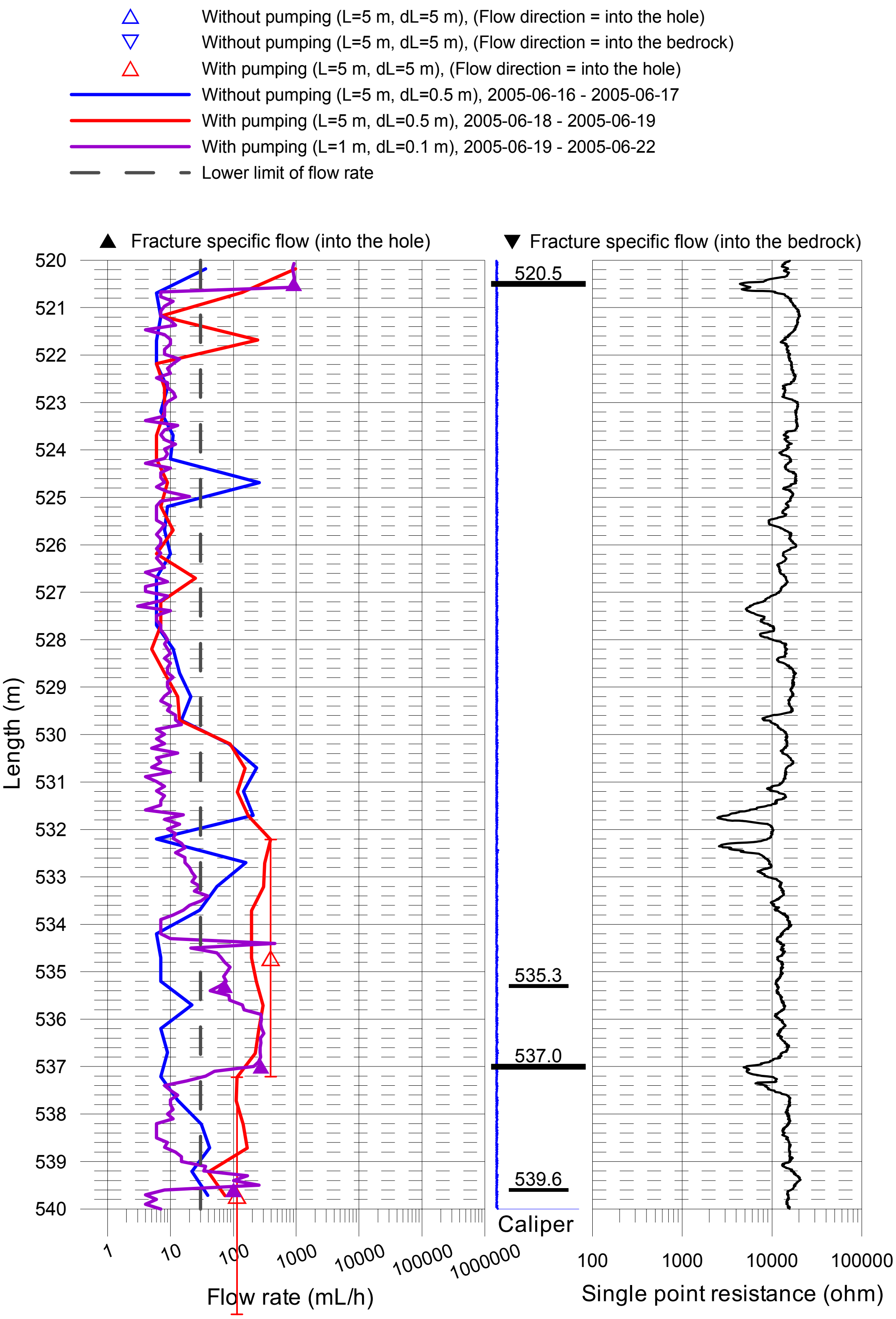
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



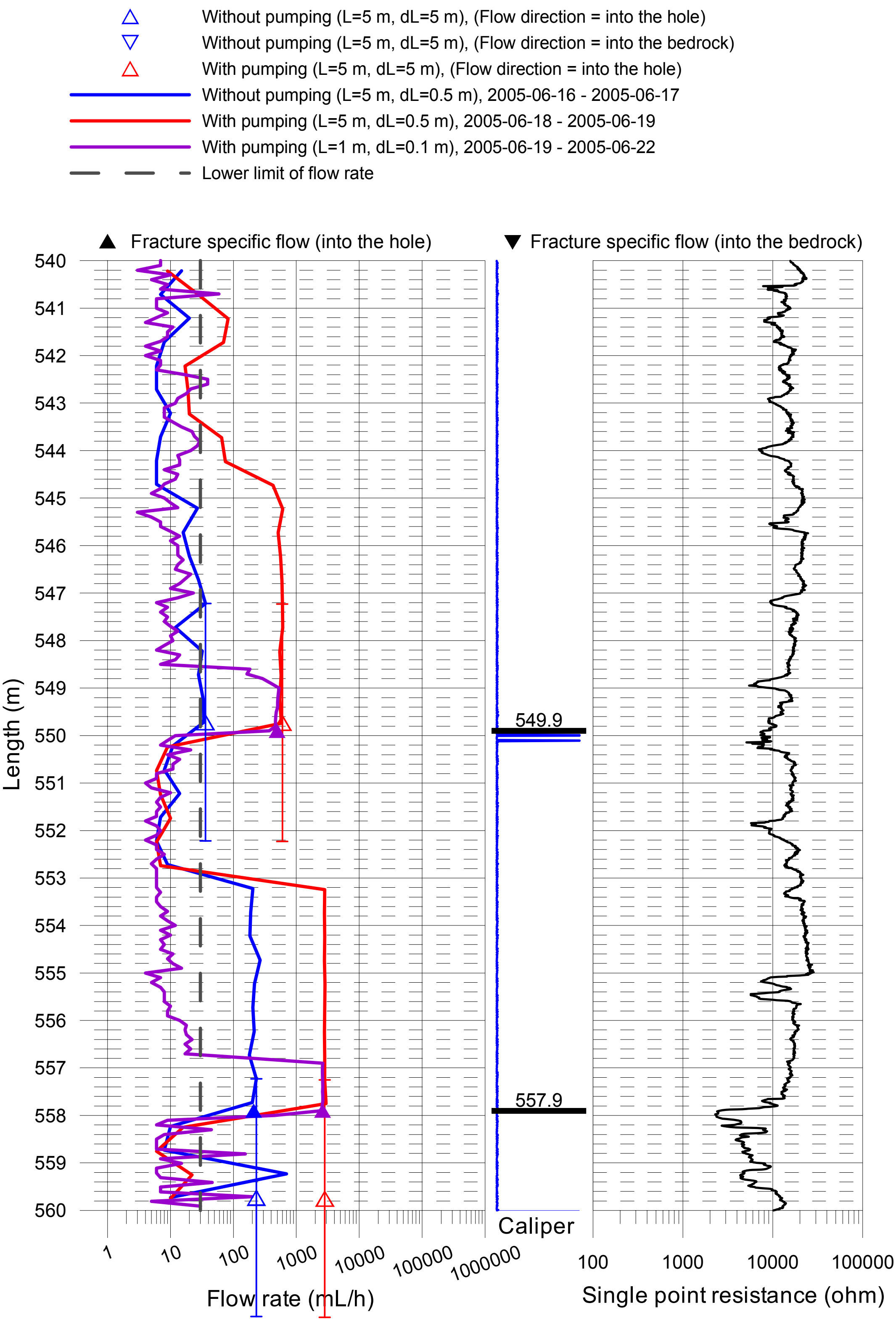
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



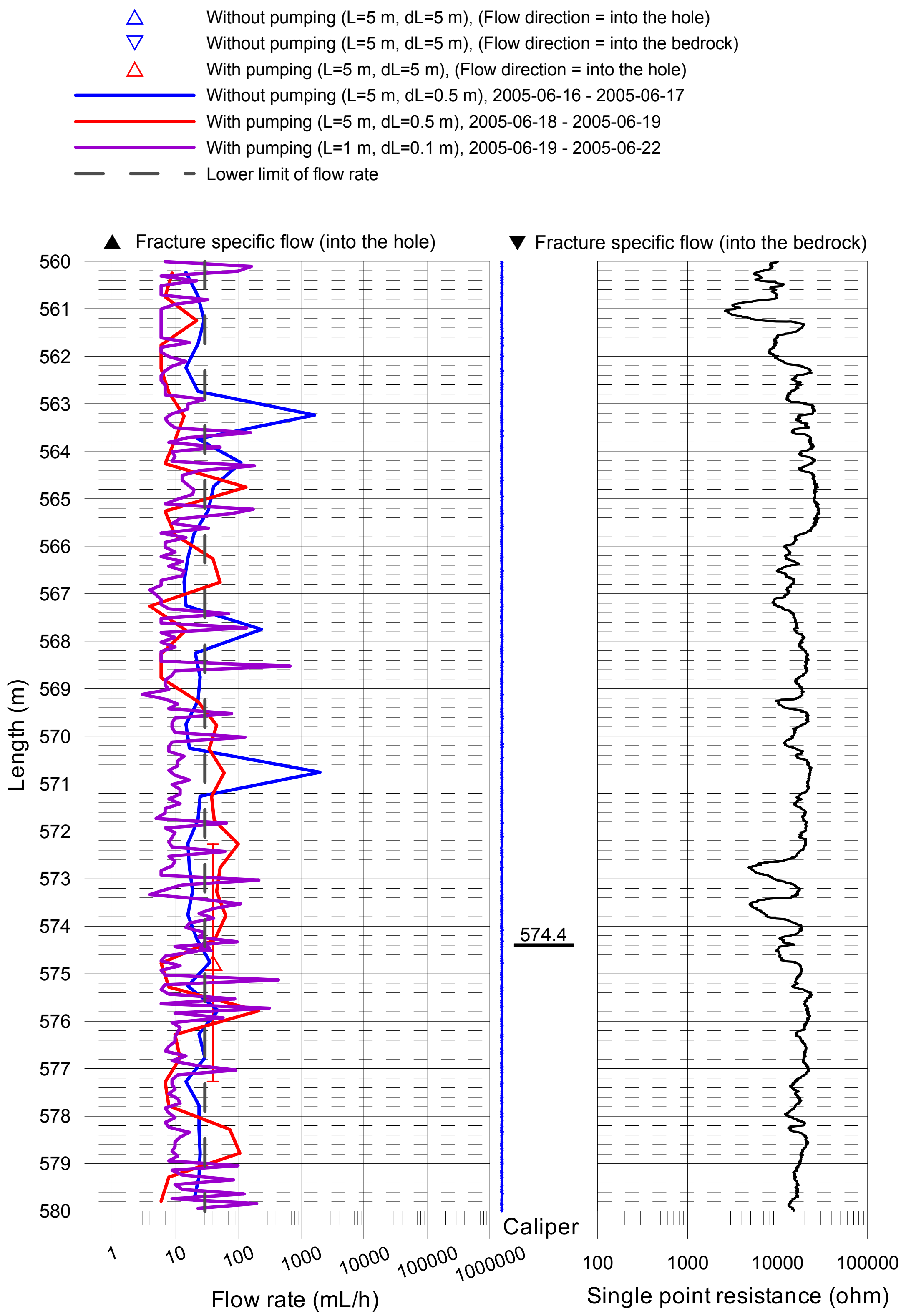
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



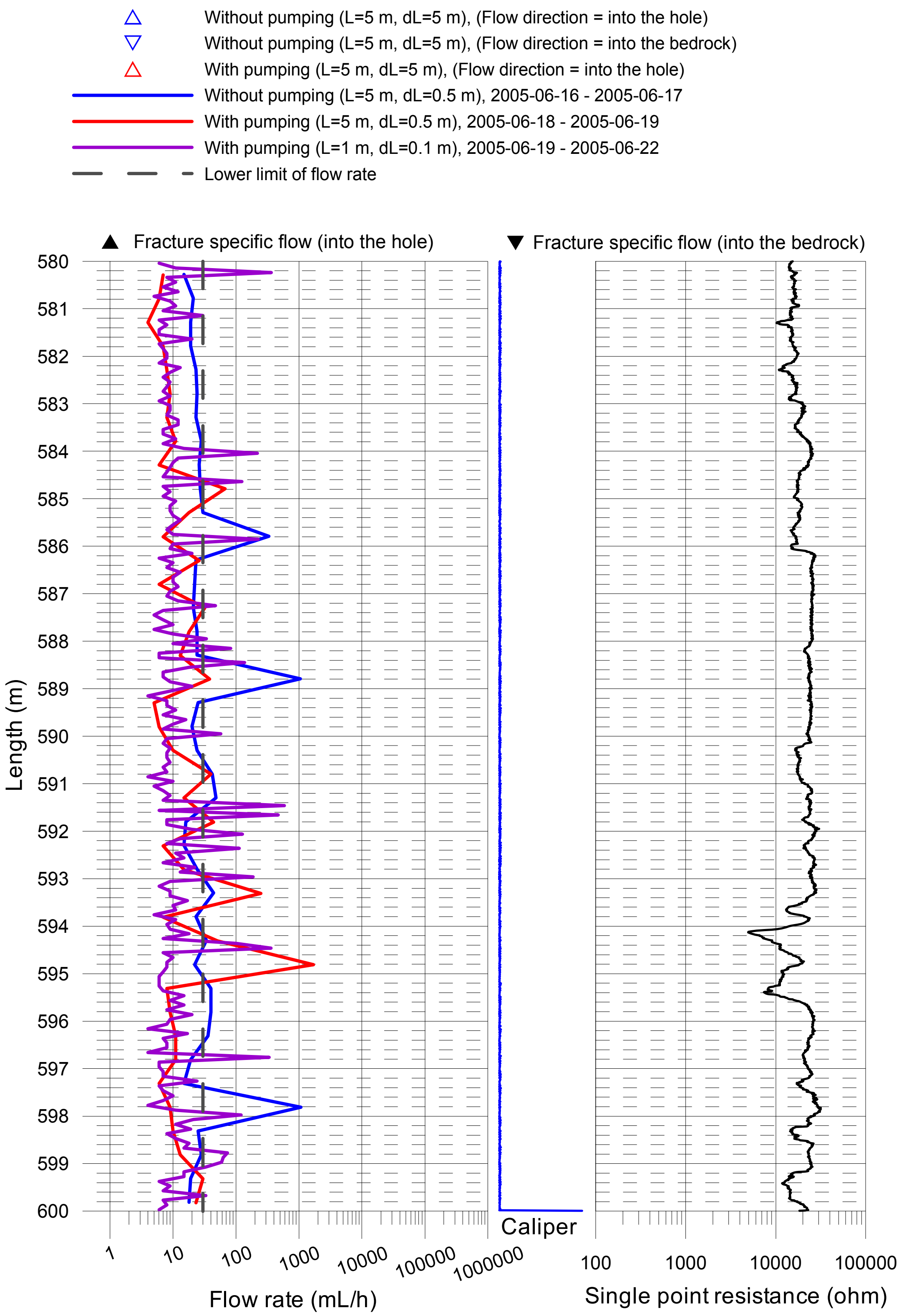
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



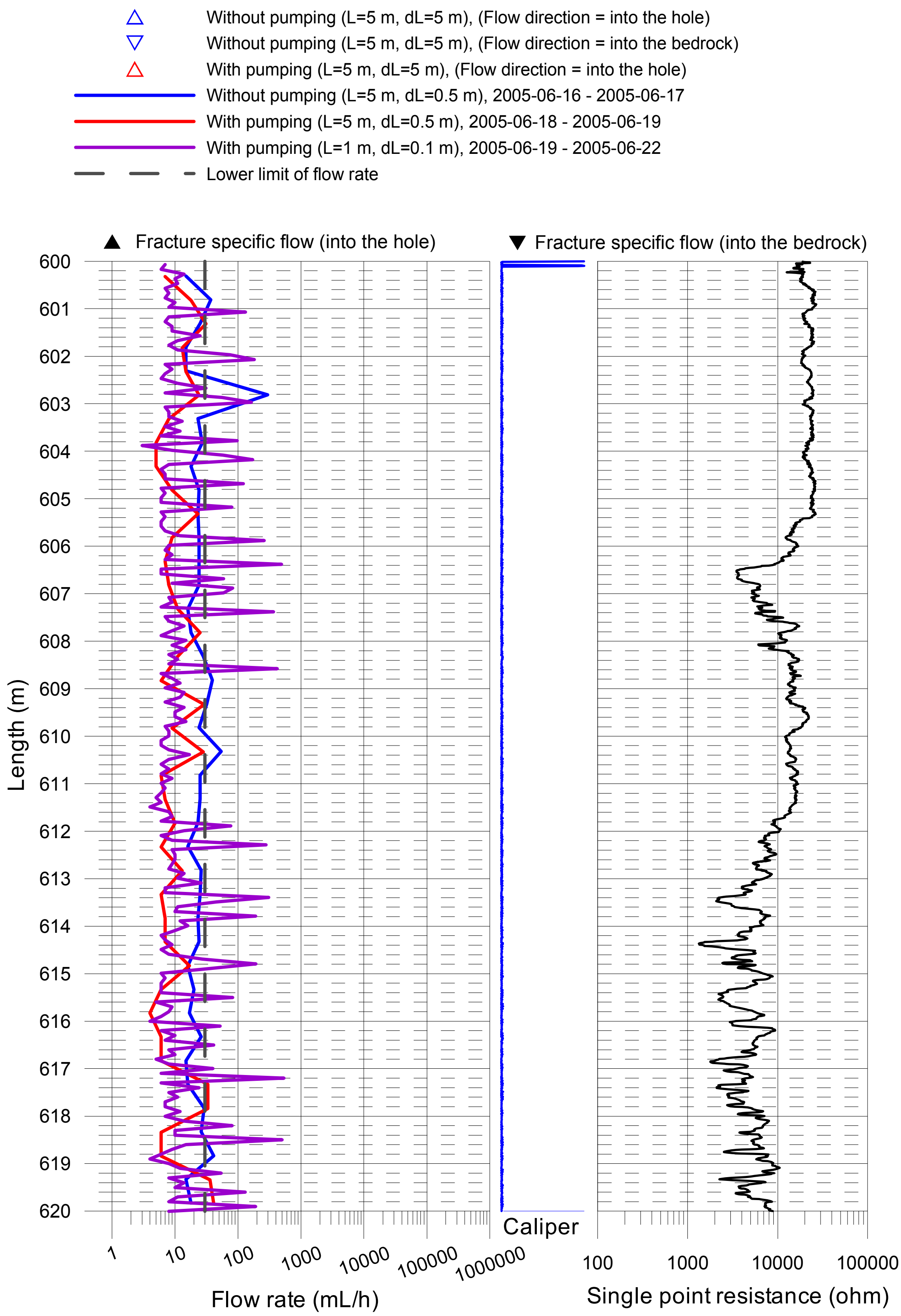
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



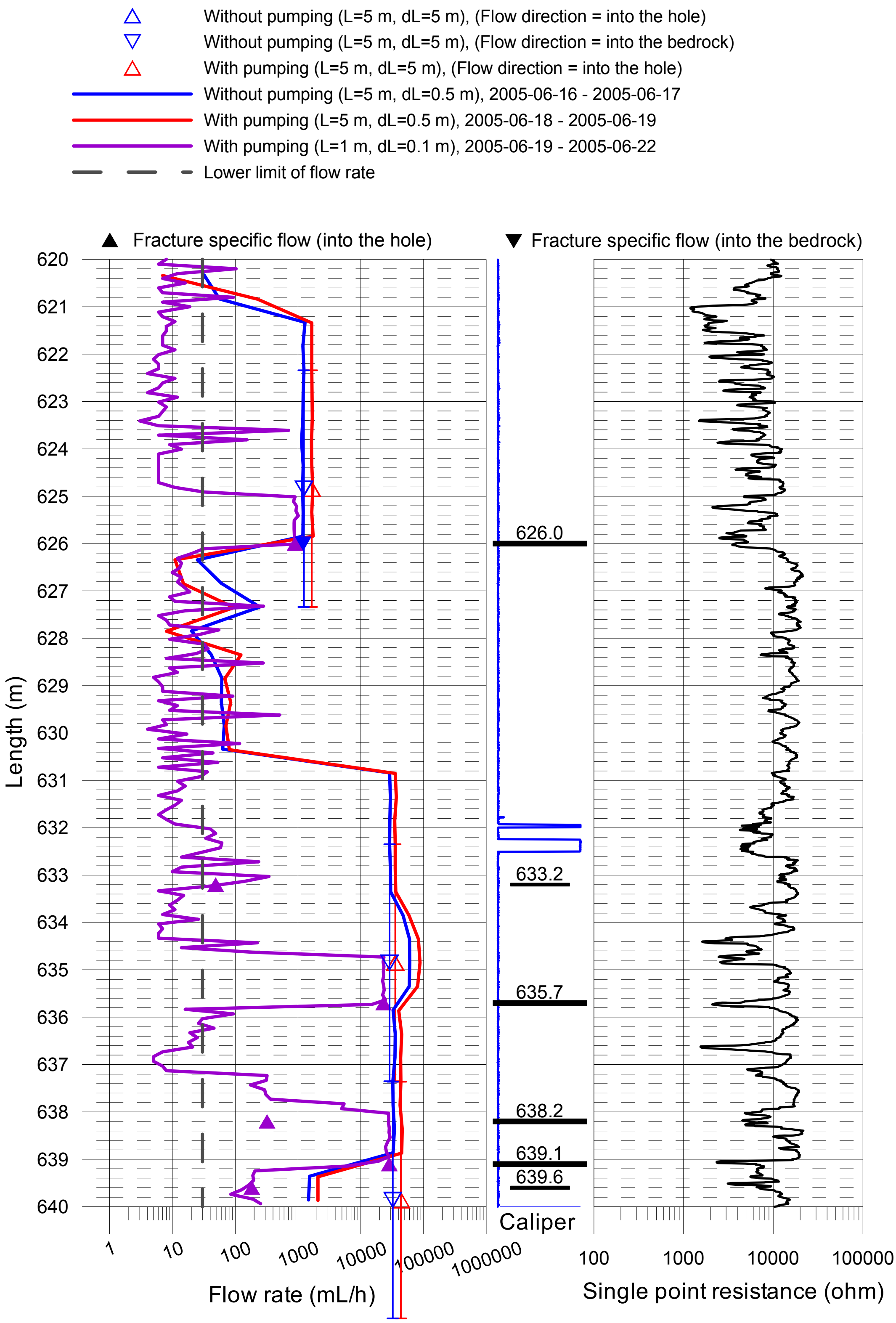
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



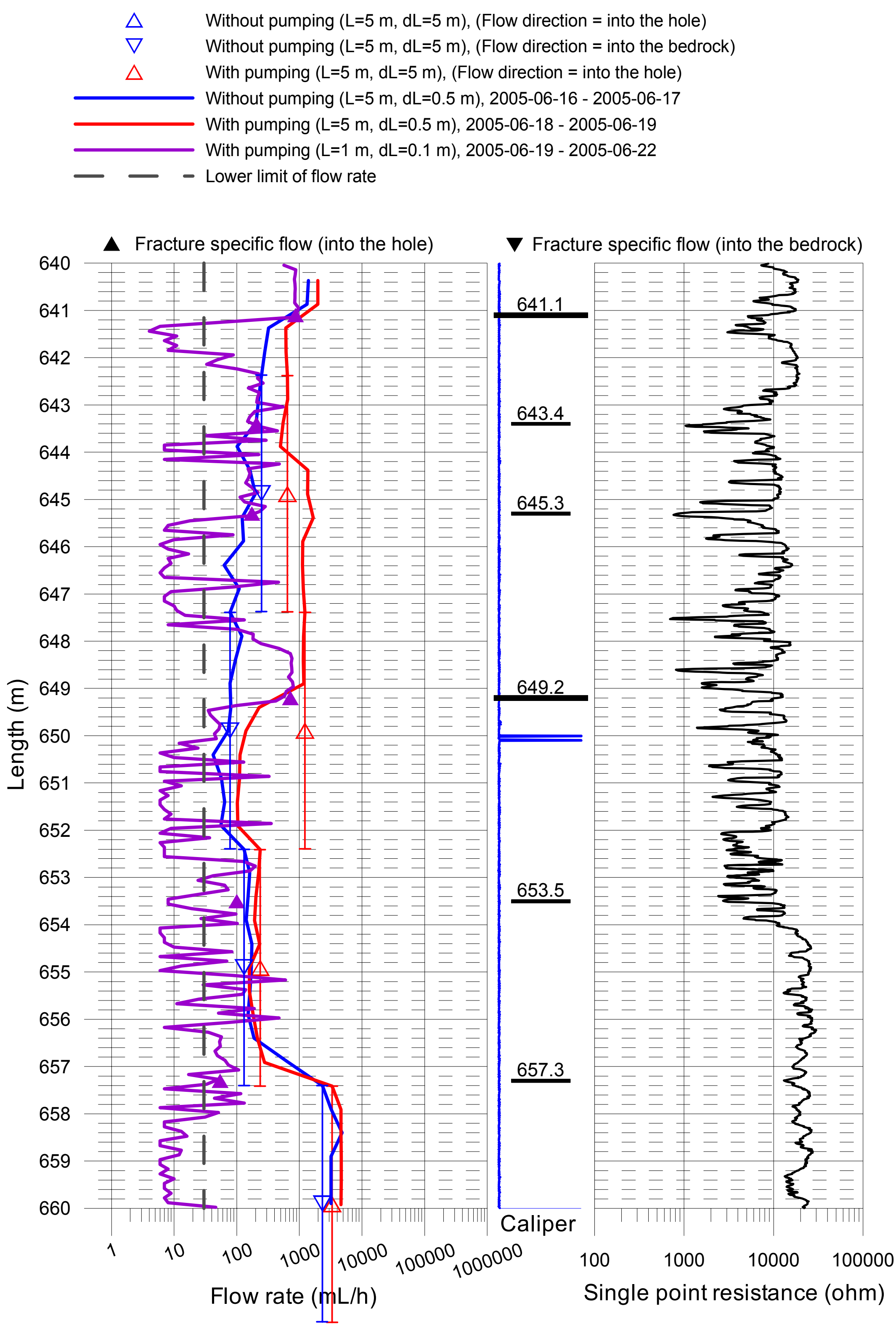
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



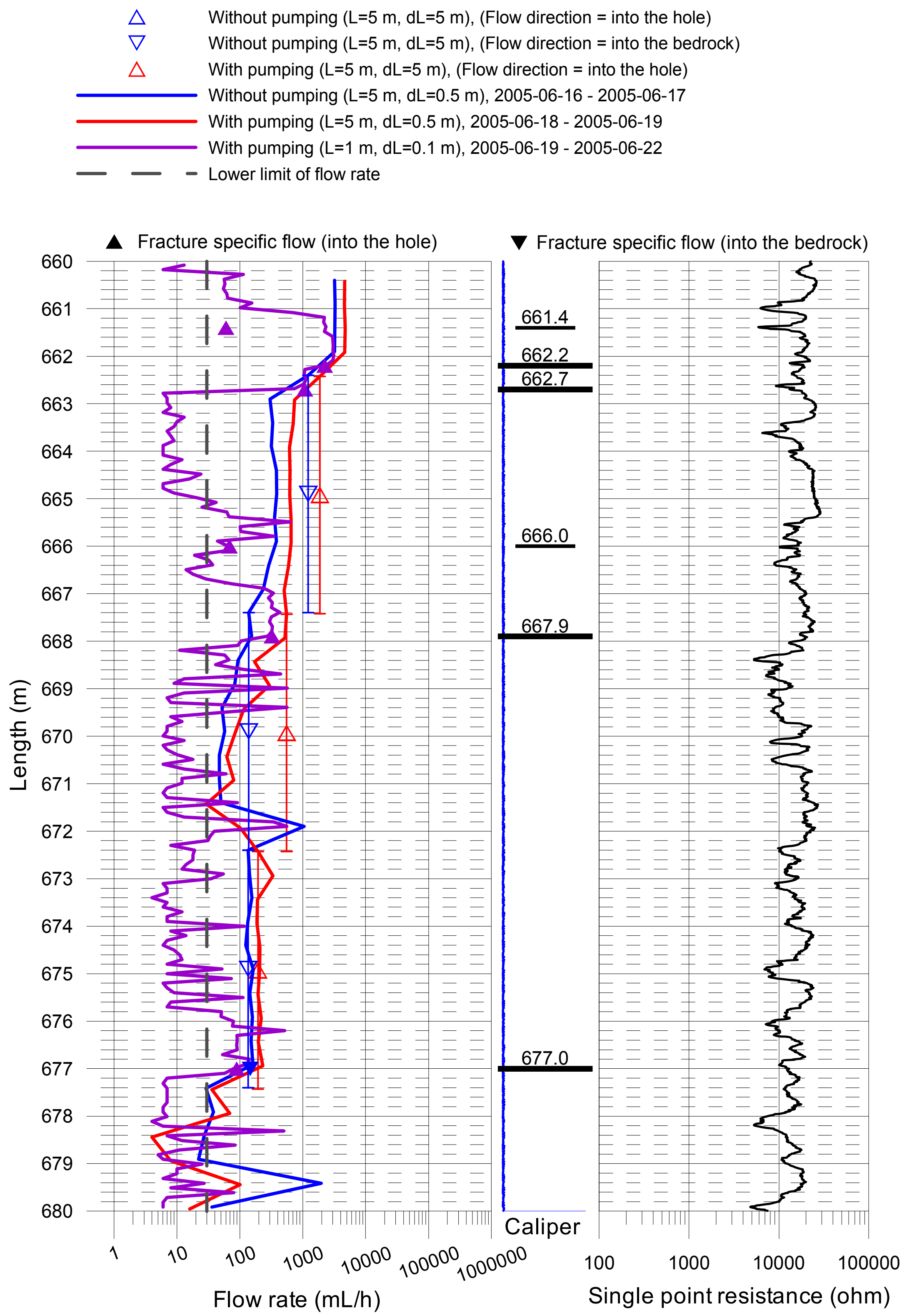
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



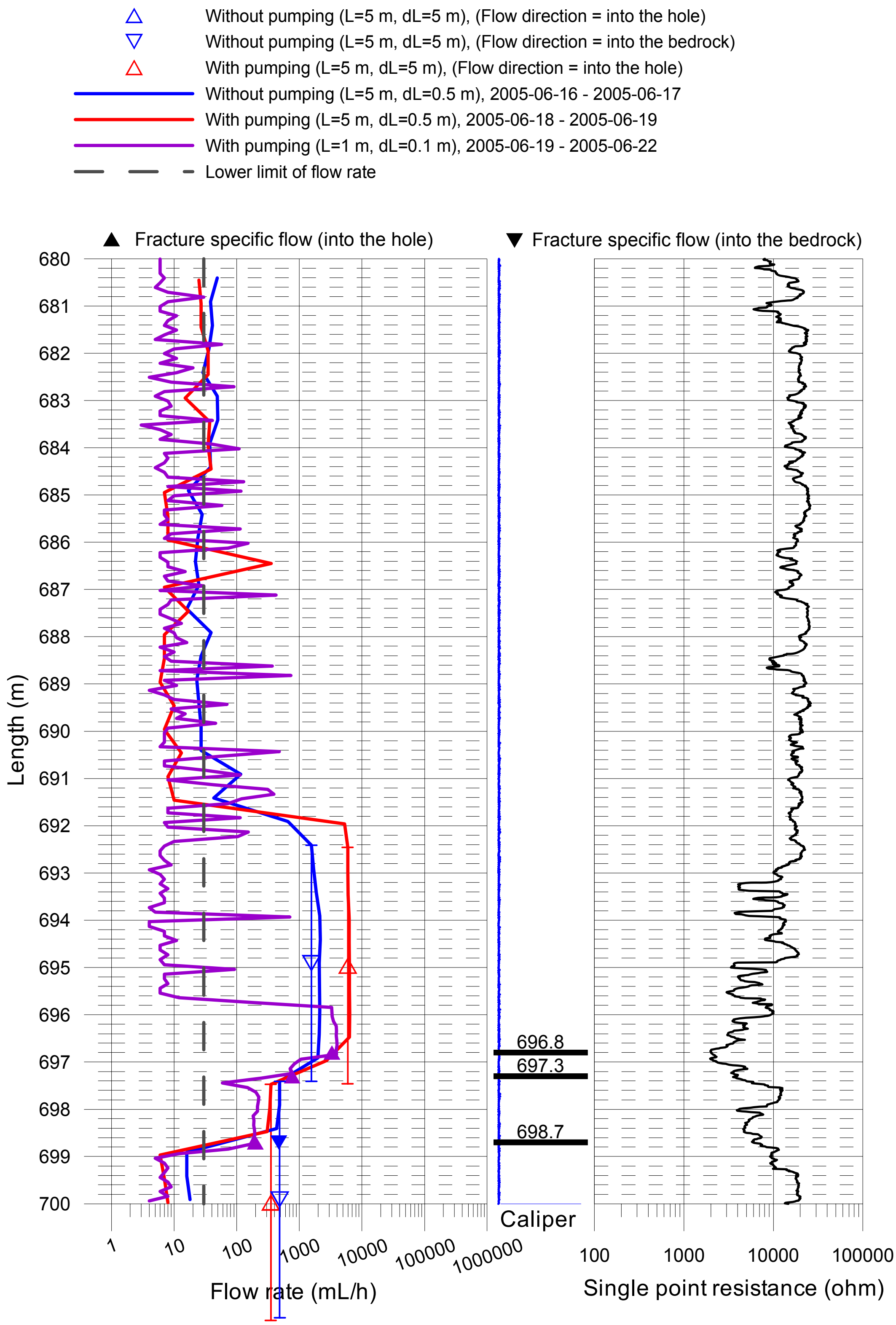
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



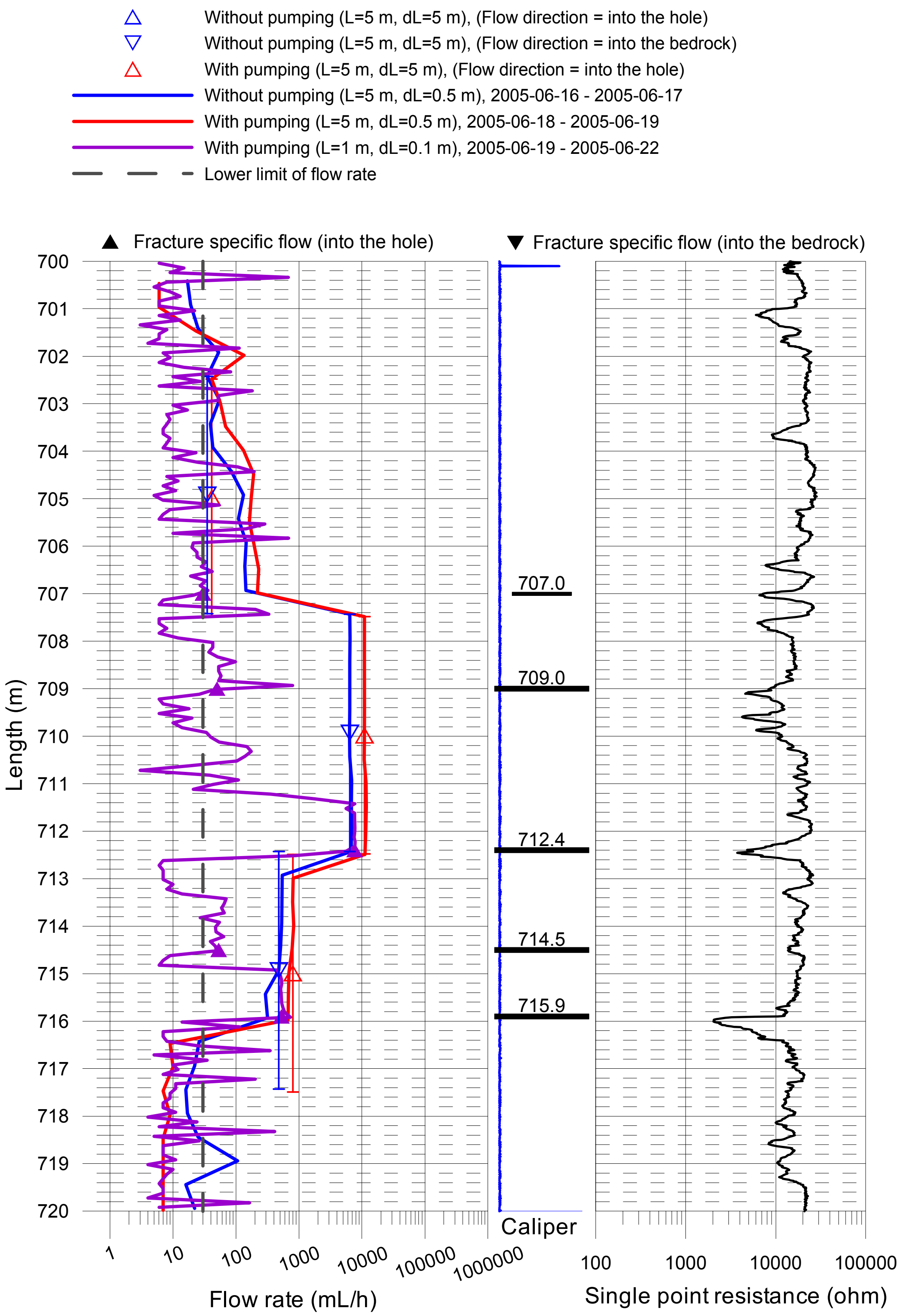
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



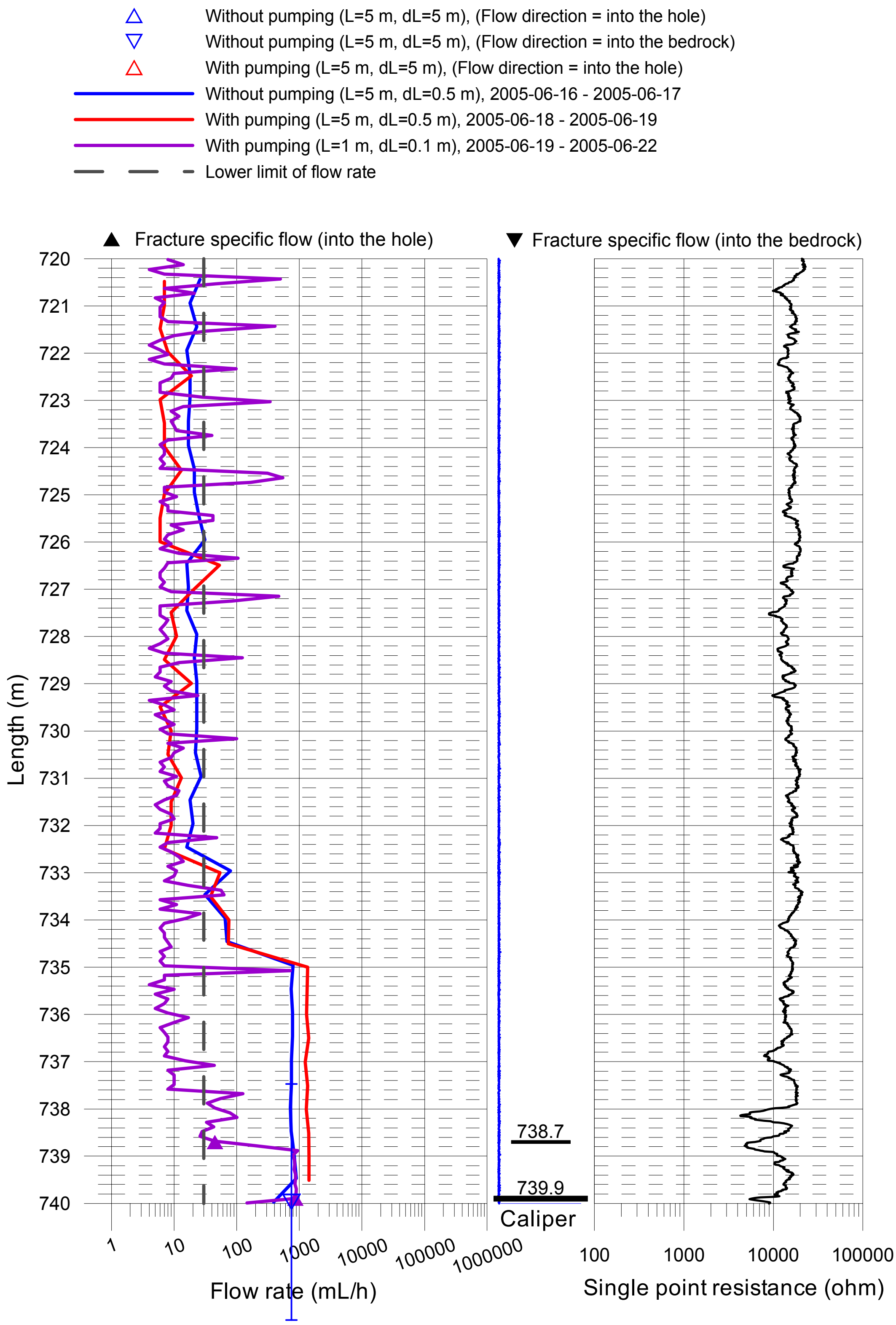
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



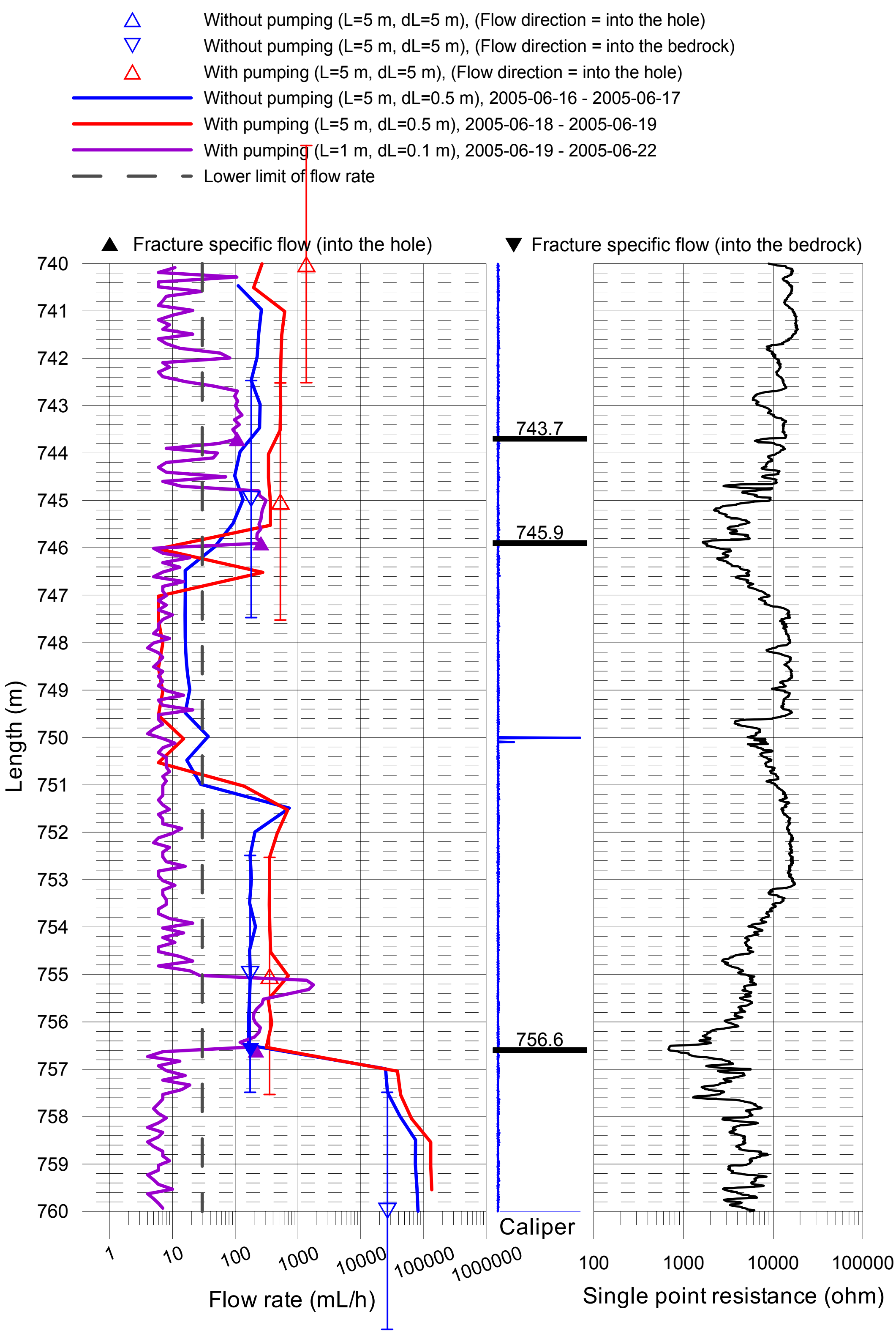
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



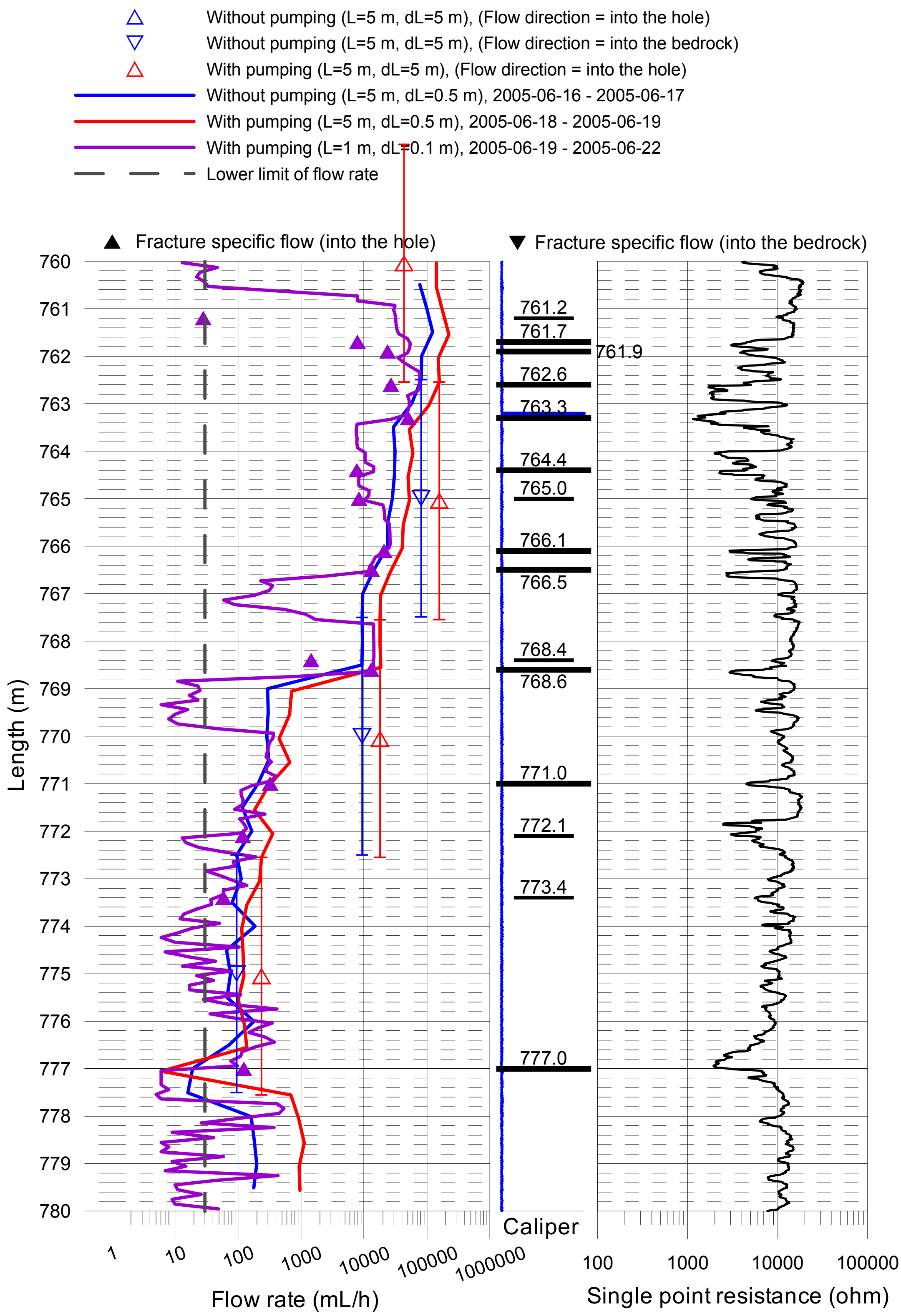
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



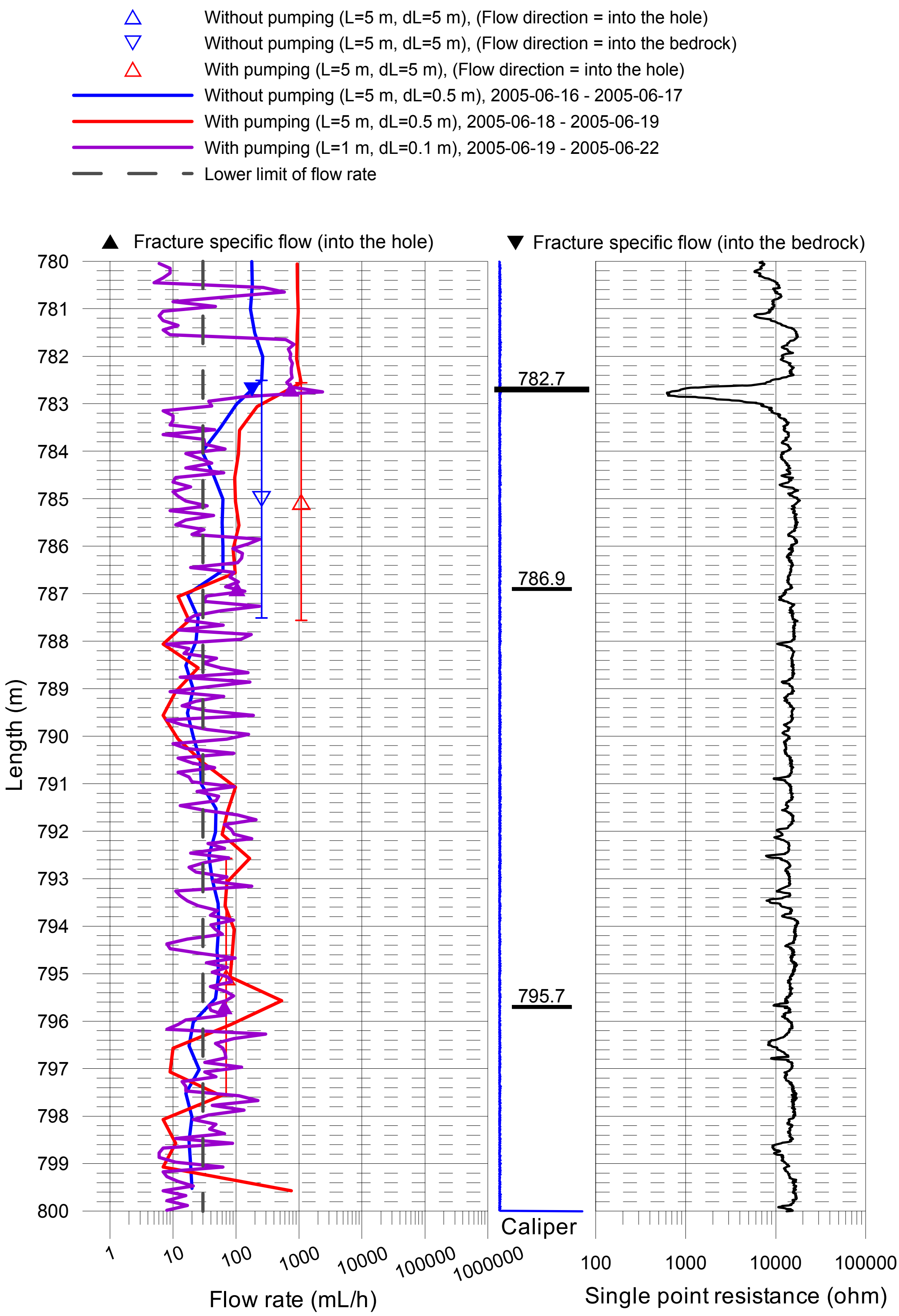
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



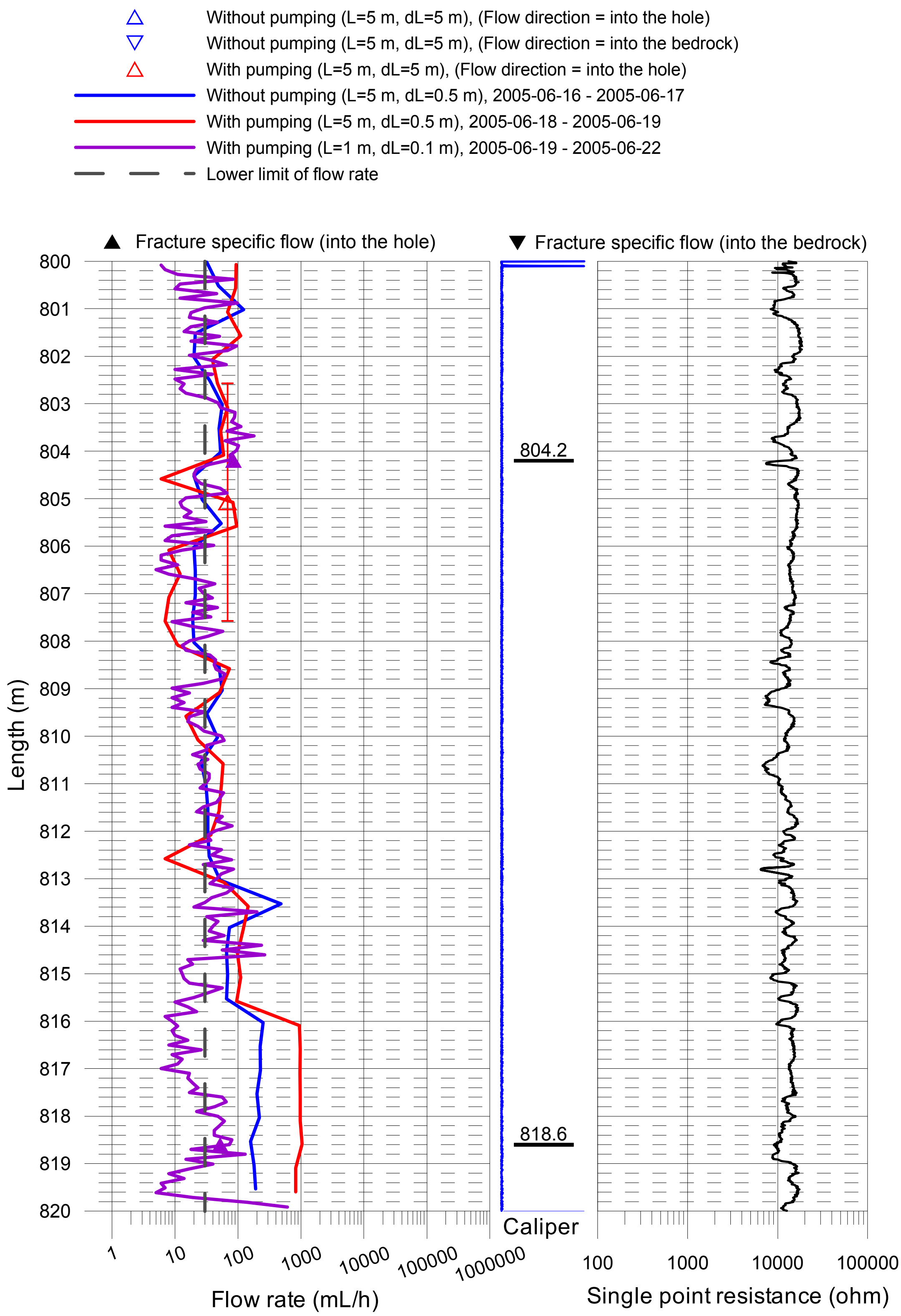
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



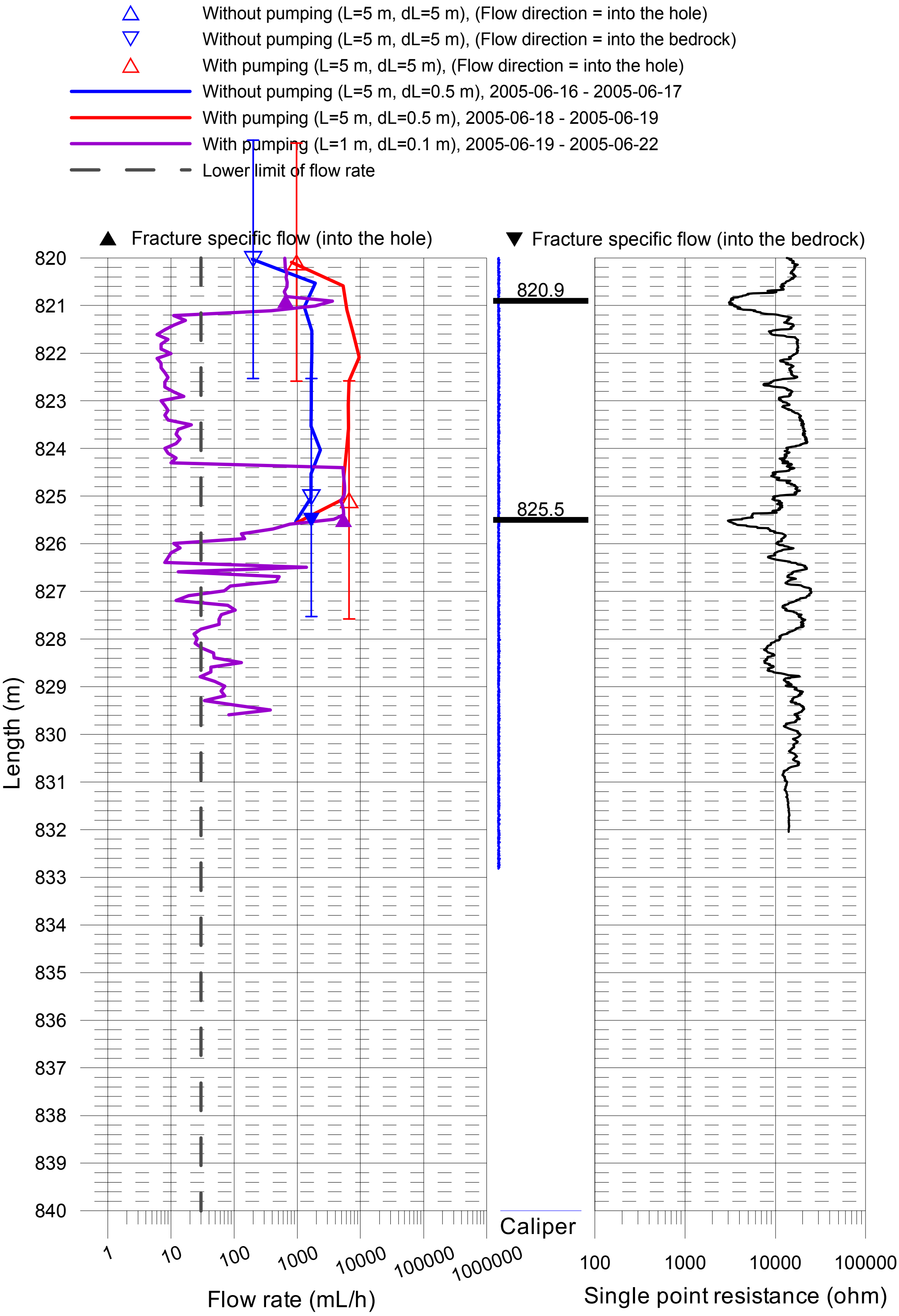
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance

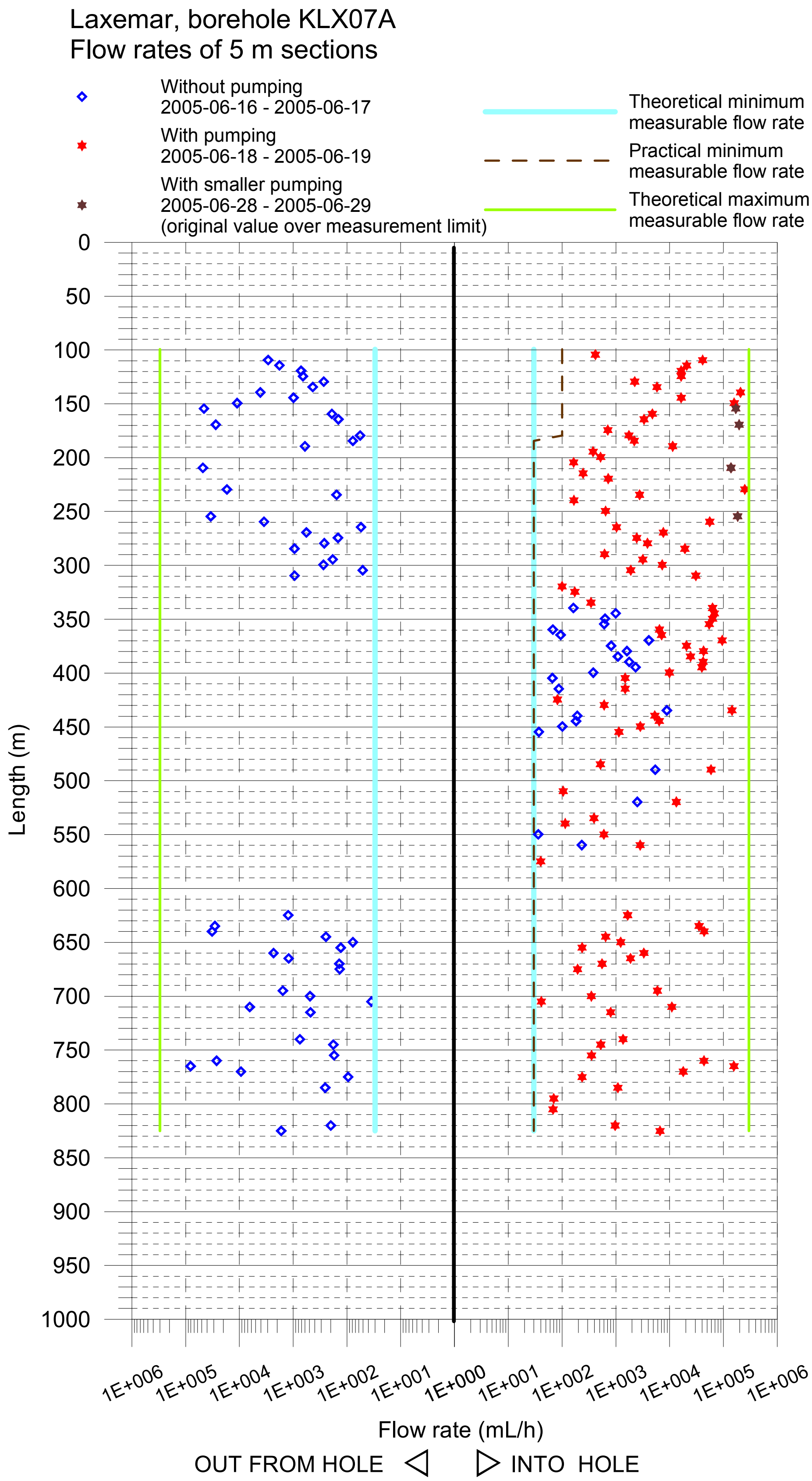


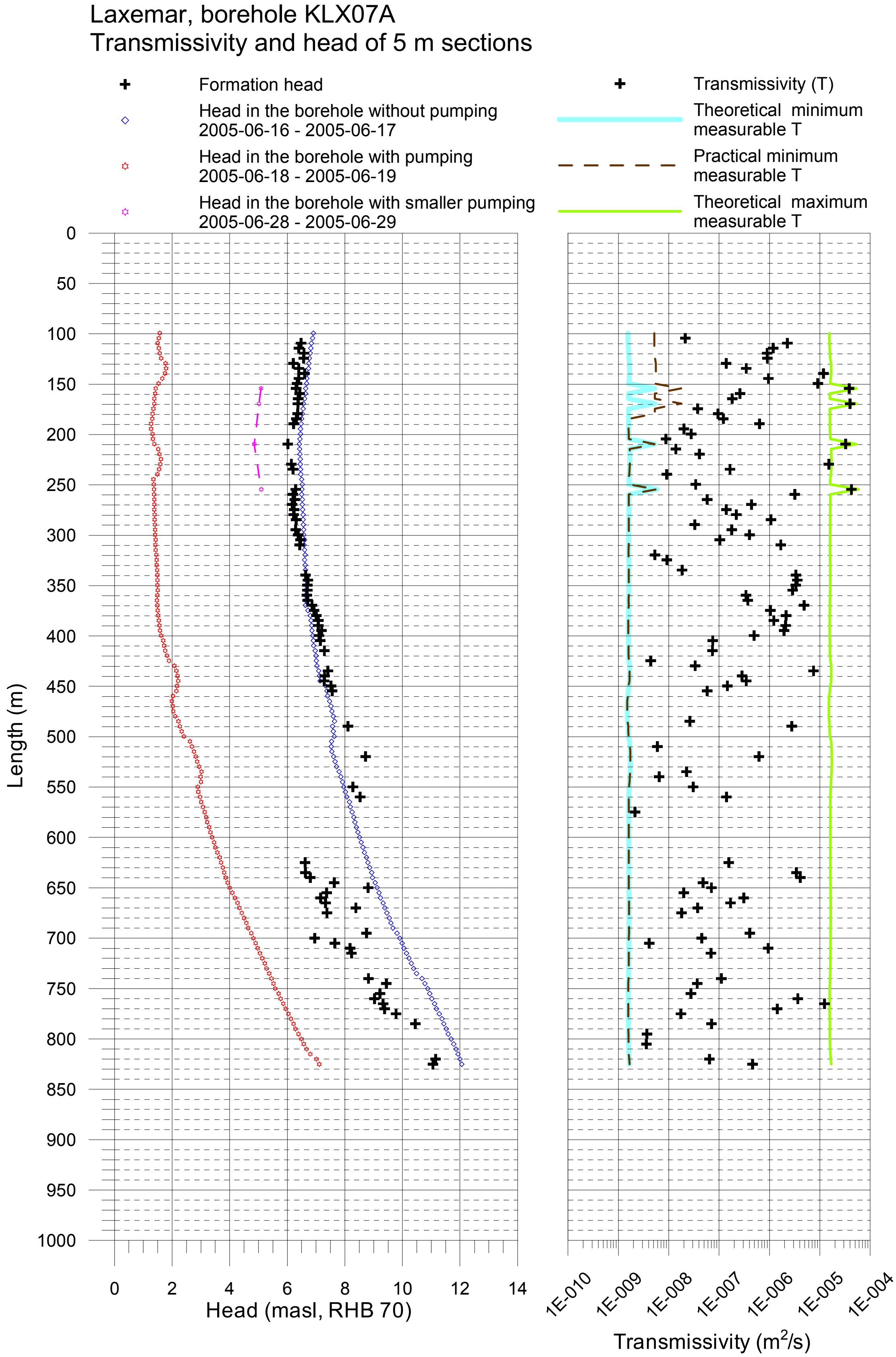
Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance



Laxemar, borehole KLX07A
Flow rate, caliper and single point resistance

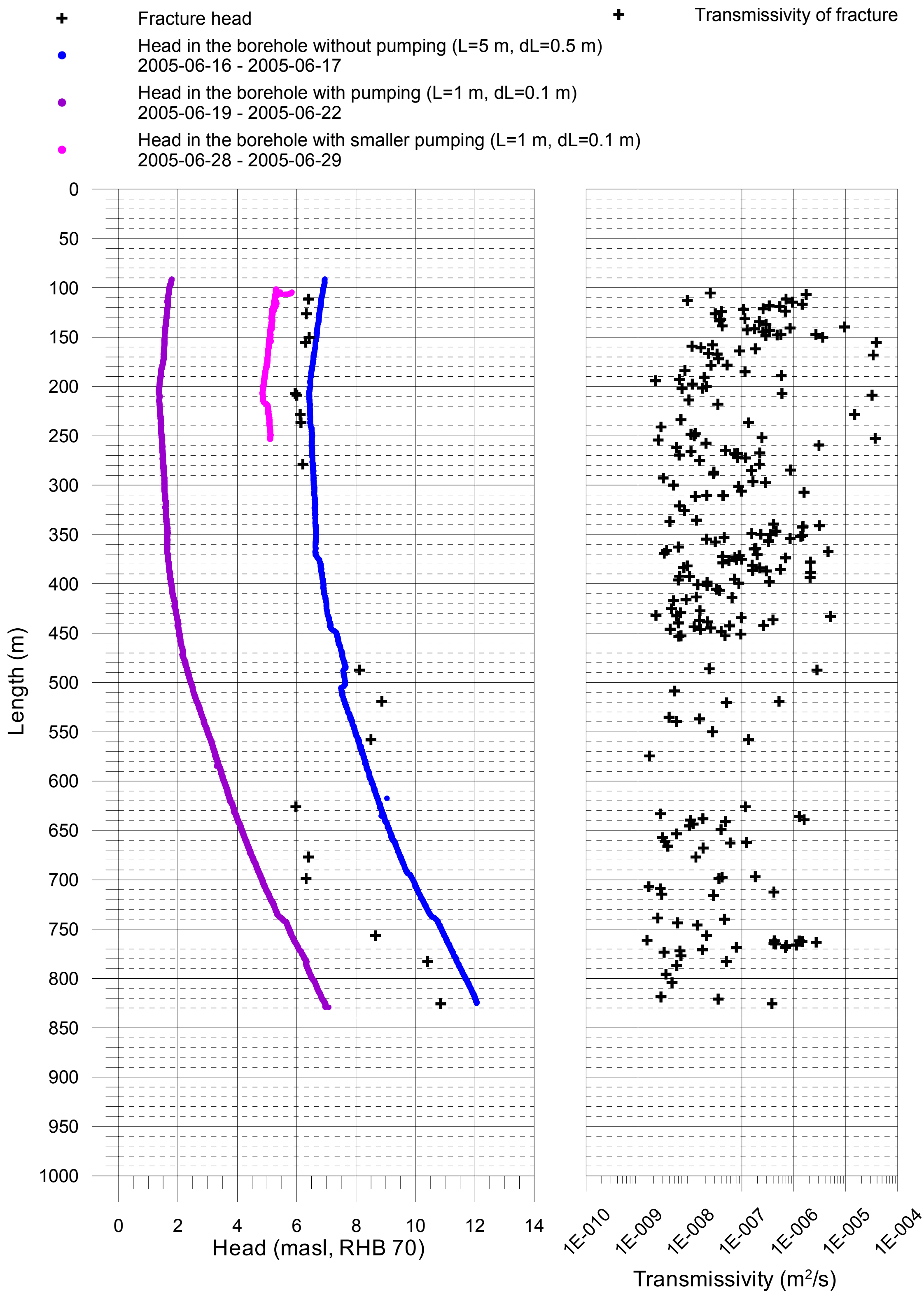



Laxemar, borehole KLX07A
Flow rates of 5 m sections
Without pumping
2005-06-16 - 2005-06-17
With pumping
2005-06-18 - 2005-06-19
With smaller pumping
2005-06-28 - 2005-06-29
(original value over measurement limit)
Theoretical minimum measurable flow rate
Practical minimum measurable flow rate
Theoretical maximum measurable flow rate
Length (m)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1E+006
1E+005
1E+004
1E+003
1E+002
1E+001
1E+000
1E+001
1E+002
1E+003
1E+004
1E+005
1E+006
Flow rate (mL/h)
OUT FROM HOLE
INTO HOLE



Laxemar, borehole KLX07A
Transmissivity and head of 5 m sections
Formation head
Head in the borehole without pumping 2005-06-16 - 2005-06-17
Head in the borehole with pumping 2005-06-18 - 2005-06-19
Head in the borehole with smaller pumping 2005-06-28 - 2005-06-29
Transmissivity (T)
Theoretical minimum measurable T
Practical minimum measurable T
Theoretical maximum measurable T
Length (m)
Head (masl, RHB 70)
Transmissivity (m2/s)

Laxemar, borehole KLX07A
Transmissivity and head of detected fractures



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)
KLX07A	96.78	827.56	5A	20050617	15:27	20050618	15:53	20050622	18:57	5	5	1.4E–3	

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 (–)
444,600		478,350		7.29	1.92		–5.37		2.6E–4		

Difference flow logging – Sequential flow logging

Borehole ID	Secup L (m)	Seclow L (m)	L_w (m)	Q_0 (m^3/s)	dh_0 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	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
KLX07A	96.78	101.78	5	–	6.91	–	1.57	–	–	100	1.5E–09	5.2E–09	1.5E–05	
KLX07A	101.78	106.78	5	–	6.88	1.16E–07	1.54	2.1E–08	–	100	1.5E–09	5.2E–09	1.5E–05	
KLX07A	106.79	111.79	5	–8.17E–07	6.84	1.14E–05	1.50	2.3E–06	6.5	100	1.5E–09	5.2E–09	1.5E–05	
KLX07A	111.80	116.80	5	–5.00E–07	6.82	5.78E–06	1.54	1.2E–06	6.4	100	1.6E–09	5.2E–09	1.6E–05	
KLX07A	116.80	121.80	5	–1.98E–07	6.80	4.56E–06	1.57	9.0E–07	6.6	100	1.6E–09	5.3E–09	1.6E–05	
KLX07A	121.80	126.80	5	–1.83E–07	6.77	4.56E–06	1.62	9.1E–07	6.6	100	1.6E–09	5.3E–09	1.6E–05	
KLX07A	126.81	131.81	5	–7.50E–08	6.75	6.22E–07	1.77	1.4E–07	6.2	100	1.7E–09	5.5E–09	1.7E–05	
KLX07A	131.81	136.81	5	–1.21E–07	6.74	1.61E–06	1.79	3.5E–07	6.4	100	1.7E–09	5.6E–09	1.7E–05	
KLX07A	136.82	141.82	5	–1.14E–06	6.70	5.78E–05	1.75	1.2E–05	6.6	100	1.7E–09	5.6E–09	1.7E–05	
KLX07A	141.82	146.82	5	–2.74E–07	6.68	4.56E–06	1.66	9.5E–07	6.4	100	1.6E–09	5.5E–09	1.6E–05	
KLX07A	146.82	151.82	5	–3.06E–06	6.67	4.42E–05	1.53	9.1E–06	6.3	100	1.6E–09	5.4E–09	1.6E–05	
KLX07A	151.83	156.83	5	–1.27E–05	6.64	4.72E–05	5.09	3.8E–05	6.3	100	5.3E–09	1.8E–08	5.3E–05	**
KLX07A	156.83	161.83	5	–5.28E–08	6.63	1.32E–06	1.41	2.6E–07	6.4	100	1.6E–09	5.3E–09	1.6E–05	
KLX07A	161.84	166.84	5	–4.00E–08	6.60	9.28E–07	1.38	1.8E–07	6.4	100	1.6E–09	5.3E–09	1.6E–05	
KLX07A	166.84	171.84	5	–7.61E–06	6.56	5.44E–05	5.02	4.0E–05	6.4	100	5.4E–09	1.8E–08	5.4E–05	**
KLX07A	171.85	176.85	5	–	6.55	1.97E–07	1.35	3.8E–08	–	100	1.6E–09	5.3E–09	1.6E–05	
KLX07A	176.86	181.86	5	–1.58E–08	6.52	4.86E–07	1.32	9.6E–08	6.4	100	1.6E–09	5.3E–09	1.6E–05	
KLX07A	181.87	186.87	5	–2.17E–08	6.50	6.11E–07	1.31	1.2E–07	6.3	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	186.88	191.88	5	–1.68E–07	6.48	3.17E–06	1.27	6.3E–07	6.2	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	191.89	196.89	5	–	6.46	1.05E–07	1.27	2.0E–08	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	196.90	201.90	5	–	6.46	1.44E–07	1.32	2.8E–08	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	201.90	206.90	5	–	6.44	4.56E–08	1.33	8.8E–09	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	206.91	211.91	5	–1.33E–05	6.42	3.83E–05	4.85	3.3E–05	6.0	30	5.3E–09	5.3E–09	5.3E–05	**

Borehole ID	Secup L (m)	Seclow L (m)	L_w (m)	Q_0 (m^3/s)	dh_0 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	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
KLX07A	211.92	216.92	5	–	6.43	6.83E–08	1.52	1.4E–08	–	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	216.92	221.92	5	–	6.44	2.01E–07	1.56	4.1E–08	–	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	221.93	226.93	5	–	6.45	–	1.61	–	–	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	226.93	231.93	5	–4.75E–06	6.45	6.94E–05	1.59	1.5E–05	6.1	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	231.93	236.93	5	–4.36E–08	6.46	7.69E–07	1.55	1.6E–07	6.2	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	236.93	241.93	5	–	6.47	4.61E–08	1.49	9.2E–09	–	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	241.93	246.93	5	–	6.50	–	1.35	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	246.93	251.93	5	–	6.52	1.79E–07	1.36	3.4E–08	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	251.93	256.93	5	–9.44E–06	6.51	5.11E–05	5.10	4.3E–05	6.3	30	5.9E–09	5.9E–09	5.9E–05	**
KLX07A	256.93	261.93	5	–9.67E–07	6.50	1.55E–05	1.37	3.2E–06	6.2	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	261.95	266.95	5	–1.53E–08	6.52	2.86E–07	1.38	5.8E–08	6.3	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	266.96	271.96	5	–1.57E–07	6.52	2.12E–06	1.38	4.4E–07	6.2	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	271.97	276.97	5	–4.08E–08	6.53	6.81E–07	1.38	1.4E–07	6.2	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	276.97	281.97	5	–7.33E–08	6.55	1.08E–06	1.39	2.2E–07	6.2	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	281.98	286.98	5	–2.64E–07	6.55	5.33E–06	1.39	1.1E–06	6.3	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	286.98	291.98	5	–	6.56	1.71E–07	1.40	3.3E–08	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	291.99	296.99	5	–5.11E–08	6.57	8.78E–07	1.41	1.8E–07	6.3	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	296.99	301.99	5	–7.61E–08	6.57	2.02E–06	1.41	4.0E–07	6.4	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	302.00	307.00	5	–1.42E–08	6.60	5.25E–07	1.43	1.0E–07	6.5	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	307.00	312.00	5	–2.62E–07	6.58	8.50E–06	1.42	1.7E–06	6.4	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	312.00	317.00	5	–	6.60	–	1.43	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	317.00	322.00	5	–	6.62	2.78E–08	1.45	5.3E–09	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	322.00	327.00	5	–	6.60	4.78E–08	1.46	9.2E–09	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	326.99	331.99	5	–	6.62	–	1.46	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	331.99	336.99	5	–	6.63	9.56E–08	1.48	1.8E–08	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	336.99	341.99	5	4.50E–08	6.63	1.75E–05	1.49	3.4E–06	6.6	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	341.99	346.99	5	2.76E–07	6.64	1.88E–05	1.49	3.6E–06	6.7	30	1.6E–09	1.6E–09	1.6E–05	

Borehole ID	Secup L (m)	Seclow L (m)	L_w (m)	Q_0 (m^3/s)	dh_0 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	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
KLX07A	347.00	352.00	5	1.75E–07	6.65	1.75E–05	1.49	3.3E–06	6.7	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	352.02	357.02	5	1.68E–07	6.64	1.51E–05	1.50	2.9E–06	6.7	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	357.05	362.05	5	1.86E–08	6.63	1.79E–06	1.49	3.4E–07	6.7	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	362.07	367.07	5	2.61E–08	6.64	1.97E–06	1.47	3.7E–07	6.7	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	367.10	372.10	5	1.15E–06	6.63	2.64E–05	1.49	4.9E–06	6.9	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	372.09	377.09	5	2.26E–07	6.72	5.72E–06	1.50	1.0E–06	6.9	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	377.09	382.09	5	4.44E–07	6.80	1.19E–05	1.52	2.1E–06	7.0	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	382.08	387.08	5	3.03E–07	6.83	6.81E–06	1.54	1.2E–06	7.1	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	387.07	392.07	5	4.92E–07	6.85	1.17E–05	1.56	2.1E–06	7.1	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	392.06	397.06	5	6.47E–07	6.86	1.11E–05	1.58	2.0E–06	7.2	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	397.06	402.06	5	1.06E–07	6.89	2.74E–06	1.62	5.0E–07	7.1	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	402.06	407.06	5	1.83E–08	6.91	4.14E–07	1.69	7.5E–08	7.2	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	407.07	412.07	5	–	6.92	–	1.72	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	412.07	417.07	5	2.42E–08	6.97	4.14E–07	1.76	7.4E–08	7.3	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	417.07	422.07	5	–	7.00	–	1.82	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	422.07	427.07	5	–	7.01	2.28E–08	1.89	4.4E–09	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	427.08	432.08	5	–	7.03	1.68E–07	2.08	3.4E–08	–	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	432.08	437.08	5	2.47E–06	7.09	4.00E–05	2.15	7.5E–06	7.4	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	437.08	442.08	5	5.33E–08	7.12	1.48E–06	2.19	2.9E–07	7.3	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	442.08	447.08	5	5.06E–08	7.14	1.78E–06	2.21	3.5E–07	7.3	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	447.07	452.07	5	2.81E–08	7.33	7.92E–07	2.17	1.5E–07	7.5	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	452.07	457.07	5	1.03E–08	7.38	3.17E–07	2.15	5.8E–08	7.6	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	457.08	462.08	5	–	7.40	–	2.03	–	–	30	1.5E–09	1.5E–09	1.5E–05	
KLX07A	462.09	467.09	5	–	7.47	–	1.99	–	–	30	1.5E–09	1.5E–09	1.5E–05	
KLX07A	467.10	472.10	5	–	7.52	–	2.02	–	–	30	1.5E–09	1.5E–09	1.5E–05	
KLX07A	472.11	477.11	5	–	7.55	–	2.04	–	–	30	1.5E–09	1.5E–09	1.5E–05	
KLX07A	477.12	482.12	5	–	7.60	–	2.11	–	–	30	1.5E–09	1.5E–09	1.5E–05	

Borehole ID	Secup L (m)	Seclow L (m)	L_w (m)	Q_0 (m^3/s)	dh_0 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	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
KLX07A	482.12	487.12	5	–	7.64	1.43E–07	2.22	2.6E–08	–	30	1.5E–09	1.5E–09	1.5E–05	
KLX07A	487.13	492.13	5	1.51E–06	7.57	1.63E–05	2.27	2.8E–06	8.1	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	492.14	497.14	5	–	7.60	–	2.33	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	497.14	502.14	5	–	7.63	–	2.41	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	502.15	507.15	5	–	7.54	–	2.62	–	–	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	507.16	512.16	5	–	7.53	2.92E–08	2.69	6.0E–09	–	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	512.17	517.17	5	–	7.55	–	2.76	–	–	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	517.18	522.18	5	6.94E–07	7.61	3.69E–06	2.82	6.2E–07	8.7	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	522.19	527.19	5	–	7.66	–	2.87	–	–	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	527.20	532.20	5	–	7.71	–	2.94	–	–	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	532.21	537.21	5	–	7.80	1.09E–07	3.02	2.3E–08	–	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	537.22	542.22	5	–	7.86	3.17E–08	2.99	6.4E–09	–	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	542.22	547.22	5	–	7.92	–	3.00	–	–	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	547.23	552.23	5	1.00E–08	7.96	1.66E–07	2.89	3.1E–08	8.3	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	552.23	557.23	5	–	8.02	–	2.91	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	557.24	562.24	5	6.44E–08	8.07	7.86E–07	2.97	1.4E–07	8.5	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	562.25	567.25	5	–	8.16	–	3.01	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	567.26	572.26	5	–	8.19	–	3.07	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	572.27	577.27	5	–	8.25	1.11E–08	3.13	2.2E–09	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	577.28	582.28	5	–	8.31	–	3.18	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	582.29	587.29	5	–	8.35	–	3.22	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	587.30	592.30	5	–	8.40	–	3.29	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	592.31	597.31	5	–	8.45	–	3.33	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	597.31	602.31	5	–	8.51	–	3.39	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	602.32	607.32	5	–	8.57	–	3.46	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	607.32	612.32	5	–	8.63	–	3.50	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	612.33	617.33	5	–	8.68	–	3.57	–	–	30	1.6E–09	1.6E–09	1.6E–05	

Borehole ID	Secup L (m)	Seclow L (m)	L_w (m)	Q_0 (m^3/s)	dh_0 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	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
KLX07A	617.33	622.33	5	–	8.75	–	3.65	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	622.34	627.34	5	–3.44E–07	8.80	4.61E–07	3.70	1.6E–07	6.6	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	627.35	632.35	5	–	8.86	–	3.76	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	632.35	637.35	5	–7.97E–06	8.93	9.81E–06	3.81	3.4E–06	6.6	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	637.36	642.36	5	–8.97E–06	8.96	1.22E–05	3.86	4.1E–06	6.8	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	642.38	647.38	5	–6.89E–08	9.05	1.79E–07	3.93	4.8E–08	7.6	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	647.39	652.39	5	–2.17E–08	9.12	3.42E–07	4.00	7.0E–08	8.8	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	652.41	657.41	5	–3.64E–08	9.19	6.56E–08	4.09	2.0E–08	7.4	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	657.41	662.41	5	–6.44E–07	9.24	9.25E–07	4.18	3.1E–07	7.2	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	662.41	667.41	5	–3.39E–07	9.33	5.19E–07	4.27	1.7E–07	7.3	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	667.42	672.42	5	–3.86E–08	9.39	1.54E–07	4.34	3.8E–08	8.4	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	672.42	677.42	5	–3.78E–08	9.46	5.39E–08	4.42	1.8E–08	7.4	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	677.43	682.43	5	–	9.54	–	4.50	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	682.43	687.43	5	–	9.60	–	4.58	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	687.44	692.44	5	–	9.67	–	4.64	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	692.44	697.44	5	–4.33E–07	9.81	1.64E–06	4.75	4.1E–07	8.8	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	697.44	702.44	5	–1.35E–07	9.91	9.72E–08	4.82	4.5E–08	7.0	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	702.45	707.45	5	–9.72E–09	9.99	1.14E–08	4.90	4.1E–09	7.7	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	707.46	712.46	5	–1.78E–06	10.05	3.06E–06	4.97	9.4E–07	8.2	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	712.46	717.46	5	–1.33E–07	10.14	2.22E–07	5.05	6.9E–08	8.2	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	717.46	722.46	5	–	10.23	–	5.13	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	722.46	727.46	5	–	10.31	–	5.22	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	727.47	732.47	5	–	10.39	–	5.28	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	732.48	737.48	5	–	10.49	–	5.37	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	737.49	742.49	5	–2.08E–07	10.68	3.78E–07	5.45	1.1E–07	8.8	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	742.50	747.50	5	–4.97E–08	10.78	1.46E–07	5.52	3.7E–08	9.4	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	747.50	752.50	5	–	10.88	–	5.58	–	–	30	1.6E–09	1.6E–09	1.6E–05	

Borehole ID	Secup L (m)	Seclow L (m)	L_w (m)	Q_0 (m^3/s)	dh_0 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	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
KLX07A	752.51	757.51	5	–4.81E–08	10.95	9.78E–08	5.70	2.8E–08	9.2	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	757.52	762.52	5	–7.36E–06	11.02	1.21E–05	5.77	3.7E–06	9.0	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	762.52	767.52	5	–2.24E–05	11.12	4.36E–05	5.86	1.2E–05	9.3	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	767.53	772.53	5	–2.60E–06	11.18	4.97E–06	5.94	1.4E–06	9.4	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	772.53	777.53	5	–2.64E–08	11.28	6.56E–08	6.04	1.7E–08	9.8	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	777.53	782.53	5	–	11.37	–	6.13	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	782.54	787.54	5	–7.06E–08	11.44	3.03E–07	6.22	7.1E–08	10.5	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	787.54	792.54	5	–	11.52	–	6.28	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	792.55	797.55	5	–	11.59	1.94E–08	6.39	3.7E–09	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	797.55	802.55	5	–	11.69	–	6.49	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	802.55	807.55	5	–	11.78	1.89E–08	6.57	3.6E–09	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	807.56	812.56	5	–	11.86	–	6.67	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	812.56	817.56	5	–	11.93	–	6.80	–	–	30	1.6E–09	1.6E–09	1.6E–05	
KLX07A	817.56	822.56	5	–5.56E–08	12.00	2.69E–07	7.01	6.4E–08	11.2	30	1.7E–09	1.7E–09	1.7E–05	
KLX07A	822.56	827.56	5	–4.64E–07	12.06	1.84E–06	7.11	4.6E–07	11.1	30	1.7E–09	1.7E–09	1.7E–05	

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

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 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	Comments
KLX07A	105.4	1.0	0.1	–	6.88	1.29E–07	1.69	2.5E–08	–	*
KLX07A	106.9	1.0	0.1	–	6.86	9.00E–06	1.69	1.7E–06	–	
KLX07A	111.5	1.0	0.1	–3.08E–07	6.83	3.39E–06	1.67	7.1E–07	6.4	
KLX07A	112.9	1.0	0.1	–	6.83	4.67E–08	1.64	8.9E–09	–	*
KLX07A	114.7	1.0	0.1	–	6.82	4.94E–06	1.64	9.4E–07	–	*
KLX07A	116.8	1.0	0.1	–	6.81	7.50E–06	1.67	1.4E–06	–	*
KLX07A	118.2	1.0	0.1	–	6.80	1.74E–06	1.66	3.3E–07	–	*
KLX07A	119.0	1.0	0.1	–	6.81	2.81E–06	1.66	5.4E–07	–	*
KLX07A	121.3	1.0	0.1	–	6.79	1.33E–06	1.64	2.6E–07	–	
KLX07A	121.9	1.0	0.1	–	6.78	5.56E–07	1.64	1.1E–07	–	*
KLX07A	123.6	1.0	0.1	–	6.77	3.56E–06	1.64	6.9E–07	–	
KLX07A	124.2	1.0	0.1	–	6.77	2.11E–07	1.63	4.1E–08	–	*
KLX07A	126.3	1.0	0.1	–1.31E–08	6.75	1.45E–07	1.62	3.0E–08	6.3	
KLX07A	131.2	1.0	0.1	–	6.74	5.92E–07	1.61	1.1E–07	–	
KLX07A	132.3	1.0	0.1	–	6.75	2.04E–07	1.60	3.9E–08	–	*
KLX07A	133.4	1.0	0.1	–	6.74	1.91E–07	1.60	3.7E–08	–	*
KLX07A	134.3	1.0	0.1	–	6.74	1.13E–06	1.60	2.2E–07	–	
KLX07A	137.0	1.0	0.1	–	6.72	1.51E–06	1.59	2.9E–07	–	
KLX07A	138.6	1.0	0.1	–	6.71	2.16E–07	1.58	4.2E–08	–	*
KLX07A	139.7	1.0	0.1	–	6.71	4.92E–05	1.58	9.5E–06	–	
KLX07A	140.8	1.0	0.1	–	6.69	4.39E–06	1.57	8.5E–07	–	
KLX07A	141.6	1.0	0.1	–	6.69	9.06E–07	1.58	1.8E–07	–	*
KLX07A	142.6	1.0	0.1	–	6.69	6.50E–07	1.57	1.3E–07	–	*
KLX07A	143.2	1.0	0.1	–	6.69	1.76E–06	1.56	3.4E–07	–	*
KLX07A	144.6	1.0	0.1	–	6.68	1.32E–06	1.56	2.5E–07	–	*
KLX07A	147.3	1.0	0.1	–	6.68	1.38E–05	1.55	2.7E–06	–	
KLX07A	147.5	1.0	0.1	–	6.68	2.92E–06	1.55	5.6E–07	–	*
KLX07A	147.8	1.0	0.1	–	6.68	2.48E–06	1.56	4.8E–07	–	
KLX07A	148.3	1.0	0.1	–	6.68	1.49E–06	1.56	2.9E–07	–	
KLX07A	150.2	1.0	0.1	–9.06E–07	6.67	1.77E–05	1.55	3.6E–06	6.4	
KLX07A	155.3	1.0	0.1	–1.31E–05	6.64	4.86E–05	5.06	3.9E–05	6.3	**
KLX07A	157.9	1.0	0.1	–	6.63	1.39E–07	1.54	2.7E–08	–	*
KLX07A	159.2	1.0	0.1	–	6.64	5.64E–08	1.54	1.1E–08	–	*
KLX07A	160.8	1.0	0.1	–	6.62	8.33E–08	1.53	1.6E–08	–	*
KLX07A	161.8	1.0	0.1	–	6.61	9.31E–07	1.53	1.8E–07	–	
KLX07A	163.9	1.0	0.1	–	6.60	4.61E–07	1.53	9.0E–08	–	
KLX07A	166.5	1.0	0.1	–	6.58	1.15E–07	1.52	2.3E–08	–	*
KLX07A	167.2	1.0	0.1	–	6.58	1.70E–07	1.52	3.3E–08	–	*
KLX07A	168.1	1.0	0.1	–	6.58	5.33E–05	5.02	3.4E–05	–	**
KLX07A	172.1	1.0	0.1	–	6.56	1.80E–07	1.52	3.5E–08	–	
KLX07A	178.3	1.0	0.1	–	6.53	2.64E–07	1.48	5.2E–08	–	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	Q_0 (m^3/s)	dh_0 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	Comments
KLX07A	178.6	1.0	0.1	–	6.53	1.30E–07	1.47	2.5E–08	–	*
KLX07A	183.9	1.0	0.1	–	6.50	4.08E–08	1.44	8.0E–09	–	*
KLX07A	185.0	1.0	0.1	–	6.50	5.89E–07	1.43	1.1E–07	–	
KLX07A	189.1	1.0	0.1	–	6.49	2.94E–06	1.42	5.7E–07	–	
KLX07A	190.6	1.0	0.1	–	6.47	9.61E–08	1.41	1.9E–08	–	
KLX07A	192.9	1.0	0.1	–	6.47	3.22E–08	1.39	6.3E–09	–	*
KLX07A	194.2	1.0	0.1	–	6.47	1.11E–08	1.40	2.2E–09	–	*
KLX07A	197.6	1.0	0.1	–	6.47	5.69E–08	1.38	1.1E–08	–	
KLX07A	200.1	1.0	0.1	–	6.46	1.05E–07	1.38	2.0E–08	–	*
KLX07A	201.8	1.0	0.1	–	6.44	8.89E–08	1.36	1.7E–08	–	
KLX07A	202.2	1.0	0.1	–	6.44	3.61E–08	1.36	7.0E–09	–	*
KLX07A	207.2	1.0	0.1	–2.81E–07	6.42	2.76E–06	1.36	5.9E–07	6.0	
KLX07A	208.9	1.0	0.1	–1.34E–05	6.42	3.72E–05	4.86	3.2E–05	6.0	**
KLX07A	213.7	1.0	0.1	–	6.44	4.86E–08	1.36	9.5E–09	–	*
KLX07A	218.0	1.0	0.1	–	6.44	1.76E–07	1.38	3.4E–08	–	
KLX07A	228.4	1.0	0.1	–4.92E–06	6.45	7.06E–05	1.40	1.5E–05	6.1	
KLX07A	233.8	1.0	0.1	–	6.46	3.39E–08	1.43	6.7E–09	–	
KLX07A	236.8	1.0	0.1	–4.11E–08	6.45	6.42E–07	1.41	1.3E–07	6.1	
KLX07A	241.1	1.0	0.1	–	6.48	1.42E–08	1.43	2.8E–09	–	*
KLX07A	247.9	1.0	0.1	–	6.51	6.44E–08	1.44	1.3E–08	–	
KLX07A	248.4	1.0	0.1	–	6.50	5.33E–08	1.44	1.0E–08	–	
KLX07A	250.1	1.0	0.1	–	6.53	6.22E–08	1.44	1.2E–08	–	*
KLX07A	252.0	1.0	0.1	–	6.52	1.25E–06	1.45	2.4E–07	–	
KLX07A	252.6	1.0	0.1	–	6.51	5.22E–05	5.11	3.7E–05	–	**
KLX07A	254.3	1.0	0.1	–	6.51	1.25E–08	1.46	2.4E–09	–	*
KLX07A	257.5	1.0	0.1	–	6.51	1.04E–07	1.46	2.0E–08	–	
KLX07A	259.5	1.0	0.1	–	6.50	1.54E–05	1.47	3.0E–06	–	
KLX07A	261.9	1.0	0.1	–	6.53	2.83E–08	1.46	5.5E–09	–	
KLX07A	264.7	1.0	0.1	–	6.52	2.46E–07	1.48	4.8E–08	–	
KLX07A	266.0	1.0	0.1	–	6.53	5.31E–08	1.48	1.0E–08	–	
KLX07A	267.3	1.0	0.1	–	6.52	1.12E–06	1.48	2.2E–07	–	
KLX07A	267.8	1.0	0.1	–	6.52	4.19E–07	1.49	8.2E–08	–	
KLX07A	268.1	1.0	0.1	–	6.51	3.69E–07	1.48	7.3E–08	–	*
KLX07A	269.5	1.0	0.1	–	6.52	3.17E–08	1.49	6.2E–09	–	
KLX07A	272.0	1.0	0.1	–	6.53	4.22E–07	1.48	8.3E–08	–	*
KLX07A	272.3	1.0	0.1	–	6.54	6.00E–07	1.48	1.2E–07	–	
KLX07A	275.1	1.0	0.1	–	6.54	7.86E–08	1.49	1.5E–08	–	
KLX07A	278.7	1.0	0.1	–7.50E–08	6.55	1.03E–06	1.51	2.2E–07	6.2	
KLX07A	284.7	1.0	0.1	–	6.56	4.39E–06	1.52	8.6E–07	–	
KLX07A	285.1	1.0	0.1	–	6.57	7.83E–07	1.51	1.5E–07	–	
KLX07A	286.7	1.0	0.1	–	6.56	1.46E–07	1.53	2.9E–08	–	
KLX07A	288.6	1.0	0.1	–	6.56	1.44E–07	1.53	2.8E–08	–	
KLX07A	292.8	1.0	0.1	–	6.58	1.56E–08	1.55	3.1E–09	–	*
KLX07A	296.4	1.0	0.1	–	6.57	8.28E–07	1.55	1.6E–07	–	
KLX07A	297.4	1.0	0.1	–	6.58	1.45E–06	1.54	2.8E–07	–	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	Q_0 (m^3/s)	dh_0 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	Comments
KLX07A	300.0	1.0	0.1	–	6.58	2.44E–08	1.56	4.8E–09	–	*
KLX07A	301.3	1.0	0.1	–	6.58	4.39E–07	1.55	8.6E–08	–	
KLX07A	306.1	1.0	0.1	–	6.59	4.97E–07	1.54	9.7E–08	–	
KLX07A	307.1	1.0	0.1	–	6.60	8.00E–06	1.55	1.6E–06	–	
KLX07A	310.3	1.0	0.1	–	6.60	1.07E–07	1.56	2.1E–08	–	*
KLX07A	310.5	1.0	0.1	–	6.61	2.18E–07	1.56	4.3E–08	–	
KLX07A	310.7	1.0	0.1	–	6.61	2.25E–07	1.57	4.4E–08	–	
KLX07A	311.5	1.0	0.1	–	6.61	6.42E–08	1.57	1.3E–08	–	*
KLX07A	321.1	1.0	0.1	–	6.63	3.19E–08	1.59	6.3E–09	–	*
KLX07A	325.7	1.0	0.1	–	6.63	3.94E–08	1.59	7.7E–09	–	
KLX07A	335.6	1.0	0.1	–	6.63	6.78E–08	1.61	1.3E–08	–	
KLX07A	336.9	1.0	0.1	–	6.63	2.08E–08	1.61	4.1E–09	–	*
KLX07A	339.6	1.0	0.1	–	6.63	2.06E–06	1.63	4.1E–07	–	
KLX07A	341.0	1.0	0.1	–	6.64	1.57E–05	1.63	3.1E–06	–	
KLX07A	342.2	1.0	0.1	–	6.64	7.56E–06	1.64	1.5E–06	–	
KLX07A	342.5	1.0	0.1	–	6.65	7.42E–06	1.65	1.5E–06	–	
KLX07A	346.8	1.0	0.1	–	6.66	2.30E–06	1.64	4.5E–07	–	
KLX07A	349.1	1.0	0.1	–	6.66	7.83E–07	1.65	1.5E–07	–	
KLX07A	349.8	1.0	0.1	–	6.65	1.17E–06	1.65	2.3E–07	–	*
KLX07A	350.1	1.0	0.1	–	6.65	1.77E–06	1.65	3.5E–07	–	
KLX07A	351.0	1.0	0.1	–	6.65	7.50E–06	1.65	1.5E–06	–	
KLX07A	352.0	1.0	0.1	–	6.65	6.86E–06	1.64	1.4E–06	–	
KLX07A	353.2	1.0	0.1	–	6.65	2.31E–07	1.63	4.5E–08	–	*
KLX07A	354.2	1.0	0.1	–	6.64	4.31E–06	1.64	8.5E–07	–	
KLX07A	354.8	1.0	0.1	–	6.65	1.06E–07	1.63	2.1E–08	–	
KLX07A	356.2	1.0	0.1	–	6.64	1.66E–06	1.63	3.3E–07	–	
KLX07A	357.1	1.0	0.1	–	6.64	1.64E–06	1.64	3.3E–07	–	
KLX07A	357.6	1.0	0.1	–	6.66	1.56E–07	1.65	3.1E–08	–	
KLX07A	362.8	1.0	0.1	–	6.63	3.00E–08	1.65	6.0E–09	–	
KLX07A	364.4	1.0	0.1	–	6.64	9.39E–07	1.65	1.9E–07	–	
KLX07A	364.6	1.0	0.1	–	6.64	8.72E–07	1.64	1.7E–07	–	
KLX07A	366.1	1.0	0.1	–	6.64	1.81E–08	1.63	3.6E–09	–	*
KLX07A	367.4	1.0	0.1	–	6.62	2.30E–05	1.63	4.6E–06	–	
KLX07A	369.1	1.0	0.1	–	6.63	1.61E–08	1.65	3.2E–09	–	*
KLX07A	370.5	1.0	0.1	–	6.63	9.86E–07	1.66	2.0E–07	–	
KLX07A	371.5	1.0	0.1	–	6.66	4.50E–07	1.67	8.9E–08	–	*
KLX07A	372.3	1.0	0.1	–	6.67	2.13E–07	1.66	4.2E–08	–	*
KLX07A	373.0	1.0	0.1	–	6.69	3.72E–07	1.66	7.3E–08	–	*
KLX07A	373.8	1.0	0.1	–	6.71	3.56E–06	1.66	7.0E–07	–	
KLX07A	375.2	1.0	0.1	–	6.74	5.08E–07	1.67	9.9E–08	–	*
KLX07A	375.7	1.0	0.1	–	6.77	4.06E–07	1.67	7.9E–08	–	
KLX07A	376.4	1.0	0.1	–	6.76	2.89E–07	1.68	5.6E–08	–	
KLX07A	377.9	1.0	0.1	–	6.78	1.06E–05	1.68	2.1E–06	–	
KLX07A	378.9	1.0	0.1	–	6.79	2.20E–07	1.70	4.3E–08	–	
KLX07A	381.2	1.0	0.1	–	6.80	8.17E–07	1.69	1.6E–07	–	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	Q_0 (m^3/s)	dh_0 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	Comments
KLX07A	381.9	1.0	0.1	–	6.82	4.56E–08	1.70	8.8E–09	–	
KLX07A	383.6	1.0	0.1	–	6.82	3.92E–08	1.70	7.6E–09	–	*
KLX07A	383.9	1.0	0.1	–	6.83	1.14E–06	1.70	2.2E–07	–	
KLX07A	385.4	1.0	0.1	–	6.83	2.86E–06	1.71	5.5E–07	–	
KLX07A	386.5	1.0	0.1	–	6.82	8.31E–07	1.71	1.6E–07	–	
KLX07A	387.0	1.0	0.1	–	6.82	1.53E–06	1.72	3.0E–07	–	
KLX07A	388.4	1.0	0.1	–	6.84	1.08E–05	1.72	2.1E–06	–	
KLX07A	392.3	1.0	0.1	–	6.87	3.31E–08	1.72	6.3E–09	–	*
KLX07A	392.6	1.0	0.1	–	6.86	5.08E–08	1.72	9.8E–09	–	
KLX07A	393.7	1.0	0.1	–	6.86	1.07E–05	1.73	2.1E–06	–	
KLX07A	395.3	1.0	0.1	–	6.88	3.72E–07	1.74	7.2E–08	–	
KLX07A	396.3	1.0	0.1	–	6.89	3.11E–08	1.76	6.0E–09	–	
KLX07A	397.7	1.0	0.1	–	6.88	1.74E–06	1.76	3.4E–07	–	
KLX07A	398.4	1.0	0.1	–	6.90	1.11E–07	1.75	2.1E–08	–	
KLX07A	399.5	1.0	0.1	–	6.90	4.53E–07	1.76	8.7E–08	–	
KLX07A	401.0	1.0	0.1	–	6.91	7.31E–08	1.79	1.4E–08	–	
KLX07A	401.7	1.0	0.1	–	6.91	1.11E–07	1.78	2.1E–08	–	
KLX07A	405.5	1.0	0.1	–	6.91	1.68E–07	1.80	3.2E–08	–	
KLX07A	406.5	1.0	0.1	–	6.92	1.91E–07	1.81	3.7E–08	–	
KLX07A	413.3	1.0	0.1	–	6.96	6.83E–08	1.84	1.3E–08	–	*
KLX07A	413.8	1.0	0.1	–	6.97	3.33E–07	1.85	6.4E–08	–	
KLX07A	416.0	1.0	0.1	–	6.98	4.33E–08	1.87	8.4E–09	–	*
KLX07A	417.0	1.0	0.1	–	6.98	2.50E–08	1.88	4.8E–09	–	*
KLX07A	425.3	1.0	0.1	–	7.00	2.28E–08	1.91	4.4E–09	–	
KLX07A	427.2	1.0	0.1	–	7.02	8.03E–08	1.93	1.6E–08	–	
KLX07A	429.3	1.0	0.1	–	7.03	3.39E–08	1.94	6.6E–09	–	
KLX07A	431.9	1.0	0.1	–	7.05	1.14E–08	1.96	2.2E–09	–	*
KLX07A	432.4	1.0	0.1	–	7.06	2.86E–08	1.95	5.5E–09	–	*
KLX07A	432.9	1.0	0.1	–	7.07	2.62E–05	1.96	5.1E–06	–	
KLX07A	434.2	1.0	0.1	–	7.09	5.03E–07	1.97	9.7E–08	–	
KLX07A	436.5	1.0	0.1	–	7.09	2.04E–06	1.99	4.0E–07	–	
KLX07A	437.2	1.0	0.1	–	7.11	7.89E–08	1.99	1.5E–08	–	
KLX07A	438.5	1.0	0.1	–	7.12	1.12E–07	2.00	2.2E–08	–	
KLX07A	439.7	1.0	0.1	–	7.12	3.08E–08	2.01	6.0E–09	–	
KLX07A	442.0	1.0	0.1	–	7.13	1.36E–06	1.98	2.6E–07	–	
KLX07A	442.5	1.0	0.1	–	7.11	3.00E–07	1.98	5.8E–08	–	*
KLX07A	443.5	1.0	0.1	–	7.13	6.22E–08	2.00	1.2E–08	–	
KLX07A	444.7	1.0	0.1	–	7.15	1.30E–07	2.01	2.5E–08	–	
KLX07A	446.0	1.0	0.1	–	7.17	2.17E–08	2.02	4.2E–09	–	*
KLX07A	446.2	1.0	0.1	–	7.18	8.25E–08	2.03	1.6E–08	–	
KLX07A	448.2	1.0	0.1	–	7.28	2.11E–07	2.04	4.0E–08	–	
KLX07A	451.0	1.0	0.1	–	7.34	5.08E–07	2.05	9.5E–08	–	
KLX07A	452.6	1.0	0.1	–	7.35	2.53E–07	2.06	4.7E–08	–	
KLX07A	452.8	1.0	0.1	–	7.36	3.61E–08	2.05	6.7E–09	–	*
KLX07A	453.2	1.0	0.1	–	7.37	3.28E–08	2.06	6.1E–09	–	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	Q_0 (m^3/s)	dh_0 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	Comments
KLX07A	486.1	1.0	0.1	–	7.62	1.26E–07	2.30	2.3E–08	–	
KLX07A	487.4	1.0	0.1	1.50E–06	7.58	1.64E–05	2.31	2.8E–06	8.1	
KLX07A	508.7	1.0	0.1	–	7.51	2.56E–08	2.51	5.1E–09	–	
KLX07A	519.2	1.0	0.1	6.67E–07	7.60	3.28E–06	2.64	5.2E–07	8.9	
KLX07A	520.5	1.0	0.1	–	7.62	2.54E–07	2.65	5.1E–08	–	
KLX07A	535.3	1.0	0.1	–	7.79	2.00E–08	2.82	4.0E–09	–	*
KLX07A	537.0	1.0	0.1	–	7.81	7.64E–08	2.85	1.5E–08	–	
KLX07A	539.6	1.0	0.1	–	7.86	2.78E–08	2.88	5.5E–09	–	*
KLX07A	549.9	1.0	0.1	–	7.97	1.37E–07	2.99	2.7E–08	–	
KLX07A	557.9	1.0	0.1	5.81E–08	8.07	7.28E–07	3.11	1.3E–07	8.5	
KLX07A	574.4	1.0	0.1	–	8.25	8.33E–09	3.28	1.7E–09	–	*
KLX07A	626.0	1.0	0.1	–3.36E–07	8.82	2.49E–07	3.86	1.2E–07	6.0	
KLX07A	633.2	1.0	0.1	–	8.91	1.36E–08	3.93	2.7E–09	–	*
KLX07A	635.7	1.0	0.1	–	8.90	6.39E–06	3.95	1.3E–06	–	
KLX07A	638.2	1.0	0.1	–	8.96	8.89E–08	4.00	1.8E–08	–	
KLX07A	639.1	1.0	0.1	–	8.97	7.92E–06	4.01	1.6E–06	–	
KLX07A	639.6	1.0	0.1	–	8.97	5.11E–08	4.01	1.0E–08	–	*
KLX07A	641.1	1.0	0.1	–	8.98	2.41E–07	4.02	4.8E–08	–	
KLX07A	643.4	1.0	0.1	–	9.04	5.75E–08	4.07	1.1E–08	–	*
KLX07A	645.3	1.0	0.1	–	9.07	4.86E–08	4.10	9.7E–09	–	*
KLX07A	649.2	1.0	0.1	–	9.11	1.99E–07	4.13	4.0E–08	–	
KLX07A	653.5	1.0	0.1	–	9.18	2.78E–08	4.19	5.5E–09	–	*
KLX07A	657.3	1.0	0.1	–	9.22	1.50E–08	4.23	3.0E–09	–	*
KLX07A	661.4	1.0	0.1	–	9.29	1.67E–08	4.31	3.3E–09	–	*
KLX07A	662.2	1.0	0.1	–	9.30	6.19E–07	4.32	1.2E–07	–	
KLX07A	662.7	1.0	0.1	–	9.32	3.00E–07	4.32	5.9E–08	–	
KLX07A	666.0	1.0	0.1	–	9.35	1.89E–08	4.35	3.7E–09	–	*
KLX07A	667.9	1.0	0.1	–	9.37	9.06E–08	4.38	1.8E–08	–	
KLX07A	677.0	1.0	0.1	–4.06E–08	9.50	2.47E–08	4.51	1.3E–08	6.4	
KLX07A	696.8	1.0	0.1	–	9.85	9.22E–07	4.79	1.8E–07	–	
KLX07A	697.3	1.0	0.1	–	9.87	2.13E–07	4.79	4.2E–08	–	
KLX07A	698.7	1.0	0.1	–1.30E–07	9.89	5.50E–08	4.81	3.6E–08	6.3	
KLX07A	707.0	1.0	0.1	–	9.99	8.33E–09	4.91	1.6E–09	–	*
KLX07A	709.0	1.0	0.1	–	10.05	1.39E–08	4.95	2.7E–09	–	
KLX07A	712.4	1.0	0.1	–	10.10	2.13E–06	5.01	4.1E–07	–	
KLX07A	714.5	1.0	0.1	–	10.14	1.47E–08	5.04	2.9E–09	–	
KLX07A	715.9	1.0	0.1	–	10.16	1.46E–07	5.08	2.8E–08	–	
KLX07A	738.7	1.0	0.1	–	10.64	1.25E–08	5.47	2.4E–09	–	*
KLX07A	739.9	1.0	0.1	–	10.68	2.40E–07	5.53	4.6E–08	–	
KLX07A	743.7	1.0	0.1	–	10.77	2.97E–08	5.66	5.8E–09	–	
KLX07A	745.9	1.0	0.1	–	10.82	7.14E–08	5.68	1.4E–08	–	
KLX07A	756.6	1.0	0.1	–4.89E–08	10.97	5.94E–08	5.84	2.1E–08	8.7	
KLX07A	761.2	1.0	0.1	–	11.06	7.78E–09	5.91	1.5E–09	–	*
KLX07A	761.7	1.0	0.1	–	11.06	2.19E–06	5.91	4.2E–07	–	
KLX07A	761.9	1.0	0.1	–	11.06	6.58E–06	5.92	1.3E–06	–	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	Q_0 (m^3/s)	dh_0 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	Comments
KLX07A	762.6	1.0	0.1	–	11.06	7.44E–06	5.94	1.4E–06	–	
KLX07A	763.3	1.0	0.1	–	11.08	1.40E–05	5.95	2.7E–06	–	
KLX07A	764.4	1.0	0.1	–	11.10	2.14E–06	5.97	4.1E–07	–	
KLX07A	765.0	1.0	0.1	–	11.13	2.32E–06	5.99	4.5E–07	–	*
KLX07A	766.1	1.0	0.1	–	11.13	5.83E–06	6.00	1.1E–06	–	
KLX07A	766.5	1.0	0.1	–	11.15	3.69E–06	6.01	7.1E–07	–	
KLX07A	768.4	1.0	0.1	–	11.17	4.03E–07	6.04	7.8E–08	–	*
KLX07A	768.6	1.0	0.1	–	11.18	3.61E–06	6.05	7.0E–07	–	
KLX07A	771.0	1.0	0.1	–	11.21	9.00E–08	6.09	1.7E–08	–	
KLX07A	772.1	1.0	0.1	–	11.24	3.31E–08	6.14	6.4E–09	–	*
KLX07A	773.4	1.0	0.1	–	11.24	1.64E–08	6.15	3.2E–09	–	*
KLX07A	777.0	1.0	0.1	–	11.29	3.44E–08	6.22	6.7E–09	–	
KLX07A	782.7	1.0	0.1	–4.97E–08	11.39	2.06E–07	6.34	5.0E–08	10.4	
KLX07A	786.9	1.0	0.1	–	11.45	2.89E–08	6.33	5.6E–09	–	*
KLX07A	795.7	1.0	0.1	–	11.61	1.81E–08	6.46	3.5E–09	–	*
KLX07A	804.2	1.0	0.1	–	11.77	2.36E–08	6.61	4.5E–09	–	*
KLX07A	818.6	1.0	0.1	–	12.00	1.44E–08	6.84	2.8E–09	–	*
KLX07A	820.9	1.0	0.1	–	12.02	1.82E–07	6.86	3.5E–08	–	
KLX07A	825.5	1.0	0.1	–4.64E–07	12.06	1.49E–06	6.97	3.8E–07	10.9	

* 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).

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 ($s_1 = h_1 – h_0$).
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).

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 (ml/h)	Number of fractures 100,000–1,000,000 (ml/h)
KLX07A	96.77	101.78	0	0	0	0	0	0
KLX07A	101.77	106.78	1	0	1	0	0	0
KLX07A	106.78	111.79	2	0	0	0	2	0
KLX07A	111.79	116.80	2	0	1	0	1	0
KLX07A	116.79	121.80	4	0	0	2	2	0
KLX07A	121.79	126.80	4	0	2	1	1	0
KLX07A	126.80	131.81	1	0	0	1	0	0
KLX07A	131.80	136.81	3	0	2	1	0	0
KLX07A	136.81	141.82	5	0	1	2	1	1
KLX07A	141.81	146.82	3	0	0	3	0	0
KLX07A	146.81	151.82	5	0	0	2	3	0
KLX07A	151.82	156.83	1	0	0	0	0	1
KLX07A	156.82	161.83	4	0	3	1	0	0
KLX07A	161.83	166.84	2	0	1	1	0	0
KLX07A	166.83	171.84	2	0	1	0	0	1
KLX07A	171.84	176.85	1	0	1	0	0	0
KLX07A	176.85	181.86	2	0	2	0	0	0
KLX07A	181.87	186.87	2	0	1	1	0	0
KLX07A	186.88	191.88	2	0	1	0	1	0
KLX07A	191.89	196.89	2	1	1	0	0	0
KLX07A	196.90	201.90	3	0	3	0	0	0
KLX07A	201.90	206.90	1	0	1	0	0	0
KLX07A	206.91	211.91	2	0	0	1	0	1
KLX07A	211.92	216.92	1	0	1	0	0	0
KLX07A	216.92	221.92	1	0	1	0	0	0
KLX07A	221.93	226.93	0	0	0	0	0	0
KLX07A	226.93	231.93	1	0	0	0	0	1
KLX07A	231.93	236.93	2	0	1	1	0	0
KLX07A	236.93	241.93	1	1	0	0	0	0
KLX07A	241.93	246.93	0	0	0	0	0	0
KLX07A	246.93	251.93	3	0	3	0	0	0
KLX07A	251.93	256.93	3	1	0	1	0	1
KLX07A	256.93	261.93	3	0	2	0	1	0
KLX07A	261.95	266.95	2	0	2	0	0	0
KLX07A	266.96	271.96	4	0	1	3	0	0
KLX07A	271.96	276.97	3	0	1	2	0	0
KLX07A	276.97	281.97	1	0	0	1	0	0
KLX07A	281.97	286.98	3	0	1	1	1	0
KLX07A	286.98	291.98	1	0	1	0	0	0
KLX07A	291.98	296.99	2	1	0	1	0	0

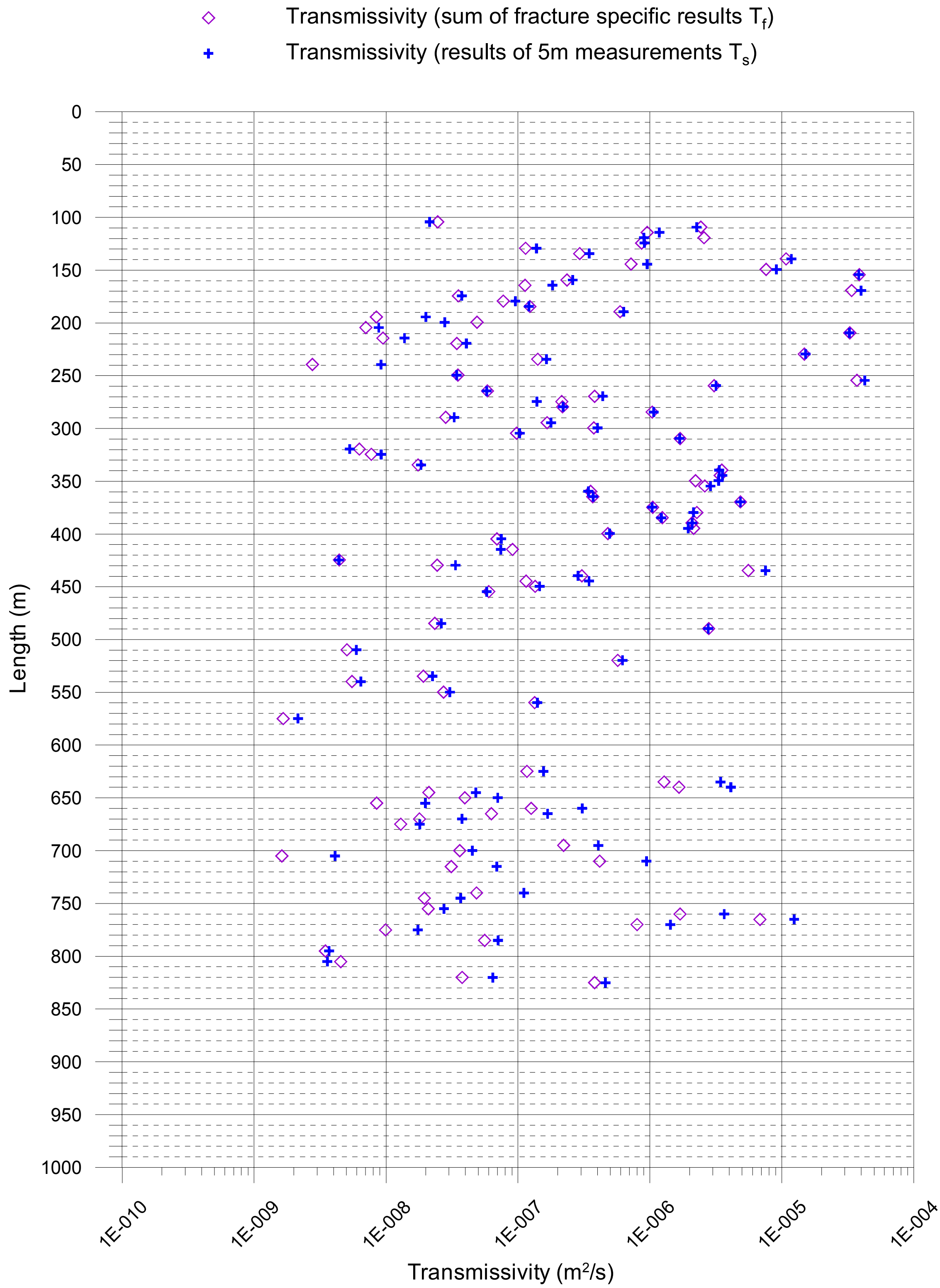
Borehole ID	Secup (m)	Seclow (m)	Number of fractures, total	Number of fractures 10–100 (ml/h)	Number of fractures 100–1,000 (ml/h)	Number of fractures 1,000–10,000 (ml/h)	Number of fractures 10,000–100,000 (ml/h)	Number of fractures 100,000–1,000,000 (ml/h)
KLX07A	296.99	301.99	3	1	0	2	0	0
KLX07A	301.99	307.00	1	0	0	1	0	0
KLX07A	307.00	312.00	5	0	4	0	1	0
KLX07A	312.00	317.00	0	0	0	0	0	0
KLX07A	316.99	322.00	1	0	1	0	0	0
KLX07A	321.99	327.00	1	0	1	0	0	0
KLX07A	326.99	331.99	0	0	0	0	0	0
KLX07A	331.99	336.99	2	1	1	0	0	0
KLX07A	336.98	341.99	2	0	0	1	1	0
KLX07A	341.98	346.99	3	0	0	1	2	0
KLX07A	346.99	352.00	4	0	0	3	1	0
KLX07A	352.00	357.02	5	0	2	1	2	0
KLX07A	357.03	362.05	2	0	1	1	0	0
KLX07A	362.06	367.07	4	1	1	2	0	0
KLX07A	367.09	372.10	4	1	0	2	1	0
KLX07A	372.08	377.09	6	0	1	4	1	0
KLX07A	377.08	382.09	4	0	2	1	1	0
KLX07A	382.07	387.08	5	0	1	3	1	0
KLX07A	387.07	392.07	1	0	0	0	1	0
KLX07A	392.06	397.06	5	0	3	1	1	0
KLX07A	397.06	402.06	5	0	3	2	0	0
KLX07A	402.06	407.06	2	0	2	0	0	0
KLX07A	407.07	412.07	0	0	0	0	0	0
KLX07A	412.07	417.07	4	1	2	1	0	0
KLX07A	417.07	422.07	0	0	0	0	0	0
KLX07A	422.07	427.07	1	1	0	0	0	0
KLX07A	427.08	432.08	3	1	2	0	0	0
KLX07A	432.08	437.08	4	0	1	2	1	0
KLX07A	437.08	442.08	4	0	3	1	0	0
KLX07A	442.08	447.08	5	1	3	1	0	0
KLX07A	447.07	452.07	2	0	1	1	0	0
KLX07A	452.07	457.07	3	0	3	0	0	0
KLX07A	457.08	462.08	0	0	0	0	0	0
KLX07A	462.09	467.09	0	0	0	0	0	0
KLX07A	467.10	472.10	0	0	0	0	0	0
KLX07A	472.11	477.11	0	0	0	0	0	0
KLX07A	477.12	482.12	0	0	0	0	0	0
KLX07A	482.12	487.12	1	0	1	0	0	0
KLX07A	487.13	492.13	1	0	0	0	1	0
KLX07A	492.14	497.14	0	0	0	0	0	0
KLX07A	497.15	502.14	0	0	0	0	0	0
KLX07A	502.16	507.15	0	0	0	0	0	0
KLX07A	507.17	512.16	1	1	0	0	0	0
KLX07A	512.17	517.17	0	0	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 (ml/h)	Number of fractures 100,000–1,000,000 (ml/h)
KLX07A	517.18	522.18	2	0	1	0	1	0
KLX07A	522.19	527.19	0	0	0	0	0	0
KLX07A	527.19	532.20	0	0	0	0	0	0
KLX07A	532.20	537.21	2	1	1	0	0	0
KLX07A	537.21	542.22	1	1	0	0	0	0
KLX07A	542.21	547.22	0	0	0	0	0	0
KLX07A	547.22	552.23	1	0	1	0	0	0
KLX07A	552.22	557.23	0	0	0	0	0	0
KLX07A	557.23	562.24	1	0	0	1	0	0
KLX07A	562.24	567.25	0	0	0	0	0	0
KLX07A	567.25	572.26	0	0	0	0	0	0
KLX07A	572.26	577.27	1	1	0	0	0	0
KLX07A	577.27	582.28	0	0	0	0	0	0
KLX07A	582.28	587.29	0	0	0	0	0	0
KLX07A	587.29	592.30	0	0	0	0	0	0
KLX07A	592.30	597.31	0	0	0	0	0	0
KLX07A	597.31	602.31	0	0	0	0	0	0
KLX07A	602.31	607.32	0	0	0	0	0	0
KLX07A	607.32	612.32	0	0	0	0	0	0
KLX07A	612.32	617.33	0	0	0	0	0	0
KLX07A	617.33	622.33	0	0	0	0	0	0
KLX07A	622.34	627.34	1	0	1	0	0	0
KLX07A	627.34	632.35	0	0	0	0	0	0
KLX07A	632.35	637.35	2	1	0	0	1	0
KLX07A	637.36	642.36	4	0	3	0	1	0
KLX07A	642.37	647.38	2	0	2	0	0	0
KLX07A	647.39	652.39	1	0	1	0	0	0
KLX07A	652.40	657.41	2	2	0	0	0	0
KLX07A	657.40	662.41	2	1	0	1	0	0
KLX07A	662.40	667.41	2	1	0	1	0	0
KLX07A	667.40	672.42	1	0	1	0	0	0
KLX07A	672.40	677.42	1	1	0	0	0	0
KLX07A	677.41	682.43	0	0	0	0	0	0
KLX07A	682.41	687.43	0	0	0	0	0	0
KLX07A	687.41	692.44	0	0	0	0	0	0
KLX07A	692.41	697.44	2	0	1	1	0	0
KLX07A	697.41	702.44	1	0	1	0	0	0
KLX07A	702.42	707.45	1	1	0	0	0	0
KLX07A	707.43	712.46	2	1	0	1	0	0
KLX07A	712.43	717.46	2	1	1	0	0	0
KLX07A	717.44	722.46	0	0	0	0	0	0
KLX07A	722.44	727.46	0	0	0	0	0	0
KLX07A	727.45	732.47	0	0	0	0	0	0
KLX07A	732.46	737.48	0	0	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 (ml/h)	Number of fractures 100,000–1,000,000 (ml/h)
KLX07A	737.47	742.49	2	1	1	0	0	0
KLX07A	742.47	747.50	2	0	2	0	0	0
KLX07A	747.48	752.50	0	0	0	0	0	0
KLX07A	752.49	757.51	1	0	1	0	0	0
KLX07A	757.49	762.52	3	1	0	1	1	0
KLX07A	762.49	767.52	6	0	0	2	4	0
KLX07A	767.50	772.53	4	0	2	1	1	0
KLX07A	772.50	777.53	2	1	1	0	0	0
KLX07A	777.51	782.53	0	0	0	0	0	0
KLX07A	782.51	787.54	2	0	2	0	0	0
KLX07A	787.51	792.54	0	0	0	0	0	0
KLX07A	792.52	797.55	1	1	0	0	0	0
KLX07A	797.52	802.55	0	0	0	0	0	0
KLX07A	802.52	807.55	1	1	0	0	0	0
KLX07A	807.53	812.56	0	0	0	0	0	0
KLX07A	812.53	817.56	0	0	0	0	0	0
KLX07A	817.53	822.56	2	1	1	0	0	0
KLX07A	822.53	827.56	1	0	0	1	0	0

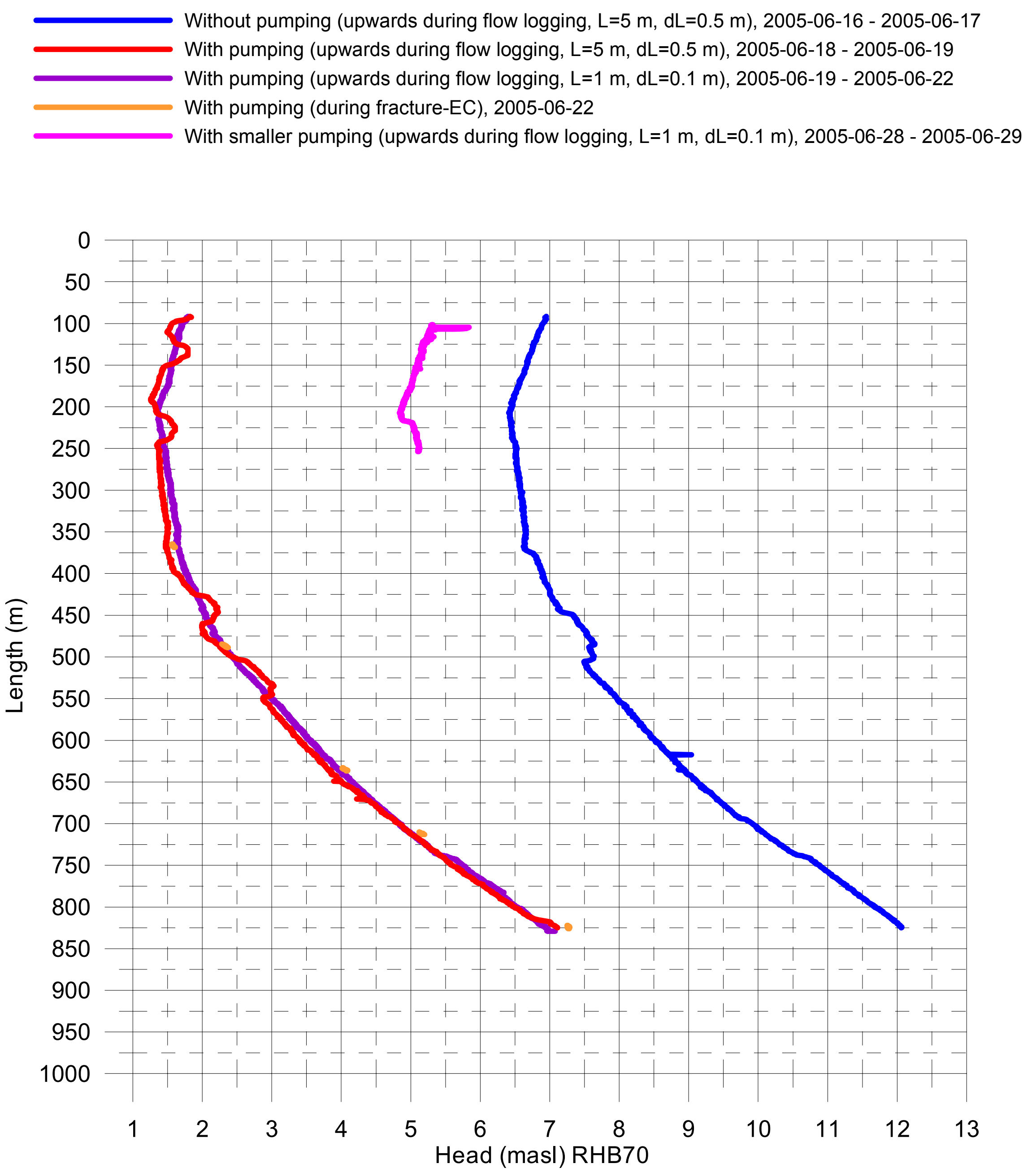
Laxemar, borehole KLX07A
Calculation of conductive fracture frequency

Laxemar, borehole KLX07A
Comparison between section transmissivity and fracture transmissivity

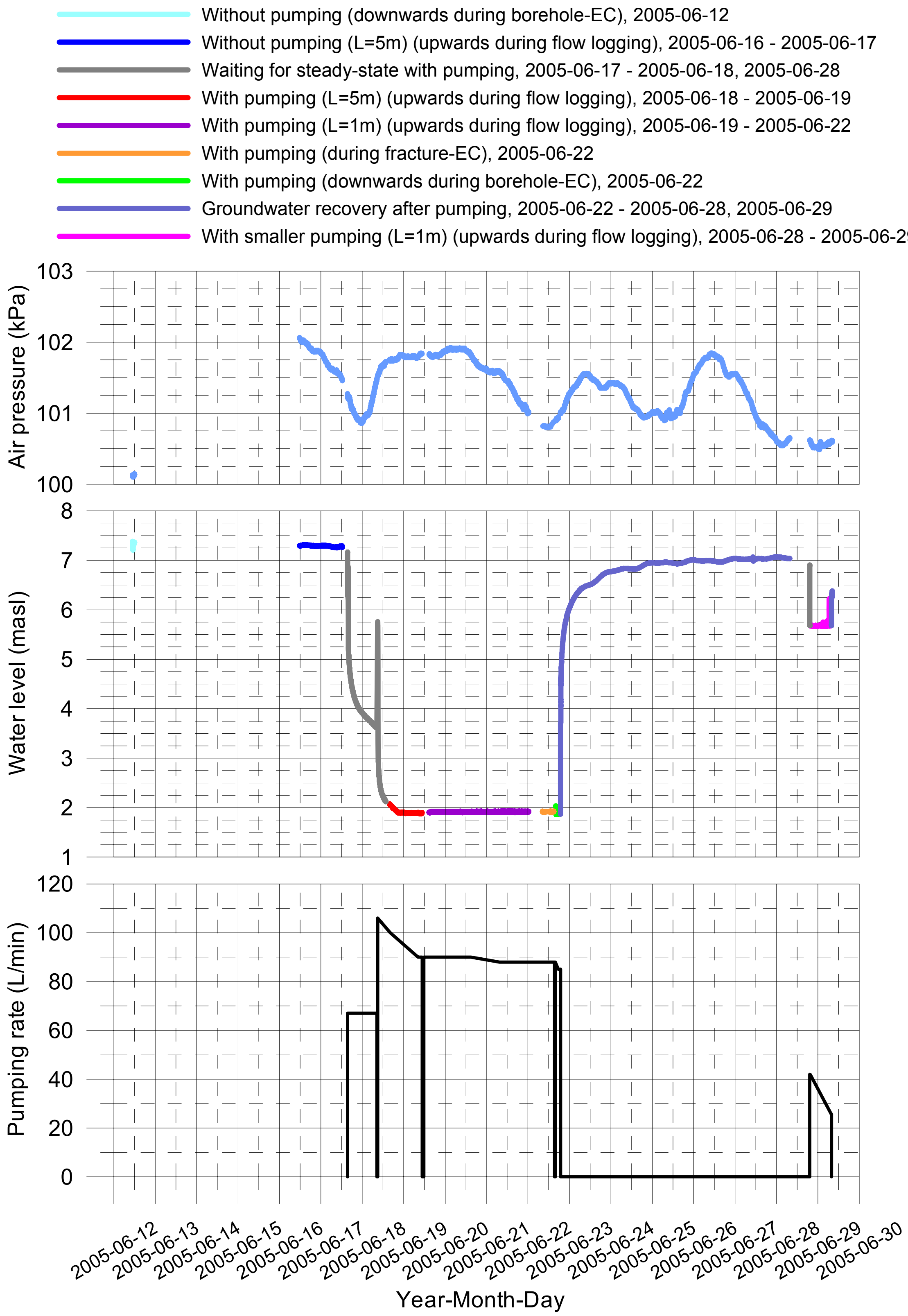


Laxemar, borehole KLX07A
Head in the borehole during flow logging

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)

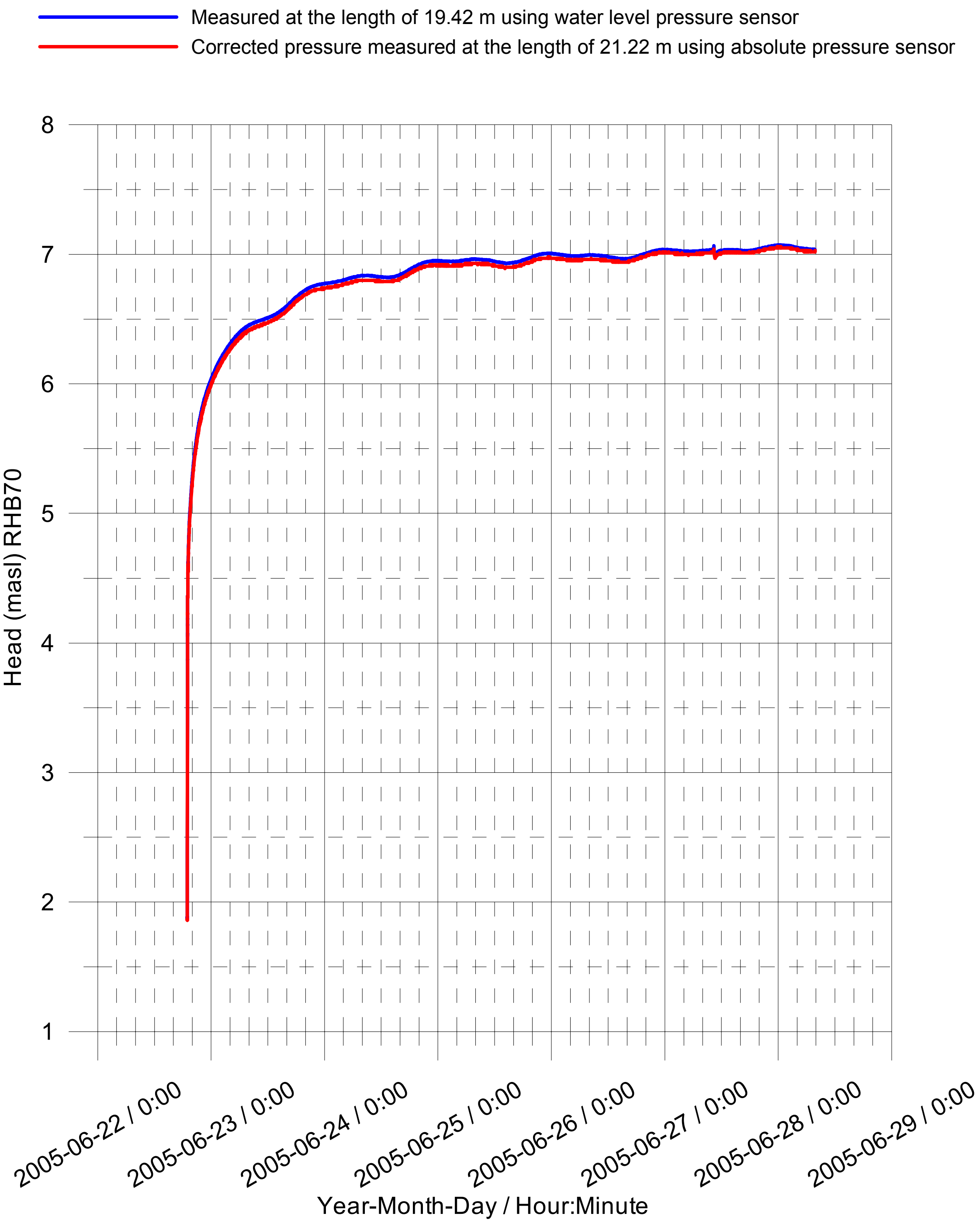


Laxemar, borehole KLX07A
Air pressure, water level in the borehole and pumping rate during flow logging

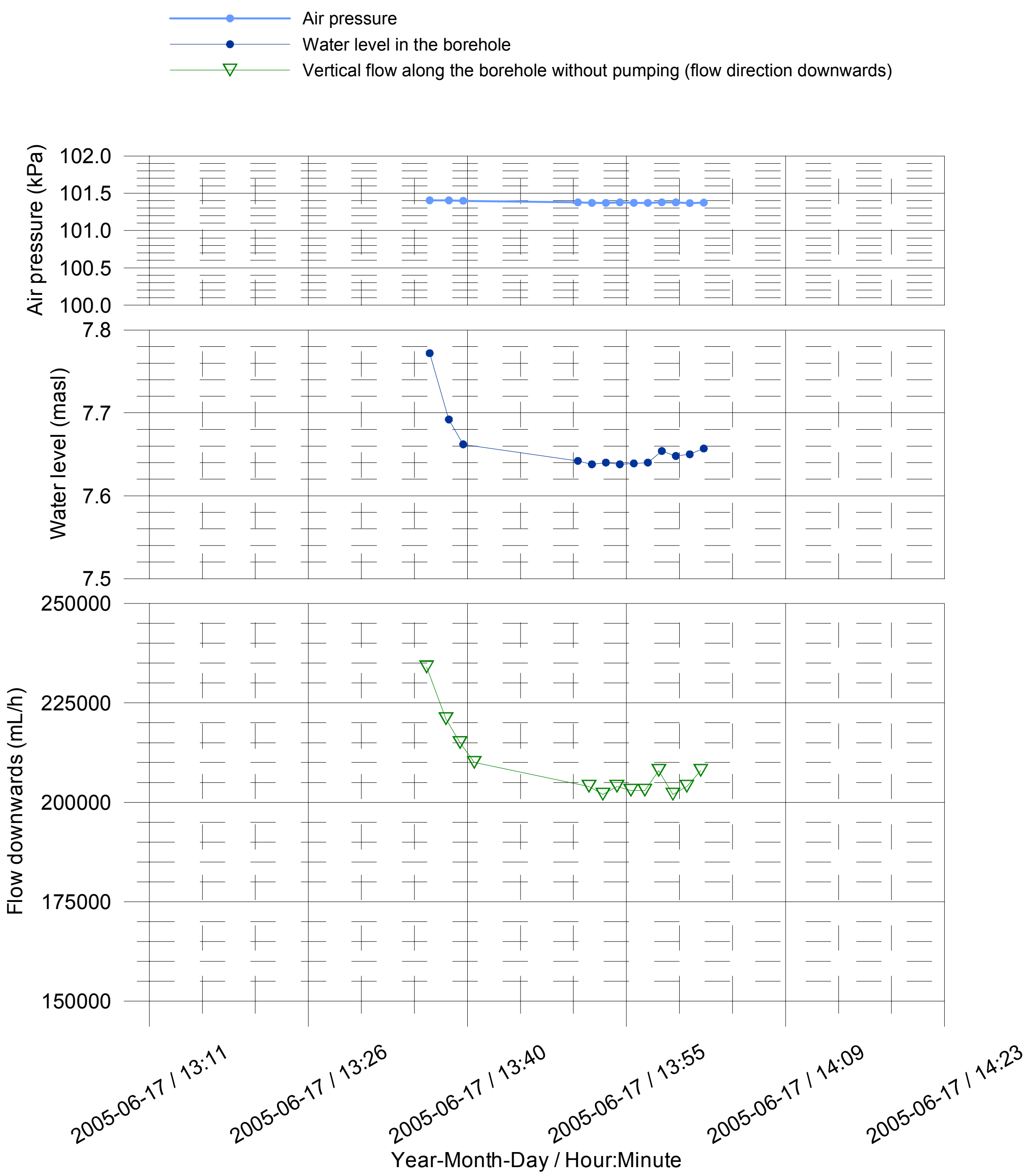


Laxemar, borehole KLX07A
Groundwater recovery after pumping

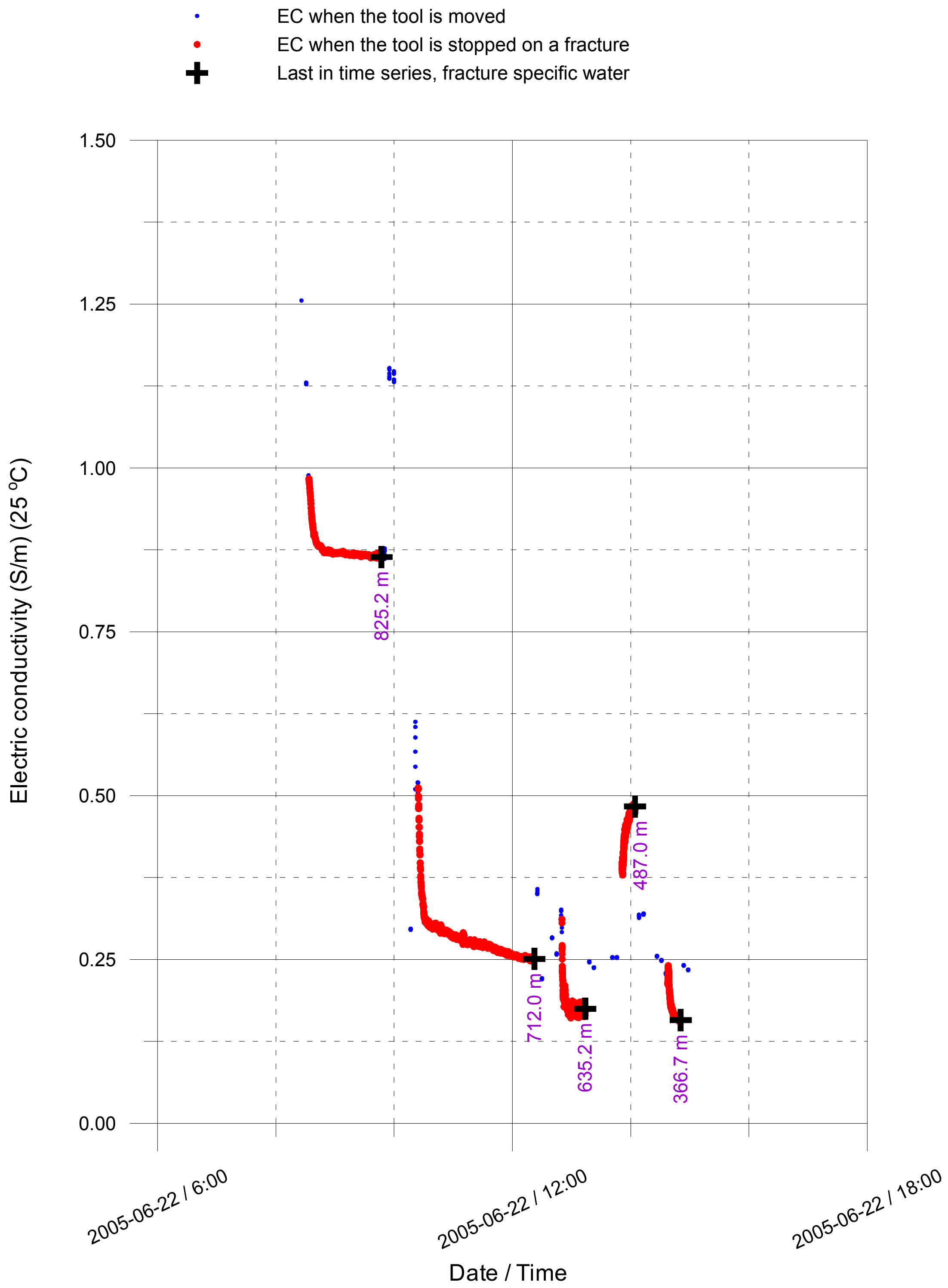
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m^3 * 9.80665 m/s^2) + Elevation (m)
Offset = 2460 Pa (Correction for absolut pressure sensor)



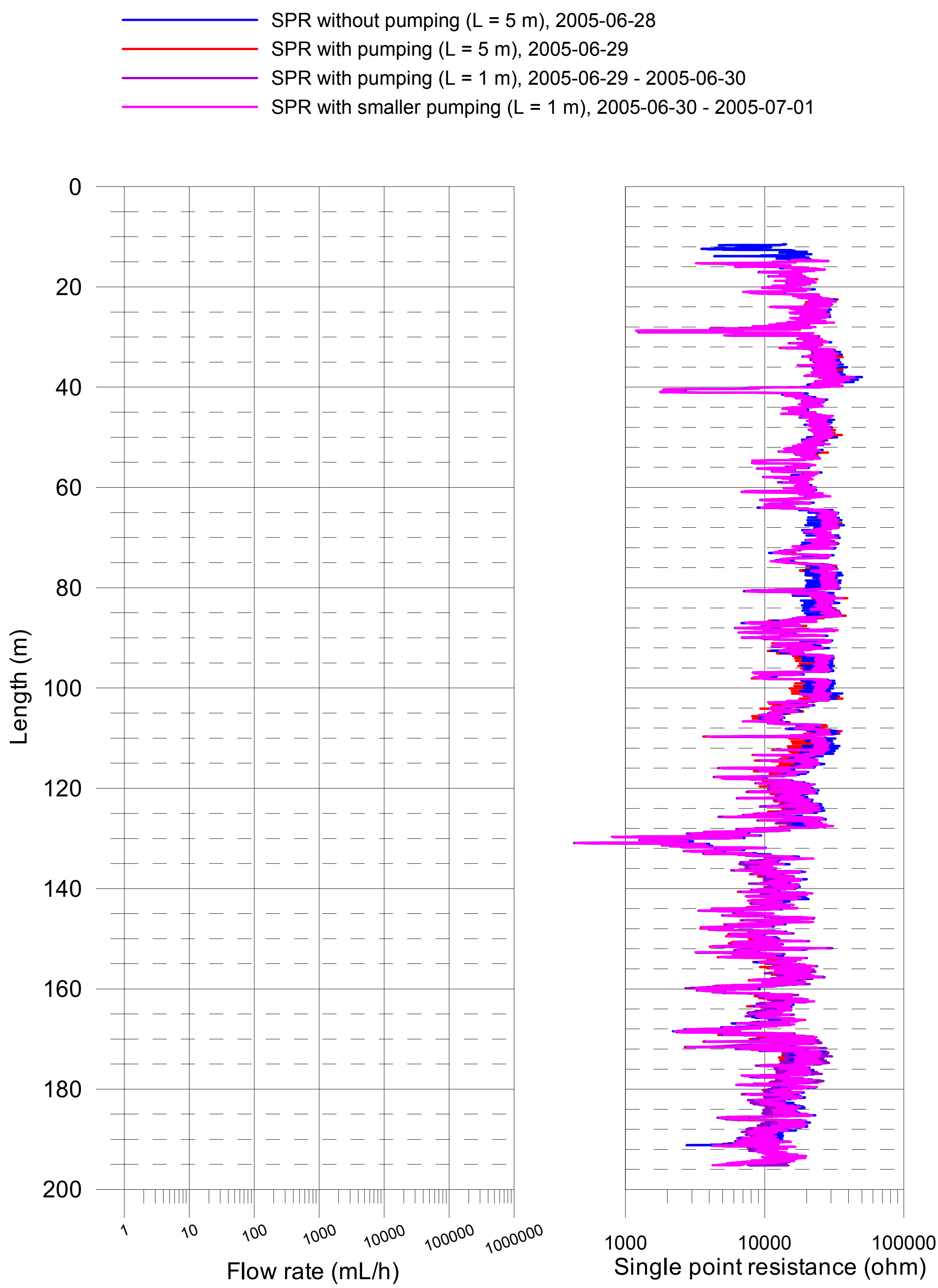
Laxemar, borehole KLX07A
Vertical flow along the borehole at the length of 101.7 m



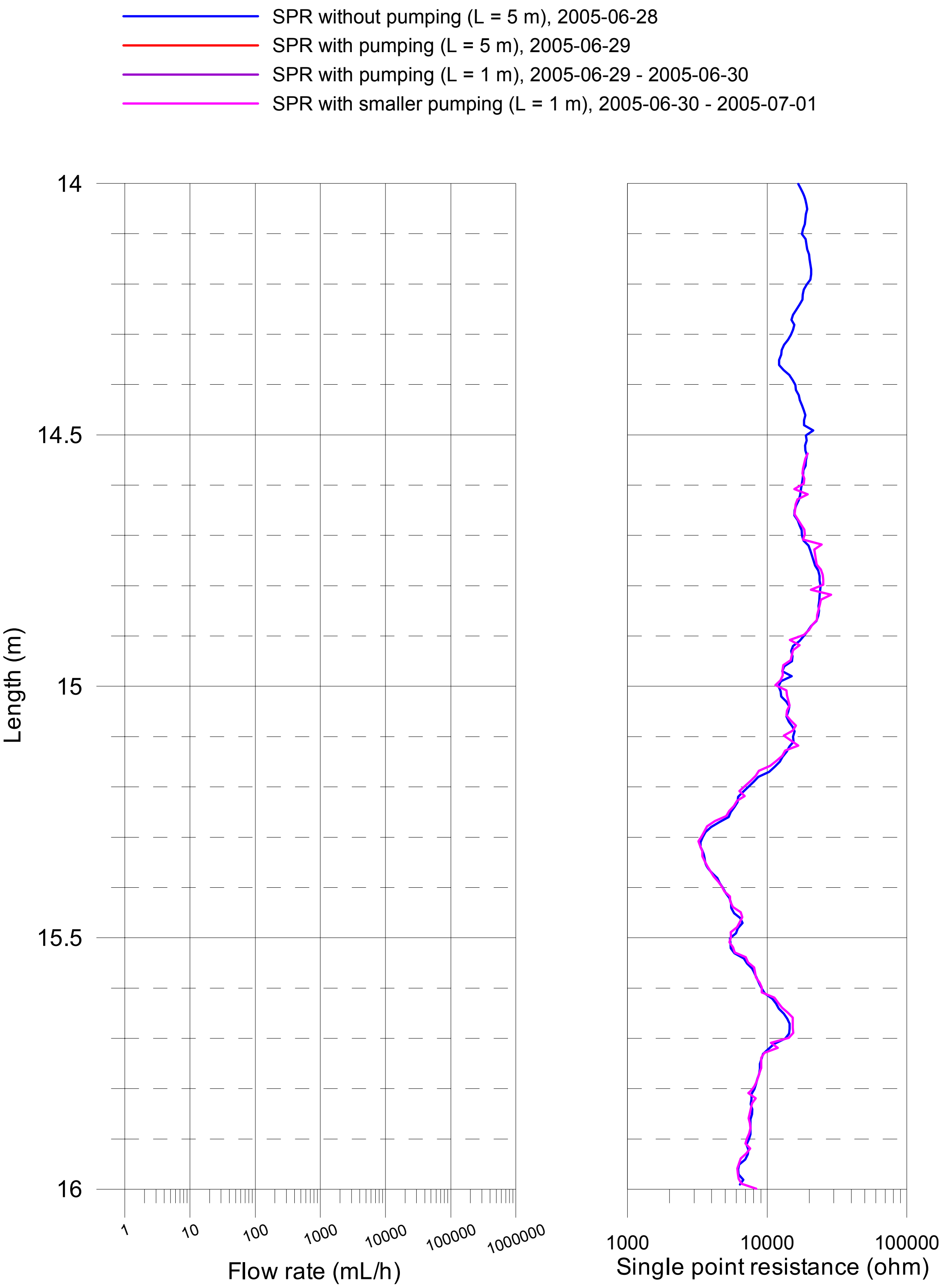
Laxemar, borehole KLX07A
Fracture-specific EC results by date



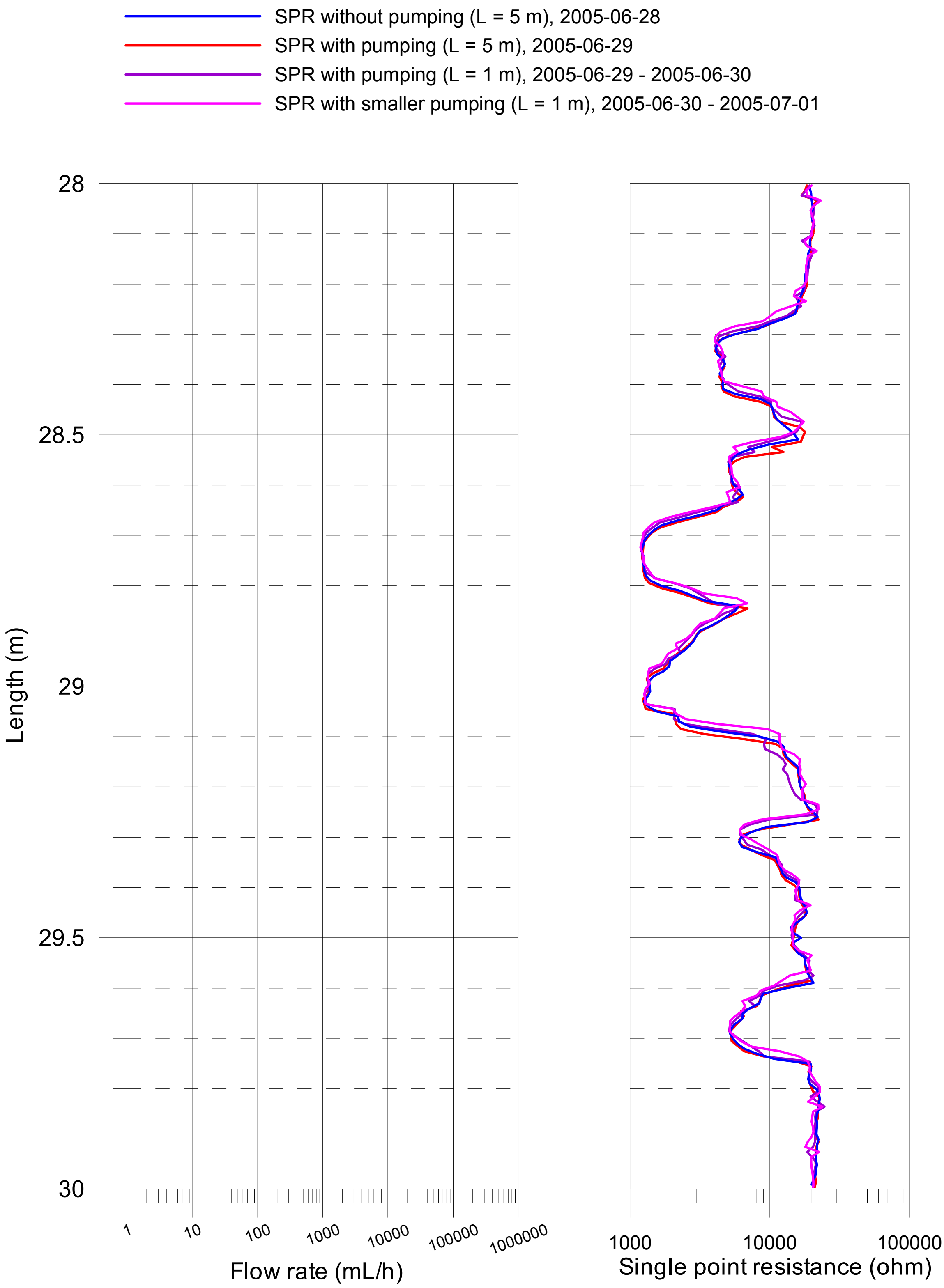
Laxemar, borehole KLX07B
SPR results after length correction



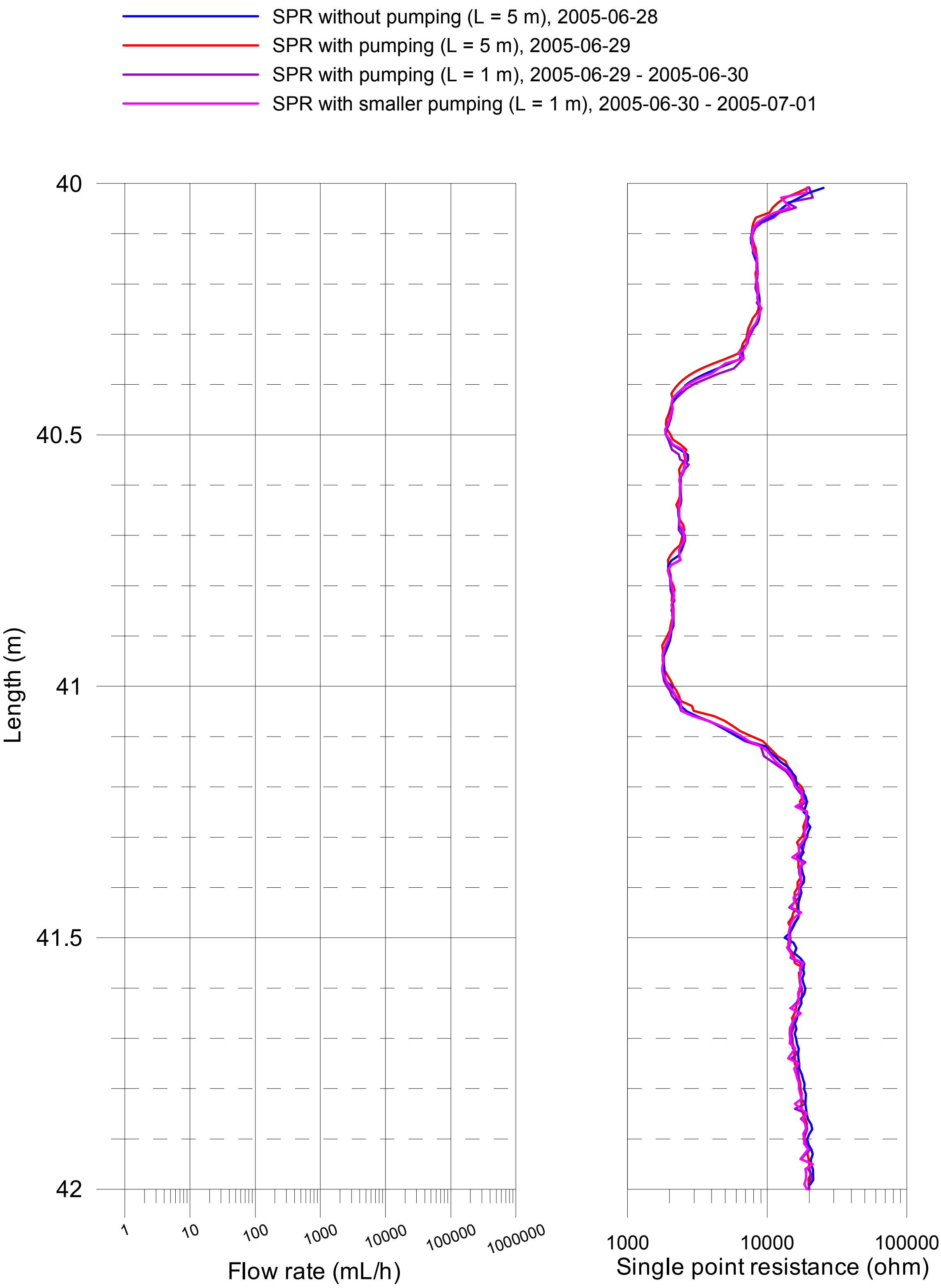
Laxemar, borehole KLX07B
SPR results after length correction



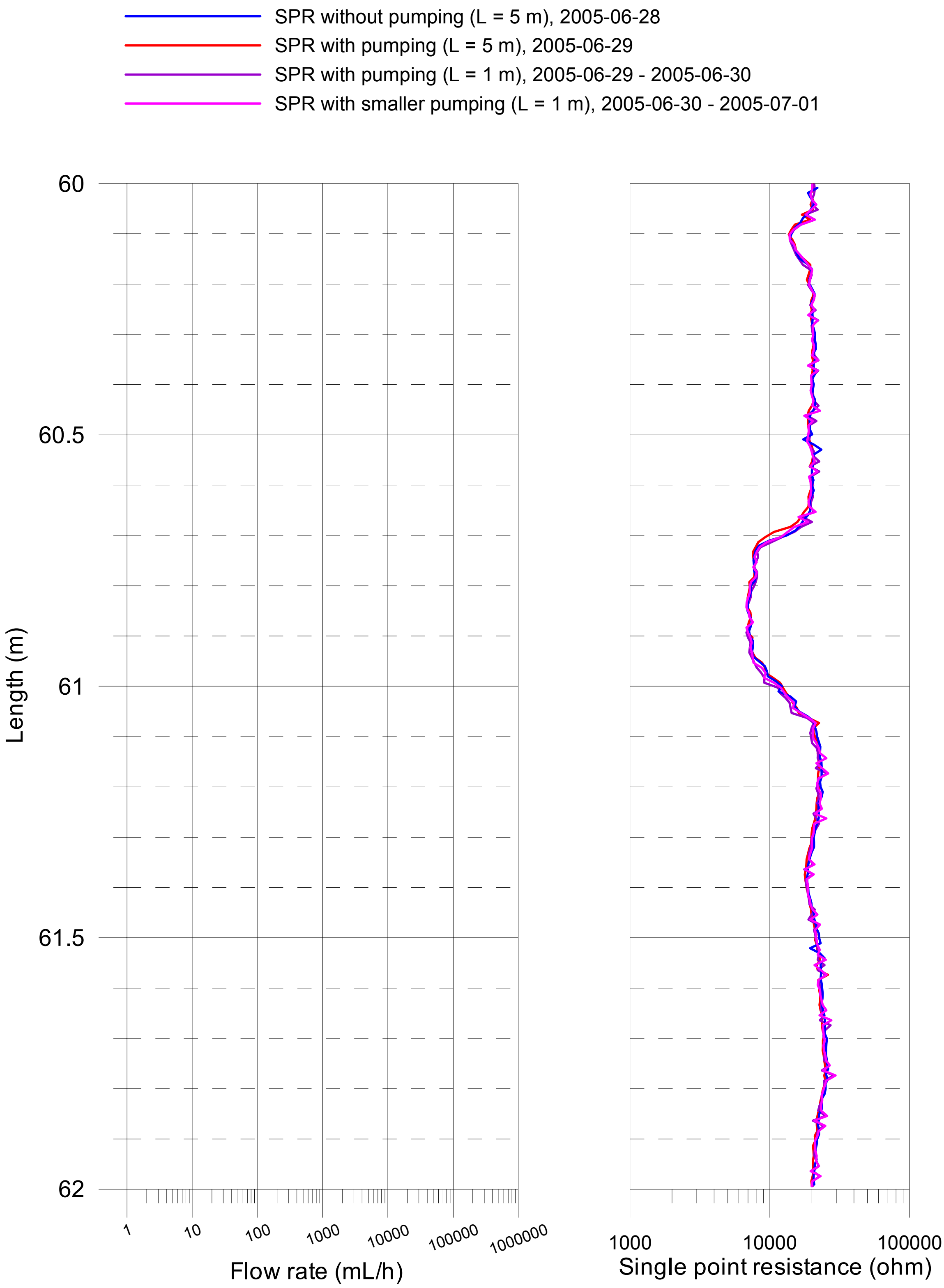
Laxemar, borehole KLX07B
SPR results after length correction



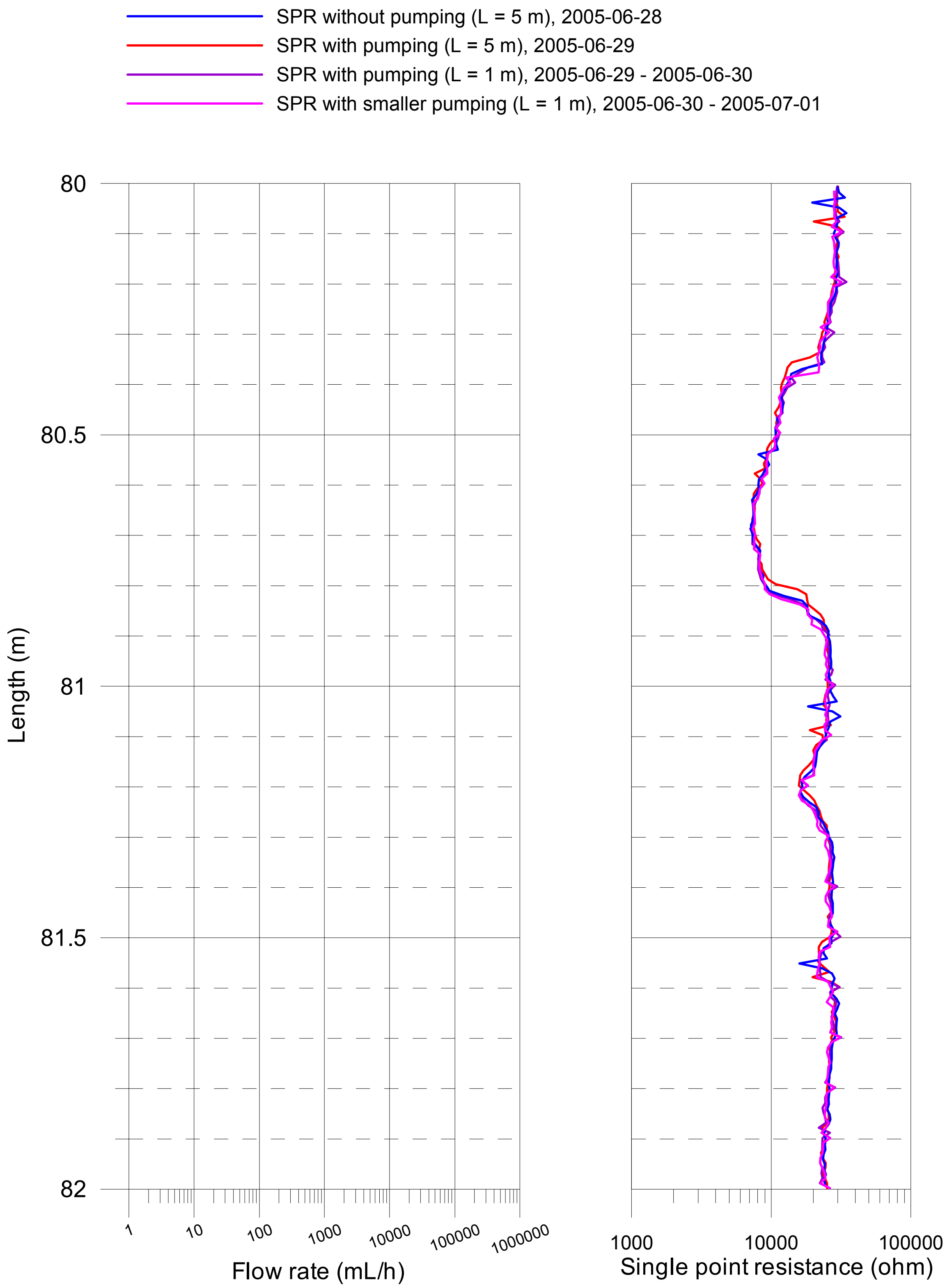
Laxemar, borehole KLX07B
SPR results after length correction



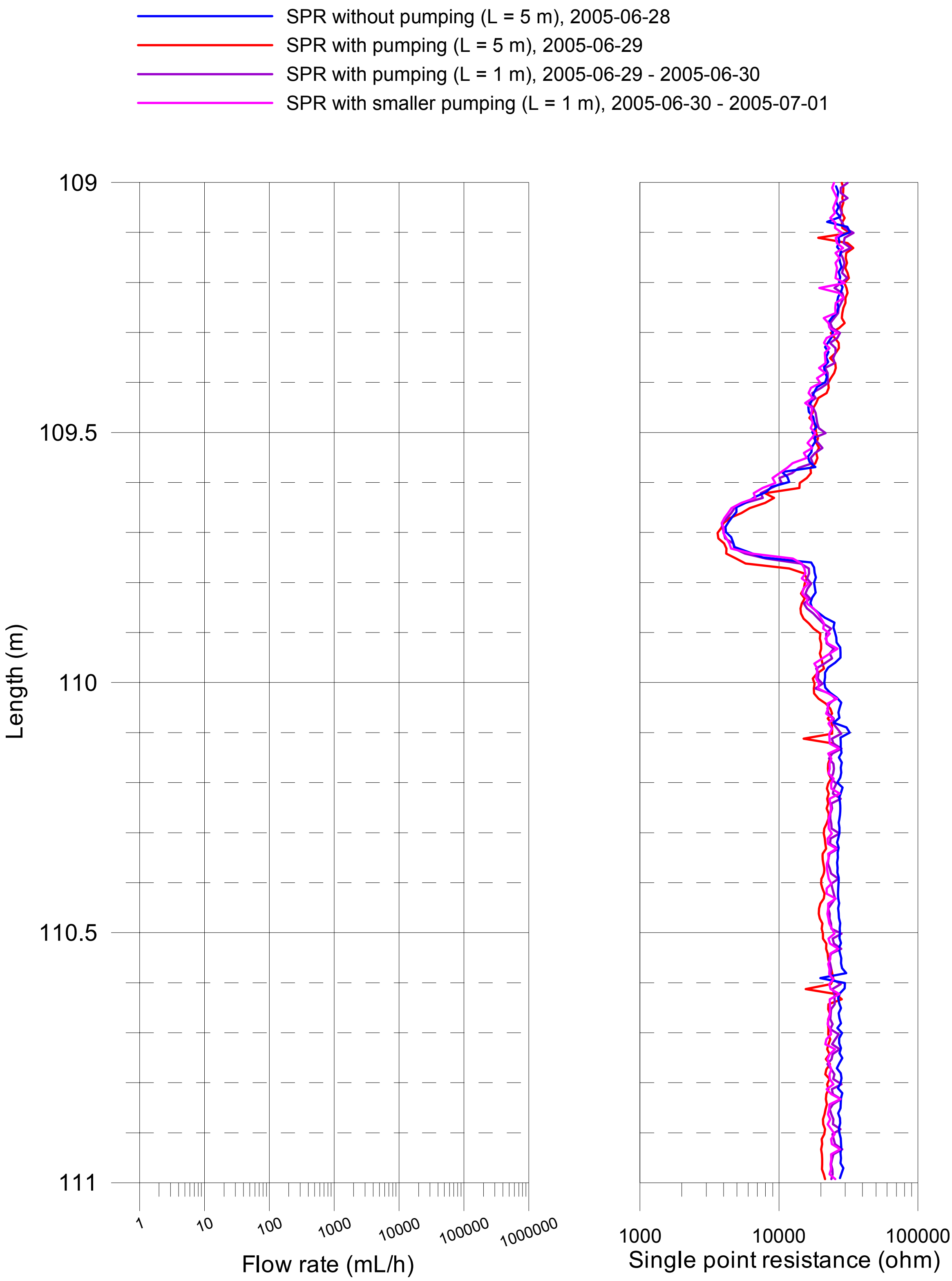
Laxemar, borehole KLX07B
SPR results after length correction



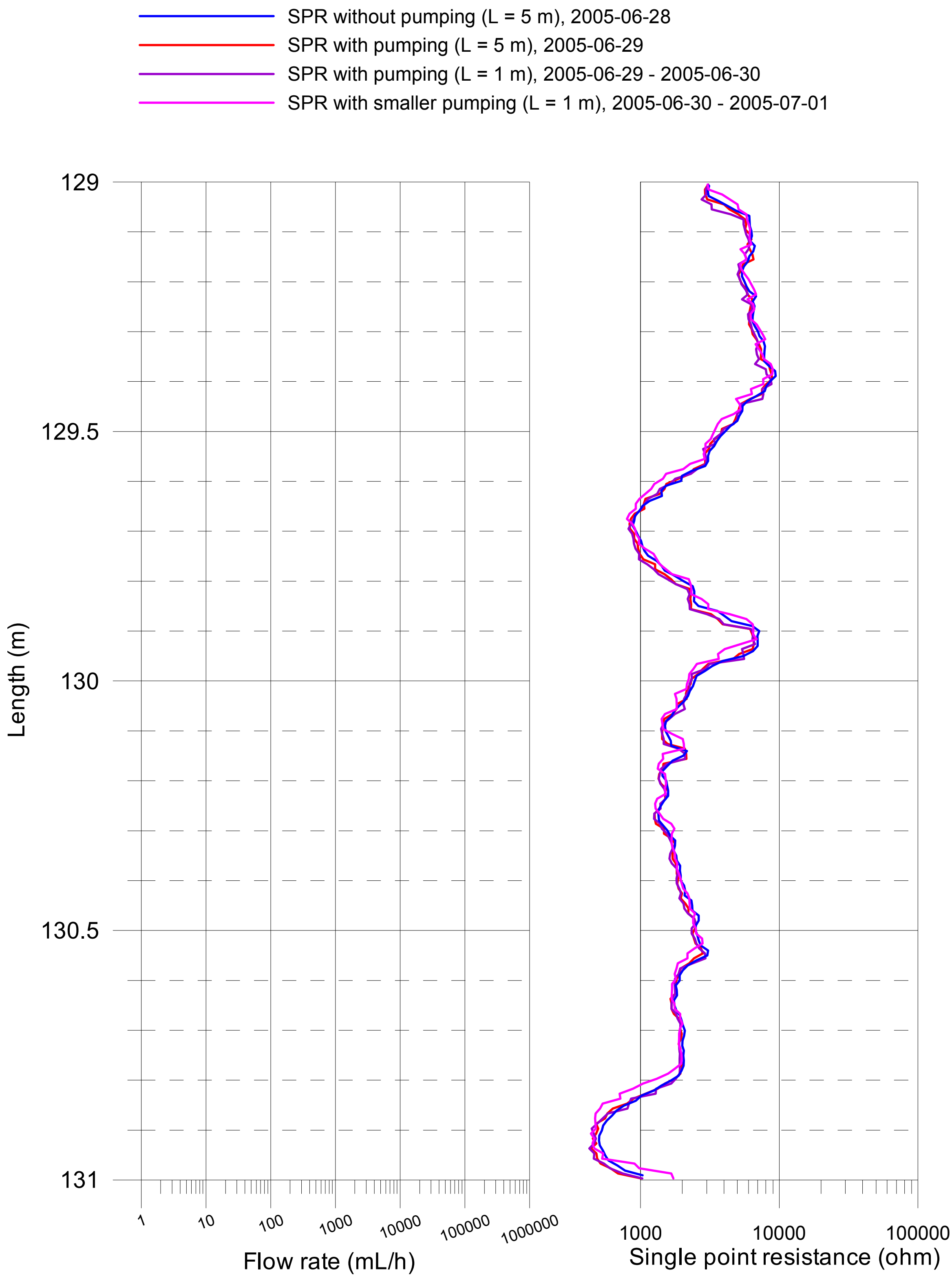
Laxemar, borehole KLX07B
SPR results after length correction



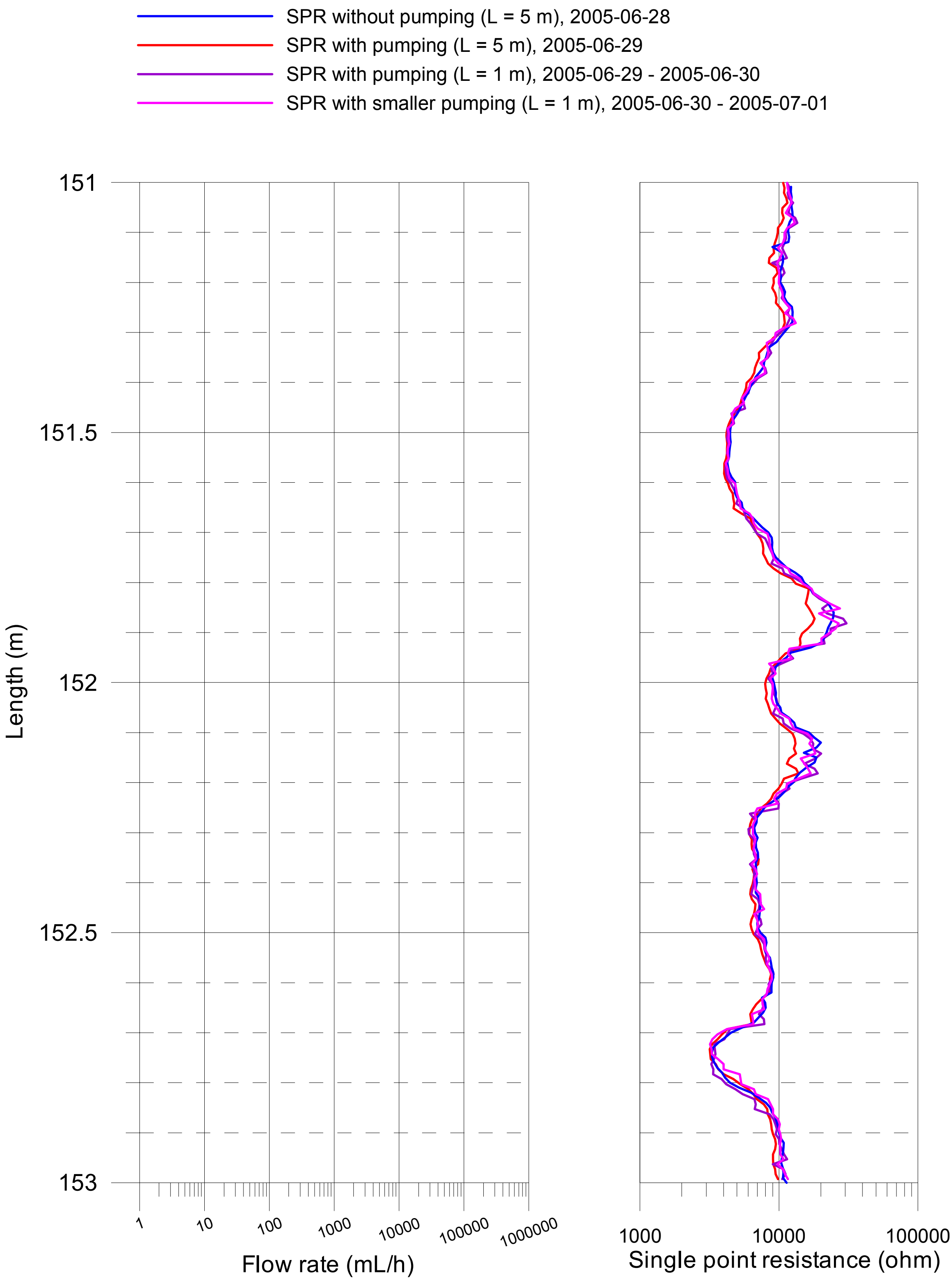
Laxemar, borehole KLX07B
SPR results after length correction



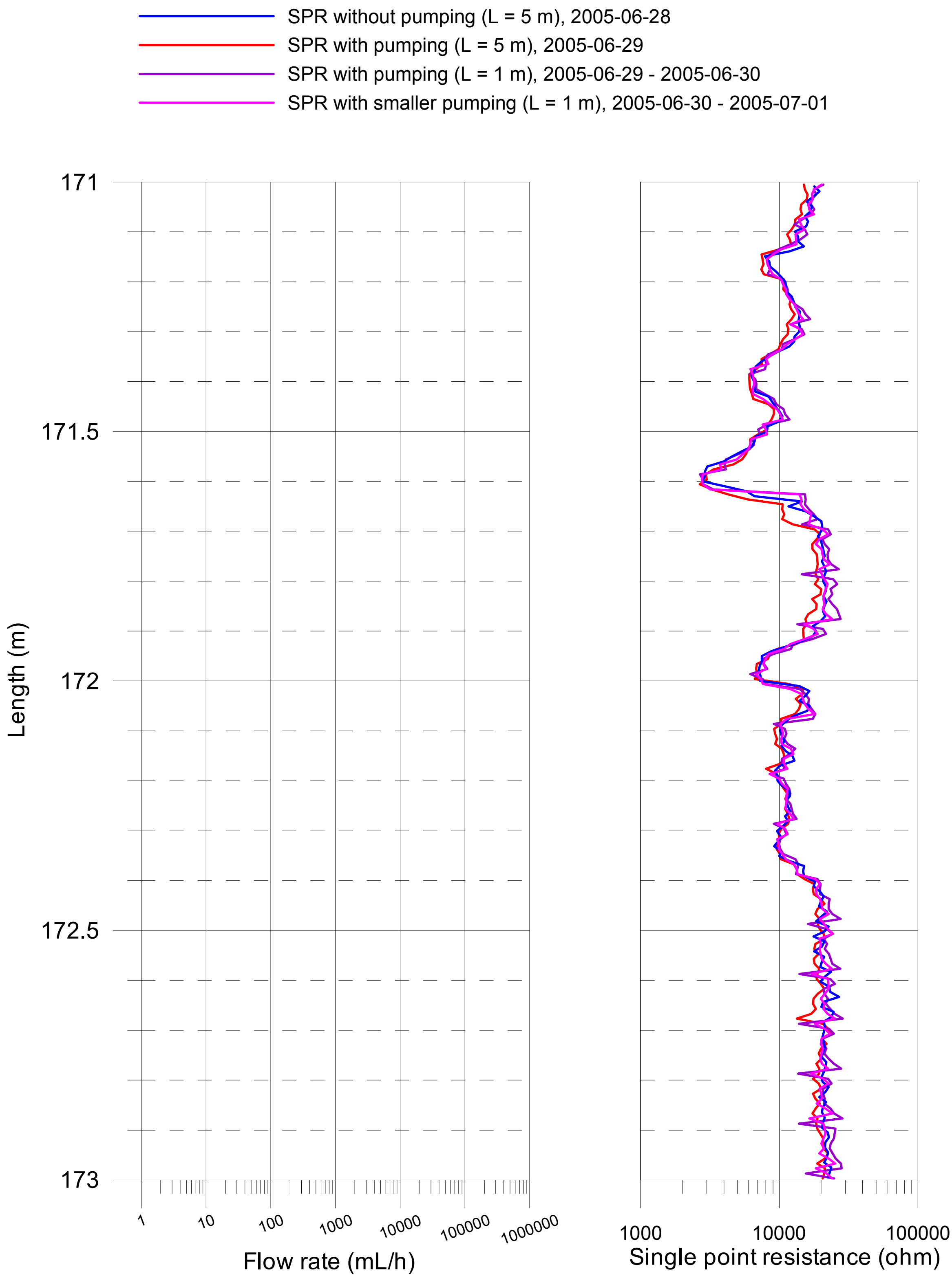
Laxemar, borehole KLX07B
SPR results after length correction



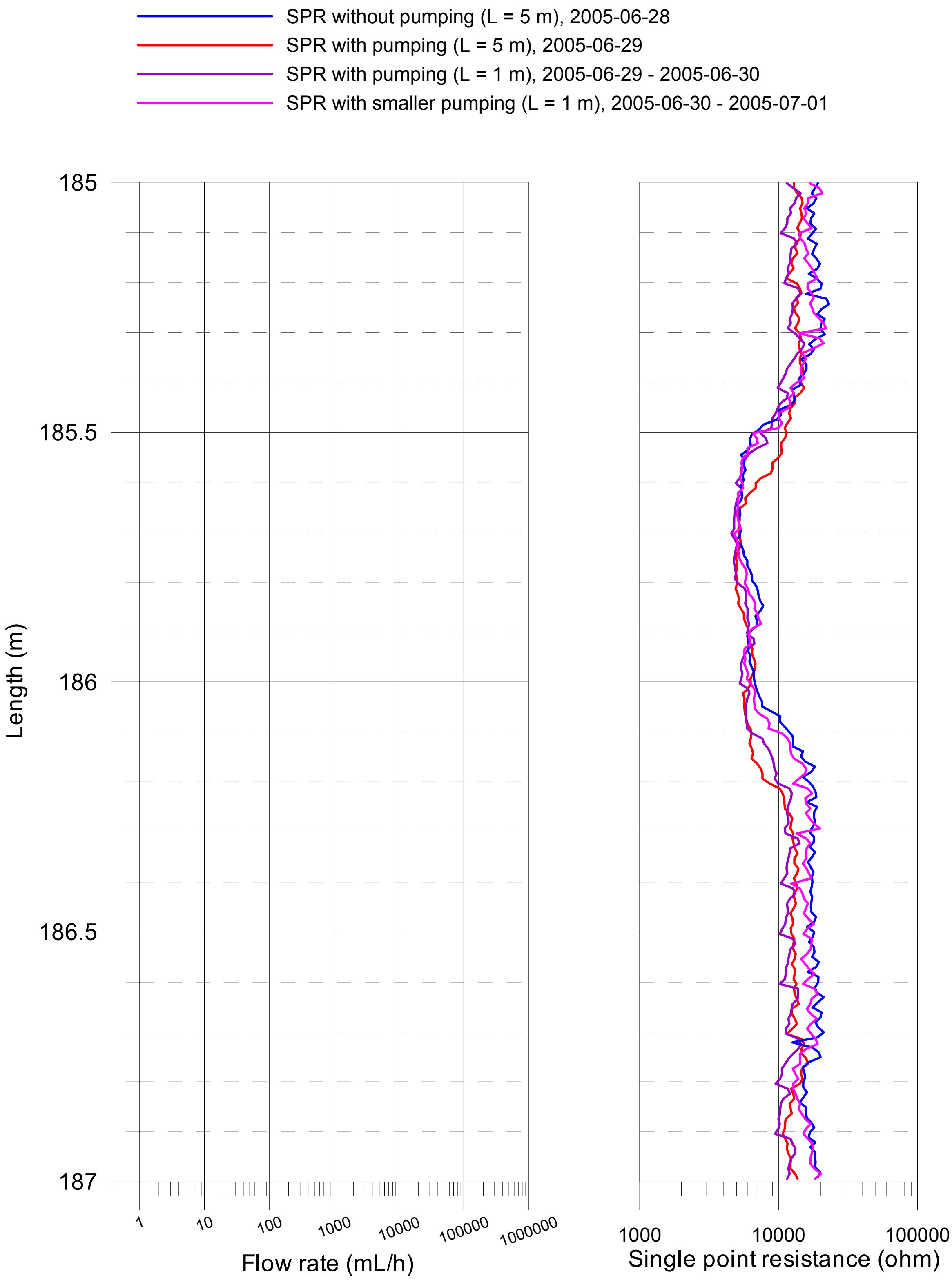
Laxemar, borehole KLX07B
SPR results after length correction



Laxemar, borehole KLX07B
SPR results after length correction

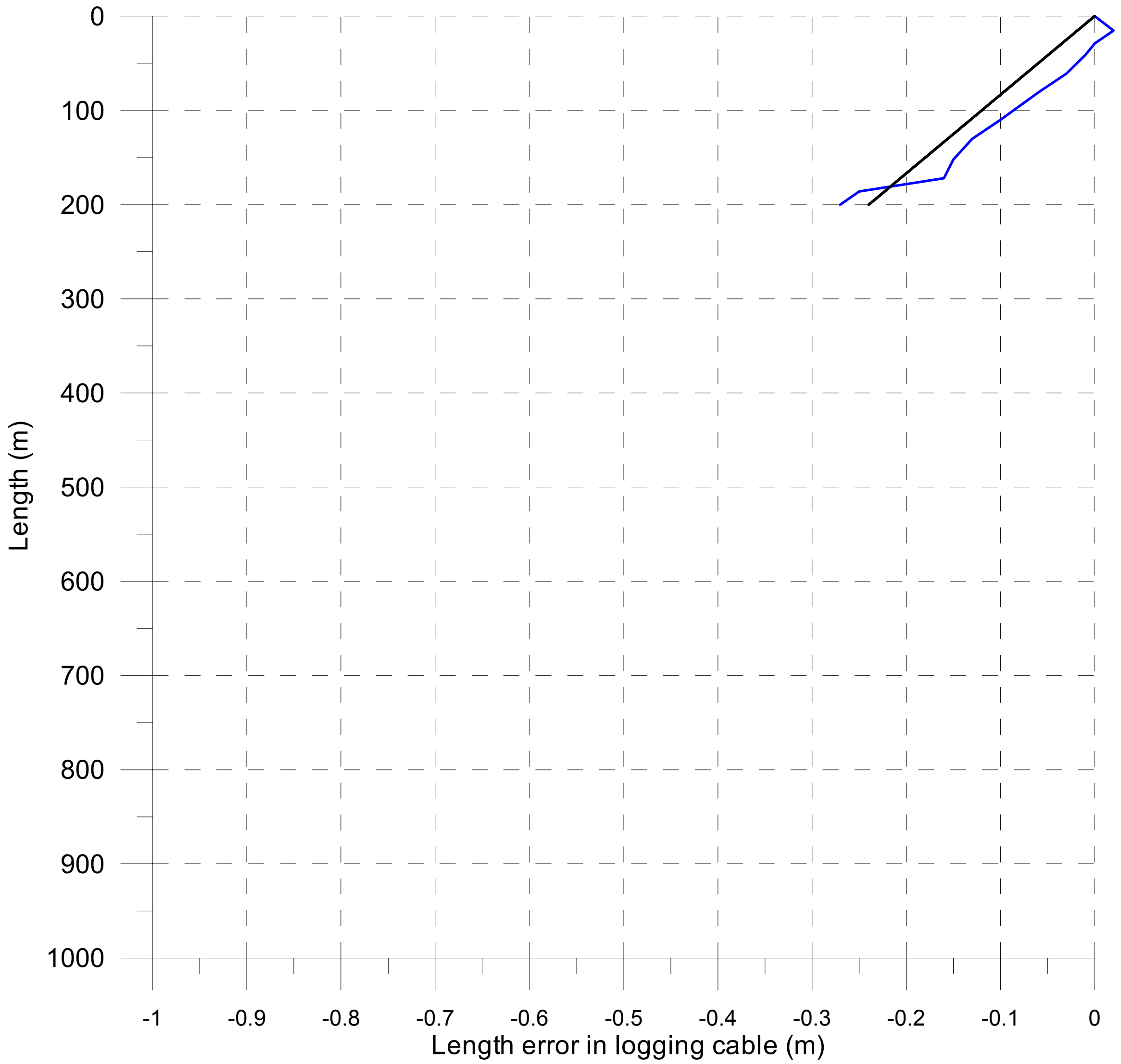


Laxemar, borehole KLX07B
SPR results after length correction

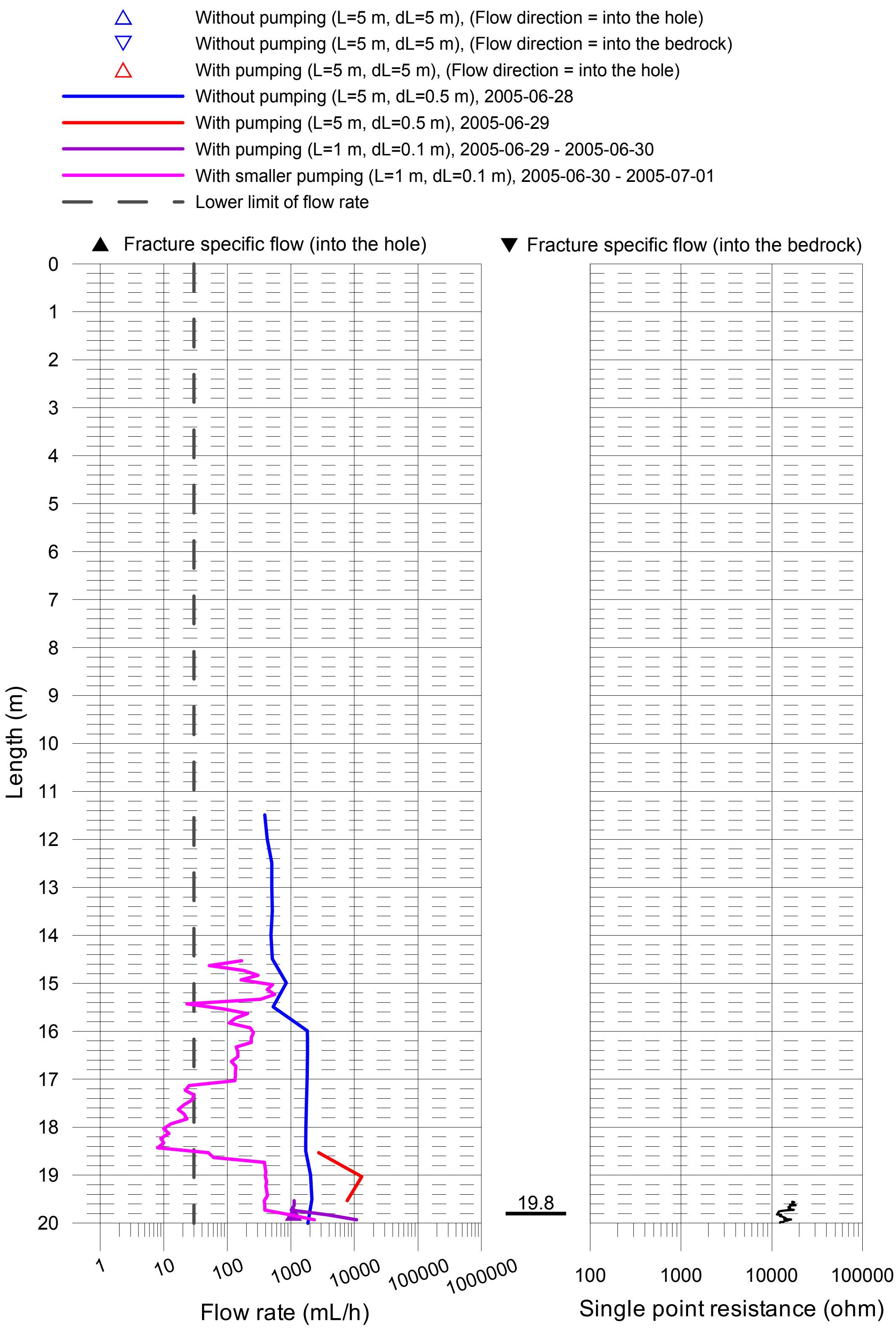


Laxemar, borehole KLX07B
Length correction

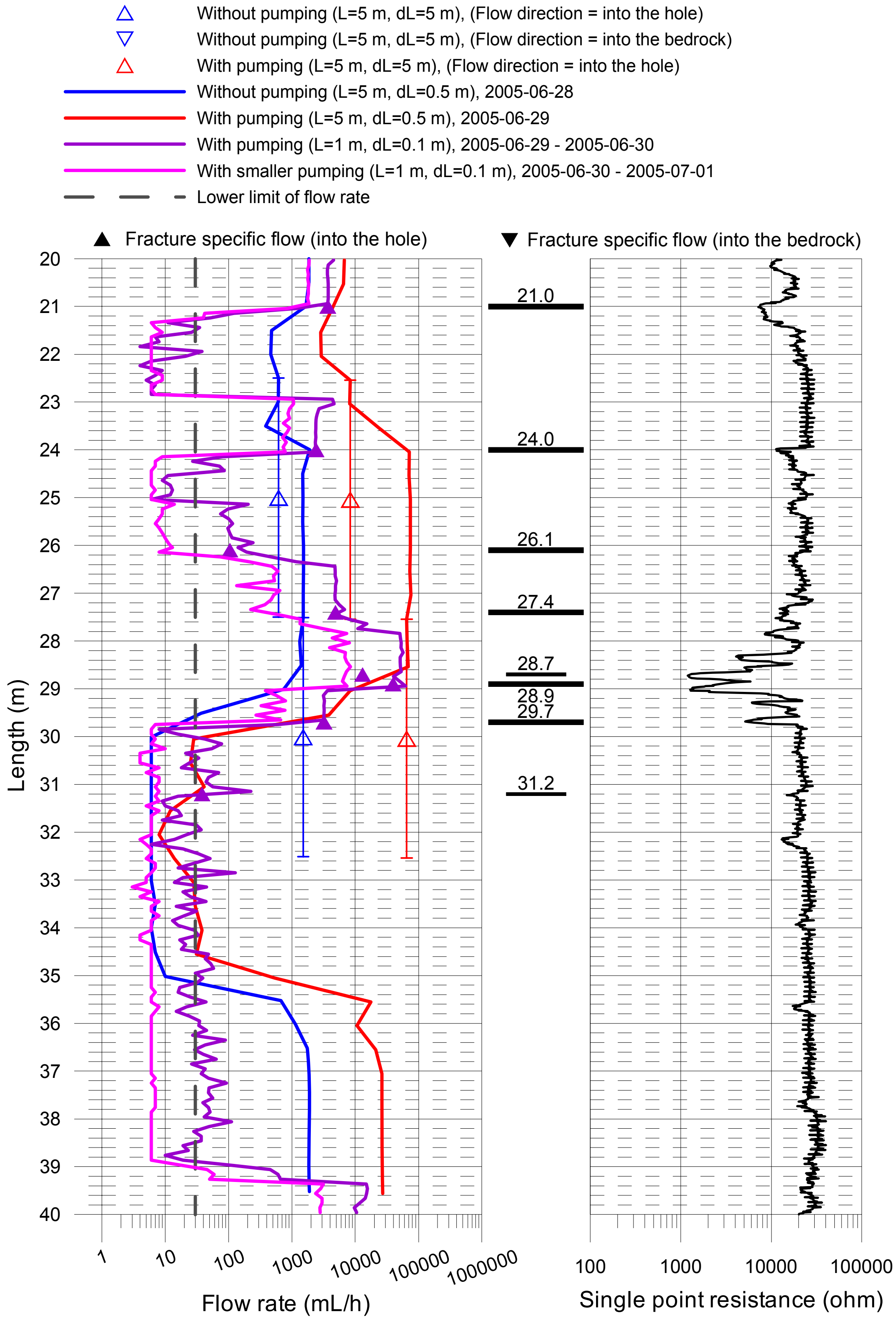
SPR without pumping (upwards) (L = 5 m), 2005-06-28
SPR with pumping (upwards) (L = 5 m), 2005-06-29
SPR with pumping (upwards) (L = 1 m), 2005-06-29 - 2005-06-30
SPR with smaller pumping (upwards) (L = 1 m), 2005-06-30 - 2005-07-01

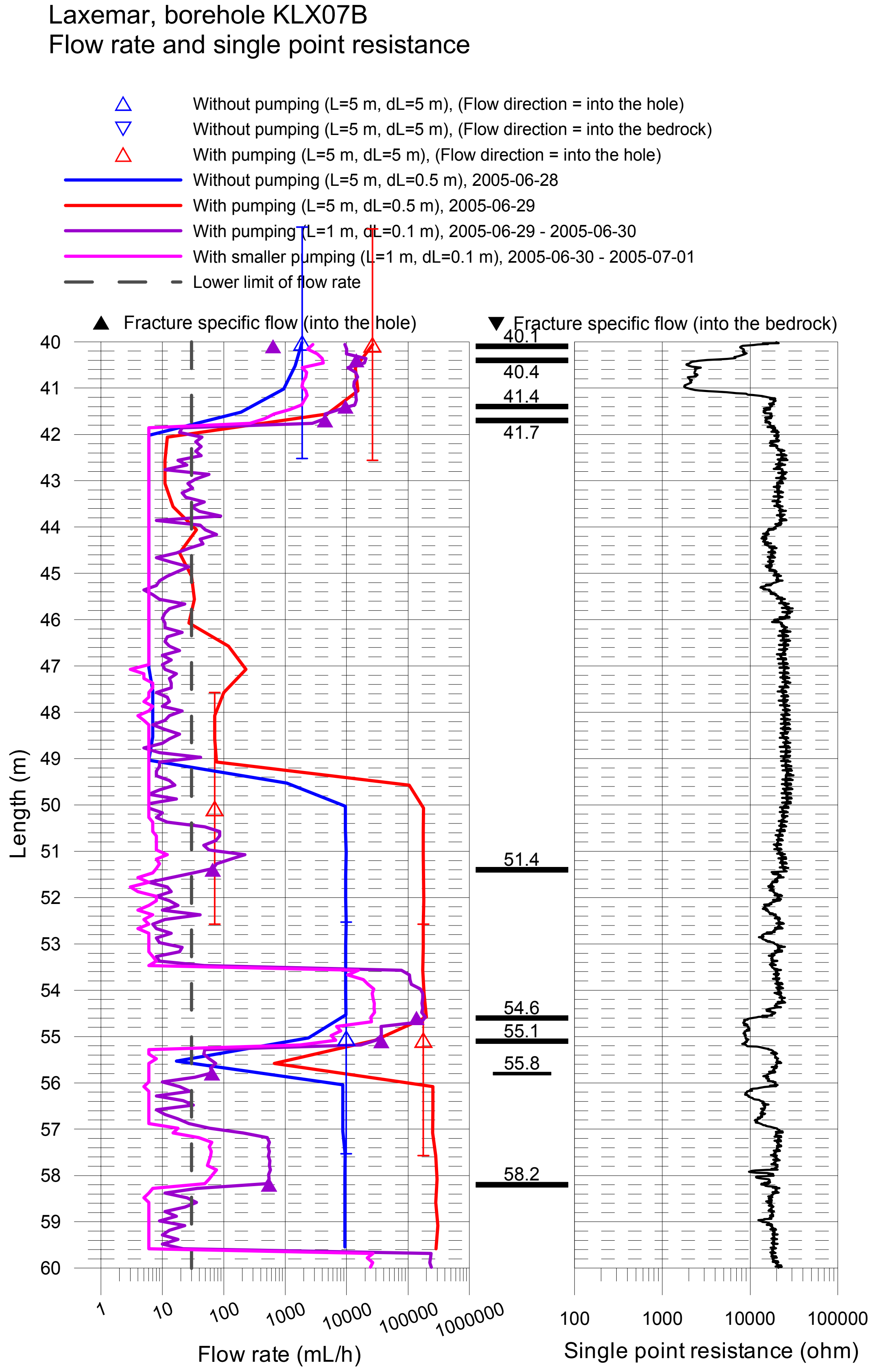


Laxemar, borehole KLX07B
Flow rate and single point resistance

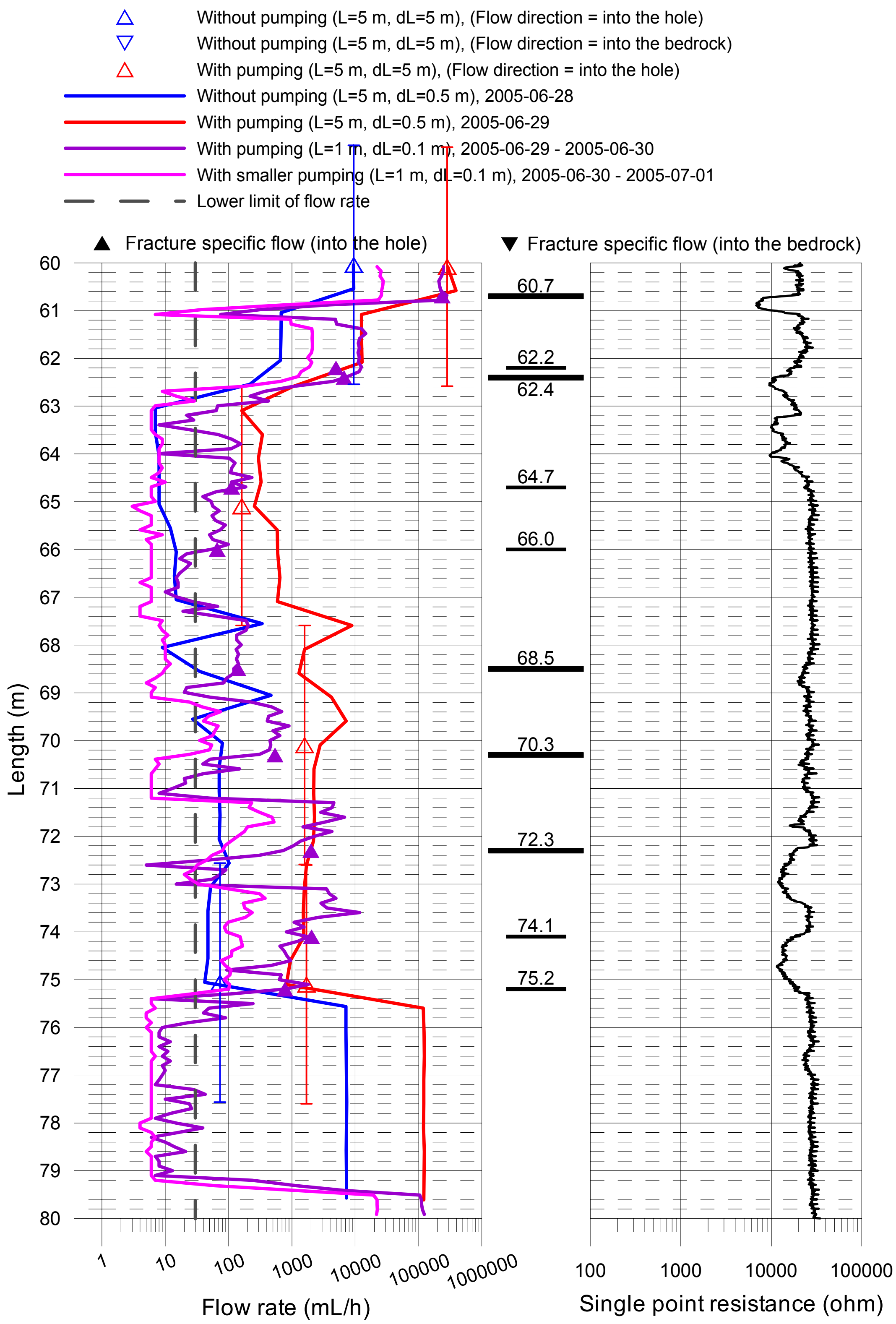


Laxemar, borehole KLX07B
Flow rate and single point resistance

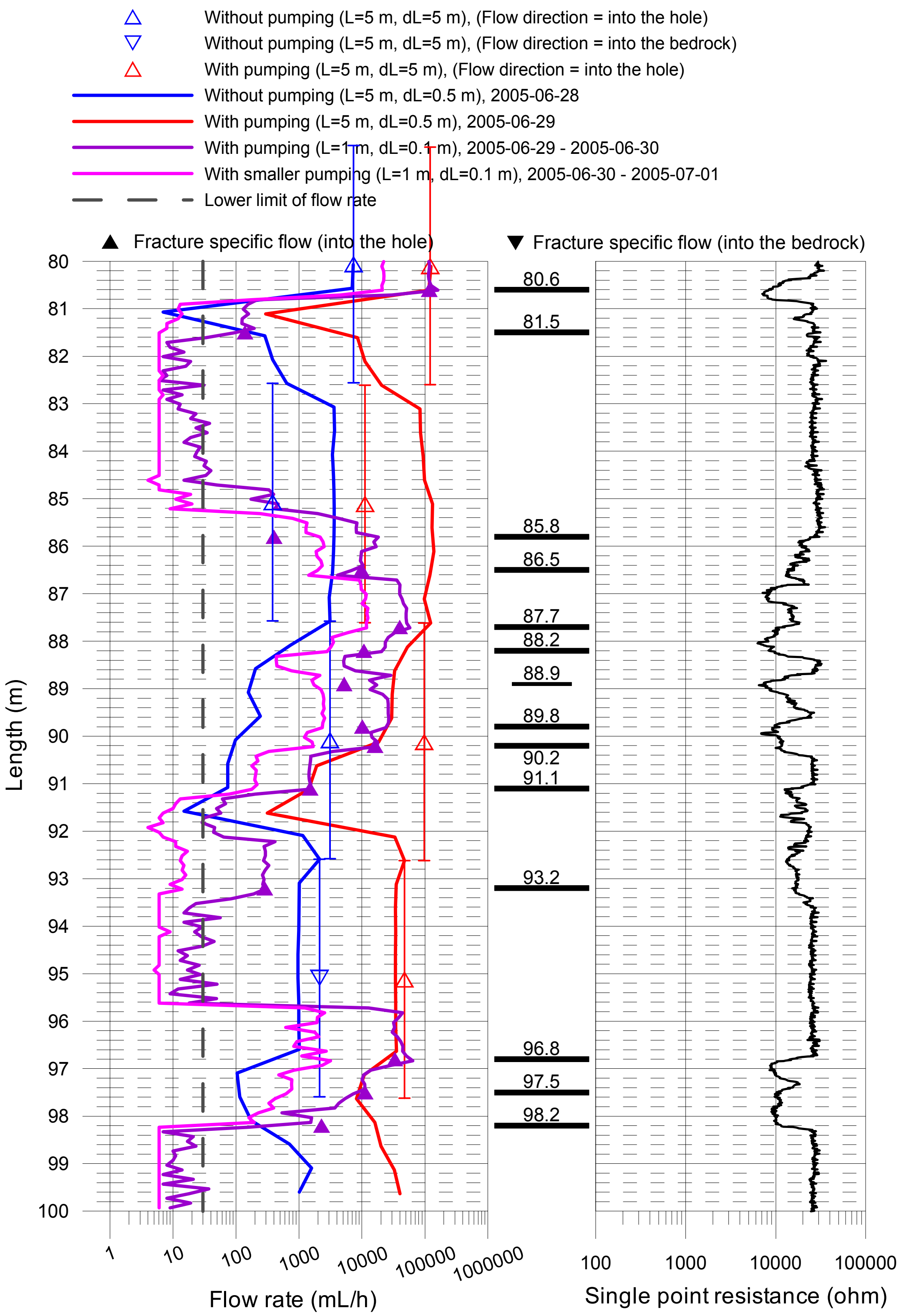


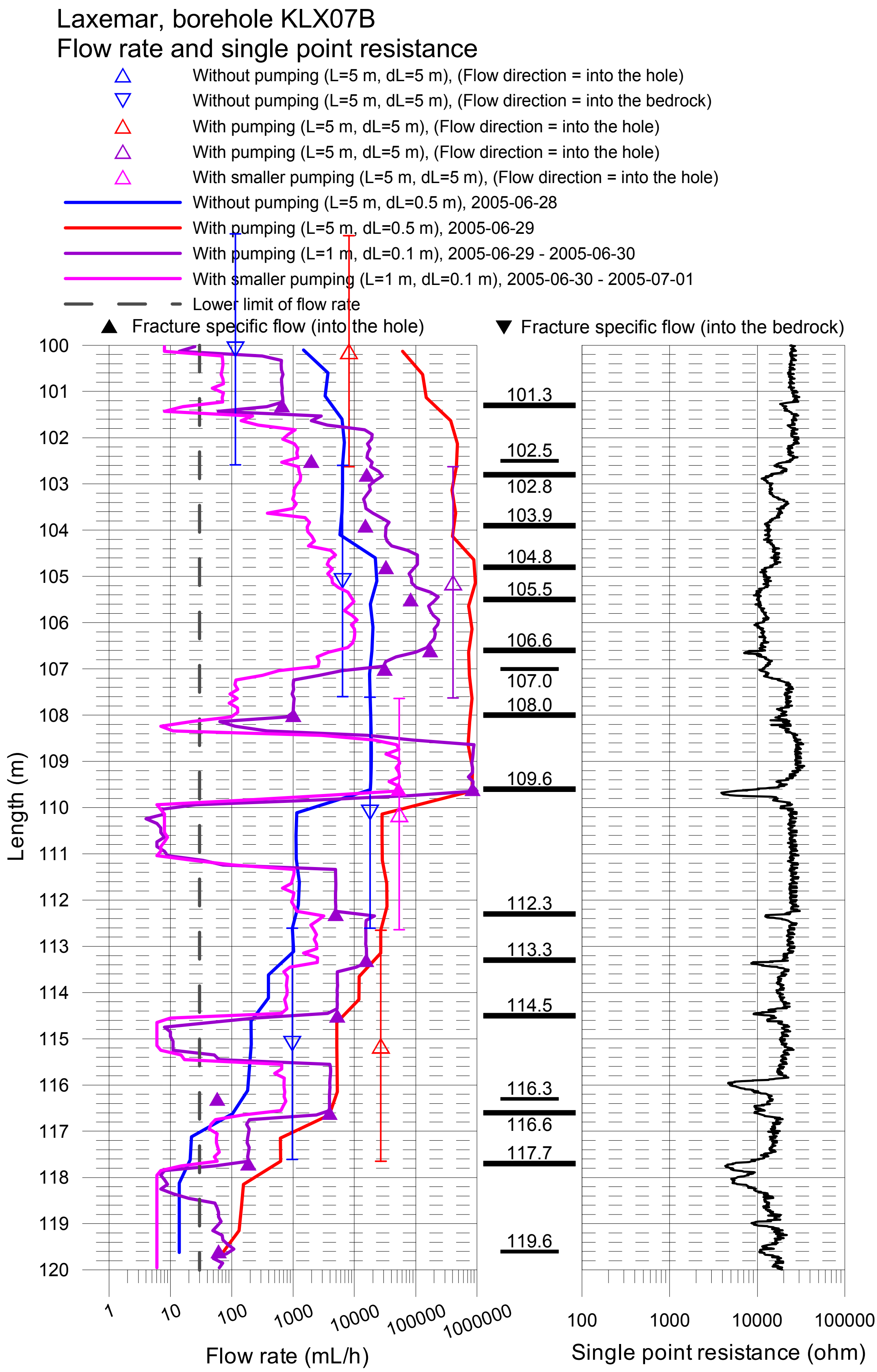

Laxemar, borehole KLX07B
Flow rate and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2005-06-28
With pumping (L=5 m, dL=0.5 m), 2005-06-29
With pumping (L=1 m, dL=0.1 m), 2005-06-29 - 2005-06-30
With smaller pumping (L=1 m, dL=0.1 m), 2005-06-30 - 2005-07-01
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
40.1
40.4
41.4
41.7
51.4
54.6
55.1
55.8
58.2
Length (m)
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
100000
Single point resistance (ohm)

Laxemar, borehole KLX07B
Flow rate and single point resistance



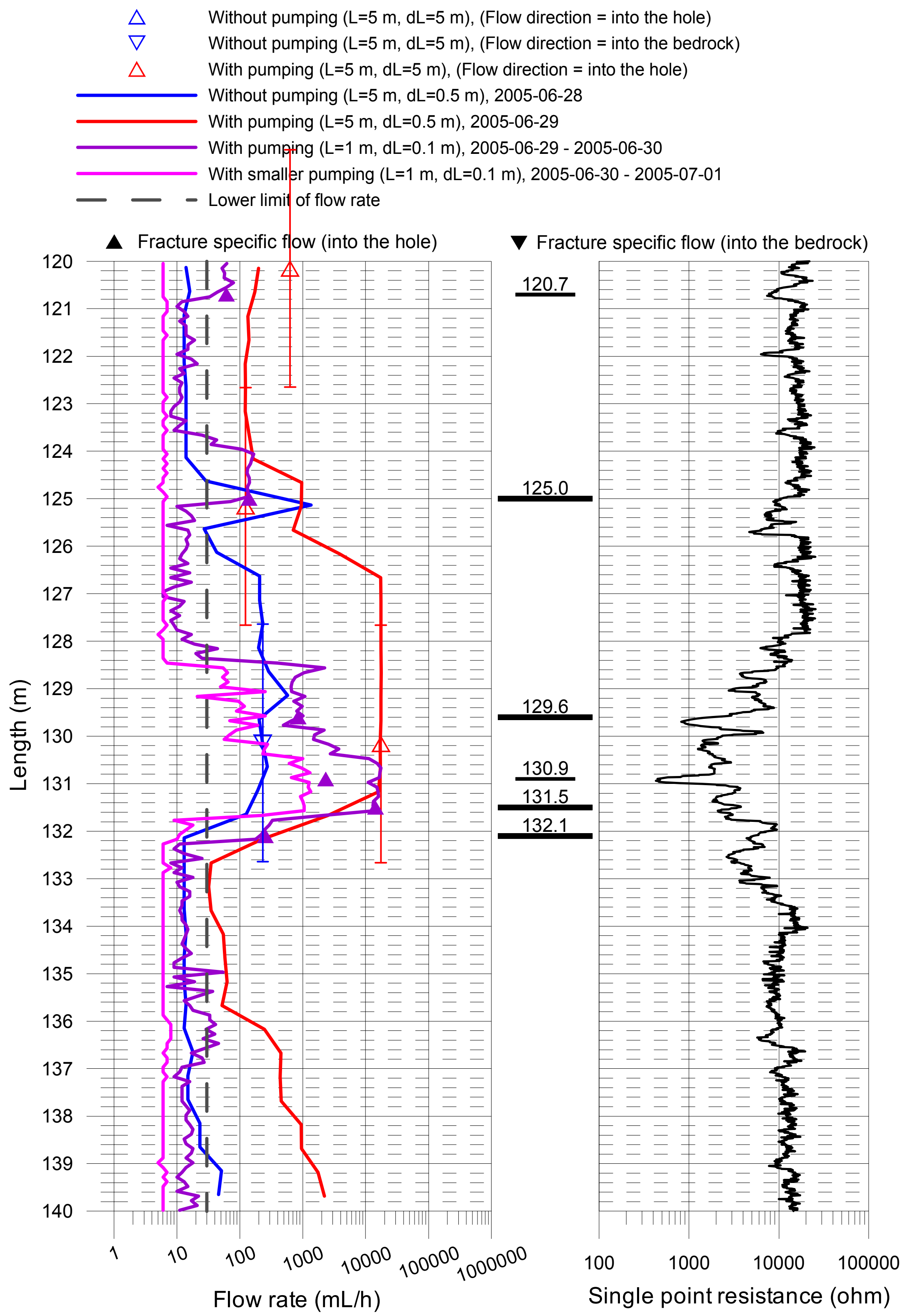
Laxemar, borehole KLX07B
Flow rate and single point resistance



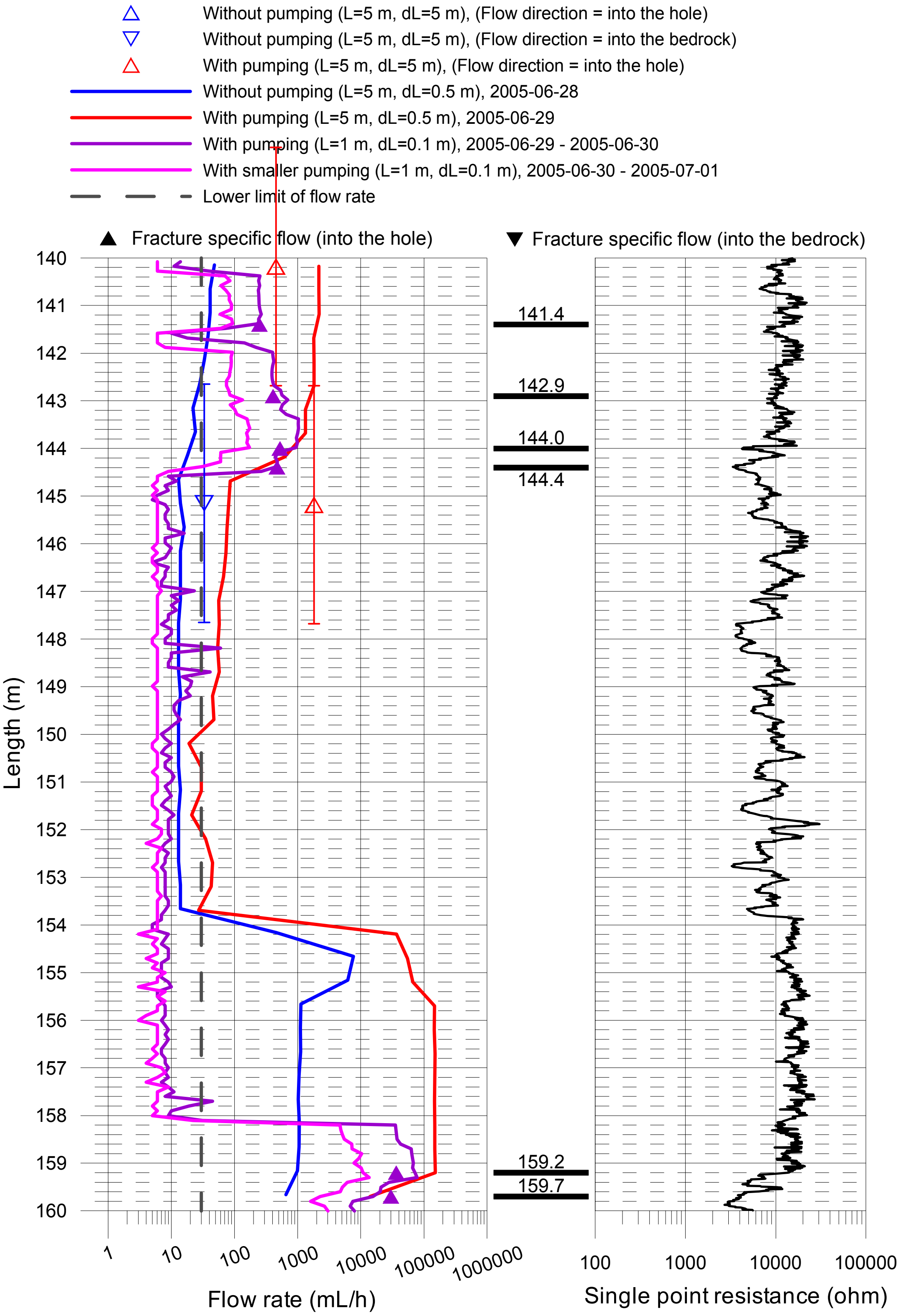


Laxemar, borehole KLX07B
Flow rate and single point resistance
Without pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=5 m), (Flow direction = into the bedrock)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
With pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
With smaller pumping (L=5 m, dL=5 m), (Flow direction = into the hole)
Without pumping (L=5 m, dL=0.5 m), 2005-06-28
With pumping (L=5 m, dL=0.5 m), 2005-06-29
With pumping (L=1 m, dL=0.1 m), 2005-06-29 - 2005-06-30
With smaller pumping (L=1 m, dL=0.1 m), 2005-06-30 - 2005-07-01
Lower limit of flow rate
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Length (m)
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
101.3
102.5
102.8
103.9
104.8
105.5
106.6
107.0
108.0
109.6
112.3
113.3
114.5
116.3
116.6
117.7
119.6
1
10
100
1000
10000
100000
1000000
Flow rate (mL/h)
100
1000
10000
100000
Single point resistance (ohm)

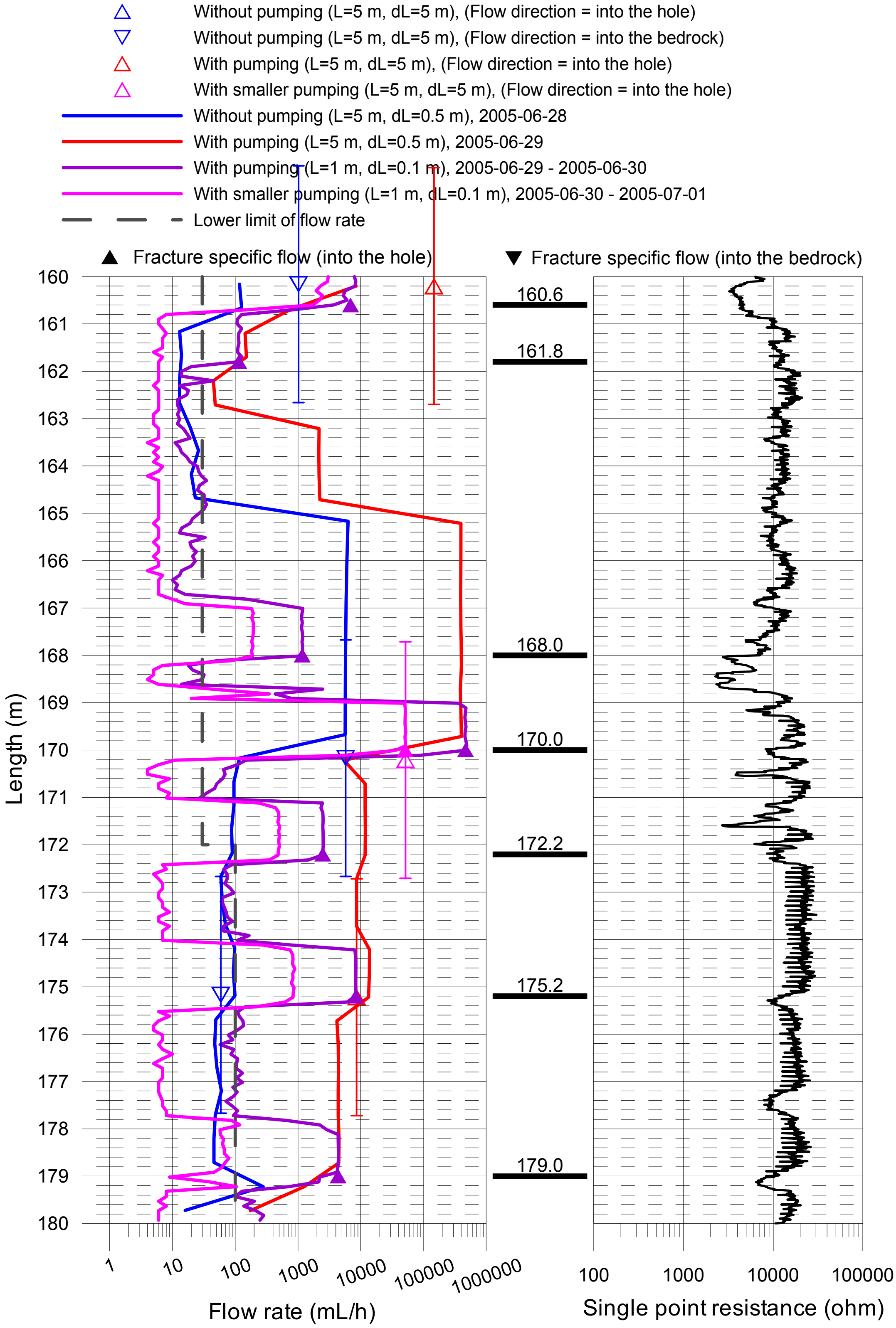
Laxemar, borehole KLX07B
Flow rate and single point resistance



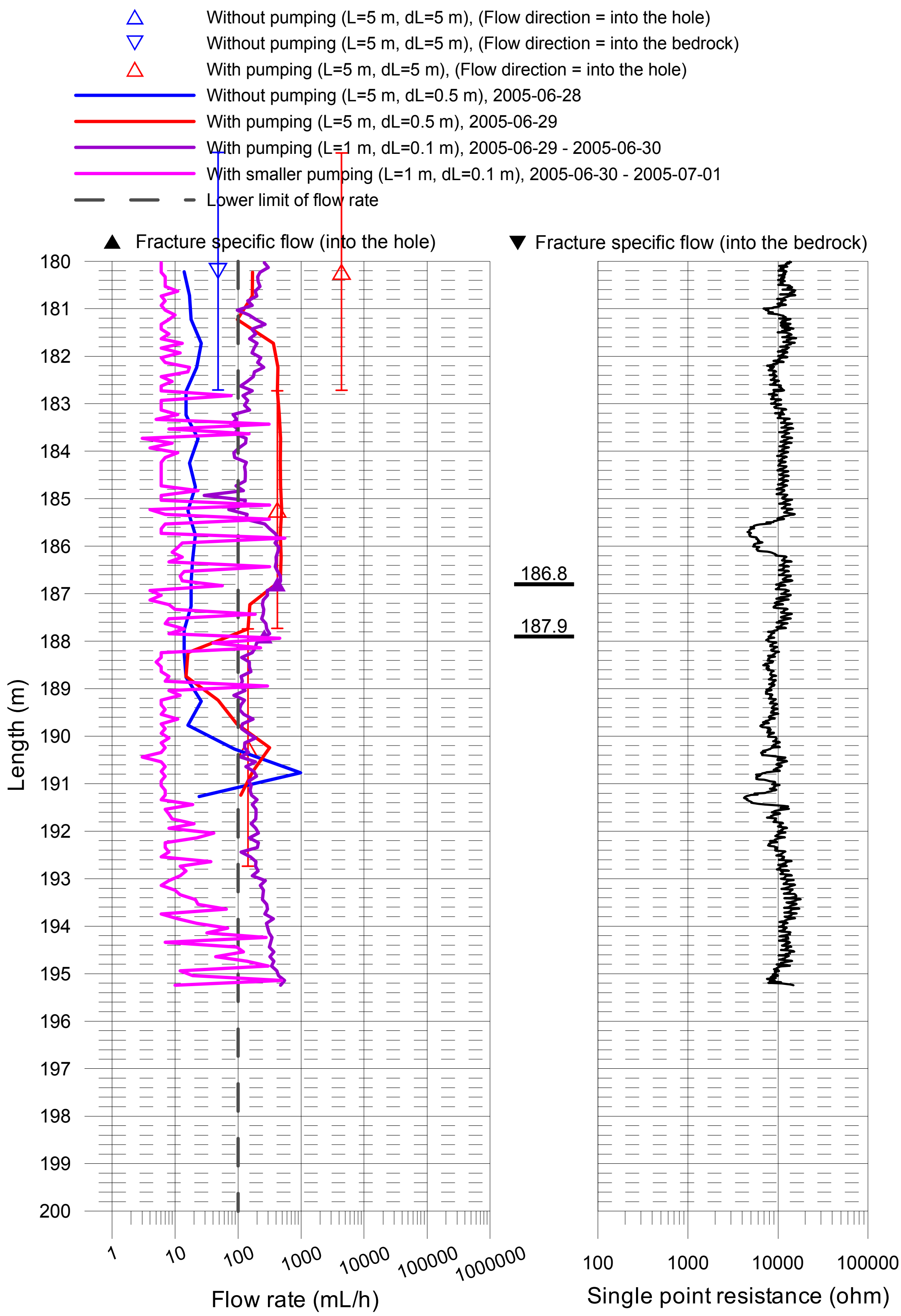
Laxemar, borehole KLX07B
Flow rate and single point resistance

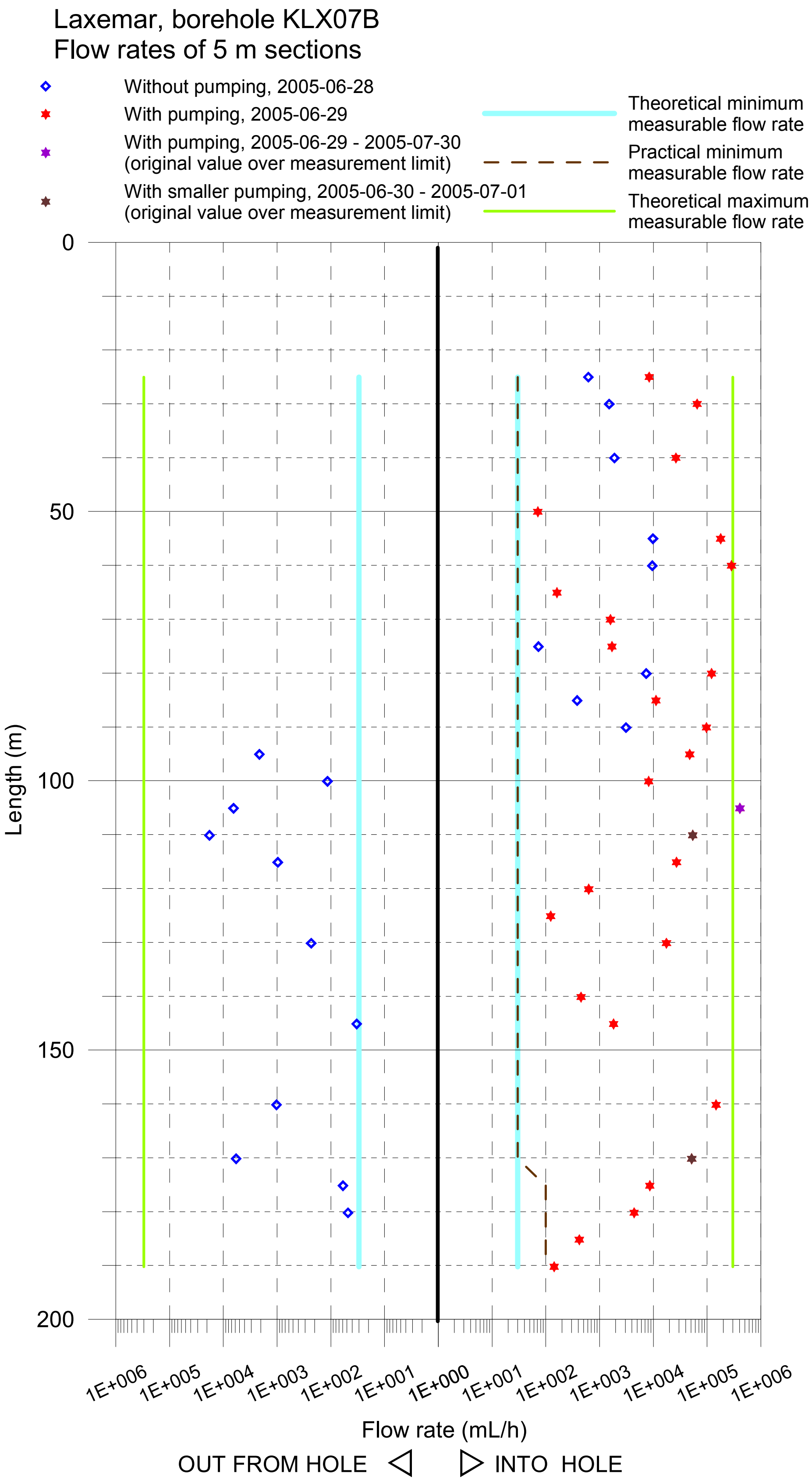


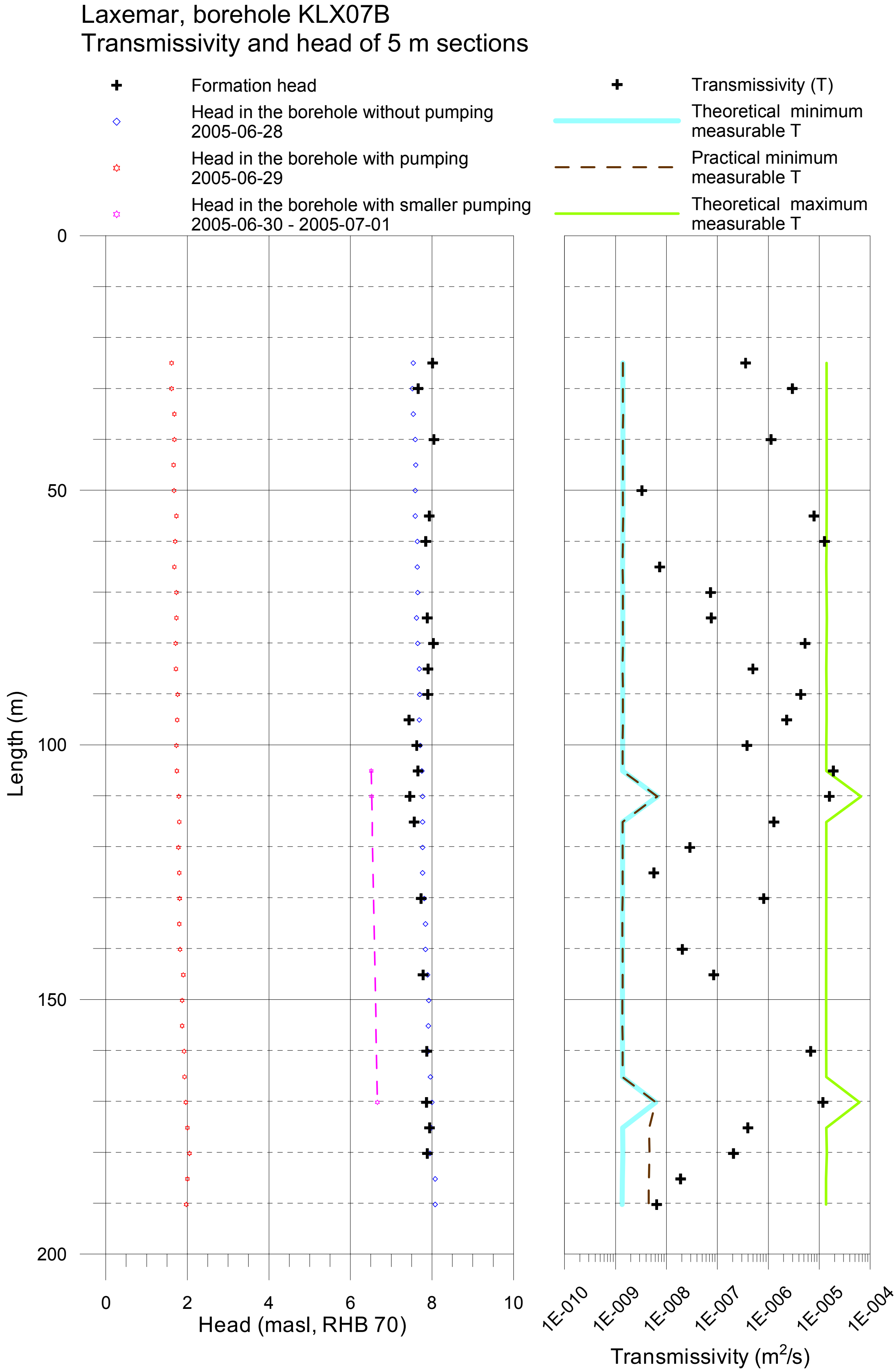
Laxemar, borehole KLX07B
Flow rate and single point resistance



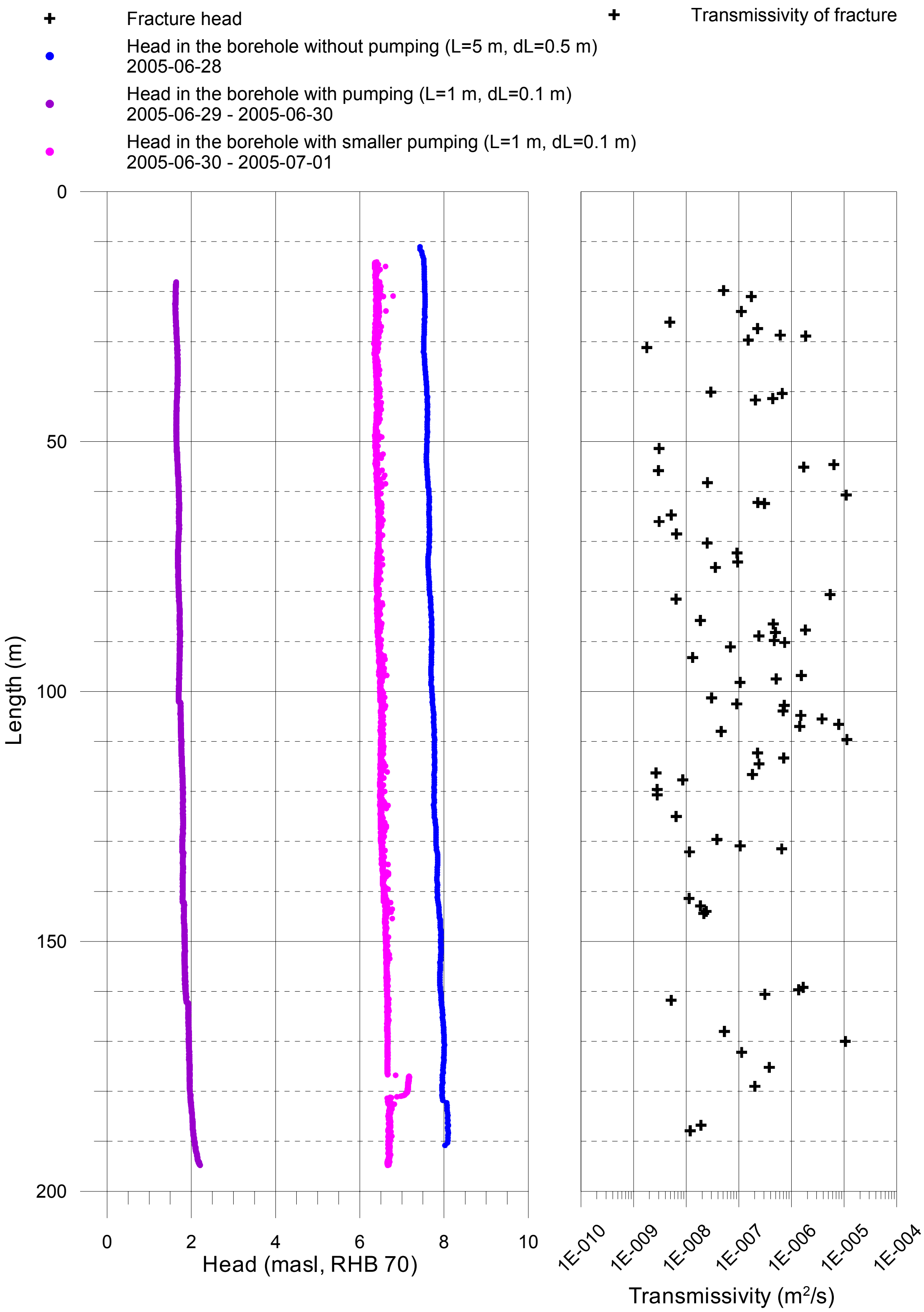
Laxemar, borehole KLX07B
Flow rate and single point resistance




Laxemar, borehole KLX07B
Flow rates of 5 m sections
Without pumping, 2005-06-28
With pumping, 2005-06-29
With pumping, 2005-06-29 - 2005-07-30 (original value over measurement limit)
With smaller pumping, 2005-06-30 - 2005-07-01 (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
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 KLX07B
Transmissivity and head of 5 m sections
Formation head
Head in the borehole without pumping 2005-06-28
Head in the borehole with pumping 2005-06-29
Head in the borehole with smaller pumping 2005-06-30 - 2005-07-01
Transmissivity (T)
Theoretical minimum measurable T
Practical minimum measurable T
Theoretical maximum measurable T
0
50
100
150
200
Length (m)
0
2
4
6
8
10
Head (masl, RHB 70)
1E-010
1E-009
1E-008
1E-007
1E-006
1E-005
1E-004
Transmissivity (m2/s)

Laxemar, borehole KLX07B
Transmissivity and head of detected fractures



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)
KLX07B	22.52	192.75	5A	20050629	11:11	20050629	13:16	20050630	09:18	5	5	4.0E–4	

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 (–)
79,620		29,820		7.60	1.74		–5.86		6.8E–5		

Difference flow logging – Sequential flow logging

Borehole ID	Secup L (m)	Seclow L (m)	L_w (m)	Q_0 (m^3/s)	dh_0 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	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
KLX07B	22.52	27.52	5	1.72E–07	7.54	2.32E–06	1.61	1.61	3.6E–07	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	27.53	32.53	5	4.19E–07	7.52	1.81E–05	1.61	1.61	3.0E–06	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	32.53	37.53	5	–	7.54	–	1.68	1.68	–	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	37.54	42.54	5	5.25E–07	7.59	7.31E–06	1.68	1.68	1.1E–06	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	42.54	47.54	5	–	7.60	–	1.66	1.66	–	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	47.55	52.55	5	–	7.59	1.97E–08	1.67	1.67	3.3E–09	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	52.55	57.55	5	2.74E–06	7.59	4.94E–05	1.73	1.73	7.9E–06	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	57.56	62.56	5	2.64E–06	7.64	7.89E–05	1.70	1.70	1.3E–05	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	62.57	67.57	5	–	7.64	4.47E–08	1.68	1.68	7.4E–09	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	67.57	72.57	5	–	7.65	4.42E–07	1.73	1.73	7.4E–08	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	72.58	77.58	5	2.03E–08	7.62	4.72E–07	1.73	1.73	7.6E–08	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	77.58	82.58	5	2.04E–06	7.65	3.36E–05	1.71	1.71	5.3E–06	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	82.59	87.59	5	1.06E–07	7.69	3.11E–06	1.72	1.72	5.0E–07	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	87.60	92.60	5	8.61E–07	7.70	2.69E–05	1.76	1.76	4.3E–06	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	92.61	97.61	5	-5.89E–07	7.69	1.31E–05	1.75	1.75	2.3E–06	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	97.61	102.61	5	-3.19E–08	7.71	2.27E–06	1.73	1.73	3.8E–07	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	102.62	107.62	5	-1.78E–06	7.75	1.13E–04	1.74	1.74	1.9E–05	30	1.4E–09	1.4E–09	1.4E–05	***
KLX07B	107.63	112.63	5	-5.00E–06	7.77	1.50E–05	6.52	6.52	1.6E–05	30	6.6E–09	6.6E–09	6.6E–05	**
KLX07B	112.63	117.63	5	-2.69E–07	7.77	7.50E–06	1.80	1.80	1.3E–06	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	117.64	122.64	5	–	7.77	1.74E–07	1.78	1.78	2.9E–08	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	122.65	127.65	5	–	7.77	3.42E–08	1.80	1.80	5.7E–09	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	127.65	132.65	5	-6.44E–08	7.81	4.86E–06	1.81	1.81	8.1E–07	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	132.66	137.66	5	–	7.84	–	1.80	1.80	–	30	1.4E–09	1.4E–09	1.4E–05	

KLX07B	137.67	142.67	5	–	7.84	1.26E–07	1.82	1.82	2.1E–08	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	142.67	147.67	5	-9.17E–09	7.89	5.06E–07	1.90	1.90	8.5E–08	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	147.68	152.68	5	–	7.92	–	1.87	1.87	–	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	152.68	157.68	5	–	7.91	–	1.87	1.87	–	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	157.68	162.68	5	-2.83E–07	7.91	4.08E–05	1.92	1.92	6.8E–06	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	162.69	167.69	5	–	7.96	–	1.93	1.93	–	30	1.4E–09	1.4E–09	1.4E–05	
KLX07B	167.69	172.69	5	-1.60E–06	8.00	1.43E–05	6.66	6.66	1.2E–05	30	6.2E–09	6.2E–09	6.2E–05	**
KLX07B	172.70	177.70	5	-1.64E–08	7.98	2.39E–06	2.00	2.00	4.0E–07	100	1.4E–09	4.6E–09	1.4E–05	
KLX07B	177.72	182.72	5	-1.33E–08	7.95	1.22E–06	2.05	2.05	2.1E–07	100	1.4E–09	4.7E–09	1.4E–05	
KLX07B	182.74	187.74	5	–	8.08	1.17E–07	2.00	2.00	1.9E–08	100	1.4E–09	4.5E–09	1.4E–05	
KLX07B	187.75	192.75	5	–	8.08	3.97E–08	1.97	1.97	6.4E–09	100	1.4E–09	4.5E–09	1.4E–05	

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

*** Values from the measurement with 1 m section length (original flow over measurement limit).

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 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	Comments
KLX07B	19.8	1.0	0.1	–	7.54	3.06E–07	1.63	5.1E–08	–	*
KLX07B	21.0	1.0	0.1	–	7.55	1.03E–06	1.63	1.7E–07	–	
KLX07B	24.0	1.0	0.1	–	7.54	6.67E–07	1.62	1.1E–07	–	
KLX07B	26.1	1.0	0.1	–	7.54	2.92E–08	1.63	4.9E–09	–	
KLX07B	27.4	1.0	0.1	–	7.53	1.35E–06	1.65	2.3E–07	–	
KLX07B	28.7	1.0	0.1	–	7.53	3.64E–06	1.65	6.1E–07	–	*
KLX07B	28.9	1.0	0.1	–	7.52	1.10E–05	1.65	1.9E–06	–	
KLX07B	29.7	1.0	0.1	–	7.52	8.92E–07	1.66	1.5E–07	–	
KLX07B	31.2	1.0	0.1	–	7.52	1.06E–08	1.66	1.8E–09	–	*
KLX07B	40.1	1.0	0.1	–	7.59	1.76E–07	1.67	2.9E–08	–	
KLX07B	40.4	1.0	0.1	–	7.59	4.00E–06	1.66	6.7E–07	–	
KLX07B	41.4	1.0	0.1	–	7.60	2.65E–06	1.66	4.4E–07	–	
KLX07B	41.7	1.0	0.1	–	7.60	1.24E–06	1.66	2.1E–07	–	
KLX07B	51.4	1.0	0.1	–	7.59	1.83E–08	1.65	3.1E–09	–	
KLX07B	54.6	1.0	0.1	–	7.59	3.81E–05	1.67	6.4E–06	–	
KLX07B	55.1	1.0	0.1	–	7.59	1.02E–05	1.68	1.7E–06	–	
KLX07B	55.8	1.0	0.1	–	7.60	1.78E–08	1.67	3.0E–09	–	*
KLX07B	58.2	1.0	0.1	–	7.62	1.51E–07	1.69	2.5E–08	–	
KLX07B	60.7	1.0	0.1	–	7.64	6.56E–05	1.70	1.1E–05	–	
KLX07B	62.2	1.0	0.1	–	7.65	1.38E–06	1.71	2.3E–07	–	*
KLX07B	62.4	1.0	0.1	–	7.64	1.84E–06	1.71	3.1E–07	–	
KLX07B	64.7	1.0	0.1	–	7.64	3.11E–08	1.71	5.2E–09	–	*
KLX07B	66.0	1.0	0.1	–	7.65	1.83E–08	1.71	3.1E–09	–	*
KLX07B	68.5	1.0	0.1	–	7.66	3.92E–08	1.71	6.5E–09	–	
KLX07B	70.3	1.0	0.1	–	7.65	1.50E–07	1.69	2.5E–08	–	
KLX07B	72.3	1.0	0.1	–	7.64	5.56E–07	1.68	9.2E–08	–	
KLX07B	74.1	1.0	0.1	–	7.62	5.67E–07	1.69	9.5E–08	–	*
KLX07B	75.2	1.0	0.1	–	7.62	2.14E–07	1.68	3.6E–08	–	*
KLX07B	80.6	1.0	0.1	–	7.66	3.25E–05	1.70	5.4E–06	–	
KLX07B	81.5	1.0	0.1	–	7.68	3.86E–08	1.71	6.4E–09	–	
KLX07B	85.8	1.0	0.1	–	7.71	1.12E–07	1.72	1.8E–08	–	
KLX07B	86.5	1.0	0.1	–	7.71	2.73E–06	1.73	4.5E–07	–	
KLX07B	87.7	1.0	0.1	–	7.71	1.11E–05	1.73	1.8E–06	–	
KLX07B	88.2	1.0	0.1	–	7.71	3.00E–06	1.73	5.0E–07	–	
KLX07B	88.9	1.0	0.1	–	7.71	1.45E–06	1.74	2.4E–07	–	*
KLX07B	89.8	1.0	0.1	–	7.70	2.83E–06	1.73	4.7E–07	–	
KLX07B	90.2	1.0	0.1	–	7.71	4.47E–06	1.74	7.4E–07	–	
KLX07B	91.1	1.0	0.1	–	7.70	4.17E–07	1.73	6.9E–08	–	
KLX07B	93.2	1.0	0.1	–	7.70	7.94E–08	1.72	1.3E–08	–	
KLX07B	96.8	1.0	0.1	–	7.69	9.28E–06	1.71	1.5E–06	–	

Borehole ID	Length to flow anom. L (m)	L_w (m)	dL (m)	Q_0 (m^3/s)	dh_0 (masl)	Q_1 (m^3/s)	dh_1 (masl)	TD (m^2/s)	hi (masl)	Comments
KLX07B	97.5	1.0	0.1	–	7.70	3.11E–06	1.70	5.1E–07	–	
KLX07B	98.2	1.0	0.1	–	7.69	6.36E–07	1.71	1.1E–07	–	
KLX07B	101.3	1.0	0.1	–	7.72	1.84E–07	1.70	3.0E–08	–	
KLX07B	102.5	1.0	0.1	–	7.73	5.50E–07	1.74	9.1E–08	–	*
KLX07B	102.8	1.0	0.1	–	7.73	4.42E–06	1.74	7.3E–07	–	
KLX07B	103.9	1.0	0.1	–	7.74	4.19E–06	1.74	6.9E–07	–	
KLX07B	104.8	1.0	0.1	–	7.76	9.08E–06	1.75	1.5E–06	–	
KLX07B	105.5	1.0	0.1	–	7.76	2.31E–05	1.75	3.8E–06	–	
KLX07B	106.6	1.0	0.1	–	7.76	4.78E–05	1.75	7.9E–06	–	
KLX07B	107.0	1.0	0.1	–	7.76	8.67E–06	1.75	1.4E–06	–	*
KLX07B	108.0	1.0	0.1	–	7.77	2.81E–07	1.75	4.6E–08	–	
KLX07B	109.6	1.0	0.1	–	7.78	1.46E–05	6.50	1.1E–05	–	**
KLX07B	112.3	1.0	0.1	–	7.78	1.37E–06	1.77	2.3E–07	–	
KLX07B	113.3	1.0	0.1	–	7.77	4.31E–06	1.78	7.1E–07	–	
KLX07B	114.5	1.0	0.1	–	7.77	1.46E–06	1.78	2.4E–07	–	
KLX07B	116.3	1.0	0.1	–	7.77	1.61E–08	1.79	2.7E–09	–	*
KLX07B	116.6	1.0	0.1	–	7.76	1.09E–06	1.78	1.8E–07	–	
KLX07B	117.7	1.0	0.1	–	7.77	5.17E–08	1.79	8.5E–09	–	
KLX07B	119.6	1.0	0.1	–	7.77	1.69E–08	1.79	2.8E–09	–	*
KLX07B	120.7	1.0	0.1	–	7.76	1.69E–08	1.80	2.8E–09	–	*
KLX07B	125.0	1.0	0.1	–	7.77	3.89E–08	1.80	6.4E–09	–	
KLX07B	129.6	1.0	0.1	–	7.81	2.34E–07	1.78	3.8E–08	–	
KLX07B	130.9	1.0	0.1	–	7.81	6.42E–07	1.79	1.1E–07	–	*
KLX07B	131.5	1.0	0.1	–	7.82	3.97E–06	1.79	6.5E–07	–	
KLX07B	132.1	1.0	0.1	–	7.84	7.06E–08	1.78	1.2E–08	–	
KLX07B	141.4	1.0	0.1	–	7.84	6.89E–08	1.79	1.1E–08	–	
KLX07B	142.9	1.0	0.1	–	7.87	1.13E–07	1.83	1.9E–08	–	
KLX07B	144.0	1.0	0.1	–	7.88	1.46E–07	1.83	2.4E–08	–	
KLX07B	144.4	1.0	0.1	–	7.88	1.31E–07	1.83	2.1E–08	–	
KLX07B	159.2	1.0	0.1	–	7.91	1.01E–05	1.85	1.7E–06	–	
KLX07B	159.7	1.0	0.1	–	7.91	8.33E–06	1.86	1.4E–06	–	
KLX07B	160.6	1.0	0.1	–	7.93	1.91E–06	1.87	3.1E–07	–	
KLX07B	161.8	1.0	0.1	–	7.93	3.17E–08	1.88	5.2E–09	–	
KLX07B	168.0	1.0	0.1	–	7.99	3.25E–07	1.94	5.3E–08	–	
KLX07B	170.0	1.0	0.1	–	8.00	1.43E–05	6.66	1.1E–05	–	**
KLX07B	172.2	1.0	0.1	–	8.00	6.89E–07	1.95	1.1E–07	–	
KLX07B	175.2	1.0	0.1	–	7.98	2.31E–06	1.95	3.8E–07	–	
KLX07B	179.0	1.0	0.1	–	7.95	1.22E–06	1.97	2.0E–07	–	
KLX07B	186.8	1.0	0.1	–	8.10	1.17E–07	2.03	1.9E–08	–	*
KLX07B	187.9	1.0	0.1	–	8.09	7.22E–08	2.05	1.2E–08	–	*

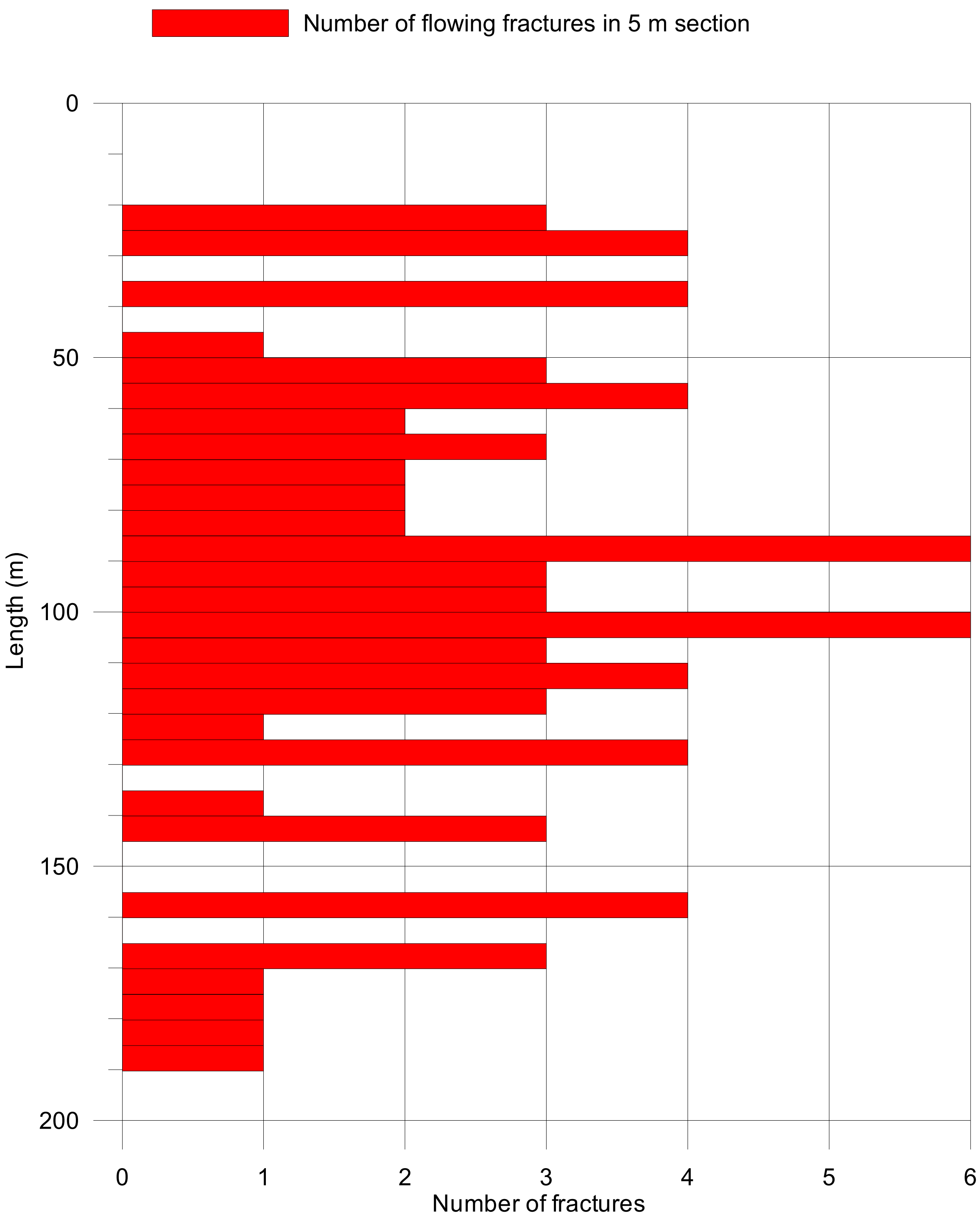
* Uncertain = The flow rate is less than 30 mL/h or the flow anomalies are overlapping or they are unclear because of noise.

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

Calculation of conductive fracture frequency

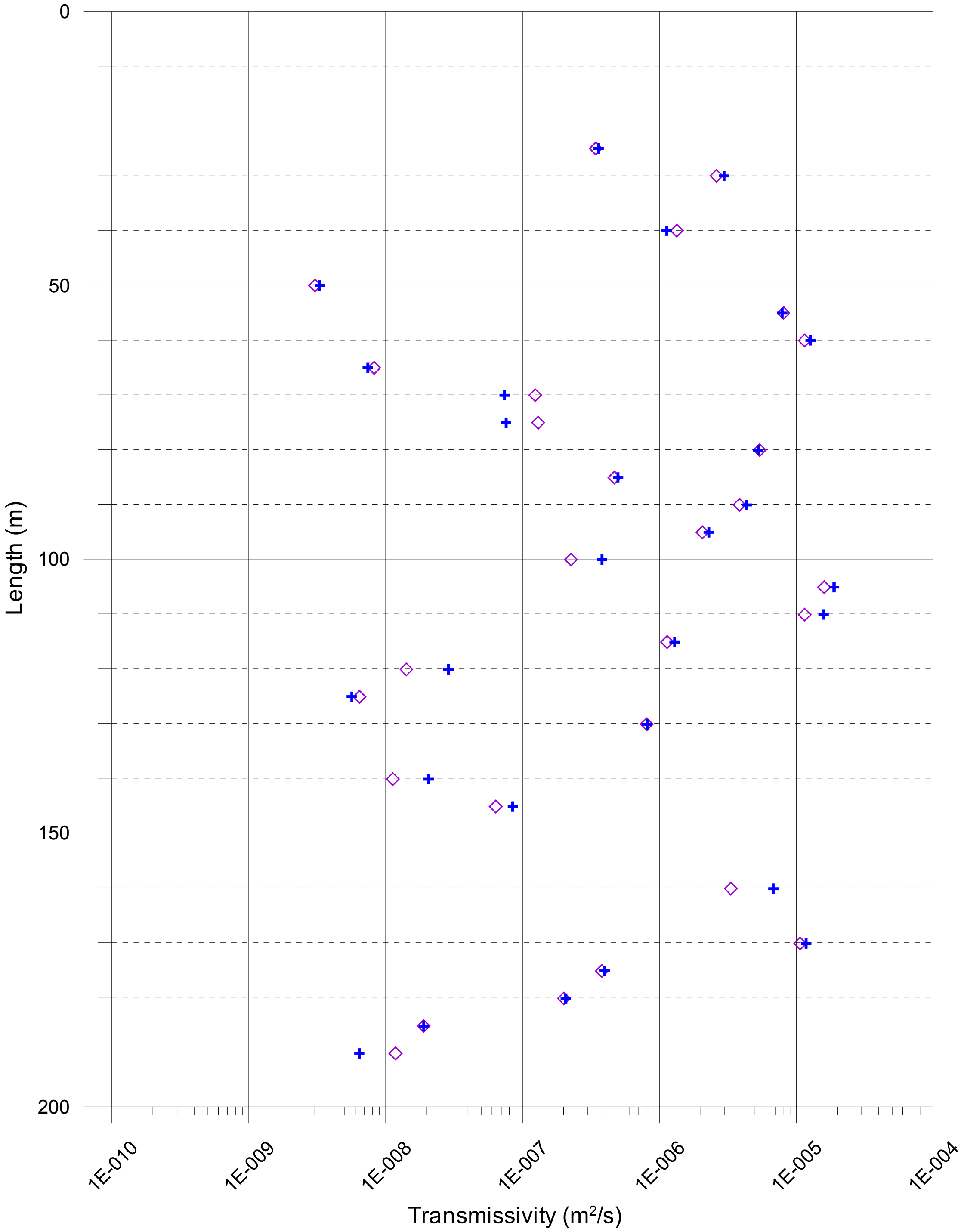
Borehole ID	Secup (m)	Seclow (m)	Number of fractures, total	Number of fractures 10–100 (ml/h)	Number of fractures 100–1,000 (ml/h)	Number of fractures 1,000–10,000 (ml/h)	Number of fractures 10,000–100,000 (ml/h)	Number of fractures 100,000–1,000,000 (ml/h)
KLX07B	22.50	27.52	3	0	1	2	0	0
KLX07B	27.51	32.53	4	1	0	1	2	0
KLX07B	32.51	37.53	0	0	0	0	0	0
KLX07B	37.52	42.54	4	0	1	2	1	0
KLX07B	42.52	47.54	0	0	0	0	0	0
KLX07B	47.53	52.55	1	1	0	0	0	0
KLX07B	52.53	57.55	3	1	0	0	1	1
KLX07B	57.54	62.56	4	0	1	2	0	1
KLX07B	62.54	67.57	2	1	1	0	0	0
KLX07B	67.55	72.57	3	0	2	1	0	0
KLX07B	72.56	77.58	2	0	1	1	0	0
KLX07B	77.56	82.58	2	0	1	0	0	1
KLX07B	82.57	87.59	2	0	1	1	0	0
KLX07B	87.58	92.60	6	0	0	2	4	0
KLX07B	92.59	97.61	3	0	1	0	2	0
KLX07B	97.59	102.61	3	0	1	2	0	0
KLX07B	102.60	107.62	6	0	0	0	5	1
KLX07B	107.61	112.63	3	0	0	2	1	0
KLX07B	112.61	117.63	4	1	0	2	1	0
KLX07B	117.62	122.64	3	2	1	0	0	0
KLX07B	122.63	127.65	1	0	1	0	0	0
KLX07B	127.64	132.65	4	0	2	1	1	0
KLX07B	132.64	137.66	0	0	0	0	0	0
KLX07B	137.65	142.67	1	0	1	0	0	0
KLX07B	142.65	147.67	3	0	3	0	0	0
KLX07B	147.66	152.68	0	0	0	0	0	0
KLX07B	152.66	157.68	0	0	0	0	0	0
KLX07B	157.66	162.68	4	0	1	1	2	0
KLX07B	162.67	167.69	0	0	0	0	0	0
KLX07B	167.67	172.69	3	0	0	2	1	0
KLX07B	172.67	177.70	1	0	0	1	0	0
KLX07B	177.71	182.72	1	0	0	1	0	0
KLX07B	182.74	187.74	1	0	1	0	0	0
KLX07B	187.76	192.75	1	0	1	0	0	0

Laxemar, borehole KLX07B
Calculation of conductive fracture frequency



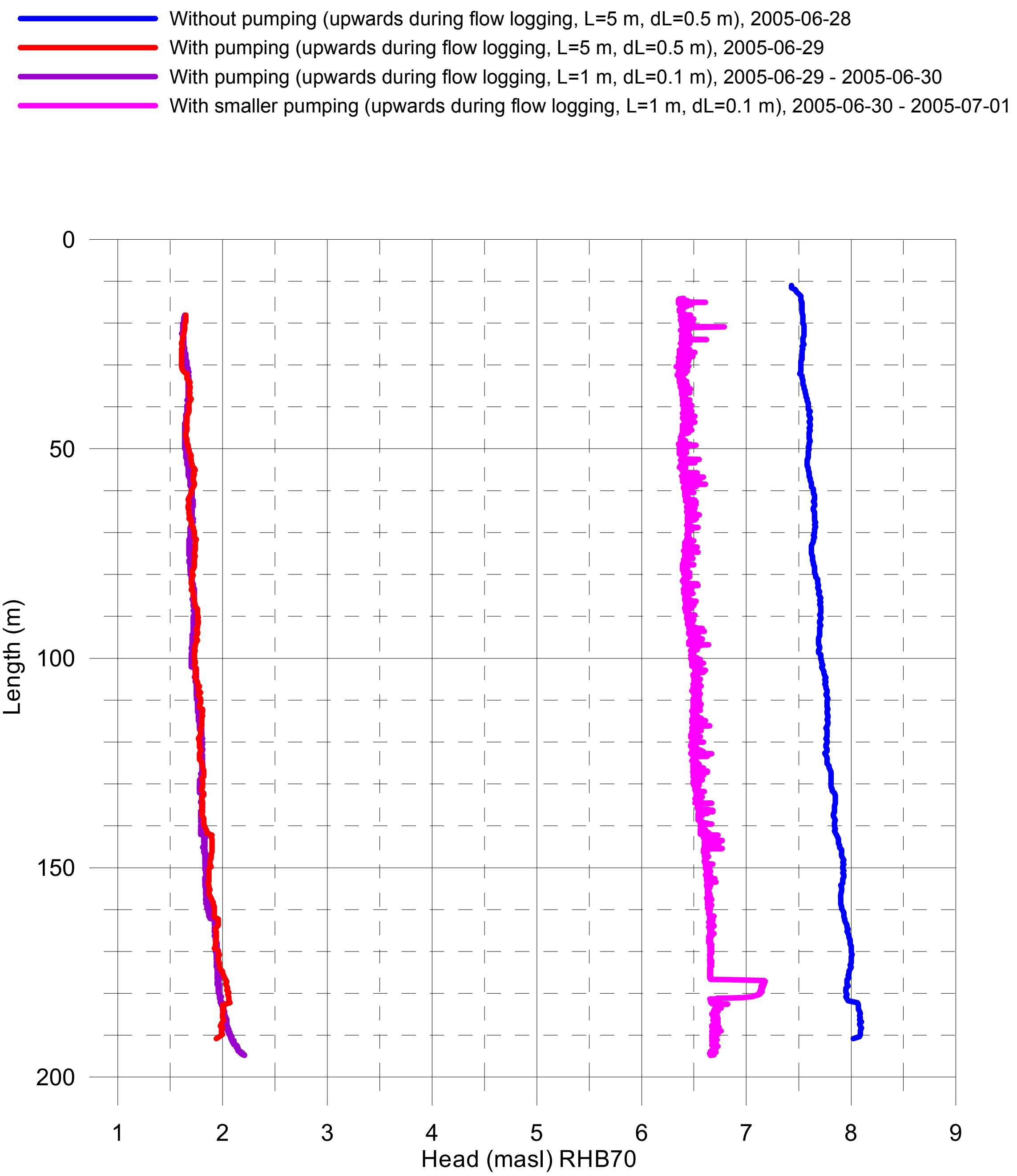
Laxemar, borehole KLX07B
Comparison between section transmissivity and fracture transmissivity

◇ Transmissivity (sum of fracture specific results T_f)
+ Transmissivity (results of 5m measurements T_s)

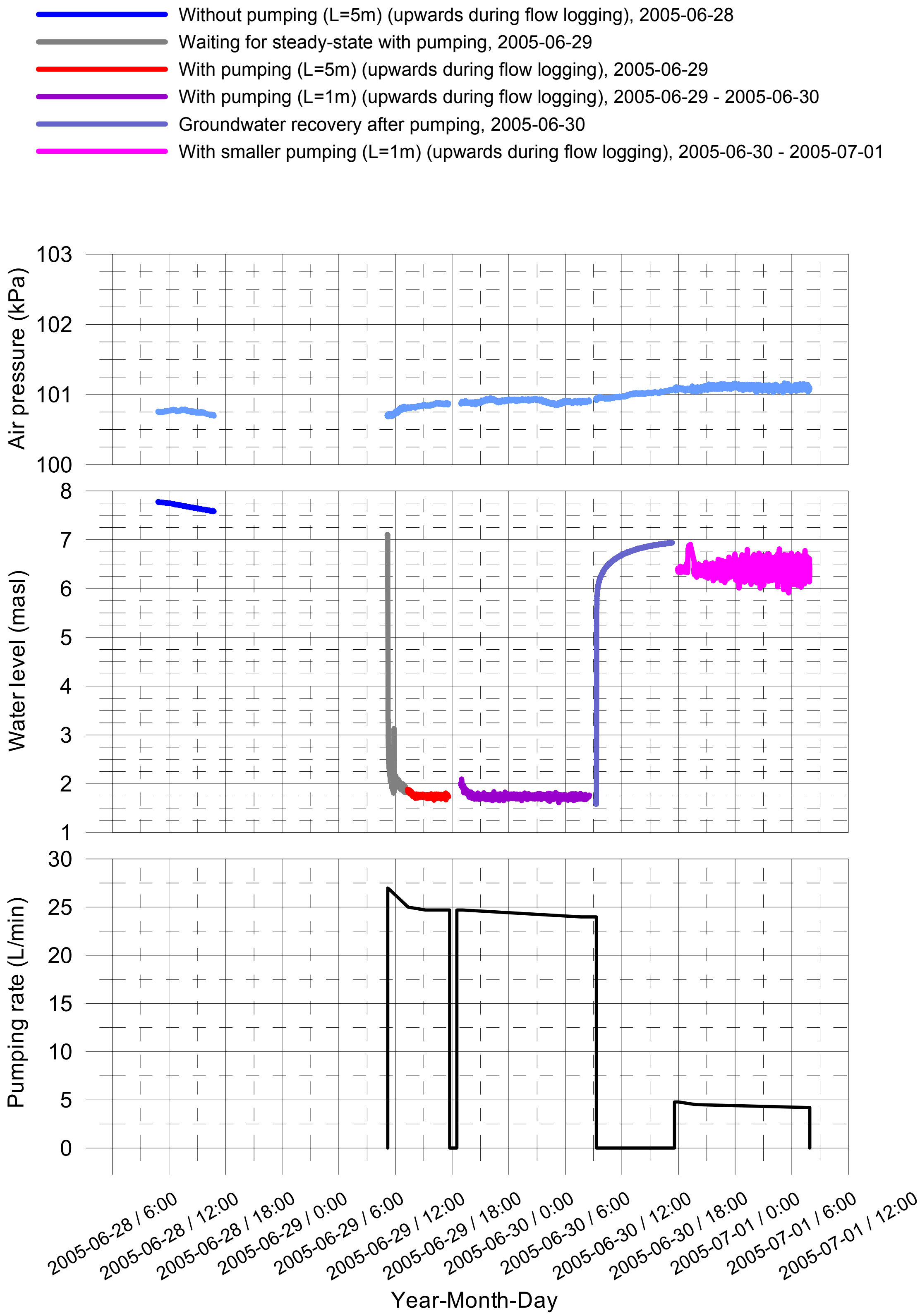


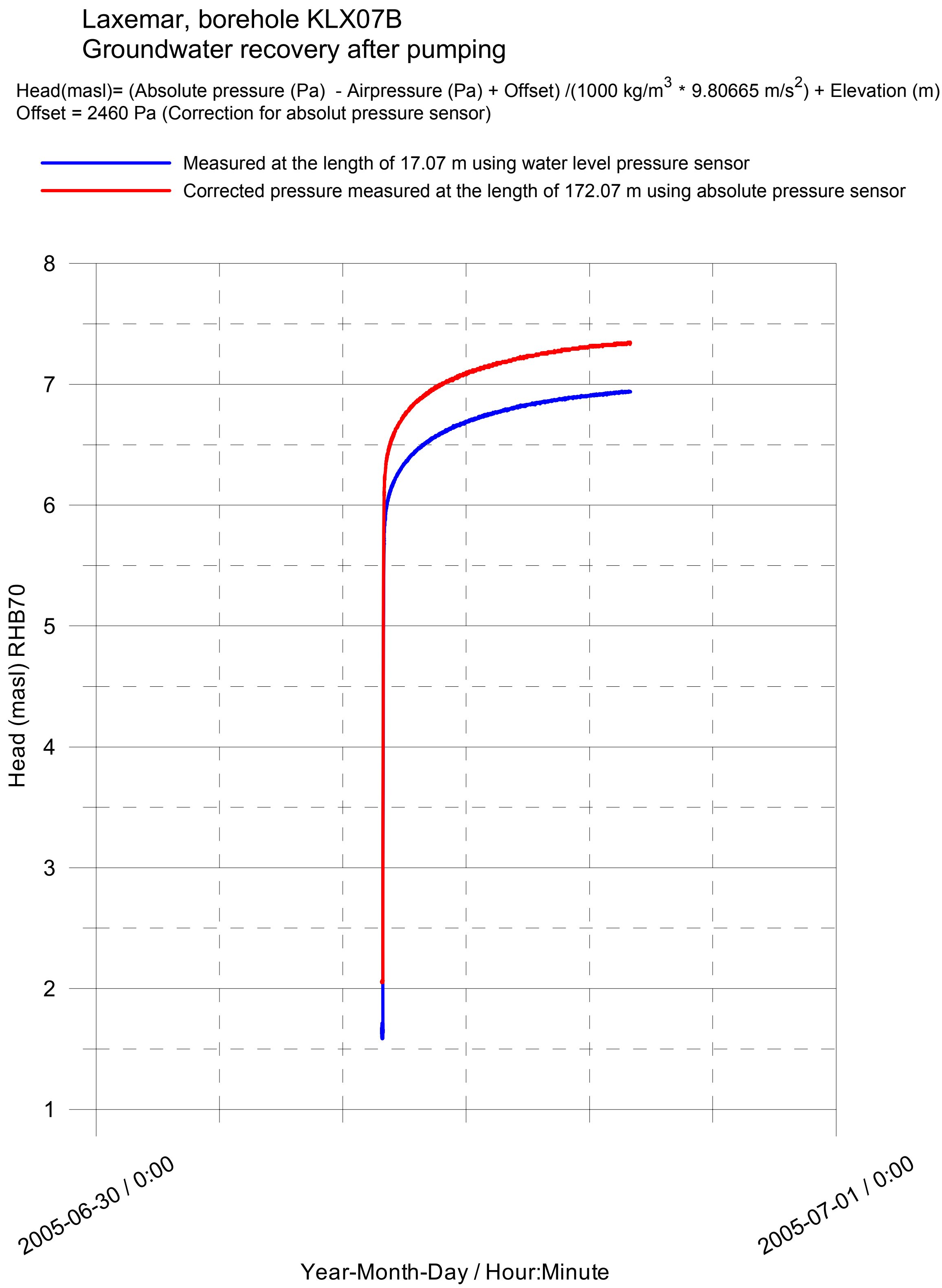
Laxemar, borehole KLX07B
Head in the borehole during flow logging

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)



Laxemar, borehole KLX07B
Air pressure, water level in the borehole and pumping rate during flow logging





Laxemar, borehole KLX07B
Groundwater recovery after pumping
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m3 * 9.80665 m/s2) + Elevation (m)
Offset = 2460 Pa (Correction for absolut pressure sensor)
Measured at the length of 17.07 m using water level pressure sensor
Corrected pressure measured at the length of 172.07 m using absolute pressure sensor
8
7
6
5
4
3
2
1
Head (masl) RHB70
2005-06-30 / 0:00
2005-07-01 / 0:00
Year-Month-Day / Hour:Minute