P-07-65

Oskarshamn site investigation

Interference difference flow logging of boreholes KLX11B-F

Subarea Laxemar

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PRG-Tec Oy

October 2007

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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 interference test as well as results of measurements carried out in five boreholes KLX11B-F at Oskarshamn, Sweden, in September and October 2006, using Posiva flow log. The primary aim of the measurements was to determine the position and flow rate of flow yielding fractures and the hydraulic connectivity between them in boreholes KLX11B-F.

The single hole difference flow logging results are reported in P-07-64. During these tests the flow rates into or out of 1 m and 5 m long test sections were measured in boreholes KLX11B-F under natural (un-pumped) as well as pumped conditions. To cover the upper part of the boreholes that was subjected to drawdown, the uppermost parts were flow logged with injection, i.e. when water was pumped into the borehole.

The hydraulic cross hole interference was observed by pumping one borehole and measuring the flow responses in all the other four boreholes. Pumped boreholes were KLX11B , KLX11D and KLX11E. These results are presented in the present report.

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

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

Electric conductivity (EC) and temperature of borehole water was also measured. The EC-measurements were conducted simultaneously with all flow logging measurements.

Sammanfattning

Differensflödesloggning är en snabb metod för bestämning av transmissivitet och hydraulisk tryckhöjd i borrhålssektioner och sprickor/sprickzoner i kärnborrhål. Denna rapport presenterar huvudprinciperna för metoden och resultat av mätningar utförda i fem borrhål KLX11B-F i Oskarshamn, Sverige, i september och oktober 2006 med Posiva flödesloggningsmetod. Det primära syftet med mätningarna var att bestämma läget och flödet för vattenförande sprickor i borrhålen och bestämma hydrauliska anslutningar mellan borrhål KLX11B-F.

Resultat ifrån enhåls differensflödesloggningen är rapporterat i P-07-64. Under dessa tester mättes flödet till eller från 1 m och 5 m långa testsektioner i borrhål KLX11B-F under såväl naturliga (icke-pumpade) som pumpade förhållanden. Övre delen av borrhålen loggades med injektion.

Den hydrauliska interferensen var observerad med pumpning, när ett borrhål pumpades och andra fyra borrhål var under flödesmätning. Pumpningen utfördes i borrhålen KLX11B, KLX11D och KLX11E. Resultat från dessa mätningar redovisas i föreliggande rapport.

Längdkalibrering gjordes baserad på längdmärkena som frästs in i borrhålsväggen vid noggrant bestämda positioner längs borrhålet. 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 samtidigt med flödesmätningarna.

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1 Introduction

This document reports the results gained by the difference flow logging, which is one of the activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with activity plan AP PS 400-06-087. The controlling documents for performing this activity are listed in Table 1-1. The list of controlling documents excludes the assignment specific quality plans. Both activity plan and method descriptions are SKB's internal controlling documents.

Two reports are produced concerning activity plan AP PS 400-06-087. One of the reports presents results of single hole tests, the other one of interference test. This document presents the results gained from the interference test in boreholes KLX11B-F.

The difference flow logging in the core drilled boreholes KLX11B-F at Oskarshamn was conducted between September 4 and October 24, 2006. The detailed dimensions of the boreholes are presented in Table 1-2. The borehole diameter is 76 mm. The location of boreholes at the drill site within the subarea of Laxemar at Oskarshamn is shown in Figure 1-1.

The field work and the subsequent data processing were conducted by PRG-Tec Oy as Posiva Oy's subcontractor. 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. SKB's internal controlling documents for the activities concerning this report.

Activity plan	Number	Version
Interference difference flow logging in boreholes KLX11B-F	AP PS 400-06-087	1.0
Method descriptions	**Number**	**Version**
Method description for difference flow logging	SKB MD 322.010e	1.0
Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning	SKB MD 600.004	1.0
Instruction for length calibration in investigation of core boreholes	SKB MD 620.010e	2.0
Instruction for analysis of injection and single-hole puming tests	SKB MD 320.004e	1.0

Table 1-2. Borehole construction, KLX11B-F.

Borehole ID	Length (m)	Inclination (degrees)	Z coord. of the top of the casing (m.a.s.l.)
KLX11B	100.200	–89.869	27.274
KLX11C	120.150	–60.523	27.191
KLX11D	120.350	–58.997	25.574
KLX11E	121.300	–60.647	22.649
KLX11F	120.050	–60.982	24.465

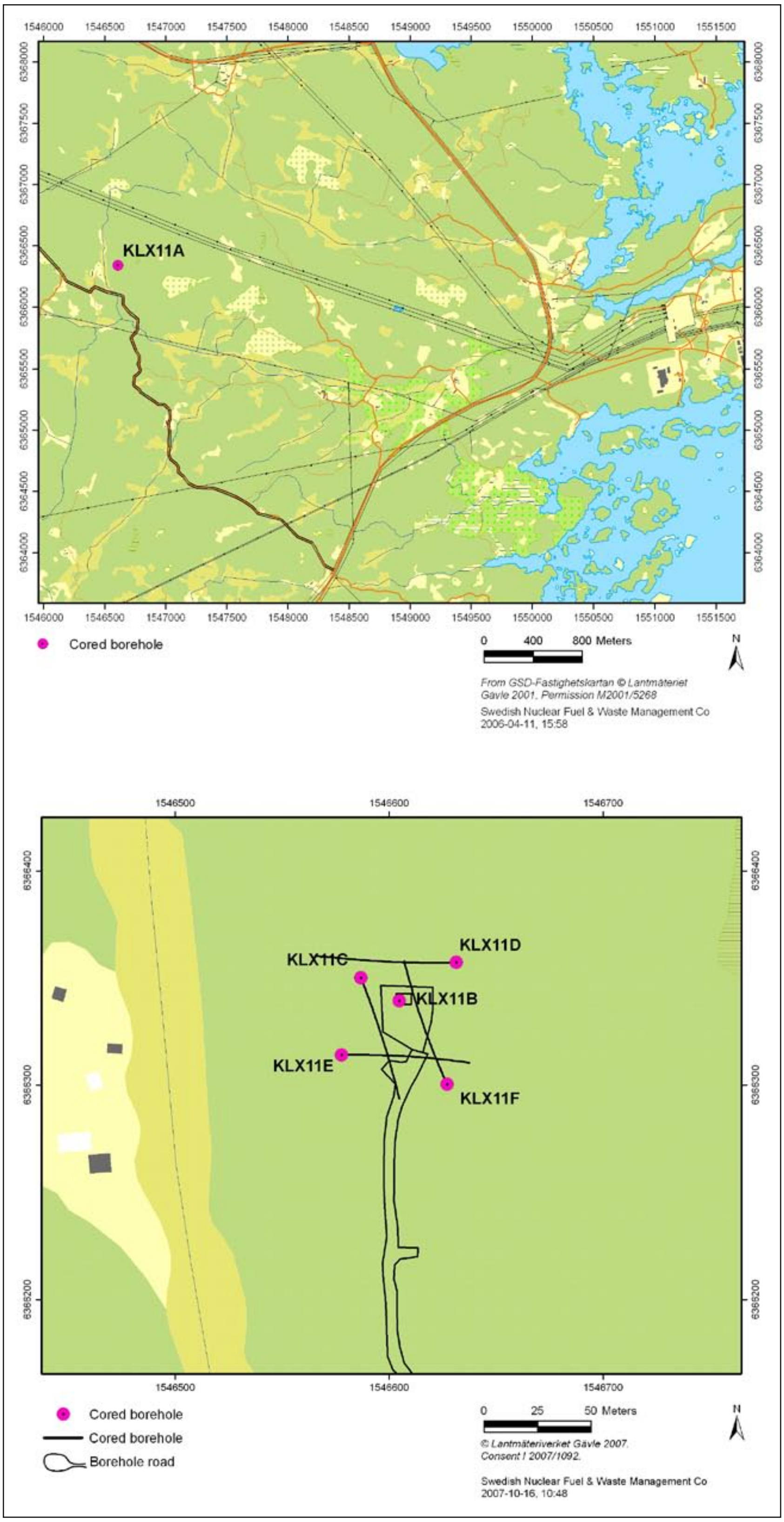

Figure 1-1. *Site map showing the locations of boreholes KLX11B-F situated in Laxemar. KLX11A is the 1000 m long borehole situated adjacent to KLX11B.*

2 Objective and scope

The objective with the present interference flow logging is to investigate the extent of hydraulically interconnected fractures or structures between the boreholes. For this purpose interference flow logging tests were conducted between five boreholes, where boreholes KLX11B, KLX11D and KLX11E were pumped in turn and the flow responses were measured in the other four boreholes.

The report present flow responses in the different boreholes. No interpretation of the hydraulic interconnection or interpretation of the interference test is made as this is outside of the scope of works.

The testing programme was conducted according to activity plan AP PS 400-06-087. This activity plan includes both single hole tests and interference tests. The results of these two tests are reported separately. This document presents the results gained from the interference test in boreholes KLX11B-F. Single hole results are presented in report P-07-64.

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.

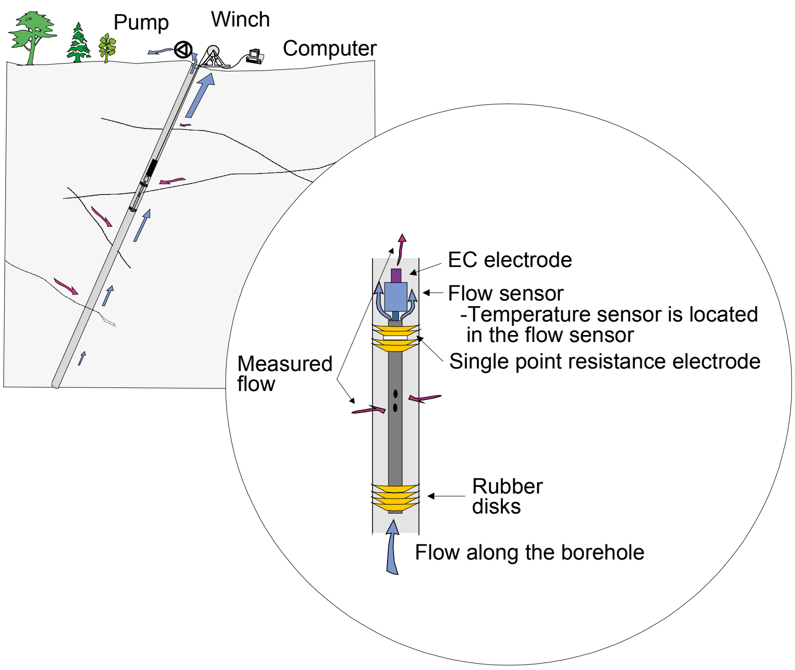

Figure 3-1. *Schematic of the downhole equipment used in the Difference flowmeter.*

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, except fracture-specific EC measurement, were performed in KLX11B-F. The hydraulic cross hole interference was observed by pumping one borehole and measuring the flow responses in all the other four boreholes. Pumped boreholes were KLX11B, KLX11D and KLX11E.

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.

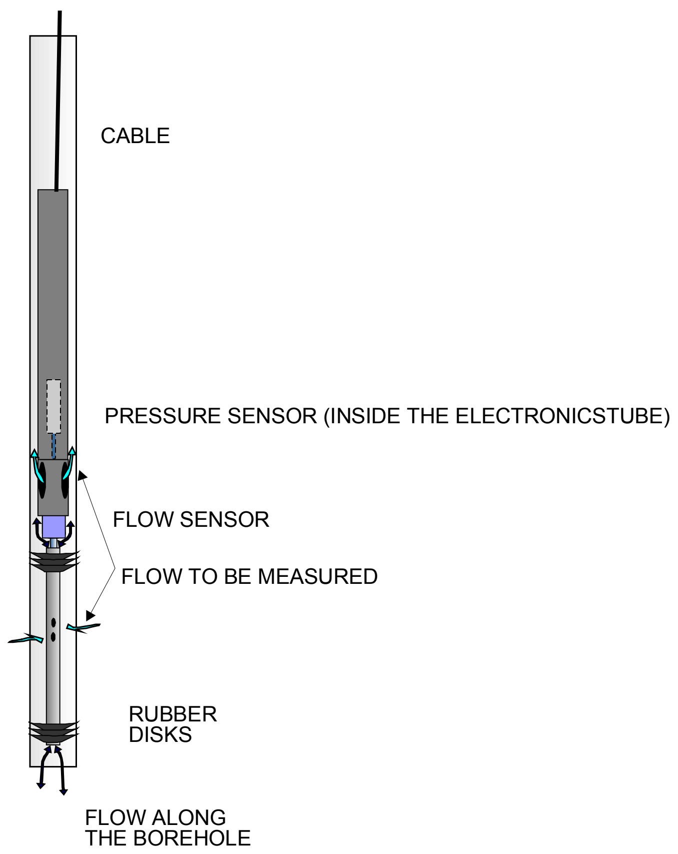

Figure 3-2. *The absolute pressure sensor is located inside the electronics tube and connected through a tube to the borehole water.*

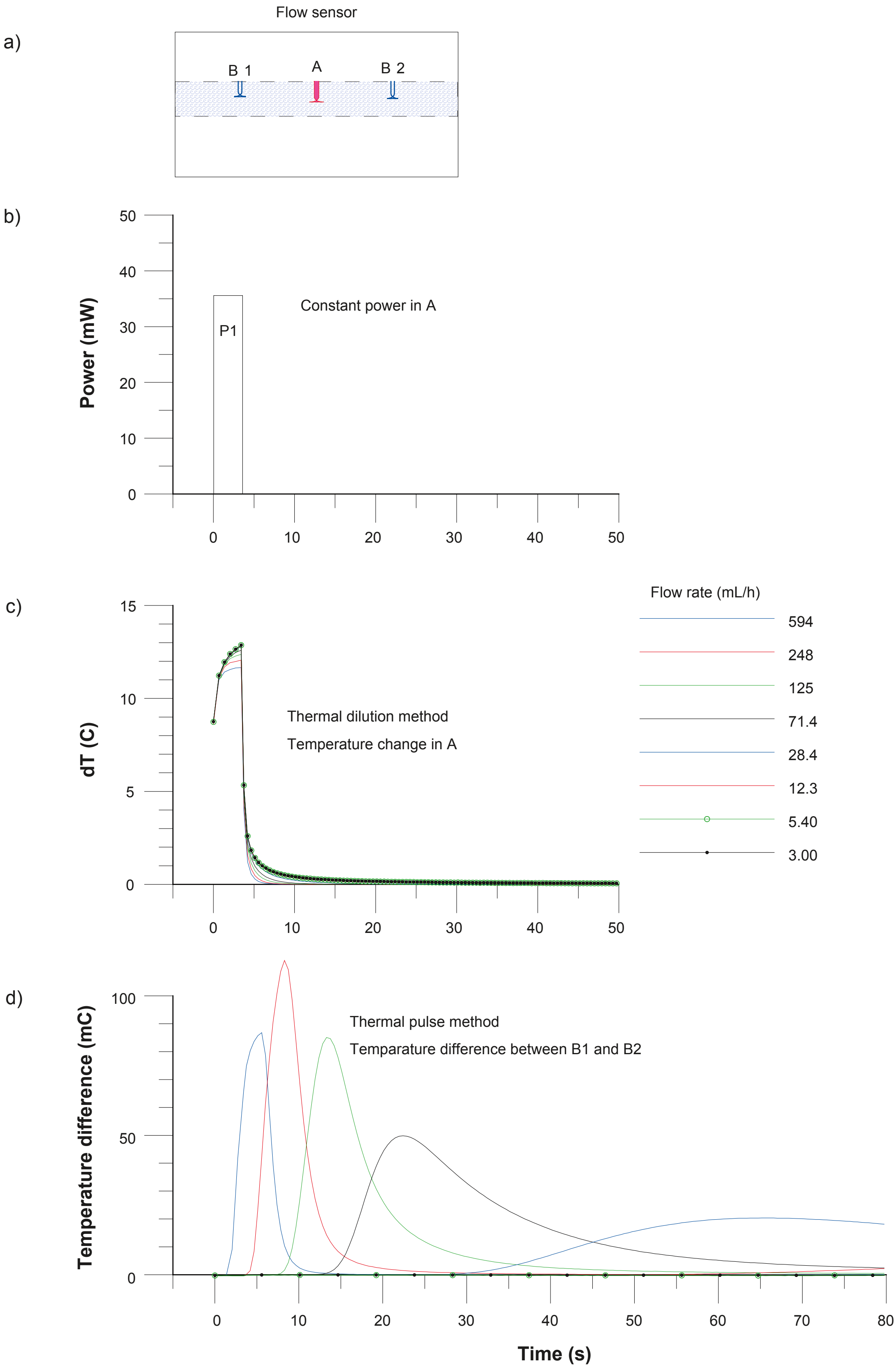

Figure 3-3. Flow measurement, flow rate <600 mL/h.

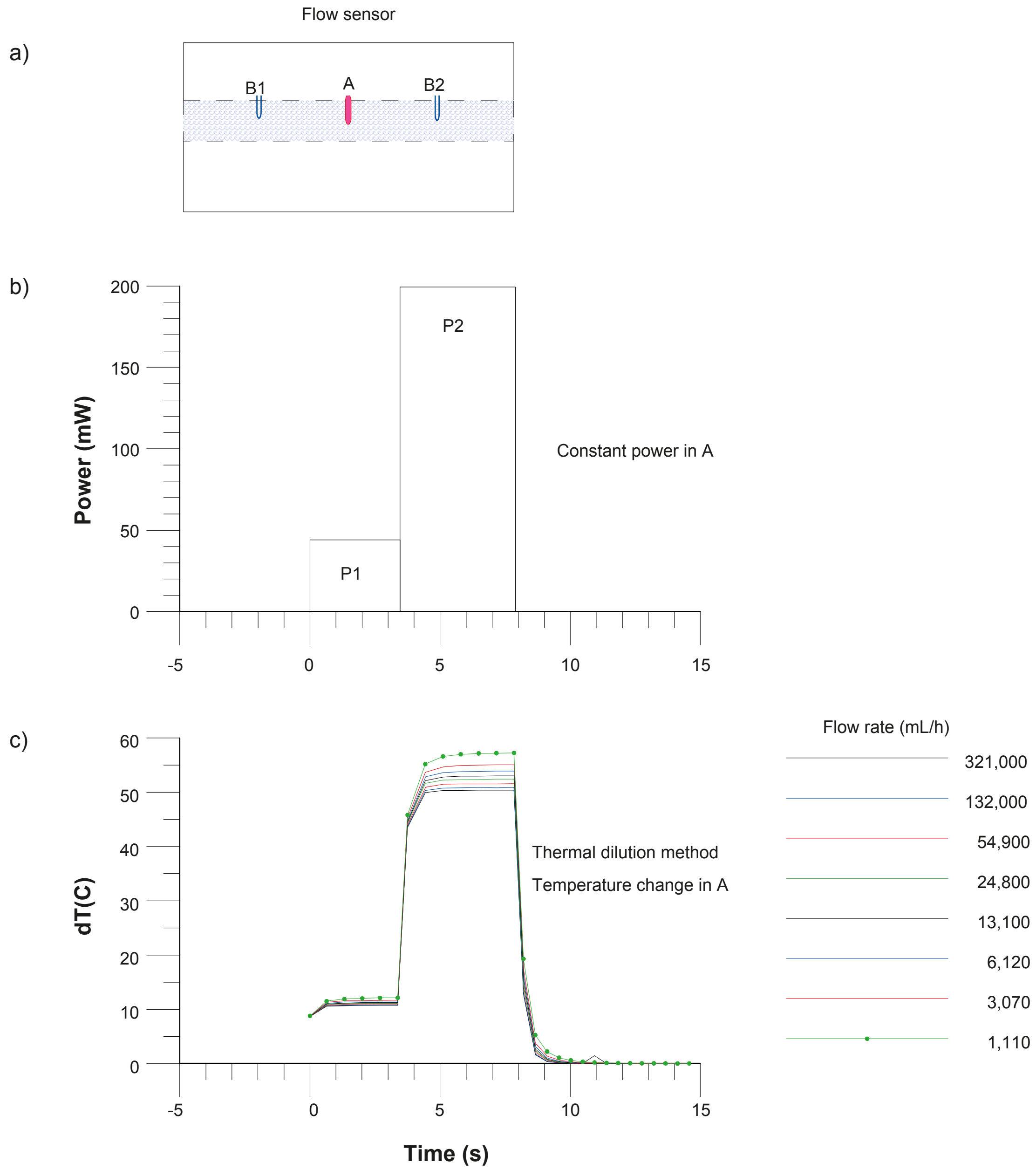

Figure 3-4. *Flow measurement, flow rate > 600 mL/h.*

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 3-4b, 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 (Figure 3-3c) and thermal pulse response (Figure 3-3d). When applying the thermal pulse method, also thermal dilution is always measured. The same heat pulse is used for both methods.

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

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

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. When flow above the measurement limit is encountered a remeasurement is performed at the specific anomaly with a reduced pumping, typically about half the original drawdown.

3.2 Interpretation

3.2.1 Single hole tests

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

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

where

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

Q is the flow rate into the borehole,

T is the transmissivity of the test section,

a is a constant depending on the assumed flow geometry.

For cylindrical flow, the constant a is:

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

where

r_0 is the radius of the well and

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

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

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

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

where

h_0 and h_1 are the hydraulic heads in the borehole at the test level,

Q_{s0} and Q_{s1} are the measured flow rates in the test section,

T_s is the transmissivity of the test section and

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

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

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

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

$h_s = (h_0 – b \cdot h_1)/(1–b)$ 3-5

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

where

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

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

$h_f = (h_0–b\ h_1)/(1–b)$ 3-7

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

where

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

h_f and T_f are the hydraulic head (far away from borehole) and the transmissivity of a fracture, respectively. Since Q_{f0} is usually not measured, it is estimated from the Q_{s0} for some fractures, i.e. for those flowing fractures that are far away from the other flowing fractures or for the fractures that have much higher flow rate than surrounding fractures.

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/.

3.2.2 Interference tests

A reference flow (Q_x) is calculated for helping evaluation of degree of interconnection. It is a qualitative tool. Reference flow can be understood as a limit flow value when evaluating the flow results from interference test. If the measured flow rate and calculated reference flow are equal, there is no interconnection between the boreholes at all. In such a case flow rate in a fracture doesn't depend on pumping in other boreholes but only on water level in the borehole where the flow is measured. If the borehole is measured with two drawdowns as described above, any other flow rate into the borehole or out from it for any hydraulic head can be calculated with the assumptions above and with the assumption of laminar flow conditions.

Calculated reference flow in a measured borehole x can be written as follows:

$Q_x = T_f \cdot a \cdot (h_f–h_x)$, 3-9

where

Q_x is the calculated reference flow in the measured borehole,

T_f is transmissivity of measured fracture,

a is a constant depending on the flow geometry,

h_x is the hydraulic head in the measured borehole at the test level. It is chosen to be the same as the hydraulic head in the measured borehole during the interference test when another borehole is pumped.

h_f is the static groundwater head of the measured zone far from the borehole, beyond the radius of influence R

Using equations 3-7 and 3-8 Q_x can be solved:

$$Q_x = (Q_{f1} \cdot (h_x - h_0) - Q_{f0} \cdot (h_x - h_1))/(h_1 - h_0) \qquad 3\text{-}10$$

Q_x is a calculated reference of flow rate for hydraulic head of h_x. Q_x is also an interpolated value of the flow rates measured earlier. If $h_x = h_0$ then $Q_x = Q_{f0}$ and if $h_x = h_1$ then $Q_x = Q_{f1}$. It is assumed that there are the same flow conditions as during the two flow measurements Q_{f0} and Q_{f1} (no disturbance from outside, such as interference from boreholes nearby). Q_x can be therefore used as a reference value for interference test, giving the limit when there is no hydraulic connection between the observed hole and the pumped hole.

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 (which uses rubber disks to isolate the flow). 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. The flow is measured using the thermal pulse and/or thermal dilution methods. Measured values are transferred into a computer in digital form.

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 guides are 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 a marked cable and a digital length counter.
Logging computer:	PC, Windows XP.
Software:	Based on MS Visual Basic.
Total power consumption:	1.5–2.5 kW depending on the pumps.
Calibrated:	Tool nr FL5 in April 2006, tool nr FL2 in August 2006.
Calibration of cable length:	Using length marks in the borehole.

Table 4-1. Range and accuracy of sensors.

Sensor	Range	Accuracy
Flow	6–300,000 mL/h	± 10% curr.value
Temperature (middle thermistor)	0–50°C	0.1°C
Temperature difference (between outer thermistors)	–2 –+2°C	0.0001°C
Electrical 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 400-06-087 (SKB internal controlling document) following the SKB Method Description 322.010e, Version 1.0 (Method description for difference flow logging). Two reports are produced concerning the activity plan. This document (P-07-65 presents the results gained of the interference test in boreholes KLX11B-F. Single hole results are presented separately in document P-07-64.

Prior to the measurements, the downhole tools and the measurement cable were disinfected. Clocks were synchronized to the normal 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 a logging cable. Immediately after the completion of the drilling operations in boreholes KLX11B-F, length marks were milled into the borehole walls 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 consists of two 20 mm wide tracks in the borehole wall. The distance between the tracks is 100 mm. The upper track defines a reference level. Necessary conditions 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 measurements for this purpose. These methods also reveal parts of the borehole widened for some reason (fracture zones, breakouts etc).

The dummy loggings (Item 8) of the boreholes were performed before any other measurements were started. This was done to assure that the measurement tools do not get stuck in the boreholes.

The combined overlapping/sequential flow logging (Items 8–17) was carried out first in all the boreholes during natural (un-pumped) conditions. Both 1 m and 5 m section lengths were used. The length increment (step length) was 0.1 m with 1 m section length and 0.5 m with 5 m section length. 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 September 11 in borehole KLX11B. Every borehole KLX11B-F was pumped and measured, and there was a waiting period during which the water level was allowed to recover. Overlapping flow logging (Items 24–33) was carried out in all the boreholes during pumped conditions with 1 m and 5 m section lengths. The length increment (step length) was 0.1 m with the 1 m section length and 0.5 m with the 5 m section length. The measurement order was KLX11B, KLX11E, KLX11D, KLX11C and KLX11F. Pumping in borehole KLX11F was stopped on the 18th of October. Water level in each borehole is presented on the date scale, see Appendices 18.1–18.5.

The interference tests (Items 34–41, 43–50 and 52–59 took place between September 14 and October 8. The same pumping sequences that were used for the single-hole tests (boreholes KLX11B, KLX11D and KLX11E) were continued and all the other boreholes were flow logged using a 5 m section (0.5 m increments) and a 1 m section (0.1 m increments).

After the pumping of a certain borehole was stopped the recovery of the water level was recorded (Items 42, 51 and 60–62).

The measurement programme was then continued with injection tests, which allow for a more complete characterisation of the upper parts of the boreholes which were subjected to drawdown during pumping. The upper parts of the boreholes were now flow logged (overlapping flow logging) with 1 m section length and 0.1 m step length (Items 63–67).

No separate activities were performed to measure the electric conductivity of borehole water. However, EC and temperature were obtained during flow loggings.

Table 5-1. Flow logging and testing in KLX11B-F. Activity schedule.

Item	Activity	Explanation	Date
2	Mobilisation at site.	Unpacking the trailer.	2006-09-04
5 & 7	Desinfection.	Cable cleaning.	2006-09-04
8	Dummy soundering in boreholes KLX11B-F.	Dummy logging. Logging without the lower rubber discs, no pumping. Depth interval 0–100.20 m at KLX11B, 0–120.15 m at KLX11C, 0–120.35 m at KLX11D, 0–121.30 m at KLX11E and 0–120.05 m at KLX11F.	2006-09-04–2006-09-11
9	Length calibration, KLX11B.	Caliber logging (SKB Caliper and SPR). Logging without the lower rubber discs, no pumping. Depth interval 0–100.20 m.	2006-09-05
10	Length calibration, KLX11C.	Caliber logging (SKB Caliper and SPR). Logging without the lower rubber discs, no pumping. Depth interval 0–120.15 m.	2006-09-07
11	Length calibration, KLX11E.	Caliber logging (SKB Caliper and SPR). Logging without the lower rubber discs, no pumping. Depth interval 0–121.30 m.	2006-09-09
12	Length calibration, KLX11D.	Caliber logging (SKB Caliper and SPR). Logging without the lower rubber discs, no pumping. Depth interval 0–120.35 m.	2006-09-07
13	Length calibration, KLX11F.	Caliber logging (SKB Caliper and SPR). Logging without the lower rubber discs, no pumping. Depth interval 0–120.05 m.	2006-09-11
14	Combined Overlapping/Sequential flow logging, KLX11B.	Section length L_w=5 m, Step length d_L=0.5 m. No pumping.	2006-09-05
15	Combined Overlapping/Sequential flow logging, KLX11C.	Section length L_w=5 m, Step length d_L=0.5 m. No pumping.	2006-09-06
16	Combined Overlapping/Sequential flow logging, KLX11D.	Section length L_w=5 m, Step length d_L=0.5 m. No pumping.	2006-09-08
17	Combined Overlapping/Sequential flow logging, KLX11E.	Section length L_w=5 m, Step length d_L=0.5 m. No pumping.	2006-09-09
18	Combined Overlapping/Sequential flow logging, KLX11F.	Section length L_w=5 m, Step length d_L=0.5 m. No pumping.	2006-09-10
19	Combined Overlapping/Sequential flow logging, KLX11B.	Section length L_w=1 m, Step length d_L=0.1 m, No pumping.	2006-09-04–2006-09-05
20	Combined Overlapping/Sequential flow logging, KLX11C.	Section length L_w=1 m, Step length d_L=0.1 m. No pumping.	2006-09-06–2006-09-07
21	Combined Overlapping/Sequential flow logging, KLX11D.	Section length L_w=1 m, Step length d_L=0.1 m. No pumping.	2006-09-07–2006-09-08
22	Combined Overlapping/Sequential flow logging, KLX11E.	Section length L_w=1 m, Step length d_L=0.1 m. No pumping.	2006-09-08–2006-09-09
23	Combined Overlapping/Sequential flow logging, KLX11F.	Section length L_w=1 m, Step length d_L=0.1 m. No pumping.	2006-09-10–2006-09-11

Item	Activity	Explanation	Date
24	Overlapping flow logging, KLX11B.	Section length L_w=5 m, Step length d_L=0.5 m at pumping.	2006-09-13
25	Overlapping flow logging, KLX11C.	Section length L_w=5 m, Step length d_L=0.5 m, at pumping.	2006-10-14
26	Overlapping flow logging, KLX11D.	Section length L_w=5 m, Step length d_L=0.5 m, at pumping.	2006-10-04
27	Overlapping flow logging, KLX11E.	Section length L_w=5 m, Step length d_L=0.5 m, at pumping.	2006-09-24
28	Overlapping flow logging, KLX11F.	Section length L_w=5 m, Step length d_L=0.5 m, at pumping.	2006-10-17
29	Overlapping flow logging, KLX11B.	Section length L_w=1 m, Step length d_L=0.1 m, at pumping.	2006-09-12
30	Overlapping flow logging, KLX11C.	Section length L_w=1 m, Step length d_L=0.1 m, at pumping.	2006-10-13–2006-10-14
31	Overlapping flow logging, KLX11D.	Section length L_w=1 m, Step length d_L=0.1 m, at pumping.	2006-10-03–2006-10-04
32	Overlapping flow logging, KLX11E.	Section length L_w=1 m, Step length d_L=0.1 m, at pumping.	2006-09-23–2006-09-24
33	Overlapping flow logging, KLX11F.	Section length L_w=1 m, Step length d_L=0.1 m, at pumping.	2006-10-17
34	Sequential flow logging/Combined in KLX11C.	Interference test. Section length L_w=5 m, Step length d_L=0.5 m. KLX11B was pumped.	2006-09-14–2006-09-14
35	Sequential flow logging/Combined in KLX11C.	Interference test. Section length L_w=1 m, Step length d_L=0.1 m. KLX11B was pumped.	2006-09-14–2006-09-15
36	Sequential flow logging/Combined in KLX11D.	Interference test. Section length L_w=5 m, Step length d_L=0.5 m. KLX11B was pumped.	2006-09-15–2006-09-15
37	Sequential flow logging/Combined in KLX11D.	Interference test. Section length L_w=1 m, Step length d_L=0.1 m. KLX11B was pumped.	2006-09-15–2006-09-16
38	Sequential flow logging/Combined in KLX11E.	Interference test. Section length L_w=5 m, Step length d_L=0.5 m. KLX11B was pumped.	2006-09-16–2006-09-16
39	Sequential flow logging/Combined in KLX11E.	Interference test. Section length L_w=1 m, Step length d_L=0.1 m. KLX11B was pumped.	2006-09-16–2006-09-17
40	Sequential flow logging/Combined in KLX11F.	Interference test. Section length L_w=5 m, Step length d_L=0.5 m. KLX11B was pumped.	2006-09-17–2006-09-17
41	Sequential flow logging/Combined in KLX11F.	Interference test. Section length L_w=1 m, Step length d_L=0.1 m. KLX11B was pumped.	2006-09-18–2006-09-19
42	Recovery transient, KLX11B.	Measurement of water level in the borehole after the pumping was stopped.	2006-09-19–2006-09-19
43	Sequential flow logging/Combined in KLX11B.	Interference test. Section length L_w=5 m, Step length d_L=0.5 m. KLX11D was pumped.	2006-10-05–2006-10-05
44	Sequential flow logging/Combined in KLX11B.	Interference test. Section length L_w=1 m, Step length d_L=0.1 m. KLX11D was pumped.	2006-10-04–2006-10-05
45	Sequential flow logging/Combined in KLX11C.	Interference test. Section length L_w=5 m, Step length d_L=0.5 m. KLX11D was pumped.	2006-10-06–2006-10-06
46	Sequential flow logging/Combined in KLX11C.	Interference test. Section length L_w=1 m, Step length d_L=0.1 m. KLX11D was pumped.	2006-10-05–2006-10-06
47	Sequential flow logging/Combined in KLX11E.	Interference test. Section length L_w=5 m, Step length d_L=0.5 m. KLX11D was pumped.	2006-10-07–2006-10-07
48	Sequential flow logging/Combined in KLX11E.	Interference test. Section length L_w=1 m, Step length d_L=0.1 m. KLX11D was pumped.	2006-10-06–2006-10-07
49	Sequential flow logging/Combined in KLX11F.	Interference test. Section length L_w=5 m, Step length d_L=0.5 m. KLX11D was pumped.	2006-10-08–2006-10-08
50	Sequential flow logging/Combined in KLX11F.	Interference test. Section length L_w=1 m, Step length d_L=0.1 m. KLX11D was pumped.	2006-10-07–2006-10-08
51	Recovery transient, KLX11D.	Measurement of water level in the borehole after the pumping was stopped.	2006-10-08–2006-10-12

Item	Activity	Explanation	Date
52	Sequential flow logging/Combined in KLX11B.	Interference test. Section length L_w=5 m, Step length d_L=0.5 m. KLX11E was pumped.	2006-09-25
53	Sequential flow logging/Combined in KLX11B.	Interference test. Section length L_w=1 m, Step length d_L=0.1 m. KLX11E was pumped.	2006-09-26
54	Sequential flow logging/Combined in KLX11C.	Interference test. Section length L_w=5 m, Step length d_L=0.5 m. KLX11E was pumped.	2006-09-26
55	Sequential flow logging/Combined in KLX11C.	Interference test. Section length L_w=1 m, Step length d_L=0.1 m. KLX11E was pumped.	2006-09-26–2006-09-27
56	Sequential flow logging/Combined in KLX11D.	Interference test. Section length L_w=5 m, Step length d_L=0.5 m. KLX11E was pumped.	2006-09-27
57	Sequential flow logging/Combined in KLX11D.	Interference test. Section length L_w=1 m, Step length d_L=0.1 m. KLX11E was pumped.	2006-09-27–2006-09-28
58	Sequential flow logging/Combined in KLX11F.	Interference test. Section length L_w=5 m, Step length d_L=0.5 m. KLX11E was pumped.	2006-09-28
59	Sequential flow logging/Combined in KLX11F.	Interference test. Section length L_w=1 m, Step length d_L=0.1 m. KLX11E was pumped.	2006-09-28–2006-09-29
60	Recovery transient, KLX11E.	Measurement of water level in the borehole after the pumping was stopped.	2006-09-29–2006-10-02
61	Recovery transient, KLX11C.	Measurement of water level in the borehole after the pumping was stopped.	2006-10-14–2006-10-16
62	Recovery transient, KLX11F.	Measurement of water level in the borehole after the pumping was stopped.	2006-10-18–2006-10-19
63	Overlapping flow logging, KLX11B.	Section length L_w=1 m, Step length d_L=0.1 m, injection. PFL logging from casing bottom to part of borehole which was subjected to drawdown.	2006-10-22
63 Extra	Overlapping flow logging, KLX11B.	Section length L_w=1 m, Step length d_L=0.1 m, smaller injection. Re-measuring fracture flows that were over the measurement limit.	2006-10-22
64	Overlapping flow logging, KLX11C.	Section length L_w=1 m, Step length d_L=0.1 m, injection. PFL logging from casing bottom to part of borehole which was subjected to drawdown.	2006-10-20
65	Overlapping flow logging, KLX11D.	Section length L_w=1 m, Step length d_L=0.1 m, injection. PFL logging from casing bottom to part of borehole which was subjected to drawdown.	2006-10-21
65 Extra	Overlapping flow logging, KLX11D.	Section length L_w=1 m, Step length d_L=0.1 m, smaller injection. Re-measuring fracture flows that were over the measurement limit.	2006-10-20
66	Overlapping flow logging, KLX11E.	Section length L_w=1 m, Step length d_L=0.1 m, injection. PFL logging from casing bottom to part of borehole which was subjected to drawdown.	2006-10-19
67	Overlapping flow logging, KLX11F.	Section length L_w=1 m, Step length d_L=0.1 m, injection. PFL logging from casing bottom to part of borehole which was subjected to drawdown.	2006-10-21
67 Extra	Overlapping flow logging, KLX11F.	Section length L_w=1 m, Step length d_L=0.1 m, smaller injection. Re-measuring fracture flows that were over the measurement limit.	2006-10-21
68	Demobilisation.		2006-10-23–2006-10-24

5.2 Nonconformities

The fractures where the flow rate had exceeded the measurement limit were re-measured with small injection. A section length of 1 m and a step length of 0.1 m were used (Items 63Extra, 65Extra and 67Extra). To be used in transmissivity and head calculations, also the undisturbed state just before the injection was measured.

Due to the length of the measuring probe and additional weights it is not physically possible to measure all the way down to the bottom of the hole. The distance between measurement point and lower end of the tool in borehole is presented in Table 5-3. For that reason the possible flow anomalies at the bottom of the borehole will not be detected.

Table 5-3. Unmeasured parts at bottom of boreholes.

KLX11B	KLX11C	KLX11D	KLX11E	KLX11F
3.65 m	3.65 m	3.65 m	3.65 m	3.65 m

6 Results

6.1 Length calibration

6.1.1 Caliper and SPR measurement

Accurate length measurements are difficult to conduct in long boreholes, i.e. the accurate position of the measurement equipment is difficult to determine. The main cause of inaccuracy is the stretching of the logging cable. The stretching depends on the tension on the cable which in turn depends, among other things, on the inclination of the borehole and the roughness (friction properties) of the borehole wall. The cable tension is higher when the borehole is measured upwards. The cables, especially a new cable, may also stretch out permanently.

Length marks on the borehole wall can be used to minimise the length errors. The length marks are initially detected with the SKB caliper tool. The length scale is first 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 the measurements except borehole EC measurements) with the original caliper/SPR-measurement.

The procedure of the length correction was the following:

- The caliper/SPR-measurements (Items 9–13) were initially length corrected in relation to the known length marks, Appendices 1–5.1, black curve. Corrections between the length marks were obtained by linear interpolation.
- The SPR curves of Items 9–13 were then compared with the SPR curves of Items 14–33 and 63–67 to obtain relative length errors of these measurement sequences.
- All SPR curves could then be synchronised, as can be seen in Appendices 1–5.

The results of the caliper and single-point resistance measurements from all measurements are presented in Appendices 1–5.1. The SPR-curves are plotted together with the caliper-data.

The caliper has been adjusted and specified to change its output from a low voltage value to a high voltage value between borehole diameters 77 mm–78 mm.

Zoomed results of the caliper and SPR data are presented in Appendices 1–5. The detected length marks are listed in Table 6-1. All the marks were detected by the caliper tool and in the single-point resistance measurements. 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. If only one length mark is detected, the decision whether it is the lower or the upper mark is made based on the shape of the SPR-anomaly. The SPR-anomaly at the length marks has a distinctive shape, which can usually be recognized. In this case there were no partially recognized length marks. Appendices 1–5 also illustrates many natural anomalies which can help in synchronising the results.

The aim of the plots in Appendices 1–5 is to verify the accuracy of the length correction. The curves in these plots are the length corrected results.

The magnitude of the length correction along the borehole is presented in Appendices 1.9, 2.11, 3.10, 4.12 and 5.10. The negative values of the error represent the situation where the logging cable has been extended, i.e. the cable is longer than the nominal length marked on it.

Table 6-1. Detected length marks.

Borehole	Length marks given by SKB (m)	Length marks detected by caliper	Length marks detected by SPR
KLX11B	50	both	yes
KLX11B	80	both	yes
KLX11C	47	both	yes
KLX11C	98	both	yes
KLX11D	50	both	yes
KLX11D	100	both	yes
KLX11E	50	both	yes
KLX11E	100	both	yes
KLX11F	50	both	yes
KLX11F	101	both	yes

Table 6-2. Approximate noise level in flow in boreholes during pumping.

Borehole	Noise level in flow (mL/h)	Comments
KLX11B	30	
KLX11C	30	
KLX11D	30	
KLX11E	30	
KLX11F	30–100	30 mL/h below 73 m

6.1.2 Estimated error in the location of detected fractures

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

1. The point interval in the overlapping mode flow measurements is 0.1 m. This could cause an error of ± 0.05 m.
2. The length of the test section is not exact. The specified section length denotes the distance between the nearest upper and lower rubber disks. Effectively, the section length can be larger. At the upper end of the test section there are four rubber disks. The distance between them is 5 cm. This will cause rounded flow anomalies: a flow may be detected already when a fracture is situated between the upper rubber disks. These phenomena can cause an error of ± 0.05 m when the short step length (0.1 m) is used.
3. There could sometimes be a need for the corrections between the length marks to be other than linear. This could cause an error of ± 0.1 m in the caliper/SPR-measurement (Items 9–13).
4. SPR curves may be imperfectly synchronized. This could cause an error of ± 0.1 m.

In the worst case, the errors from sources 1, 2, 3 and 4 are summed and the total estimated error between the length marks will be ± 0.3 m.

The situation is slightly better near the length marks. In the worst case, the errors from sources 1, 2 and 4 are summed and the total estimated error will be ± 0.2 m.

To know the location accurately is important when different measurements are compared, for instance flow logging and borehole TV. In a case like that the situation may not be as severe as in the worst case above, since some of the length errors are systematic and the error is nearly constant in fractures that are close to each other. However, the error caused by source 1 is random.

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

The errors given above are estimations and are based on the experiences and observations from earlier measurements.

6.2 Electrical conductivity and temperature of borehole water

The electrical conductivity of borehole water (EC) was measured simultaneously with all flow logging measurements. Normally EC is measured as a separate activity. Difference between the separate and the simultaneous EC measurement is, that in simultaneous measurement water changes slower in the test section. The measured EC value does not therefore represent the situation in borehole so accurately than it does in separate measurement that is performed without the lower rubber discs.

The temperature of the borehole water was also measured during 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 Appendices 16.1–16.5 correspond to the EC results in Appendices 15.1–15.5.

6.3 Pressure measurements

Absolute pressure was registered with the flow measurements in Items 14–33 and 63–67. The pressure sensor measures the sum of hydrostatic pressure in the borehole and air pressure. Air pressure was also registered separately, Appendices 18.1–18.5. The hydraulic head along the borehole is determined in the following way. First, 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 and Cherry 1979/:

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

where

h_{fw} is the hydraulic head (metres above sea level) according to the RHB 70 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 9.80665 m/s^2 and

z is the elevation of measurement (metres above sea level) according to the RHB 70 reference system.

A tool-specific offset is subtracted from absolute pressure raw data. With tool number FL5 offset was 2.46 kPa (Items 14–24, 26, 27, 29–32, 42, 51 and 60) and with FL2 offset was 2.30 kPa (Items 25, 28, 33 and 61–67).

Exact z-coordinates are important in head calculation, 10 cm error in z-coordinate means 10 cm error in head.

The calculated head values are presented in a graph in Appendices 17.1–17.5. h_{fw} is the head utilized in the calculations described in equations 3-1 to 3-10.

6.4 Flow logging

Interference flow measurements were carried out in boreholes using five meter and one meter section lengths. A combined logging mode was used; thermal pulse (with 5 m/1 m length increments) and thermal dilution (with 0.5 m /0.1 m length increments) measurements were carried out during the same run.

Boreholes KLX11B, KLX11D and KLX11E were pumped in turn during the test and all other boreholes were measured during these pumping periods. The normal single hole measurements (flow measurements without pumping any borehole and with pumping the hole under test) were also carried out in each borehole. Therefore each borehole was measured several times. Single hole results are presented in more detail in separate report (P-07-64).

The combined plots of results are presented in Appendices 6–10. The calculated reference flow as defined in Chapter 3.2 (equation 3-10) is also presented for comparison. Flow direction is shown with triangles. Fracture-specific flow rates during hydraulic crosshole interference test including calculated reference flows are also presented in tables, Appendices 13.1–13.5.

The results of the measurements with a 5 m section length are presented in tables, see Appendices 12.1–12.5. Only the results with a 5 m length increment are used. Secup and Seclow in Appendices 12.1–12.5 are the distances along the borehole from the reference level (top of the casing tube) to the upper end of the test section and to the lower end of the test section, respectively. The Secup and Seclow values for the two sequences (measurements at un-pumped and pumped conditions) are not exactly identical, due to a minor difference in the cable stretching. The difference between these two sequences was small. Secup and seclow given in Appendices 12.1–12.5 are calculated as the average of these two values. The same flow rates as in Appendices 12.1–12.5 are also plotted in Appendices 6–10.

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. 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 1 or 5 meter (sequential mode). The thermal pulse method was only used for flow direction, not for flow rate which would take even longer time. Longer flow direction measurement has to be done in un-pumped conditions and during the interference tests.

The noise levels were near 30 mL/h. In some places anomalies below the theoretical limit of the thermal dilution method (30 mL/h) could be detected. The noise line (grey dashed line) was never drawn below 30 mL/h, because the values of flow rate measured below 30 mL/h are uncertain.

Detected fractures are shown in Appendices 6–10 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. If a fracture is not detected under pumped conditions (due to high noise level), the line is marked grey.

6.5 Groundwater level and pumping rate

Water levels were observed in all boreholes. Results are presented together with pumping rates and air pressure in Appendices 18.1–18.5. Time and name of pumped borehole is also presented in these plots. In Table 6-3 is a summary of the obtained pumping rates and drawdowns.

Table 6-3 Pumped flows and drawdowns during the interference testing.

Pumped borehole		Observation hole				
Borehole	**Pumping rate (L/min)**	**Drawdown KLX11B (m)**	**Drawdown KLX11C (m)**	**Drawdown KLX11D (m)**	**Drawdown KLX11E (m)**	**Drawdown KLX11F (m)**
KLX11B	16	9.44	4.58	3.35	4.30	3.87
KLX11D	21.1	2.01	2.45	9.75	1.7	1.33
KLX11E	2.3	1.29	1.21	0.62	10.07	0.75

7 Summary

In this study, the Posiva Flow Log/Difference Flow method has been used to determine hydraulic interferences between boreholes KLX11B-F at Oskarshamn (P-07-65). This test includes also single hole measurements in each borehole. Single hole results are reported in a separate report (P-07-64). During the interference test, one of the boreholes was pumped in turn and the flow responses were measured in the other boreholes. Pumped boreholes were KLX11B, KLX11D and KLX11E. Clear flow responses caused by pumping were detected though their interpretation is outside of the scope of this work.

The distribution of saline water along the borehole was logged simultaneously with the flow measurements by electric conductivity and temperature measurements of the borehole water. Absolute pressure in boreholes was also registered.

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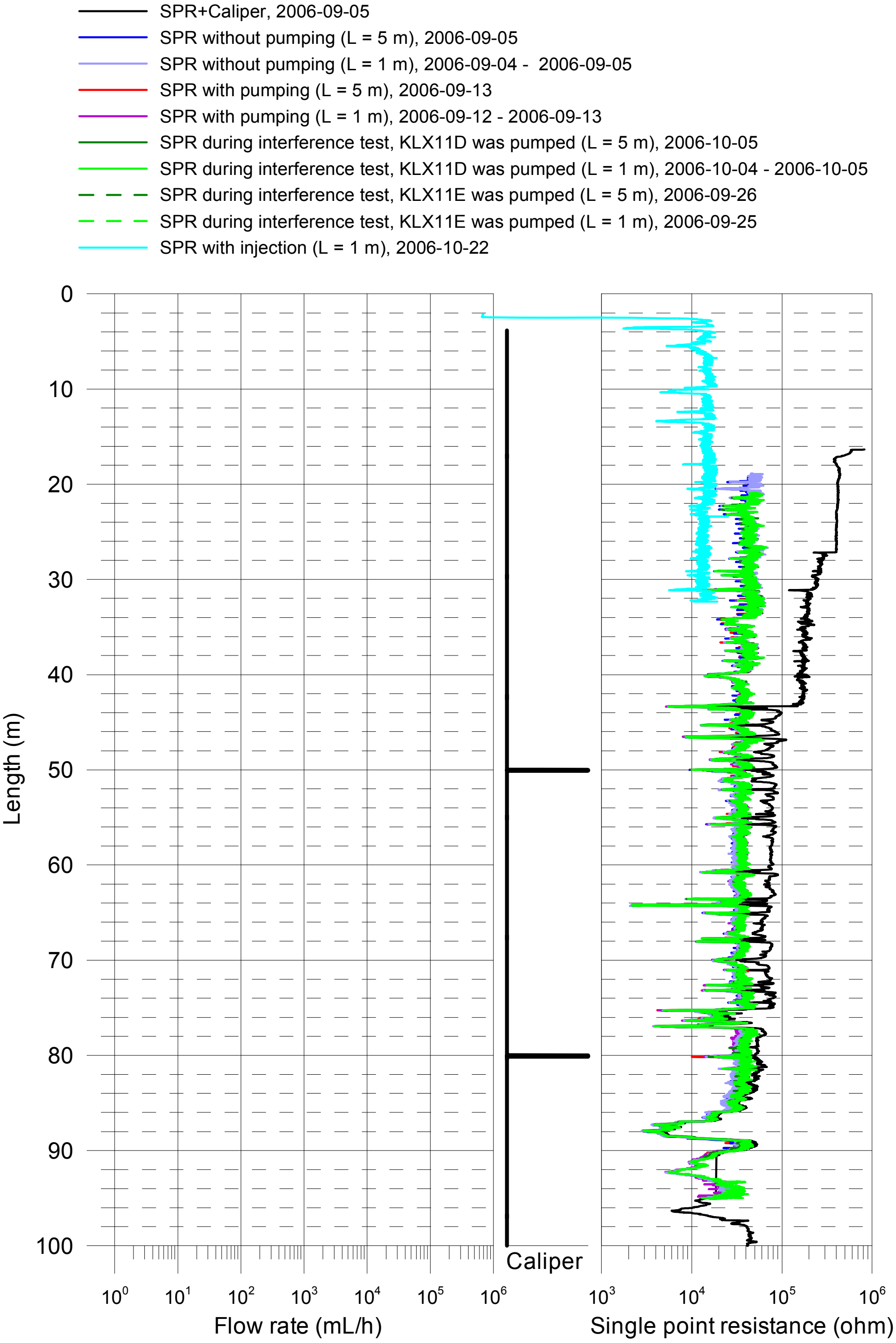
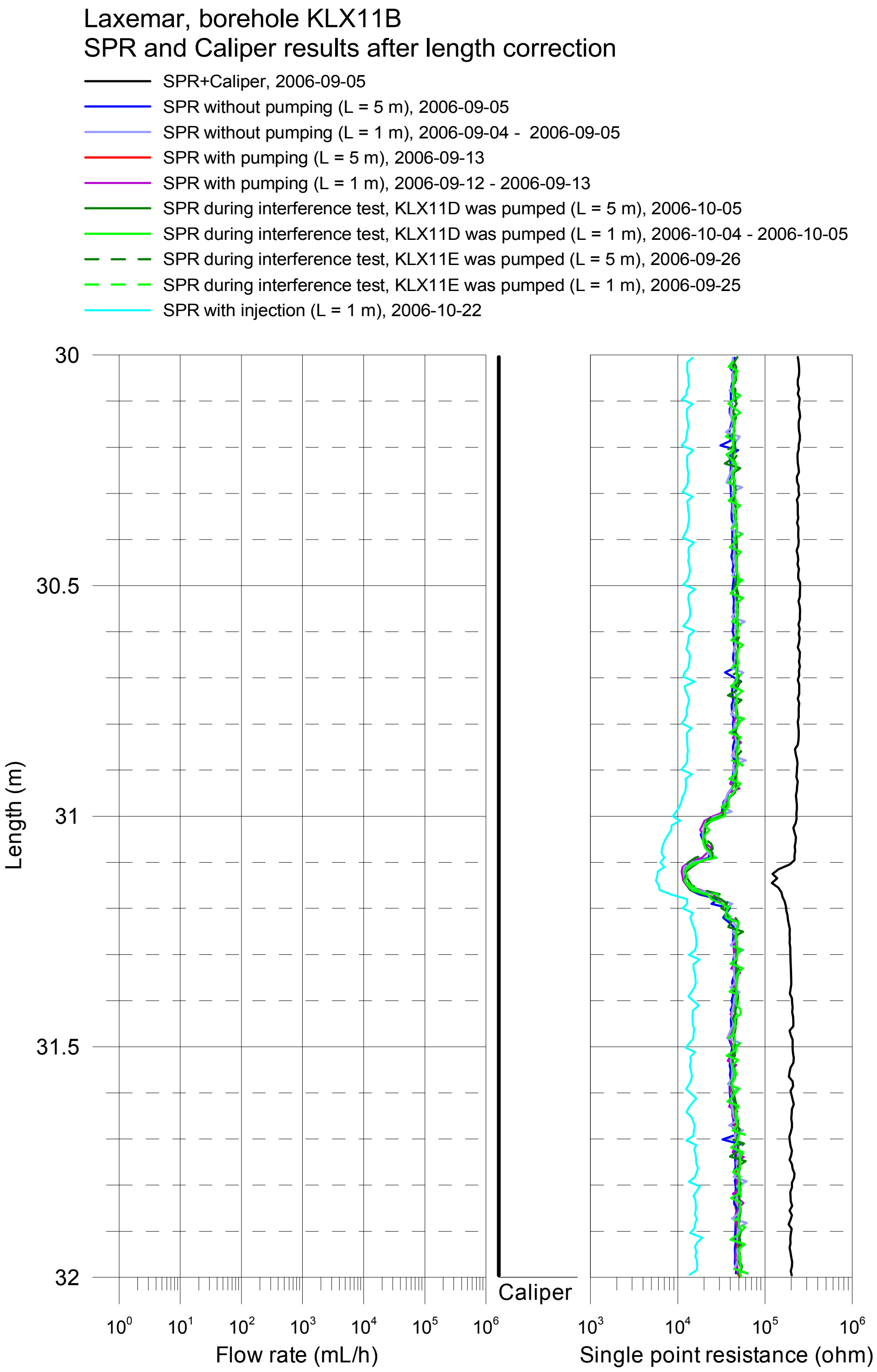
Appendix 1.1

Laxemar, borehole KLX11B
SPR and Caliper results after length correction

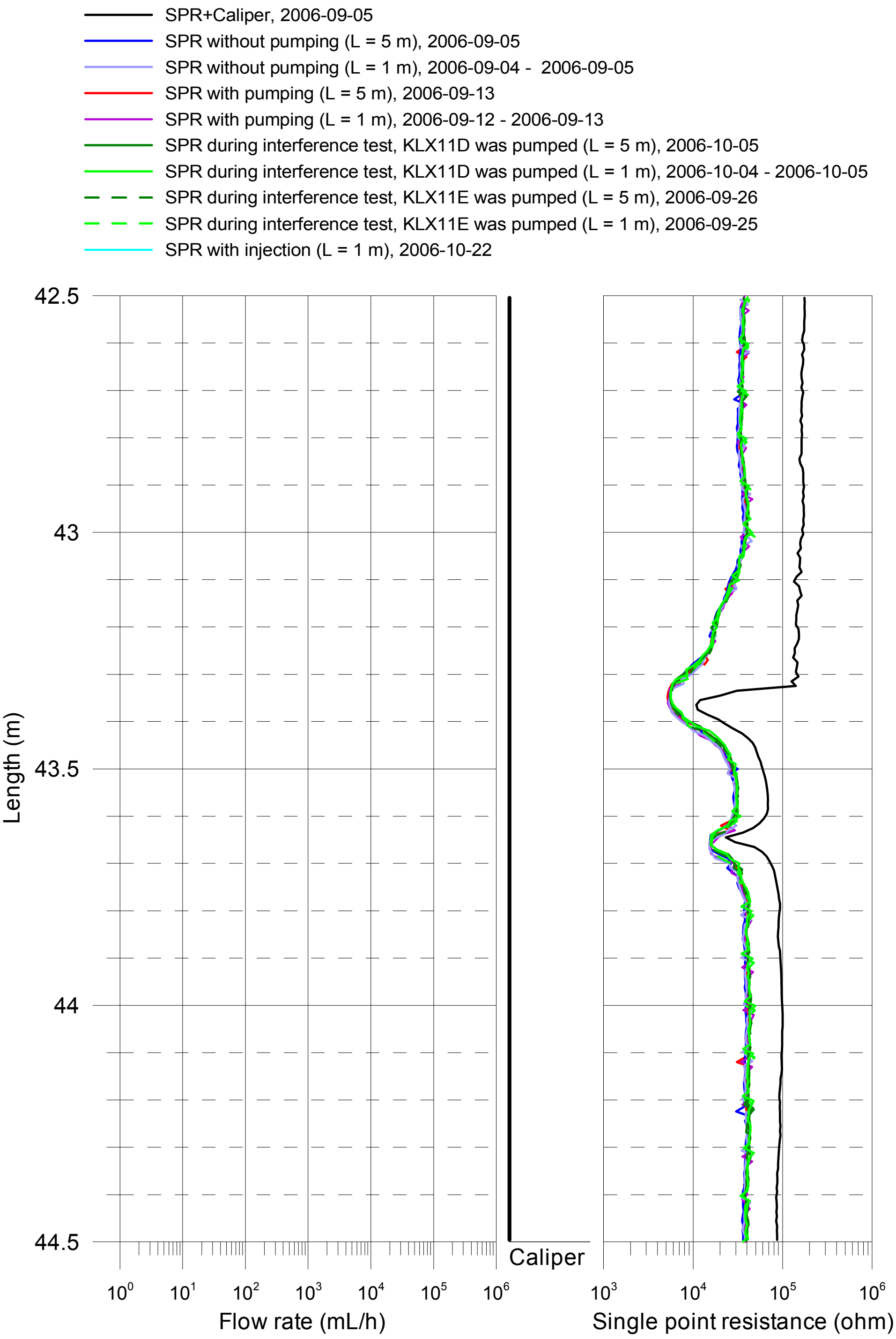


Appendix 1.2


Laxemar, borehole KLX11B
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-05
SPR without pumping (L = 5 m), 2006-09-05
SPR without pumping (L = 1 m), 2006-09-04 - 2006-09-05
SPR with pumping (L = 5 m), 2006-09-13
SPR with pumping (L = 1 m), 2006-09-12 - 2006-09-13
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-05
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-04 - 2006-10-05
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-26
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-25
SPR with injection (L = 1 m), 2006-10-22
Length (m)
30
30.5
31
31.5
32
Caliper
Flow rate (mL/h)
Single point resistance (ohm)

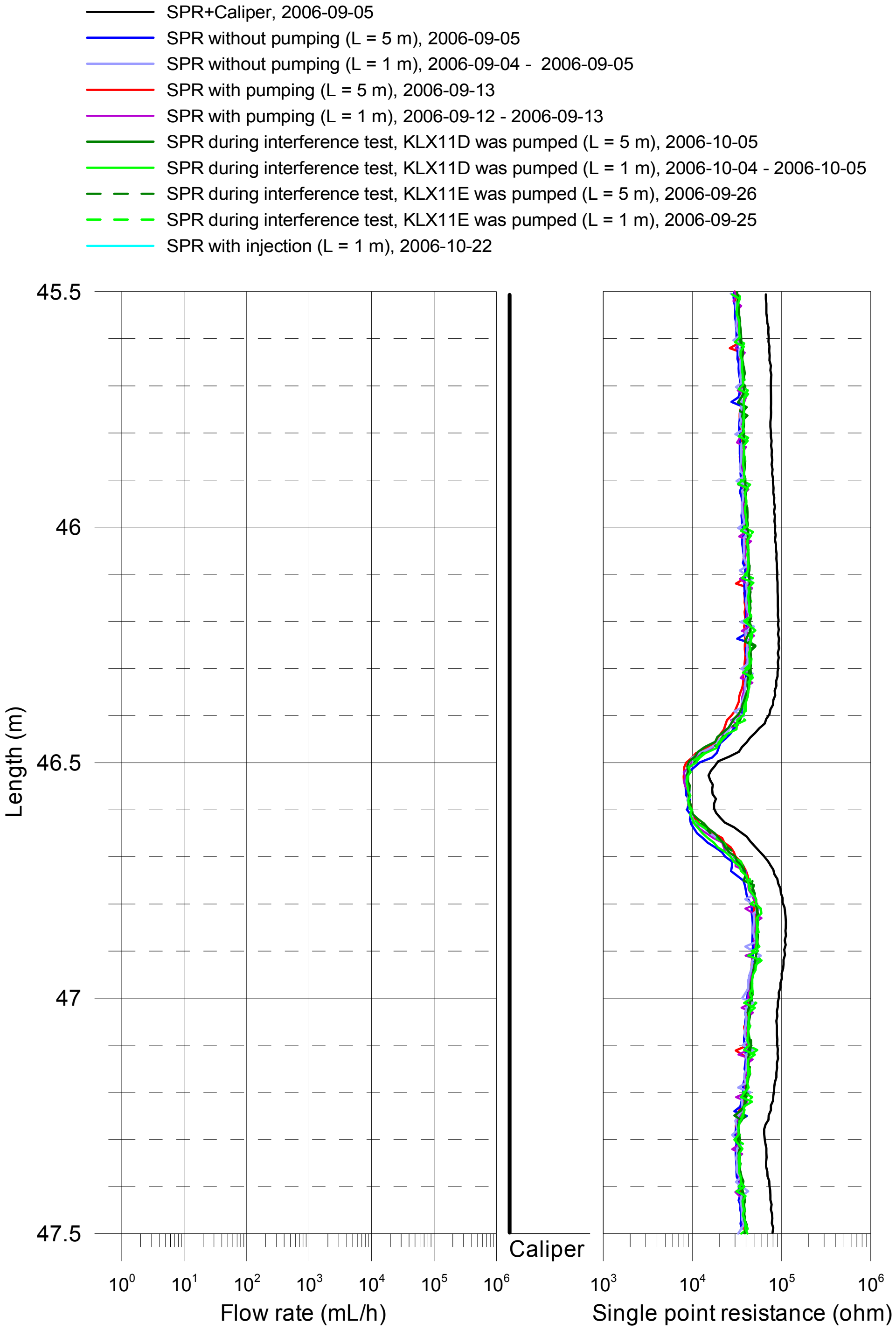
Appendix 1.3

Laxemar, borehole KLX11B
SPR and Caliper results after length correction

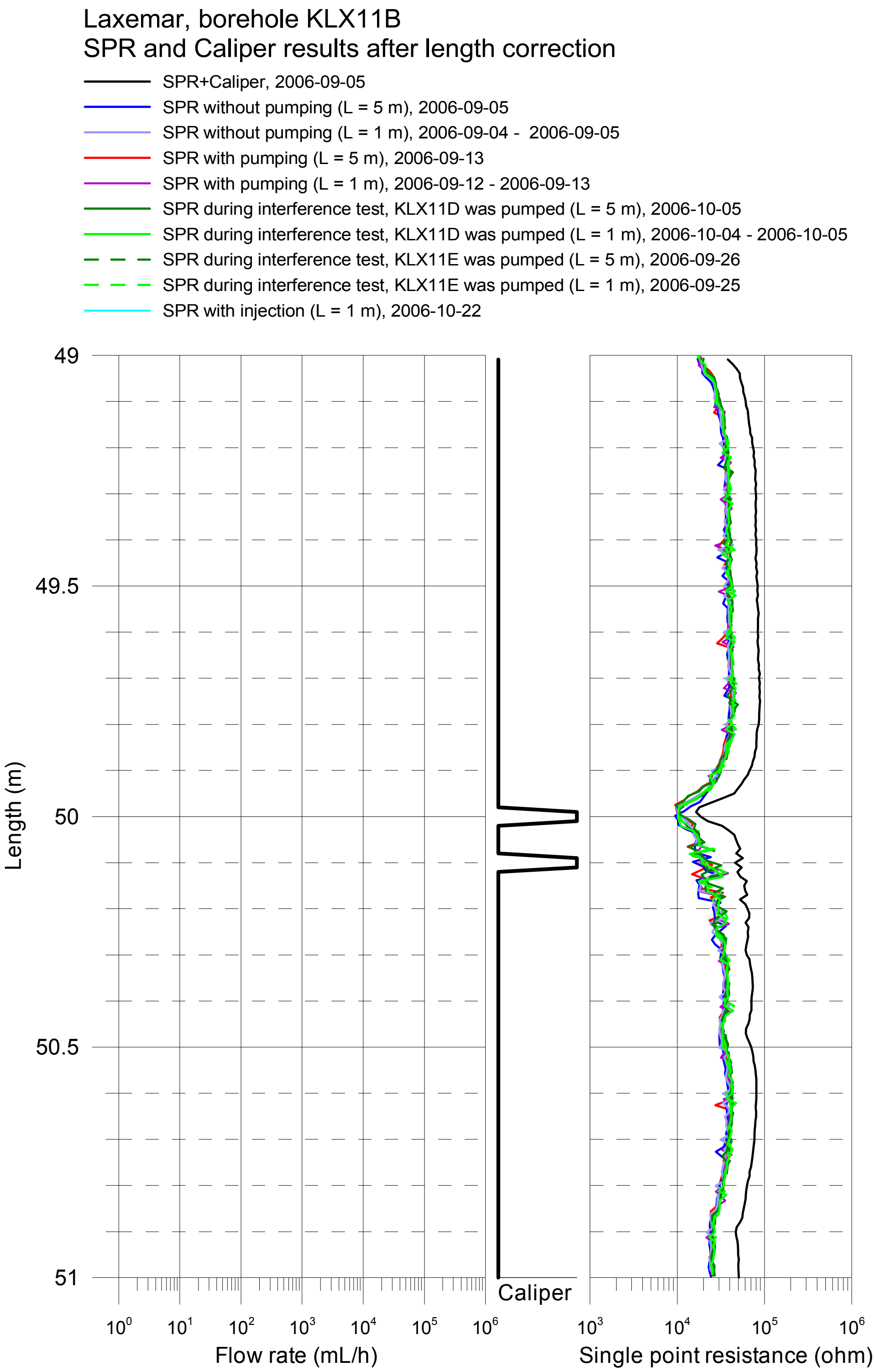


Appendix 1.4

Laxemar, borehole KLX11B
SPR and Caliper results after length correction

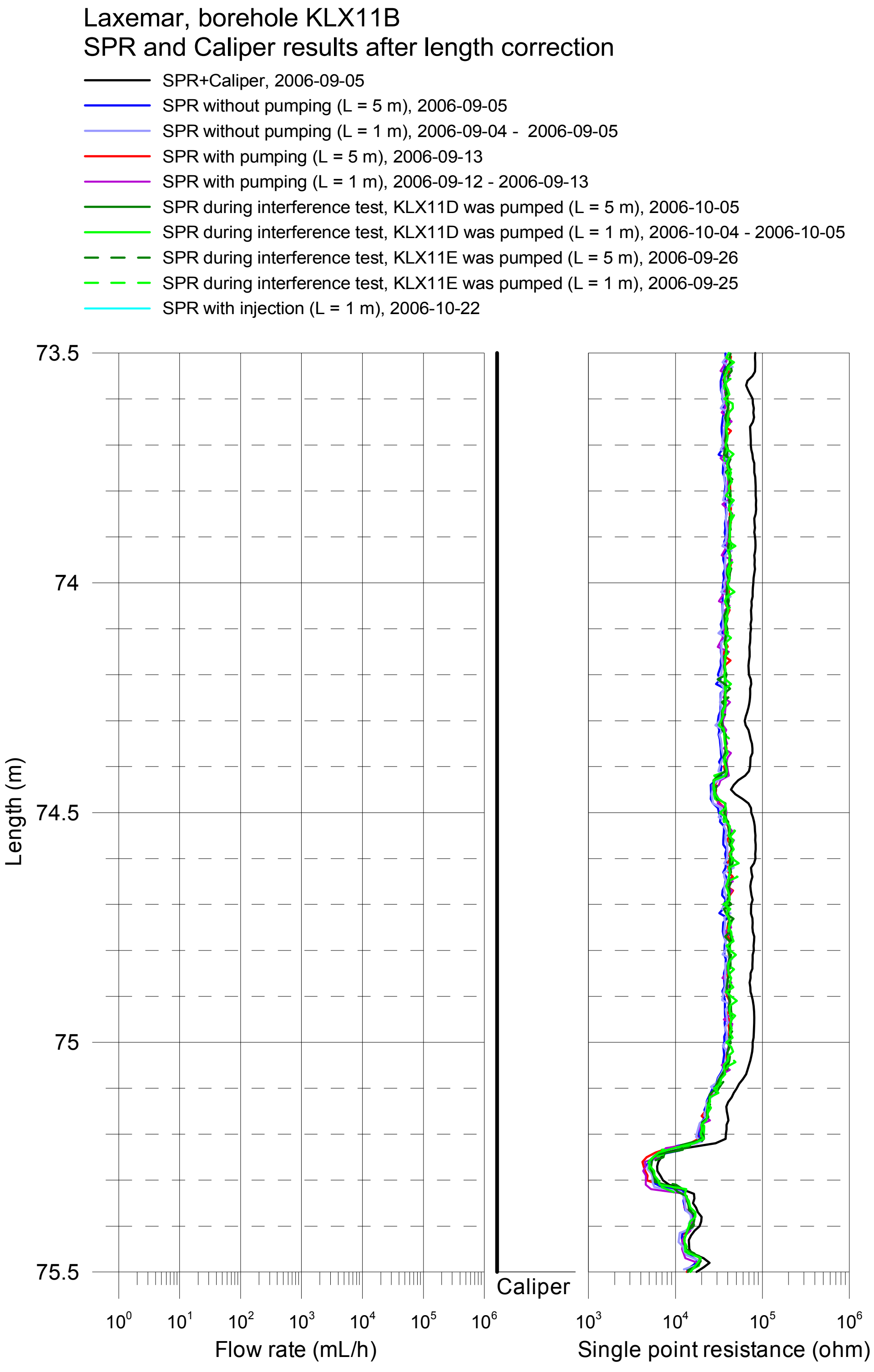


Appendix 1.5



Laxemar, borehole KLX11B
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-05
SPR without pumping (L = 5 m), 2006-09-05
SPR without pumping (L = 1 m), 2006-09-04 - 2006-09-05
SPR with pumping (L = 5 m), 2006-09-13
SPR with pumping (L = 1 m), 2006-09-12 - 2006-09-13
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-05
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-04 - 2006-10-05
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-26
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-25
SPR with injection (L = 1 m), 2006-10-22
Length (m)
49
49.5
50
50.5
51
Caliper
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)
10^3 10^4 10^5 10^6
Single point resistance (ohm)

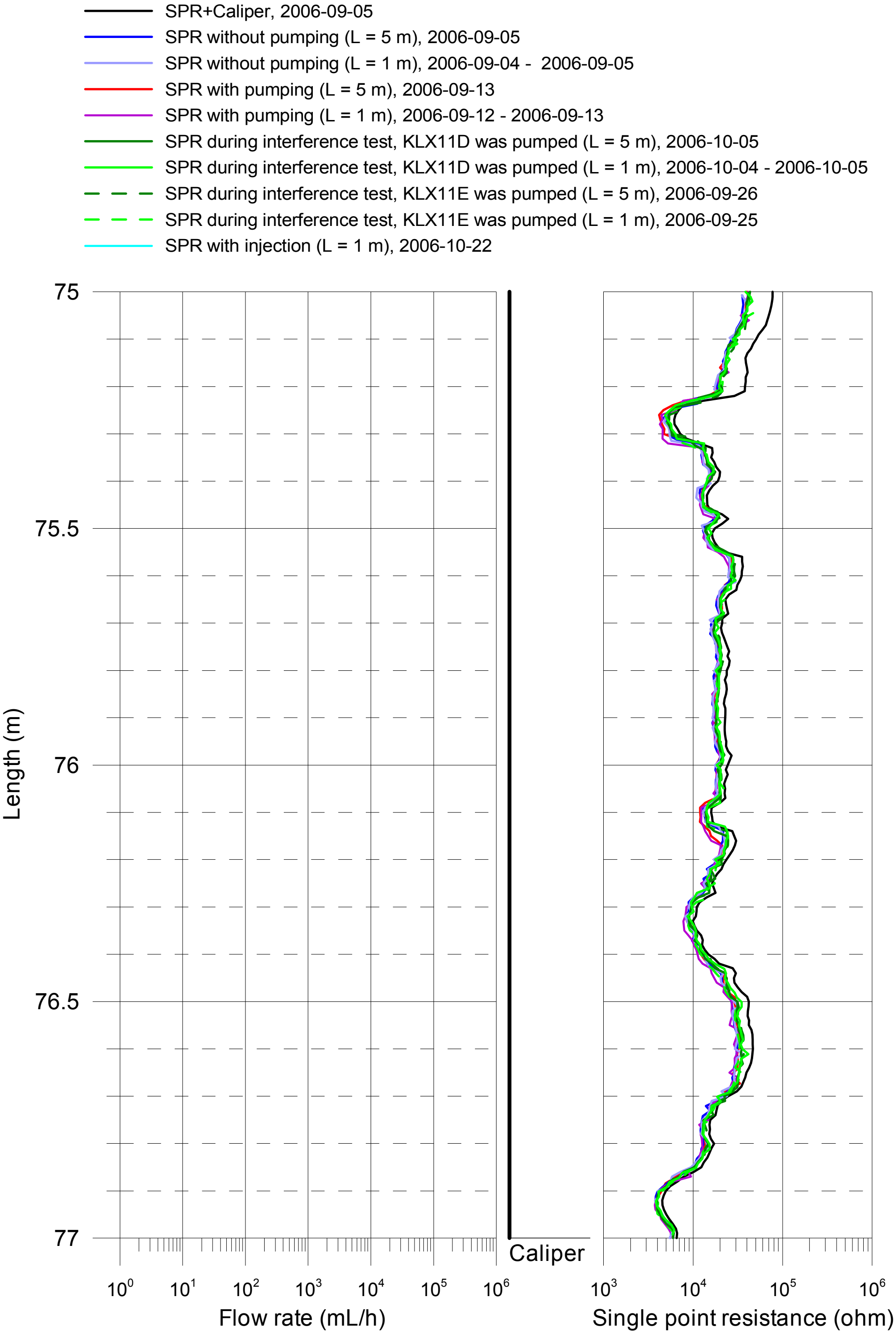
Appendix 1.6



Laxemar, borehole KLX11B
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-05
SPR without pumping (L = 5 m), 2006-09-05
SPR without pumping (L = 1 m), 2006-09-04 - 2006-09-05
SPR with pumping (L = 5 m), 2006-09-13
SPR with pumping (L = 1 m), 2006-09-12 - 2006-09-13
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-05
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-04 - 2006-10-05
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-26
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-25
SPR with injection (L = 1 m), 2006-10-22
Length (m)
73.5
74
74.5
75
75.5
Caliper
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)
10^3 10^4 10^5 10^6
Single point resistance (ohm)

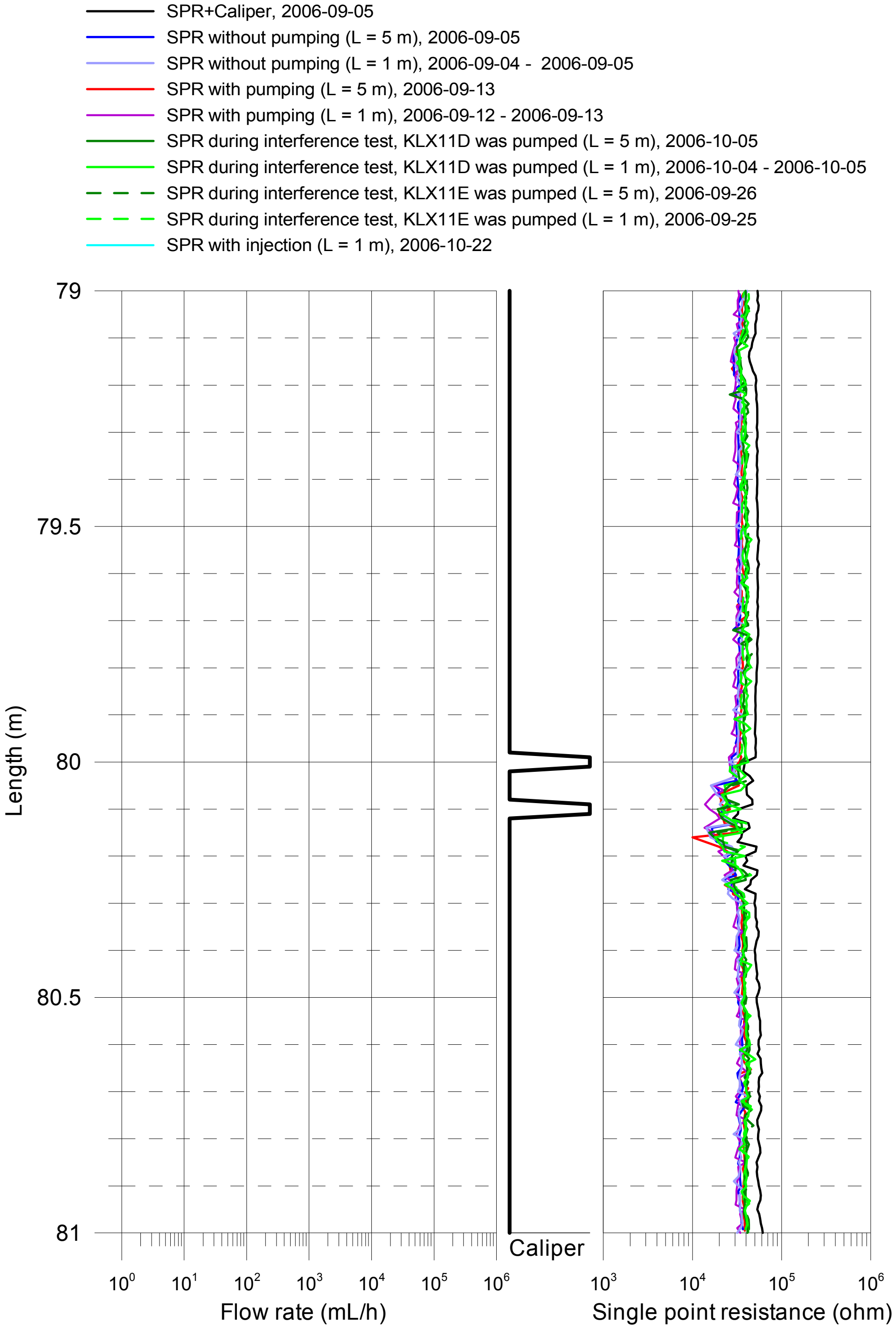
Appendix 1.7

Laxemar, borehole KLX11B
SPR and Caliper results after length correction

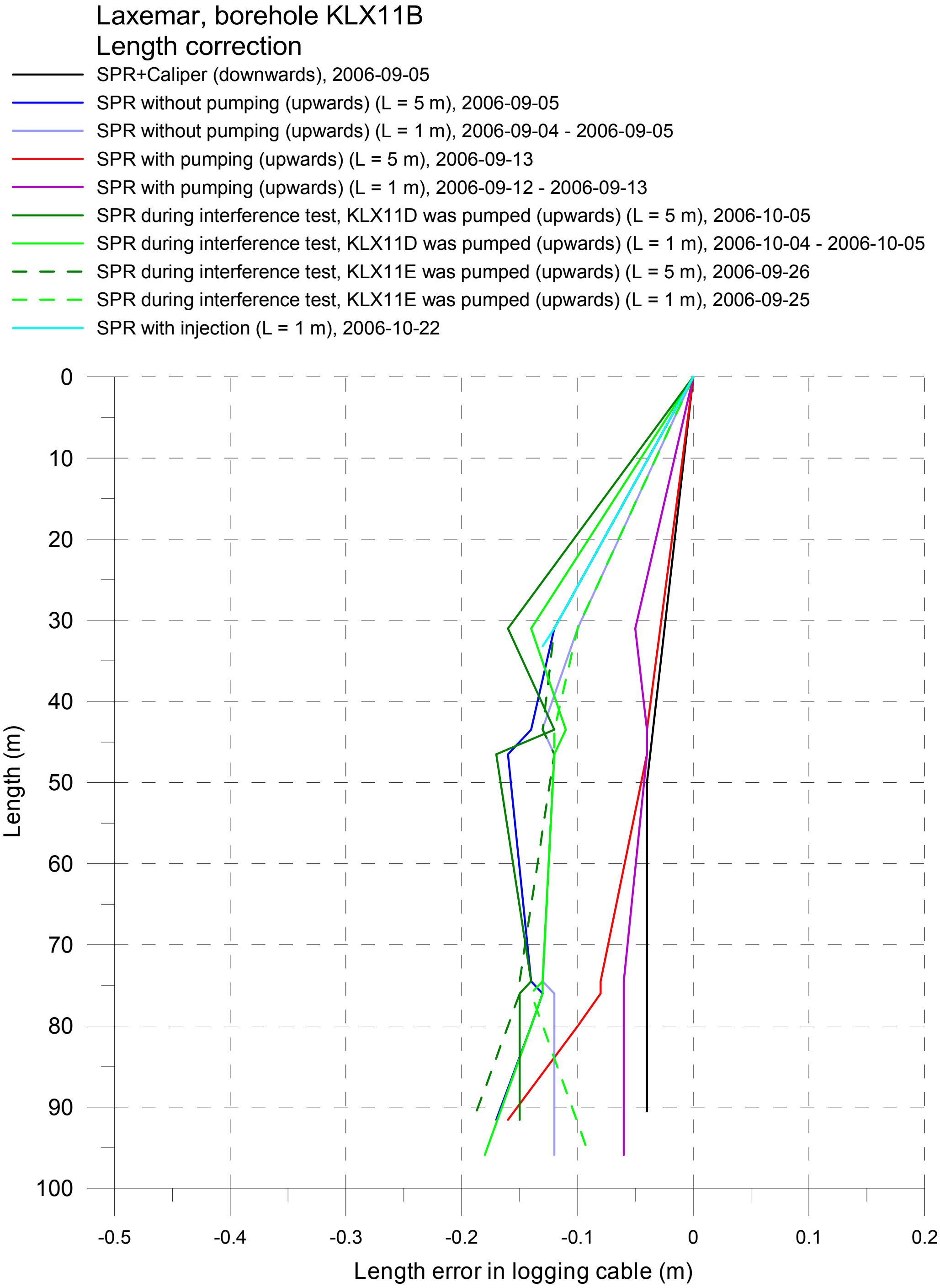


Appendix 1.8

Laxemar, borehole KLX11B
SPR and Caliper results after length correction



Appendix 1.9

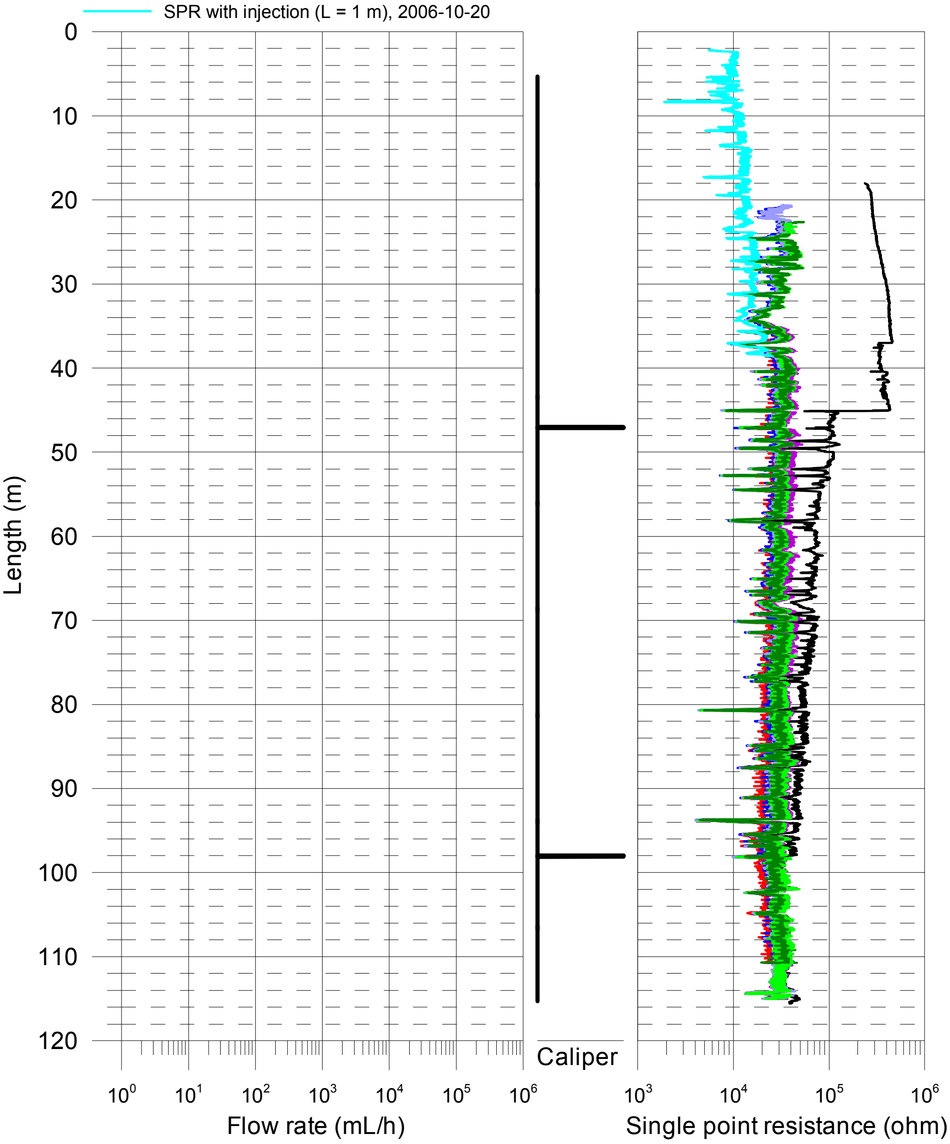


Laxemar, borehole KLX11B
Length correction
SPR+Caliper (downwards), 2006-09-05
SPR without pumping (upwards) (L = 5 m), 2006-09-05
SPR without pumping (upwards) (L = 1 m), 2006-09-04 - 2006-09-05
SPR with pumping (upwards) (L = 5 m), 2006-09-13
SPR with pumping (upwards) (L = 1 m), 2006-09-12 - 2006-09-13
SPR during interference test, KLX11D was pumped (upwards) (L = 5 m), 2006-10-05
SPR during interference test, KLX11D was pumped (upwards) (L = 1 m), 2006-10-04 - 2006-10-05
SPR during interference test, KLX11E was pumped (upwards) (L = 5 m), 2006-09-26
SPR during interference test, KLX11E was pumped (upwards) (L = 1 m), 2006-09-25
SPR with injection (L = 1 m), 2006-10-22
Length (m)
0
10
20
30
40
50
60
70
80
90
100
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
Length error in logging cable (m)

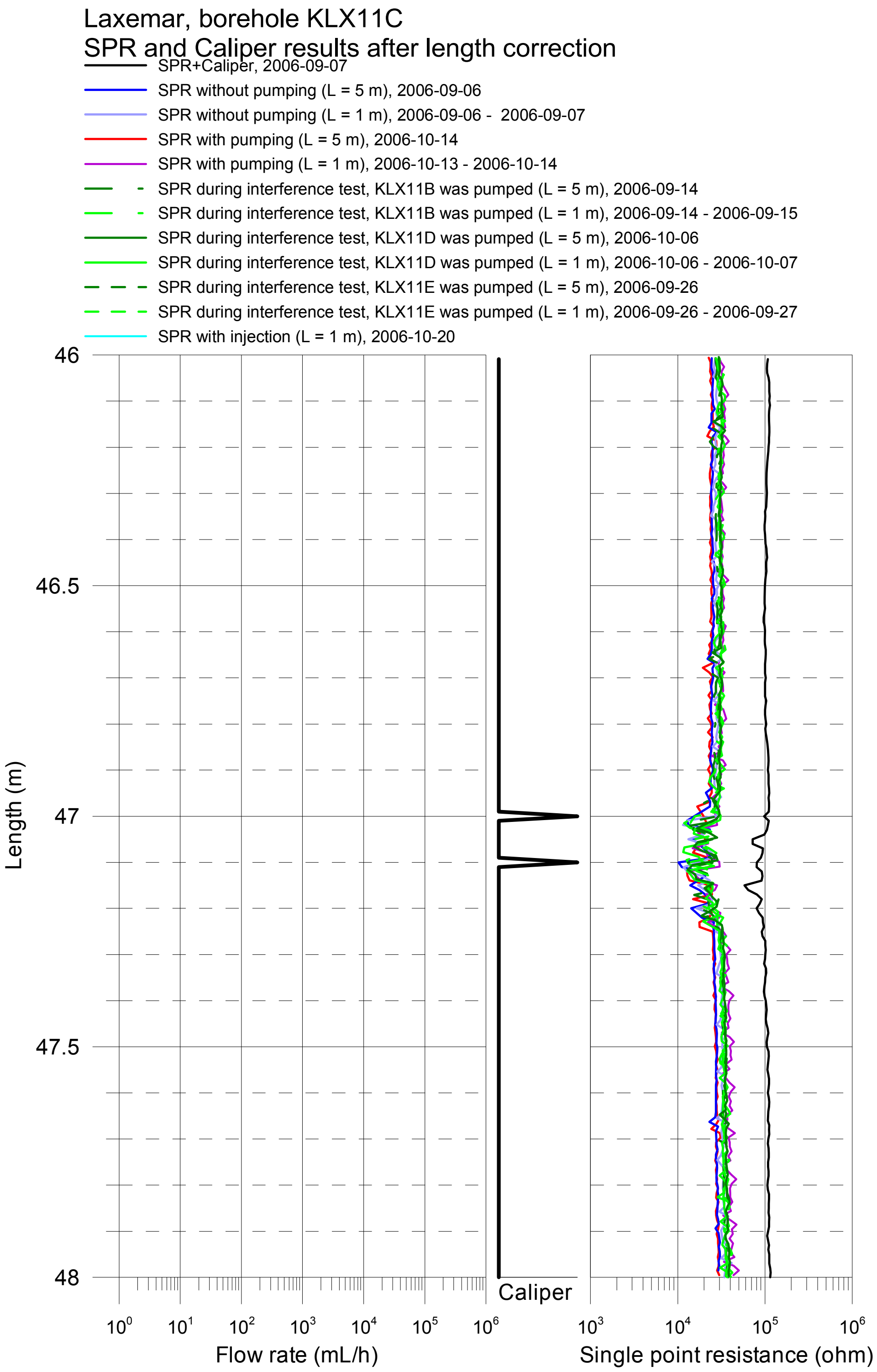
Appendix 2.1

Laxemar, borehole KLX11C
SPR and Caliper results after length correction

- SPR+Caliper, 2006-09-07
- SPR without pumping (L = 5 m), 2006-09-06
- SPR without pumping (L = 1 m), 2006-09-06 - 2006-09-07
- SPR with pumping (L = 5 m), 2006-10-14
- SPR with pumping (L = 1 m), 2006-10-13 - 2006-10-14
- SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-14
- SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-14 - 2006-09-15
- SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-06
- SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-06 - 2006-10-07
- SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-26
- SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-26 - 2006-09-27
- SPR with injection (L = 1 m), 2006-10-20

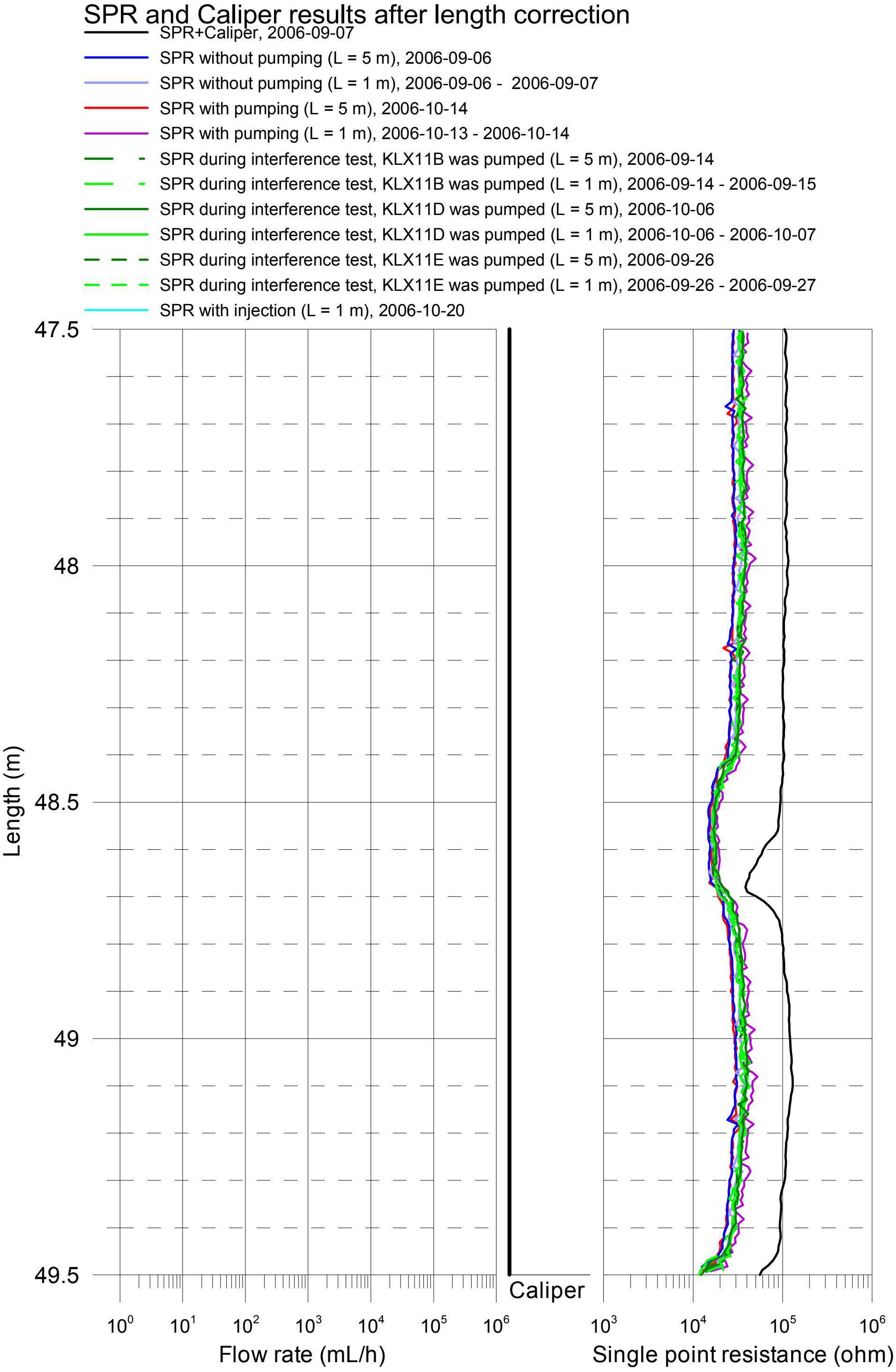


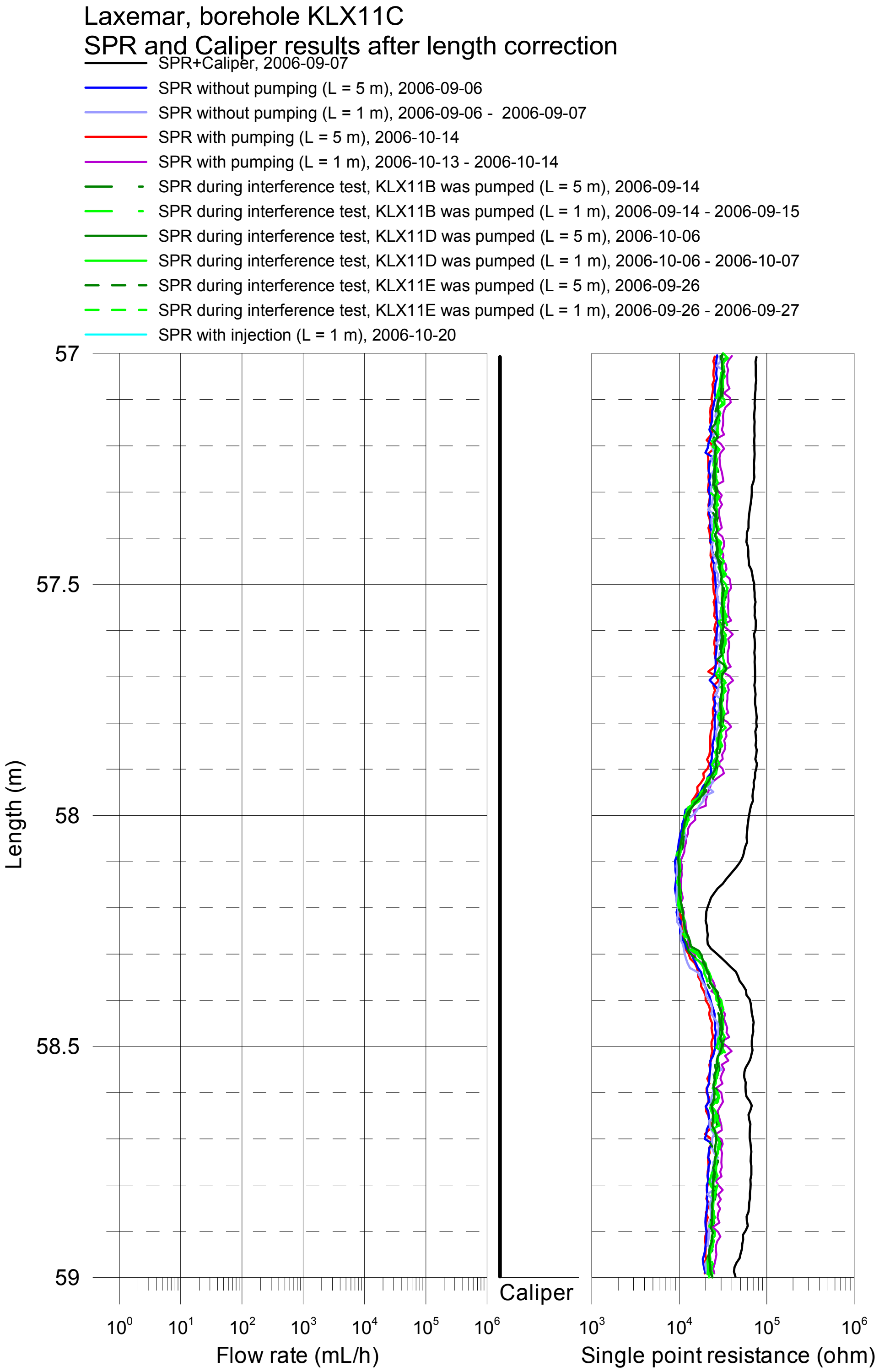
Appendix 2.2



Laxemar, borehole KLX11C
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-07
SPR without pumping (L = 5 m), 2006-09-06
SPR without pumping (L = 1 m), 2006-09-06 - 2006-09-07
SPR with pumping (L = 5 m), 2006-10-14
SPR with pumping (L = 1 m), 2006-10-13 - 2006-10-14
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-14
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-14 - 2006-09-15
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-06
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-06 - 2006-10-07
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-26
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-26 - 2006-09-27
SPR with injection (L = 1 m), 2006-10-20
Length (m)
46
46.5
47
47.5
48
Caliper
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)
10^3 10^4 10^5 10^6
Single point resistance (ohm)

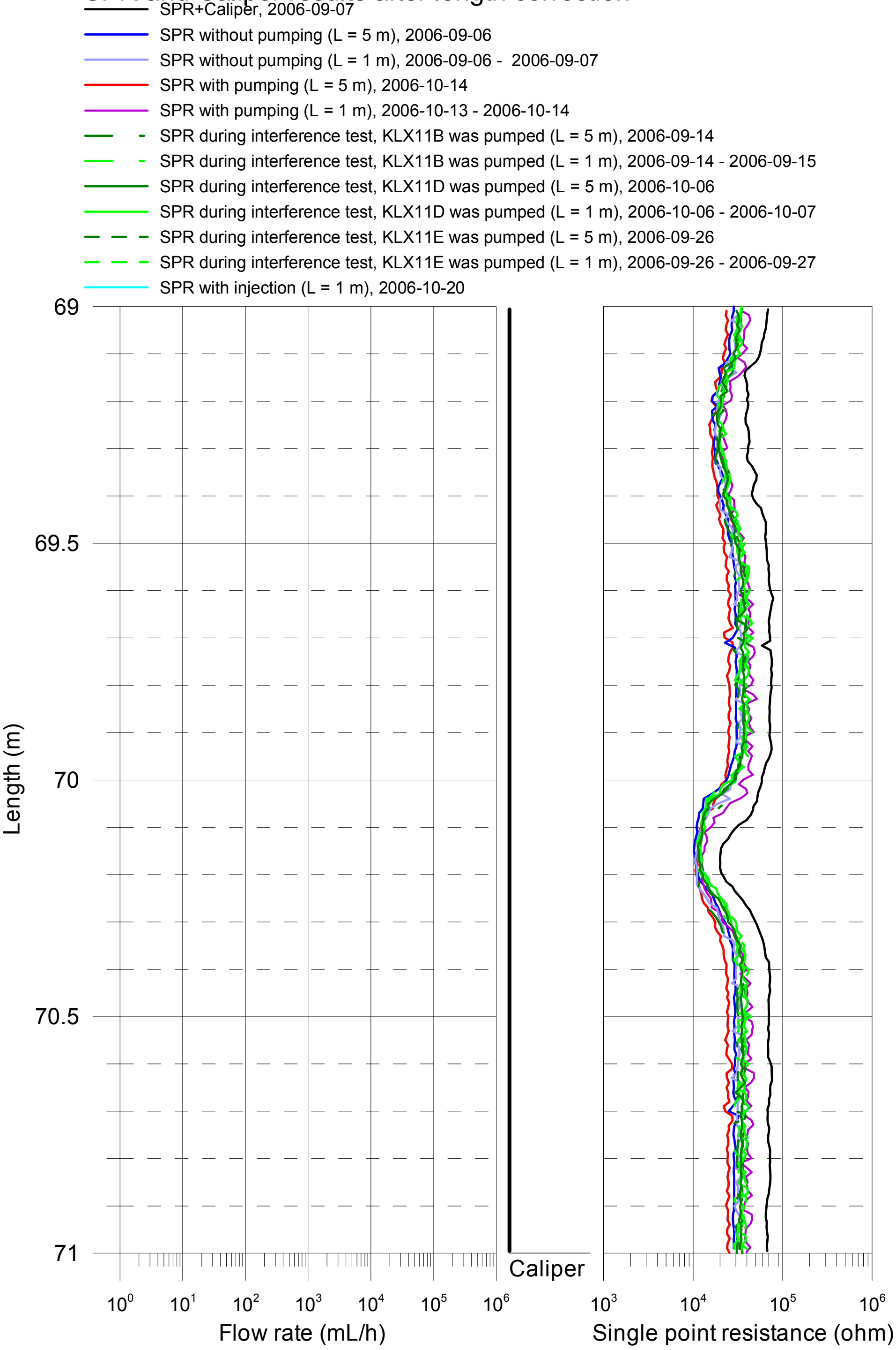
Laxemar, borehole KLX11C
SPR and Caliper results after length correction




Laxemar, borehole KLX11C
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-07
SPR without pumping (L = 5 m), 2006-09-06
SPR without pumping (L = 1 m), 2006-09-06 - 2006-09-07
SPR with pumping (L = 5 m), 2006-10-14
SPR with pumping (L = 1 m), 2006-10-13 - 2006-10-14
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-14
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-14 - 2006-09-15
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-06
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-06 - 2006-10-07
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-26
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-26 - 2006-09-27
SPR with injection (L = 1 m), 2006-10-20
Length (m)
57
57.5
58
58.5
59
Caliper
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)
10^3 10^4 10^5 10^6
Single point resistance (ohm)

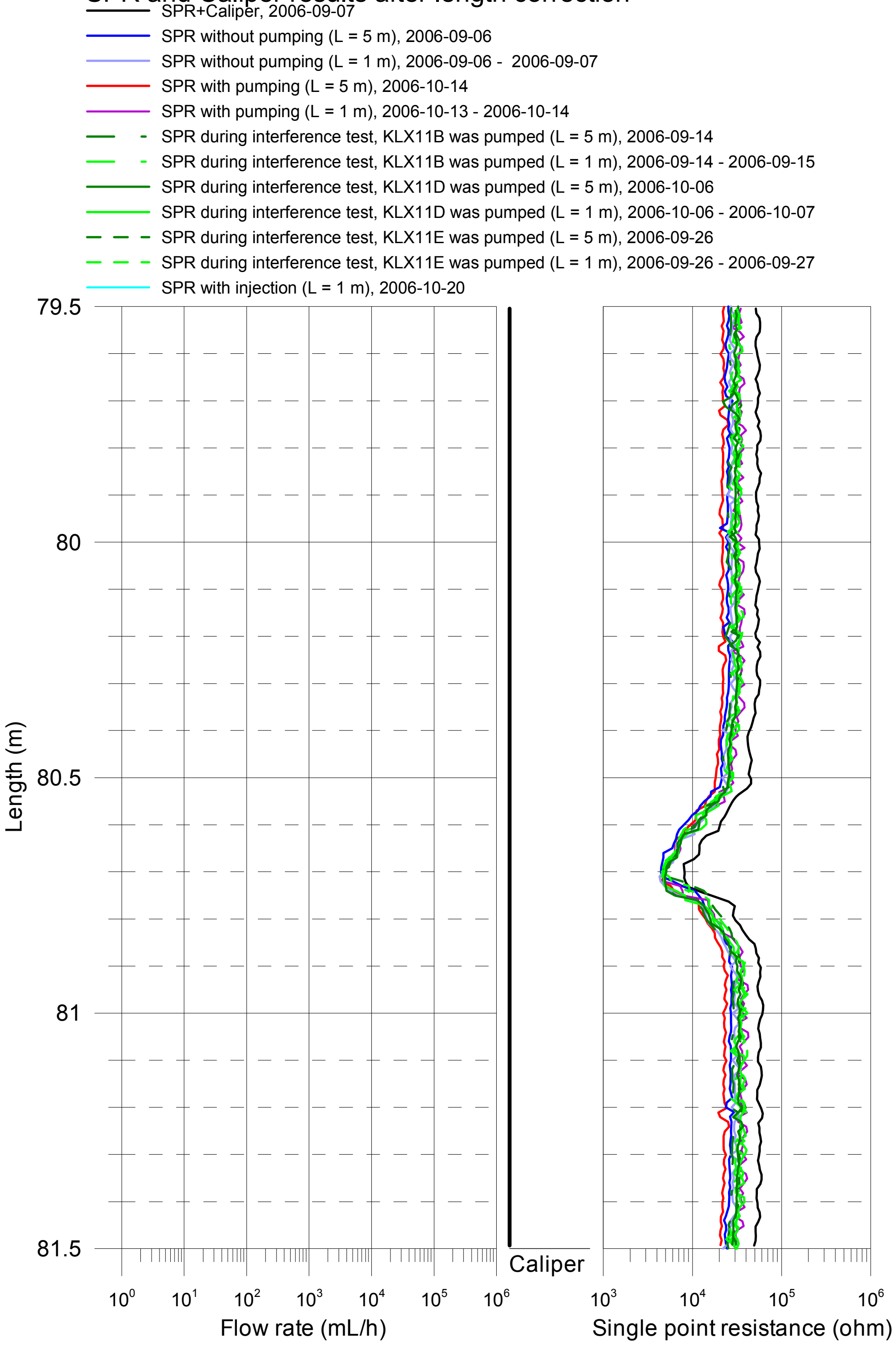
Appendix 2.5

Laxemar, borehole KLX11C
SPR and Caliper results after length correction

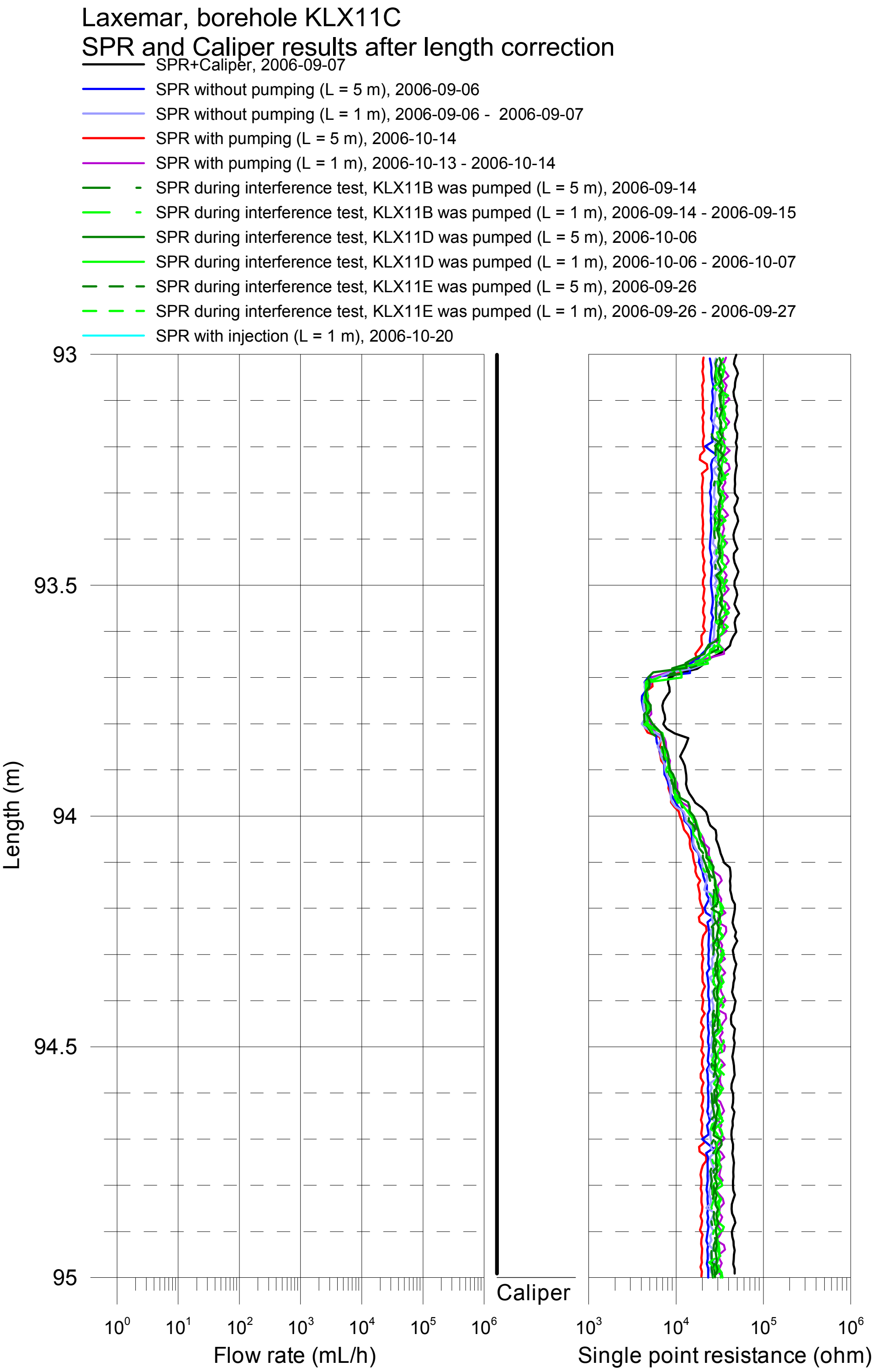


Appendix 2.6

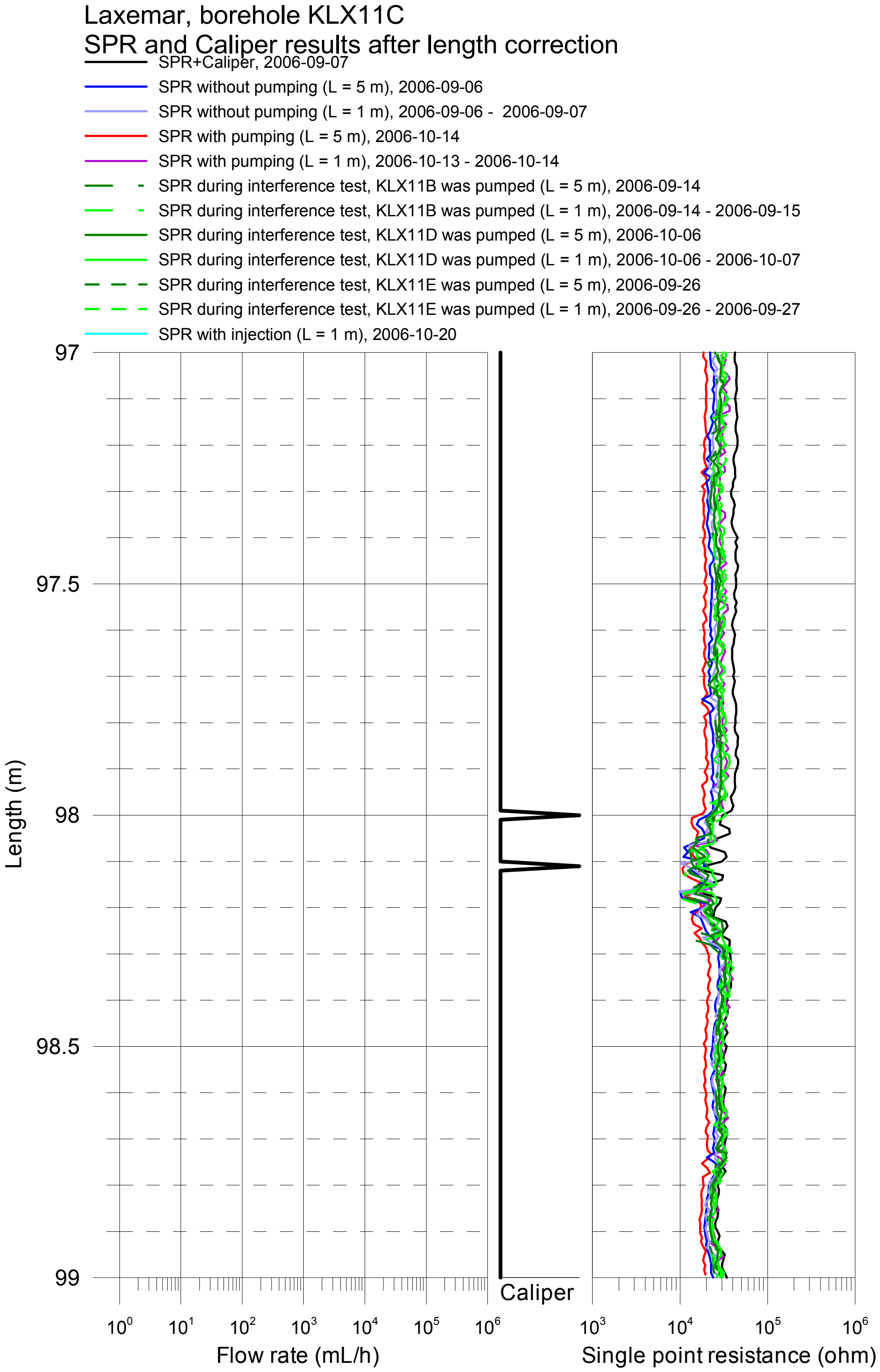
Laxemar, borehole KLX11C
SPR and Caliper results after length correction



Appendix 2.7

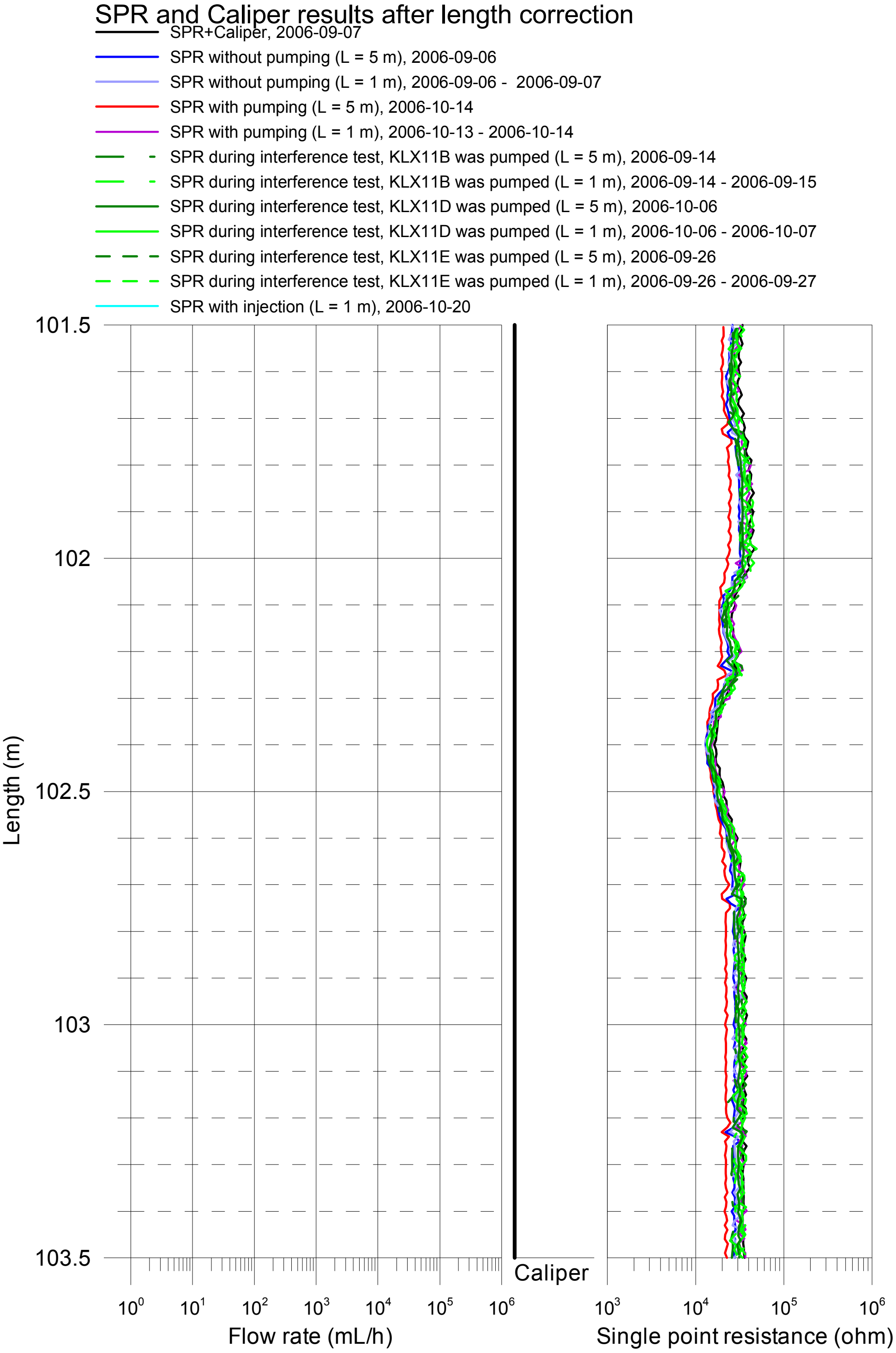

Laxemar, borehole KLX11C
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-07
SPR without pumping (L = 5 m), 2006-09-06
SPR without pumping (L = 1 m), 2006-09-06 - 2006-09-07
SPR with pumping (L = 5 m), 2006-10-14
SPR with pumping (L = 1 m), 2006-10-13 - 2006-10-14
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-14
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-14 - 2006-09-15
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-06
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-06 - 2006-10-07
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-26
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-26 - 2006-09-27
SPR with injection (L = 1 m), 2006-10-20
Length (m)
93
93.5
94
94.5
95
Caliper
Flow rate (mL/h)
Single point resistance (ohm)

Appendix 2.8


Laxemar, borehole KLX11C
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-07
SPR without pumping (L = 5 m), 2006-09-06
SPR without pumping (L = 1 m), 2006-09-06 - 2006-09-07
SPR with pumping (L = 5 m), 2006-10-14
SPR with pumping (L = 1 m), 2006-10-13 - 2006-10-14
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-14
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-14 - 2006-09-15
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-06
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-06 - 2006-10-07
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-26
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-26 - 2006-09-27
SPR with injection (L = 1 m), 2006-10-20
Length (m)
97
97.5
98
98.5
99
Caliper
Flow rate (mL/h)
Single point resistance (ohm)

Appendix 2.9

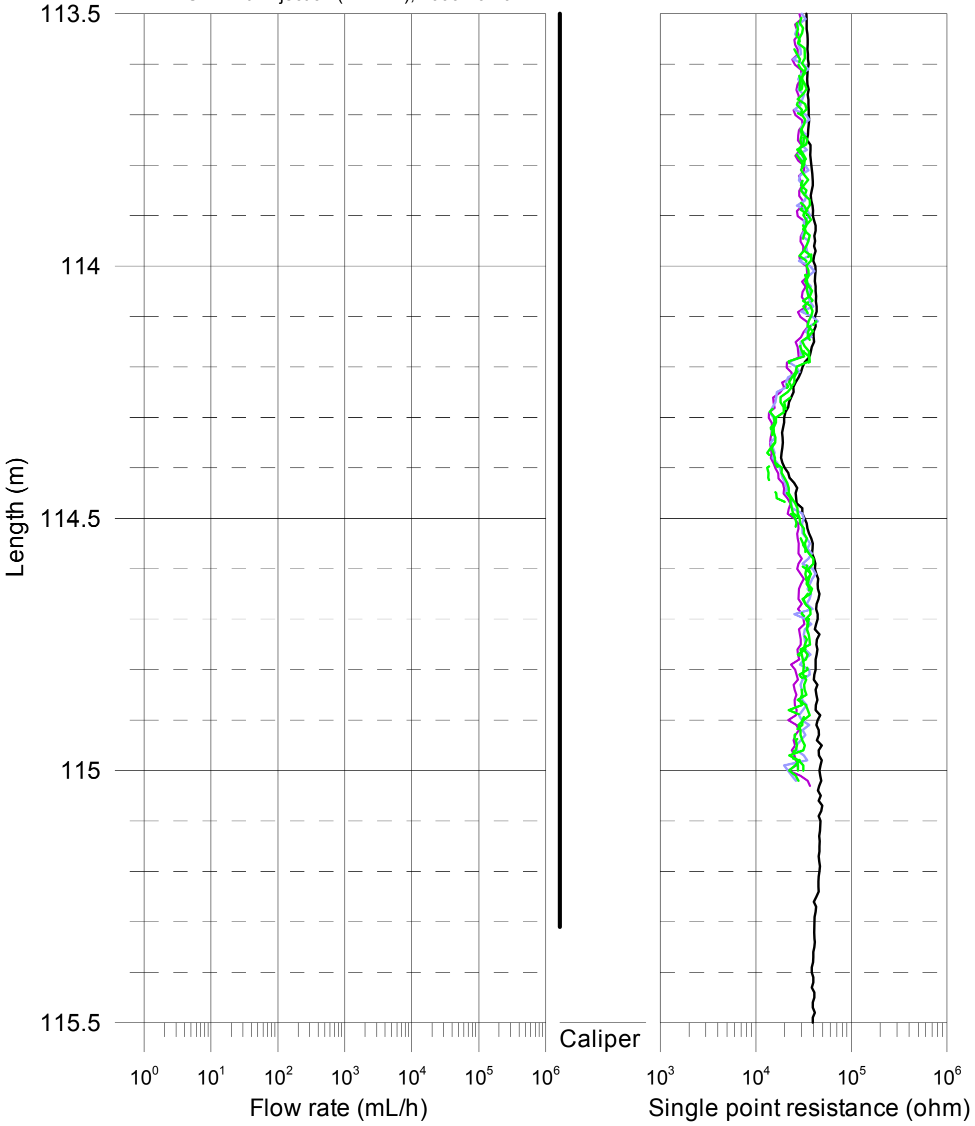
Laxemar, borehole KLX11C
SPR and Caliper results after length correction



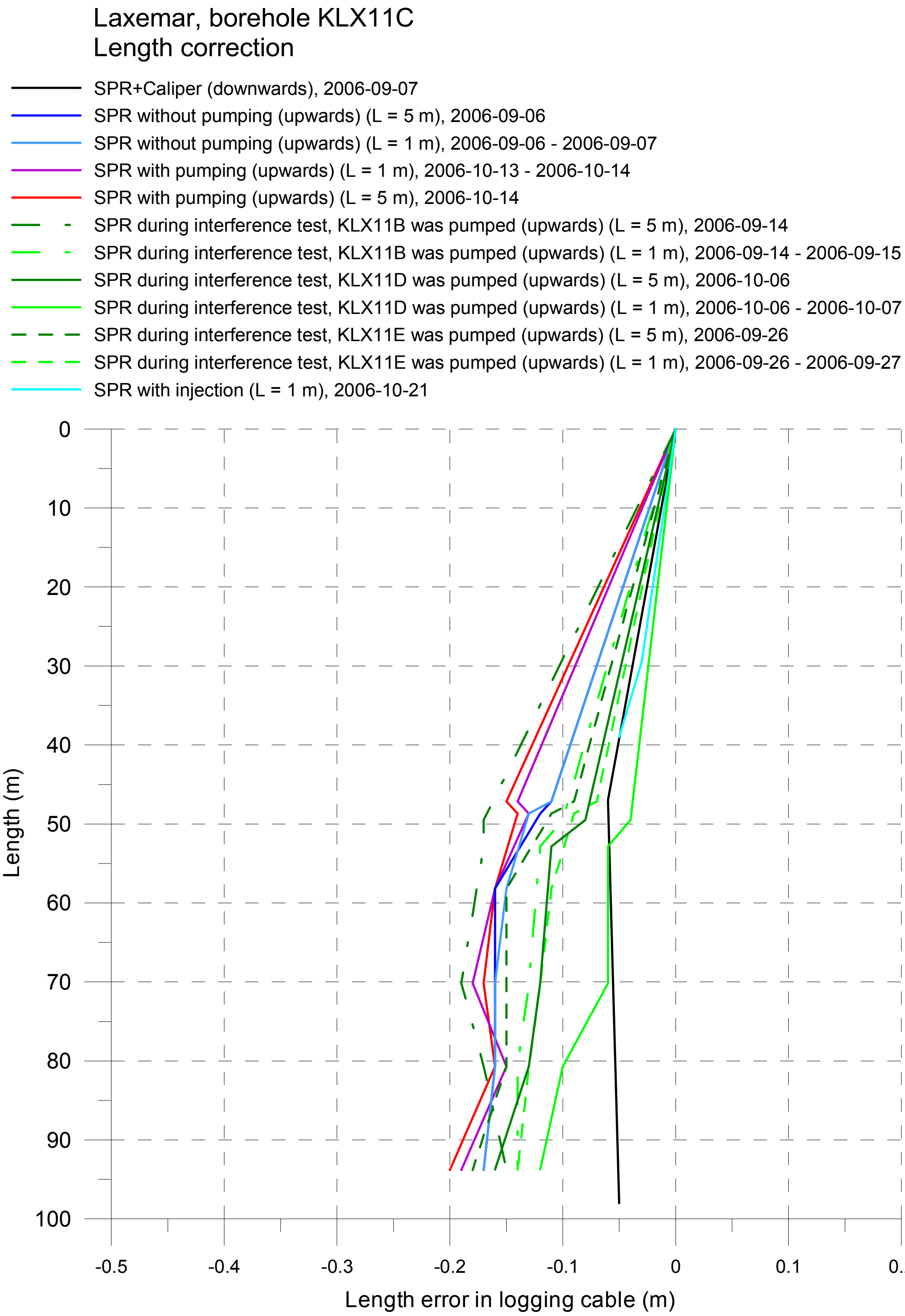
Appendix 2.10

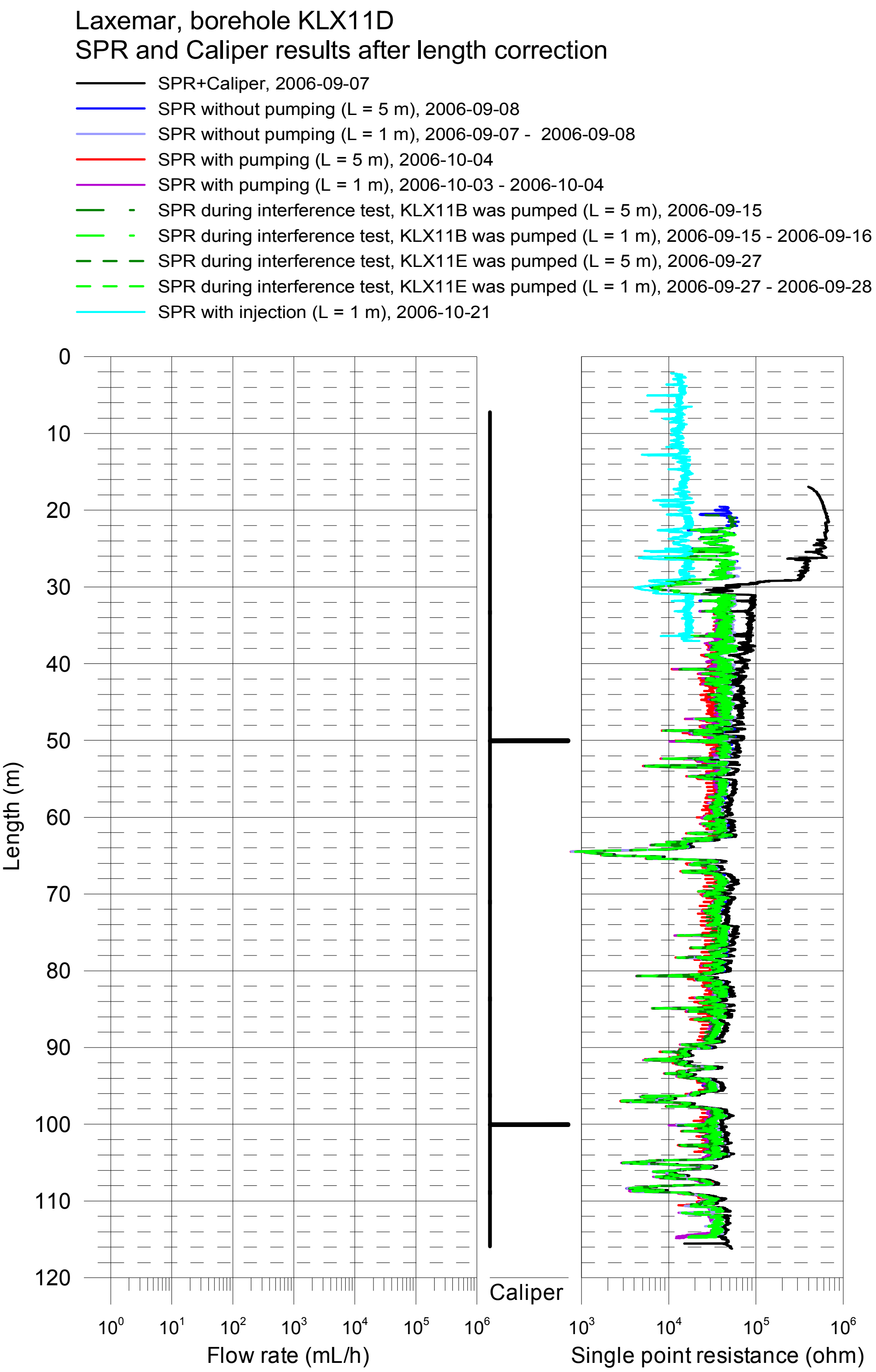
Laxemar, borehole KLX11C
SPR and Caliper results after length correction

SPR+Caliper, 2006-09-07
SPR without pumping (L = 5 m), 2006-09-06
SPR without pumping (L = 1 m), 2006-09-06 - 2006-09-07
SPR with pumping (L = 5 m), 2006-10-14
SPR with pumping (L = 1 m), 2006-10-13 - 2006-10-14
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-14
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-14 - 2006-09-15
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-06
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-06 - 2006-10-07
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-26
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-26 - 2006-09-27
SPR with injection (L = 1 m), 2006-10-20



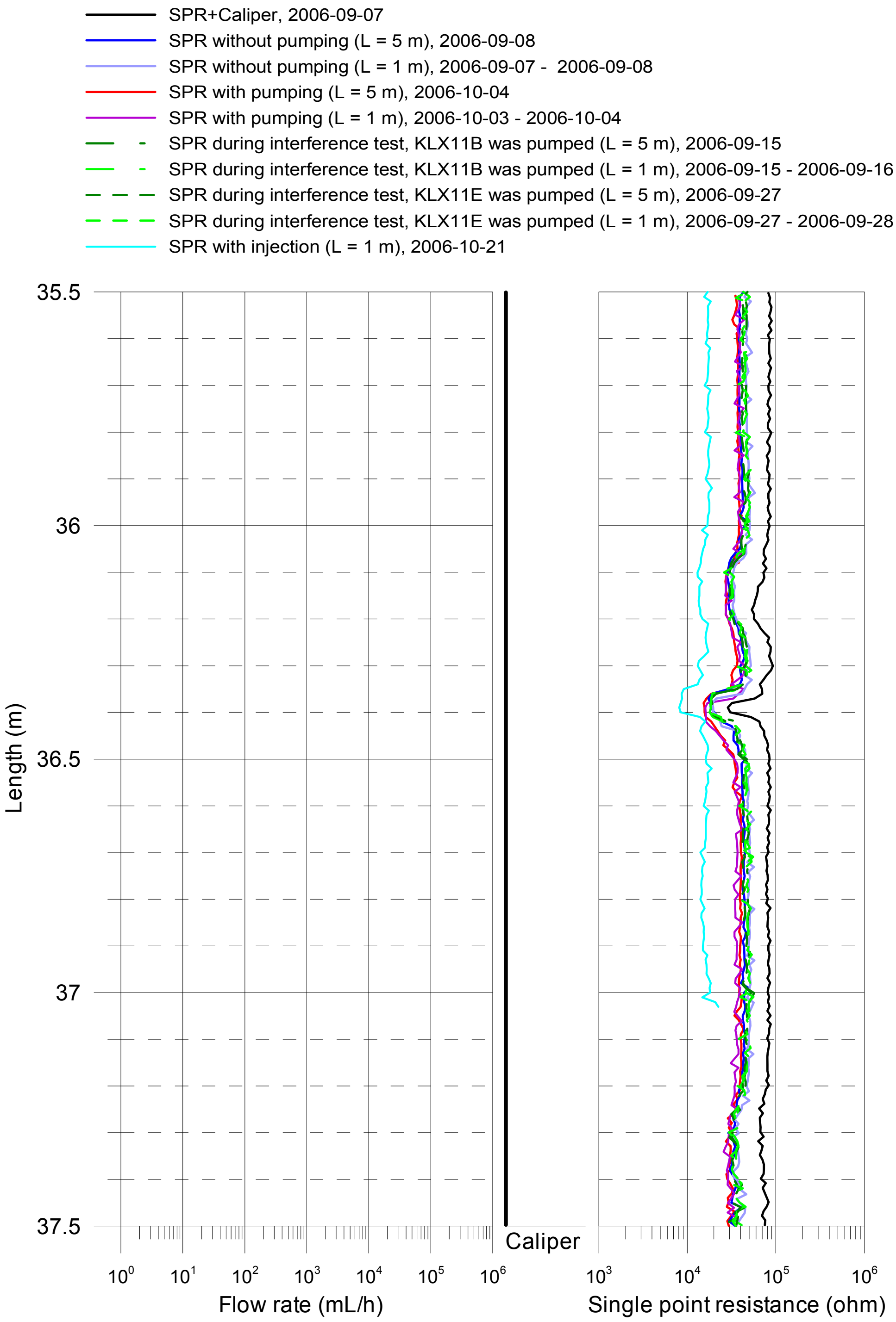
Appendix 2.11

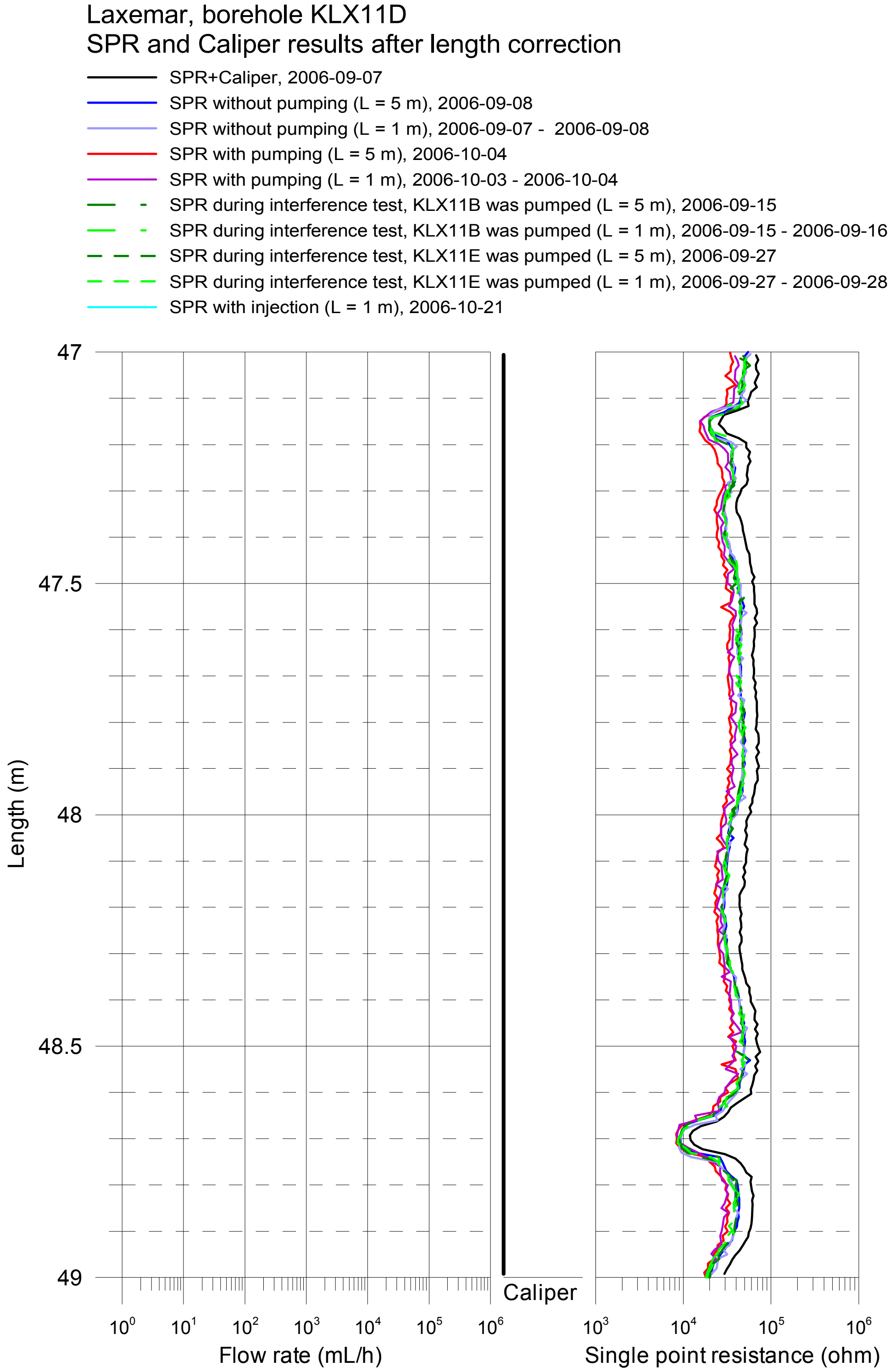



Laxemar, borehole KLX11D
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-07
SPR without pumping (L = 5 m), 2006-09-08
SPR without pumping (L = 1 m), 2006-09-07 - 2006-09-08
SPR with pumping (L = 5 m), 2006-10-04
SPR with pumping (L = 1 m), 2006-10-03 - 2006-10-04
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-15
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-15 - 2006-09-16
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-27
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-27 - 2006-09-28
SPR with injection (L = 1 m), 2006-10-21
Length (m)
Caliper
Flow rate (mL/h)
Single point resistance (ohm)

Appendix 3.2

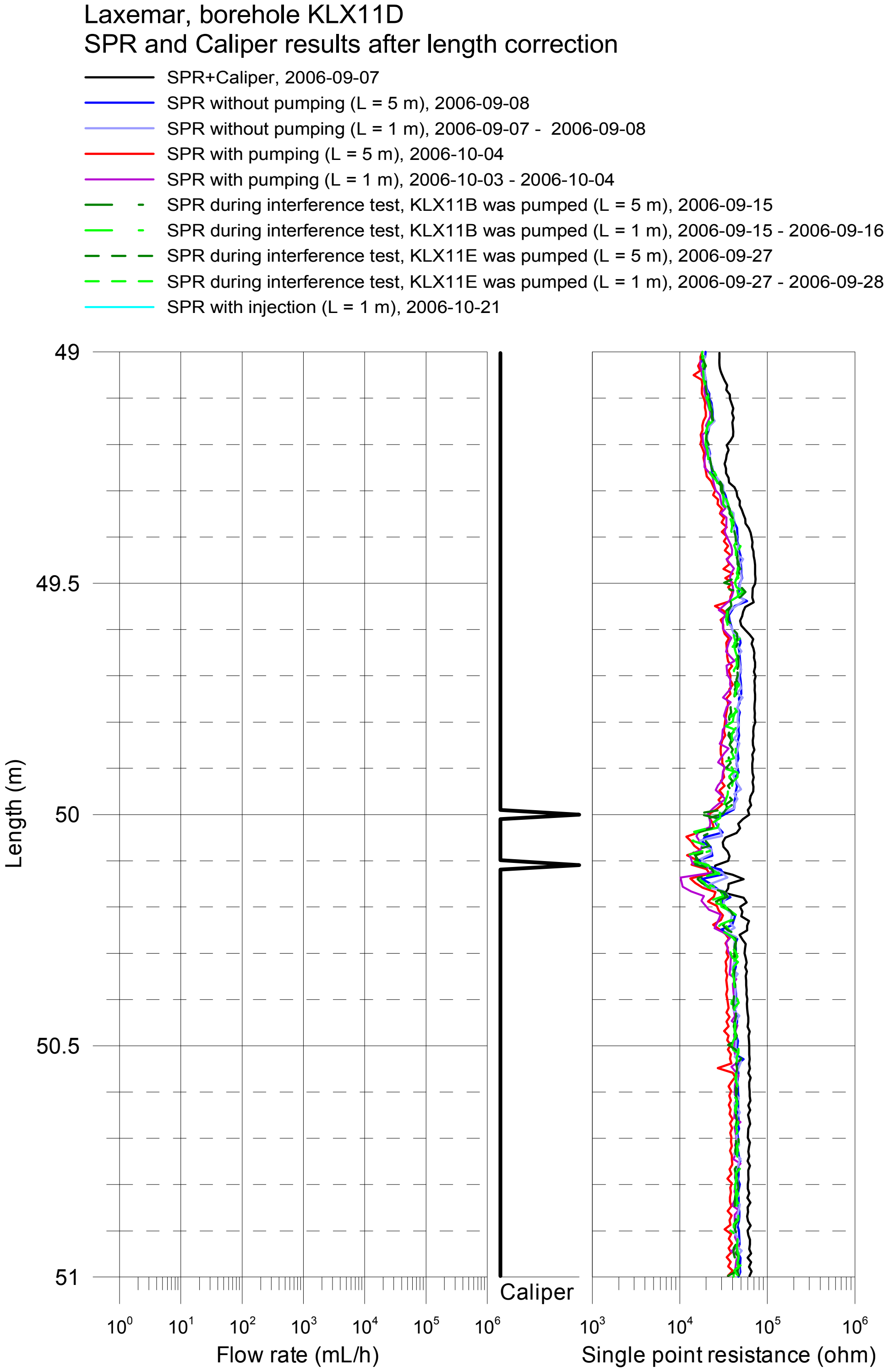
Laxemar, borehole KLX11D
SPR and Caliper results after length correction





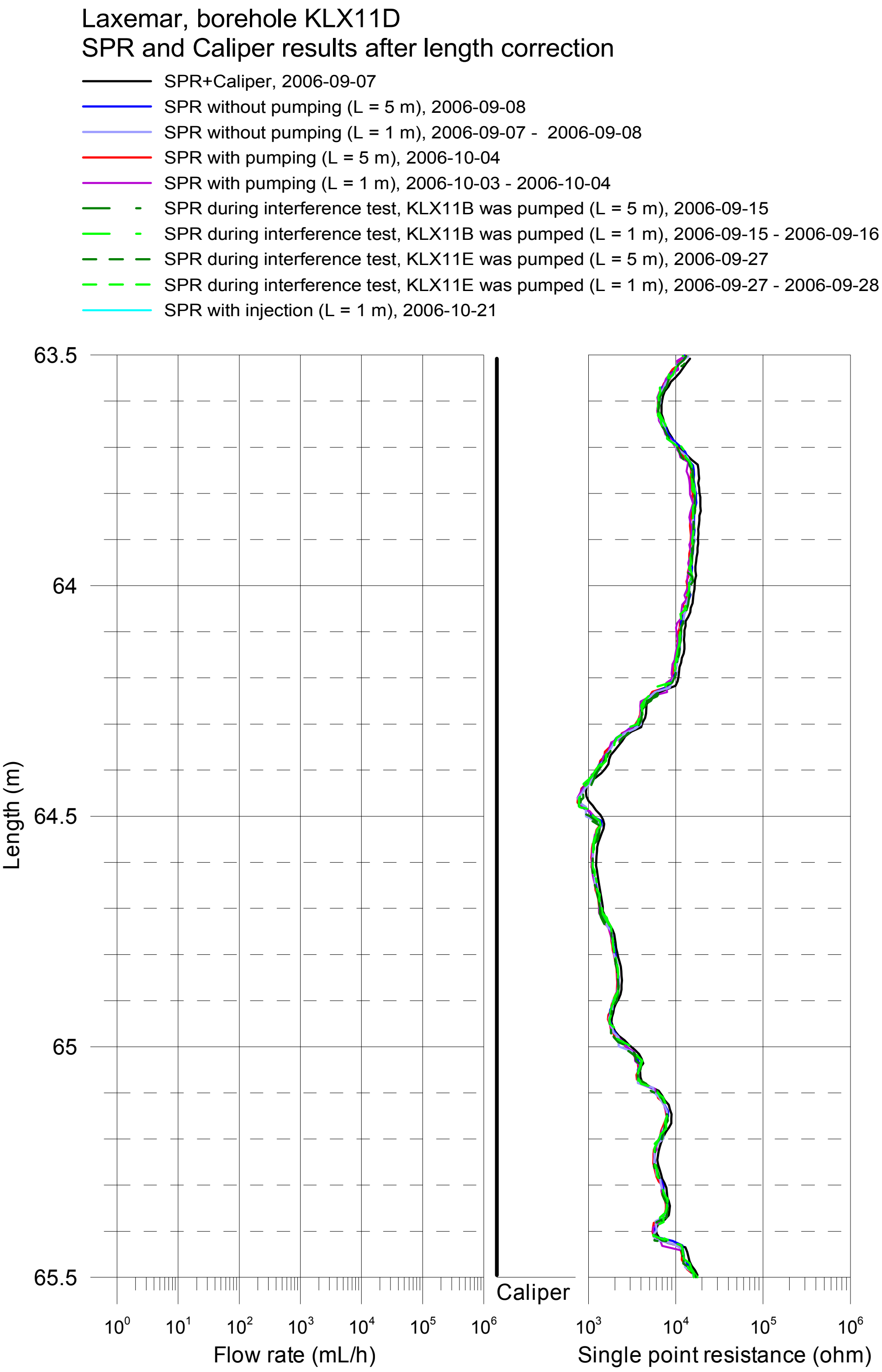
Laxemar, borehole KLX11D
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-07
SPR without pumping (L = 5 m), 2006-09-08
SPR without pumping (L = 1 m), 2006-09-07 - 2006-09-08
SPR with pumping (L = 5 m), 2006-10-04
SPR with pumping (L = 1 m), 2006-10-03 - 2006-10-04
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-15
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-15 - 2006-09-16
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-27
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-27 - 2006-09-28
SPR with injection (L = 1 m), 2006-10-21
Length (m)
47
47.5
48
48.5
49
Caliper
Flow rate (mL/h)
Single point resistance (ohm)

Appendix 3.4

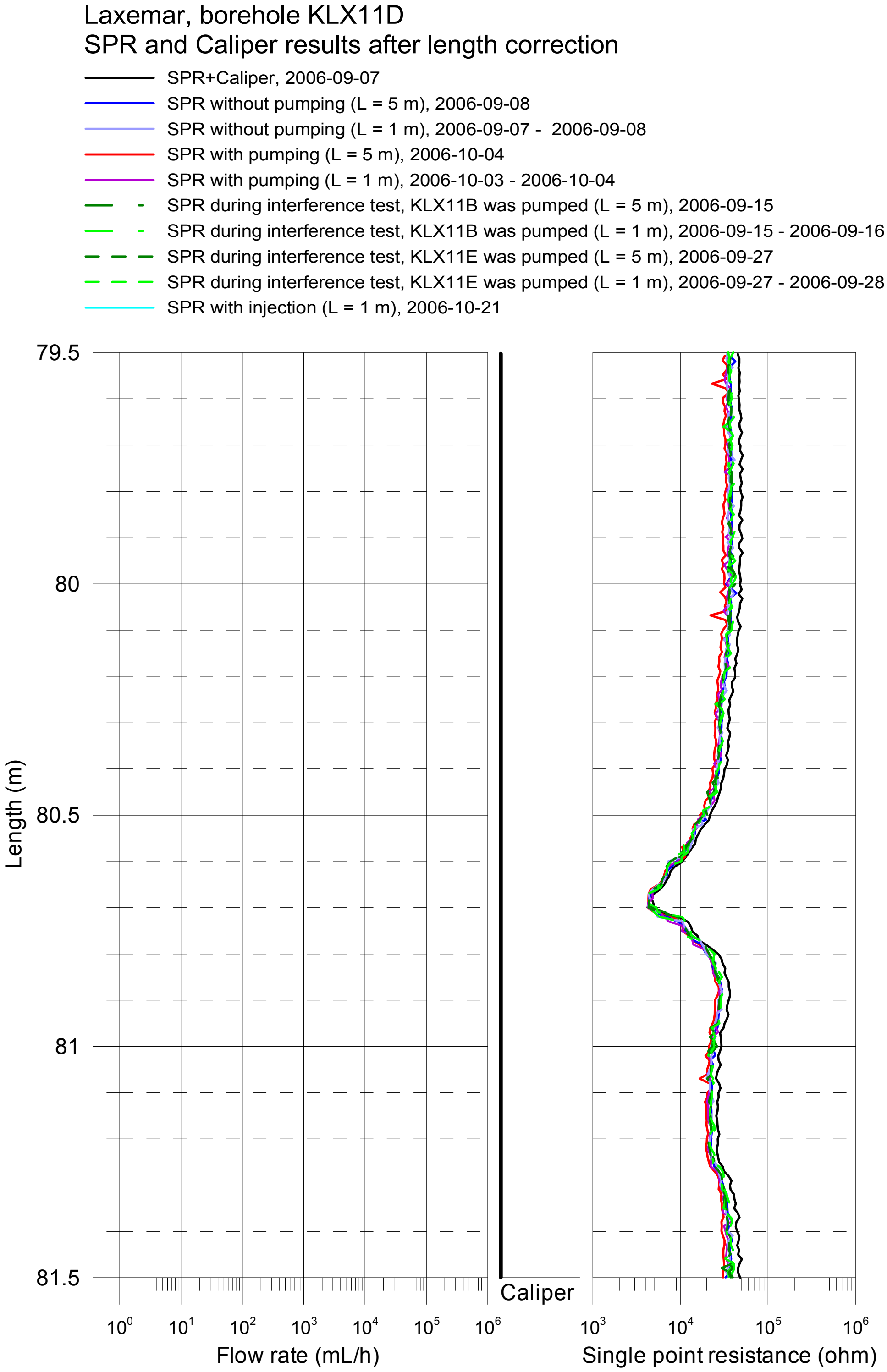


Laxemar, borehole KLX11D
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-07
SPR without pumping (L = 5 m), 2006-09-08
SPR without pumping (L = 1 m), 2006-09-07 - 2006-09-08
SPR with pumping (L = 5 m), 2006-10-04
SPR with pumping (L = 1 m), 2006-10-03 - 2006-10-04
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-15
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-15 - 2006-09-16
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-27
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-27 - 2006-09-28
SPR with injection (L = 1 m), 2006-10-21
Length (m)
49
49.5
50
50.5
51
Caliper
10^0
10^1
10^2
10^3
10^4
10^5
10^6
Flow rate (mL/h)
10^3
10^4
10^5
10^6
Single point resistance (ohm)

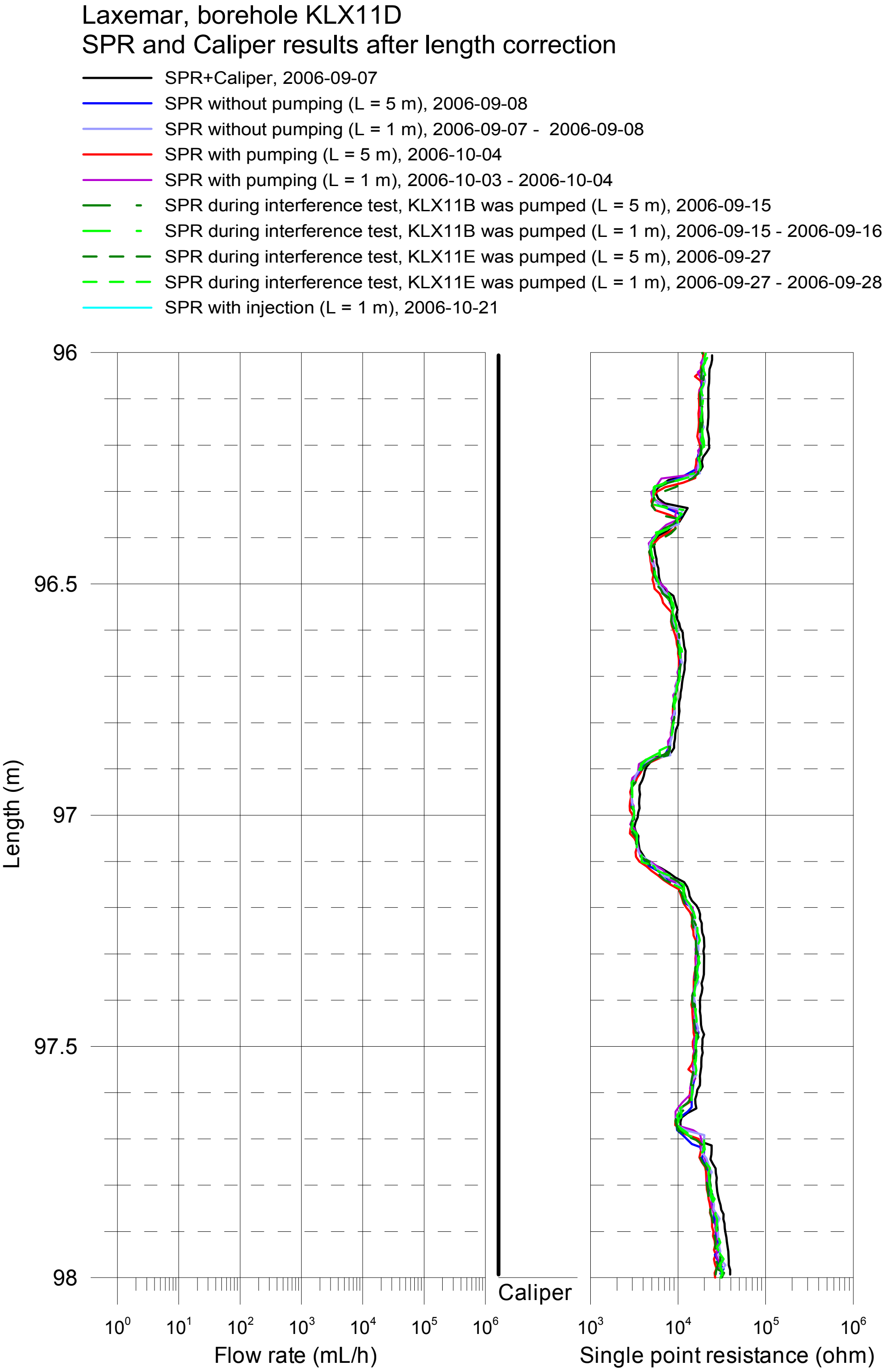
Appendix 3.5



Laxemar, borehole KLX11D
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-07
SPR without pumping (L = 5 m), 2006-09-08
SPR without pumping (L = 1 m), 2006-09-07 - 2006-09-08
SPR with pumping (L = 5 m), 2006-10-04
SPR with pumping (L = 1 m), 2006-10-03 - 2006-10-04
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-15
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-15 - 2006-09-16
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-27
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-27 - 2006-09-28
SPR with injection (L = 1 m), 2006-10-21
63.5
64
64.5
65
65.5
Length (m)
Caliper
10^0
10^1
10^2
10^3
10^4
10^5
10^6
Flow rate (mL/h)
10^3
10^4
10^5
10^6
Single point resistance (ohm)

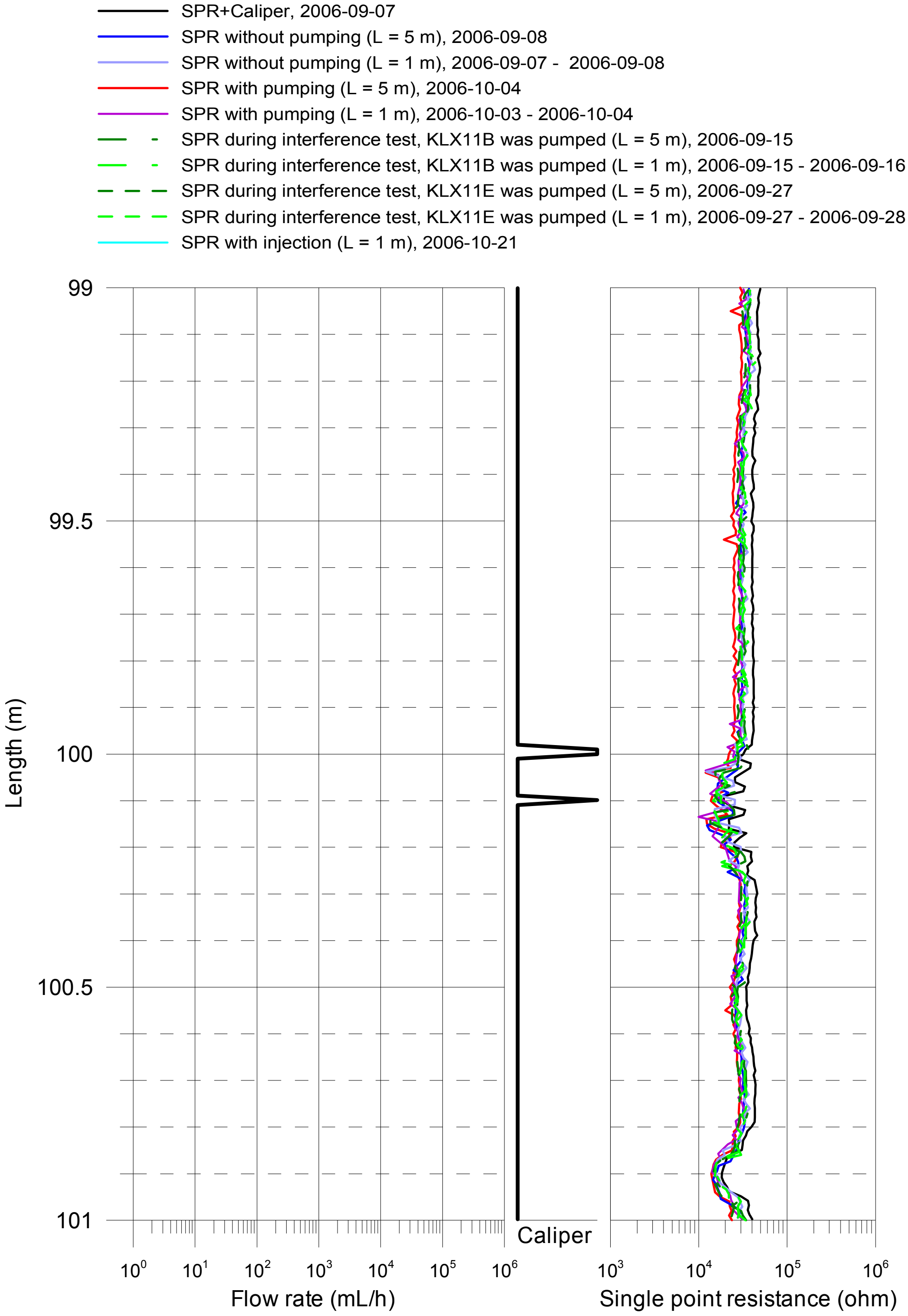

Laxemar, borehole KLX11D
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-07
SPR without pumping (L = 5 m), 2006-09-08
SPR without pumping (L = 1 m), 2006-09-07 - 2006-09-08
SPR with pumping (L = 5 m), 2006-10-04
SPR with pumping (L = 1 m), 2006-10-03 - 2006-10-04
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-15
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-15 - 2006-09-16
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-27
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-27 - 2006-09-28
SPR with injection (L = 1 m), 2006-10-21
Length (m)
79.5
80
80.5
81
81.5
Caliper
Flow rate (mL/h)
Single point resistance (ohm)

Appendix 3.7

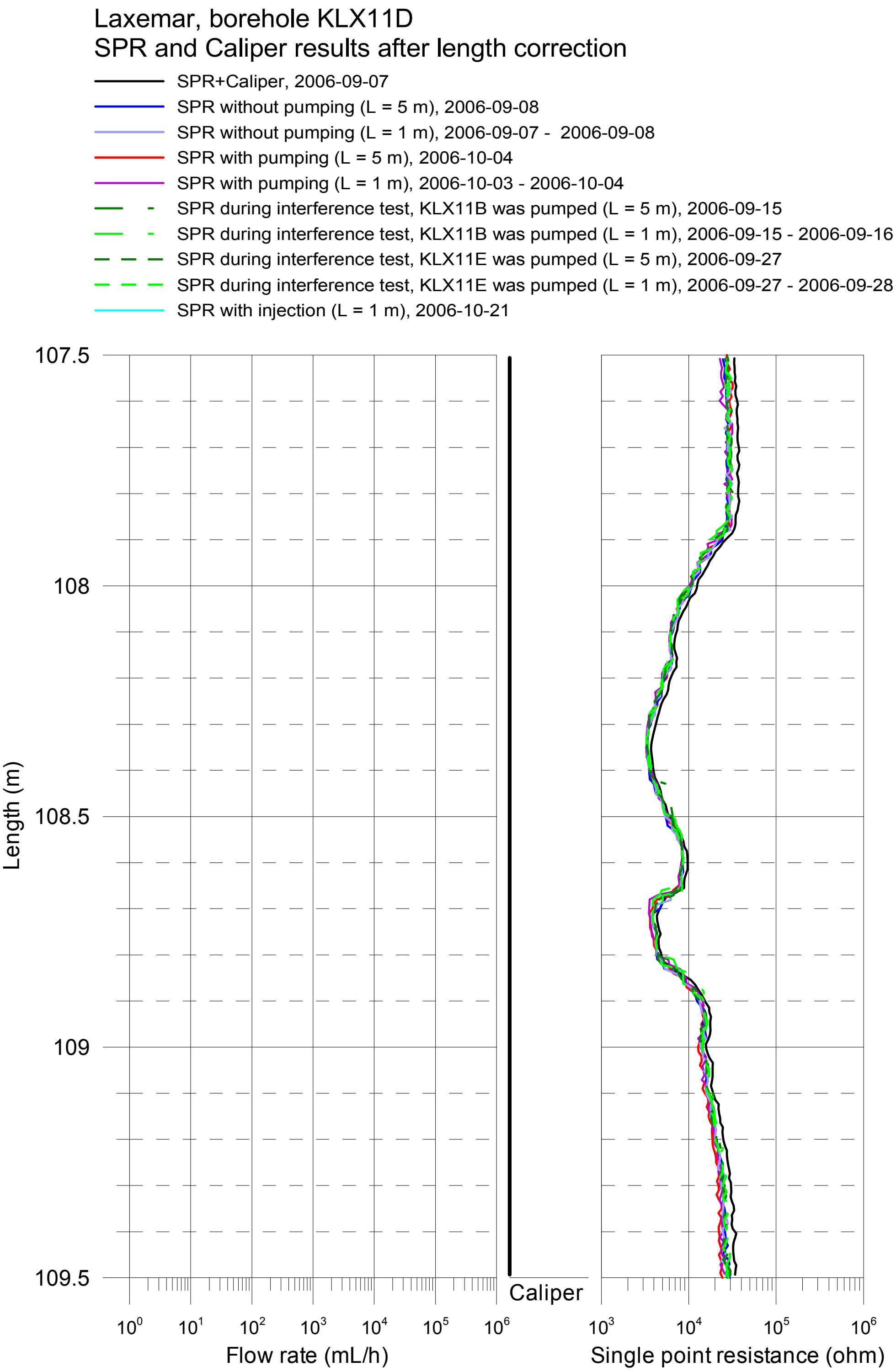


Laxemar, borehole KLX11D
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-07
SPR without pumping (L = 5 m), 2006-09-08
SPR without pumping (L = 1 m), 2006-09-07 - 2006-09-08
SPR with pumping (L = 5 m), 2006-10-04
SPR with pumping (L = 1 m), 2006-10-03 - 2006-10-04
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-15
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-15 - 2006-09-16
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-27
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-27 - 2006-09-28
SPR with injection (L = 1 m), 2006-10-21
96
96.5
97
97.5
98
Length (m)
Caliper
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)
10^3 10^4 10^5 10^6
Single point resistance (ohm)

Laxemar, borehole KLX11D
SPR and Caliper results after length correction

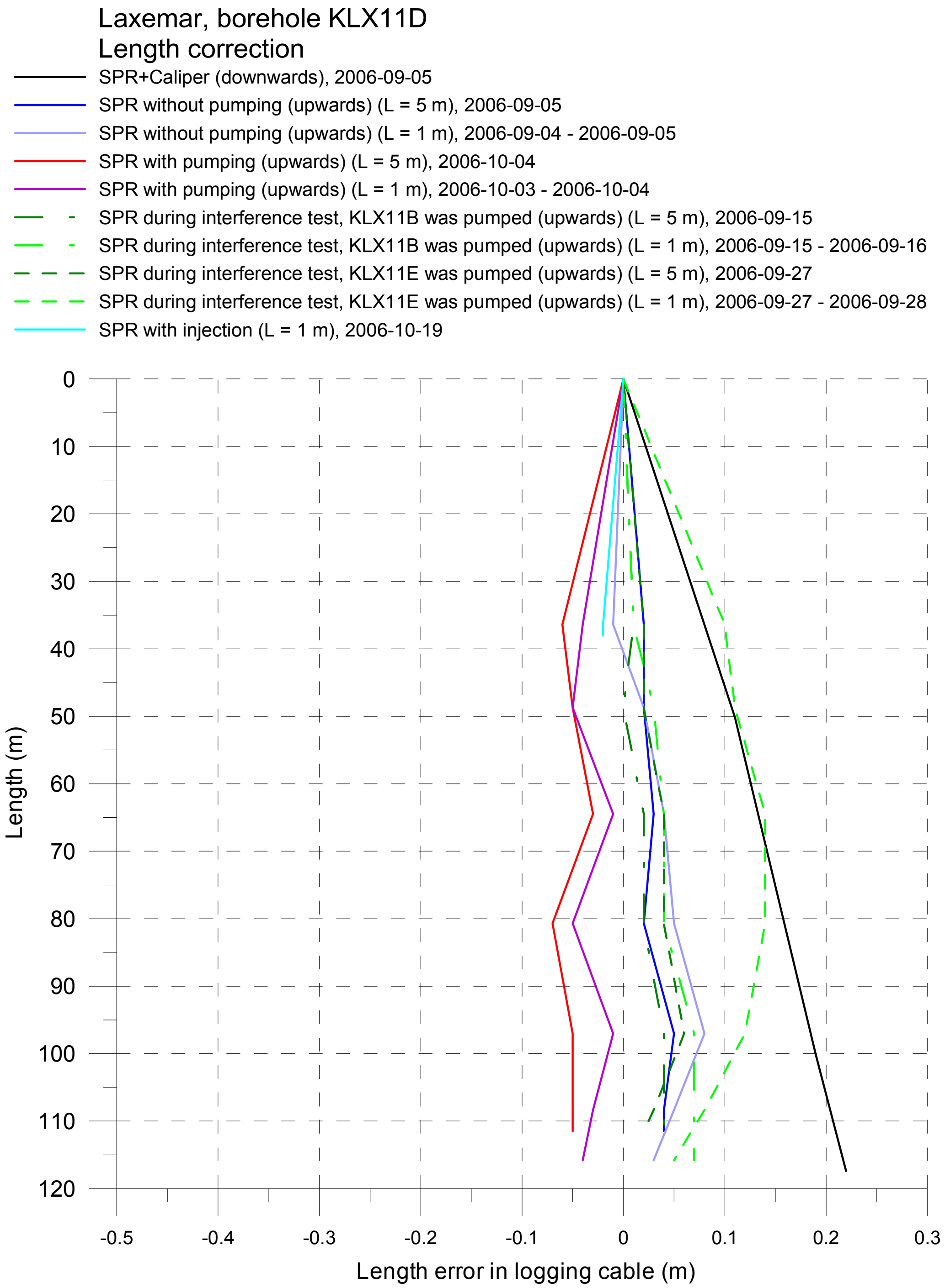


Appendix 3.9

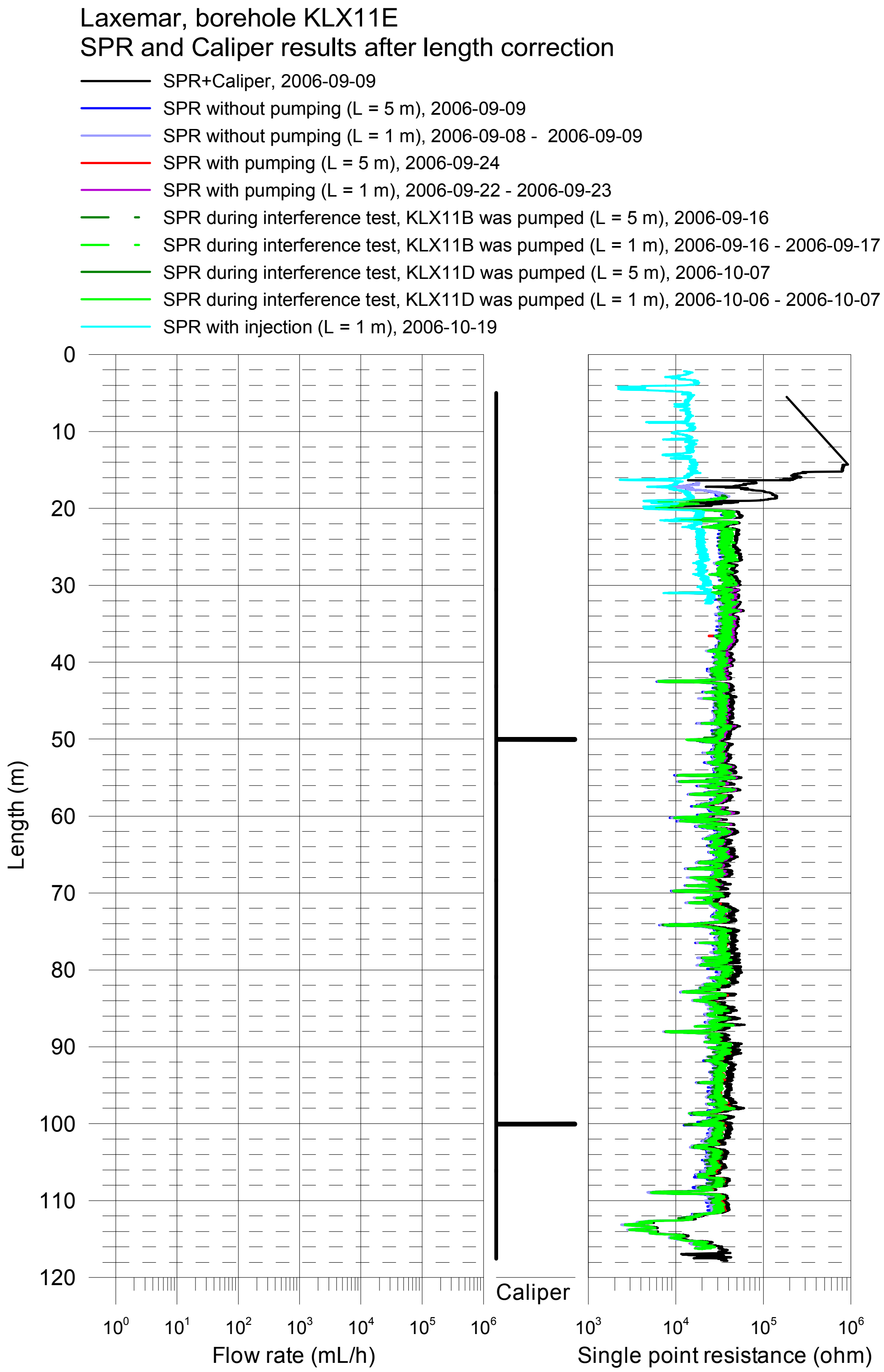


Laxemar, borehole KLX11D
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-07
SPR without pumping (L = 5 m), 2006-09-08
SPR without pumping (L = 1 m), 2006-09-07 - 2006-09-08
SPR with pumping (L = 5 m), 2006-10-04
SPR with pumping (L = 1 m), 2006-10-03 - 2006-10-04
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-15
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-15 - 2006-09-16
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-27
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-27 - 2006-09-28
SPR with injection (L = 1 m), 2006-10-21
107.5
108
108.5
109
109.5
Length (m)
Caliper
Flow rate (mL/h)
Single point resistance (ohm)

Appendix 3.10

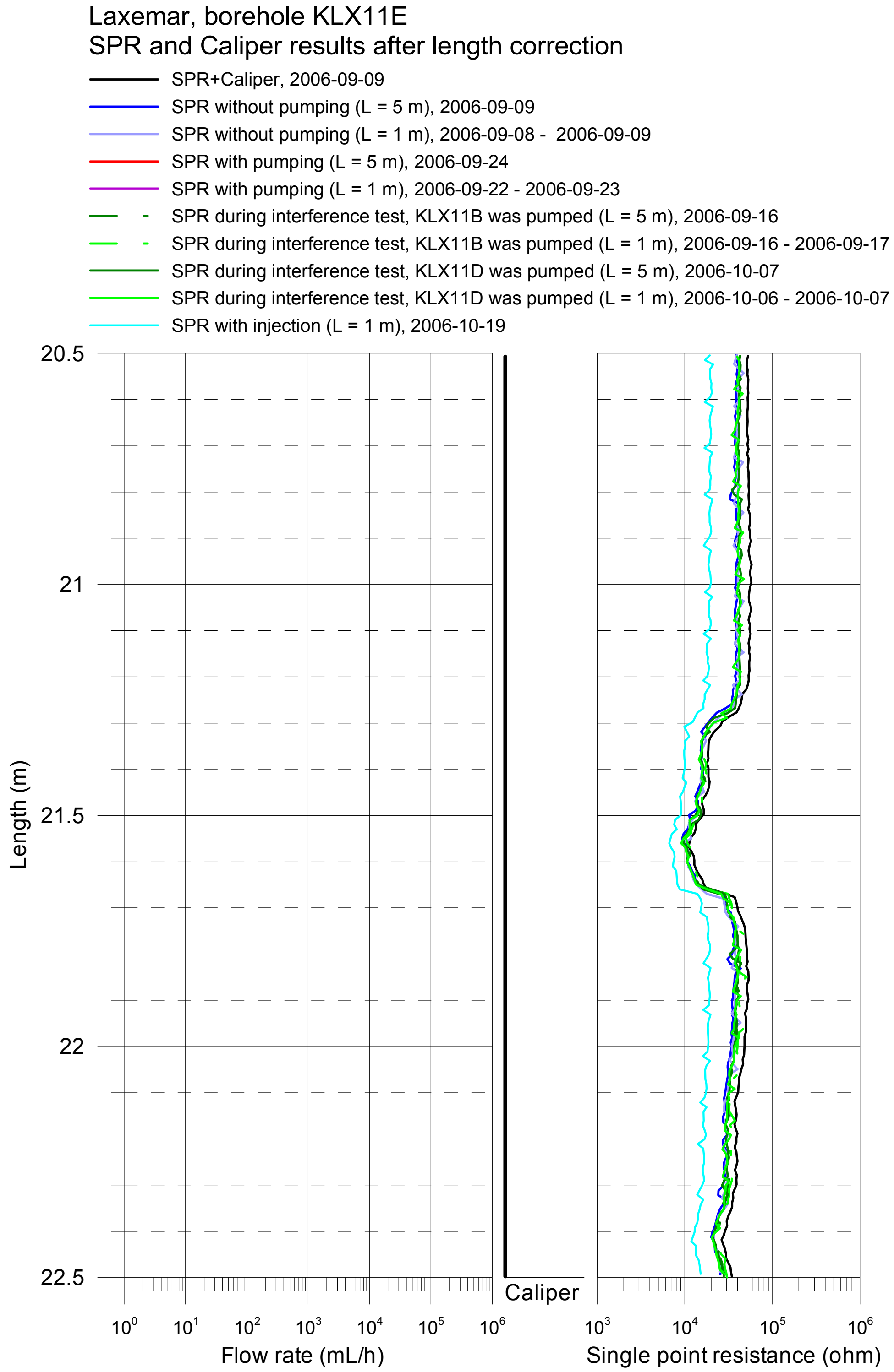


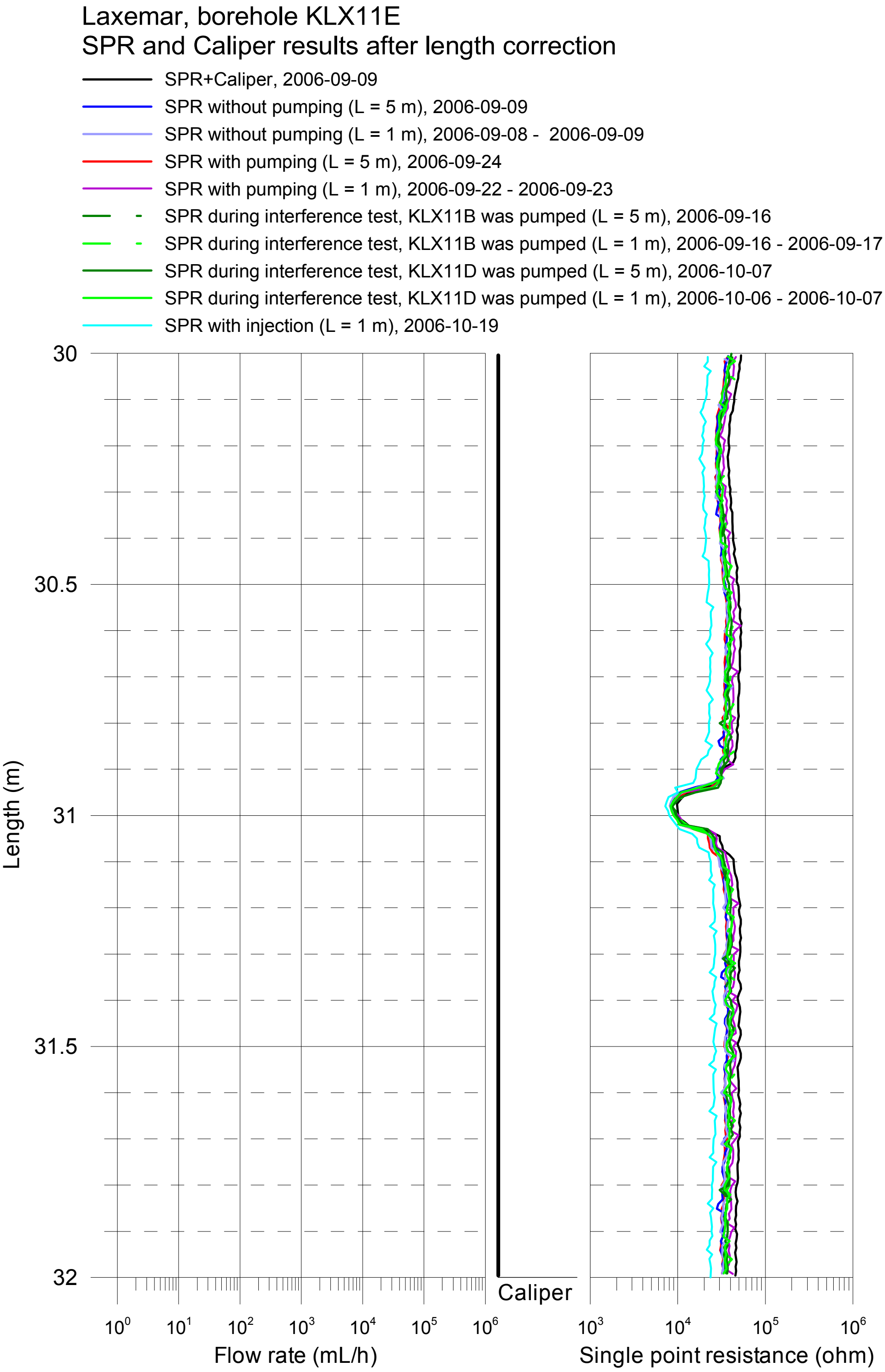
Appendix 4.1



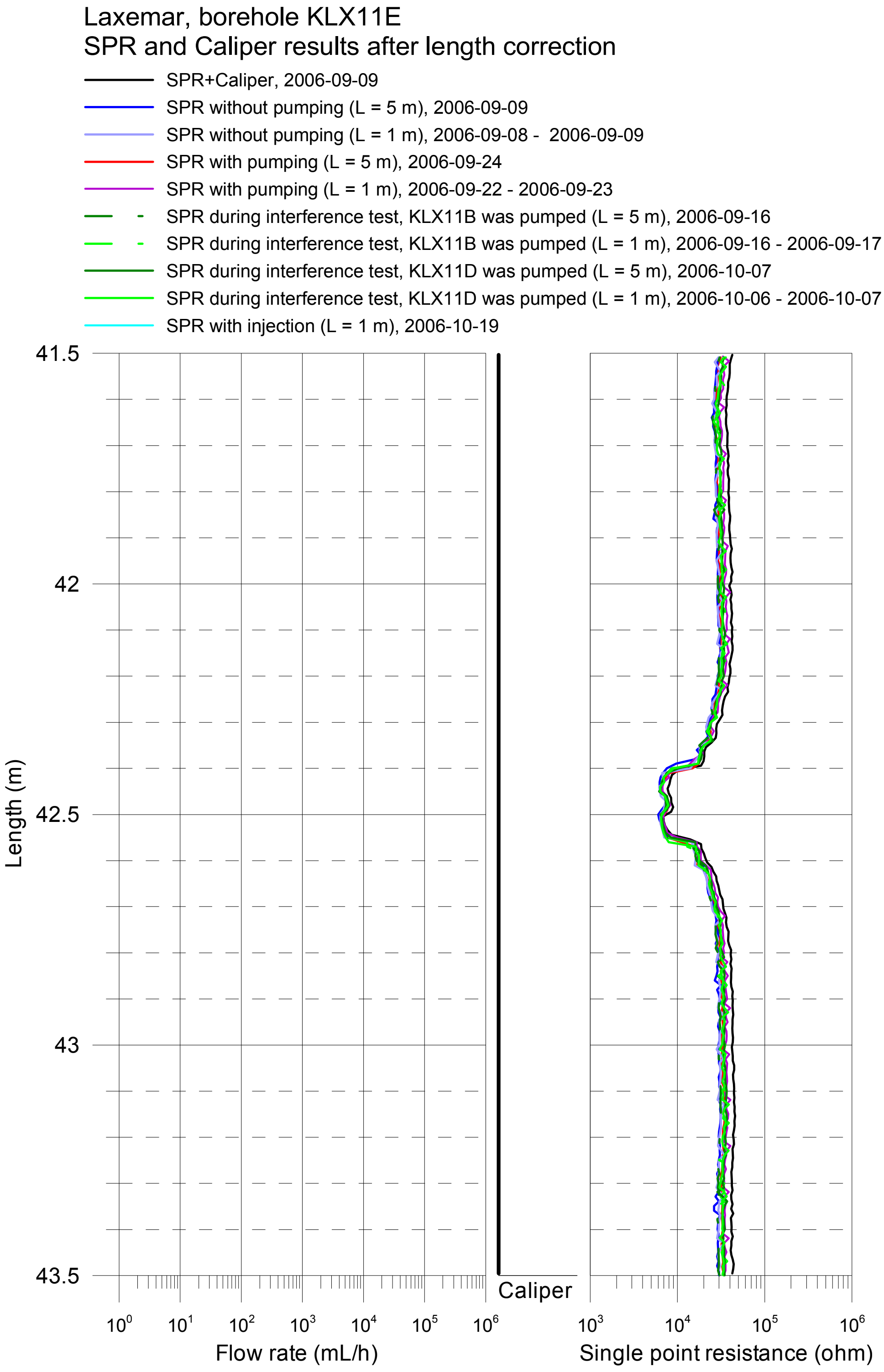
Laxemar, borehole KLX11E
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-09
SPR without pumping (L = 5 m), 2006-09-09
SPR without pumping (L = 1 m), 2006-09-08 - 2006-09-09
SPR with pumping (L = 5 m), 2006-09-24
SPR with pumping (L = 1 m), 2006-09-22 - 2006-09-23
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-16
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-16 - 2006-09-17
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-07
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-06 - 2006-10-07
SPR with injection (L = 1 m), 2006-10-19
Length (m)
Caliper
Flow rate (mL/h)
Single point resistance (ohm)

Appendix 4.2


Laxemar, borehole KLX11E
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-09
SPR without pumping (L = 5 m), 2006-09-09
SPR without pumping (L = 1 m), 2006-09-08 - 2006-09-09
SPR with pumping (L = 5 m), 2006-09-24
SPR with pumping (L = 1 m), 2006-09-22 - 2006-09-23
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-16
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-16 - 2006-09-17
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-07
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-06 - 2006-10-07
SPR with injection (L = 1 m), 2006-10-19
Length (m)
20.5
21
21.5
22
22.5
Caliper
10^0
10^1
10^2
10^3
10^4
10^5
10^6
Flow rate (mL/h)
10^3
10^4
10^5
10^6
Single point resistance (ohm)

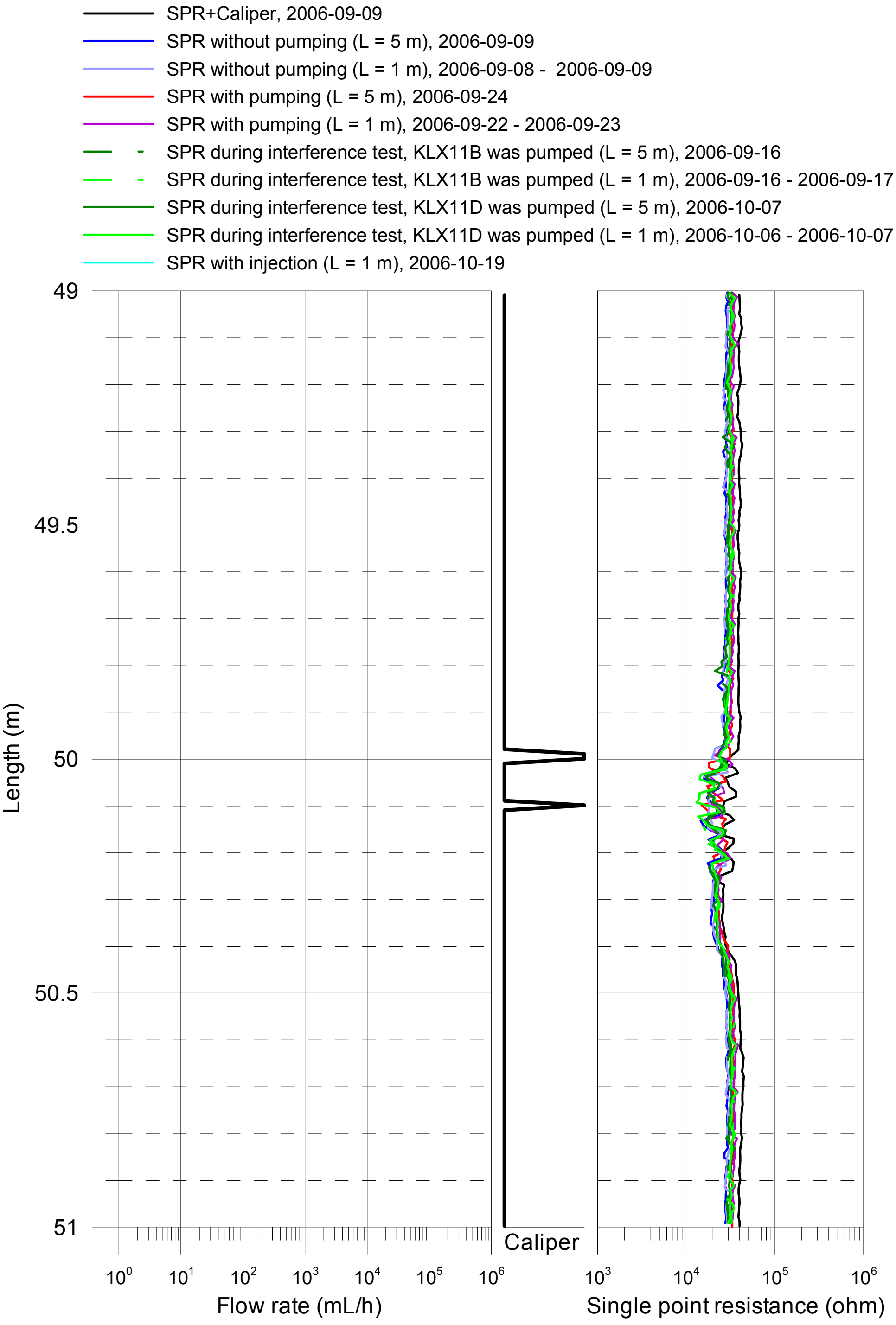

Laxemar, borehole KLX11E
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-09
SPR without pumping (L = 5 m), 2006-09-09
SPR without pumping (L = 1 m), 2006-09-08 - 2006-09-09
SPR with pumping (L = 5 m), 2006-09-24
SPR with pumping (L = 1 m), 2006-09-22 - 2006-09-23
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-16
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-16 - 2006-09-17
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-07
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-06 - 2006-10-07
SPR with injection (L = 1 m), 2006-10-19
Length (m)
30
30.5
31
31.5
32
Caliper
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)
10^3 10^4 10^5 10^6
Single point resistance (ohm)

Appendix 4.4

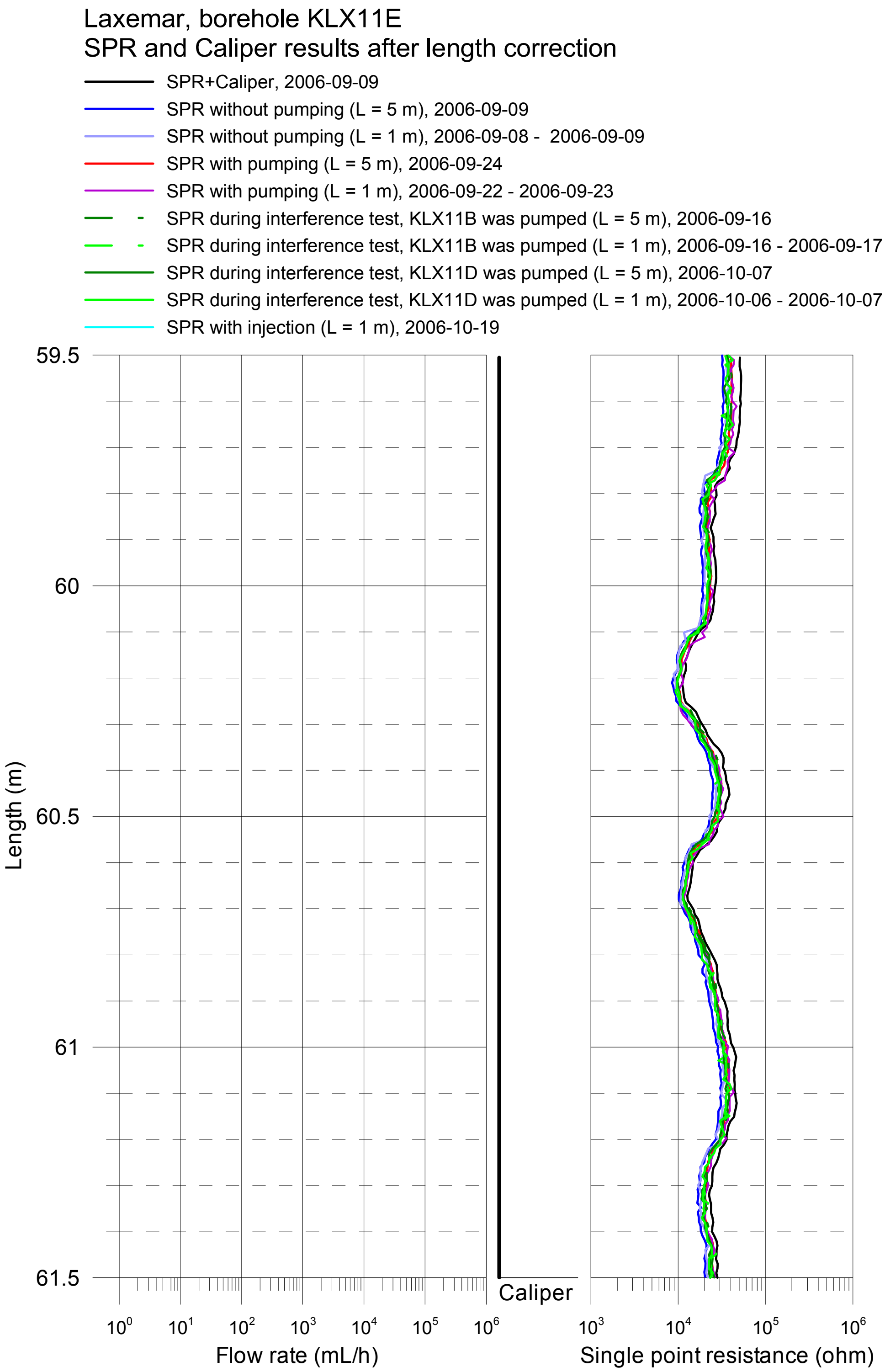

Laxemar, borehole KLX11E
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-09
SPR without pumping (L = 5 m), 2006-09-09
SPR without pumping (L = 1 m), 2006-09-08 - 2006-09-09
SPR with pumping (L = 5 m), 2006-09-24
SPR with pumping (L = 1 m), 2006-09-22 - 2006-09-23
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-16
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-16 - 2006-09-17
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-07
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-06 - 2006-10-07
SPR with injection (L = 1 m), 2006-10-19
Length (m)
41.5
42
42.5
43
43.5
Caliper
Flow rate (mL/h)
Single point resistance (ohm)

Appendix 4.5

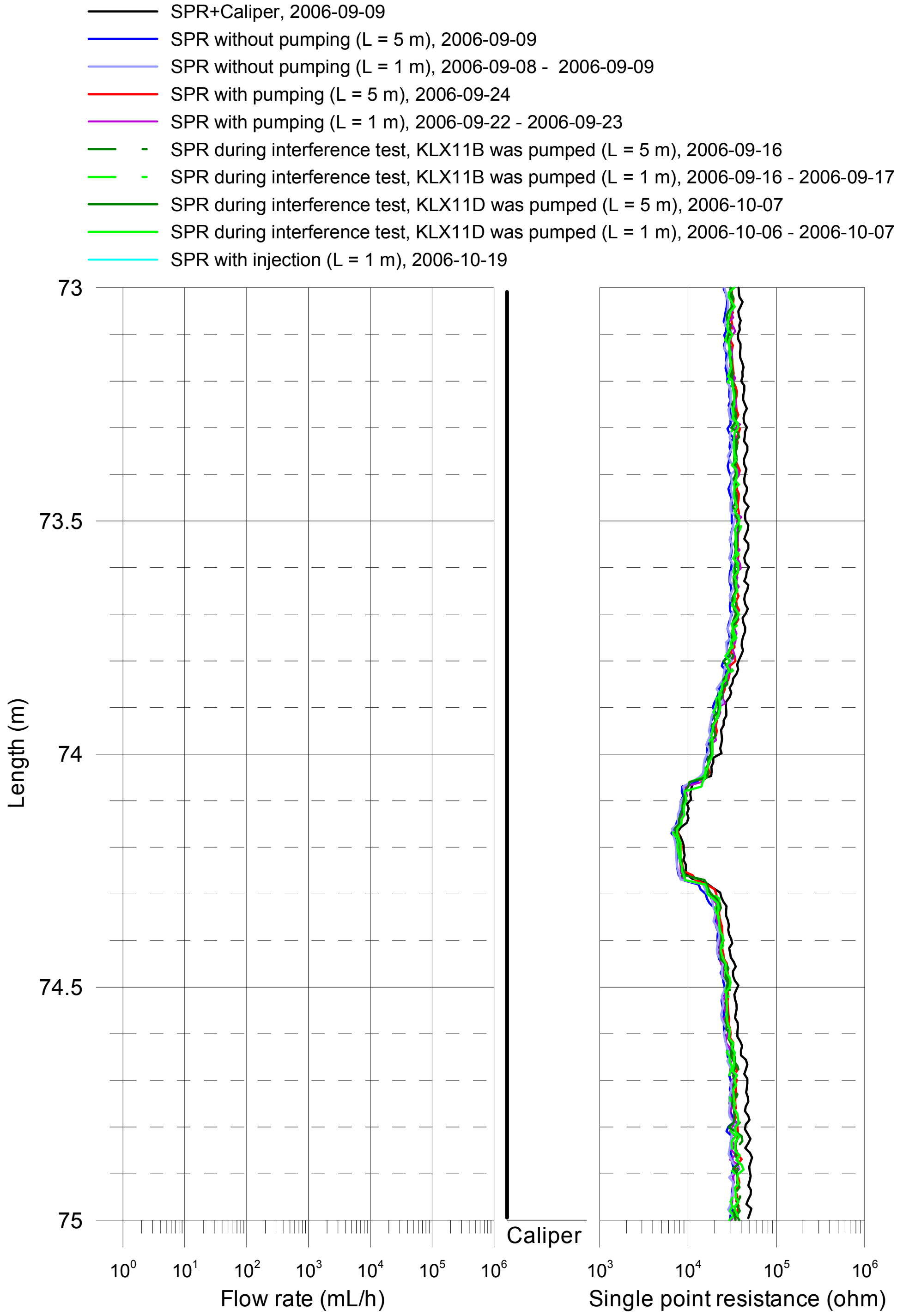
Laxemar, borehole KLX11E
SPR and Caliper results after length correction



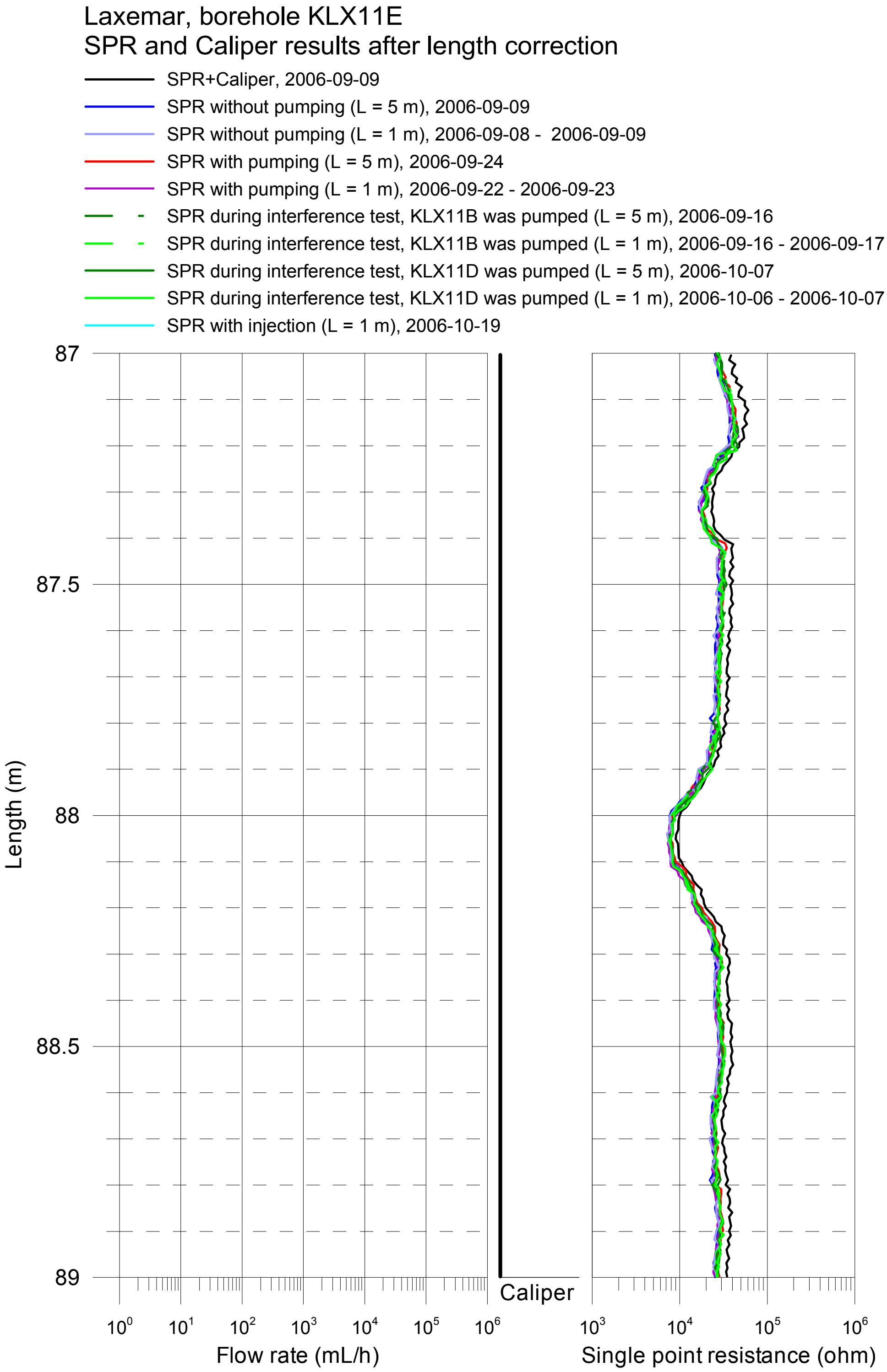
Appendix 4.6


Laxemar, borehole KLX11E
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-09
SPR without pumping (L = 5 m), 2006-09-09
SPR without pumping (L = 1 m), 2006-09-08 - 2006-09-09
SPR with pumping (L = 5 m), 2006-09-24
SPR with pumping (L = 1 m), 2006-09-22 - 2006-09-23
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-16
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-16 - 2006-09-17
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-07
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-06 - 2006-10-07
SPR with injection (L = 1 m), 2006-10-19
59.5
60
60.5
61
61.5
Length (m)
Caliper
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)
10^3 10^4 10^5 10^6
Single point resistance (ohm)

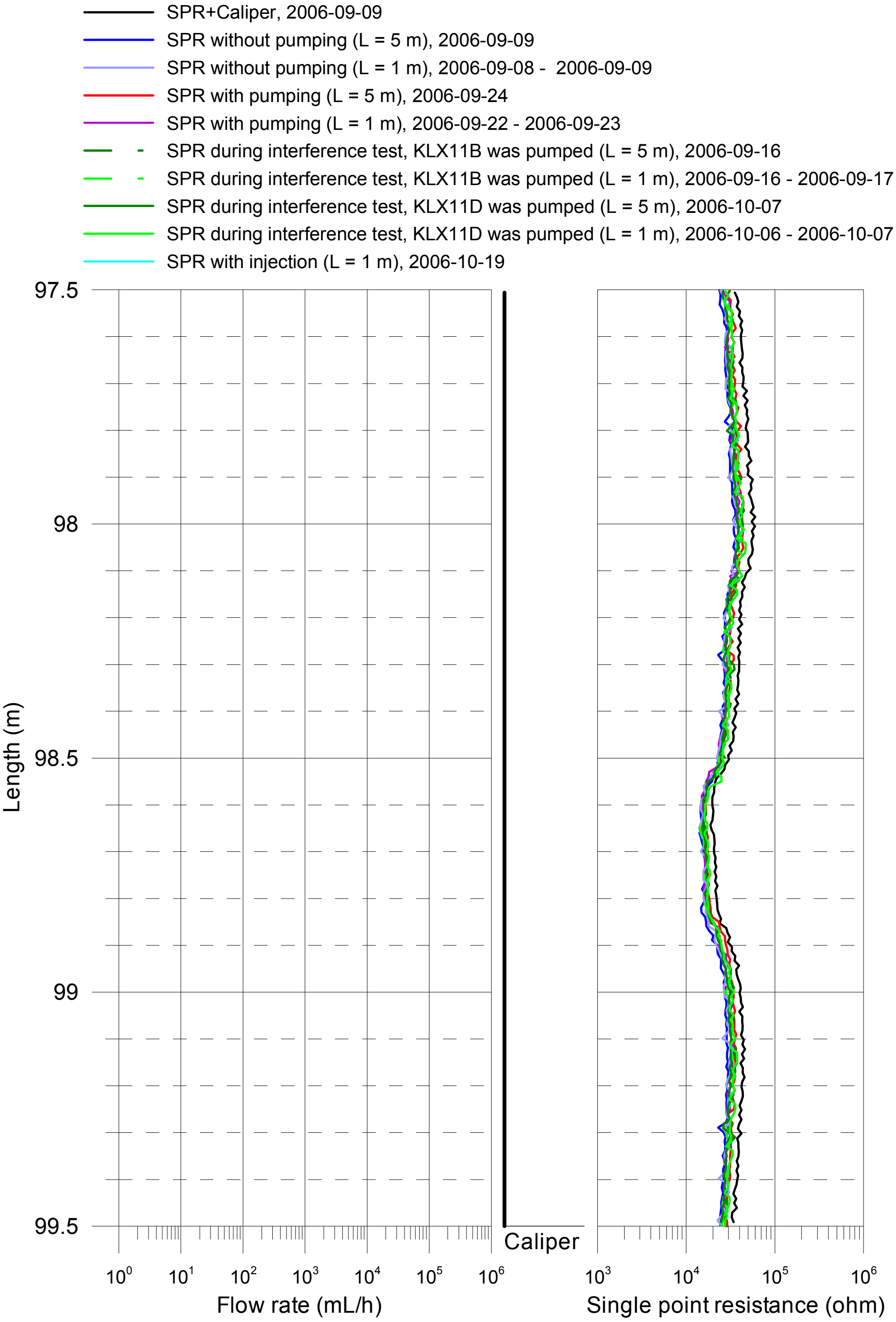
Laxemar, borehole KLX11E
SPR and Caliper results after length correction



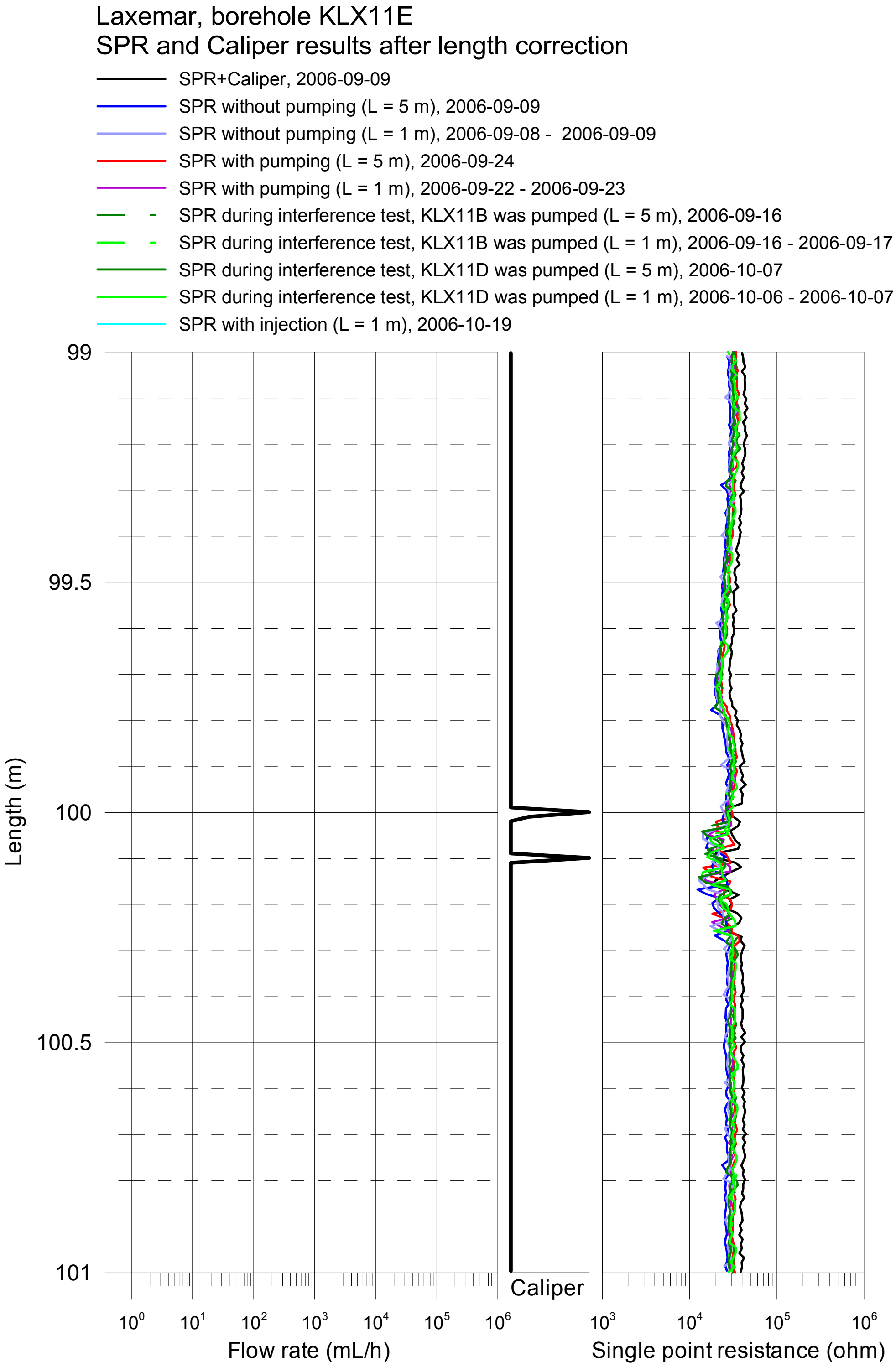
Appendix 4.8

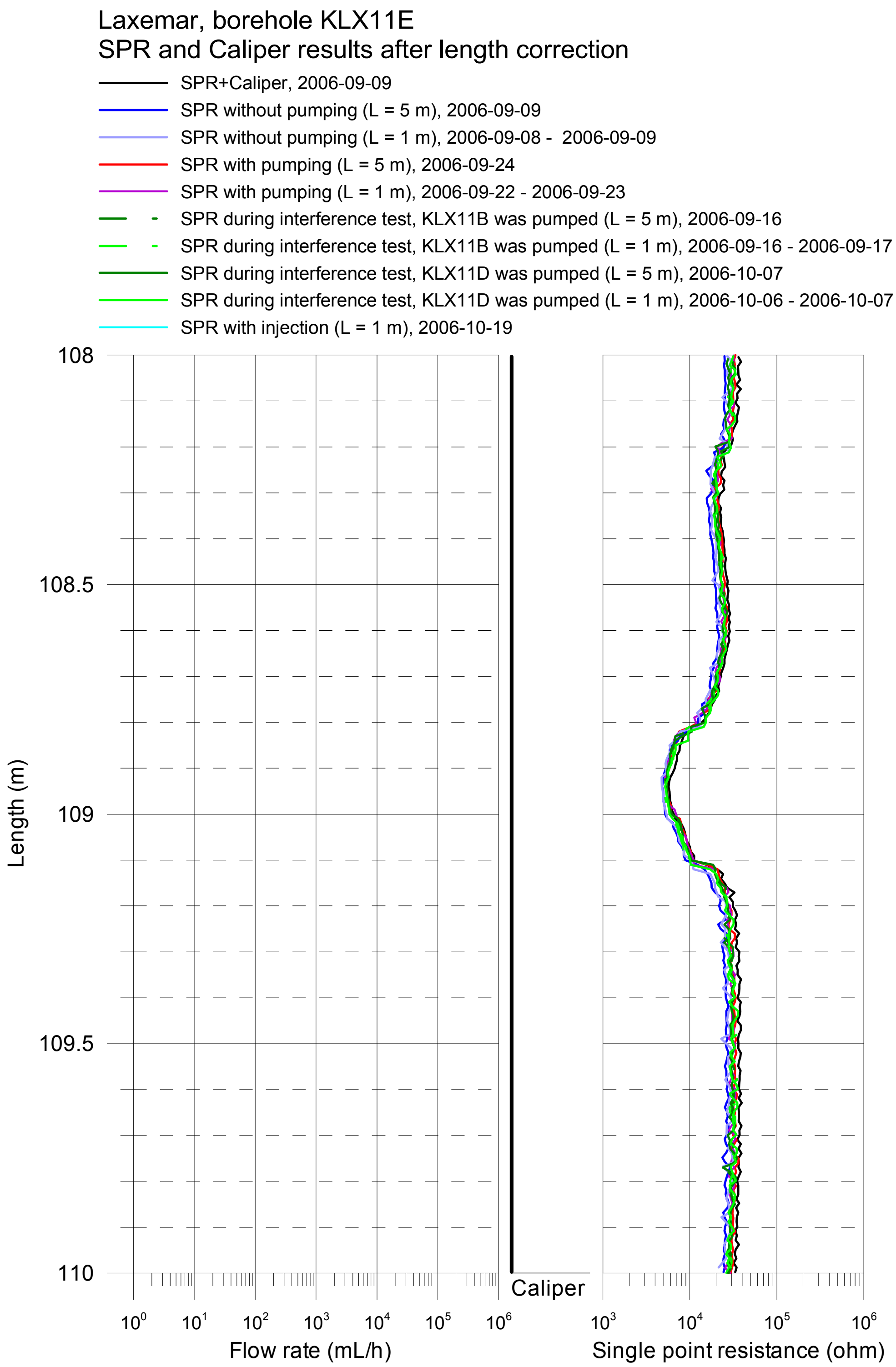

Laxemar, borehole KLX11E
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-09
SPR without pumping (L = 5 m), 2006-09-09
SPR without pumping (L = 1 m), 2006-09-08 - 2006-09-09
SPR with pumping (L = 5 m), 2006-09-24
SPR with pumping (L = 1 m), 2006-09-22 - 2006-09-23
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-16
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-16 - 2006-09-17
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-07
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-06 - 2006-10-07
SPR with injection (L = 1 m), 2006-10-19
Length (m)
87
87.5
88
88.5
89
Caliper
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)
10^3 10^4 10^5 10^6
Single point resistance (ohm)

Laxemar, borehole KLX11E
SPR and Caliper results after length correction

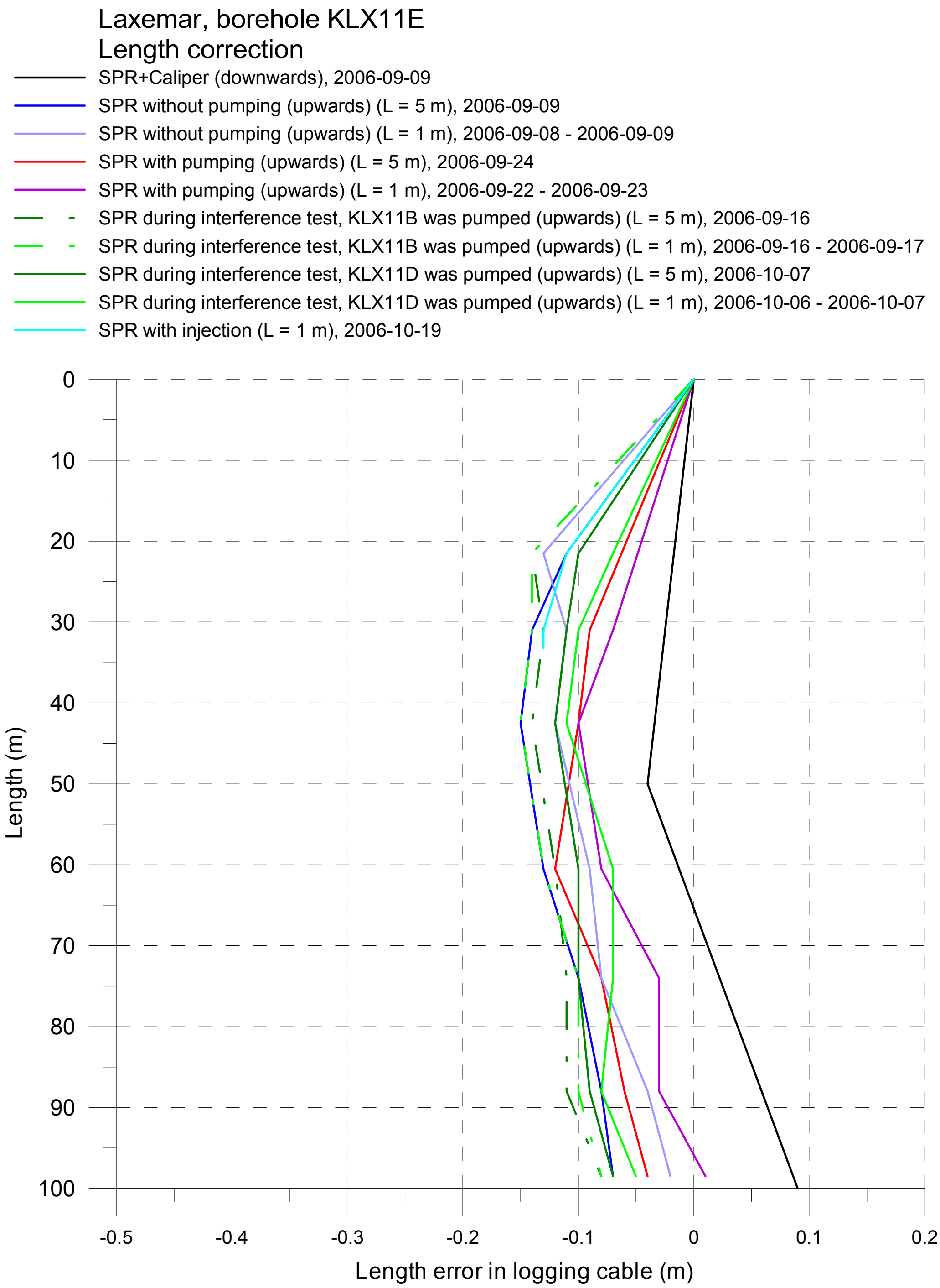


Appendix 4.10



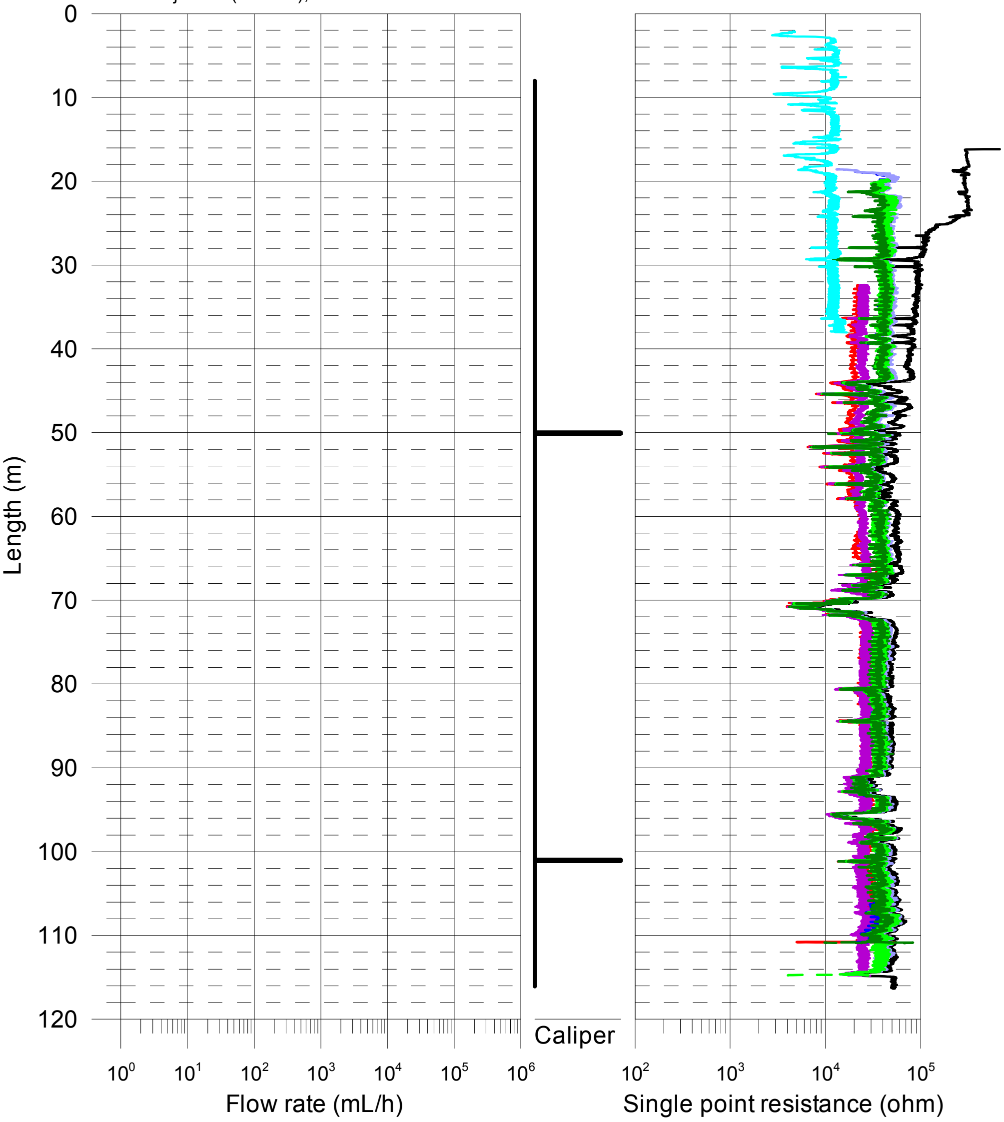

Laxemar, borehole KLX11E
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-09
SPR without pumping (L = 5 m), 2006-09-09
SPR without pumping (L = 1 m), 2006-09-08 - 2006-09-09
SPR with pumping (L = 5 m), 2006-09-24
SPR with pumping (L = 1 m), 2006-09-22 - 2006-09-23
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-16
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-16 - 2006-09-17
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-07
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-06 - 2006-10-07
SPR with injection (L = 1 m), 2006-10-19
108
108.5
109
109.5
110
Length (m)
Caliper
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)
10^3 10^4 10^5 10^6
Single point resistance (ohm)

Appendix 4.12

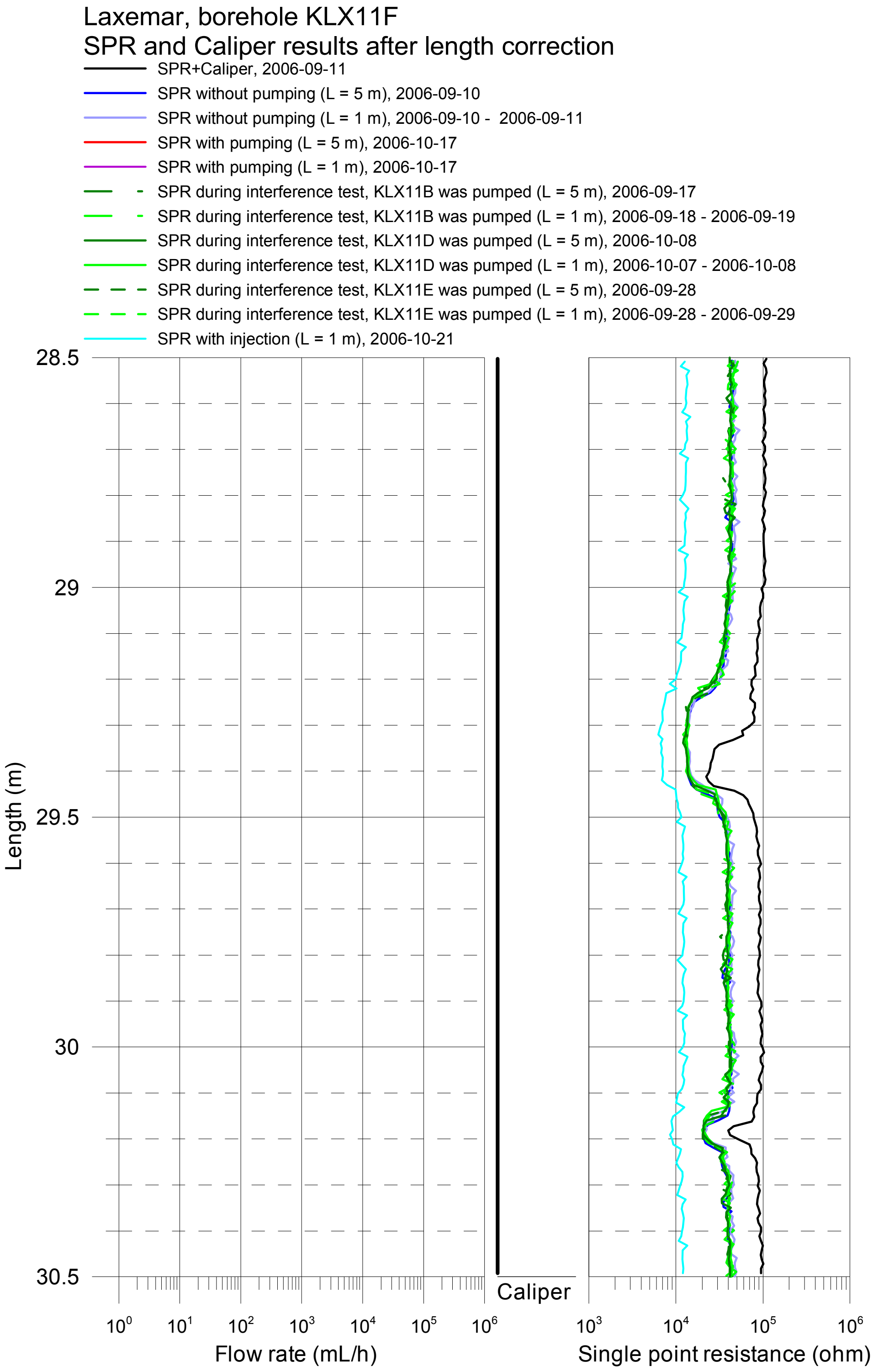


Laxemar, borehole KLX11F
SPR and Caliper results after length correction

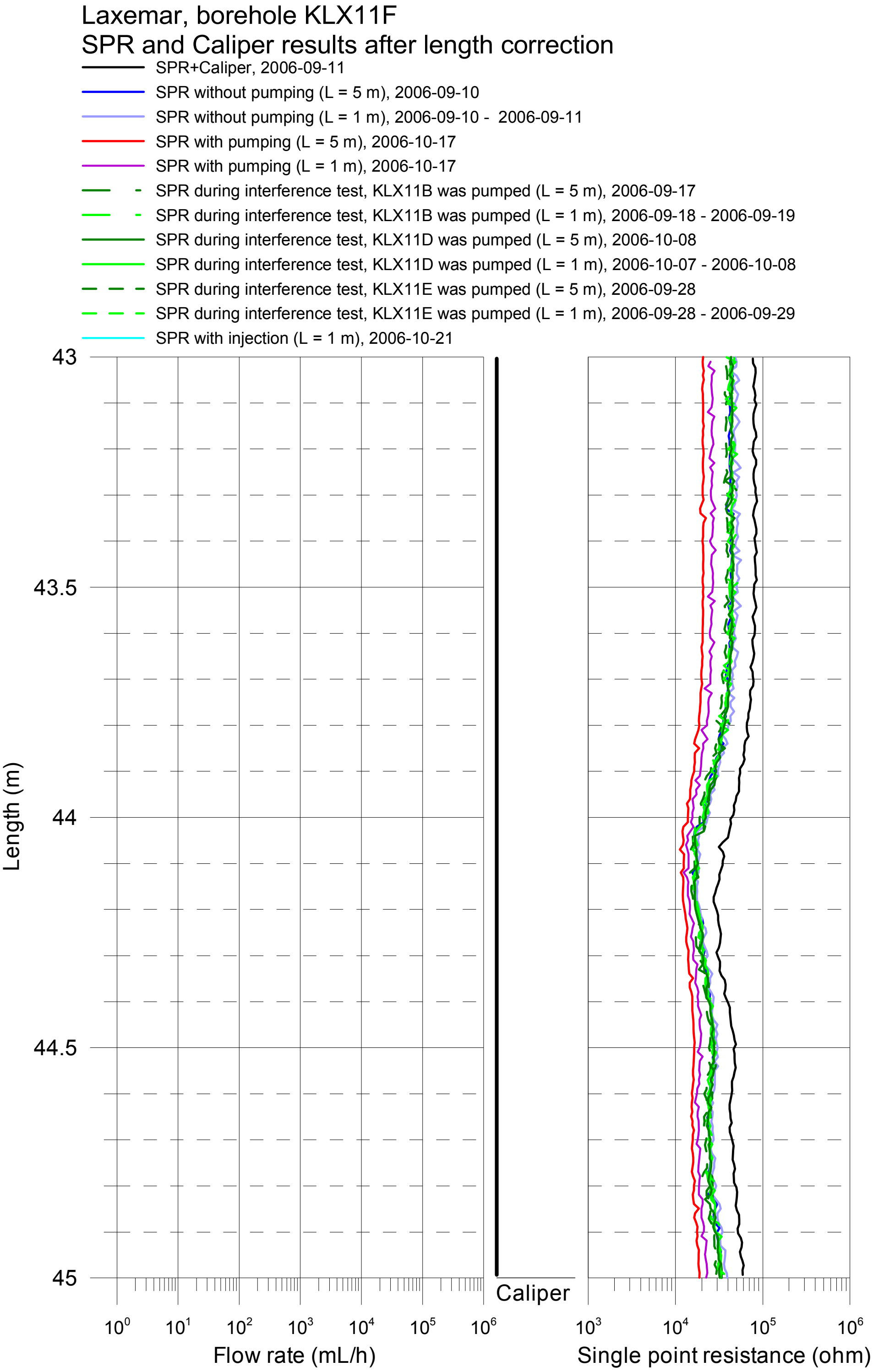
- SPR+Caliper, 2006-09-11
- SPR without pumping (L = 5 m), 2006-09-10
- SPR without pumping (L = 1 m), 2006-09-10 - 2006-09-11
- SPR with pumping (L = 5 m), 2006-10-17
- SPR with pumping (L = 1 m), 2006-10-17
- SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-17
- SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-18 - 2006-09-19
- SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-08
- SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-07 - 2006-10-08
- SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-28
- SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-28 - 2006-09-29
- SPR with injection (L = 1 m), 2006-10-21



Appendix 5.2

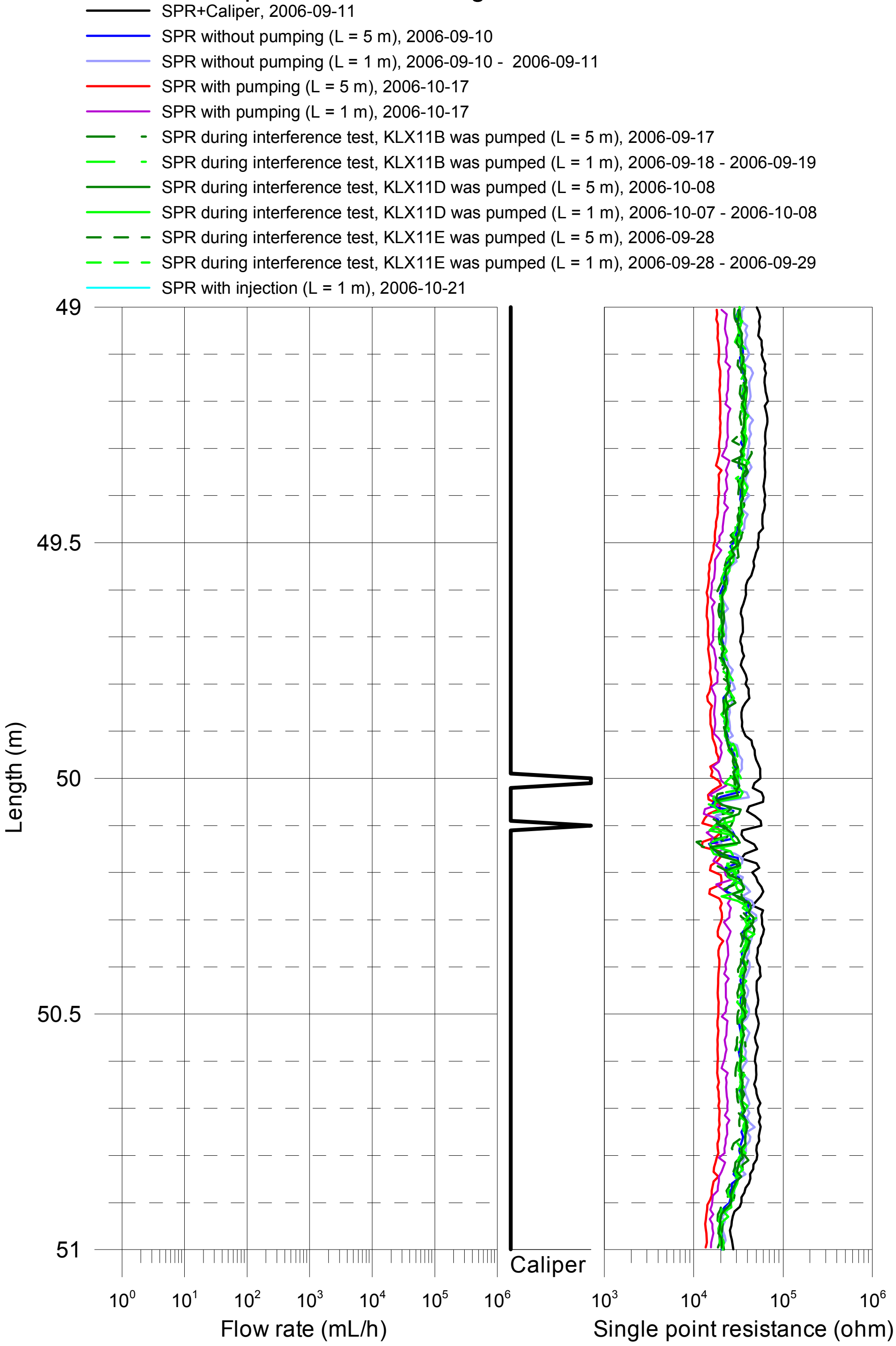


Laxemar, borehole KLX11F
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-11
SPR without pumping (L = 5 m), 2006-09-10
SPR without pumping (L = 1 m), 2006-09-10 - 2006-09-11
SPR with pumping (L = 5 m), 2006-10-17
SPR with pumping (L = 1 m), 2006-10-17
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-17
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-18 - 2006-09-19
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-08
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-07 - 2006-10-08
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-28
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-28 - 2006-09-29
SPR with injection (L = 1 m), 2006-10-21
28.5
29
29.5
30
30.5
Length (m)
Caliper
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)
10^3 10^4 10^5 10^6
Single point resistance (ohm)

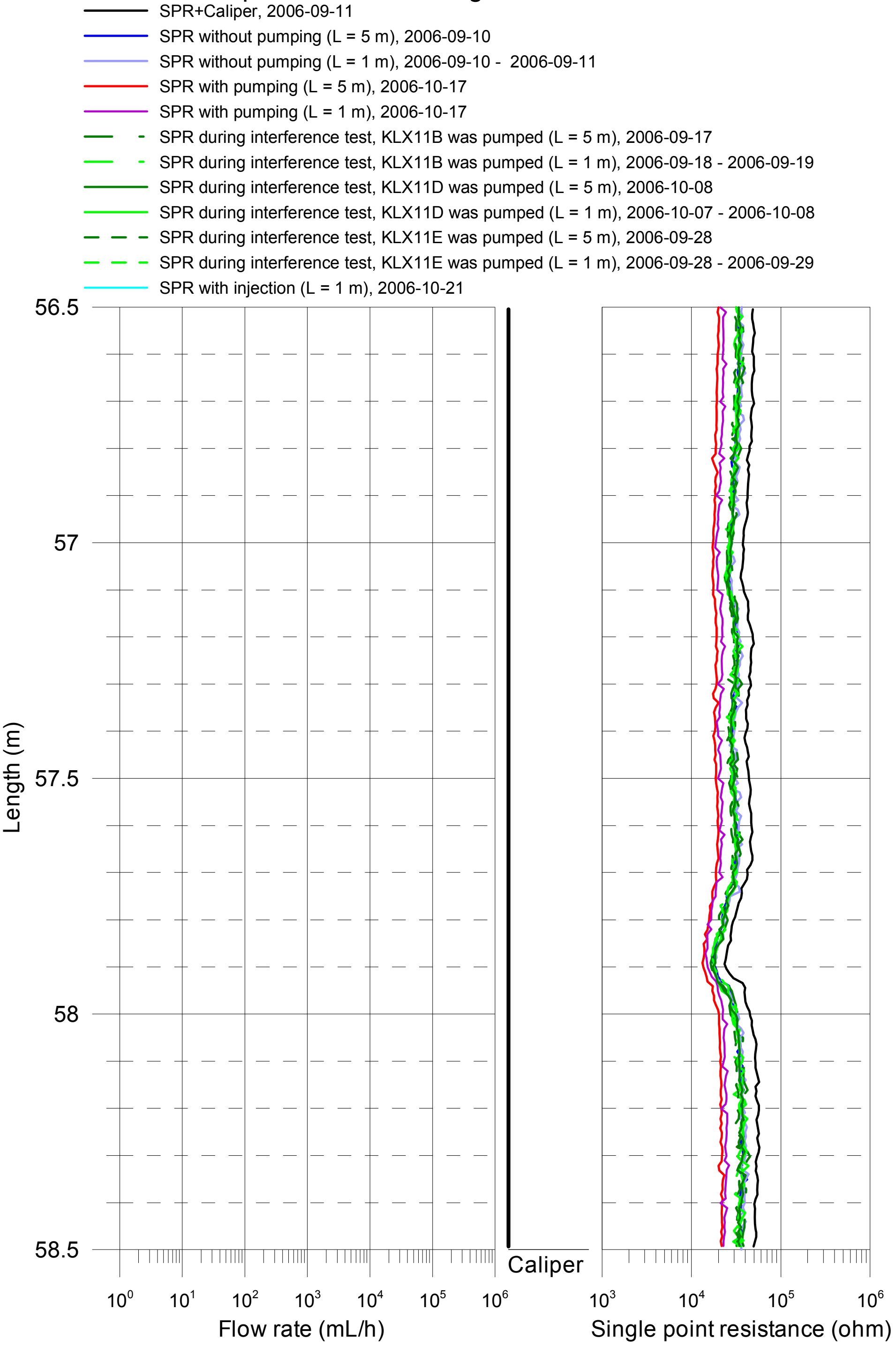


Laxemar, borehole KLX11F
SPR and Caliper results after length correction
SPR+Caliper, 2006-09-11
SPR without pumping (L = 5 m), 2006-09-10
SPR without pumping (L = 1 m), 2006-09-10 - 2006-09-11
SPR with pumping (L = 5 m), 2006-10-17
SPR with pumping (L = 1 m), 2006-10-17
SPR during interference test, KLX11B was pumped (L = 5 m), 2006-09-17
SPR during interference test, KLX11B was pumped (L = 1 m), 2006-09-18 - 2006-09-19
SPR during interference test, KLX11D was pumped (L = 5 m), 2006-10-08
SPR during interference test, KLX11D was pumped (L = 1 m), 2006-10-07 - 2006-10-08
SPR during interference test, KLX11E was pumped (L = 5 m), 2006-09-28
SPR during interference test, KLX11E was pumped (L = 1 m), 2006-09-28 - 2006-09-29
SPR with injection (L = 1 m), 2006-10-21
43
43.5
44
44.5
45
Length (m)
Caliper
10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)
10^3 10^4 10^5 10^6
Single point resistance (ohm)

Laxemar, borehole KLX11F
SPR and Caliper results after length correction

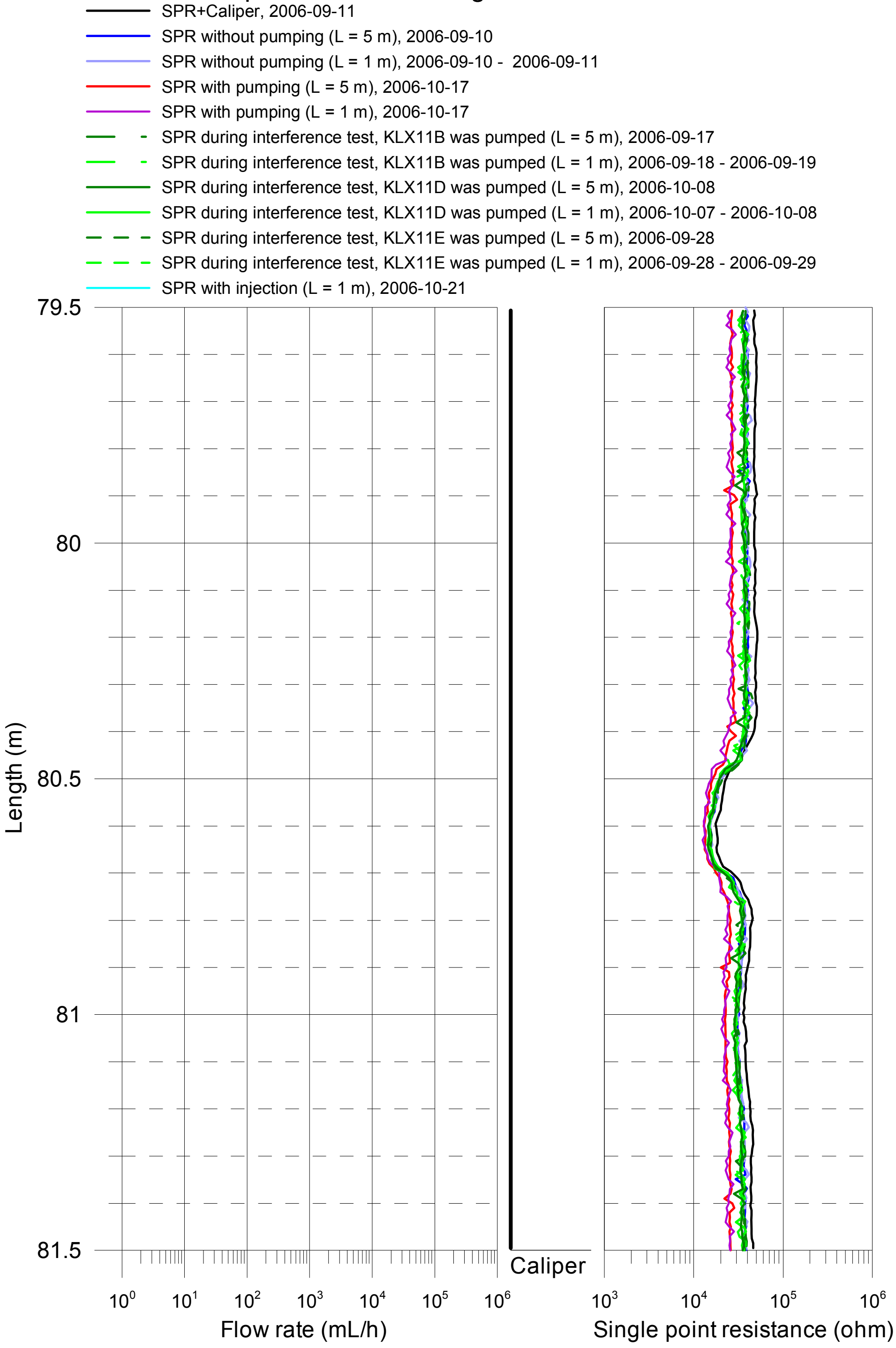


Laxemar, borehole KLX11F
SPR and Caliper results after length correction

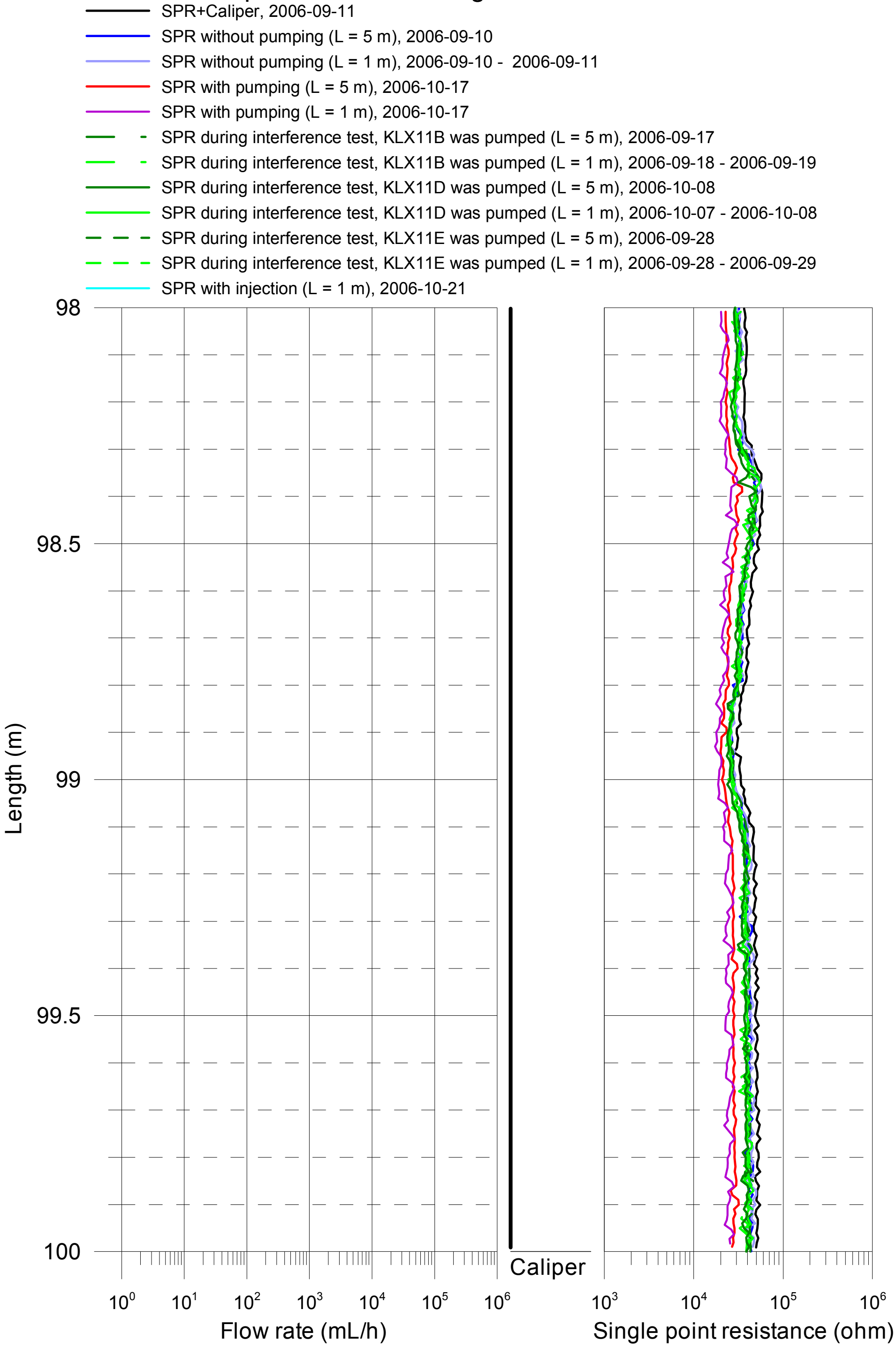


Appendix 5.6

Laxemar, borehole KLX11F
SPR and Caliper results after length correction

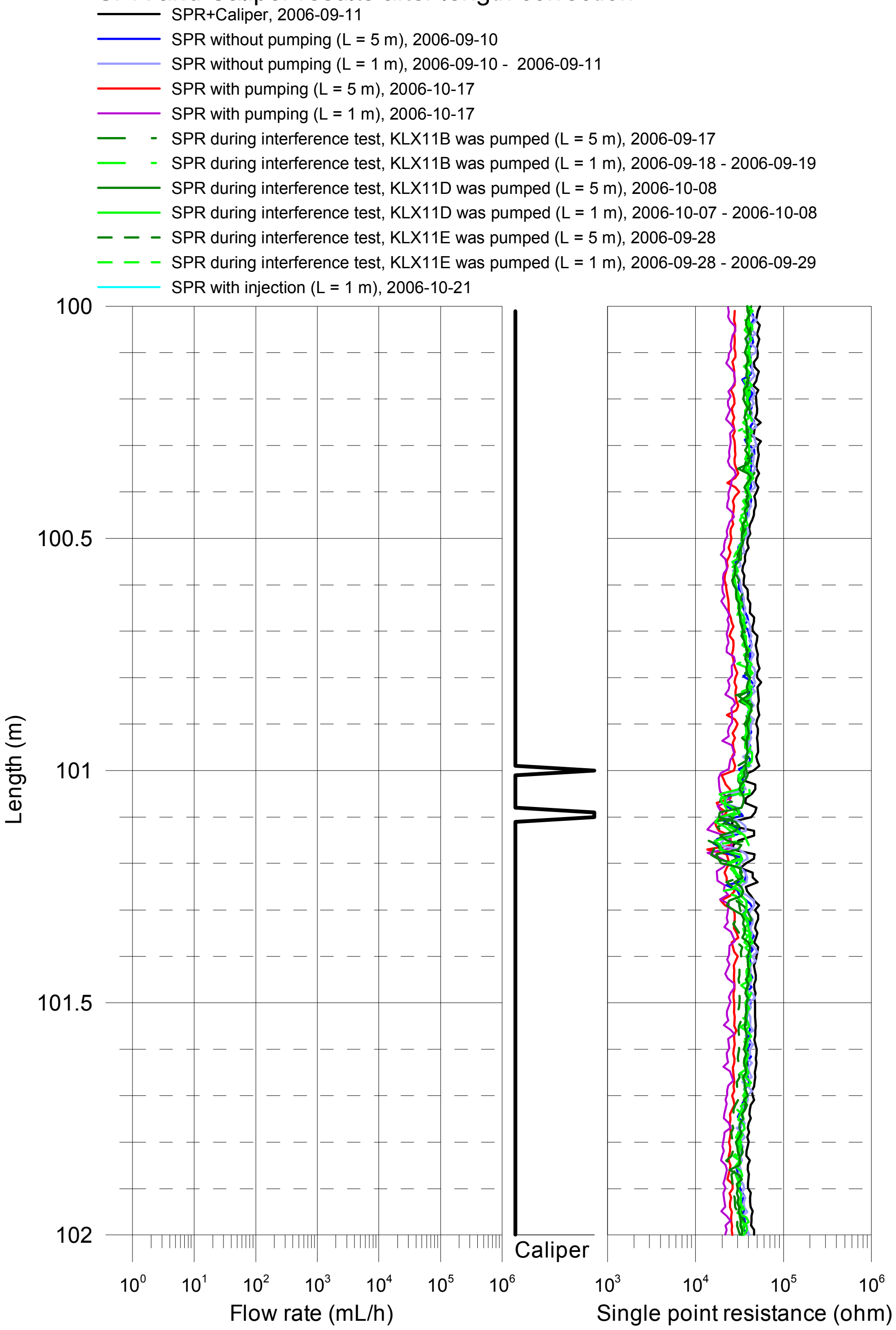


Laxemar, borehole KLX11F
SPR and Caliper results after length correction

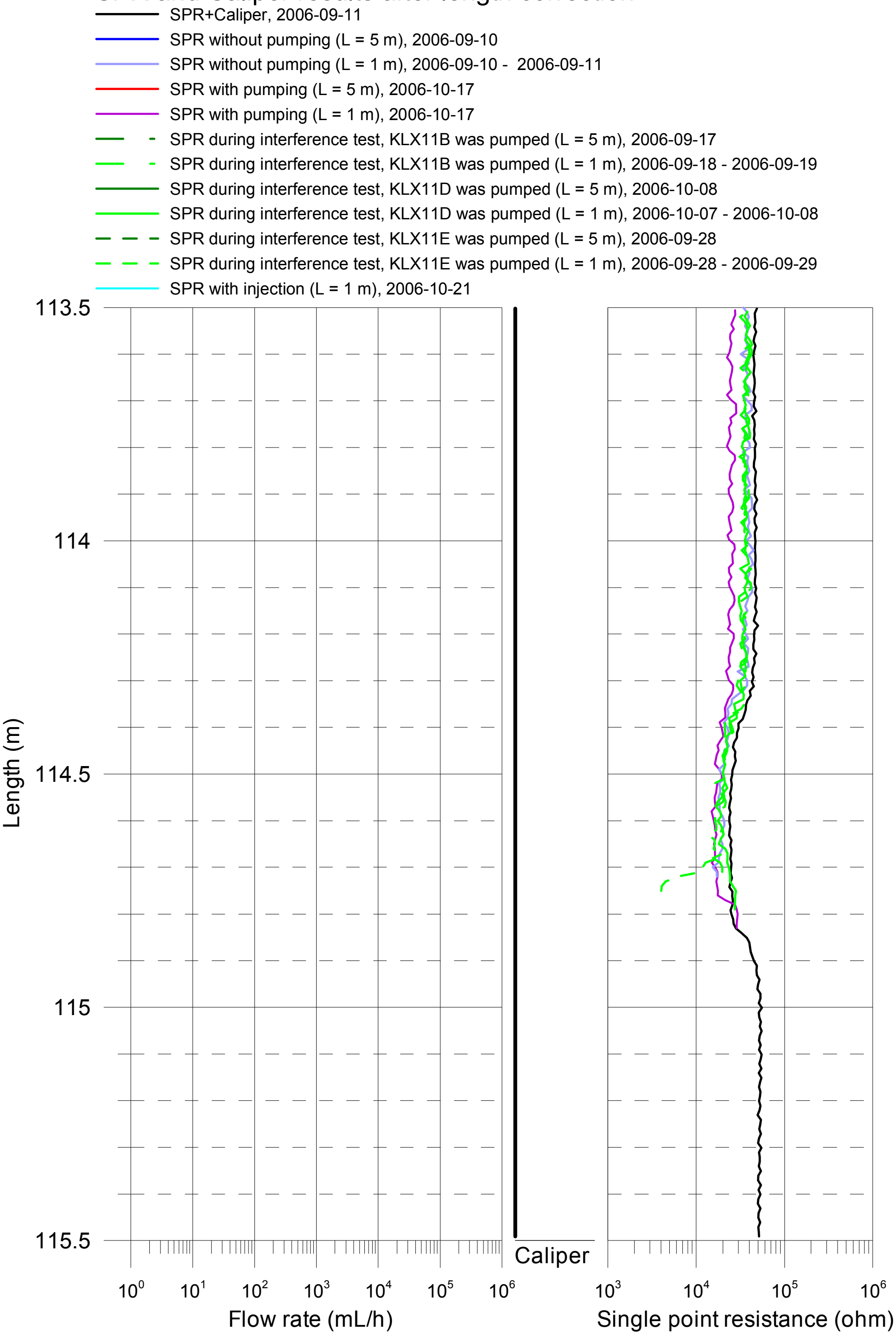


Appendix 5.8

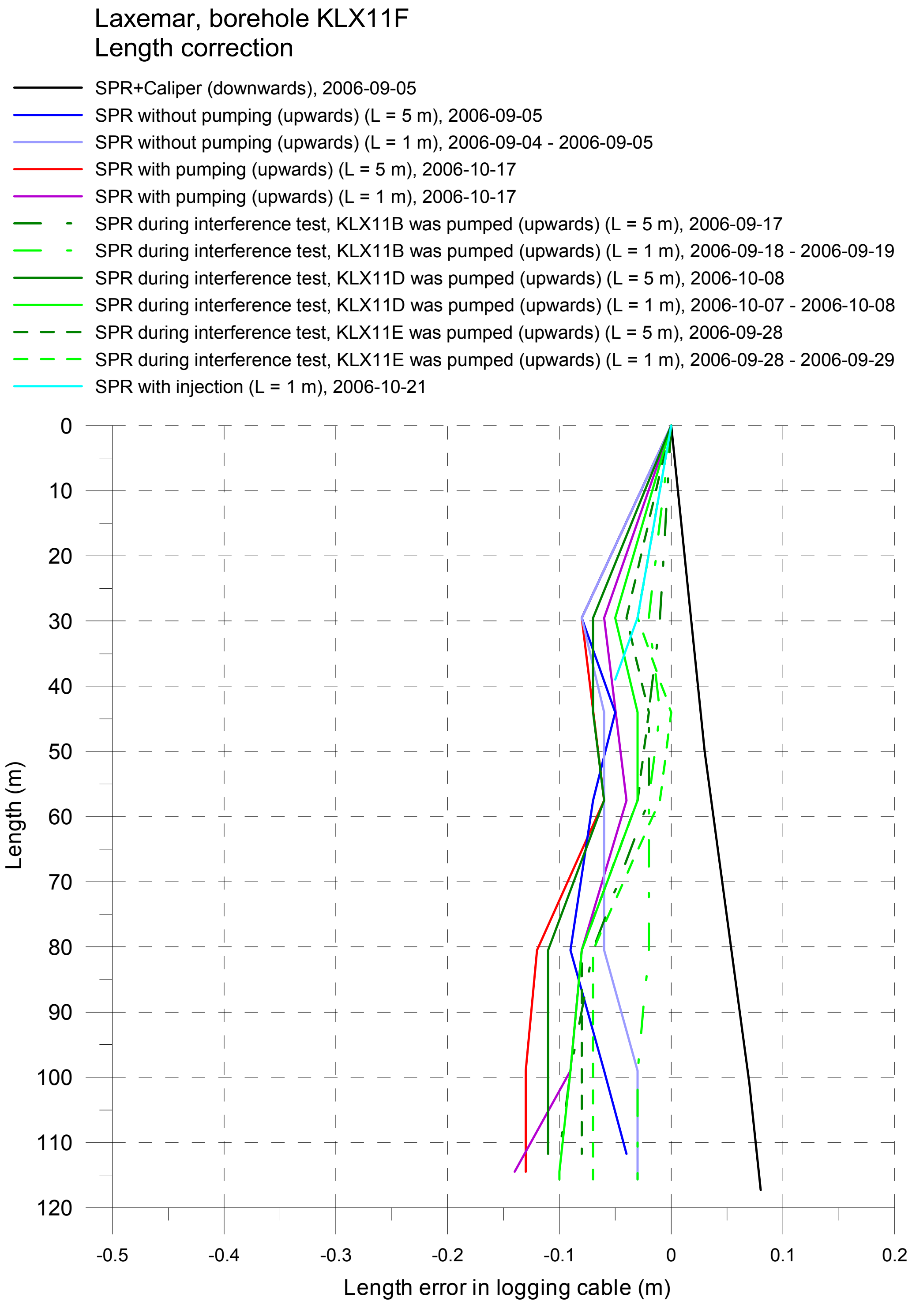
Laxemar, borehole KLX11F
SPR and Caliper results after length correction



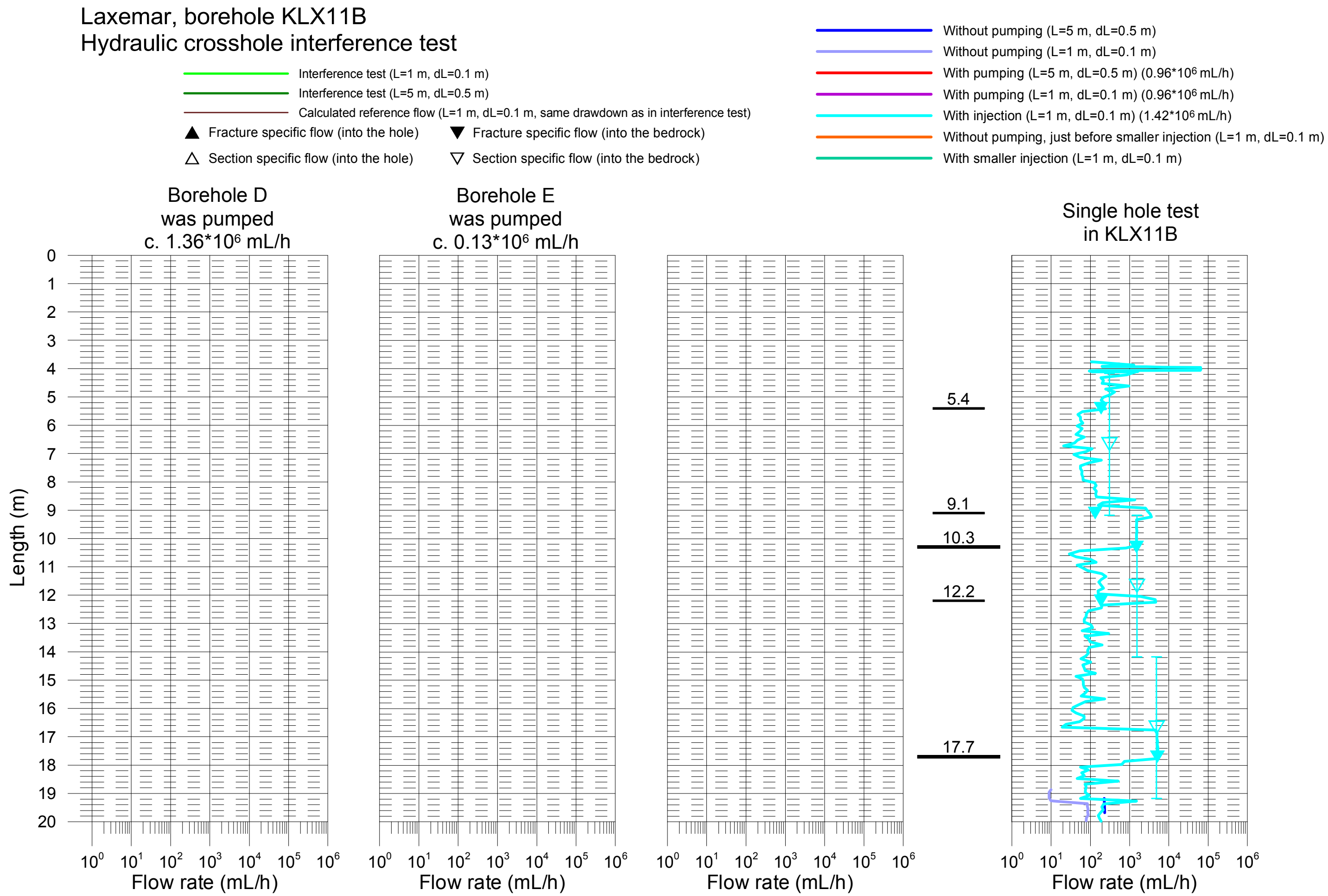
Laxemar, borehole KLX11F
SPR and Caliper results after length correction



Appendix 5.10

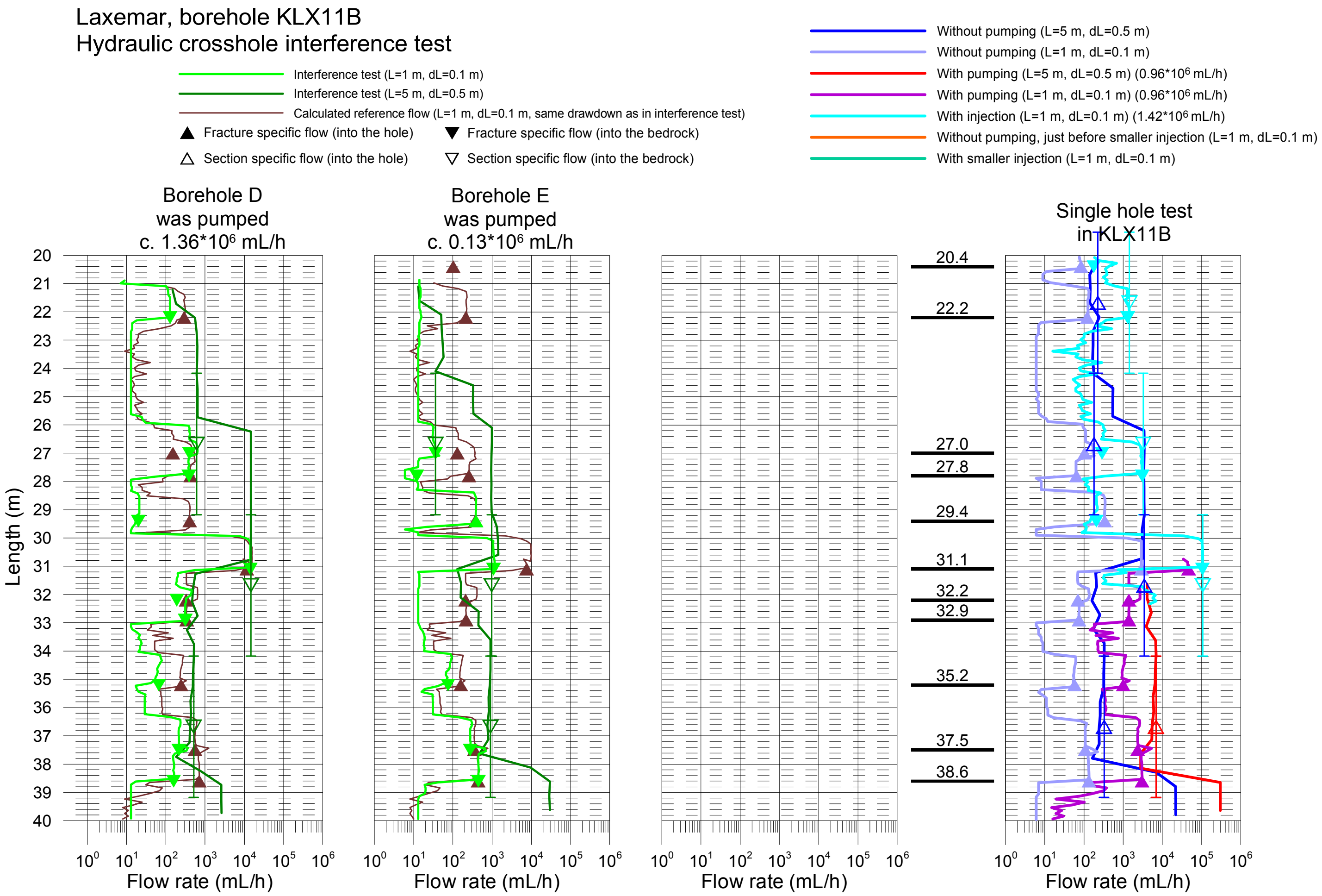


Appendix 6.1



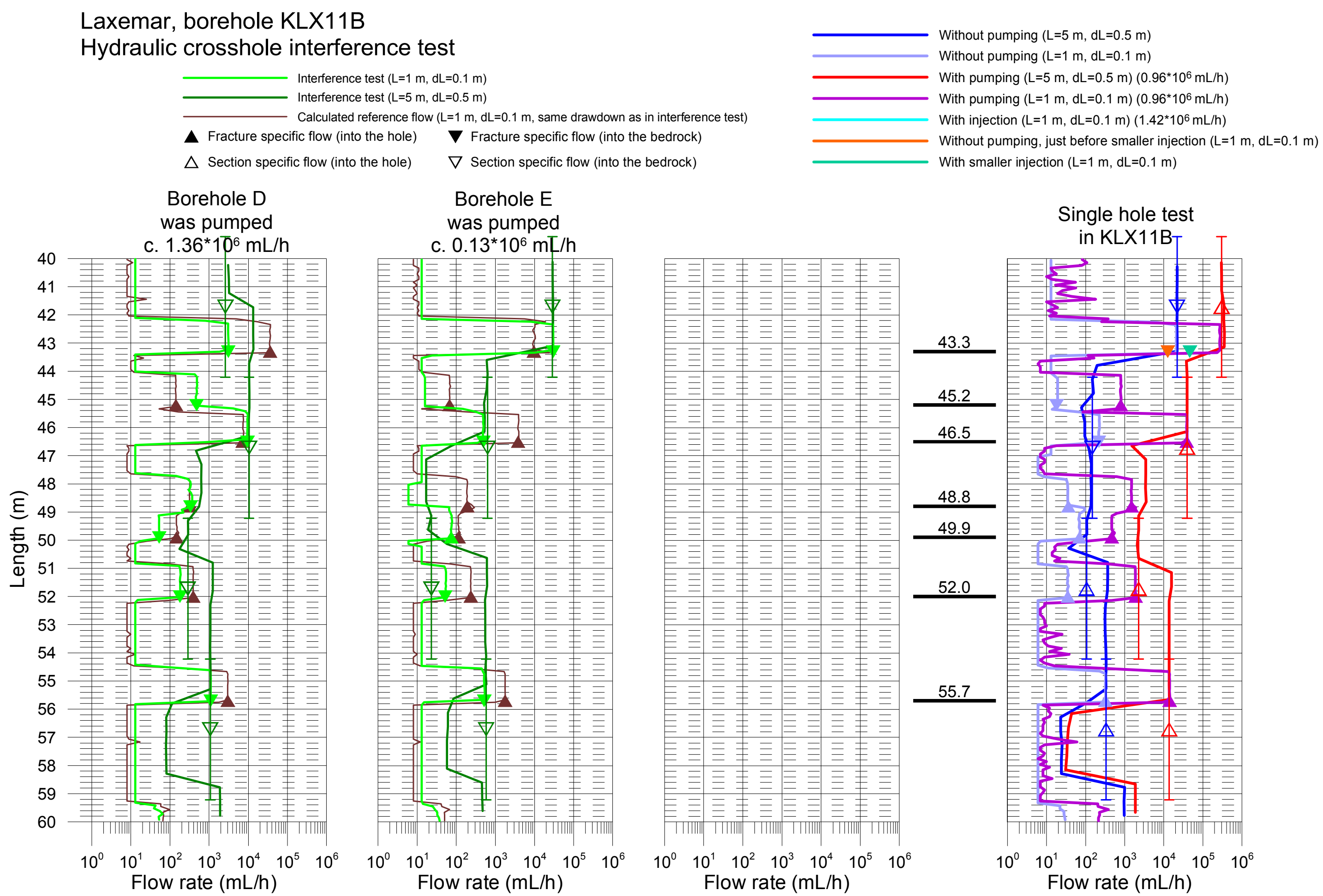
Laxemar, borehole KLX11B
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.96*10⁶ mL/h)
With pumping (L=1 m, dL=0.1 m) (0.96*10⁶ mL/h)
With injection (L=1 m, dL=0.1 m) (1.42*10⁶ mL/h)
Without pumping, just before smaller injection (L=1 m, dL=0.1 m)
With smaller injection (L=1 m, dL=0.1 m)
Borehole D was pumped c. 1.36*10⁶ mL/h
Borehole E was pumped c. 0.13*10⁶ mL/h
Single hole test in KLX11B
Length (m)
Flow rate (mL/h)
5.4
9.1
10.3
12.2
17.7

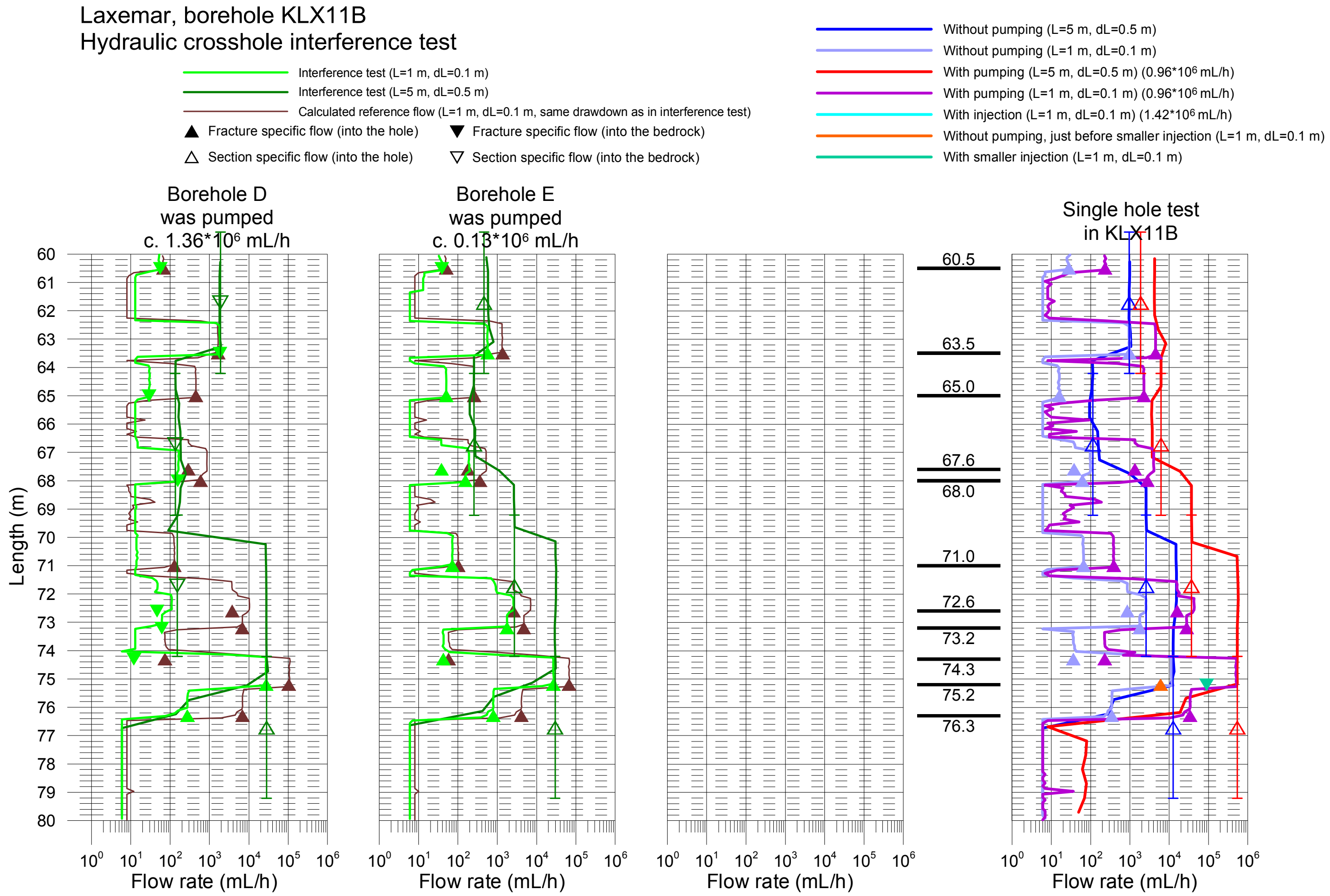
Appendix 6.2



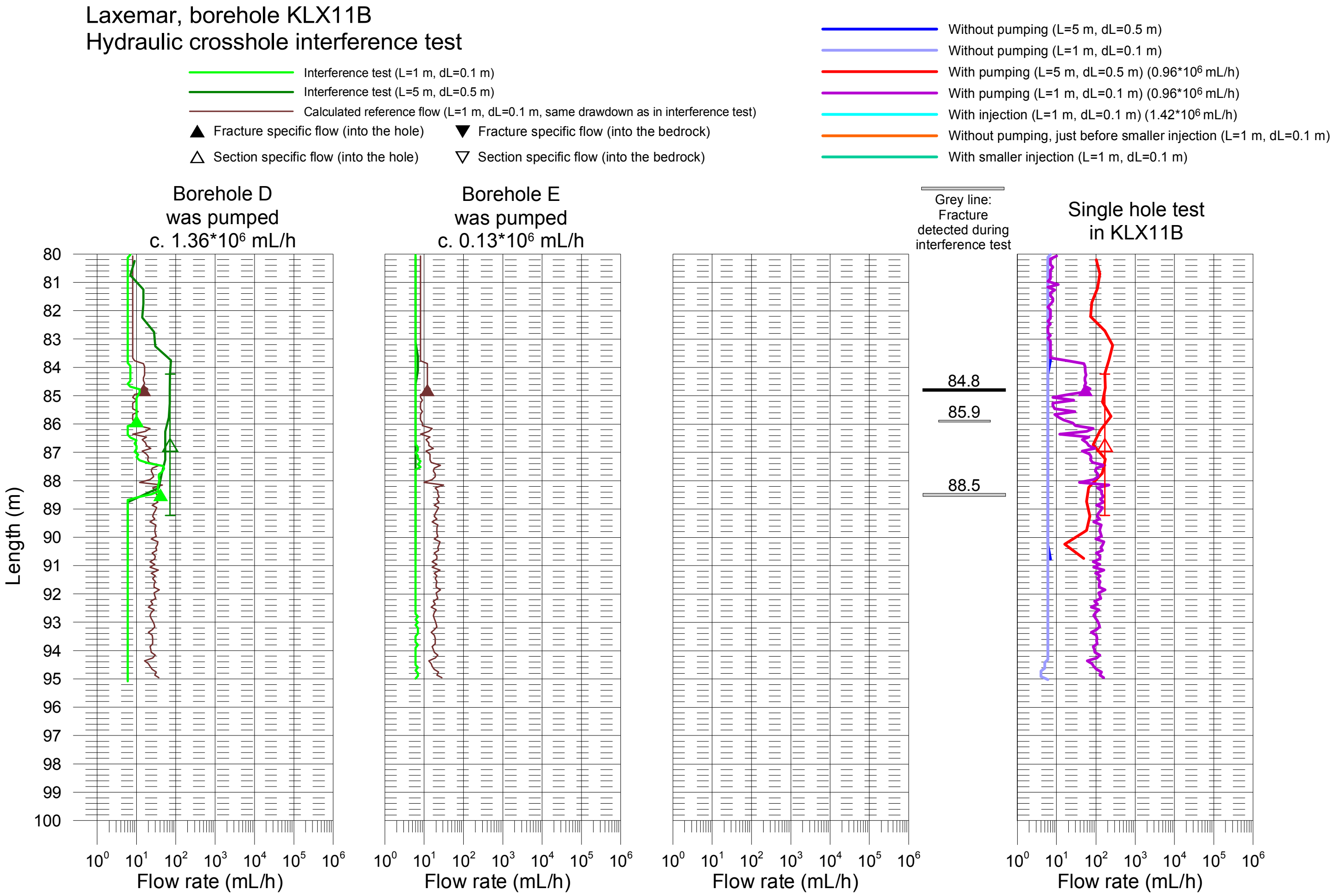
Laxemar, borehole KLX11B
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.96*10⁶ mL/h)
With pumping (L=1 m, dL=0.1 m) (0.96*10⁶ mL/h)
With injection (L=1 m, dL=0.1 m) (1.42*10⁶ mL/h)
Without pumping, just before smaller injection (L=1 m, dL=0.1 m)
With smaller injection (L=1 m, dL=0.1 m)
Borehole D was pumped c. 1.36*10⁶ mL/h
Borehole E was pumped c. 0.13*10⁶ mL/h
Single hole test in KLX11B
Length (m)
Flow rate (mL/h)
20.4
22.2
27.0
27.8
29.4
31.1
32.2
32.9
35.2
37.5
38.6

Appendix 6.3


Laxemar, borehole KLX11B
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.96*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (0.96*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (1.42*10^6 mL/h)
Without pumping, just before smaller injection (L=1 m, dL=0.1 m)
With smaller injection (L=1 m, dL=0.1 m)
Borehole D was pumped c. 1.36*10^6 mL/h
Borehole E was pumped c. 0.13*10^6 mL/h
Single hole test in KLX11B
Length (m)
Flow rate (mL/h)
43.3
45.2
46.5
48.8
49.9
52.0
55.7

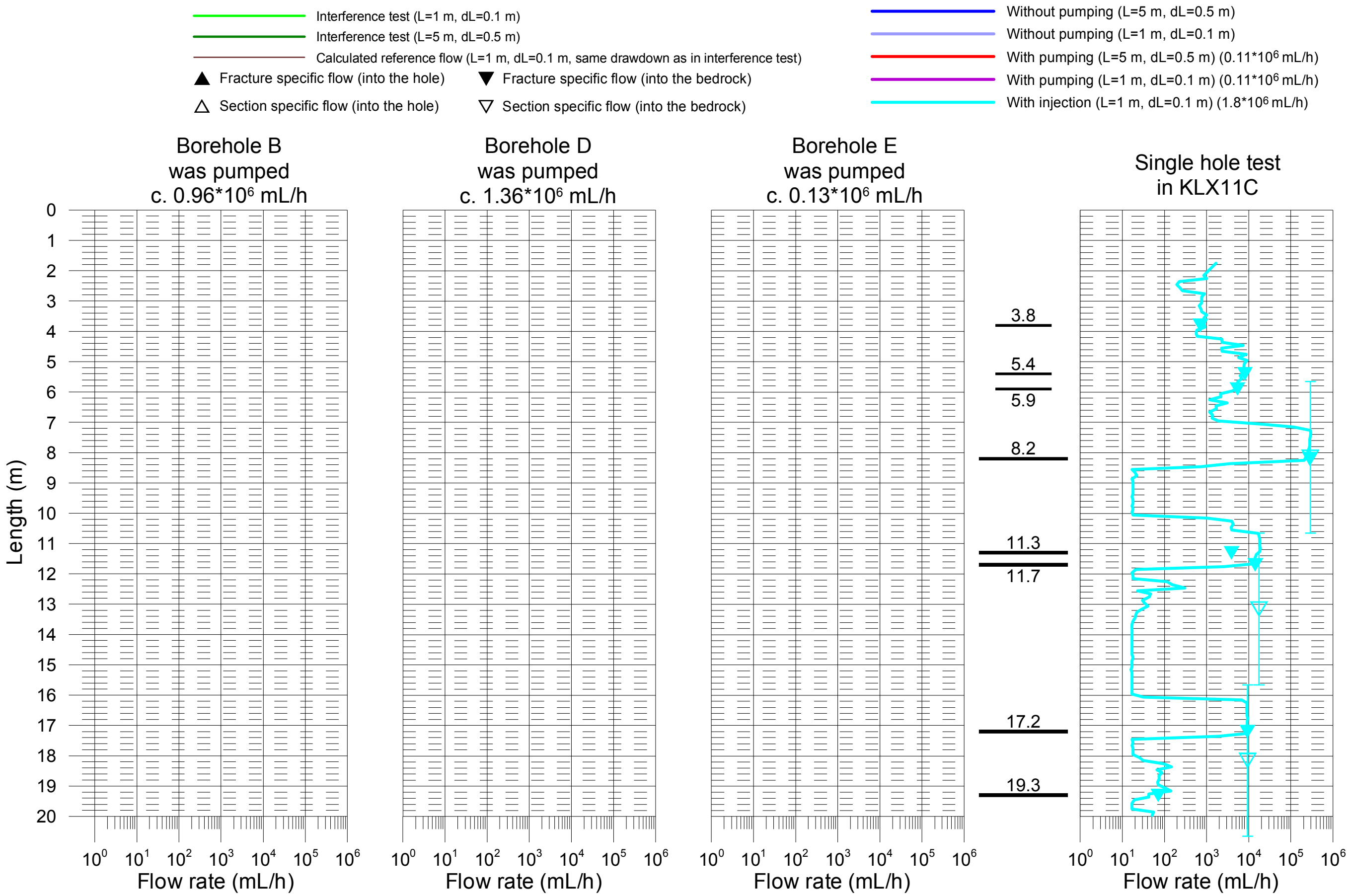

Laxemar, borehole KLX11B
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.96*10⁶ mL/h)
With pumping (L=1 m, dL=0.1 m) (0.96*10⁶ mL/h)
With injection (L=1 m, dL=0.1 m) (1.42*10⁶ mL/h)
Without pumping, just before smaller injection (L=1 m, dL=0.1 m)
With smaller injection (L=1 m, dL=0.1 m)
Borehole D was pumped c. 1.36*10⁶ mL/h
Borehole E was pumped c. 0.13*10⁶ mL/h
Single hole test in KLX11B
Length (m)
Flow rate (mL/h)
60.5
63.5
65.0
67.6
68.0
71.0
72.6
73.2
74.3
75.2
76.3

Appendix 6.5


Laxemar, borehole KLX11B
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.96*10⁶ mL/h)
With pumping (L=1 m, dL=0.1 m) (0.96*10⁶ mL/h)
With injection (L=1 m, dL=0.1 m) (1.42*10⁶ mL/h)
Without pumping, just before smaller injection (L=1 m, dL=0.1 m)
With smaller injection (L=1 m, dL=0.1 m)
Borehole D was pumped c. 1.36*10⁶ mL/h
Borehole E was pumped c. 0.13*10⁶ mL/h
Grey line: Fracture detected during interference test
Single hole test in KLX11B
84.8
85.9
88.5
Length (m)
Flow rate (mL/h)

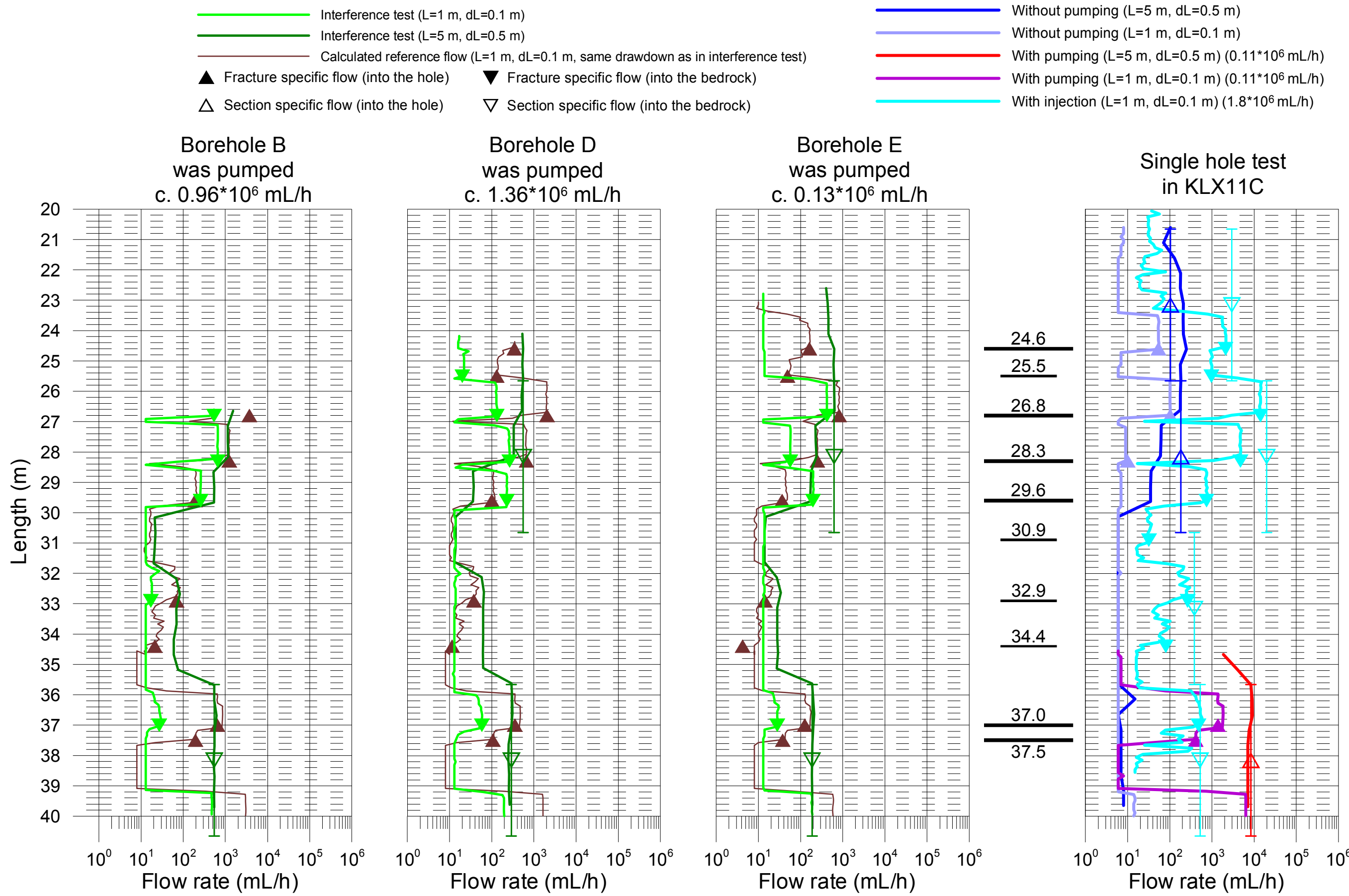
Appendix 7.1

Laxemar, borehole KLX11C
Hydraulic crosshole interference test

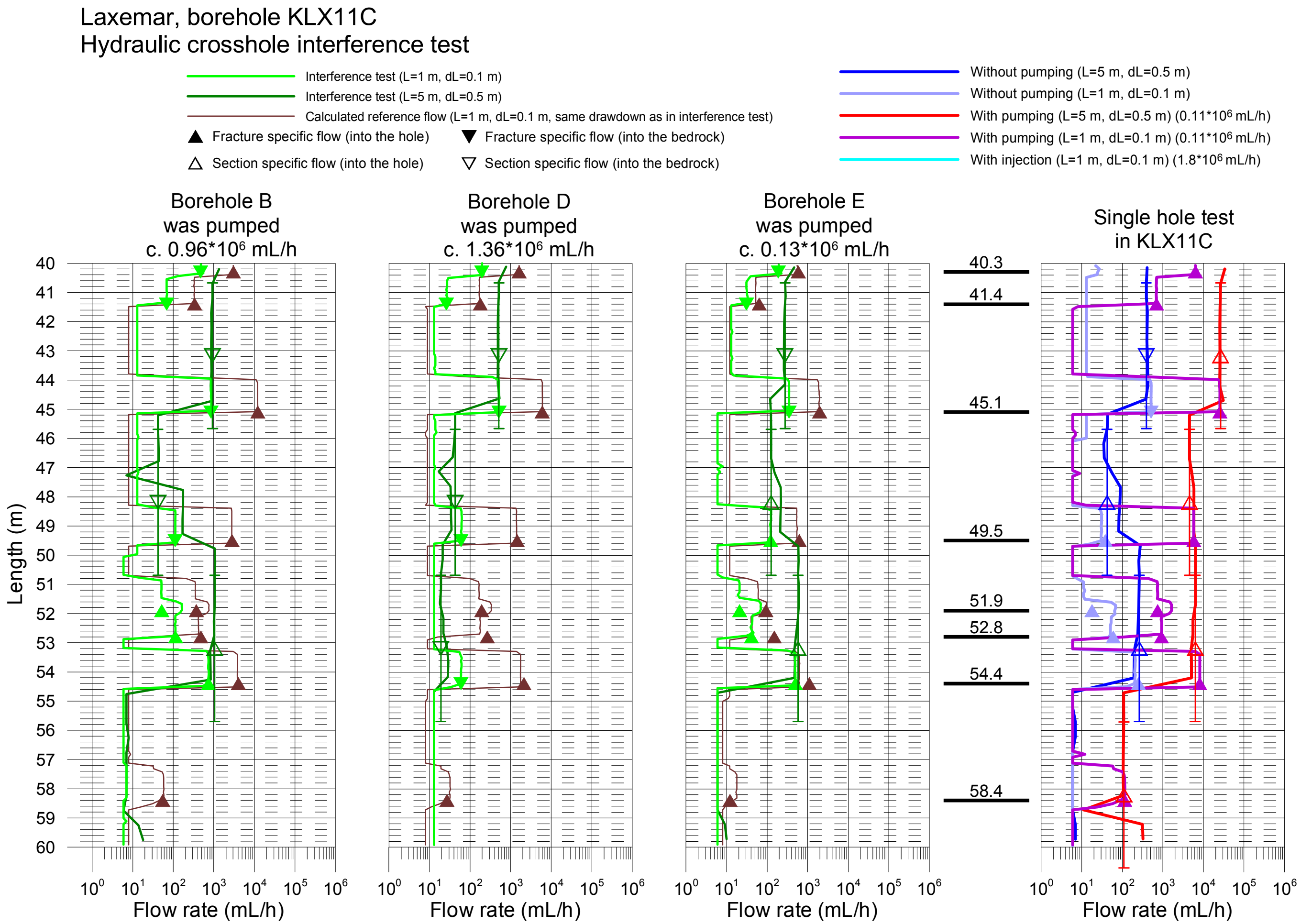


Appendix 7.2

Laxemar, borehole KLX11C
Hydraulic crosshole interference test

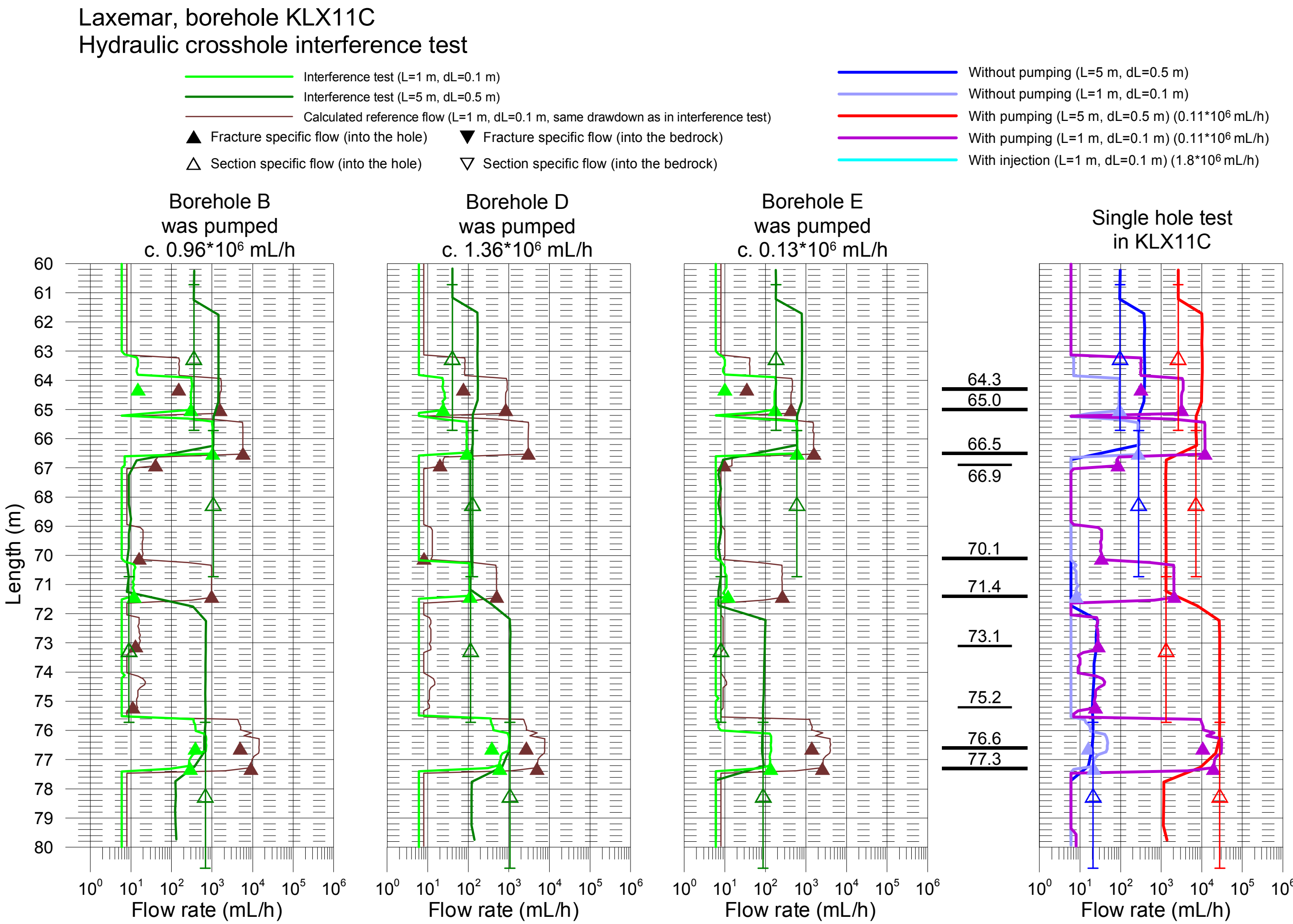


Appendix 7.3



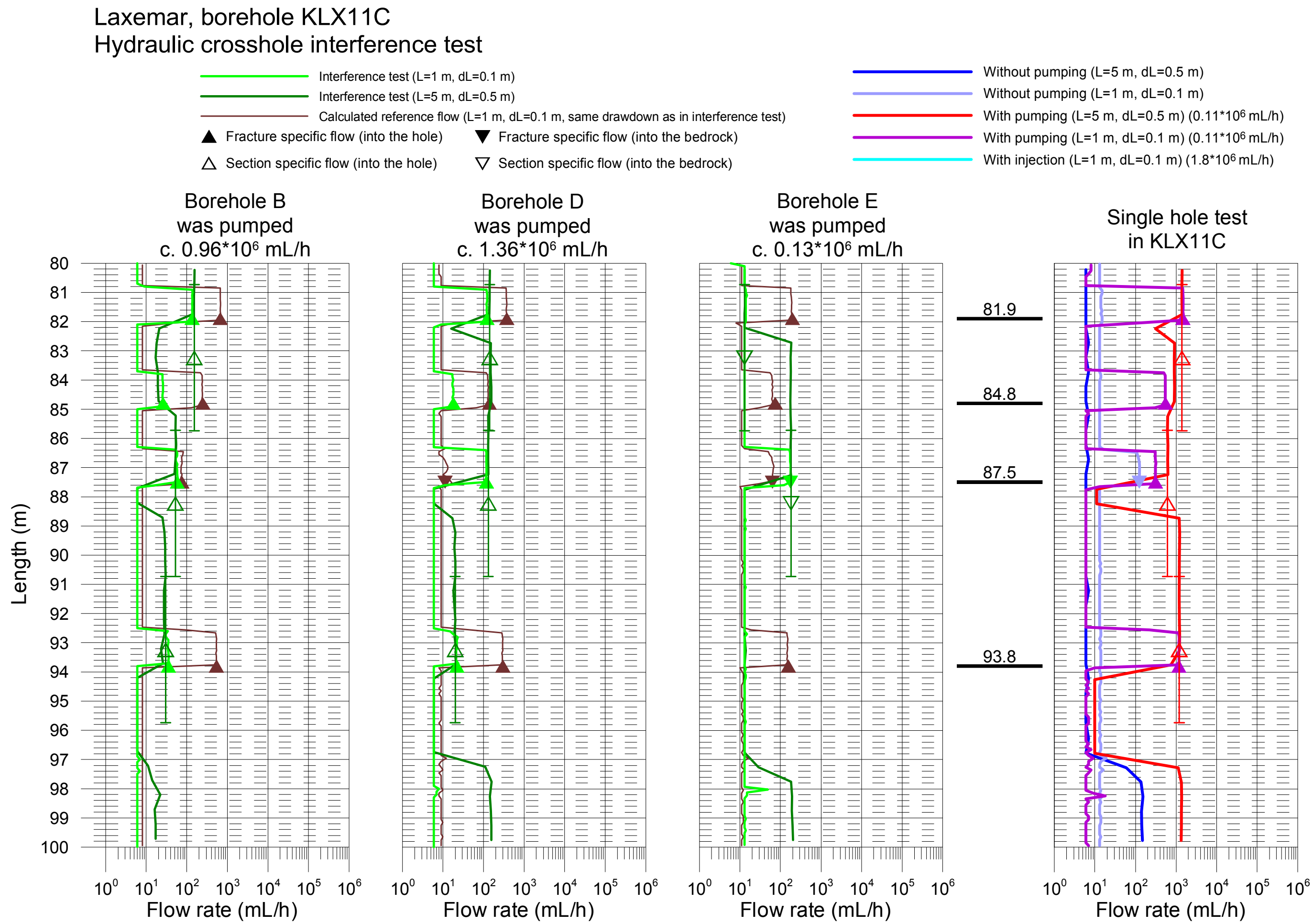
Laxemar, borehole KLX11C
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.11*10⁶ mL/h)
With pumping (L=1 m, dL=0.1 m) (0.11*10⁶ mL/h)
With injection (L=1 m, dL=0.1 m) (1.8*10⁶ mL/h)
Borehole B was pumped c. 0.96*10⁶ mL/h
Borehole D was pumped c. 1.36*10⁶ mL/h
Borehole E was pumped c. 0.13*10⁶ mL/h
Single hole test in KLX11C
Length (m)
Flow rate (mL/h)
40.3
41.4
45.1
49.5
51.9
52.8
54.4
58.4

Appendix 7.4



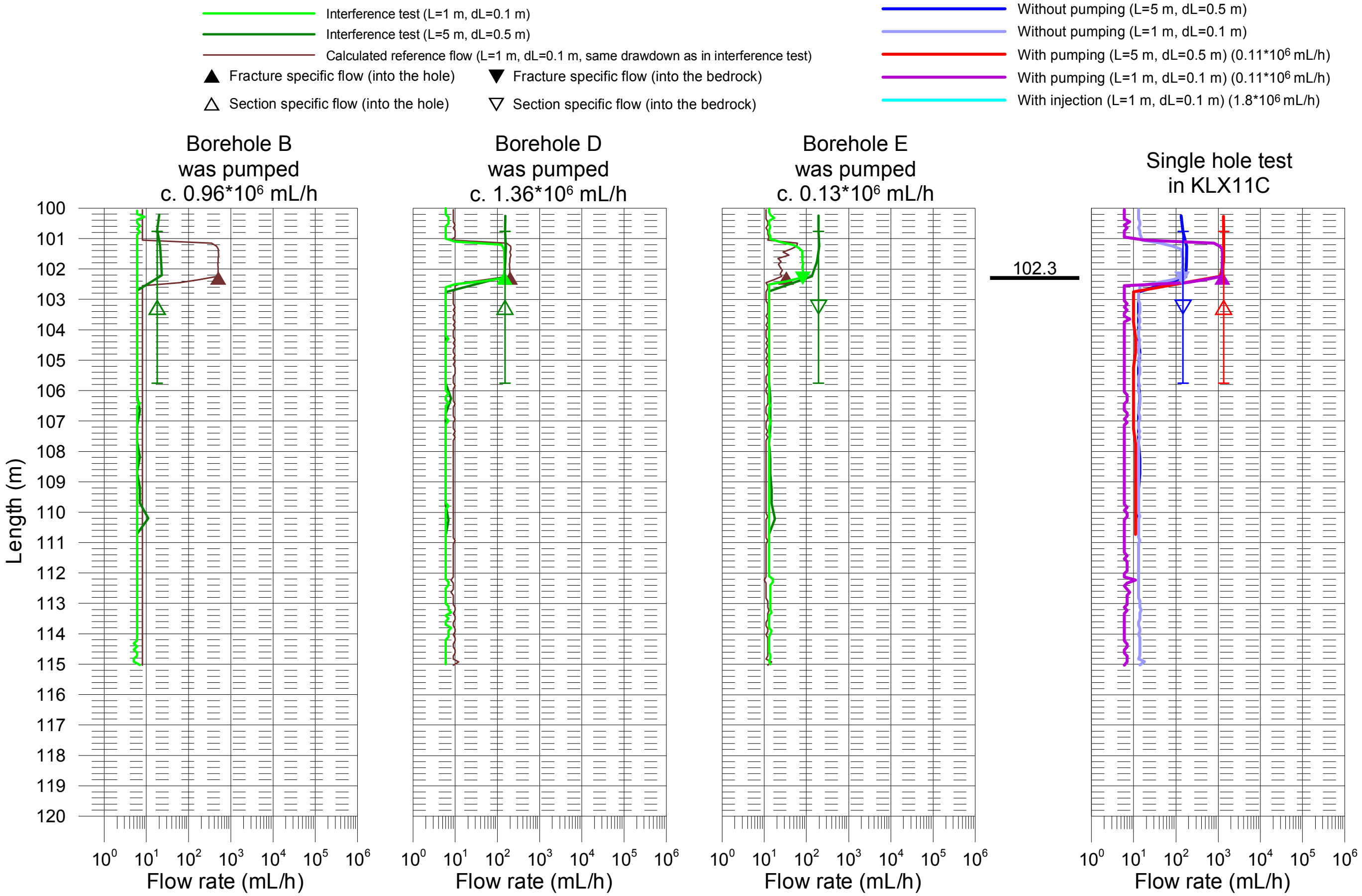
Laxemar, borehole KLX11C
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.11*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (0.11*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (1.8*10^6 mL/h)
Borehole B was pumped c. 0.96*10^6 mL/h
Borehole D was pumped c. 1.36*10^6 mL/h
Borehole E was pumped c. 0.13*10^6 mL/h
Single hole test in KLX11C
Length (m)
Flow rate (mL/h)
64.3
65.0
66.5
66.9
70.1
71.4
73.1
75.2
76.6
77.3

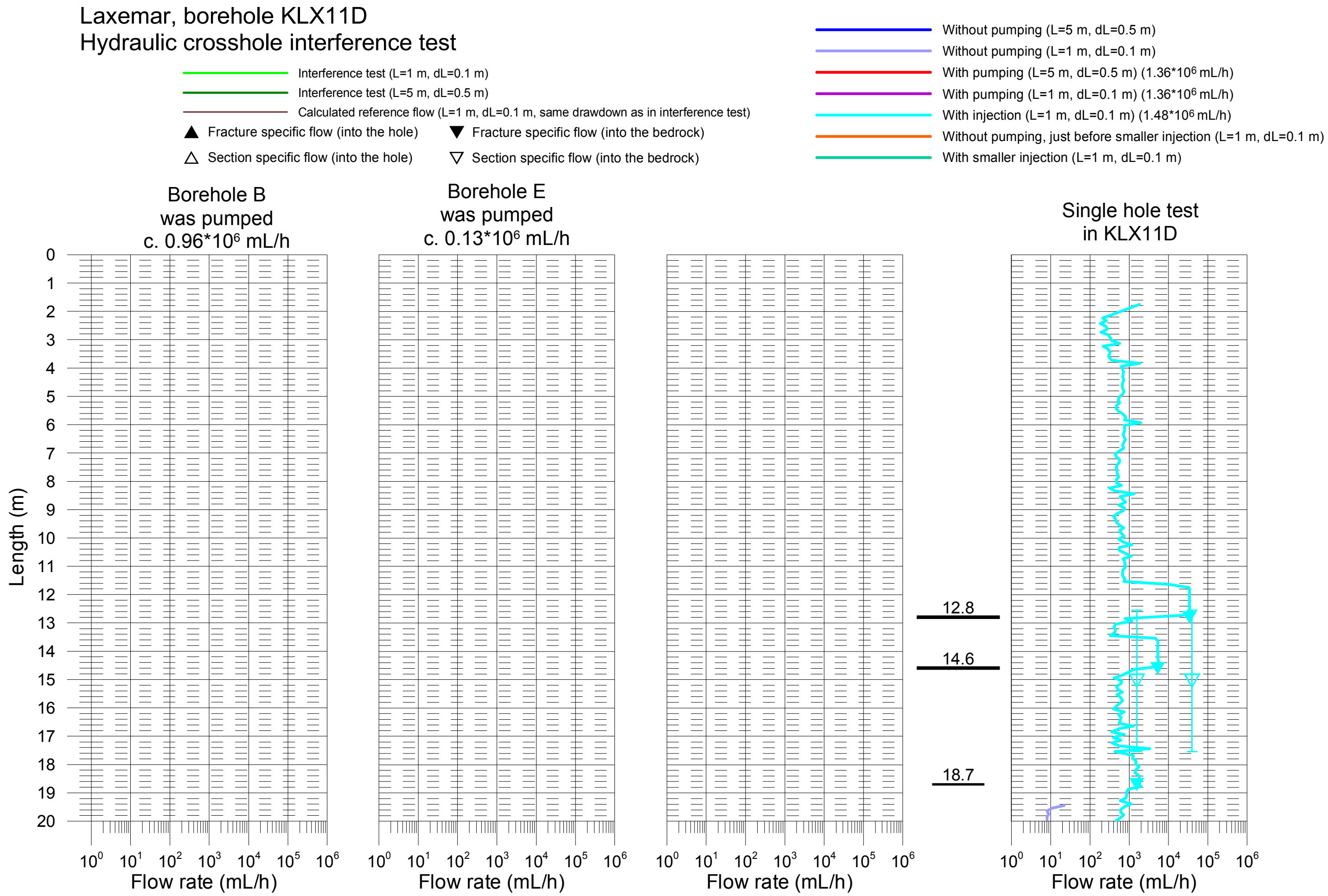
Appendix 7.5

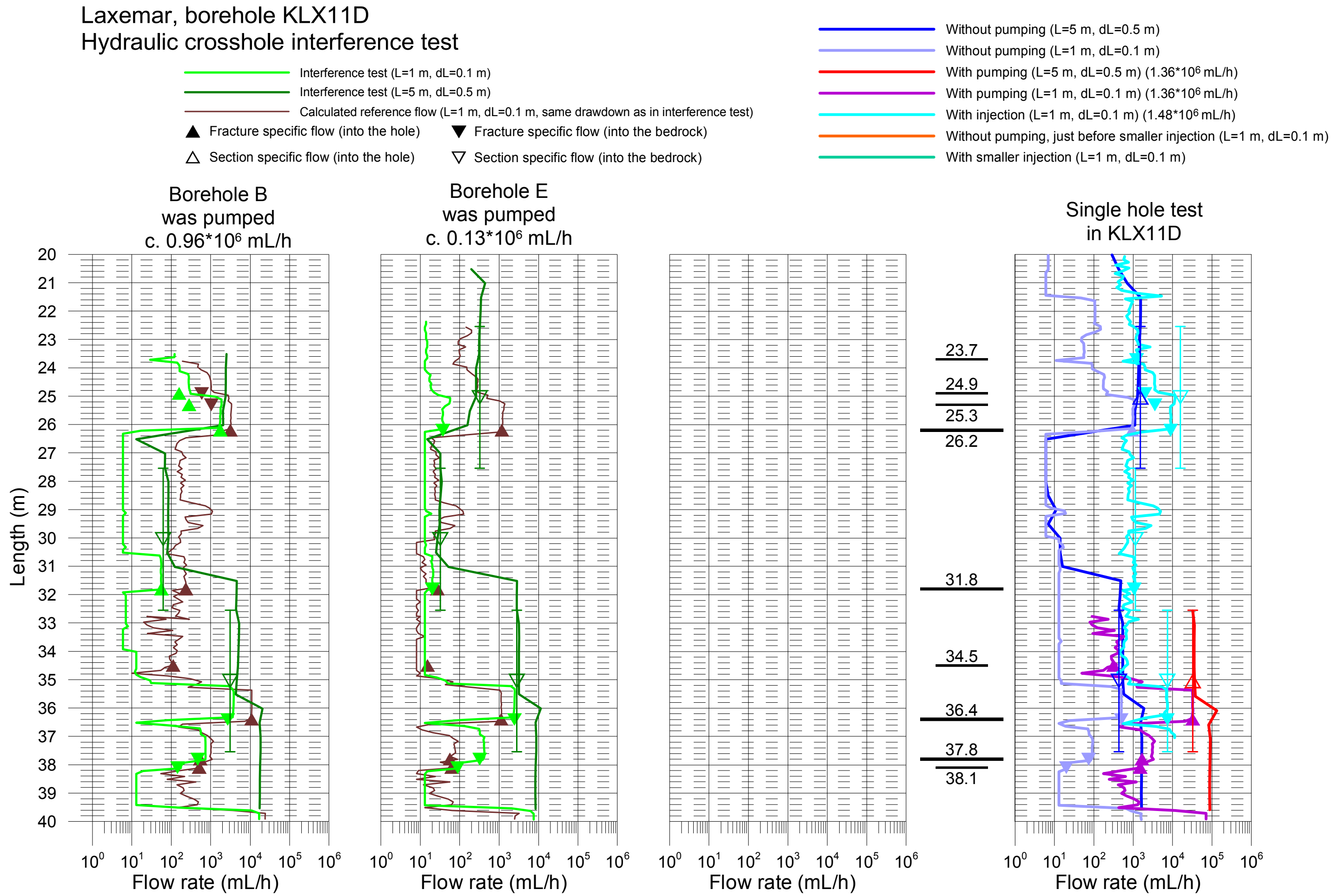


Laxemar, borehole KLX11C
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.11*10⁶ mL/h)
With pumping (L=1 m, dL=0.1 m) (0.11*10⁶ mL/h)
With injection (L=1 m, dL=0.1 m) (1.8*10⁶ mL/h)
Borehole B was pumped c. 0.96*10⁶ mL/h
Borehole D was pumped c. 1.36*10⁶ mL/h
Borehole E was pumped c. 0.13*10⁶ mL/h
Single hole test in KLX11C
Length (m)
Flow rate (mL/h)
81.9
84.8
87.5
93.8

Laxemar, borehole KLX11C
Hydraulic crosshole interference test

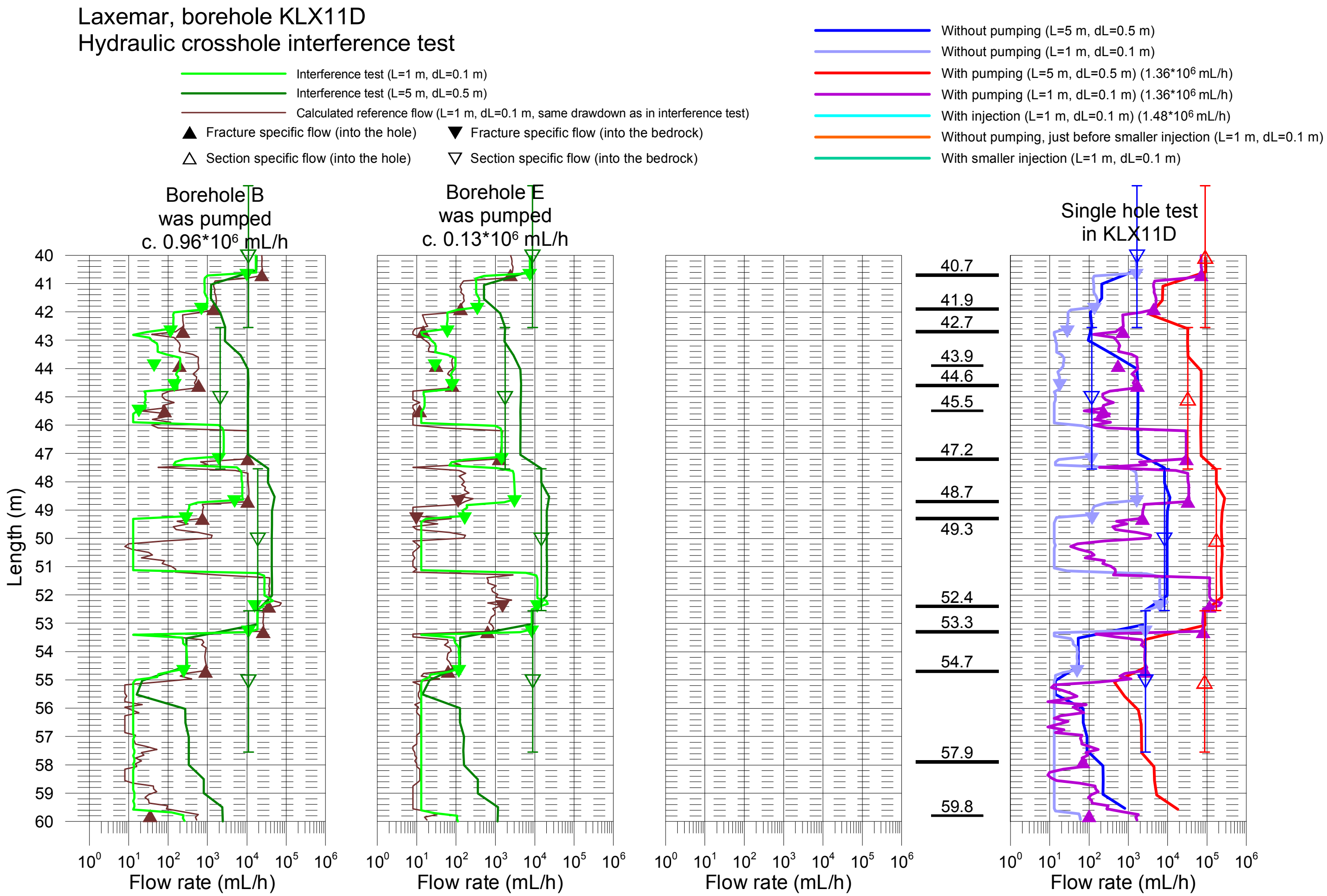



Laxemar, borehole KLX11D
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.36*10⁶ mL/h)
With pumping (L=1 m, dL=0.1 m) (1.36*10⁶ mL/h)
With injection (L=1 m, dL=0.1 m) (1.48*10⁶ mL/h)
Without pumping, just before smaller injection (L=1 m, dL=0.1 m)
With smaller injection (L=1 m, dL=0.1 m)
Borehole B was pumped c. 0.96*10⁶ mL/h
Borehole E was pumped c. 0.13*10⁶ mL/h
Single hole test in KLX11D
Length (m)
Flow rate (mL/h)
12.8
14.6
18.7



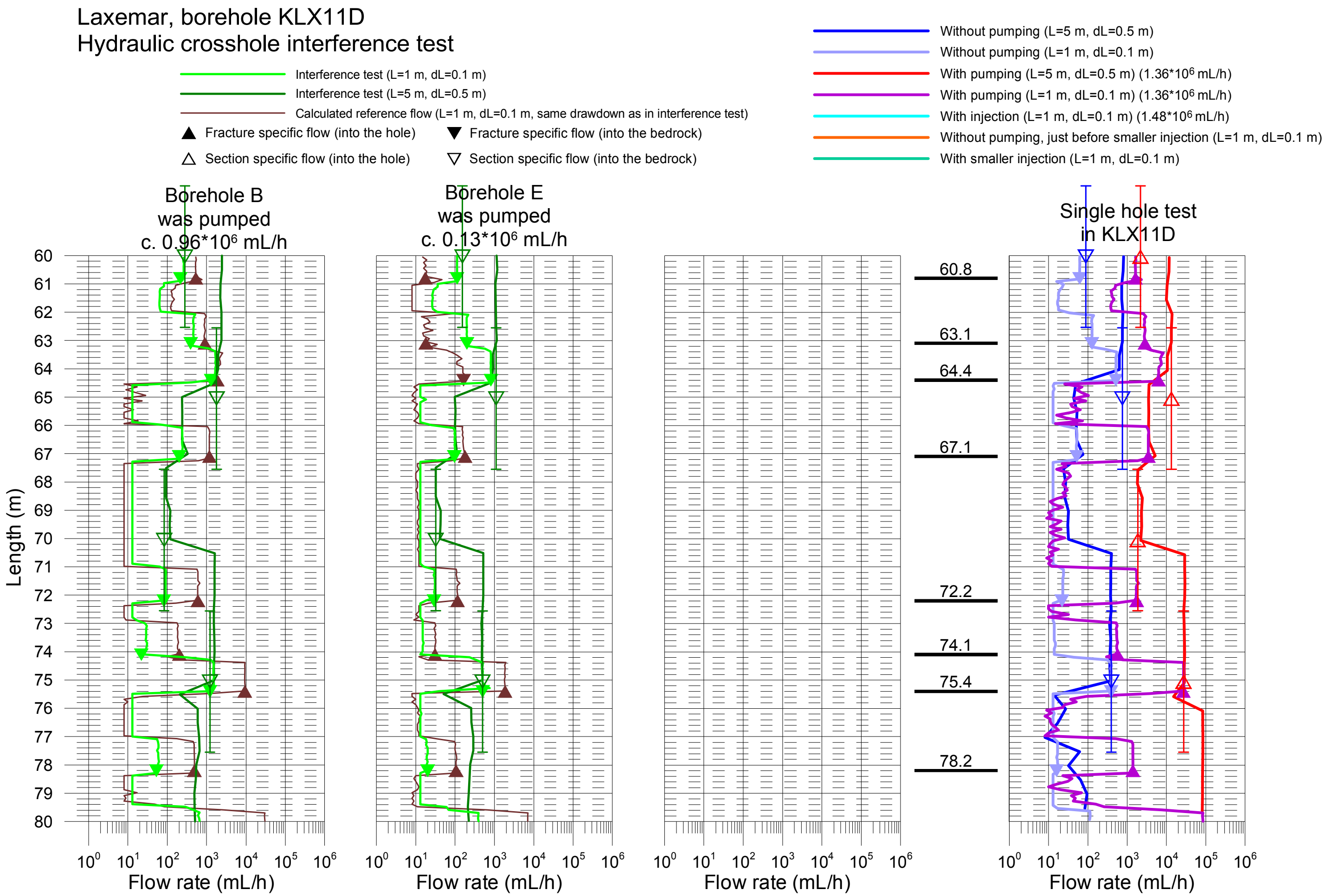
Laxemar, borehole KLX11D
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.36*10⁶ mL/h)
With pumping (L=1 m, dL=0.1 m) (1.36*10⁶ mL/h)
With injection (L=1 m, dL=0.1 m) (1.48*10⁶ mL/h)
Without pumping, just before smaller injection (L=1 m, dL=0.1 m)
With smaller injection (L=1 m, dL=0.1 m)
Borehole B was pumped c. 0.96*10⁶ mL/h
Borehole E was pumped c. 0.13*10⁶ mL/h
Single hole test in KLX11D
Length (m)
Flow rate (mL/h)
23.7
24.9
25.3
26.2
31.8
34.5
36.4
37.8
38.1

Appendix 8.3

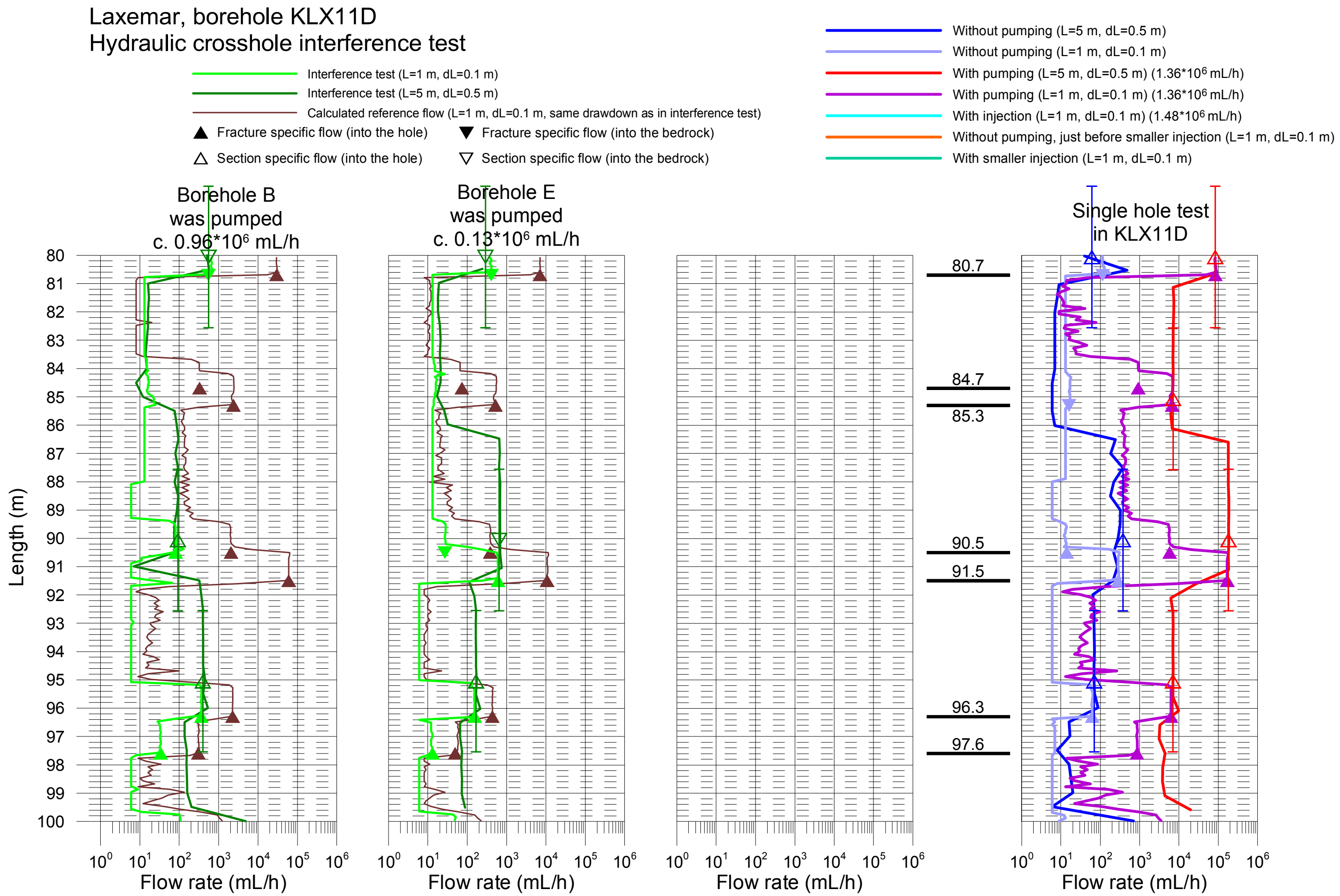


Laxemar, borehole KLX11D
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.36*10⁶ mL/h)
With pumping (L=1 m, dL=0.1 m) (1.36*10⁶ mL/h)
With injection (L=1 m, dL=0.1 m) (1.48*10⁶ mL/h)
Without pumping, just before smaller injection (L=1 m, dL=0.1 m)
With smaller injection (L=1 m, dL=0.1 m)
Borehole B was pumped c. 0.96*10⁶ mL/h
Borehole E was pumped c. 0.13*10⁶ mL/h
Single hole test in KLX11D
Length (m)
Flow rate (mL/h)
40.7
41.9
42.7
43.9
44.6
45.5
47.2
48.7
49.3
52.4
53.3
54.7
57.9
59.8

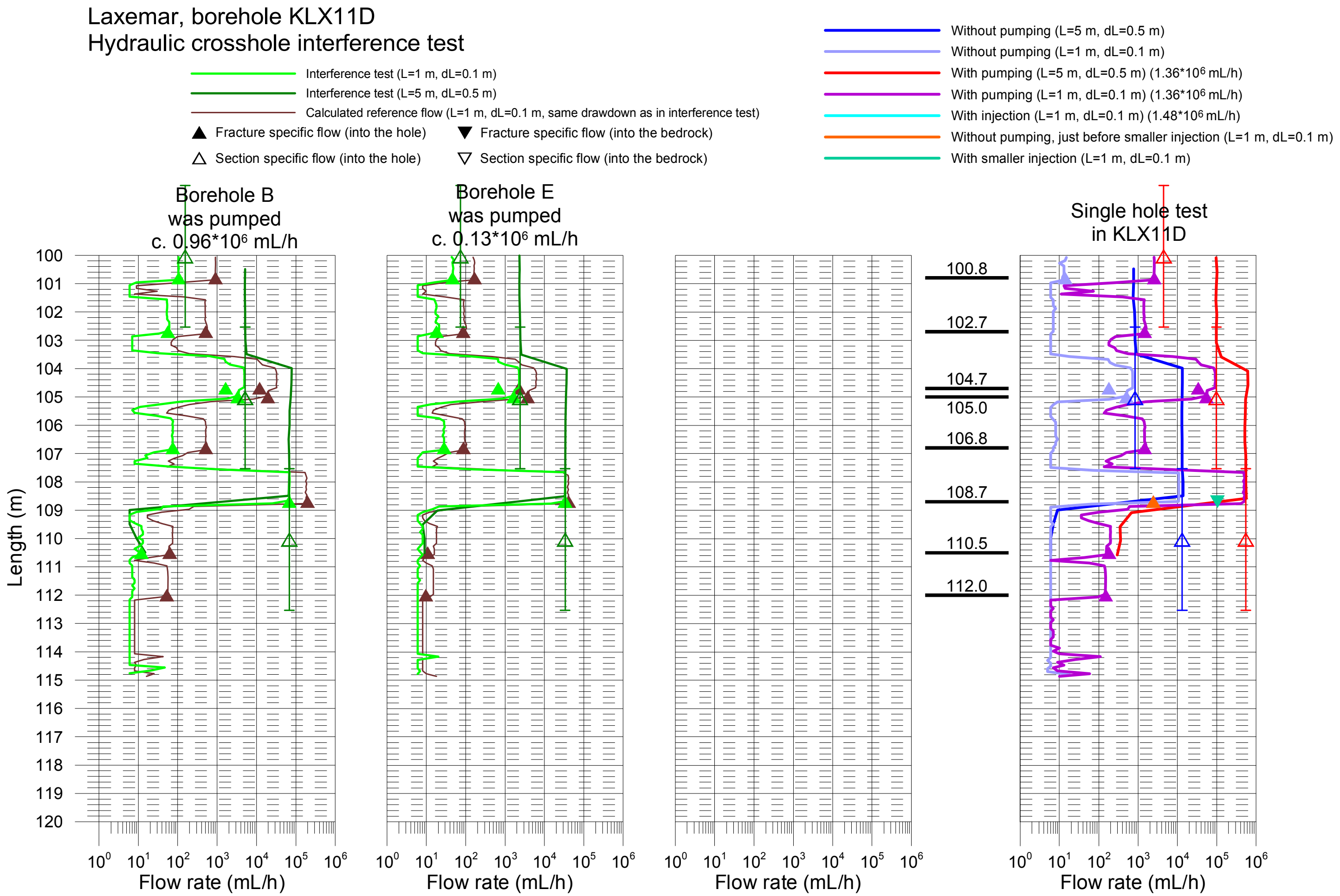
Appendix 8.4



Laxemar, borehole KLX11D
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.36*10⁶ mL/h)
With pumping (L=1 m, dL=0.1 m) (1.36*10⁶ mL/h)
With injection (L=1 m, dL=0.1 m) (1.48*10⁶ mL/h)
Without pumping, just before smaller injection (L=1 m, dL=0.1 m)
With smaller injection (L=1 m, dL=0.1 m)
Borehole B was pumped c. 0.96*10⁶ mL/h
Borehole E was pumped c. 0.13*10⁶ mL/h
Single hole test in KLX11D
Length (m)
Flow rate (mL/h)
60.8
63.1
64.4
67.1
72.2
74.1
75.4
78.2

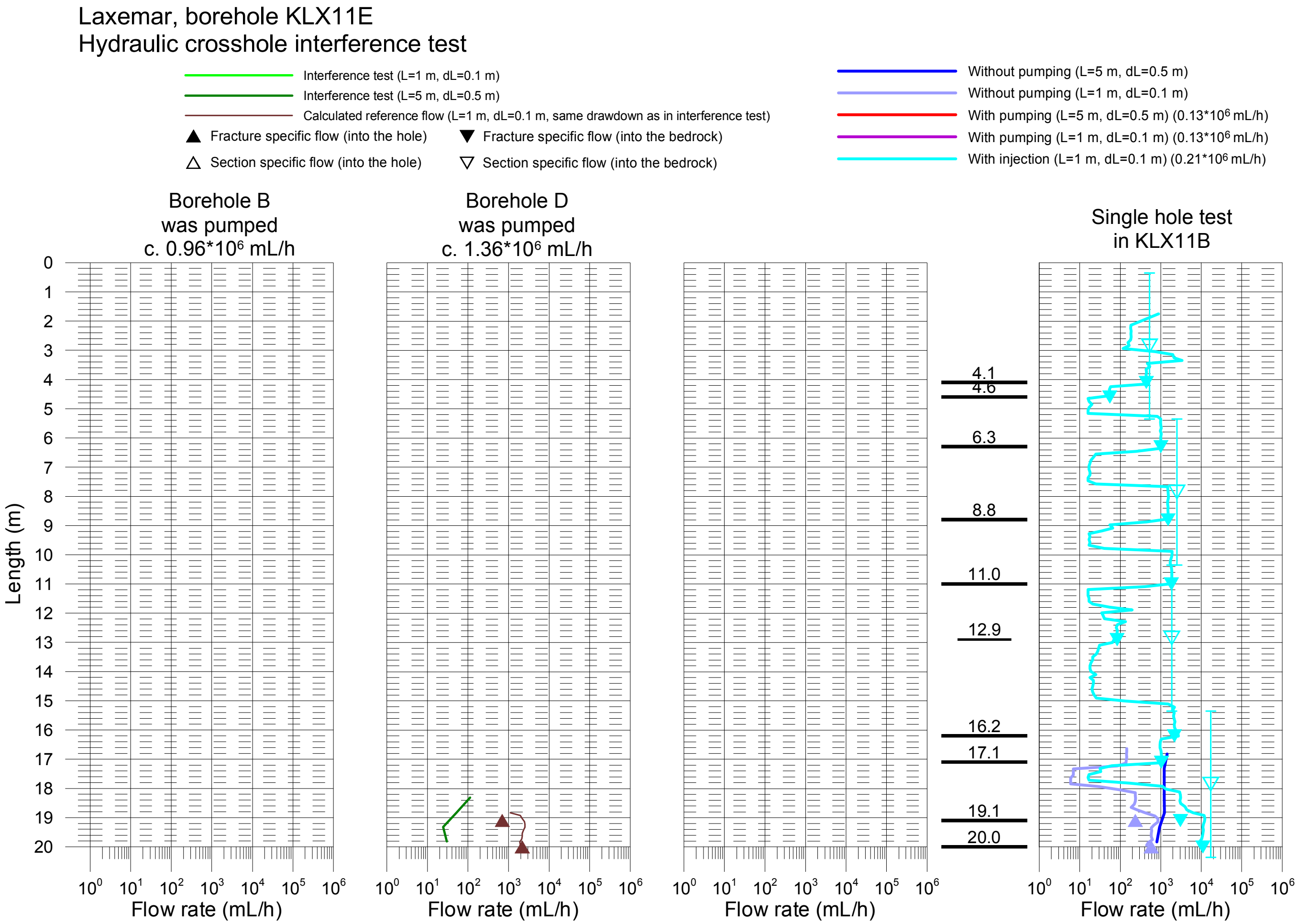

Laxemar, borehole KLX11D
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.36*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (1.36*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (1.48*10^6 mL/h)
Without pumping, just before smaller injection (L=1 m, dL=0.1 m)
With smaller injection (L=1 m, dL=0.1 m)
Borehole B was pumped c. 0.96*10^6 mL/h
Borehole E was pumped c. 0.13*10^6 mL/h
Single hole test in KLX11D
Length (m)
Flow rate (mL/h)
80.7
84.7
85.3
90.5
91.5
96.3
97.6

Appendix 8.6



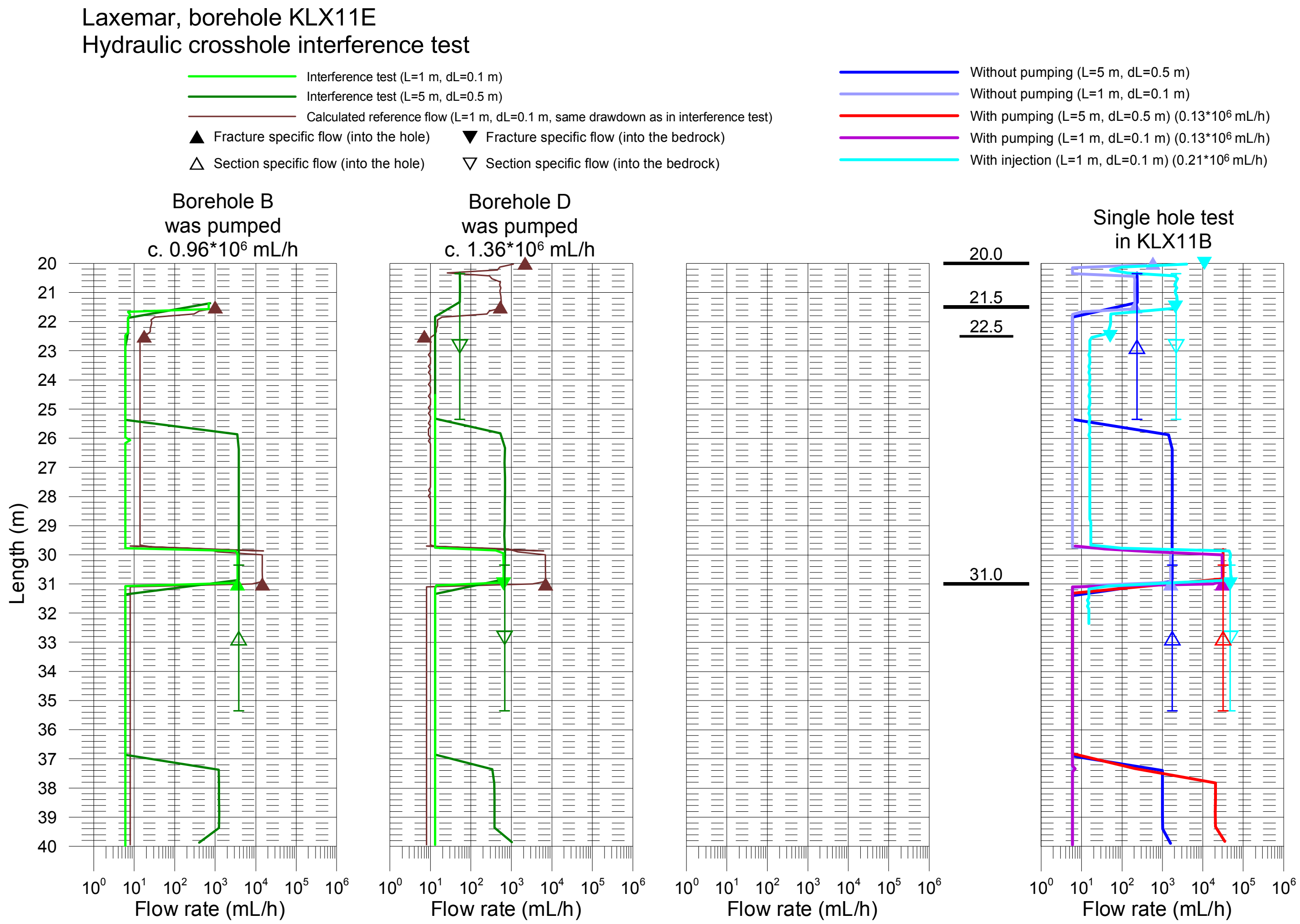
Laxemar, borehole KLX11D
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.36*10⁶ mL/h)
With pumping (L=1 m, dL=0.1 m) (1.36*10⁶ mL/h)
With injection (L=1 m, dL=0.1 m) (1.48*10⁶ mL/h)
Without pumping, just before smaller injection (L=1 m, dL=0.1 m)
With smaller injection (L=1 m, dL=0.1 m)
Borehole B was pumped c. 0.96*10⁶ mL/h
Borehole E was pumped c. 0.13*10⁶ mL/h
Single hole test in KLX11D
Length (m)
100.8
102.7
104.7
105.0
106.8
108.7
110.5
112.0
Flow rate (mL/h)

Appendix 9.1

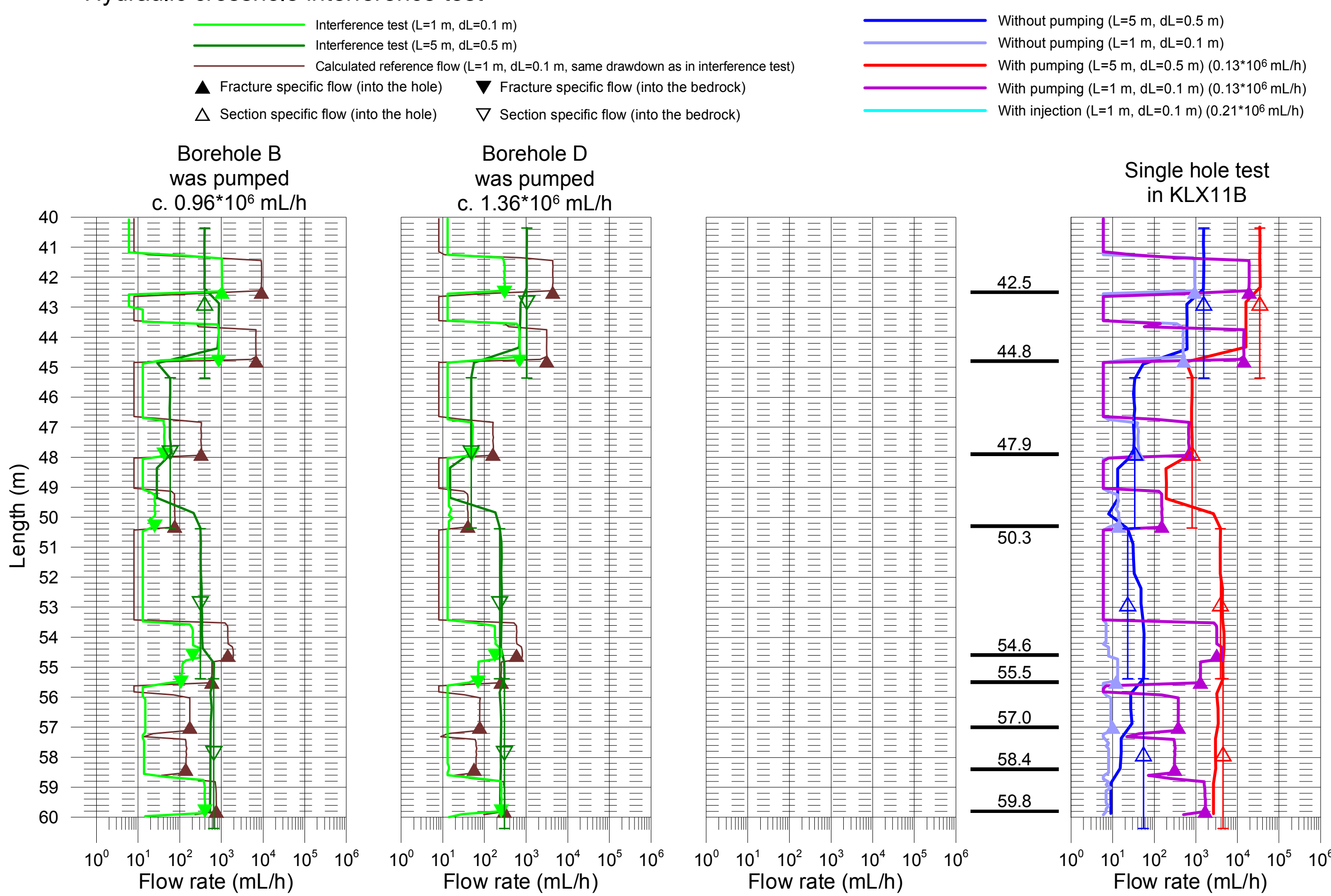


Laxemar, borehole KLX11E
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.13*10⁶ mL/h)
With pumping (L=1 m, dL=0.1 m) (0.13*10⁶ mL/h)
With injection (L=1 m, dL=0.1 m) (0.21*10⁶ mL/h)
Borehole B was pumped c. 0.96*10⁶ mL/h
Borehole D was pumped c. 1.36*10⁶ mL/h
Single hole test in KLX11B
Length (m)
Flow rate (mL/h)
4.1
4.6
6.3
8.8
11.0
12.9
16.2
17.1
19.1
20.0

Appendix 9.2

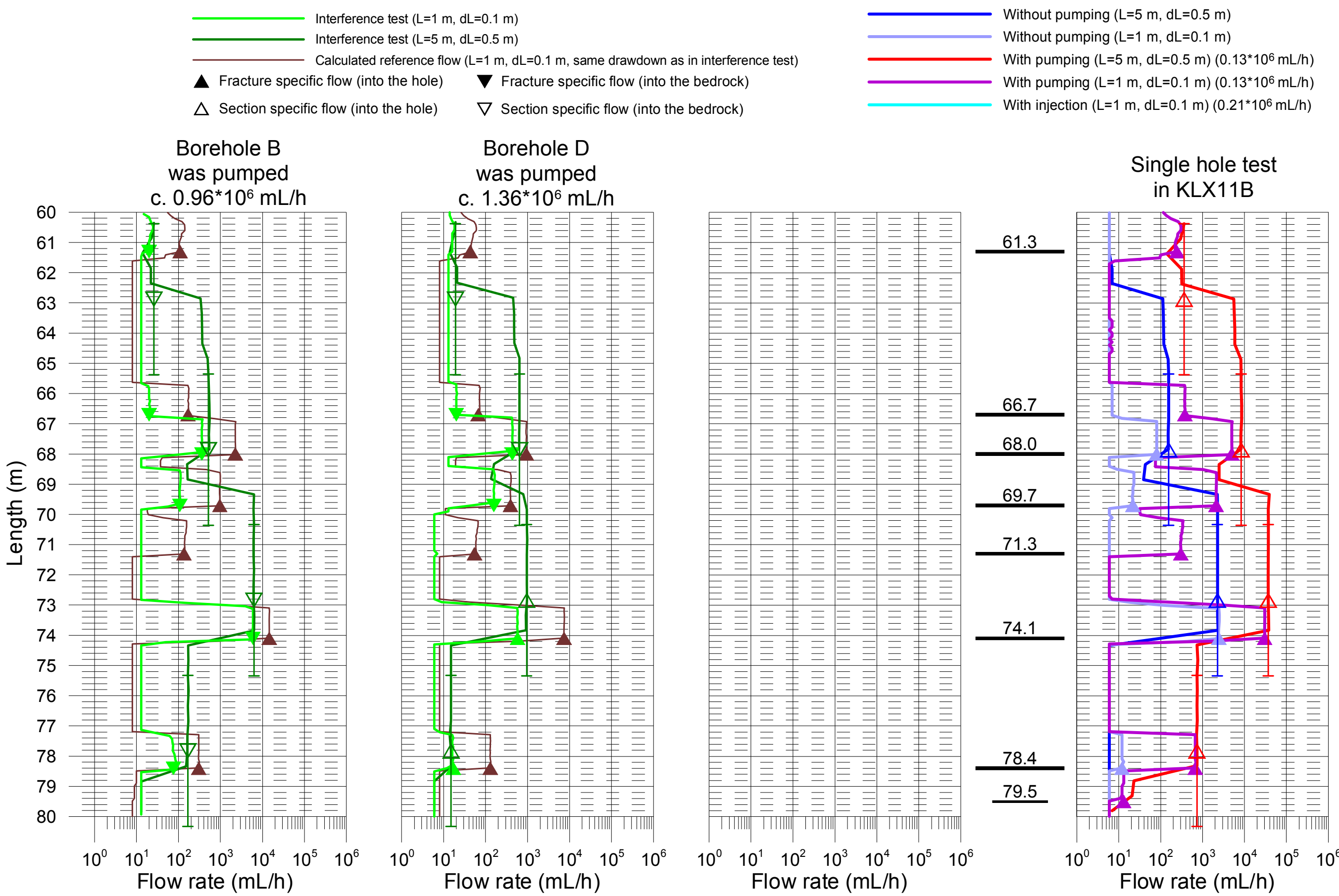

Laxemar, borehole KLX11E
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.13*10⁶ mL/h)
With pumping (L=1 m, dL=0.1 m) (0.13*10⁶ mL/h)
With injection (L=1 m, dL=0.1 m) (0.21*10⁶ mL/h)
Borehole B
was pumped
c. 0.96*10⁶ mL/h
Borehole D
was pumped
c. 1.36*10⁶ mL/h
Single hole test
in KLX11B
20.0
21.5
22.5
31.0
Length (m)
Flow rate (mL/h)
Flow rate (mL/h)
Flow rate (mL/h)
Flow rate (mL/h)

Laxemar, borehole KLX11E
Hydraulic crosshole interference test

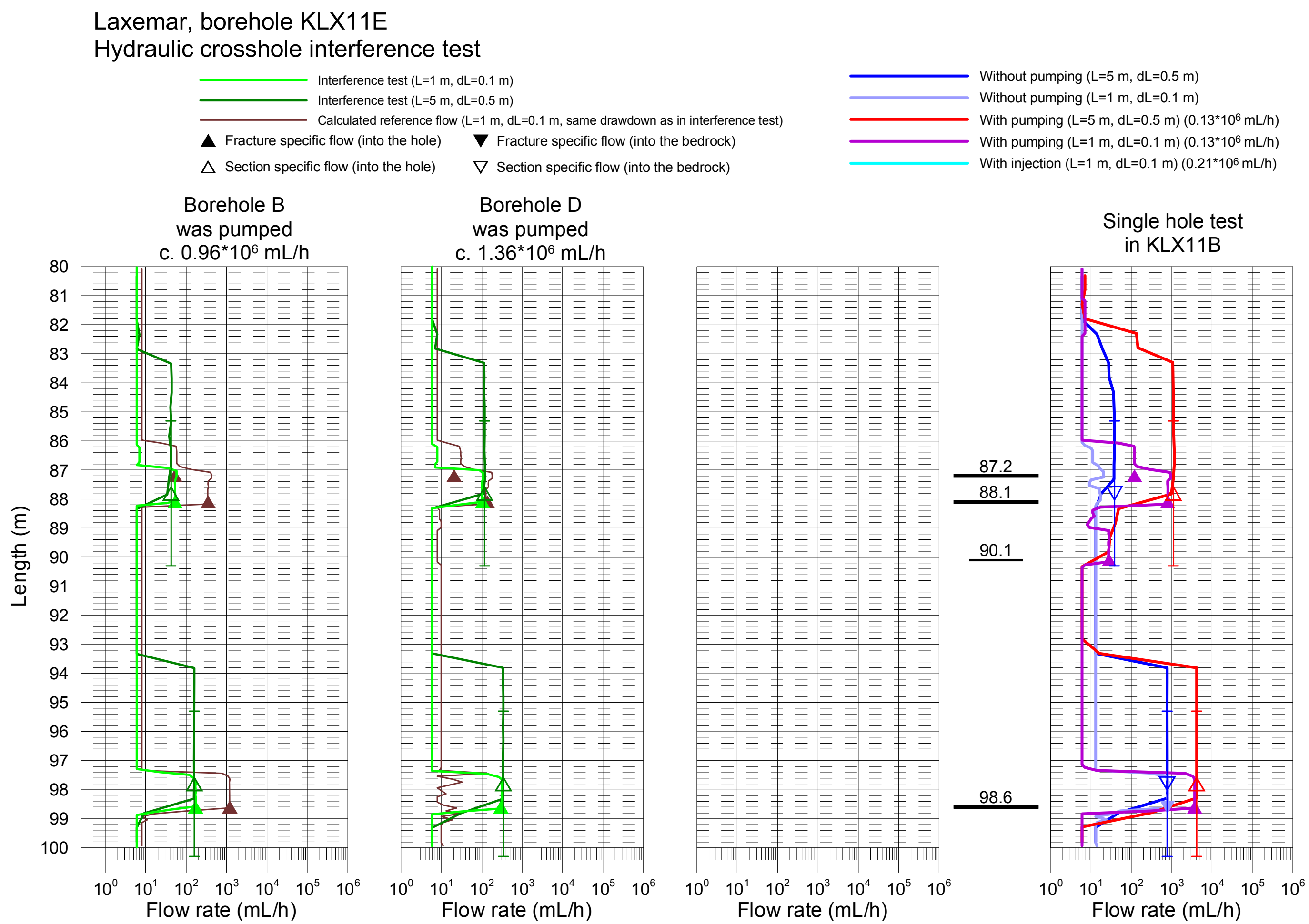


Appendix 9.4

Laxemar, borehole KLX11E
Hydraulic crosshole interference test

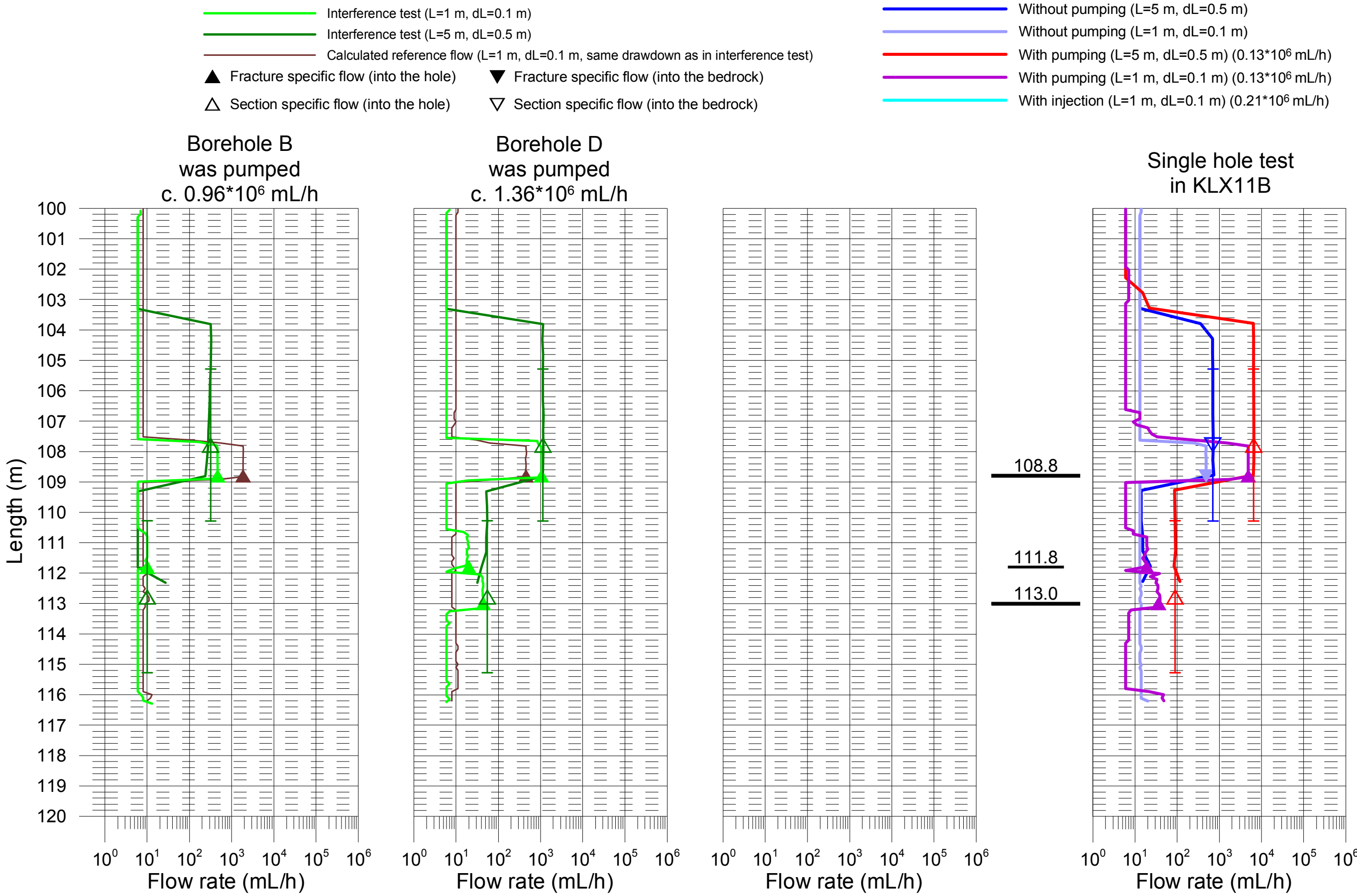


Appendix 9.5

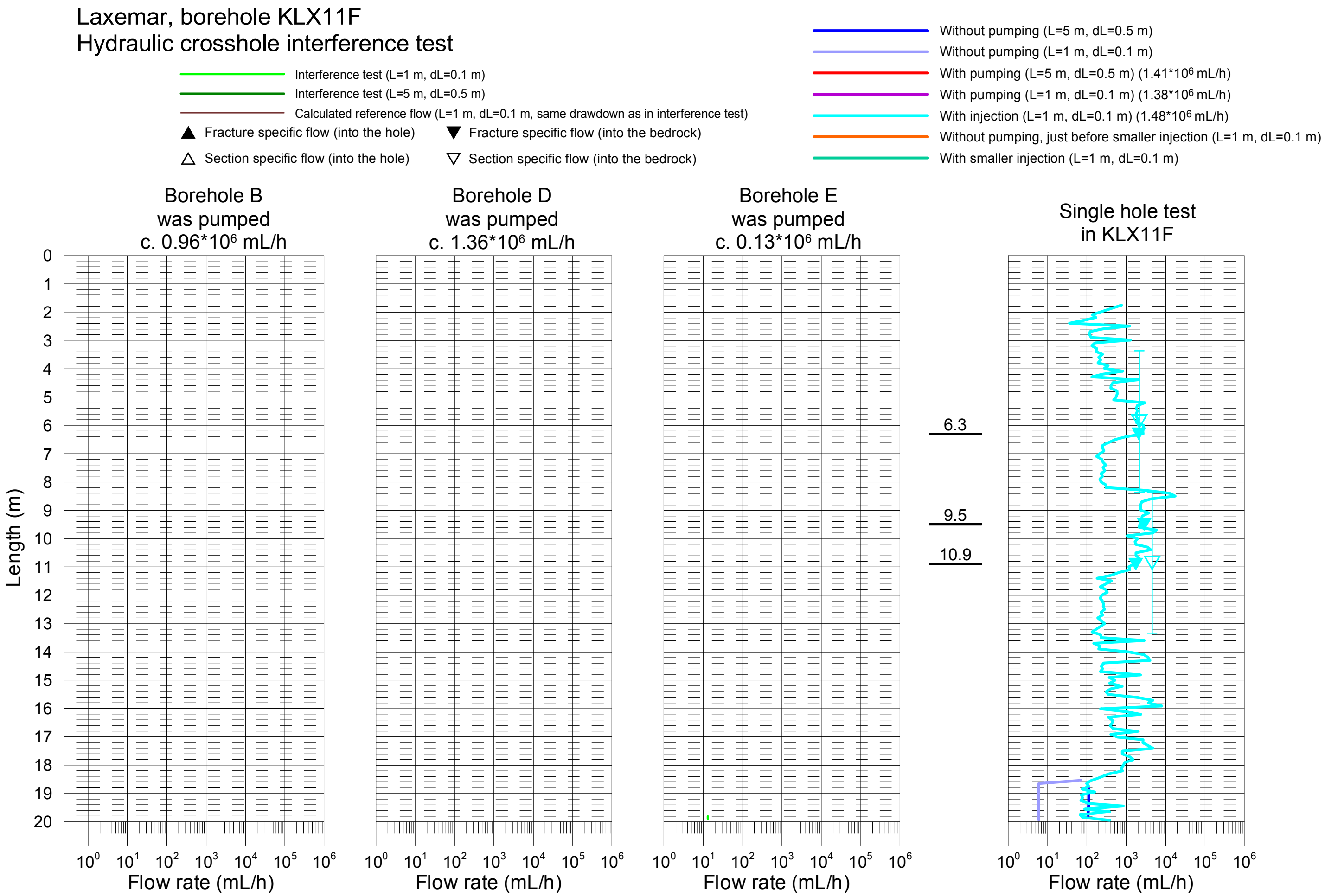


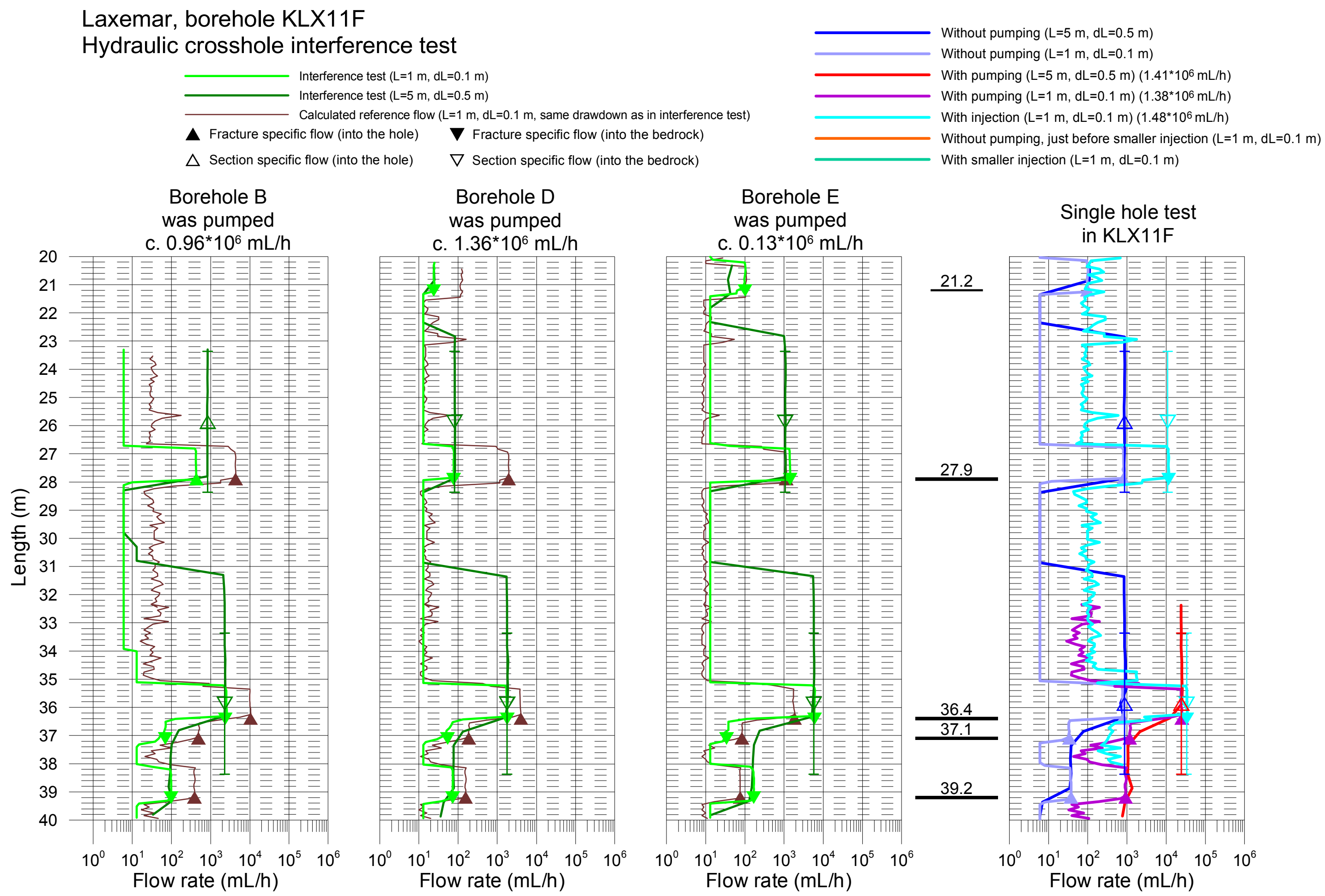
Laxemar, borehole KLX11E
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (0.13*10^6 mL/h)
With pumping (L=1 m, dL=0.1 m) (0.13*10^6 mL/h)
With injection (L=1 m, dL=0.1 m) (0.21*10^6 mL/h)
Borehole B was pumped c. 0.96*10^6 mL/h
Borehole D was pumped c. 1.36*10^6 mL/h
Single hole test in KLX11B
Length (m)
Flow rate (mL/h)
87.2
88.1
90.1
98.6

Laxemar, borehole KLX11E
Hydraulic crosshole interference test

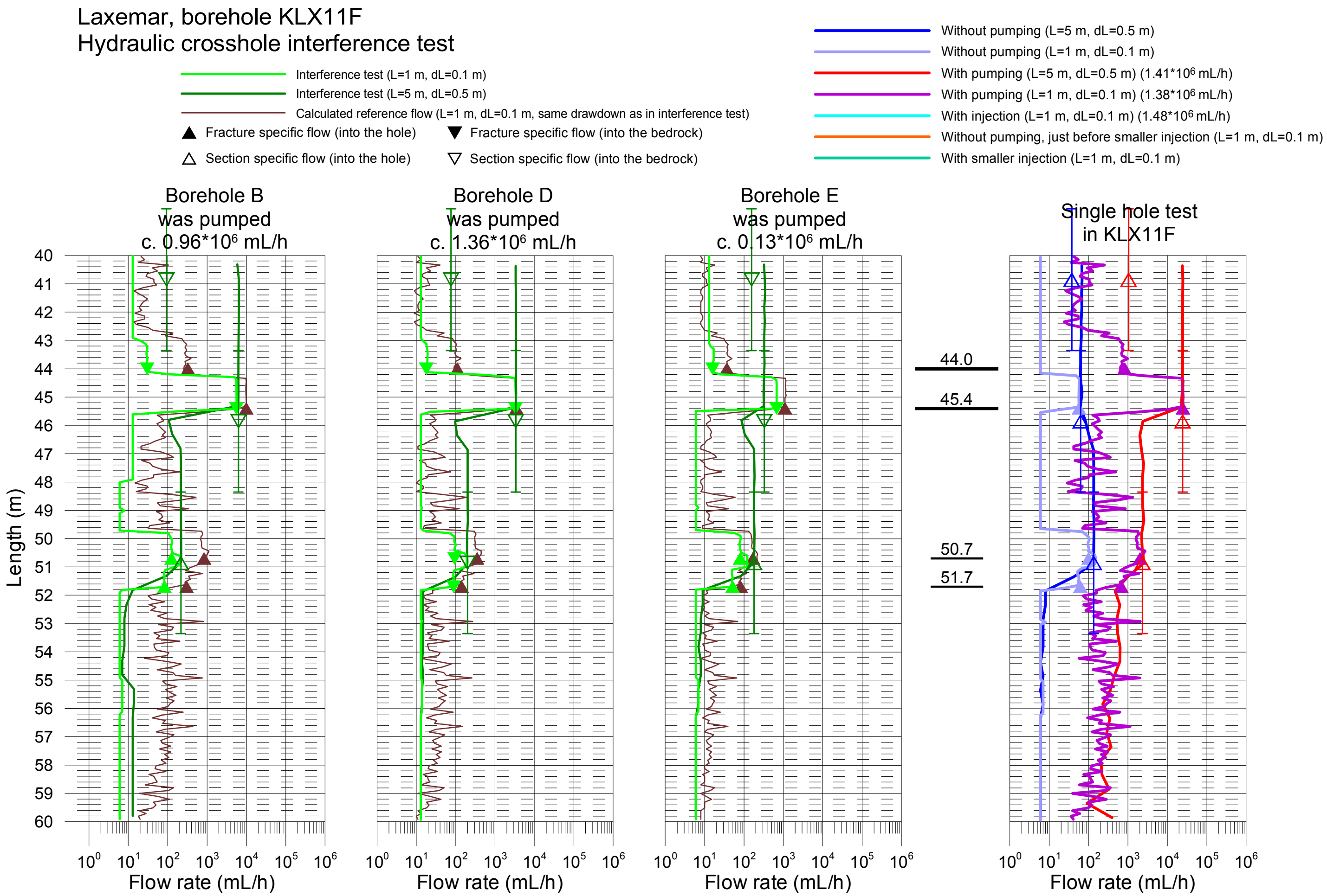


Appendix 10.1

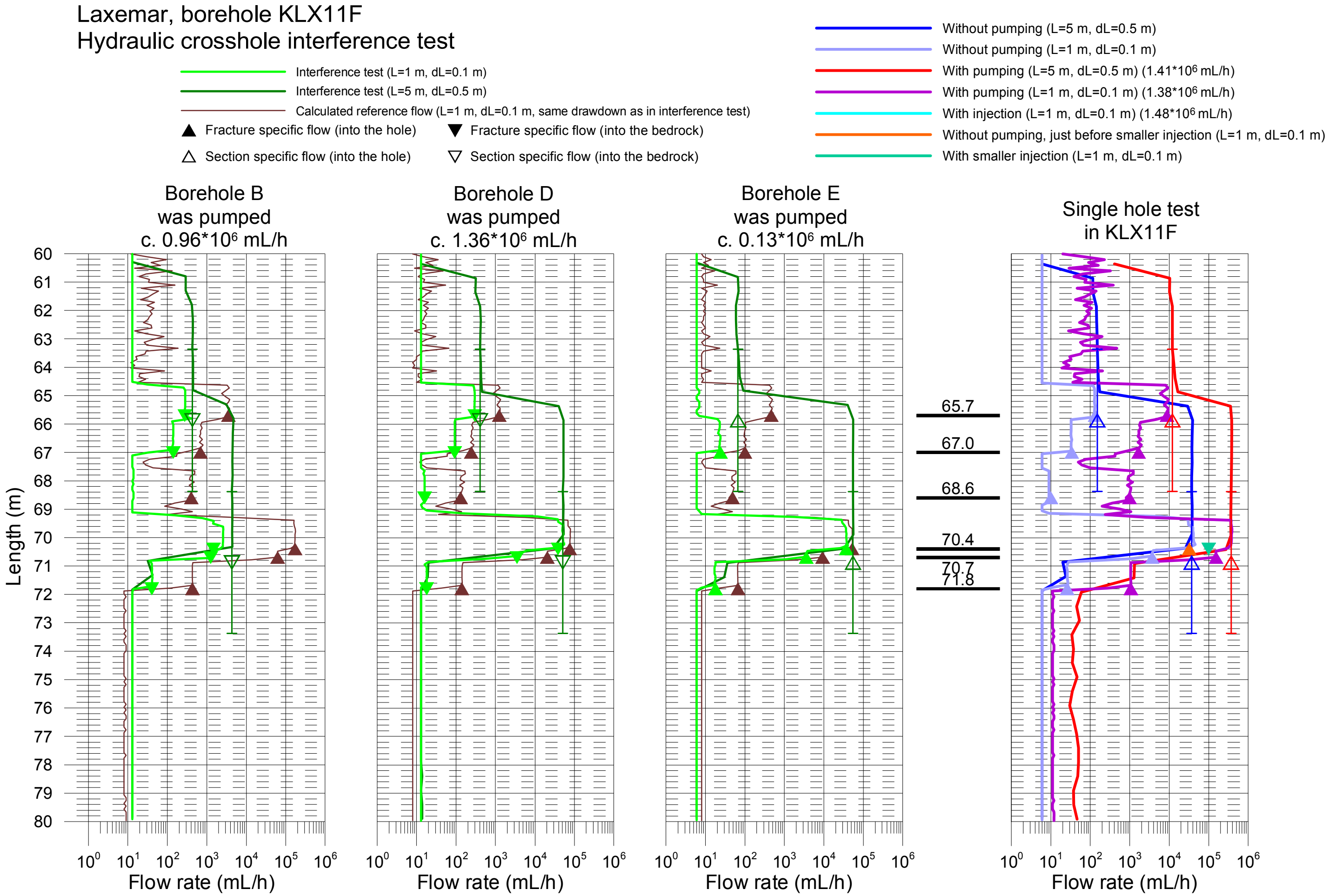



Laxemar, borehole KLX11F
Hydraulic crosshole interference test
Interference test (L=1 m, dL=0.1 m)
Interference test (L=5 m, dL=0.5 m)
Calculated reference flow (L=1 m, dL=0.1 m, same drawdown as in interference test)
Fracture specific flow (into the hole)
Fracture specific flow (into the bedrock)
Section specific flow (into the hole)
Section specific flow (into the bedrock)
Without pumping (L=5 m, dL=0.5 m)
Without pumping (L=1 m, dL=0.1 m)
With pumping (L=5 m, dL=0.5 m) (1.41*10⁶ mL/h)
With pumping (L=1 m, dL=0.1 m) (1.38*10⁶ mL/h)
With injection (L=1 m, dL=0.1 m) (1.48*10⁶ mL/h)
Without pumping, just before smaller injection (L=1 m, dL=0.1 m)
With smaller injection (L=1 m, dL=0.1 m)
Borehole B was pumped c. 0.96*10⁶ mL/h
Borehole D was pumped c. 1.36*10⁶ mL/h
Borehole E was pumped c. 0.13*10⁶ mL/h
Single hole test in KLX11F
Length (m)
Flow rate (mL/h)
21.2
27.9
36.4
37.1
39.2

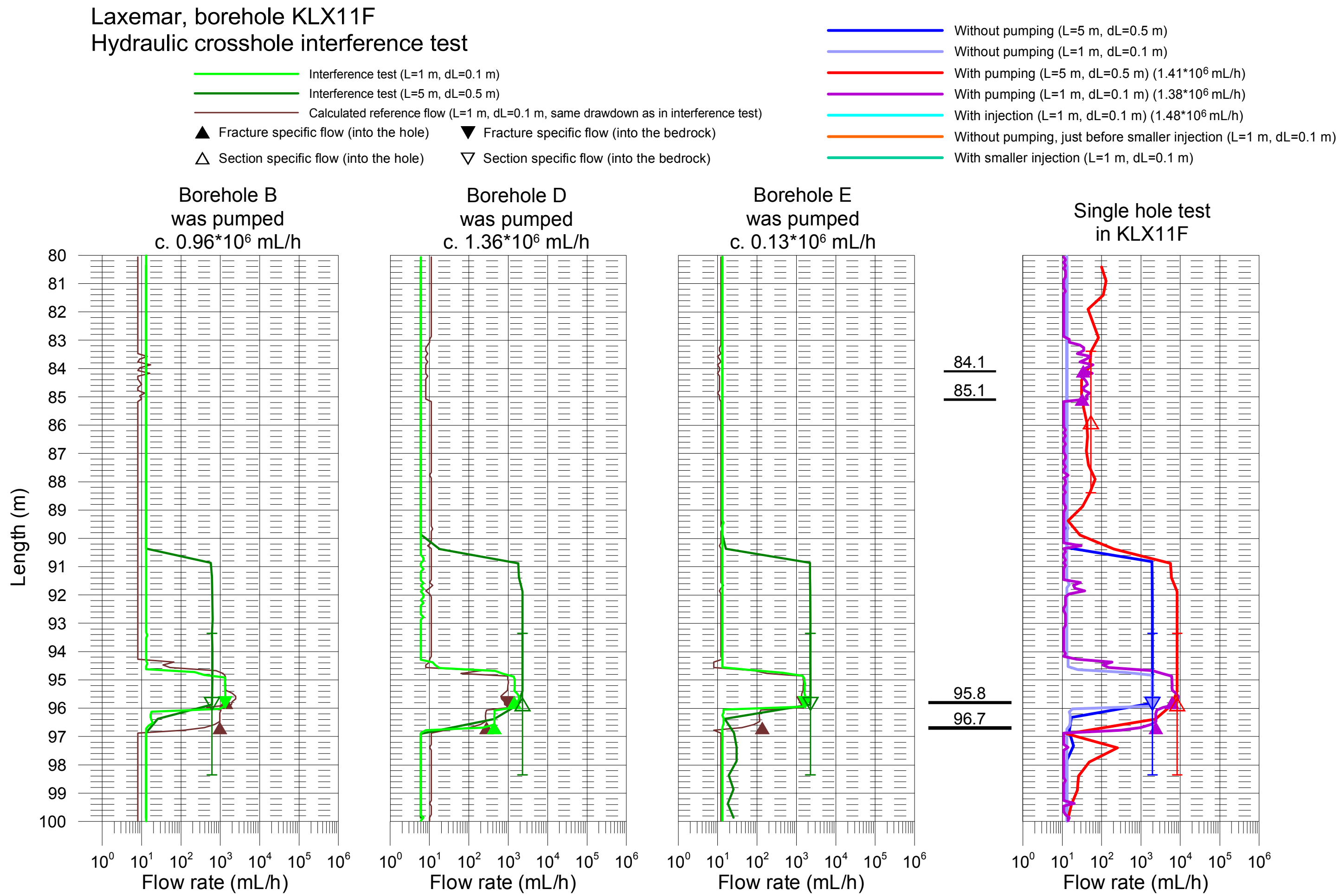
Appendix 10.3



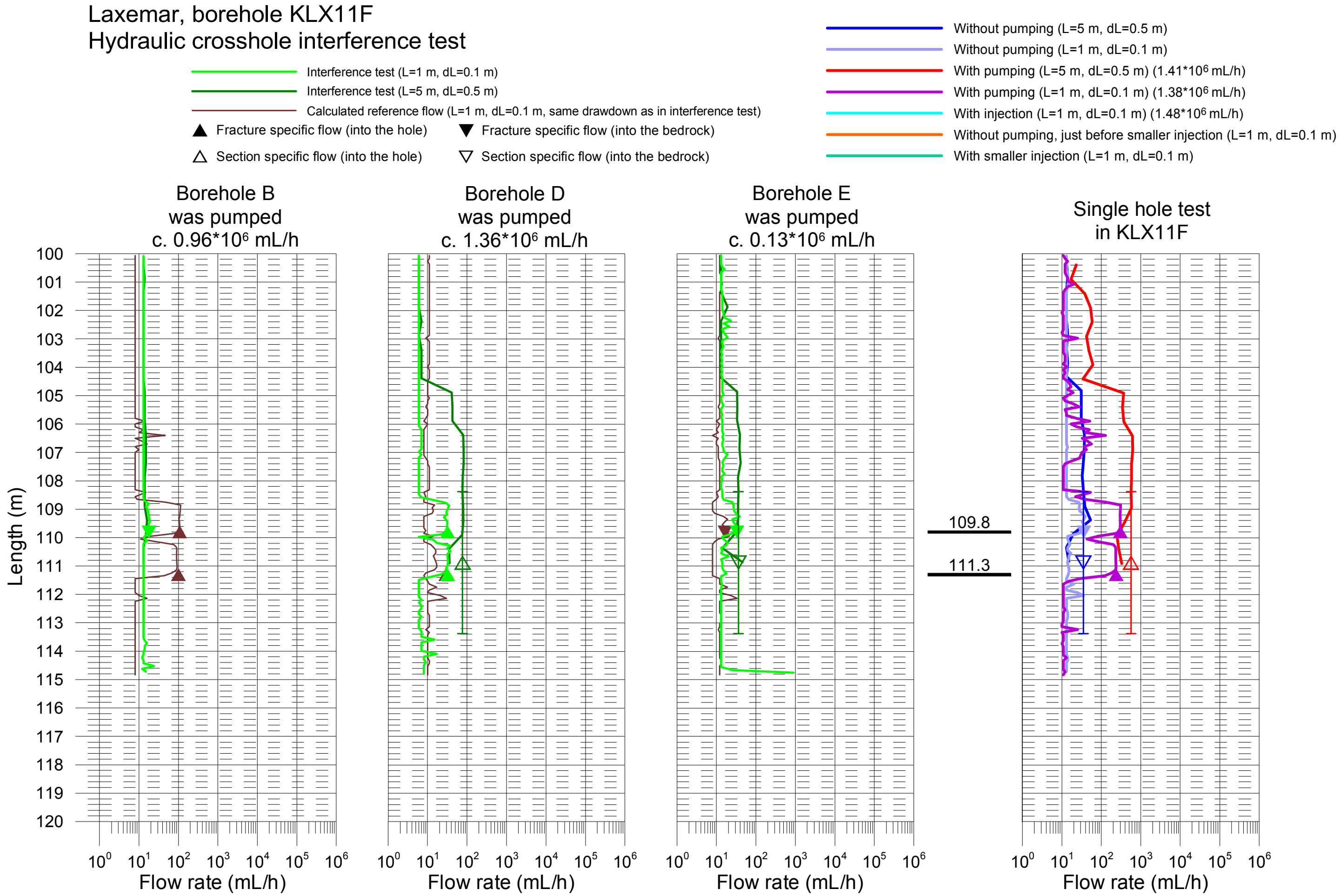
Appendix 10.4



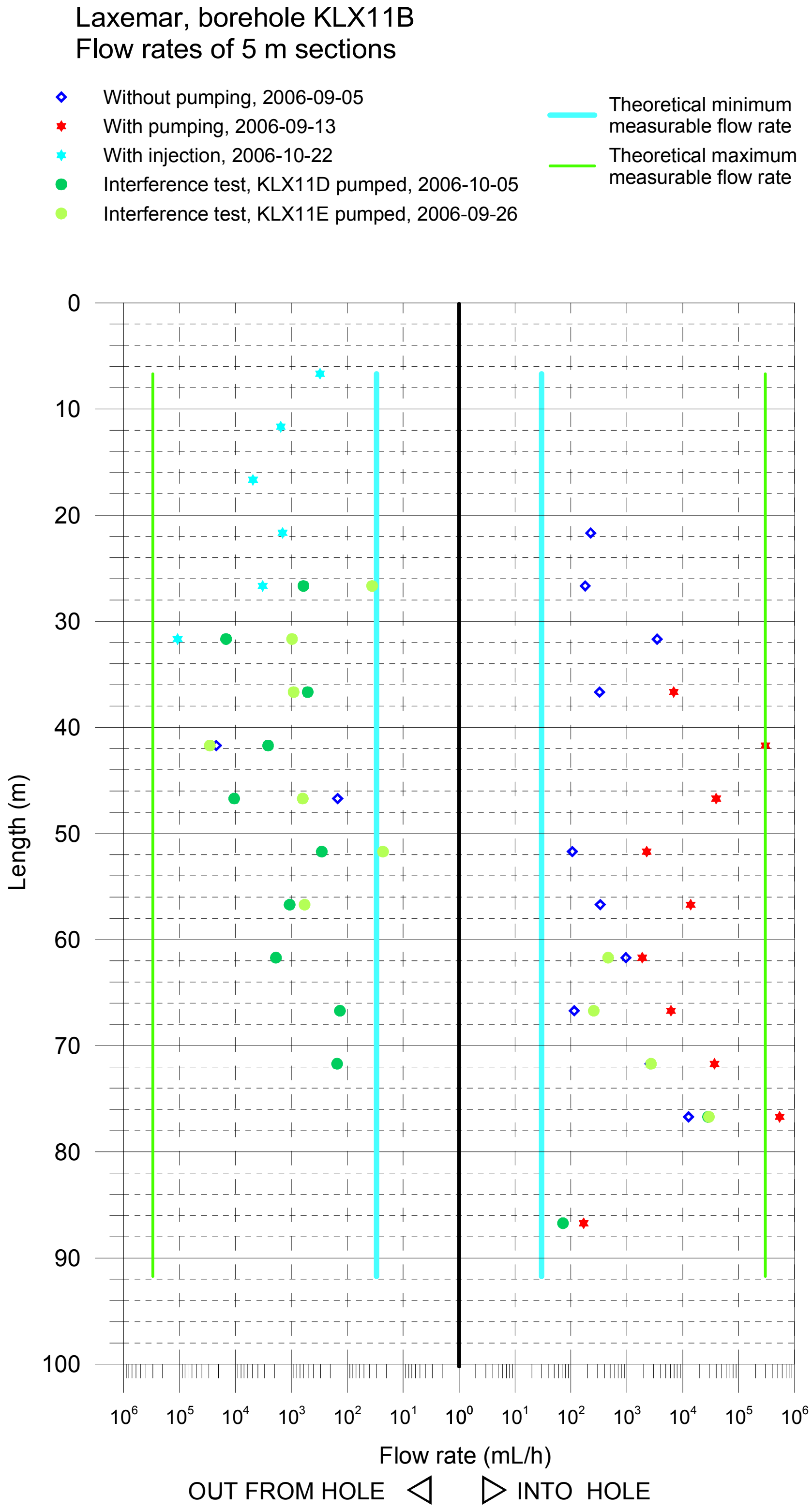
Appendix 10.5



Appendix 10.6

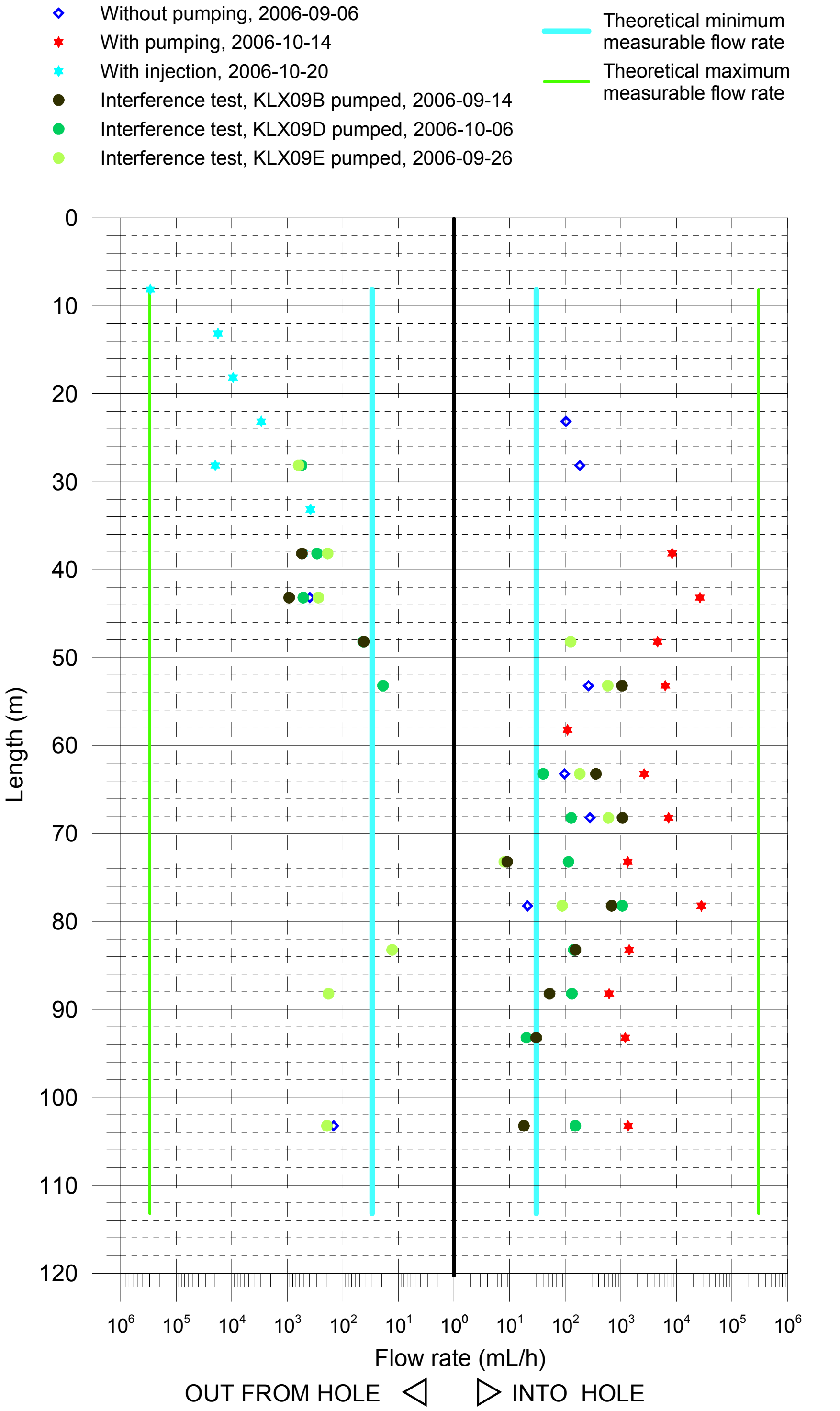


Appendix 11.1

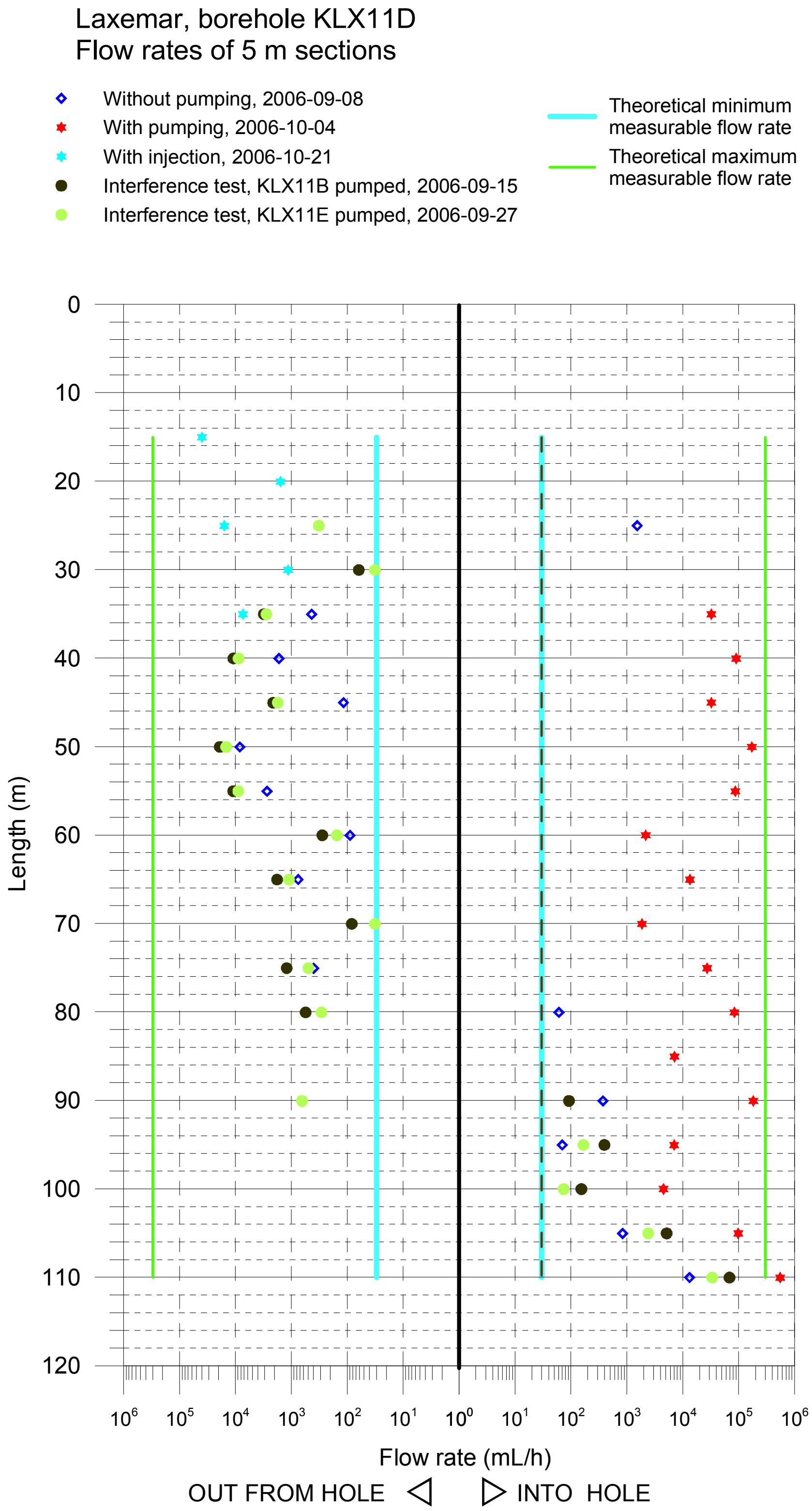


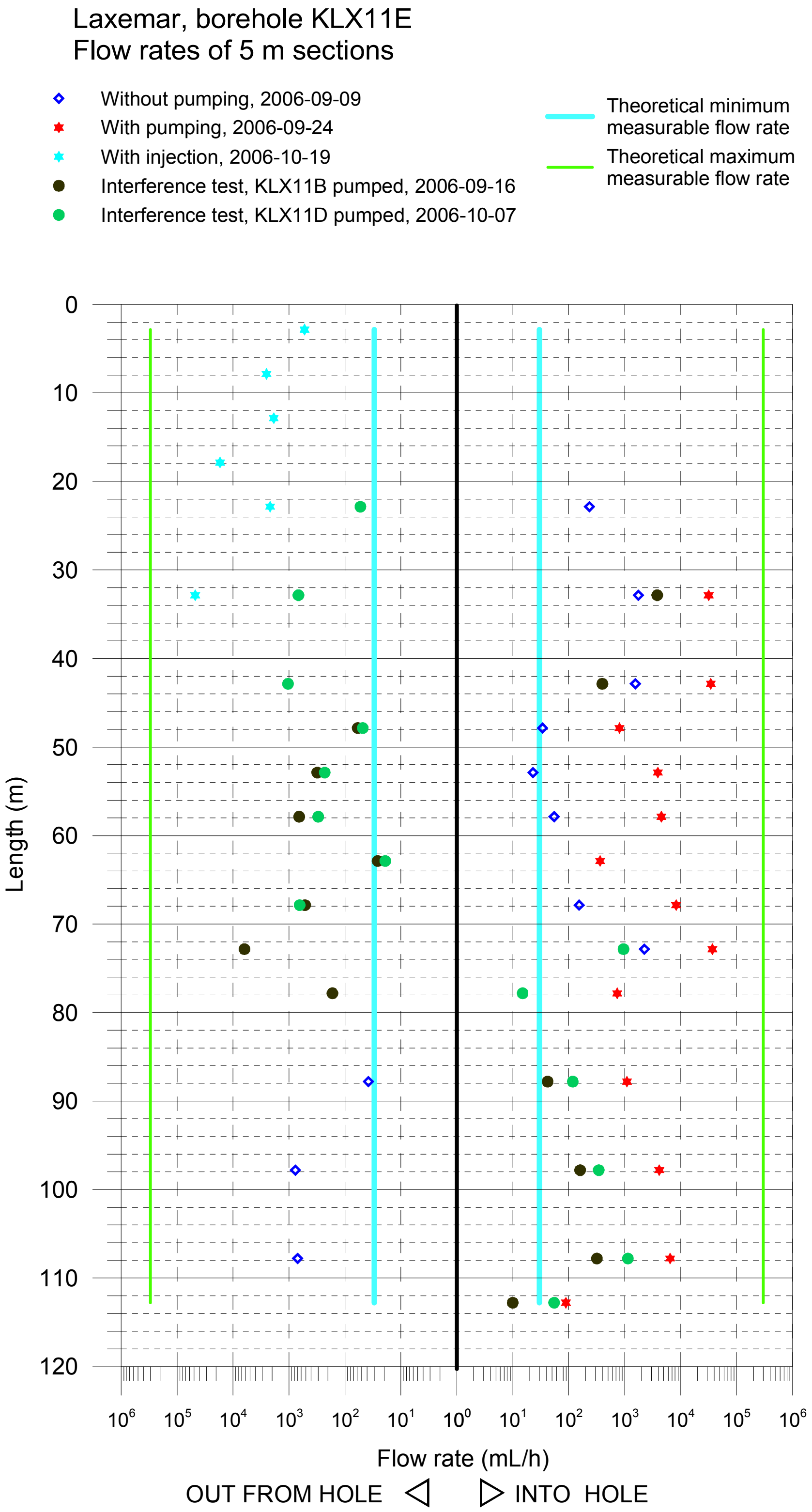
Appendix 11.2

Laxemar, borehole KLX11C
Flow rates of 5 m sections

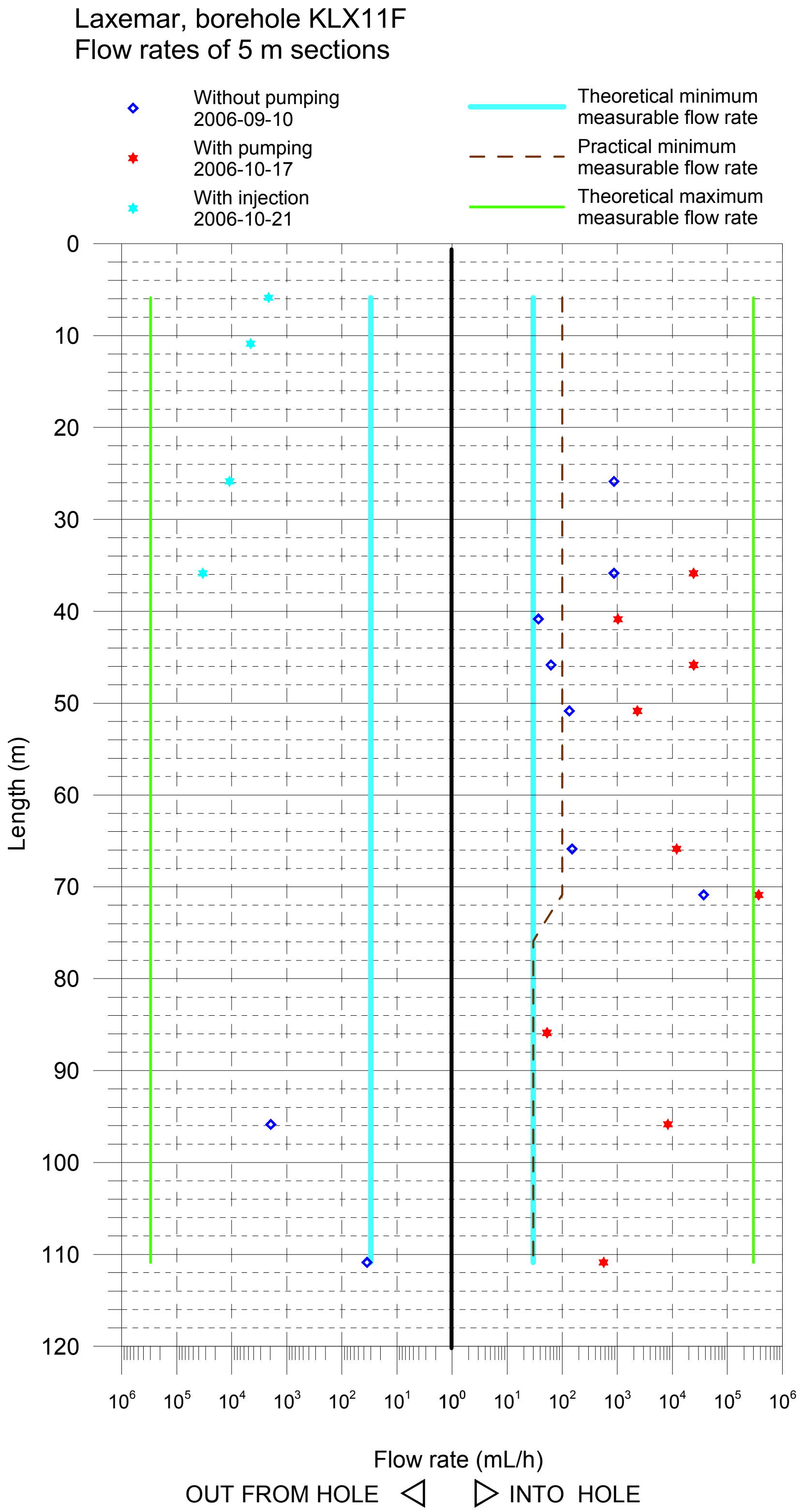


Appendix 11.3




Laxemar, borehole KLX11E
Flow rates of 5 m sections
Without pumping, 2006-09-09
With pumping, 2006-09-24
With injection, 2006-10-19
Interference test, KLX11B pumped, 2006-09-16
Interference test, KLX11D pumped, 2006-10-07
Theoretical minimum measurable flow rate
Theoretical maximum measurable flow rate
Length (m)
0
10
20
30
40
50
60
70
80
90
100
110
120
10^6 10^5 10^4 10^3 10^2 10^1 10^0 10^1 10^2 10^3 10^4 10^5 10^6
Flow rate (mL/h)
OUT FROM HOLE
INTO HOLE

Appendix 11.5



Appendix 12.1

Difference flow logging – Sequential flow logging during hydraulic crosshole interference test.

Borehole ID	Secup L (m)	Seclow L (m)	L_w (m)	h_{DFW} (m.a.s.l.)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Q_E (m^3/s)
KLX11B	4.18	9.18	5.0	–	–	–	–
KLX11B	9.18	14.18	5.0	–	–	–	–
KLX11B	14.18	19.18	5.0	–	–	–	–
KLX11B	19.18	24.18	5.0	–	–	–	–
KLX11B	24.18	29.18	5.0	8.27	–1.70E–07	9.34	–1.00E–08
KLX11B	29.18	34.18	5.0	8.27	–4.10E–06	9.34	–2.70E–07
KLX11B	34.18	39.18	5.0	8.27	–1.40E–07	9.38	–2.50E–07
KLX11B	39.22	44.22	5.0	8.27	–7.20E–07	9.37	–8.00E–06
KLX11B	44.22	49.22	5.0	8.31	–2.90E–06	9.40	–1.70E–07
KLX11B	49.22	54.22	5.0	8.32	–7.90E–08	9.39	–6.40E–09
KLX11B	54.22	59.22	5.0	8.32	–3.00E–07	9.39	–1.60E–07
KLX11B	59.22	64.22	5.0	8.35	–5.30E–07	9.38	1.28E–07
KLX11B	64.22	69.22	5.0	8.34	–3.80E–08	9.42	7.11E–08
KLX11B	69.21	74.21	5.0	8.34	–4.20E–08	9.39	7.53E–07
KLX11B	74.21	79.21	5.0	8.34	7.86E–06	9.39	8.17E–06
KLX11B	79.22	84.22	5.0	8.34	–	9.40	–
KLX11B	84.24	89.24	5.0	8.38	2.00E–08	9.36	–
KLX11B	89.26	94.26	5.0	8.34	–	9.28	–

Appendix 12.2

Difference flow logging – Sequential flow logging during hydraulic crosshole interference test.

Borehole ID	Secup L (m)	Seclow L (m)	L_w (m)	h_{BFW} (m.a.s.l.)	Q_B (m^3/s)	h_{DFW} (m.a.s.l.)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Q_E (m^3/s)
KLX11C	5.66	10.66	5.0	–	–	–	–	–	–
KLX11C	10.66	15.66	5.0	–	–	–	–	–	–
KLX11C	15.66	20.66	5.0	–	–	–	–	–	–
KLX11C	20.66	25.66	5.0	–	–	–	–	–	–
KLX11C	25.66	30.66	5.0	–	–	8.21	–1.54E–07	9.46	–1.74E–07
KLX11C	30.66	35.66	5.0	6.18	–	8.28	–	9.43	–
KLX11C	35.66	40.66	5.0	6.15	–1.51E–07	8.32	–8.11E–08	9.45	–5.22E–08
KLX11C	40.67	45.67	5.0	6.08	–2.58E–07	8.33	–1.43E–07	9.45	–7.67E–08
KLX11C	45.69	50.69	5.0	6.03	–1.17E–08	8.35	–1.19E–08	9.45	3.47E–08
KLX11C	50.70	55.70	5.0	6.03	2.92E–07	8.28	–5.28E–09	9.42	1.61E–07
KLX11C	55.71	60.71	5.0	6.04	–	8.28	–	9.39	–
KLX11C	60.72	65.72	5.0	6.03	9.89E–08	8.25	1.11E–08	9.39	5.06E–08
KLX11C	65.73	70.73	5.0	6.06	2.97E–07	8.25	3.56E–08	9.39	1.66E–07
KLX11C	70.73	75.73	5.0	6.13	2.50E–09	8.24	3.17E–08	9.39	2.22E–09
KLX11C	75.72	80.72	5.0	6.24	1.89E–07	8.28	2.94E–07	9.39	2.44E–08
KLX11C	80.74	85.74	5.0	6.40	4.22E–08	8.31	3.94E–08	9.39	–3.61E–09
KLX11C	85.73	90.73	5.0	6.45	1.44E–08	8.33	3.64E–08	9.43	–5.06E–08
KLX11C	90.74	95.74	5.0	6.52	8.33E–09	8.29	5.56E–09	9.44	–
KLX11C	95.74	100.74	5.0	6.58	–	8.34	–	9.47	–
KLX11C	100.76	105.76	5.0	6.66	5.00E–09	11.84	4.19E–08	9.50	–5.39E–08
KLX11C	105.75	110.75	5.0	6.71	–	11.88	–	9.60	–
KLX11C	110.73	115.73	5.0	6.79	–	11.88	–	9.66	–

Appendix 12.3

Difference flow logging – Sequential flow logging during hydraulic crosshole interference test.

Borehole ID	Secup L (m)	Seclow L (m)	L_w (m)	h_{BFW} (m.a.s.l.)	Q_B (m^3/s)	h_{EFW} (m.a.s.l.)	Q_E (m^3/s)
KLX11D	12.55	17.55	5.0	–	–	–	–
KLX11D	17.55	22.55	5.0	–	–	–	–
KLX11D	22.55	27.55	5.0	–	–	10.35	–8.94E–08
KLX11D	27.55	32.55	5.0	7.49	–1.72E–08	10.36	–8.89E–09
KLX11D	32.55	37.55	5.0	7.52	–8.61E–07	10.34	–7.78E–07
KLX11D	37.55	42.55	5.0	7.52	–3.03E–06	10.38	–2.43E–06
KLX11D	42.55	47.55	5.0	7.53	–5.89E–07	10.36	–4.86E–07
KLX11D	47.55	52.55	5.0	7.54	–5.28E–06	10.37	–4.08E–06
KLX11D	52.56	57.56	5.0	7.57	–3.06E–06	10.37	–2.47E–06
KLX11D	57.54	62.54	5.0	7.57	–7.78E–08	10.39	–4.25E–08
KLX11D	62.55	67.55	5.0	7.58	–5.00E–07	10.41	–3.06E–07
KLX11D	67.55	72.55	5.0	7.61	–2.31E–08	10.50	–8.89E–09
KLX11D	72.56	77.56	5.0	7.63	–3.36E–07	10.63	–1.38E–07
KLX11D	77.56	82.56	5.0	7.64	–1.54E–07	10.64	–8.06E–08
KLX11D	82.57	87.57	5.0	7.67	–	10.68	–
KLX11D	87.56	92.56	5.0	7.68	2.56E–08	10.74	–1.79E–07
KLX11D	92.55	97.55	5.0	7.74	1.10E–07	10.72	4.64E–08
KLX11D	97.54	102.54	5.0	7.72	4.28E–08	10.64	2.06E–08
KLX11D	102.54	107.54	5.0	7.71	1.43E–06	10.51	6.69E–07
KLX11D	107.54	112.54	5.0	7.75	1.90E–05	10.38	9.33E–06

Appendix 12.4

Difference flow logging – Sequential flow logging during hydraulic crosshole interference test.

Borehole ID	Secup L (m)	Seclow L (m)	L_w (m)	h_{BFW} (m.a.s.l.)	Q_B (m^3/s)	h_{DFW} (m.a.s.l.)	Q_D (m^3/s)
KLX11E	0.36	5.36	5.0	–	–	–	–
KLX11E	5.36	10.36	5.0	–	–	–	–
KLX11E	10.36	15.36	5.0	–	–	–	–
KLX11E	15.36	20.36	5.0	–	–	–	–
KLX11E	20.36	25.36	5.0	–	–	8.66	–1.47E–08
KLX11E	25.36	30.36	5.0	5.80	–	8.69	–
KLX11E	30.36	35.36	5.0	5.84	1.06E–06	8.67	–1.88E–07
KLX11E	35.36	40.36	5.0	5.89	–	8.66	–
KLX11E	40.37	45.37	5.0	5.98	1.11E–07	8.63	–2.89E–07
KLX11E	45.36	50.36	5.0	6.05	–1.64E–08	8.54	–1.33E–08
KLX11E	50.39	55.39	5.0	6.08	–8.67E–08	8.49	–6.39E–08
KLX11E	55.38	60.38	5.0	6.14	–1.83E–07	8.51	–8.33E–08
KLX11E	60.38	65.38	5.0	6.18	–7.22E–09	8.49	–5.28E–09
KLX11E	65.36	70.36	5.0	6.25	–1.44E–07	8.50	–1.79E–07
KLX11E	70.34	75.34	5.0	6.24	–1.74E–06	8.53	2.64E–07
KLX11E	75.33	80.33	5.0	6.23	–4.64E–08	8.54	4.17E–09
KLX11E	80.32	85.32	5.0	6.27	–	8.58	–
KLX11E	85.31	90.31	5.0	6.32	1.17E–08	8.59	3.28E–08
KLX11E	90.32	95.32	5.0	6.36	–	8.64	–
KLX11E	95.30	100.30	5.0	6.41	4.44E–08	8.72	9.56E–08
KLX11E	100.30	105.30	5.0	6.46	–	8.70	–
KLX11E	105.29	110.29	5.0	6.57	8.83E–08	8.69	3.17E–07
KLX11E	110.28	115.28	5.0	6.69	2.78E–09	8.68	1.53E–08

Appendix 12.5

Difference flow logging – Sequential flow logging during hydraulic crosshole interference test.

Borehole ID	Secup L (m)	Seclow L (m)	L_w (m)	h_{BFW} (m.a.s.l.)	Q_B (m^3/s)	h_{DFW} (m.a.s.l.)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Q_E (m^3/s)
KLX11F	3.37	8.37	5.0	–	–	–	–	–	–
KLX11F	8.37	13.37	5.0	–	–	–	–	–	–
KLX11F	13.37	18.37	5.0	–	–	–	–	–	–
KLX11F	18.37	23.37	5.0	–	–	–	–	–	–
KLX11F	23.37	28.37	5.0	6.38	2.34E–07	8.97	–2.25E–08	9.36	–2.97E–07
KLX11F	28.37	33.37	5.0	6.38	–	8.97	–	9.33	–
KLX11F	33.37	38.37	5.0	6.38	–6.39E–07	8.96	–4.97E–07	9.34	–1.59E–06
KLX11F	38.36	43.36	5.0	6.44	–2.58E–08	8.85	–2.11E–08	9.38	–4.33E–08
KLX11F	43.36	48.36	5.0	6.45	–1.75E–06	8.85	–9.31E–07	9.51	–9.11E–08
KLX11F	48.36	53.36	5.0	6.46	6.00E–08	8.81	–5.56E–08	9.49	5.00E–08
KLX11F	53.35	58.35	5.0	6.45	–	8.76	–	9.50	–
KLX11F	58.36	63.36	5.0	6.41	–	8.74	–	9.53	–
KLX11F	63.37	68.37	5.0	6.42	–1.21E–07	8.77	–1.13E–07	9.49	1.86E–08
KLX11F	68.38	73.38	5.0	6.43	–1.20E–06	8.83	–1.42E–05	9.57	1.52E–05
KLX11F	73.40	78.40	5.0	6.43	–	8.84	–	9.56	–
KLX11F	78.39	83.39	5.0	6.42	–	8.82	–	9.53	–
KLX11F	83.39	88.39	5.0	6.46	–	8.85	–	9.56	–
KLX11F	88.39	93.39	5.0	6.50	–	8.84	–	9.52	–
KLX11F	93.36	98.36	5.0	6.56	–1.71E–07	8.85	6.39E–07	9.47	–6.28E–07
KLX11F	98.37	103.37	5.0	6.58	–	8.82	–	9.45	–
KLX11F	103.37	108.37	5.0	6.57	–	8.87	–	9.45	–
KLX11F	108.38	113.38	5.0	6.46	–	8.67	2.14E–08	9.39	–1.00E–08

Appendix 13.1

PFL – Difference flow logging – Inferred flow anomalies from overlapping flow logging during hydraulic crosshole interference test.

Borehole ID	Length to flow anom. L (m)	L_w (m)	d_L (m)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	Comments
KLX11B	5.4	1.0	0.1	–	–	–	–	–	–	*
KLX11B	9.1	1.0	0.1	–	–	–	–	–	–	*
KLX11B	10.3	1.0	0.1	–	–	–	–	–	–	
KLX11B	12.2	1.0	0.1	–	–	–	–	–	–	*
KLX11B	17.7	1.0	0.1	–	–	–	–	–	–	
KLX11B	20.4	1.0	0.1	–	–	–	9.22	2.81E–08	–	
KLX11B	22.2	1.0	0.1	8.34	8.03E–08	–3.56E–08	9.24	5.91E–08	–	
KLX11B	27.0	1.0	0.1	8.30	4.17E–08	–1.11E–07	9.23	3.57E–08	–1.00E–08	
KLX11B	27.8	1.0	0.1	8.30	1.19E–07	–1.07E–07	9.22	7.10E–08	–3.33E–09	
KLX11B	29.4	1.0	0.1	8.31	1.12E–07	–5.56E–09	9.20	1.04E–07	1.08E–07	
KLX11B	31.1	1.0	0.1	8.31	3.19E–06	–3.94E–06	9.20	2.10E–06	–3.03E–07	
KLX11B	32.2	1.0	0.1	8.30	9.17E–08	–5.28E–08	9.20	5.82E–08	–	
KLX11B	32.9	1.0	0.1	8.30	9.38E–08	–8.72E–08	9.20	6.01E–08	–	
KLX11B	35.2	1.0	0.1	8.32	6.78E–08	–1.83E–08	9.23	4.37E–08	–2.08E–08	
KLX11B	37.5	1.0	0.1	8.33	1.54E–07	–5.94E–08	9.22	9.74E–08	–7.61E–08	
KLX11B	38.6	1.0	0.1	8.32	1.96E–07	–4.36E–08	9.23	1.22E–07	–1.24E–07	
KLX11B	43.3	1.0	0.1	8.35	1.01E–05	3.09E+03	9.23	2.68E–06	–8.28E–06	
KLX11B	45.2	1.0	0.1	8.36	3.92E–08	–1.32E–07	9.25	1.88E–08	–	
KLX11B	46.5	1.0	0.1	8.38	2.00E–06	–2.66E–06	9.25	1.05E–06	–1.36E–07	
KLX11B	48.8	1.0	0.1	8.34	8.90E–08	–9.33E–08	9.22	5.30E–08	–	
KLX11B	49.9	1.0	0.1	8.36	4.07E–08	–1.47E–08	9.19	3.15E–08	2.06E–08	
KLX11B	52.0	1.0	0.1	8.37	1.09E–07	–5.00E–08	9.21	6.52E–08	–1.44E–08	
KLX11B	55.7	1.0	0.1	8.36	8.34E–07	–3.06E–07	9.25	4.88E–07	–1.44E–07	
KLX11B	60.5	1.0	0.1	8.39	1.88E–08	–1.56E–08	9.24	1.39E–08	–1.08E–08	

Borehole ID	Length to flow anom. L (m)	L_w (m)	d_L (m)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	Comments
KLX11B	63.5	1.0	0.1	8.40	4.58E–07	–5.14E–07	9.22	3.77E–07	1.57E–07	
KLX11B	65.0	1.0	0.1	8.39	1.25E–07	–8.06E–09	9.23	7.15E–08	1.39E–08	
KLX11B	67.6	1.0	0.1	8.40	8.00E–08	–	9.22	5.00E–08	1.06E–08	
KLX11B	68.0	1.0	0.1	8.39	1.64E–07	–4.33E–08	9.22	1.00E–07	4.28E–08	
KLX11B	71.0	1.0	0.1	8.41	3.54E–08	–	9.22	2.80E–08	2.00E–08	
KLX11B	72.6	1.0	0.1	8.41	1.05E–06	–1.28E–08	9.20	7.09E–07	–	
KLX11B	73.2	1.0	0.1	8.41	1.90E–06	–1.69E–08	9.21	1.31E–06	4.94E–07	
KLX11B	74.3	1.0	0.1	8.38	2.03E–08	–3.33E–09	9.20	1.59E–08	1.17E–08	
KLX11B	75.2	1.0	0.1	8.40	1.86E–05	7.64E–06	9.20	2.88E–05	7.39E–06	
KLX11B	76.3	1.0	0.1	8.40	1.90E–06	7.64E–08	9.21	1.14E–06	2.21E–07	
KLX11B	84.8	1.0	0.1	8.46	4.23E–09	–	9.19	3.33E–09	–	
KLX11B	85.9	1.0	0.1	8.45	–	2.78E–09	9.18	–	–	*,**
KLX11B	88.5	1.0	0.1	8.46	–	1.14E–08	9.17	–	–	**

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

** Found only during hydraulic crosshole interference test

PFL – Difference flow logging – Inferred flow anomalies from overlapping flow logging during hydraulic crosshole interference test.

Borehole ID	Length to flow anom. L (m)	L_w (m)	d_L (m)	h_{BFW} (m.a.s.l.)	Calc Ref Q_B (m^3/s)	Q_B (m^3/s)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	Comments
KLX11C	3.8	1.0	0.1	–	–	–	–	–	–	–	–	–	*
KLX11C	8.2	1.0	0.1	–	–	–	–	–	–	–	–	–	
KLX11C	5.4	1.0	0.1	–	–	–	–	–	–	–	–	–	*
KLX11C	5.9	1.0	0.1	–	–	–	–	–	–	–	–	–	*
KLX11C	11.3	1.0	0.1	–	–	–	–	–	–	–	–	–	
KLX11C	11.7	1.0	0.1	–	–	–	–	–	–	–	–	–	
KLX11C	17.2	1.0	0.1	–	–	–	–	–	–	–	–	–	
KLX11C	19.3	1.0	0.1	–	–	–	–	–	–	–	–	–	
KLX11C	24.6	1.0	0.1	–	–	–	8.25	9.53E–08	–	9.66	4.50E–08	–	
KLX11C	25.5	1.0	0.1	–	–	–	8.28	3.64E–08	–5.56E–09	9.70	1.36E–08	–	*
KLX11C	26.8	1.0	0.1	6.24	1.04E–06	–1.5E–07	8.26	5.64E–07	–3.67E–08	9.70	2.27E–07	–1.17E–07	
KLX11C	28.3	1.0	0.1	6.22	3.45E–07	–1.8E–07	8.25	1.84E–07	–7.28E–08	9.70	6.93E–08	–1.58E–08	
KLX11C	29.6	1.0	0.1	6.17	5.32E–08	–7.2E–08	8.23	2.79E–08	–6.28E–08	9.68	1.01E–08	–5.47E–08	
KLX11C	30.9	1.0	0.1	6.14	–	–	8.20	–	–	9.67	–	–	*
KLX11C	32.9	1.0	0.1	6.13	1.93E–08	–4.7E–09	8.15	1.04E–08	–	9.63	3.95E–09	–	*
KLX11C	34.4	1.0	0.1	6.09	5.89E–09	–	8.13	3.18E–09	–	9.64	1.17E–09	–	*
KLX11C	37.0	1.0	0.1	6.04	1.80E–07	–7.5E–09	8.08	9.79E–08	–1.61E–08	9.65	3.49E–08	–7.78E–09	
KLX11C	37.5	1.0	0.1	6.03	5.43E–08	–	8.07	2.96E–08	–	9.65	1.04E–08	–	
KLX11C	40.3	1.0	0.1	5.95	8.44E–07	–1.3E–07	8.07	4.51E–07	–5.39E–08	9.62	1.63E–07	–5.22E–08	
KLX11C	41.4	1.0	0.1	5.94	9.29E–08	–1.9E–08	8.06	4.97E–08	–7.22E–09	9.63	1.77E–08	–8.61E–09	
KLX11C	45.1	1.0	0.1	5.90	3.36E–06	–2.4E–07	8.13	1.67E–06	–1.43E–07	9.62	5.51E–07	–9.64E–08	
KLX11C	49.5	1.0	0.1	5.89	7.80E–07	–3.1E–08	8.20	4.00E–07	–1.67E–08	9.60	1.70E–07	3.39E–08	
KLX11C	51.9	1.0	0.1	5.90	1.03E–07	1.44E–08	8.26	5.34E–08	–	9.58	2.59E–08	5.83E–09	

Borehole ID	Length to flow anom. L (m)	L_w (m)	d_L (m)	h_{BFW} (m.a.s.l.)	Calc Ref Q_B (m^3/s)	Q_B (m^3/s)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	Comments
KLX11C	52.8	1.0	0.1	5.92	1.33E–07	3.17E–08	8.28	7.40E–08	–	9.58	4.17E–08	1.14E–08	
KLX11C	54.4	1.0	0.1	5.95	1.12E–06	2.04E–07	8.30	5.90E–07	–1.67E–08	9.57	3.03E–07	1.37E–07	
KLX11C	58.4	1.0	0.1	5.99	1.52E–08	–	8.34	7.51E–09	–	9.60	3.38E–09	–	
KLX11C	64.3	1.0	0.1	6.00	4.16E–08	4.17E–09	8.30	2.09E–08	–	9.55	9.64E–09	2.78E–09	
KLX11C	65.0	1.0	0.1	6.00	4.32E–07	8.39E–08	8.27	2.32E–07	6.67E–09	9.55	1.19E–07	4.83E–08	
KLX11C	66.5	1.0	0.1	5.99	1.61E–06	2.86E–07	8.33	8.37E–07	2.56E–08	9.53	4.40E–07	1.68E–07	
KLX11C	66.9	1.0	0.1	6.01	1.12E–08	–	8.33	5.55E–09	–	9.52	2.65E–09	–	*
KLX11C	70.1	1.0	0.1	6.03	4.41E–09	–	8.29	2.25E–09	–	9.43	–	–	
KLX11C	71.4	1.0	0.1	6.02	2.71E–07	3.33E–09	8.29	1.39E–07	3.06E–08	9.43	7.31E–08	3.33E–09	
KLX11C	73.1	1.0	0.1	6.04	3.62E–09	–	8.26	–	–	9.41	–	–	*
KLX11C	75.2	1.0	0.1	6.05	3.10E–09	–	8.22	–	–	9.40	–	–	*
KLX11C	76.6	1.0	0.1	6.05	1.37E–06	1.07E–07	8.18	7.42E–07	1.06E–07	9.38	3.87E–07	–	
KLX11C	77.3	1.0	0.1	6.06	2.52E–06	8.06E–08	8.17	1.37E–06	1.65E–07	9.38	7.05E–07	3.75E–08	
KLX11C	81.9	1.0	0.1	6.15	1.86E–07	3.78E–08	8.14	1.04E–07	3.39E–08	9.35	5.48E–08	–	
KLX11C	84.8	1.0	0.1	6.17	6.87E–08	7.22E–09	8.14	3.88E–08	5.00E–09	9.34	2.06E–08	–	
KLX11C	87.5	1.0	0.1	6.17	2.09E–08	1.61E–08	8.17	–3.12E–09	3.28E–08	9.36	–1.74E–08	–4.89E–08	
KLX11C	93.8	1.0	0.1	6.20	1.49E–07	9.72E–09	8.23	8.35E–08	6.11E–09	9.47	4.34E–08	–	
KLX11C	102.3	1.0	0.1	6.26	1.40E–07	–	8.41	5.54E–08	4.08E–08	9.59	9.23E–09	–2.28E–08	

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

Appendix 13.3

PFL – Difference flow logging – Inferred flow anomalies from overlapping flow logging during hydraulic crosshole interference test.

Borehole ID	Length to flow anom. L (m)	L_w (m)	d_L (m)	h_{BFW} (m.a.s.l.)	Calc Ref Q_B (m^3/s)	Q_B (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	Comments
KLX11D	12.8	1.0	0.1	–	–	–	–	–	–	
KLX11D	14.6	1.0	0.1	–	–	–	–	–	–	
KLX11D	18.7	1.0	0.1	–	–	–	–	–	–	*
KLX11D	23.7	1.0	0.1	7.60	–	–	–	–	–	*
KLX11D	24.9	1.0	0.1	7.57	–1.63E–07	4.36E–08	–	–	–	*
KLX11D	25.3	1.0	0.1	7.58	–2.90E–07	7.83E–08	–	–	–	*
KLX11D	26.2	1.0	0.1	7.57	8.77E–07	4.86E–07	10.56	3.24E–07	–1.03E–08	
KLX11D	31.8	1.0	0.1	7.54	6.53E–08	1.56E–08	10.46	7.52E–09	–5.56E–09	
KLX11D	34.5	1.0	0.1	7.54	3.09E–08	–	10.38	4.22E–09	–	*
KLX11D	36.4	1.0	0.1	7.56	3.04E–06	–7.50E–07	10.36	3.10E–07	–6.75E–07	
KLX11D	37.8	1.0	0.1	7.54	1.50E–07	–1.29E–07	10.31	1.56E–08	–8.89E–08	
KLX11D	38.1	1.0	0.1	7.53	1.42E–07	–4.03E–08	10.31	1.74E–08	–2.44E–08	*
KLX11D	40.7	1.0	0.1	7.56	6.65E–06	–2.76E–06	10.31	6.70E–07	–2.08E–06	
KLX11D	41.9	1.0	0.1	7.55	4.02E–07	–1.95E–07	10.28	3.57E–08	–9.61E–08	
KLX11D	42.7	1.0	0.1	7.54	6.57E–08	–3.22E–08	10.31	4.02E–09	–1.67E–08	
KLX11D	43.9	1.0	0.1	7.54	5.40E–08	–1.22E–08	10.33	8.62E–09	–8.06E–09	*
KLX11D	44.6	1.0	0.1	7.55	1.65E–07	–4.00E–08	10.35	2.20E–08	–2.22E–08	
KLX11D	45.5	1.0	0.1	7.57	2.26E–08	–5.00E–09	10.40	3.27E–09	–	*
KLX11D	47.2	1.0	0.1	7.60	2.90E–06	–5.36E–07	10.51	3.46E–07	–3.97E–07	
KLX11D	48.7	1.0	0.1	7.61	2.92E–06	–1.36E–06	10.53	–3.15E–08	–8.44E–07	
KLX11D	49.3	1.0	0.1	7.62	2.05E–07	–7.81E–08	10.53	–2.71E–09	–4.61E–08	
KLX11D	52.4	1.0	0.1	7.69	1.00E–05	–4.36E–06	10.62	–4.20E–07	–3.19E–06	
KLX11D	53.3	1.0	0.1	7.72	7.23E–06	–3.06E–06	10.62	1.75E–07	–2.33E–06	
KLX11D	54.7	1.0	0.1	7.73	2.48E–07	–6.92E–08	10.62	1.75E–08	–3.25E–08	

Borehole ID	Length to flow anom. L (m)	L_w (m)	d_L (m)	h_{BFW} (m.a.s.l.)	Calc Ref Q_B (m^3/s)	Q_B (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	Comments
KLX11D	57.9	1.0	0.1	7.73	–	–	10.59	–	–	
KLX11D	59.8	1.0	0.1	7.74	9.65E–09	–	10.59	–	–	*
KLX11D	60.8	1.0	0.1	7.74	1.47E–07	–5.92E–08	10.59	4.79E–09	–3.11E–08	
KLX11D	63.1	1.0	0.1	7.76	2.51E–07	–1.09E–07	10.59	4.97E–09	–5.53E–08	
KLX11D	64.4	1.0	0.1	7.76	5.18E–07	–3.58E–07	10.56	–4.54E–08	–2.26E–07	
KLX11D	67.1	1.0	0.1	7.78	3.28E–07	–5.56E–08	10.48	4.95E–08	–2.67E–08	
KLX11D	72.2	1.0	0.1	7.81	1.66E–07	–2.28E–08	10.43	3.19E–08	–8.06E–09	
KLX11D	74.1	1.0	0.1	7.81	5.63E–08	–6.11E–09	10.41	8.53E–09	–	
KLX11D	75.4	1.0	0.1	7.81	2.59E–06	–3.36E–07	10.40	5.16E–07	–1.38E–07	
KLX11D	78.2	1.0	0.1	7.83	1.35E–07	–1.47E–08	10.40	2.93E–08	–5.56E–09	
KLX11D	80.7	1.0	0.1	7.83	8.28E–06	–1.53E–07	10.42	1.95E–06	–1.13E–07	
KLX11D	84.7	1.0	0.1	7.85	9.12E–08	–	10.49	2.04E–08	–	
KLX11D	85.3	1.0	0.1	7.86	6.67E–07	–	10.50	1.44E–07	–	
KLX11D	90.5	1.0	0.1	7.91	5.72E–07	2.25E–08	10.67	1.07E–07	–7.50E–09	
KLX11D	91.5	1.0	0.1	7.91	1.68E–05	–	10.70	2.96E–06	1.69E–07	
KLX11D	96.3	1.0	0.1	7.94	6.28E–07	1.01E–07	10.74	1.21E–07	4.28E–08	
KLX11D	97.6	1.0	0.1	7.94	8.45E–08	9.44E–09	10.77	1.38E–08	3.61E–09	
KLX11D	100.8	1.0	0.1	7.97	2.52E–07	2.94E–08	10.75	4.62E–08	1.28E–08	
KLX11D	102.7	1.0	0.1	7.96	1.43E–07	1.56E–08	10.76	2.38E–08	5.00E–09	
KLX11D	104.7	1.0	0.1	7.97	3.34E–06	4.56E–07	10.74	6.20E–07	1.86E–07	
KLX11D	105.0	1.0	0.1	7.97	5.41E–06	9.31E–07	10.75	1.04E–06	4.61E–07	
KLX11D	106.8	1.0	0.1	7.97	1.43E–07	2.08E–08	10.75	2.43E–08	7.78E–09	
KLX11D	108.7	1.0	0.1	7.97	5.49E–05	1.89E–05	10.76	1.15E–05	9.36E–06	
KLX11D	110.5	1.0	0.1	7.95	1.74E–08	3.33E–09	10.72	2.97E–09	–	
KLX11D	112.0	1.0	0.1	7.91	1.46E–08	–	10.67	2.69E–09	–	

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

Appendix 13.4

PFL – Difference flow logging – Inferred flow anomalies from overlapping flow logging during hydraulic crosshole interference test.

Borehole ID	Length to flow anom. L (m)	L_w (m)	d_L (m)	h_{BFW} (m.a.s.l.)	Calc Ref Q_B (m^3/s)	Q_B (m^3/s)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	Comments
KLX11E	4.1	1.0	0.1	–	–	–	–	–	–	
KLX11E	4.6	1.0	0.1	–	–	–	–	–	–	
KLX11E	6.3	1.0	0.1	–	–	–	–	–	–	
KLX11E	8.8	1.0	0.1	–	–	–	–	–	–	
KLX11E	11.0	1.0	0.1	–	–	–	–	–	–	
KLX11E	12.9	1.0	0.1	–	–	–	–	–	–	*
KLX11E	16.2	1.0	0.1	–	–	–	–	–	–	
KLX11E	17.1	1.0	0.1	–	–	–	–	–	–	
KLX11E	19.1	1.0	0.1	–	–	–	8.38	1.94E–07	–	
KLX11E	20.0	1.0	0.1	–	–	–	8.37	6.07E–07	–	
KLX11E	21.5	1.0	0.1	5.82	2.80E–07	–	8.36	1.48E–07	–	
KLX11E	22.5	1.0	0.1	5.83	4.86E–09	–	8.36	1.97E–09	–	*
KLX11E	31.0	1.0	0.1	5.84	4.07E–06	9.86E–07	8.38	1.94E–06	–1.77E–07	
KLX11E	42.5	1.0	0.1	5.89	2.53E–06	2.86E–07	8.37	1.22E–06	–8.39E–08	
KLX11E	44.8	1.0	0.1	5.89	1.88E–06	–2.39E–07	8.38	8.72E–07	–1.94E–07	
KLX11E	47.9	1.0	0.1	5.91	9.03E–08	–1.17E–08	8.41	4.42E–08	–1.42E–08	
KLX11E	50.3	1.0	0.1	5.92	2.09E–08	–6.94E–09	8.41	1.11E–08	–	
KLX11E	54.6	1.0	0.1	5.94	3.93E–07	–5.72E–08	8.45	1.64E–07	–4.97E–08	
KLX11E	55.5	1.0	0.1	5.93	1.62E–07	–3.00E–08	8.45	6.98E–08	–1.94E–08	
KLX11E	57.0	1.0	0.1	5.96	4.82E–08	–	8.52	2.12E–08	–	
KLX11E	58.4	1.0	0.1	5.96	3.86E–08	–	8.55	1.56E–08	–	
KLX11E	59.8	1.0	0.1	5.96	2.08E–07	–1.12E–07	8.56	8.35E–08	–7.06E–08	
KLX11E	61.3	1.0	0.1	5.96	3.05E–08	–5.56E–09	8.62	1.19E–08	–	
KLX11E	66.7	1.0	0.1	6.02	4.70E–08	–5.56E–09	8.66	1.84E–08	–5.56E–09	

Borehole ID	Length to flow anom. L (m)	L_w (m)	d_L (m)	h_{BFW} (m.a.s.l.)	Calc Ref Q_B (m^3/s)	Q_B (m^3/s)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	Comments
KLX11E	68.0	1.0	0.1	6.05	6.27E-07	-1.01E-07	8.68	2.59E-07	-1.21E-07	
KLX11E	69.7	1.0	0.1	6.07	2.66E-07	-3.00E-08	8.69	1.09E-07	-4.33E-08	
KLX11E	71.3	1.0	0.1	6.13	3.75E-08	-	8.68	1.51E-08	-	
KLX11E	74.1	1.0	0.1	6.20	4.05E-06	-1.64E-06	8.71	2.05E-06	1.61E-07	
KLX11E	78.4	1.0	0.1	6.22	8.36E-08	-2.11E-08	8.73	3.57E-08	4.72E-09	
KLX11E	79.5	1.0	0.1	6.22	-	-	8.77	-	-	*
KLX11E	87.2	1.0	0.1	6.26	1.46E-08	-	8.80	5.74E-09	-	
KLX11E	88.1	1.0	0.1	6.26	9.72E-08	1.47E-08	8.79	3.87E-08	2.92E-08	
KLX11E	90.1	1.0	0.1	6.28	-	-	8.80	-	-	*
KLX11E	98.6	1.0	0.1	6.28	3.34E-07	4.75E-08	8.84	-	8.31E-08	
KLX11E	108.8	1.0	0.1	6.34	5.19E-07	1.28E-07	8.90	1.26E-07	2.94E-07	
KLX11E	111.8	1.0	0.1	6.30	-	2.78E-09	8.94	-	5.56E-09	*
KLX11E	113.0	1.0	0.1	6.32	-	-	8.93	-	1.22E-08	

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

Appendix 13.5

PFL – Difference flow logging – Inferred flow anomalies from overlapping flow logging during hydraulic crosshole interference test.

Borehole ID	Length to flow anom. L (m)	L_w (m)	d_L (m)	h_{BFW} (m.a.s.l.)	Calc Ref Q_B (m^3/s)	Q_B (m^3/s)	h_{DFW} (m.a.s.l.)	Calc Ref Q_D (m^3/s)	Q_D (m^3/s)	h_{EFW} (m.a.s.l.)	Calc Ref Q_E (m^3/s)	Q_E (m^3/s)	Comments
KLX11F	6.3	1.0	0.1	–	–	–	–	–	–	–	–	–	*
KLX11F	9.5	1.0	0.1	–	–	–	–	–	–	–	–	–	*
KLX11F	10.9	1.0	0.1	–	–	–	–	–	–	–	–	–	*
KLX11F	21.2	1.0	0.1	–	–	–	8.99	–	–6.67E–09	9.87	–	–2.81E–08	*
KLX11F	27.9	1.0	0.1	6.19	1.20E–06	1.20E–07	8.89	5.43E–07	–2.14E–08	9.84	3.13E–07	–3.97E–07	
KLX11F	36.4	1.0	0.1	6.20	2.90E–06	–6.56E–07	8.87	1.11E–06	–4.97E–07	9.76	5.13E–07	–1.67E–06	
KLX11F	37.1	1.0	0.1	6.21	1.36E–07	–1.94E–08	8.87	5.18E–08	–1.50E–08	9.77	2.33E–08	–9.44E–09	
KLX11F	39.2	1.0	0.1	6.21	1.08E–07	–2.72E–08	8.85	4.32E–08	–2.03E–08	9.76	2.10E–08	–4.67E–08	
KLX11F	44.0	1.0	0.1	6.20	9.09E–08	–8.33E–09	8.81	3.07E–08	–5.00E–09	9.70	1.01E–08	–4.44E–09	
KLX11F	45.4	1.0	0.1	6.19	2.74E–06	–1.55E–06	8.77	9.56E–07	–9.22E–07	9.71	3.06E–07	–1.88E–07	
KLX11F	50.7	1.0	0.1	6.17	2.34E–07	3.47E–08	8.73	9.68E–08	–2.61E–08	9.67	4.65E–08	2.22E–08	*
KLX11F	51.7	1.0	0.1	6.17	8.34E–08	2.31E–08	8.72	3.92E–08	–2.44E–08	9.66	2.29E–08	1.42E–08	*
KLX11F	65.7	1.0	0.1	6.11	9.81E–07	–7.72E–08	8.72	3.46E–07	–8.33E–08	9.61	1.29E–07	–	
KLX11F	67.0	1.0	0.1	6.13	1.91E–07	–3.94E–08	8.76	6.77E–08	–2.58E–08	9.61	2.78E–08	6.67E–09	
KLX11F	68.6	1.0	0.1	6.13	1.12E–07		8.82	3.62E–08	–4.44E–09	9.63	1.35E–08	–	
KLX11F	70.4	1.0	0.1	6.14	4.81E–05	–4.08E–07	8.89	2.12E–05	–1.07E–05	9.66	1.45E–05	1.03E–05	
KLX11F	70.7	1.0	0.1	6.15	1.73E–05	–3.47E–07	8.91	5.69E–06	–9.69E–07	9.65	2.58E–06	9.92E–07	
KLX11F	71.8	1.0	0.1	6.13	1.20E–07	–1.11E–0–8	8.93	3.92E–08	–5.00E–09	9.64	1.85E–08	5.00E–09	
KLX11F	84.1	1.0	0.1	6.13	–		9.02	–	–	9.62	–	–	*
KLX11F	85.1	1.0	0.1	6.12	–	–	9.01	–	–	9.61	–	–	*
KLX11F	95.8	1.0	0.1	6.16	3.84E–07	–3.69E–07	9.04	–2.72E–07	3.94E–07	9.66	–4.13E–07	–4.56E–07	
KLX11F	96.7	1.0	0.1	6.16	2.71E–07	–	9.04	7.84E–08	1.23E–07	9.65	3.75E–08	–	
KLX11F	109.8	1.0	0.1	6.13	2.96E–08	–5.00E–09	9.04	–	8.89E–09	9.65	–4.56E–09	–9.17E–09	
KLX11F	111.3	1.0	0.1	6.15	2.77E–08	–	9.01	8.13E–09	8.89E–09	9.64	–	–	

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

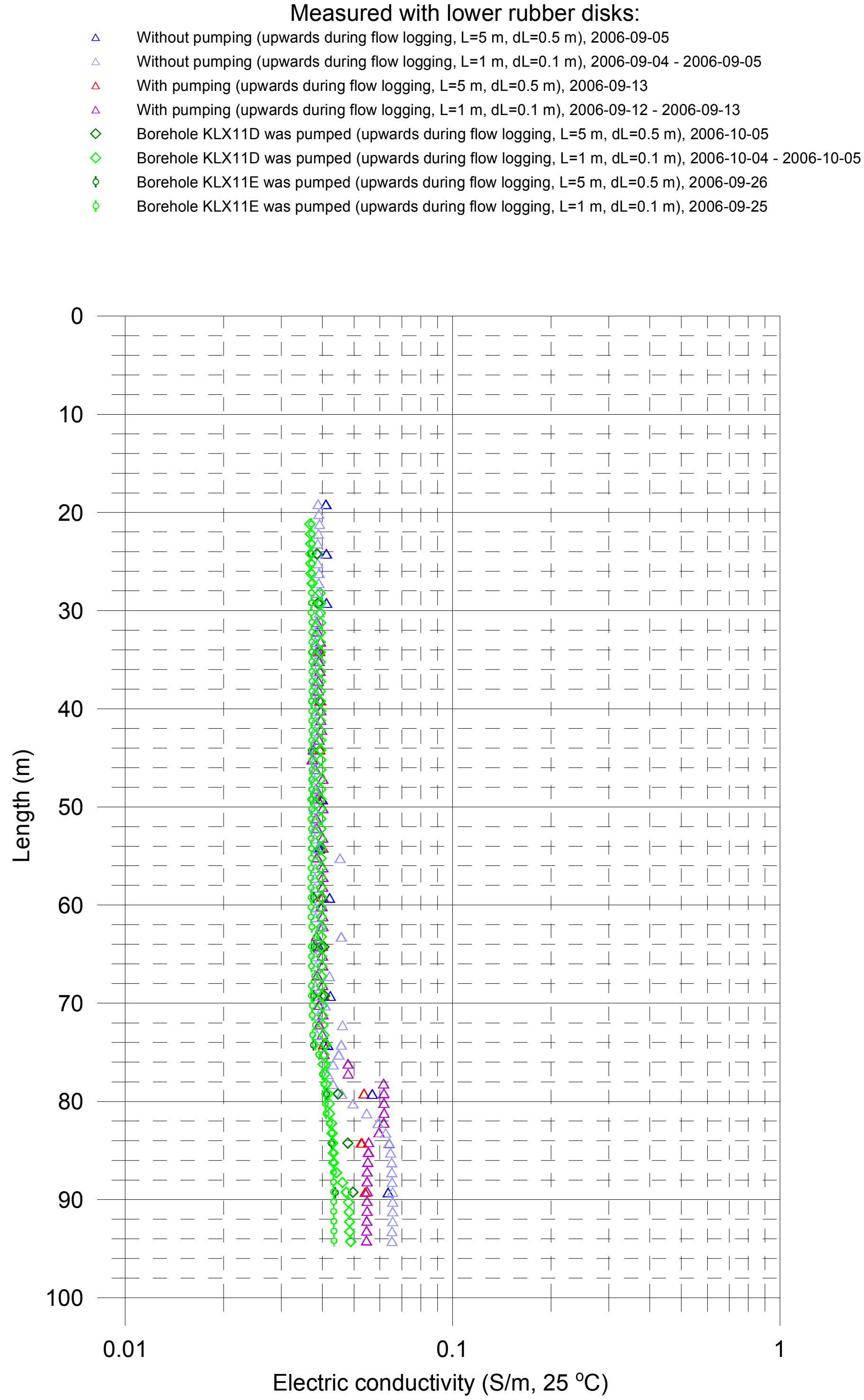
Appendix 14

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.
L_w	m	Section length used in the difference flow logging.
d_L	m	Step length (increment) used in the difference flow logging.
Q_B	m^3/s	Measured flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX11B was pumped).
Q_D	m^3/s	Measured flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX11D was pumped).
Q_E	m^3/s	Measured flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX11E was pumped).
Calc Ref Q_B	m^3/s	Calculated reference flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX11B was pumped).
Calc Ref Q_D	m^3/s	Calculated reference flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX11D was pumped).
Calc Ref Q_E	m^3/s	Calculated reference flow rate through the test section or flow anomaly during hydraulic crosshole interference test (Borehole KLX11E was pumped).
h_{BFW}	m.a.s.l.	Corrected initial hydraulic head along the hole due to e.g. varying salinity conditions of the borehole fluid during hydraulic crosshole interference test (Borehole KLX11B was pumped).
h_{DFW}	m.a.s.l.	Corrected initial hydraulic head along the hole due to e.g. varying salinity conditions of the borehole fluid during hydraulic crosshole interference test (Borehole KLX11D was pumped).
h_{EFW}	m.a.s.l.	Corrected initial hydraulic head along the hole due to e.g. varying salinity conditions of the borehole fluid during hydraulic crosshole interference test (Borehole KLX11E was pumped).

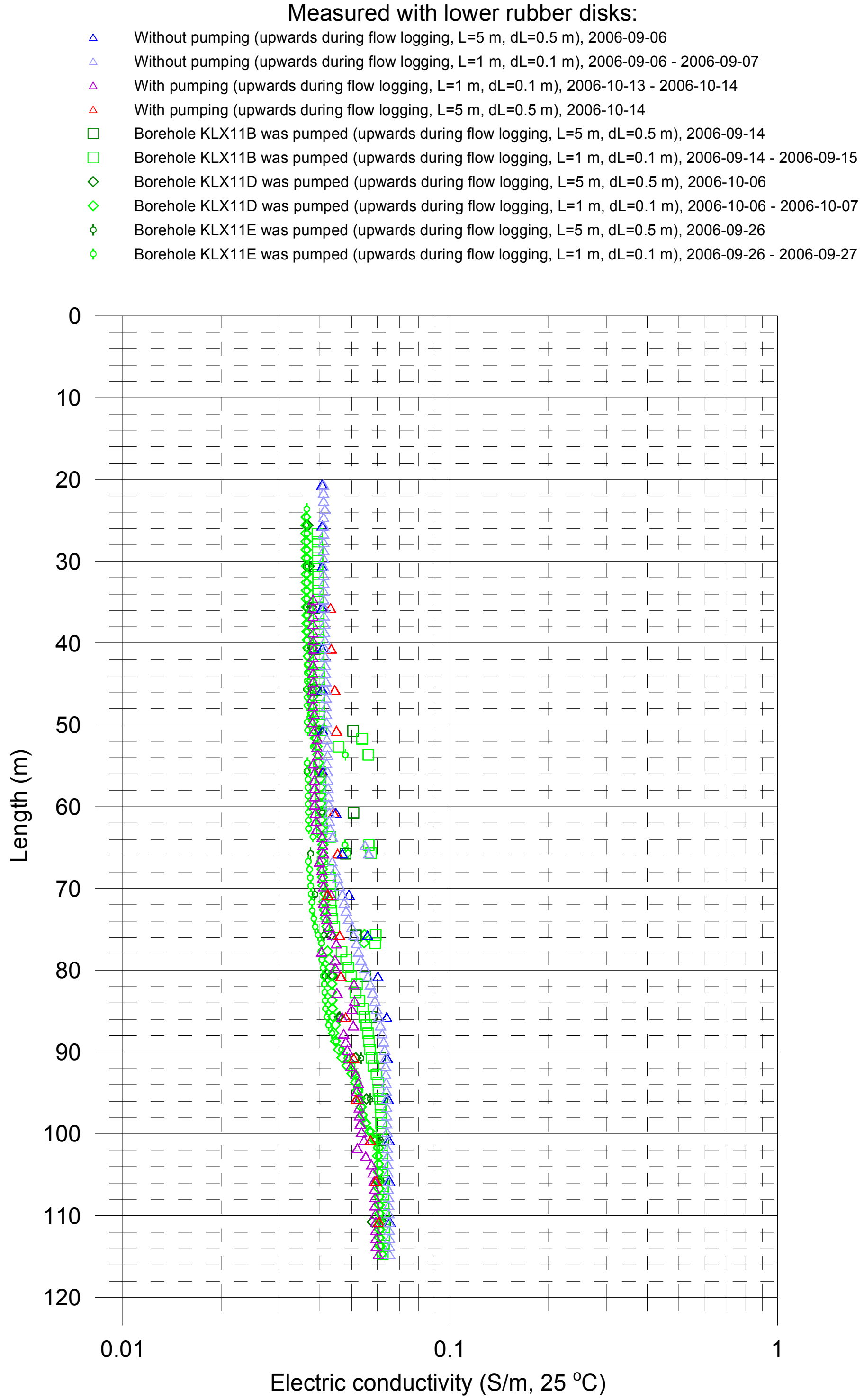
Appendix 15.1

Laxemar, borehole KLX11B
Electric conductivity of borehole water



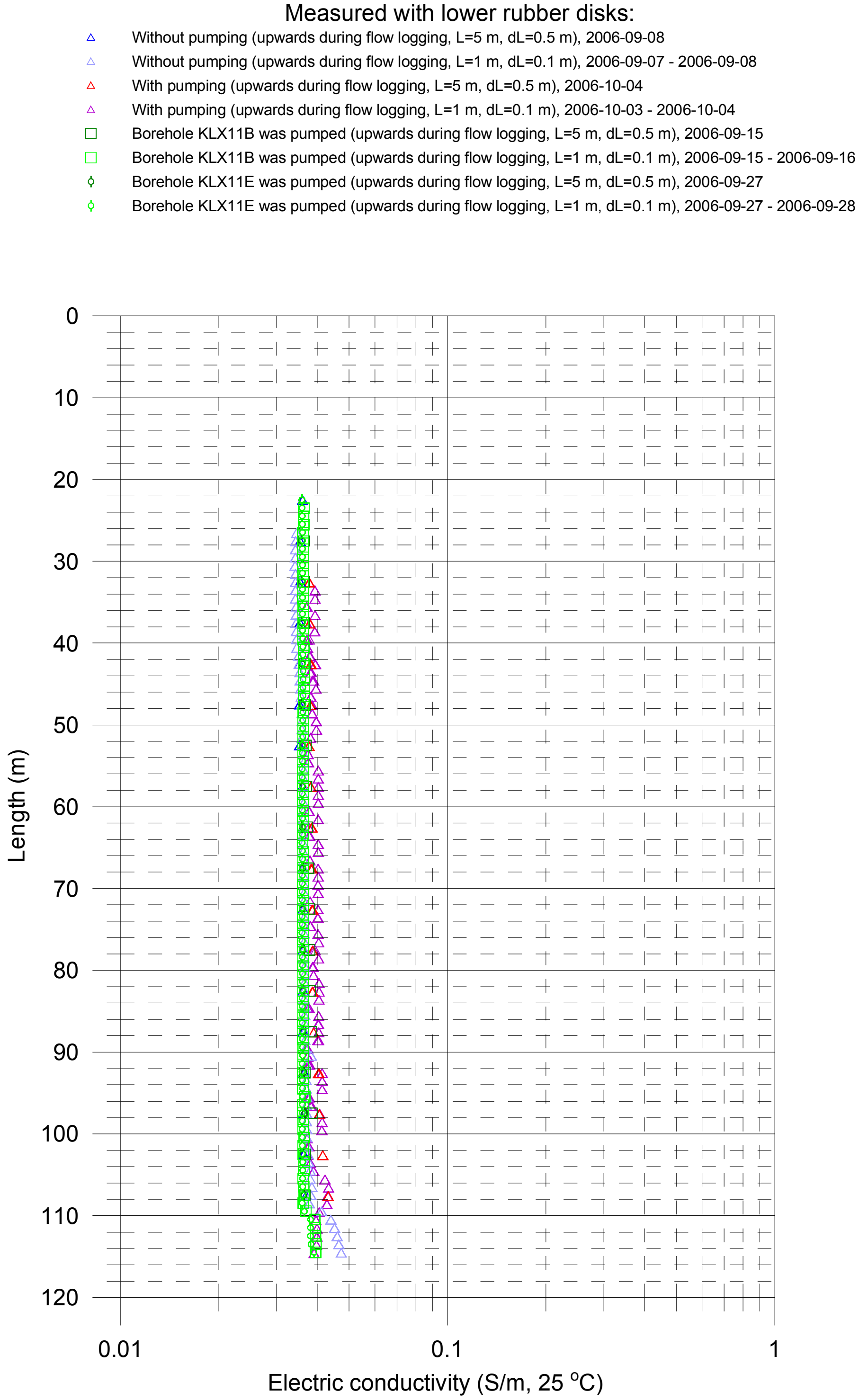
Appendix 15.2

Laxemar, borehole KLX11C
Electric conductivity of borehole water



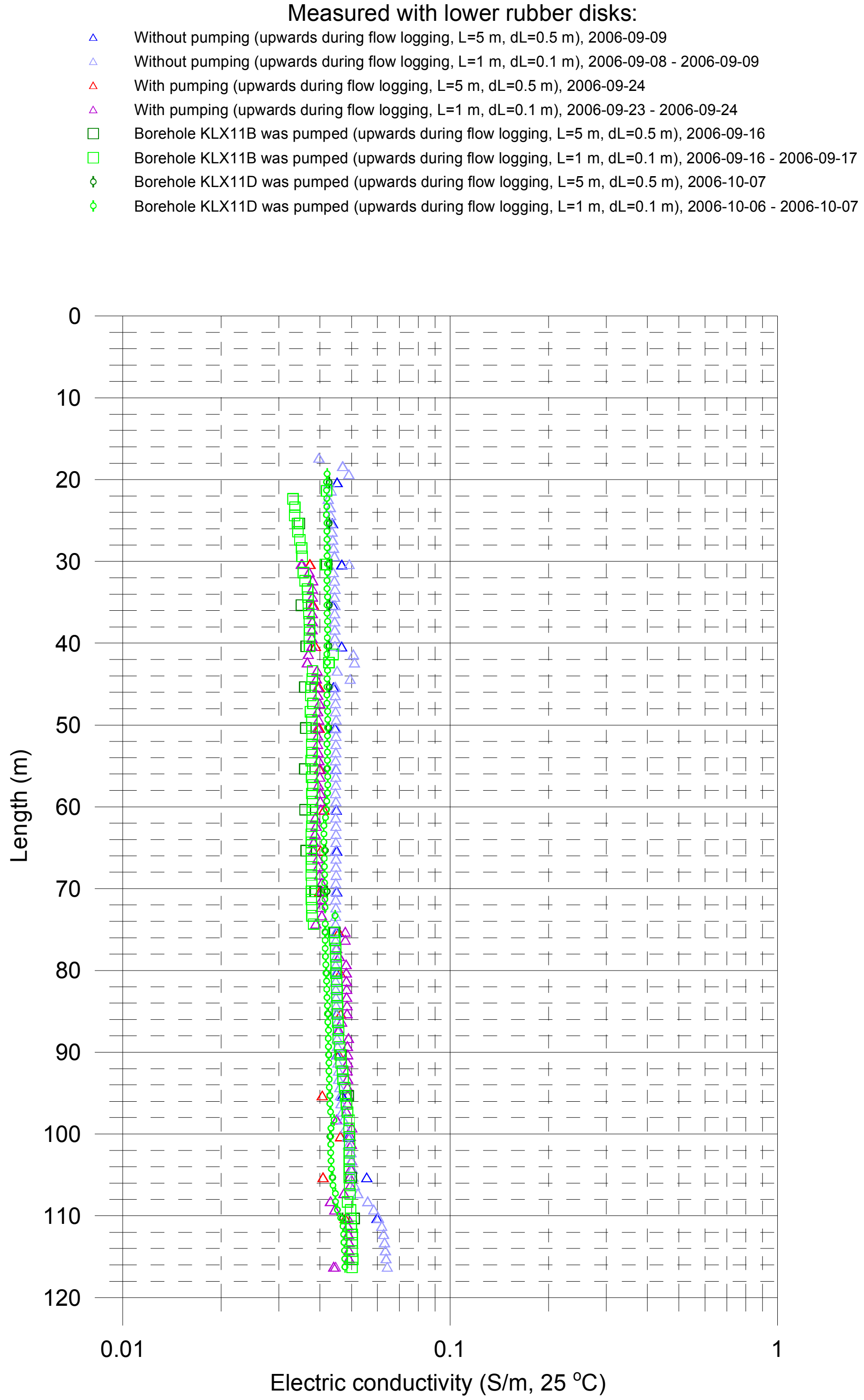
Appendix 15.3

Laxemar, borehole KLX11D
Electric conductivity of borehole water



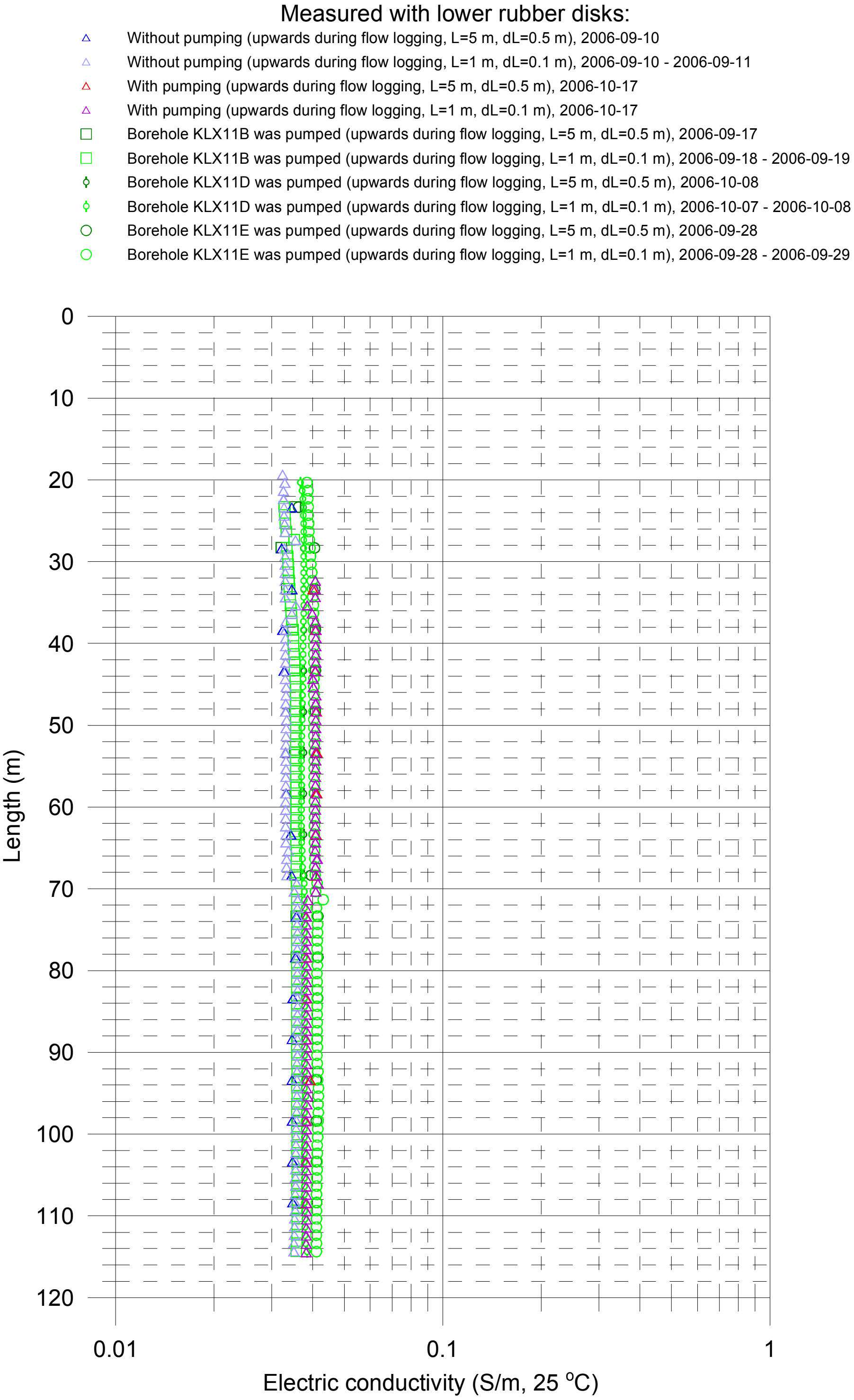
Appendix 15.4

Laxemar, borehole KLX11E
Electric conductivity of borehole water



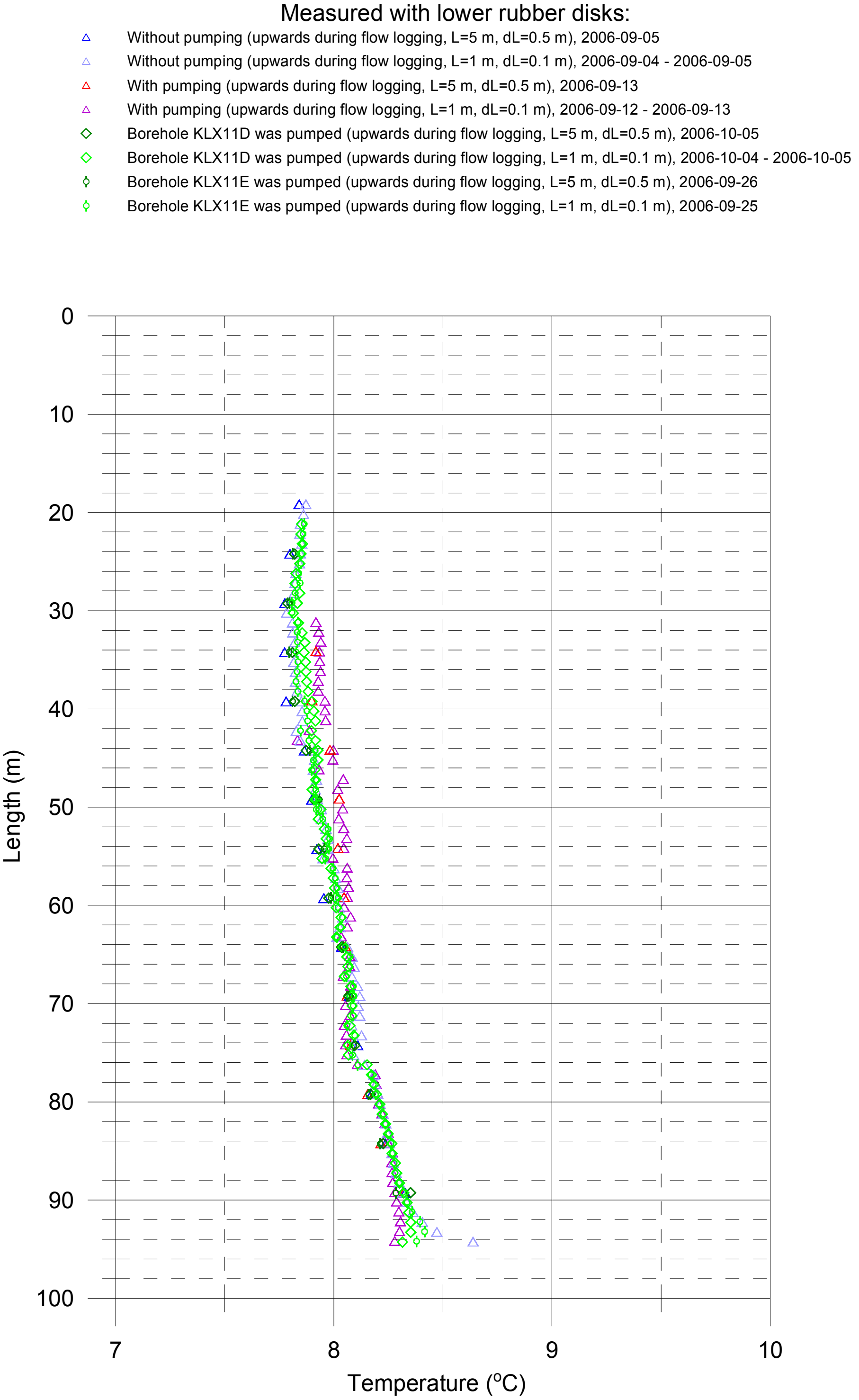
Appendix 15.5

Laxemar, borehole KLX11F
Electric conductivity of borehole water



Appendix 16.1

Laxemar, borehole KLX11B
Temperature of borehole water

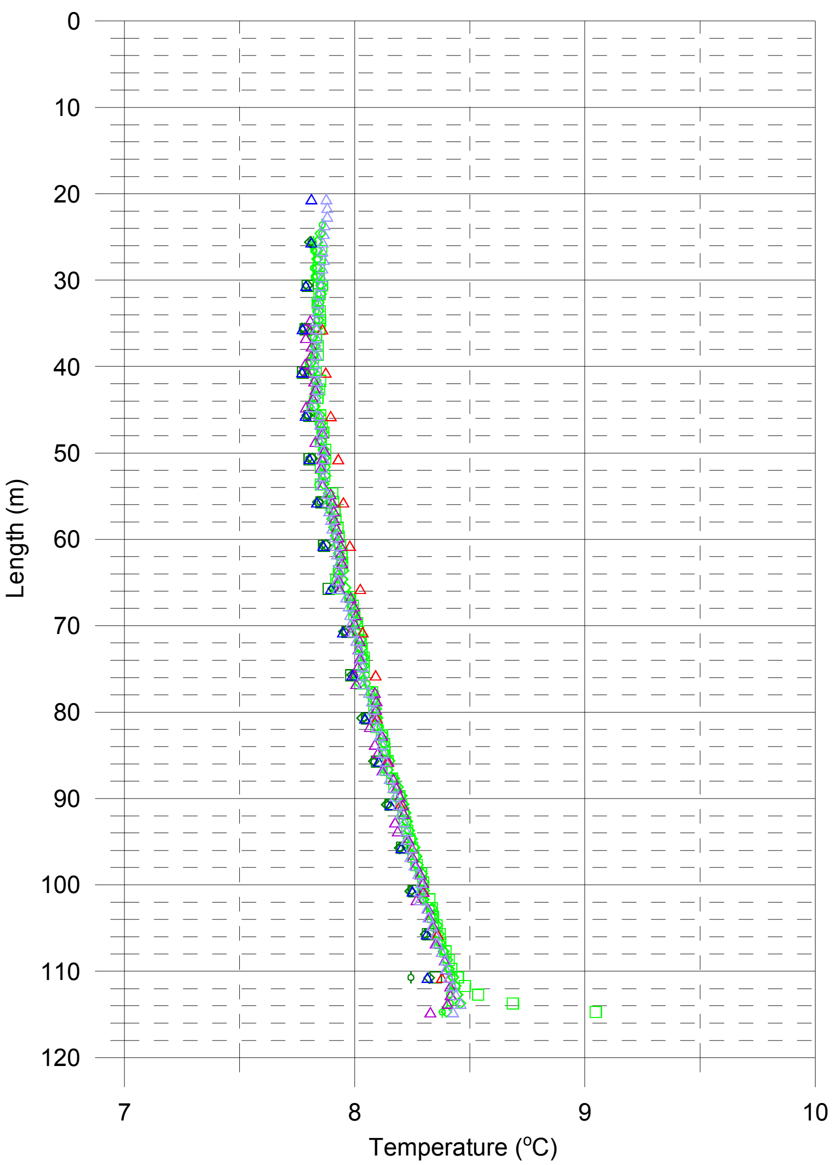


Appendix 16.2

Laxemar, borehole KLX11C
Temperature of borehole water

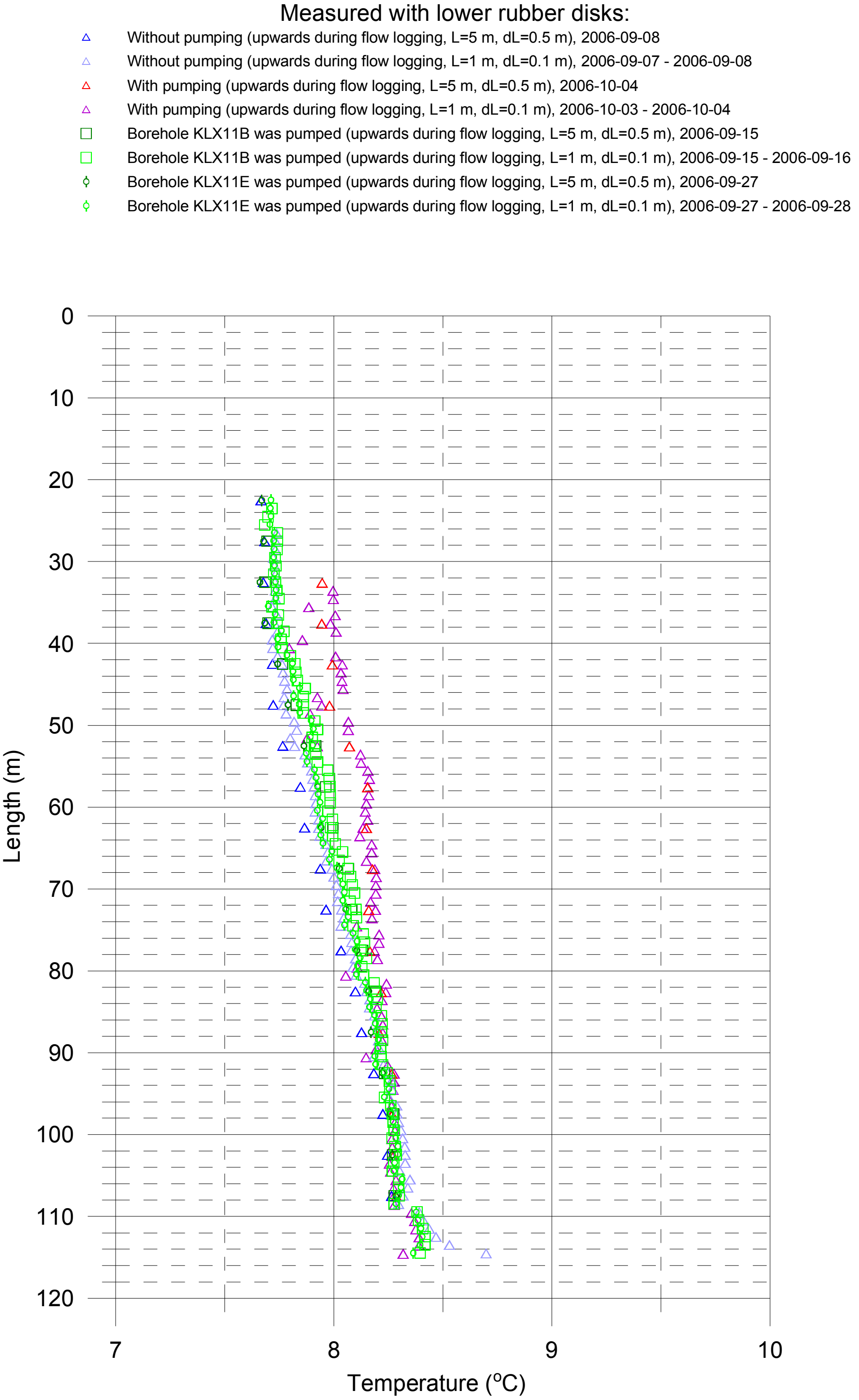
Measured with lower rubber disks:

- Without pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-09-06
- Without pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-09-06 - 2006-09-07
- With pumping (upwards during flow logging, L=1 m, dL=0.1 m), 2006-10-13 - 2006-10-14
- With pumping (upwards during flow logging, L=5 m, dL=0.5 m), 2006-10-14
- Borehole KLX11B was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-09-14
- Borehole KLX11B was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-09-14 - 2006-09-15
- Borehole KLX11D was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-10-06
- Borehole KLX11D was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-10-05 - 2006-10-06
- Borehole KLX11E was pumped (upwards during flow logging, L=5 m, dL=0.5 m), 2006-09-26
- Borehole KLX11E was pumped (upwards during flow logging, L=1 m, dL=0.1 m), 2006-09-26 - 2006-09-27



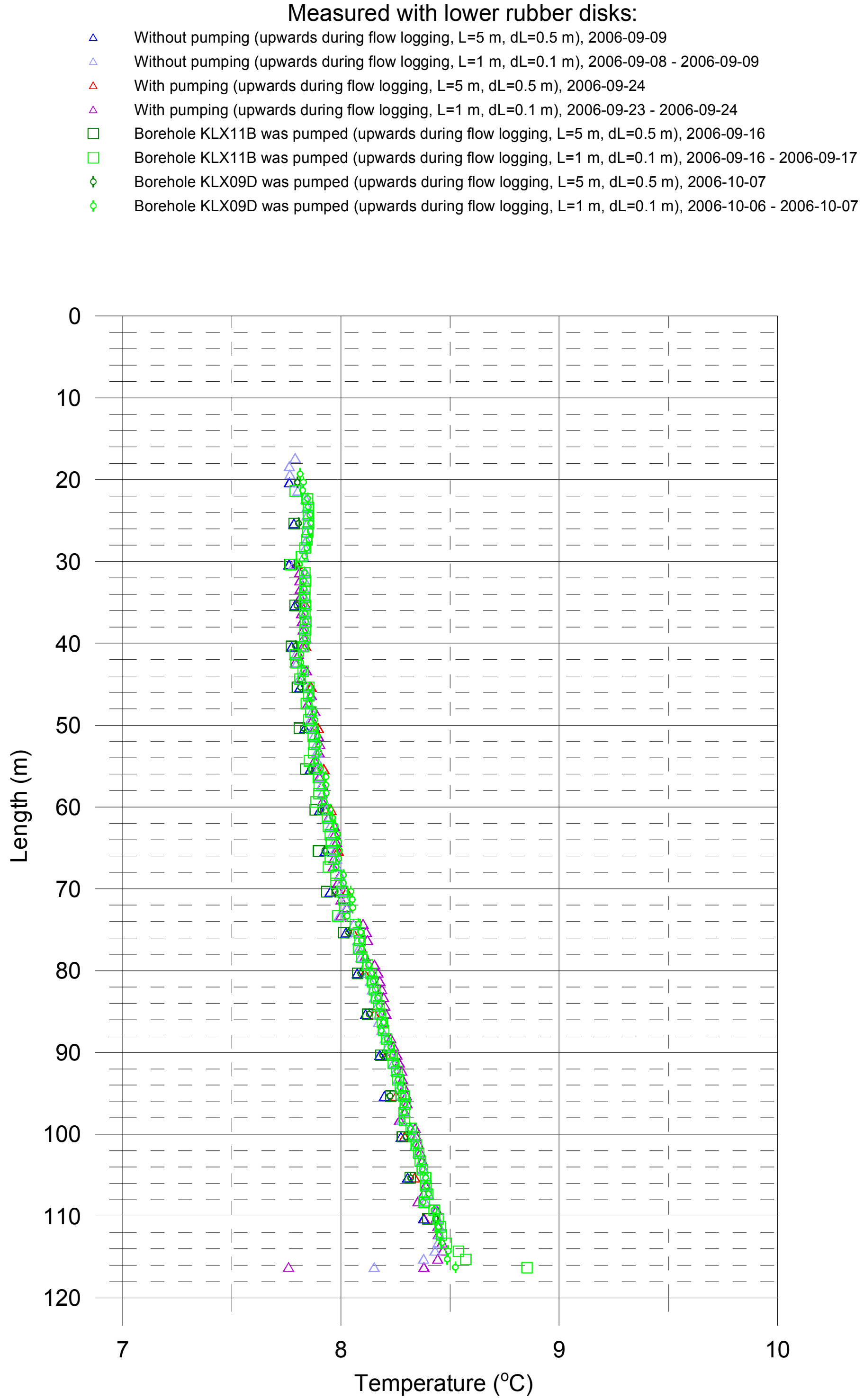
Appendix 16.3

Laxemar, borehole KLX11D
Temperature of borehole water



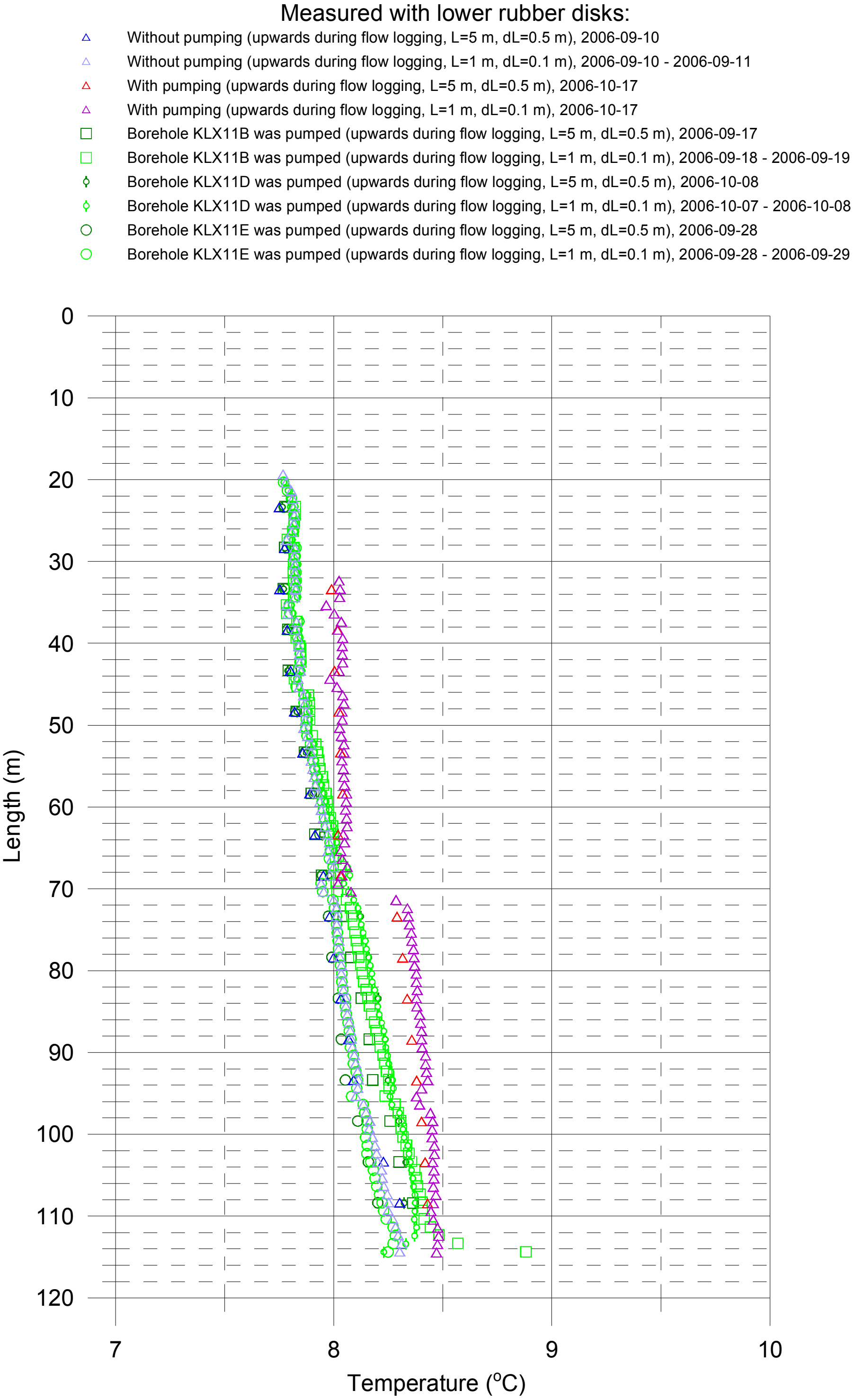
Appendix 16.4

Laxemar, borehole KLX11E
Temperature of borehole water



Appendix 16.5

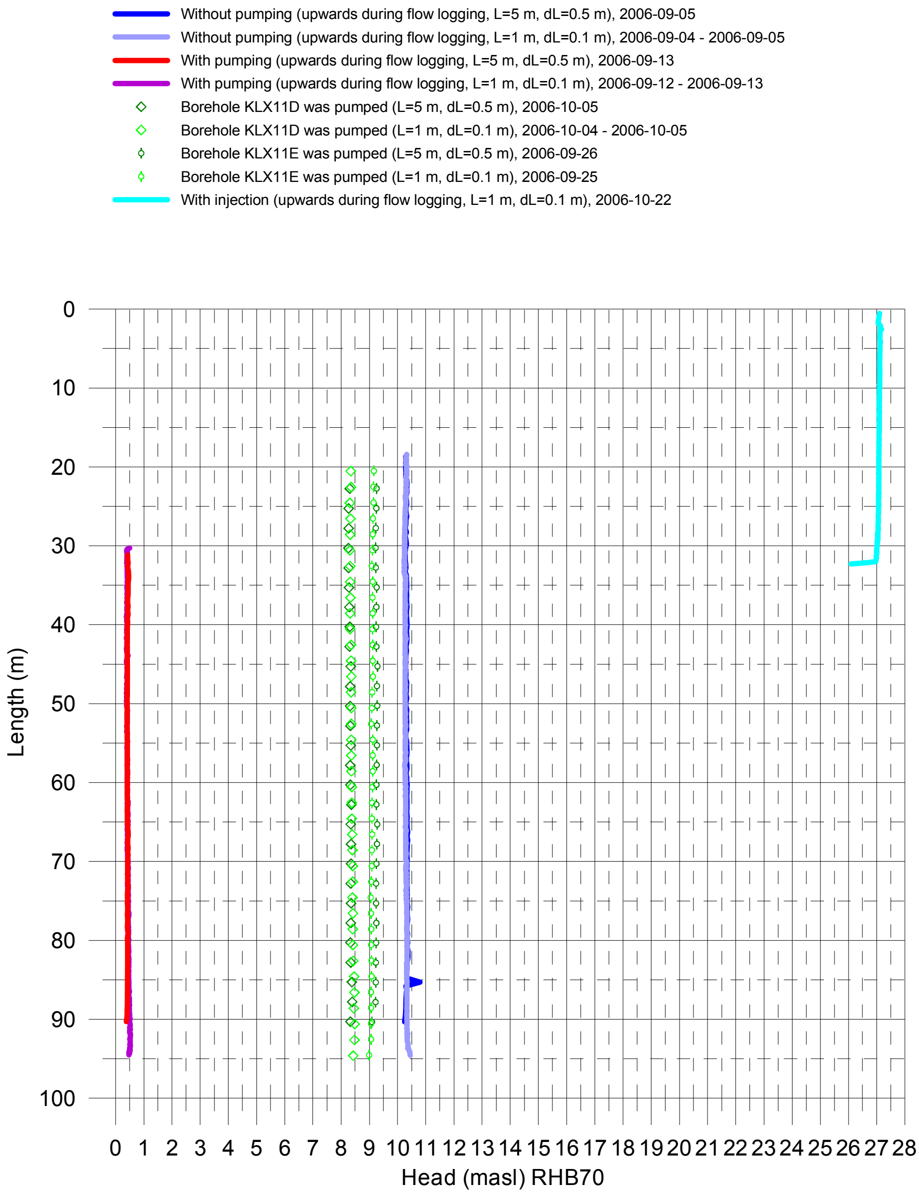
Laxemar, borehole KLX11F
Temperature of borehole water



Appendix 17.1

Laxemar, borehole KLX11B
Head in the borehole during flow logging

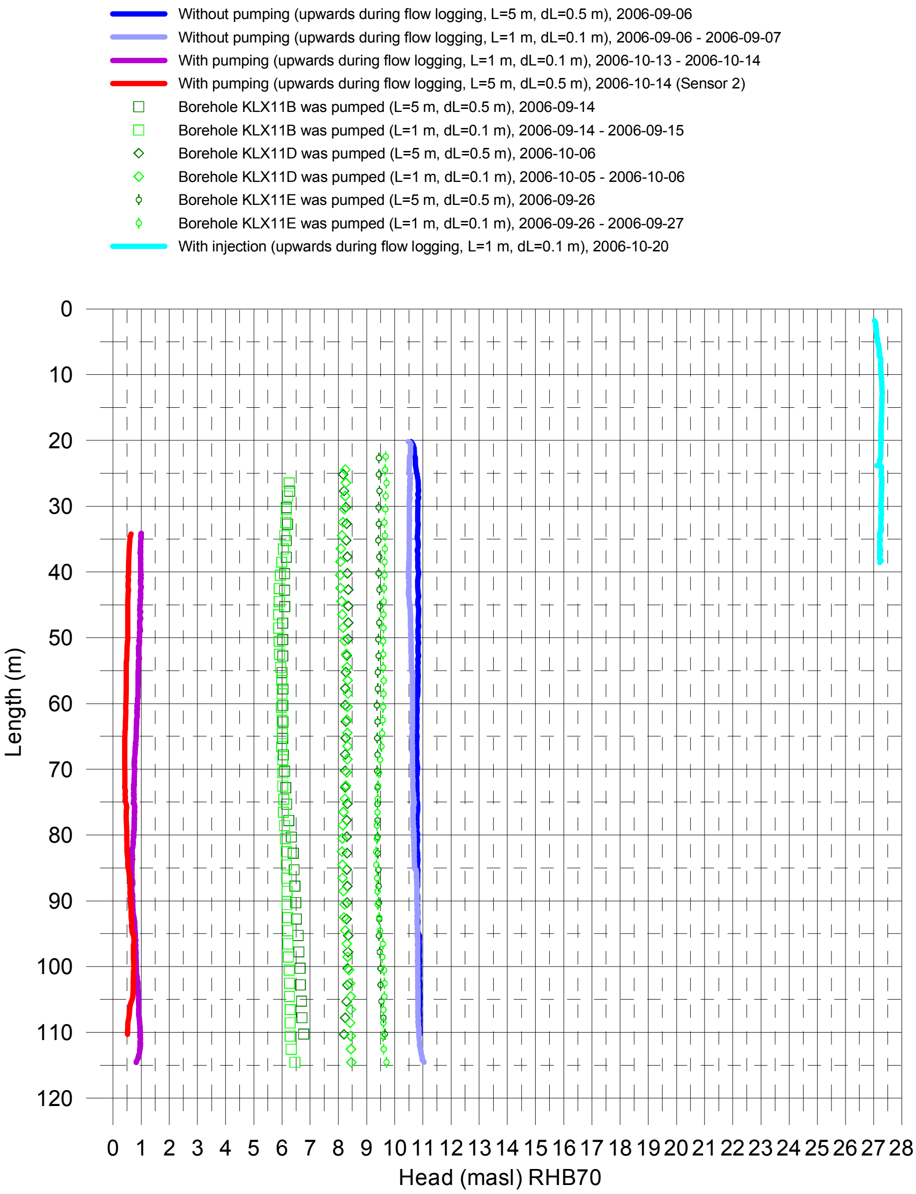
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m^3 * 9.80665 m/s^2) + Elevation (m)
Offset = 2460 Pa (Correction for absolut pressure sensor)



Appendix 17.2

Laxemar, borehole KLX11C
Head in the borehole during flow logging

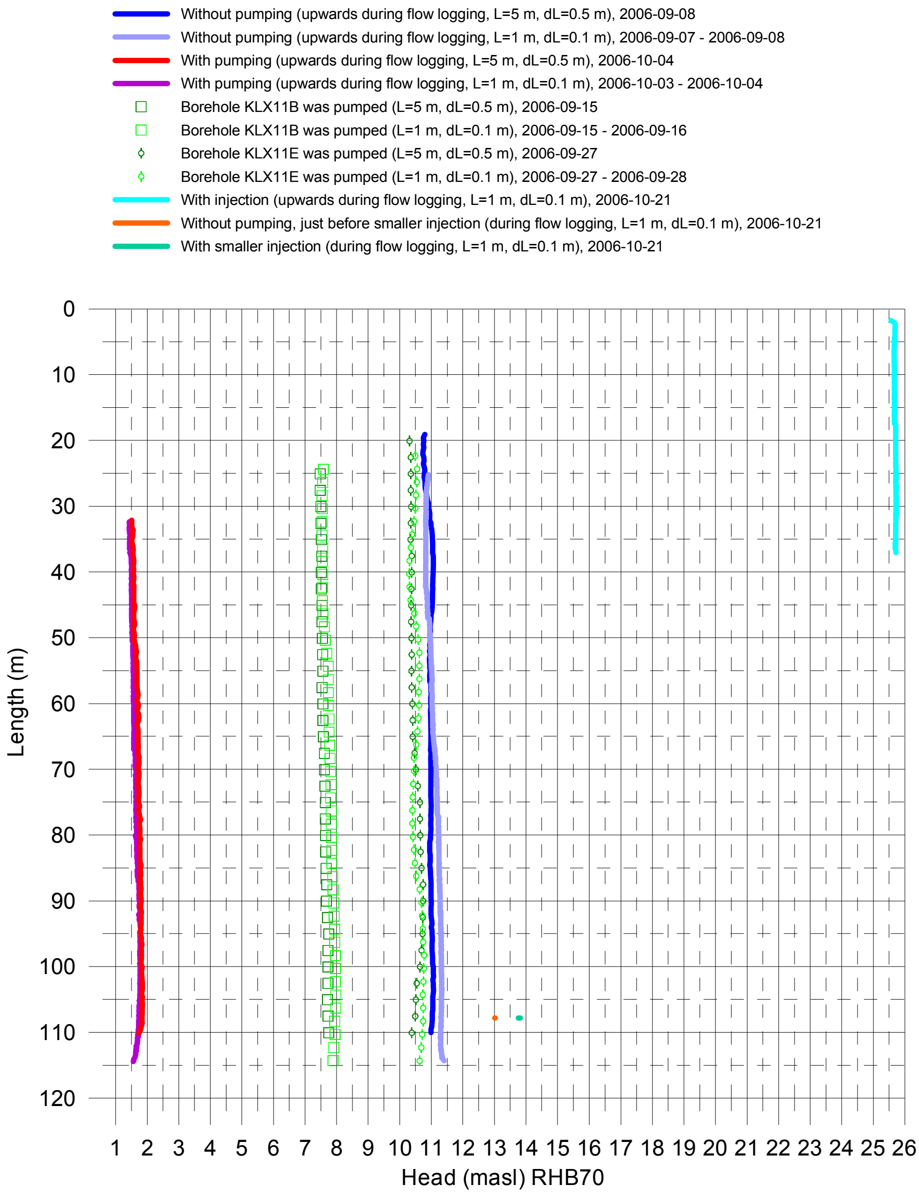
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m^3 * 9.80665 m/s^2) + Elevation (m)
Offset = 2460 Pa (Correction for absolut pressure sensor)



Appendix 17.3

Laxemar, borehole KLX11D
Head in the borehole during flow logging

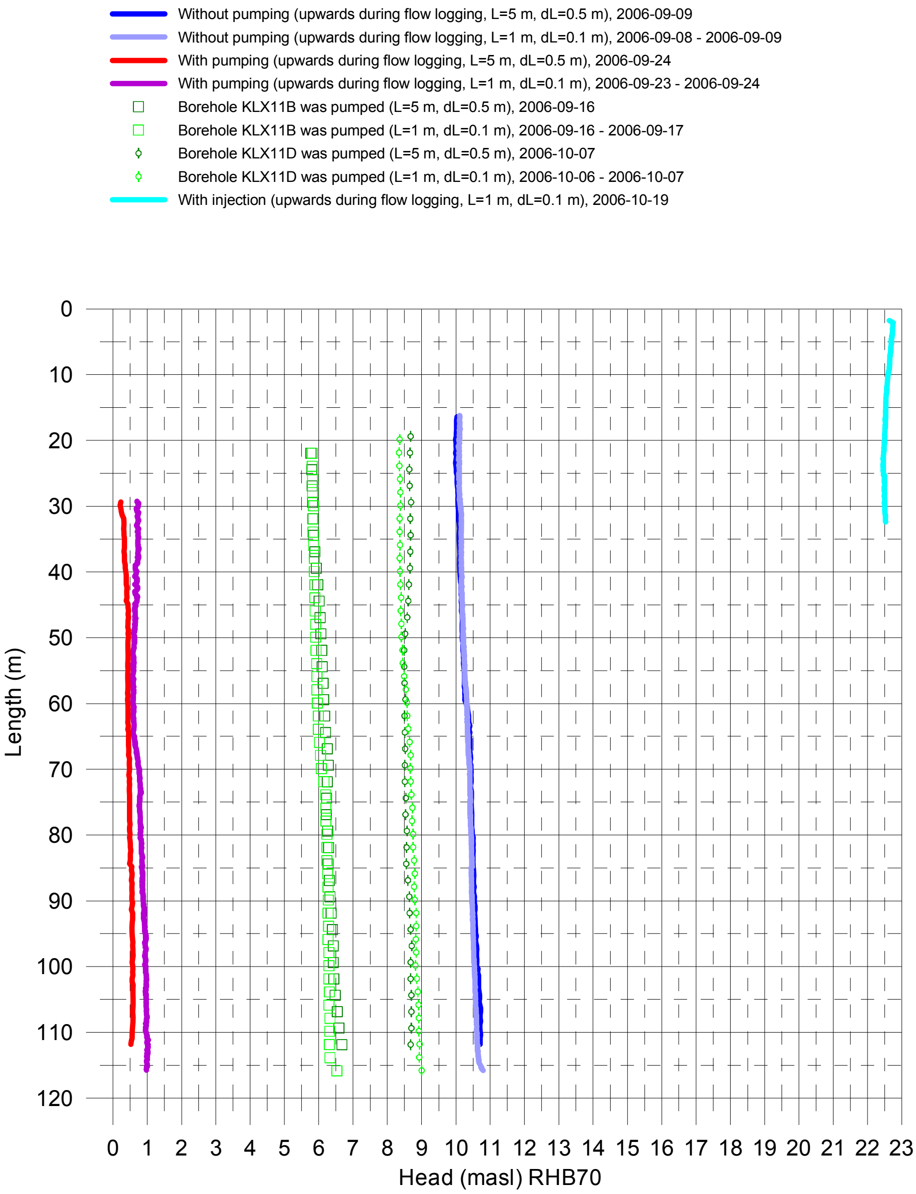
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m^3 * 9.80665 m/s^2) + Elevation (m)
Offset = 2460 Pa (Correction for absolut pressure sensor)



Appendix 17.4

Laxemar, borehole KLX11E
Head in the borehole during flow logging

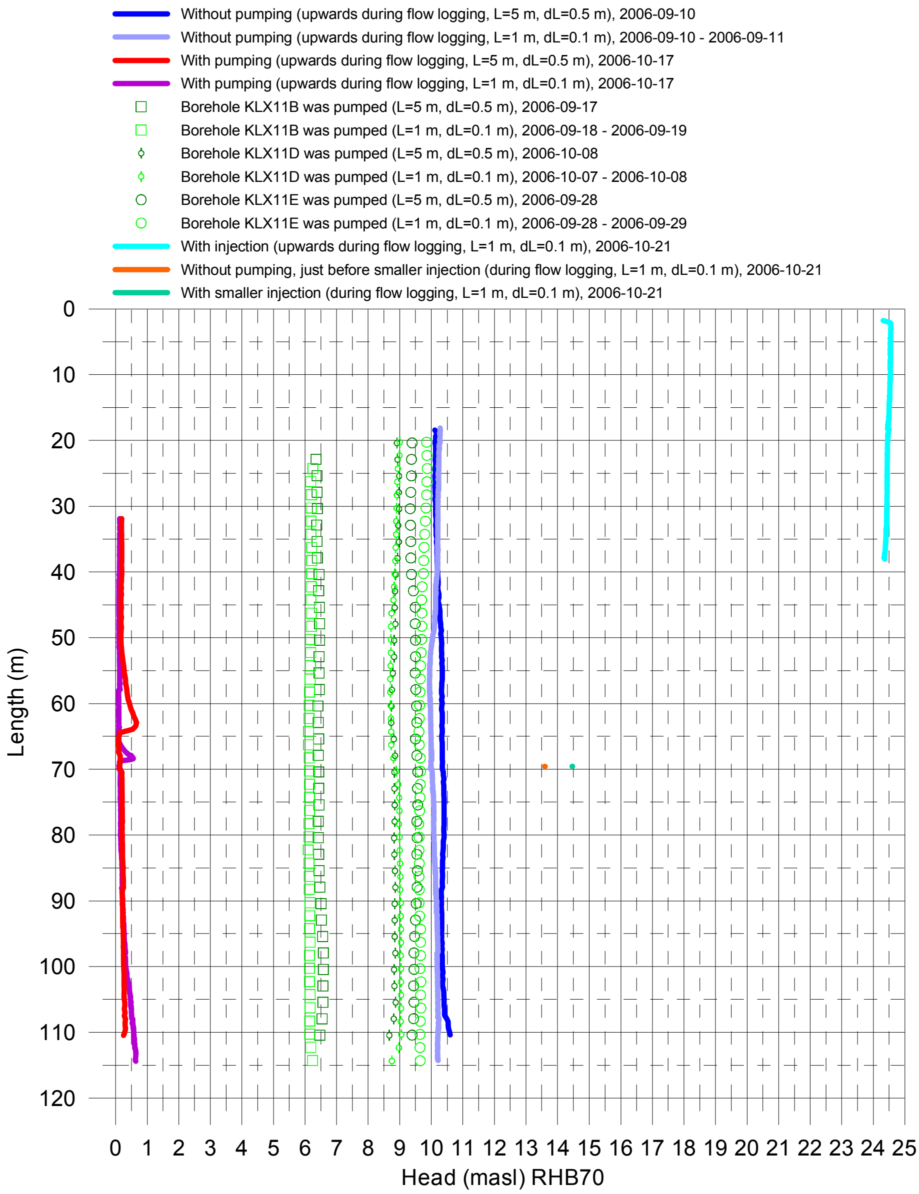
Head(masl)= (Absolute pressure (Pa) - Airpressure (Pa) + Offset) /(1000 kg/m^3 * 9.80665 m/s^2) + Elevation (m)
Offset = 2460 Pa (Correction for absolut pressure sensor)



Appendix 17.5

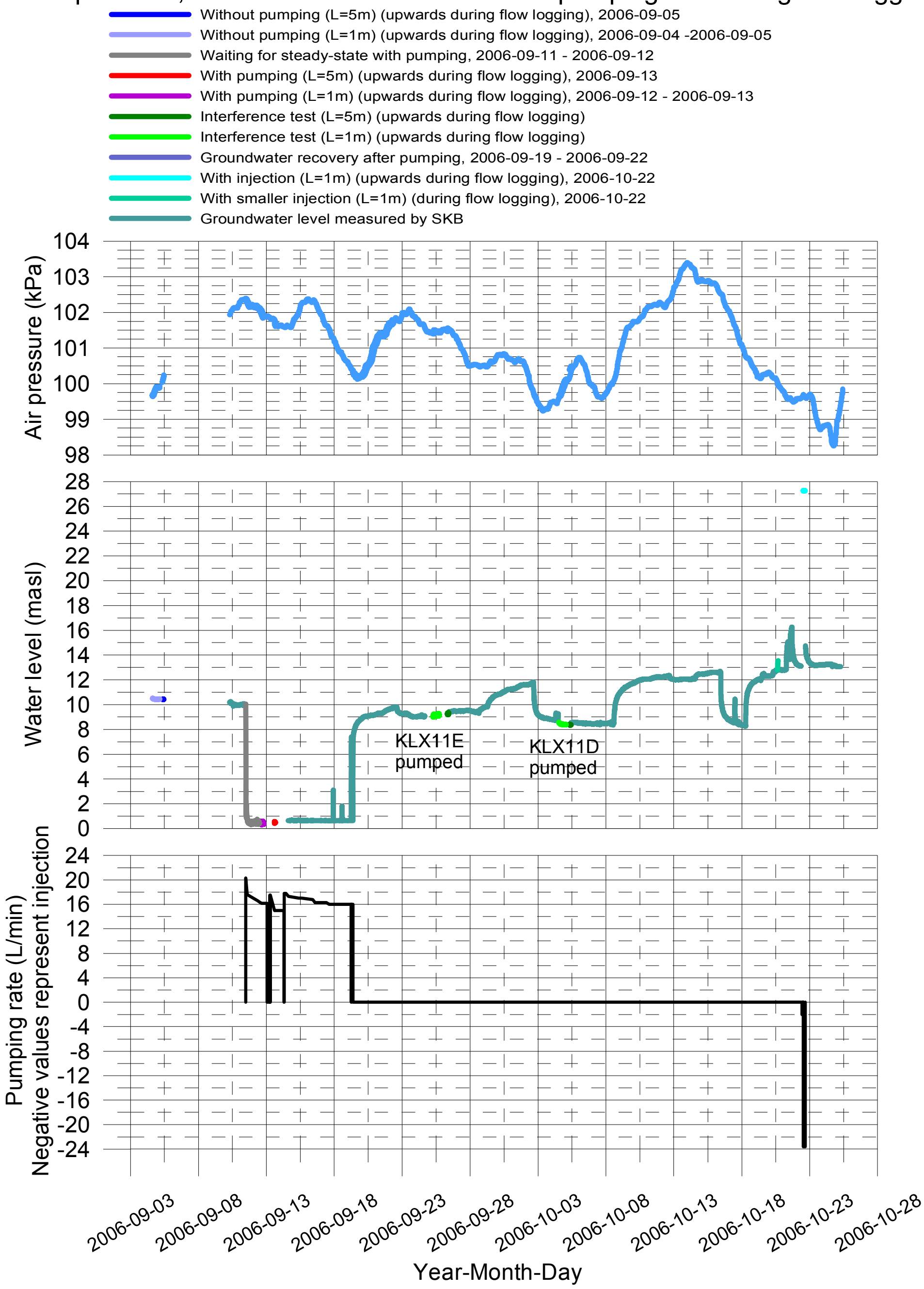
Laxemar, borehole KLX11F
Head in the borehole during flow logging

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

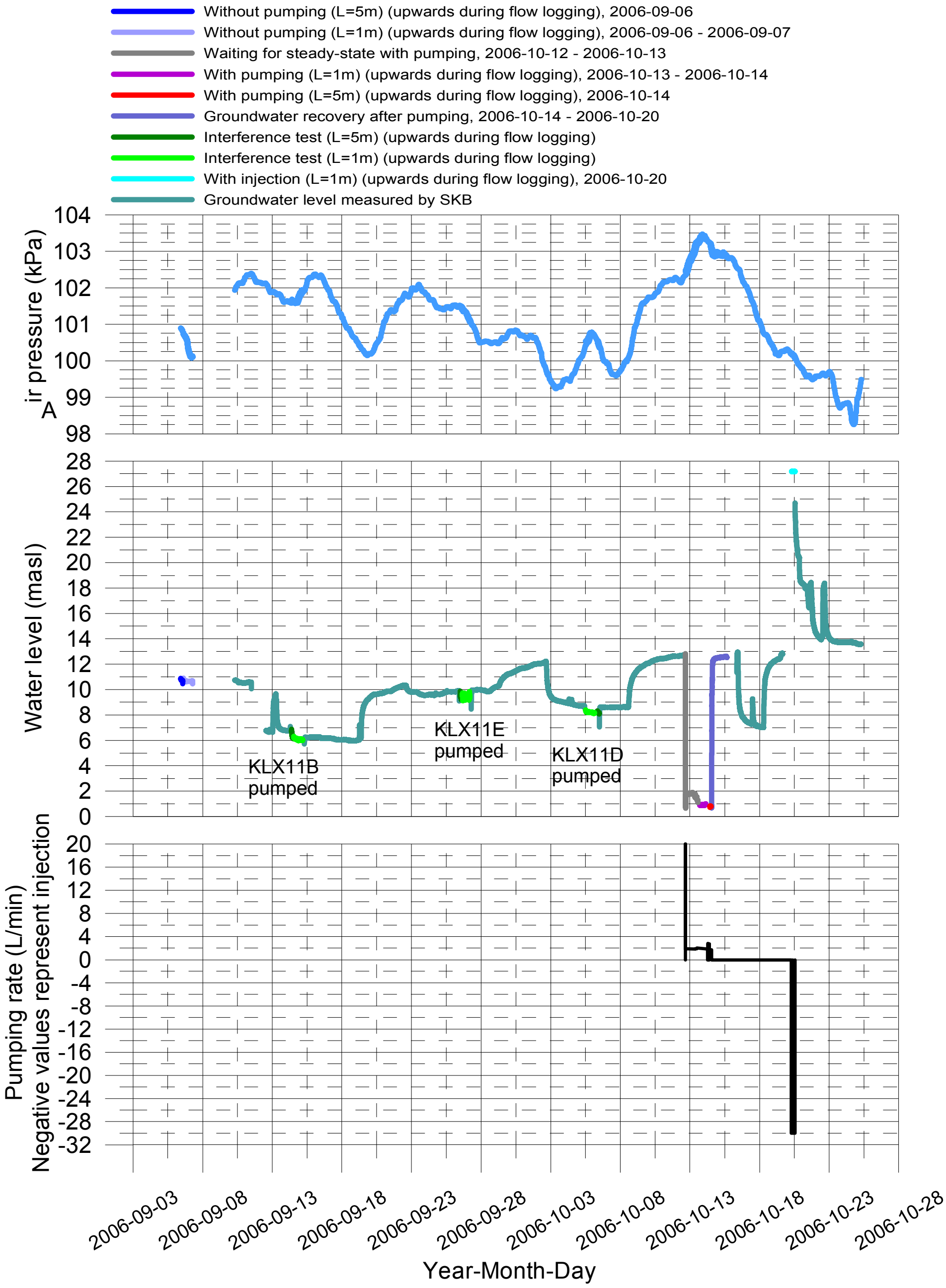


Appendix 18.1

Laxemar, borehole KLX11B
Air pressure, water level in the borehole and pumping rate during flow logging



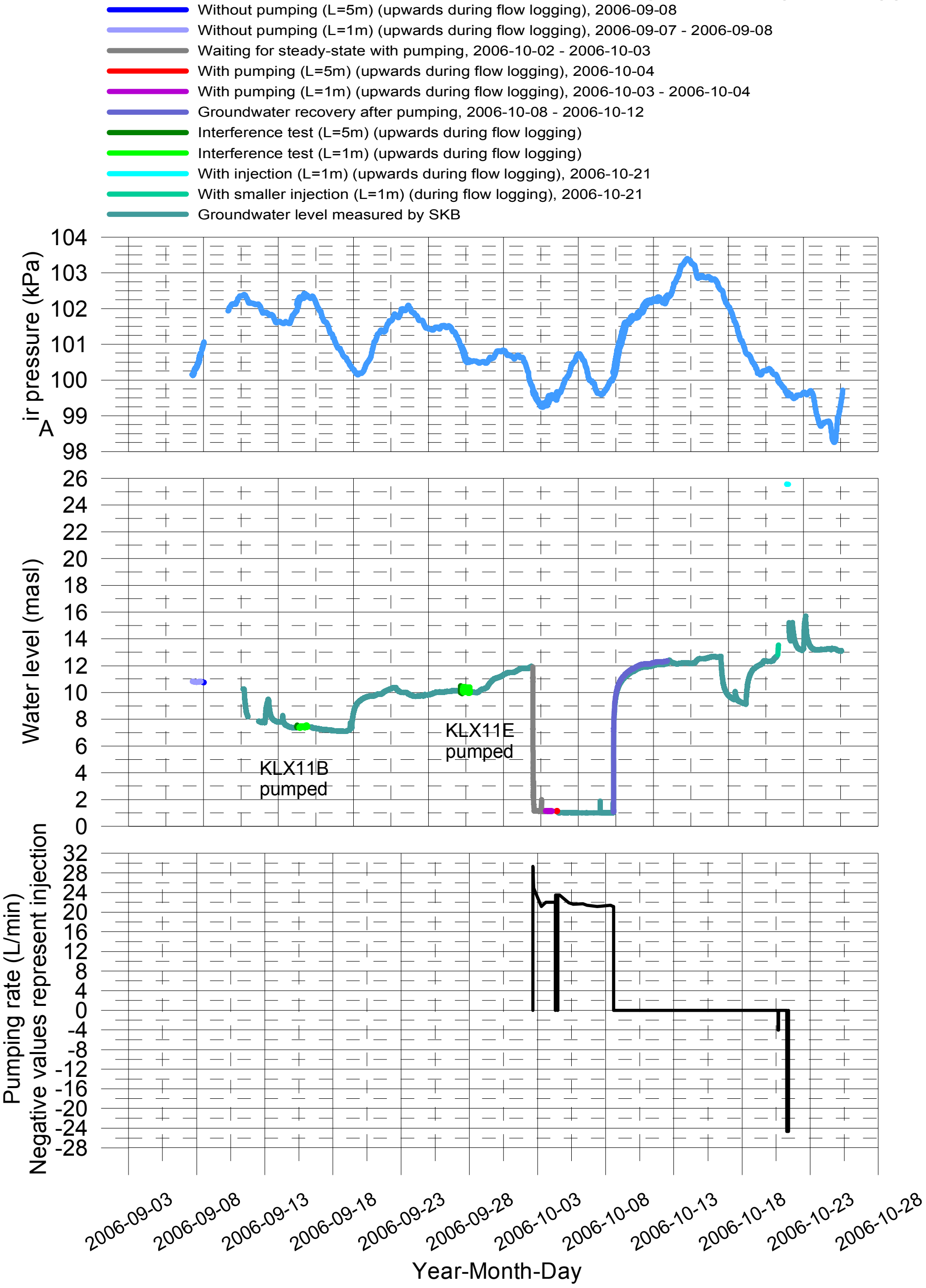
Laxemar, borehole KLX11C
Air pressure, water level in the borehole and pumping rate during flow logging



Appendix 18.3

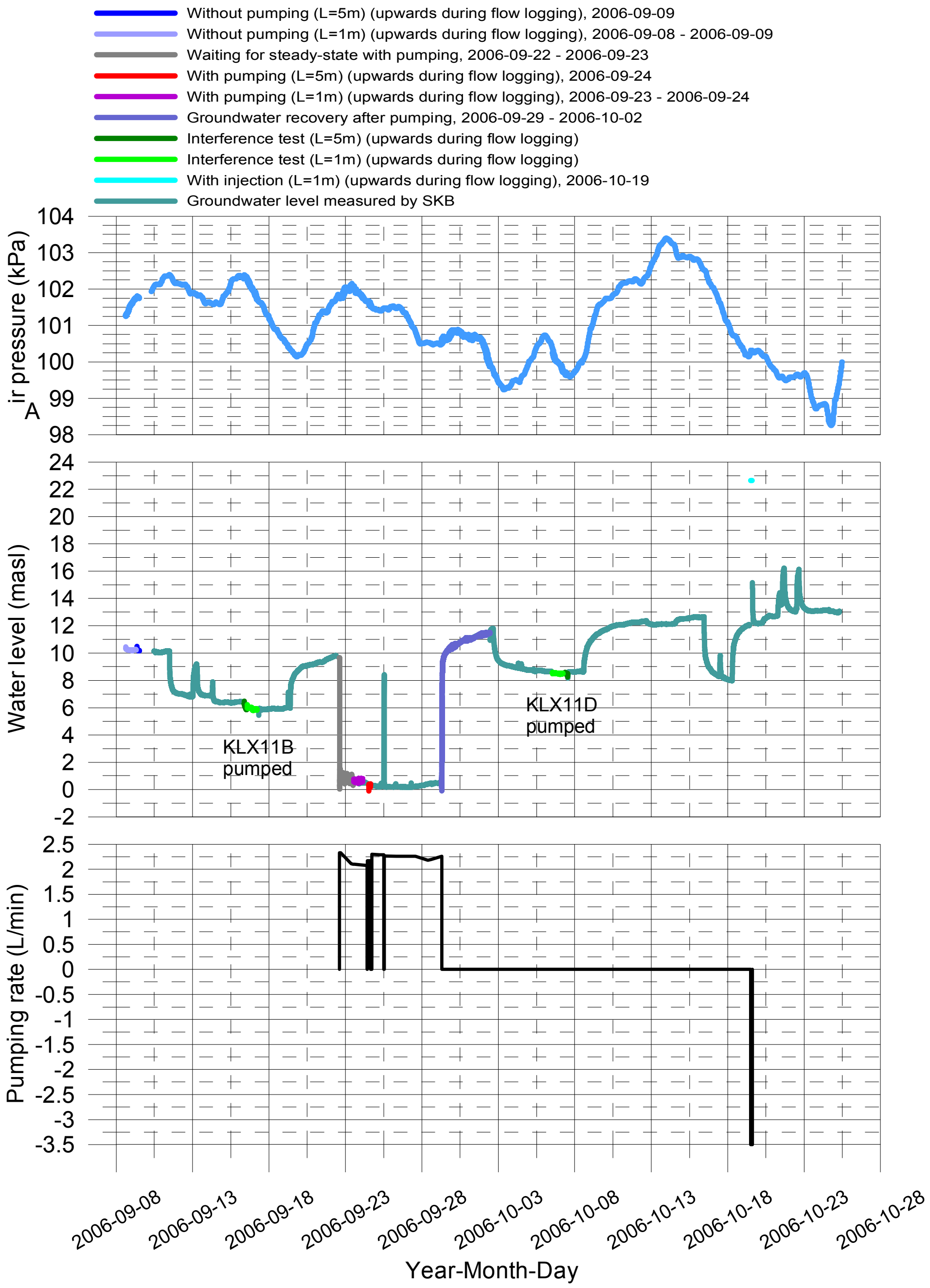
Laxemar, borehole KLX11D

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



Appendix 18.4

Laxemar, borehole KLX11E
Air pressure, water level in the borehole and pumping rate during flow logging



Appendix 18.5

Laxemar, borehole KLX11F
Air pressure, water level in the borehole and pumping rate during flow logging