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Oskarshamn site investigation

Hydraulic injection tests in Borehole KLX20A, 2006

Subarea Laxemar

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January 2007

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Keywords: Site/project, Hydrogeology, Hydraulic tests, Injection test, Hydraulic parameters, Transmissivity, Constant head.

Abstract

Hydraulic injection tests have been performed in Borehole KLX20A at the Laxemar area, Oskarshamn. The tests are part of the general program for site investigations and specifically for the Laxemar subarea. The hydraulic testing programme has the aim to characterise the rock with respect to its hydraulic properties of the fractured zones and rock mass between them. Data is subsequently delivered for the site descriptive model.

This report describes the results and primary data evaluation of the hydraulic injection tests in borehole KLX20A performed between 07^{th} and 12^{th} of November 2006.

The objective of the hydrotests was to describe the rock around the borehole with respect of hydraulic parameters, mainly transmissivity (T) and hydraulic conductivity (K) at different measurement scales of 100 m and 20 m sections. Transient evaluation during flow and recovery period provided additional information such as flow regimes, hydraulic boundaries and cross-over flows. Constant pressure injection tests were conducted between 102.20–448.00 m below ToC. The results of the test interpretation are presented as transmissivity, hydraulic conductivity and hydraulic freshwater head.

Sammanfattning

Injektionstester har utförts i borrhål KLX20A i delområde Laxemar, Oskarshamn. Testerna är en del av SKB:s platsundersökningar. Hydraultestprogrammet där injektionstesterna ingår har som mål att karakterisera berget med avseende på dess hydrauliska egenskaper av sprickzoner och mellanliggande bergmassa. Data från testerna används vid den platsbeskrivande modelleringen av området.

Denna rapport redovisar resultaten och utvärderingar av primärdata de hydrauliska injektionstesterna i borrhål KLX20A. Testerna utfördes mellan den 07 november till den 12 november 2006.

Syftet med hydraultesterna var framförallt att beskriva bergets hydrauliska egenskaper runt borrhålet med avseende på hydrauliska parametrar, i huvudsak transmissvitet (T) och hydraulisk konduktivitet (K) vid olika mätskalor av 100 m och 20 m sektioner. Transient utvärdering under injektions- och återhämntningsfasen gav ytterligare information avseende flödesgeometri, hydrauliska gränser och sprickläckage. Injektionstester utfördes mellan 102,20–448,00 m borrhålslängd. Resultaten av testutvärderingen presenteras som transmissivitet, hydraulisk konduktivitet och grundvattennivå uttryckt i ekvivalent sötvattenpelare (fresh-water head).

Contents

Appendices attatched on CD

1 Introduction

A general program for site investigations presenting survey methods has been prepared /SKB 2001/, as well as a site-specific program for the investigations in the Simpevarp area /SKB 2006/. The hydraulic injection tests form part of the site characterization program under item 1.1.5.8 in the work breakdown structure of the execution programme, /SKB 2002/.

Measurements were carried out in borehole KLX20A between 07th and 12th of November 2006 following the methodology described in SKB MD 323.001 and in the activity plan AP PS 400-06-112 (SKB controlling documents). Data and results were delivered to the SKB site characterization database SICADA and are traceable by the activity plan number.

The hydraulic testing programme has the aim to characterise the rock with respect to its hydraulic properties of the fractured zones and rock mass between them. This report describes the results and primary data evaluation of the hydraulic injection tests in borehole KLX20A. The commission was conducted by Golder Associates AB and Golder Associates GmbH.

Borehole KLX20A is situated in the Laxemar area approximately 4 km west of the nuclear power plant of Simpevarp, Figure 1-1. The borehole was drilled from February 2006 to April 2006 at 457.92 m length with an inner diameter of 76 mm and an inclination of –49.813°. The upper 99.50 m is cased with large diameter telescopic casing ranging from diameter (outer diameter) 208 mm–323 mm.

The work was carried out in accordance with activity plan AP PS 400-06-112. In Table 1-1 controlling documents for performing this activity are listed. Activity plan and method descriptions are SKB's internal controlling documents. Measurements were conducted utilising SKB's custom made testing equipment PSS2.

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

Activity plan	**Number**	**Version**
Hydraulic pumping and injection tests in borehole KLX20A	AP PS 400-06-112	1.0
Method descriptions	**Number**	**Version**
Hydraulic injection tests	SKB MD 323.001	1.0
Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning	SKB MD 600.004	1.0
Instruktion för längdkalibrering vid undersökningar I kärnborrhål	SKB MD 620.010	1.0
Allmäna ordning-, skydds- och miljöregler för platsundersökningar Oskarshamn	SKB SDPO-003	1.0
Miljökontrollprogram Platsundersökningar	SKB SDP-301	1.0
Hantering av primärdata vid platsundersökningar	SKB SDP-508	1.0

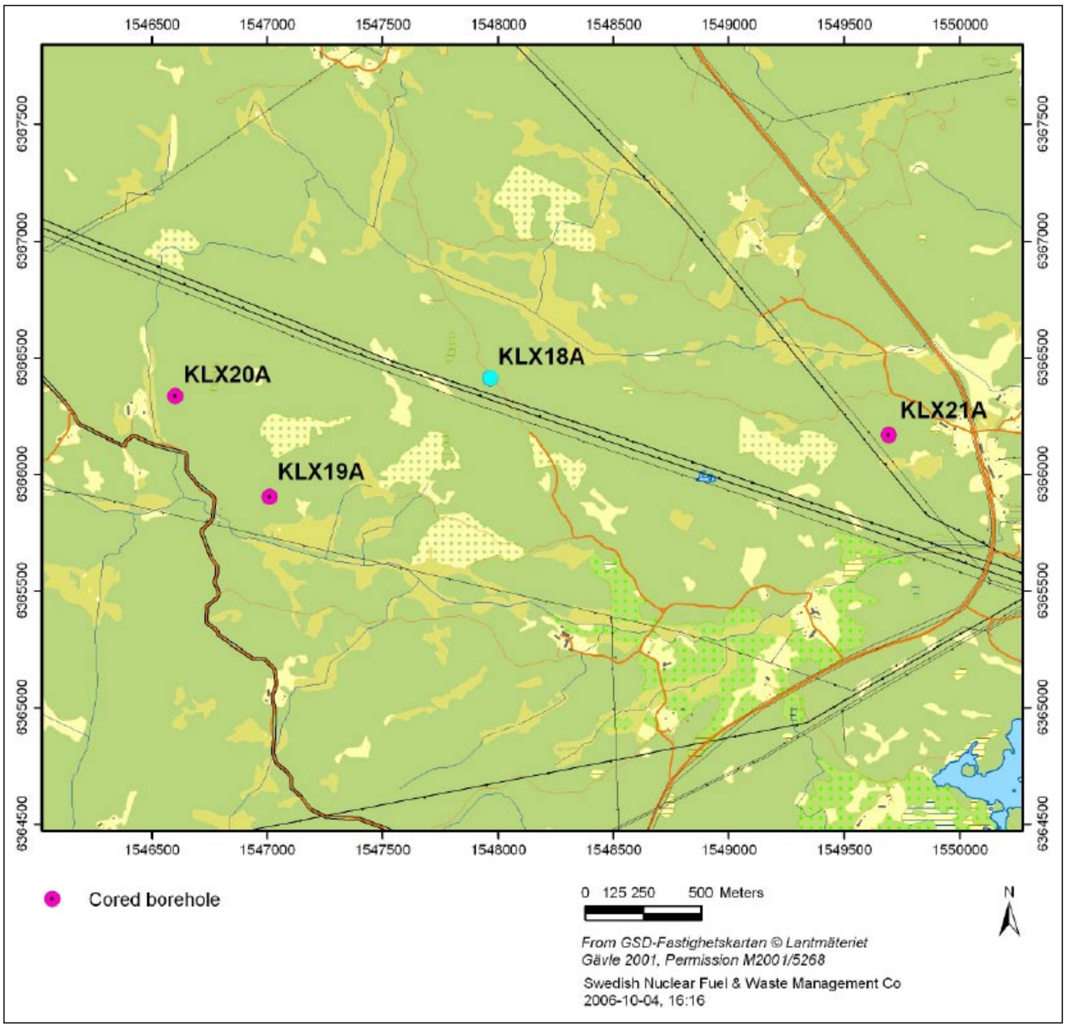

Figure 1-1. *The investigation area Laxemar, Oskarshamn with location of borehole KLX20A.*

2 Objective and scope

The objective of the hydrotests in borehole KLX20A is to describe the rock around the borehole with respect to hydraulic parameters, mainly transmissivity (T) and hydraulic conductivity (K). This is done at different measurement scales of 100 m and 20 m sections. Among these parameters transient evaluation during the flow and recovery period provides additional information such as flow regimes, hydraulic boundaries and cross-over flows.

The scope of work consisted of preparation of the PSS2 tool which included cleaning of the down-hole tools, calibration and functional checks, injection tests of 100 m and 20 m test sections, analyses and reporting.

Preparation for testing was done according to the Quality plan. This step mainly consists of functions checks of the equipment to be used, the PSS2 tool. Calibration checks and function checks were documented in the daily log and/or relevant documents.

The following hydraulic injection tests were performed between 07^{th} and 12^{th} November 2006.

Between 307.5 m and 407.5 m no 20 m tests were performed because the appropriate 100 m section shows a flow below measurement limit (1 ml/min). The remaining 40 m (407.5 m–448.0 m) were not tested, too. These tests were skipped because of a very tight bottom zone which causes a strong pressure decrease in the borehole while moving the 100 m section tool upwards. To minimize the risk for the tool and the borehole it was decided not to run to this depth again (approved by SKB).

2.1 Borehole

The borehole is telescope drilled with specifications on its construction according to Table 2-2. The reference point of the borehole is the centre of top of casing (ToC), given as elevation in table below. The Swedish National coordinate system (RT90) is used in the x-y direction and RHB70 in the z-direction. Northing and Easting refer to the top of the boreholes at the ground surface. The borehole diameter in Table 2-2 refers to the final diameter of the drill bit after drilling to full depth.

Table 2-1. Performed injection tests at borehole KLX20A.

No. of injection tests	Interval	Positions	Time/test	Total test time
4	100 m	107.50–448.00 m	125 min	8.3 hrs
12	20 m	102.20–307.50 m	90 min	18.0 hrs
Total:		26.3 hrs		

* Excluding repeated tests.

Table 2-2. Information about KLX20A (from SICADA (2006-09-15)).

Title	Value				
Old idcode name(s):	KLX20A				
Comment:	No comment exists				
Borehole length (m):	457.920				
Reference level:	TOC				
Drilling period(s):	**From date**	**To date**	**Secup (m)**	**Seclow (m)**	**Drilling type**
	2006-02-22	2006-03-08	0.300	100.000	Percussion drilling
	2006-03-25	2006-04-24	99.910	457.920	Core drilling
Starting point coordinate:	**Length (m)**	**Northing (m)**	**Easting (m)**	**Elevation (m.a.s.l.)**	**Coord system**
(centerpoint of TOC)	0.000	6366334.571	1546604.889	27.242	RT90-RHB70
Angles:	**Length (m)**	**Bearing**	**Inclination (– = down)**		
	0.000	270.605	–49.813	RT90-RHB70	
Borehole diameter:	**Secup (m)**	**Seclow (m)**	**Hole diam (m)**		
	0.300	6.000	0.340		
	6.000	99.900	0.253		
	99.900	99.910	0.162		
	99.910	100.900	0.086		
	100.900	457.920	0.076		
Core diameter:	**Secup (m)**	**Seclow (m)**	**Core diam (m)**		
	99.910	100.400	0.072		
	100.400	457.920	0.050		
Casing diameter:	**Secup (m)**	**Seclow (m)**	**Case in (m)**	**Case out (m)**	
	0.000	99.470	0.200	0.208	
	0.300	6.000	0.310	0.323	
	99.470	99.500	0.170	0.208	
Cone dimensions:	**Secup (m)**	**Seclow (m)**	**Cone in (m)**	**Cone out (m)**	
	96.080	99.090	0.100	0.104	
	99.090	100.900	0.080	0.084	
Grove milling:	**Length (m)**	**Trace detectable**			
	110.000	YES			
	150.000	YES			
	200.000	YES			
	250.000	YES			
	300.000	YES			
	350.000	YES			
	400.000	YES			
	430.000	YES			

2.2 Injection tests

Injection tests were conducted according to the Activity Plan AP PS 400-06-112 and the method description for hydraulic injection tests, SKB MD 323.001 (SKB internal documents). Tests were done in 100 m test sections between 107.50–448.00 m below ToC and in 20 m test sections between 102.20–307.50 m below ToC (see Table 2-3). The initial criteria for performing injection tests in 20 m sections was a measurable flow of Q > 0.001 L/min in the previous measured 100 m tests covering the smaller test sections (see Figure 2-1). The measurements were performed with SKBs custom made equipment for hydraulic testing called PSS2.

Table 2-3. Tests performed.

Bh ID	Test section (m bToC)	Test type[1]	Test no	Test start Date, time	Test stop Date, time
KLX20A	107.50–207.50	3	1	061108 20:26:00	061108 23:06:00
KLX20A	207.50–307.50	3	1	061109 07:43:00	061109 09:37:00
KLX20A	307.50–407.50	4B	1	061109 11:20:00	061109 13:55:00
KLX20A	307.50–407.50	3	2	061109 23:16:00	061110 00:16:00
KLX20A	348.00–448.00	3	1	061109 14:54:00	061109 17:40:00
KLX20A	102.20–122.20	3	1	061110 19:13:00	061110 21:06:00
KLX20A	107.50–127.50	3	1	061110 21:58:00	061110 23:27:00
KLX20A	127.50–147.50	3	1	061111 00:09:00	061111 02:17:00
KLX20A	147.50–167.50	3	1	061111 06:37:00	061111 08:17:00
KLX20A	167.50–187.50	3	1	061111 08:50:00	061111 09:20:00
KLX20A	187.50–207.50	3	1	061111 11:05:00	061111 13:27:00
KLX20A	193.50–203.50	3	1	061111 13:59:00	061111 16:02:00
KLX20A	213.00–233.00	3	1	061111 16:40:00	061111 18:20:00
KLX20A	233.00–253.00	4B	1	061111 19:04:00	061111 20:30:00
KLX20A	253.00–273.00	3	1	061111 21:21:00	061111 22:46:00
KLX20A	273.00–293.00	3	1	061111 23:23:00	061112 00:49:00
KLX20A	287.50–307.50	3	1	061112 01:25:00	061112 03:43:00

1) 3: Injection test; 4B Pulse injection test.

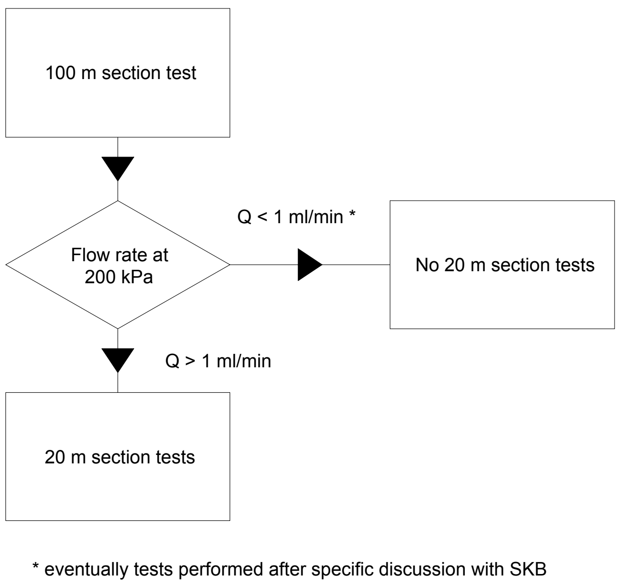

Figure 2-1. *Flow chart for test sections.*

No other additional measurements except the actual hydraulic tests and related measurements of packer position and water level in annulus of borehole KLX20A were conducted.

2.3 Control of equipment

Control of equipment was mainly performed according to the Quality plan. The basis for equipment handling is described in the "Mätssystembeskrivning" SKB MD 345.101-123 which is composed of two parts 1) management description, 2) drawings and technical documents of the modified PSS2 tool.

Function checks were performed before and during the tests. Among these pressure sensors were checked at ground level and while running in the hole calculated to the static head. Temperature was checked at ground level and while running in. Leakage checks at joints in the pipe string were done at least every 100 m of running in respectively prior to every test performance.

Any malfunction was recorded, and measures were taken accordingly for proper operation. Approval was made according to SKB site manager, or Quality plan and the "Mätssystembeskrivning".

3 Equipment

3.1 Description of equipment

The equipment called PSS2 (Pipe String System 2) is a highly integrated tool for testing boreholes at great depth (see conceptual drawing in the next figure). The system is built inside a container suitable for testing at any weather. Briefly, the components consists of a hydraulic rig, down-hole equipment including packers, pressure gauges, shut-in tool and level indicator, racks for pump, gauge carriers, breakpins, etc. shelfs and drawers for tools and spare parts.

There are three spools for a multi-signal cable, a test valve hose and a packer inflation hose. There is a water tank for injection purposes, pressure vessels for injection of packers, to open test valve and for low flow injection. The PSS2 has been upgraded with a computerized flow regulation system. The office part of the container consists of a computer, regulation valves for the nitrogen system, a 24 V back-up system in case of power shut-offs and a flow regulation board.

PSS2 is documented in photographs 1–6.

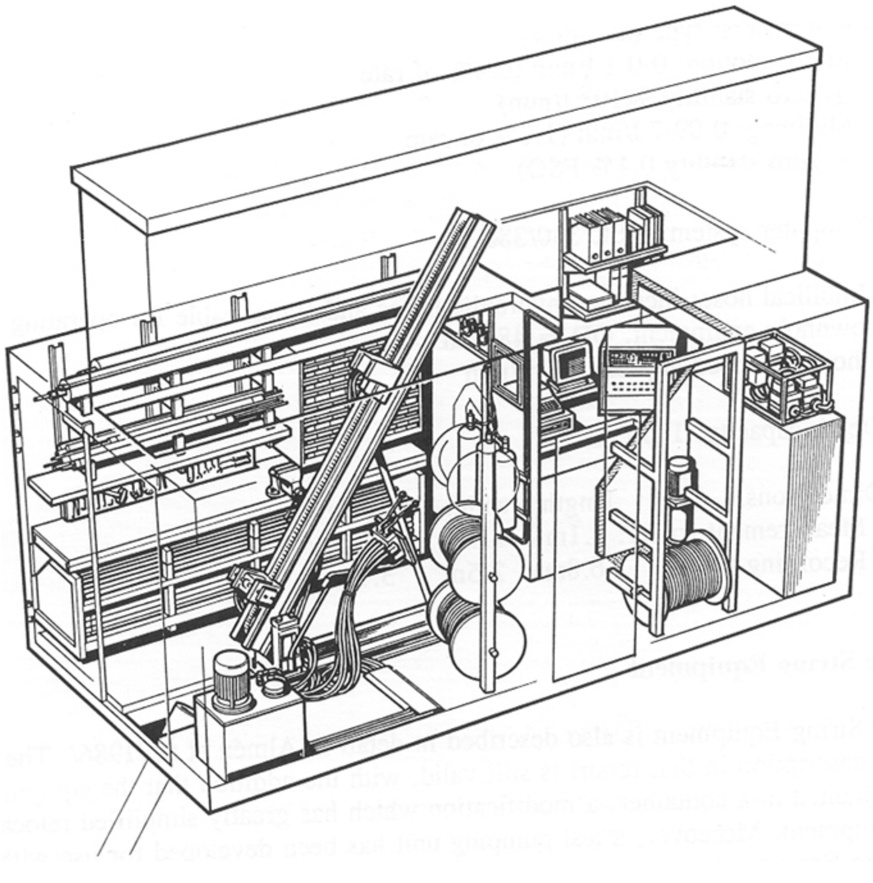

Figure 3-1. *A view of the layout and equipment of PSS2.*

Photo 1. *Hydraulic rig.*

Photo 2. *Rack for pump, down-hole equipment, workbench and drawers for tools.*

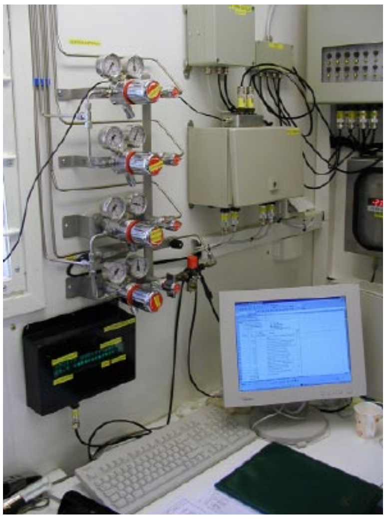

Photo 3. *Computer room, displays and gas regulators.*

Photo 4. *Pressure vessels for test valve, packers and injection.*

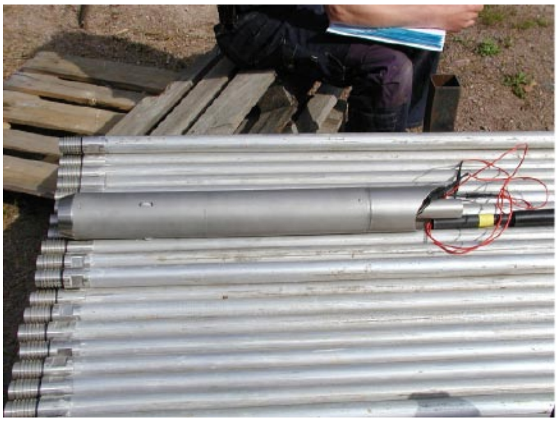

Photo 5. *Positioner, bottom end of down-in-hole string.*

Photo 6. *Packer and gauge carrier.*

The down-hole equipment consists from bottom to top of the following equipment:

- Level indicator – SS 630 mm pipe with OD 73 mm with 3 plastic wheels connected to a Hallswitch.
- Gauge carrier – SS 1.5 m carrying bottom section pressure transducer and connections from positioner.
- Lower packer – SS and PUR 1,5 m with OD 72 mm, stiff ends, tightening length 1,0 m, maximum pressure 6.5 MPa, working pressure 1.6 MPa.
- Gauge carrier with breakpin – SS 1.75 m carrying test section pressure transducer, temperature sensor and connections for sensors below. Breakpin with maximum load of 47.3 (± 1.0) kN. The gauge carrier is covered by split pipes and connected to a stone catcher on the top.
- Pop joint – SS 1.0 or 0.5 m with OD 33 mm and ID 21 mm, double O-ring fittings, trapezoid thread, friction loss of 3kPa/m at 50 L/min.
- Pipe string – SS 3.0 m with OD 33 mm and ID 21 mm, double O-ring fittings, trapezoid thread, friction loss of 3kPa/m at 50 L/min.
- Contact carrier – SS 1,0 m carrying connections for sensors below and
- Upper packer – SS and PUR 1.5 m with OD 72 mm, fixed ends, seal length 1.0 m, maximum pressure 6.5 MPa, working pressure 1.6 MPa.
- Breakpin – SS 250 mm with OD 33.7 mm. Maximum load of 47.3 (± 1.0) kN.
- Gauge carrier – SS 1.5 m carrying top section pressure transducer, connections from sensors below. Flow pipe is double bent at both ends to give room for sensor equipment. The pipe gauge carrier is covered by split pipes.
- Shut-in tool (test valve) – SS 1.0 m with a OD of 48 mm, Teflon coated valve piston, friction loss of 11 kPa at 10 L/min (260 kPa–50L/min). Working pressure 2.8–4.0 MPa. Breakpipe with maximum load of 47.3 (± 1.0) kN. The shut-in tool is covered by split pipes and connected to a stone catcher on the top.

The tool scheme is presented in Figure 3-2.

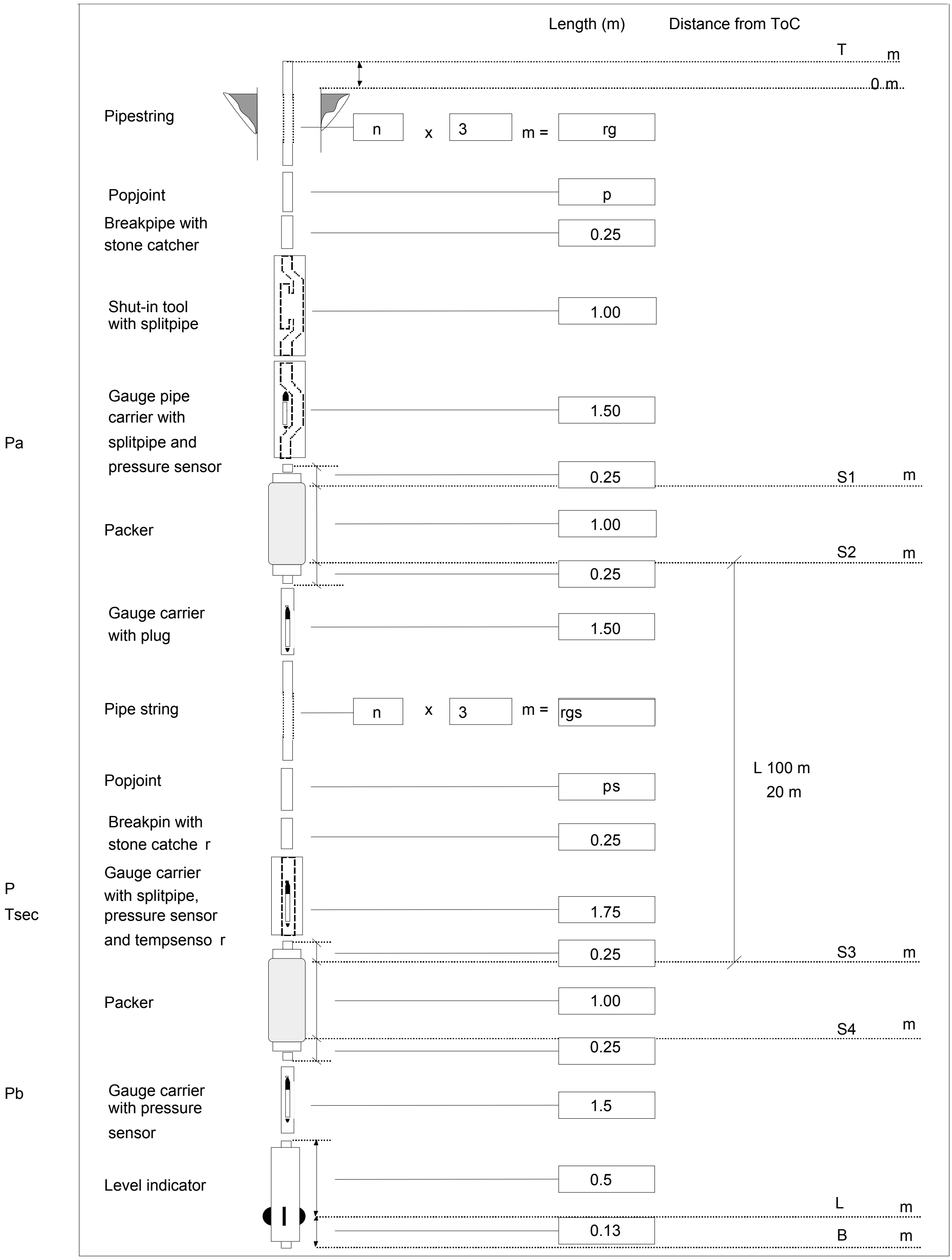

Figure 3-2. *Schematic drawing of the down-hole equipment in the PSS2 system.*

3.2 Sensors

Table 3-1. Technical specifications of sensors.

Keyword	Sensor	Name	Value/range	Unit	Comments
$P_{sec,a,b}$	Pressure	Druck PTX 162–1464abs	9–30 4–20 0–13,5 ±0,1	VDC mA MPa % of FS	
$T_{sec,surf,air}$	Temperature	BGI	18–24 4–20 0–32 ±0,1	VDC mA °C °C	
Q_{big}	Flow	Micro motion Elite sensor	0–100 ± 0,1	kg/min %	Massflow
Q_{small}	Flow	Micro motion Elite sensor	0–1,8 ± 0,1	kg/min %	Massflow
p_{air}	Pressure	Druck PTX 630	9–30 4–20 0–120 ±0,1	VDC mA KPa % of FS	
p_{pack}	Pressure	Druck PTX 630	9–30 4–20 0–4 ±0,1	VDC mA MPa % of FS	
$p_{in,out}$	Pressure	Druck PTX 1400	9–28 4–20 0–2,5 ±0,15	VDC mA MPa % of FS	
L	Level indicator				Length correction

Table 3-2. Sensor positions and wellbore storage (WBS) controlling factors.

Borehole information		Sensors		Equipment affecting WBS coefficient			
ID	Test section (m)	Type	Position (m fr ToC)	Position	Function	Outer diameter (mm)	Volume in test section (m³)
KLX20A	107.50–207.50	p_a p T p_b L	102.11 203.37 203.20 206.01 206.25	Test section	Signal cable Pump string Packer line	9.1 33 6	0.454
KLX20A	102.20–122.20	p_a p T p_b L	102.11 123.37 123.20 126.01 126.25	Test section	Signal cable Pump string Packer line	9.1 33 6	0.091

3.3 Data acquisition system

The data acquisition system in the PSS2 container contains a stationary PC with the software Orchestrator, pump- and injection test parameters such as pressure, temperature and flow are monitored and sensor data collected. A second laptop PC is connected to the stationary PC through a network containing evaluation software, Flowdim. While testing, data from previously tested section is converted with IPPlot and entered in Flowdim for evaluation.

The data acquisition system starts and stops the test automatically or can be disengaged for manual operation of magnetic and regulation valves within the injection/pumping system. The flow regulation board is used for differential pressure and valve settings prior testing and for monitoring valves during actual test. An outline of the data acquisition system is outlined in Figure 3-3.

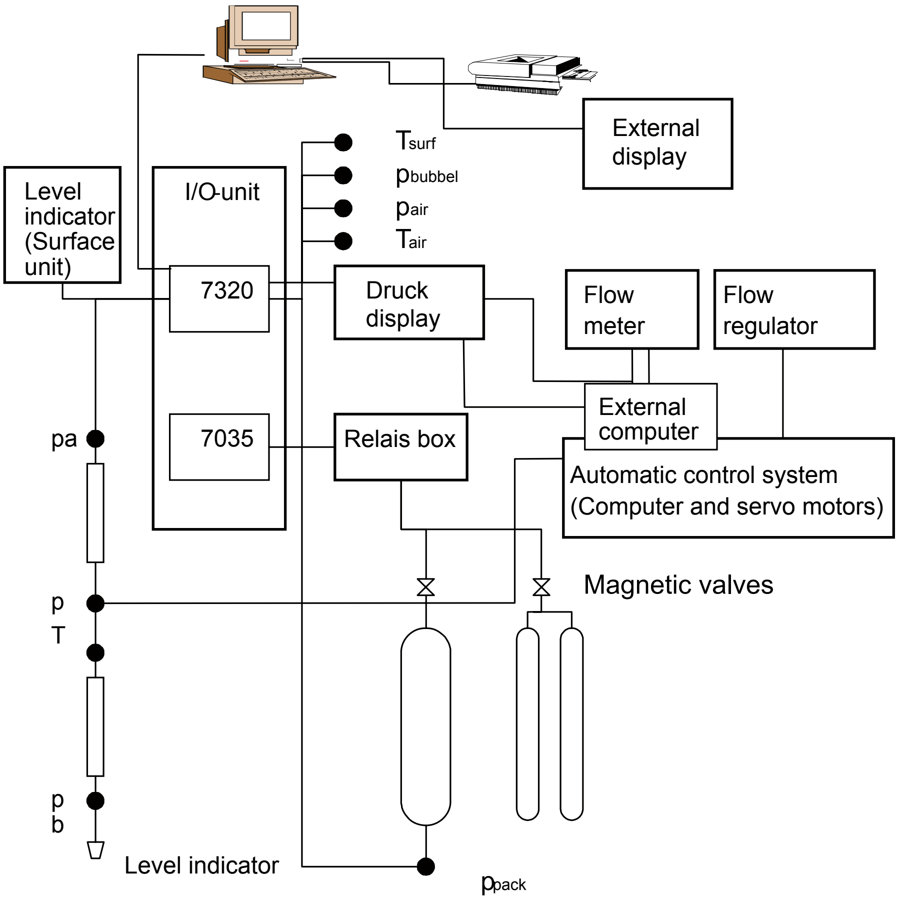

Figure 3-3. *Schematic drawing of the data acquisition system and the flow regulation control system in PSS2.*

4 Execution

4.1 Preparations

Following preparation work and functional checks were conducted prior to starting test activities:

- Place pallets and container, lifting rig up, installing fence on top of container, lifting tent on container.
- Clean and disinfect of Multikabel and hoses for packer and test valve. Clean the tubings with hot steam.
- Filling injection tank with water out of the borehole HLX14.
- Filling buffer tank with water and tracer it with Uranin; take water sample.
- Filling vessels.
- Filling the hoses for test valve and packer.
- Entering calibration constants to system and regulation unit.
- Synchronize clocks on all computers.
- Function check of shut-in tool both ends, overpressure by 900 kPa for 5 min (OK).
- Check pressure gauges against atmospheric pressure and than on test depth against column of water.
- Translate all protocols into English (where necessary).
- Filling packers with water and de-air.
- Measure and assemble test tool.

4.2 Length correction

By running in with the test tool, a level indicator is incorporated at the bottom of the tool. The level indicator is able to record groves milled into the borehole wall. The depths of these groves are given by SKB in the activity plan (s. Table 2-2) and the measured depth is counter checked against the number/length of the tubes build in. The achieved correction value, based on linear interpolation between the reference marks, is used to adjust the location of the packers for the test sections to avoid wrong placements and minimize elongation effects of the test string.

4.3 Execution of field work

4.3.1 Test principle

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a shut-in pressure recovery (CHir) was conducted. Regularly the CHi and CHir phases were analysed quantitatively, in cases of very low section transmissivity, the PI phase was analysed.

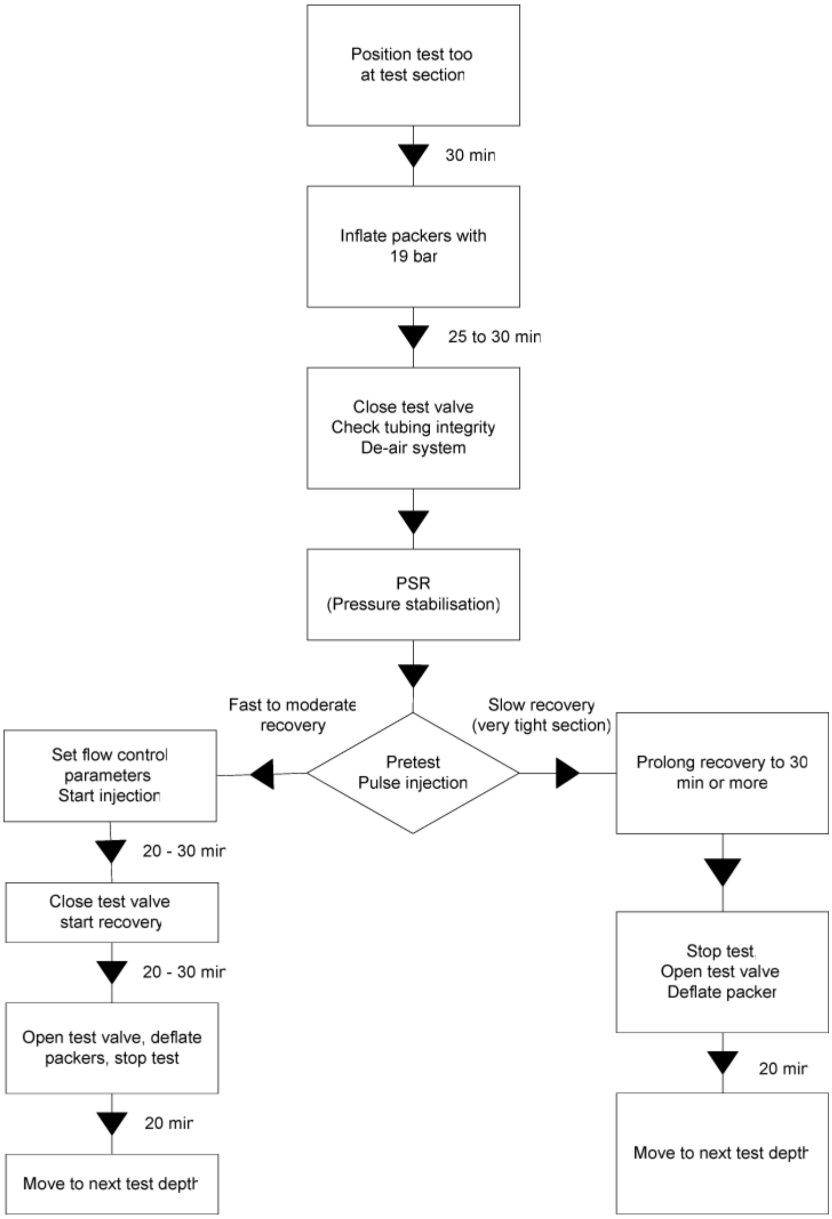

Figure 4-1. *Flow chart for test performance.*

4.3.2 Test procedure

A typical test cycle includes the following phases: 1) Transfer of down-hole equipment to the next section. 2) Packer inflation. 3) Pressure stabilisation. 4) Preliminary Pulse injection. 5) Constant head injection. 6) Pressure recovery. 7) Packer deflation.

The preliminary pulse injection (Step 4) derives the first estimations of the formation transmissivity. It is conducted by applying a pressure difference of approx. 200 kPa to the static formation pressure. If the pulse recovery indicates a very low transmissivity (flow probably below 1 ml/min) the pulse recovery is prolonged and no constant head injection test is performed. The decision to continue the pulse or to conduct an injection tests is based on the pressure response of the pulse recovery. A pressure recovery less than 50 % during the first ten minutes of the pulse indicates a low transmissivity. In such a case no injection test will be conducted.

The pressure static recovery (PSR) after packer inflation and before the pulse gives a direct measure of the magnitude of the packer compliance. A steep PSR indicates extremely low test section transmissivity. In such a case the packer compliance would influence the subsequent pulse test too much and introduce very large uncertainties. Therfore tests with this behaviour would be stopped after PSR phase.

If the preliminary pulse injection test indicates a formation transmissivity with a flow above 1 ml/min a constant head injection test (Step 5 and 6) is carried out. It is applied with a constant injection pressure of approx. 200 kPa (20 m water column) above the static formation pressure in the test section. Before start of the injection tests, approximately stable pressure conditions prevailed in the test section. After the injection period, the pressure recovery in the section is measured. In cases, where small flow rates were expected, the automatic regulation unit was switched off and the test was performed manually (determined by the preliminary pulse injection). In those cases, the constant difference pressure was usually unequal to 200 kPa.

In cases when the derived transmissivity of a test section influences the subsequent test program the constant head injection was conducted even if the preliminary pulse indicates a very tight section (e.g. flow below 1 ml/min). The injection phase is then performed to verify the results of the pulse.

The duration for each phase is presented in Table 4-1.

4.4 Data handling/post processing

The data handling followed several stages. The data acquisition software (Orchestrator) produced an ASCII raw data file (*.ht2) which contains the data in voltage and milliampere format plus calibration coefficients. The *.ht2 files were processed to *.dat files using the SKB program called IPPlot. These files contain the time, pressure, flow rate and temperature data. The *.dat files were synthesised in Excel to a *.xls file for plotting purposes. Finally, the test data to be delivered to SKB were exported from Excel in *.csv format. These files were also used for the subsequent analysis (field and final) of the injection phase (CHi). The synthesised data of the recovery phase (CHir) was used for the field analysis and to receive preliminary results for concistency reviews.

Table 4-1. Durations for packer inflation, pressure stabilisation, injection and recovery phase and packer deflation.

Step	Phase	Time
1	• Position test tool to new test section (correct position using the borehole markers)	Approx. 30 min.
2	• Inflate packers with appr. 1900 kPa	25 min.
3	• Close test valve	10 min.
	• Check tubing integrity with appr. 800 kPa	5 min.
	• De-air system	2 min.
4	• Pretest, pulse injection (duration depends on the formation transmissivity)	…
5*	• Set automatic flow control parameters or setting for manual test	5 min.
	• Start injection	20 to 45 min.
6*	• Close test valve, start recovery	20 min. or more
	• Open test valve	10 min.
7	• Deflate packers	25 min.
	• Move to next test depth	…

* Step 5 and 6 conducted if the preliminary pulse indicates a formation transmissivity with a sufficient flow.

4.5 Analyses and interpretations

4.5.1 Analysis software

The tests were analysed using a type curve matching method. The analysis was performed using Golder's test analysis program FlowDim. FlowDim is an interactive analysis environment allowing the user to interpret constant pressure, constant rate and slug/pulse tests in source as well as observation boreholes. The program allows the calculation of type-curves for homogeneous, dual porosity and composite flow models in variable flow geometries from linear to spherical.

4.5.2 Analysis approach

Constant pressure tests are analysed using a rate inverse approach. The method initially known as the /Jacob and Lohman 1952/ method was further improved for the use of type curve derivatives and for different flow models.

Constant pressure recovery tests are analysed using the method described by /Gringarten 1986/ and /Bourdet et al. 1989/ by using type curve derivatives calculated for different flow models.

Pulse tests are analysed by using the pressure deconvolution method described by /Peres et al. 1989/ with improvements introduced by /Chakabarty and Enachescu 1997/.

4.5.3 Analysis methodology

Each of the relevant test phases is subsequently analyzed using the following steps:

- **Injection Tests.**
  - Identification of the flow model by evaluation of the derivative on the log-log diagnostic plot. Initial estimates of the model parameters are obtained by conventional straight-line analysis.
  - Superposition type curve matching in log-log coordinates. A non-linear regression algorithm is used to provide optimized model parameters in the latter stages.
  - Non-linear regression in semi-log coordinates (superposition HORNER plot; /Horner 1951/). In this stage of the analysis, the static formation pressure is selected for regression.

The test analysis methodology is best explained in /Horne 1990/.

- **Pre-test for the Injection Tests.**

The test cycle always starts with a pulse injection phase with the aim of deriving a first estimation of the formation transmissivity. In cases when the pulse recovery is low (indicating low transmissivity) the pulse phase is extended and analysed as the main phase for the test.

The transmissivity derived from a pulse test is strongly influenced by the wellbore storage coefficient used as an input in the analysis. The wellbore storage coefficient is calculated as $C = dV/dP$ where dV is the volume difference injected during the brief flow period of the pulse and dP is the initial pressure difference of the pulse. dV is directly measured either by using the flowmeter readings or water level measurements in the injection vessel.

It should be noted though that there is large uncertainty connected with the determination of the wellbore storage coefficient (probably one order of magnitude), which will implicitly translate into uncertainty in the derived transmissivity. Figure 4-2 below show an example of a typical pressure versus time evolution for such a tight section.

- Flow model identification and type curve analysis in the deconvolution Peres Plot /Peres et al. 1989, Chakrabarty and Enachescu 1997/. A non-linear regression algorithm is used to provide optimized model parameters in the later stages. An example of type curves is presented in Figure 4-3.

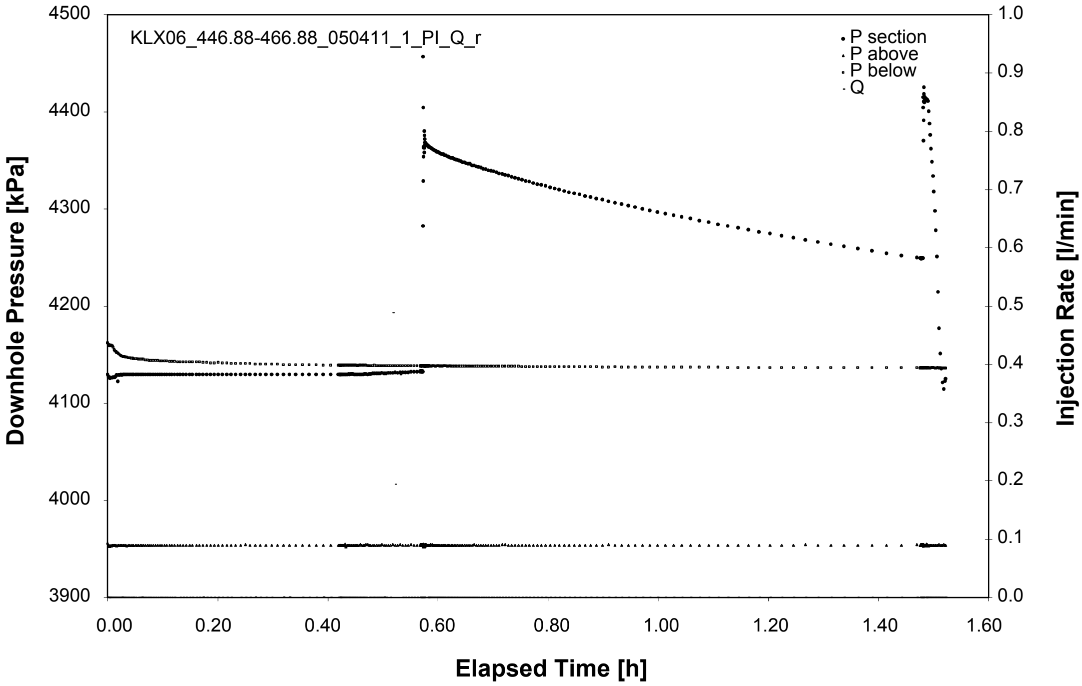

Figure 4-2. Typical pressure versus time plot of a Pulse injection test.

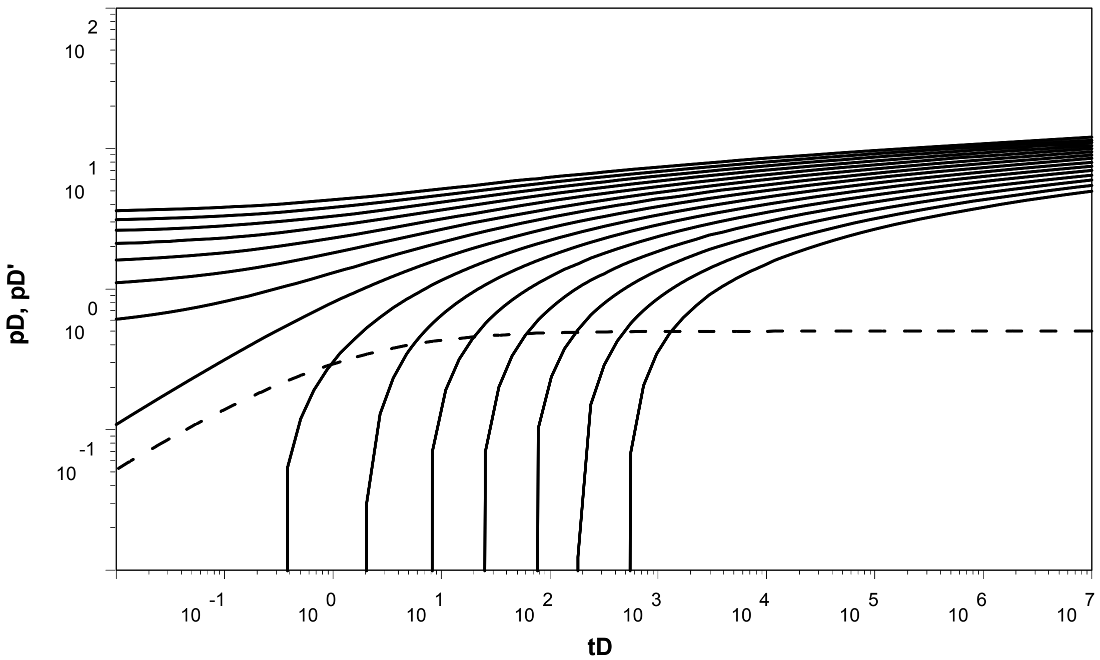

Figure 4-3. Deconvolution type curve set for pulse test analysis.

4.5.4 Correlation between storativity and skin factor

For the analysis of the conducted hydraulic tests below 100 m depth a storativity of $1 \cdot 10^{-6}$ is assumed (SKB MD 320.004e). Based on this assumption the skin will be calculated. In the following the correlation between storativity and skin for the relevant test phases will be explained in greater detail.

- **Injection phase (CHi)/Pulse tests (Pi)**

  Due to the fact that the early time data of the CHi and Pi phases, respectively, is not available or too noisy (attributed to the automatic regulation system) the storativity and the skin factor become correlated. Consequently they cannot be solved independently any more. In this case as a result of the analysis one determines the correlation group e^{2s}/S. This means that in such cases the skin factor can only be calculated when assuming the storativity as known.

- **Recovery phase (CHir)**

  The wellbore storage coefficient (C) is determined by matching the early time data with the corresponding type curve. The derived C-value is introduced in the equation of the type curve parameter:

$$(C_D e^{2s})_M = \frac{C \rho g}{2\pi r_w^2 S} e^{2s}$$

The equation above has two unknowns, the storativity (S) and the skin factor (s) which expresses the fact that for the case of constant rate and pressure recovery tests the storativity and the skin factor are 100% correlated. Therefore, the equation can only be either solved for skin by assuming that the storativity is known or solved for storativity by assuming the skin as known.

4.5.5 Determination of the ri-index and calculation of the radius of influence (ri)

The analysis provides also the radius of influence and the ri-index, which describes the late time behaviour of the derivative.

RI-Index

The determination of the ri-Index is based on the shape of the derivative plotted in log-log coordinates and describes the behaviour of the derivative after the time t_2, representing the end of the near wellbore response. The ri-index also describes the flow regime at the end of the test. Following ri-indices can be assigned:

- ri-index = 0: The middle and late time derivative shows a horizontal stabilization. This pressure response indicates that the size of the hydraulic feature is greater than the radius of influence. The calculated radius of influence is based on the entire test time t_P.
- ri-index = 1: The derivative shows an upward trend at late times, indicating a decrease of transmissivity or a barrier boundary at some distance from the borehole. The size of the hydraulic feature near the borehole is estimated as the radius of influence based on t_2.
- ri-index = –1: The derivative shows a downward trend at late times, indicating an increase of transmissivity or a constant head boundary at some distance from the borehole. The size of the hydraulic feature near the borehole is estimated as the radius of influence based on t_2.

Figure 4-4 presents the relationship between the shape of derivative and the ri-index.

If no radial flow stabilization can be observed the ri-index is based on the flow regime at the end of the test: i.e. ri-index = 1 for tests with a derivative showing an upward trend at the end and a ri-index= –1 for tests with a derivative showing a downward trend. In such cases the calculated radius of influence is based on the entire test time t_P.

The assignment of the ri-index is based on /Rhen 2005/.

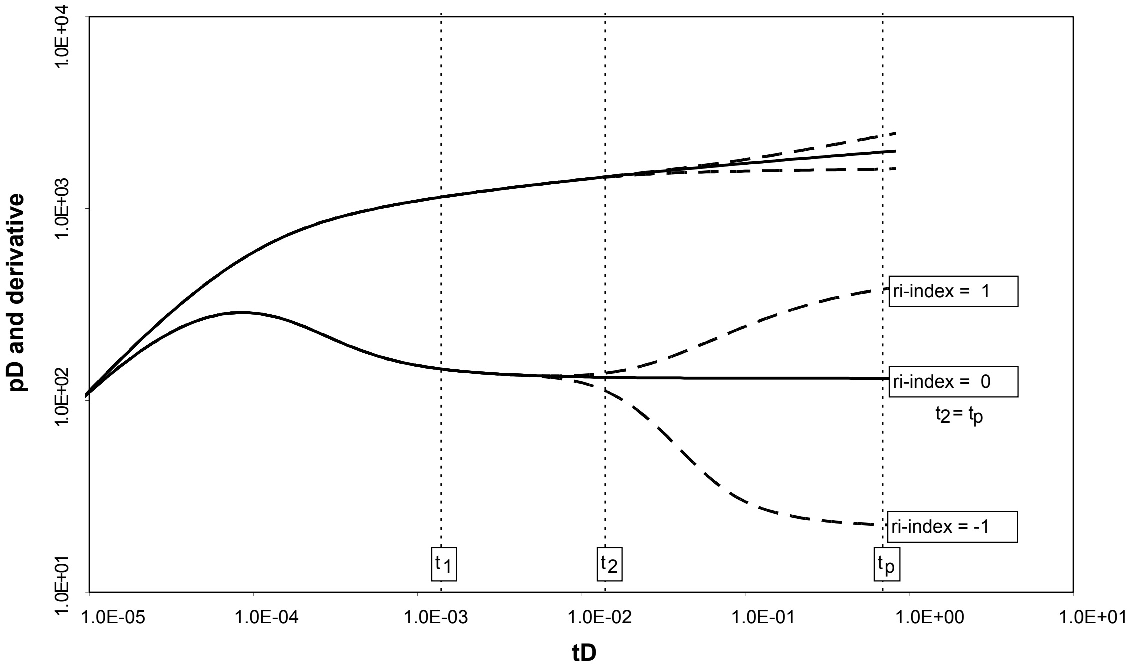

Figure 4-4. *Schematic plot of the assignments for the ri-indices.*

Calculation of the radius of influence

The radius of influence (ri) is calculated as follows:

$$ri = 1.89 * \sqrt{\frac{T_T}{S_T} * t_2} \;\; [\text{m}]$$

T_T recommended inner zone transmissivity [m²/s]

t_2 time when hydraulic formation properties changes (see previous chapter) [s]

S_T for the calculation of the ri the storage coefficient (S) is estimated from the transmissivity /Rhen 2005/:

$S_T = 0.007 * T_T^{0.5}$ [–]

4.5.6 Steady state analysis

In addition to the type curve analysis, an interpretation based on the assumption of stationary conditions was performed as described by /Moye 1967/.

4.5.7 Flow models used for analysis

The flow models used in analysis were derived from the shape of the pressure derivative calculated with respect to log time and plotted in log-log coordinates.

In several cases the pressure derivative suggests a change of transmissivity with the distance from the borehole. In such cases a composite flow model was used in the analysis.

If there were different flow models matching the data in comparable quality, the simplest model was preferred.

The flow dimension displayed by the test can be diagnosed from the slope of the pressure derivative. A slope of 0.5 indicates linear flow, a slope of 0 (horizontal derivative) indicates radial flow and a slope of –0.5 indicates spherical flow. The flow dimension diagnosis was commented for each of the tests. At tests where a flow regime could not clearly identified from the test data, we assume in general a radial flow regime as the most simple flow model available. The value of p* was then calculated according to this assumption.

In cases when the infinite acting radial flow (IARF) phase was not supported by the data the derivative was extrapolated using the most conservative assumption, which is that the derivative would stabilise short time after test end. In such cases the additional uncertainty was accounted for in the estimation of the transmissivity confidence ranges.

4.5.8 Calculation of the static formation pressure and equivalent freshwater head

The static formation pressure (p*) measured at transducer depth, was derived from the pressure recovery (CHir) following the constant pressure injection phase by using:

(1) straight line extrapolation in cases infinite acting radial flow (IARF) occurred,

(2) type curve extrapolation in cases infinite acting radial flow (IARF) is unclear or was not reached.

The equivalent freshwater head (expressed in meters above sea level) was calculated from the extrapolated static formation pressure (p*), corrected for athmospheric pressure measured by the surface gauge and corrected for the vertical depth considering the inclination of the drill hole, by assuming a water density of 1000 kg/m^3 (freshwater). The equivalent freshwater head is the static water level an individual test interval would show if isolated and connected to the surface by tubing full of freshwater. Figure 4-5 shows the methodology schematically.

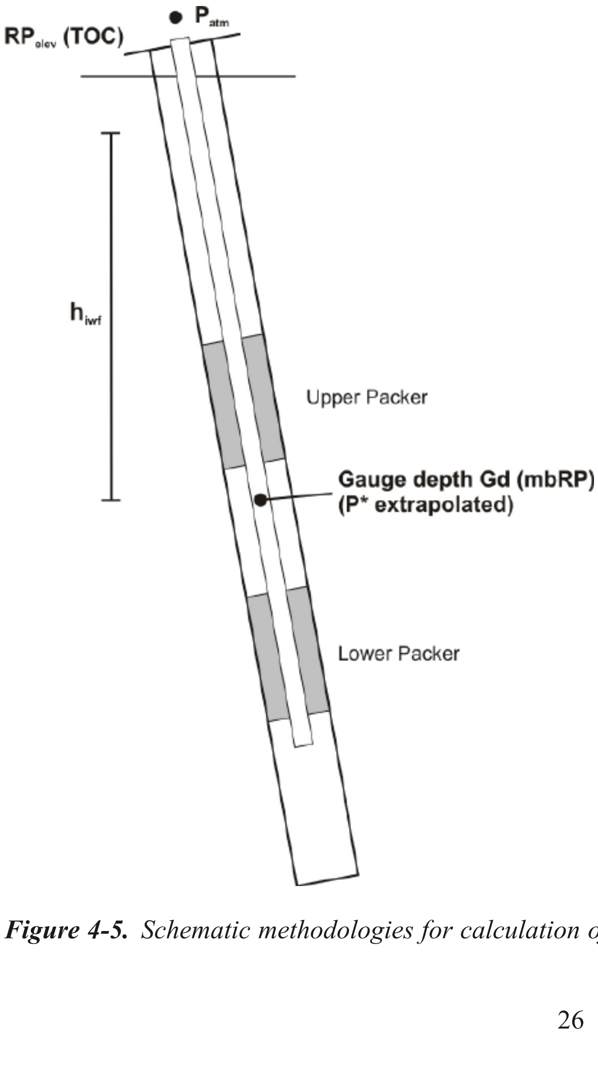

Figure 4-5. Schematic methodologies for calculation of the freshwater head.

The freshwater head in meters above sea level is calculated as following:

$$head = \frac{(p^* - p_{atm})}{\rho \cdot g}$$

which is the p* value expressed in a water column of freshwater.

With consideration of the elevation of the reference point (RP) and the gauge depth (Gd), the freshwater head h_{iwf} is:

$$h_{iwf} = RP_{elev} - Gd + \frac{(p^* - p_{atm})}{\rho \cdot g}.$$

4.5.9 Derivation of the recommended transmissivity and the confidence range

In most of the cases more than one analysis was conducted on a specific test. Typically both test phases were analysed (CHi and CHir) and in some cases the CHi or the CHir phase was analysed using two different flow models. The parameter sets (i.e. transmissivities) derived from the individual analyses of a specific test usually differ. In the case when the differences are small (which is typically the case) the recommended transmissivity value is chosen from the test phase that shows the best data and derivative quality.

In cases when the difference in results of the individual analyses was large (more than half order of magnitude) the test phases were compared and the phase showing the best derivative quality was selected.

The confidence range of the transmissivity was derived using expert judgement. Factors considered were the range of transmissivities derived from the individual analyses of the test as well as additional sources of uncertainty such as noise in the flow rate measurement, numeric effects in the calculation of the derivative or possible errors in the measurement of the wellbore storage coefficient. No statistical calculations were performed to derive the confidence range of transmissivity.

In cases when changing transmissivity with distance from the borehole (composite model) was diagnosted, the transmissivity of the zone, which was showing the better derivative quality, was recommended.

In cases when the infinite acting radial flow (IARF) phase was not supported by the data the additional uncertainty was accounted for in the estimation of the transmissivity confidence ranges.

4.6 Nonconformities

According to the inclination of the borehole of –49.8° and a designated operation range of the PSS tool of 55° to 90° borehole inclination, specific confirmation was given by SKB to perform the required tests in KLX20A. However, due to the PSS container geometry it was necessary to replace the container after lifting the hydraulic rig prior to start with injection tests to adjust the position above the borehole.

After finishing the 100 m section tests, a strong pressure decrease was observed while moving the tool upwards. To minimize the risk for the tool and the borehole it was decided not to run to the bottom end of the borehole with the 20 m sections again. Therefore, SKB approved to skip 20 m section tests for the depth range of 407.5 m–448 m.

5 Results

In the following, results of all tests are presented and analysed. Section 5.1 presents the 100 m tests, 5.2 the 20 m tests. The results are given as general comments to test performance, the identified flow regimes and calculated parameters and finally the parameters which are considered as most representative are chosen and justification is given. All results are also summarised in Table 6-1 and 6-2 of the Summary chapter. In addition, the results are presented in Appendices 3 and 5.

The results are stored in the primary data base (SICADA). The SICADA data base contains data that will be used for further interpretation (modelling). The data are traceable in SICADA by the Activity plan number (AP PS 400-06-112; SKB controlling document).

5.1 100 m single-hole injection tests

In the following, the 100 m section tests conducted in borehole KLX20A are presented and analysed.

5.1.1 Section 107.50–207.50 m, test no. 1, injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The pressure response and the recovery of the pulse test indicated a high formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a recovery phase (CHir) was conducted. Only the CHi and CHir phases were analysed quantitatively.

The CHi phase was conducted using a pressure difference of 200 kPa. No hydraulic connection to the adjacent zones was observed. The injection rate decreased from 16 L/min at start of the CHi phase to 8 L/min at the end, indicating a high interval transmissivity (consistent with the pulse recovery). Both phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the CHi phase shows a flat derivative, indicating radial flow. A homogeneous radial flow model was chosen for the analysis of the CHi phase. The derivative of the CHir phase shows a horizontal stabilization at middle and late times. A homogeneous radial flow model with wellbore storage and skin was chosen for the analysis. The analysis is presented in Appendix 2-1.

Selected representative parameters

The recommended transmissivity of $1.3 \cdot 10^{-5}$ m^2/s was derived from the analysis of the CHir phase, which shows the better data and derivative quality. The confidence range for the interval transmissivity is estimated to be $7.0 \cdot 10^{-6}$ m^2/s to $4.0 \cdot 10^{-5}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 1,508.0 kPa.

The analyses of the CHi and CHir phases show consistency. No further analysis is recommended.

5.1.2 Section 207.50–307.50 m, test no. 1, injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The pressure response and the recovery of the pulse test indicated a high formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a recovery phase (CHir) was conducted. Only the CHi and CHir phases were analysed quantitatively.

The CHi phase was conducted using a pressure difference of 197 kPa. No hydraulic connection to the adjacent zones was observed. The injection rate decreased from 6 L/min at start of the CHi phase to 4 L/min at the end, indicating a high interval transmissivity (consistent with the pulse recovery). Both phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the derivative of the CHi phase shows a horizontal stabilization at early times, followed by an upward trend at middle times and a kind of stabilization at late times. This behaviour is typical for a decrease of transmissivity at some distance from the borehole. The response of the CHir phase is consistent to the CHi phase. A two shell composite flow model was used for the analysis of both phases. The analysis is presented in Appendix 2-2.

Selected representative parameters

The recommended transmissivity of $4.0\cdot10^{-6}$ m^2/s was derived from the analysis of the CHi phase (inner zone), which shows the clearest flow stabilization. The confidence range for the interval transmissivity is estimated to be $1.0\cdot10^{-6}$ m^2/s to $8.0\cdot10^{-6}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 2,264.2 kPa.

The analyses of the CHi and CHir phases show consistency. No further analysis is recommended.

5.1.3 Section 307.50–407.50 m, test no. 1 and 2, pulse injection

Comments to test

The first test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The very slow recovery of the pulse test indicated a very low formation transmissivity. To verify the results of the pulse injection test, a second test was conducted in this section consisting of a constant head injection phase only. During this injection the flow rate dropped below the measurement limit (1 mL/min). Based on this result the constant head injection was skipped and only the pulse injection was analysed.

During the brief injection phase of the pulse injection a total volume of about 28 mL was injected (derived from the flow meter readings). This injected volume produced a pressure increase of 167 kPa. Using a dV/dP approach, the wellbore storage coefficient relevant for the subsequent pressure recovery can be calculated to $1.7\cdot10^{-10}$ m^3/Pa. It should be noted though that there is large uncertainty connected with the determination of the wellbore storage coefficient (probably one order of magnitude), which will implicitly translate into uncertainty in the derived transmissivity.

Flow regime and calculated parameters

For the interpretation a flow dimension of 2 (radial flow) was assumed. In case of the present test the deconvolved PI pressure derivative shows a continuing upward trend at middle times, which can be interpreted as a change of transmissivity away from the test section. The PI phase was analysed using a two shell composite flow model with decreasing transmissivity at some distance from the borehole. The analysis is presented in Appendix 2-3.

Selected representative parameters

The recommended transmissivity of $4.0 \cdot 10^{-11}$ m²/s was derived from the analysis of the Pi phase (outer zone). The confidence range for the interval transmissivity is estimated to be $1.0 \cdot 10^{-11}$ to $9.0 \cdot 10^{-11}$ m²/s. The flow dimension displayed during the test is 2. The static pressure could not be extrapolated due to the very low transmissivity.

No further analysis is recommended.

5.1.4 Section 348.00–448.00 m, test no. 1, injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The pressure response and the slow recovery of the pulse test indicated a low formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a recovery phase (CHir) was conducted. Only the CHi and CHir phases were analysed quantitatively.

The CHi phase was conducted using a pressure difference of 177 kPa. No hydraulic connection to the adjacent zones was observed. Due to the expected small injection rate, the CHi phase was conducted without the automatic regulation, directly from the injection vessel with N_2 backpressure. However, the pressure stayed stable during the injection phase. The injection rate decreased from 30 mL/min at start of the CHi phase to 3 mL/min at the end, indicating a low interval transmissivity (consistent with the pulse recovery). Both phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the derivative of the CHi phase shows an upward trend at middle times and a stabilization at late times, indicating a change of transmissivity at some distance from the borehole. A two shell composite flow model with decreasing transmissivity was chosen for the analysis of the CHi phase. The derivative of the CHir phase shows an upward trend at late times and a two shell composite flow model with wellbore storage and skin was chosen for the analysis. The analysis is presented in Appendix 2-4.

Selected representative parameters

The recommended transmissivity of $9.0 \cdot 10^{-10}$ m²/s was derived from the analysis of the CHi phase (outer zone), which shows the best data and derivative quality. The confidence range for the interval transmissivity is estimated to be $5.0 \cdot 10^{-10}$ m²/s to $5.0 \cdot 10^{-9}$ m²/s. The flow dimension displayed during the test is 2. The static pressure could not be extrapolated due to the low transmissivity.

The analyses of the CHi and CHir phases show consistency. No further analysis is recommended.

5.2 20 m single-hole injection tests

In the following, the 20 m section tests conducted in borehole KLX20A are presented and analysed.

5.2.1 Section 102.20–122.20 m, test no. 1, injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The pressure response and the fast recovery of the pulse test indicated a high formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a recovery phase (CHir) was conducted. Only the CHi and CHir phases were analysed quantitatively.

The CHi phase was conducted using a pressure difference of 221 kPa. No hydraulic connection to the adjacent zones was observed. The injection rate decreased from 8 L/min at start of the CHi phase to 5 L/min at the end, indicating a high interval transmissivity (consistent with the pulse recovery). Both phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the derivatives of the CHi and CHir phases show a downward trend at middle times followed by a horizontal stabilization at late times. This is typical for a change of transmissivity at some distance from the borehole and radial flow. A two shell composite flow model with increasing transmissivity was chosen for the analysis of both phases. The analysis is presented in Appendix 2-5.

Selected representative parameters

The recommended transmissivity of $4.2 \cdot 10^{-06}$ m^2/s was derived from the analysis of the CHir phase (outer zone), which shows the clearest flow stabilization. The confidence range for the interval transmissivity is estimated to be $1.0 \cdot 10^{-06}$ m^2/s to $8.0 \cdot 10^{-6}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 880.9 kPa.

The analyses of the CHi and CHir phases show consistency. No further analysis is recommended.

5.2.2 Section 107.50–127.50 m, test no. 1, injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The pressure response and the fast recovery of the pulse test indicated a high formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a recovery phase (CHir) was conducted. Only the CHi and CHir phases were analysed quantitatively.

The CHi phase was conducted using a pressure difference of 199 kPa. No hydraulic connection to the adjacent zones was observed. The injection rate decreased from 5 L/min at start of the CHi phase to 3 L/min at the end, indicating a high interval transmissivity (consistent with the pulse recovery). Both phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the derivative of the CHi phase shows a downward trend at middle times followed by a horizontal stabilization at late times. This is typical for a change of transmissivity at some distance from the borehole and radial flow. A two shell composite flow model with increasing transmissivity was used for the analysis of the CHi phase. The response of the CHir phase is similar to the response of the CHi phase and a two shell composite flow model with wellbore storage and skin was chosen for the analysis. The analysis is presented in Appendix 2-6.

Selected representative parameters

The recommended transmissivity of $3.6 \cdot 10^{-06}$ m^2/s was derived from the analysis of the CHir phase (outer zone), which shows a horizontal flow stabilization. The confidence range for the interval transmissivity is estimated to be $1.0 \cdot 10^{-06}$ m^2/s to $7.0 \cdot 10^{-6}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 923.5 kPa.

The analyses of the CHi and CHir phases show consistency. No further analysis is recommended.

5.2.3 Section 127.50–147.50 m, test no. 1, injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The pressure response and the recovery of the pulse test indicated a high formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a recovery phase (CHir) was conducted. Only the CHi and CHir phases were analysed quantitatively.

The CHi phase was conducted using a pressure difference of 210 kPa. No hydraulic connection to the adjacent zones was observed. The injection rate decreased from 7 L/min at start of the CHi phase to 5 L/min at the end, indicating a high interval transmissivity (consistent with the pulse recovery). Both phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the CHi phase shows a flat derivative, which is indicative for radial flow. A homogeneous radial flow model was chosen for the analysis of the CHi phase. The derivative of the CHir phase shows a slight horizontal stabilization at late times. The CHir phase was matched using a homogeneous radial flow model with wellbore storage and skin. The analysis is presented in Appendix 2-7.

Selected representative parameters

The recommended transmissivity of $5.3 \cdot 10^{-06}$ m^2/s was derived from the analysis of the CHi phase, which shows a clear horizontal flow stabilization. The confidence range for the interval transmissivity is estimated to be $3.0 \cdot 10^{-06}$ m^2/s to $8.0 \cdot 10^{-6}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 1,078.1 kPa.

The analyses of the CHi and CHir phases show consistency. No further analysis is recommended.

5.2.4 Section 147.50–167.50 m, test no. 1, injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The pressure response and the recovery of the pulse test indicated a low formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a recovery phase (CHir) was conducted. Only the CHi and CHir phases were analysed quantitatively.

The CHi phase was conducted using a pressure difference of 200 kPa. No hydraulic connection to the adjacent zones was observed. Due to the low flow rate the recorded data of the injection phase is very noisy. The injection rate decreased from approx. 4 mL/min at start of the CHi phase to 3 mL/min at the end, indicating a low interval transmissivity (consistent with the pulse recovery). The CHir phase shows no problems and is adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the CHi phase does not allow clear flow model identification. However, a homogeneous radial flow model was chosen for the analysis of the CHi phase. The derivative of the CHir phase shows a downward trend at late times. This indicates a transition form wellbore storage and skin dominated flow to pure formation flow. The CHir phase was matched using a two shell radial flow model with wellbore storage and skin. The analysis is presented in Appendix 2-8.

Selected representative parameters

The recommended transmissivity of $3.2 \cdot 10^{-09}$ m^2/s was derived from the analysis of the CHir phase (inner zone), which shows the better data and derivative quality. The confidence range for the interval transmissivity is estimated to be $9.0 \cdot 10^{-10}$ m^2/s to $5.0 \cdot 10^{-9}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure could not be extrapolated due to the low transmissivity.

The analyses of the CHi and CHir phases show some inconsistency as far as the chosen flow models concerned. This can be attributed to the poor data quality of the CHi phase. However, regarding the derived transmissivities both phases show consistency. No further analysis is recommended.

5.2.5 Section 167.50–187.50 m, test no. 1, injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The pressure response and the recovery of the pulse test indicated a medium formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a recovery phase (CHir) was conducted. Only the CHi and CHir phases were analysed quantitatively.

The CHi phase was conducted using a pressure difference of 195 kPa. No hydraulic connection to the adjacent zones was observed. The injection rate decreased from 137 mL/min at start of the CHi phase to 60 mL/min at the end, indicating a medium interval transmissivity (consistent with the pulse recovery). Both phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the derivative of the CHi phase shows an upward trend at middle times, followed by horizontal flow stabilization at late times. This response indicates a change in transmissivity at some distance from the borehole. The behaviour of the CHir derivative is similar. A two shell composite flow model was used for the analysis of the CHi and CHir phase. The analysis is presented in Appendix 2-9.

Selected representative parameters

The recommended transmissivity of $2.9 \cdot 10^{-08}$ m^2/s was derived from the analysis of the CHi phase (outer zone), which shows the clearest flow stabilization. The confidence range for the interval transmissivity is estimated to be $9.0 \cdot 10^{-09}$ m^2/s to $5.0 \cdot 10^{-8}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 1,361.7 kPa

The analyses of the CHi and CHir phases show consistency. No further analysis is recommended.

5.2.6 Section 187.50–207.50 m, test no. 1, injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The pressure response and the slow recovery of the pulse test indicated a low formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a recovery phase (CHir) was conducted. Only the CHi and CHir phases were analysed quantitatively.

The CHi phase was conducted using a pressure difference of 175 kPa. No hydraulic connection to the adjacent zones was observed. Due to the expected small injection rate, the CHi phase was conducted without the automatic regulation, directly from the injection vessel with N_2 backpressure. Because of this, the difference pressure dropped by approx. 3 kPa during the injection phase. The injection rate decreased from 10 mL/min at start of the CHi phase to 2 mL/min at the end, indicating a low interval transmissivity (consistent with the pulse recovery). Both phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the derivative of the CHi phase was matched using a homogeneous radial flow model. The derivative of the CHir phase shows a continuous upward trend and the response is still influenced by near wellbore effects like wellbore storage and skin. A homogeneous radial flow model with wellbore storage and skin was used for the analysis of the CHir phase. The analysis is presented in Appendix 2-10.

Selected representative parameters

The recommended transmissivity of $2.2 \cdot 10^{-10}$ m^2/s was derived from the analysis of the CHi phase, which shows the better data and derivative quality. The confidence range for the interval transmissivity is estimated to be $9.0 \cdot 10^{-11}$ m^2/s to $6.0 \cdot 10^{-10}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure could not be extrapolated due to the low transmissivity.

The analyses of the CHi and CHir phases show consistency. No further analysis is recommended.

5.2.7 Section 193.50–203.50 m, test no. 1, injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The pressure response and the slow recovery of the pulse test indicated a low formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a recovery phase (CHir) was conducted. Only the CHi and CHir phases were analysed quantitatively.

The CHi phase was conducted using a pressure difference of 178 kPa. No hydraulic connection to the adjacent zones was observed. Due to the expected small injection rate, the CHi phase was conducted without the automatic regulation, directly from the injection vessel with N_2 backpressure. Because of this, the difference pressure dropped by approx. 4 kPa during the injection phase. The injection rate decreased from 20 mL/min at start of the CHi phase to 4 mL/min at the end, indicating a low interval transmissivity (consistent with the pulse recovery). Both phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the derivative of the CHi phase was matched using a homogeneous radial flow model. The derivative of the CHir phase shows a continuous upward trend and the response is still influenced by near wellbore effects like wellbore storage and skin. A homogeneous radial flow model with wellbore storage and skin was used for the analysis of the CHir phase. The analysis is presented in Appendix 2-11.

Selected representative parameters

The recommended transmissivity of $1.1 \cdot 10^{-09}$ m^2/s was derived from the analysis of the CHi phase, which shows the better data and derivative quality. The confidence range for the interval transmissivity is estimated to be $6.0 \cdot 10^{-10}$ m^2/s to $5.0 \cdot 10^{-09}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure could not be extrapolated due to the low transmissivity.

The analyses of the CHi and CHir phases show consistency. No further analysis is recommended.

5.2.8 Section 213.00–233.00 m, test no. 1, injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The pressure response and the recovery of the pulse test indicated a medium formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a recovery phase (CHir) was conducted. Only the CHi and CHir phases were analysed quantitatively.

The CHi phase was conducted using a pressure difference of 226 kPa. No hydraulic connection to the adjacent zones was observed. The injection rate decreased from 100 mL/min at start of the CHi phase to 35 mL/min at the end, indicating a medium interval transmissivity (consistent with the pulse recovery). Both phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the CHi phase shows a flat derivative, indicating radial flow. A homogeneous radial flow model was used for the analysis of the CHi phase. The derivative of the CHir phase shows slight horizontal flow stabilization at late times. A homogeneous radial flow model with wellbore storage and skin was chosen for the analysis of the CHir phase. The analysis is presented in Appendix 2-12.

Selected representative parameters

The recommended transmissivity of $1.6 \cdot 10^{-08}$ m^2/s was derived from the analysis of the CHir phase, which shows the better data and derivative quality. The confidence range for the interval transmissivity is estimated to be $7.0 \cdot 10^{-09}$ m^2/s to $4.0 \cdot 10^{-8}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 1,705.4 kPa

The analyses of the CHi and CHir phases show consistency. No further analysis is recommended.

5.2.9 Section 233.00–253.00 m, test no. 1, pulse injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The very slow recovery of the pulse test indicated a very low formation transmissivity. Based on this result no constant pressure injection test was performed. Instead, the recovery of the pulse injection test was analysed.

During the brief injection phase of the pulse injection a total volume of about 7 mL was injected (derived from the flow meter readings). This injected volume produced a pressure increase of 161 kPa. Using a dV/dP approach, the wellbore storage coefficient relevant for the subsequent pressure recovery can be calculated to $7.1 \cdot 10^{-12}$ m^3/Pa. It should be noted though that there is large uncertainty connected with the determination of the wellbore storage coefficient (probably one order of magnitude), which will implicitly translate into uncertainty in the derived transmissivity.

Flow regime and calculated parameters

For the interpretation a flow dimension of 2 (radial flow) was assumed. In case of the present test the deconvolved PI pressure derivative shows an upward trend and middle and late times, indicating a decrease of transmissivity at some distance from the borehole. The PI phase was analysed using a two shell composite flow model. The analysis is presented in Appendix 2-13.

Selected representative parameters

The recommended transmissivity of $1.7 \cdot 10^{-11}$ m^2/s was derived from the analysis of the Pi phase (outer zone). The confidence range for the interval transmissivity is estimated to be $7.0 \cdot 10^{-12}$ to $4.0 \cdot 10^{-11}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure could not be extrapolated due to the very low transmissivity.

No further analysis is recommended.

5.2.10 Section 253.00–273.00 m, test no. 1, injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The pressure response and the recovery of the pulse test indicated a high formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a recovery phase (CHir) was conducted. Only the CHi and CHir phases were analysed quantitatively.

The CHi phase was conducted using a pressure difference of 198 kPa. The pressure in the section below increased during the injection phase by approx. 70 kPa, indicating a connection to the test section. The injection rate decreased from 8 L/min at start of the CHi phase to 4 L/min at the end, indicating a high interval transmissivity (consistent with the pulse recovery). Both phases show no problems and are adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the derivative of the CHi phase shows a horizontal stabilization at early times, followed by an upward trend at middle times and a kind of stabilization at late times. This behaviour is typical for a decrease of transmissivity at some distance from the borehole. The response of the CHir phase is consistent to the CHi phase. A two shell composite flow model was used for the analysis of both phases. The analysis is presented in Appendix 2-14.

Selected representative parameters

The recommended transmissivity of $3.4\cdot10^{-6}$ m^2/s was derived from the analysis of the CHi phase (inner zone), which shows the clearest flow stabilization. The confidence range for the interval transmissivity is estimated to be $9.0\cdot10^{-7}$ m^2/s to $7.0\cdot10^{-6}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 2,015.3 kPa.

The analyses of the CHi and CHir phases show consistency. No further analysis is recommended.

5.2.11 Section 273.00–293.00 m, test no. 1, injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The pressure response and the recovery of the pulse test indicated a medium formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a recovery phase (CHir) was conducted. Only the CHi and CHir phases were analysed quantitatively.

The CHi phase was conducted using a pressure difference of 201 kPa. No hydraulic connection to the adjacent zones was observed. The automatic regulation functioned well. However, the recorded pressure data are noisy. The injection rate decreased from 750 mL/min at start of the CHi phase to 680 mL/min at the end, indicating a medium interval transmissivity (consistent with the pulse recovery). The CHir phase recovered relatively fast, but is still adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the CHi phase shows a noisy but relative flat derivative. A homogeneous radial flow model was used for the analysis of the CHi phase. The derivative of the CHir phase shows a steep upward trend at middle times, which is consistent with a high positive skin, and horizontal flow stabilization at late times. A homogeneous radial flow model with wellbore storage and skin was chosen for the analysis of the CHir phase. The analysis is presented in Appendix 2-15.

Selected representative parameters

The recommended transmissivity of $2.5\cdot10^{-6}$ m^2/s was derived from the analysis of the CHir phase, which shows a flow stabilization at late times. The confidence range for the interval transmissivity is estimated to be $5.0\cdot10^{-7}$ m^2/s to $4.0\cdot10^{-6}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 2,159.9 kPa.

Apart from the high positive skin derived from the CHir phase, the analyses of both phases show consistency. No further analysis is recommended.

5.2.12 Section 287.50–307.50 m, test no. 1, injection

Comments to test

The test design consisted of a preliminary pulse injection test conducted with the goal of deriving a first estimate of the formation transmissivity. The pressure response and the recovery of the pulse test indicated a medium formation transmissivity. Based on this result a sequence consisting of a constant pressure injection phase (CHi) and a recovery phase (CHir) was conducted. Only the CHi and CHir phases were analysed quantitatively.

The CHi phase was conducted using a pressure difference of 200 kPa. No hydraulic connection to the adjacent zones was observed. The automatic regulation functioned well. However, the recorded flow and pressure data are very noisy. The injection rate decreased from 37 mL/min at start of the CHi phase to 35 mL/min at the end, indicating a medium interval transmissivity (consistent with the pulse recovery). The CHir phase shows a relatively fast recovery, but is still adequate for quantitative analysis.

Flow regime and calculated parameters

The flow dimension is interpreted from the slope of the semi-log derivative plotted in log-log coordinates. In case of the present test the derivative of the CHi phase does not allow flow model identification. However, a homogeneous radial flow model was used for the analysis of the CHi phase. The derivative of the CHir phase shows a steep upward trend at middle times, which is consistent with a high positive skin, and a kind of horizontal flow stabilization at late times. A homogeneous radial flow model with wellbore storage and skin was chosen for the analysis of the CHir phase. The analysis is presented in Appendix 2-16.

Selected representative parameters

The recommended transmissivity of $1.0 \cdot 10^{-7}$ m^2/s was derived from the analysis of the CHir phase, which shows the better data and derivative quality. The confidence range for the interval transmissivity is estimated to be $4.0 \cdot 10^{-8}$ m^2/s to $5.0 \cdot 10^{-7}$ m^2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 2,265.0 kPa.

The analyses of the CHi and CHir phases show some inconsistency regarding the derived transmissivities. This can be attributed to the poor data quality of the CHi phase. No further analysis is recommended.

6 Summary of results

This chapter summarizes the basic test parameters and analysis results. In addition, the correlation between steady state and transient transmissivities as well as between the matched and the theoretical wellbore storage (WBS) coefficient are presented and discussed.

6.1 General test data and results

Table 6-1. General test data from hydraulic tests in KLX20A (for nomenclature see Appendix 4 and below).

Borehole secup (m)	Borehole seclow (m)	Date and time for test, start YYYYMMDD hh:mm	Date and time for test, stop YYYYMMDD hh:mm	Q_p (m**3/s)	Q_m (m**3/s)	t_p (s)	t_F (s)	p_0 (kPa)	p_i (kPa)	p_p (kPa)	p_F (kPa)	Te_w (°C)	Test phases measured Analysed test phases marked bold
107.50	207.50	20061108 20:26	20061108 23:06	1.38E–04	1.49E–04	1,800	3,600	1,511	1,509	1,709	1,511	9.3	CHi/CHir
207.50	307.50	20061109 07:43	20061109 09:37	6.17E–05	7.17E–05	1,800	1,800	2,258	2,256	2,453	2,279	10.3	CHi/CHir
307.50	407.50	20061109 11:20	20061109 13:55	#NV	#NV	10	4,860	2,973	2,988	3,155	3,108	11.3	Pi
348.00	448.00	20061109 14:54	20061109 17:40	4.17E–08	7.67E–08	1,800	1,800	3,241	3,248	3,425	3,349	11.7	CHi/CHir
102.20	122.20	20061110 19:13	20061110 21:06	8.50E–05	9.03E–05	1,200	2,400	885	884	1,105	887	8.4	CHi/CHir
107.50	127.50	20061110 21:58	20061110 23:27	4.83E–05	5.20E–05	1,200	1,200	928	928	1,127	932	8.4	CHi/CHir
127.50	147.50	20061111 00:09	20061111 02:17	8.08E–05	8.68E–05	1,200	3,600	1,080	1,080	1,290	1,080	8.7	CHi/CHir
147.50	167.50	20061111 06:37	20061111 08:17	4.50E–08	4.67E–08	1,200	1,200	1,231	1,225	1,425	1,230	8.9	CHi/CHir
167.50	187.50	20061111 08:50	20061111 09:20	1.00E–06	1.27E–06	1,200	1,800	1,380	1,377	1,572	1,397	9.1	CHi/CHir
187.50	207.50	20061111 11:05	20061111 13:27	2.67E–08	4.33E–08	1,200	2,400	1,528	1,534	1,709	1,613	9.3	CHi/CHir
193.50	213.50	20061111 13:59	20061111 16:02	6.67E–08	1.00E–07	1,200	1,200	1,570	1,574	1,752	1,638	9.3	CHi/CHir
213.00	233.00	20061111 16:40	20061111 18:20	5.83E–07	6.67E–07	1,200	1,200	1,716	1,716	1,942	1,741	9.5	CHi/CHir
233.00	253.00	20061111 19:04	20061111 20:30	#NV	#NV	10	2,400	1,865	1,902	2,063	2,007	9.7	Pi
253.00	273.00	20061111 21:21	20061111 22:46	6.20E–05	7.10E–05	1,200	1,200	2,013	2,008	2,206	2,028	9.9	CHi/CHir
273.00	293.00	20061111 23:23	20061112 00:49	1.13E–05	1.16E–05	1,200	1,200	2,164	2,161	2,362	2,161	10.1	CHi/CHir
287.50	307.50	20061112 01:25	20061112 03:43	5.83E–07	6.33E–07	1,800	3,600	2,269	2,266	2,466	2,265	10.3	CHi/CHir

Nomenclature.

Q_p	Flow in test section immediately before stop of flow [m³/s]
Q_m	Arithmetical mean flow during perturbation phase [m³/s]
t_p	Duration of perturbation phase [s]
t_f	Duration of recovery phase [s]
p_0	Pressure in borehole before packer inflation [kPa]
p_i	Pressure in test section before start of flowing [kPa]
p_p	Pressure in test section before stop of flowing [kPa]
p_F	Pressure in test section at the end of the recovery [kPa]
Te_w	Temperature in test section
TEST PHASES	CHI: CONSTANT HEAD INJECTION PHASE
	CHir: Recovery phase following the constant head injection phase
	Pi: Pulse injection phase
#NV	not analysed/no values

Table 6-2. Results from analysis of hydraulic tests in KLX20A (for nomenclature see Appendix 4 and below).

Interval position		Stationary flow parameters		Transient analysis Flow regime		Formation parameters											Static conditions	
up m btoc	low m btoc	Q/s m^2/s	T_M m^2/s	Perturb. Phase	Recovery Phase	T_{f1} m^2/s	T_{f2} m^2/s	T_{s1} m^2/s	T_{s2} m^2/s	T_T m^2/s	T_{TMIN} m^2/s	T_{TMAX} m^2/s	C m^3/Pa	ξ –	dt_1 min	dt_2 min	p* kPa	h_{wif} masl
107.50	207.50	6.76E–06	8.80E–06	2	WBS2	8.8E–06	#NV	1.3E–05	#NV	1.3E–05	7.0E–06	4.0E–05	9.6E–09	2.3	2.05	20.76	1508.0	12.67
207.50	307.50	3.07E–06	4.00E–06	22	WBS22	4.0E–06	2.0E–06	8.7E–06	3.1E–06	4.0E–06	1.0E–06	8.0E–06	1.4E–09	–0.9	0.42	2.18	2264.2	14.88
307.50	407.50	#NV	#NV	#NV	22	#NV	#NV	3.4E–09	4.0E–11	4.0E–11	1.0E–11	9.0E–11	1.7E–10	–1.5	#NV	#NV	#NV	#NV
348.00	448.00	2.31E–09	3.01E–09	22	WBS22	2.6E–09	9.0E–10	2.7E–09	6.9E–10	9.0E–10	5.0E–10	5.0E–09	2.3E–10	–1.9	4.98	27.12	#NV	#NV
102.20	122.20	3.77E–06	3.95E–06	22	WBS22	3.7E–06	5.3E–06	3.5E–06	4.2E–06	4.2E–06	1.0E–06	8.0E–06	3.9E–09	–1.9	3.42	17.84	880.9	13.29
107.50	127.50	2.38E–06	2.49E–06	22	WBS22	2.8E–06	4.3E–06	1.6E–06	3.6E–06	3.6E–06	1.0E–06	7.0E–06	1.1E–09	–2.4	3.35	18.78	923.5	13.56
127.50	147.50	3.78E–06	3.95E–06	2	WBS2	5.3E–06	#NV	9.6E–06	#NV	5.3E–06	3.0E–06	8.0E–06	6.6E–09	1.3	0.64	12.42	1078.1	14.02
147.50	167.50	2.21E–09	2.31E–09	2	WBS22	2.7E–09	#NV	3.2E–09	4.01E–09	3.2E–09	9.0E–10	5.0E–09	7.7E–11	7.4	#NV	#NV	#NV	#NV
167.50	187.50	5.03E–08	5.26E–08	22	WBS22	1.2E–07	2.9E–08	3.2E–08	1.4E–08	2.9E–08	9.0E–09	5.0E–08	1.9E–10	3.4	5.83	16.44	1361.7	12.75
187.50	207.50	1.49E–09	1.56E–09	2	WBS2	2.2E–10	#NV	1.4E–10	#NV	2.2E–10	9.0E–11	6.0E–10	1.3E–10	–2.8	#NV	#NV	#NV	#NV
193.50	213.50	3.67E–09	3.84E–09	2	WBS2	1.1E–09	#NV	9.0E–10	#NV	1.1E–09	6.0E–10	5.0E–09	2.4E–10	–2.5	7.44	17.40	#NV	#NV
213.00	233.00	2.53E–08	2.65E–08	2	WBS2	2.0E–08	#NV	1.6E–08	#NV	1.6E–08	7.0E–09	4.0E–08	2.3E–10	–1.6	13.08	19.74	1705.4	13.67
233.00	253.00	#NV	#NV	#NV	22	#NV	#NV	1.7E–11	6.0E–13	1.7E–11	7.0E–12	4.0E–11	7.1E–12	0.3	0.20	1.22	#NV	#NV
253.00	273.00	3.07E–06	3.21E–06	22	WBS22	3.4E–06	1.8E–06	7.8E–06	3.3E–06	3.4E–06	9.0E–07	7.0E–06	7.8E–10	–2.6	0.67	2.08	2015.3	15.19
273.00	293.00	5.53E–07	5.79E–07	2	WBS2	1.4E–06	#NV	2.5E–06	#NV	2.5E–06	5.0E–07	4.0E–06	1.8E–10	20.4	0.60	10.38	2159.9	14.99
287.50	307.50	2.86E–08	2.99E–08	2	WBS2	3.0E–08	#NV	1.0E–07	#NV	1.0E–07	4.0E–08	5.0E–07	5.7E–11	15.2	2.52	12.72	2265.0	14.96

Nomenclature.

Q/s	Specific capacity
T_M	Transmissivity according to Moye (1967)
Flow regime	The flow regime description refers to the recommended model used in the transient analysis. WBS denotes wellbore storage and skin and is followed by a set of numbers describing the flow dimension used in the analysis (1 = linear flow, 2 = radial flow, 3 = spherical flow). If only one number is used (e.g. WBS2 or 2) a homogeneous flow model (1 composite zone) was used in the analysis, if two numbers are given (WBS22 or 22) a 2 zones composite model was used.
T_f	Transmissivity derived from the analysis of the perturbation phase (CHi). In case a homogeneous flow model was used only one T_f value is reported, in case a two zone composite flow model was used both T_{f1} (inner zone) and T_{f2} (outer zone) are given.
T_s	Transmissivity derived from the analysis of the recovery phase (CHir or Pi). In case a homogeneous flow model was used only one T_s value is reported, in case a two zone composite flow model was used both T_{s1} (inner zone) and T_{s2} (outer zone) are given.
T_T	Recommended transmissivity
T_{TMIN}	Confidence range lower limit
T_{TMAX}	Confidence range upper limit
C	Wellbore storage coefficient
ξ	Skin factor (calculated based on a Storativity of $1 \cdot 10^{-6}$)
dt_1	Estimated start time of evaluation
dt_2	Estimated stop time of evaluation
p*	The parameter p* denoted the static formation pressure (measured at transducer depth) and was derived from the HORNER plot of the CHir phase using straight line or type-curve extrapolation
h_{wif}	Fresh-water head (based on transducer depth and p*)
#NV	Not analysed/no values

Table 6-3. Results from the ri-index calculation of hydraulic tests in KLX20A (see Section 4.5.5 for details and nomenclature).

Borehole secup (m)	Borehole seclow (m)	Recommended transmissivity T_T (m²/s)	Time t_2 for radius of influence calculation (s)	ri - index (–)	Radius of Influence (m)
107.50	207.50	1.3E–05	3,600	0	254.85
207.50	307.50	4.0E–06	131	1	36.50
307.50	407.50	4.0E–11	4,860	1	12.53
348.00	448.00	9.0E–10	1,800	1	16.59
102.20	122.20	4.2E–06	2,400	–1	158.22
107.50	127.50	3.6E–06	1,200	–1	107.79
127.50	147.50	5.3E–06	1,200	0	118.56
147.50	167.50	3.2E–09	#NV	–1	#NV
167.50	187.50	2.9E–08	1,200	1	32.17
187.50	207.50	2.2E–10	1,200	0	9.56
193.50	213.50	1.1E–09	1,200	0	14.12
213.00	233.00	1.6E–08	1,200	0	27.74
233.00	253.00	1.7E–11	73	1	1.24
253.00	273.00	3.4E–06	125	1	34.23
273.00	293.00	2.5E–06	1,200	0	98.79
287.50	307.50	1.0E–07	3,600	0	76.22

The Figures 6-1 to 6-3 present the transmissivity, conductivity and hydraulic freshwater head profiles.

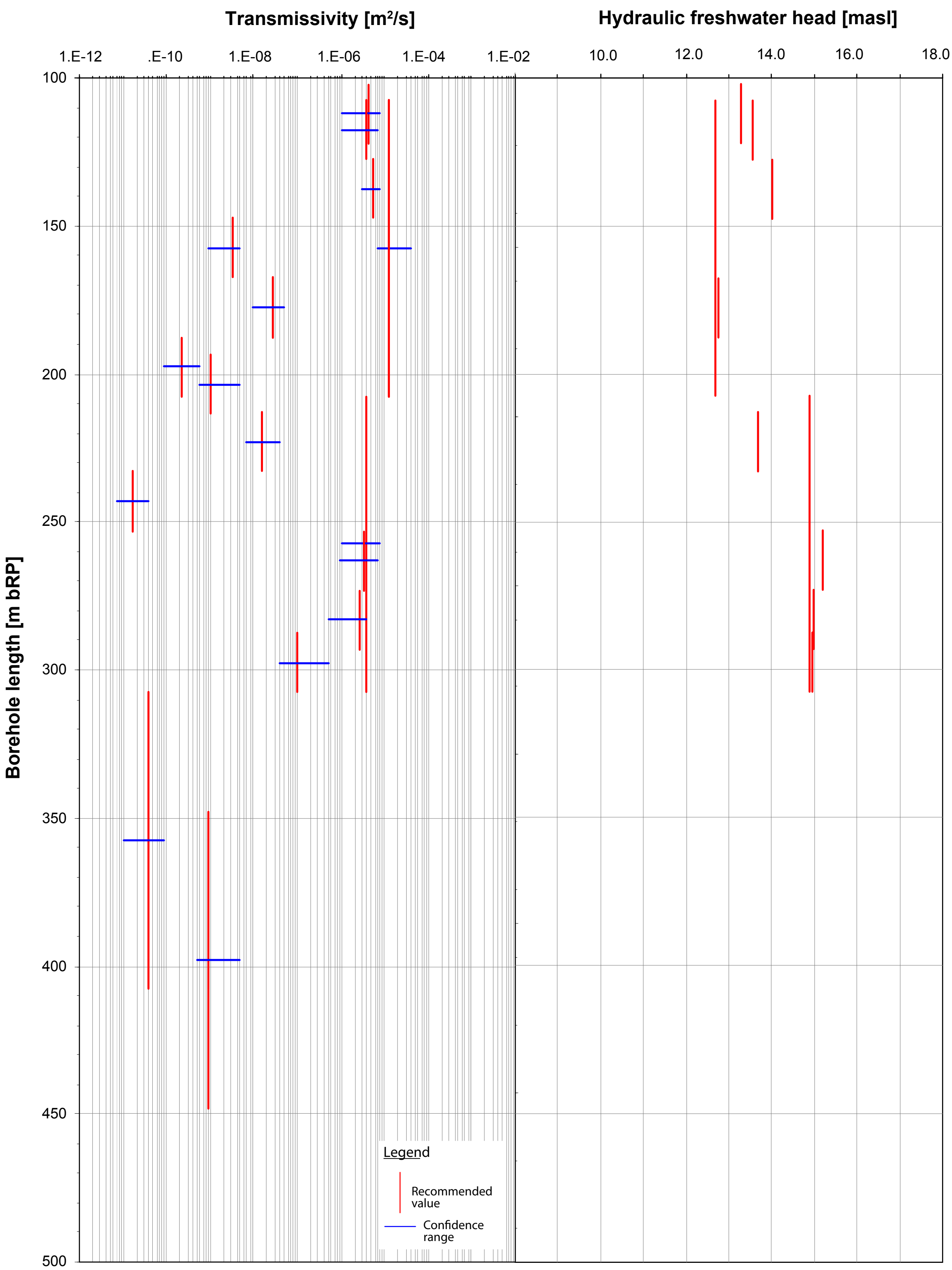

Figure 6-1. Results summary – profiles of transmissivity and equivalent freshwater head, transmissivities derived from injection tests, freshwater head extrapolated.

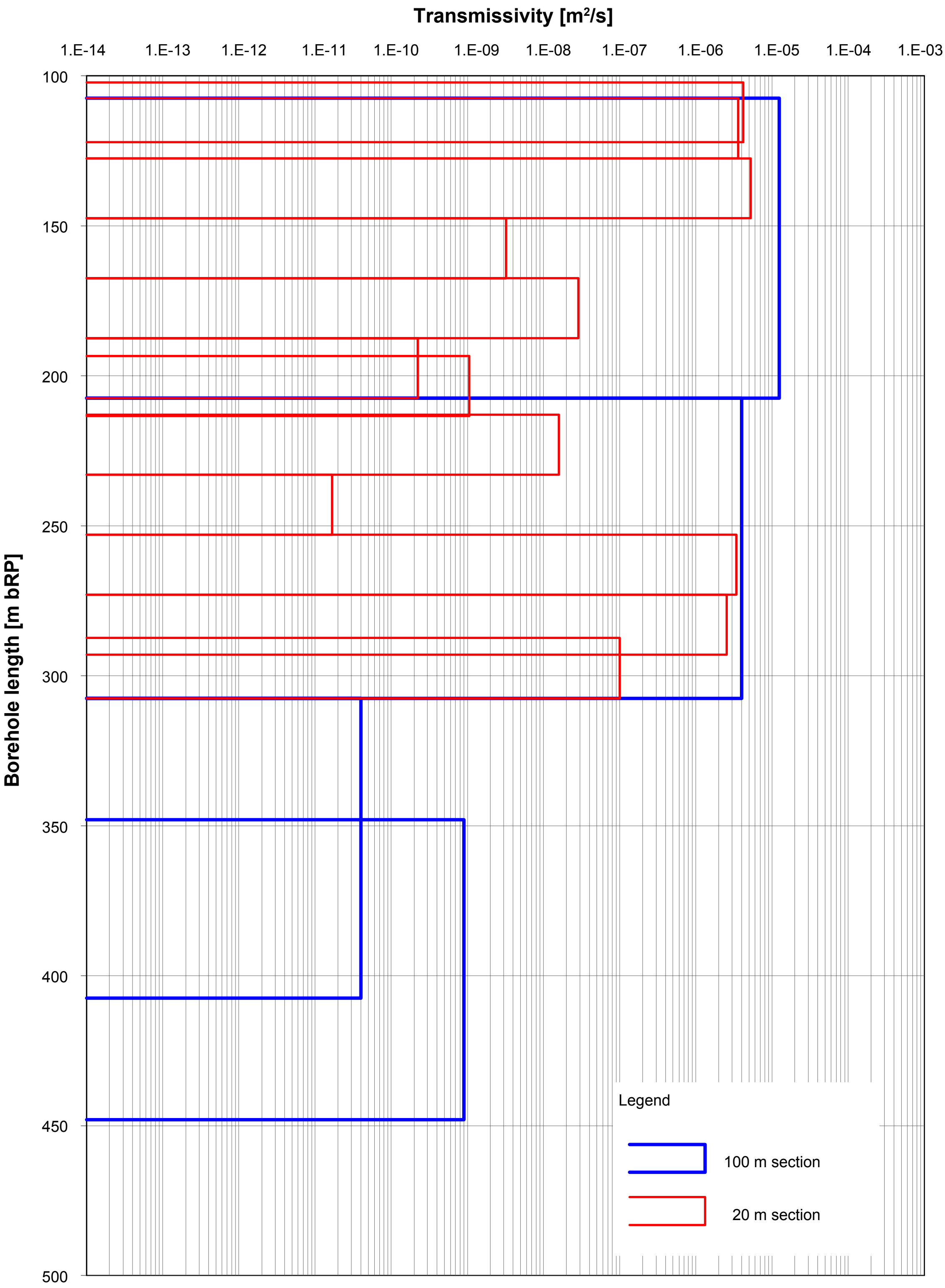

Figure 6-2. Results summary – profile of transmissivity.

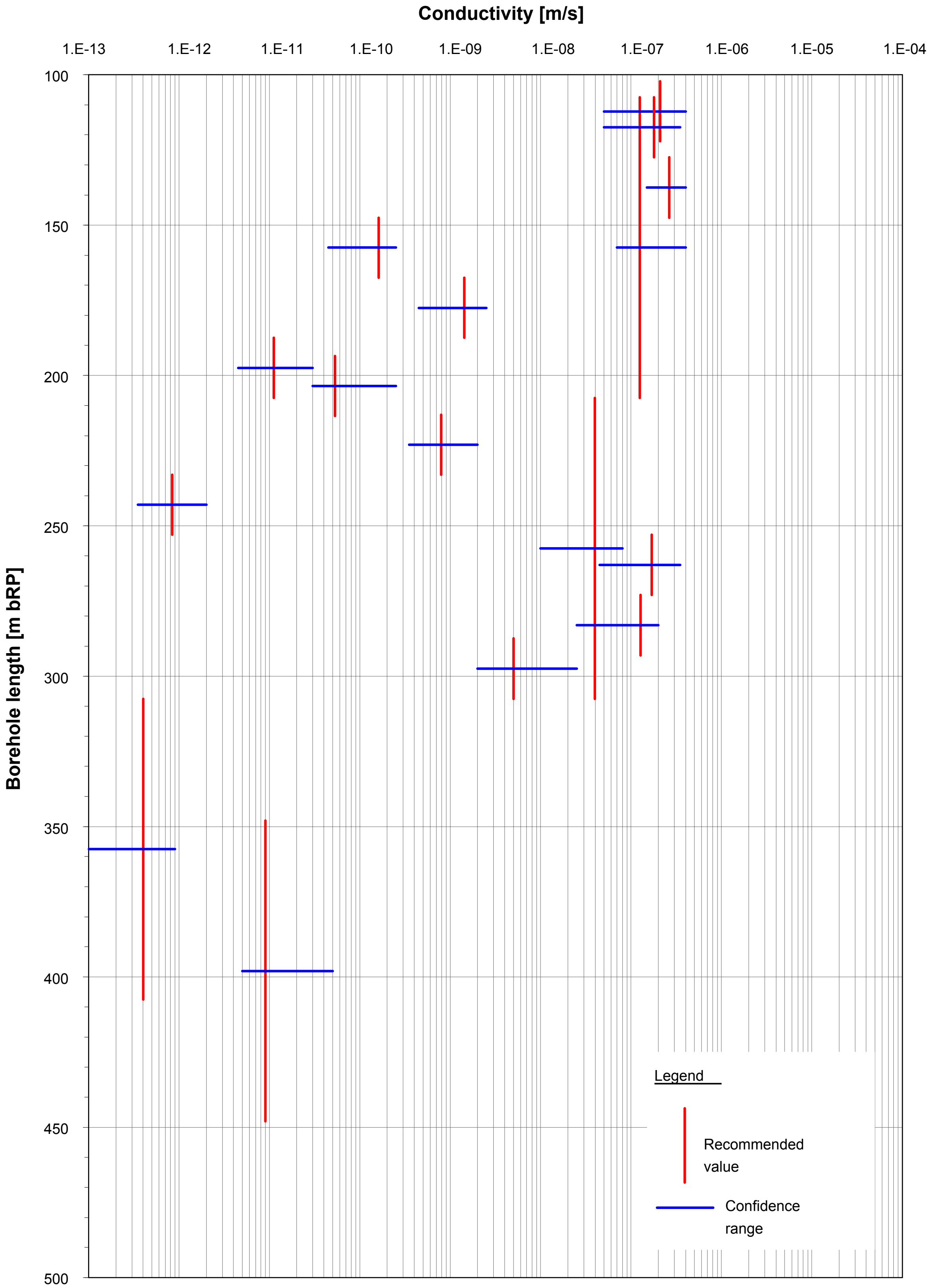

Figure 6-3. Results summary – profile of hydraulic conductivity.

6.2 Correlation analysis

A correlation analysis was used with the aim of examining the consistency of results and deriving general conclusion regarding the testing and analysis methods used.

6.2.1 Comparison of steady state and transient analysis results

The steady state derived transmissivities (T_M) and specific capacities (Q/s) were compared in a cross-plot with the recommended transmissivity values derived from the transient analysis (see Figure 6-4).

The correlation analysis shows that the transmissivities derived from the steady state analysis differ by less than one order of magnitude from the transmissivities derived from the transient analysis.

6.2.2 Comparison between the matched and theoretical wellbore storage coefficient

The wellbore storage coefficient describes the capacity of the test interval to store fluid as result to an unit pressure change in the interval. For a closed system (i.e. closed downhole valve) the theoretical value of the wellbore storage coefficient is given by the product between the interval volume and the test zone compressibility. The interval volume is calculated from the borehole radius and interval length. There are uncertainties concerning the interval volume calculation. Cavities or high transmissivity fractures intersecting the interval may enlarge the effective volume of the interval.

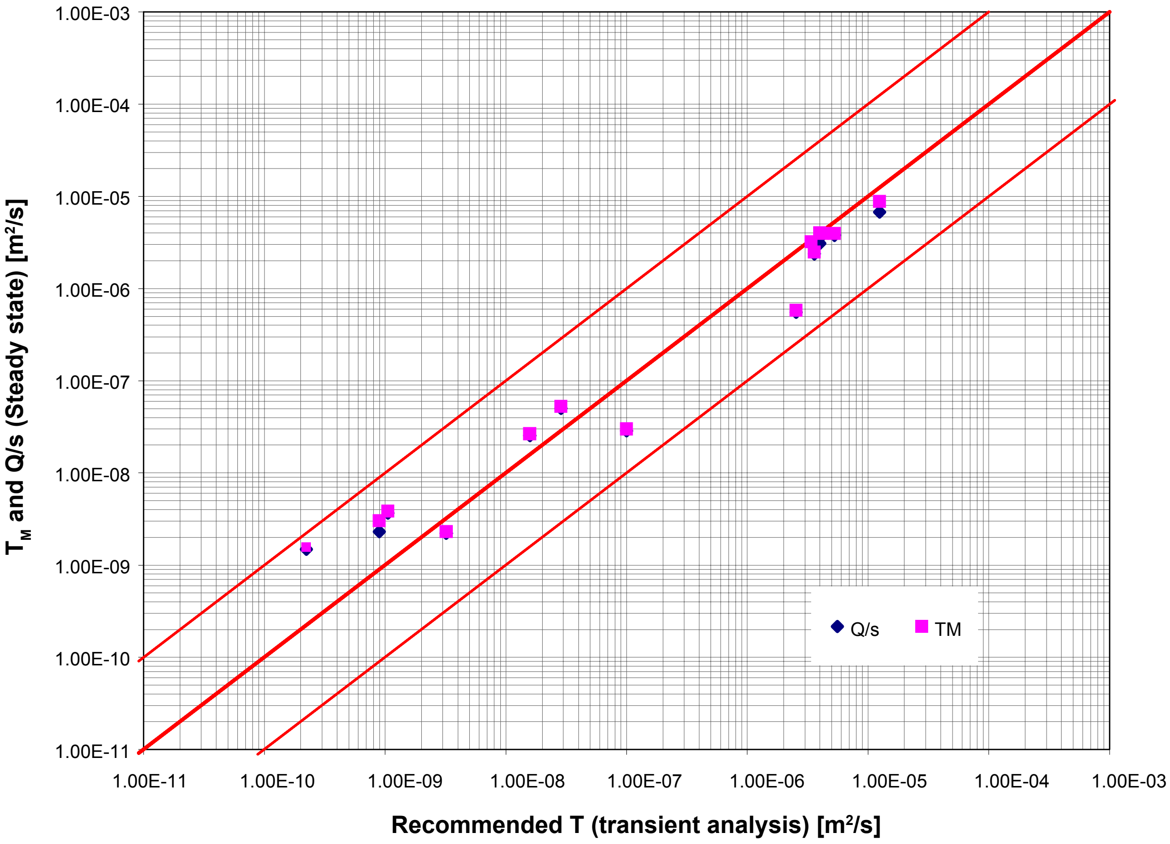

Figure 6-4. *Correlation analysis of transmissivities derived by steady state and transient methods.*

The test zone compressibility is given by the sum of compressibilities of the individual components present in the interval (water, packer elements, other test tool components, and the borehole wall). The water compressibility depends on the temperature and salinity. However, for temperature and salinity values as encountered at the Oskarshamn site the water compressibility varies only slightly between $4.5 \cdot 10^{-10}$ and $5.0 \cdot 10^{-10}$ 1/Pa.

A water compressibility of $5 \cdot 10^{-10}$ 1/Pa and a rock compressibility of $1 \cdot 10^{-10}$ 1/Pa was assumed for the analysis. In addition, the test zone compressibility is influenced by the test tool (packer compliance). The test tool compressibility was calculated as follow:

$$c = \frac{\Delta V}{\Delta p} * \frac{1}{V} \quad [1/\text{Pa}]$$

ΔV Volume change of 2 Packers (The volume change was estimated at $7 \cdot 10^{-7}$ m³/100 kPa based on the results of laboratory tests conducted by GEOSIGMA) [m³]

Δp Pressure change in test section (usually $2 \cdot 10^{5}$ Pa) [Pa]

V Volume in test section [m³]

The following table (see Table 6-4) presents the calculated compressibilities for each relevant section length. The average value for the test tool compressibility based on different section length is $5 \cdot 10^{-11}$ 1/Pa.

The sum of the compressibilities (water, rock, test tool) leads to a test zone compressibility with a value of $7 \cdot 10^{-10}$ 1/Pa. This value is used for the calculation of the theoretical wellbore storage coefficient.

The matched wellbore storage coefficient is derived from the transient type curve analysis by matching the unit slope early times derivative plotted in log-log coordinates.

The following figure (Figure 6-5) presents a cross-plot of the matched and theoretical wellbore storage coefficients.

It can be seen that the matched wellbore storage coefficients differ up to two orders of magnitude from the theoretical. This phenomenon was already observed at the previous boreholes. A two or three orders of magnitude increase is difficult to explain by volume uncertainty. Even if large fractures are connected to the interval, a volume increase by two orders of magnitude does not seem probable. This discrepancy is not fully understood, but following hypotheses may be formulated:

- increased compressibility of the packer system,
- as shown by previous work conducted at site, the phenomenon of increased wellbore storage coefficients can be explained by turbulent flow induced by the test in the vicinity of the borehole. Considering the fact that deviations concerning the wellbore storage rather occur in test sections with a higher transmissivity (which can lead to turbulent flow) seems to rest upon this hypothesis.

Table 6-4. Test tool compressibility values based on packer displacement.

Length of test section [m]	Volume in test section [m³]	Compressibility [1/Pa]
20	0.091	$8 \cdot 10^{-11}$
100	0.454	$2 \cdot 10^{-11}$
Average compressibility:		$5 \cdot 10^{-11}$

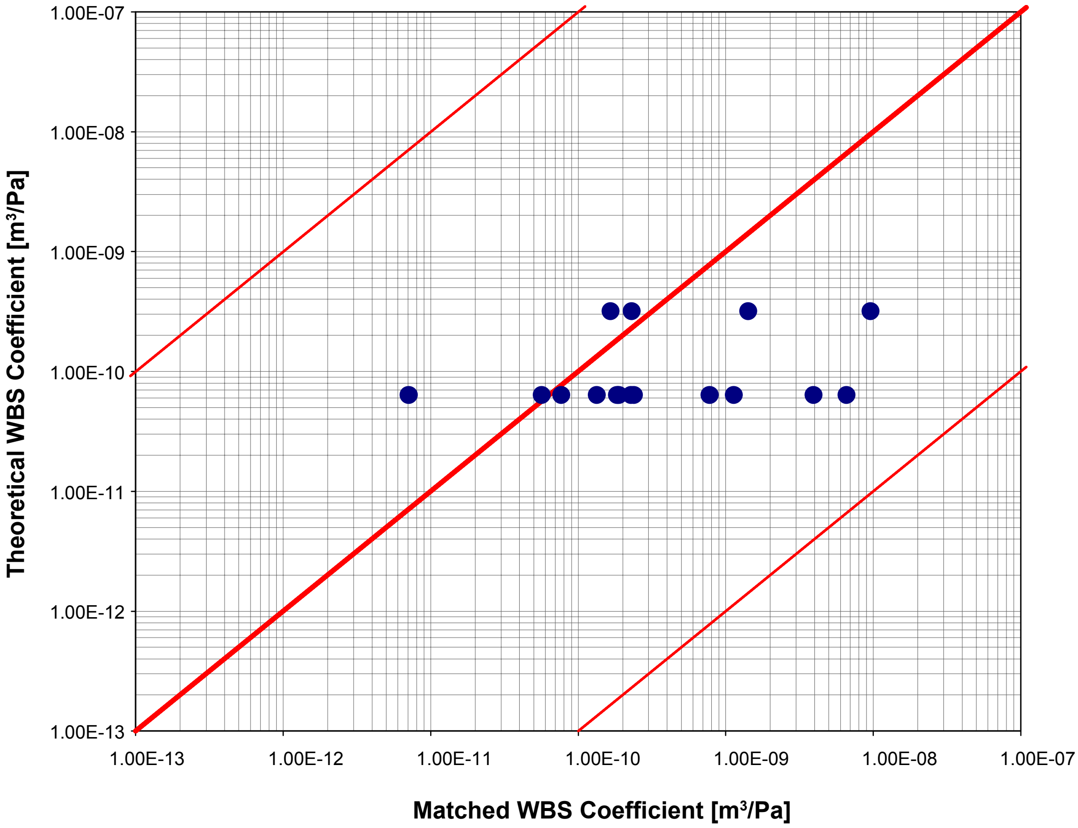

Figure 6-5. *Correlation analysis of theoretical and matched wellbore storage coefficients.*

7 Conclusions

7.1 Transmissivity

Figure 6-1 presents a profile of transmissivity, including the confidence ranges derived from the transient analysis. The method used for deriving the recommended transmissivity and its confidence range is described in Section 4.5.9.

Whenever possible, the transmissivities derived are representative for the “undisturbed formation” further away from the borehole. The borehole vicinity was typically described by using a skin effect.

If the conducted preliminary pulse injection (PI) showed a slow recovery the pulse test was prolonged and no further injection test was performed. The pulse test was used for a quantitative analysis. In two cases the preliminary pulse was prolonged and the recommended transmissivity is $1.7 \cdot 10^{-11}$ m²/s and $4.0 \cdot 10^{-11}$ m²/s, respectively.

The recommended transmissivities derived from the conducted injection tests (CHi and CHir) range between $2.2 \cdot 10^{-10}$ m²/s and $1.3 \cdot 10^{-05}$ m²/s.

All of the 20 m sections show smaller transmissivities than the appropriate longer interval what is the normal expected situation. Therefore, no crossflow or connections to adjacent zones happened by performing the tests.

7.2 Equivalent freshwater head

Figure 6-1 presents a profile of the derived equivalent freshwater head expressed in meters above sea level. The method used for deriving the equivalent freshwater head is described in Section 4.5.8.

The head profile shows the freshwater head ranges from 12.7 m to 15.2 m. Between 300 m and 450 m no fresh water head was derived, because of the low transmissivity.

The uncertainty related to the derived freshwater heads is dependent on the test section transmissivity. Due to the relatively short pressure recovery phase, the static pressure extrapolation becomes increasingly uncertain at lower transmissivities.

7.3 Flow regimes encountered

The flow models used in analysis were derived from the shape of the pressure derivative calculated with respect to log time and plotted in log-log coordinates.

In several cases the pressure derivative suggests a change of transmissivity with the distance from the borehole. In such cases a composite flow model was used in the analysis.

If there were different flow models matching the data in comparable quality, the simplest model was preferred.

In some cases very large skins has been observed. This is unusual and should be further examined. There are several possible explanations to this behaviour:

- If the behaviour is to be completely attributed to changes of transmissivity in the formation, this indicates the presence of larger transmissivity zones in the borehole vicinity, which could be caused by steep fractures that do not intersect the test interval, but are connected to the interval by lower transmissivity fractures. The fact that in many cases the test derivatives of adjacent test sections converge at late times seems to support this hypothesis.
- A further possibility is that the large skins are caused by turbulent flow taking place in the tool or in fractures connected to the test interval. This hypothesis is more difficult to examine. However, considering the fact that some high skins were observed in sections with transmissivities as low as $1 \cdot 10^{-8}$ m^2/s (which imply low flow rates) seems to speak against this hypothesis.

The flow dimension displayed by the test can be diagnosed from the slope of the pressure derivative. A slope of 0.5 indicates linear flow, a slope of 0 (horizontal derivative) indicates radial flow and a slope of –0.5 indicates spherical flow. The flow dimension diagnosis was commented for each of the tests. In all of the cases it was possible to get a good match quality by using radial flow geometry. In no cases an alternative analysis with a flow dimension unequal to two was performed.

8 References

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APPENDIX 1

File Description Table

HYDROTESTING WITH PSS					DRILLHOLE IDENTIFICATION NO.: KLX20A				
TEST- AND FILEPROTOCOL					Testorder dated : 2006-11-07				
Teststart		Interval boundaries		Name of Datafiles		Testtype	Copied to disk/CD	Plotted (date)	Sign.
Date	Time	Upper	Lower	(*.HT2-file)	(*.CSV-file)				
2006-11-08	20:26	107.50	207.50	__KLX20A_0107.50_200611082026.ht2	KLX20A_107.50-207.50_061108_1_CHir_Q_r.csv	Chir	2006-11-14	2006-11-08	
2006-11-09	07:43	207.50	307.50	__KLX20A_0207.50_200611090743.ht2	KLX20A_207.50-307.50_061109_1_CHir_Q_r.csv	Chir	2006-11-14	2006-11-09	
2006-11-09	11:20	307.50	407.50	__KLX20A_0307.50_200611091120.ht2	KLX20A_307.50-407.50_061109_1_Pi_Q_r.csv	Pi	2006-11-14	2006-11-09	
2006-11-09	14:54	348.00	448.00	__KLX20A_0348.00_200611091454.ht2	KLX20A_348.00-448.00_061109_1_CHir_Q_r.csv	CHir	2006-11-14	2006-11-09	
2006-11-09	23:16	307.50	407.50	__KLX20A_0307.50_200611092316.ht2	KLX20A_307.50-407.50_061109_2_CHir_Q_r.csv	CHir	2006-11-14	2006-11-09	
2006-11-10	19:13	102.20	122.20	__KLX20A_0102.20_200611101913.ht2	KLX20A_102.20-122.20_061110_1_CHir_Q_r.csv	CHir	2006-11-14	2006-11-10	
2006-11-10	21:58	107.50	127.50	__KLX20A_0107.50_200611102158.ht2	KLX20A_107.50-127.50_061110_1_CHir_Q_r.csv	CHir	2006-11-14	2006-11-10	
2006-11-11	00:09	127.50	147.50	__KLX20A_0127.50_200611110009.ht2	KLX20A_127.50-147.50_061111_1_CHir_Q_r.csv	CHir	2006-11-14	2006-11-11	
2006-11-11	06:37	147.50	167.50	__KLX20A_0147.50_200611110637.ht2	KLX20A_147.50-167.50_061111_1_CHir_Q_r.csv	CHir	2006-11-14	2006-11-11	
2006-11-11	08:50	167.50	187.50	__KLX20A_0167.50_200611110850.ht2	KLX20A_167.50-187.50_061111_1_CHir_Q_r.csv	CHir	2006-11-14	2006-11-11	
2006-11-11	11:05	187.50	207.50	__KLX20A_0187.50_200611111105.ht2	KLX20A_187.50-207.50_061111_1_CHir_Q_r.csv	CHir	2006-11-14	2006-11-11	
2006-11-11	13:59	193.50	213.50	__KLX20A_0193.50_200611111359.ht2	KLX20A_193.50-213.50_061111_1_CHir_Q_r.csv	CHir	2006-11-14	2006-11-11	
2006-11-11	16:40	213.00	233.00	__KLX20A_0213.00_200611111640.ht2	KLX20A_213.00-233.00_061111_1_CHir_Q_r.csv	CHir	2006-11-14	2006-11-11	
2006-11-11	19:04	233.00	253.00	__KLX20A_0233.00_200611111904.ht2	KLX20A_233.00-253.00_061111_1_Pi_Q_r.csv	Pi	2006-11-14	2006-11-11	
2006-11-11	21:21	253.00	353.00	__KLX20A_0253.00_200611112121.ht2	KLX20A_253.00-273.00_061111_1_CHir_Q_r.csv	CHir	2006-11-14	2006-11-11	

HYDROTESTING WITH PSS					DRILLHOLE IDENTIFICATION NO.: KLX20A				
TEST- AND FILEPROTOCOL					**Testorder dated : 2006-11-07**				
Teststart		Interval boundaries		Name of Datafiles		Testtype	Copied to disk/CD	Plotted (date)	Sign.
Date	Time	Upper	Lower	(*.HT2-file)	(*.CSV-file)				
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2006-11-12	01:25	287.50	307.50	__KLX20A_0287.50_200611120125.ht2	KLX20A_287.50-307.50_061112_1_CHir_Q_r.csv	Chir	2006-11-14	2006-11-12	

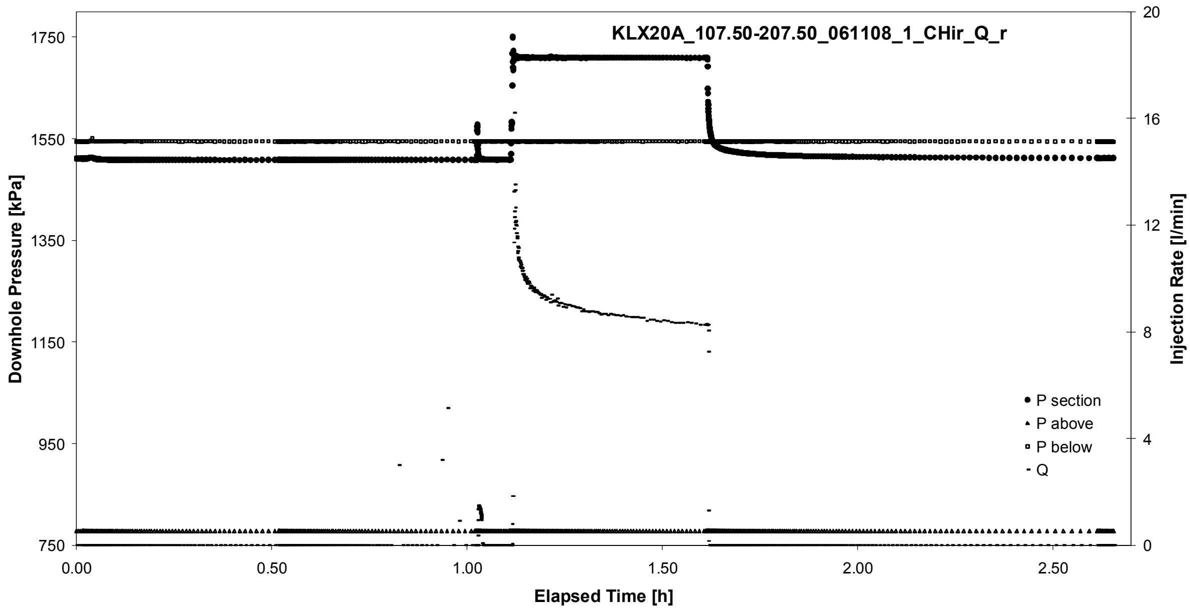
APPENDIX 2

Analysis diagrams

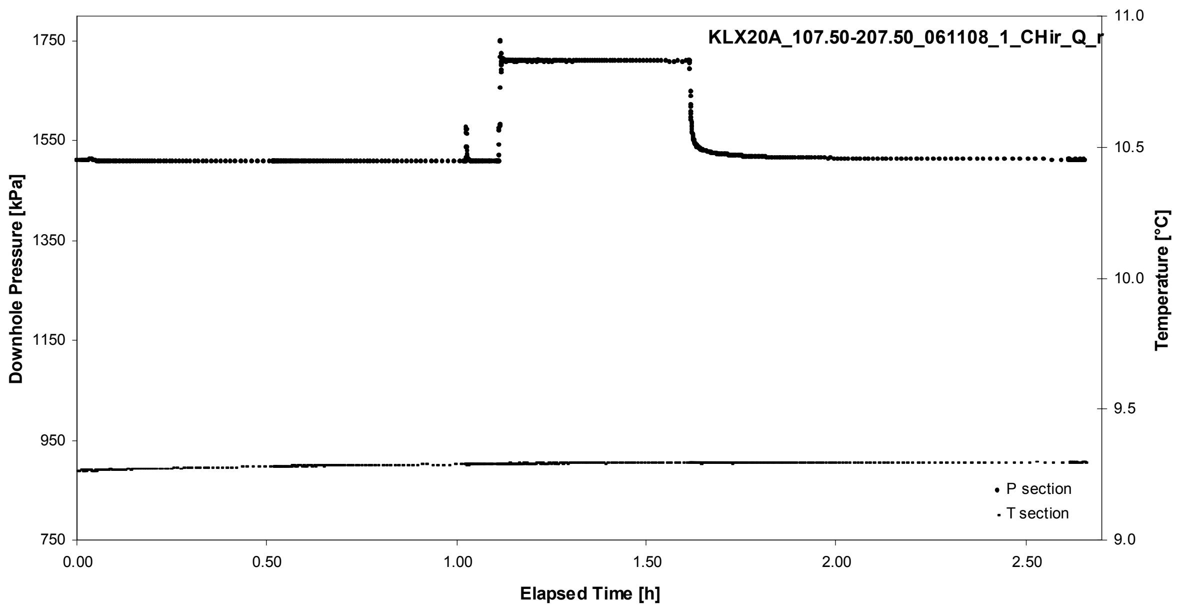
APPENDIX 2-1

Test 107.50 – 207.50 m

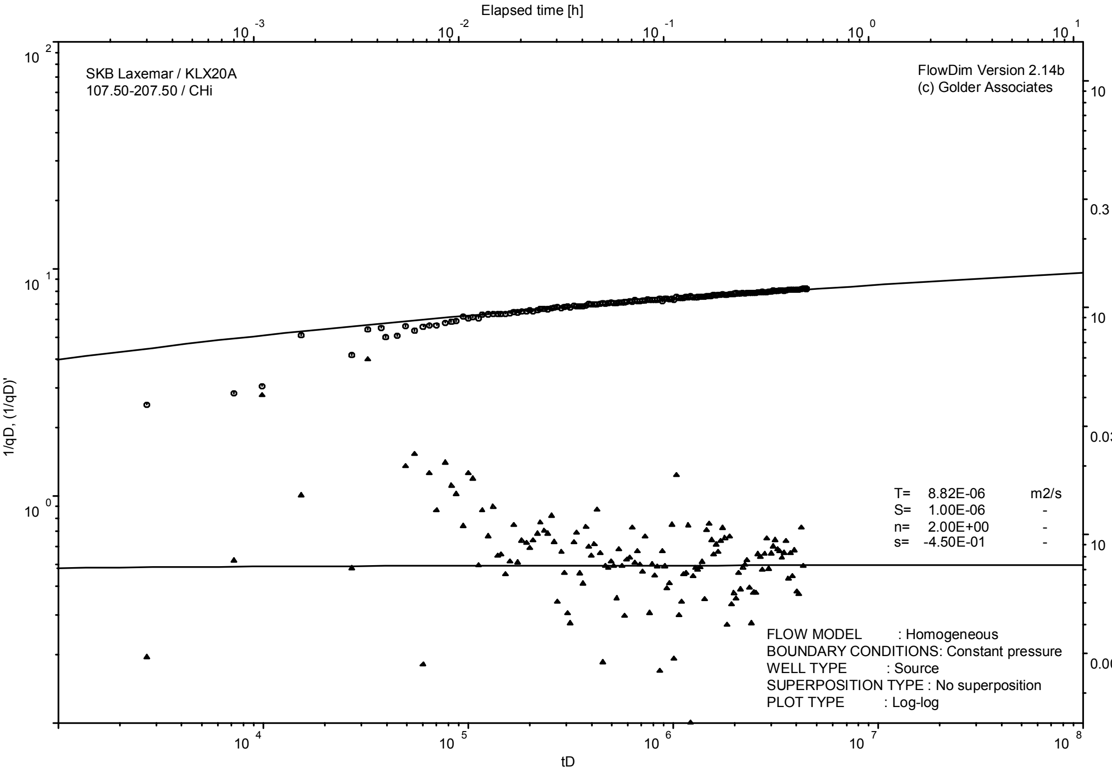
Analysis diagrams



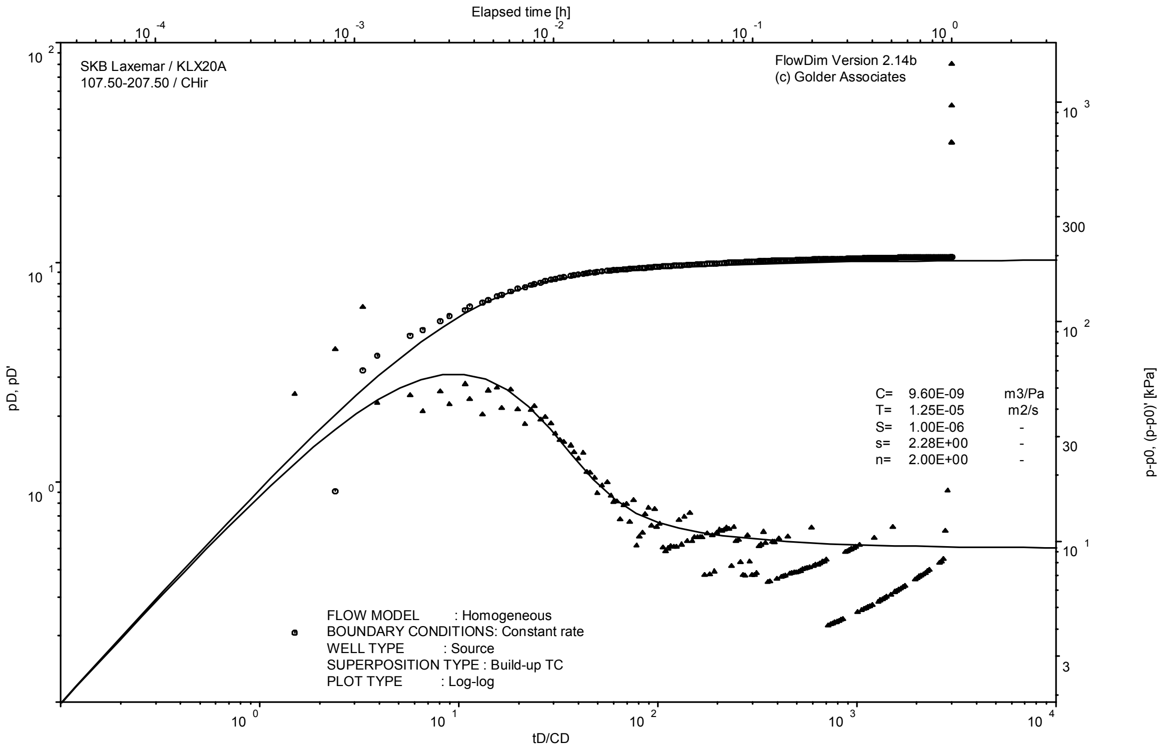
Pressure and flow rate vs. time; cartesian plot



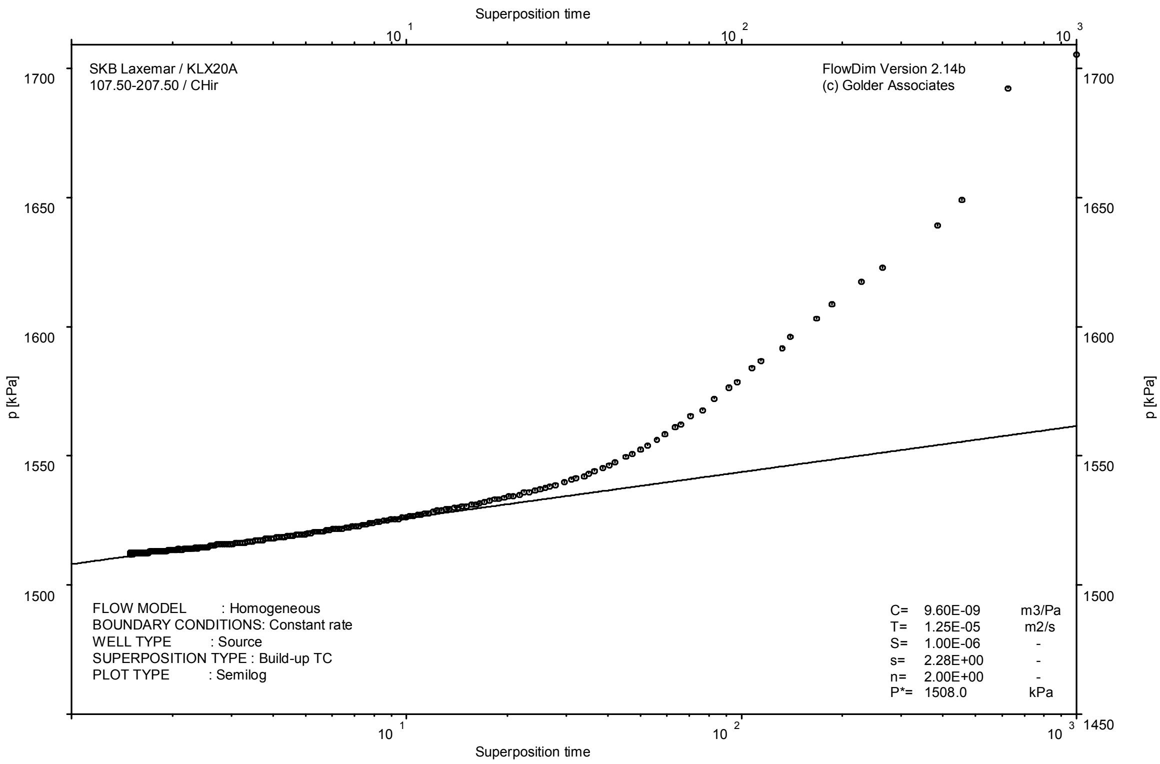
Interval pressure and temperature vs. time; cartesian plot



CHI phase; log-log match



CHIR phase; log-log match

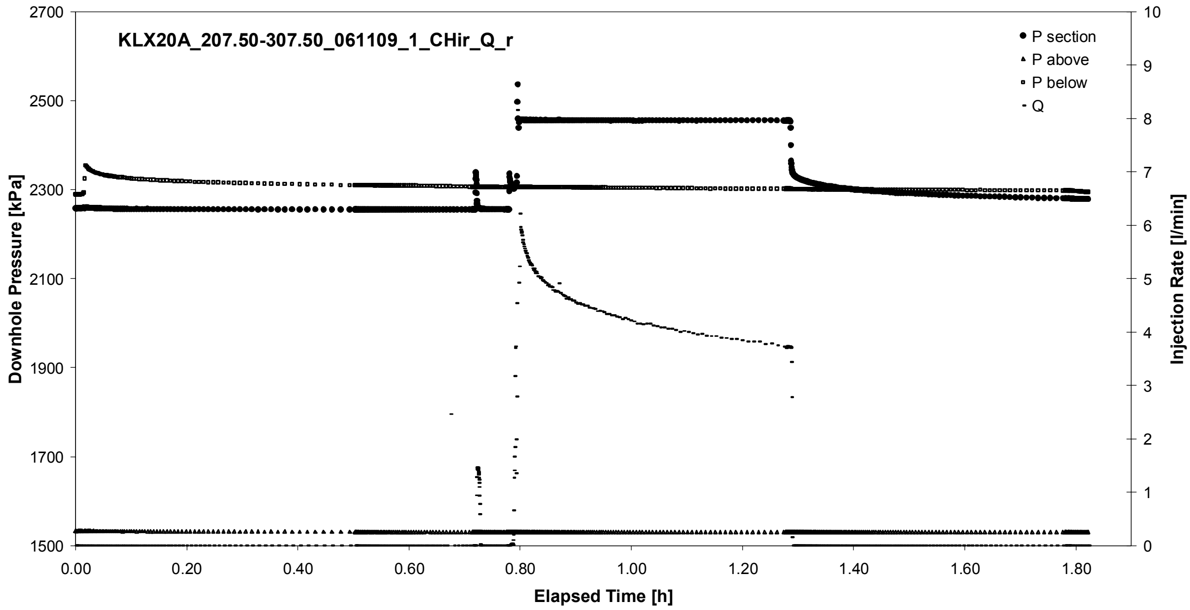


CHIR phase; HORNER match

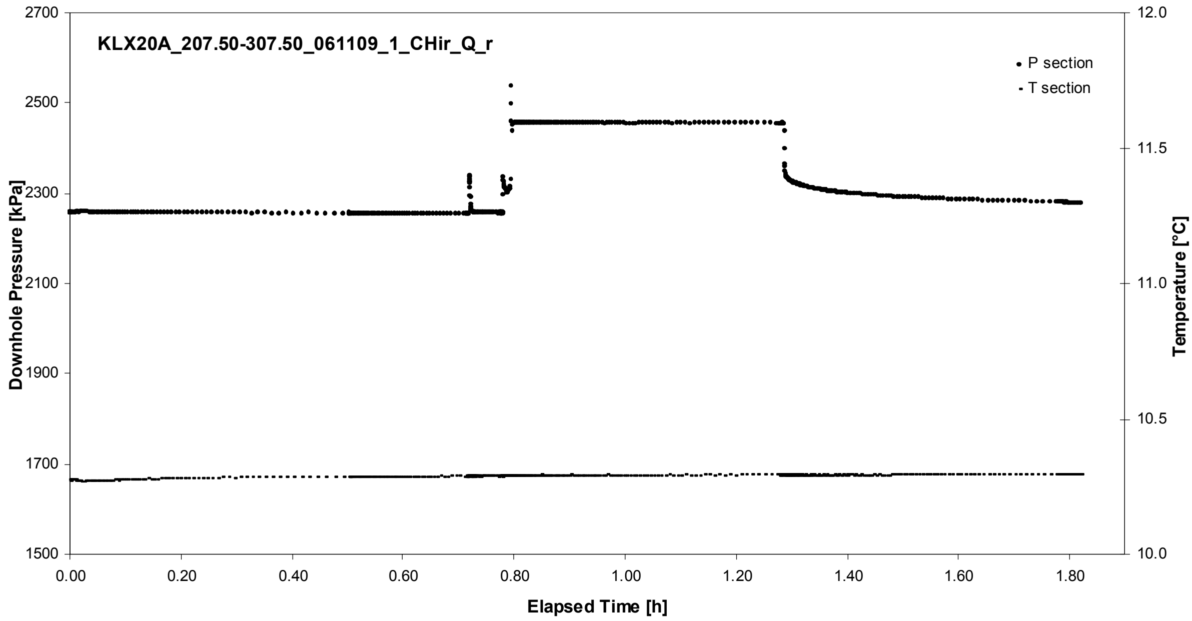
APPENDIX 2-2

Test 207.50 – 307.50 m

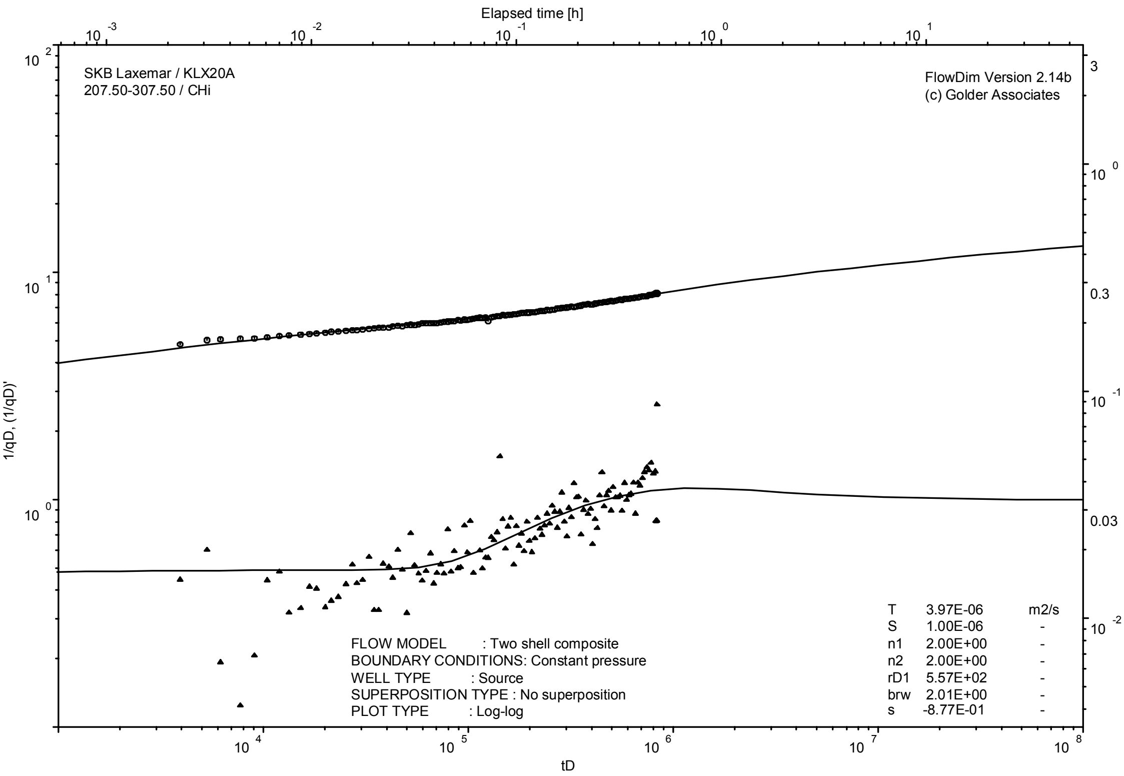
Analysis diagrams



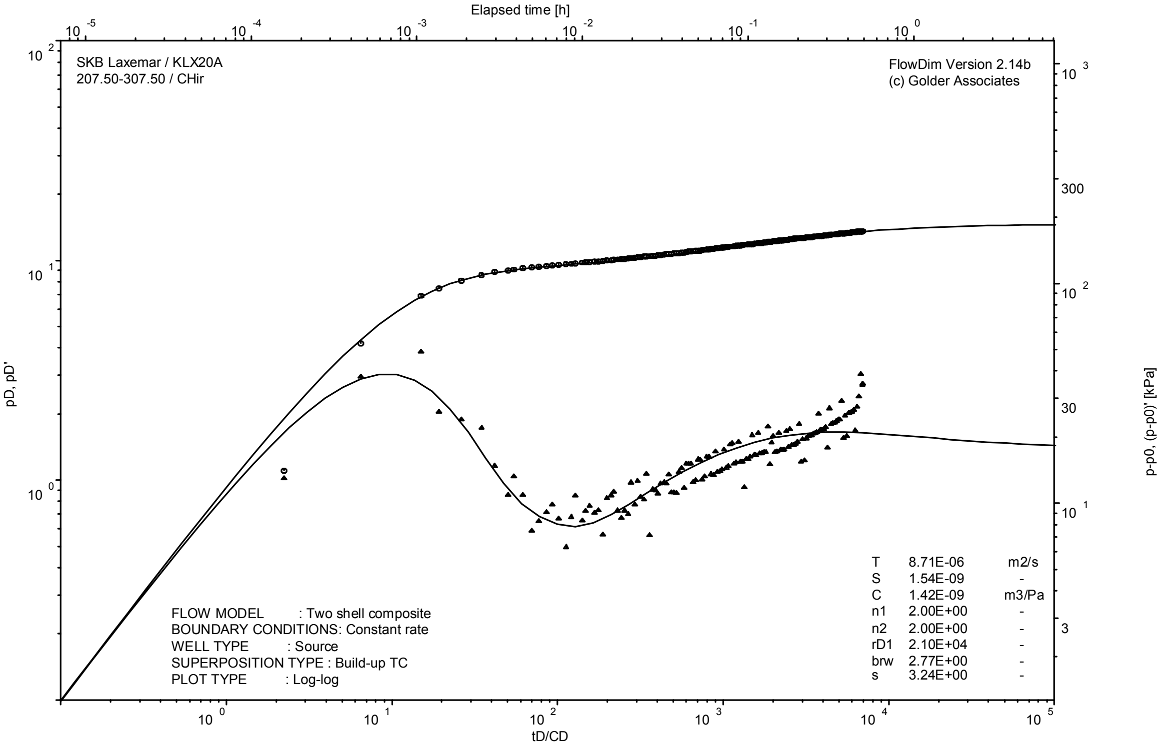
Pressure and flow rate vs. time; cartesian plot



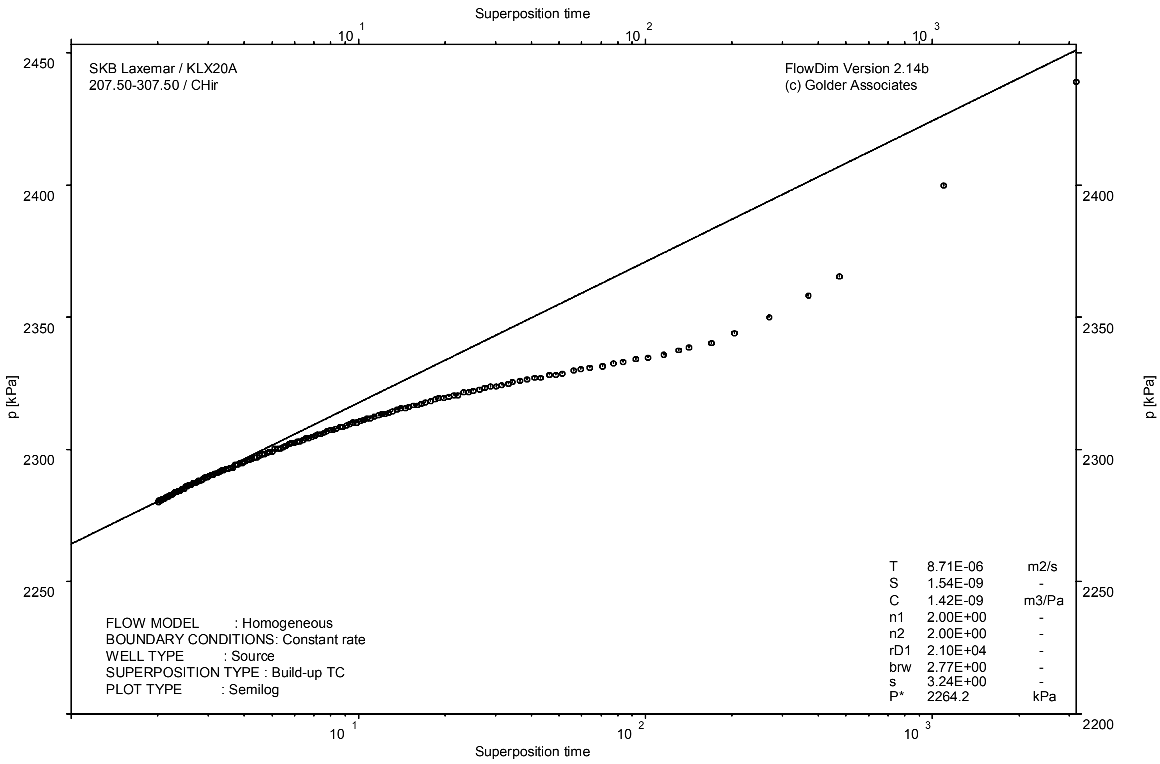
Interval pressure and temperature vs. time; cartesian plot



CHI phase; log-log match



CHIR phase; log-log match

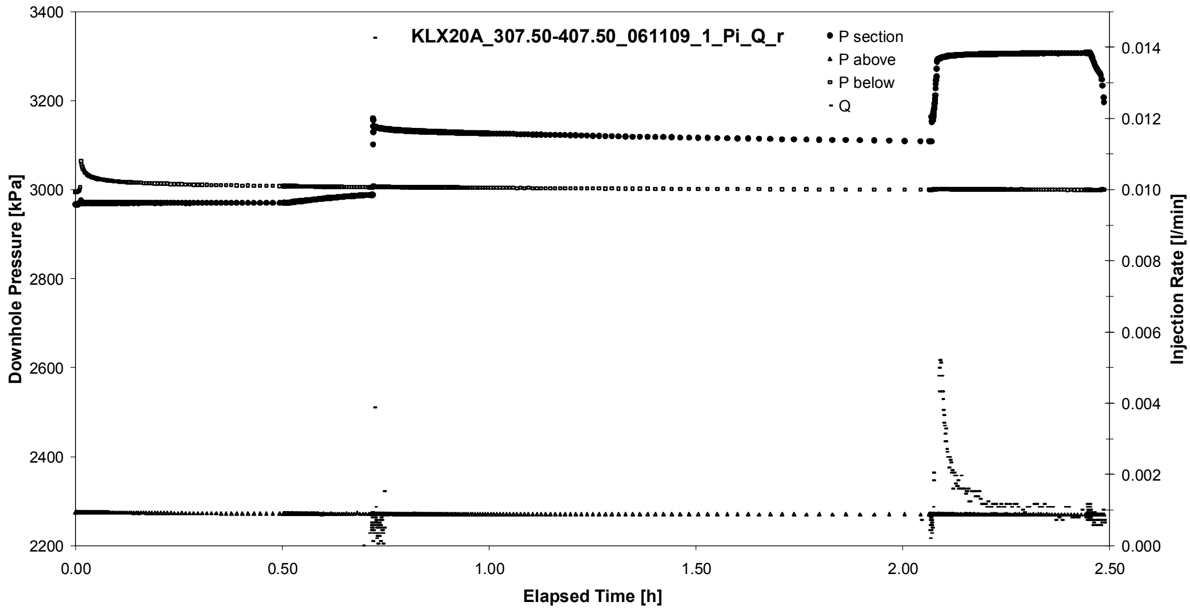


CHIR phase; HORNER match

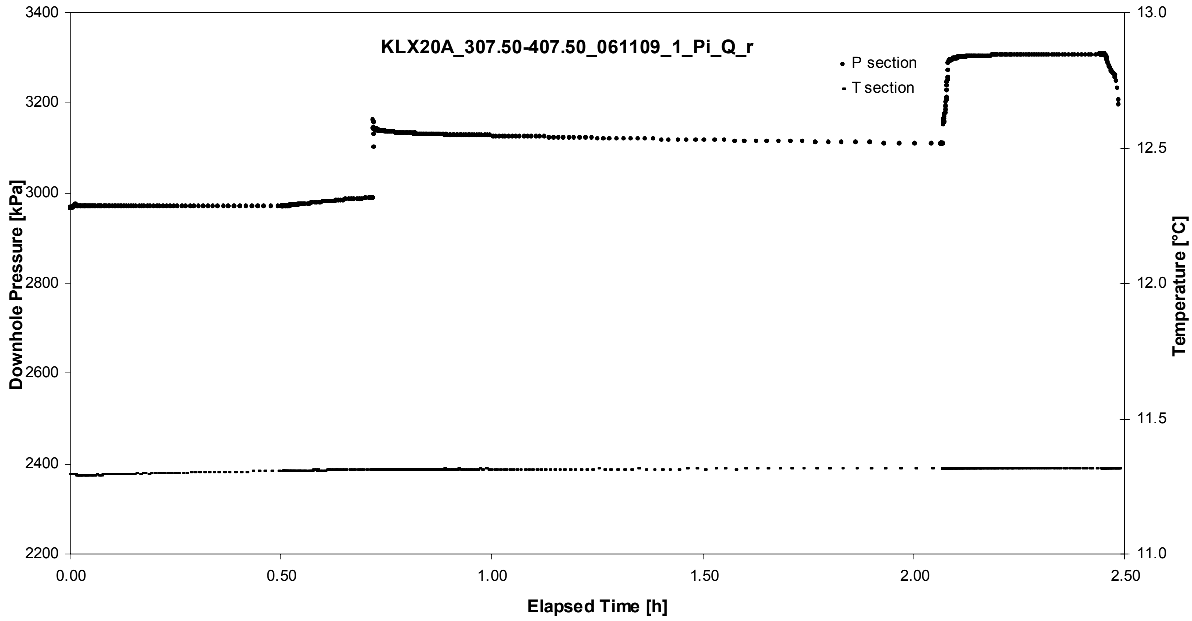
APPENDIX 2-3

Test 307.50 – 407.50 m

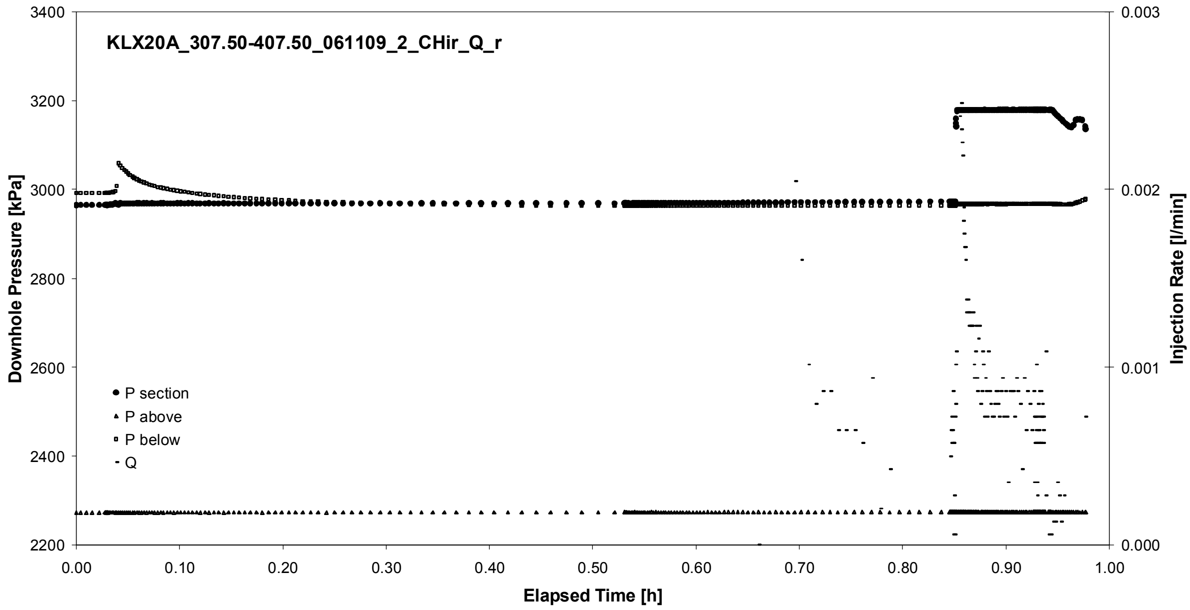
Analysis diagrams



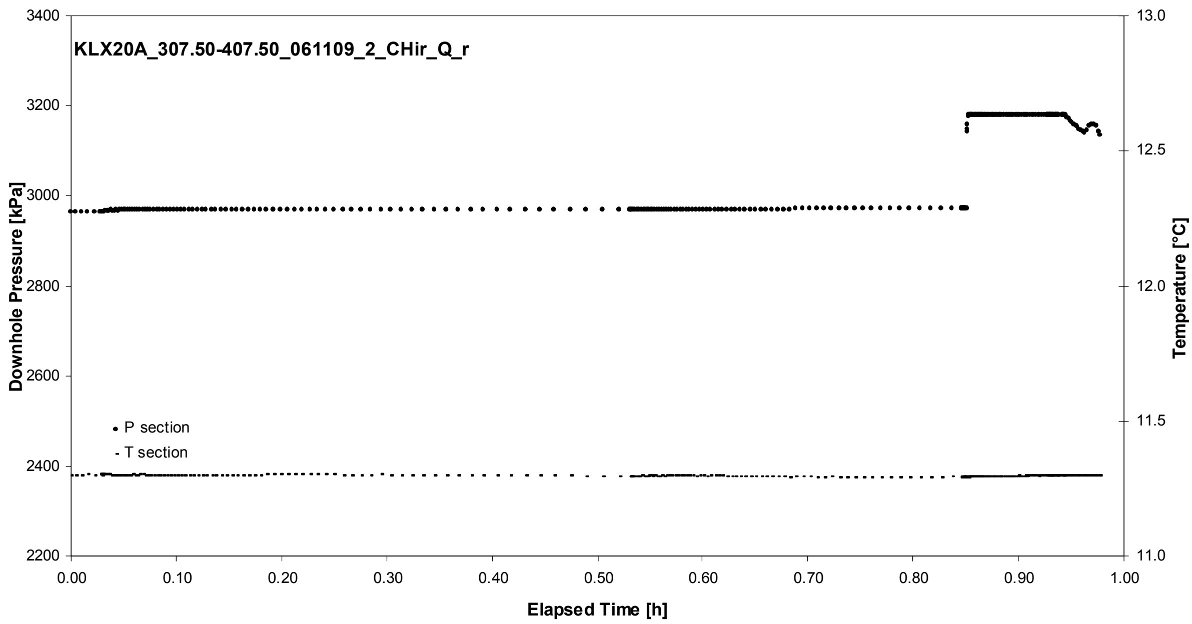
Pressure and flow rate vs. time; cartesian plot (analysed)



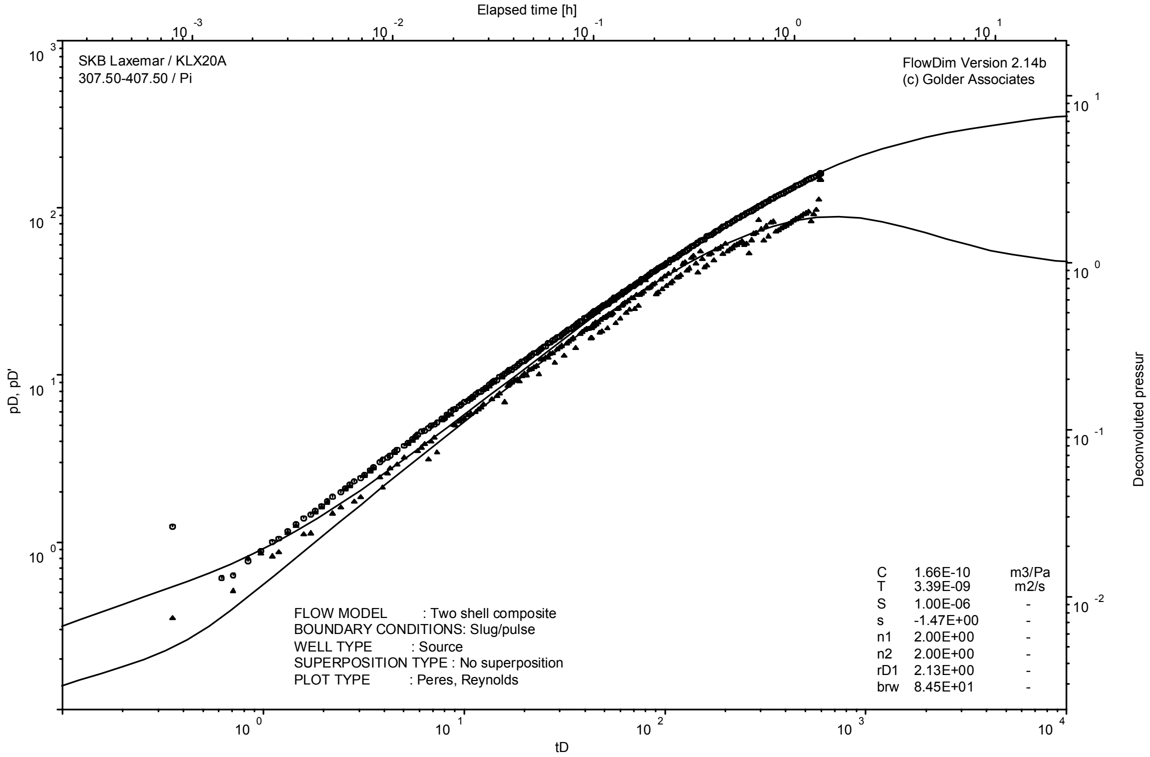
Interval pressure and temperature vs. time; cartesian plot (analysed)



Pressure and flow rate vs. time; cartesian plot



Interval pressure and temperature vs. time; cartesian plot

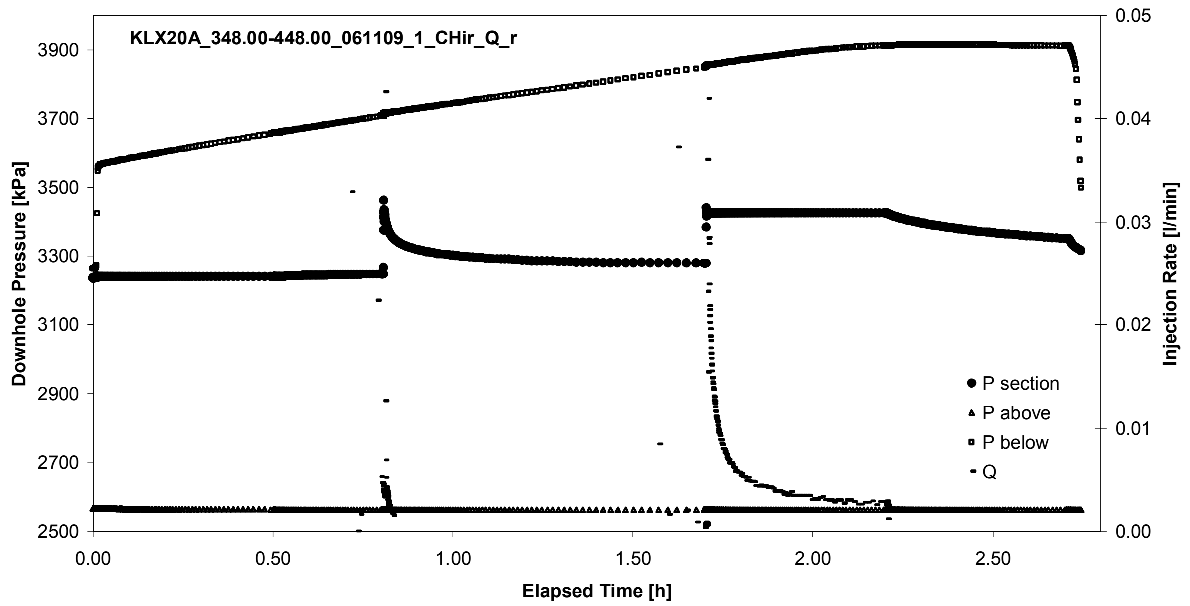


Pulse injection; deconvolution match

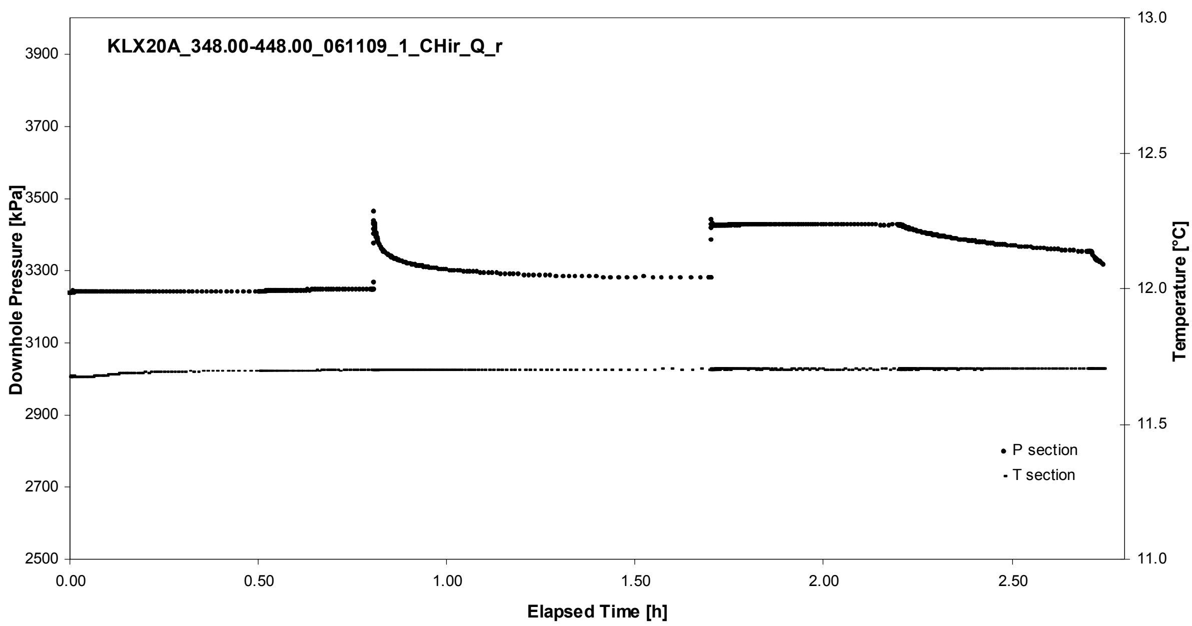
APPENDIX 2-4

Test 348.00 – 448.00 m

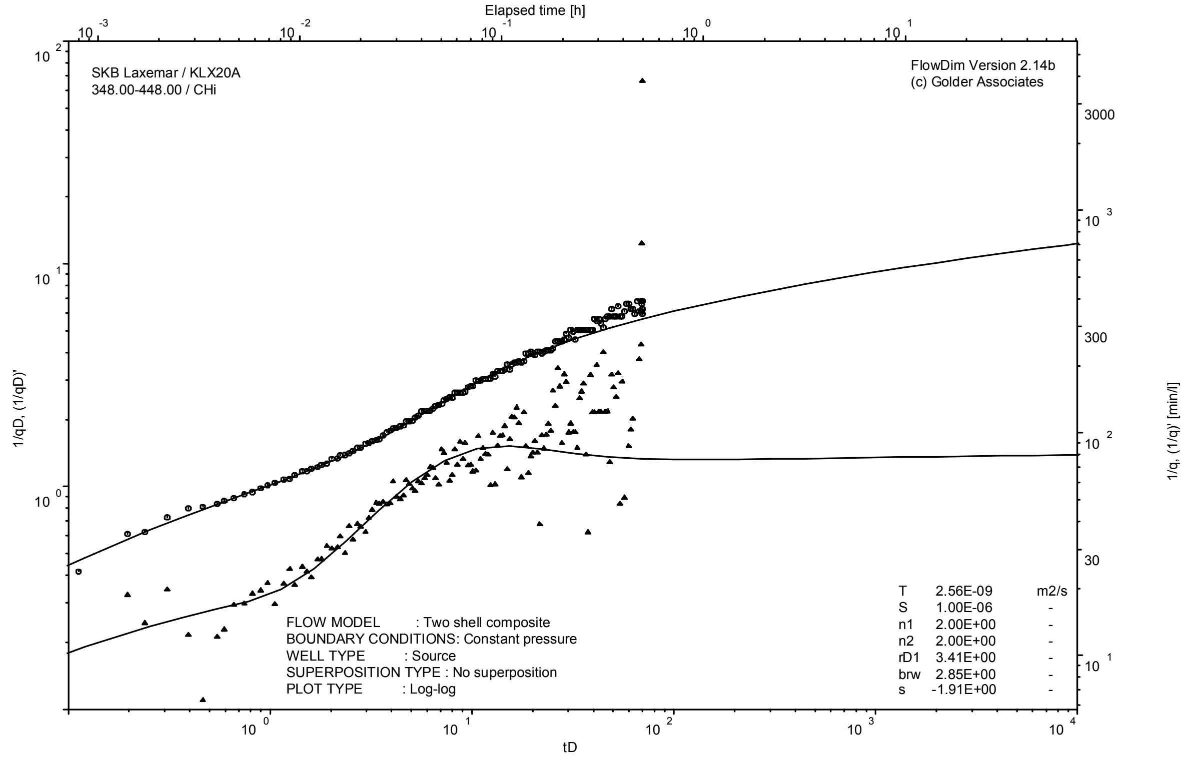
Analysis diagrams



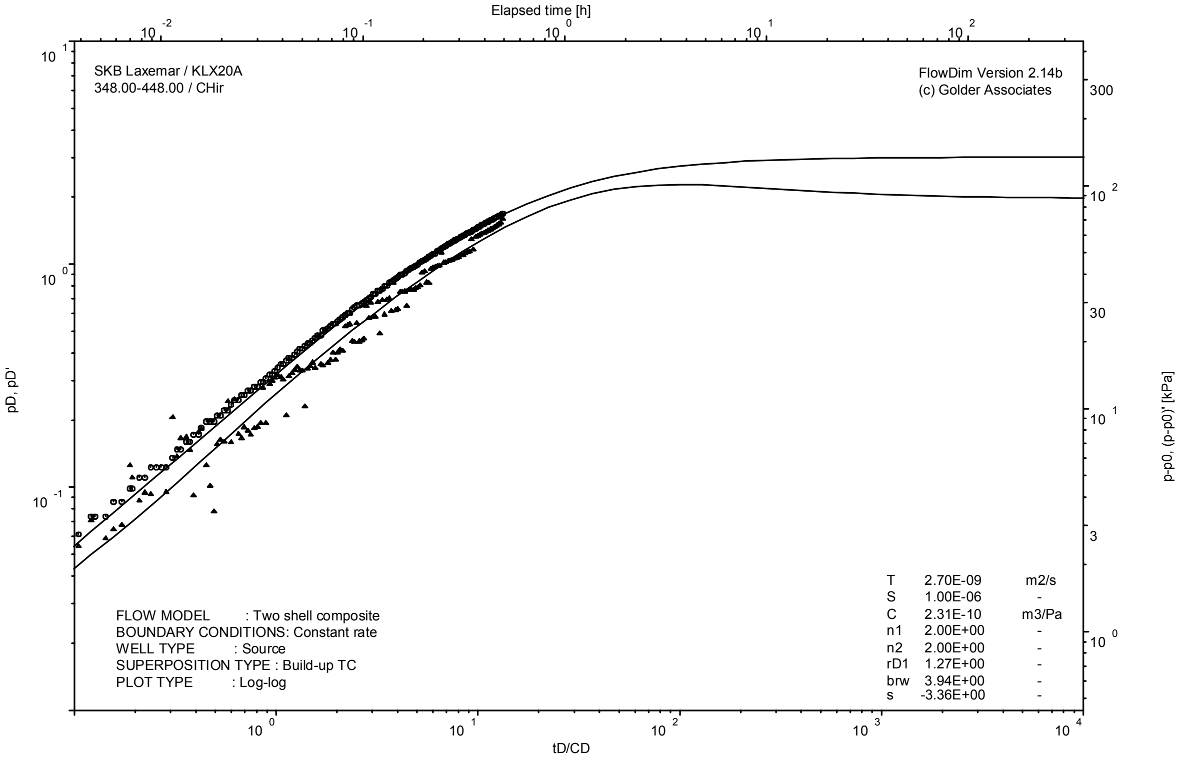
Pressure and flow rate vs. time; cartesian plot



Interval pressure and temperature vs. time; cartesian plot



CHI phase; log-log match



CHIR phase; log-log match

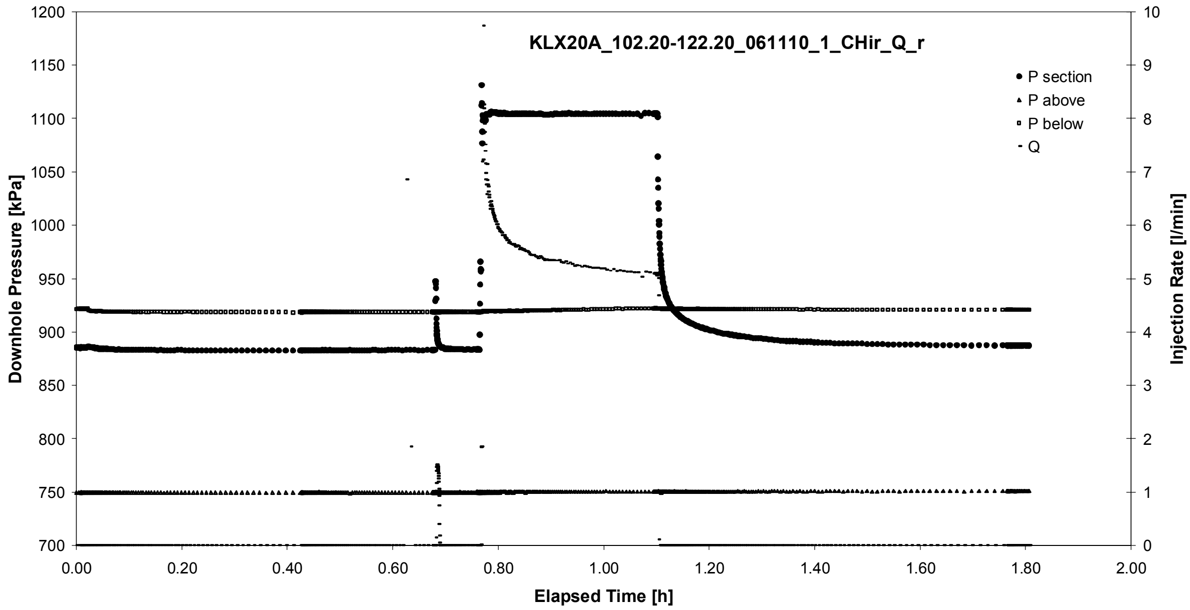
Not analysable

CHIR phase; HORNER match

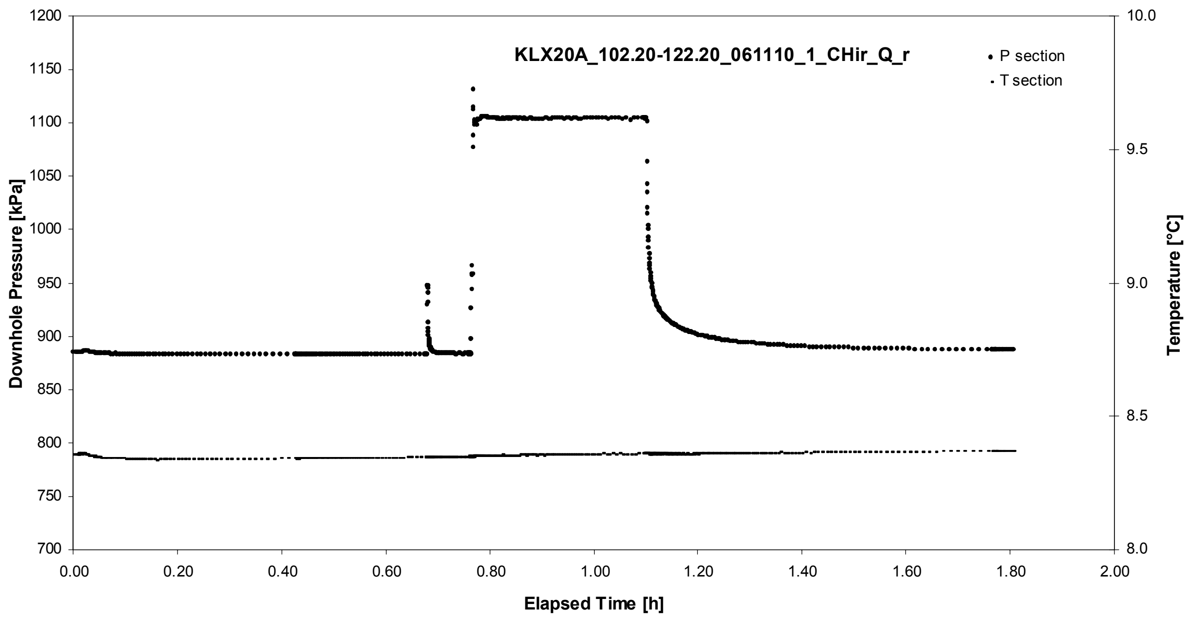
APPENDIX 2-5

Test 102.20 – 122.20 m

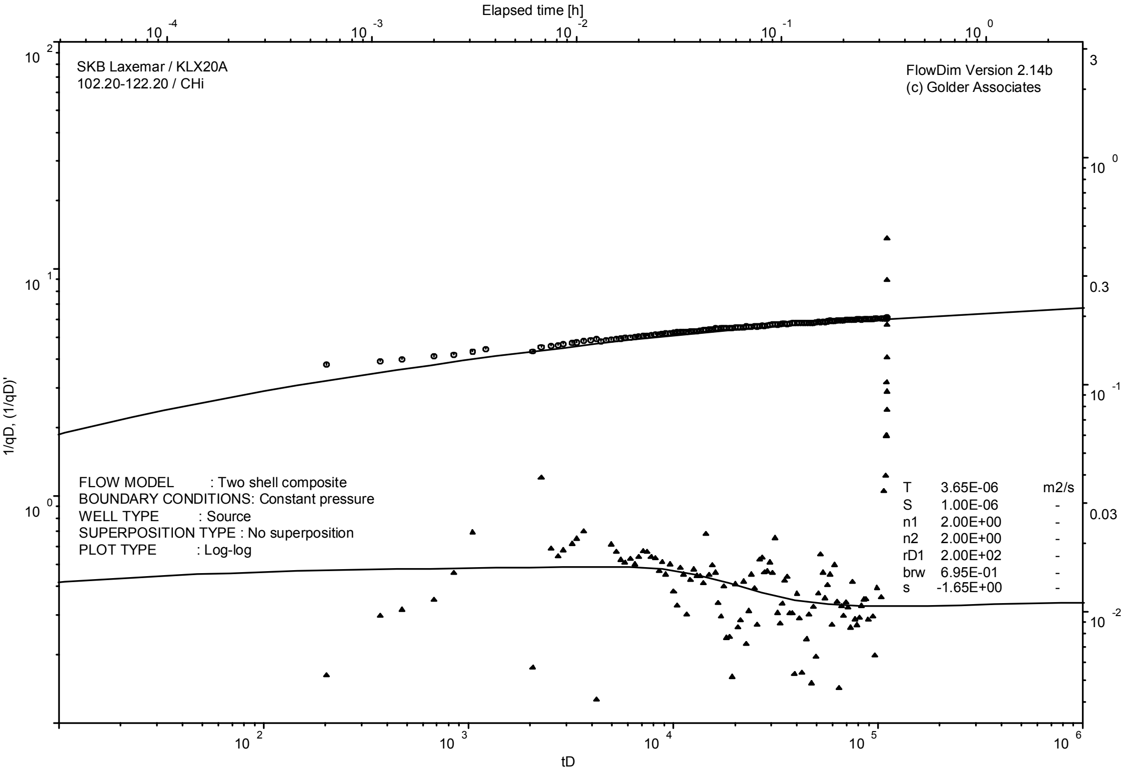
Analysis diagrams



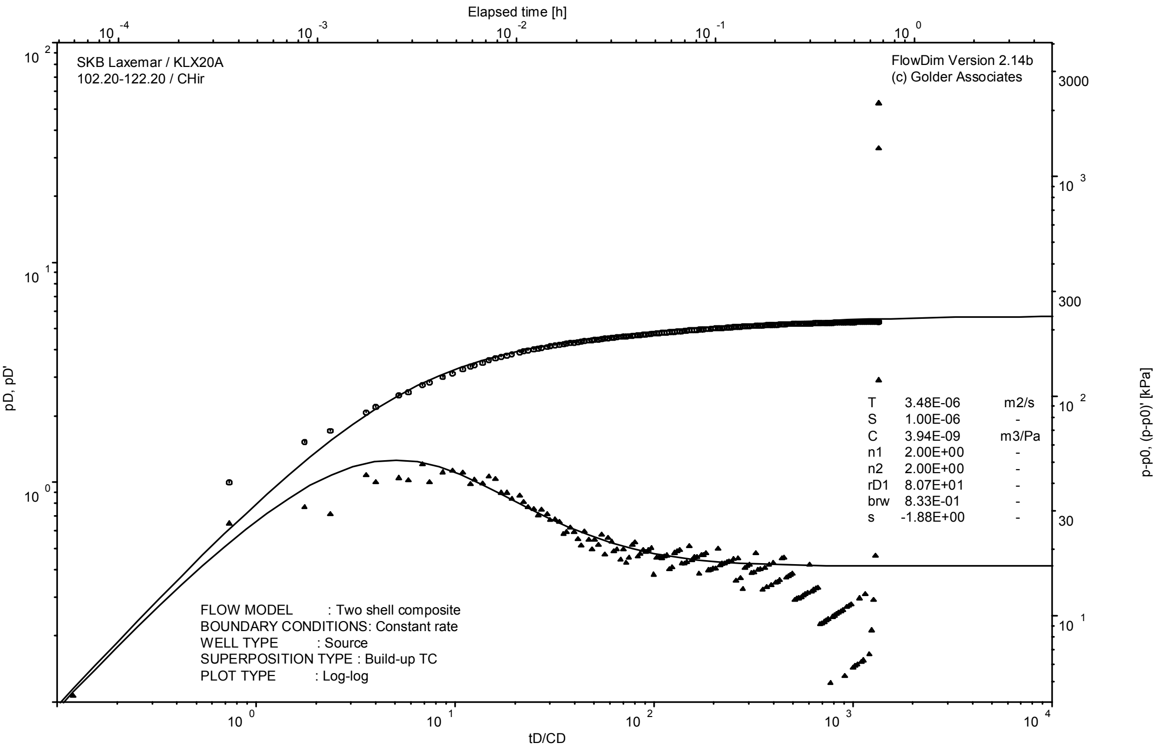
Pressure and flow rate vs. time; cartesian plot



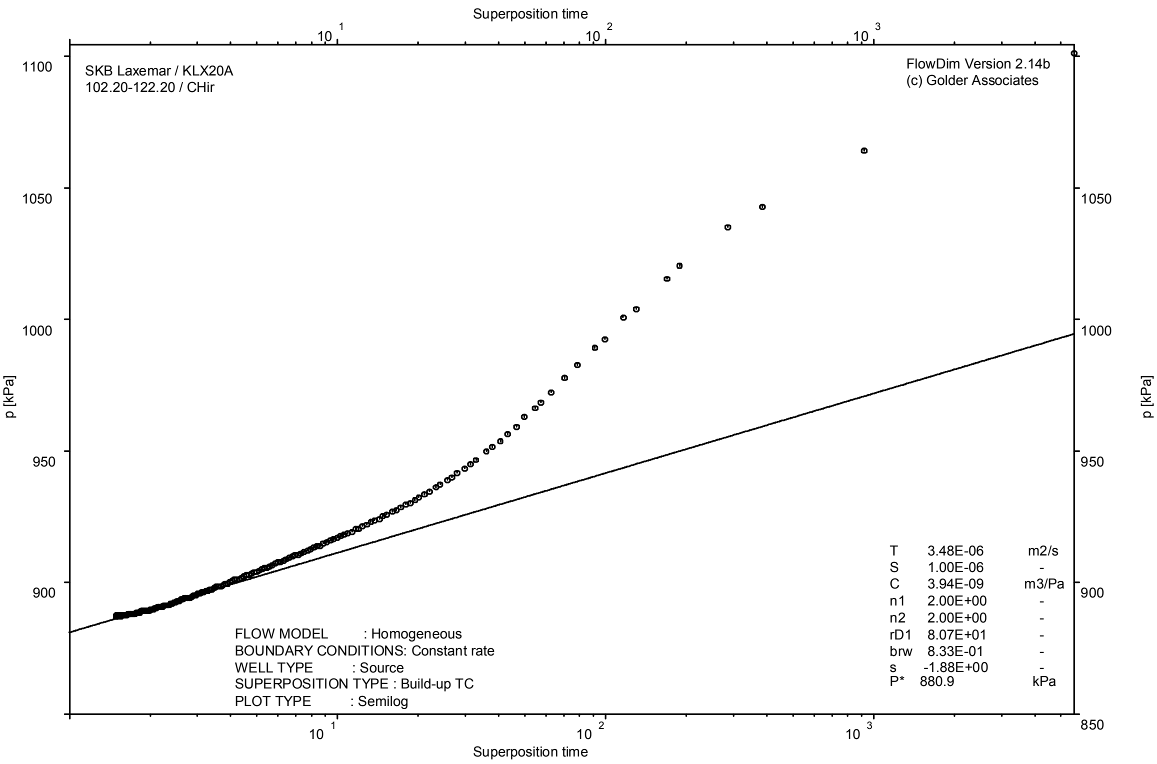
Interval pressure and temperature vs. time; cartesian plot



CHI phase; log-log match



CHIR phase; log-log match

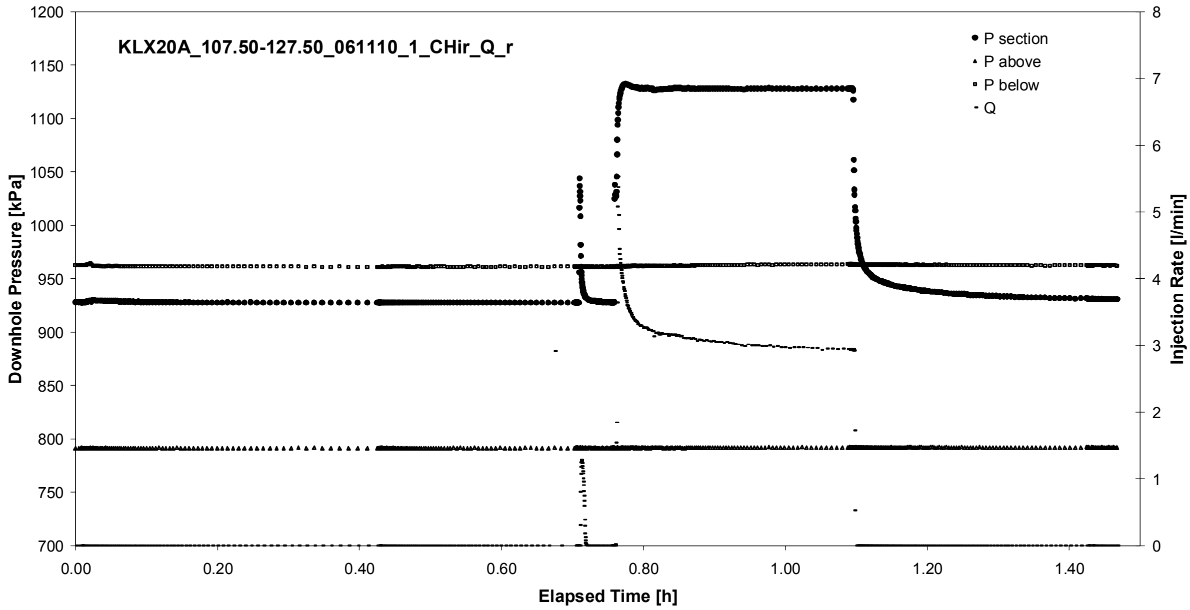


CHIR phase; HORNER match

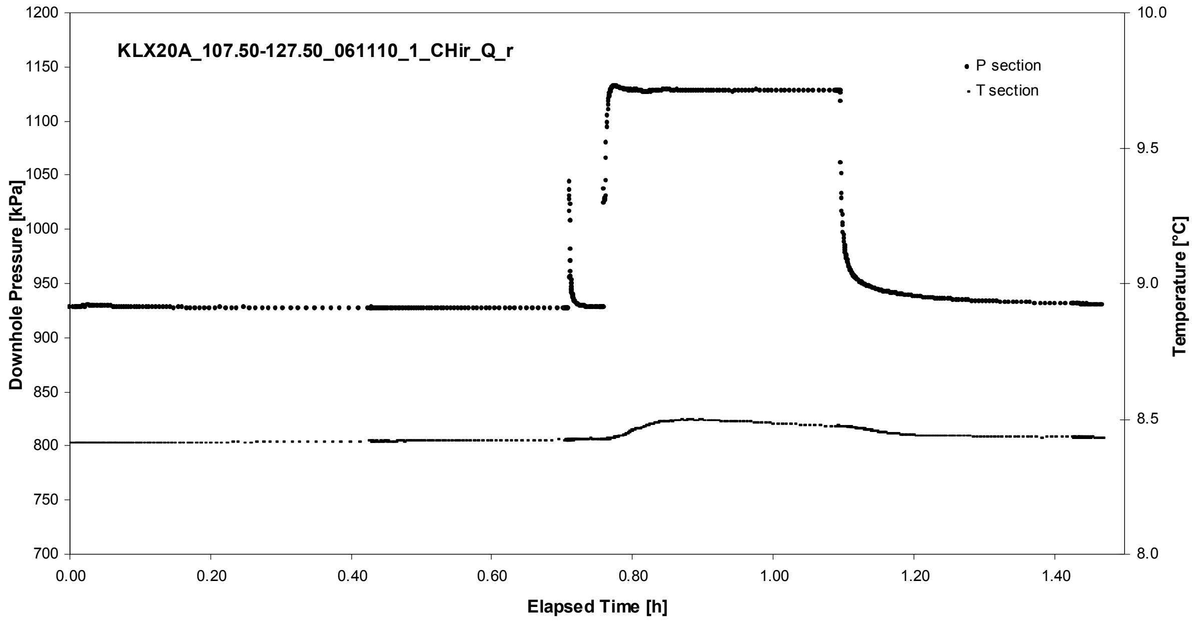
APPENDIX 2-6

Test 107.50 – 127.50 m

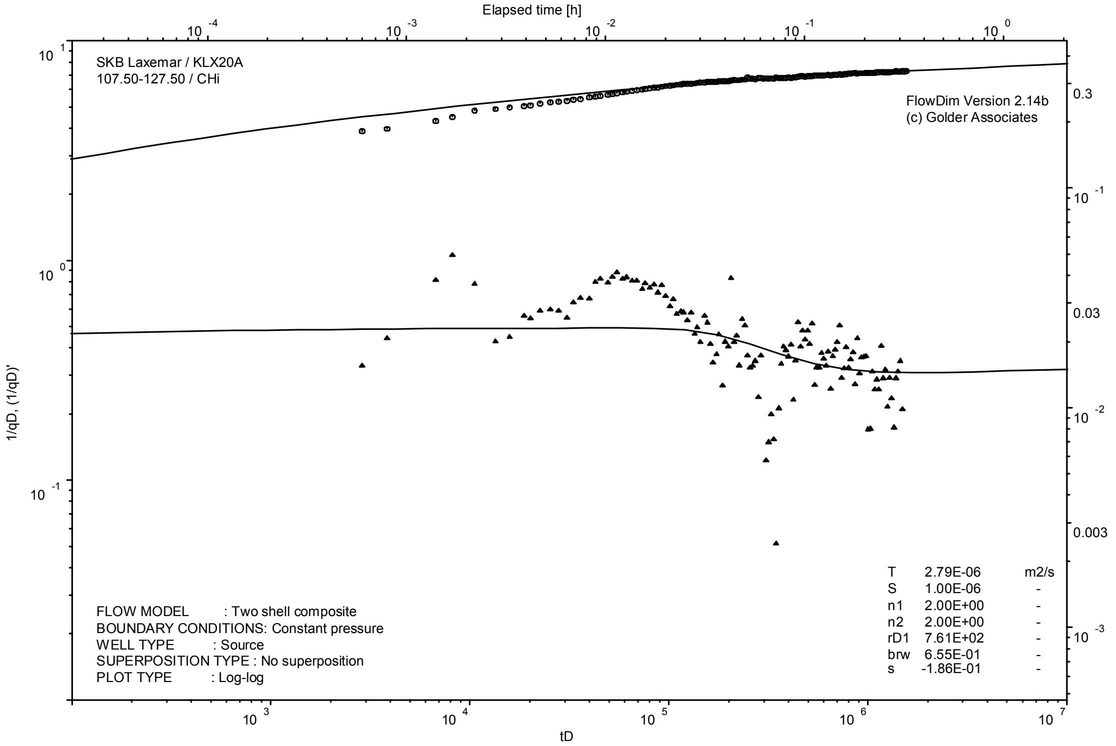
Analysis diagrams



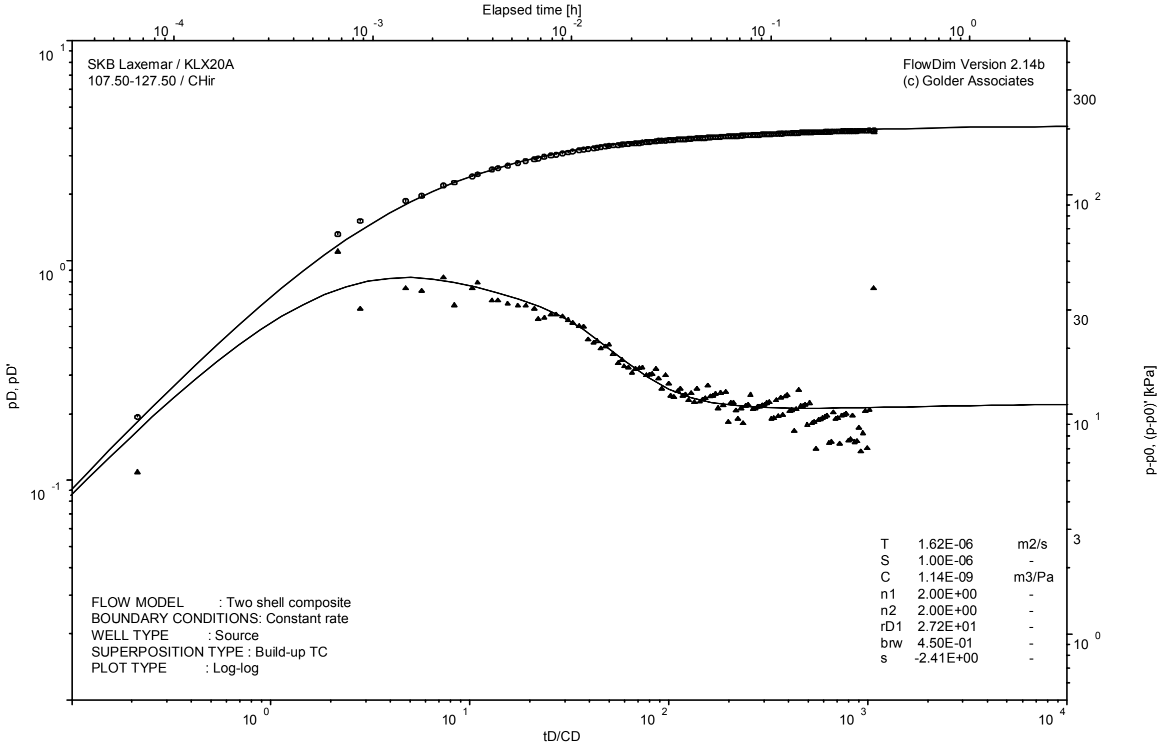
Pressure and flow rate vs. time; cartesian plot



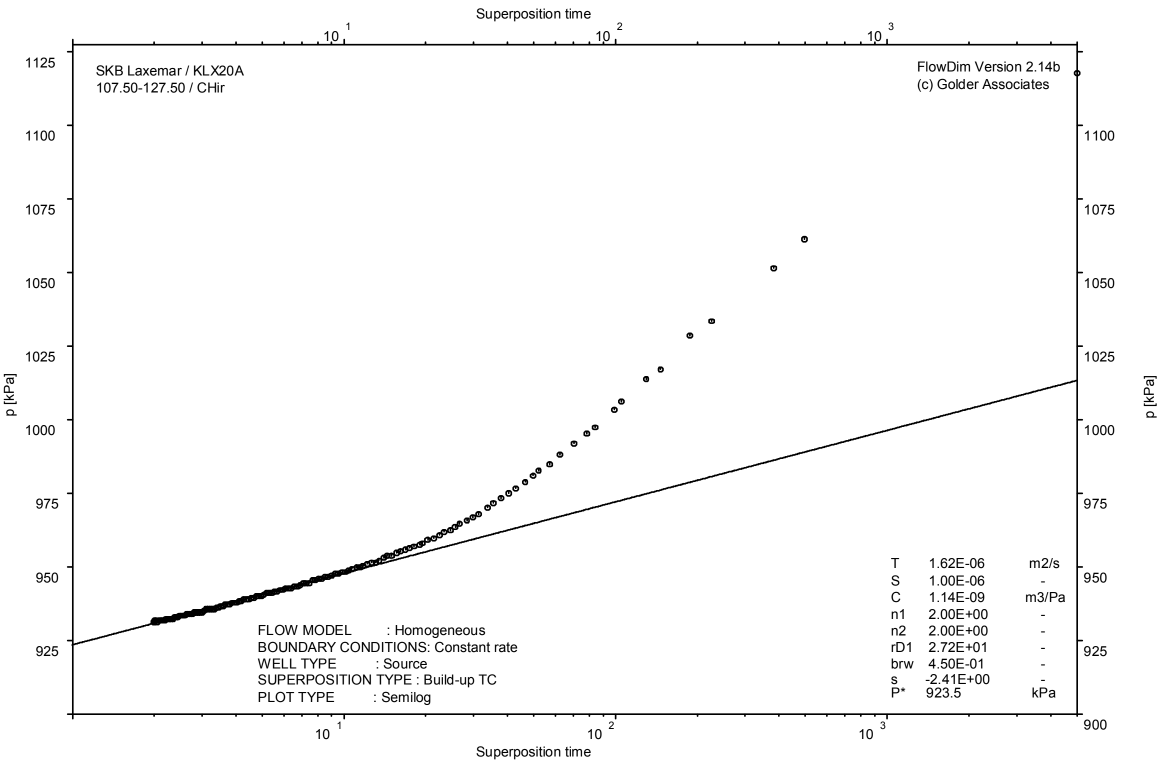
Interval pressure and temperature vs. time; cartesian plot



CHI phase; log-log match



CHIR phase; log-log match

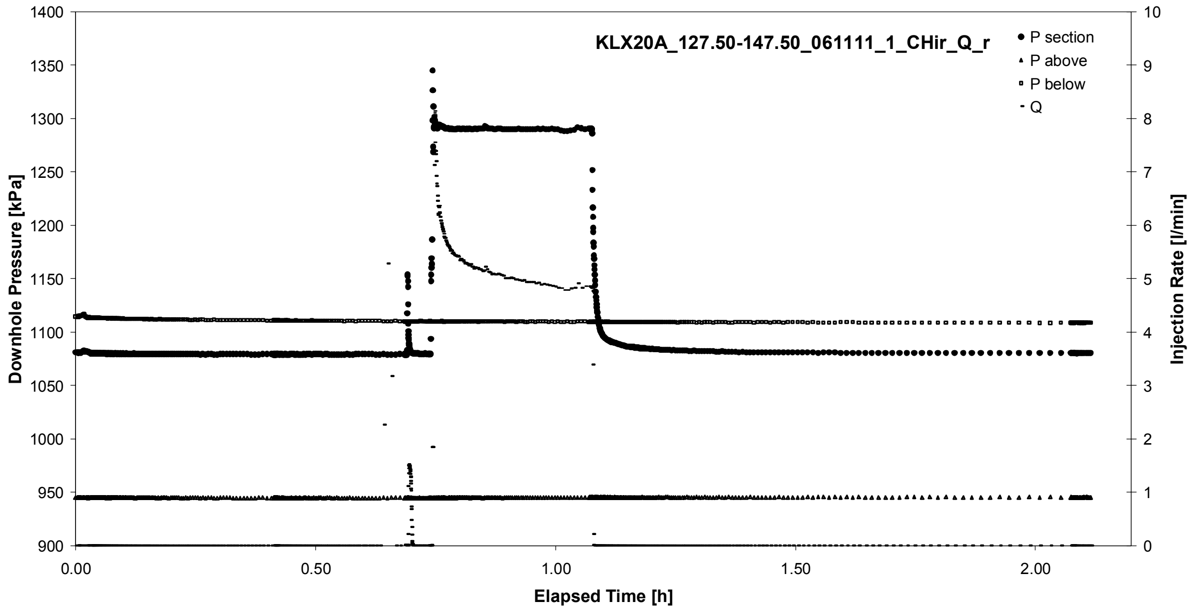


CHIR phase; HORNER match

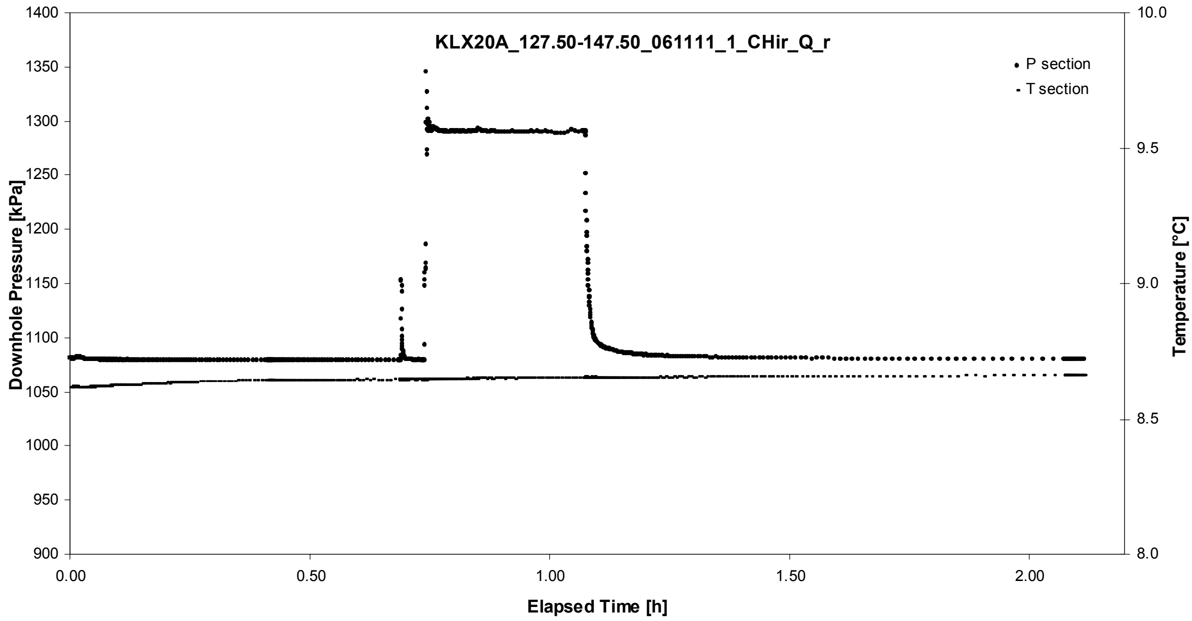
APPENDIX 2-7

Test 127.50 – 147.50 m

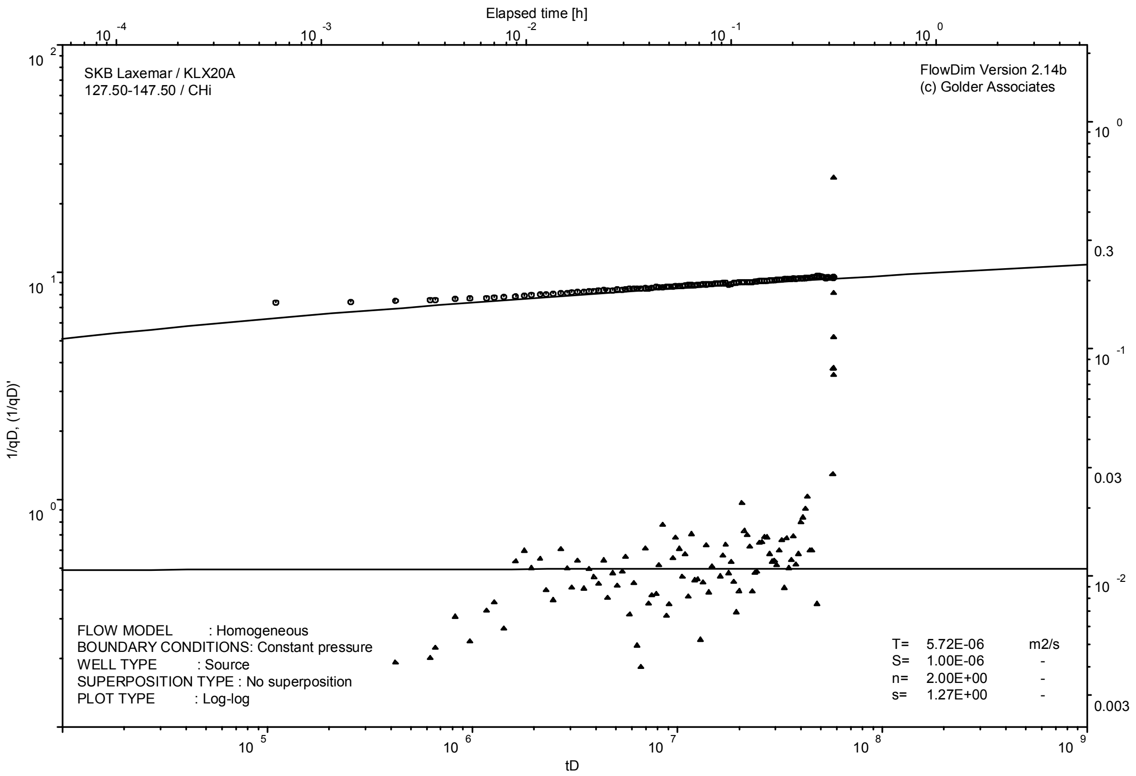
Analysis diagrams



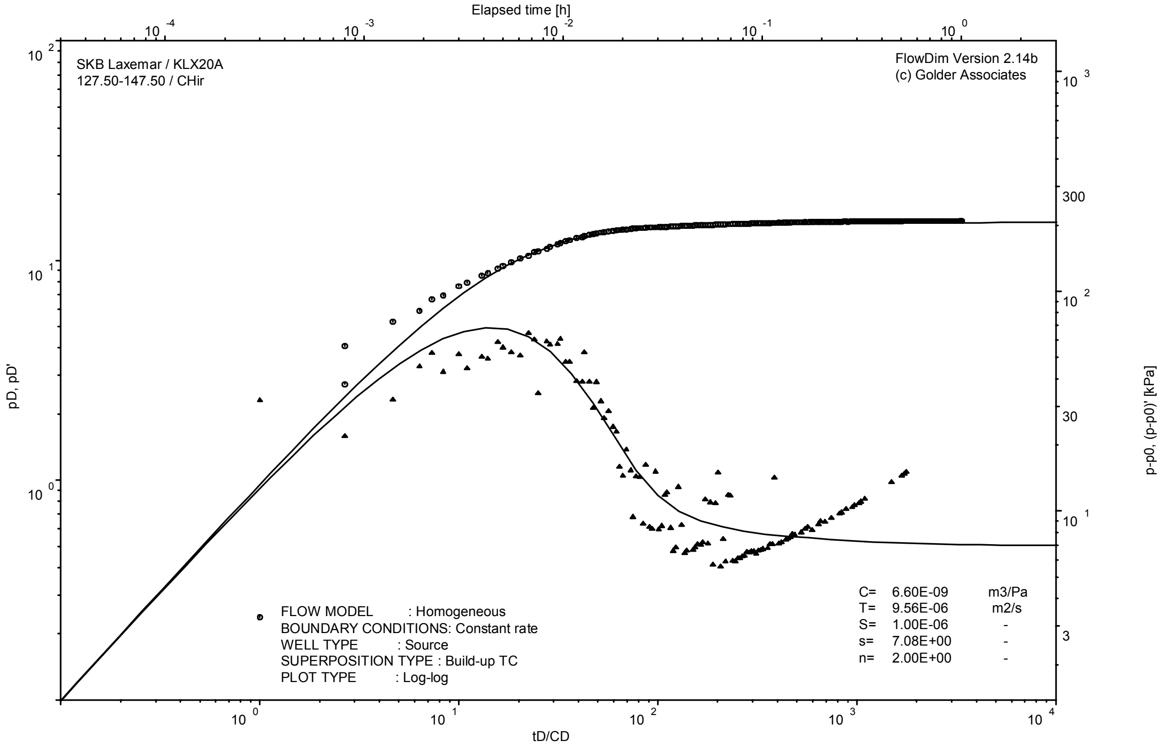
Pressure and flow rate vs. time; cartesian plot



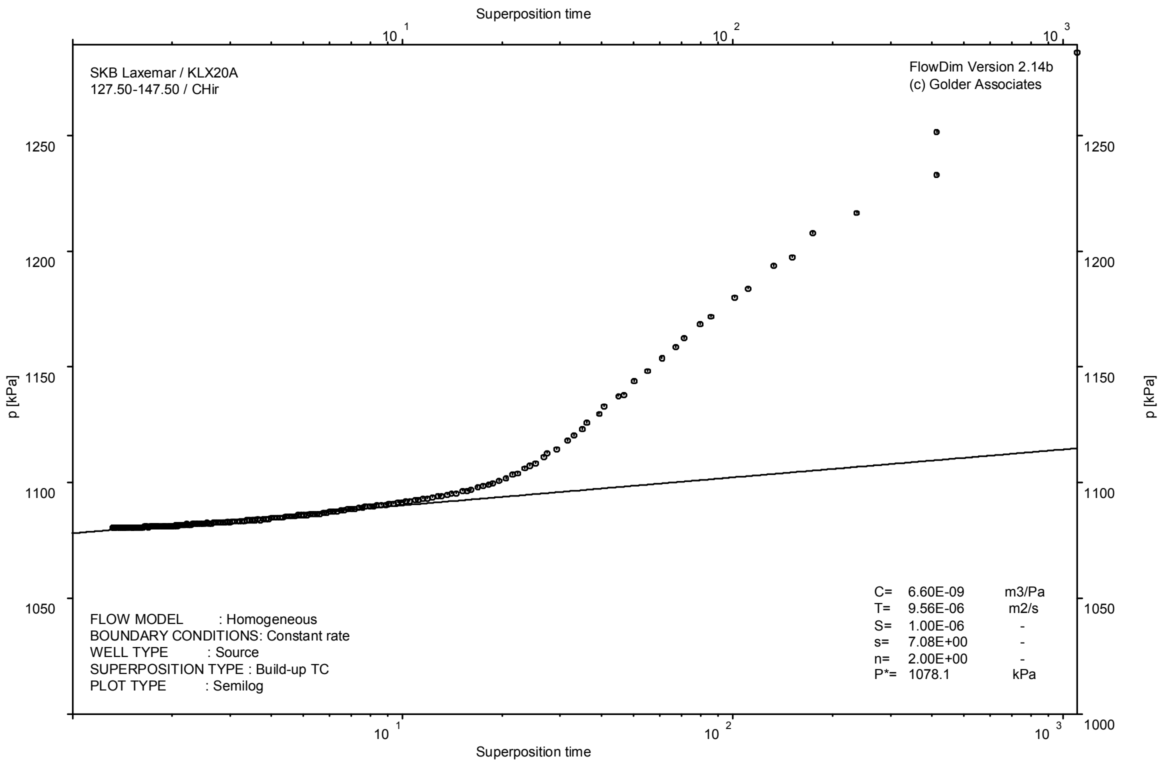
Interval pressure and temperature vs. time; cartesian plot



CHI phase; log-log match



CHIR phase; log-log match

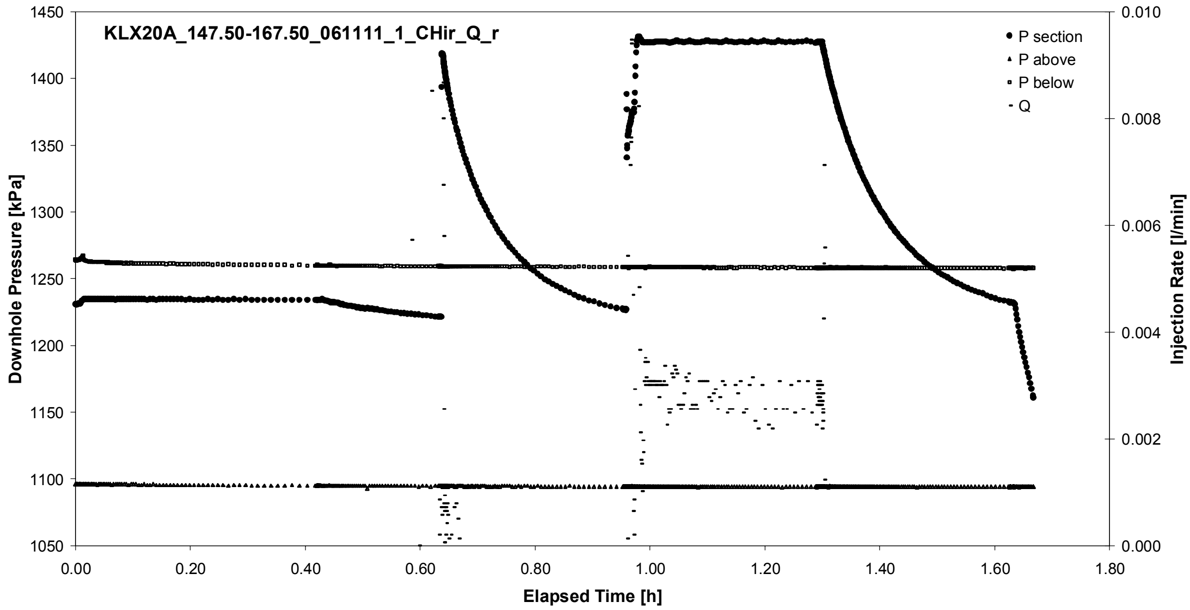


CHIR phase; HORNER match

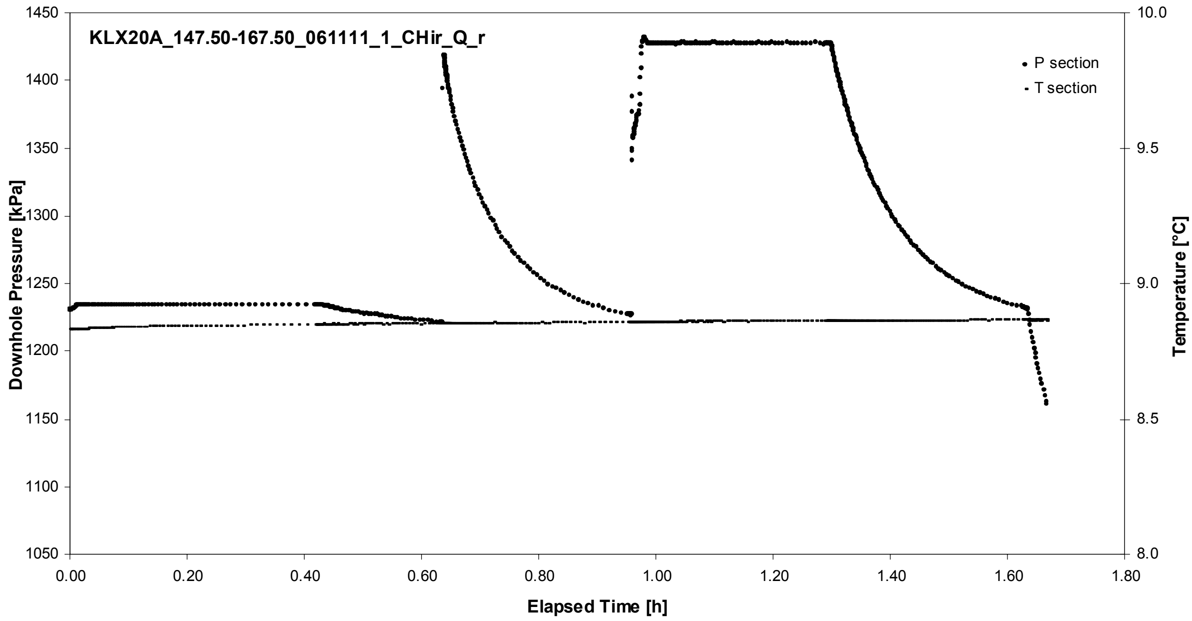
APPENDIX 2-8

Test 147.50 – 167.50 m

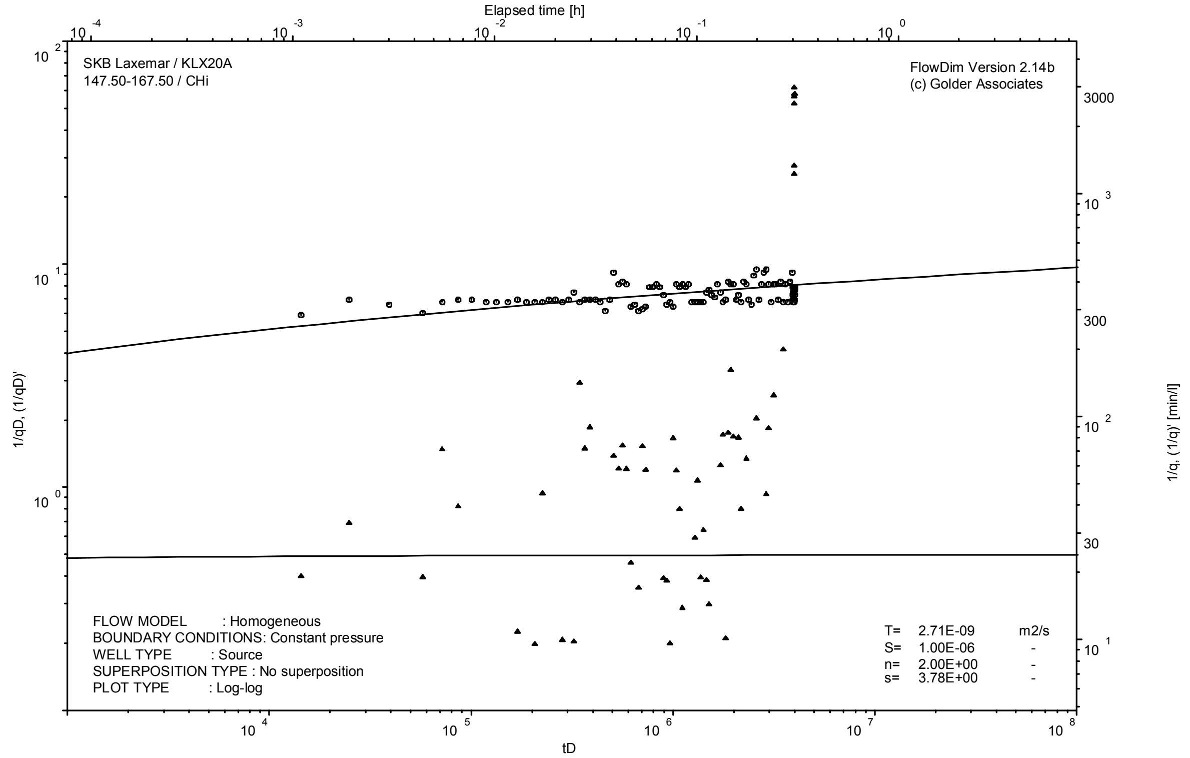
Analysis diagrams



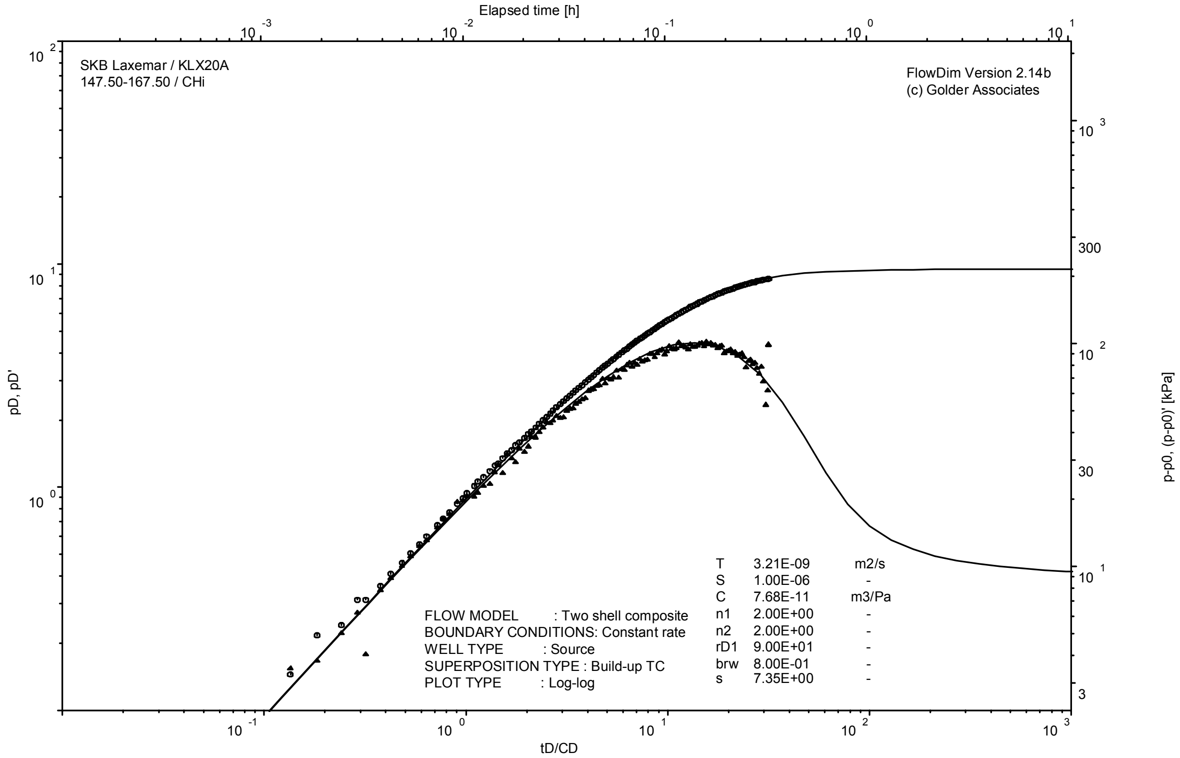
Pressure and flow rate vs. time; cartesian plot



Interval pressure and temperature vs. time; cartesian plot



CHI phase; log-log match



CHIR phase; log-log match

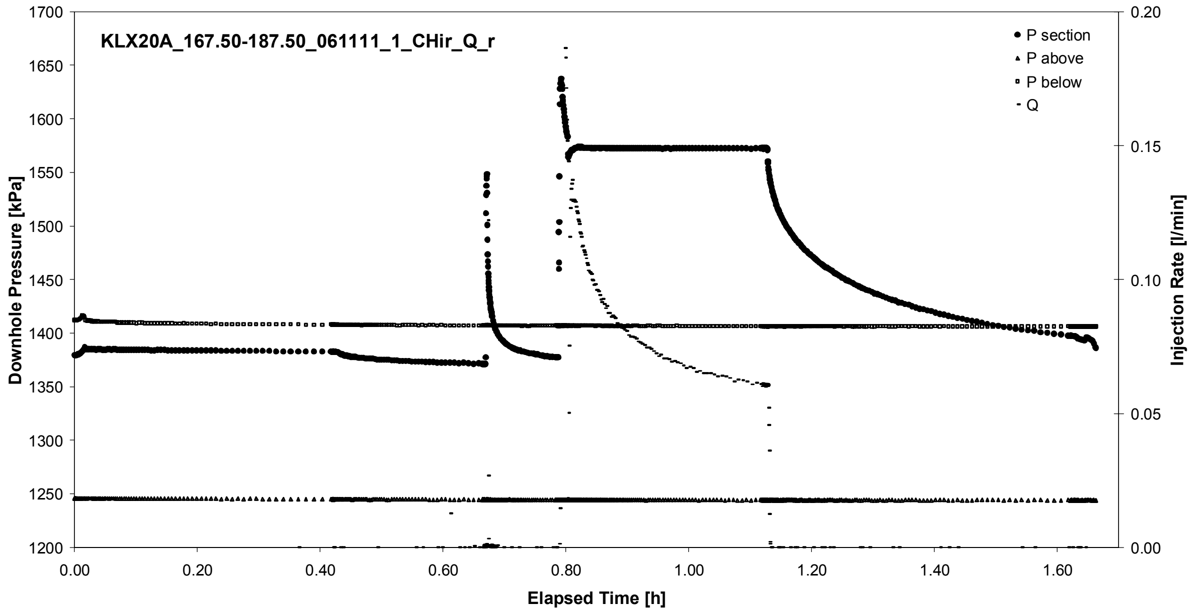
Not analysable

CHIR phase; HORNER match

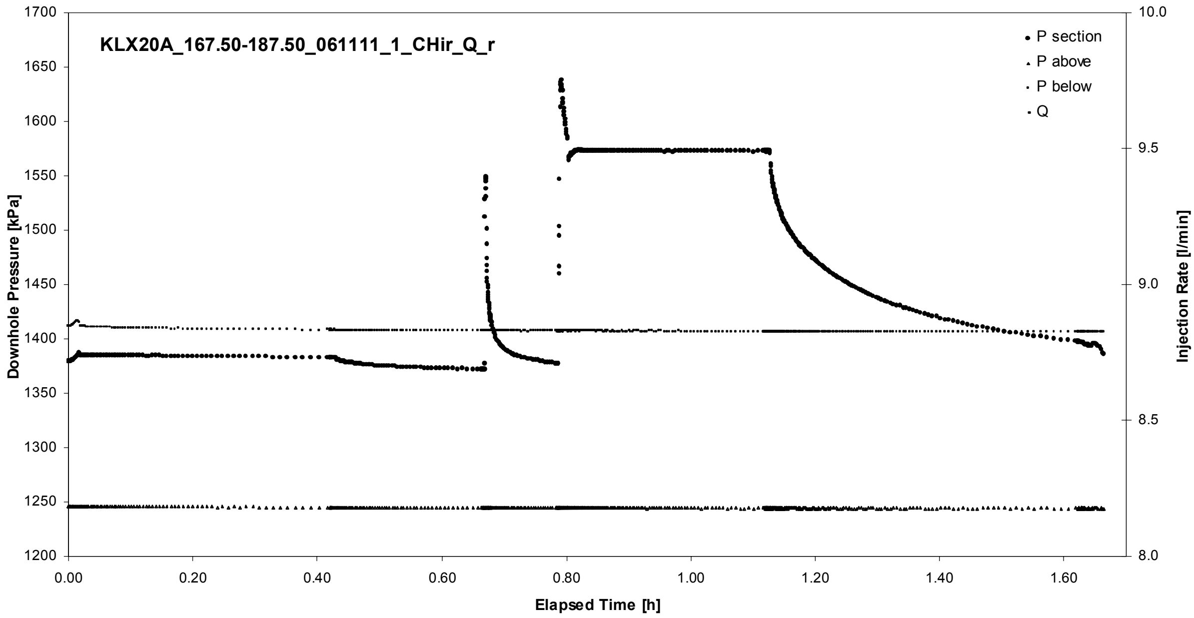
APPENDIX 2-9

Test 167.50 – 187.50 m

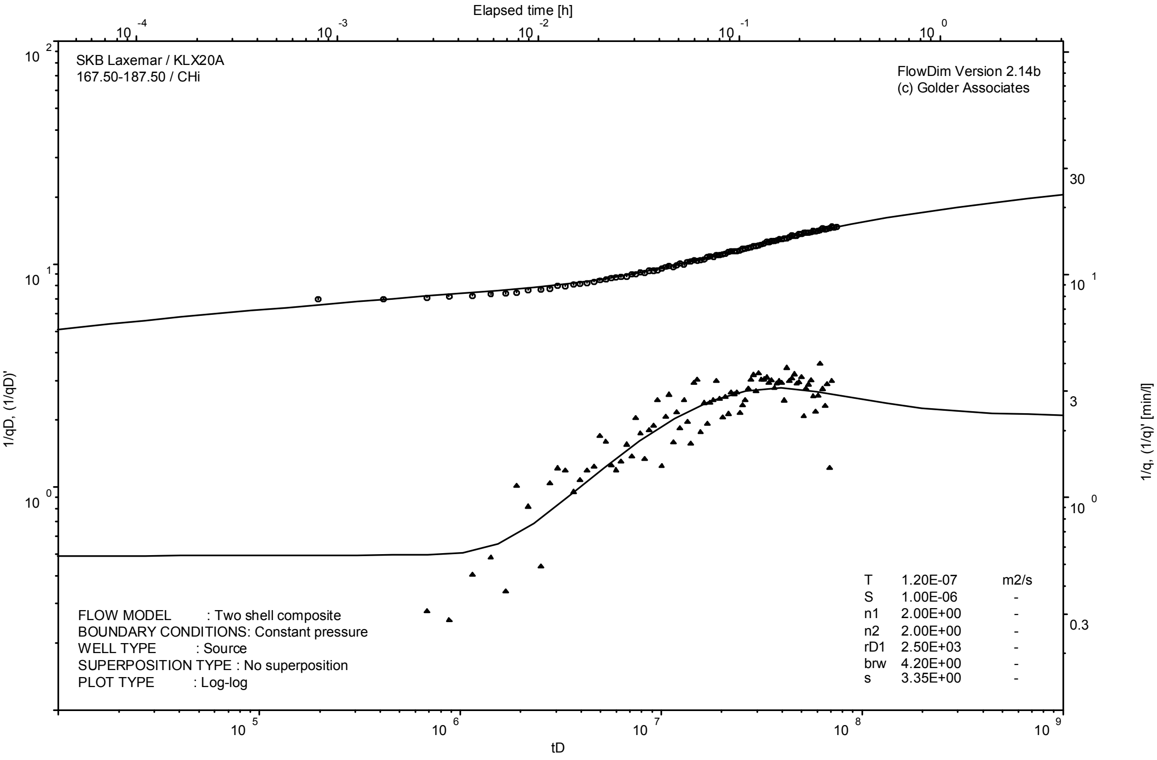
Analysis diagrams



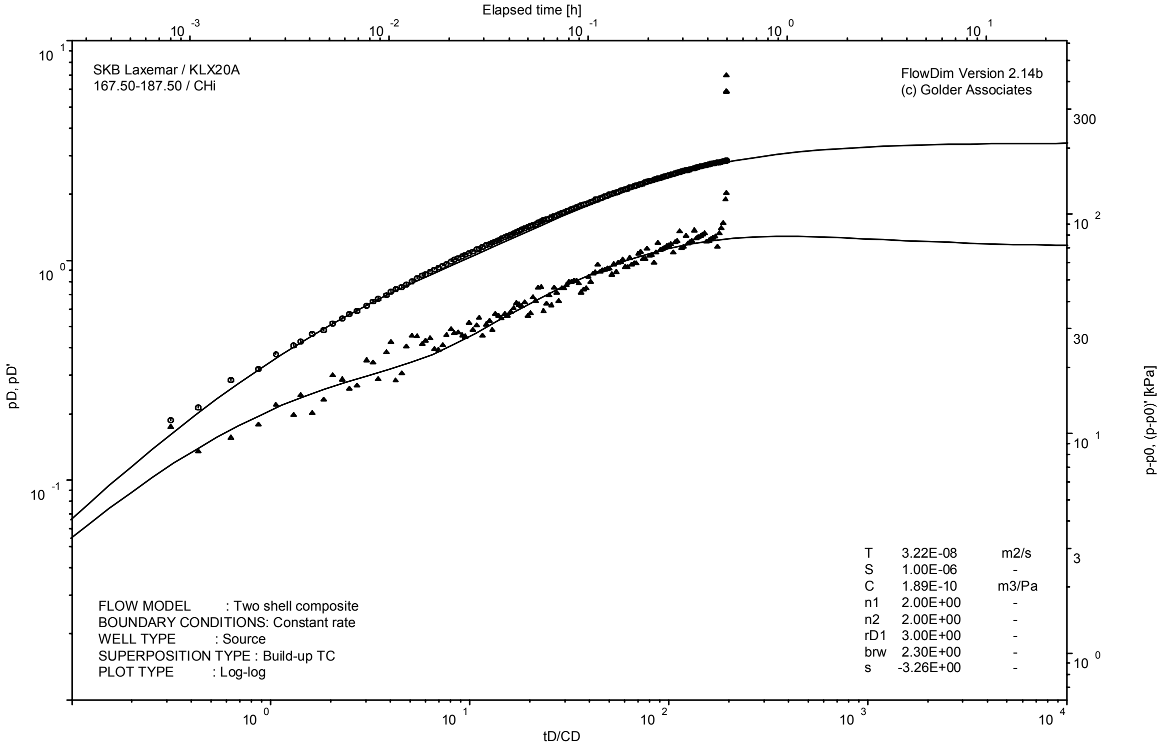
Pressure and flow rate vs. time; cartesian plot



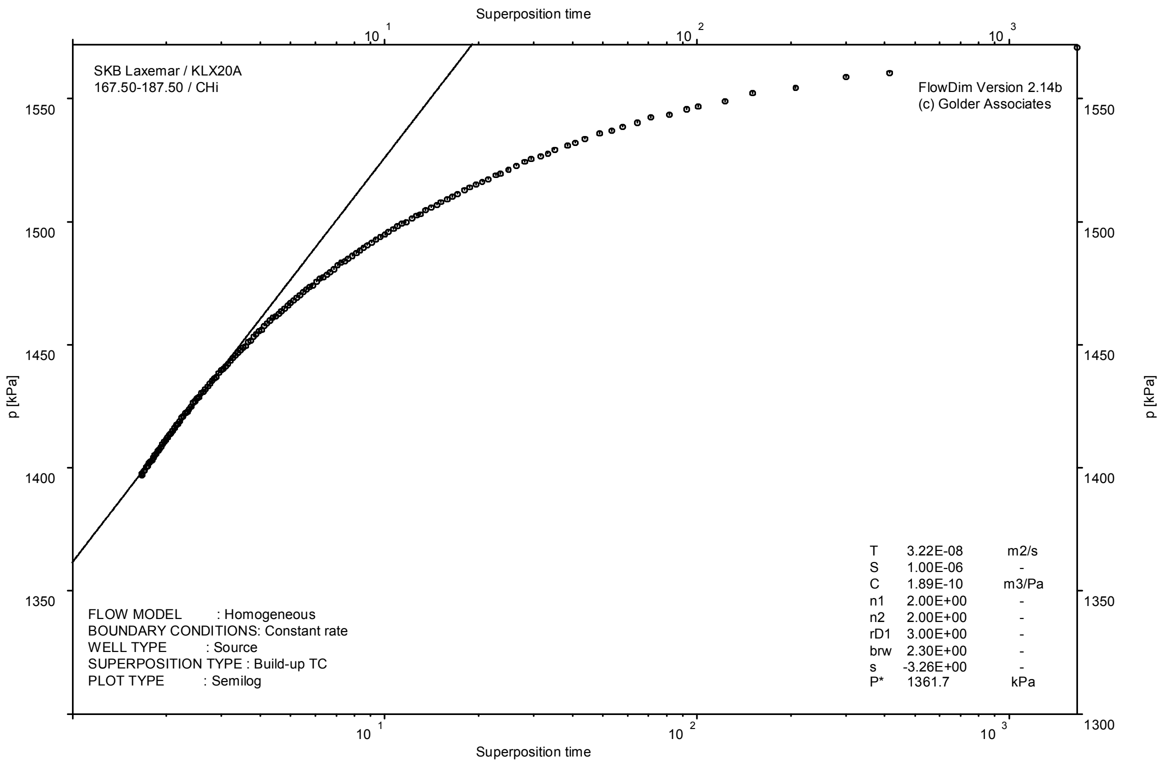
Interval pressure and temperature vs. time; cartesian plot



CHI phase; log-log match



CHIR phase; log-log match

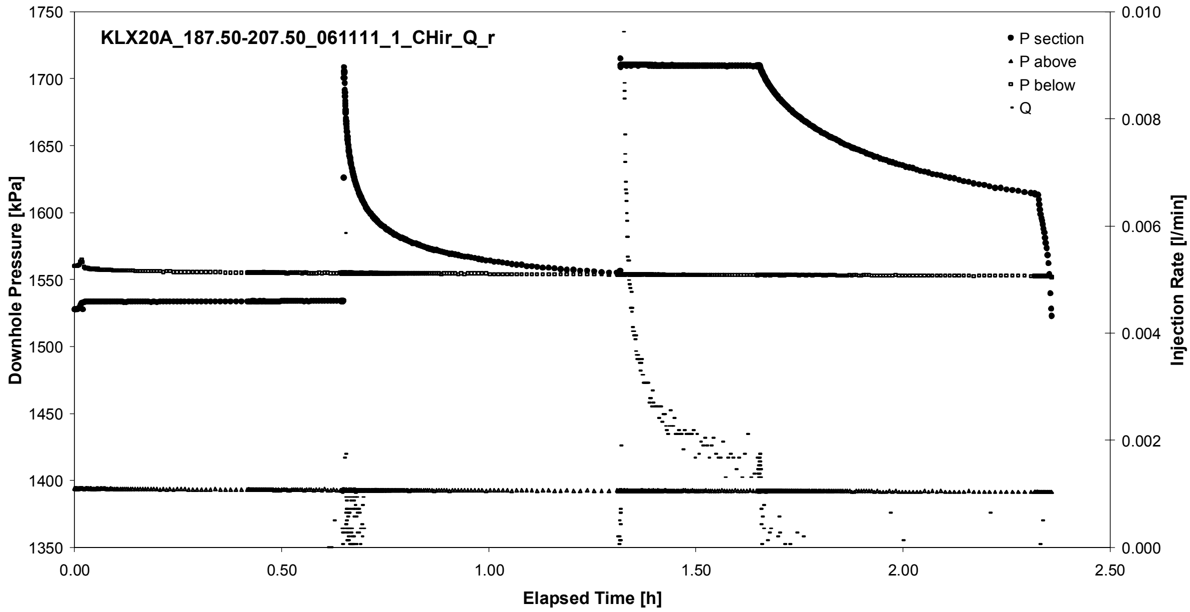


CHIR phase; HORNER match

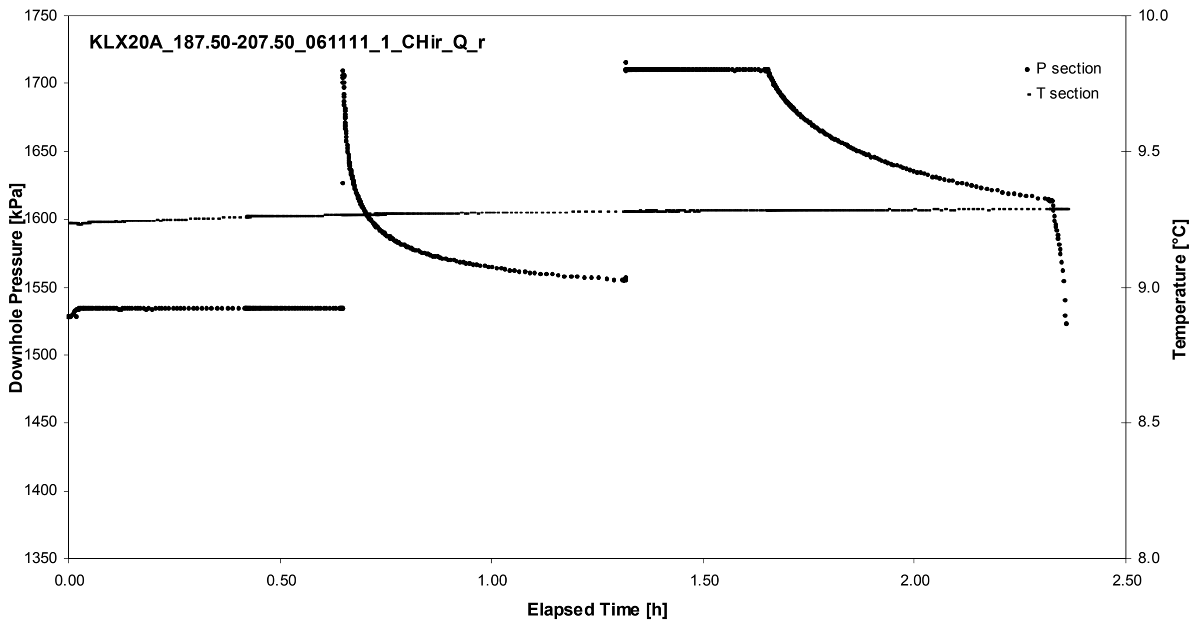
APPENDIX 2-10

Test 187.50 – 207.50 m

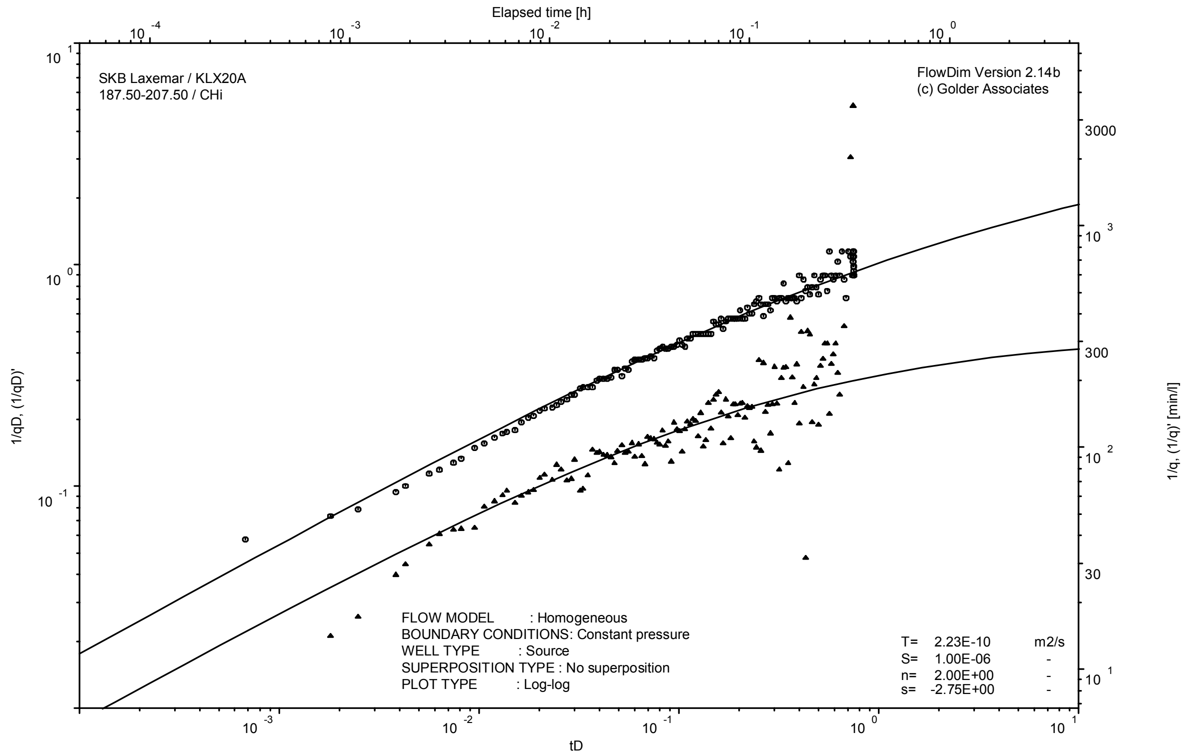
Analysis diagrams



Pressure and flow rate vs. time; cartesian plot

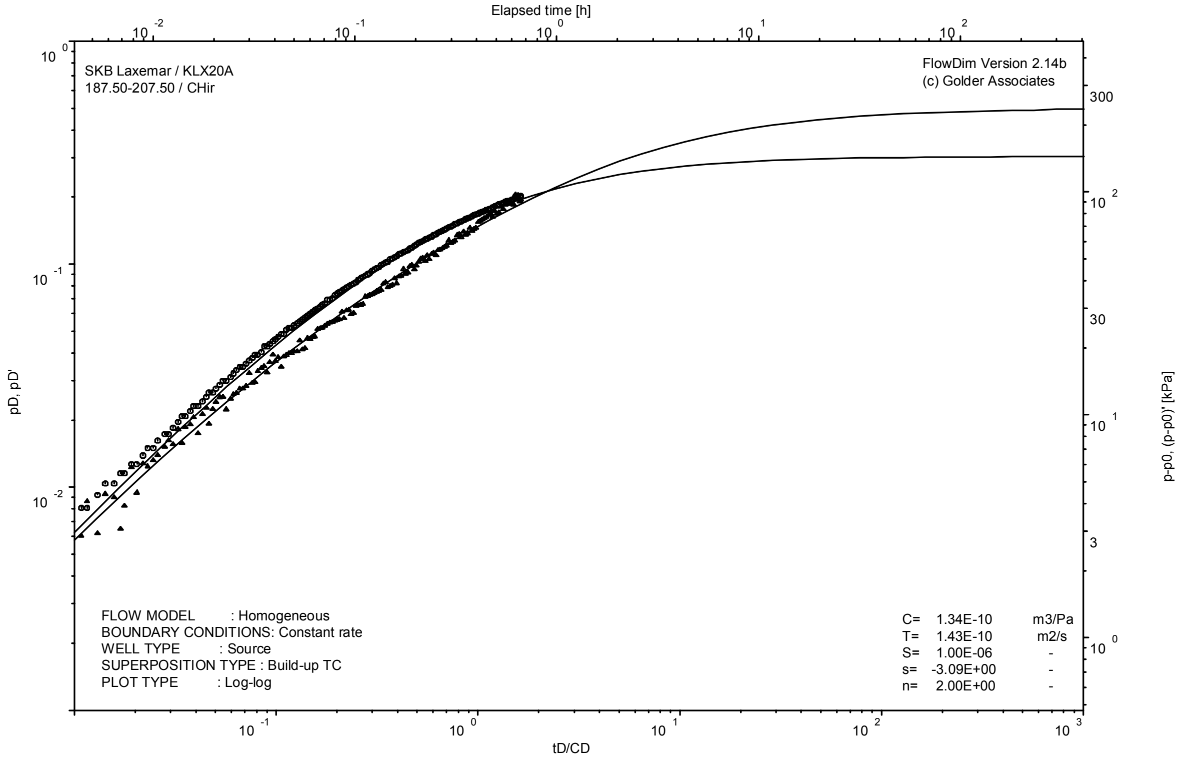


Interval pressure and temperature vs. time; cartesian plot



CHI phase; log-log match

Not analysable



CHIR phase; log-log match

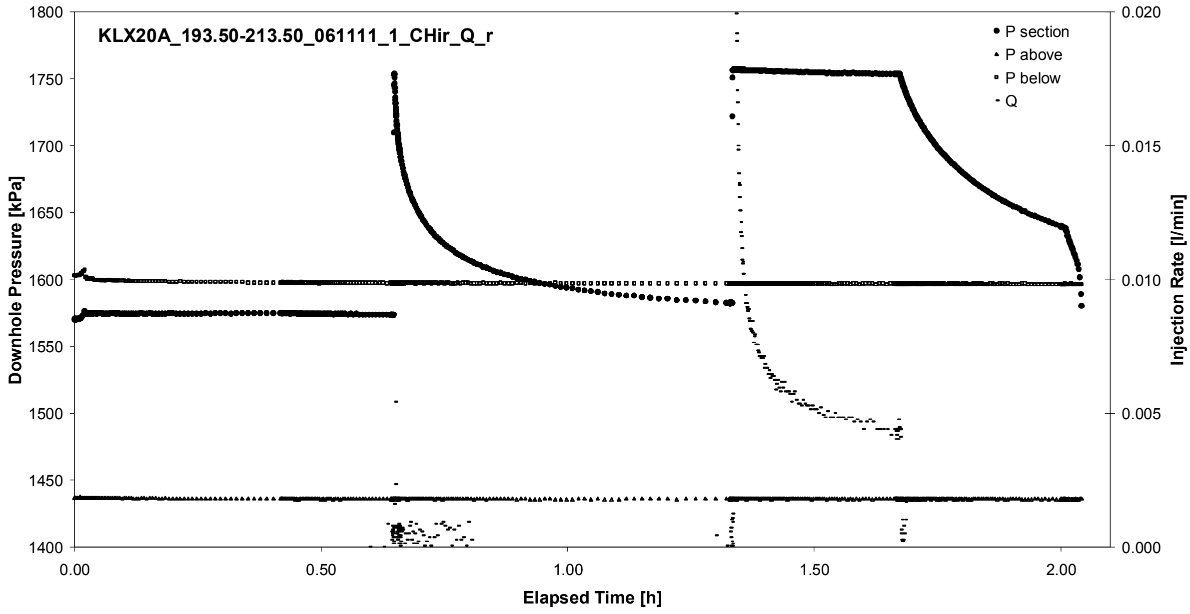
Not analysable

CHIR phase; HORNER match

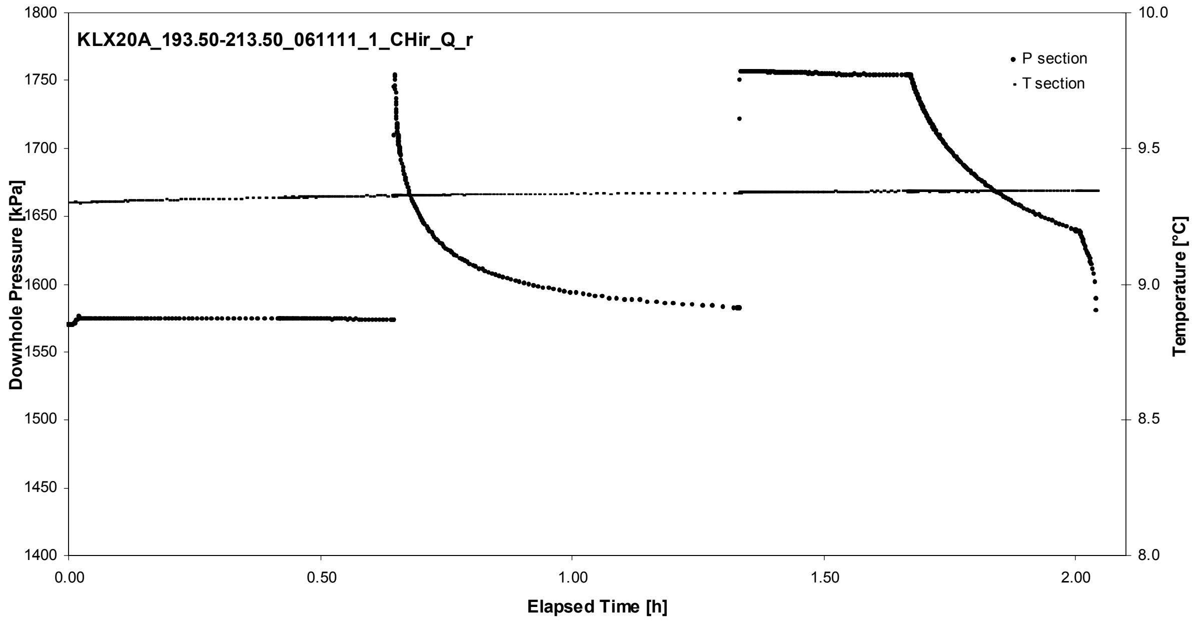
APPENDIX 2-11

Test 193.50 – 213.50 m

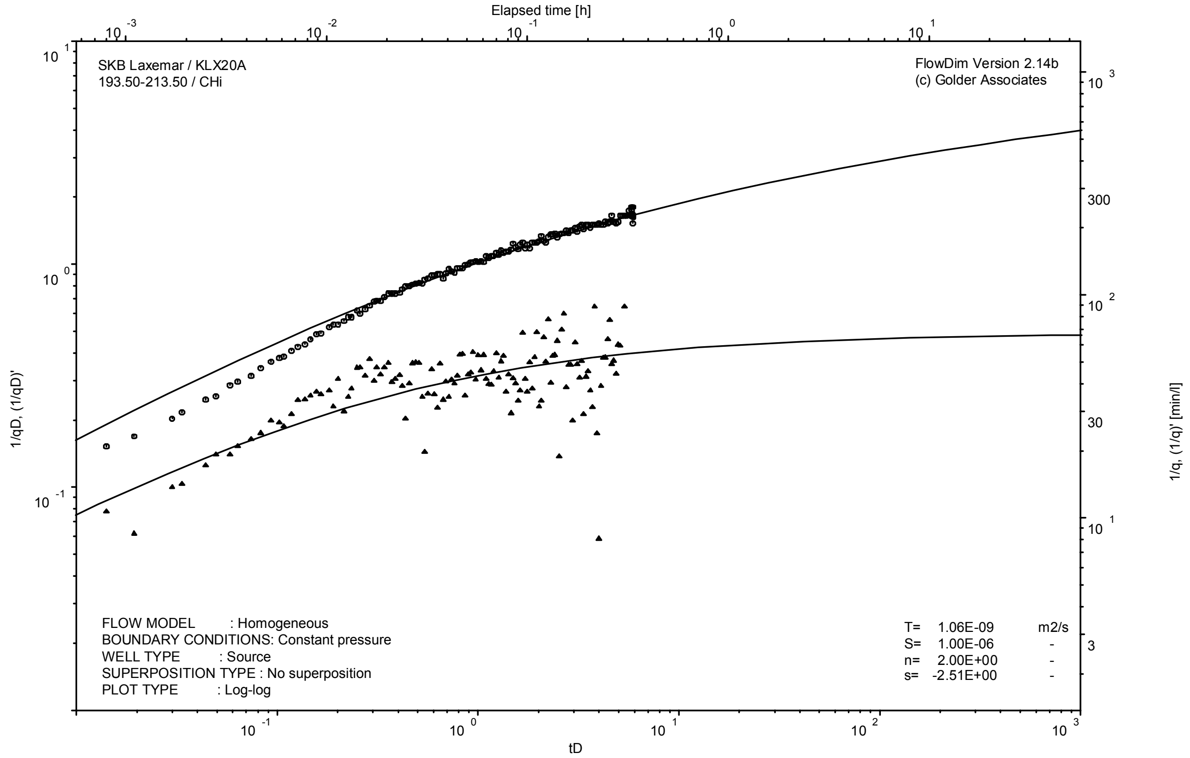
Analysis diagrams



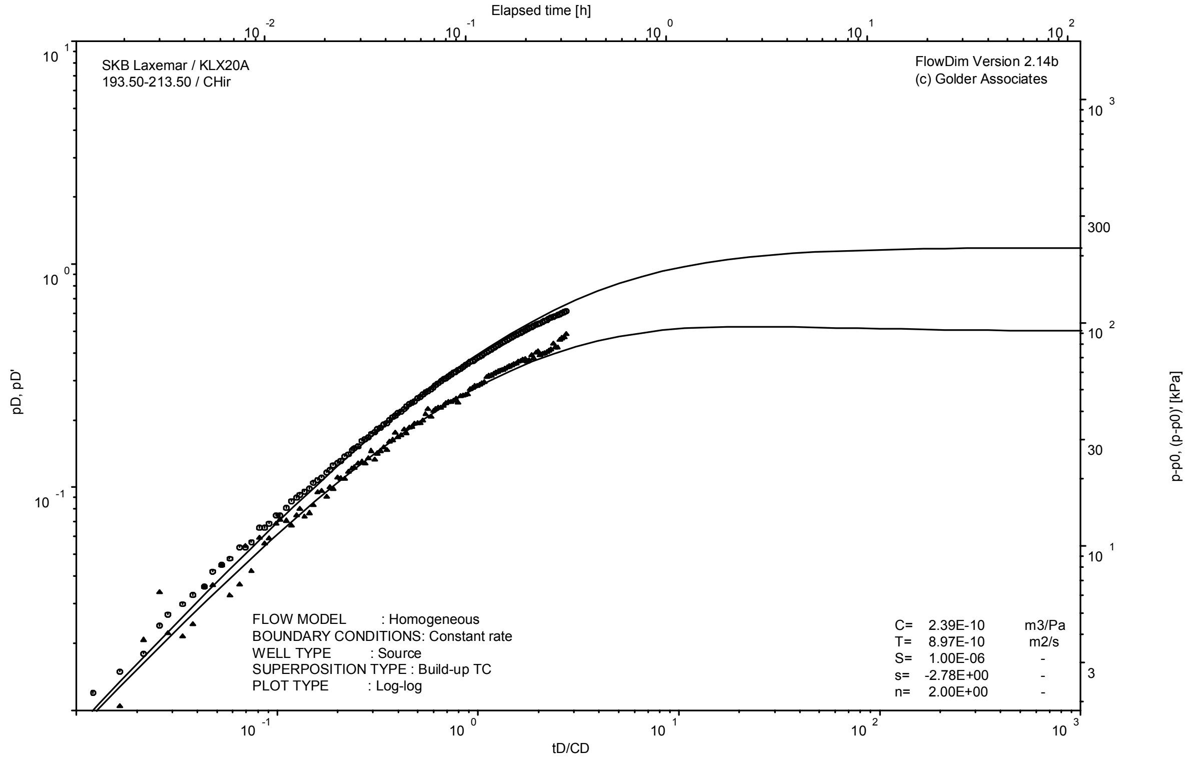
Pressure and flow rate vs. time; cartesian plot



Interval pressure and temperature vs. time; cartesian plot



CHI phase; log-log match



CHIR phase; log-log match

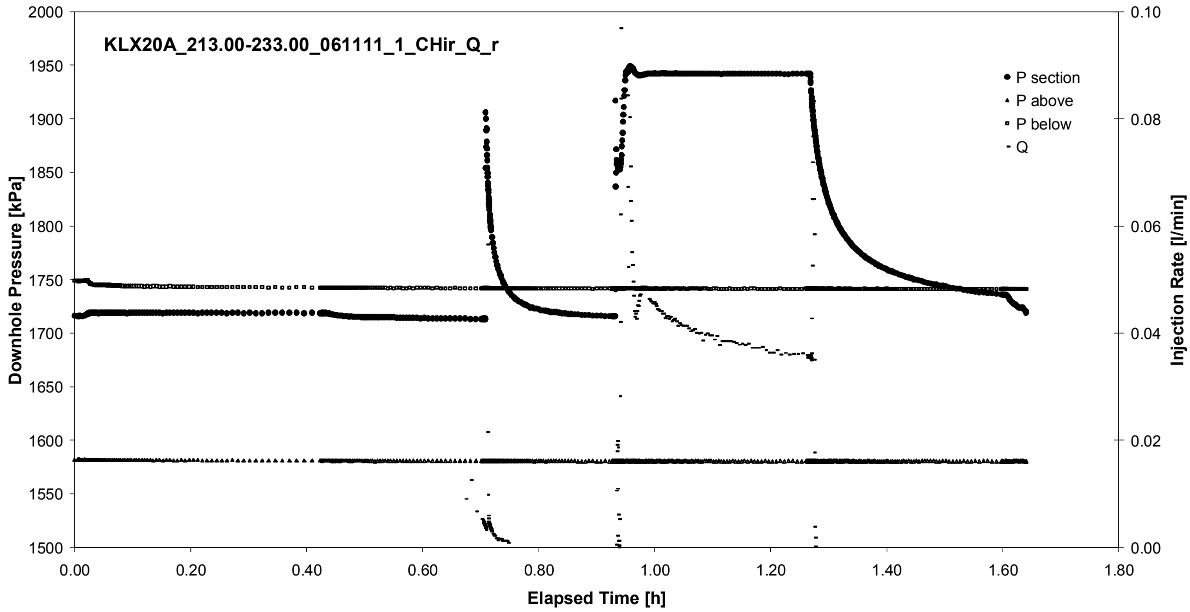
Not analysable

CHIR phase; HORNER match

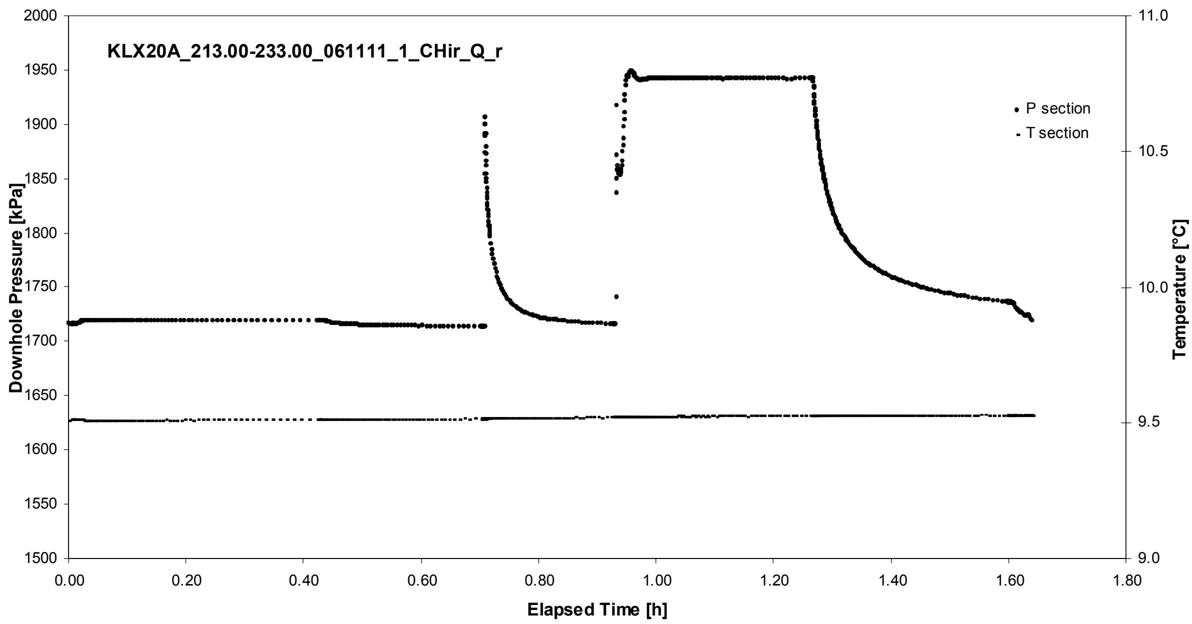
APPENDIX 2-12

Test 213.00 – 233.00 m

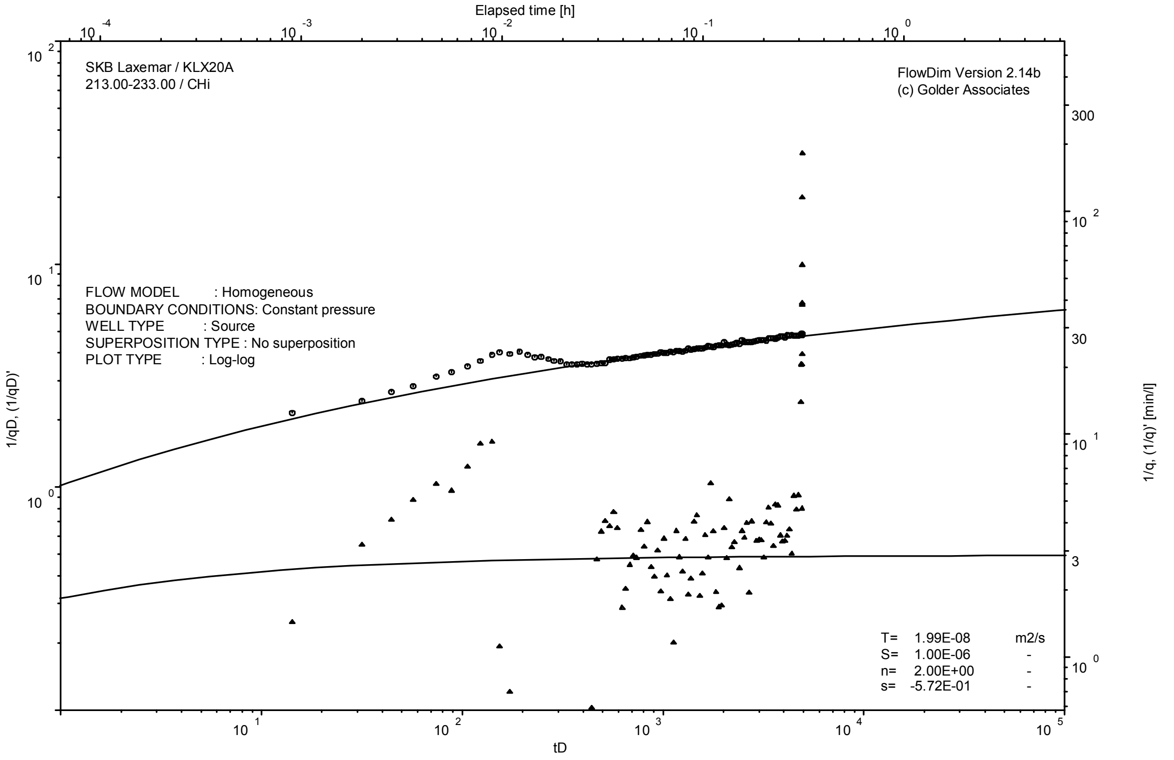
Analysis diagrams



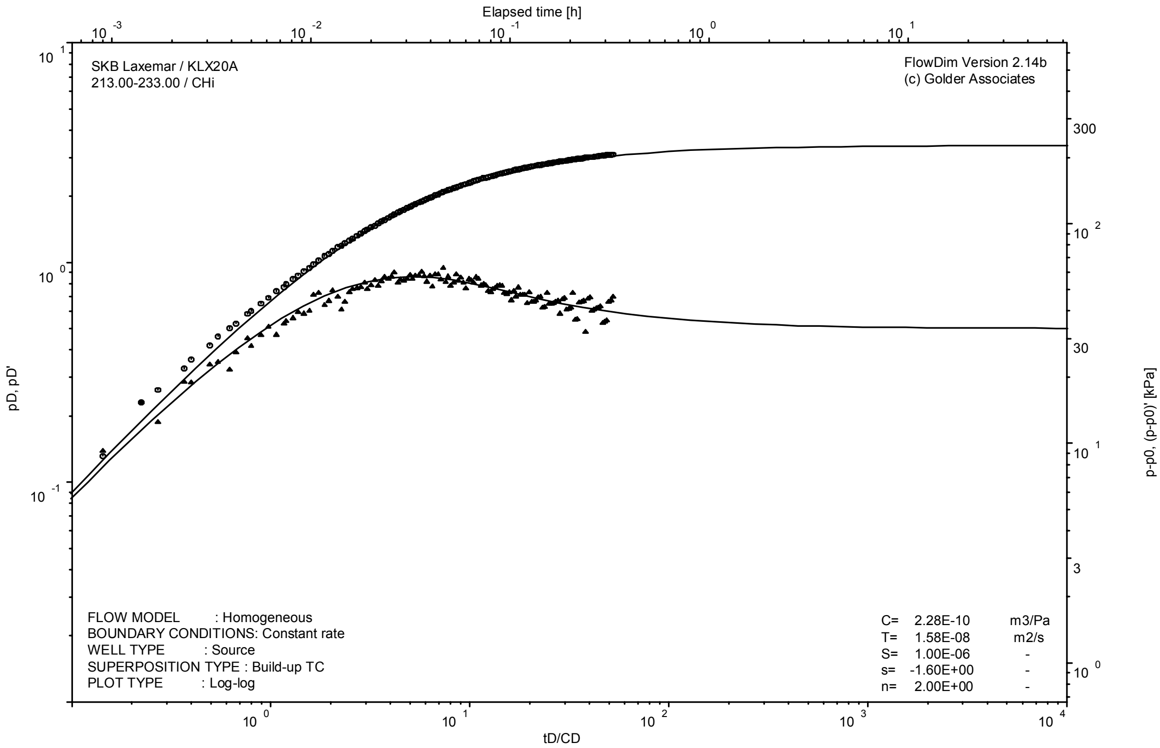
Pressure and flow rate vs. time; cartesian plot



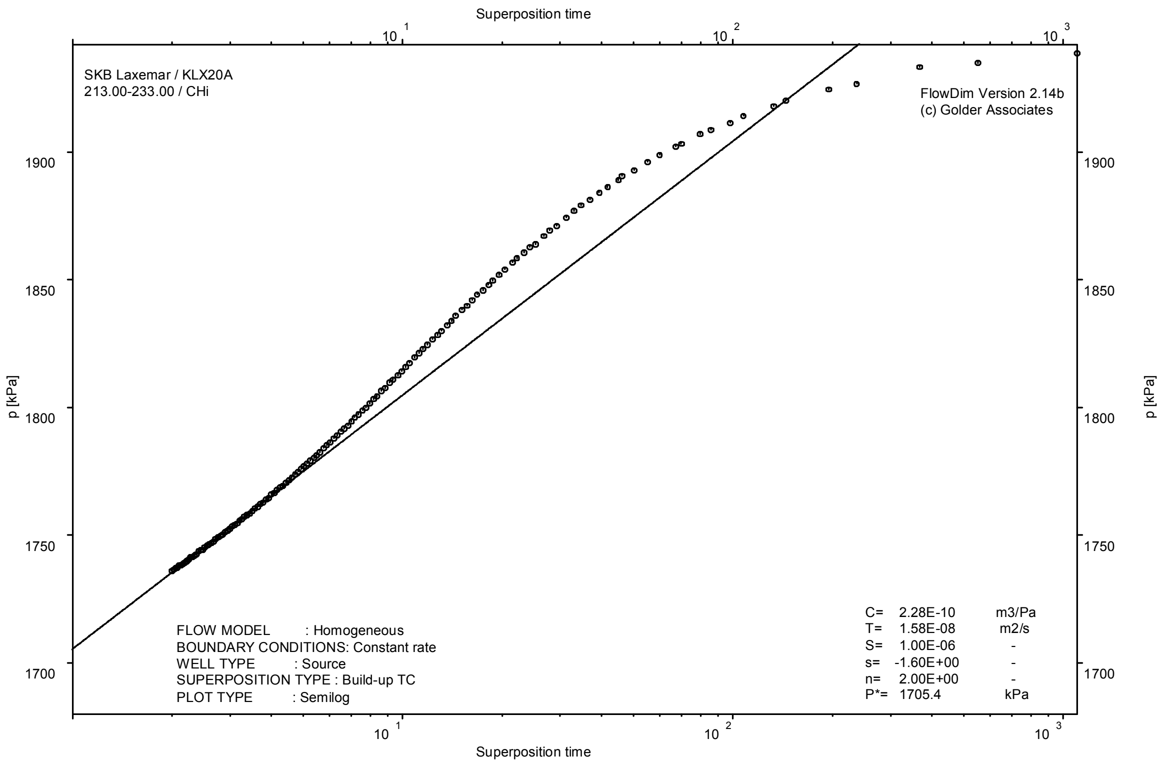
Interval pressure and temperature vs. time; cartesian plot



CHI phase; log-log match



CHIR phase; log-log match

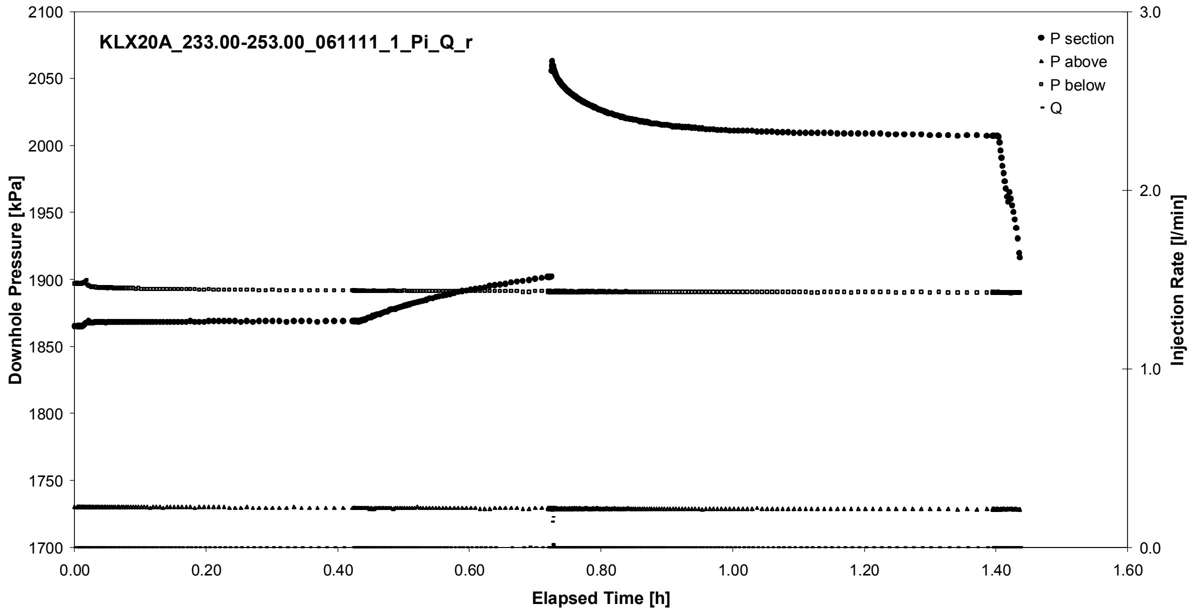


CHIR phase; HORNER match

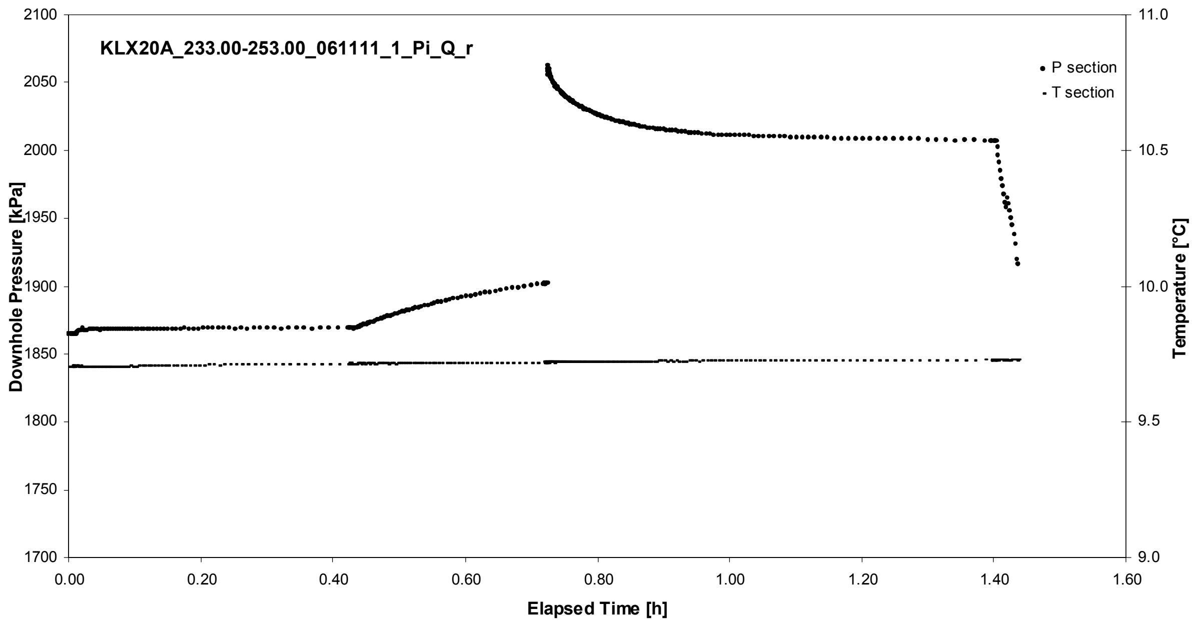
APPENDIX 2-13

Test 233.00 – 253.00 m

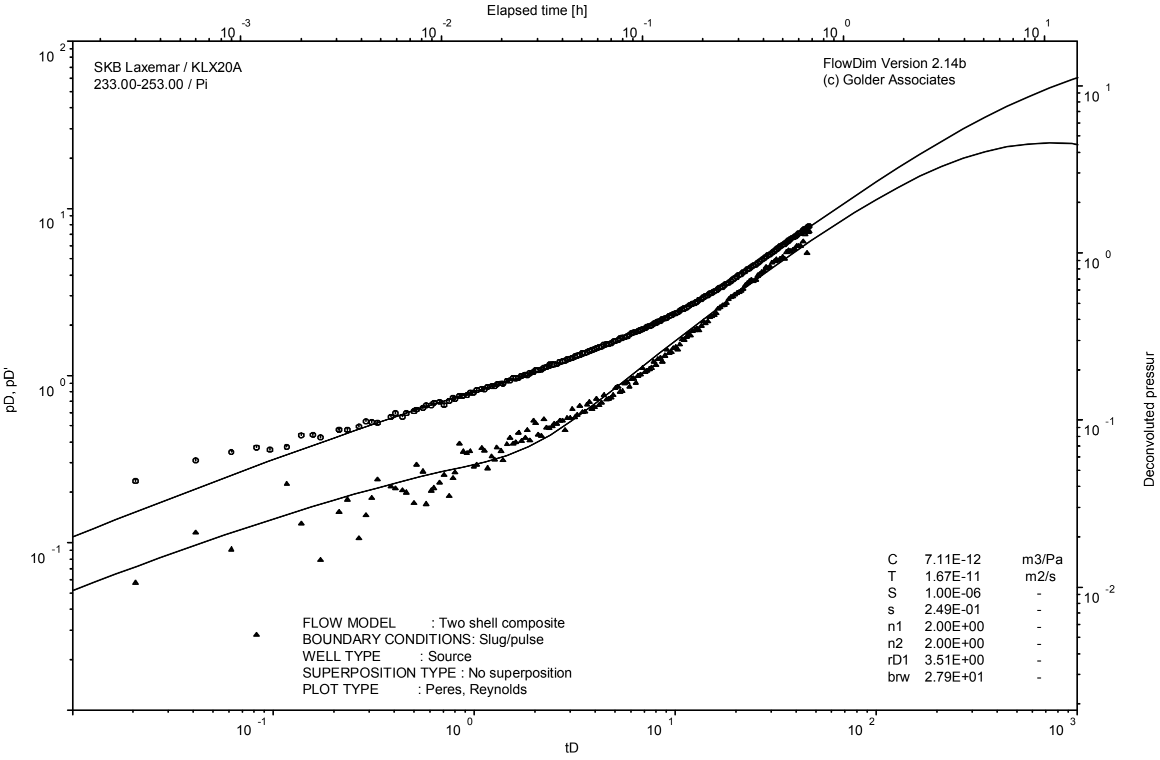
Analysis diagrams



Pressure and flow rate vs. time; cartesian plot



Interval pressure and temperature vs. time; cartesian plot

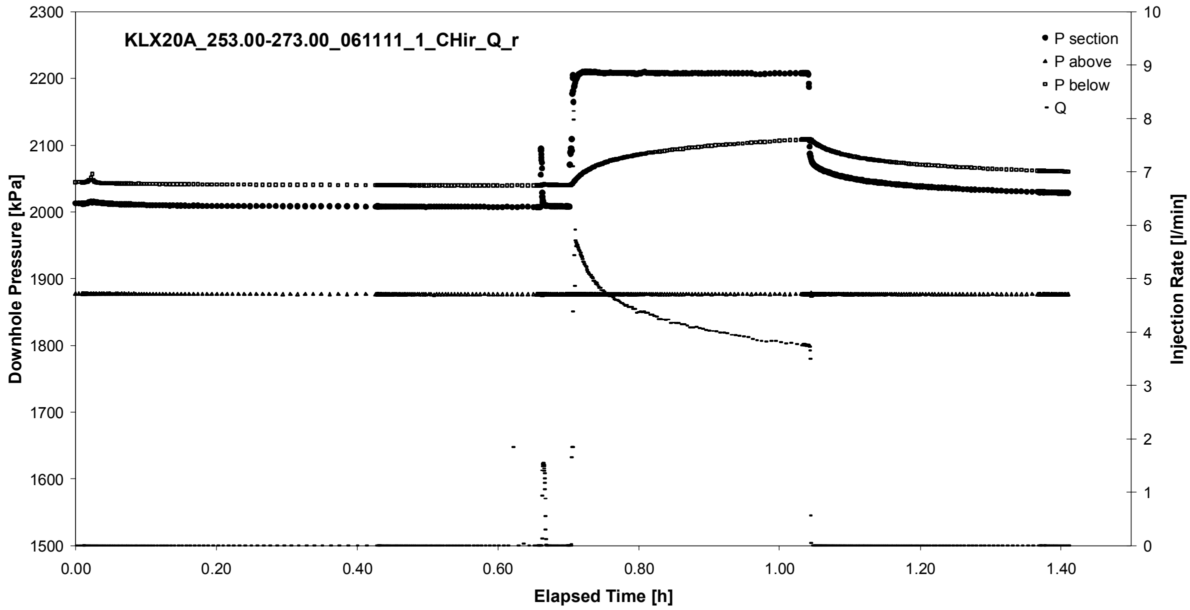


Pulse injection; deconvolution plot

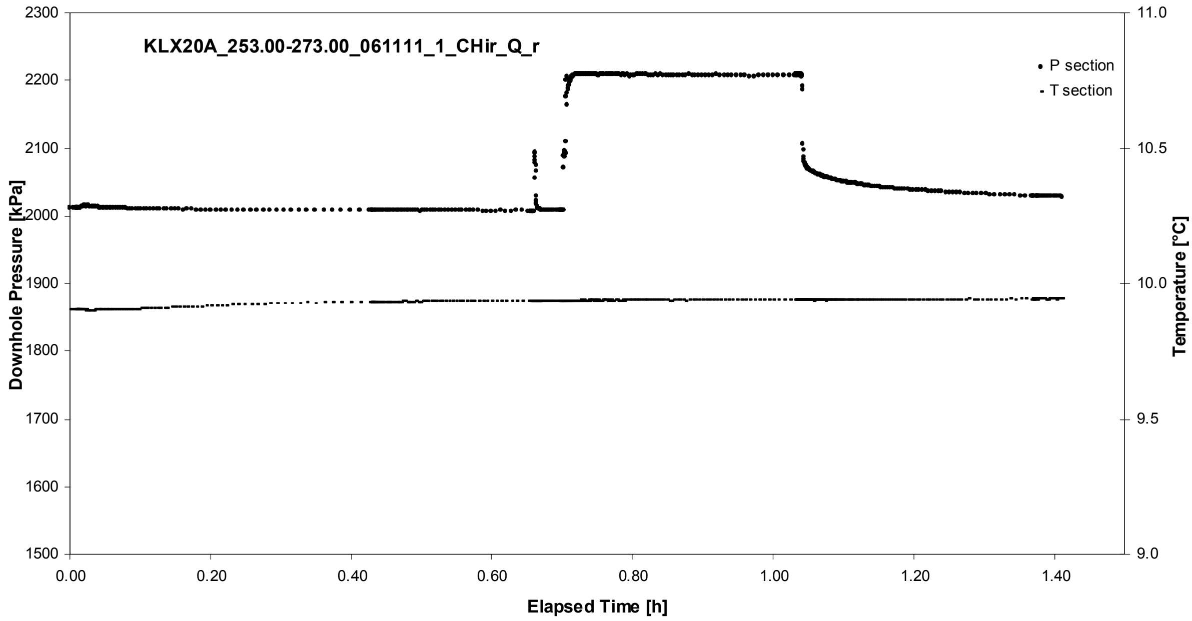
APPENDIX 2-14

Test 253.00 – 273.00 m

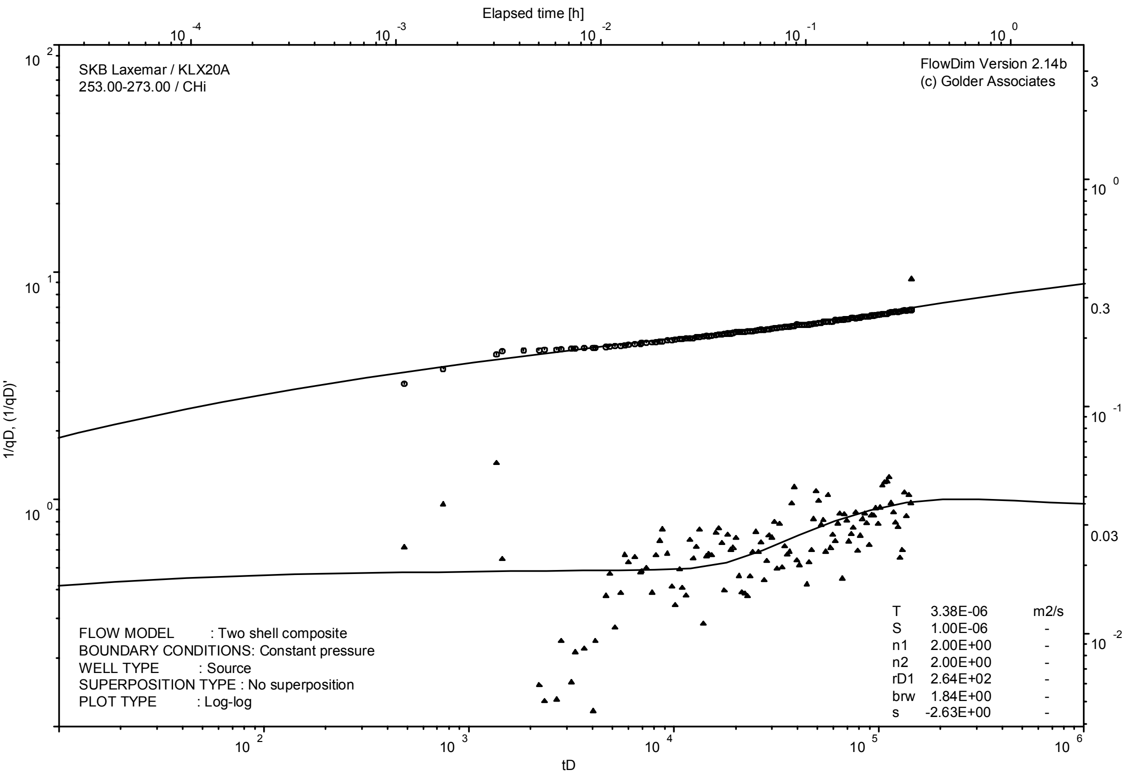
Analysis diagrams



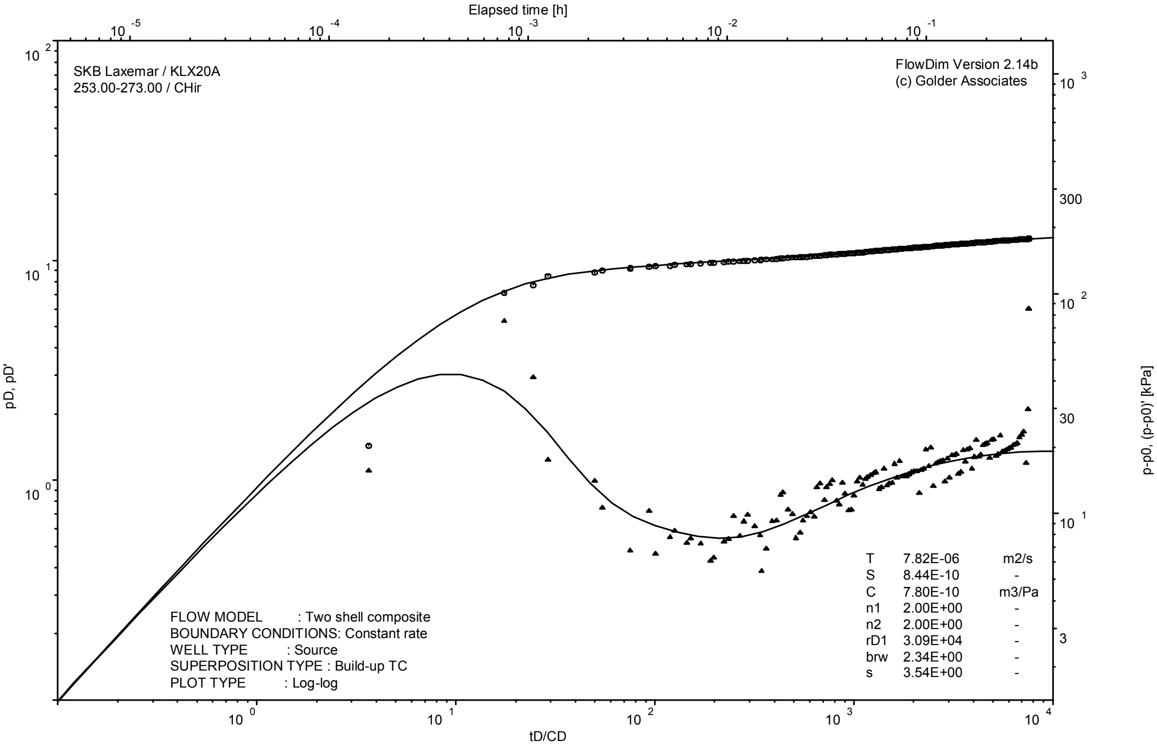
Pressure and flow rate vs. time; cartesian plot



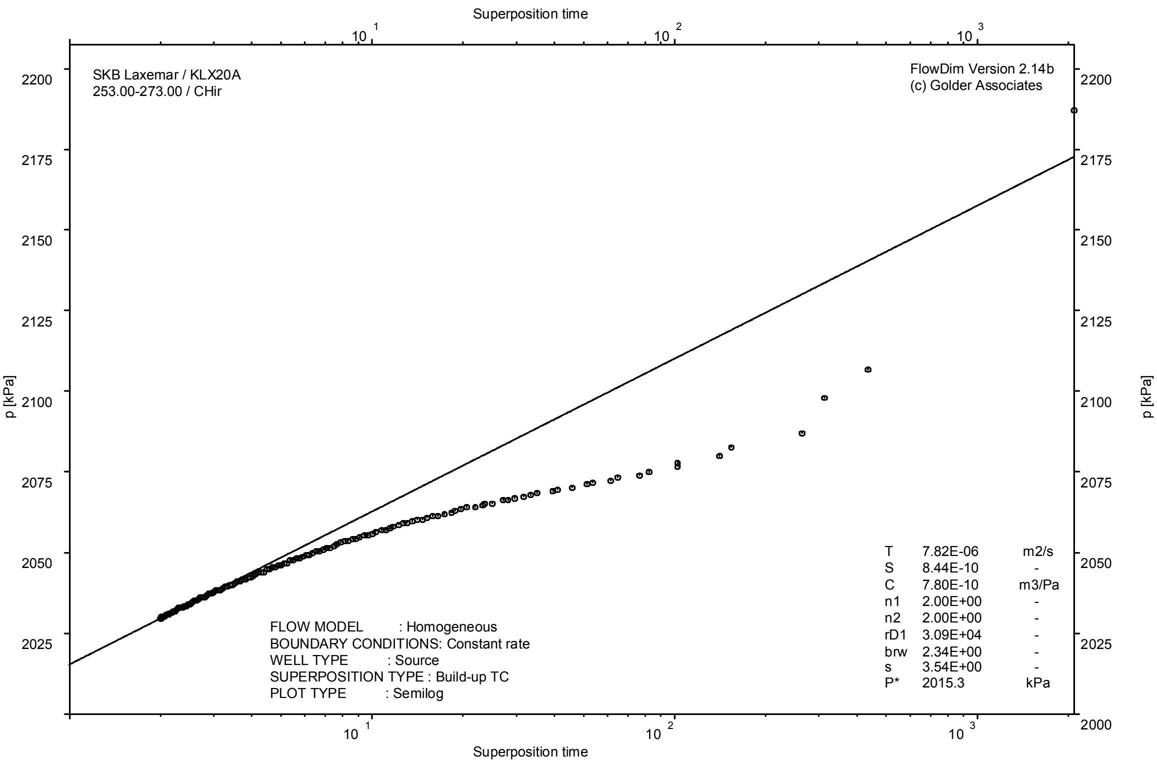
Interval pressure and temperature vs. time; cartesian plot



CHI phase; log-log match



CHIR phase; log-log match

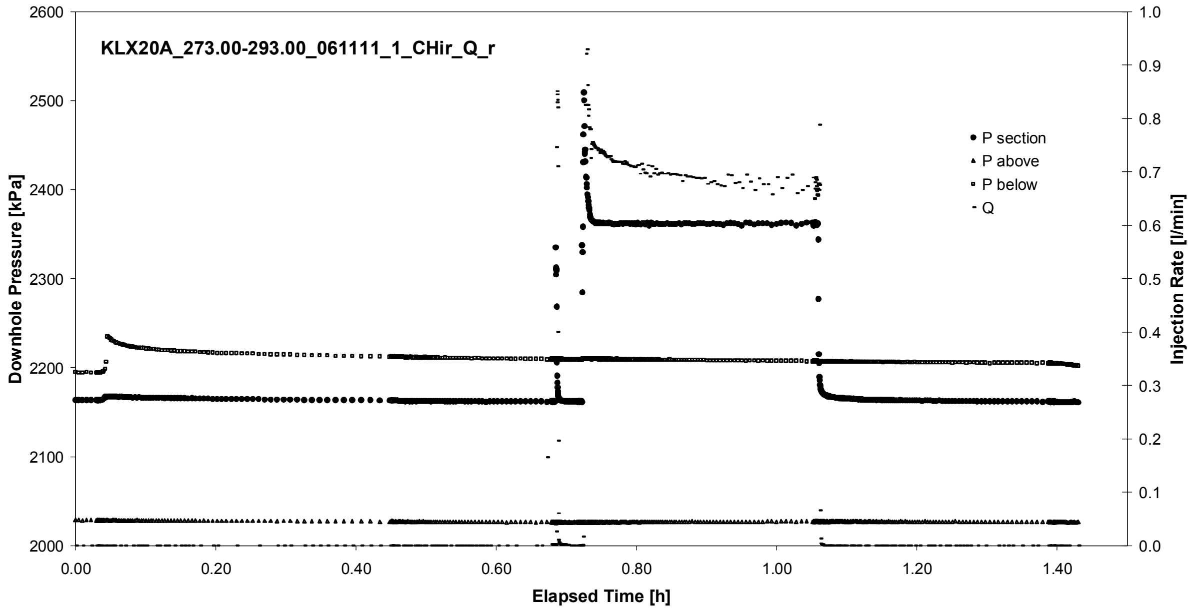


CHIR phase; HORNER match

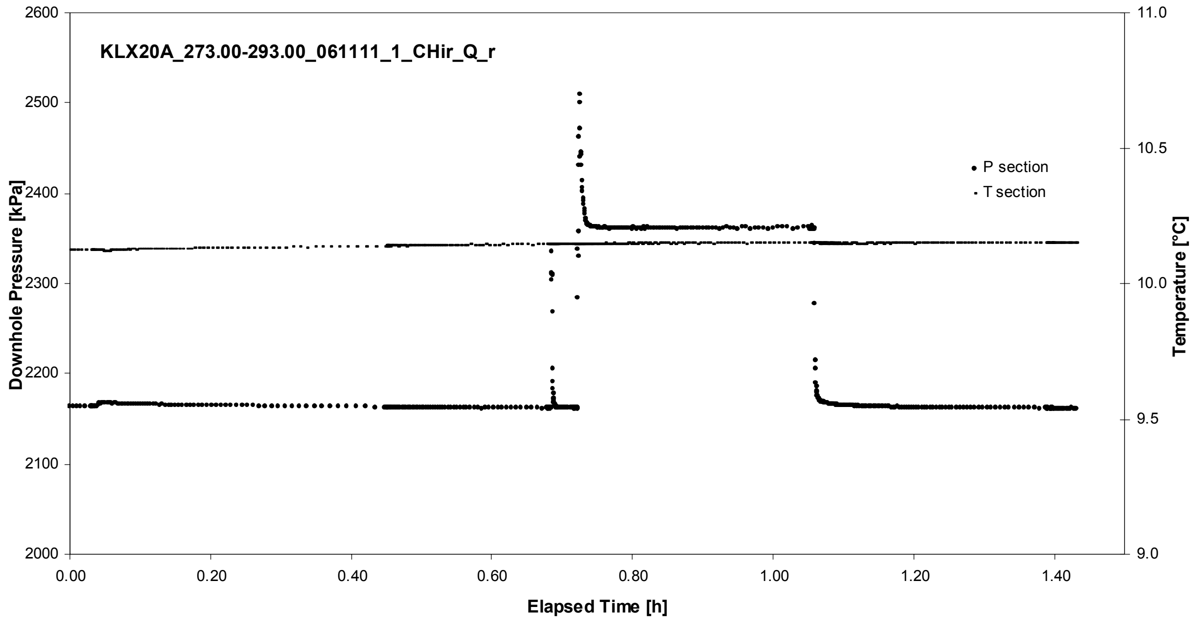
APPENDIX 2-15

Test 273.00 – 293.00 m

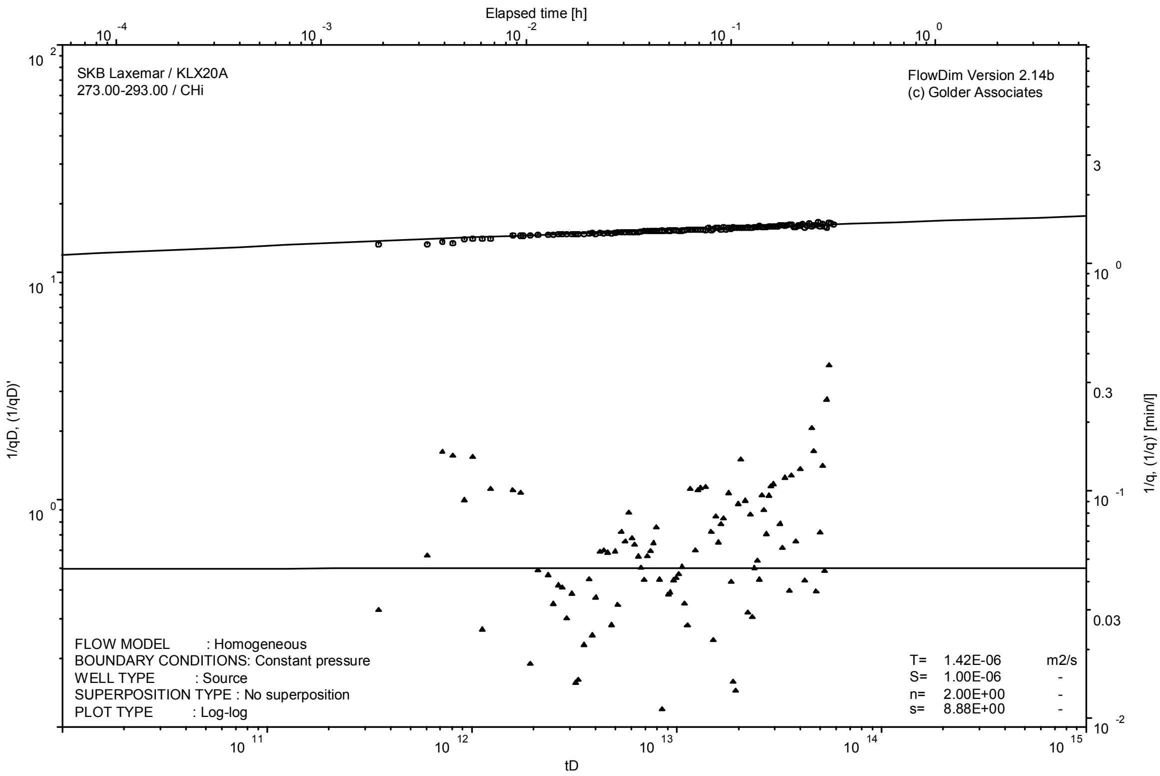
Analysis diagrams



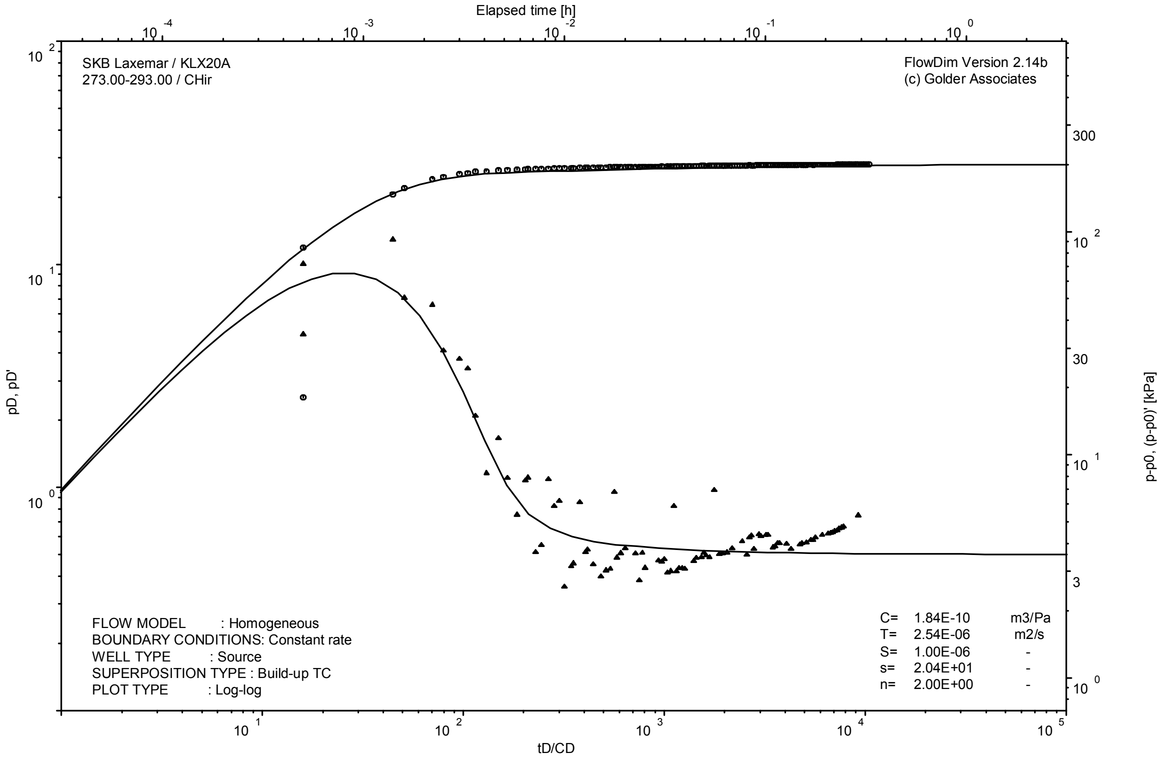
Pressure and flow rate vs. time; cartesian plot



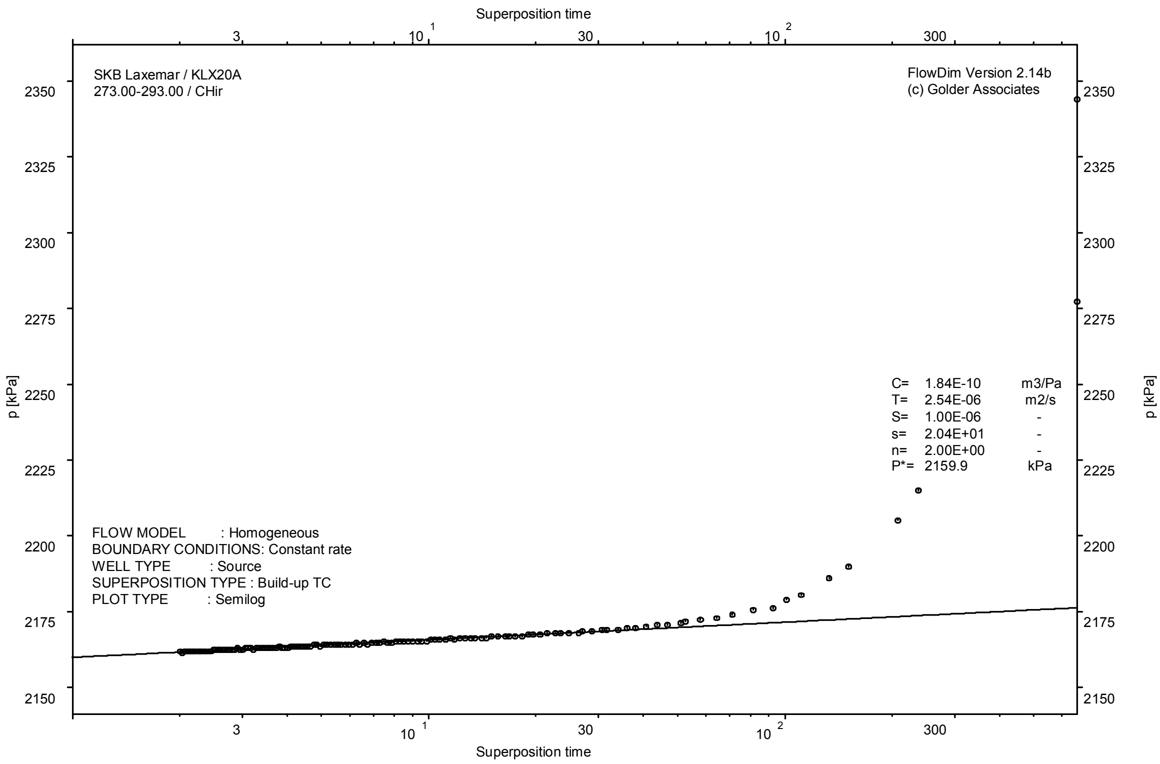
Interval pressure and temperature vs. time; cartesian plot



CHI phase; log-log match



CHIR phase; log-log match

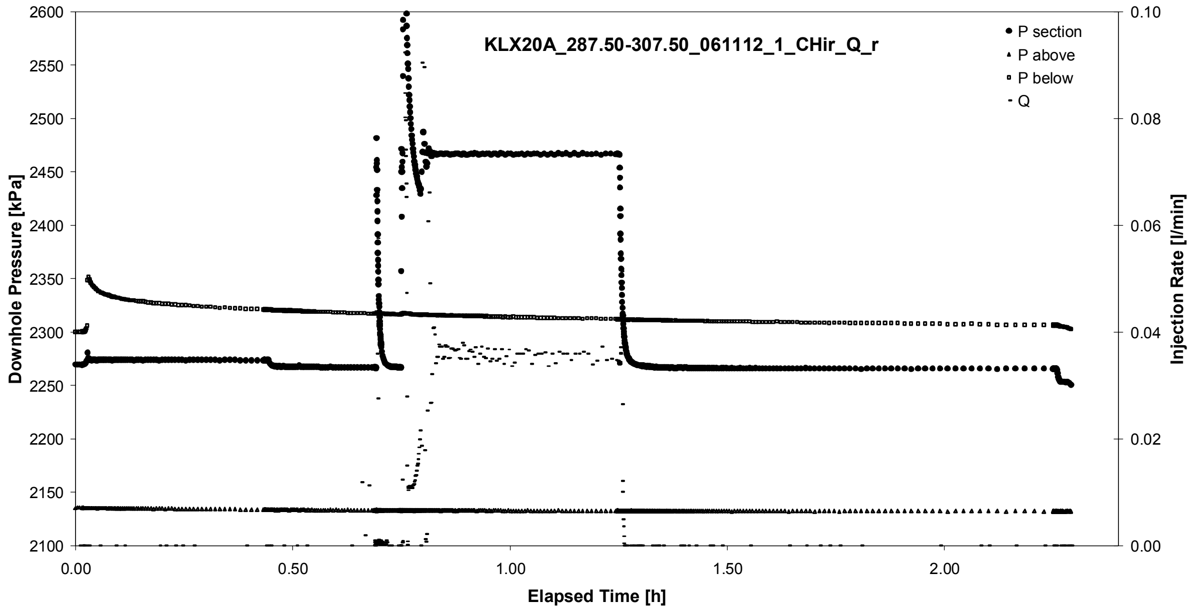


CHIR phase; HORNER match

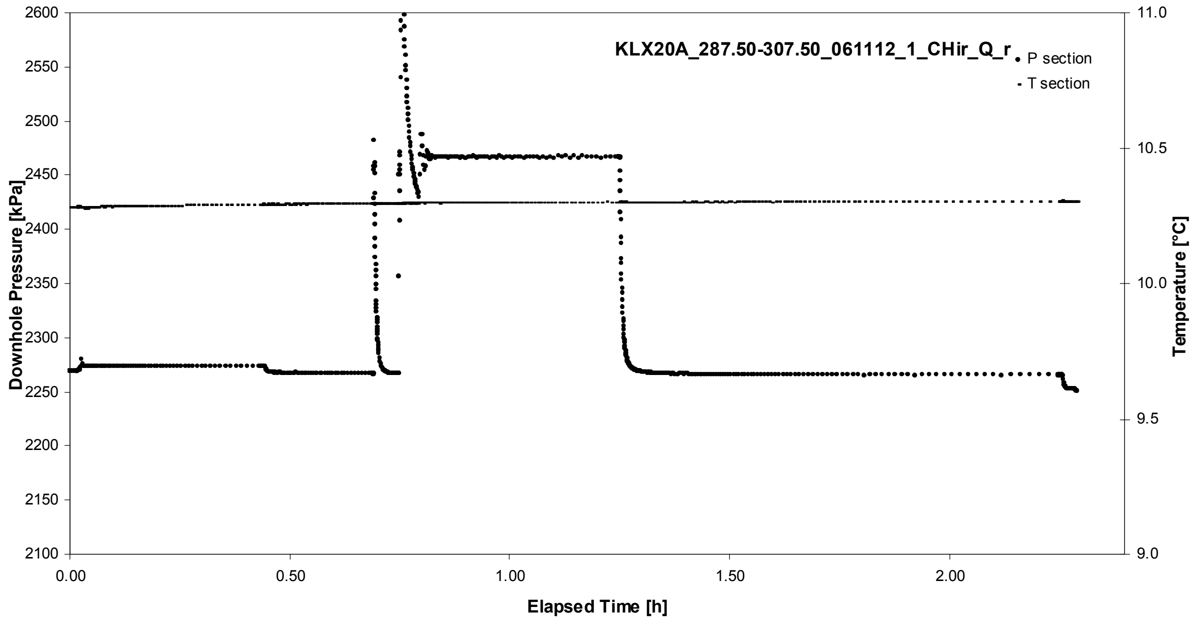
APPENDIX 2-16

Test 287.50 – 307.50 m

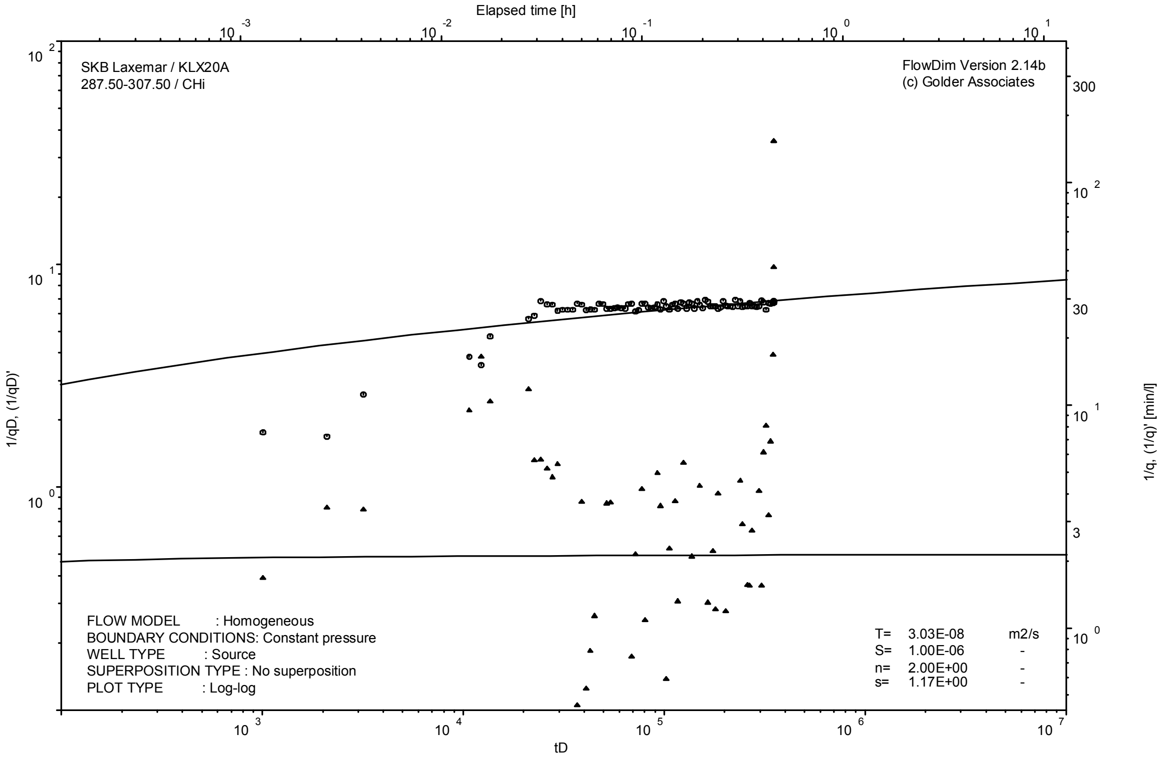
Analysis diagrams



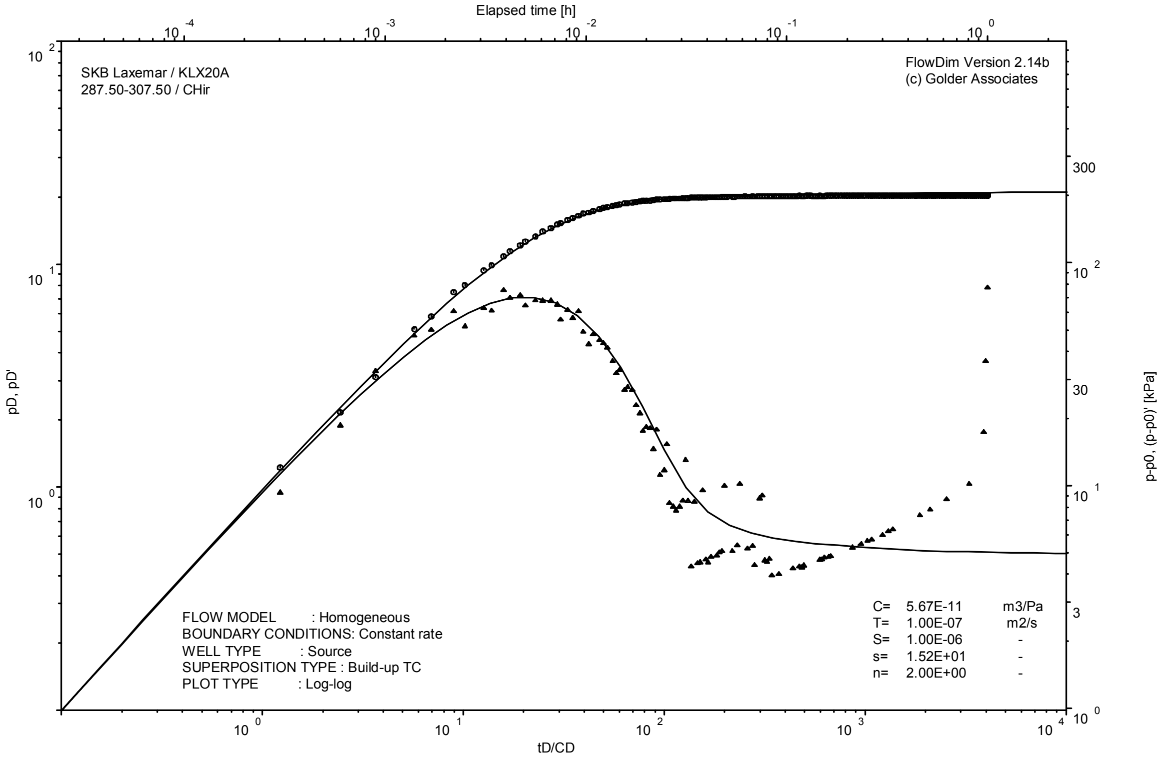
Pressure and flow rate vs. time; cartesian plot



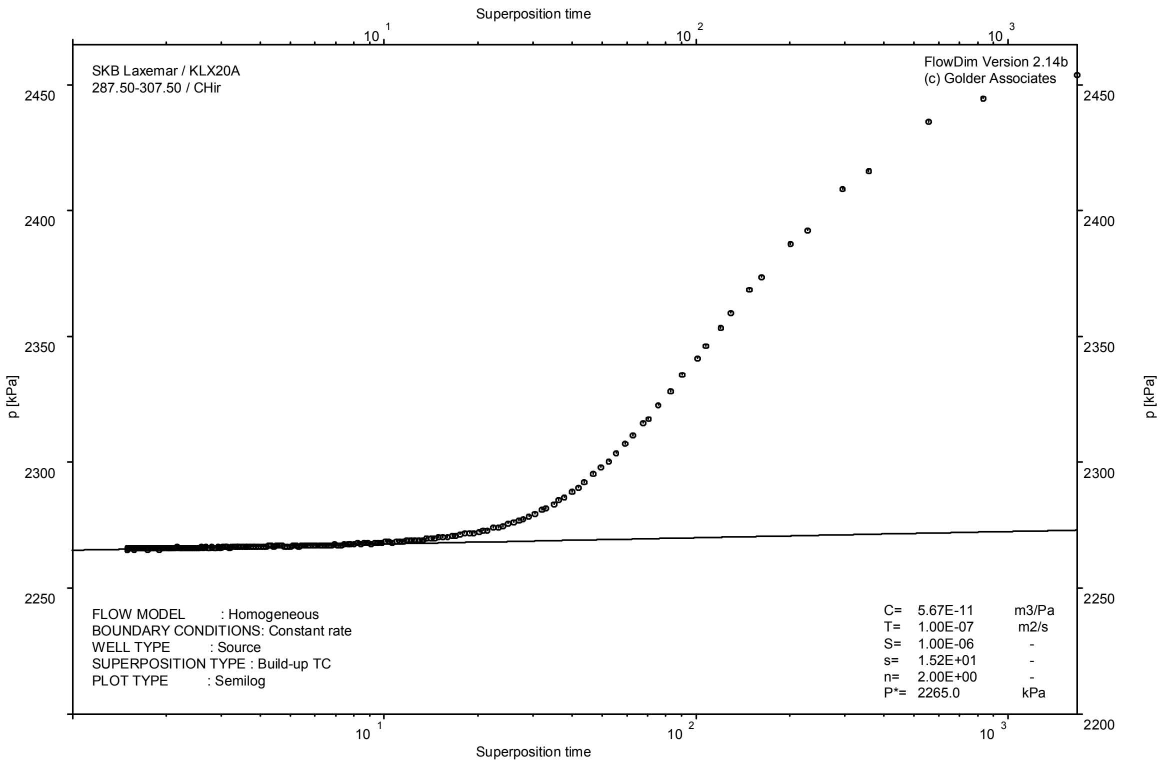
Interval pressure and temperature vs. time; cartesian plot



CHI phase; log-log match



CHIR phase; log-log match



CHIR phase; HORNER match

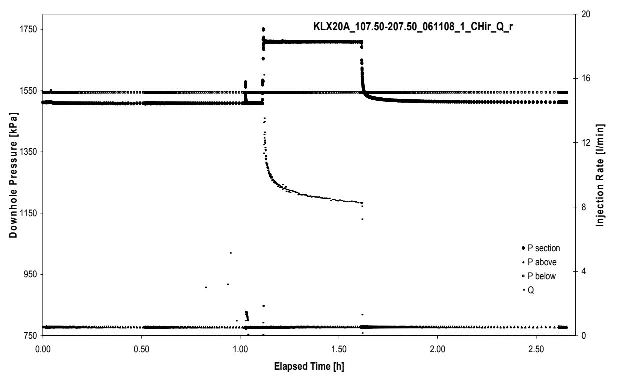
APPENDIX 3

Test Summary Sheets

Test Summary Sheet

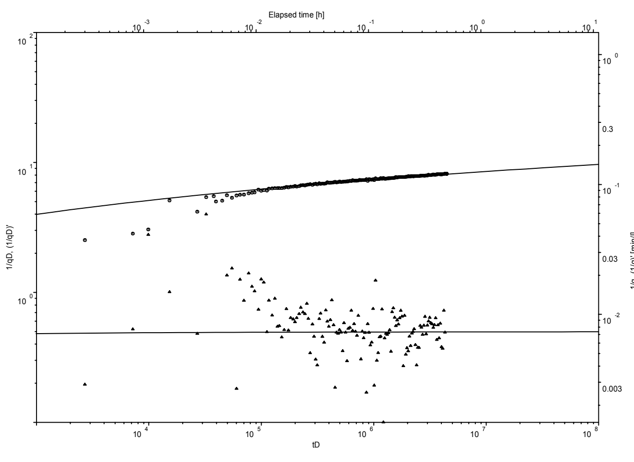
Project:	Oskarshamn site investigation	Test type:[1]	CHir
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061108 20:26
Test section from - to (m):	107.50-127.50 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

Linear plot Q and p

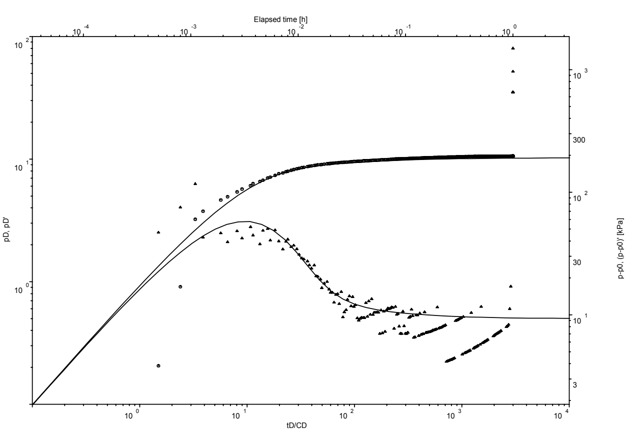


Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa) =	1511		
p_i (kPa) =	1509		
p_p(kPa) =	1709	p_F (kPa) =	1511
Q_p (m^3/s)=	1.38E-04		
tp (s) =	1800	t_F (s) =	3600
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	9.3		
Derivative fact.=	0.06	Derivative fact.=	0.03
Results		**Results**	
Q/s (m^2/s)=	6.8E-06		
T_M (m^2/s)=	8.8E-06		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	1.01	dt_1 (min) =	2.05
dt_2 (min) =	28.74	dt_2 (min) =	20.76
T (m^2/s) =	8.8E-06	T (m^2/s) =	1.3E-05
S (-) =	1.0E-06	S (-) =	1.0E-06
K_s (m/s) =	8.8E-08	K_s (m/s) =	1.3E-07
S_s (1/m) =	1.0E-08	S_s (1/m) =	1.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	9.6E-09
C_D (-) =	NA	C_D (-) =	1.1E+00
ξ (-) =	-0.5	ξ (-) =	2.3
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Selected representative parameters.			
dt_1 (min) =	2.05	C (m^3/Pa) =	9.6E-09
dt_2 (min) =	20.76	C_D (-) =	1.1E+00
T_T (m^2/s) =	1.3E-05	ξ (-) =	2.3
S (-) =	1.0E-06		
K_s (m/s) =	1.3E-07		
S_s (1/m) =	1.0E-08		

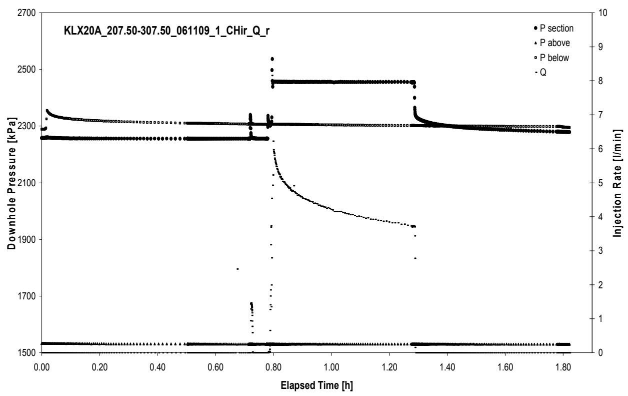
Comments:

The recommended transmissivity of 1.3E-5 m2/s was derived from the analysis of the CHir phase, which shows the better data and derivative quality. The confidence range for the interval transmissivity is estimated to be 7E-6 m2/s to 4E-5 m2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 1,508.0 kPa.

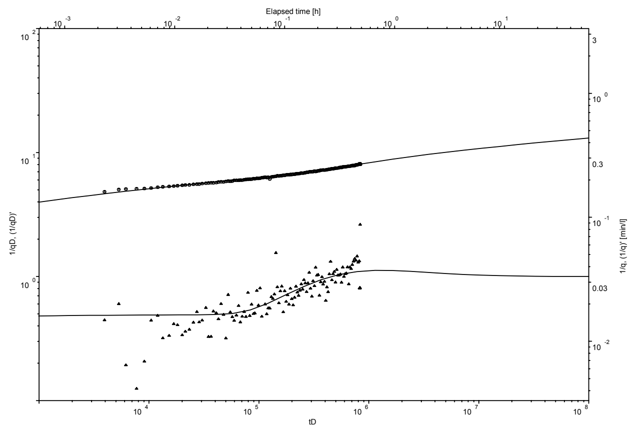
Test Summary Sheet

Project:	Oskarshamn site investigation	Test type:[1]	CHir
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061109 07:43
Test section from - to (m):	207.50-307.50 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

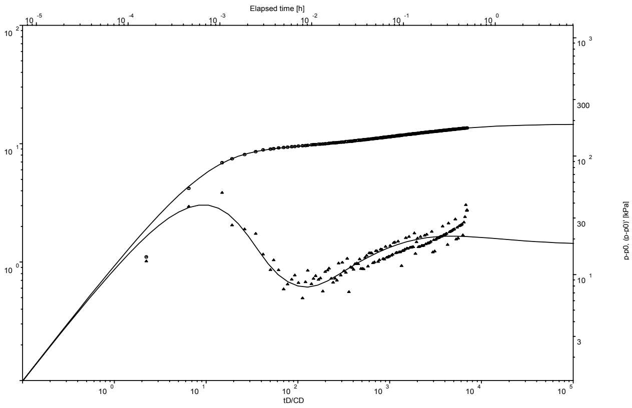
Linear plot Q and p



Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Flow period		**Recovery period**	
Indata		**Indata**	
p_0 (kPa) =	2258		
p_i (kPa) =	2256		
p_p(kPa) =	2453	p_F (kPa) =	2279
Q_p (m^3/s)=	6.17E-05		
tp (s) =	1800	t_F (s) =	1800
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	10.3		
Derivative fact.=	0.04	Derivative fact.=	0.03
Results		**Results**	
Q/s (m^2/s)=	3.1E-06		
T_M (m^2/s)=	4.0E-06		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	0.42	dt_1 (min) =	0.33
dt_2 (min) =	2.18	dt_2 (min) =	0.71
T (m^2/s) =	4.0E-06	T (m^2/s) =	8.7E-06
S (-) =	1.0E-06	S (-) =	1.0E-06
K_s (m/s) =	4.0E-08	K_s (m/s) =	8.7E-08
S_s (1/m) =	1.0E-08	S_s (1/m) =	1.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	1.4E-09
C_D (-) =	NA	C_D (-) =	1.6E-01
ξ (-) =	-0.9	ξ (-) =	3.2
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Selected representative parameters.			
dt_1 (min) =	0.42	C (m^3/Pa) =	1.4E-09
dt_2 (min) =	2.18	C_D (-) =	1.6E-01
T_T (m^2/s) =	4.0E-06	ξ (-) =	-0.9
S (-) =	1.0E-06		
K_s (m/s) =	4.0E-08		
S_s (1/m) =	1.0E-08		

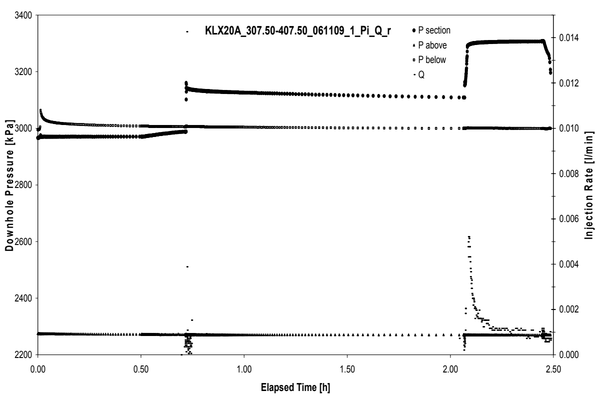
Comments:

The recommended transmissivity of 4.0E-6 m2/s was derived from the analysis of the CHi phase (inner zone), which shows the clearest flow stabilization. The confidence range for the interval transmissivity is estimated to be 1E-6 m2/s to 8E-6 m2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 2,264.2 kPa.

Test Summary Sheet

Project:	Oskarshamn site investigation	Test type:[1]	Pi
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061109 11:20
Test section from - to (m):	307.50-407.50 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

Linear plot Q and p

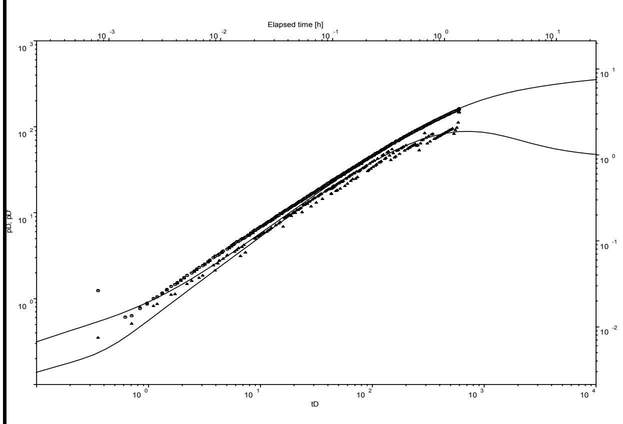


Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa) =	2973		
p_i (kPa) =	2988		
p_p(kPa) =	3155	p_F (kPa) =	3108
Q_p (m^3/s)=	NA		
tp (s) =	10.2	t_F (s) =	4860
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	11.3		
Derivative fact.=	NA	Derivative fact.=	0.02
Results		**Results**	
Q/s (m^2/s)=	NA		
T_M (m^2/s)=	NA		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	NA	dt_1 (min) =	NA
dt_2 (min) =	NA	dt_2 (min) =	NA
T (m^2/s) =	NA	T (m^2/s) =	4.0E-11
S (-) =	NA	S (-) =	1.0E-06
K_s (m/s) =	NA	K_s (m/s) =	4.0E-13
S_s (1/m) =	NA	S_s (1/m) =	1.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	1.7E-10
C_D (-) =	NA	C_D (-) =	1.8E-02
ξ (-) =	NA	ξ (-) =	-1.5
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Log-Log plot incl. derivates- flow period

Not analysable

Log-Log plot incl. derivatives- recovery period



Selected representative parameters.			
dt_1 (min) =	NA	C (m^3/Pa) =	1.7E-10
dt_2 (min) =	NA	C_D (-) =	1.8E-02
T_T (m^2/s) =	4.0E-11	ξ (-) =	-1.5
S (-) =	1.0E-06		
K_s (m/s) =	4.0E-13		
S_s (1/m) =	1.0E-08		

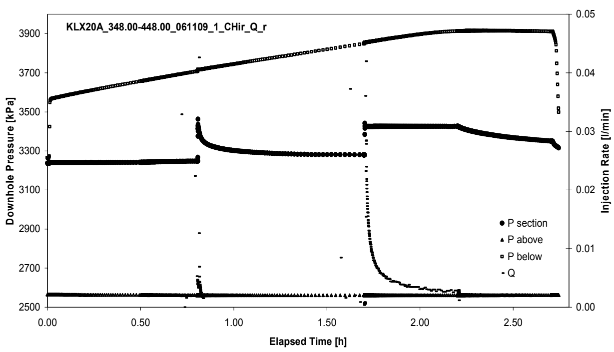
Comments:

The recommended transmissivity of 4.0E-11 m2/s was derived from the analysis of the Pi phase (outer zone). The confidence range for the interval transmissivity is estimated to be 1E-11 to 9E-11 m2/s. The flow dimension displayed during the test is 2. The static pressure could not be extrapolated due to the very low transmissivity.

Test Summary Sheet

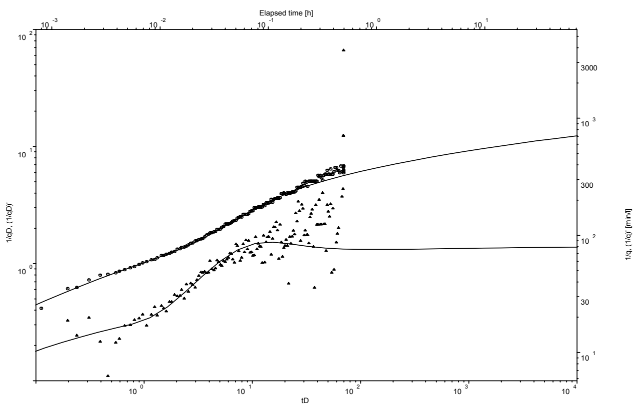
Project:	Oskarshamn site investigation	Test type:[1]	CHir
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061109 14:54
Test section from - to (m):	348.00-448.00 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

Linear plot Q and p

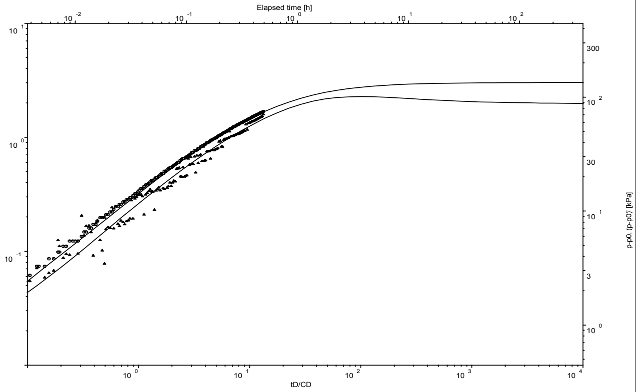


Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa) =	3241		
p_i (kPa) =	3248		
p_p(kPa) =	3425	p_F (kPa) =	3349
Q_p (m^3/s)=	4.17E-08		
tp (s) =	1800	t_F (s) =	1800
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	11.7		
Derivative fact.=	0.06	Derivative fact.=	0.02
Results		**Results**	
Q/s (m^2/s)=	2.3E-09		
T_M (m^2/s)=	3.0E-09		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	4.98	dt_1 (min) =	NA
dt_2 (min) =	27.12	dt_2 (min) =	NA
T (m^2/s) =	9.0E-10	T (m^2/s) =	6.9E-10
S (-) =	1.0E-06	S (-) =	1.0E-06
K_s (m/s) =	9.0E-12	K_s (m/s) =	6.9E-12
S_s (1/m) =	1.0E-08	S_s (1/m) =	1.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	2.3E-10
C_D (-) =	NA	C_D (-) =	2.5E-02
ξ (-) =	-1.9	ξ (-) =	-3.4
T_{GRF}(m^2/s) =		T_{GRF}(m^2/s) =	
S_{GRF}(-) =		S_{GRF}(-) =	
D_{GRF} (-) =		D_{GRF} (-) =	

Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Selected representative parameters.			
dt_1 (min) =	4.98	C (m^3/Pa) =	2.3E-10
dt_2 (min) =	27.12	C_D (-) =	2.5E-02
T_T (m^2/s) =	9.0E-10	ξ (-) =	-1.9
S (-) =	1.0E-06		
K_s (m/s) =	9.0E-12		
S_s (1/m) =	1.0E-08		

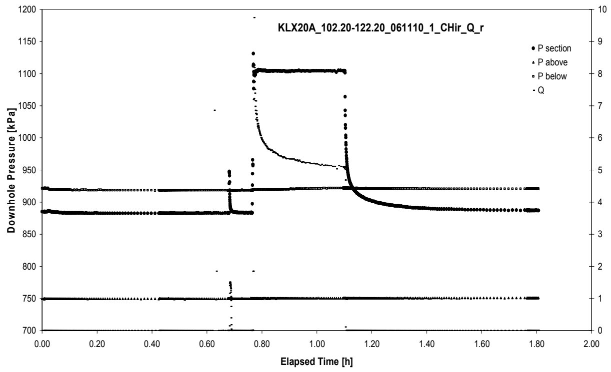
Comments:

The recommended transmissivity of 9.0E-10 m2/s was derived from the analysis of the CHi phase (outer zone), which shows the best data and derivative quality. The confidence range for the interval transmissivity is estimated to be 5E-10 m2/s to 5E-9 m2/s. The flow dimension displayed during the test is 2. The static pressure could not be extrapolated due to the low transmissivity.

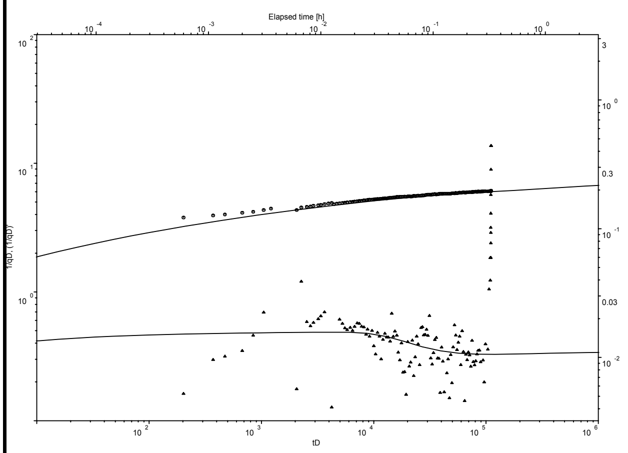
Test Summary Sheet

Project:	Oskarshamn site investigation	Test type:[1]	CHir
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061110 19:13
Test section from - to (m):	102.20-122.20 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

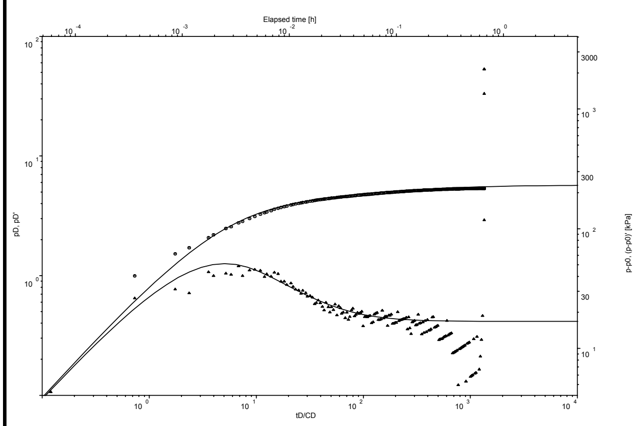
Linear plot Q and p



Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Flow period		**Recovery period**	
Indata		**Indata**	
p_0 (kPa) =	885		
p_i (kPa) =	884		
p_p(kPa) =	1105	p_F (kPa) =	887
Q_p (m^3/s)=	8.50E-05		
tp (s) =	1200	t_F (s) =	2400
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	8.4		
Derivative fact.=	0.04	Derivative fact.=	0.04
Results		**Results**	
Q/s (m^2/s)=	3.8E-06		
T_M (m^2/s)=	3.9E-06		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	6.78	dt_1 (min) =	3.42
dt_2 (min) =	16.68	dt_2 (min) =	17.84
T (m^2/s) =	5.3E-06	T (m^2/s) =	4.2E-06
S (-) =	1.0E-06	S (-) =	1.0E-06
K_s (m/s) =	2.7E-07	K_s (m/s) =	2.1E-07
S_s (1/m) =	5.0E-08	S_s (1/m) =	5.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	3.9E-09
C_D (-) =	NA	C_D (-) =	4.3E-01
ξ (-) =	-1.7	ξ (-) =	-1.9
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Selected representative parameters.			
dt_1 (min) =	3.42	C (m^3/Pa) =	3.9E-09
dt_2 (min) =	17.84	C_D (-) =	4.3E-01
T_T (m^2/s) =	4.2E-06	ξ (-) =	-1.9
S (-) =	1.0E-06		
K_s (m/s) =	2.1E-07		
S_s (1/m) =	5.0E-08		

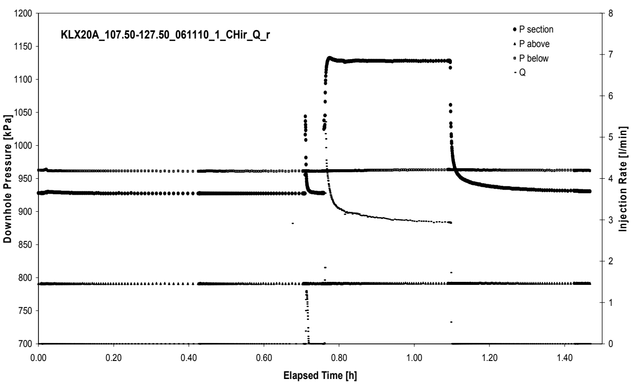
Comments:

The recommended transmissivity of 4.2E-06 m2/s was derived from the analysis of the CHir phase (outer zone), which shows the clearest flow stabilization. The confidence range for the interval transmissivity is estimated to be 1E-06 m2/s to 8E-6 m2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 880.9 kPa.

Test Summary Sheet

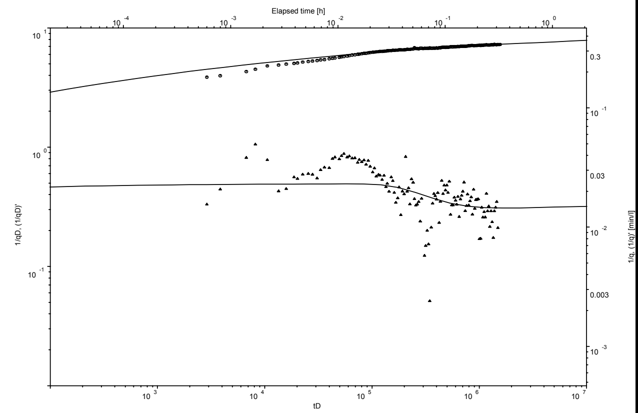
Project:	Oskarshamn site investigation	Test type:[1]	CHir
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061110 21:58
Test section from - to (m):	107.50-127.50 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

Linear plot Q and p

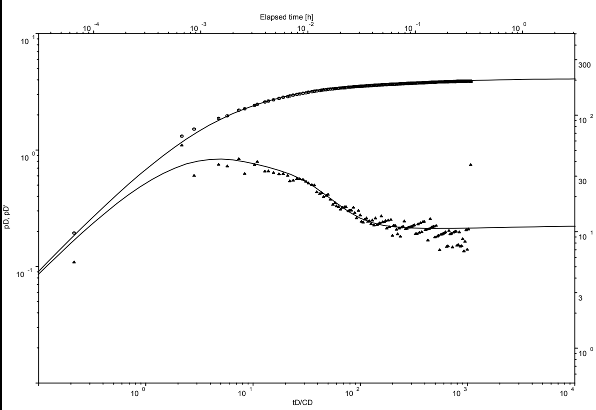


Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa) =	928		
p_i (kPa) =	928		
p_p(kPa) =	1127	p_F (kPa) =	932
Q_p (m^3/s)=	4.83E-05		
tp (s) =	1200	t_F (s) =	1200
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	8.4		
Derivative fact.=	0.07	Derivative fact.=	0.04
Results		**Results**	
Q/s (m^2/s)=	2.4E-06		
T_M (m^2/s)=	2.5E-06		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	9.96	dt_1 (min) =	3.35
dt_2 (min) =	17.70	dt_2 (min) =	18.78
T (m^2/s) =	4.3E-06	T (m^2/s) =	3.6E-06
S (-) =	1.0E-06	S (-) =	1.0E-06
K_s (m/s) =	2.2E-07	K_s (m/s) =	1.8E-07
S_s (1/m) =	5.0E-08	S_s (1/m) =	5.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	1.1E-09
C_D (-) =	NA	C_D (-) =	1.3E-01
ξ (-) =	-1.9	ξ (-) =	-2.4
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Selected representative parameters.			
dt_1 (min) =	3.35	C (m^3/Pa) =	1.1E-09
dt_2 (min) =	18.78	C_D (-) =	1.3E-01
T_T (m^2/s) =	3.6E-06	ξ (-) =	-2.4
S (-) =	1.0E-06		
K_s (m/s) =	1.8E-07		
S_s (1/m) =	5.0E-08		

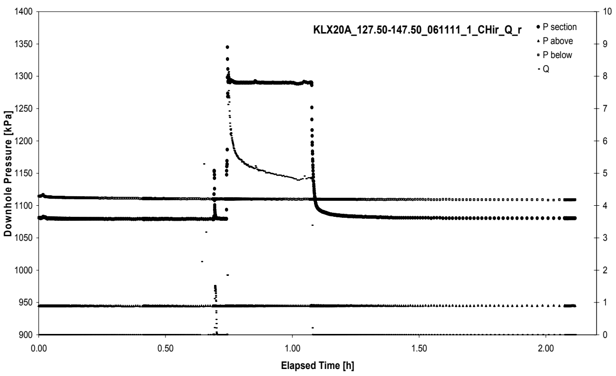
Comments:

The recommended transmissivity of 3.6E-06 m2/s was derived from the analysis of the CHir phase (outer zone), which shows a horizontal flow stabilization. The confidence range for the interval transmissivity is estimated to be 1E-06 m2/s to 7E-6 m2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 923.5 kPa.

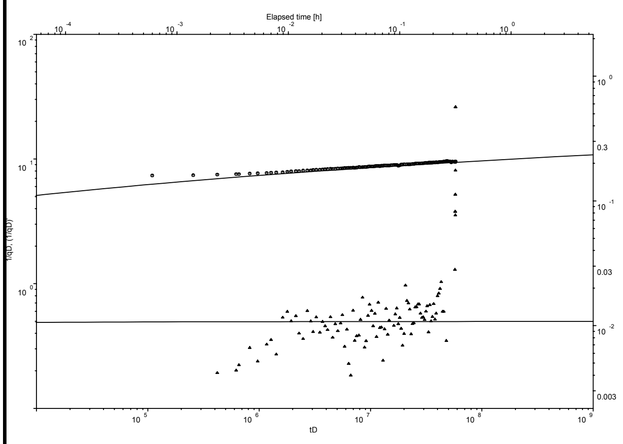
Test Summary Sheet

Project:	Oskarshamn site investigation	Test type:[1]	CHir
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061111 00:09
Test section from - to (m):	127.50-147.50 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

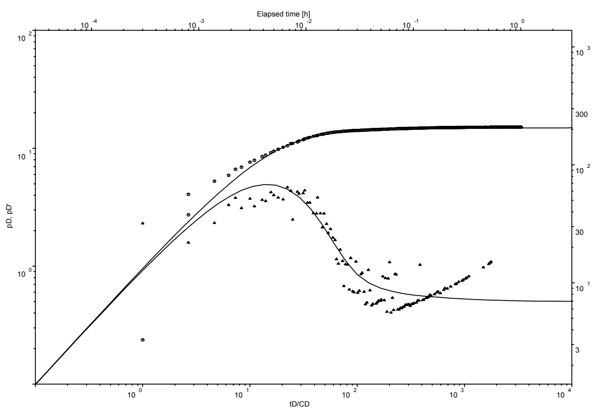
Linear plot Q and p



Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Flow period		**Recovery period**	
Indata		**Indata**	
p_0 (kPa) =	1080		
p_i (kPa) =	1080		
p_p(kPa) =	1290	p_F (kPa) =	1080
Q_p (m^3/s)=	8.08E-05		
tp (s) =	1200	t_F (s) =	3600
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	8.7		
Derivative fact.=	0.05	Derivative fact.=	0.01
Results		**Results**	
Q/s (m^2/s)=	3.8E-06		
T_M (m^2/s)=	4.0E-06		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	0.64	dt_1 (min) =	2.36
dt_2 (min) =	12.42	dt_2 (min) =	9.48
T (m^2/s) =	5.3E-06	T (m^2/s) =	9.6E-06
S (-) =	1.0E-06	S (-) =	1.0E-06
K_s (m/s) =	2.9E-07	K_s (m/s) =	4.8E-07
S_s (1/m) =	5.0E-08	S_s (1/m) =	5.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	6.6E-09
C_D (-) =	NA	C_D (-) =	7.3E-01
ξ (-) =	1.3	ξ (-) =	7.1
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Selected representative parameters.			
dt_1 (min) =	0.64	C (m^3/Pa) =	6.6E-09
dt_2 (min) =	12.42	C_D (-) =	7.3E-01
T_T (m^2/s) =	5.3E-06	ξ (-) =	1.3
S (-) =	1.0E-06		
K_s (m/s) =	2.9E-07		
S_s (1/m) =	5.0E-08		

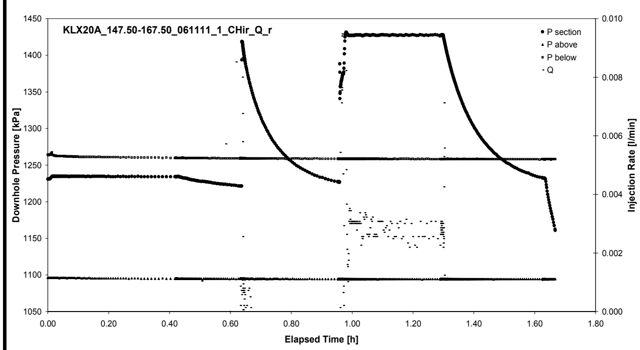
Comments:

The recommended transmissivity of 5.3E-06 m2/s was derived from the analysis of the CHi phase, which shows a clear horizontal flow stabilization. The confidence range for the interval transmissivity is estimated to be 3E-06 m2/s to 8E-6 m2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 1,078.1 kPa.

Test Summary Sheet

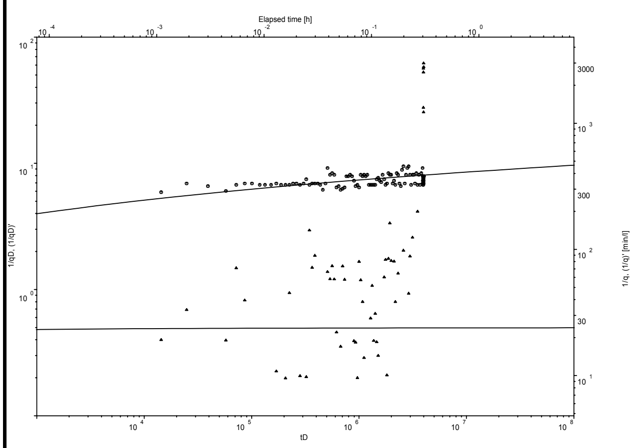
Project:	Oskarshamn site investigation	Test type:[1]	CHir
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061111 06:37
Test section from - to (m):	147.50-167.50 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

Linear plot Q and p

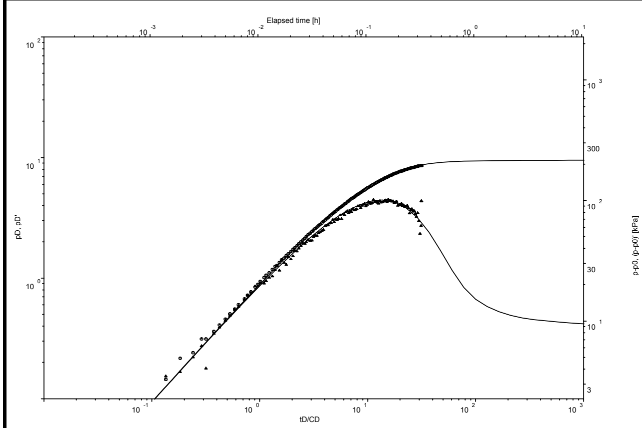


Flow period		**Recovery period**	
Indata		**Indata**	
p_0 (kPa) =	1231		
p_i (kPa) =	1225		
p_p(kPa) =	1425	p_F (kPa) =	1230
Q_p (m^3/s)=	4.50E-08		
tp (s) =	1200	t_F (s) =	1200
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	8.9		
Derivative fact.=	0.17	Derivative fact.=	0.03
Results		**Results**	
Q/s (m^2/s)=	2.2E-09		
T_M (m^2/s)=	2.3E-09		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	NA	dt_1 (min) =	NA
dt_2 (min) =	NA	dt_2 (min) =	NA
T (m^2/s) =	2.7E-09	T (m^2/s) =	3.2E-09
S (-) =	1.0E-06	S (-) =	1.0E-06
K_s (m/s) =	1.4E-10	K_s (m/s) =	1.6E-10
S_s (1/m) =	5.0E-08	S_s (1/m) =	5.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	7.7E-11
C_D (-) =	NA	C_D (-) =	8.5E-03
ξ (-) =	3.8	ξ (-) =	7.4
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Selected representative parameters.			
dt_1 (min) =	NA	C (m^3/Pa) =	7.7E-11
dt_2 (min) =	NA	C_D (-) =	8.5E-03
T_T (m^2/s) =	3.2E-09	ξ (-) =	7.4
S (-) =	1.0E-06		
K_s (m/s) =	1.6E-10		
S_s (1/m) =	5.0E-08		

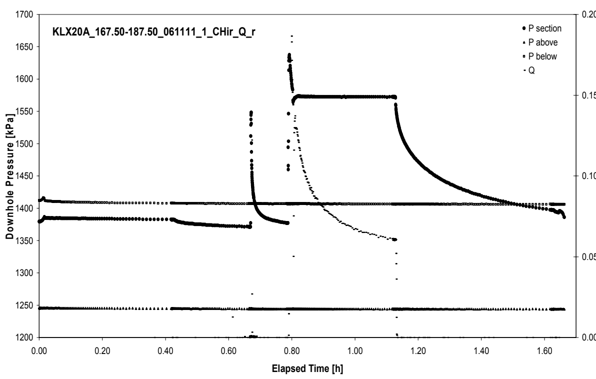
Comments:

The recommended transmissivity of 3.2E-09 m2/s was derived from the analysis of the CHir phase (inner zone), which shows the better data and derivative quality. The confidence range for the interval transmissivity is estimated to be 9E-10 m2/s to 5E-9 m2/s. The flow dimension displayed during the test is 2. The static pressure could not be extrapolated due to the low transmissivity.

Test Summary Sheet

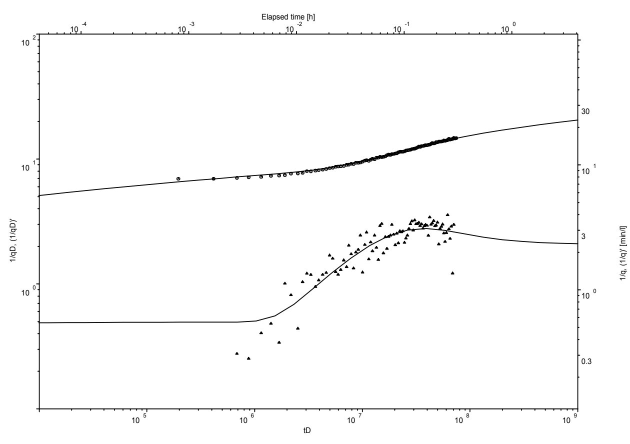
Project:	Oskarshamn site investigation	Test type:[1]	CHir
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061111 08:50
Test section from - to (m):	167.50-187.50 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

Linear plot Q and p

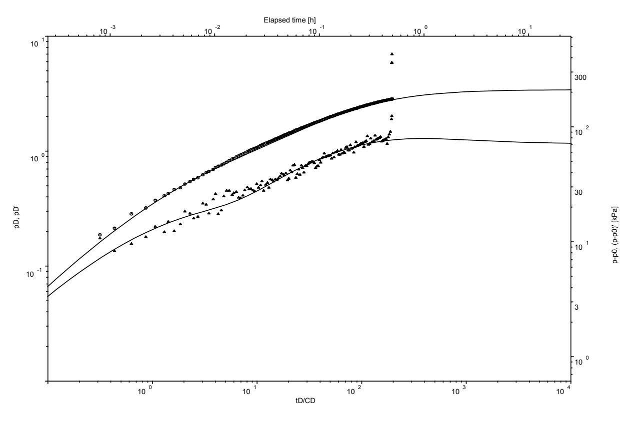


Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa) =	1380		
p_i (kPa) =	1377		
p_p(kPa) =	1572	p_F (kPa) =	1397
Q_p (m^3/s)=	1.00E-06		
tp (s) =	1200	t_F (s) =	1800
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	9.1		
Derivative fact.=	0.05	Derivative fact.=	0.02
Results		**Results**	
Q/s (m^2/s)=	5.0E-08		
T_M (m^2/s)=	5.3E-08		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	5.83	dt_1 (min) =	22.02
dt_2 (min) =	16.44	dt_2 (min) =	26.04
T (m^2/s) =	2.9E-08	T (m^2/s) =	1.4E-08
S (-) =	1.0E-06	S (-) =	1.0E-06
K_s (m/s) =	1.5E-09	K_s (m/s) =	7.0E-10
S_s (1/m) =	5.0E-08	S_s (1/m) =	5.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	1.9E-10
C_D (-) =	NA	C_D (-) =	2.1E-02
ξ (-) =	3.4	ξ (-) =	-3.3
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Selected representative parameters.

dt_1 (min) =	5.83	C (m^3/Pa) =	1.9E-10
dt_2 (min) =	16.44	C_D (-) =	2.1E-02
T_T (m^2/s) =	2.9E-08	ξ (-) =	3.4
S (-) =	1.0E-06		
K_s (m/s) =	1.5E-09		
S_s (1/m) =	5.0E-08		

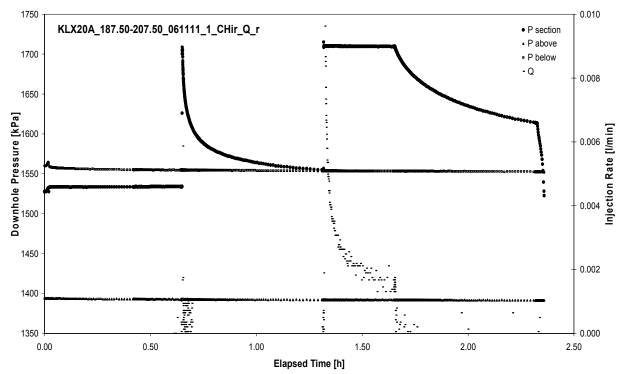
Comments:

The recommended transmissivity of 2.9E-08 m2/s was derived from the analysis of the CHi phase (outer zone), which shows the clearest flow stabilization. The confidence range for the interval transmissivity is estimated to be 9E-09 m2/s to 5E-8 m2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 1,361.7 kPa

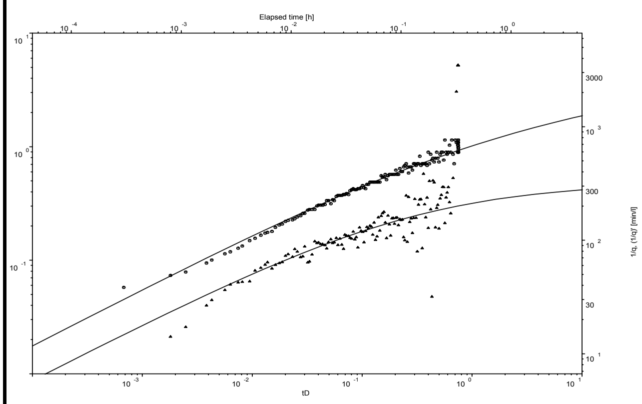
Test Summary Sheet

Project:	Oskarshamn site investigation	Test type:[1]	CHir
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061111 11:05
Test section from - to (m):	187.50-207.50 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

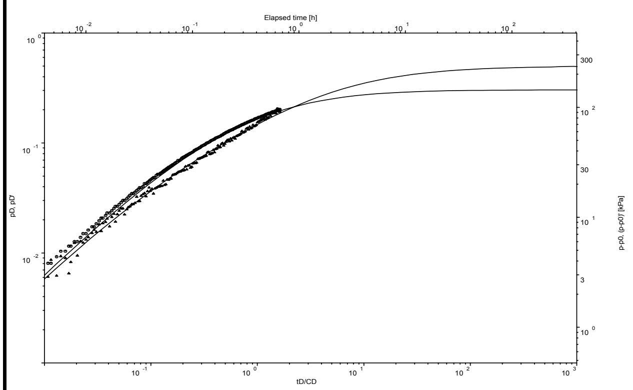
Linear plot Q and p



Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Flow period		**Recovery period**	
Indata		**Indata**	
p_0 (kPa) =	1528		
p_i (kPa) =	1534		
p_p(kPa) =	1709	p_F (kPa) =	1613
Q_p (m^3/s)=	2.67E-08		
tp (s) =	1200	t_F (s) =	2400
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	9.3		
Derivative fact.=	0.2	Derivative fact.=	0.07
Results		**Results**	
Q/s (m^2/s)=	1.5E-09		
T_M (m^2/s)=	1.6E-09		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	NA	dt_1 (min) =	NA
dt_2 (min) =	NA	dt_2 (min) =	NA
T (m^2/s) =	2.2E-10	T (m^2/s) =	1.4E-10
S (-) =	1.0E-06	S (-) =	1.0E-06
K_s (m/s) =	1.1E-11	K_s (m/s) =	7.2E-12
S_s (1/m) =	5.0E-08	S_s (1/m) =	5.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	1.4E-10
C_D (-) =	NA	C_D (-) =	1.6E-02
ξ (-) =	-2.8	ξ (-) =	-3.1
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Selected representative parameters.			
dt_1 (min) =	NA	C (m^3/Pa) =	1.4E-10
dt_2 (min) =	NA	C_D (-) =	1.6E-02
T_T (m^2/s) =	2.2E-10	ξ (-) =	-2.8
S (-) =	1.0E-06		
K_s (m/s) =	1.1E-11		
S_s (1/m) =	5.0E-08		

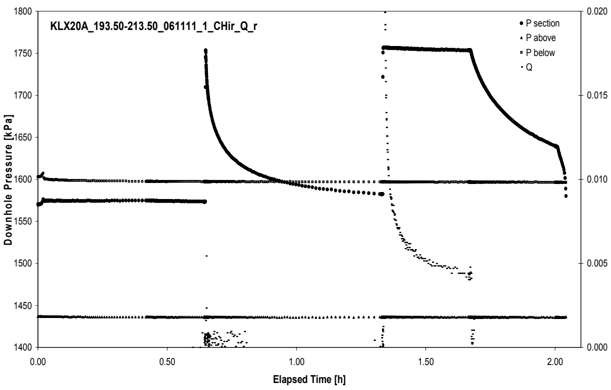
Comments:

The recommended transmissivity of 2.2E-10 m2/s was derived from the analysis of the CHi phase, which shows the better data and derivative quality. The confidence range for the interval transmissivity is estimated to be 9E-11 m2/s to 6E-10 m2/s. The flow dimension displayed during the test is 2. The static pressure could not be extrapolated due to the low transmissivity.

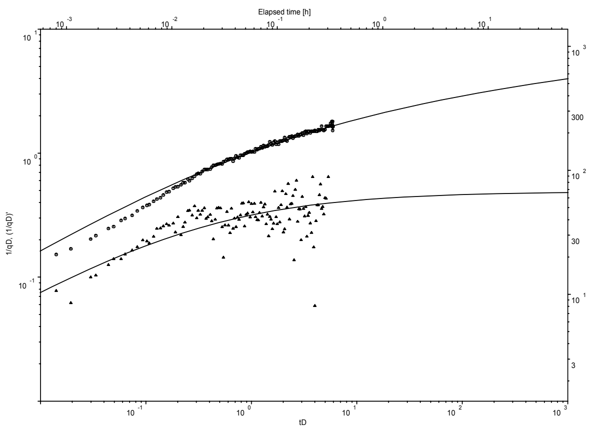
Test Summary Sheet

Project:	Oskarshamn site investigation	Test type:[1]	CHir
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061111 13:59
Test section from - to (m):	193.50-213.50 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

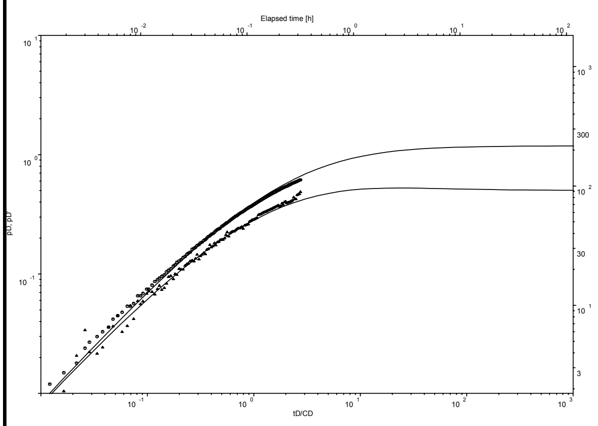
Linear plot Q and p



Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Flow period		**Recovery period**	
Indata		**Indata**	
p_0 (kPa) =	1570		
p_i (kPa) =	1574		
p_p(kPa) =	1752	p_F (kPa) =	1638
Q_p (m^3/s)=	6.67E-08		
tp (s) =	1200	t_F (s) =	1200
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	9.3		
Derivative fact.=	0.08	Derivative fact.=	0.06
Results		**Results**	
Q/s (m^2/s)=	3.7E-09		
T_M (m^2/s)=	3.8E-09		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	7.44	dt_1 (min) =	NA
dt_2 (min) =	17.40	dt_2 (min) =	NA
T (m^2/s) =	1.1E-09	T (m^2/s) =	9.0E-10
S (-) =	1.0E-06	S (-) =	1.0E-06
K_s (m/s) =	5.3E-11	K_s (m/s) =	4.5E-11
S_s (1/m) =	5.0E-08	S_s (1/m) =	5.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	2.4E-10
C_D (-) =	NA	C_D (-) =	2.6E-02
ξ (-) =	-2.5	ξ (-) =	-2.8
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Selected representative parameters.			
dt_1 (min) =	7.44	C (m^3/Pa) =	2.4E-10
dt_2 (min) =	17.40	C_D (-) =	2.6E-02
T_T (m^2/s) =	1.1E-09	ξ (-) =	-2.5
S (-) =	1.0E-06		
K_s (m/s) =	5.3E-11		
S_s (1/m) =	5.0E-08		

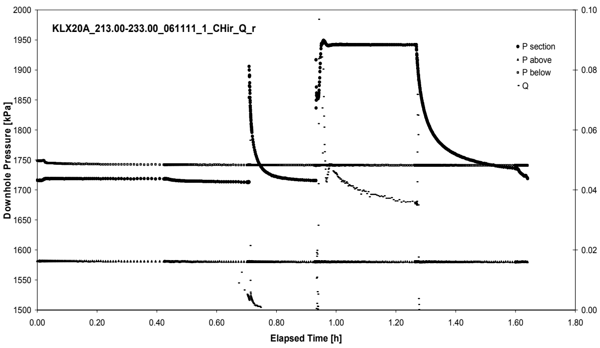
Comments:

The recommended transmissivity of 1.1E-09 m2/s was derived from the analysis of the CHi phase, which shows the better data and derivative quality. The confidence range for the interval transmissivity is estimated to be 6E-10 m2/s to 5E-09 m2/s. The flow dimension displayed during the test is 2. The static pressure could not be extrapolated due to the low transmissivity.

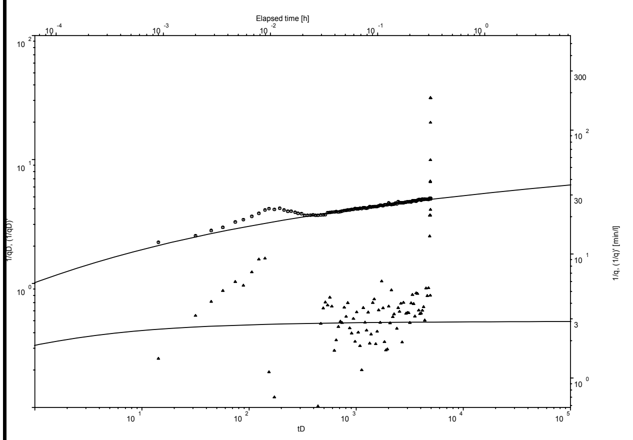
Test Summary Sheet

Project:	Oskarshamn site investigation	Test type:[1]	CHir
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061111 16:40
Test section from - to (m):	213.00-233.00 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

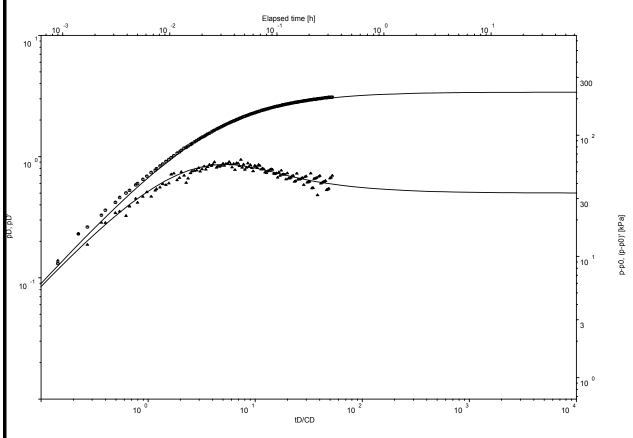
Linear plot Q and p



Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa) =	1716		
p_i (kPa) =	1716		
p_p(kPa) =	1942	p_F (kPa) =	1741
Q_p (m^3/s)=	5.83E-07		
tp (s) =	1200	t_F (s) =	1200
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	9.5		
Derivative fact.=	0.05	Derivative fact.=	0.02
Results		**Results**	
Q/s (m^2/s)=	2.5E-08		
T_M (m^2/s)=	2.6E-08		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	2.80	dt_1 (min) =	13.08
dt_2 (min) =	12.00	dt_2 (min) =	19.74
T (m^2/s) =	2.0E-08	T (m^2/s) =	1.6E-08
S (-) =	1.0E-06	S (-) =	1.0E-06
K_s (m/s) =	1.0E-09	K_s (m/s) =	7.9E-10
S_s (1/m) =	5.0E-08	S_s (1/m) =	5.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	2.3E-10
C_D (-) =	NA	C_D (-) =	2.5E-02
ξ (-) =	-0.6	ξ (-) =	-1.6
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Selected representative parameters.

dt_1 (min) =	13.08	C (m^3/Pa) =	2.3E-10
dt_2 (min) =	19.74	C_D (-) =	2.5E-02
T_T (m^2/s) =	1.6E-08	ξ (-) =	-1.6
S (-) =	1.0E-06		
K_s (m/s) =	7.9E-10		
S_s (1/m) =	5.0E-08		

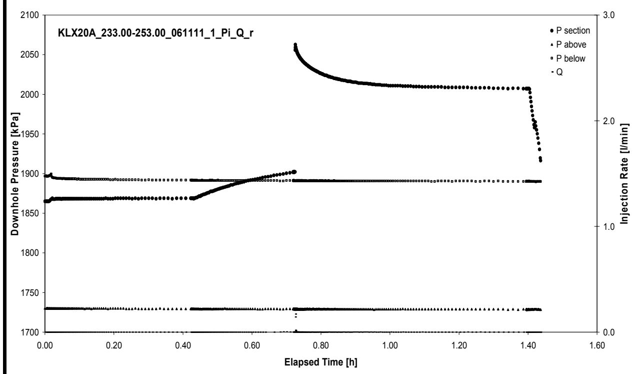
Comments:

The recommended transmissivity of 1.6E-08 m2/s was derived from the analysis of the CHir phase, which shows the better data and derivative quality. The confidence range for the interval transmissivity is estimated to be 7E-09 m2/s to 4E-8 m2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 1,705.4 kPa

Test Summary Sheet

Project:	Oskarshamn site investigation	Test type:[1]	Pi
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061111 19:04
Test section from - to (m):	233.00-253.00 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

Linear plot Q and p

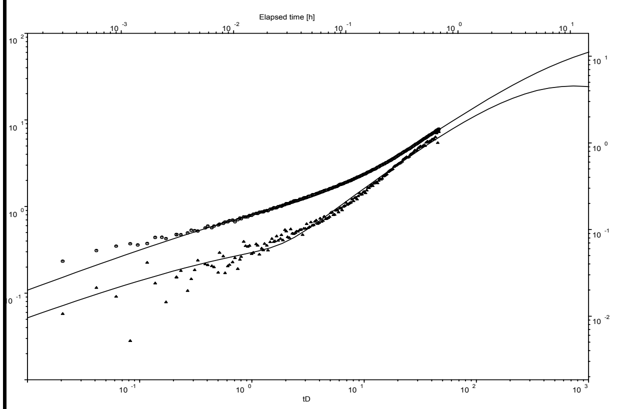


Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa) =	1865		
p_i (kPa) =	1902		
p_p(kPa) =	2063	p_F (kPa) =	2007
Q_p (m^3/s)=	#NV		
tp (s) =	10	t_F (s) =	2400
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	9.7		
Derivative fact.=	NA	Derivative fact.=	0.07
Results		**Results**	
Q/s (m^2/s)=	NA		
T_M (m^2/s)=	NA		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	NA	dt_1 (min) =	0.20
dt_2 (min) =	NA	dt_2 (min) =	1.22
T (m^2/s) =	NA	T (m^2/s) =	1.7E-11
S (-) =	NA	S (-) =	1.0E-06
K_s (m/s) =	NA	K_s (m/s) =	8.4E-13
S_s (1/m) =	NA	S_s (1/m) =	5.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	7.1E-12
C_D (-) =	NA	C_D (-) =	7.8E-04
ξ (-) =	NA	ξ (-) =	-0.2
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Log-Log plot incl. derivates- flow period

Not analysed

Log-Log plot incl. derivatives- recovery period



Selected representative parameters.

dt_1 (min) =	0.20	C (m^3/Pa) =	7.1E-12
dt_2 (min) =	1.22	C_D (-) =	7.8E-04
T_T (m^2/s) =	1.7E-11	ξ (-) =	-0.2
S (-) =	1.0E-06		
K_s (m/s) =	8.4E-13		
S_s (1/m) =	5.0E-08		

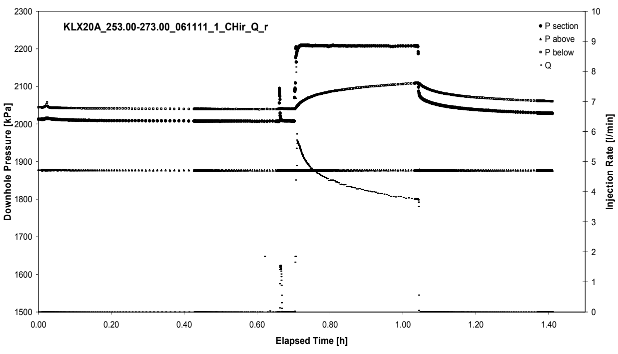
Comments:

The recommended transmissivity of 1.7E-11 m2/s was derived from the analysis of the Pi phase (outer zone). The confidence range for the interval transmissivity is estimated to be 7E-12 to 4E-11 m2/s. The flow dimension displayed during the test is 2. The static pressure could not be extrapolated due to the very low transmissivity.

Test Summary Sheet

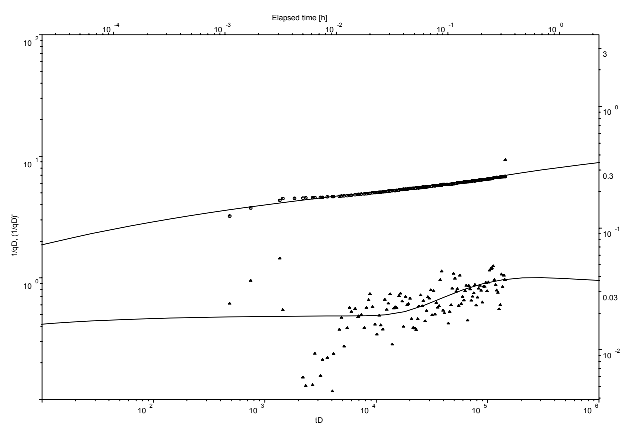
Project:	Oskarshamn site investigation	Test type:[1]	CHir
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061111 21:21
Test section from - to (m):	253.00-273.00 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

Linear plot Q and p

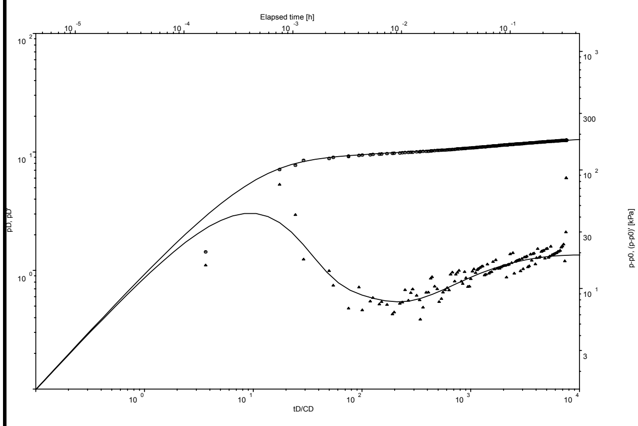


Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa) =	2013		
p_i (kPa) =	2008		
p_p(kPa) =	2206	p_F (kPa) =	2028
Q_p (m^3/s)=	6.20E-05		
tp (s) =	1200	t_F (s) =	1200
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	9.9		
Derivative fact.=	0.02	Derivative fact.=	0.04
Results		**Results**	
Q/s (m^2/s)=	3.1E-06		
T_M (m^2/s)=	3.2E-06		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	0.67	dt_1 (min) =	0.31
dt_2 (min) =	2.08	dt_2 (min) =	0.70
T (m^2/s) =	3.4E-06	T (m^2/s) =	7.8E-06
S (-) =	1.0E-06	S (-) =	1.0E-06
K_s (m/s) =	1.7E-07	K_s (m/s) =	3.9E-07
S_s (1/m) =	5.0E-08	S_s (1/m) =	5.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	7.8E-10
C_D (-) =	NA	C_D (-) =	8.6E-02
ξ (-) =	-2.6	ξ (-) =	3.5
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Selected representative parameters.

dt_1 (min) =	0.67	C (m^3/Pa) =	7.8E-10
dt_2 (min) =	2.08	C_D (-) =	8.6E-02
T_T (m^2/s) =	3.4E-06	ξ (-) =	-2.6
S (-) =	1.0E-06		
K_s (m/s) =	1.7E-07		
S_s (1/m) =	5.0E-08		

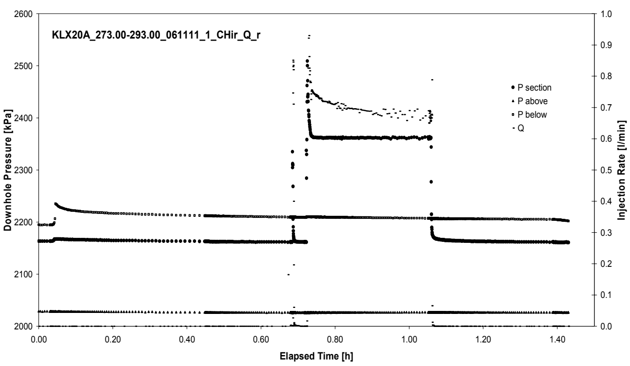
Comments:

The recommended transmissivity of 3.4E-6 m2/s was derived from the analysis of the CHi phase (inner zone), which shows the clearest flow stabilization. The confidence range for the interval transmissivity is estimated to be 9E-7 m2/s to 7E-6 m2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 2,015.3 kPa.

Test Summary Sheet

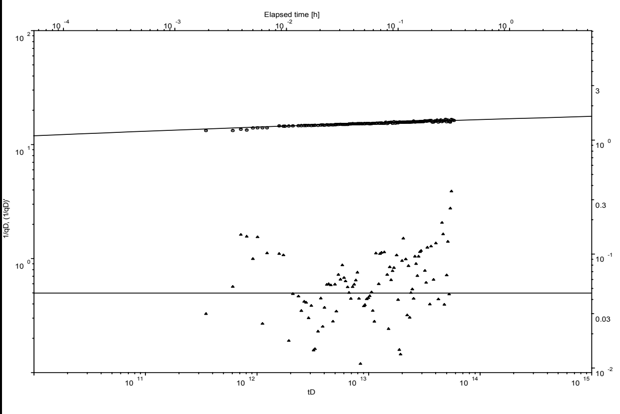
Project:	Oskarshamn site investigation	Test type:[1]	CHir
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061111 23:23
Test section from - to (m):	273.00-293.00 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

Linear plot Q and p

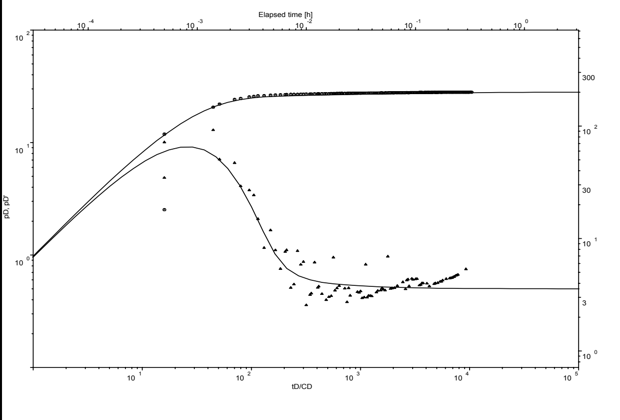


Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa) =	2164		
p_i (kPa) =	2161		
p_p(kPa) =	2362	p_F (kPa) =	2161
Q_p (m^3/s)=	1.13E-05		
tp (s) =	1200	t_F (s) =	1200
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	10.1		
Derivative fact.=	0.08	Derivative fact.=	0.02
Results		**Results**	
Q/s (m^2/s)=	5.5E-07		
T_M (m^2/s)=	5.8E-07		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	1.22	dt_1 (min) =	0.60
dt_2 (min) =	17.22	dt_2 (min) =	10.38
T (m^2/s) =	1.4E-06	T (m^2/s) =	2.5E-06
S (-) =	1.0E-06	S (-) =	1.0E-06
K_s (m/s) =	7.1E-08	K_s (m/s) =	1.3E-07
S_s (1/m) =	5.0E-08	S_s (1/m) =	5.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	1.8E-10
C_D (-) =	NA	C_D (-) =	2.0E-02
ξ (-) =	8.9	ξ (-) =	20.4
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Selected representative parameters.

dt_1 (min) =	0.60	C (m^3/Pa) =	1.8E-10
dt_2 (min) =	10.38	C_D (-) =	2.0E-02
T_T (m^2/s) =	2.5E-06	ξ (-) =	20.4
S (-) =	1.0E-06		
K_s (m/s) =	1.3E-07		
S_s (1/m) =	5.0E-08		

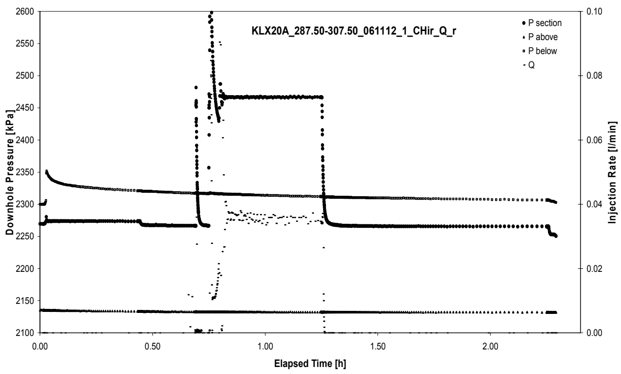
Comments:

The recommended transmissivity of 2.5E-6 m2/s was derived from the analysis of the CHir phase, which shows a flow stabilization at late times. The confidence range for the interval transmissivity is estimated to be 5E-7 m2/s to 4E-6 m2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 2,159.9 kPa.

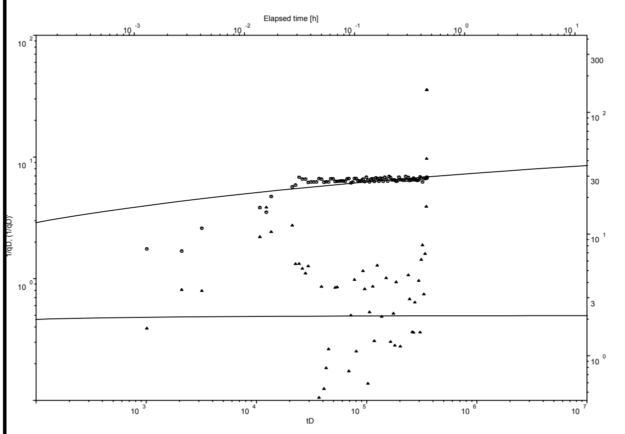
Test Summary Sheet

Project:	Oskarshamn site investigation	Test type:[1]	CHir
Area:	Laxemar	Test no:	1
Borehole ID:	KLX20A	Test start:	061112 01:25
Test section from - to (m):	287.50-307.50 m	Responsible for test execution:	Stephan Rohs Philipp Wolf
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	Cristian Enachescu

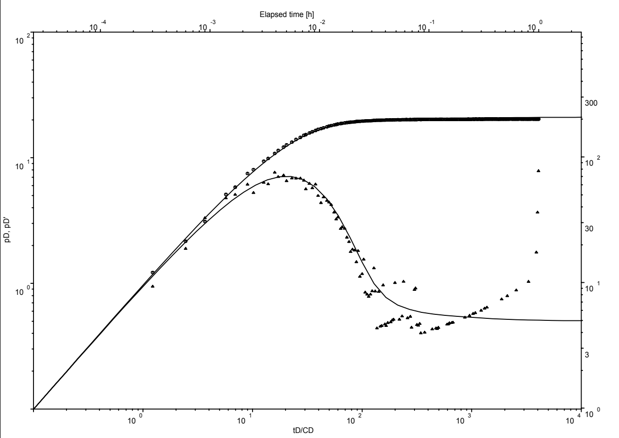
Linear plot Q and p



Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Flow period		**Recovery period**	
Indata		**Indata**	
p_0 (kPa) =	2269		
p_i (kPa) =	2266		
p_p(kPa) =	2466	p_F (kPa) =	2265
Q_p (m^3/s)=	5.83E-07		
tp (s) =	1800	t_F (s) =	3600
S el S^* (-)=	1.00E-06	S el S^* (-)=	1.00E-06
EC_w (mS/m)=			
$Temp_w$(gr C)=	10.3		
Derivative fact.=	0.1	Derivative fact.=	0.02
Results		**Results**	
Q/s (m^2/s)=	2.9E-08		
T_M (m^2/s)=	3.0E-08		
Flow regime:	transient	Flow regime:	transient
dt_1 (min) =	NA	dt_1 (min) =	2.52
dt_2 (min) =	NA	dt_2 (min) =	12.72
T (m^2/s) =	3.0E-08	T (m^2/s) =	1.0E-07
S (-) =	1.0E-06	S (-) =	1.0E-06
K_s (m/s) =	1.5E-09	K_s (m/s) =	5.0E-09
S_s (1/m) =	5.0E-08	S_s (1/m) =	5.0E-08
C (m^3/Pa) =	NA	C (m^3/Pa) =	5.7E-11
C_D (-) =	NA	C_D (-) =	6.2E-03
ξ (-) =	1.2	ξ (-) =	15.2
T_{GRF}(m^2/s) =	NA	T_{GRF}(m^2/s) =	NA
S_{GRF}(-) =	NA	S_{GRF}(-) =	NA
D_{GRF} (-) =	NA	D_{GRF} (-) =	NA

Selected representative parameters.			
dt_1 (min) =	2.52	C (m^3/Pa) =	5.7E-11
dt_2 (min) =	12.72	C_D (-) =	6.2E-03
T_T (m^2/s) =	1.0E-07	ξ (-) =	15.2
S (-) =	1.0E-06		
K_s (m/s) =	5.0E-09		
S_s (1/m) =	5.0E-08		

Comments:

The recommended transmissivity of 1.0E-7 m2/s was derived from the analysis of the CHir phase, which shows the better data and derivative quality. The confidence range for the interval transmissivity is estimated to be 4E-8 m2/s to 5E-7 m2/s. The flow dimension displayed during the test is 2. The static pressure measured at transducer depth, was derived from the CHir phase using straight line extrapolation in the Horner plot to a value of 2,265.0 kPa.

APPENDIX 4

Nomenclature

Character	SICADA designation	Explanation	Dimension	Unit
Variables, constants				
A_w		Horizontal area of water surface in open borehole, not including area of signal cables, etc.	$[L^2]$	m^2
b		Aquifer thickness (Thickness of 2D formation)	[L]	m
B		Width of channel	[L]	m
L		Corrected borehole length	[L]	m
L_0		Uncorrected borehole length	[L]	m
L_p		Point of application for a measuring section based on its centre point or centre of gravity for distribution of transmissivity in the measuring section.	[L]	m
L_w		Test section length.	[L]	m
dL		Step length, Positive Flow Log - overlapping flow logging. (step length, PFL)	[L]	m
r		Radius	[L]	m
r_w		Borehole, well or soil pipe radius in test section.	[L]	m
r_{we}		Effective borehole, well or soil pipe radius in test section. (Consideration taken to skin factor)	[L]	m
r_s		Distance from test section to observation section, the shortest distance.	[L]	m
r_t		Distance from test section to observation section, the **interpreted** shortest distance via conductive structures.	[L]	m
r_D		Dimensionless radius, $r_D=r/r_w$	-	-
z		Level above reference point	[L]	m
z_r		Level for reference point on borehole	[L]	m
z_{wu}		Level for test section (section that is being flowed), upper limitation	[L]	m
z_{wl}		Level for test section (section that is being flowed), lower limitation	[L]	m
z_{ws}		Level for sensor that measures response in test section (section that is flowed)	[L]	m
z_{ou}		Level for observation section, upper limitation	[L]	m
z_{ol}		Level for observation section, lower limitation	[L]	m
z_{os}		Level for sensor that measures response in observation section	[L]	m
E		Evaporation: hydrological budget:	$[L^3/(T\ L^2)]$ $[L^3/T]$	mm/y, mm/d, m^3/s
ET		Evapotranspiration hydrological budget:	$[L^3/(T\ L^2)]$ $[L^3/T]$	mm/y, mm/d, m^3/s
P		Precipitation hydrological budget:	$[L^3/(T\ L^2)]$ $[L^3/T]$	mm/y, mm/d, m^3/s
R		Groundwater recharge hydrological budget:	$[L^3/(T\ L^2)]$ $[L^3/T]$	mm/y, mm/d, m^3/s
D		Groundwater discharge hydrological budget:	$[L^3/(T\ L^2)]$ $[L^3/T]$	mm/y, mm/d, m^3/s
Q_R		Run-off rate	$[L^3/T]$	m^3/s
Q_p		Pumping rate	$[L^3/T]$	m^3/s
Q_I		Infiltration rate	$[L^3/T]$	m^3/s
Q		Volumetric flow. Corrected flow in flow logging ($Q_1 – Q_0$) (Flow rate)	$[L^3/T]$	m^3/s
Q_0		Flow in test section during undisturbed conditions (flow logging).	$[L^3/T]$	m^3/s
Q_p		Flow in test section immediately before stop of flow. Stabilised pump flow in flow logging.	$[L^3/T]$	m^3/s

Character	SICADA designation	Explanation	Dimension	Unit
Q_m		Arithmetical mean flow during perturbation phase.	$[L^3/T]$	m^3/s
Q_1		Flow in test section during pumping with pump flow Q_{p1}, (flow logging).	$[L^3/T]$	m^3/s
Q_2		Flow in test section during pumping with pump flow Q_{p1}, (flow logging).	$[L^3/T]$	m^3/s
ΣQ	SumQ	Cumulative volumetric flow along borehole	$[L^3/T]$	m^3/s
ΣQ_0	SumQ0	Cumulative volumetric flow along borehole, undisturbed conditions (ie, not pumped)	$[L^3/T]$	m^3/s
ΣQ_1	SumQ1	Cumulative volumetric flow along borehole, with pump flow Q_{p1}	$[L^3/T]$	m^3/s
ΣQ_2	SumQ2	Cumulative volumetric flow along borehole, with pump flow Q_{p2}	$[L^3/T]$	m^3/s
ΣQ_{C1}	SumQC1	Corrected cumulative volumetric flow along borehole, ΣQ_1-ΣQ_0	$[L^3/T]$	m^3/s
ΣQ_{C2}	SumQC2	Corrected cumulative volumetric flow along borehole, ΣQ_2-ΣQ_0	$[L^3/T]$	m^3/s
q		Volumetric flow per flow passage area (Specific discharge (Darcy velocity, Darcy flux, Filtration velocity)).	$([L^3/T*L^2]$	m/s
V		Volume	$[L^3]$	m^3
V_w		Water volume in test section.	$[L^3]$	m^3
V_p		Total water volume injected/pumped during perturbation phase.	$[L^3]$	m^3
v		Velocity	$([L^3/T*L^2]$	m/s
v_a		Mean transport velocity (Average linear velocity (Average linear groundwater velocity, Mean microscopic velocity));. $v_a=q/n_e$	$([L^3/T*L^2]$	m/s
t		Time	[T]	hour,min,s
t_0		Duration of rest phase before perturbation phase.	[T]	s
t_p		Duration of perturbation phase. (from flow start as far as p_p).	[T]	s
t_F		Duration of recovery phase (from p_p to p_F).	[T]	s
t_1, t_2 etc		Times for various phases during a hydro test.	[T]	hour,min,s
dt		Running time from start of flow phase and recovery phase respectively.	[T]	s
dt_e		$dt_e = (dt \cdot tp) / (dt + tp)$ Agarwal equivalent time with dt as running time for recovery phase.	[T]	s
t_D		$t_D = T \cdot t / (S \cdot r_w^2)$. Dimensionless time	-	-
p		Static pressure; including non-dynamic pressure which depends on water velocity. Dynamic pressure is normally ignored in estimating the potential in groundwater flow relations.	$[M/(LT)^2]$	kPa
p_a		Atmospheric pressure	$[M/(LT)^2]$	kPa
p_t		Absolute pressure; $p_t=p_a+p_g$	$[M/(LT)^2]$	kPa
p_g		Gauge pressure; Difference between absolute pressure and atmospheric pressure.	$[M/(LT)^2]$	kPa
p_0		Initial pressure before test begins, prior to packer expansion.	$[M/(LT)^2]$	kPa
p_i		Pressure in measuring section before start of flow.	$[M/(LT)^2]$	kPa
p_f		Pressure during perturbation phase.	$[M/(LT)^2]$	kPa
p_s		Pressure during recovery.	$[M/(LT)^2]$	kPa
p_p		Pressure in measuring section before flow stop.	$[M/(LT)^2]$	kPa
p_F		Pressure in measuring section at end of recovery.	$[M/(LT)^2]$	kPa
p_D		$p_D=2\pi \cdot T \cdot p/(Q \cdot \rho_w g)$, Dimensionless pressure	-	-
dp		Pressure difference, drawdown of pressure surface between two points of time.	$[M/(LT)^2]$	kPa

Character	SICADA designation	Explanation	Dimension	Unit
dp_f		$dp_f = p_i - p_f$ or $= p_f - p_i$, drawdown/pressure increase of pressure surface between two points of time during perturbation phase. dp_f usually expressed positive.	$[M/(LT)^2]$	kPa
dp_s		$dp_s = p_s - p_p$ or $= p_p - p_s$, pressure increase/drawdown of pressure surface between two points of time during recovery phase. dp_s usually expressed positive.	$[M/(LT)^2]$	kPa
dp_p		$dp_p = p_i - p_p$ or $= p_p - p_i$, **maximal** pressure increase/drawdown of pressure surface between two points of time during perturbation phase. dp_p expressed positive.	$[M/(LT)^2]$	kPa
dp_F		$dp_F = p_p - p_F$ or $= p_F - p_p$, **maximal** pressure increase/drawdown of pressure surface between two points of time during recovery phase. dp_F expressed positive.	$[M/(LT)^2]$	kPa
H		Total head; (potential relative a reference level) (indication of h for phase as for p). $H=h_e+h_p+h_v$	[L]	m
h		Groundwater pressure level (hydraulic head (piezometric head; possible to use for level observations in boreholes, static head)); (indication of h for phase as for p). $h=h_e+h_p$	[L]	m
h_e		Height of measuring point (Elevation head); Level above reference level for measuring point.	[L]	m
h_p		Pressure head; Level above reference level for height of measuring point of stationary column of water giving corresponding static pressure at measuring point	[L]	m
h_v		Velocity head; height corresponding to the lifting for which the kinetic energy is capable (usually neglected in hydrogeology)	[L]	m
s		Drawdown; Drawdown from undisturbed level (same as dh_p, positive)	[L]	m
s_p		Drawdown in measuring section before flow stop.	[L]	m
			[L]	
h_0		Initial above reference level before test begins, prior to packer expansion.	[L]	m
h_i		Level above reference level in measuring section before start of flow.	[L]	m
h_f		Level above reference level during perturbation phase.	[L]	m
h_s		Level above reference level during recovery phase.	[L]	m
h_p		Level above reference level in measuring section before flow stop.	[L]	m
h_F		Level above reference level in measuring section at end of recovery.	[L]	m
dh		Level difference, drawdown of water level between two points of time.	[L]	m
dh_f		$dh_f = h_i - h_f$ or $= h_f - h_i$, drawdown/pressure increase of pressure surface between two points of time during perturbation phase. dh_f usually expressed positive.	[L]	m
dh_s		$dh_s = h_s - h_p$ or $= h_p - h_s$, pressure increase/drawdown of pressure surface between two points of time during recovery phase. dh_s usually expressed positive.	[L]	m
dh_p		$dh_p = h_i - h_p$ or $= h_p - h_i$, maximal pressure increase/drawdown of pressure surface between two points of time during perturbation phase. dh_p expressed positive.	[L]	m
dh_F		$dh_F = h_p - h_F$ or $= h_F - h_p$, maximal pressure increase/drawdown of pressure surface between two points of time during perturbation phase. dh_F expressed positive.	[L]	m
Te_w		Temperature in the test section (taken from temperature logging). Temperature		°C
Te_{w0}		Temperature in the test section during undisturbed conditions (taken from temperature logging).		°C

Character	SICADA designation	Explanation	Dimension	Unit
Te_o		Temperature in the observation section (taken from temperature logging). Temperature		^oC
EC_w		Electrical conductivity of water in test section.		mS/m
EC_{w0}		Electrical conductivity of water in test section during undisturbed conditions.		mS/m
EC_o		Electrical conductivity of water in observation section		mS/m
TDS_w		Total salinity of water in the test section.	$[M/L^3]$	mg/L
TDS_{w0}		Total salinity of water in the test section during undisturbed conditions.	$[M/L^3]$	mg/L
TDS_o		Total salinity of water in the observation section.	$[M/L^3]$	mg/L
g		Constant of gravitation (9.81 $m*s^{-2}$) (Acceleration due to gravity)	$[L/T^2]$	m/s^2
π	pi	Constant (approx 3.1416).	[-]	
r		Residual. r= p_c-p_m , r= h_c-h_m, etc. Difference between measured data (p_m, h_m, etc) and estimated data (p_c, h_c, etc)		
ME		Mean error in residuals. $ME = \frac{1}{n}\sum_{i=1}^{n} r_i$		
NME		Normalized ME. NME=ME/(x_{MAX}-x_{MIN}), x: measured variable considered.		
MAE		Mean absolute error. $MAE = \frac{1}{n}\sum_{i=1}^{n} \lvert r_i \rvert$		
NMAE		Normalized MAE. NMAE=MAE/(x_{MAX}-x_{MIN}), x: measured variable considered.		
RMS		Root mean squared error. $RMS = \left(\frac{1}{n}\sum_{i=1}^{n} r_i^2\right)^{0.5}$		
NRMS		Normalized RMR. NRMR=RMR/(x_{MAX}-x_{MIN}), x: measured variable considered.		
SDR		Standard deviation of residual. $SDR = \left(\frac{1}{n-1}\sum_{i=1}^{n} (r_i - ME)^2\right)^{0.5}$		
SEMR		Standard error of mean residual. $SEMR = \left(\frac{1}{n(n-1)}\sum_{i=1}^{n} (r_i - ME)^2\right)^{0.5}$		
Parameters				
Q/s		Specific capacity s=dp_p or s=s_p=h_0-h_p (open borehole)	$[L^2/T]$	m^2/s
D		Interpreted flow dimension according to Barker, 1988.	[-]	-
dt_1		Time of starting for semi-log or log-log evaluated characteristic counted from start of flow phase and recovery phase respectively.	[T]	s
dt_2		End of time for semi-log or log-log evaluated characteristic counted from start of flow phase and recovery phase respectively.	[T]	s
dt_L		Response time to obtain 0.1 m (or 1 kPa) drawdown in observation section counted from start of recovery phase.	[T]	s
TB		Flow capacity in a one-dimensional structure of width B and transmissivity T. Transient evaluation of one-dimensional structure	$[L^3/T]$	m^3/s
T		Transmissivity	$[L^2/T]$	m^2/s
T_M		Transmissivity according to Moye (1967)	$[L^2/T]$	m^2/s
T_Q		Evaluation based on Q/s and regression curve between Q/s and T, as example see Rhén et al (1997) p. 190.	$[L^2/T]$	m^2/s
T_S		Transmissivity evaluated from slug test	$[L^2/T]$	m^2/s

Character	SICADA designation	Explanation	Dimension	Unit
T_D		Transmissivity evaluated from PFL-Difference Flow Meter	$[L^2/T]$	m^2/s
T_I		Transmissivity evaluated from Impeller flow log	$[L^2/T]$	m^2/s
T_{Sf}, T_{Lf}		Transient evaluation based on semi-log or log-log diagram for perturbation phase in injection or pumping.	$[L^2/T]$	m^2/s
T_{Ss}, T_{Ls}		Transient evaluation based on semi-log or log-log diagram for recovery phase in injection or pumping.	$[L^2/T]$	m^2/s
T_T		Transient evaluation (log-log or lin-log). Judged best evaluation of T_{Sf}, T_{Lf}, T_{Ss}, T_{Ls}	$[L^2/T]$	m^2/s
T_{NLR}		Evaluation based on non-linear regression.	$[L^2/T]$	m^2/s
T_{Tot}		Judged most representative transmissivity for particular test section and (in certain cases) evaluation time with respect to available data (made by SKB at a later stage).	$[L^2/T]$	m^2/s
K		Hydraulic conductivity	[L/T]	m/s
K_s		Hydraulic conductivity based on spherical flow model	[L/T]	m/s
K_m		Hydraulic conductivity matrix, intact rock	[L/T]	m/s
k		Intrinsic permeability	$[L^2]$	m^2
kb		Permeability-thickness product: $kb=k \cdot b$	$[L^3]$	m^3
SB		Storage capacity in a one-dimensional structure of width B and storage coefficient S. Transient evaluation of one-dimensional structure	[L]	m
SB*		Assumed storage capacity in a one-dimensional structure of width B and storage coefficient S. Transient evaluation of one-dimensional structure	[L]	m
S		Storage coefficient, (Storativity)	[-]	-
S*		Assumed storage coefficient	[-]	-
S_y		Theoretical specific yield of water (Specific yield; unconfined storage. Defined as total porosity (n) minus retention capacity (S_r)	[-]	-
S_{ya}		Specific yield of water (Apparent specific yield); unconfined storage, field measuring. Corresponds to volume of water achieved on draining saturated soil or rock in free draining of a volumetric unit. $S_{ya}= S_y$ (often called S_y in literature)	[-]	-
S_r		Specific retention capacity, (specific retention of water, field capacity) (Specific retention); unconfined storage. Corresponds to water volume that the soil or rock has left after free draining of saturated soil or rock.	[-]	-
S_f		Fracture storage coefficient	[-]	-
S_m		Matrix storage coefficient	[-]	-
S_{NLR}		Storage coefficient, evaluation based on non-linear regression	[-]	-
S_{Tot}		Judged most representative storage coefficient for particular test section and (in certain cases) evaluation time with respect to available data (made by SKB at a later stage).	[-]	-
S_s		Specific storage coefficient; confined storage.	[1/L]	1/m
S_s*		Assumed specific storage coefficient; confined storage.	[1/L]	1/m
c_f		Hydraulic resistance: The hydraulic resistance is an aquitard with a flow vertical to a two-dimensional formation. The inverse of c is also called Leakage coefficient. $c_f=b'/K'$ where b´ is thickness of the aquitard and K´ its hydraulic conductivity across the aquitard.	[T]	s
L_f		Leakage factor: $L_f =(K \cdot b \cdot c_f)^{0.5}$ where K represents characteristics of the aquifer.	[L]	m
ξ	Skin	Skin factor	[-]	-

Character	SICADA designation	Explanation	Dimension	Unit
ξ^*	Skin	Assumed skin factor	[-]	-
C		Wellbore storage coefficient	$[(LT^2)\cdot M^2]$	m^3/Pa
C_D		$C_D = C\cdot\rho_w g /(2\pi\cdot S\cdot r_w^2)$, Dimensionless wellbore storage coefficient	[-]	-
ω	Stor-ratio	$\omega= S_f /(S_f + S_m)$, storage ratio (Storativity ratio); the ratio of storage coefficient between that of the fracture and total storage.	[-]	-
λ	Interflow-coeff	$\lambda= \alpha\cdot (K_m / K_f) \cdot r_w^2$ interporosity flow coefficient.	[-]	-
T_{GRF}		Transmissivity interpreted using the GRF method	$[L^2/T]$	m^2/s
S_{GRF}		Storage coefficient interpreted using the GRF method	[1/L]	1/m
D_{GRF}		Flow dimension interpreted using the GRF method	[-]	-
c_w		Water compressibility; corresponding to β in hydrogeological literature.	$[(LT^2)/M]$	1/Pa
c_r		Pore-volume compressibility, (rock compressibility); Corresponding to α/n in hydrogeological literature.	$[(LT^2)/M]$	1/Pa
c_t		$c_t = c_r + c_w$, total compressibility; compressibility per volumetric unit of rock obtained through multiplying by the total porosity, n. (Presence of gas or other fluids can be included in c_t if the degree of saturation (volume of respective fluid divided by n) of the pore system of respective fluid is also included)	$[(LT^2)/M]$	1/Pa
nc_t		Porosity-compressibility factor: $nc_t= n\cdot c_t$	$[(LT^2)/M]$	1/Pa
nc_tb		Porosity-compressibility-thickness product: $nc_tb= n\cdot c_t\cdot b$	$[(L^2T^2)/M]$	m/Pa
n		Total porosity	-	-
n_e		Kinematic porosity, (Effective porosity)	-	-
e		Transport aperture. $e = n_e\cdot b$	[L]	m
ρ	Density	Density	$[M/L^3]$	$kg/(m^3)$
ρ_w	Density-w	Fluid density in measurement section during pumping/injection	$[M/L^3]$	$kg/(m^3)$
ρ_o	Density-o	Fluid density in observation section	$[M/L^3]$	$kg/(m^3)$
ρ_{sp}	Density-sp	Fluid density in standpipes from measurement section	$[M/L^3]$	$kg/(m^3)$
μ	my	Dynamic viscosity	[M/LT]	Pa s
μ_w	my	Dynamic viscosity (Fluid density in measurement section during pumping/injection)	[M/LT]	Pa s
FC_T		Fluid coefficient for intrinsic permeability, transference of k to K; $K=FC_T\cdot k$; $FC_T=\rho_w\cdot g/\mu_w$	[1/LT]	1/(ms)
FC_S		Fluid coefficient for porosity-compressibility, transference of c_t to S_s ; $S_s=FC_S\cdot n\cdot c_t$; $FC_S=\rho_w\cdot g$	$[M/T^2L^2]$	Pa/m
Index on K, T and S				
S		S: semi-log		
L		L: log-log		
f		Pump phase or injection phase, designation following S or L (withdrawal)		
s		Recovery phase, designation following S or L (recovery)		
NLR		NLR: Non-linear regression. Performed on the entire test sequence, perturbation and recovery		
M		Moye		
GRF		Generalised Radial Flow according to Barker (1988)		
m		Matrix		
f		Fracture		
T		Judged best evaluation based on transient evaluation.		

Character	SICADA designation	Explanation	Dimension	Unit
Tot		Judged most representative parameter for particular test section and (in certain cases) evaluation time with respect to available data (made by SKB at a later stage).		
b		Bloch property in a numerical groundwater flow model		
e		Effective property (constant) within a domain in a numerical groundwater flow model.		
Index on p and Q				
0		Initial condition, undisturbed condition in open holes		
i		Natural, "undisturbed" condition of formation parameter		
f		Pump phase or injection phase (withdrawal, flowing phase)		
s		Recovery, shut-in phase		
p		Pressure or flow in measuring section at end of perturbation period		
F		Pressure in measuring section at end of recovery period.		
m		Arithmetical mean value		
c		Estimated value. The index is placed last if index for “where” and “what” are used. Simulated value		
m		Measured value. The index is placed last if index for “where” and “what” are used. Measured value		
Some miscellaneous indexes on p and h				
w		Test section (final difference pressure during flow phase in test section can be expressed dp_{wp}; First index shows “where” and second index shows “what”)		
o		Observation section (final difference pressure during flow phase in observation section can be expressed dp_{op}; First index shows “where” and second index shows “what”)		
f		Fresh-water head. Water is normally pumped up from section to measuring hoses where pressure and level are observed. Density of the water is therefore approximately the same as that of the measuring section. Measured groundwater level is therefore normally represented by what is defined as point-water head. If pressure at the measuring level is recalculated to a level for a column of water with density of fresh water above the measuring point it is referred to as fresh-water head and h is indicated last by an f. Observation section (final level during flow phase in observation section can be expressed h_{opf}; the first index shows “where” and the second index shows “what” and the last one “recalculation”)		

APPENDIX 5

SICADA data tables

(Simplified version v1.4)

SICADA/Data Import Template

File Identity	
Created By	Stephan Rohs
Created	2006-11-22

Compiled By	
Quality Check For Delivery	
Delivery Approval	

Activity Type	KLX 20A KLX 20 - Injection test

Project	AP PS 400-06-112

Activity Information						**Additional Activity Data**				
						C10	P20	P200	P220	R25
Idcode	**Start Date**	**Stop Date**	**Secup (m)**	**Seclow (m)**	**Section No**	**Company**	**Field crew manager**	**Field crew**	**evaluating data**	**Report**
KLX20A	2006-11-08 20:26	2006-11-12 03:43	102.20	448.00		Golder Associates	Reinder van der Wall	Stephan Rohs, Philipp Wolf, Mesgena Gebrezghi, Nikolaj Sokrut	Cristian Enacescu, Philipp Wolf, Stephan Rohs	Stephan Rohs

Table	plu_s_hole_test_d
	PLU Injection and pumping, General information

Column	Datatype	Unit	Column Description
site	CHAR		Investigation site name
activity_type	CHAR		Activity type code
start_date	DATE		Date (yymmdd hh:mm:ss)
stop_date	DATE		Date (yymmdd hh:mm:ss)
project	CHAR		project code
idcode	CHAR		Object or borehole identification code
secup	FLOAT	m	Upper section limit (m)
seclow	FLOAT	m	Lower section limit (m)
section_no	INTEGER	number	Section number
test_type	CHAR		Test type code (1-7), see table description
formation_type	CHAR		1: Rock, 2: Soil (superficial deposits)
start_flow_period	DATE	yyyymmdd	Date & time of pumping/injection start (YYYY-MM-DD hh:mm:ss)
stop_flow_period	DATE	yyyymmdd	Date & time of pumping/injection stop (YYYY-MM-DD hh:mm:ss)
flow_rate_end_qp	FLOAT	m**3/s	Flow rate at the end of the flowing period
value_type_qp	CHAR		0:true value,-1<lower meas.limit1:>upper meas.limit
mean_flow_rate_qm	FLOAT	m**3/s	Arithmetic mean flow rate during flow period
q_measl__l	FLOAT	m**3/s	Estimated lower measurement limit of flow rate
q_measl__u	FLOAT	m**3/s	Estimated upper measurement limit of flow rate
tot_volume_vp	FLOAT	m**3	Total volume of pumped or injected water
dur_flow_phase_tp	FLOAT	s	Duration of the flowing period of the test
dur_rec_phase_tf	FLOAT	s	Duration of the recovery period of the test
initial_head_hi	FLOAT	m	Hydraulic head in test section at start of the flow period
head_at_flow_end_hp	FLOAT	m	Hydraulic head in test section at stop of the flow period.
final_head_hf	FLOAT	m	Hydraulic head in test section at stop of recovery period.
initial_press_pi	FLOAT	kPa	Groundwater pressure in test section at start of flow period
press_at_flow_end_pp	FLOAT	kPa	Groundwater pressure in test section at stop of flow period.
final_press_pf	FLOAT	kPa	Ground water pressure at the end of the recovery period.
fluid_temp_tew	FLOAT	oC	Measured section fluid temperature, see table description
fluid_elcond_ecw	FLOAT	mS/m	Measured section fluid el. conductivity,see table descr.
fluid_salinity_tdsw	FLOAT	mg/l	Total salinity of section fluid based on EC,see table descr.
fluid_salinity_tdswm	FLOAT	mg/l	Tot. section fluid salinity based on water sampling,see...
reference	CHAR		SKB report No for reports describing data and evaluation
comments	VARCHAR		Short comment to data
error_flag	CHAR		If error_flag = "*" then an error occured and an error
in_use	CHAR		If in_use = "*" then the activity has been selected as
sign	CHAR		Signature for QA data accknowledge (QA - OK)
lp	FLOAT	m	Hydraulic point of application

idcode	start_date	stop_date	secup	seclow	section_no	test_type	formation_type	start_flow_period	stop_flow_period	flow_rate_end_qp	value_type_qp	mean_flow_rate_qm	q_measl__l	q_measl__u	tot_volume_vp
KLX20A	2006-11-08 20:26:00	2006-11-08 23:06:00	107.50	207.50		3	1	2006-11-08 21:33:52	2006-11-08 22:04:02	1.38E-04	0	1.49E-04	1.67E-08	8.33E-04	2.68E-01
KLX20A	2006-11-09 07:43:00	2006-11-09 09:37:00	207.50	307.50		3	1	2006-11-09 08:35:33	2006-11-09 09:05:43	6.17E-05	0	7.17E-05	1.67E-08	8.33E-04	1.29E-01
KLX20A	2006-11-09 11:20:00	2006-11-09 13:55:00	307.50	407.50		4B	1	2006-11-09 12:09:27	2006-11-09 12:09:37	#NV	-1	#NV	1.67E-08	8.33E-04	2.77E-05
KLX20A	2006-11-09 14:54:00	2006-11-09 17:40:00	348.00	448.00		3	1	2006-11-09 16:37:55	2006-11-09 17:08:05	4.17E-08	0	7.67E-08	1.67E-08	8.33E-04	1.38E-04
KLX20A	2006-11-10 19:13:00	2006-11-10 21:06:00	102.20	122.20		3	1	2006-11-10 20:03:43	2006-11-10 20:23:53	8.50E-05	0	9.03E-05	1.67E-08	8.33E-04	1.08E-01
KLX20A	2006-11-10 21:58:00	2006-11-10 23:27:00	107.50	127.50		3	1	2006-11-10 22:44:54	2006-11-10 23:05:04	4.83E-05	0	5.20E-05	1.67E-08	8.33E-04	5.20E-05
KLX20A	2006-11-11 00:09:00	2006-11-11 02:17:00	127.50	147.50		3	1	2006-11-11 00:54:54	2006-11-11 01:15:04	8.08E-05	0	8.68E-05	1.67E-08	8.33E-04	1.04E-01
KLX20A	2006-11-11 06:37:00	2006-11-11 08:17:00	147.50	167.50		3	1	2006-11-11 07:35:27	2006-11-11 07:55:37	4.50E-08	0	4.67E-08	1.67E-08	8.33E-04	5.60E-05
KLX20A	2006-11-11 08:50:00	2006-11-11 09:20:00	167.50	187.50		3	1	2006-11-11 08:38:41	2006-11-11 08:58:51	1.00E-06	0	1.27E-06	1.67E-08	8.33E-04	1.52E-03
KLX20A	2006-11-11 11:05:00	2006-11-11 13:27:00	187.50	207.50		3	1	2006-11-11 12:25:32	2006-11-11 12:45:42	2.67E-08	0	4.33E-08	1.67E-08	8.33E-04	5.20E-05
KLX20A	2006-11-11 13:59:00	2006-11-11 16:02:00	193.50	213.50		3	1	2006-11-11 15:20:42	2006-11-11 15:40:52	6.67E-08	0	1.00E-07	1.67E-08	8.33E-04	1.20E-04
KLX20A	2006-11-11 16:40:00	2006-11-11 18:20:00	213.00	233.00		3	1	2006-11-11 17:37:53	2006-11-11 17:58:03	5.83E-07	0	6.67E-07	1.67E-08	8.33E-04	8.00E-04
KLX20A	2006-11-11 19:04:00	2006-11-11 20:30:00	233.00	253.00		4B	1	2006-11-11 19:48:47	2006-11-11 19:48:57	#NV	-1	#NV	1.67E-08	8.33E-04	1.12E-06
KLX20A	2006-11-11 21:21:00	2006-11-11 22:46:00	253.00	273.00		3	1	2006-11-11 22:04:24	2006-11-11 22:24:34	6.20E-05	0	7.10E-05	1.67E-08	8.33E-04	8.52E-02
KLX20A	2006-11-11 23:23:00	2006-11-12 00:49:00	273.00	293.00		3	1	2006-11-12 00:07:49	2006-11-12 00:27:59	1.13E-05	0	1.16E-05	1.67E-08	8.33E-04	1.39E-02
KLX20A	2006-11-12 01:25:00	2006-11-12 03:43:00	287.50	307.50		3	1	2006-11-12 02:11:03	2006-11-12 02:41:13	5.83E-07	0	6.33E-07	1.67E-08	8.33E-04	1.14E-03

idcode	secup	seclow	dur_flow_phase_tp	dur_rec_phase_tf	initial_head_hi	head_at_flow_end_hp	final_head_hf	initial_press_pi	press_at_flow_end_pp	final_press_pf	fluid_temp_tew	fluid_elcond_ecw	fluid_salinity_tdsw	fluid_salinity_tdswm	reference	comments	lp
KLX20A	107.50	207.50	1800	3600				1509	1709	1511	9.3						157.50
KLX20A	207.50	307.50	1800	1800				2256	2453	2279	10.3						257.50
KLX20A	307.50	407.50	10	4860				2988	3155	3108	11.3						357.50
KLX20A	348.00	448.00	1800	1800				3248	3425	3349	11.7						398.00
KLX20A	102.20	122.20	1200	2400				884	1105	887	8.4						152.20
KLX20A	107.50	127.50	1200	1200				928	1127	932	8.4						157.50
KLX20A	127.50	147.50	1200	3600				1080	1290	1080	8.7						177.50
KLX20A	147.50	167.50	1200	1200				1225	1425	1230	8.9						197.50
KLX20A	167.50	187.50	1200	1800				1377	1572	1397	9.1						217.50
KLX20A	187.50	207.50	1200	2400				1534	1709	1613	9.3						197.50
KLX20A	193.50	213.50	1200	1200				1574	1752	1638	9.3						203.50
KLX20A	213.00	233.00	1200	1200				1716	1942	1741	9.5						223.00
KLX20A	233.00	253.00	10	2400				1902	2063	2007	9.7						243.00
KLX20A	253.00	273.00	1200	1200				2008	2206	2028	9.9						263.00
KLX20A	273.00	293.00	1200	1200				2161	2362	2161	10.1						283.00
KLX20A	287.50	307.50	1800	3600				2266	2466	2265	10.3						297.50

Table	plu_s_hole_test_ed1
	PLU Single hole tests, pumping/injection. Basic evaluation

Column	Datatype	Unit	Column Description
site	CHAR		Investigation site name
activity_type	CHAR		Activity type code
start_date	DATE		Date (yymmdd hh:mm:ss)
stop_date	DATE		Date (yymmdd hh:mm:ss)
project	CHAR		project code
idcode	CHAR		Object or borehole identification code
secup	FLOAT	m	Upper section limit (m)
seclow	FLOAT	m	Lower section limit (m)
section_no	INTEGER	number	Section number
test_type	CHAR		Test type code (1-7), see table description!
formation_type	CHAR		Formation type code. 1: Rock, 2: Soil (superficial deposits)
lp	FLOAT	m	Hydraulic point of application for test section, see descr.
seclen_class	FLOAT	m	Planned ordinary test interval during test campaign.
spec_capacity_q_s	FLOAT	m**2/s	Specific capacity (Q/s) of test section, see table descript.
value_type_q_s	CHAR		0:true value,-1:Q/s<lower meas.limit,1:Q/s>upper meas.limit
transmissivity_tq	FLOAT	m**2/s	Tranmissivity based on Q/s, see table description
value_type_tq	CHAR		0:true value,-1:TQ<lower meas.limit,1:TQ>upper meas.limit.
bc_tq	CHAR		Best choice code. 1 means TQ is best choice of T, else 0
transmissivity_moye	FLOAT	m**2/s	Transmissivity,TM, based on Moye (1967)
bc_tm	CHAR		Best choice code. 1 means Tmoye is best choice of T, else 0
value_type_tm	CHAR		0:true value,-1:TM<lower meas.limit,1:TM>upper meas.limit.
hydr_cond_moye	FLOAT	m/s	K_M: Hydraulic conductivity based on Moye (1967)
formation_width_b	FLOAT	m	b:Aquifer thickness repr. for T(generally b=Lw) ,see descr.
width_of_channel_b	FLOAT	m	B:Inferred width of formation for evaluated TB
tb	FLOAT	m**3/s	TB:Flow capacity in 1D formation of T & width B, see descr.
l_measl_tb	FLOAT	m**3/s	Estimated lower meas. limit for evaluated TB,see description
u_measl_tb	FLOAT	m**3/s	Estimated upper meas. limit of evaluated TB,see description
sb	FLOAT	m	SB:S=storativity,B=width of formation,1D model,see descript.
assumed_sb	FLOAT	m	SB* : Assumed SB,S=storativity,B=width of formation,see...
leakage_factor_lf	FLOAT	m	Lf:1D model for evaluation of Leakage factor
transmissivity_tt	FLOAT	m**2/s	TT:Transmissivity of formation, 2D radial flow model,see...
value_type_tt	CHAR		0:true value,-1:TT<lower meas.limit,1:TT>upper meas.limit,
bc_tt	CHAR		Best choice code. 1 means TT is best choice of T, else 0
l_measl_q_s	FLOAT	m**2/s	Estimated lower meas. limit for evaluated TT,see table descr
u_measl_q_s	FLOAT	m**2/s	Estimated upper meas. limit for evaluated TT,see description
storativity_s	FLOAT		S:Storativity of formation based on 2D rad flow,see descr.
assumed_s	FLOAT		Assumed Storativity,2D model evaluation,see table descr.
bc_s	FLOAT		Best choice of S (Storativity) ,see descr.
ri	FLOAT	m	Radius of influence
ri_index	CHAR		ri index=index of radius of influence :-1,0 or 1, see descr.
leakage_coeff	FLOAT	1/s	K'/b':2D rad flow model evaluation of leakage coeff,see desc
hydr_cond_ksf	FLOAT	m/s	Ksf:3D model evaluation of hydraulic conductivity,see desc.
value_type_ksf	CHAR		0:true value,-1:Ksf<lower meas.limit,1:Ksf>upper meas.limit,
l_measl_ksf	FLOAT	m/s	Estimated lower meas.limit for evaluated Ksf,see table desc.
u_measl_ksf	FLOAT	m/s	Estimated upper meas.limit for evaluated Ksf,see table descr
spec_storage_ssf	FLOAT	1/m	Ssf:Specific storage,3D model evaluation,see table descr.
assumed_ssf	FLOAT	1/m	Ssf*:Assumed Spec.storage,3D model evaluation,see table des.
c	FLOAT	m**3/pa	C: Wellbore storage coefficient; flow or recovery period
cd	FLOAT		CD: Dimensionless wellbore storage coefficient
skin	FLOAT		Skin factor;best estimate of flow/recovery period,see descr.
dt1	FLOAT	s	Estimated start time of evaluation, see table description
dt2	FLOAT	s	Estimated stop time of evaluation. see table description
t1	FLOAT	s	Start time for evaluated parameter from start flow period
t2	FLOAT	s	Stop time for evaluated parameter from start of flow period
dte1	FLOAT	s	Start time for evaluated parameter from start of recovery
dte2	FLOAT	s	Stop time for evaluated parameter from start of recovery
p_horner	FLOAT	kPa	p*:Horner extrapolated pressure, see table description
transmissivity_t_nlr	FLOAT	m**2/s	T_NLR Transmissivity based on None Linear Regression...
storativity_s_nlr	FLOAT		S_NLR=storativity based on None Linear Regression,see..
value_type_t_nlr	CHAR		0:true value,-1:T_NLR<lower meas.limit,1:>upper meas.limit
bc_t_nlr	CHAR		Best choice code. 1 means T_NLR is best choice of T, else 0
c_nlr	FLOAT	m**3/pa	Wellbore storage coefficient, based on NLR, see descr.
cd_nlr	FLOAT		Dimensionless wellbore storage constant, see table descrip.
skin_nlr	FLOAT		Skin factor based on Non Linear Regression,see desc.
transmissivity_t_grf	FLOAT	m**2/s	T_GRF:Transmissivity based on Genelized Radial Flow,see...
value_type_t_grf	CHAR		0:true value,-1:T_GRF<lower meas.limit,1:>upper meas.limit
bc_t_grf	CHAR		Best choice code. 1 means T_GRF is best choice of T, else 0
storativity_s_grf	FLOAT		S_GRF:Storativity based on Generalized Radial Flow, see des.
flow_dim_grf	FLOAT		Inferred flow dimesion based on Generalized Rad. Flow model
comment	VARCHAR	no_unit	Short comment to the evaluated parameters
error_flag	CHAR		If error_flag = "*" then an error occured and an error
in_use	CHAR		If in_use = "*" then the activity has been selected as
sign	CHAR		Signature for QA data accknowledge (QA - OK)

idcode	start_date	stop_date	secup	seclow	section_no	test_type	formation_type	lp	seclen_class	spec_capacity_q_s	value_type_q_s	transmissivity_tq	value_type_tq	bc_tq	transmissivity_moye	bc_tm	value_type_tm	hydr_cond_moye	n_width_b	width_of_channel_b
KLX20A	2006-11-08 20:26:00	2006-11-08 23:06:00	107.50	207.50		3	1	157.50	100	6.76E-06	0				8.80E-06	0	0	8.80E-08		
KLX20A	2006-11-09 07:43:00	2006-11-09 09:37:00	207.50	307.50		3	1	257.50	100	3.07E-06	0				4.00E-06	0	0	4.00E-08		
KLX20A	2006-11-09 11:20:00	2006-11-09 13:55:00	307.50	407.50		4B	1	357.50	100	#NV	0				#NV	0	0	#NV		
KLX20A	2006-11-09 14:54:00	2006-11-09 17:40:00	348.00	448.00		3	1	398.00	100	2.31E-09	0				3.01E-09	0	0	3.01E-11		
KLX20A	2006-11-10 19:13:00	2006-11-10 21:06:00	102.20	122.20		3	1	152.20	20	3.77E-06	0				3.95E-06	0	0	1.98E-07		
KLX20A	2006-11-10 21:58:00	2006-11-10 23:27:00	107.50	127.50		3	1	157.50	20	2.38E-06	0				2.49E-06	0	0	1.25E-07		
KLX20A	2006-11-11 00:09:00	2006-11-11 02:17:00	127.50	147.50		3	1	177.50	20	3.78E-06	0				3.95E-06	0	0	1.98E-07		
KLX20A	2006-11-11 06:37:00	2006-11-11 08:17:00	147.50	167.50		3	1	197.50	20	2.21E-09	0				2.31E-09	0	0	1.16E-10		
KLX20A	2006-11-11 08:50:00	2006-11-11 09:20:00	167.50	187.50		3	1	217.50	20	5.03E-08	0				5.26E-08	0	0	2.63E-09		
KLX20A	2006-11-11 11:05:00	2006-11-11 13:27:00	187.50	207.50		3	1	197.50	20	1.49E-09	0				1.56E-09	0	0	7.80E-11		
KLX20A	2006-11-11 13:59:00	2006-11-11 16:02:00	193.50	213.50		3	1	203.50	20	3.67E-09	0				3.84E-09	0	0	1.92E-10		
KLX20A	2006-11-11 16:40:00	2006-11-11 18:20:00	213.00	233.00		3	1	223.00	20	2.53E-08	0				2.65E-08	0	0	1.33E-09		
KLX20A	2006-11-11 19:04:00	2006-11-11 20:30:00	233.00	253.00		4B	1	243.00	20	#NV	0				#NV	0	0	#NV		
KLX20A	2006-11-11 21:21:00	2006-11-11 22:46:00	253.00	273.00		3	1	263.00	20	3.07E-06	0				3.21E-06	0	0	1.61E-07		
KLX20A	2006-11-11 23:23:00	2006-11-12 00:49:00	273.00	293.00		3	1	283.00	20	5.53E-07	0				5.79E-07	0	0	2.90E-08		
KLX20A	2006-11-12 01:25:00	2006-11-12 03:43:00	287.50	307.50		3	1	297.50	20	2.86E-08	0				2.99E-08	0	0	1.50E-09		

idcode	secup	seclow	tb	l_measl_tb	u_measl_tb	sb	assumed_sb	leakage_factor_lf	transmissivity_tt	value_type_tt	bc_tt	l_measl_q_s	u_measl_q_s	storativity_s	assumed_s	bc_s	ri	ri_index	leakage_coeff	hydr_cond_ksf	value_type_ksf	l_measl_ksf	u_measl_ksf	spec_storage_ssf	assumed_ssf
KLX20A	107.50	207.50							1.25E-05	0	1	7.00E-06	4.00E-05	1.00E-06	1.00E-06		254.85	0							
KLX20A	207.50	307.50							3.97E-06	0	1	1.00E-06	8.00E-06	1.00E-06	1.00E-06		36.50	1							
KLX20A	307.50	407.50							4.01E-11	0	1	1.00E-11	9.00E-11	1.00E-06	1.00E-06		12.53	1							
KLX20A	348.00	448.00							8.98E-10	0	1	5.00E-10	5.00E-09	1.00E-06	1.00E-06		16.59	1							
KLX20A	102.20	122.20							4.18E-06	0	1	1.00E-06	8.00E-06	1.00E-06	1.00E-06		158.22	-1							
KLX20A	107.50	127.50							3.60E-06	0	1	1.00E-06	7.00E-06	1.00E-06	1.00E-06		107.79	-1							
KLX20A	127.50	147.50							5.27E-06	0	1	3.00E-06	8.00E-06	1.00E-06	1.00E-06		118.56	0							
KLX20A	147.50	167.50							3.21E-09	0	1	9.00E-10	5.00E-09	1.00E-06	1.00E-06		#NV	-1							
KLX20A	167.50	187.50							2.86E-08	0	1	9.00E-09	5.00E-08	1.00E-06	1.00E-06		32.17	1							
KLX20A	187.50	207.50							2.23E-10	0	1	9.00E-11	6.00E-10	1.00E-06	1.00E-06		9.56	0							
KLX20A	193.50	213.50							1.06E-09	0	1	6.00E-10	5.00E-09	1.00E-06	1.00E-06		14.12	0							
KLX20A	213.00	233.00							1.58E-08	0	1	7.00E-09	4.00E-08	1.00E-06	1.00E-06		27.74	0							
KLX20A	233.00	253.00							1.67E-11	0	1	7.00E-12	4.00E-11	1.00E-06	1.00E-06		1.24	1							
KLX20A	253.00	273.00							3.38E-06	0	1	9.00E-07	7.00E-06	1.00E-06	1.00E-06		34.23	1							
KLX20A	273.00	293.00							2.54E-06	0	1	5.00E-07	4.00E-06	1.00E-06	1.00E-06		98.79	0							
KLX20A	287.50	307.50							1.00E-07	0	1	4.00E-08	5.00E-07	1.00E-06	1.00E-06		76.22	0							

idcode	secup	seclow	c	cd	skin	dt1	dt2	t1	t2	dte1	dte2	p_horner	transmissivity_t_nlr	storativity_s_nlr	value_type_t_nlr	bc_t_nlr	c_nlr	cd_nlr	skin_nlr	transmissivity_t_grf	value_type_t_grf	bc_t_grf	storativity_s_grf	flow_dim_grf	comment
KLX20A	107.50	207.50	9.60E-09	1.06E+00	2.28	122.8	1245.6					1508.0													
KLX20A	207.50	307.50	1.42E-09	1.57E-01	-0.88	25.2	131.0					2264.2													
KLX20A	307.50	407.50	1.66E-10	1.83E-02	-1.47	#NV	#NV					#NV													
KLX20A	348.00	448.00	2.31E-10	2.55E-02	-1.91	298.8	1627.2					#NV													
KLX20A	102.20	122.20	3.94E-09	4.34E-01	-1.88	205.2	1070.3					880.9													
KLX20A	107.50	127.50	1.14E-09	1.26E-01	-2.41	201.2	1126.8					923.5													
KLX20A	127.50	147.50	6.60E-09	7.27E-01	1.27	38.2	745.2					1078.1													
KLX20A	147.50	167.50	7.68E-11	8.46E-03	7.35	#NV	#NV					#NV													
KLX20A	167.50	187.50	1.89E-10	2.08E-02	3.35	349.9	986.4					1361.7													
KLX20A	187.50	207.50	1.34E-10	1.48E-02	-2.75	#NV	#NV					#NV													
KLX20A	193.50	213.50	2.39E-10	2.63E-02	-2.50	446.4	1044.0					#NV													
KLX20A	213.00	233.00	2.28E-10	2.51E-02	-1.60	784.8	1184.4					1705.4													
KLX20A	233.00	253.00	7.11E-12	7.84E-04	0.25	12.2	73.2					#NV													
KLX20A	253.00	273.00	7.80E-10	8.60E-02	-2.63	40.0	124.9					2015.3													
KLX20A	273.00	293.00	1.84E-10	2.03E-02	20.38	36.0	622.8					2159.9													
KLX20A	287.50	307.50	5.67E-11	6.25E-03	15.20	151.2	763.2					2265.0													

Table	plu_s_hole_test_obs Data of observation sections of single hole test		
Column	**Datatype**	**Unit**	**Column Description**
site	CHAR		Investigation site name
activity_type	CHAR		Activity type code
idcode	CHAR		Object or borehole identification code
start_date	DATE		Date (yymmdd hh:mm:ss)
secup	FLOAT	m	Upper section limit (m)
seclow	FLOAT	m	Lower section limit (m)
obs_secup	FLOAT	m	Upper limit of observation section
obs_seclow	FLOAT	m	Lower limit of observation section
pi_above	FLOAT	kPa	Groundwater pressure above test section,start of flow period
pp_above	FLOAT	kPa	Groundwater pressure above test section,at stop flow period
pf_above	FLOAT	kPa	Groundwater pressure above test section at stop recovery per
pi_below	FLOAT	kPa	Groundwater pressure below test section at start flow period
pp_below	FLOAT	kPa	Groundwater pressure below test section at stop flow period
pf_below	FLOAT	kPa	Groundwater pressure below test section at stop recovery per
comments	VARCHAR		Comment text row (unformatted text)

idcode	start_date	stop_date	secup	seclow	section_no	obs_secup	obs_seclow	pi_above	pp_above	pf_above	pi_below	pp_below	pf_below	comments
KLX20A	061108 20:26:00	061108 23:06:00	107.50	207.50		208.50	457.92	778	779	778	1545	1545	1545	
KLX20A	061109 07:43:00	061109 09:37:00	207.50	307.50		308.50	457.92	1530	1530	1530	2306	2301	2298	
KLX20A	061109 11:20:00	061109 13:55:00	307.50	407.50		408.50	457.92	2271	2271	2270	3006	3007	3000	
KLX20A	061109 14:54:00	061109 17:40:00	348.00	448.00		449.00	457.92	2562	2562	2562	3849	3913	3912	
KLX20A	061110 19:13:00	061110 21:06:00	102.20	122.20		123.20	457.92	750	750	751	919	922	921	
KLX20A	061110 21:58:00	061110 23:27:00	107.50	127.50		128.50	457.92	791	792	792	961	963	963	
KLX20A	061111 00:09:00	061111 02:17:00	127.50	147.50		148.50	457.92	944	945	945	1110	1109	1109	
KLX20A	061111 06:37:00	061111 08:17:00	147.50	167.50		168.50	457.92	1094	1094	1094	1258	1259	1259	
KLX20A	061111 08:50:00	061111 09:20:00	167.50	187.50		188.50	457.92	1244	1244	1244	1407	1407	1406	
KLX20A	061111 11:05:00	061111 13:27:00	187.50	207.50		208.50	457.92	1392	1392	1391	1554	1553	1552	
KLX20A	061111 13:59:00	061111 16:02:00	193.50	213.50		214.50	457.92	1436	1436	1436	1597	1597	1596	
KLX20A	061111 16:40:00	061111 18:20:00	213.00	233.00		234.00	457.92	1581	1581	1580	1741	1742	1741	
KLX20A	061111 19:04:00	061111 20:30:00	233.00	253.00		254.00	457.92	1730	1729	1728	1891	1891	1890	
KLX20A	061111 21:21:00	061111 22:46:00	253.00	273.00		274.00	457.92	1877	1877	1877	2040	2109	2061	
KLX20A	061111 23:23:00	061112 00:49:00	273.00	293.00		294.00	457.92	2026	2027	2026	2209	2208	2205	
KLX20A	061112 01:25:00	061112 03:43:00	287.50	307.50		308.50	457.92	2133	2132	2132	2317	2312	2307	