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Forsmark site investigation

Single-hole hydraulic tests in borehole KFM11A

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August 2007

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This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

Data in SKB's database can be changed for different reasons. Minor changes in SKB's database will not necessarily result in a revised report. Data revisions may also be presented as supplements, available at www.skb.se.

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Abstract

Borehole KFM11A is a deep core-drilled borehole within the site investigations in the Forsmark area. The borehole which penetrates the region Singö deformation zone is about 851 m long and it is cased to 71 m and the gap between the casing and the borehole wall is grouted. The inclination of the borehole is c 61 degrees from the horizontal plane at the surface. The borehole diameter below casing is 77.3 mm.

This report presents injection tests as well as one pumping test, performed using the pipe string system PSS3 in borehole KFM11A and the test results.

The main aim of the injection tests in KFM11A was to characterize the hydraulic conditions of the rock adjacent to the borehole on 20 m measurement scale from 490.0 to 840.0 metres along the borehole. Hydraulic parameters such as transmissivity and hydraulic conductivity were determined using analysis methods for stationary as well as transient conditions together with the dominating flow regime and possible outer hydraulic boundaries.

For about 60% of the tests, some period with pseudo-radial flow could be identified making a relatively straight-forward transient evaluation possible. The sections 690.0–710.00 and 770.0–840.0 contribute most to the total transmissivity in KFM11A.

The injection tests provide a database for statistical analysis of the hydraulic conductivity distribution along the borehole. However, since no difference flow logging was made in the borehole and only measurements with a 20-m test section were conducted, only a limited statistical analysis was possible.

Sammanfattning

Borrhål KFM11A är ett djupt kärnborrhål borrat inom ramen för platsundersökningarna i Forsmarksområdet. Borrhålet som penetrerar den regionala deformationszon som benämns Singözonen är ca 851 m långt och det är försett med foderrör som har spaltinjekterats till 71 m. Lutningen i borrhålet är ca 61 grader från horisontalplanet vid ytan och borrhålsdiametern under foderröret är 77,3 mm.

Denna rapport beskriver injektionstester samt ett pumptest genomförda med rörgångssystemet PSS3 i borrhål KFM11A samt resultaten från desamma.

Huvudsyftet med injektionstesterna var att karaktärisera de hydrauliska förhållandena i berget i anslutning till borrhålet med mätskalan 20 m mellan 490 och 840 meter längs borrhålet. Hydrauliska parametrar såsom transmissivitet och hydraulisk konduktivitet tillsammans med dominerande flödesregim och eventuella yttre hydrauliska randvillkor bestämdes med hjälp av analysmetoder för såväl stationära som transienta förhållanden.

Under drygt 60 % av testerna kunde en viss period med pseudoradiellt flöde identifieras vilket möjliggjorde en standardmässig transient utvärdering. Sektionerna 690–710 och 770–840 m bidrar mest till den totala transmissiviteten i KFM11A.

Resultaten från injektionstesterna utgör en databas för statistisk analys av den hydrauliska konduktivitetens fördelning längs borrhålet. Eftersom ingen differensflödesloggning har utförts och mätningarna endast skedde med en 20 m testsektion, har dock endast en begränsad statistisk analys utförts.

Contents

8 Appendices on CD

1 Introduction

Injection tests and later on a pumping test were carried out in borehole KFM11A at Forsmark, Sweden, in June and July 2007 respectively, by Geosigma AB. Borehole KFM11A is a deep, cored borehole within the on-going site investigation in the Forsmark area. The location of the borehole is shown in Figure 1-1. The borehole is about 851 m long, cased and grouted to c 71 m and at the collaring inclined c 61 degrees from the horizontal plane. The borehole is designed as a so called telescopic borehole, with an enlarged diameter in the upper approximately 71 m, below which the borehole diameter is c 77.3 mm. The borehole penetrates a regional deformation zone named the Singö zone, and some unstable parts of the borehole have been reinforced with perforated steel plates, so called PLEX-plates.

This document reports the results obtained from the hydraulic tests in borehole KFM11A. The activity is performed within the Forsmark site investigation. The work was carried out in compliance with the SKB internal controlling documents presented in Table 1-1. Data and results were delivered to the SKB site characterization database, Sicada, where they are traceable by the Activity Plan number. No difference flow logging was performed in this borehole.

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Figure 1-1. *The investigation area at Forsmark including the candidate area selected for more detailed investigations.*

Table 1-1. SKB internal controlling documents for performance of the activity.

Activity Plans	**Number**	**Version**
Hydraulic injection tests in borehole KFM11A with PSS3	AP PF 400-07-032	1.0
Method Documents	**Number**	**Version**
Mätsystembeskrivning (MSB) – Allmän del. Pipe String System (PSS3)	SKB MD 345.100	1.0
Mätsystembeskrivning för: Kalibrering, PSS3	SKB MD 345.122	1.0
Mätsystembeskrivning för: Skötsel, service, serviceprotokoll, PSS3	SKB MD 345.124	1.0
Metodbeskrivning för hydrauliska injektionstester	SKB MD 323.001	1.0
Instruktion för analys av injektions- och enhålspumptester	SKB MD 320.004	1.0
Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning	SKB MD 600.004	1.0

Original data from the reported activity are stored in the primary database Sicada, where they are traceable by the Activity Plan number (AP PF 400-07-032). Only data in SKB's databases are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the databases may be revised, if needed. Such revisions will not necessarily result in a revision of the P-report, although the normal procedure is that major data revisions entail a revision of the P-report. Minor data revisions are normally presented as supplements, available at www.skb.se.

2 Objectives

The main aim of the injection tests in borehole KFM11A was to characterize the hydraulic properties of the rock adjacent to the borehole on the 20 m measurement scale with special focus on the hydraulic conditions of the Singö deformation zone in relation to the surrounding rock. The primary parameter to be determined was hydraulic transmissivity from which hydraulic conductivity can be derived. The results of the injection tests provide a database which can be used for statistical analyses of the hydraulic conductivity distribution along the borehole. Some basic statistical analyses are presented in this report.

Other hydraulic parameters of interest were flow regimes and outer hydraulic boundaries. These parameters were analysed using transient evaluation on the test responses during the flow- and recovery periods.

3 Scope

3.1 Borehole data

Technical data of the tested borehole are shown in Table 3-1 and in Appendix 4. The reference point of the borehole is defined as the centre of top of casing (ToC), given as “Elevation” in the table below. The Swedish National coordinate system (RT90) is used for the horizontal coordinates together with RHB70 for the elevation. “Northing” and “Easting” refer to the top of the boreholes.

Table 3-1. Pertinent technical data of borehole KFM11A (printout from SKB database, Sicada).

Borehole length (m):	851.21	Center of flange			
Drilling period(s):	**From date**	**To date**	**Secup (m)**	**Seclow (m)**	**Drilling type**
	2006-04-12	2006-05-02	0.00	71.06	Percussion drilling
	2006-08-29	2006-11-20	71.06	851.21	Core drilling
	2007-03-14	2007-04-02	71.06	851.21	Core drilling
Starting point coordinate:	**Length (m)**	**Northing (m)**	**Easting (m)**	**Elevation**	**Coord system**
	0.00	6701103.82	1632366.75	2.95	RT90-RHB70
	3.00	6701104.93	1632367.69	0.33	RT90-RHB70
Angles:	**Length (m)**	**Bearing**	**Inclination (– = down)**		**Coord system**
	0.00	40.25	–60.86		RT90-RHB70
Borehole diameter:	**Secup (m)**	**Seclow (m)**	**Hole diam (m)**		
	0.30	12.30	0.340		
	12.30	71.00	0.242		
	71.00	71.06	0.160		
	71.06	72.81	0.086		
	72.81	851.21	0.077		
	497.30	501.00	0.084		
	521.45	523.65	0.084		
Core diameter:	**Secup (m)**	**Seclow (m)**	**Core diam (m)**		
	71.06	851.15	0.051		
Casing diameter:	**Secup (m)**	**Seclow (m)**	**Case in (m)**	**Case out (m)**	
	0.00	64.77	0.200	0.208	
	0.30	12.22	0.310	0.323	
	12.22	12.30	0.281	0.340	borrsko
	64.77	70.77	0.200	0.210	
	70.77	70.80	0.170	0.208	borrsko, 70, 80 total längd rör + sko
	497.40	499.40	0.082	0.084	Plate is damaged, inner diameter sometimes 77 mm
	521.55	523.55	0.082	0.082	
	623.80	625.80	0.082	0.084	

3.2 Tests performed

The hydraulic tests in borehole KFM11A included both injection and pumping tests. The hydraulic tests were performed according to Activity Plan AP PF 400-07-032 (see Table 1-1), and are listed in Table 3-2. Since some hydrochemical sampling was to be conducted in the section 690.0–710.0, a pumping test was performed in this section instead of an injection test to prevent the water from contamination with Uranine. The hydraulic tests were carried out with the Pipe String System (PSS3). The test procedure and the equipment are described in the measurement system description for PSS (SKB MD 345.100) and in the corresponding method descriptions for hydraulic tests (SKB MD 323.001, Table 1-1).

Two of the tests were not performed as intended because the time for achieving a constant head in the test sections 508.5–528.5 and 670.0–690.0 m was judged to be too long. This was due to an unexpectedly high and low transmissivity respectively, in these sections. The failed tests were interrupted and later repeated. Test number (Test no in Table 3-2) refers to the number of tests performed in the actual section. For evaluation, data from the last test in each section were used.

The positions of the packers during the hydraulic tests were, as far as possible, placed consecutively. However, due to the risk of damaging the packers when expanded on a major fracture in the wall of the borehole, some positions had to be shifted. Hence four borehole intervals were measured with overlapping test sections (see Section 5.5).

Table 3-2. Single-hole hydraulic tests performed in borehole KFM11A.

Borehole Bh ID	Test section secup	seclow	Section length	Test type[1] (1–6)	Test no	Test start date, time YYYYMMDD hh:mm	Test stop date, time YYYYMMDD hh:mm
KFM11A	470.00	490.00	20.00	3	1	2007-06-04 15:33	2007-06-04 16:55
KFM11A	488.50	508.50	20.00	3	1	2007-06-05 09:23	2007-06-05 10:40
KFM11A	508.50	528.50	20.00	3	1	2007-06-05 11:08	2007-06-05 11:54
KFM11A	508.50	528.50	20.00	3	2	2007-06-05 12:52	2007-06-05 14:11
KFM11A	514.50	534.50	20.00	3	1	2007-06-05 14:33	2007-06-05 15:25
KFM11A	530.00	550.00	20.00	3	1	2007-06-05 15:49	2007-06-05 17:02
KFM11A	550.00	570.00	20.00	3	1	2007-06-07 08:48	2007-06-07 10:13
KFM11A	570.00	590.00	20.00	3	1	2007-06-07 10:35	2007-06-07 11:53
KFM11A	590.00	610.00	20.00	3	1	2007-06-07 13:05	2007-06-07 14:21
KFM11A	610.00	630.00	20.00	3	1	2007-06-07 14:49	2007-06-07 16:05
KFM11A	630.00	650.00	20.00	3	1	2007-06-07 16:36	2007-06-07 17:50
KFM11A	650.00	670.00	20.00	3	1	2007-06-08 08:20	2007-06-08 09:37
KFM11A	670.00	690.00	20.00	3	1	2007-06-08 09:58	2007-06-08 10:38
KFM11A	670.00	690.00	20.00	3	2	2007-06-08 10:41	2007-06-08 12:47
KFM11A	690.00	710.00	20.00	1B	1	2007-07-09 14:09	2007-07-10 09:17
KFM11A	710.00	730.00	20.00	3	1	2007-06-08 13:32	2007-06-08 14:51
KFM11A	730.00	750.00	20.00	3	1	2007-06-08 15:16	2007-06-08 16:33
KFM11A	750.00	770.00	20.00	3	1	2007-06-11 08:35	2007-06-11 09:51
KFM11A	770.00	790.00	20.00	3	1	2007-06-11 13:26	2007-06-11 14:41
KFM11A	790.00	810.00	20.00	3	1	2007-06-11 15:10	2007-06-11 16:27
KFM11A	810.00	830.00	20.00	3	1	2007-06-12 08:38	2007-06-12 09:54
KFM11A	820.00	840.00	20.00	3	1	2007-06-12 12:34	2007-06-12 13:51

[1] 1B: Pumping test, 3: Injection test.

3.3 Equipment checks

The PSS3 equipment was serviced, according to SKB internal controlling documents (SKB MD 345.124, service, and SKB MD 345.122, calibration), in November 2006.

Functioning checks of the equipment were performed during the installation of the PSS equipment at the test site. In order to check the function of the pressure sensors, the air pressure was recorded and found to be as expected. While lowering, the sensors showed good agreement with the total head of water ($p/\rho g$).

Simple functioning checks of down-hole sensors were done at every change of test section interval. Checks were also made continuously while lowering the pipe string along the borehole.

4 Description of equipment

4.1 Overview

4.1.1 Measurement container

All of the equipment needed to perform the hydraulic tests is located in a steel container (Figure 4-1). The container is divided into two compartments; a data-room and a workshop. The container is placed on pallets in order to obtain a suitable working level in relation to the borehole casing.

The hoisting rig is of a hydraulic chain-feed type. The jaws, holding the pipe string, are opened hydraulically and closed mechanically by springs. The rig is equipped with a load transmitter and the load limit may be adjusted. The maximum load is 22 kN.

The packers and the test valve are operated hydraulically by water filled pressure vessels. Expansion and release of packers, as well as opening and closing of the test valve, is done using magnetic valves controlled by the software in the data acquisition system.

The injection system consists of a tank, a pump and a flow meter. The injection flow rate may be manually or automatically controlled. At small flow rates, a water filled pressure vessel connected to a nitrogen gas regulator is used instead of the pump.

4.1.2 Down-hole equipment

A schematic drawing of the down-hole equipment is shown in Figure 4-2. The pipe string consists of aluminium pipes of 3 m length, connected by stainless steel taps sealed with double o-rings. Pressure is measured above (P_a), within (P) and below (P_b) the test section, which is isolated by two packers. Due to the risk of problems when passing the damaged PLEX-plate, later described in Section 5.2.3, an extra pressure sensor, instead of the temperature sensor, was used in the test section (see Figure 4-2). This sensor was to be used if the regular pressure sensor failed (see Section 5.5). The hydraulic connection between the pipe string and the test section can be closed or opened by a test valve operated by the measurement system.

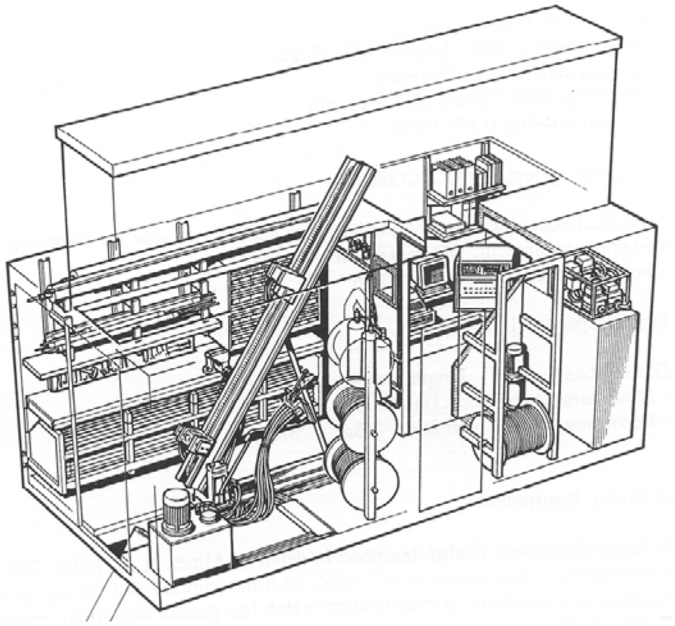

Figure 4-1. *Outline of the PSS3 container with equipment.*

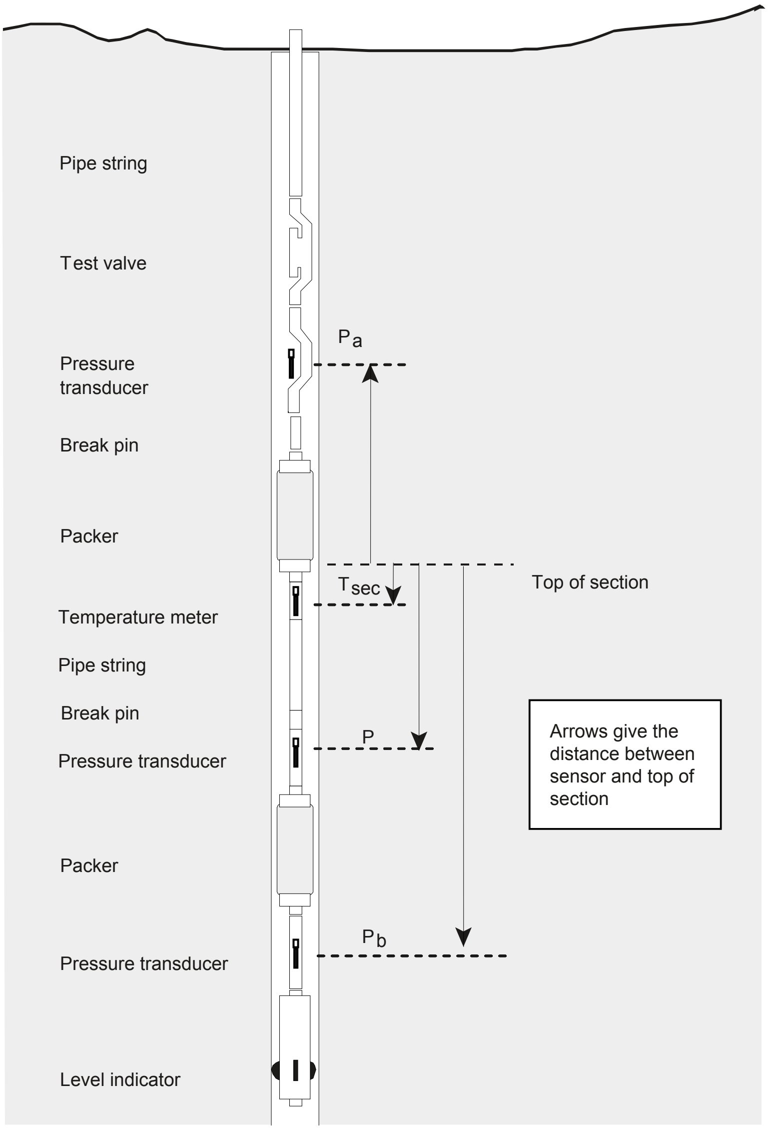

Figure 4-2. *Schematic drawing of the down-hole equipment in the PSS3 system.* T_{sec} *is replaced by an extra pressure sensor.*

At the lower end of the borehole equipment, a level indicator (calliper type) gives a signal as the reference depth marks along the borehole are passed. The length of the test section may be varied (5, 20 or 100 metres).

4.2 Measurement sensors

Technical data for the measurement sensors in the PSS system together with corresponding data of the system are shown in Table 4-1. The sensors are components of the PSS system. The accuracy of the PSS system may also be affected by the I/O-unit, cf. Figure 4-3, and the calibration of the system.

The sensor positions are fixed relative to the top of the test section. In Table 4-2, the position of the sensors is given with top of test section as reference (Figure 4-2).

Table 4-1. Technical data for sensors together with estimated data for the PSS system (based on current experience).

Technical specification Parameter		Unit	Sensor	PSS	Comments
Absolute pressure	Output signal	mA	4–20		
	Meas. range	MPa	0–13.5		
	Resolution	kPa	< 1.0		
	Accuracy 1)	% F.S	0.1		
Differential pressure, 200 kPa	Accuracy	kPa		< ±5	Estimated value
Temperature	Output signal	mA	4–20		
	Meas. range	°C	0–32		
	Resolution	°C	< 0.01		
	Accuracy	°C	±0.1		
Flow Qbig	Output signal	mA	4–20		
	Meas. range	m^3/s	$1.67 \cdot 10^{-5}$–$1.67 \cdot 10^{-3}$		The specific accuracy is depending on actual flow
	Resolution	m^3/s	$6.7 \cdot 10^{-8}$		
	Accuracy 2)	% O.R	0.15–0.7	< 1.5	
Flow Qsmall	Output signal	mA	4–20		
	Meas. range	m^3/s	$1.67 \cdot 10^{-8}$–$1.67 \cdot 10^{-5}$		The specific accuracy is depending on actual flow
	Resolution	m^3/s	$6.7 \cdot 10^{-10}$		
	Accuracy 3)	% O.R	0.1–3.5	0.5–20	

1) 0.1% of Full Scale. Includes hysteresis, linearity and repeatability.

2) Maximum error in % of actual reading (% o.r.).

3) Maximum error in % of actual reading (% o.r.). The higher numbers correspond to the lower flow.

Table 4-2. Position of sensors in the borehole and displacement volume of equipment in the 20 m test section in borehole KFM11A.

Parameter	20 m (L)	(m)
Equipment displacement volume in test section 1)	13	
Total volume of test section 2)	93.9	
Position for sensor P_a, pressure above test section, (m above secup) 3)		1.87
Position for sensor P, pressure in test section, (m above secup) 3)		–19.12
Position for sensor T_{sec}, temperature in test section, (m above secup) 3,4)		–0.99
Position for sensor P_b, pressure below test section, (m above secup) 3)		–22.00

1) Displacement volume in test section due to pipe string, signal cable, sensors and packer ends (in litres).

2) Total volume of test section ($V = \text{section length} \cdot \pi \cdot d^2/4$) (in litres).

3) Position of sensor relative top of test section. A negative value indicates a position below top of test section, (secup).

4) This temperature sensor was replaced by an extra pressure sensor.

4.3 Data acquisition system

The data acquisition system in the PSS equipment contains a standard office PC connected to an I/O-unit (Datascan 7320). Using the Orchestrator software, pumping and hydraulic tests are monitored and borehole sensor data are collected. In addition to the borehole parameters, packer and atmospheric pressure, container air temperature and water temperature are logged. Test evaluation may be performed on-site after a conducted test. An external display enables monitoring of test parameters.

The data acquisition system may be used to start and stop the automatic control system (computer and servo motors). These are connected as shown in Figure 4-3. The control system monitors the flow regulator and uses differential pressure across the regulating valve together with pressure in test section as input signals.

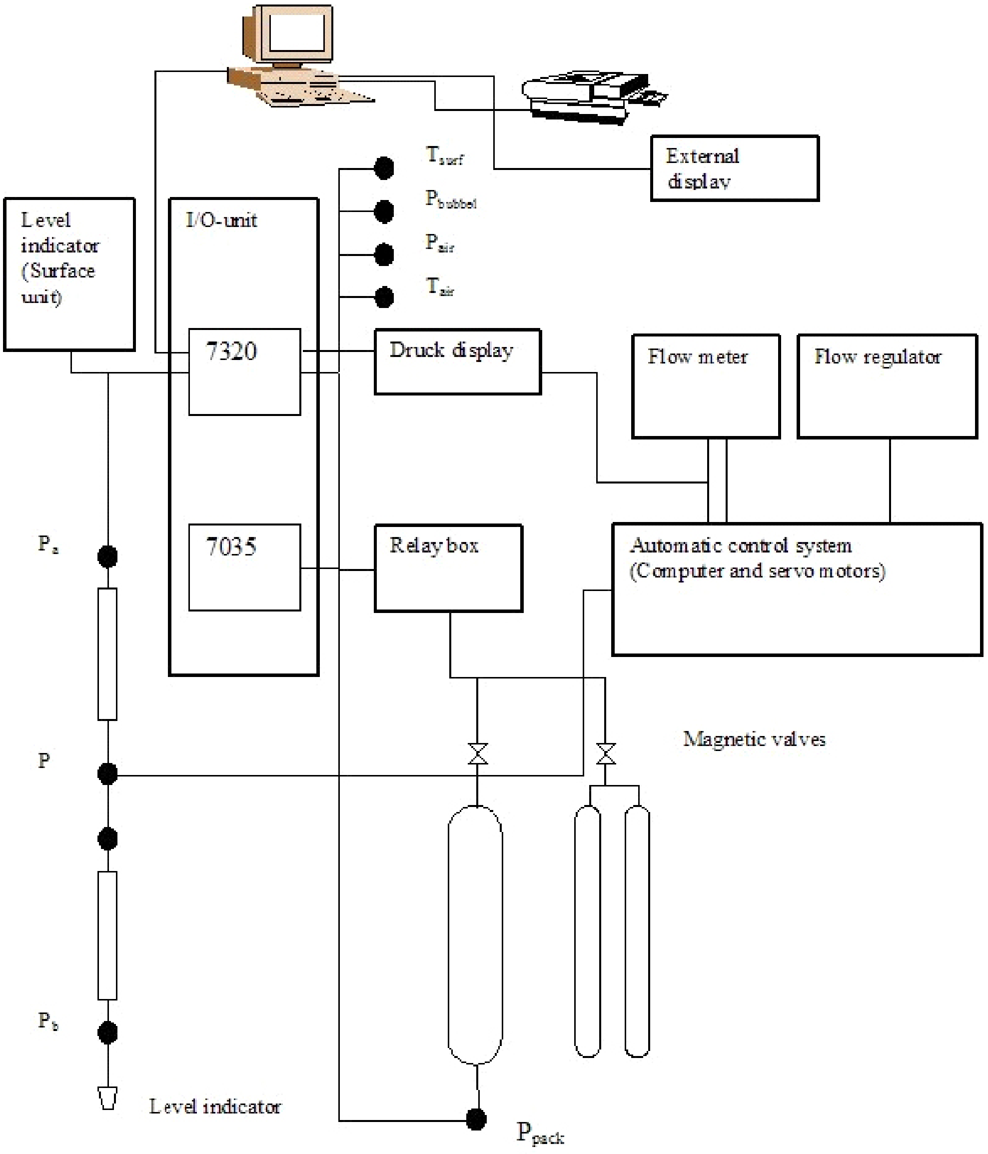

Figure 4-3. Schematic drawing of the data acquisition system and the automatic control system in PSS.

5 Execution

5.1 Preparation

5.1.1 Calibration

All sensors included in PSS are calibrated at the Geosigma engineering service station in Uppsala. Calibration is generally performed at least every year. Results from calibration, e.g. calibration constants, of sensors are kept in a document folder in PSS. If a sensor is replaced at the test site, calibration constants are altered as well. If a new, un-calibrated, sensor is to be used, calibration may be performed afterwards and data re-calculated.

5.1.2 Functioning checks

Equipment functioning checks were performed during the establishment of PSS at the test site. Simple function checks of down-hole sensors were done at every change of test section length, as well as while lowering the pipe string along the borehole.

5.1.3 Cleaning of equipment

Cleaning of the borehole equipment was performed according to the cleaning instruction SKB MD 600.004 (see Table 1-1), level 2.

5.2 Test performance

5.2.1 Test principle

The hydraulic tests in KFM11A were carried out while maintaining a constant head of generally 200 kPa (20 m) in the test section. Before start of the injection period, approximately steady-state pressure conditions prevailed in the test section. After the injection period, the pressure recovery was measured.

For injection tests in KFM11A the injection phase was interrupted if the injection flow was clearly below the measurement limit. Thereafter, the recovery was measured for at least 5 minutes to verify the low conductivity of the section.

The pumping test performed in section 690.0–710.0 m was also conducted as a constant head pumping test with a slightly decreased pressure of about 190 kPa (19 m) in the test section.

5.2.2 Test procedure

Generally, the tests were performed according to the Activity Plan AP PF 400-07-032. Exceptions to this are presented in Section 5.5.

A test cycle of a standard injection test includes the following phases: 1) Transfer of down-hole equipment to the next section, 2) Packer inflation, 3) Pressure stabilisation, 4) Injection, 5) Pressure recovery and 6) Packer deflation. The estimated times for the various phases during the injection tests are presented in Table 5-1. The test cycle during the pumping test in section 690.0–710.0 m included the same phases, except for the injection period. Estimated times for each phase were slightly different though. The flow period was prolonged to about 2.5 h due to the longer time needed to achieve a stable pressure, and the recovery period lasted for about 16 h.

Table 5-1. Packer inflation times, pressure stabilisation times and test times used for the injection tests in KFM11A.

Test section length (m)	Packer inflation time (min)	Time for pressure stabilisation (min)	Injection period (min)	Recovery period (min)	Total time/test (min)[1)]
20	25	5	20	20	70

[1)] Exclusive of trip times in the borehole.

5.2.3 Test strategy

Before any tests were performed in KFM11A, a bent PLEX-plate blocking the borehole had to be pressed out in order to enable passing it with the test section. This was made by using a resistant packer mounted in the end of the pipe string. A dummy was also fit above the packer. The packer was pressed in several positions on the bent area of the PLEX-plate. Then the dummy was lowered to ensure that the test section later on would pass it without damaging the packers or get stuck.

The tests in 20 m sections were, as far as possible, carried out in consecutive intervals. However, to be able to test as much as possible of the borehole without damaging the packers, the section limits had to be shifted in a few cases. Hence some parts of the borehole were measured with overlapping 20-m sections, cf. Section 5.5.

5.3 Data handling

With the PSS system, primary data are handled using the Orchestrator software (Version 2.3.8). During a test, data are continuously logged in *.odl-files. After the test is finished, a report file (*.ht2) with space separated data is generated. The *.ht2-file (mio-format) contains logged parameters as well as test-specific information, such as calibration constants and background data. The parameters are presented as percentage of sensor measurement range and not in engineering units. The report file in ASCII-format is the raw data file delivered to the data base Sicada.

The *.ht2-files are automatically named with borehole id, top of test section and date and time of test start (as for example __KFM11A_0470.00_200706041533.ht2) The name differs slightly from the convention stated in Instruction for analysis of injection and single-hole pumping tests, SKB MD 320.004. Using the IPPLOT software (Version 3.0), the *.ht2-files are converted to parameter files suitable for plotting using the code SKB-plot and analysis with the AQTESOLV software.

A backup of data files was created on a regular basis by CD-storage and by sending the files to the Geosigma office in Uppsala by a file transfer protocol. A file description table is presented in Appendix 1.

5.4 Analysis and interpretation

5.4.1 General

As described in Section 5.2.1, the hydraulic tests in KFM11A were performed as transient constant head tests followed by a pressure recovery period. From the injection period, the (reciprocal) flow rate versus time was plotted in log-log and lin-log diagrams together with the corresponding derivative. From the recovery period, the pressure was plotted versus Agarwal equivalent time in lin-log and log-log diagrams, respectively, together with the corresponding derivative. The routine data processing of the measured data was done according to the Instruction for analysis of injection and single-hole pumping tests (SKB MD 320.004).

For evaluation of the test data, no corrections of the measured flow rate and absolute pressure data (e.g. due to barometric pressure variations or tidal fluctuations) have been made. For short-time single-hole tests, such corrections are generally not needed, unless very small pressure changes are applied. No subtraction of the barometric pressure from the measured absolute pressure has been made, since the length of the test periods are short relative to the time scale for barometric pressure changes. In addition, pressure differences rather than the pressure magnitudes are used by the evaluation.

5.4.2 Measurement limit for flow rate and specific flow rate

The estimated standard lower measurement limit for flow rate for hydraulic tests with PSS is c 1 mL/min ($1.7 \cdot 10^{-8}$ m^3/s). However, if the flow rate for a test was close to, or below, the standard lower measurement limit, a test-specific estimate of the lower measurement limit of flow rate was made. The test-specific lower limit was based on the measurement noise level of the flow rate before and after the injection period. The decisive factor for the varying lower measurement limit is not identified, but it might be of both technical and hydraulic character.

The lower measurement limit for transmissivity is defined in terms of the specific flow rate (Q/s). The minimum specific flow rate corresponds to the estimated lower measurement limit of the flow rate together with the actual injection pressure during the test, see Table 5-2. The intention during this test campaign was to use a standard injection pressure of 200 kPa (20 m water column). Still, the injection pressure can be considerably different (see Section 6.2.3). An apparently low injection pressure is often the result of a test section of low conductivity due to a pressure increase, caused by packer expansion, before the injection start. A highly conductive section may also result in a low injection pressure due to limited flow capacity of PSS.

Whenever the final flow rate (Q_p) was not defined (i.e. not clearly above the measurement noise before and after the injection period), the estimated lower measurement limit for specific flow rate was based on the estimated lower measurement limit for flow rate for the specific test and a standard injection pressure of 200 kPa. This is done in order to avoid excessively high, apparent estimates of the specific flow rate for these low conductivity sections, which would have resulted if the actual pressure difference at start of injection had been used as injection pressure.

The lower measurement limits for the flow rate correspond to different values of steady-state transmissivity, T_M, depending on the section lengths used in the factor C_M in Moye's formula, as described in the Instruction for analysis of injection and single-hole pumping tests (SKB MD 320.004), see Table 5-2.

The practical upper measurement limit of hydraulic transmissivity for the PSS system is estimated at a flow rate of c 30 L/min ($5 \cdot 10^{-4}$ m^3/s) and an injection pressure of c 1 m. Thus, the upper measurement limit for the specific flow rate is $5 \cdot 10^{-4}$ m^2/s. However, the practical upper measurement limit may vary, depending on e.g. depth of the test section (friction losses in the pipe string).

Table 5-2. Estimated lower measurement limit for specific flow rate and steady-state transmissivity for different injection pressures and estimated lower measurement limits for flow rate for the hydraulic tests in borehole KFM11A.

r_w (m)	L_w (m)	Q-measl-L (m^3/s)	Injection pressure (kPa)	Q/s-measl-L (m^2/s)	Factor C_M in Moye's formula	T_M-measl-L (m^2/s)
0.0387	20	1.7E–08	100	1.6E–09	1.04	1.7E–09
0.0387	20	1.7E–08	200	8.2E–10	1.04	8.5E–10
0.0387	20	1.7E–08	300	5.5E–10	1.04	5.7E–10
0.0387	20	1.2E–08	100	1.2E–09	1.04	1.2E–09
0.0387	20	1.2E–08	200	5.9E–10	1.04	6.1E–10
0.0387	20	1.2E–08	300	3.9E–10	1.04	4.1E–10
0.0387	20	5.0E–09	100	4.9E–10	1.04	5.1E–10
0.0387	20	5.0E–09	200	2.5E–10	1.04	2.6E–10
0.0387	20	5.0E–09	300	1.6E–10	1.04	1.7E–10

5.4.3 Qualitative analysis

Initially, a qualitative evaluation of actual flow regimes, e.g. wellbore storage (WBS), pseudo-linear flow regime (PLF), pseudo-radial flow regime (PRF), pseudo-spherical flow regime (PSF) and pseudo-stationary flow regime (PSS), respectively, was performed. In addition, indications of outer boundary conditions during the tests were identified. The qualitative evaluation was mainly interpreted from the log-log plots of flow rate and pressure together with the corresponding derivatives.

In particular, time intervals with pseudo-radial flow, reflected by a constant (horizontal) derivative in the test diagrams, were identified. Pseudo-linear flow may, at the beginning of the test, be reflected by a straight line of slope 0.5 or less in log-log diagrams, both for the measured variable (flow rate or pressure) and the derivative. A true spherical flow regime is reflected by a straight line with a slope of –0.5 for the derivative. However, other slopes may indicate transitions to pseudo-spherical (leaky) or pseudo-stationary flow. The latter flow regime corresponds to almost stationary conditions with a derivative approaching zero.

The interpreted flow regimes can also be described in terms of the distance from the borehole:

- **Inner zone:** Representing very early responses that may correspond to the fracture properties close to the borehole which may possibly be affected by turbulent head losses. These properties are generally reflected by the skin factor.
- **Middle zone:** Representing the first response from which it is considered possible to evaluate the hydraulic properties of the formation close to the borehole.
- **Outer zone:** Representing the response at late times of hydraulic structure (s) connected to the hydraulic feature for the middle zone. Sometimes it is possible to deduce the possible character of the actual feature or boundary and evaluate the hydraulic properties.

Due to the limited resolution of the flow meter and pressure sensor, the derivative may some times indicate a false horizontal line by the end of periods with pseudo-stationary flow. Apparent no-flow (NFB) and constant head boundaries (CHB), or equivalent boundary conditions of fractures, are reflected by an increase/decrease of the derivative, respectively.

5.4.4 Quantitative analysis

Injection tests

A preliminary steady-state analysis of transmissivity according to Moye's formula (denoted T_M) was made for the injection period for all tests in conjunction with the qualitative analysis according to the following equations:

$$T_M = \frac{Q_p \cdot \rho_w \cdot g}{dp_p} \cdot C_M \qquad (5\text{-}1)$$

$$C_M = \frac{1 + \ln\left(\frac{L_w}{2r_w}\right)}{2\pi} \qquad (5\text{-}2)$$

Q_p = flow rate by the end of the flow period (m^3/s)

ρ_w = density of water (kg/m^3)

g = acceleration of gravity (m/s^2)

C_M = geometrical shape factor (–)

dp_p = injection pressure $p_p - p_i$ (Pa)

r_w = borehole radius (m)

L_w = section length (m)

From the results of the qualitative evaluation, appropriate interpretation models for the quantitative evaluation of the tests were selected. When possible, transient analysis was made on both the injection and recovery periods of the tests.

The transient analysis was performed using a special version of the test analysis software AQTESOLV, which enables both visual and automatic type curve matching. The quantitative transient evaluation is generally carried out as an iterative process of manual type curve matching and automatic matching. For the injection period, a model based on the Jacob and Lohman /1/ solution was applied for estimating the transmissivity and skin factor for an assumed value on the storativity when a certain period with pseudo-radial flow could be identified. The model is based on the effective wellbore radius concept to account for non-zero (negative) skin factors according to Hurst, Clark and Brauer /2/.

In borehole KFM11A, the storativity was calculated using an empirical regression relationship between storativity and transmissivity, see Equation 5-3 /3/.

$$S = 0.0007 \cdot T^{0.5} \qquad (5\text{-}3)$$

S = storativity (–)

T = transmissivity (m^2/s)

Firstly, the transmissivity and skin factor were obtained by type curve matching on the data curve using a fixed storativity value of 10^{-6}, according to the instruction SKB MD 320.004. From the transmissivity value obtained, the storativity was then calculated according to Equation 5-3 and the type curve matching was repeated. In most cases the change of storativity did not significantly alter the calculated transmissivity by the new type curve matching. Instead, the estimated skin factor, which is strongly correlated to the storativity using the effective borehole radius concept, was altered correspondingly.

For transient analysis of the recovery period, a model presented by Dougherty-Babu /4/ was used when a certain period with pseudo-radial flow could be identified. In this model, a variety of transient solutions for flow in fractured porous media are available, accounting for e.g. wellbore storage and skin effects, double porosity etc. The solution for wellbore storage and skin effects is analogous to the corresponding solution presented in Earlougher /5/ based on the effective wellbore radius concept to account for non-zero (negative) skin factors. However, for tests in isolated test sections, wellbore storage are represented by a radius of a fictive standpipe (denoted fictive casing radius, r (c)) connected to the test section, cf. Equation 5-6. This concept is equivalent to calculating the wellbore storage coefficient C from the compressibility in an isolated test section according to Equation 5-5. The storativity was calculated using Equation 5-3 in the same way as described above for the transient analysis of the injection period. In addition, the wellbore storage coefficient was estimated, both from the simulated value on the fictive casing radius r(c) and from the slope of 1:1 in the log-log recovery plots.

For tests characterized by pseudo-spherical (leaky) flow or pseudo-stationary flow during the injection period, a model by Hantush /6/ for constant head tests was adopted for the evaluation. In this model, the skin factor is not separated but can be calculated from the simulated effective borehole radius according to Equation 5-4. This model also allows calculation of the wellbore storage coefficient according to Equation 5-6. In addition, the leakage coefficient K'/b' can be calculated from the simulated leakage factor r/B. The corresponding model for constant flow rate tests, Hantush /7/, was applied for evaluation of the recovery period for tests showing pseudo-spherical- or pseudo-stationary flow during this period.

$$\zeta = ln(r_w/r_{wf}) \tag{5-4}$$

ζ = skin factor

rw = borehole radius (m)

rwf = effective borehole radius

Some tests showed fracture responses (initial slope of 0.5 or less in a log-log plot). A model for an equivalent single fracture was then used for the transient analysis as a complement to standard models for pseudo-radial flow. The model presented in Ozkan-Raghavan /8, 9/ for a uniform-flux vertical fracture embedded in a porous medium was employed. With this model the hydraulic conductivity of the rock perpendicular (K_x) and parallel (K_y) to the fracture can be estimated. In this case, the quotient K_x/K_y was assumed to be 1.0 (one). Type curve matching provided values of K_x and L_f assuming a value on the specific storativity S_s based on Equation 5-3, where L_f is the theoretical fracture length. The test section length was then used to convert K_x and S_s to transmissivity $T = K_x \cdot L$ and to storativity $S = S_s \cdot L$, respectively of the rock in analysis by fracture models. Such estimates of transmissivity from fracture models may be compared with corresponding values from models for pseudo-radial flow in the same test section.

The different transient estimates of transmissivity from the injection and recovery period, respectively, were then compared and examined. One of these was chosen as the best representative value of the transient transmissivity of the formation adjacent to the test section. This value is denoted T_T. In cases with more than one pseudo-radial flow regime during the injection or recovery period, the first one is in most cases assumed as the most representative for the hydraulic conditions in the rock close to the tested section.

Finally, a representative value of transmissivity of the test section, T_R, was chosen from T_T and T_M. The latter transmissivity is to be chosen whenever a transient evaluation of the test data is not possible or not being considered as reliable. If the flow rate by the end of an injection period (Q_p) is too low to be defined, and thus neither T_T nor T_M can be estimated, the representative transmissivity for the test section is considered to be less than T_M based on the estimated lower measurement limit for Q/s (i.e. $T_R < T_M = Q/s\text{-measl-}L \cdot C_M$).

Estimated values of the borehole storage coefficient, C, based on actual borehole geometrical data and assumed fluid properties are shown in Table 5-3 together with the estimated effective C_{eff} from laboratory experiments /10/. The net water volume in the test section, V_w, has in Table 5-3 been calculated by subtracting the volume of equipment in the test section (pipes and thin hoses) from the total volume of the test section. For an isolated test section, the wellbore storage coefficient, C, may be calculated as by Almén et al. /11/:

$$C = V_w \cdot c_w = L_w \cdot \pi \cdot r_w^2 \cdot c_w \tag{5-5}$$

V_w = water volume in test section (m^3)

r_w = nominal borehole radius (m)

L_w = section length (m)

c_w = compressibility of water (Pa^{-1})

When appropriate, estimation of the actual borehole storage coefficient C in the test sections was made from the recovery period, based on the early borehole response with 1:1 slope in the log-log diagrams. The coefficient C was calculated only for tests with a well-defined line of slope 1:1 in the beginning of the recovery period. In the most conductive sections, this period occurred during very short periods at early test times. The latter values may be compared with the net values of C based on geometry and the value of C_{eff} based on laboratory experiments /10/, (Table 5-3).

Furthermore, when using the model by Dougherty-Babu /4/ or Hantush /7/, a fictive casing radius, r(c), is obtained from the parameter estimation of the recovery period. This value can then be used for calculating C as by Almén et al. /11/:

$$C = \frac{\pi \cdot r(c)^2}{\rho \cdot g} \tag{5-6}$$

Although this calculation was not done regularly and the results are not presented in this report, the calculations corresponded in most cases well to the value of C obtained from the line of slope 1:1 in the beginning of the recovery period.

The estimated values of C from the tests may differ from the net values in Table 5-3 based on geometry. For example, the effective compressibility for an isolated test section may sometimes be higher than the water compressibility due to e.g. packer compliance, resulting in increased C-values.

The radius of influence at a certain time may be estimated from Jacob's approximation of the Theis' well function, Cooper and Jacob /12/:

Table 5-3. Calculated net value of C, based on the actual geometrical properties of the borehole and equipment configuration in the test section (C_{net}) together with the effective wellbore storage coefficient (C_{eff}) for injection tests from laboratory experiments /10/.

r_w (m)	L_w (m)	Volume of test section (m^3)	Volume of equipment in section (m^3)	V_w (m^3)	C_{net} (m^3/Pa)	C_{eff} (m^3/Pa)
0.0387	20	0.094	0.013	0.081	3.7E–11	4.4E–11

$$r_i = \sqrt{\frac{2.25Tt}{S}} \qquad (5\text{-}7)$$

T = representative transmissivity from the test (m^2/s)

S = storativity estimated from Equation 5-3

r_i = radius of influence (m)

t = time after start of injection (s)

If a certain time interval of pseudo-radial flow (PRF) from t_1 to t_2 can be identified during the test, the radius of influence is estimated using time t_2 in Equation 5-7. If no interval of PRF can be identified, the actual total flow time t_p is used. The radius of influence can be used to deduce the length of the hydraulic feature (s) tested.

Furthermore, an r_i-index (–1, 0 or 1) is defined to characterize the hydraulic conditions by the end of the test. The r_i-index is defined as shown below. It is assumed that a certain time interval of PRF can be identified between t_1 and t_2 during the test.

- r_i-index = 0: The transient response indicates that the size of the hydraulic feature tested is greater than the radius of influence based on the actual test time ($t_2 = t_p$), i.e. the PRF is continuing at stop of the test. This fact is reflected by a flat derivative at this time.
- r_i-index = 1: The transient response indicates that the hydraulic feature tested is connected to a hydraulic feature with lower transmissivity or an apparent barrier boundary (NFB). This fact is reflected by an increase of the derivative. The size of the hydraulic feature tested is estimated as the radius of influence based on t_2.
- r_i-index = –1: The transient response indicates that the hydraulic feature tested is connected to a hydraulic feature with higher transmissivity or an apparent constant head boundary (CHB). This fact is reflected by a decrease of the derivative. The size of the hydraulic feature tested is estimated as the radius of influence based on t_2.

If a certain time interval of PRF cannot be identified during the test, the r_i-indices –1 and 1 are defined as above. In such cases the radius of influence is estimated using the flow time t_p in Equation 5-7.

In some tests there may be signs of pressure interference in the section above or below the test section due to a hydraulic interconnection of the sections. This kind of pressure interference may result in an overestimation of the transmissivity in the test section. If pressure interference is detected during a test, a qualitative evaluation is performed to determine if it is likely that the estimated transmissivity of the test section is overestimated or not. The qualitative evaluation includes a comparison of the injection pressure and evaluated transmissivity of the test section with the corresponding pressure interference and transmissivity of the borehole interval in which interference is observed. Furthermore, a comparison with transmissivity from tests with other section lengths is made to detect deviating results. The type of dominating flow regime in the test section may also support the qualitative evaluation whether the interference is likely to affect the evaluated transmissivity or not.

5.5 Nonconformities

The test program in KFM11A was carried out according to the Activity Plan AP PF 400-07-032 with the following exceptions:

- The tests in the sections 508.5–528.5 and 670.0–690.0 m were conducted twice since the first test in each section was considered to provide uncertain information.

- The length of the borehole as well as fractures in the borehole made measurements with overlapping sections necessary. The borehole intervals 488.5–490.0, 514.5–528.5, 530.0–534.5 and 820.0–830.0 were measured with overlapping 20–m sections.
- Due to the risk of getting stuck below the damaged PLEX-plate at 497.4–499.4 m an extra pressure sensor was mounted in the test section instead of the temperature sensor. This sensor was to be used if the original pressure sensor in the section should break down. Hence no temperature data were collected.
- Due to lack of time, an uncalibrated pressure sensor was used to measure the pressure above the test section (Pa). A simple calibration was conducted while lowering the test section whereby the raw data and pressure values were compared with the pressure sensor in the test section. Values registered by the uncalibrated pressure sensor were in good agreement with the calibrated sensor, hence no adjustment of the calibration constants were made.

6 Results

6.1 Nomenclature and symbols

The nomenclature and symbols used for the results of the hydraulic tests in KFM11A are in accordance with the Instruction for analysis of injection and single-hole pumping tests (SKB MD 320.004). Additional symbols are explained in the text and in Appendix 5. Symbols used by the AQTESOLV software are explained in Appendix 3.

Original data from the reported activity are stored in the primary database Sicada. Data are traceable in Sicada by the Activity Plan number (AP PF 400-07-032).

6.2 Routine evaluation of the single-hole hydraulic tests

6.2.1 General test data

General test data and selected pressure and flow data from all tests are listed in Appendix 2.1 and 2.2, respectively.

6.2.2 Length corrections

The down-hole equipment is supplied with a level indicator located c 3 m below the lower packer in the test section, see Figure 4-2. The level indicator transmits a signal each time a reference mark in the borehole is passed. In KFM11A, reference marks were milled into the borehole wall at approximately every 50 m.

During the hydraulic tests in KFM11A with the PSS, length reference marks were detected as presented in Table 6-1. As seen from Table 6-1, all of the length marks of the borehole were detected, except for the one at 100 m. At each detected mark, the length scale for the hydraulic tests was adjusted according to the reported length to the reference mark.

Table 6-1. Detected reference marks during the hydraulic tests and after drilling in KFM11A.

Borehole length (m)	Detected during the hydraulic tests in 20 m sections
100	No
149.2	Yes
200	Yes
250	Yes
300	Yes
350	Yes
400	Yes
449	Yes
497	Yes
550	Yes
603	Yes
648	Yes
700	Yes
750	Yes
801	No[1)]

[1)] Not detected after the grove milling according to Sicada printout 070627.

The largest difference between the reported and measured lengths at the reference marks during the hydraulic tests was 0.24 m, at the 750 m reference mark. The difference between two consecutive measurements over a 50 m borehole interval was 0.09 m or less in all cases.

Since the length scale was adjusted in the field every time a reference mark was detected and since the difference between consecutive marks was small, it was not found worthwhile to make any further adjustments after the measurements, e.g. by linear interpolation between reference marks.

6.2.3 General results

For the hydraulic tests, transient evaluation was conducted, whenever possible, both on the injection and recovery periods (e.g. transmissivity T_f and T_s, respectively) according to the methods described in Section 5.4.4. The steady-state transmissivity (T_M) was calculated by Moye's formula according to Equation 5-1. Hydraulic tests with a final flow rate below the measurement limit, Q_p, or with a non-definable flow regime were only evaluated by the steady-state method. All other tests were evaluated with both transient and steady-state methods. The quantitative analysis was conducted using the AQTESOLV software. A summary of the results of the routine evaluation of the hydraulic tests can be seen in Table 6-2.

The dominating transient flow regimes during the injection and recovery periods, as interpreted from the qualitative test evaluation, are listed in Table 6-2 and further commented on in Section 6.2.4. The transmissivity considered as the most reliable from the transient evaluation of the flow- and recovery periods of the tests was selected as T_T, see Table 6-2.The borehole displays for about 50% of the tests a PRF as the dominating flow regime during the injection period. Dominating flow regimes during the recovery of the tests were PSF and PRF often preceded by WBS.

In 17 out of 18 tests with a definable final flow rate in KFM11A, the transient evaluation of the injection period was considered to give the most representative transmissivity value for the section. For one of the tests, the transient evaluation of the recovery period was considered most representative. Two of the tests had a final flow rate below the measurement limit, Q_p, hence T_M was chosen as representative for these sections.

The total transmissivity of KFM11A is dominated by the intervals between 690.0–710.00 and 770.0–840.0 m (see Figure 6-1).

If the final flow rate Q_p was below the actual test-specific measurement limit, the representative transmissivity value was assumed to be less than the estimated T_M, based on Q/s-measl-L.

In Table 6-2, estimated transmissivity values in the test sections in KFM11A according to steady-state (T_M) and most representative evaluation (T_R) are presented. If the transmissivity value is below the measurement limit (Q_p could not be defined), the most representative transmissivity value, T_R, was considered to be less than T_M, based on Q/s-measl-L, for the test section.

The estimated standard lower measurement limit for flow rate for hydraulic tests with PSS is c 1 mL/min ($1.7 \cdot 10^{-8}$ m^3/s). Two of the hydraulic tests in KFM11A were interrupted due to no detectable flow. Hence a test-specific estimate of the lower measurement limit based on the noise level was made. The lower measurement limit for transmissivity is defined in terms of the specific flow rate (Q/s) cf. Section 5.4.2.

Selected test diagrams are presented in Appendix 3. In general, one linear diagram showing the entire test sequence together with lin-log and log-log diagrams from the injection and recovery periods, respectively, are presented for the hydraulic tests. The quantitative analysis was performed from such diagrams using the AQTESOLV software. From hydraulic tests with a flow rate below the estimated lower measurement limit for the specific test, only the linear diagram is presented. The results of the routine evaluation of the tests in borehole KFM11A are also compiled in appropriate tables in Appendix 5 to be stored in the Sicada database.

Table 6-2. Estimated transmissivity values from the hydraulic tests in 20 m test sections in KFM11A.

Secup	Seclow	Test start	b	Flow regime 1)		T_M	T_f	T_s	T_T	T_R 2)	ξ	t_1	t_2	dte_1	dte_2	C	r_i	r_i-index
(m)	(m)	YYYY-MM-DD hh:mm	(m)	injection	Recovery	(m^2/s)	(m^2/s)	(m^2/s)	(m^2/s)	(m^2/s)	(–)	(s)	(s)	(s)	(s)	(m^3/Pa)	(m)	(–)
470.00	490.00	2007-06-04 15:33	20.0	PRF–>PSF	PRF–>PSF	5.80E–08	3.64E–08	2.86E–08	3.64E–08	3.64E–08	–2.24	50	400	40	200		15.66	–1
488.50	508.50	2007-06-05 09:23	20.0	–>PRF	WBS–>	3.11E–08	1.51E–08	2.21E–08	1.51E–08	1.51E–08	–3.35	200	1,223			6.46E–10	21.98	0
508.50	528.50	2007-06-05 12:52	20.0	–	–	< 2.55E–10				< 2.55E–10							–	–
514.50	534.50	2007-06-05 14:33	20.0	–	–	< 2.55E–10				< 2.55E–10							–	–
530.00	550.00	2007-06-05 15:49	20.0	PLF	PLF	2.11E–09	1.32E–10	4.06E–10	4.06E–10	4.06E–10	5.52						8.79	1
550.00	570.00	2007-06-07 08:48	20.0	PLF–>NFB	PLF–>NFB	3.21E–10	1.31E–10		1.31E–10	1.31E–10	–4.86						6.65	1
570.00	590.00	2007-06-07 10:35	20.0	PSF	WBS–>PSF?	5.07E–09	1.85E–09	9.26E–10	1.85E–09	1.85E–09	–3.08					6.88E–11	13.02	–1
590.00	610.00	2007-06-07 13:05	20.0	–>PSF?	WBS–>PSF?	3.13E–08	7.12E–08		7.12E–08	7.12E–08	9.65					6.05E–11	32.39	0
610.00	630.00	2007-06-07 14:49	20.0	–>PSF	WBS–>PSF?	1.00E–08	1.43E–08	3.08E–09	1.43E–08	1.43E–08	2.93	250	1,200			3.57E–11	21.46	0
630.00	650.00	2007-06-07 16:36	20.0	PRF	WBS–>	2.79E–09	2.67E–09		2.67E–09	2.67E–09	0.33	20	1,225			5.33E–11	14.26	0
650.00	670.00	2007-06-08 08:20	20.0	–>PRF?	WBS–>PRF?	2.68E–09	3.82E–10	2.93E–10	3.82E–10	3.82E–10	–4.95	20	1,100			6.83E–11	8.31	–1
670.00	690.00	2007-06-08 10:41	20.0	–>PRF	–>PRF?	3.15E–07	1.04E–07	1.11E–07	1.04E–07	1.04E–07	–4.95	300	1,265				36.18	0
690.00	710.00	2007-07-09 14:09	20.0	PRF	–>PRF–> (PSS)	7.33E–07	7.59E–07	9.70E–07	7.59E–07	7.59E–07	–1.62	600	9,047	100	5,100		159.17	0
710.00	730.00	2007-06-08 13:32	20.0	–>PRF	WBS–>	6.01E–09	2.71E–09	1.05E–09	2.71E–09	2.71E–09	–3.23	150	1,223			3.00E–11	14.30	0
730.00	750.00	2007-06-08 15:16	20.0	PRF	WBS–>PRF	1.06E–08	6.15E–09	7.61E–09	6.15E–09	6.15E–09	–2.47	50	1,225	130	900	5.14E–11	17.58	0
750.00	770.00	2007-06-11 08:35	20.0	PRF	WBS–>PRF	2.26E–08	9.79E–09	1.25E–08	9.79E–09	9.79E–09	–3.57	100	1,230	50	700		19.78	0
770.00	790.00	2007-06-11 13:26	20.0	PSF	PSF	5.54E–07	3.01E–07	3.78E–07	3.01E–07	3.01E–07	–3.13						46.54	0
790.00	810.00	2007-06-11 15:10	20.0	PRF	PSF	1.03E–06	1.22E–06	1.04E–06	1.22E–06	1.22E–06	0.26	100	1,250				66.60	0
810.00	830.00	2007-06-12 08:38	20.0	PRF–>PSF	PRF–>PSF	7.25E–07	5.55E–07	7.17E–07	5.55E–07	5.55E–07	–1.91	100	200	50	200		21.88	–1
820.00	840.00	2007-06-12 12:34	20.0	PSF	PSF	4.74E–07	3.52E–07	4.25E–07	3.52E–07	3.52E–07	–1.75						48.32	–1
508.50	528.50	2007-06-05 11:08	20.0	–	–	0.00E+00			0.00E+00	0.00E+00	0.00	0	0	0	0	0.00E+00	0.00	0
670.00	690.00	2007-06-08 09:58	20.0	–	–	0.00E+00			0.00E+00	0.00E+00	0.00	0	0	0	0	0.00E+00	0.00	0

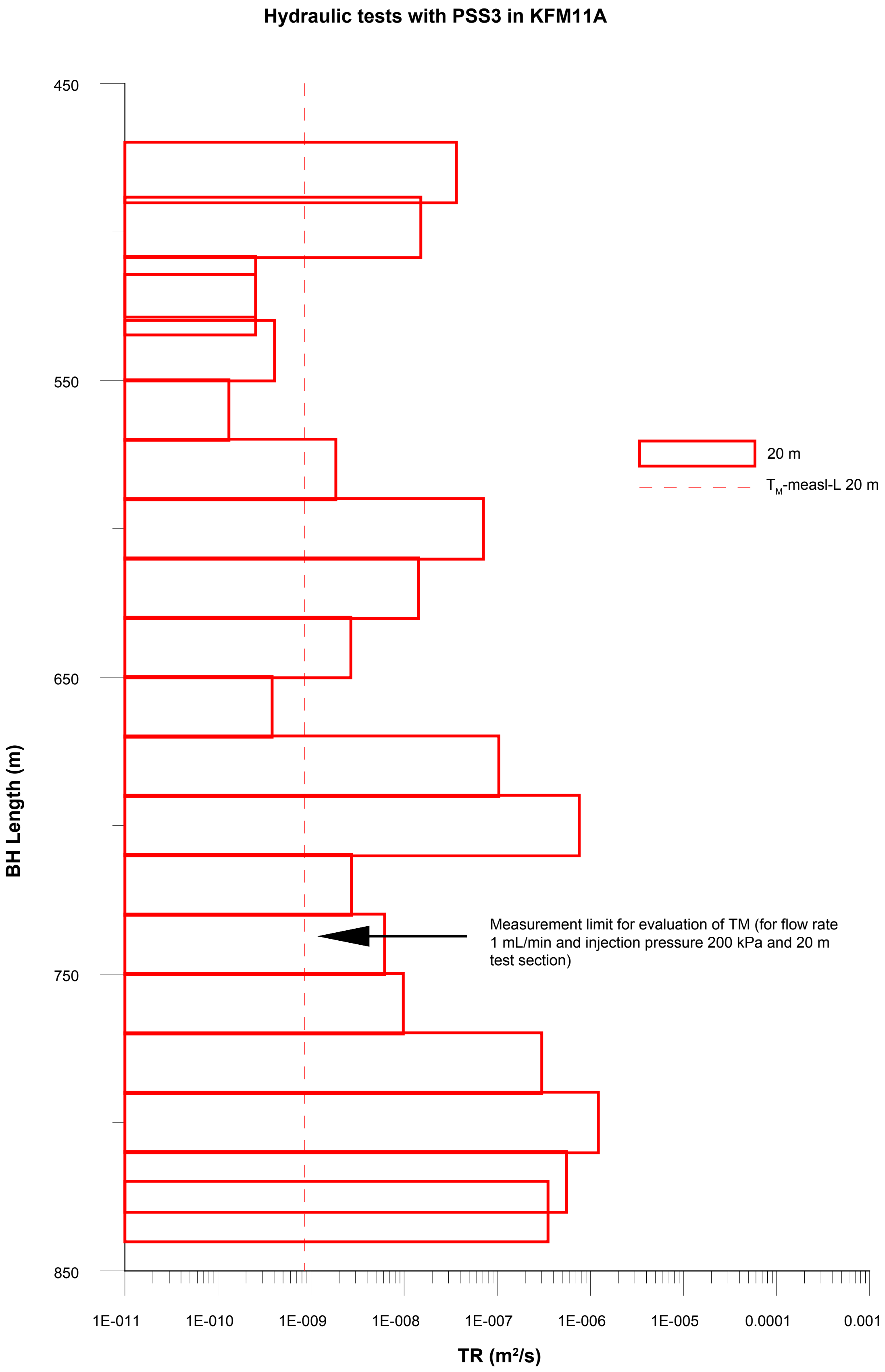

***Figure 6-1.** Estimated representative transmissivity values (T_R) from hydraulic tests with 20 m sections in borehole KFM11A. Estimated transmissivity for the lower standard measurement limit from stationary evaluation (T_M-measl-L) for 20 m test section lengths is also shown.*

For a few tests, a type curve fit is displayed in the diagrams in Appendix 3 despite the fact that the estimated parameters from the fit are judged as ambiguous or non-representative and not included in the result tables in Sicada. For these tests, the type curve fit is presented as an example, e.g. to illustrate that an assumption of pseudo-radial flow regime is not justified for the test and some other flow regime is dominating or, alternatively, to show one possible fit in the case of unambiguous evaluation. For example, for test responses showing only wellbore storage or no flow boundary response, no unambiguous transient evaluation is possible.

In Figure 6-2, a comparison of calculated transmissivities in 20 m sections from steady-state evaluation (T_M) and transmissivity values from the transient evaluation (T_T) is shown. The agreement between the two populations is good. Steady-state analysis of transmissivity according to Moye's formula (denoted T_M) may slightly overestimate the transmissivity if steady-state conditions do not prevail in the borehole. In addition, skin effects (both positive and negative) may cause discrepancies between transient and steady-state evaluation. For example, a test showing a strong negative skin factor (fracture response) with an interpreted PLF from the transient evaluation of the injection period may result in a much higher (c one order of magnitude) steady-state transmissivity. For low values of transmissivity, discrepancies in transmissivity may also occur due to the definition of the lower measurement limit in transient and steady-state evaluation, respectively. In the latter evaluation the measurement limit is based on the test-specific flow rate while in transient evaluation, the transmissivity is based on the change of the (inverse) flow rate during the injection period.

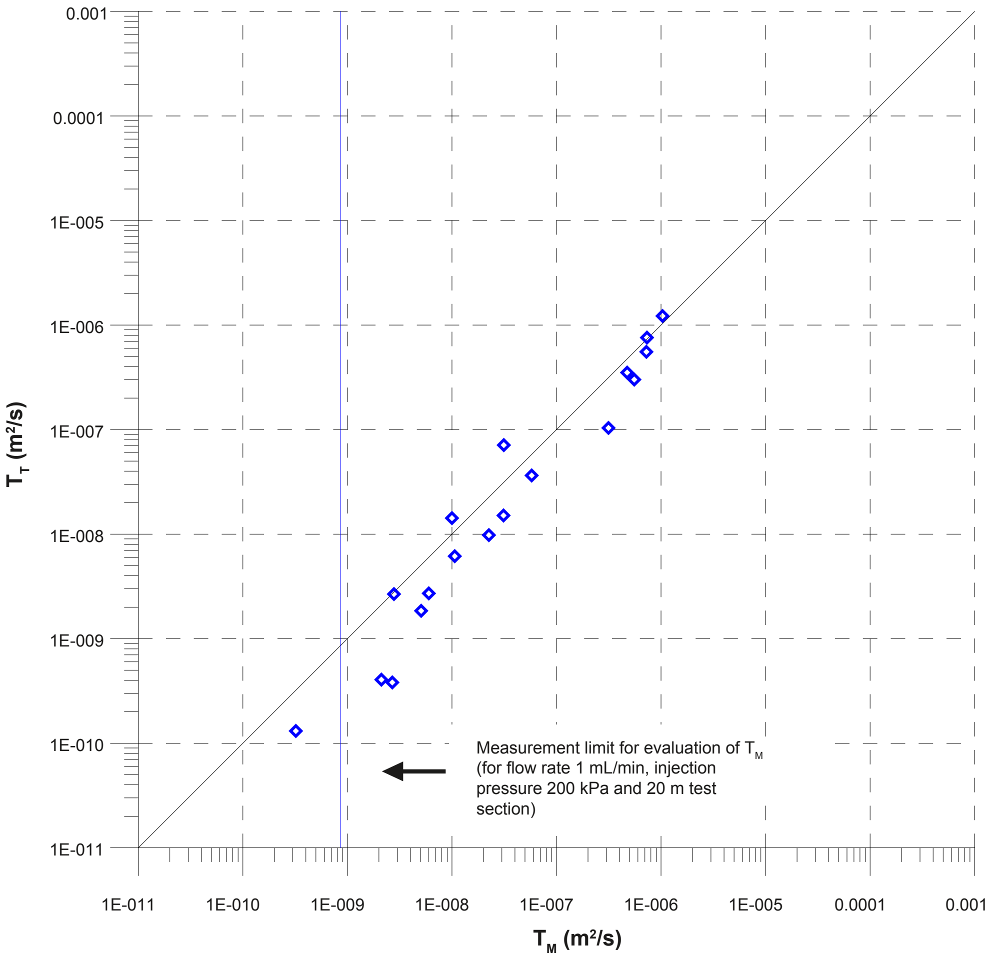

Figure 6-2. *Estimated transmissivities in 20 m sections from steady-state (T_M) and transient (T_T) evaluation for the hydraulic tests in KFM11A.*

In cases where apparent no-flow boundaries appear at the end of the injection period and transient evaluation is performed on the early part of the data curve, the steady-state transmissivity T_M may be low in comparison with the transient estimate of transmissivity. In this case, two different zones of the bedrock are measured during the early and late parts of the injection period, respectively.

The lower standard measurement limit of steady-state transmissivity in 20 m sections based on a flow rate of 1 mL/min and an injection pressure of 20 m is indicated in Figure 6-2. However, for some test sections in KFM11A, the actual injection pressure was considerably different, as previously denoted in Section 5.4.2. The highest injection pressure during the tests in KFM11A was 29.66 m, and the lowest 19.65 m.

The wellbore storage coefficient, C, was calculated from the straight line with a unit slope in the log-log diagrams from the recovery period, see Table 6-3. The coefficient C was only calculated for tests with a well-defined line of unit slope in the beginning of the recovery period. In the most conductive sections, this period occurred during very short intervals at very early times and is not visible in the diagrams. In sections with a very low transmissivity, the estimates of C may be uncertain due to difficulties in defining an accurate time for the start of the recovery period. Furthermore, the resolution of the pressure sensors causes the recovery to be quite scattered in sections of low transmissivity. The values of C presented in Table 6-3 may be compared with the net values of C, C_{net} (based on geometry), and the value of C obtained from laboratory experiments, C_{eff} /11/, both found in Table 5-3. Figure 6-3 shows a comparison between the C values calculated from the straight line with a unit slope in the log-log diagrams from the recovery period and the C values obtained from laboratory experiments, $C_{eff.}$.

The number of hydraulic tests with a well-defined line of unit slope from which it was possible to calculate C from the recovery was 8 out of 18 tests with a definable Q_p. Table 6-3 and Figure 6-3 show that the calculated C-values from the tests generally were close to the effective wellbore storage coefficient obtained from laboratory experiments, C_{eff}, while one was higher. The higher C-value observed in the test may partly be explained by the compressibility contribution of the rock formation and water in good hydraulic connection (i.e. open fractures or cavities) with the section and partly by uncertainties in the determination of C from the tests.

When constructing 95% confidence intervals (using a t-distribution) from calculated values of C from the tests with 20 m section length, the values of C_{net} listed in Table 5-3 are outside these confidence intervals while C_{eff} is within the same interval. The wellbore storage coefficient was also calculated from the simulation of the recovery responses in AQTESOLV based on the estimated radius of the fictive standpipe, r(c), to the test section according to Equation 5-6.

Table 6-3. Summary of the routine evaluation of the single-hole hydraulic tests in borehole KFM11A.

Secup (m)	Seclow (m)	Test start YYYY-MM-DD hh:mm	b (m)	Flow regime [1] injection	Recovery	T_M (m²/s)	T_f (m²/s)	T_s (m²/s)	T_T (m²/s)	T_R [2] (m²/s)	ξ (–)	t_1 (s)	t_2 (s)	dte_1 (s)	dte_2 (s)	C (m³/Pa)	r_i (m)	r_i-index (–)
470.00	490.00	2007-06-04 15:33	20.0	PRF–>PSF	PRF–>PSF	5.80E–08	3.64E–08	2.86E–08	3.64E–08	3.64E–08	–2.24	50	400	40	200		15.66	–1
488.50	508.50	2007-06-05 09:23	20.0	–>PRF	WBS–>	3.11E–08	1.51E–08	2.21E–08	1.51E–08	1.51E–08	–3.35	200	1,223			6.46E–10	21.98	0
508.50	528.50	2007-06-05 12:52	20.0	–	–	< 2.55E–10				< 2.55E–10							–	–
514.50	534.50	2007-06-05 14:33	20.0	–	–	< 2.55E–10				< 2.55E–10							–	–
530.00	550.00	2007-06-05 15:49	20.0	PLF	PLF	2.11E–09	1.32E–10	4.06E–10	4.06E–10	4.06E–10	5.52						8.79	1
550.00	570.00	2007-06-07 08:48	20.0	PLF–>NFB	PLF–>NFB	3.21E–10	1.31E–10		1.31E–10	1.31E–10	–4.86						6.65	1
570.00	590.00	2007-06-07 10:35	20.0	PSF	WBS–>PSF?	5.07E–09	1.85E–09	9.26E–10	1.85E–09	1.85E–09	–3.08					6.88E–11	13.02	–1
590.00	610.00	2007-06-07 13:05	20.0	–>PSF?	WBS–>PSF?	3.13E–08	7.12E–08		7.12E–08	7.12E–08	9.65					6.05E–11	32.39	0
610.00	630.00	2007-06-07 14:49	20.0	–>PSF	WBS–>PSF?	1.00E–08	1.43E–08	3.08E–09	1.43E–08	1.43E–08	2.93	250	1,200			3.57E–11	21.46	0
630.00	650.00	2007-06-07 16:36	20.0	PRF	WBS–>	2.79E–09	2.67E–09		2.67E–09	2.67E–09	0.33	20	1,225			5.33E–11	14.26	0
650.00	670.00	2007-06-08 08:20	20.0	–>PRF?	WBS–>PRF?	2.68E–09	3.82E–10	2.93E–10	3.82E–10	3.82E–10	–4.95	20	1,100			6.83E–11	8.31	–1
670.00	690.00	2007-06-08 10:41	20.0	–>PRF	–>PRF?	3.15E–07	1.04E–07	1.11E–07	1.04E–07	1.04E–07	–4.95	300	1,265				36.18	0
690.00	710.00	2007-07-09 14:09	20.0	PRF	–>PRF–>(PSS)	7.33E–07	7.59E–07	9.70E–07	7.59E–07	7.59E–07	–1.62	600	9,047	100	5,100		159.17	0
710.00	730.00	2007-06-08 13:32	20.0	–>PRF	WBS–>	6.01E–09	2.71E–09	1.05E–09	2.71E–09	2.71E–09	–3.23	150	1,223			3.00E–11	14.30	0
730.00	750.00	2007-06-08 15:16	20.0	PRF	WBS–>PRF	1.06E–08	6.15E–09	7.61E–09	6.15E–09	6.15E–09	–2.47	50	1,225	130	900	5.14E–11	17.58	0
750.00	770.00	2007-06-11 08:35	20.0	PRF	WBS–>PRF	2.26E–08	9.79E–09	1.25E–08	9.79E–09	9.79E–09	–3.57	100	1,230	50	700		19.78	0
770.00	790.00	2007-06-11 13:26	20.0	PSF	PSF	5.54E–07	3.01E–07	3.78E–07	3.01E–07	3.01E–07	–3.13						46.54	0
790.00	810.00	2007-06-11 15:10	20.0	PRF	PSF	1.03E–06	1.22E–06	1.04E–06	1.22E–06	1.22E–06	0.26	100	1,250				66.60	0
810.00	830.00	2007-06-12 08:38	20.0	PRF–>PSF	PRF–>PSF	7.25E–07	5.55E–07	7.17E–07	5.55E–07	5.55E–07	–1.91	100	200	50	200		21.88	–1
820.00	840.00	2007-06-12 12:34	20.0	PSF	PSF	4.74E–07	3.52E–07	4.25E–07	3.52E–07	3.52E–07	–1.75						48.32	–1

[1] The acronyms in the column “Flow regime” are as follows: wellbore storage (WBS), pseudo-linear flow (PLF), pseudo-radial flow (PRF), pseudo-spherical flow (PSF), pseudo-stationary flow (PSS) and apparent no-flow boundary (NFB). The flow regime definitions are further discussed in Section 5.4.3 above.

[2] For the tests where Q_p was not detected, T_R was assumed to be less than T_M based on the estimated Q/s-measl-L.

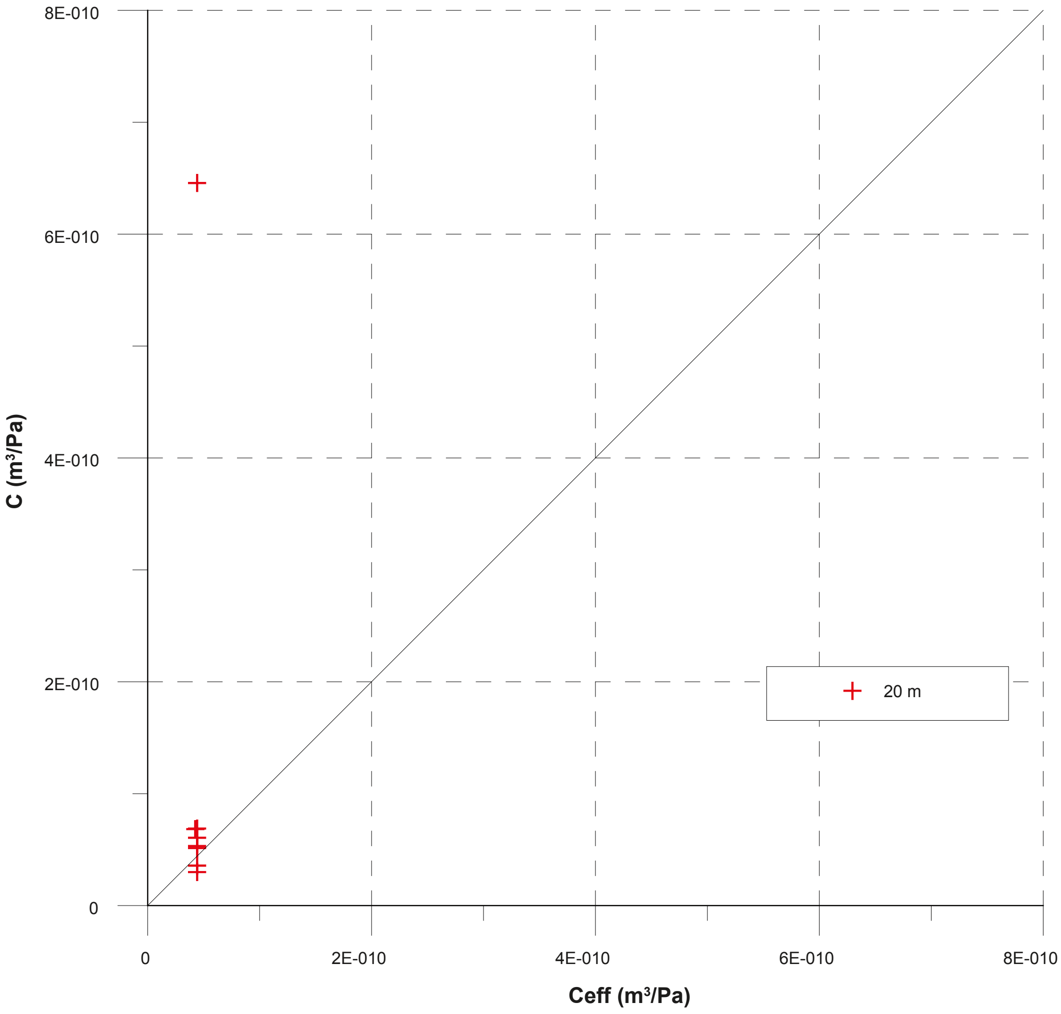

***Figure 6-3.** The wellbore storage coefficient calculated from the straight line with a unit slope in the log-log diagrams from the recovery period, C, from the hydraulic tests in 20 m in KFM11A compared to the wellbore storage coefficient obtained from laboratory experiments, C_{eff}.*

6.2.4 Comments on the tests

Short comments on each test follow below. Tests were performed within the interval 470.0–840.0 m in KFM11A. Flow regimes and hydraulic boundaries, as discussed in Section 5.4.3, are in the text referred to as:

WBS = Wellbore storage
PRF = Pseudo-radial flow regime
PLF = Pseudo-linear flow regime
PSF = Pseudo-spherical flow regime
PSS = Pseudo-stationary flow regime
NFB = No-flow boundary
CHB = Constant-head boundary

470.0–490.0 m

During the injection period a PRF is indicated between c 50–400 s transitioning to a PSF by the end. The recovery period also exhibits a PRF at intermediate times transitioning to a PSF by the end. Transient evaluations using the Hurst-Clark-Brauer model and the Hantush model give consistent results for the injection period. The model by Dougherty-Babu of the recovery period supports the estimated transmissivity value from the Hurst-Clark-Brauer model. The transient evaluation of the injection period is regarded as the most representative.

488.5–508.5 m

Due to a poor initial pressure regulation, the time to achieve a stable injection pressure was unusually long for this test. Still, an obvious PRF is displayed after c 200 s lasting for the rest of the period. Recovery begins with a WBS followed by a transition towards some other flow regime. The transient evaluation of the recovery period as well as the stationary transmissivity TM supports the results from the injection period. The transient evaluation from the injection period was chosen as representative for the test section.

508.5–528.5 m

The test section has a low transmissivity. Since the flow rate was not detectable, neither steady-state nor transient evaluation of transmissivity was possible. Hence, in accordance with AP PF 400-07-032, the injection time was shortened. As a result TM, based on Q/s-measl-L, was considered to be the most representative transmissivity value for this section.

514.5–534.5 m

The test section has a low transmissivity. Since the flow rate was not detectable, neither steady-state nor transient evaluation of transmissivity was possible. Hence, in accordance with AP PF 400-07-032, the injection time was shortened. As a result TM, based on Q/s-measl-L, was considered to be the most representative transmissivity value for this section.

530.0–550.0 m

Due to an unfortunate change between pressure regulating valves, the injection pressure becomes somewhat unstable after c 5 minutes. Both the injection- and recovery period display a PLF transitioning towards a possible PRF. The transient evaluation of the recovery period is regarded as the most representative for the test section.

550.0–570.0 m

After initial PLF an apparent NFB is indicated during both the injection and recovery period. The total pressure recovery was only c 10 m of the applied injection pressure of c 25 m, indicating a low-transmissive section. An approximate transient evaluation was made from the fist part of the flow period. No unambiguous transient evaluation can be made from the recovery period. Although uncertain, the transient evaluation from the injection period was considered to be the most representative for this section. Since the measurement noise with a zero flow was centred slightly below zero, the flow rate measurement limit as well as the flow data were manually elevated by 1.48·10–9 m^3/s.

570.0–590.0 m

The injection period is dominated by a PSF and the recovery period is showing initial WBS followed by a transition period. The transient evaluation of the injection period is regarded as the most representative for the test section. Due to a small leakage in the pipe string the measurement noise with a zero flow was centred slightly above zero, hence the flow rate measurement limit as well as the flow data were manually lowered by 1.06·10–9 m^3/s.

590.0–610.0 m

The injection displays a rather constant flow during the entire test and the flow regime is turning to an apparent PSF/PSS after about 30 s. Recovery begins with WBS followed by a transition period towards a possible PSF/PSS at the end. The transient evaluation indicates an apparent, high skin factor for both periods. No unambiguous transient evaluation is possible on the recovery period, but an exemplifying evaluation is presented. The transient evaluation on the injection period is chosen as representative for the section.

610.0–630.0 m

Due to a poor initial pressure regulation, the time to achieve a stable injection pressure was unusually long for this test. In addition, the flow rate data are scattered. Still, after about 250 s an apparent PSF is indicated for the rest of the period. The recovery period displays WBS followed by a transition to a possible PSF. The transient evaluation of the injection period is selected as representative for the test section.

630.0–650.0 m

The injection period shows a clear PRF throughout the period after the pressure has stabilized after about 20 s. The recovery period only displays a WBS followed by a transition period. No unambiguous transient evaluation is possible on the recovery period. The transient evaluation from the injection period is chosen as representative for this section.

650.0–670.0 m

Due to a drifting gas pressure the flow at the end of the injection period was unstable. Hence, all transient evaluations is made on a period between 20 and 1,100 s when the pressure was stable. For the same reason, the stationary transmissivity TM does not provide a representative value. During both the injection and recovery period a transition period towards a possible PRF is indicated (after initial WBS during the latter period). Consistent results were obtained from both periods. The transient evaluation from the injection is chosen as representative for this section.

670.0–690.0 m

This section was previously injected for a short while but the test was interrupted due to a higher transmissivity than expected. The test was repeated after a few hours. The injection period begins with a transition towards a PRF which occurred after about 300 s lasting to the end of the period. The recovery period is also dominated by a transition towards a possible PRF. The transient evaluation from the injection period is chosen as representative for this section.

690.0–710.0 m

This test was performed as a pumping test with a constant head. The time to achieve a stable pressure was rather long. Hence the pumping period was kept longer than for an injection test. The drawdown period is dominated by an obvious PRF from c 600 s, from where the pressure was stable to the end of the period. The recovery period starts with a transition to a PRF that lasts from c 100 to about 5,100 s were the flow turns towards a possible PSS. The transient evaluations as well as the stationary give consistent results and the transmissivity from the drawdown period is chosen as representative for this section.

710.0–730.0 m

After an initial transition period the flow during injection turns into a PRF after about 150 s to the rest of the period. The recovery period shows initial WBS followed by a transition period. Consistent results were obtained from both periods. The transient evaluation from the injection period is chosen as representative for the section.

730.0–750.0 m

After the initial pressure stabilization the injection period displays an obvious PRF from c 50 s and throughout the period. The recovery periods starts with WBS followed by a transition into an approximate PRF after c 130 s continuing for the rest of the period. Consistent results were obtained from both periods. The transient evaluation from the injection period is chosen as representative for the section.

750.0–770.0 m

Both the injection and recovery period display a clear PRF at the end of the periods (after initial WBS during the recovery period). Consistent results were obtained from both periods. The transient evaluation from the injection period is chosen as representative for the section.

770.0–790.0 m

The injection period as well as the recovery period displays a PSF throughout the periods. Consistent results were obtained from both periods. The transient evaluation from the injection period is chosen as representative for the section. The pressure in the section below the test section increased by c 6 kPa during the injection period. The transmissivity in the section below 790 m is lower than the transmissivity in the section 770.0–790.0 m. Hence this small pressure interference should not have resulted in an overestimation of the transmissivity in the latter section.

790.0–810.0 m

After the initial pressure stabilization an obvious PRF develops after c 100 s for the rest of the injection period. The entire recovery period is dominated by a PSF. The responses during the injection and recovery period were thus not quite consistent. However, consistent results were obtained from both periods. The transient evaluation from the injection period is chosen as representative for the section. The pressure in the section below the test section increased by c 9.3 kPa during the injection period. The transmissivity in the section below 810 m is lower than the transmissivity in the section 790.0–810.0 m, hence this relatively small pressure interference should not have resulted in an overestimation of the transmissivity in the latter section.

810.0–830.0 m

During the injection period a short period of PRF occurred between c 100–200 s, then transitioning to a PSF. The recovery period also begins with a PRF between c 50–200 s followed by a transition to a PSF by the end. Consistent results were obtained from both periods. The transient evaluation from the injection period is chosen as representative for the section.

820.0–840.0 m

The flow regimes in this section are quite similar as in the previous, partly overlapping section 810.0–830.0 m. The injection period is dominated by a PSF after about 200 s to the end of the period. The recovery period is also dominated by a transition to a PSF. Consistent results were obtained from both periods. The transient evaluation from the injection period is chosen as representative for the section.

6.2.5 Flow regimes

A summary of the frequency of identified flow regimes is presented in Table 6-4, which shows all identified flow regimes during the tests. For example, a pseudo-radial flow regime (PRF) transitioning to a pseudo-spherical flow regime (PSF) will contribute to one observation of PRF and one observation of PSF. The numbers within parenthesis denote the number of tests where the actual flow regime is the only one present.

It should be noted that the interpretation of flow regimes is only tentative and just based on visual inspection of the data curves. It should also be observed that the number of tests with a pseudo-linear flow regime during the beginning of the injection period may be underestimated due to the fact that a certain time is required for achieving a constant pressure, which fact may mask the initial flow regime.

Table 6-4 shows that in c 61% of the tests with a definable final flow rate, a certain period of pseudo-radial flow during the injection period could be identified for KFM11A. For the recovery period, the corresponding result is c 39%.

For only 3 tests in the borehole, more than one flow regime during the injection period could be identified. These transitions in KFM11A during the injection period were as follows: two tests from PRF to PSF and one test from PLF to NFB. During the recovery period, 50% of the tests showed more than one flow regime. The most common transitions were from WBS to PRF and WBS to PSF.

6.3 Basic statistics of hydraulic conductivity distributions in different scales

Some basic statistical parameters were calculated for the steady-state hydraulic conductivity (K_M) distributions from the hydraulic tests in borehole KFM11A. Since measurements only have been made in one scale in this borehole, these figures are most useful in comparison with corresponding figures in other boreholes. The hydraulic conductivity is obtained by dividing the transmissivity by the section length, in this case T_M/L_w. Tests below the measurement limit are assigned a transmissivity value at the lower measurement limit. The same basic statistical parameters were derived for the hydraulic conductivity considered most representative ($K_R = T_R/L_w$), including all tests. Results from all tests are included in the statistical analyses of both K_R and K_M. In the statistical analysis, the logarithm (base 10) of K_M and K_R was used. Selected results are shown in Table 6-5.

Table 6-4. Interpreted flow regimes during the hydraulic tests in KFM11A. The figure within the parenthesis shows the number of tests with only one interpreted flow regime.

Section length (m)	Number of tests	Borehole interval (m)	Number of tests with definable Q_p	Injection period					Recovery period					
				PLF	PRF	PSF	PSS	NFB	WBS	PLF	PRF	PSF	PSS	NFB
20	20	470.0–840.0	18	2(1)	11(9)	7(5)	0(0)	1(0)	9(3)	2(1)	7(1)	8(3)	1(0)	1(0)

Table 6-5. Basic statistical parameters for steady-state hydraulic conductivity (K_M) and hydraulic conductivity considered most representative (K_R) in borehole KFM11A. L_w = section length, m = arithmetic mean, s = standard deviation.

Parameter	Unit	KFM11A $L_w = 20$ m
Measured borehole interval	m	470.0–840.0
Number of tests	–	20
N:o of tests below E.L.M.L.[1)]	–	2
m (Log10(KM))	Log10 (m/s)	–8.80
s (Log10(KM))	–	1.06
m (Log10(KR))	Log10 (m/s)	–9.22
s (Log10(KR))	–	1.28

[1)] Number of tests where Q_p could not be defined (E.L.M.L. = estimated test-specific lower measurement limit).

7 References

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8 Appendices

Appendix 1: File description table
Appendix 2.1: General test data
Appendix 2.2: Pressure and flow data
Appendix 3: Test diagrams – Hydraulic tests
Appendix 4: Borehole technical data
Appendix 5: Sicada tables

APPENDIX 1. File description table

Bh id	Test section		Test type	Test no	Test start Date, time	Test stop Date, time	Data files of raw and primary data	Parameters in file	Comments
idcode	(m)	(m)	(1-6)1)		YYYYMMDD hh:mm	YYYYMMDD hh:mm	__Borehole id_secup_date and time of test start		
KFM11A	470.00	490.00	3	1	2007-06-04 15:33	2007-06-04 16:55	__KFM11A_0470.00_200706041533.ht2	P, Q, Te	
KFM11A	488.50	508.50	3	1	2007-06-05 09:23	2007-06-05 10:40	__KFM11A_0488.50_200706050923.ht2	P, Q, Te	
KFM11A	508.50	528.50	3	1	2007-06-05 11:08	2007-06-05 11:54	__KFM11A_0508.50_200706051108.ht2	P, Q, Te	Interrupted2)
KFM11A	508.50	528.50	3	2	2007-06-05 12:52	2007-06-05 14:11	__KFM11A_0508.50_200706051252.ht2	P, Q, Te	Reperformed
KFM11A	514.50	534.50	3	1	2007-06-05 14:33	2007-06-05 15:25	__KFM11A_0514.50_200706051433.ht2	P, Q, Te	
KFM11A	530.00	550.00	3	1	2007-06-05 15:49	2007-06-05 17:02	__KFM11A_0530.00_200706051549.ht2	P, Q, Te	
KFM11A	550.00	570.00	3	1	2007-06-07 08:48	2007-06-07 10:13	__KFM11A_0550.00_200706070848.ht2	P, Q, Te	
KFM11A	570.00	590.00	3	1	2007-06-07 10:35	2007-06-07 11:53	__KFM11A_0570.00_200706071035.ht2	P, Q, Te	
KFM11A	590.00	610.00	3	1	2007-06-07 13:05	2007-06-07 14:21	__KFM11A_0590.00_200706071305.ht2	P, Q, Te	
KFM11A	610.00	630.00	3	1	2007-06-07 14:49	2007-06-07 16:05	__KFM11A_0610.00_200706071449.ht2	P, Q, Te	
KFM11A	630.00	650.00	3	1	2007-06-07 16:36	2007-06-07 17:50	__KFM11A_0630.00_200706071636.ht2	P, Q, Te	
KFM11A	650.00	670.00	3	1	2007-06-08 08:20	2007-06-08 09:37	__KFM11A_0650.00_200706080820.ht2	P, Q, Te	
KFM11A	670.00	690.00	3	1	2007-06-08 09:58	2007-06-08 10:38	__KFM11A_0670.00_200706080958.ht2	P, Q, Te	Interrupted2)
KFM11A	670.00	690.00	3	2	2007-06-08 10:41	2007-06-08 12:47	__KFM11A_0670.00_200706081041.ht2	P, Q, Te	Reperformed
KFM11A	690.00	710.00	1B	1	2007-07-09 14:09	2007-07-10 09:17	__KFM11A_0690.00_200707091409.ht2	P, Q, Te	
KFM11A	710.00	730.00	3	1	2007-06-08 13:32	2007-06-08 14:51	__KFM11A_0710.00_200706081332.ht2	P, Q, Te	
KFM11A	730.00	750.00	3	1	2007-06-08 15:16	2007-06-08 16:33	__KFM11A_0730.00_200706081516.ht2	P, Q, Te	
KFM11A	750.00	770.00	3	1	2007-06-11 08:35	2007-06-11 09:51	__KFM11A_0750.00_200706110835.ht2	P, Q, Te	
KFM11A	770.00	790.00	3	1	2007-06-11 13:26	2007-06-11 14:41	__KFM11A_0770.00_200706111326.ht2	P, Q, Te	
KFM11A	790.00	810.00	3	1	2007-06-11 15:10	2007-06-11 16:27	__KFM11A_0790.00_200706111510.ht2	P, Q, Te	
KFM11A	810.00	830.00	3	1	2007-06-12 08:38	2007-06-12 09:54	__KFM11A_0810.00_200706120838.ht2	P, Q, Te	
KFM11A	820.00	840.00	3	1	2007-06-12 12:34	2007-06-12 13:51	__KFM11A_0820.00_200706121234.ht2	P, Q, Te	

1) 1B: Pumping test, 3: Injection test

2) Due to an instable injection pressure this tests was interrupted and hence re-performed later

Appendix 2.1. General test data

Borehole:	KFM11A
Testtype:	CHir (Constant Head injection and recovery)[1]
Field crew:	H Andersson, J. Florberger, J. Harrström, KJ Mattsson, E. Walger
General comment:	

Test section secup	**Test section seclow**	**Test start**	**Start of flow period**	**Stop of flow period**	**Test stop**	**Total flow time t_p**	**Total recovery time t_F**
(m)	(m)	YYYYMMDD hh:mm	YYYYMMDD hh:mm:ss	YYYYMMDD hh:mm:ss	YYYYMMDD hh:mm	(min)	(min)
470.00	490.00	2007-06-04 15:33	2007-06-04 16:13:25	2007-06-04 16:33:48	2007-06-04 16:55	20	20
488.50	508.50	2007-06-05 09:23	2007-06-05 09:57:59	2007-06-05 10:18:22	2007-06-05 10:40	20	20
508.50	528.50	2007-06-05 12:52	2007-06-05 13:28:45	2007-06-05 13:49:09	2007-06-05 14:11	20	20
514.50	534.50	2007-06-05 14:33	2007-06-05 15:05:57	2007-06-05 15:15:01	2007-06-05 15:25	9	8
530.00	550.00	2007-06-05 15:49	2007-06-05 16:20:26	2007-06-05 16:40:56	2007-06-05 17:02	21	20
550.00	570.00	2007-06-07 08:48	2007-06-07 09:31:17	2007-06-07 09:51:20	2007-06-07 10:13	20	20
570.00	590.00	2007-06-07 10:35	2007-06-07 11:11:23	2007-06-07 11:31:50	2007-06-07 11:53	20	20
590.00	610.00	2007-06-07 13:05	2007-06-07 13:39:12	2007-06-07 13:59:36	2007-06-07 14:21	20	20
610.00	630.00	2007-06-07 14:49	2007-06-07 15:23:15	2007-06-07 15:43:41	2007-06-07 16:05	20	20
630.00	650.00	2007-06-07 16:36	2007-06-07 17:08:05	2007-06-07 17:28:30	2007-06-07 17:50	20	20
650.00	670.00	2007-06-08 08:20	2007-06-08 08:54:51	2007-06-08 09:15:16	2007-06-08 09:37	20	20
670.00	690.00	2007-06-08 10:41	2007-06-08 12:04:36	2007-06-08 12:25:39	2007-06-08 12:47	21	20
690.00[1]	710.00	2007-07-09 14:09	2007-07-09 14:38:42	2007-07-09 17:09:31	2007-07-10 09:17	151	962
710.00	730.00	2007-06-08 13:32	2007-06-08 14:09:00	2007-06-08 14:29:23	2007-06-08 14:51	20	20
730.00	750.00	2007-06-08 15:16	2007-06-08 15:50:49	2007-06-08 16:11:18	2007-06-08 16:33	20	20
750.00	770.00	2007-06-11 08:35	2007-06-11 09:09:01	2007-06-11 09:29:33	2007-06-11 09:51	21	20
770.00	790.00	2007-06-11 13:26	2007-06-11 13:59:21	2007-06-11 14:19:49	2007-06-11 14:41	20	20
790.00	810.00	2007-06-11 15:10	2007-06-11 15:45:12	2007-06-11 16:05:40	2007-06-11 16:27	20	20
810.00	830.00	2007-06-12 08:38	2007-06-12 09:11:53	2007-06-12 09:32:10	2007-06-12 09:54	20	20
820.00	840.00	2007-06-12 12:34	2007-06-12 13:08:32	2007-06-12 13:28:57	2007-06-12 13:51	20	20
508.50[2]	528.50	2007-06-05 11:08	2007-06-05 11:43:44	2007-06-05 12:04:12	2007-06-05 11:54	20	1
670.00[2]	690.00	2007-06-08 09:58	2007-06-08 10:31:05	2007-06-08 10:33:17	2007-06-08 10:38	2	3

[1] The test in section 690.0-710 m was conducted as a pumping test.

[2] Due to an unstable injection pressure this tests was interrupted and hence re-performed later.

Appendix 2.2 Pressure and flow data

Summary of pressure and flow data for all tests in KFM11A

Test section		**Pressure**			**Flow**		
secup	**seclow**	**p_i**	**p_p**	**p_F**	**Q_p**[1]	**Q_m**[1]	**V_p**[1]
(m)	(m)	(kPa)	(kPa)	(kPa)	(m^3/s)	(m^3/s)	(m^3)
470.00	490.00	4401.01	4635.12	4407.74	1.325E-06	1.47E-06	1.79E-03
488.50	508.50	4553.29	4762	4591.73	6.339E-07	8.5E-07	1.04E-03
508.50	528.50	4724.51	4965.33	4896.00			
514.50	534.50	4775.04	5009.15	4998.17			
530.00	550.00	4897.24	5095.77	5002.01	4.096E-08	9.13E-08	1.12E-04
550.00	570.00	5062.01	5307.93	5208.52	7.719E-09	2.84E-08	3.41E-05
570.00	590.00	5185.31	5461.166	5190.94	1.367E-07	1.6E-07	1.96E-04
590.00	610.00	5331.55	5622.65	5332.09	8.912E-07	9.02E-07	1.11E-03
610.00	630.00	5502.36	5699.54	5502.91	1.928E-07	2E-07	2.46E-04
630.00	650.00	5709.15	5949.43	5711.06	6.541E-08	7.76E-08	9.52E-05
650.00	670.00	5862.11	6100.74	5940.65	6.256E-08	8.81E-08	1.08E-04
670.00	690.00	6016.99	6216.6	6048.84	6.134E-06	7.68E-06	9.70E-03
690.00[2]	710.00	6161.988	5969.148	6150.45	1.381E-05	1.51E-05	1.37E-01
710.00	730.00	6331.01	6531.58	6344.87	1.177E-07	1.68E-07	2.06E-04
730.00	750.00	6492.35	6735.39	6507.46	2.524E-07	2.98E-07	3.67E-04
750.00	770.00	6649.7	6879.83	6665.63	5.078E-07	6.29E-07	7.75E-04
770.00	790.00	6806.23	7007.94	6813.37	1.092E-05	1.17E-05	1.44E-02
790.00	810.00	6963.32	7158.84	6969.91	1.973E-05	2.09E-05	2.57E-02
810.00	830.00	7118.196	7318.67	7124.79	1.419E-05	1.5E-05	1.83E-02
820.00	840.00	7197.29	7395.43	7201.13	9.172E-06	9.59E-06	1.18E-02
508.50[3]	528.50	4724.24	5140.69	5132.73	1.946E-08	1.1E-07	5.39E-05
670.00[3]	690.00	6010.81	6258.66	6049.39	1.168E-05	1.32E-05	1.74E-03

[1] No value indicates a flow below measurement limit (measurement limit is unique for each test but nominally 1.67 E-8 m^3/s).

[2] The test in section 690.0-710 m was conducted as a pumping test.

[3] Due to an unstable injection pressure this tests was interrupted and hence re-performed later.

p_i	Pressure in test section before start of flow period
p_p	Pressure in test section before stop of flow period
p_F	Pressure in test section at the end of recovery period
Q_p	Flow rate just before stop of flow period
Q_m	Mean (arithmetic) flow rate during flow period
V_p	Total volume injected during the flow period

Appendix 3. Test diagrams – hydraulic tests

In the following pages the selected test diagrams are presented for all test sections. A linear diagram of pressure and flow rate is presented for each test. For most tests are lin-log and log-log diagrams presented, from injection and recovery period respectively. From the tests with a flow rate below the estimated lower measurement limit for the specific test, only the linear diagram is presented. Additionally, for a few tests, a type curve fit is displayed in the diagrams despite the the fact that the estimated parameters from the fit are judged as non-representative. For these tests, the type curve fit is presented, as an example, to illustrate that an assumption of a certain flow regime is not justified for the test. Instead, some other flow regime is likely to dominate.

Nomenclature for Aqtesolv:
T = transmissivity (m^2/s)
S = storativity (-)
K_z/K_r = ratio of hydraulic conductivities in the vertical and radial direction (set to 1)
Sw = skin factor
r(w) = borehole radius (m)
r(c) = effective casing radius (m)
C = well loss constant (set to 0)
r/B = leakage factor (-)

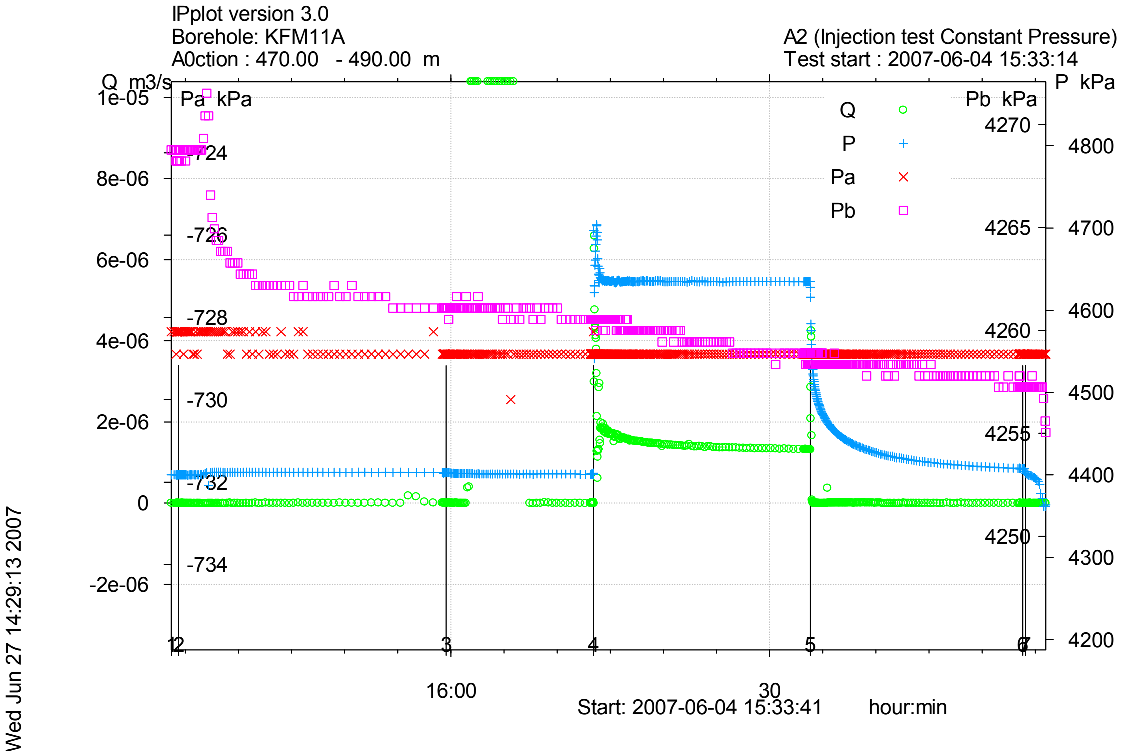


Figure A3-1. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 470.0-490.0 m in borehole KFM11A.*

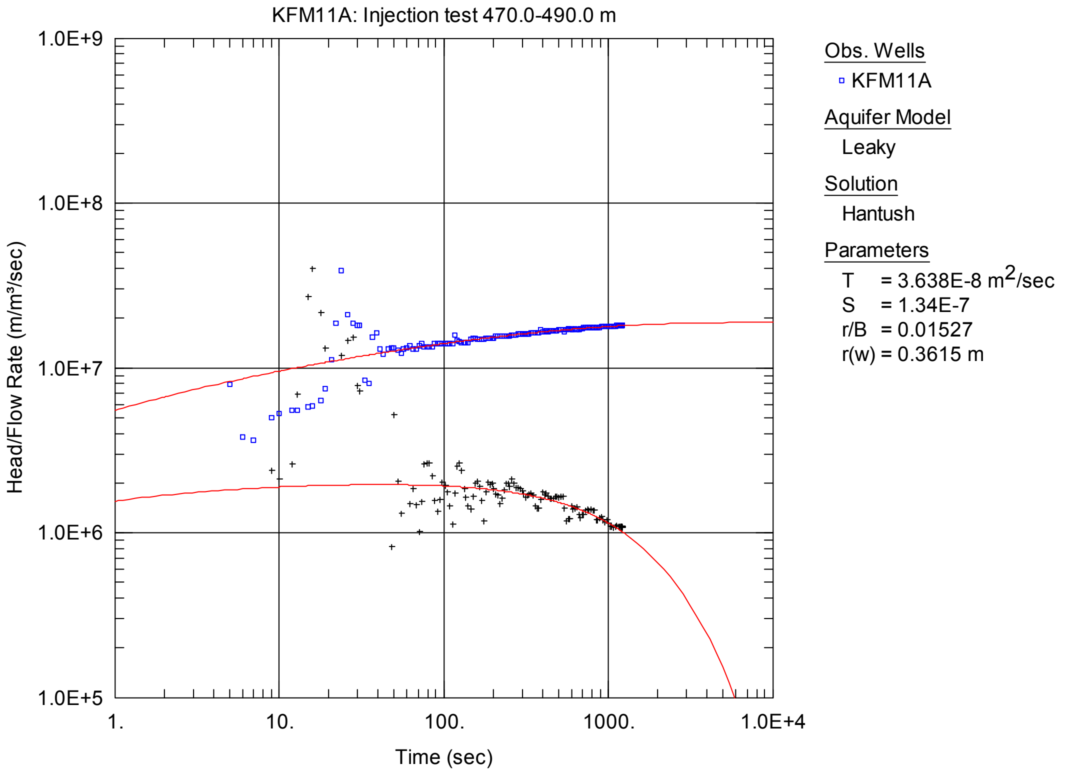


Figure A3-2. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 470.0-490.0 m in KFM11A.*

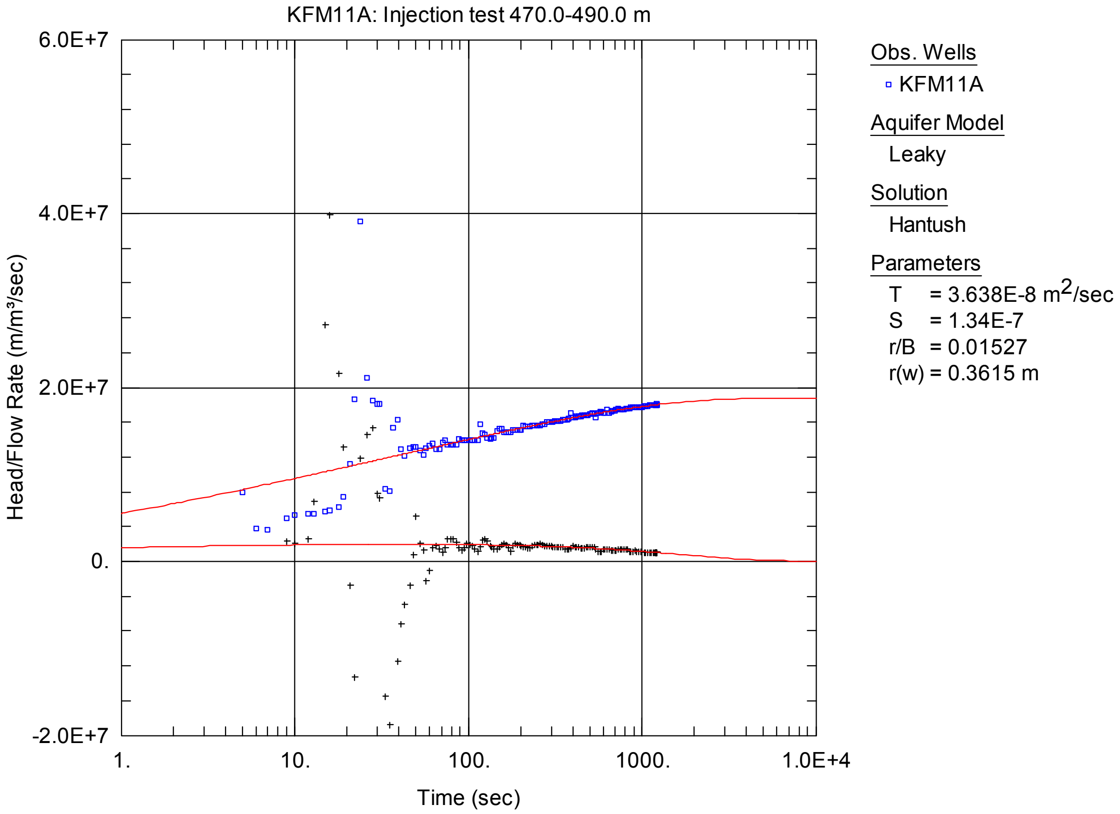


Figure A3-3. Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 470.0-490.0 m in KFM11A.

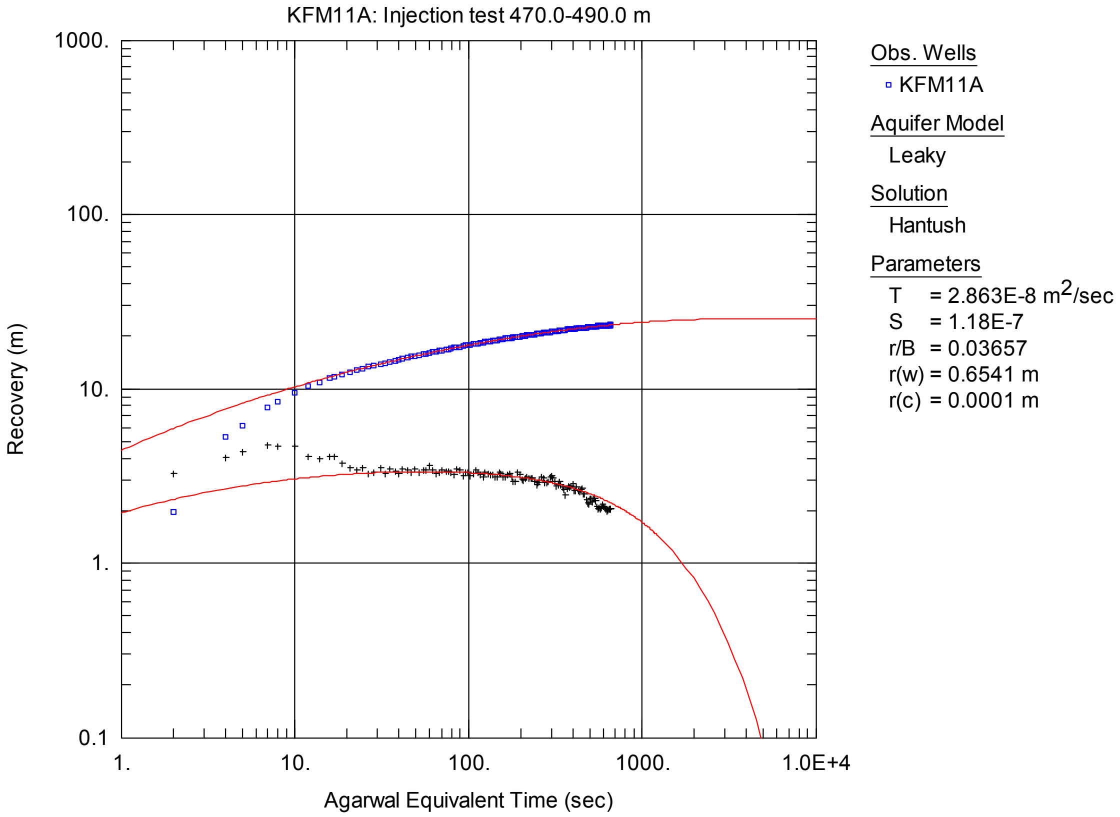


Figure A3-4. Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 470.0-490.0 m in KFM11A.

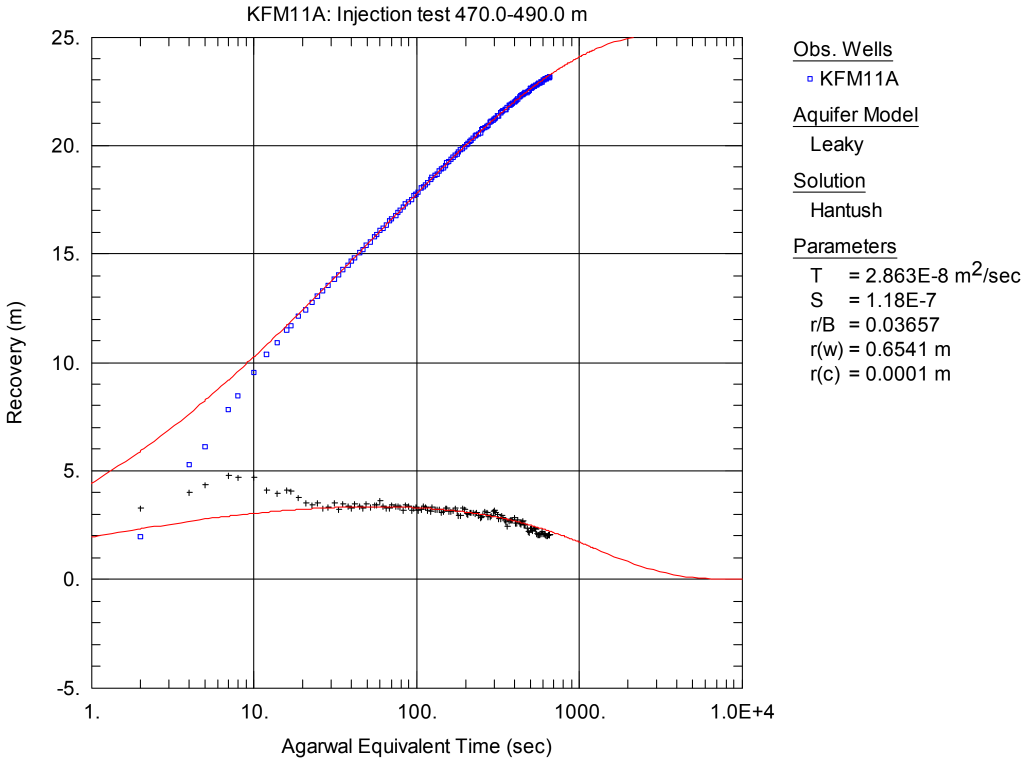


Figure A3-5. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 470.0-490.0 m in KFM11A.*

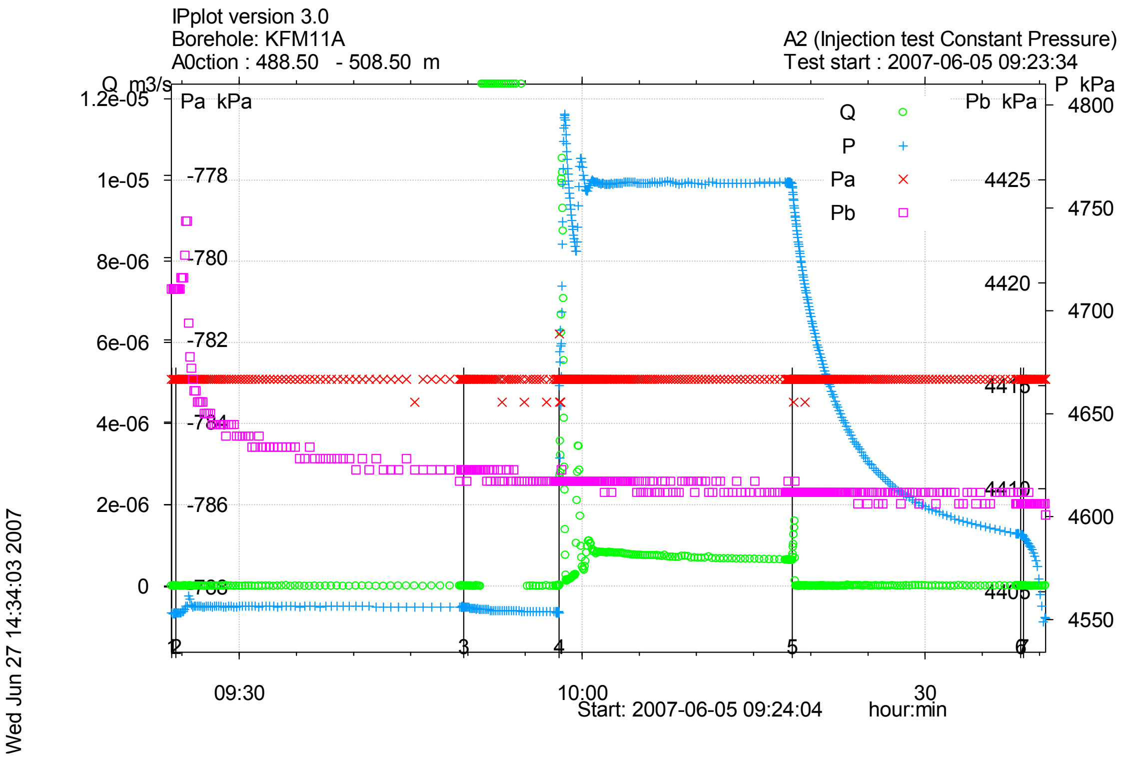


Figure A3-6. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 488.5-508.5 m in borehole KFM11A.*

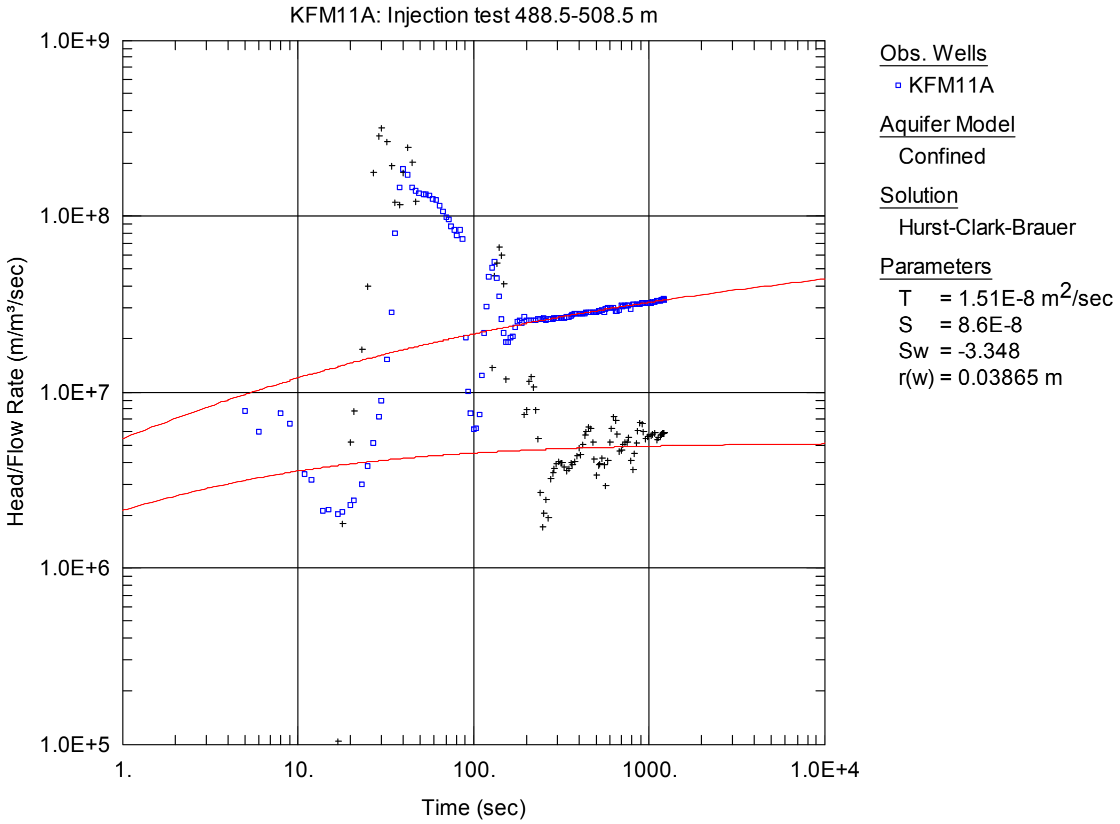


Figure A3-7. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 488.5-508.5 m in KFM11A.*

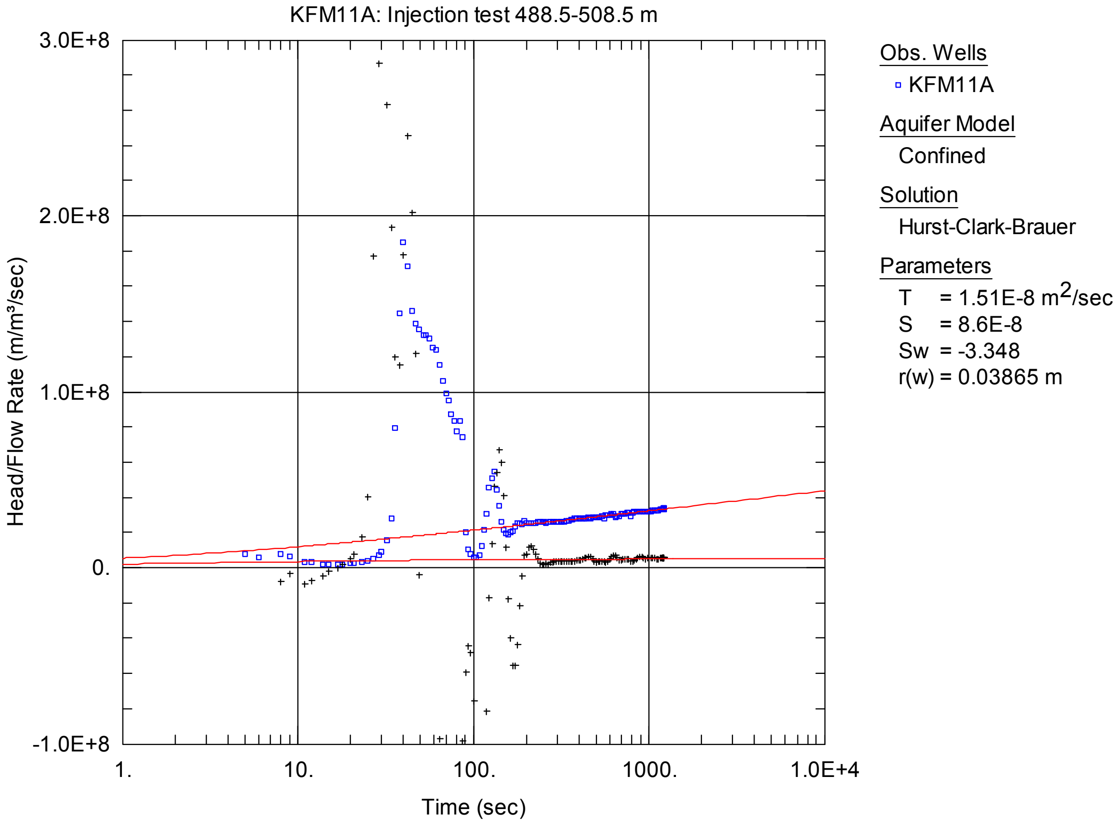


Figure A3-8. *Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 488.5-508.5 m in KFM11A.*

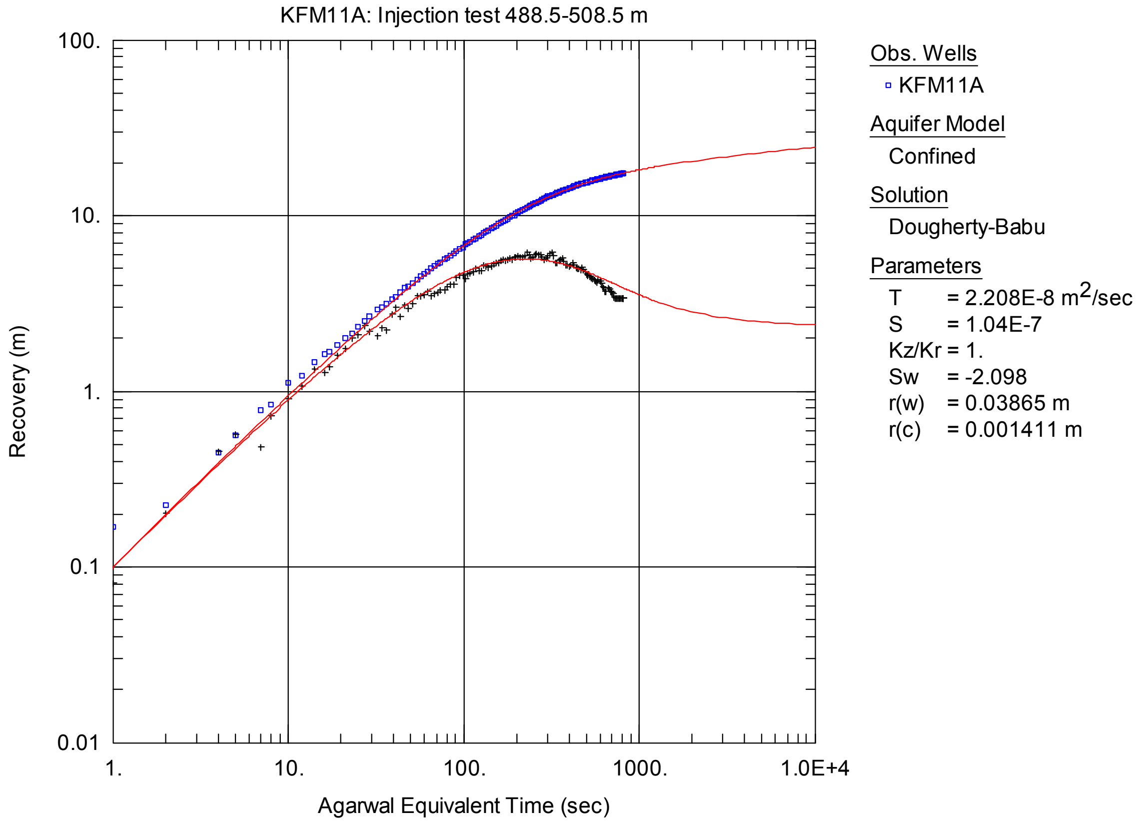


Figure A3-9. *Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 488.5-508.5 m in KFM11A.*

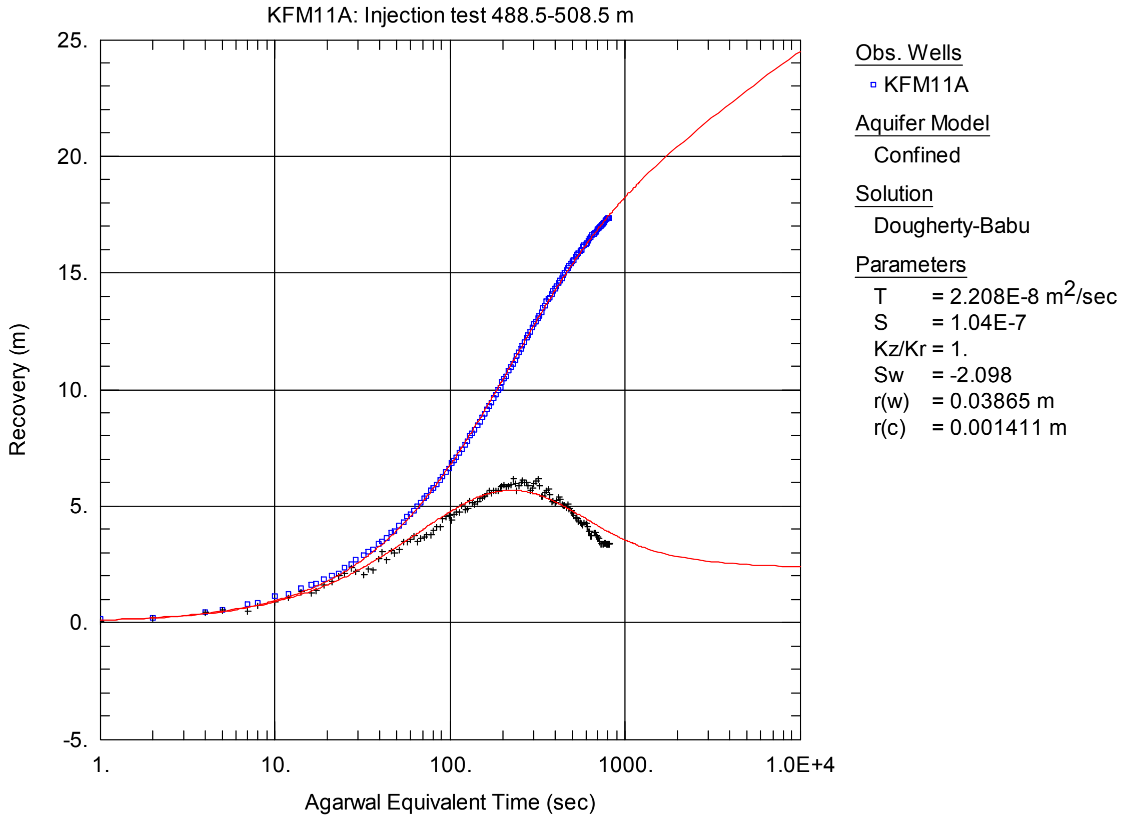


Figure A3-10. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 488.5-508.5 m in KFM11A.*

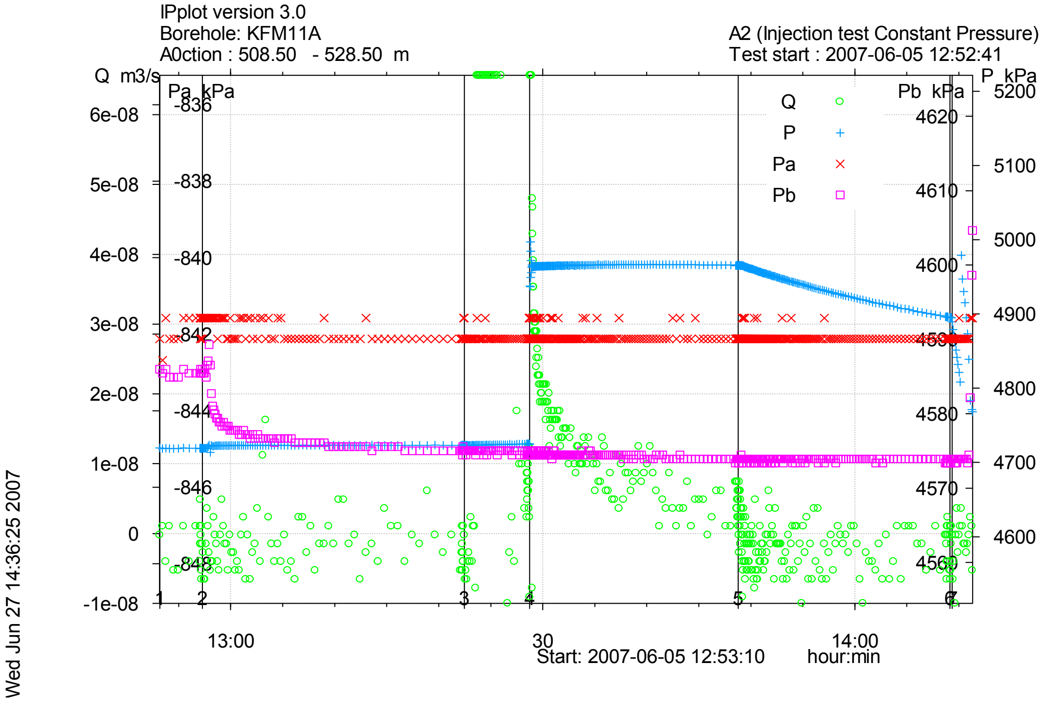


Figure A3-11. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 508.5-528.5 m in borehole KFM11A.*

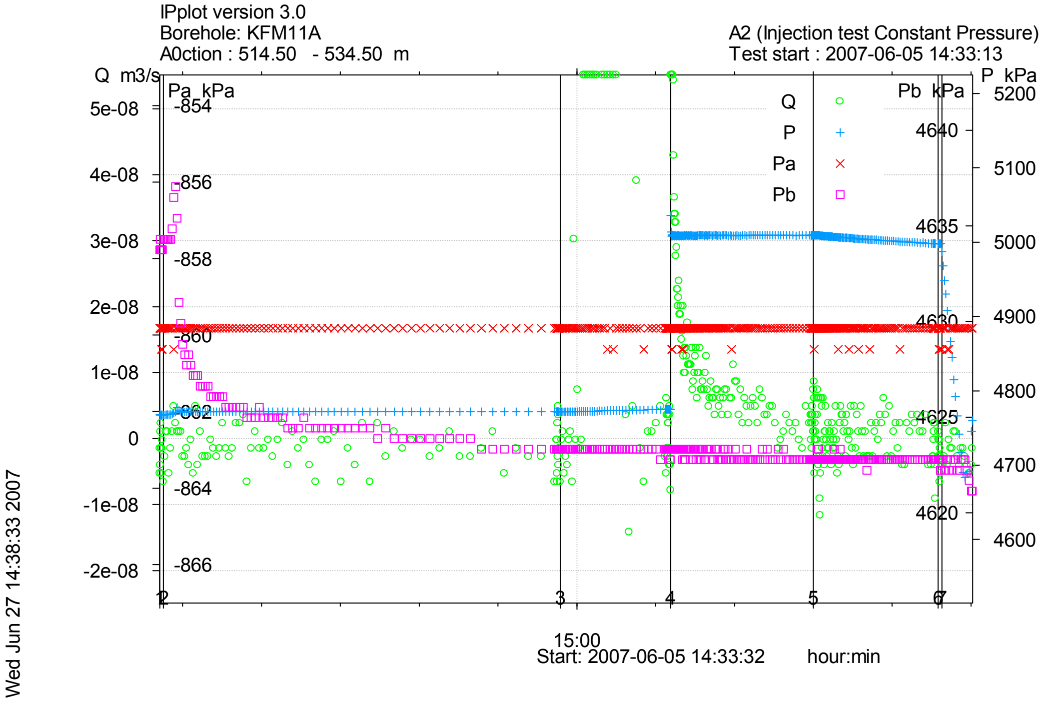


Figure A3-12. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 514.5-534.5 m in borehole KFM11A.*

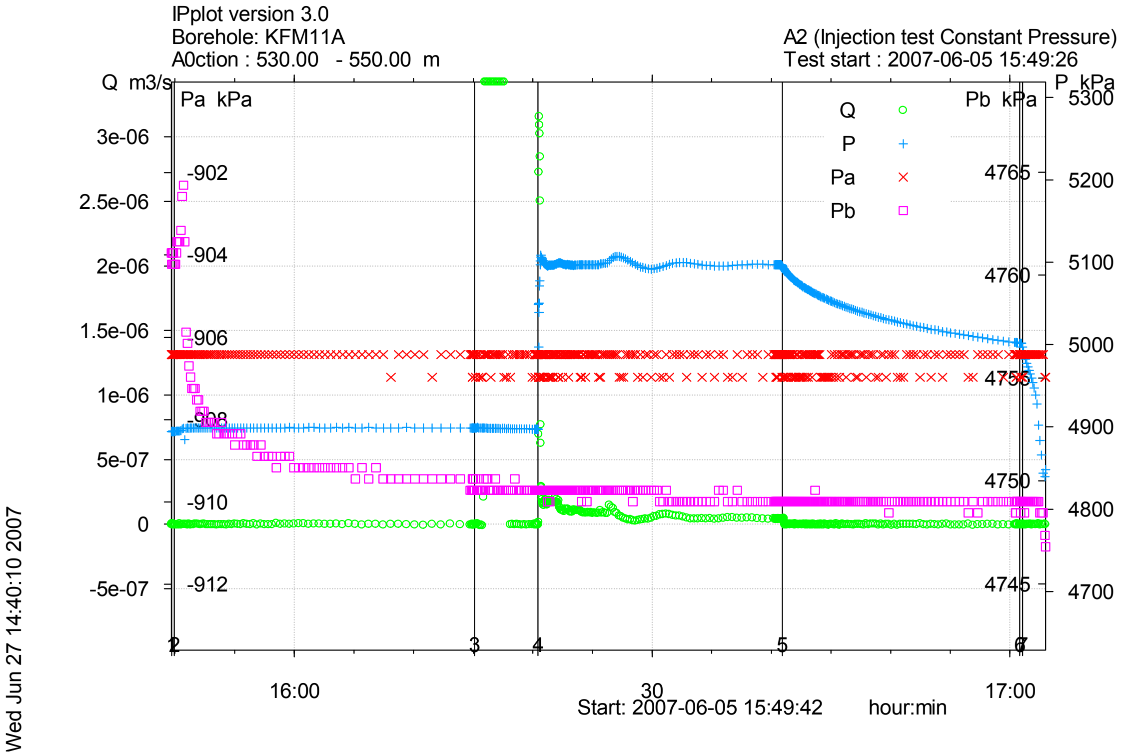


Figure A3-13. Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 530.0-550.0 m in borehole KFM11A.

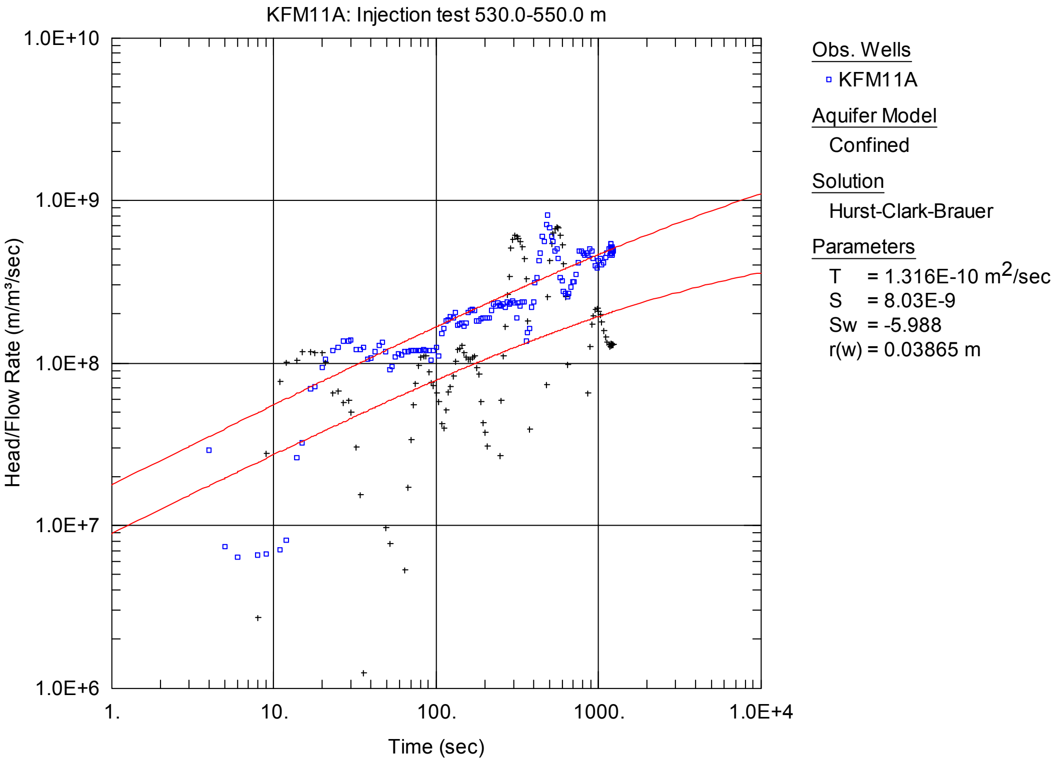


Figure A3-14. Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 530.0-550.0 m in KFM11A.

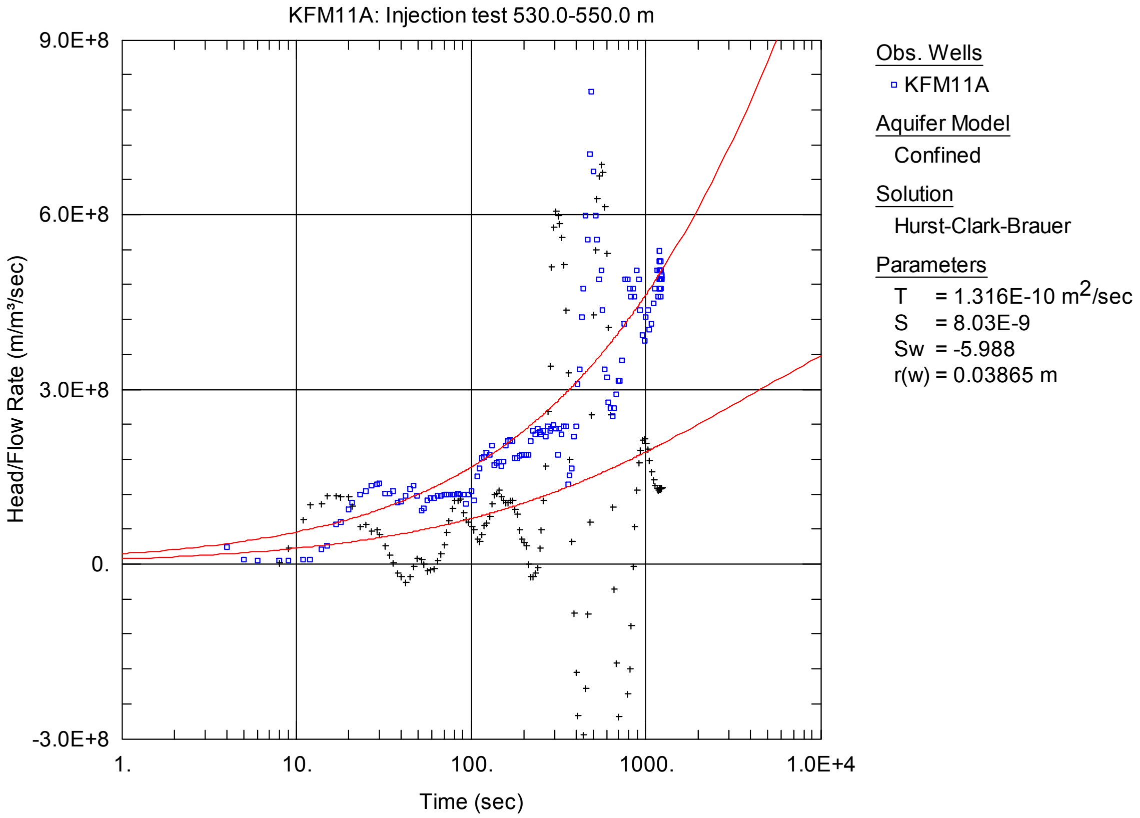


Figure A3-15. *Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 530.0-550.0 m in KFM11A.*

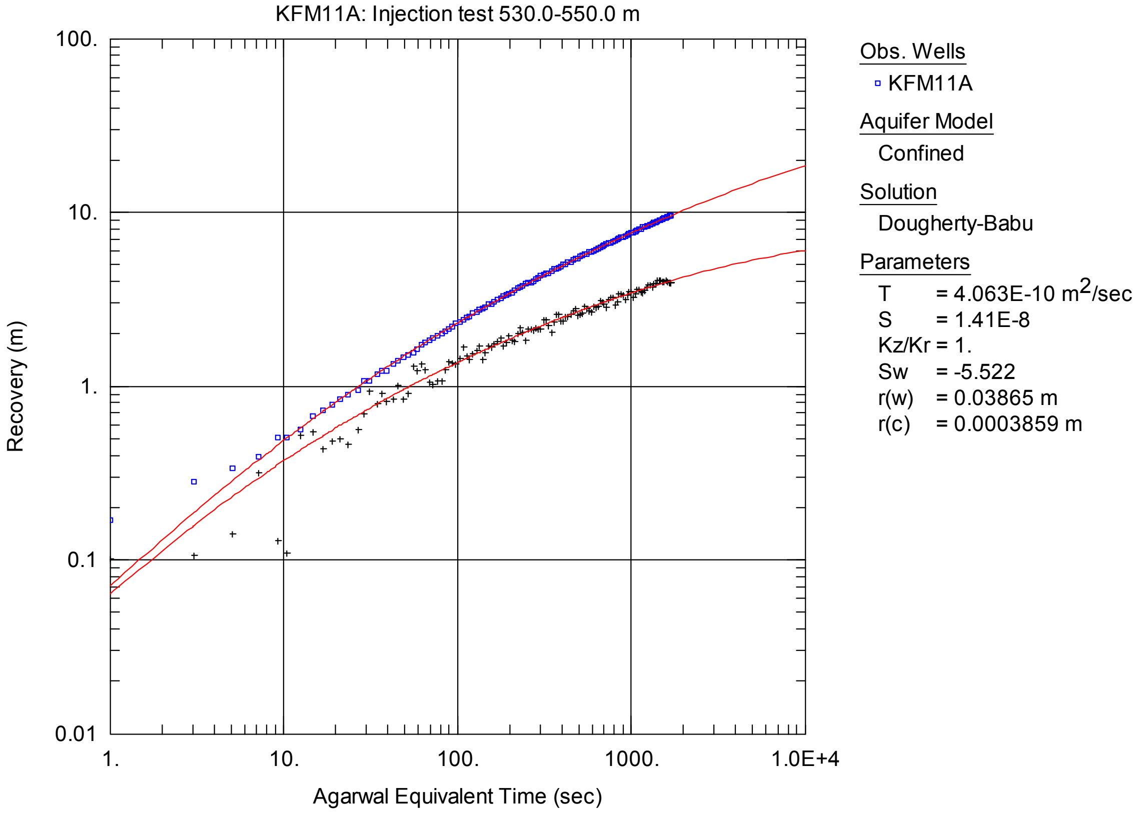


Figure A3-16. *Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 530.0-550.0 m in KFM11A.*

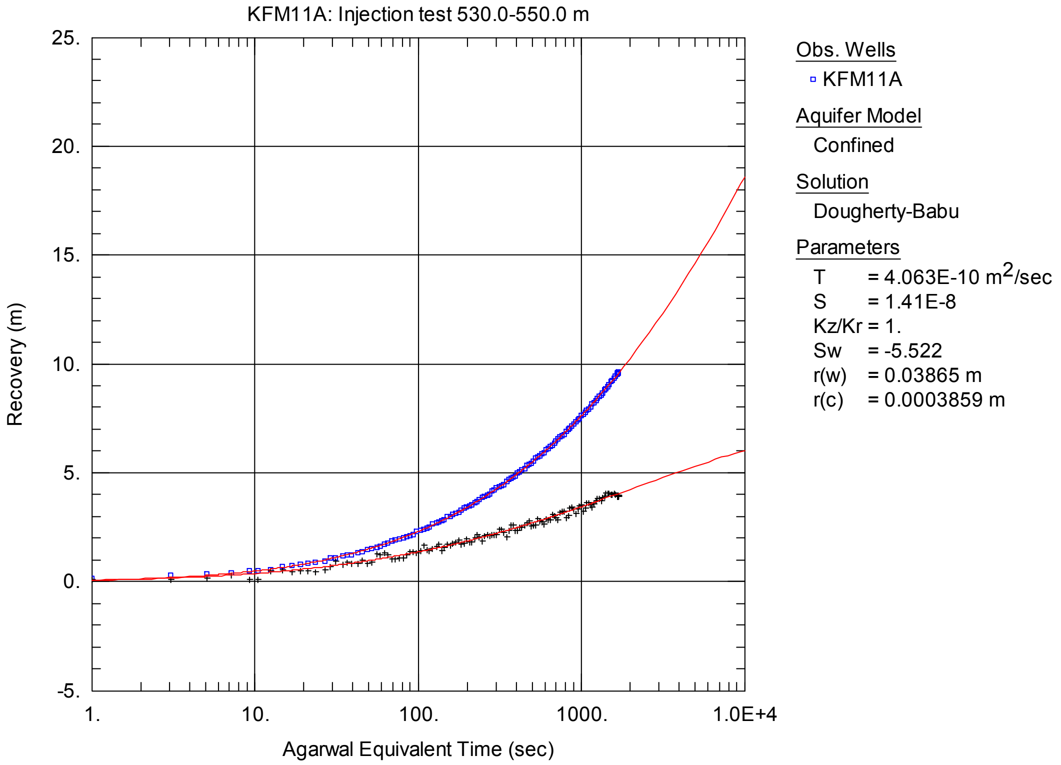


Figure A3-17. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 530.0-550.0 m in KFM11A.*

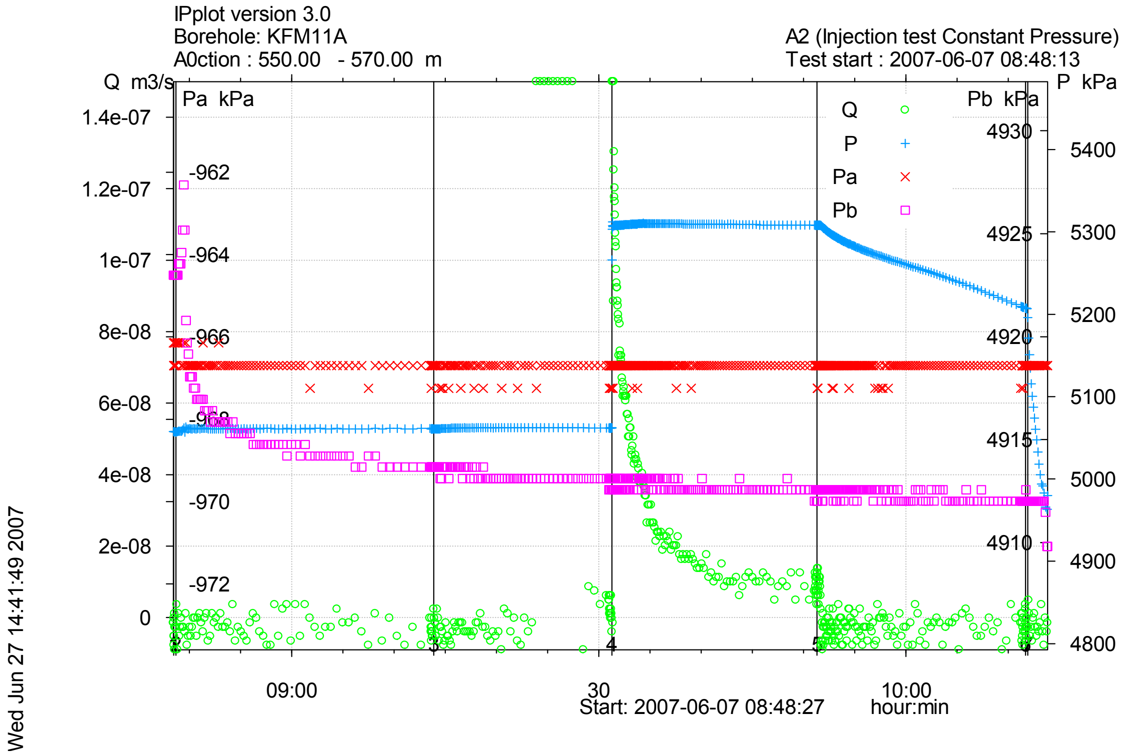


Figure A3-18. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 550.0-570.0 m in borehole KFM11A.*

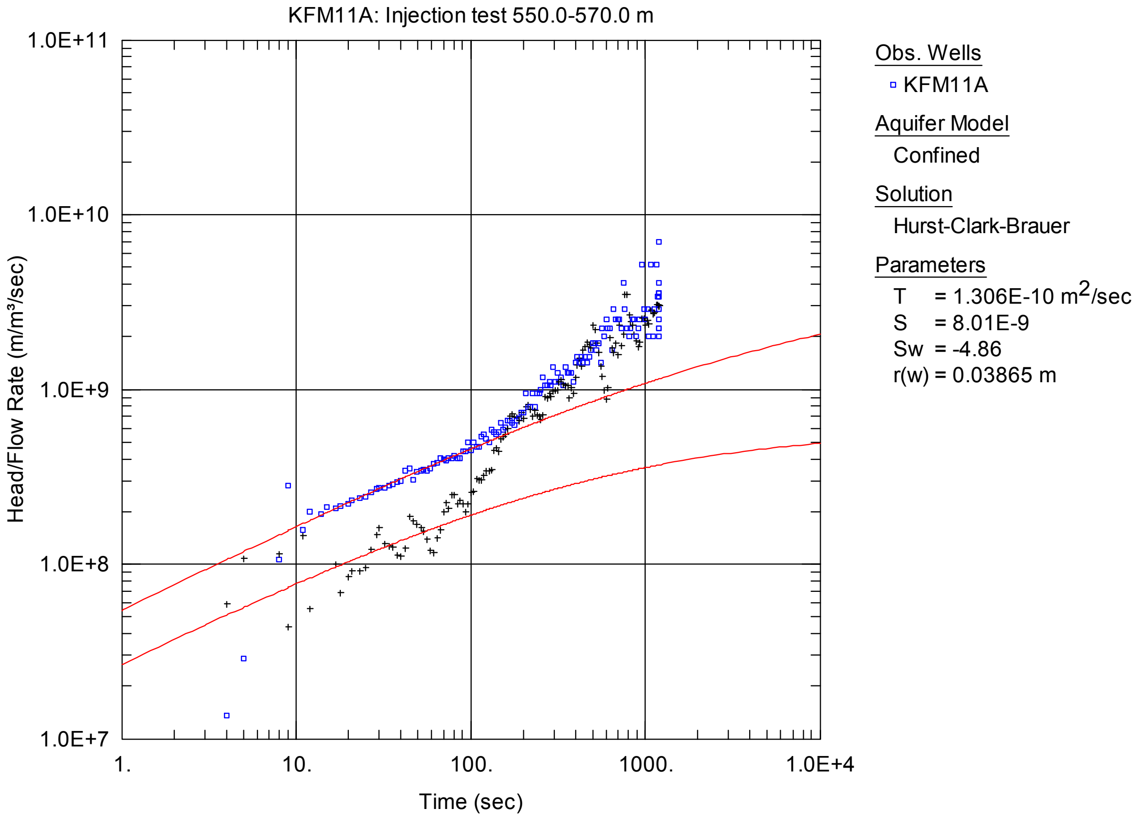


***Figure A3-19.** Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 550.0-570.0 m in KFM11A.*

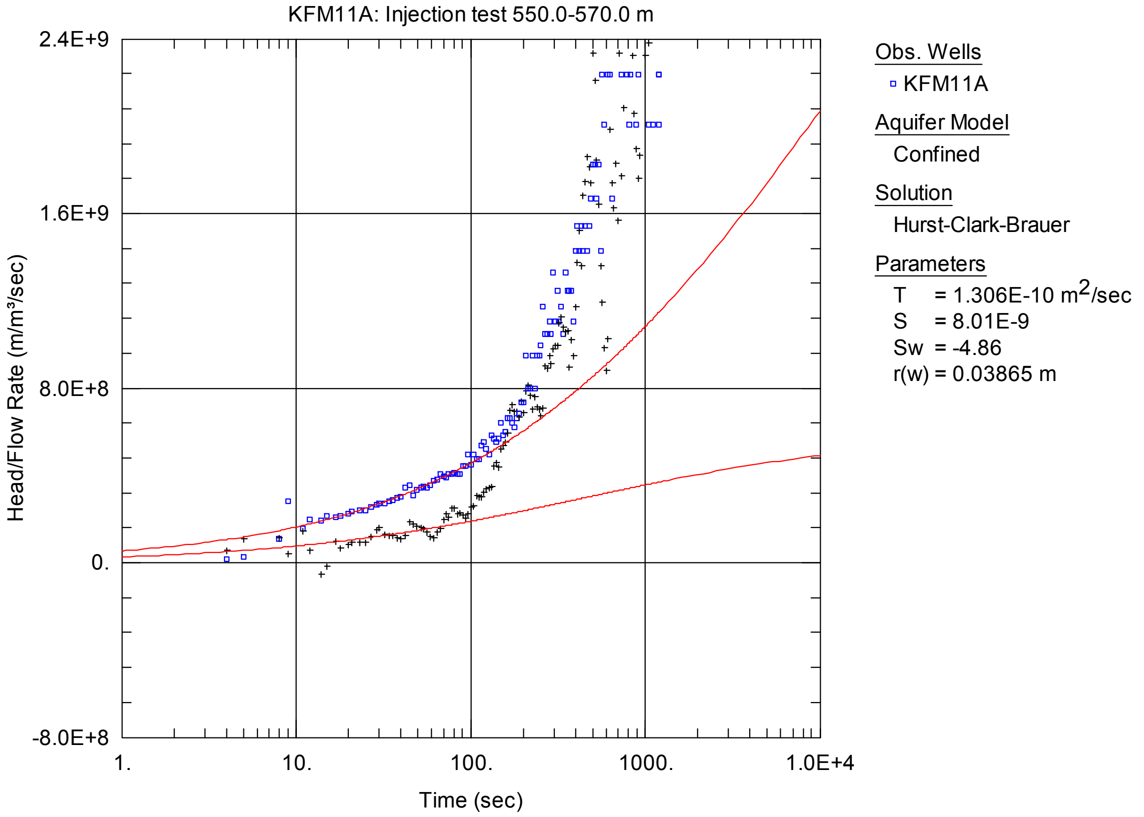


***Figure A3-20.** Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 550.0-570.0 m in KFM11A.*

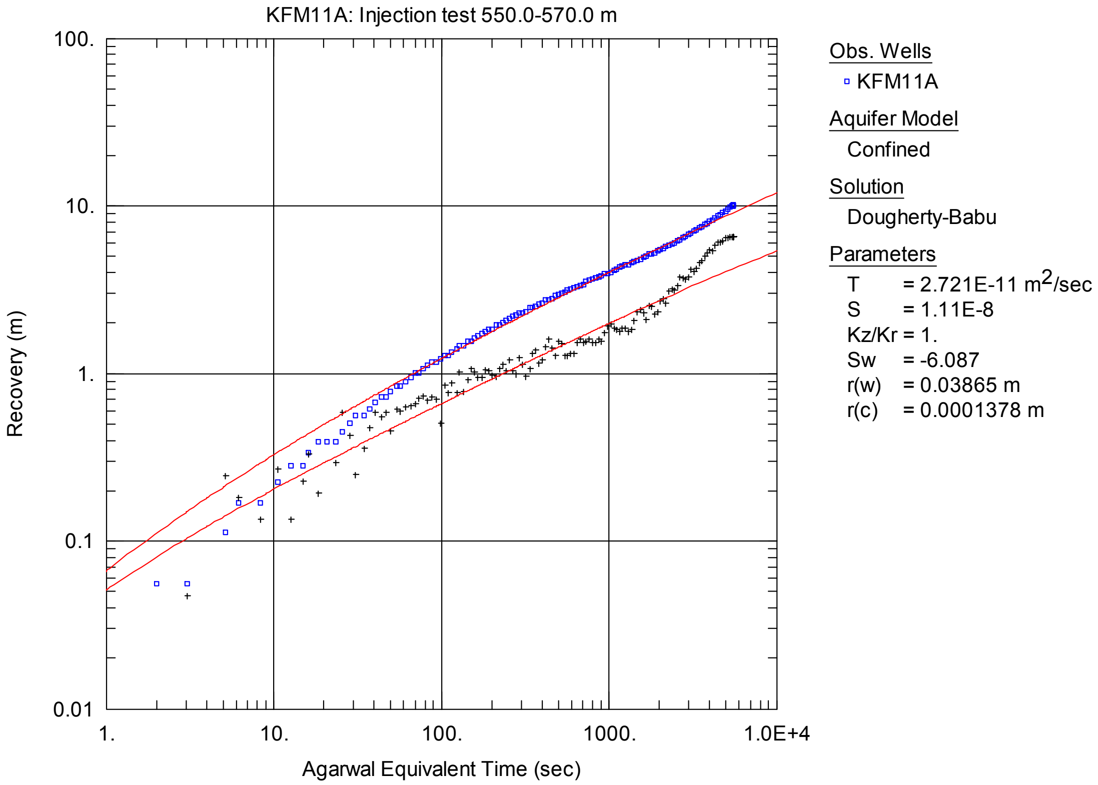


Figure A3-21. *Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 550.0-570.0 m in KFM11A. The type curve fit is showing a possible, however not unambiguous, evaluation.*

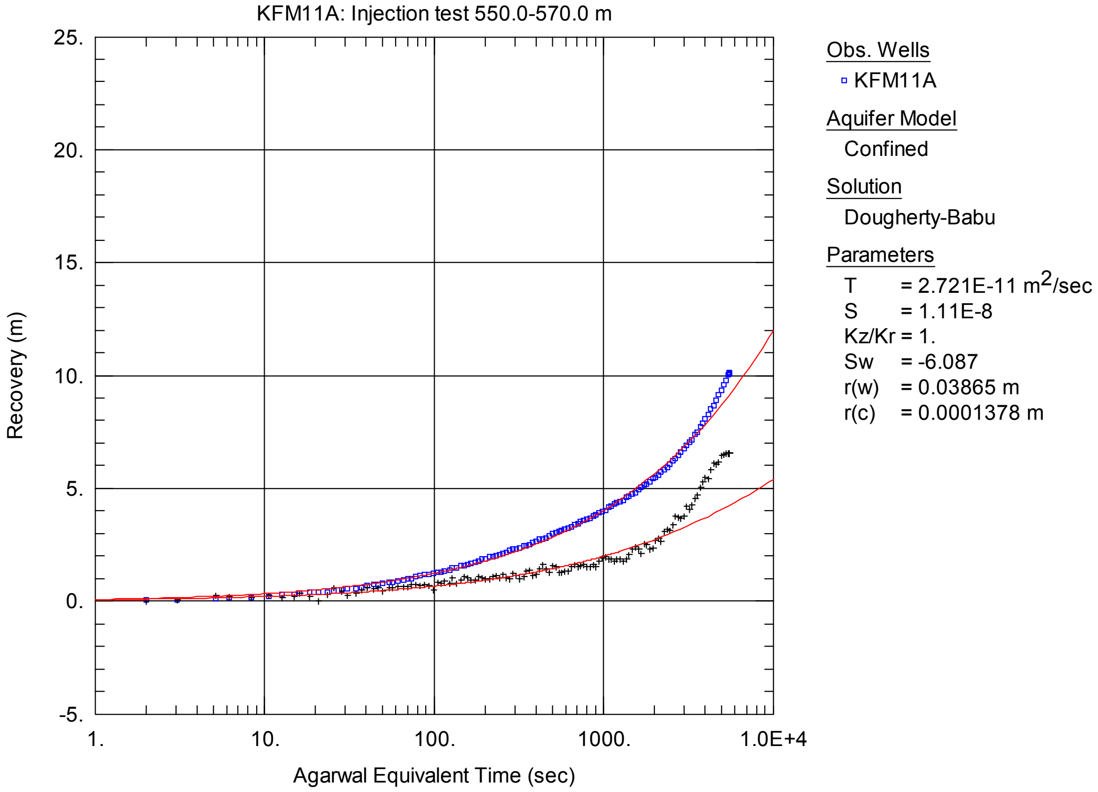


Figure A3-22. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 550.0-570.0 m in KFM11A. The type curve fit is showing a possible, however not unambiguous, evaluation.*

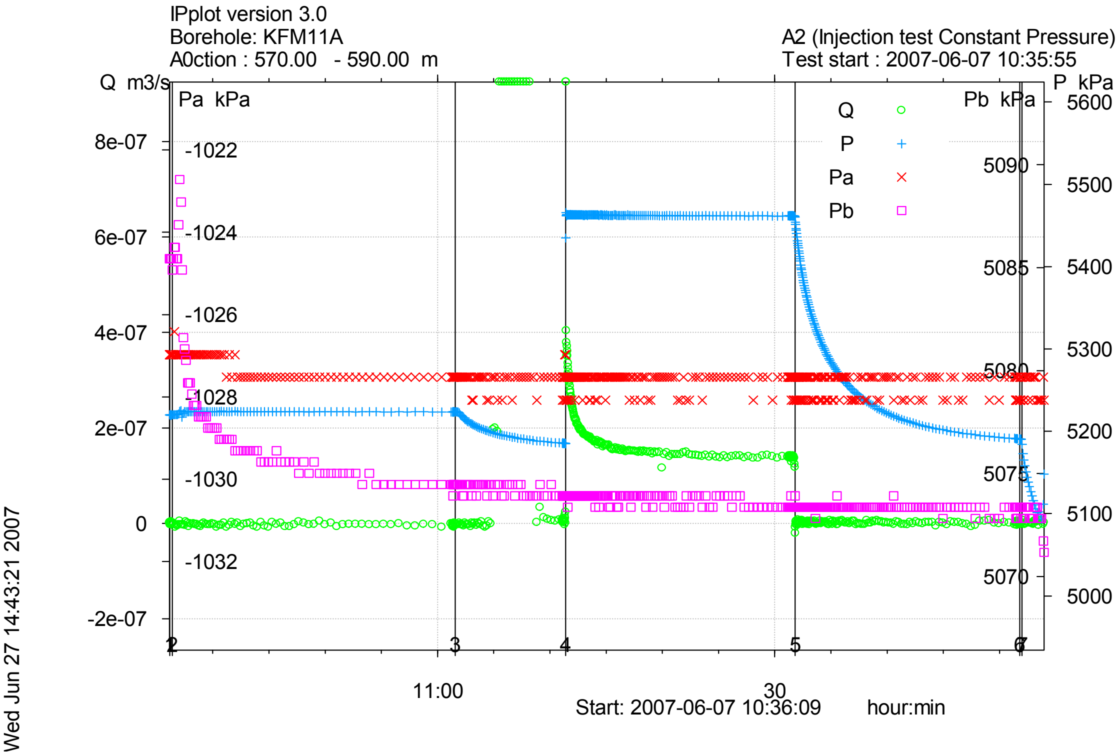


Figure A3-23. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 570.0-590.0 m in borehole KFM11A.*

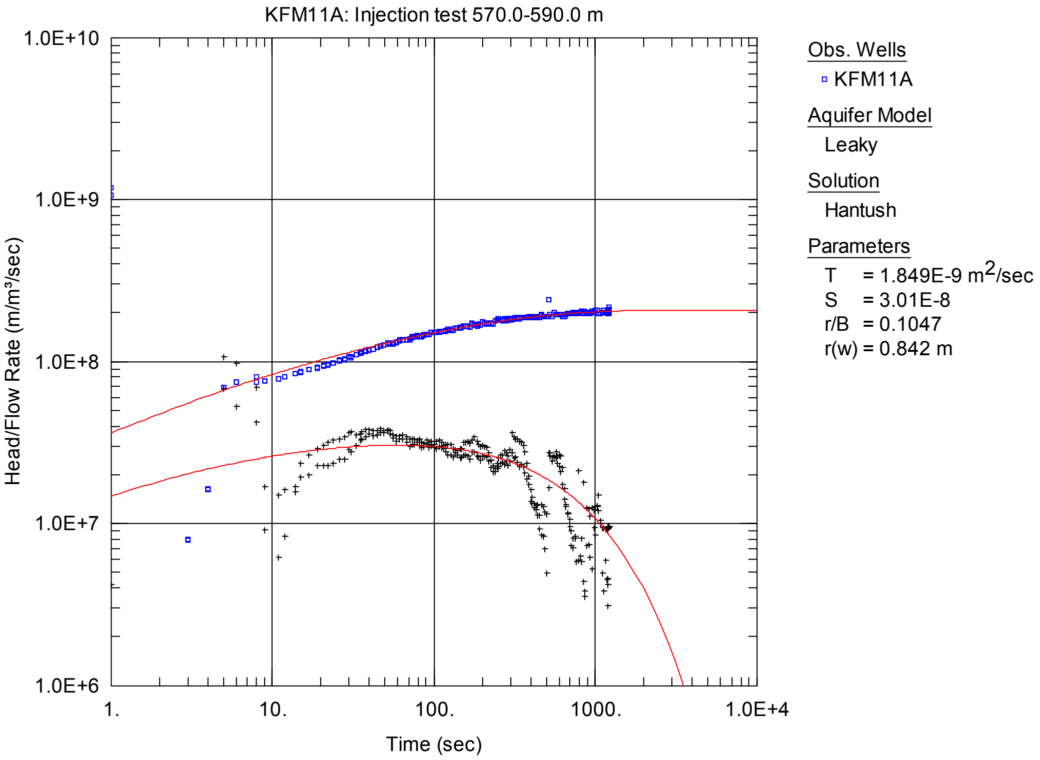


Figure A3-24. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 570.0-590.0 m in KFM11A.*

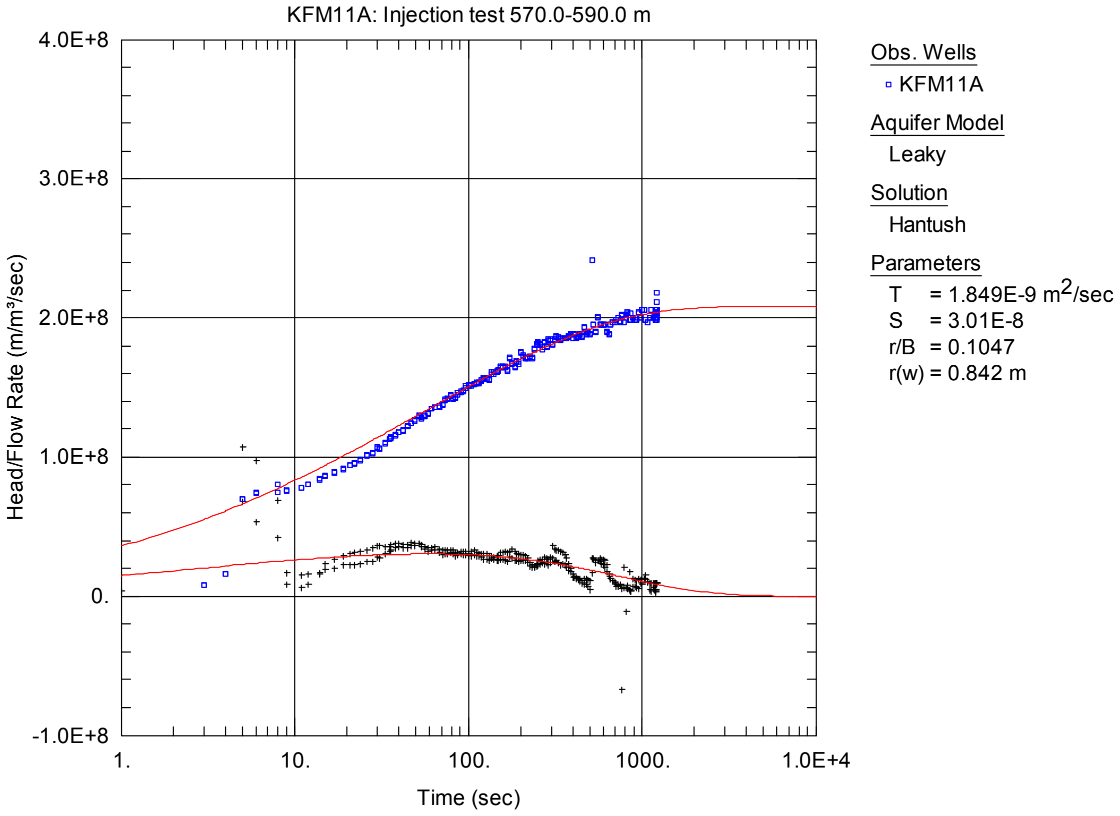


Figure A3-25. *Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 570.0-590.0 m in KFM11A.*

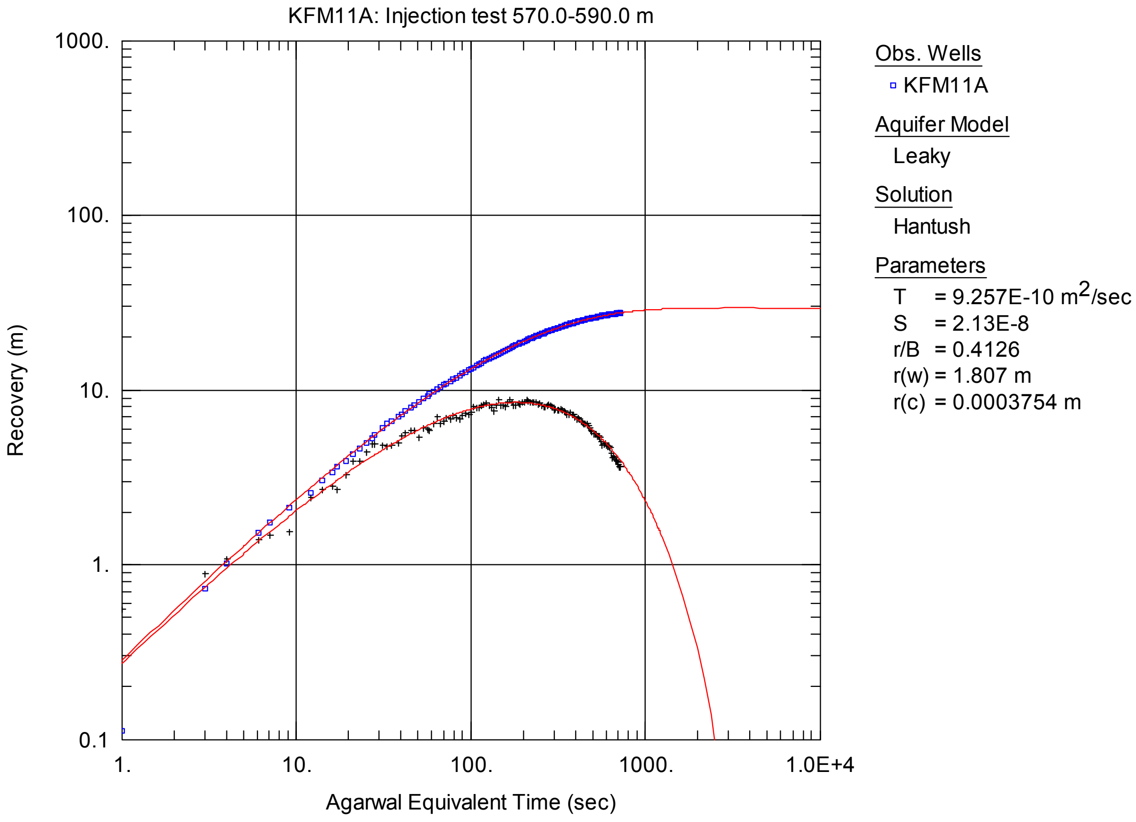


Figure A3-26. *Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 570.0-590.0 m in KFM11A.*

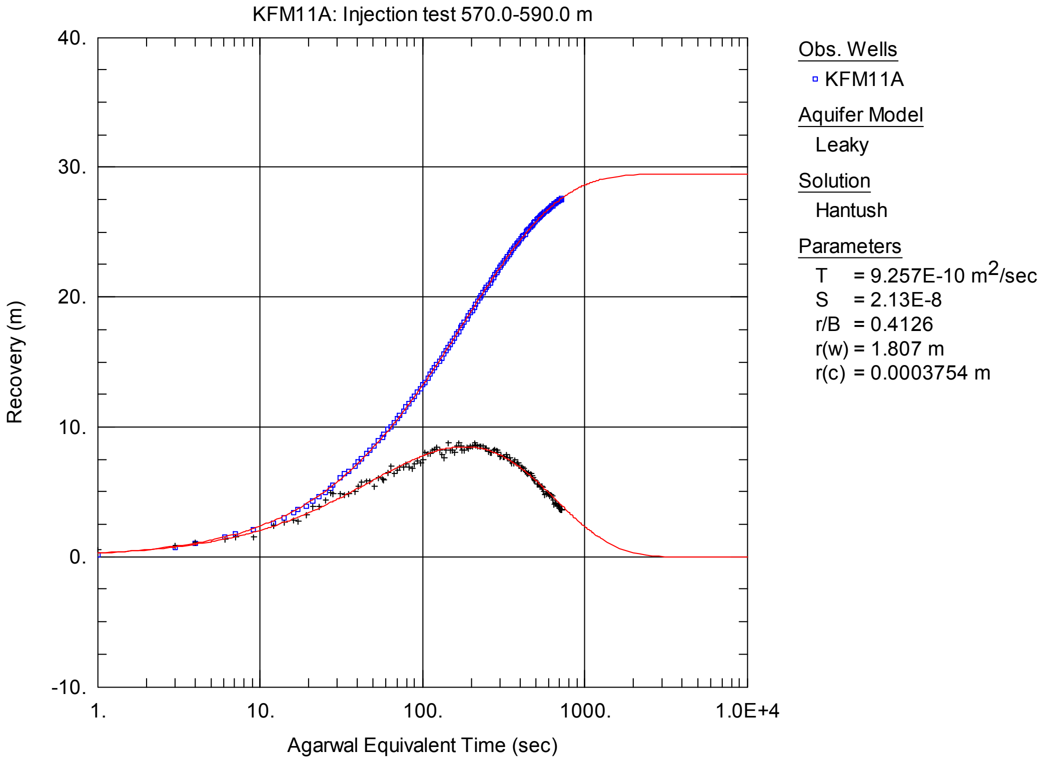


Figure A3-27. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 570.0-590.0 m in KFM11A.*

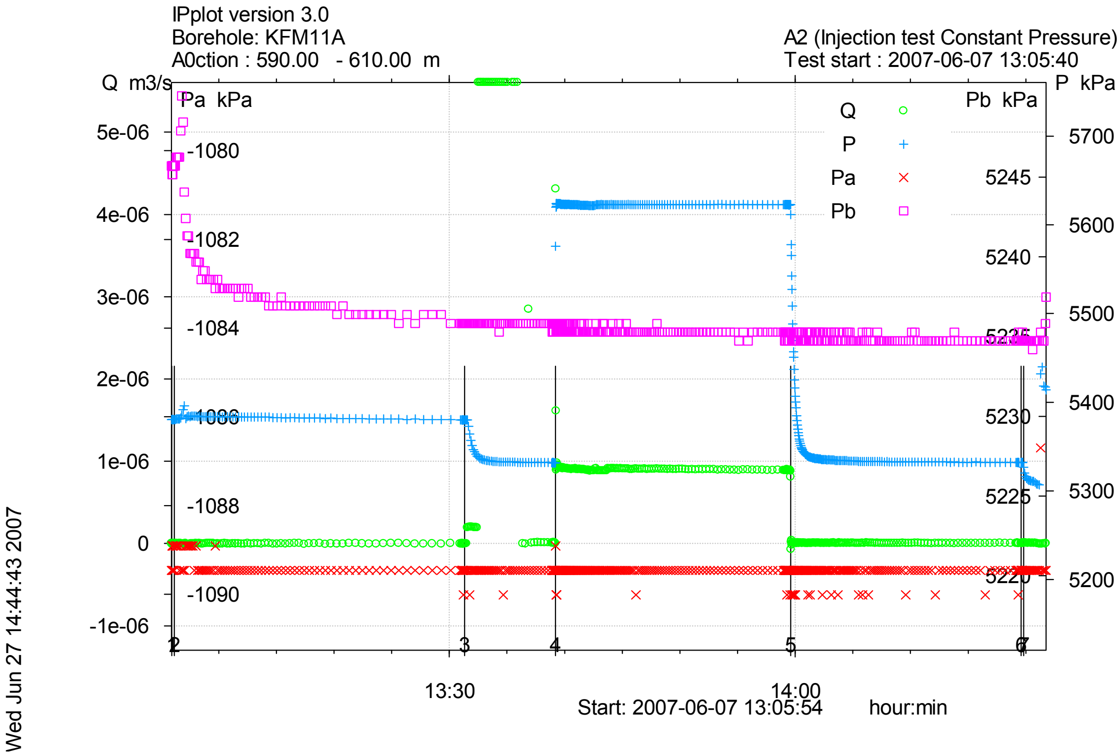


Figure A3-28. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 590.0-610.0 m in borehole KFM11A.*

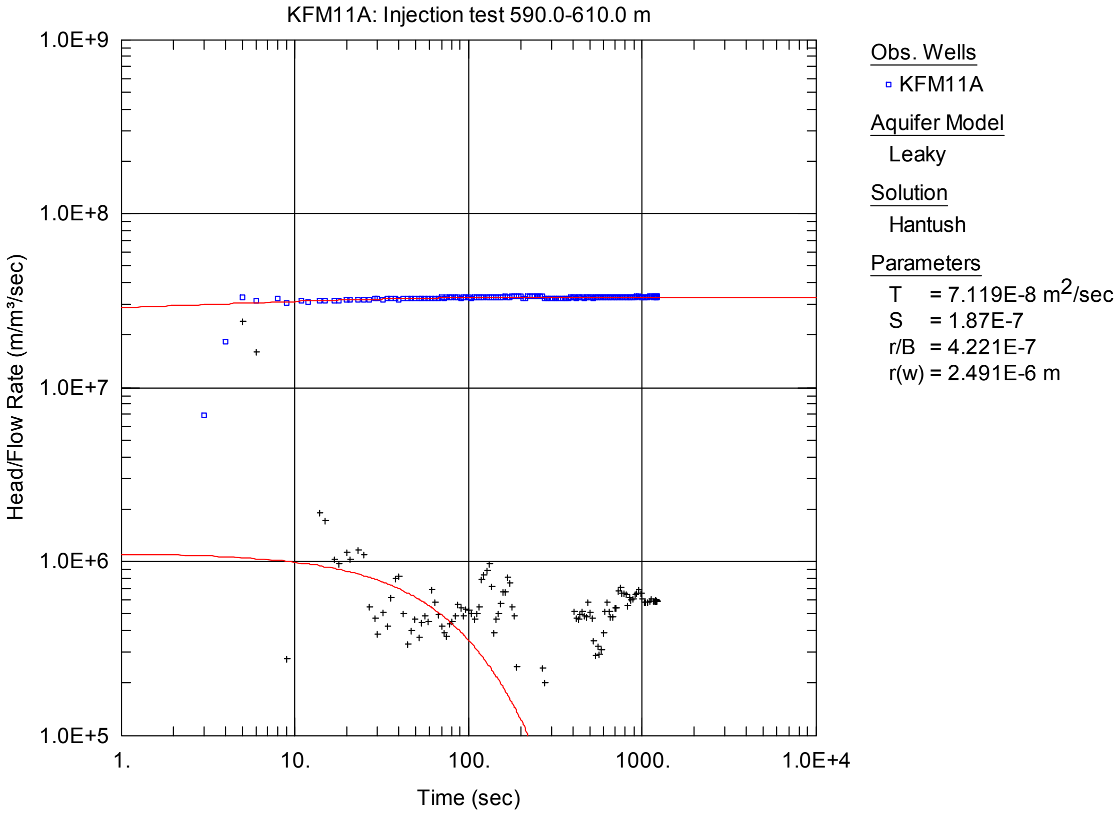


Figure A3-29. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 590.0-610.0 m in KFM11A.*

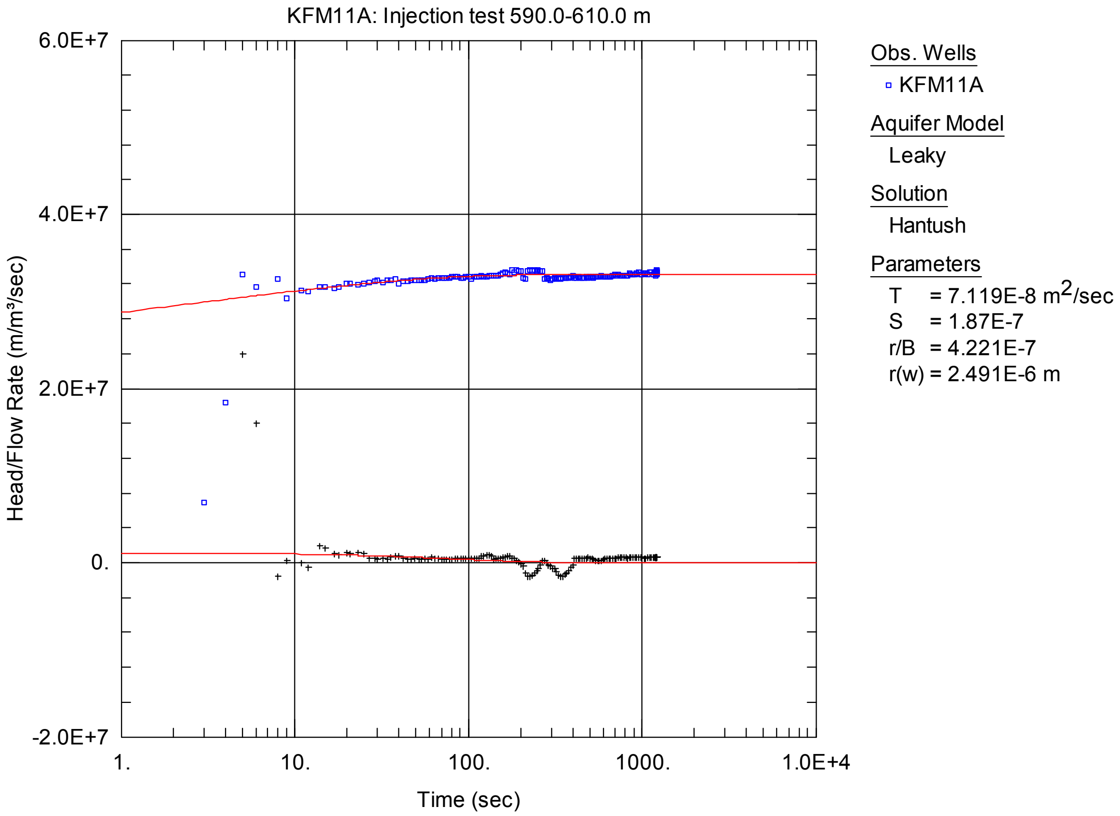


Figure A3-30. *Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 590.0-610.0 m in KFM11A.*

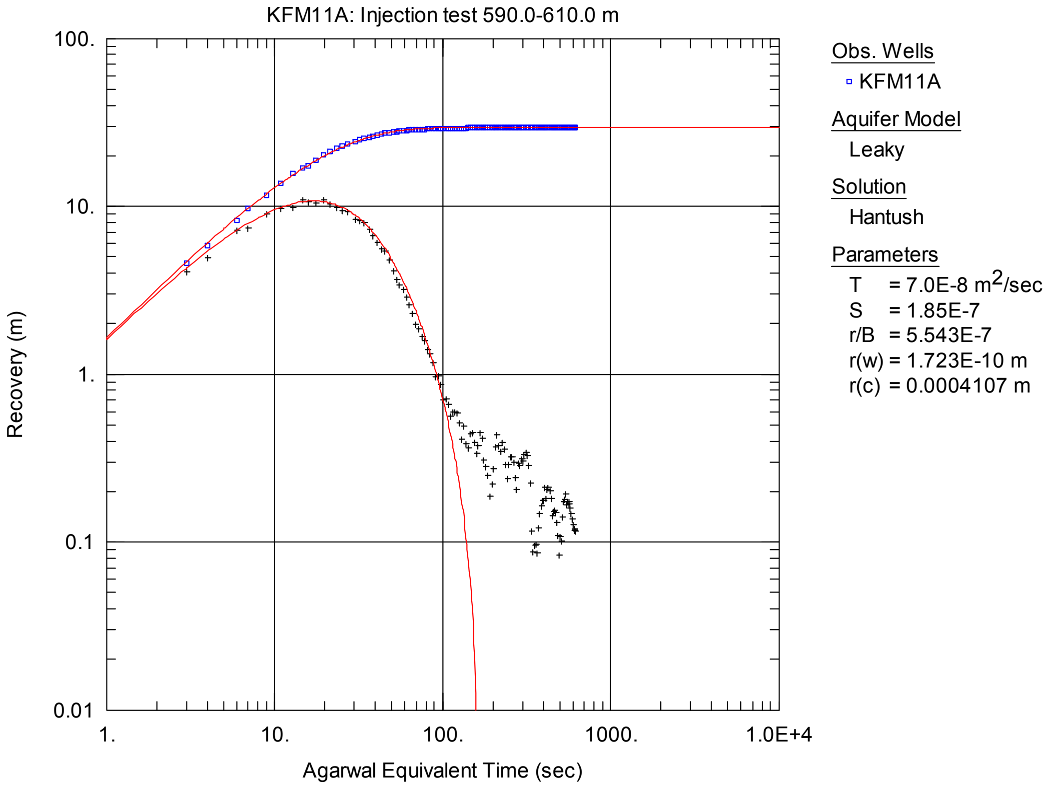


Figure A3-31. *Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 590.0-610.0 m in KFM11A. The type curve fit is showing a possible, however not unambiguous, evaluation.*

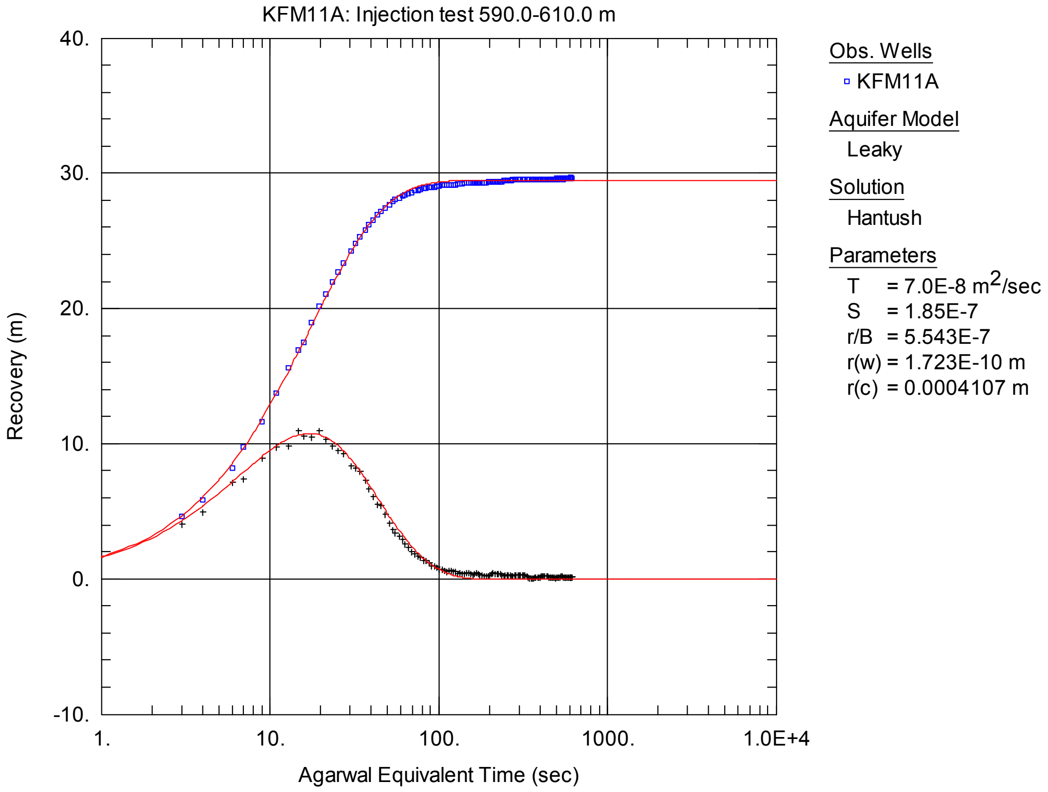


Figure A3-32. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 590.0-610.0 m in KFM11A. The type curve fit is showing a possible, however not unambiguous, evaluation.*

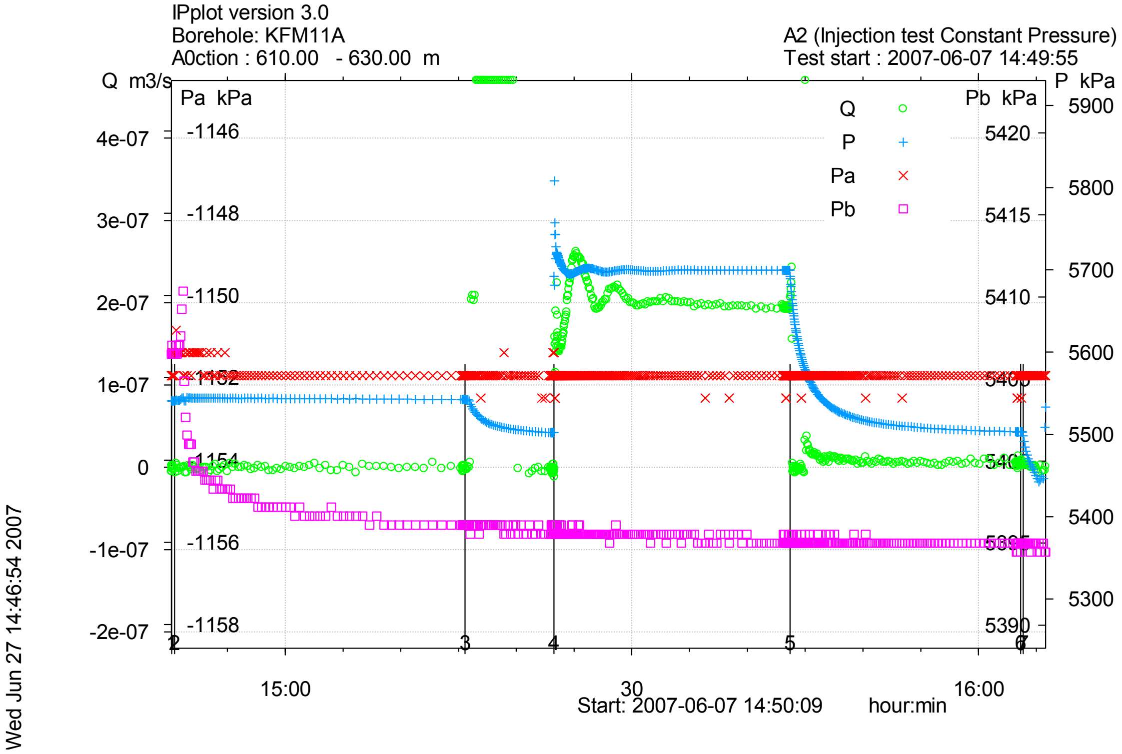


Figure A3-33. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 610.0-630.0 m in borehole KFM11A.*

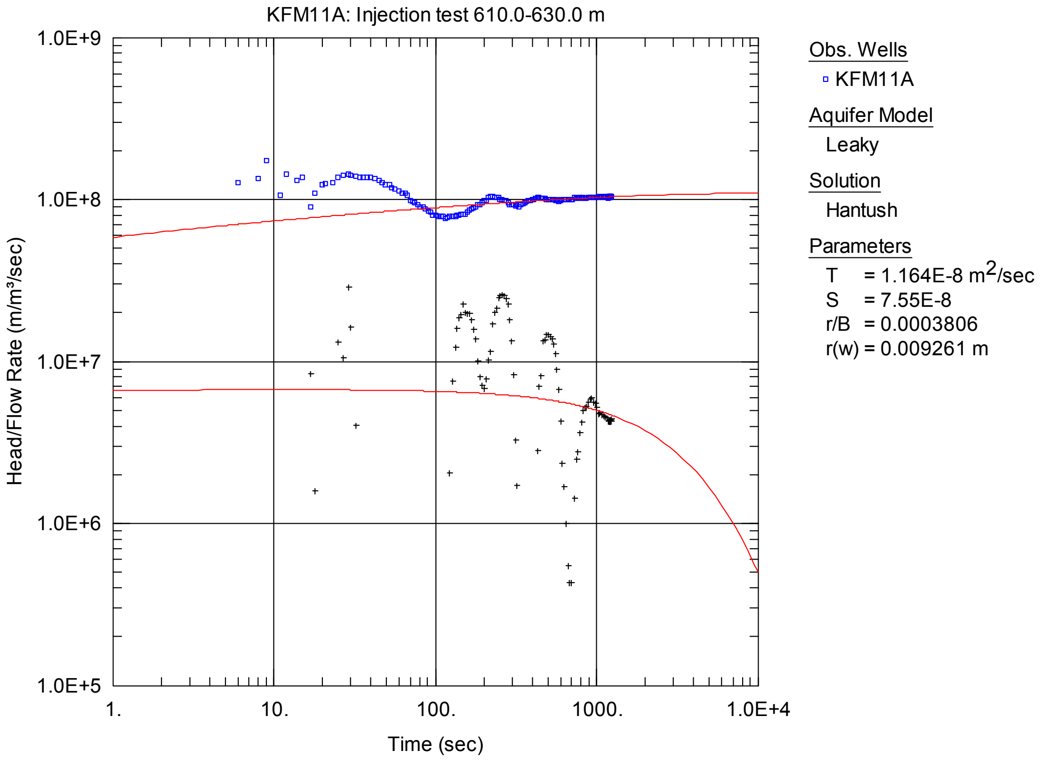


Figure A3-34. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 610.0-630.0 m in KFM11A.*

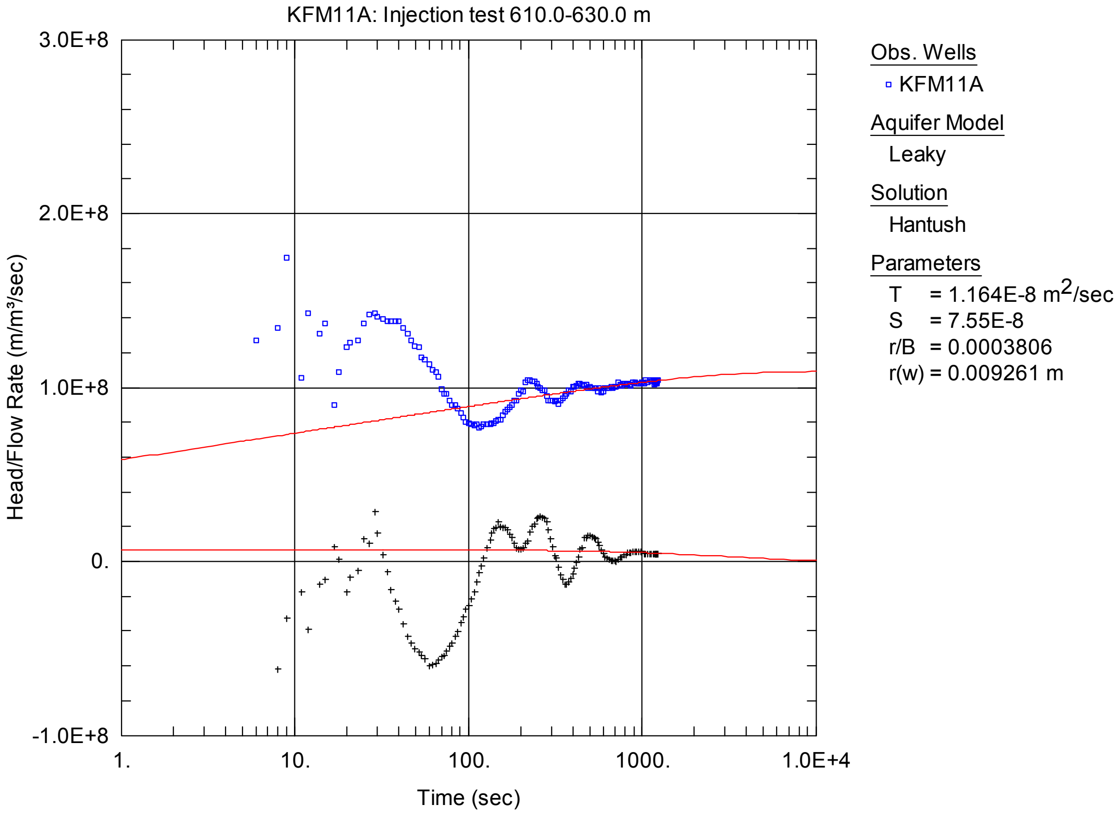


Figure A3-35. Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 610.0-630.0 m in KFM11A.

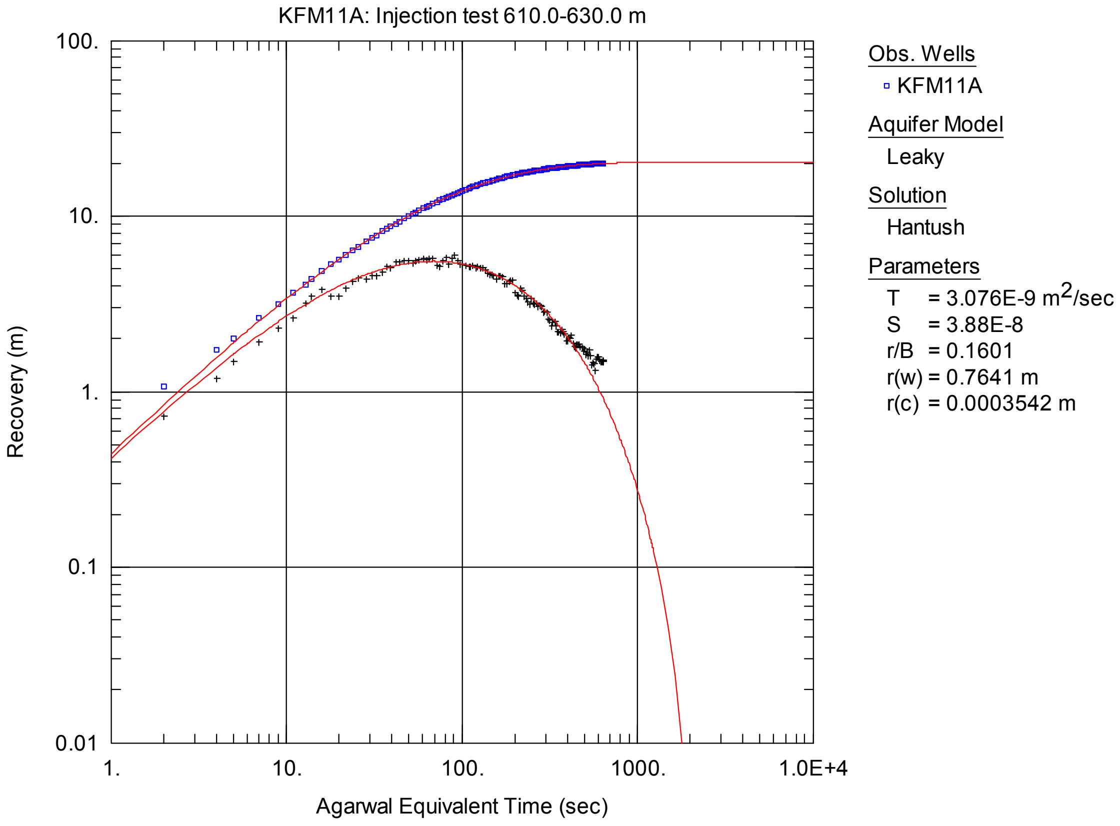


Figure A3-36. Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 610.0-630.0 m in KFM11A.

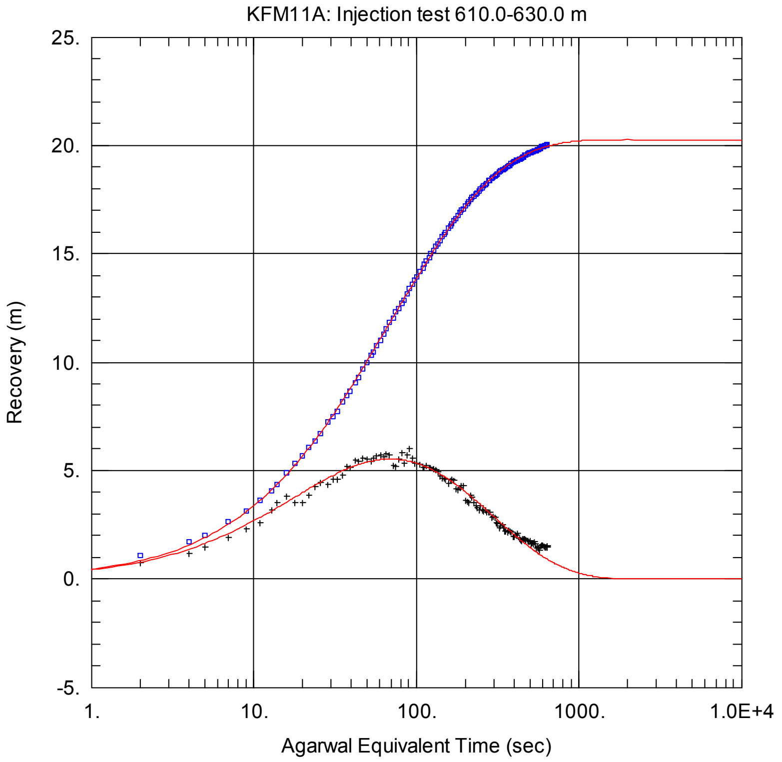


Figure A3-37. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 610.0-630.0 m in KFM11A.*

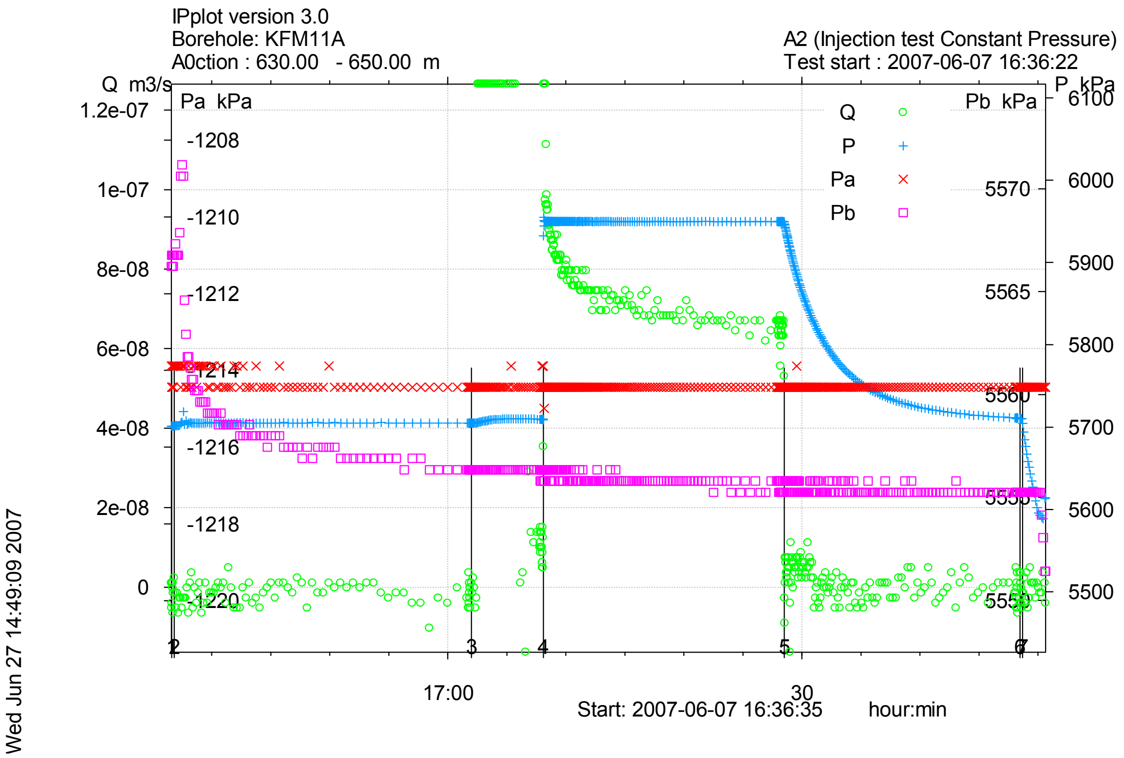


Figure A3-38. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 630.0-650.0 m in borehole KFM11A.*

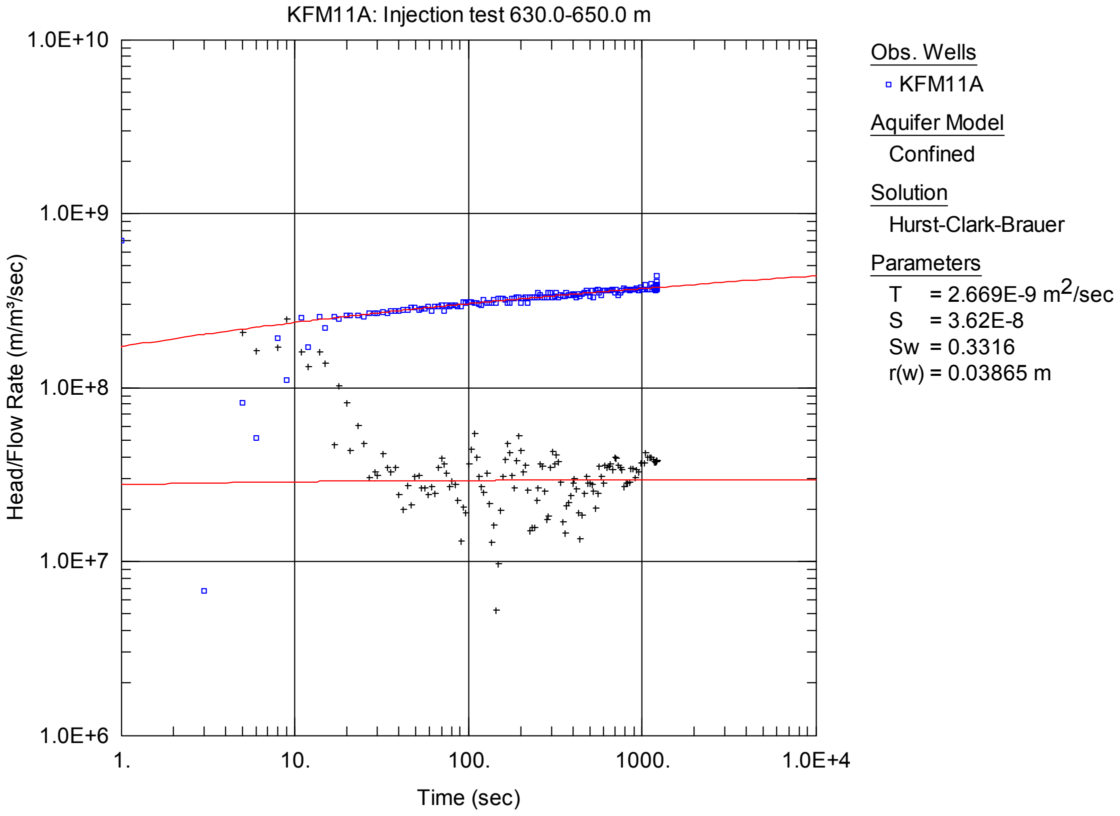


Figure A3-39. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 630.0-650.0 m in KFM11A.*

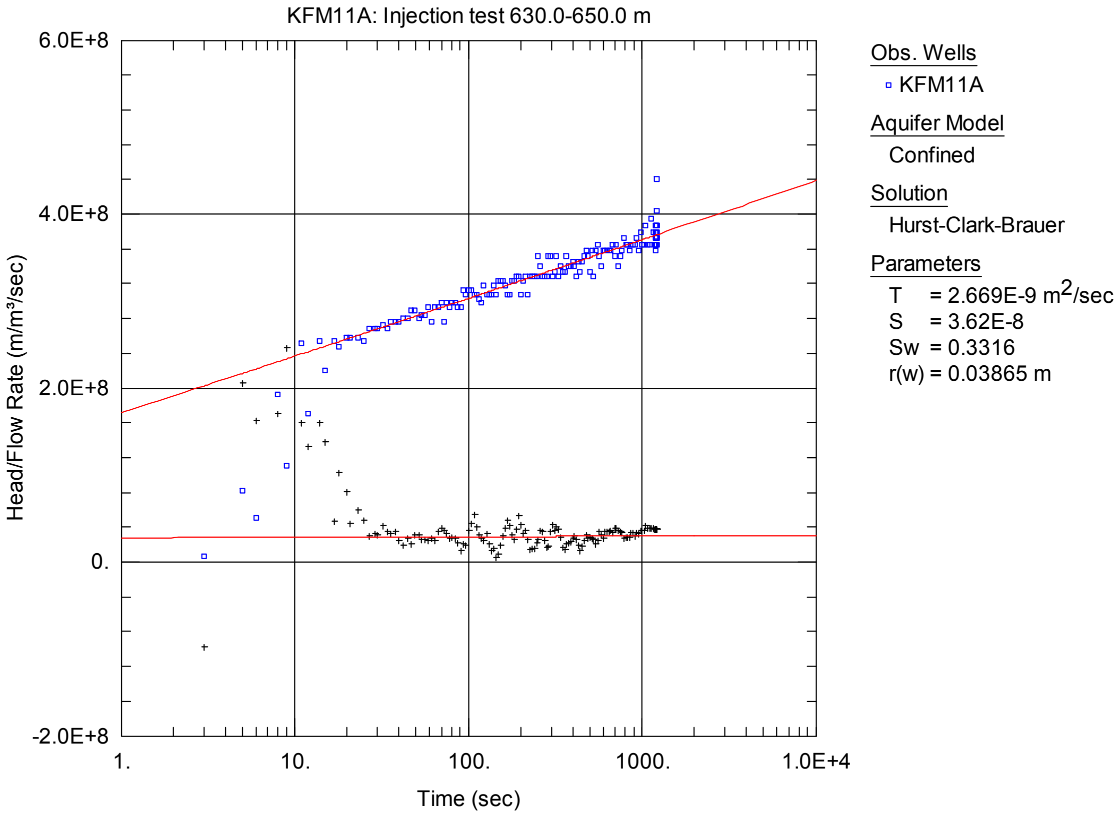


Figure A3-40. *Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 630.0-650.0 m in KFM11A.*

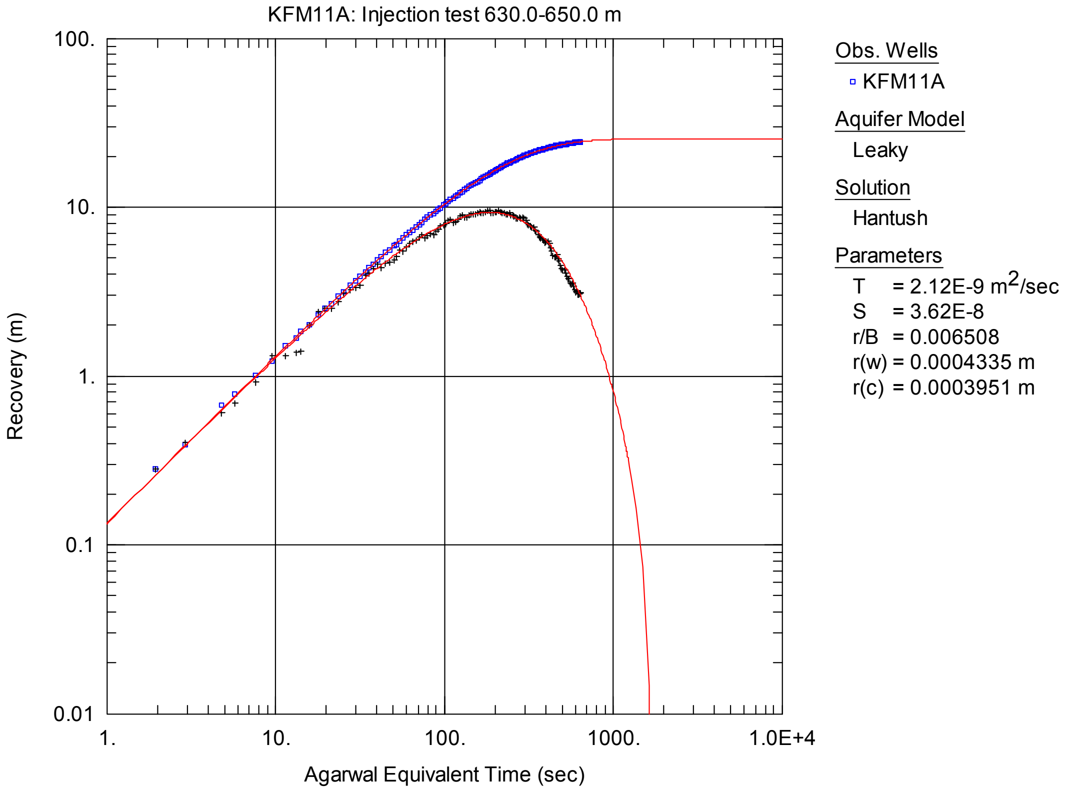


Figure A3-41. *Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 630.0-650.0 m in KFM11A. The type curve fit is showing a possible, however not unambiguous, evaluation.*

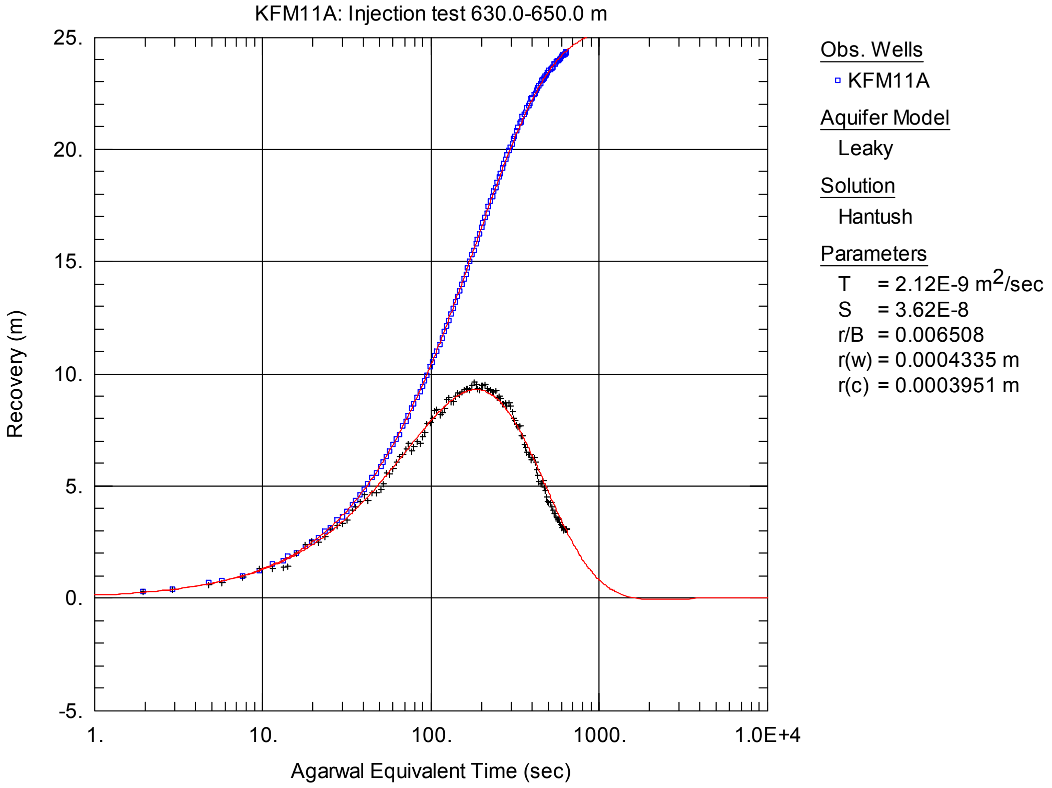


Figure A3-42. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 630.0-650.0 m in KFM11A. The type curve fit is showing a possible, however not unambiguous, evaluation.*

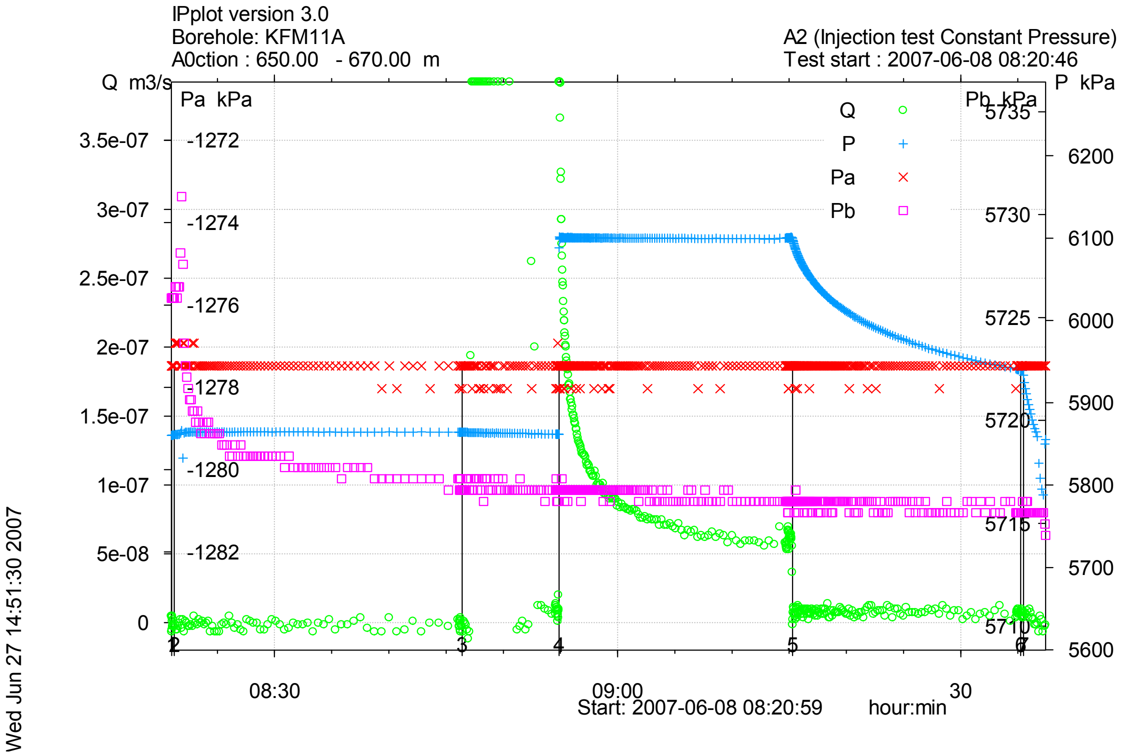


Figure A3-43. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 650.0-670.0 m in borehole KFM11A.*

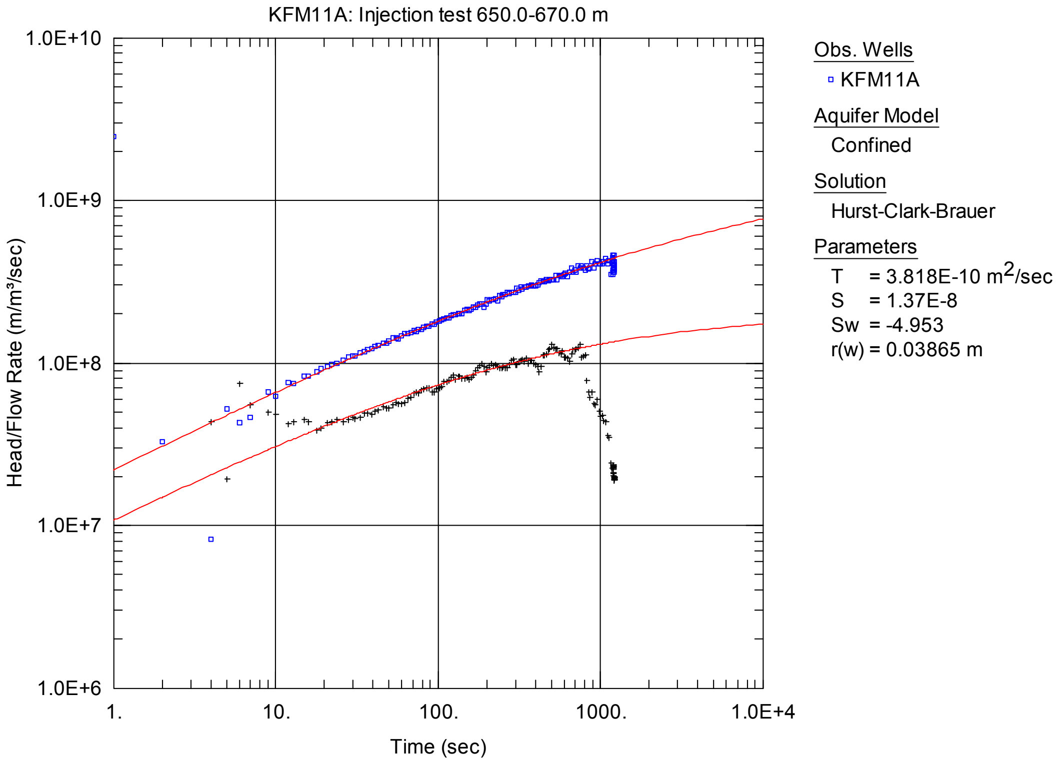


Figure A3-44. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 650.0-670.0 m in KFM11A.*

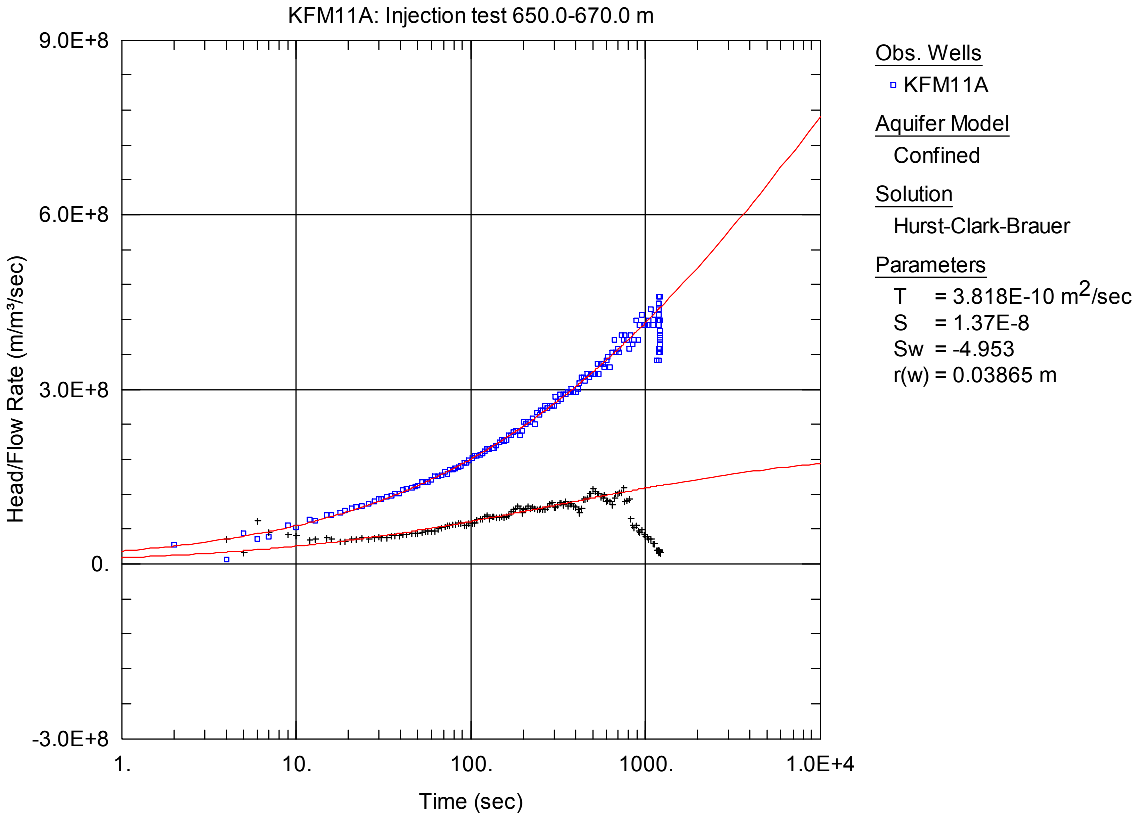


Figure A3-45. *Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 650.0-670.0 m in KFM11A.*

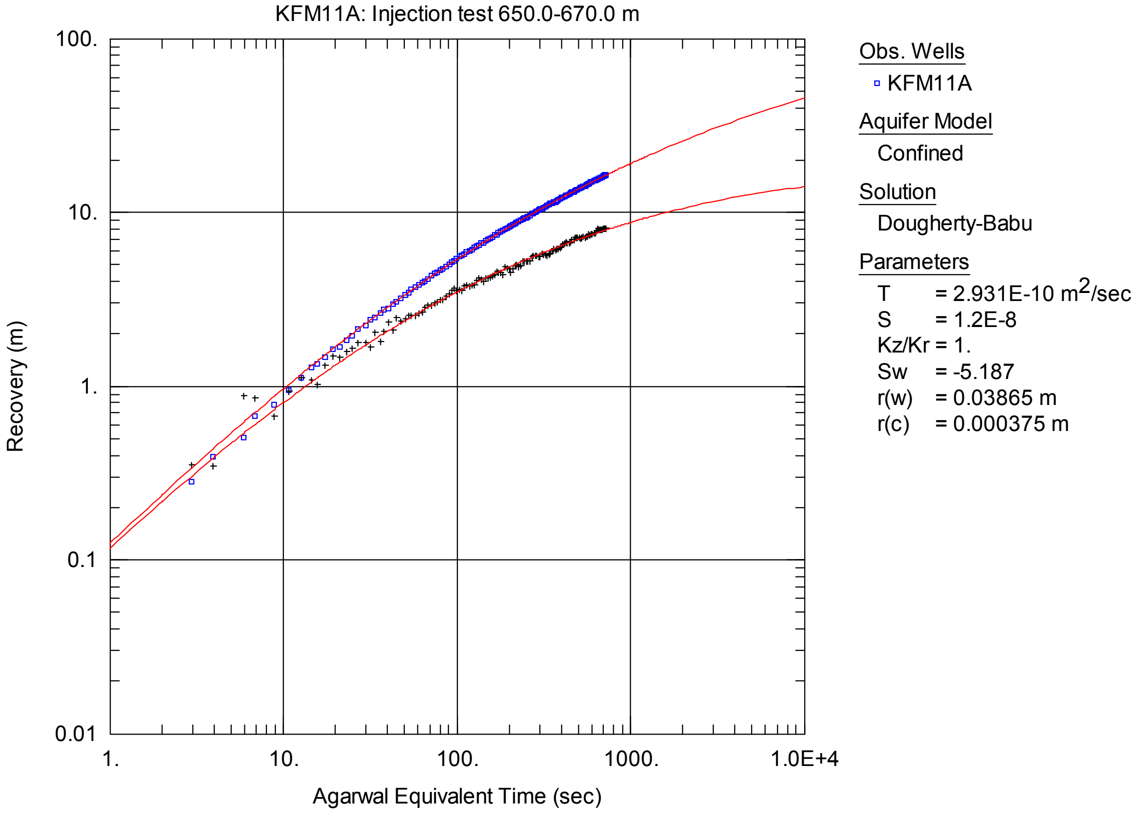


Figure A3-46. *Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 650.0-670.0 m in KFM11A.*

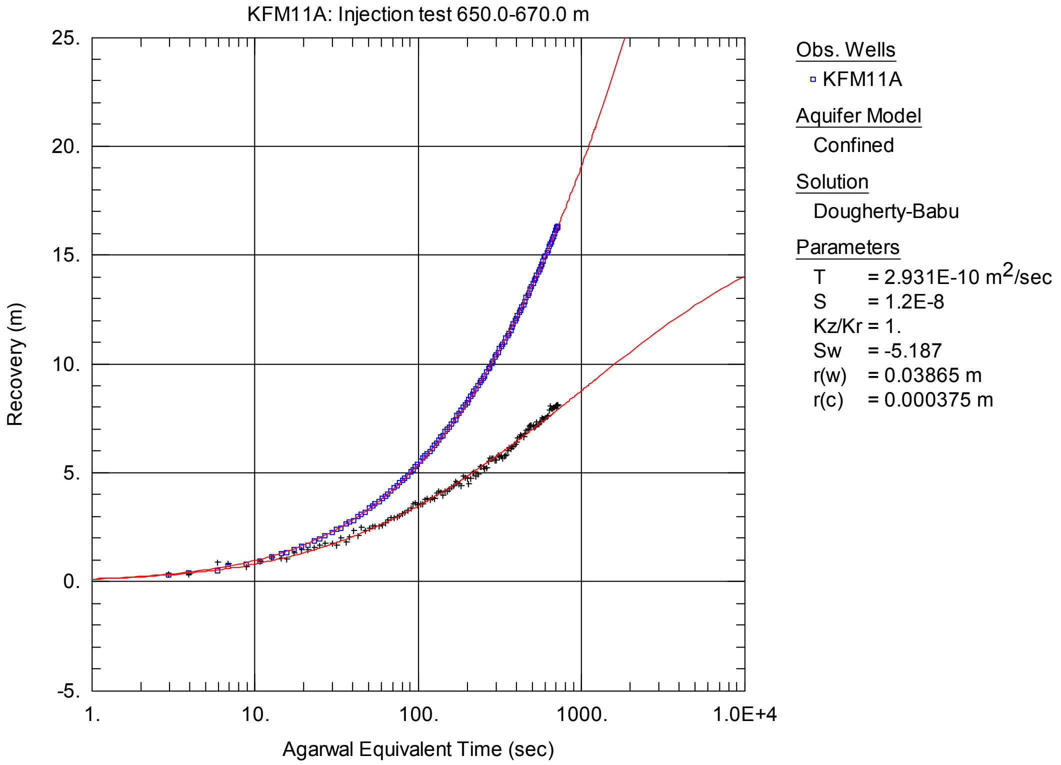


Figure A3-47. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 650.0-670.0 m in KFM11A.*

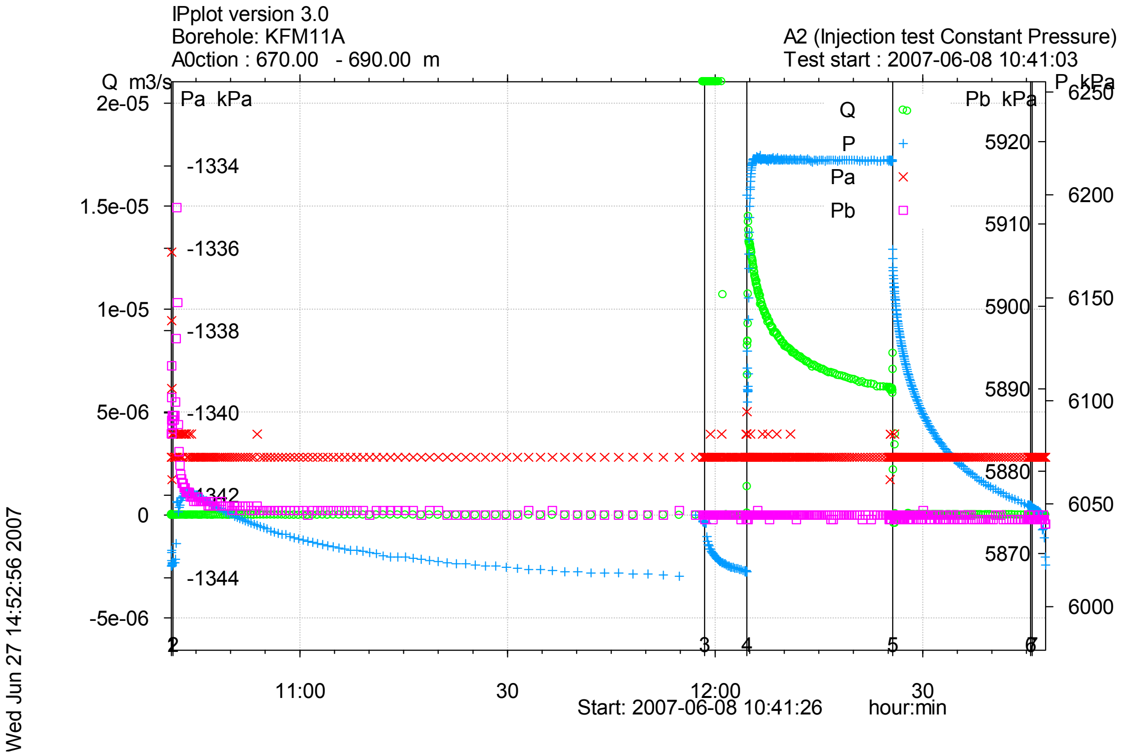


Figure A3-48. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 670.0-690.0 m in borehole KFM11A.*

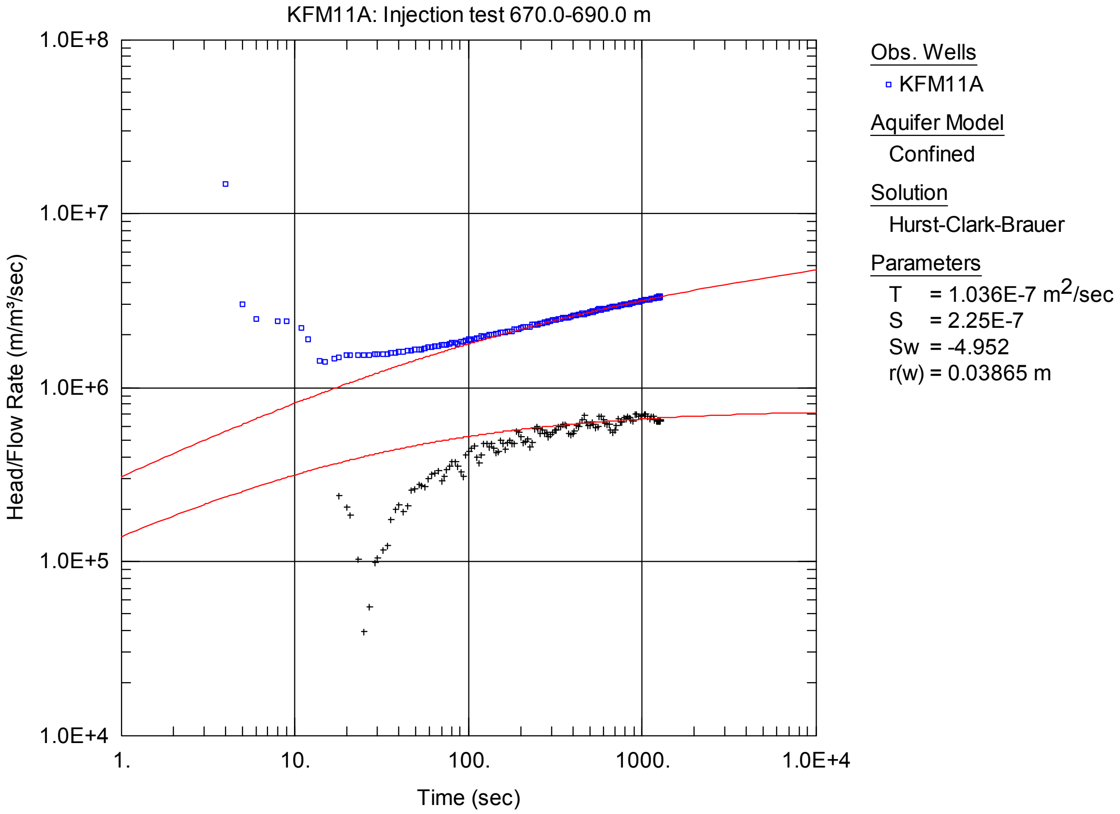


Figure A3-49. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 670.0-690.0 m in KFM11A.*

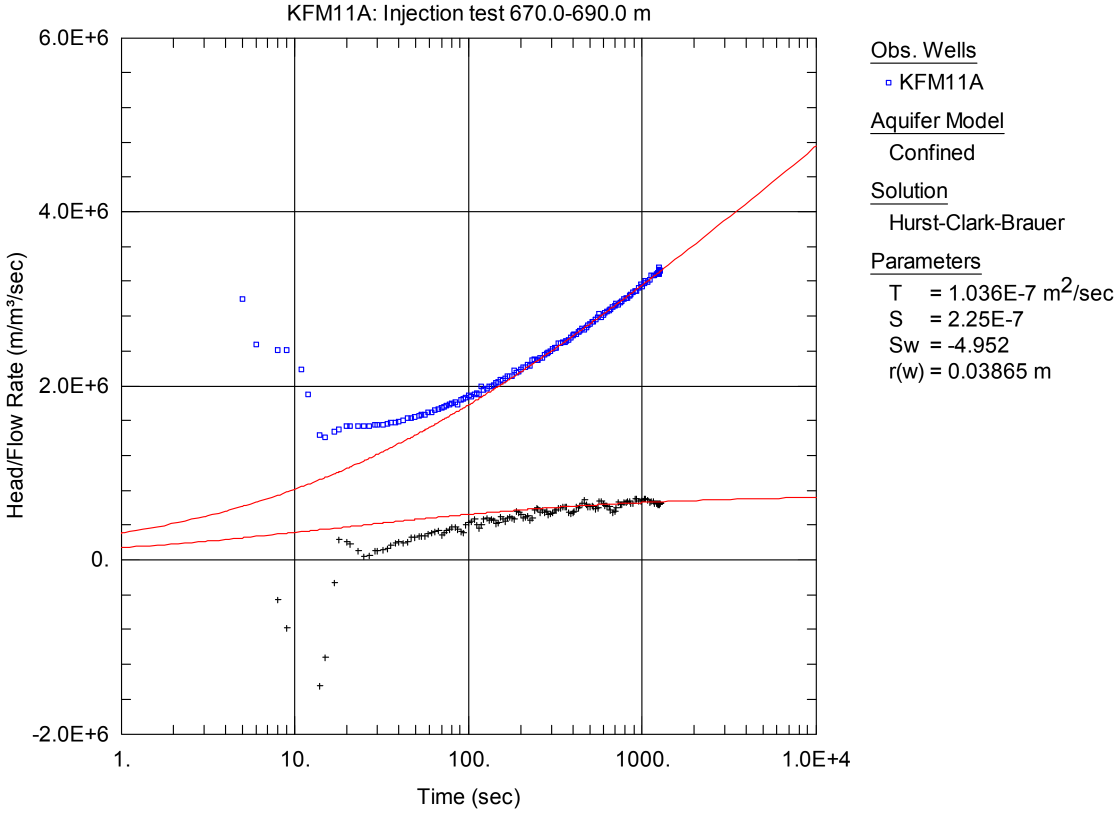


Figure A3-50. *Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 670.0-690.0 m in KFM11A.*

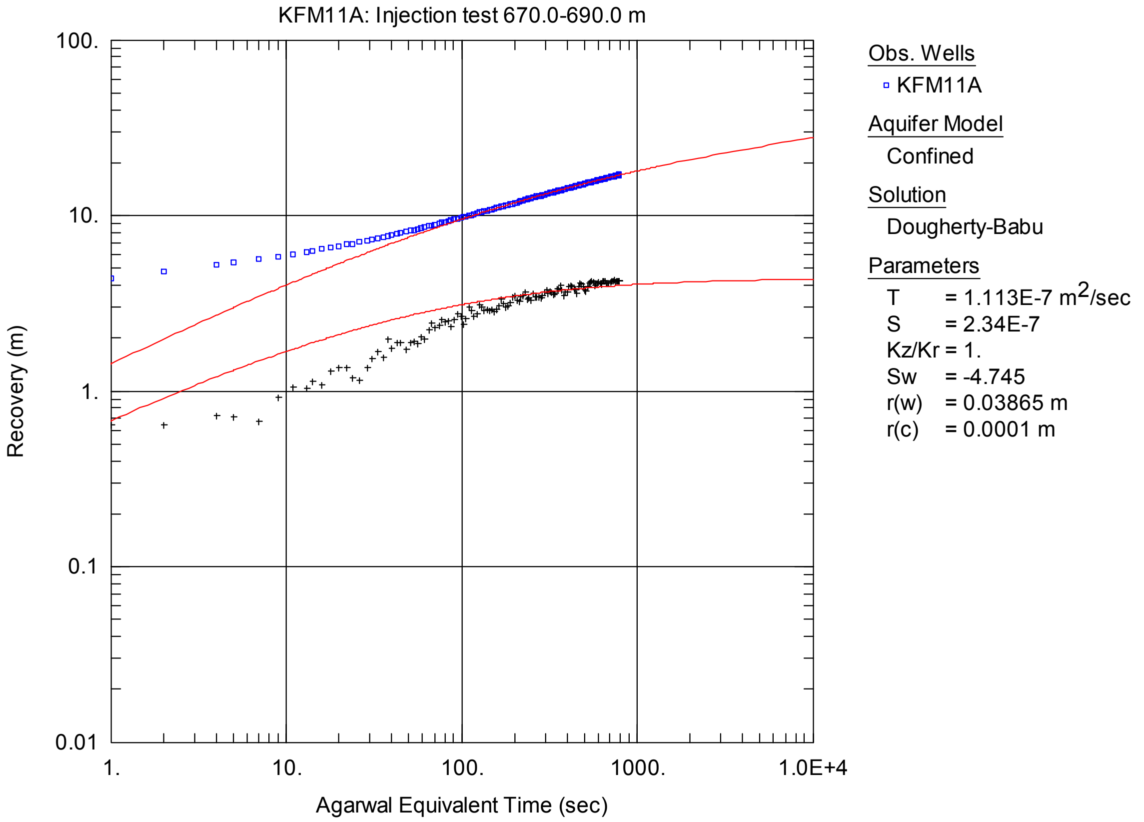


Figure A3-51. *Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 670.0-690.0 m in KFM11A.*

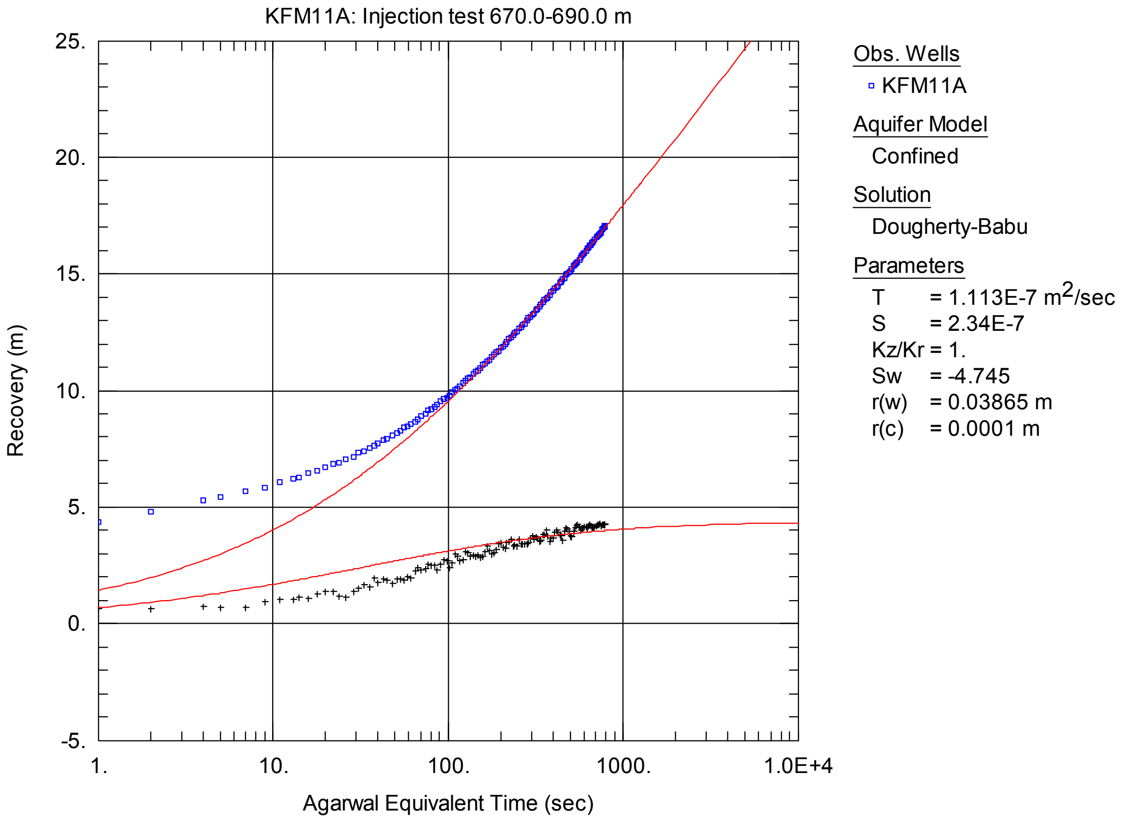


Figure A3-52. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 670.0-690.0 m in KFM11A.*

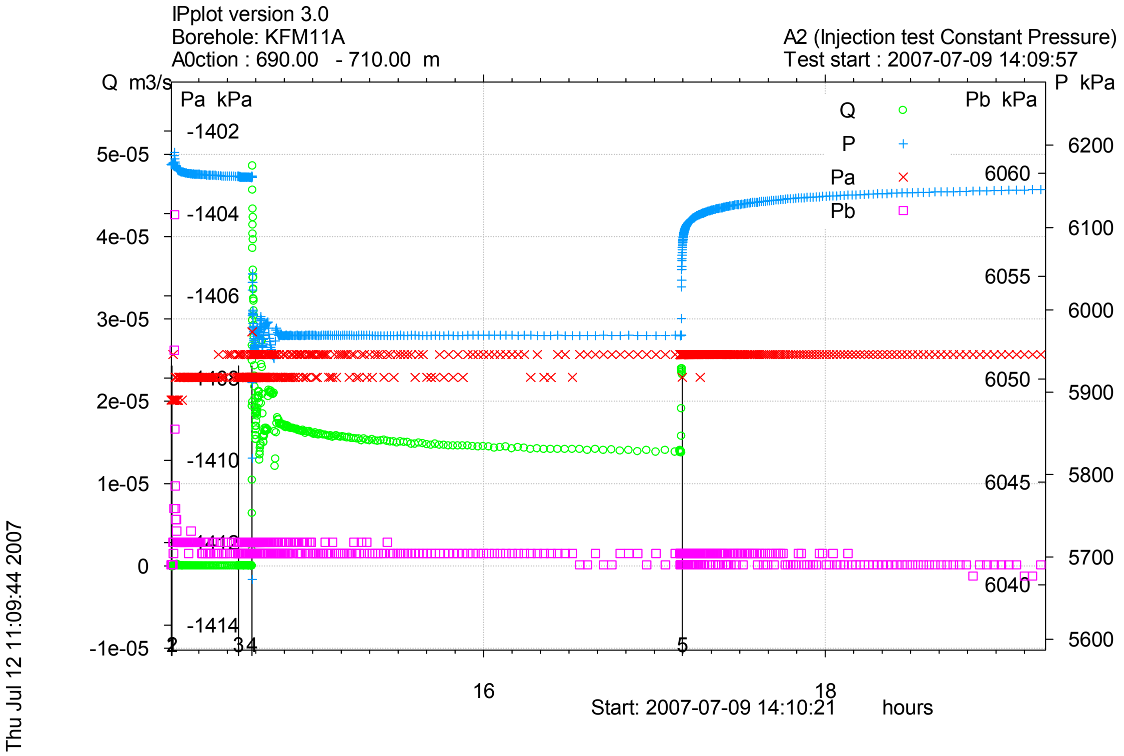


Figure A3-53. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the pumping test in section 690.0-710.0 m in borehole KFM11A.*

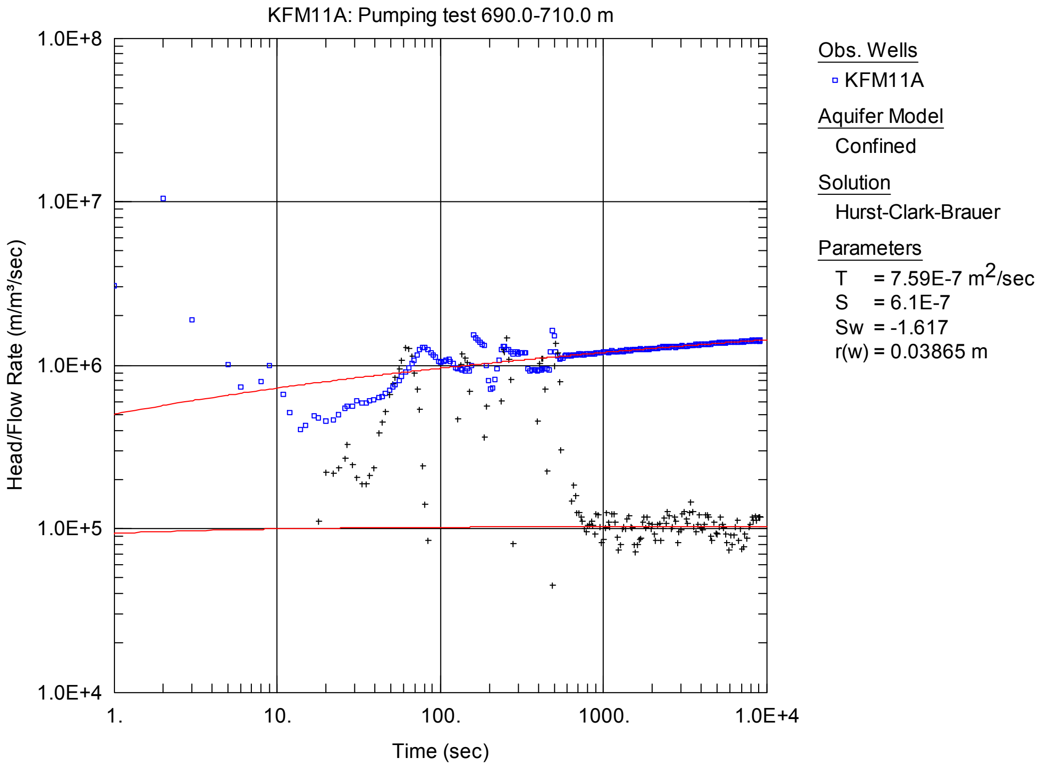


Figure A3-54. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the pumping test in section 690.0-710.0 m in KFM11A.*

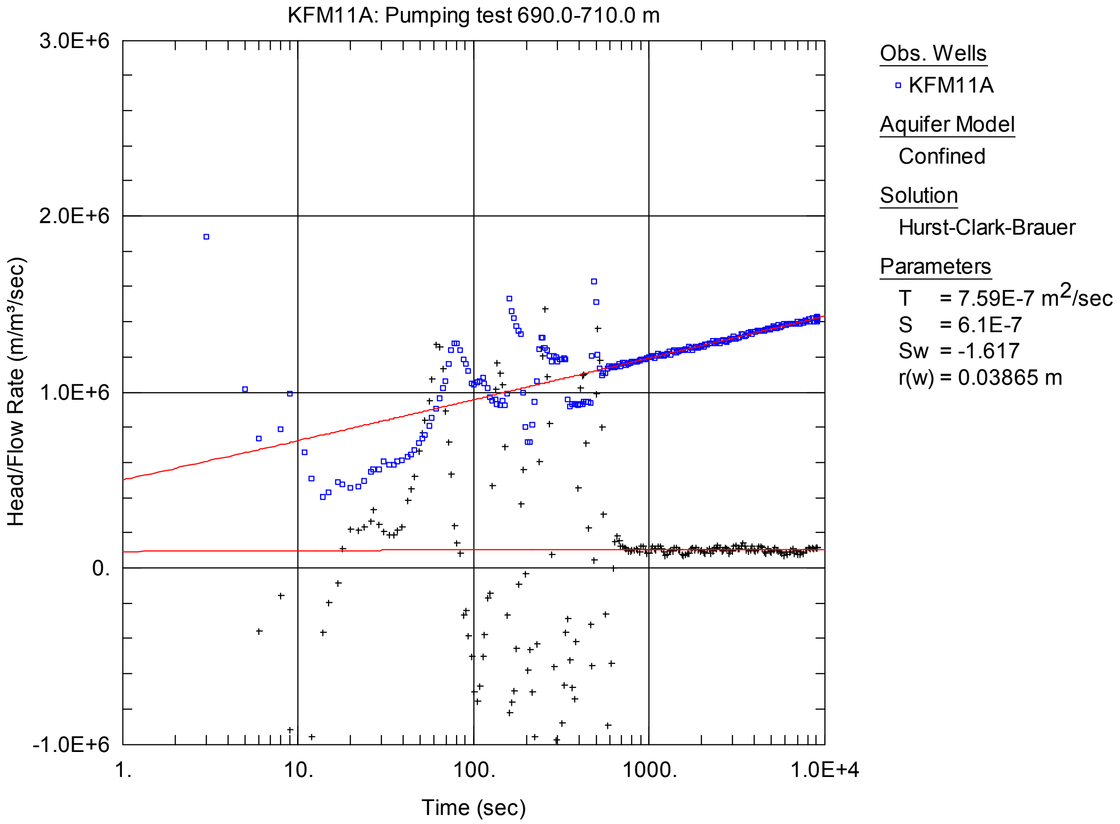


Figure A3-55. *Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the pumping test in section 690.0-710.0 m in KFM11A.*

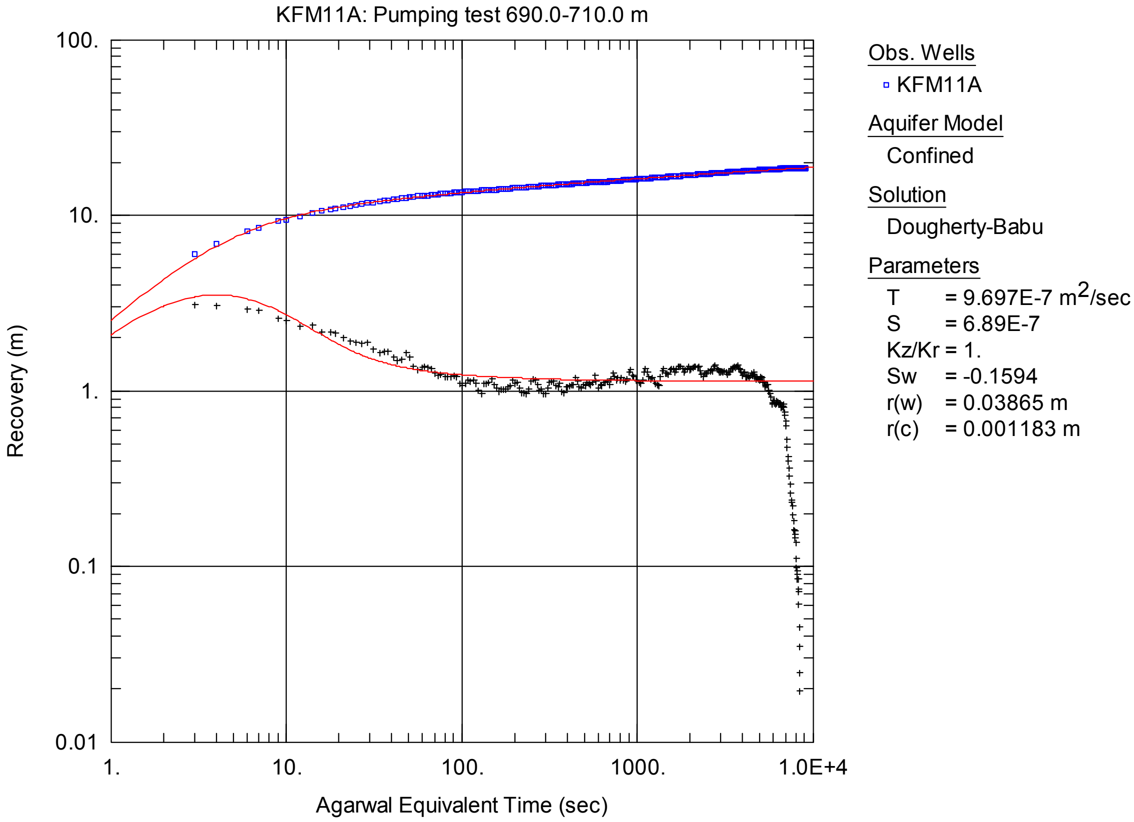


Figure A3-56. *Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the pumping test in section 690.0-710.0 m in KFM11A.*

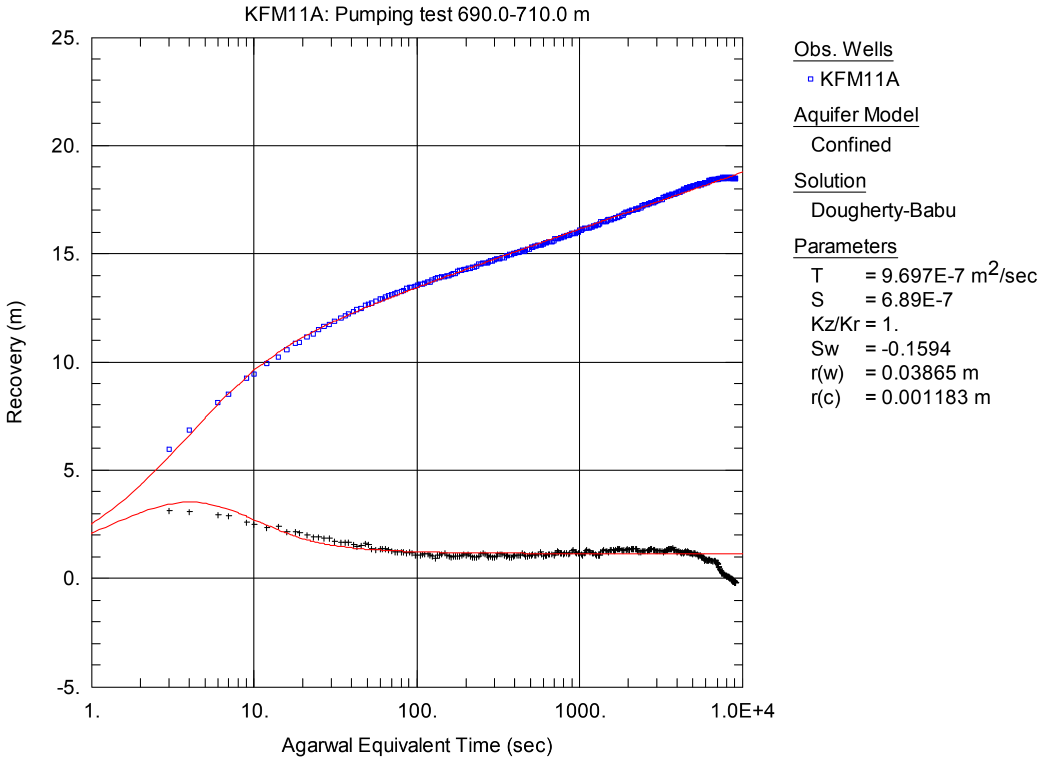


Figure A3-57. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the pumping test in section 690.0-710.0 m in KFM11A.*

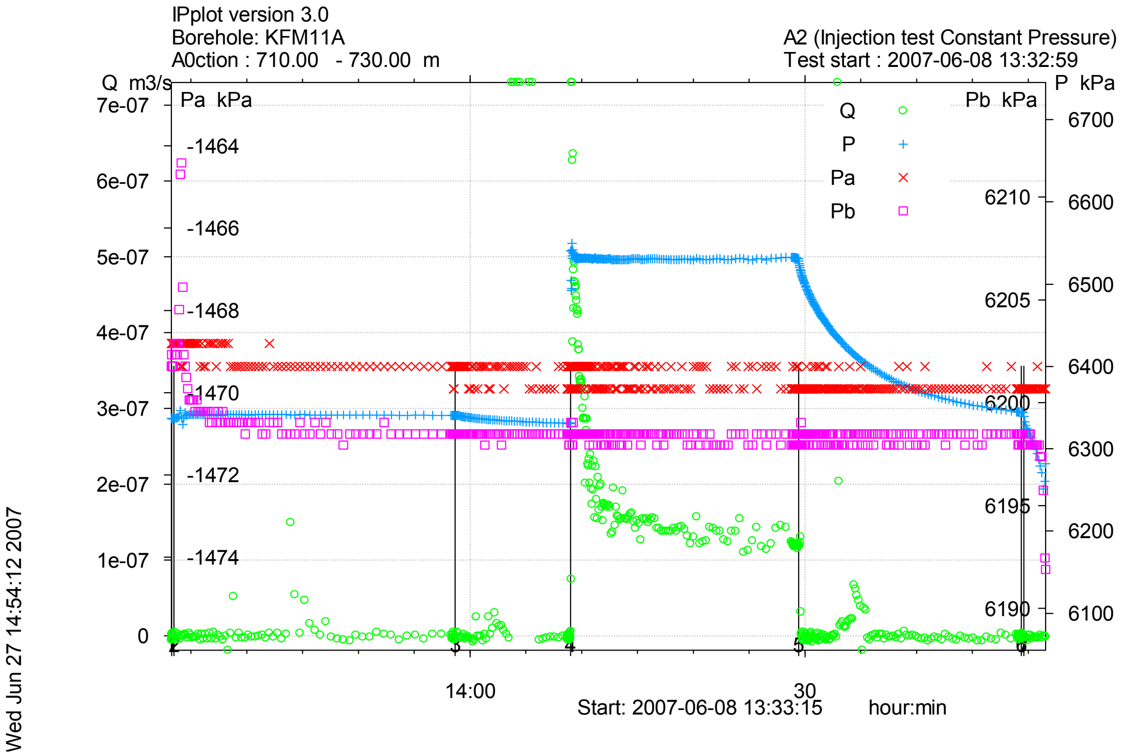


Figure A3-58. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 710.0-730.0 m in borehole KFM11A.*

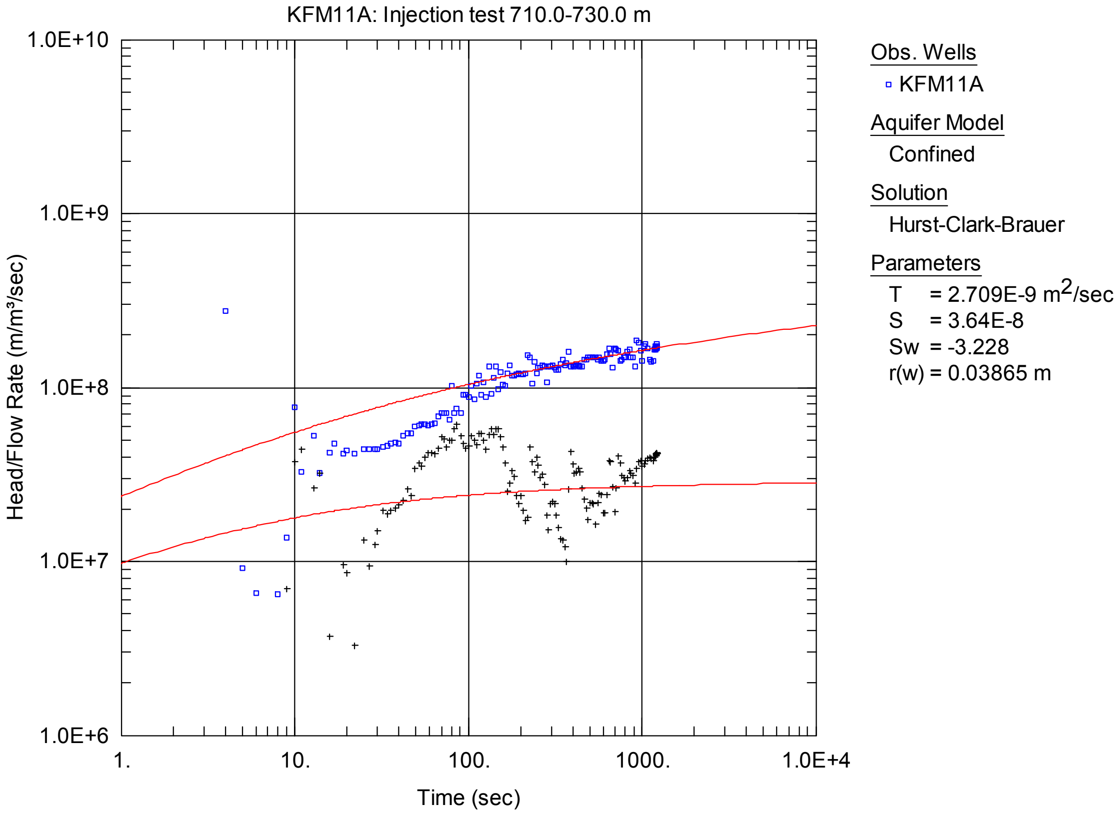


Figure A3-59. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 710.0-730.0 m in KFM11A.*

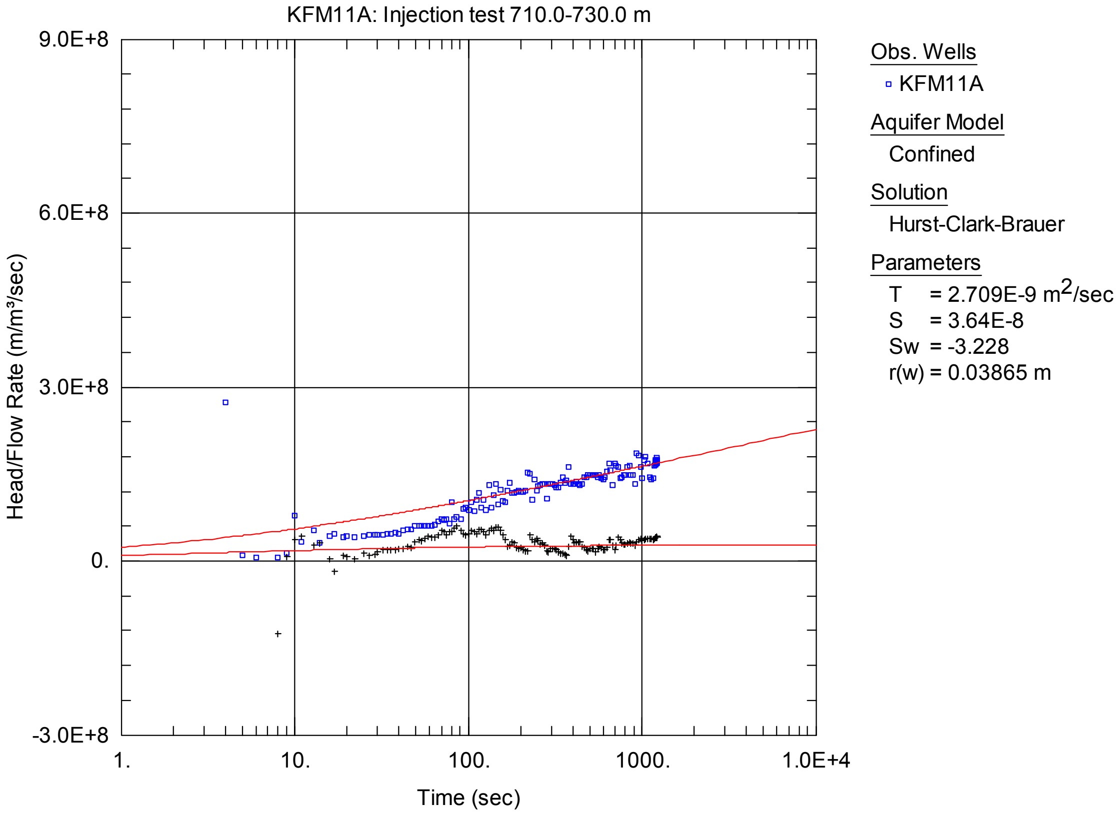


Figure A3-60. *Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 710.0-730.0 m in KFM11A.*

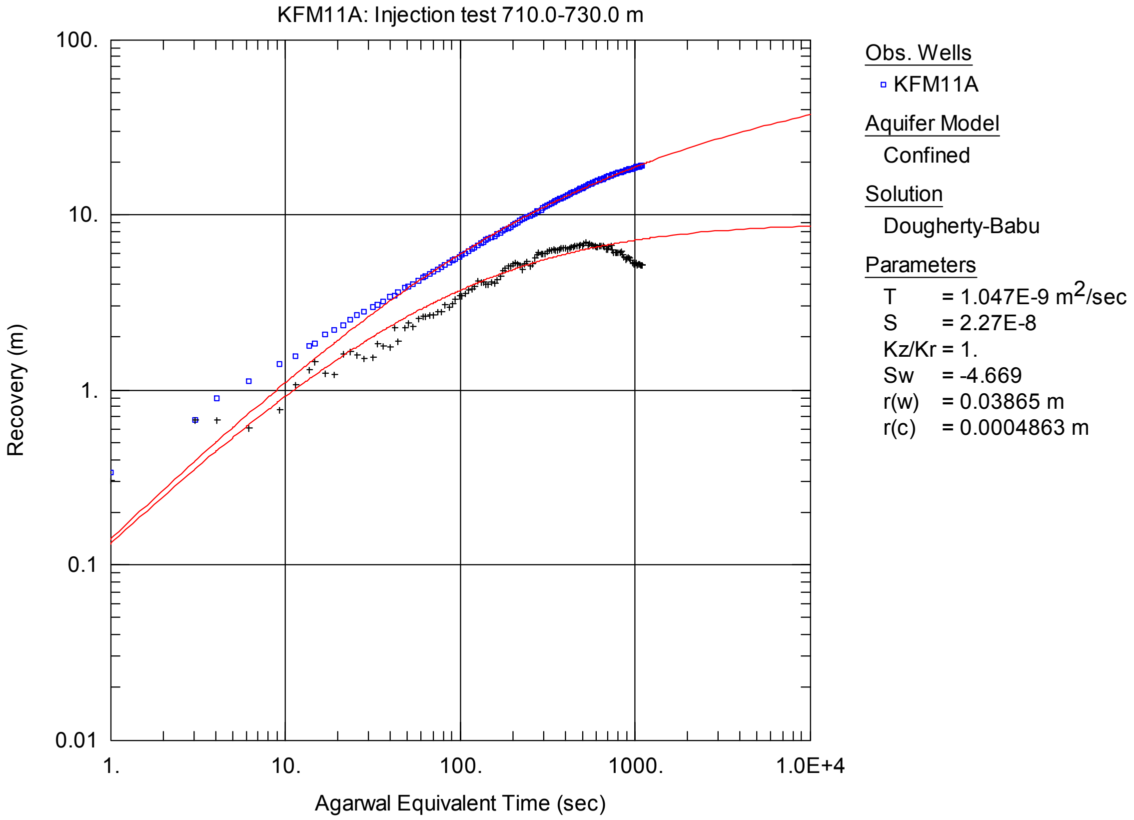


Figure A3-61. *Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 710.0-730.0 m in KFM11A.*

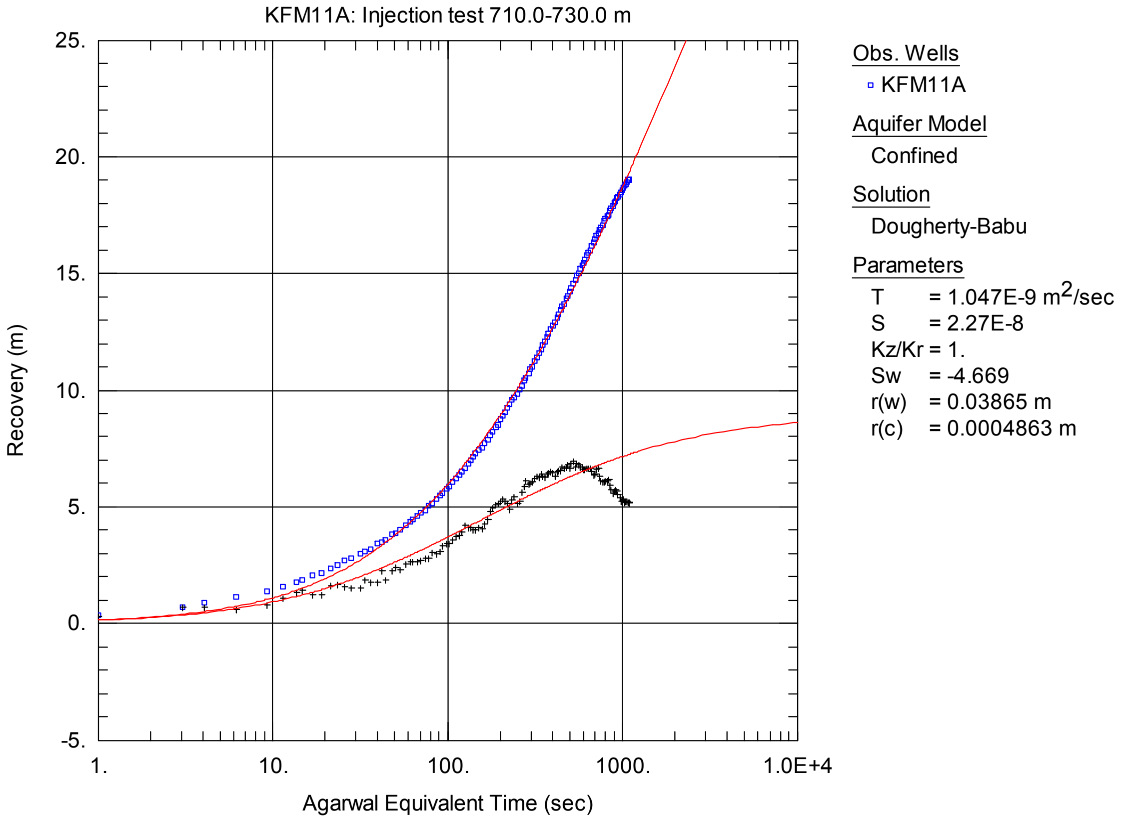


Figure A3-62. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 710.0-730.0 m in KFM11A.*

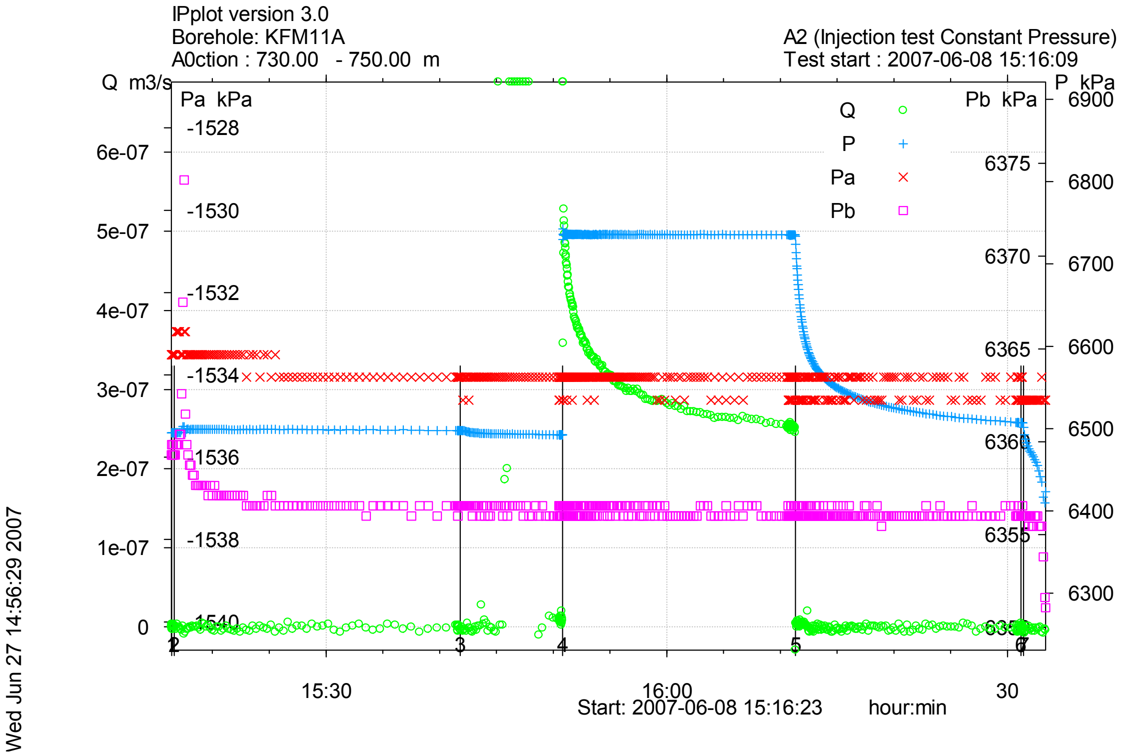


Figure A3-63. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 730.0-750.0 m in borehole KFM11A.*

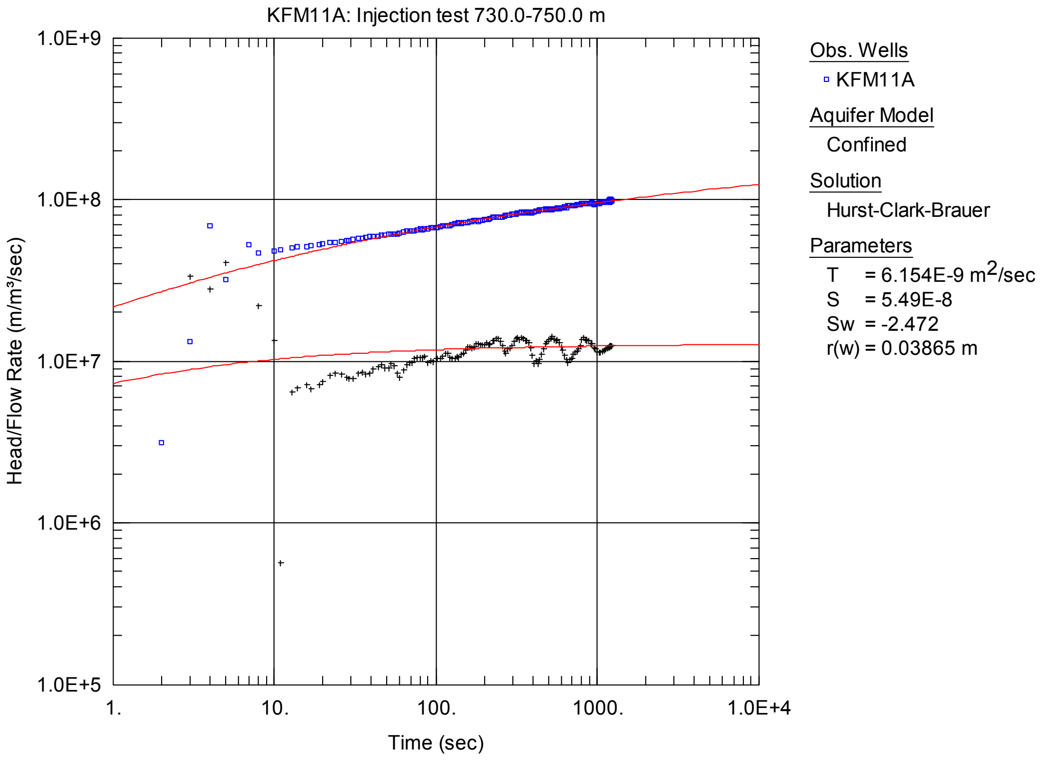


Figure A3-64. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 730.0-750.0 m in KFM11A.*

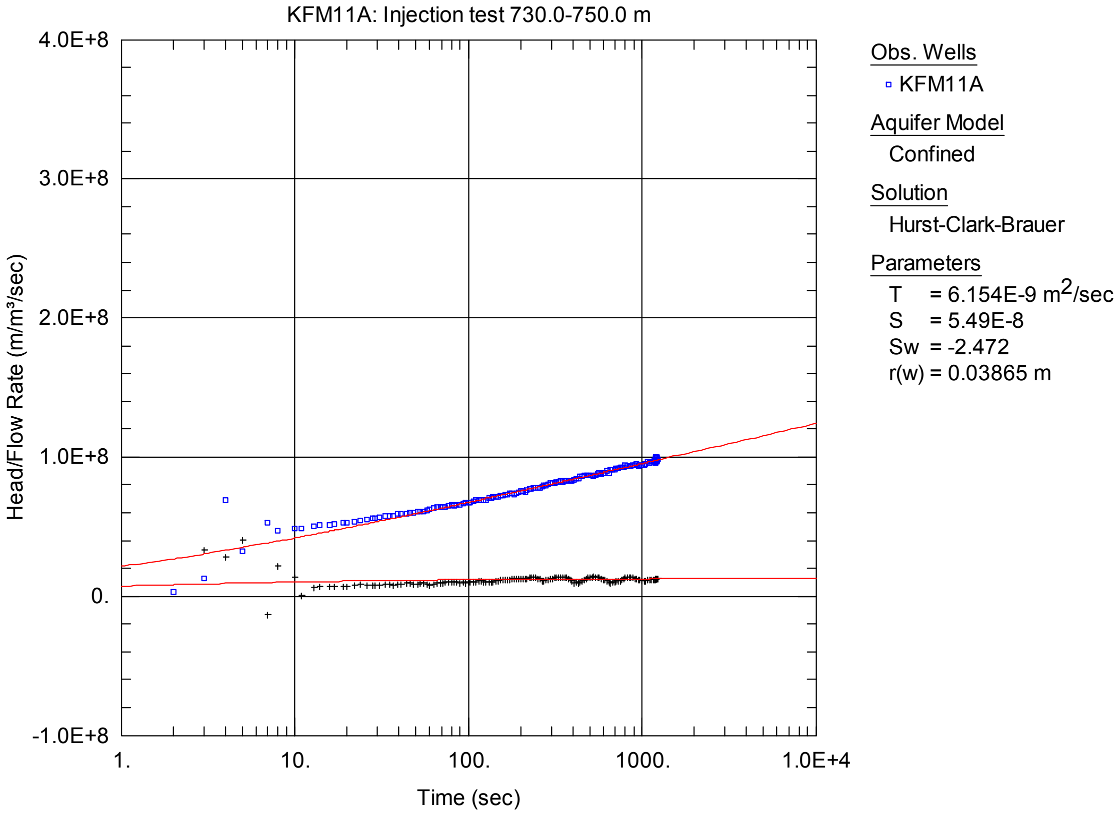


Figure A3-65. *Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 730.0-750.0 m in KFM11A.*

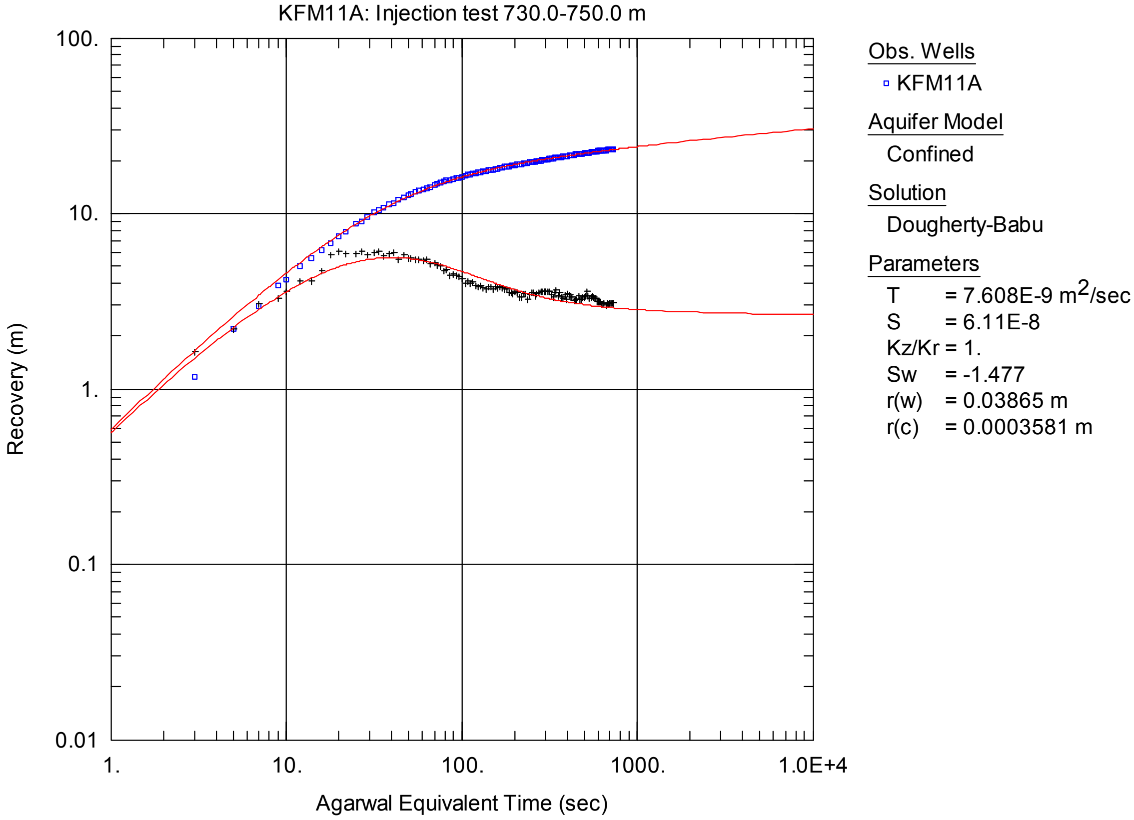


Figure A3-66. *Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 730.0-750.0 m in KFM11A.*

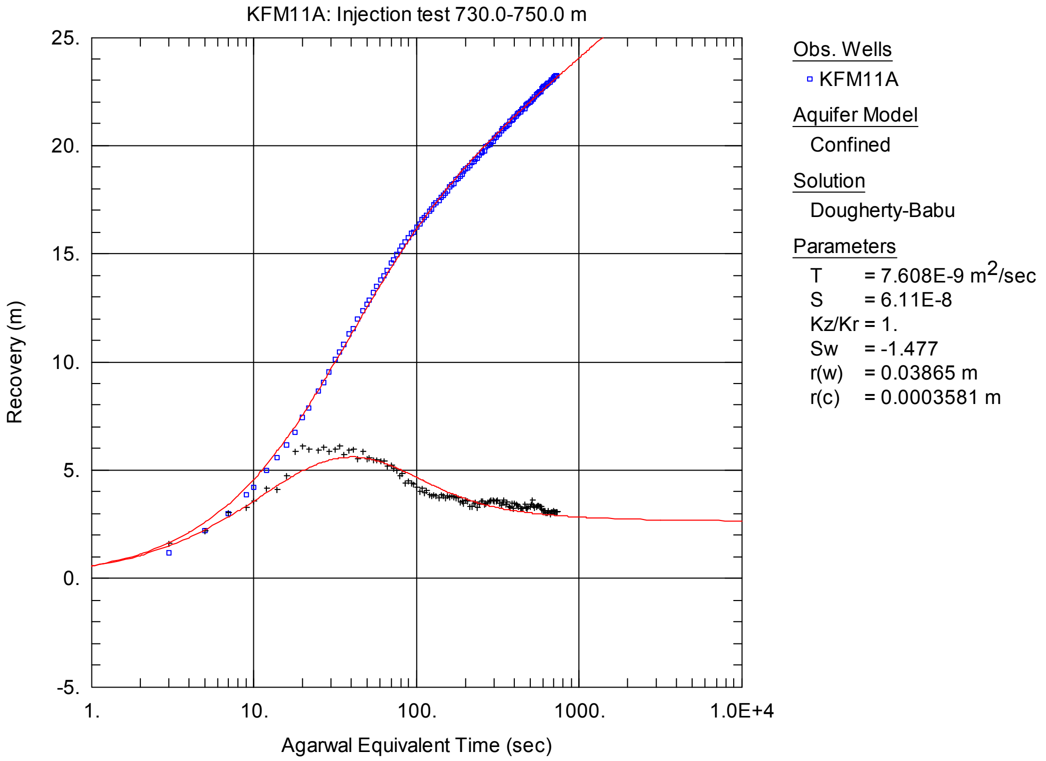


Figure A3-67. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 730.0-750.0 m in KFM11A.*

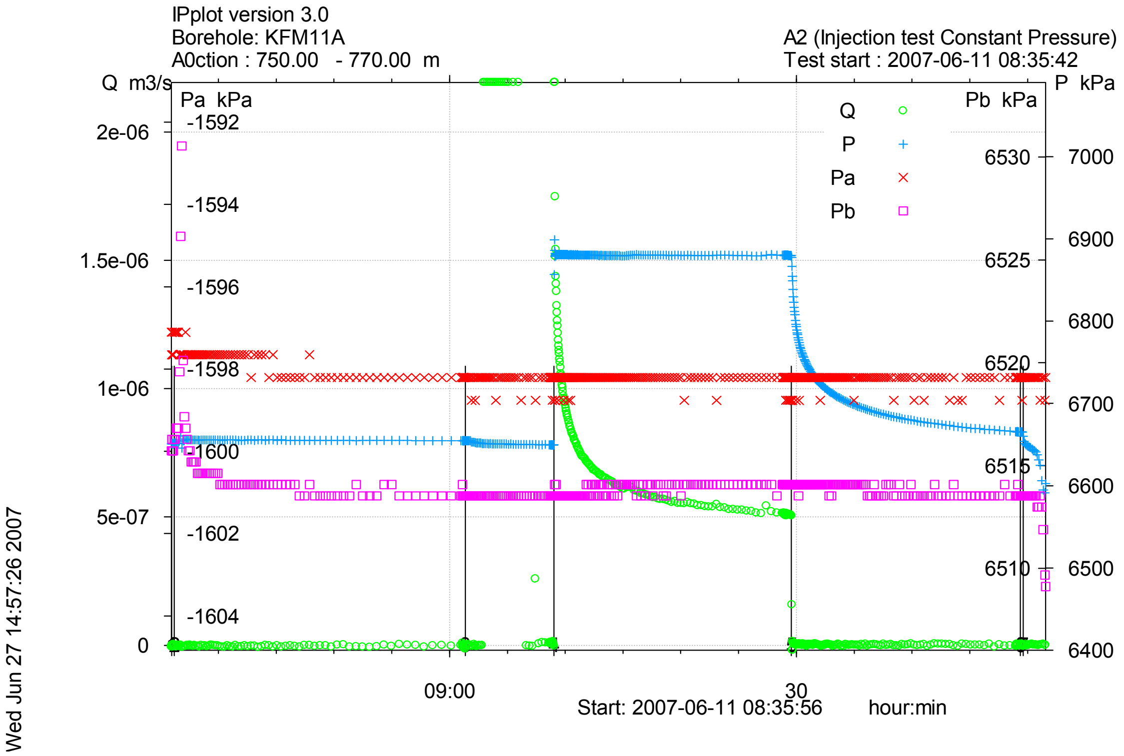


Figure A3-68. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 750.0-770.0 m in borehole KFM11A.*

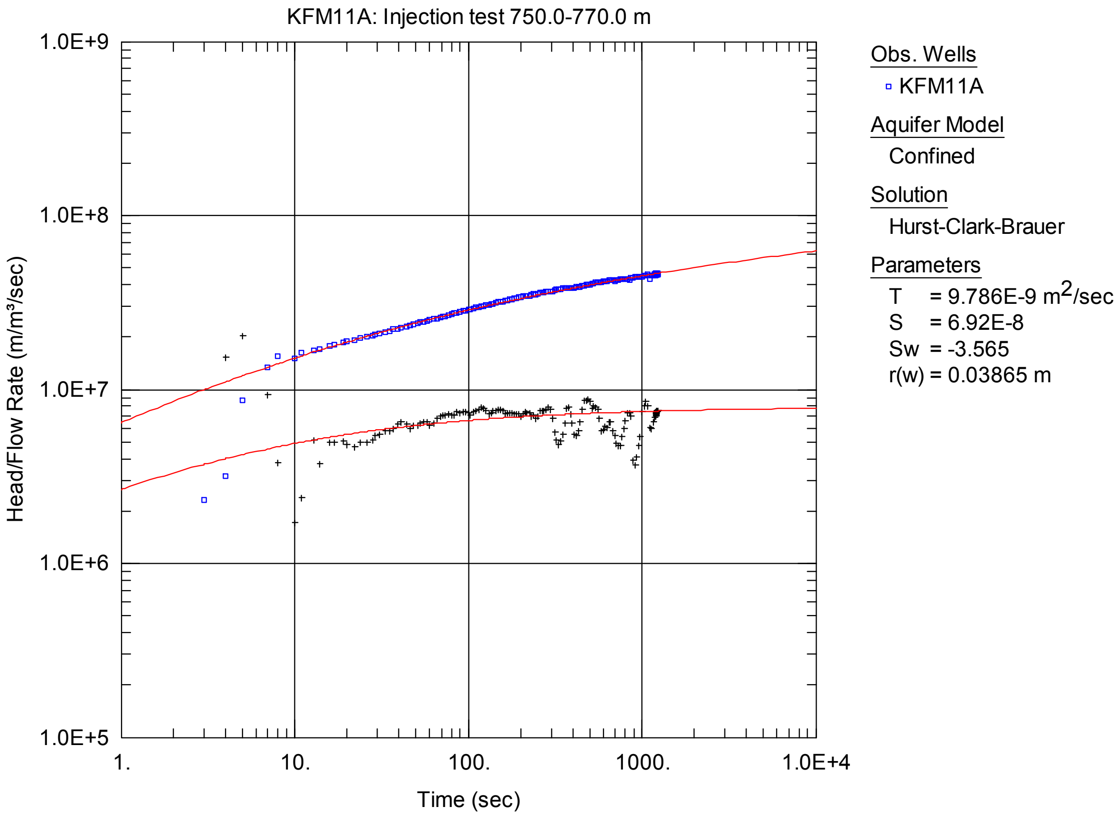


Figure A3-69. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 750.0-770.0 m in KFM11A.*

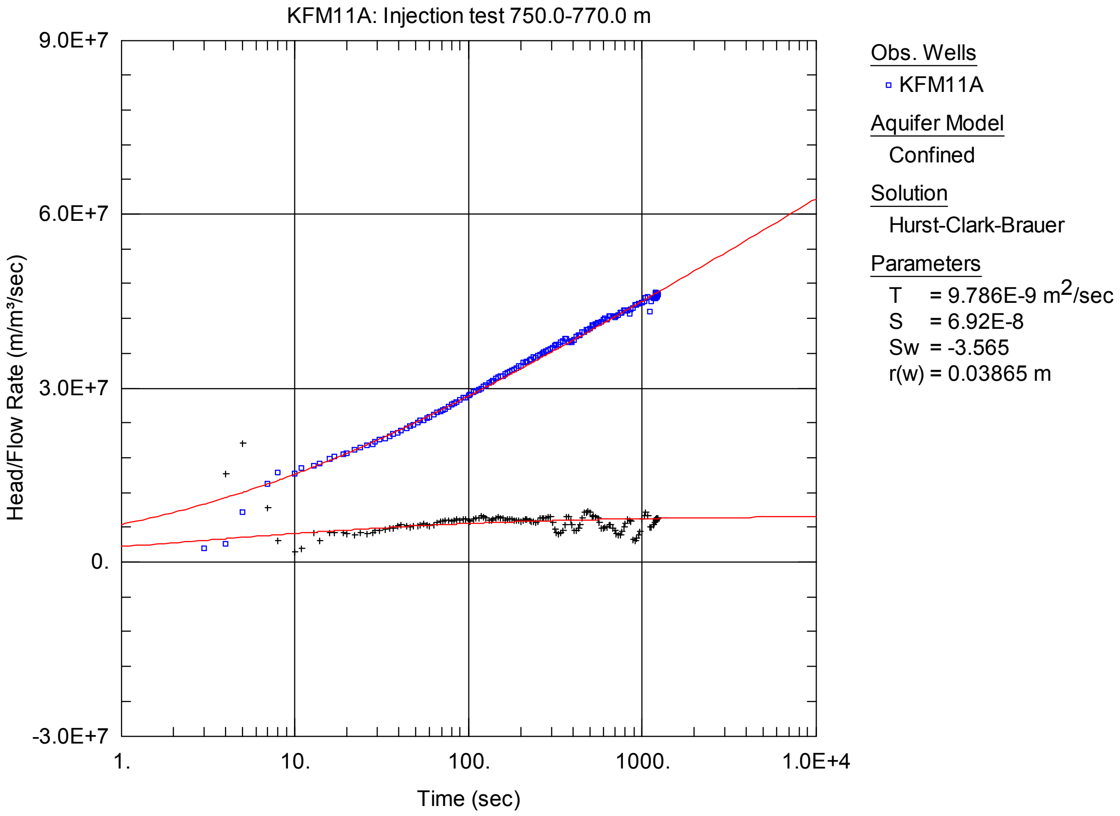


Figure A3-70. *Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 750.0-770.0 m in KFM11A.*

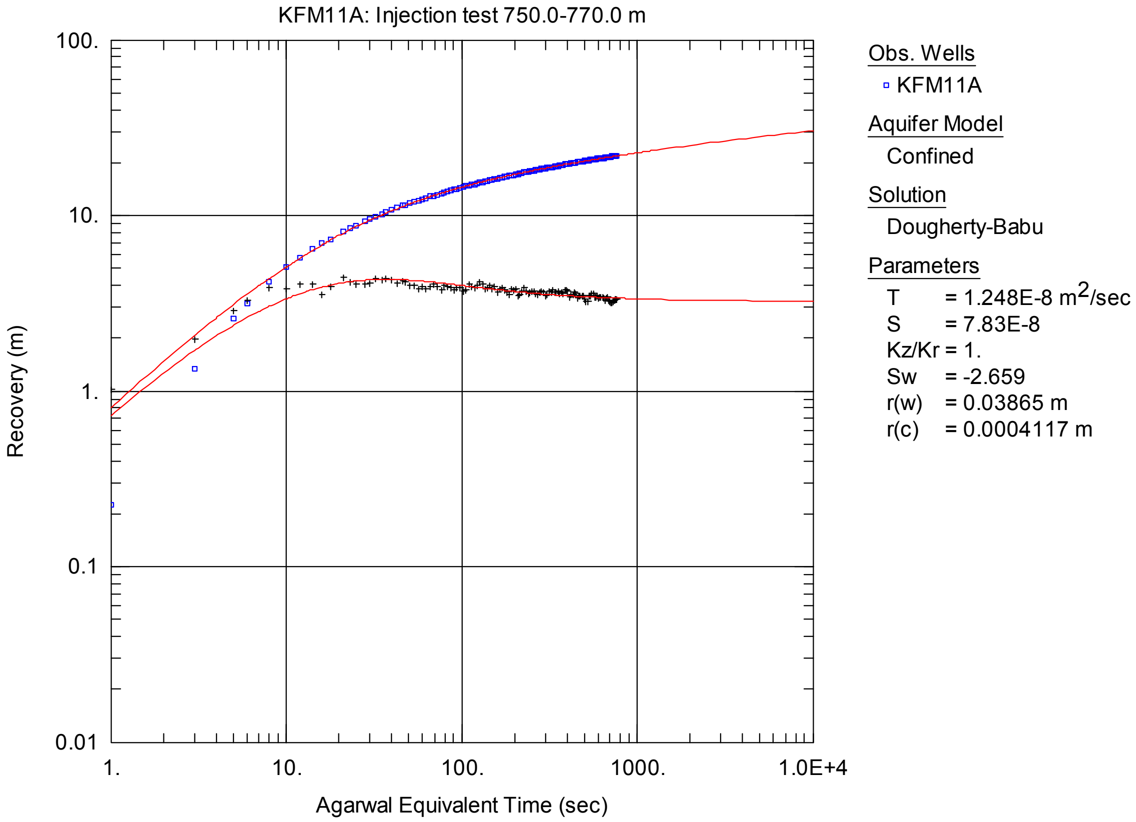


Figure A3-71. *Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 750.0-770.0 m in KFM11A.*

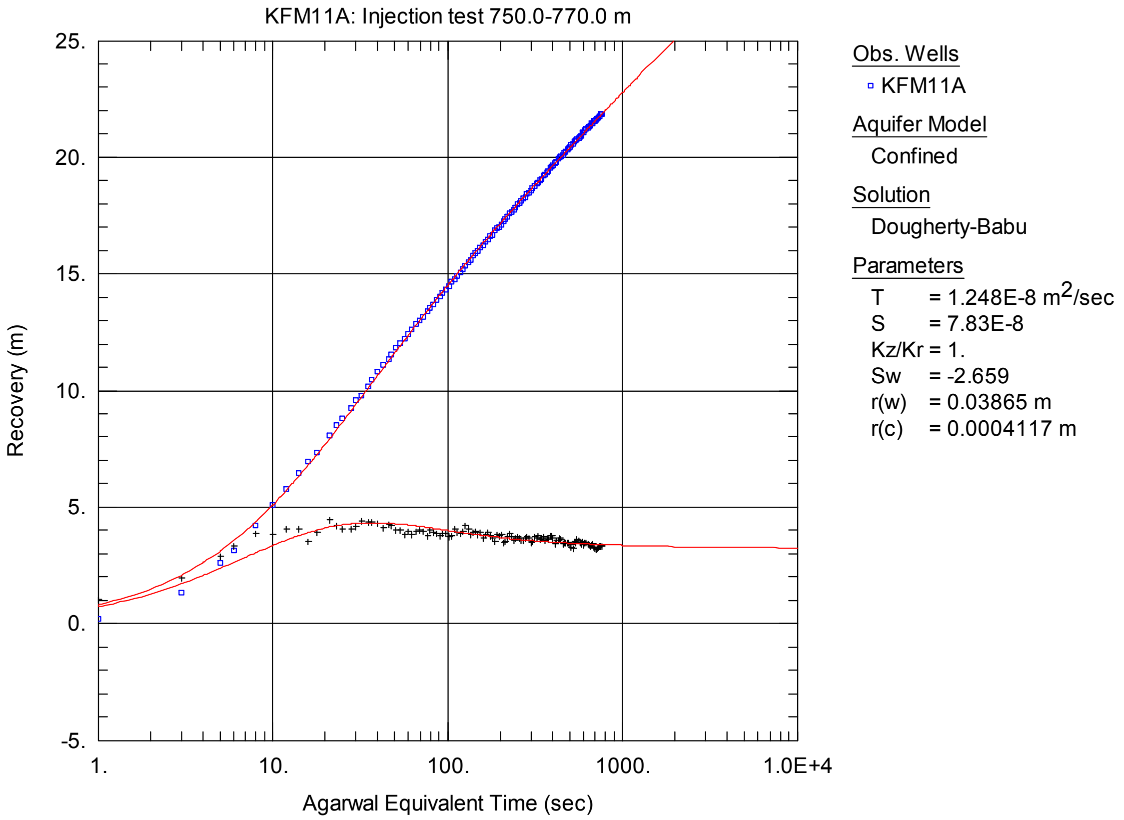


Figure A3-72. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 750.0-770.0 m in KFM11A.*

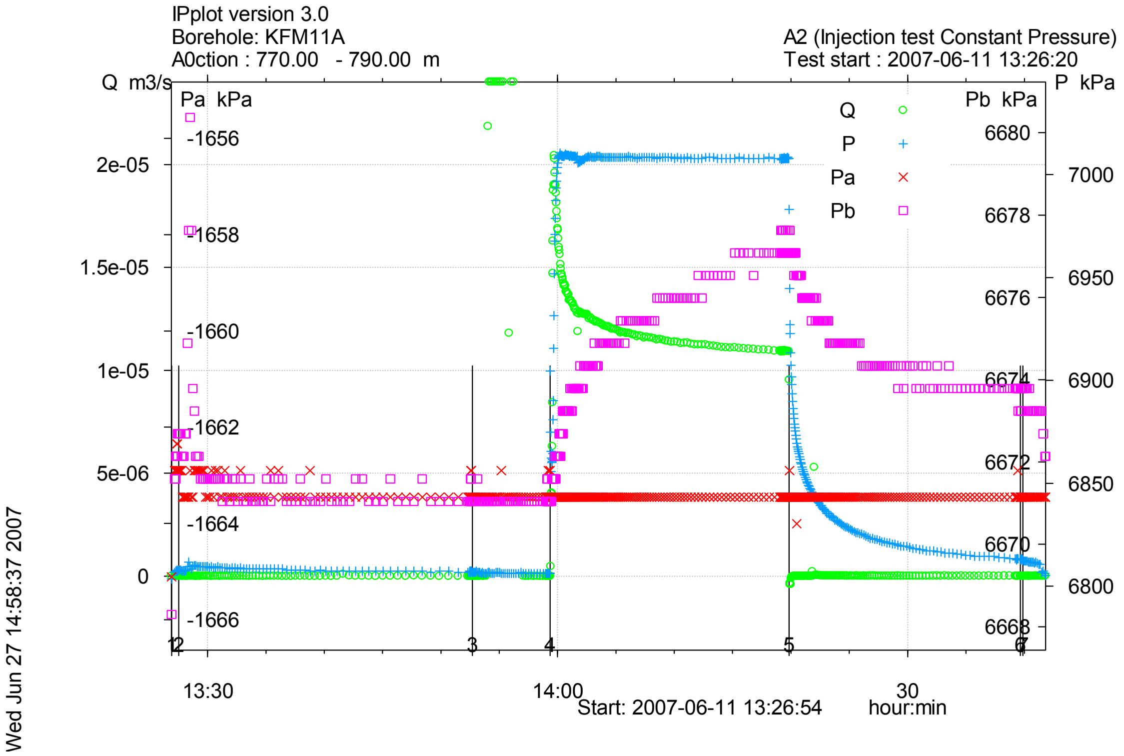


Figure A3-73. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 770.0-790.0 m in borehole KFM11A.*

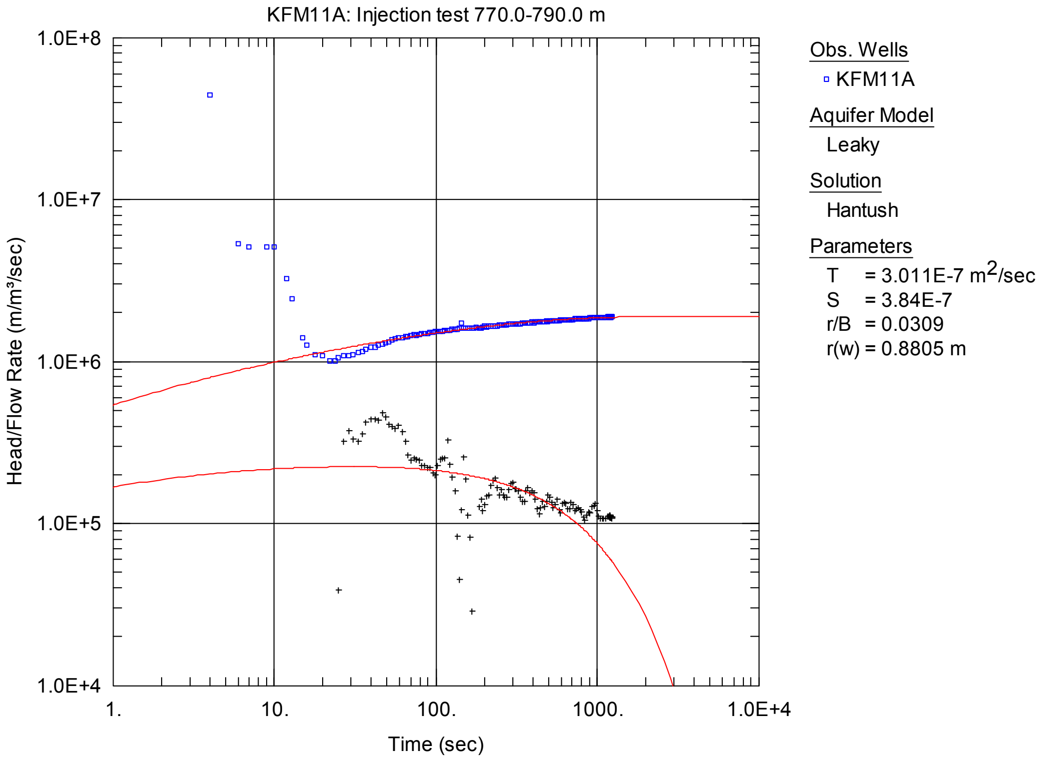


Figure A3-74. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 770.0-790.0 m in KFM11A.*

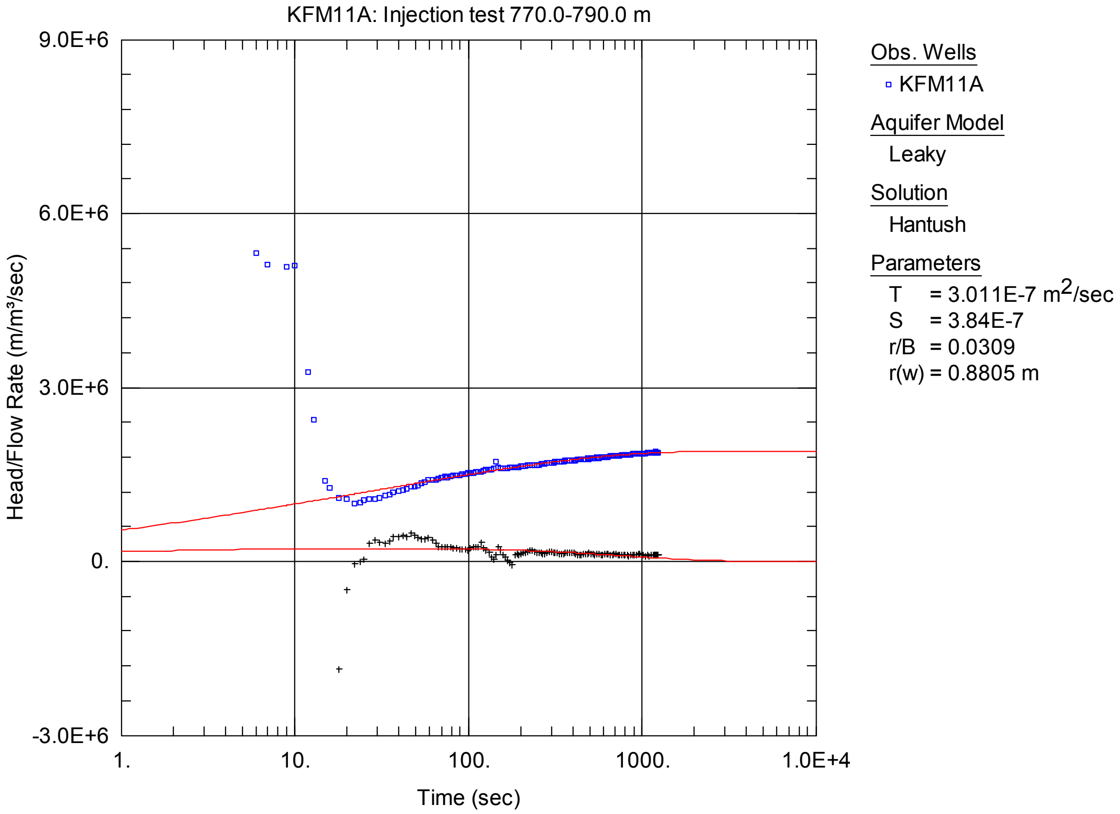


Figure A3-75. Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 770.0-790.0 m in KFM11A.

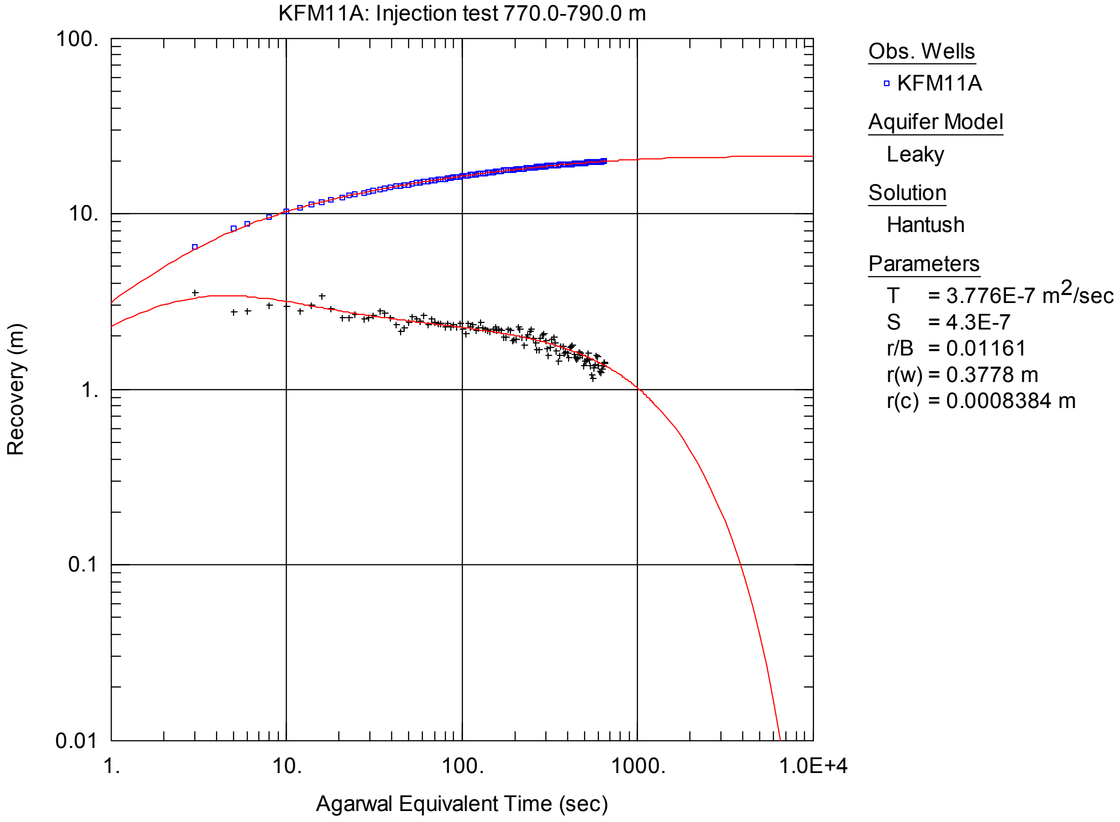


Figure A3-76. Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 770.0-790.0 m in KFM11A.

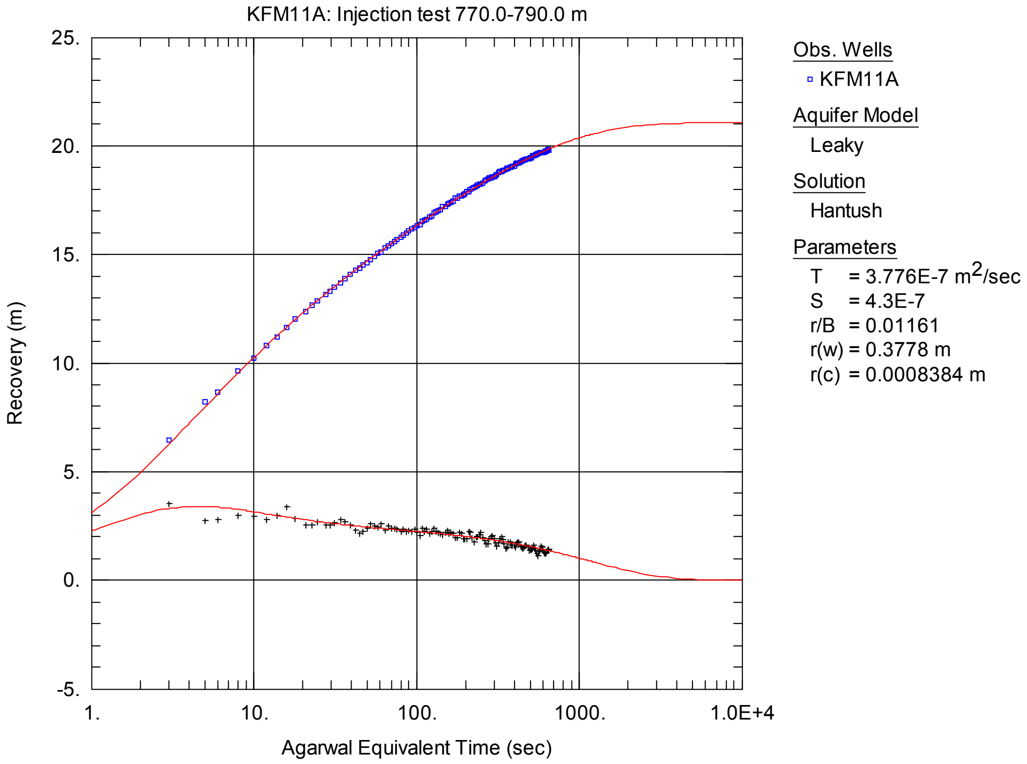


Figure A3-77. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 770.0-790.0 m in KFM11A.*

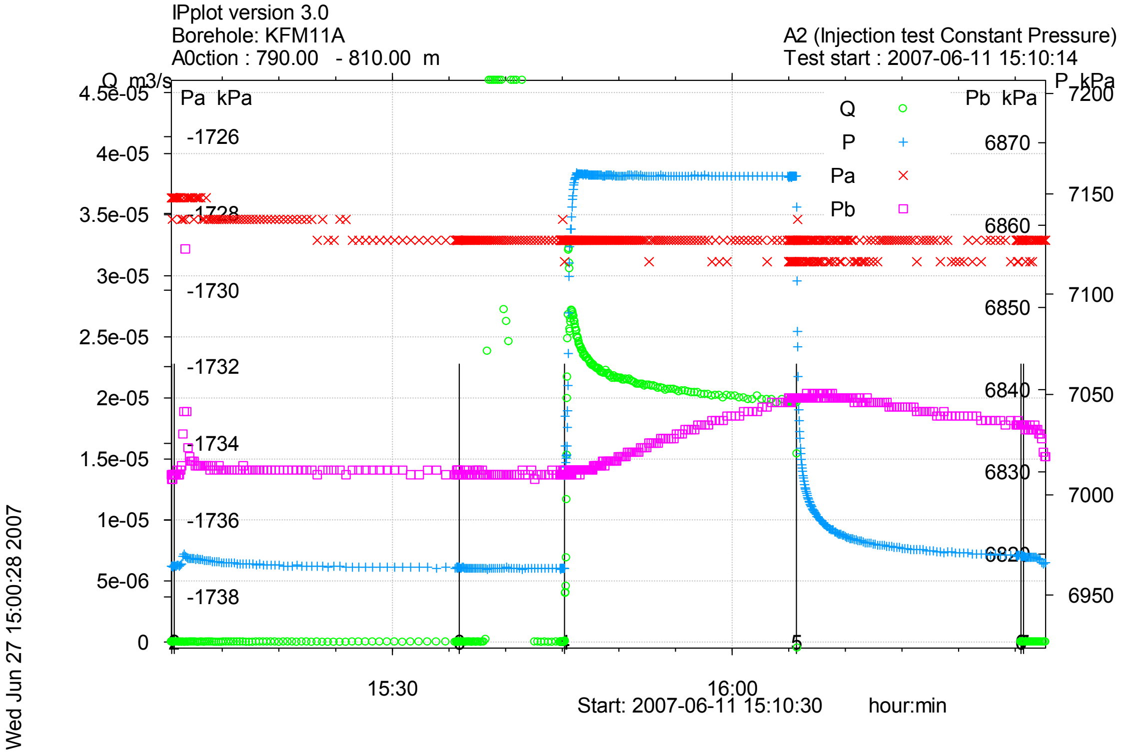


Figure A3-78. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 790.0-810.0 m in borehole KFM11A.*

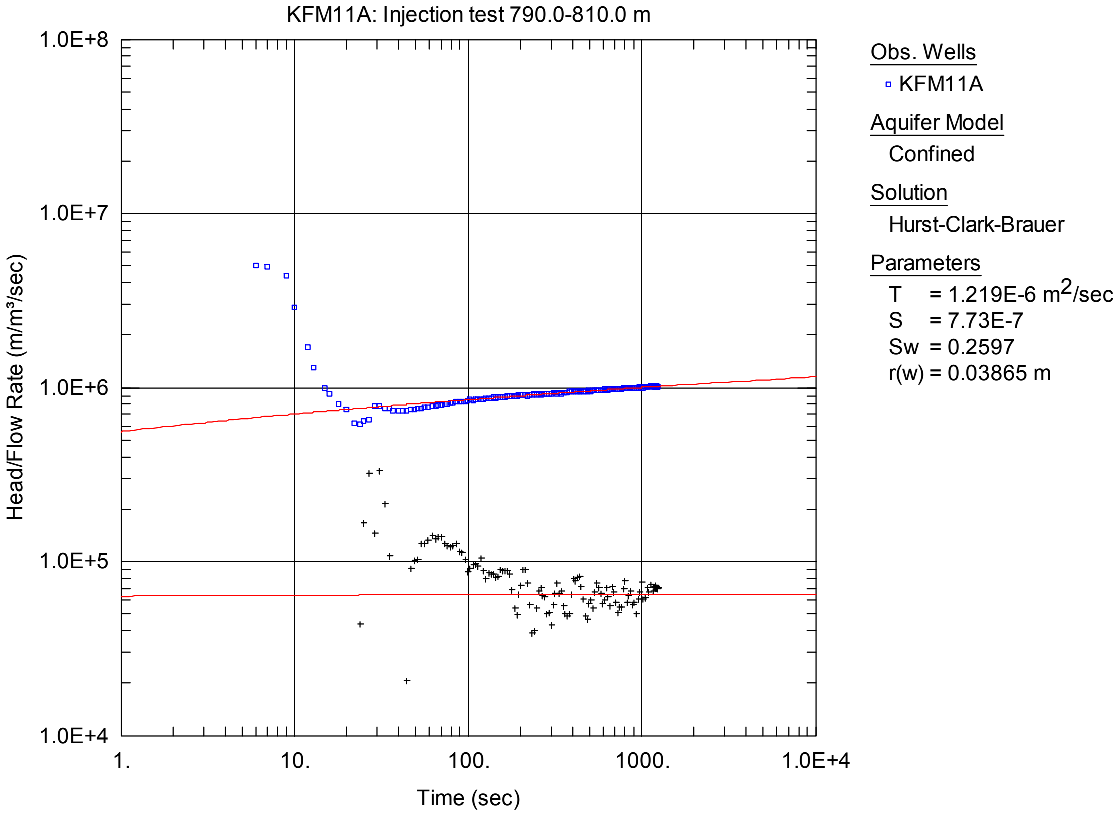


Figure A3-79. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 790.0-810.0 m in KFM11A.*

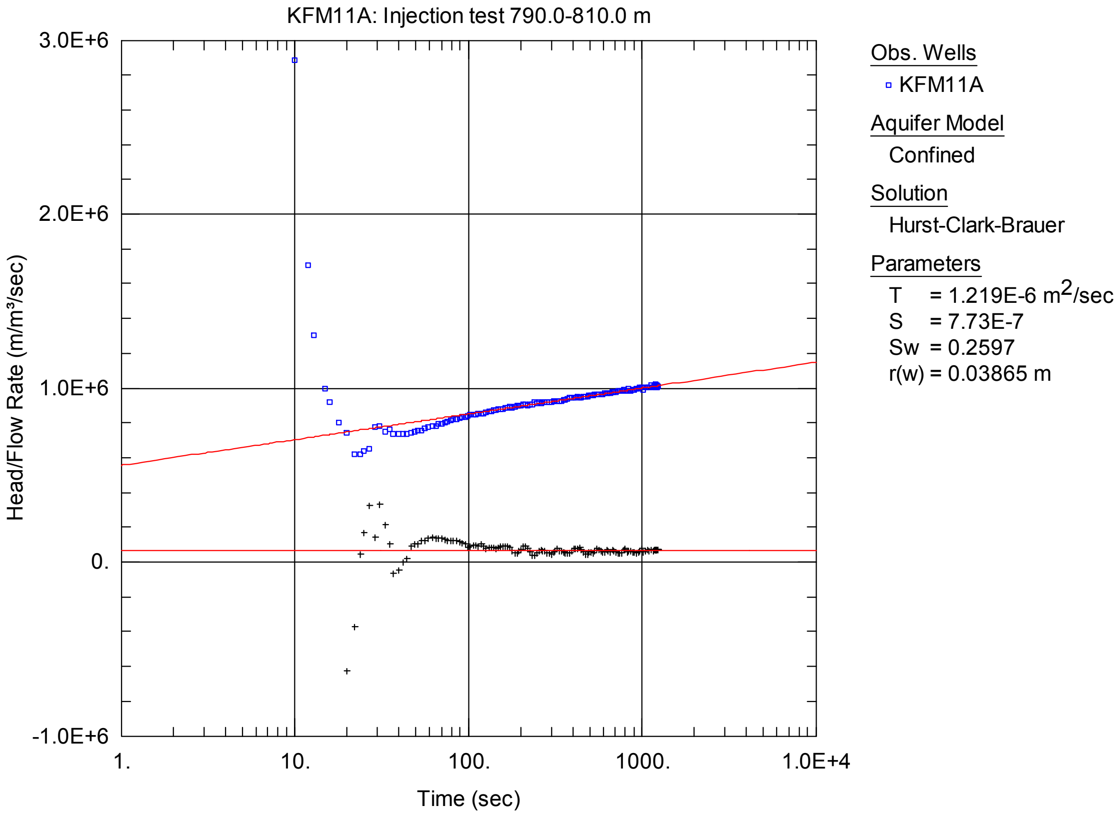


Figure A3-80. *Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 790.0-810.0 m in KFM11A.*

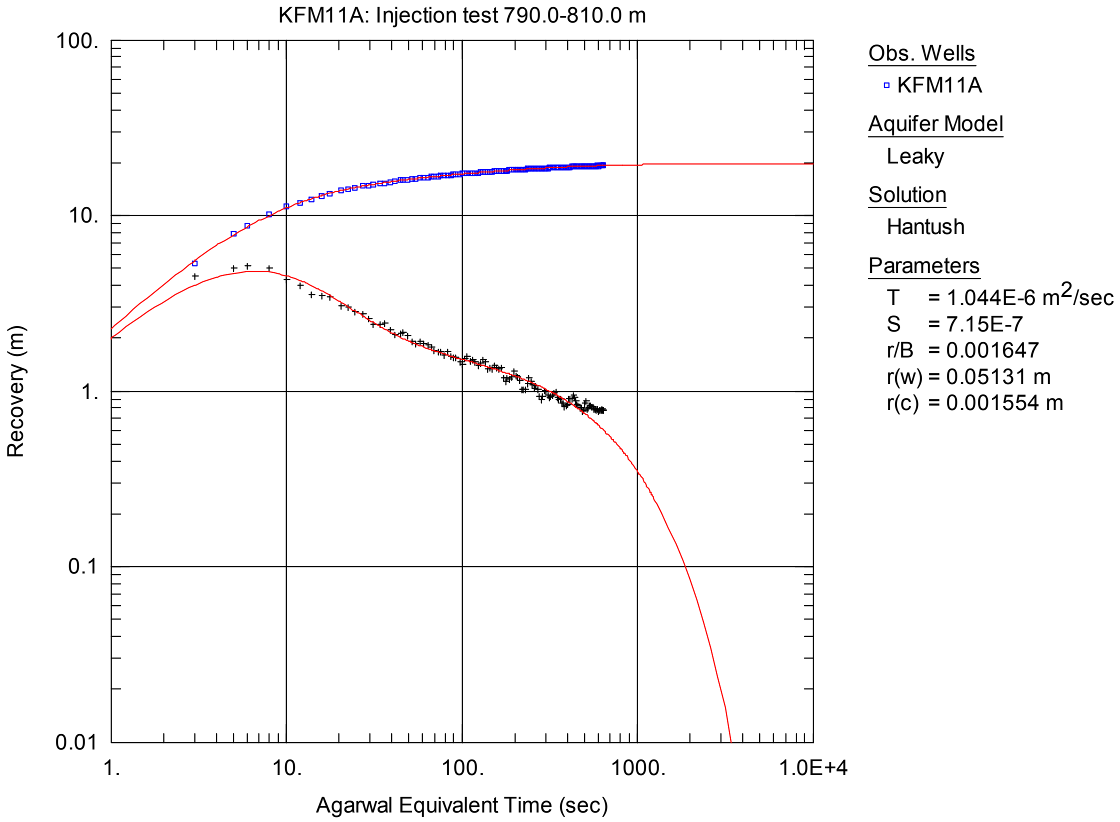


***Figure A3-81.** Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 790.0-810.0 m in KFM11A.*

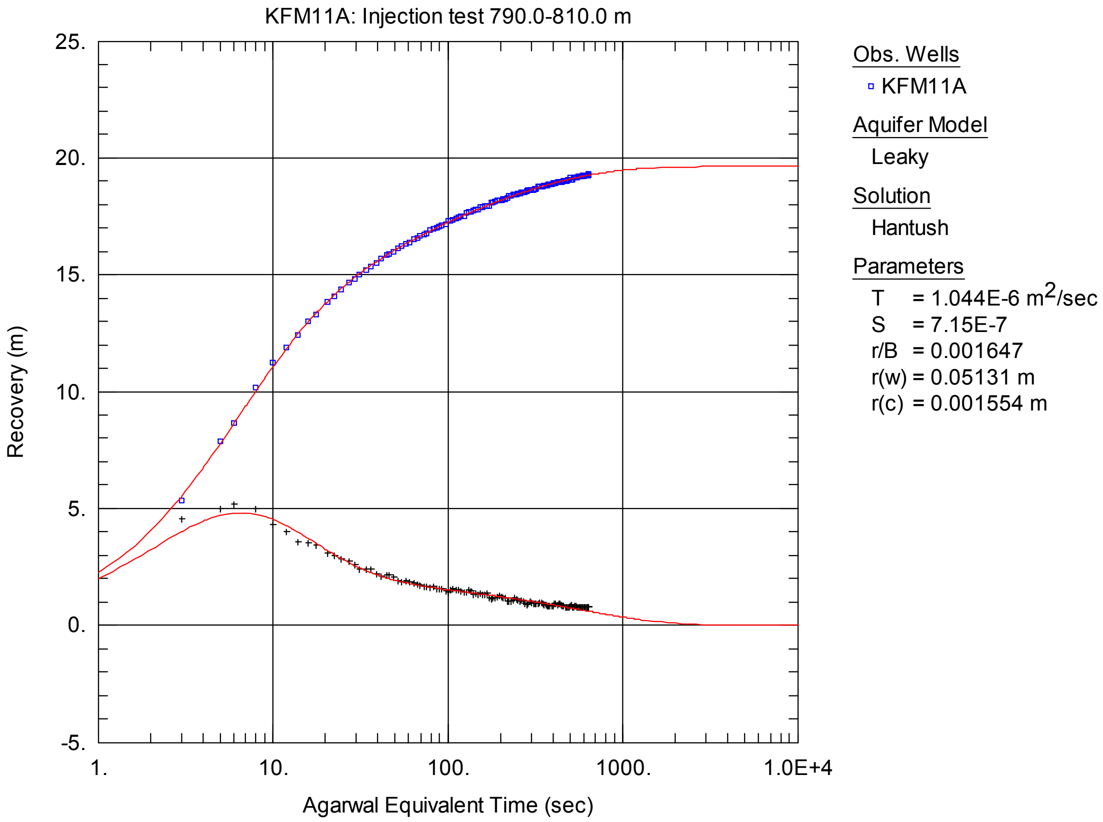


***Figure A3-82.** Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 790.0-810.0 m in KFM11A.*

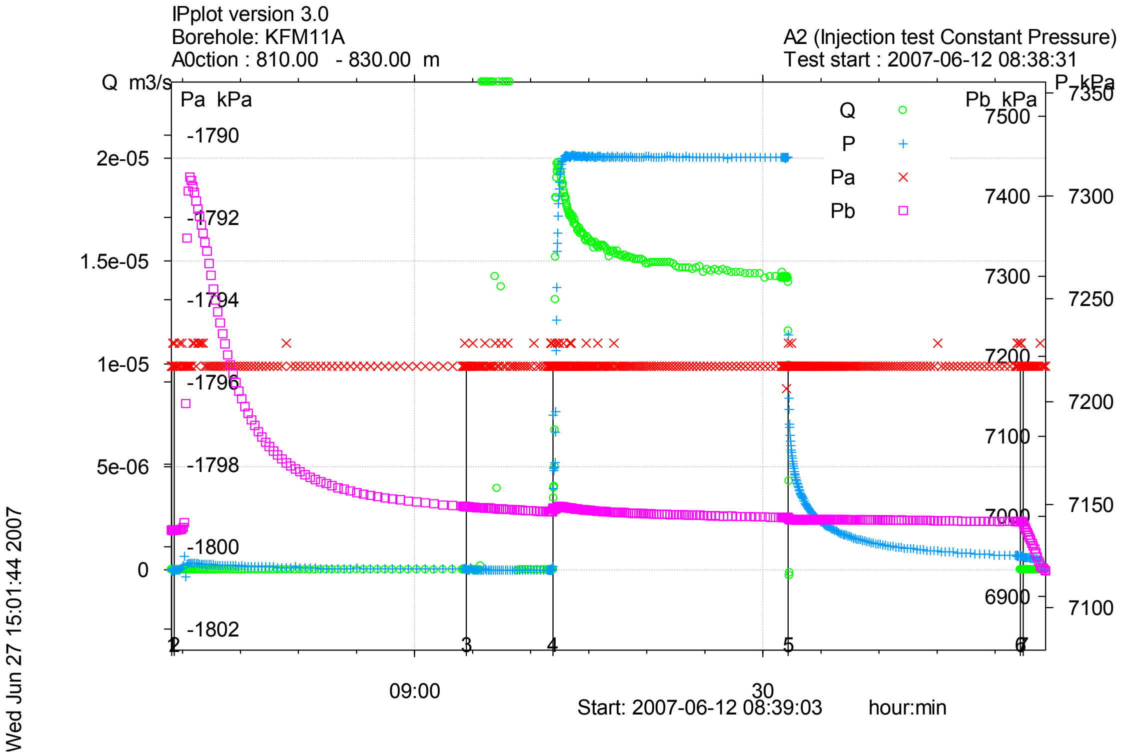


Figure A3-83. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 810.0-830.0 m in borehole KFM11A.*

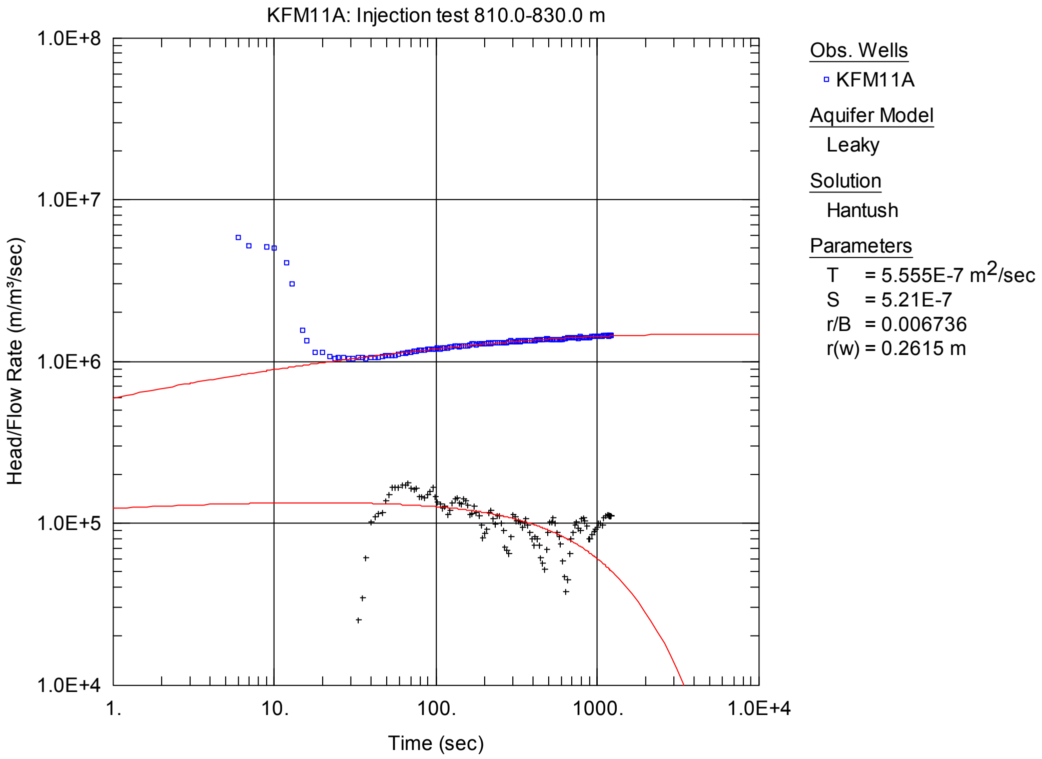


Figure A3-84. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 810.0-830.0 m in KFM11A.*

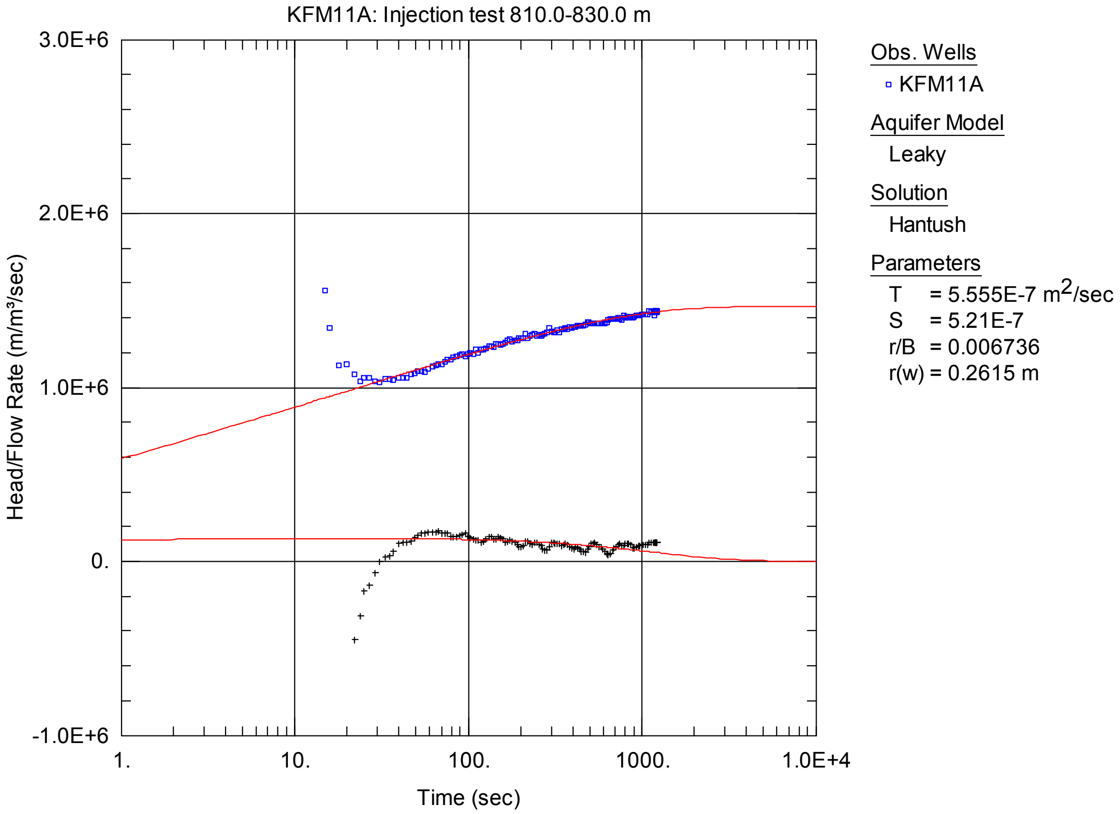


Figure A3-85. *Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 810.0-830.0 m in KFM11A.*

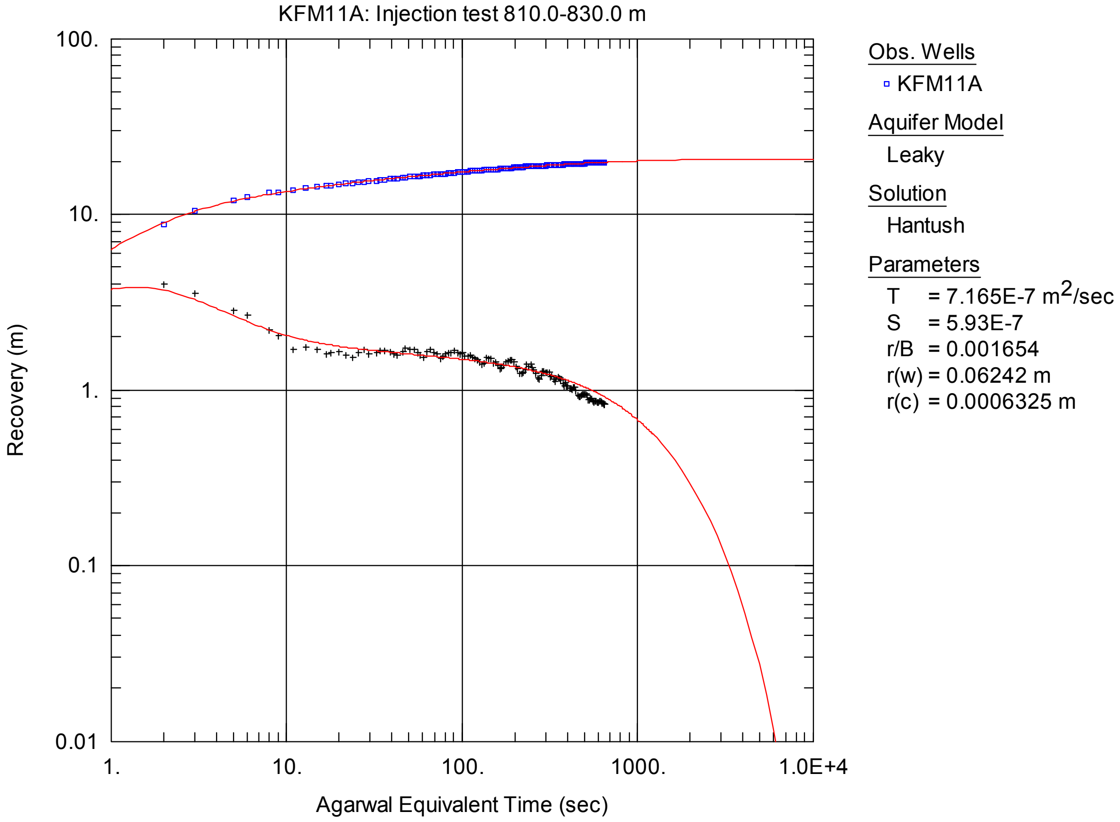


Figure A3-86. *Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 810.0-830.0 m in KFM11A.*

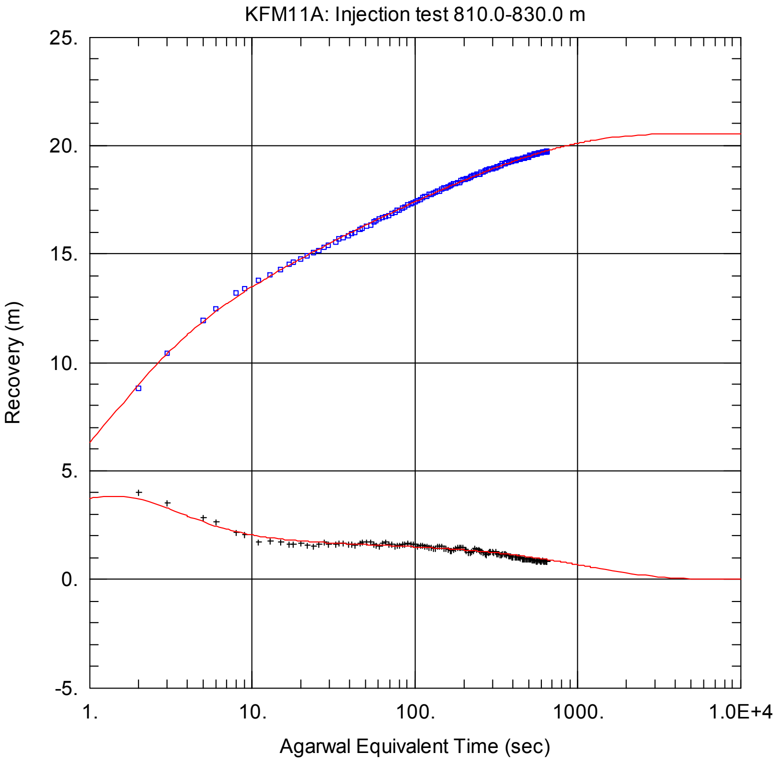


Figure A3-87. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 810.0-830.0 m in KFM11A.*

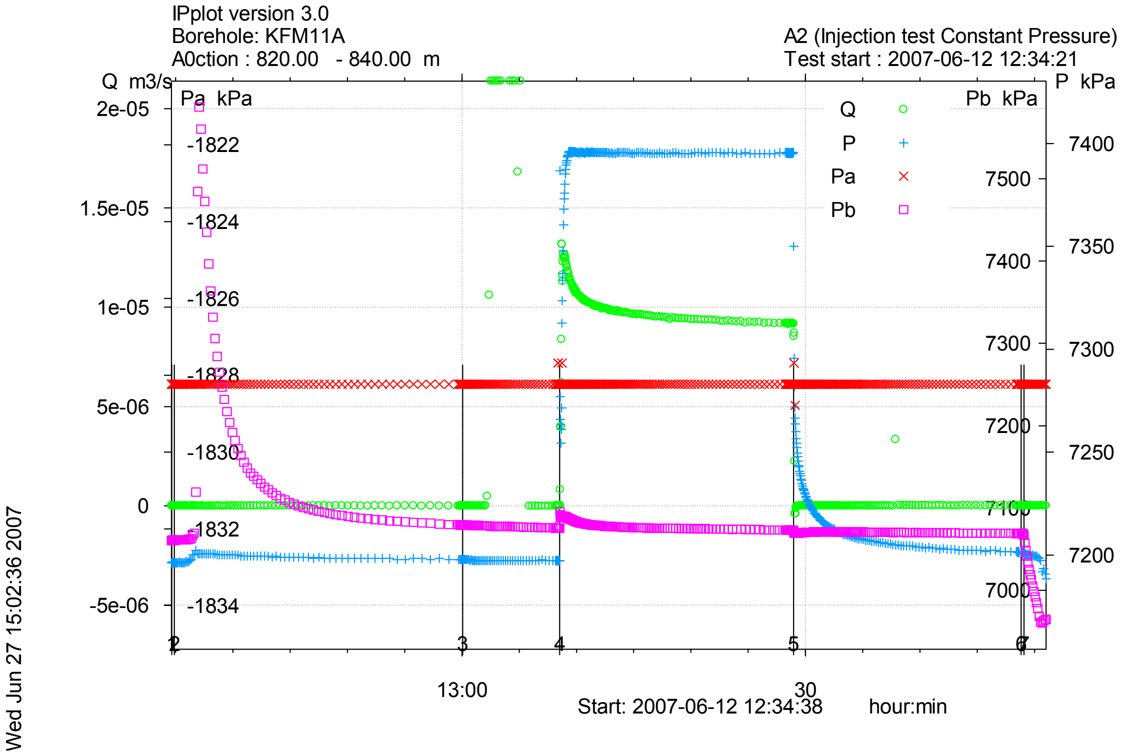


Figure A3-88. *Linear plot of flow rate (Q), pressure (P), pressure above section (Pa) and pressure below section (Pb) versus time from the injection test in section 820.0-840.0 m in borehole KFM11A.*

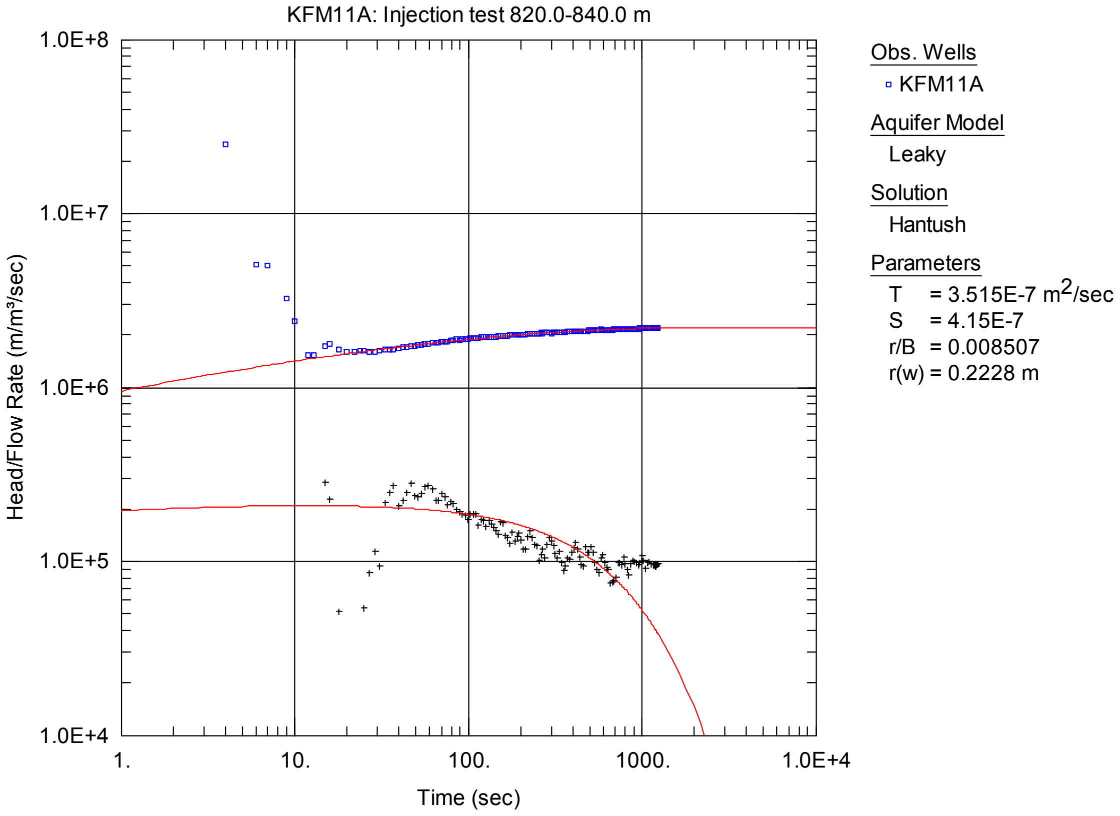


Figure A3-89. *Log-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 820.0-840.0 m in KFM11A.*

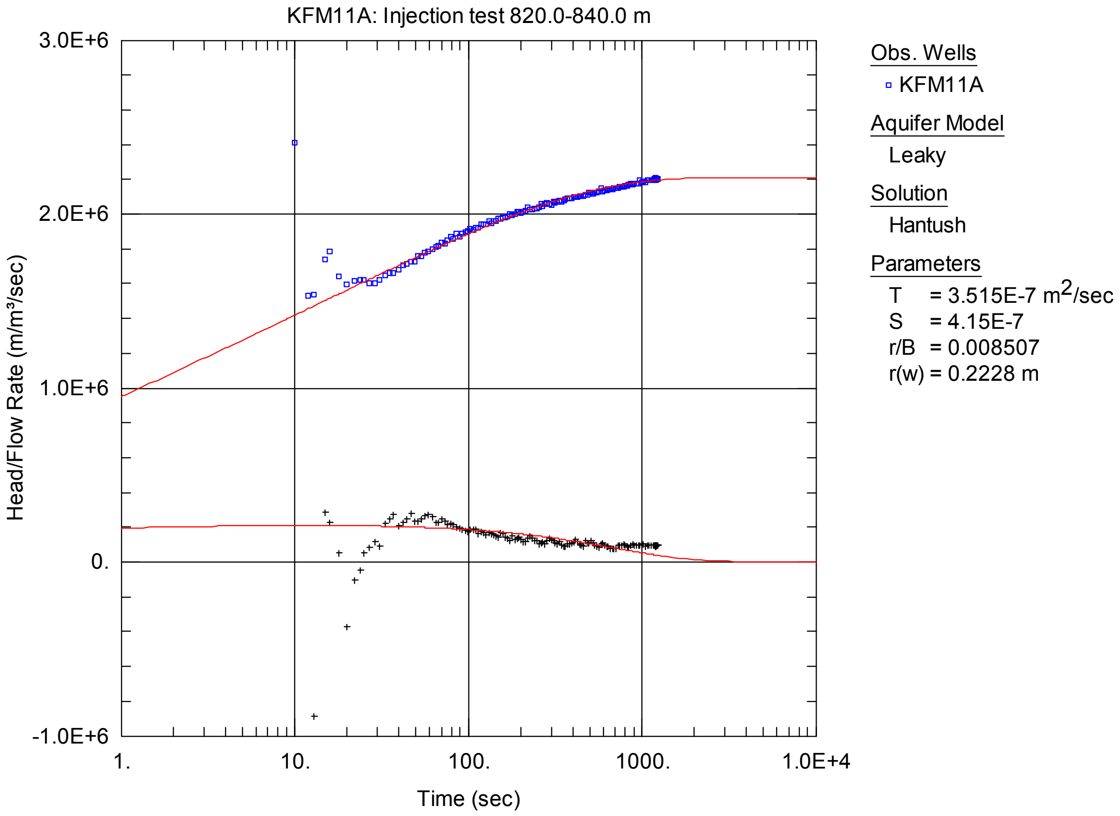


Figure A3-90. *Lin-log plot of head/flow rate (□) and derivative (+) versus time, from the injection test in section 820.0-840.0 m in KFM11A.*

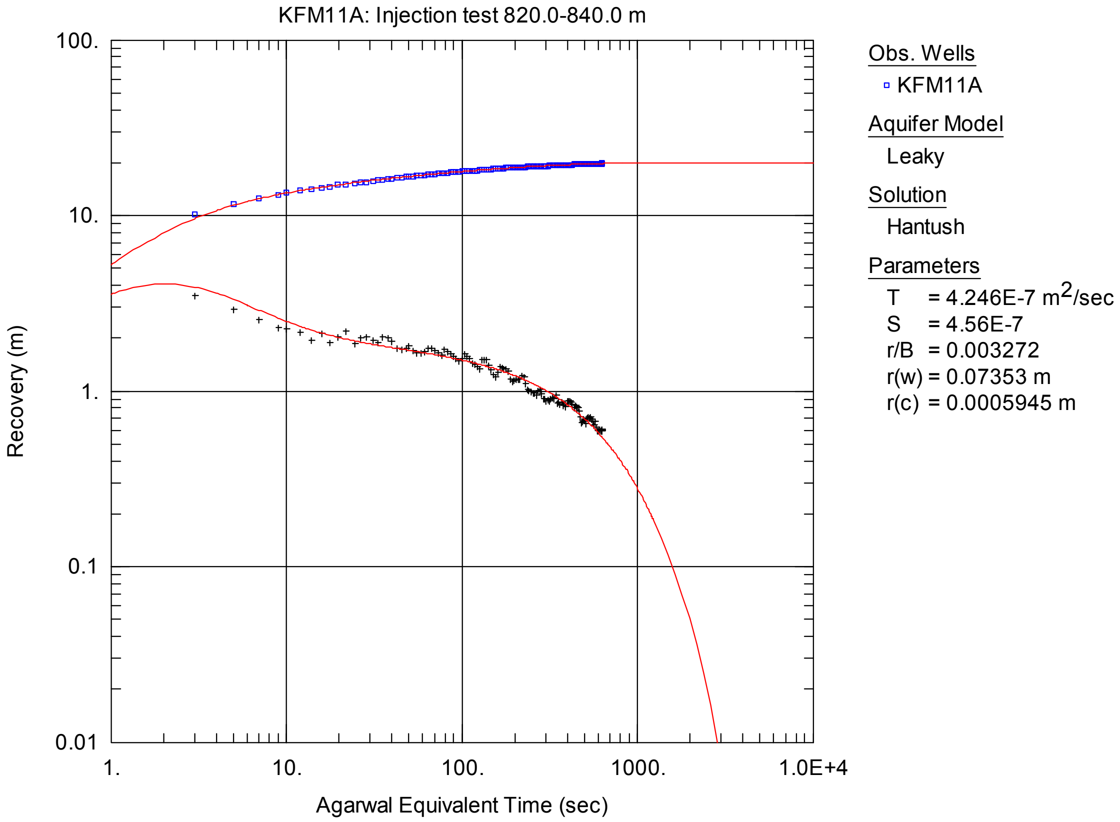


Figure A3-91. *Log-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 820.0-840.0 m in KFM11A.*

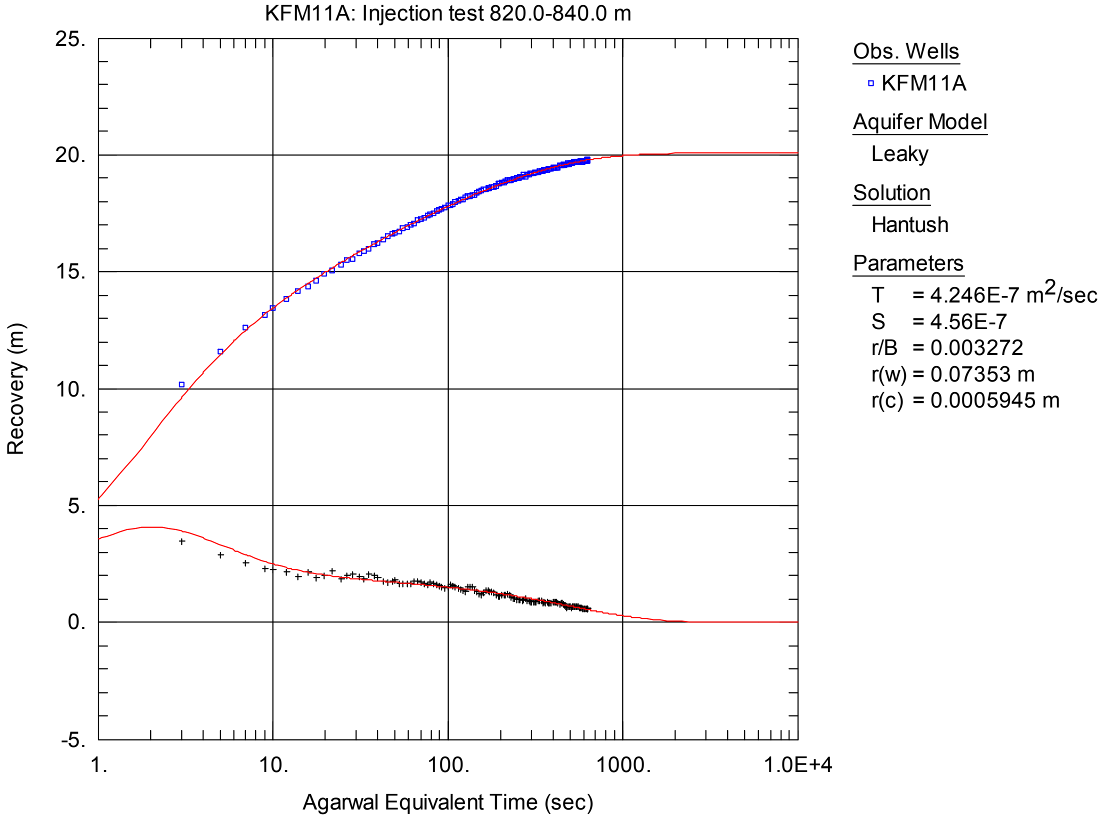
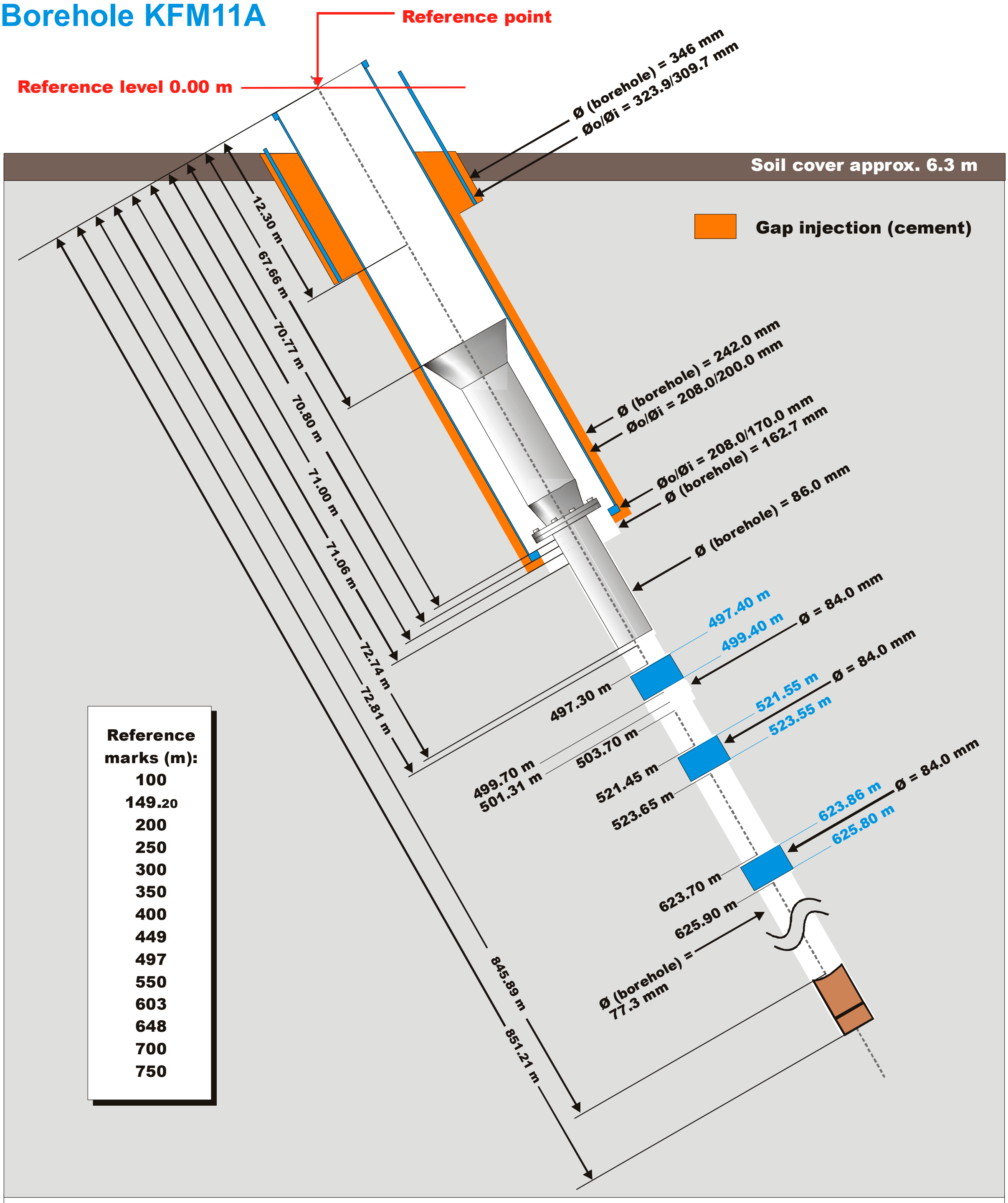


Figure A3-92. *Lin-log plot of recovery (□) and derivative (+) versus equivalent time, from the injection test in section 820.0-840.0 m in KFM11A.*

Appendix 4. Borehole technical data

Technical data

Borehole KFM11A



Drilling reference point

Northing: 6701103.82 (m), RT90 2,5 gon V 0:-15

Easting: 1632366.75 (m), RT90 2,5 gon V 0:-15

Elevation: 2.95 (m), RHB 70

Orientation

Bearing (degrees): 40.25°

Inclination (degrees): -60.86°

Borehole

Length: 851.21 m

Percussion drilling period

Drilling start date: 2006-04-12

Drilling stop date: 2006-05-02

Core drilling period

Drilling start date: 2006-08-29

Drilling stop date: 2006-11-16

2007-04-08

Appendix 5. Sicada tables

Nomenclature plu_s_hole_test_d

Column	Datatype	Unit	Column Description	Alt. Symbol
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-L**
Q_measl__u	FLOAT	m**3/s	Estimated upper measurement limit of flow rate	Q-measl-U
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	

Nomenclature plu_s_hole_test_ed1

Column	Datatype	Unit	Column Description	Alt. Symbol
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)	

Column	Datatype	Unit	Column Description	Alt. Symbol
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.	Q/s
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)	T_M
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)	K_M
formation_width_b	FLOAT	m	b:Aquifer thickness repr. for T(generally b=Lw) ,see descr.	b
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...	T_T
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	Q/s-measl-L
U_measl_q_s	FLOAT	m**2/s	Estimated upper meas. limit for evaluated TT,see description	Q/s-measl-U
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	C
cd	FLOAT		CD: Dimensionless wellbore storage coefficient	
skin	FLOAT		Skin factor;best estimate of flow/recovery period,see descr.	ξ
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	t_1
t2	FLOAT	s	Stop time for evaluated parameter from start of flow period	t_2
dte1	FLOAT	s	Start time for evaluated parameter from start of recovery	dte_1
dte2	FLOAT	s	Stop time for evaluated parameter from start of recovery	dte_2
P_horner	FLOAT	kPa	p*:Horner extrapolated pressure, see table description	

Column	Datatype	Unit	Column Description	Alt. Symbol
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)	

Nomenclature plu_s_hole_test_obs

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)

KFM11A plu_s_hole_test_d. Left (This result table to SICADA includes more columns which are empty, these columns are not presented here.)

idcode	start_date	stop_date	secup	seclow	test_type	Formation_type	start_flow_period	stop_flow_period	flow_rate_end_qp	Value_type_qp	mean_flow_rate_qm
KFM11A	20070604 15:33	20070604 16:55	470.00	490.00	3	1	20070604 16:13:25	20070604 16:33:48	1.33E-06	0	1.47E-06
KFM11A	20070605 09:23	20070605 10:40	488.50	508.50	3	1	20070605 09:57:59	20070605 10:18:22	6.34E-07	0	8.50E-07
KFM11A	20070605 12:52	20070605 14:11	508.50	528.50	3	1	20070605 13:28:45	20070605 13:49:09		-1	
KFM11A	20070605 14:33	20070605 15:25	514.50	534.50	3	1	20070605 15:05:57	20070605 15:15:01		-1	
KFM11A	20070605 15:49	20070605 17:02	530.00	550.00	3	1	20070605 16:20:26	20070605 16:40:56	4.10E-08	0	9.13E-08
KFM11A	20070607 08:48	20070607 10:13	550.00	570.00	3	1	20070607 09:31:17	20070607 09:51:20	7.72E-09	0	2.84E-08
KFM11A	20070607 10:35	20070607 11:53	570.00	590.00	3	1	20070607 11:11:23	20070607 11:31:50	1.37E-07	0	1.60E-07
KFM11A	20070607 13:05	20070607 14:21	590.00	610.00	3	1	20070607 13:39:12	20070607 13:59:36	8.91E-07	0	9.02E-07
KFM11A	20070607 14:49	20070607 16:05	610.00	630.00	3	1	20070607 15:23:15	20070607 15:43:41	1.93E-07	0	2.00E-07
KFM11A	20070607 16:36	20070607 17:50	630.00	650.00	3	1	20070607 17:08:05	20070607 17:28:30	6.54E-08	0	7.76E-08
KFM11A	20070608 08:20	20070608 09:37	650.00	670.00	3	1	20070608 08:54:51	20070608 09:15:16	6.26E-08	0	8.81E-08
KFM11A	20070608 10:41	20070608 12:47	670.00	690.00	3	1	20070608 12:04:36	20070608 12:25:39	6.13E-06	0	7.68E-06
KFM11A1)	20070709 14:09	20070710 09:17	690.00	710.00	3	1	20070709 14:38:42	20070709 17:09:31	1.38E-05	0	1.51E-05
KFM11A	20070608 13:32	20070608 14:51	710.00	730.00	3	1	20070608 14:09:00	20070608 14:29:23	1.18E-07	0	1.68E-07
KFM11A	20070608 15:16	20070608 16:33	730.00	750.00	3	1	20070608 15:50:49	20070608 16:11:18	2.52E-07	0	2.98E-07
KFM11A	20070611 08:35	20070611 09:51	750.00	770.00	3	1	20070611 09:09:01	20070611 09:29:33	5.08E-07	0	6.29E-07
KFM11A	20070611 13:26	20070611 14:41	770.00	790.00	3	1	20070611 13:59:21	20070611 14:19:49	1.09E-05	0	1.17E-05
KFM11A	20070611 15:10	20070611 16:27	790.00	810.00	3	1	20070611 15:45:12	20070611 16:05:40	1.97E-05	0	2.09E-05
KFM11A	20070612 08:38	20070612 09:54	810.00	830.00	3	1	20070612 09:11:53	20070612 09:32:10	1.42E-05	0	1.50E-05
KFM11A	20070612 12:34	20070612 13:51	820.00	840.00	3	1	20070612 13:08:32	20070612 13:28:57	9.17E-06	0	9.59E-06
KFM11A2)	20070605 11:08	20070605 11:54	508.50	528.50	3	1	20070605 11:43:44	20070605 12:04:07	1.95E-08	0	1.10E-07
KFM11A2)	20070608 09:58	20070608 10:38	670.00	690.00	3	1	20070608 10:31:05	20070608 10:51:26	1.17E-05	0	1.32E-05

1) The test in section 690.0-710 m was conducted as a pumping test.
2) Incomplete test, interrupted and re-performed later.

KFM11A plu_s_hole_test_d. Right (This result table to SICADA includes more columns which are empty, these columns are not presented here.)

idcode	secup	seclow	q_measl__l	q_measl__u	tot_volume_vp	dur_flow_phase_tp	dur_rec_phase_tf	initial_press_pi	press_at_flow_end_pp	final_press_pf	fluid_temp_tew
KFM11A	470.00	490.00	1.7E-08	1.0E-03	1.79E-03	1223	1200	4401.01	4635.12	4407.74	0.00
KFM11A	488.50	508.50	1.7E-08	1.0E-03	1.04E-03	1223	1200	4553.29	4762.00	4591.73	0.00
KFM11A	508.50	528.50	4.9E-09	1.0E-03		1224	1221	4724.51	4965.33	4896.00	0.00
KFM11A	514.50	534.50	4.9E-09	1.0E-03		544	475	4775.04	5009.15	4998.17	0.00
KFM11A	530.00	550.00	4.9E-09	1.0E-03	1.12E-04	1230	1194	4897.24	5095.77	5002.01	0.00
KFM11A	550.00	570.00	4.9E-09	1.0E-03	3.41E-05	1203	1221	5062.01	5307.93	5208.52	0.00
KFM11A	570.00	590.00	1.7E-08	1.0E-03	1.96E-04	1227	1198	5185.31	5461.17	5190.94	0.00
KFM11A	590.00	610.00	1.7E-08	1.0E-03	1.11E-03	1224	1199	5331.55	5622.65	5332.09	0.00
KFM11A	610.00	630.00	1.7E-08	1.0E-03	2.46E-04	1226	1197	5502.36	5699.54	5502.91	0.00
KFM11A	630.00	650.00	1.7E-08	1.0E-03	9.52E-05	1225	1197	5709.15	5949.43	5711.06	0.00
KFM11A	650.00	670.00	1.7E-08	1.0E-03	1.08E-04	1225	1197	5862.11	6100.74	5940.65	0.00
KFM11A	670.00	690.00	1.7E-08	1.0E-03	9.70E-03	1263	1197	6016.99	6216.60	6048.84	0.00
KFM11A1)	690.00	710.00	1.7E-08	1.0E-03	1.37E-01	9049	57745	6161.99	5969.15	6150.45	0.00
KFM11A	710.00	730.00	1.7E-08	1.0E-03	2.06E-04	1223	1197	6331.01	6531.58	6344.87	0.00
KFM11A	730.00	750.00	1.7E-08	1.0E-03	3.67E-04	1229	1191	6492.35	6735.39	6507.46	0.00
KFM11A	750.00	770.00	1.7E-08	1.0E-03	7.75E-04	1232	1189	6649.70	6879.83	6665.63	0.00
KFM11A	770.00	790.00	1.7E-08	1.0E-03	1.44E-02	1228	1189	6806.23	7007.94	6813.37	0.00
KFM11A	790.00	810.00	1.7E-08	1.0E-03	2.57E-02	1228	1189	6963.32	7158.84	6969.91	0.00
KFM11A	810.00	830.00	1.7E-08	1.0E-03	1.83E-02	1217	1200	7118.20	7318.67	7124.79	0.00
KFM11A	820.00	840.00	1.7E-08	1.0E-03	1.18E-02	1225	1193	7197.29	7395.43	7201.13	0.00
KFM11A2)	508.50	528.50	1.7E-08	1.0E-03	5.39E-05	1223	44	4724.24	5140.69	5132.73	0.00
KFM11A2)	670.00	690.00	1.7E-08	1.0E-03	1.74E-03	1221	174	6010.81	6258.66	6049.39	0.00

1) The test in section 690.0-710 m was conducted as a pumping test.

2) Incomplete test, interrupted and re-performed later.

KFM11A plu_s_hole_test_ed1. Left (This result table to SICADA includes more columns which are empty, these columns are not presented here.)

idcode	start_date	stop_date	secup	seclow	test_type	formation_type	spec_capacity_q_s	value_type_q_s	transmissivity_moye	value_type_tm	bc_tm	hydr_cond_moye	formation_width_b
KFM11A	20070604 15:33	20070604 16:55	470.00	490.00	3	1	5.55E-08	0	5.80E-08	0	0	2.90E-09	20.00
KFM11A	20070605 09:23	20070605 10:40	488.50	508.50	3	1	2.98E-08	0	3.11E-08	0	0	1.55E-09	20.00
KFM11A	20070605 12:52	20070605 14:11	508.50	528.50	3	1	2.44E-10	-1	2.55E-10	-1	0	1.27E-11	20.00
KFM11A	20070605 14:33	20070605 15:25	514.50	534.50	3	1	2.44E-10	-1	2.55E-10	-1	0	1.27E-11	20.00
KFM11A	20070605 15:49	20070605 17:02	530.00	550.00	3	1	2.02E-09	0	2.11E-09	0	0	1.06E-10	20.00
KFM11A	20070607 08:48	20070607 10:13	550.00	570.00	3	1	3.08E-10	0	3.21E-10	0	0	1.61E-11	20.00
KFM11A	20070607 10:35	20070607 11:53	570.00	590.00	3	1	4.86E-09	0	5.07E-09	0	0	2.54E-10	20.00
KFM11A	20070607 13:05	20070607 14:21	590.00	610.00	3	1	3.00E-08	0	3.13E-08	0	0	1.57E-09	20.00
KFM11A	20070607 14:49	20070607 16:05	610.00	630.00	3	1	9.60E-09	0	1.00E-08	0	0	5.01E-10	20.00
KFM11A	20070607 16:36	20070607 17:50	630.00	650.00	3	1	2.67E-09	0	2.79E-09	0	0	1.39E-10	20.00
KFM11A	20070608 08:20	20070608 09:37	650.00	670.00	3	1	2.57E-09	0	2.68E-09	0	0	1.34E-10	20.00
KFM11A	20070608 10:41	20070608 12:47	670.00	690.00	3	1	3.02E-07	0	3.15E-07	0	0	1.57E-08	20.00
KFM11A[1]	20070709 14:09	20070710 09:17	690.00	710.00	1B	1	7.03E-07	0	7.33E-07	0	0	3.67E-08	20.00
KFM11A	20070608 13:32	20070608 14:51	710.00	730.00	3	1	5.76E-09	0	6.01E-09	0	0	3.00E-10	20.00
KFM11A	20070608 15:16	20070608 16:33	730.00	750.00	3	1	1.02E-08	0	1.06E-08	0	0	5.32E-10	20.00
KFM11A	20070611 08:35	20070611 09:51	750.00	770.00	3	1	2.17E-08	0	2.26E-08	0	0	1.13E-09	20.00
KFM11A	20070611 13:26	20070611 14:41	770.00	790.00	3	1	5.31E-07	0	5.54E-07	0	0	2.77E-08	20.00
KFM11A	20070611 15:10	20070611 16:27	790.00	810.00	3	1	9.90E-07	0	1.03E-06	0	0	5.17E-08	20.00
KFM11A	20070612 08:38	20070612 09:54	810.00	830.00	3	1	6.95E-07	0	7.25E-07	0	0	3.62E-08	20.00
KFM11A	20070612 12:34	20070612 13:51	820.00	840.00	3	1	4.54E-07	0	4.74E-07	0	0	2.37E-08	20.00
KFM11A[2]	20070605 11:08	20070605 11:54	508.50	528.50	3	1							20.00
KFM11A[2]	20070608 09:58	20070608 10:38	670.00	690.00	3	1							20.00

[1] The test in section 690.0-710 m was conducted as a pumping test.

[2] Incomplete test, interrupted and re-performed later.

KFM11A plu_s_hole_test_ed1. Right (This result table to SICADA includes more columns which are empty, these columns are not presented here.)

idcode	secup	seclow	transmissivity_tt	value_type_tt	bc_tt	l_measl_q_s	u_measl_q_s	assumed_s	bc_s	ri	ri_index	c	skin	t1	t2	dte1	dte2
KFM11A	470.00	490.00	3.64E-08	0	1	7.0E-10	5.0E-04	1.34E-07	1.34E-07	15.66	-1		-2.24	50	400		
KFM11A	488.50	508.50	1.51E-08	0	1	7.8E-10	5.0E-04	8.60E-08	8.60E-08	21.98	0	6.46E-10	-3.35	200	1223		
KFM11A	508.50	528.50		-1	0	2.4E-10	5.0E-04										
KFM11A	514.50	534.50		-1	0	2.4E-10	5.0E-04										
KFM11A	530.00	550.00	4.06E-10	0	1	2.4E-10	5.0E-04	1.41E-08	1.41E-08	8.79	1		5.52				
KFM11A	550.00	570.00	1.31E-10	0	1	1.9E-10	5.0E-04	8.01E-09	8.01E-09	6.65	1		-4.86				
KFM11A	570.00	590.00	1.85E-09	0	1	5.9E-10	5.0E-04	3.01E-08	3.01E-08	13.02	-1	6.88E-11	-3.08				
KFM11A	590.00	610.00	7.12E-08	0	1	5.6E-10	5.0E-04	1.87E-07	1.87E-07	32.39	0	6.05E-11	9.65				
KFM11A	610.00	630.00	1.43E-08	0	1	8.3E-10	5.0E-04	8.36E-08	8.36E-08	21.46	0	3.57E-11	2.93	250	1200		
KFM11A	630.00	650.00	2.67E-09	0	1	6.8E-10	5.0E-04	3.62E-08	3.62E-08	14.26	0	5.33E-11	0.33	20	1225		
KFM11A	650.00	670.00	3.82E-10	0	1	6.9E-10	5.0E-04	1.37E-08	1.37E-08	8.31	-1	6.83E-11	-4.95	20	1100		
KFM11A	670.00	690.00	1.04E-07	0	1	8.2E-10	5.0E-04	2.25E-07	2.25E-07	36.18	0		-4.95	300	1265		
KFM11A1[1]	690.00	710.00	7.59E-07	0	1	8.5E-10	5.0E-04	6.10E-07	6.10E-07	159.17	0		-1.62	600	9047		
KFM11A	710.00	730.00	2.71E-09	0	1	8.2E-10	5.0E-04	3.64E-08	3.64E-08	14.30	0	3.00E-11	-3.23	150	1223		
KFM11A	730.00	750.00	6.15E-09	0	1	6.7E-10	5.0E-04	5.49E-08	5.49E-08	17.58	0	5.14E-11	-2.47	50	1225		
KFM11A	750.00	770.00	9.79E-09	0	1	7.1E-10	5.0E-04	6.92E-08	6.92E-08	19.78	0		-3.57	100	1230		
KFM11A	770.00	790.00	3.01E-07	0	1	8.1E-10	5.0E-04	3.84E-07	3.84E-07	46.54	0		-3.13				
KFM11A	790.00	810.00	1.22E-06	0	1	8.4E-10	5.0E-04	7.73E-07	7.73E-07	66.60	0		0.26	100	1250		
KFM11A	810.00	830.00	5.55E-07	0	1	8.2E-10	5.0E-04	5.21E-07	5.21E-07	21.88	-1		-1.91	100	200		
KFM11A	820.00	840.00	3.52E-07	0	1	8.3E-10	5.0E-04	4.15E-07	4.15E-07	48.32	-1		-1.75				
KFM11A[2]	508.50	528.50	0.00E+00	0	0	0.0E+00	0.0E+00	0.00E+00	0.00E+00	0.00	0	0.00E+00	0.00				
KFM11A[2]	670.00	690.00	0.00E+00	0	0	0.0E+00	0.0E+00	0.00E+00	0.00E+00	0.00	0	0.00E+00	0.00				

[1] The test in section 690.0-710 m was conducted as a pumping test.

[2] Incomplete test, interrupted and re-performed later.

KFM11A plu_s_hole_test_obs. Injection tests (This result table to SICADA includes more columns which are empty, these columns are not presented here.)

idcode	start_date	stop_date	secup	seclow	obs_secup	obs_seclow	pi_above	pp_above	pf_above	pi_below	pp_below	pf_below	comments
KFM11A	20070604 15:33	20070604 16:55	470.00	490.00		71.00	469.00	-728.75	-728.89	-728.89			
KFM11A	20070604 15:33	20070604 16:55	470.00	490.00		491.00	851.21				4260.53	4258.89	4257.24
KFM11A	20070605 09:23	20070605 10:40	488.50	508.50		71.00	487.50	-782.96	-782.96	-782.96			
KFM11A	20070605 09:23	20070605 10:40	488.50	508.50		509.50	851.21				4410.36	4409.82	4409.82
KFM11A	20070605 12:52	20070605 14:11	508.50	528.50		71.00	507.50	-841.99	-842.12	-842.12			
KFM11A	20070605 12:52	20070605 14:11	508.50	528.50		529.50	851.21				4574.61	4573.93	4573.93
KFM11A	20070605 14:33	20070605 15:25	514.50	534.50		71.00	513.50	-859.83	-859.83	-859.83			
KFM11A	20070605 14:33	20070605 15:25	514.50	534.50		535.50	851.21				4623.05	4622.77	4622.77
KFM11A	20070605 15:49	20070605 17:02	530.00	550.00		71.00	529.00	-906.42	-906.42	-906.42			
KFM11A	20070605 15:49	20070605 17:02	530.00	550.00		551.00	851.21				4749.55	4749.00	4749.00
KFM11A	20070607 08:48	20070607 10:13	550.00	570.00		71.00	549.00	-966.70	-966.70	-966.70			
KFM11A	20070607 08:48	20070607 10:13	550.00	570.00		571.00	851.21				4912.70	4912.42	4912.01
KFM11A	20070607 10:35	20070607 11:53	570.00	590.00		71.00	569.00	-1027.52	-1027.80	-1028.08			
KFM11A	20070607 10:35	20070607 11:53	570.00	590.00		591.00	851.21				5073.91	5073.36	5072.82
KFM11A	20070607 13:05	20070607 14:21	590.00	610.00		71.00	589.00	-1089.46	-1089.60	-1089.46			
KFM11A	20070607 13:05	20070607 14:21	590.00	610.00		611.00	851.21				5235.82	5235.14	5234.72
KFM11A	20070607 14:49	20070607 16:05	610.00	630.00		71.00	609.00	-1151.95	-1151.95	-1151.95			
KFM11A	20070607 14:49	20070607 16:05	610.00	630.00		631.00	851.21				5395.68	5395.27	5394.99
KFM11A	20070607 16:36	20070607 17:50	630.00	650.00		71.00	629.00	-1214.30	-1214.44	-1214.44			
KFM11A	20070607 16:36	20070607 17:50	630.00	650.00		651.00	851.21				5556.21	5555.38	5555.24
KFM11A	20070608 08:20	20070608 09:37	650.00	670.00		71.00	649.00	-1277.48	-1277.48	-1277.48			
KFM11A	20070608 08:20	20070608 09:37	650.00	670.00		671.00	851.21				5716.61	5716.06	5715.51
KFM11A	20070608 10:41	20070608 12:47	670.00	690.00		71.00	669.00	-1340.93	-1341.07	-1341.07			
KFM11A	20070608 10:41	20070608 12:47	670.00	690.00		691.00	851.21				5874.53	5874.67	5874.13
KFM11A	20070709 14:09	20070710 09:17	690.00	710.00		71.00	689.00	-1407.71	-1407.43	-1406.88			
KFM11A	20070709 14:09	20070710 09:17	690.00	710.00		711.00	851.21				6041.80	6041.39	6038.78
KFM11A	20070608 13:32	20070608 14:51	710.00	730.00		71.00	709.00	-1469.36	-1469.64	-1469.91			
KFM11A	20070608 13:32	20070608 14:51	710.00	730.00		731.00	851.21				6198.48	6198.08	6198.48
KFM11A	20070608 15:16	20070608 16:33	730.00	750.00		71.00	729.00	-1534.06	-1534.20	-1534.62			

idcode	start_date	stop_date	secup	seclow	obs_secup	obs_seclow	pi_above	pp_above	pf_above	pi_below	pp_below	pf_below	comments
KFM11A	20070608 15:16	20070608 16:33	730.00	750.00		751.00	851.21				6356.28	6356.15	6356.01
KFM11A	20070611 08:35	20070611 09:51	750.00	770.00		71.00	749.00	-1598.21	-1598.35	-1598.21			
KFM11A	20070611 08:35	20070611 09:51	750.00	770.00		771.00	851.21				6513.52	6514.08	6513.52
KFM11A	20070611 13:26	20070611 14:41	770.00	790.00		71.00	769.00	-1663.31	-1663.45	-1663.45			
KFM11A	20070611 13:26	20070611 14:41	770.00	790.00		791.00	851.21				6671.04	6677.21	6673.24
KFM11A	20070611 15:10	20070611 16:27	790.00	810.00		71.00	789.00	-1728.70	-1728.98	-1728.70			
KFM11A	20070611 15:10	20070611 16:27	790.00	810.00		811.00	851.21				6829.65	6838.99	6835.70
KFM11A	20070612 08:38	20070612 09:54	810.00	830.00		71.00	809.00	-1795.62	-1795.62	-1795.62			
KFM11A	20070612 08:38	20070612 09:54	810.00	830.00		831.00	851.21				7006.52	6998.70	6993.21
KFM11A	20070612 12:34	20070612 13:51	820.00	840.00		841.00	851.21	-1828.23	-1828.23	-1828.23			
KFM11A	20070612 12:34	20070612 13:51	820.00	840.00		71.00	819.00				7076.22	7073.33	7068.94
KFM11A	20070605 11:08	20070605 11:54	508.50	528.50	71.00	507.50	-842.12	-842.12	-842.12				Incomplete test, interrupted and re-performed later.
KFM11A	20070605 11:08	20070605 11:54	508.50	528.50	529.50	851.21				4574.48	4574.34	4574.48	Incomplete test, interrupted and re-performed later.
KFM11A	20070608 09:58	20070608 10:38	670.00	690.00	71.00	669.00	-1340.93	-1341.07	-1341.07				Incomplete test, interrupted and re-performed later.
KFM11A	20070608 09:58	20070608 10:38	670.00	690.00	691.00	851.21				5875.50	5875.09	5875.23	Incomplete test, interrupted and re-performed later.