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Oskarshamn site investigation

Hydraulic interference tests in HLX34, HLX37 and HLX42

Laxemar subarea

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Abstract

This report documents the results from 3 interference tests performed in the Laxemar subarea between June 2005 and May 2007. The active boreholes used for pumping are HLX37, HLX42 and HLX34. At each pumping the pressure response in a number of observation boreholes have been evaluated.

The main purposes of the interference tests were to document how different fracture zones of the rock are connected hydraulically, to quantify their hydraulic properties and to clarify whether there are any hydraulic boundaries in the area.

The interference tests were performed by pumping and creating a drawdown in the pumping borehole while registering the pressure responses in some adjacent observation sections. In totally 9 sections in 6 observation boreholes the pressure was monitored during the interference tests.

The flow period of the interference tests lasted between 3 and 6 days. Responses were detected in 7 observation sections. All observation sections with a detected response as well as the pumping boreholes were evaluated quantitatively using methods for transient evaluation. Due to occasionally long distances and/or relatively bad hydraulic connection to the pumping borehole the results from the transient evaluation of the observation sections may be uncertain. It is possible that the evaluated transmissivity values more reflect the hydraulic conditions close to the pumping borehole rather than the conditions around the evaluated observation boreholes in such cases. However, the estimated hydraulic diffusivity based on the response times for the selected sections was in good agreement with the corresponding estimates from the transient analysis.

Some observation sections were influenced by tidal effects, and probably to some extent also by changes of the sea level. Primarily due to the tidal effects the pressure data from certain observation sections exhibit an oscillating behaviour which may complicate the transient analysis, particularly in sections with small drawdown.

Sammanfattning

Denna rapport innehåller resultaten från 3 interferenstest som har genomförts i Laxemarområdet mellan juni 2005 och maj 2007. De borrhål som använts som pumphål är HLX37, HLX42 och HLX34. Vid varje pumpning har ett antal observationshål undersökts.

Syftet med de utförda interferenstesterna var att dokumentera hur spricksystemen i berget hänger ihop hydrauliskt, kvantifiera bergets hydrauliska egenskaper samt att klargöra om det finns några hydrauliska gränser inom området.

Interferenstesterna utfördes genom att en tryckavsänkning skapades genom pumpning i respektive pumphål samtidigt som tryckresponser registrerades i olika observationssektioner i ett eller flera omgivande borrhål. Totalt pumpades det i 3 borrhål och trycket i sammanlagt 6 observationsborrhål med 9 sektioner övervakades och ingick i interfenstesten.

Pumpfasen för interferenstesten pågick i mellan 3 och 6 dagar för de olika pumpningarna. Responser detekterades i 7 observationshål. Alla pumphål samt de observationssektioner där respons detekterades har utvärderats kvantitativt med metoder för transient utvärdering. Resultaten från den transienta utvärderingen av observationshålen kan vara osäkra på grund av de emellanåt långa avstånden till, och/eller den relativt dåliga hydrauliska kontakten med pumphålet. I dessa fall är det möjligt att de utvärderade transmissiviteterna mer återspeglar de hydrauliska förhållandena i närheten av pumphålet snarare än förhållandena runt de utvärderade observationshålen.

Några observationssektioner är påverkade av tidaleffekter. Vissa berörda sektioner uppvisar ett oscillerande beteende beroende på framförallt tidaleffekterna. Detta kan komplicera den transienta analysen, speciellt i sektioner med små avsänkningar.

Contents

1 Introduction

This report documents the results from 3 hydraulic interference tests performed within the site investigation in the subarea Laxemar at Oskarshamn. Interference tests are performed in order to study how different fracture zones are connected hydraulically, to quantify their hydraulic properties and to clarify whether there are any major hydraulic boundaries in the area. The locations of the boreholes involved in the interference tests are shown in Figure 1-1. The tests were carried out in between June 2005 and May 2007.

The interference tests and evaluations have been made according to the activity plans and method descriptions listed in Table 1-1. Both the activity plans and method descriptions are internal controlling documents of SKB.

The 3 boreholes used as pumping boreholes and the surrounding boreholes which served as observation wells are listed in Table 1-2. The times referred to in these tables are the chosen start and stop times of the flow period.

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

Pumping borehole	Activity plan number (execution)	Activity plan number (evaluation)
HLX34	AP PS 400-05-034	AP PS 400-05-034
HLX37	AP PS 400-05-069	AP PS 400-06-115
HLX42	AP PS 400-07-45	AP PS 400-07-25
Method documents	**Number**	**Version**
Instruktion för analys av injektions- och enhålspumptester	SKB MD 320.004	1.0
Metodbeskrivning för interferenstester	SKB MD 330.003	1.0

Table 1-2. Interference tests performed.

Pumping borehole	Observation borehole	Test start date and time (YYYY-MM-DD tt:mm)	Test stop date and time (YYYY-MM-DD tt:mm)
HLX34	HLX35, HLX13	2005-06-16 13:20	2005-06-20 08:11
HLX37	HLX28, HLX32,	2005-10-18 11:34	2005-10-24 11:06
HLX42	KLX16A	2007-05-15 09:17	2007-05-18 10:15

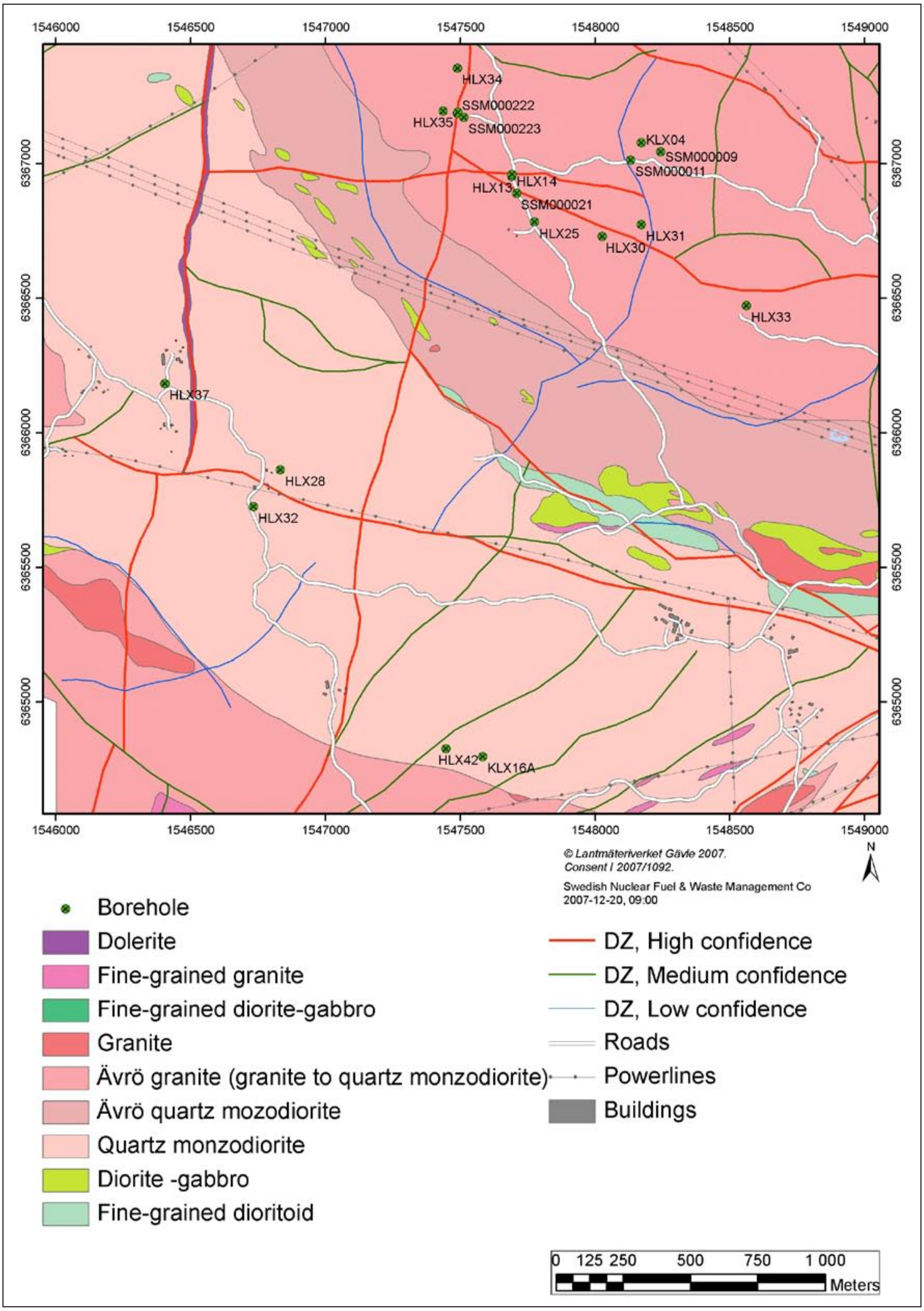


Figure 1-1. The investigation area at Oskarshamn including part of the candidate area Laxemar selected for more detailed investigations. The positions of the boreholes included in the interference tests are displayed.

2 Objectives

The main aim of hydraulic interference tests is to get support for interpretations of geologic structures in regard to their hydraulic and geometric properties deduced from single-hole tests. Furthermore, interference tests may provide information about the hydraulic connectivity and hydraulic boundary conditions within the tested area. Finally, interference tests make up the basis for calibration of numerical models of the area.

The interference tests were performed by pumping in altering boreholes and monitoring pressure responses in different observation sections in surrounding boreholes. All boreholes monitored for responses are part of the HMS, the Hydro Monitoring System at Oskarshamn. In total, 4 observation boreholes with 7 sections were included in the interference tests.

3 Scope

3.1 Boreholes tested

Technical data of the boreholes tested are presented in Table 3-1.

The reference point in the boreholes is always top of casing (ToC). The Swedish National coordinate system (RT90 2.5 gon V 0:-15) is used in the x-y-direction together with RHB70 in the z-direction. The coordinates of the boreholes at ground surface are shown in Table 3-2. All section positions are given as length along the borehole (not vertical distance from ToC). All times presented are Swedish summer times i.e. when appropriate; adjustment for daylight saving time has been made for all reported times.

Table 3-1. Pertinent technical data of the boreholes included in the interference tests which showed responses. (From Sicada).

Borehole data							
Bh ID	**Elevation of top of casing (ToC) (m.a.s.l.)**	**Borehole interval from ToC (m)**	**Casing/ Bh-diam. (m)**	**Inclination-top of Bh (from horizontal plane (°)**	**Dip-direction-top of borehole (from local N) (°)**	**Remarks**	**Drilling finished date (YYYY-MM-DD)**
KLX16A	18.85	0.30–11.25	0.096	–64.98	294.37	Borehole	2007-01-09
		11.25–433.55	0.076			Borehole	
		0.00–11.25	0.077			Casing ID	
HLX13	17.39	0–12.00	0.190	–58.07	184.18	Borehole	2004-02-26
		12.00–200.20	0.140			Borehole	
		0–11.78	0.168			Casing ID	
		11.78–11.85	0.147			Casing ID	
HLX28	13.42	0.00–6.10	0.190	–59.49	201.38	Borehole	2004-10-02
		6.10–154.20	0.136			Borehole	
		0.00–5.94	0.160			Casing ID	
		5.94–6.03	0.147			Casing ID	
HLX32	10.84	0.00–12.30	0.191	–58.67	28.59	Borehole	2005-01-11
		12.30–162.60	0.140			Borehole	
		0.00–12.21	0.160			Casing ID	
		12.21–12.30	0.147			Casing ID	
HLX34	14.29	0.00–9.10	0.190	–59.73	101.07	Borehole	2005-06-14
		9.10–151.8	0.137			Borehole	
		0.00–8.94	0.160			Casing ID	
		8.94–9.03	0.147			Casing ID	
HLX35	14.44	0.00–6.10	0.190	–59.88	102.22	Borehole	2005-06-02
		6.10–151.80	0.140			Borehole	
		0.00–5.94	0.160			Casing ID	
HLX37	15.19	0.00–12.10	0.190	–59.25	86.18	Borehole	2005-09-28
		12.10–121.50	0.140			Borehole	
		121.50–199.80	0.139			Borehole	
		0.00–11.94	0.160			Casing ID	
		11.94–12.03	0.142			Casing ID	
HLX42	12.88	0.30–9.10	0.180	–57.11	321.51	Borehole	2006-11-16
		9.10–152.60	0.139			Borehole	
		0.00–9.01	0.160			Casing ID	
		9.01–9.10	0.143			Casing ID	
		5.94–6.03	0.147			Casing ID	

Table 3-2. Coordinates of the boreholes included in the interference tests. (From Sicada).

Borehole data		
Bh ID	**Northing (m)**	**Easting (m)**
KLX16A	6364797.69	1547584.06
HLX13	6366953.00	1547690.42
HLX28	6365861.70	1546834.47
HLX32	6365725.79	1546734.36
HLX34	6367355.13	1547489.56
HLX35	6367194.79	1547437.79
HLX36	6366172.12	1546558.50
HLX37	6366183.66	1546406.21
HLX42	6364827.04	1547446.73

3.2 Tests performed

Three separate hydraulic interference tests were performed and the results are presented in this report. All borehole sections involved in the interference tests are listed in Table 3-3 to Table 3-8. The amount of data extracted from HMS (Hydro Monitoring System) from the observation boreholes was chosen so as to receive data from an appropriate time period providing information about the pressure conditions prior to, as well as during and after, the interference test. HMS is registering pressure continuously.

The column "Test section" in the tables below reports the hydraulically active section length. In most boreholes the upper part of the upper section is cased to some depth. The casing length is not included in the "Test section". The casing length of each borehole can be found in Table 3-1.

The interpreted points of application, calculated as explained below, and lengths of the borehole sections involved in the interference test together with the distances between the pumping borehole and the observation borehole sections are shown in the tables below. The distances are calculated as the distance between the points of application in the pumping borehole and the points of application in respective observation section using a routine in the Sicada database.

The points of application in the pumping borehole and in the different observation borehole sections, respectively were in general selected as the midpoints of the sections. This is true for all boreholes except the pumping borehole HLX34 and the associated observation borehole HLX35. In these boreholes the point of application is based on the position of the flow anomaly assumed to contribute to the major part of the transmissivity in each section. If several parts of the section have comparable values of transmissivity a point of balance calculation was made to estimate the point of application.

3.2.1 Interference test in HLX34

Table 3-3. Borehole sections with responses in the interference test in HLX34, see Figure 1-1.

Bh ID	Test section (m)	Test type[1]	Test configuration
HLX34	9.0–151.8	1B	Open borehole
HLX13	11.78–200.20	2	Open borehole
HLX35:1	65.0–151.8	2	Below packer
HLX35:2	6.0–64.0	2	Above packer

[1)] 1B: Pumping test-submersible pump, 2: Interference test.

Table 3-4. Points of application and lengths of the test sections in the interference test in HLX34.

Bh ID	Test section (m)	Point of application (m below ToC)	Section length (m)	Distance to HLX34 (m)
HLX34	9.0–151.8	112.0	142.8	0
HLX13	11.78–200.20	100.0	188.42	462
HLX35:1	65.0–151.8	127.5	86.8	171
HLX35:2	6.0–64.0	29.0	58.0	190

3.2.2 Interference test in HLX37

Table 3-5. Borehole sections with responses in the interference test in HLX37, see Figure 1-1.

Bh ID	Test section (m)	Test type[1]	Test configuration
HLX37	12.0–199.8	1B	Open borehole
HLX28	6.0–154.2	2	Open borehole
HLX32	16.0–162.6	2	Open borehole

[1)] 1B: Pumping test-submersible pump, 2: Interference test.

Table 3-6. Points of application and lengths of the test sections in the interference test in HLX37.

Bh ID	Test section (m)	Point of application (m below ToC)	Section length (m)	Distance to HLX37 (m)
HLX37	12.0–199.8	105.9	187.8	
HLX28	6.0–154.2	80.1	148.2	510
HLX32	16.0–162.6	87.5	150.3	511

3.2.3 Interference test in HLX42

Table 3-7. Borehole sections with responses in the interference test in HLX42, see Figure 1-1.

Bh ID	Test section (m)	Test type[1]	Test configuration
HLX42	9.1–152.6	1B	Open borehole
KLX16A:1	327.0–433.6	2	Below packer
KLX16A:2	191.0–326.0	2	Between packers
KLX16A:3	11.3–190.0	2	Above packer

[1)] 1B: Pumping test-submersible pump, 2: Interference test.

Table 3-8. Points of application and lengths of the test sections in the interference test in HLX42.

Bh ID	Test section (m)	Point of application (m below ToC)	Section length (m)	Distance to HLX42 (m)
HLX42	9.1–152.6	80.9	143.5	
KLX16A:1	327.0–433.6	380.3	106.6	273
KLX16A:2	191.0–326.0	258.5	135.0	176
KLX16A:3	11.3–190.0	100.7	178.7	135

4 Description of equipment

4.1 Overview

The equipment consisted of the pumped hole units described in 4.2 below and of the observation hole instrumentation described in 4.3.

All the observation sections included in the interference test are part of the SKB hydro monitoring system (HMS), where pressure is recorded continuously.

4.2 Equipment when testing boreholes HLX34, HLX37 and HLX42

The pumping and interference test was performed with an integrated field unit at the pumped borehole, Figure 4-1, consisting of a container housing

- a submersible pump: Grundfoss SPE5-70, range is about 5–100 L/min,
- an absolute pressure transducer: Druck PTX1830, 10 bar range and ± 0.1% accuracy,
- a water level dipper,
- a flow gauge: Krohne IFM1010 electromagnetic, 0–150 L/min.

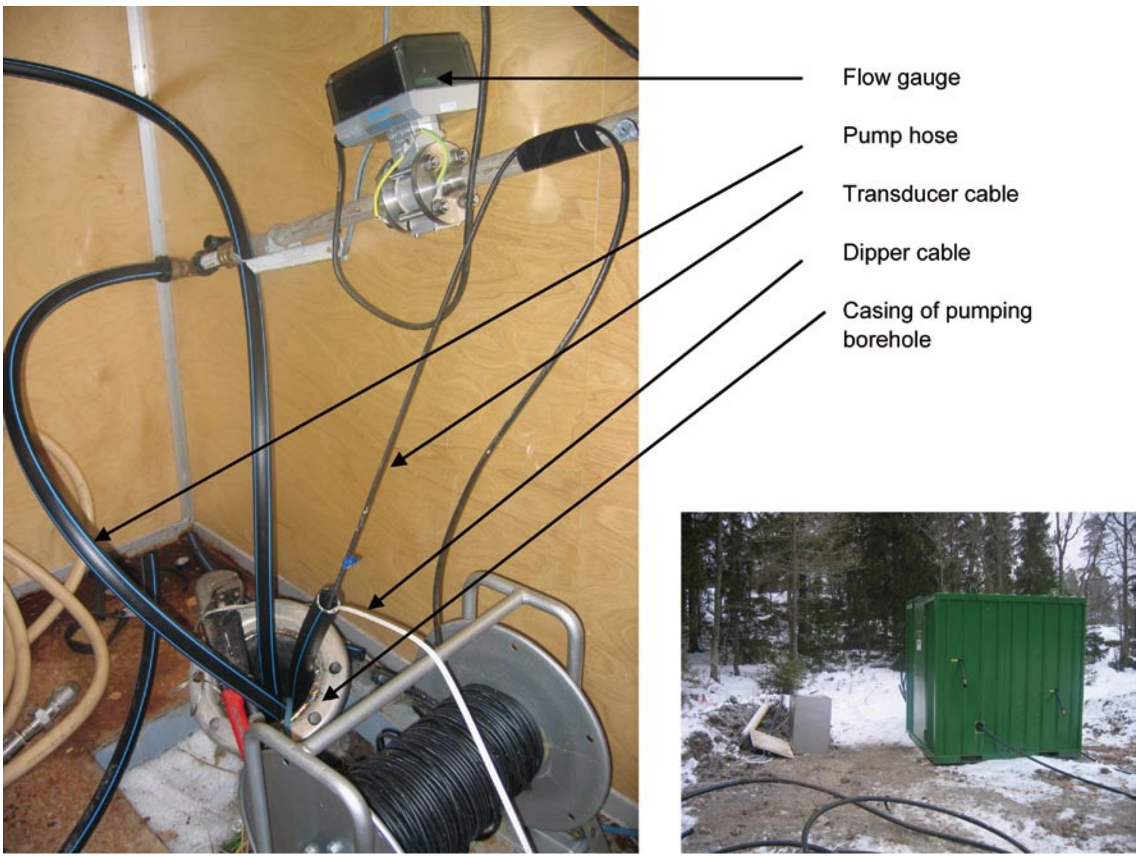


Figure 4-1. *Container housing the testing equipment (right) and instrumentation inside (left) in borehole.*

4.3 Observation hole equipment

All the observation sections included in the interference test are part of the SKB hydro monitoring system (HMS), where pressure is recorded continuously.

For all observation sections in these trests the utilised pressure gauge/logger was a MiniTroll 30PSIA, with accuracy ± 0.1% FS.

5 Execution

5.1 Preparations

Generally the equipment was installed down the hole at least one day ahead of pump start and logging of water groundwater head was initiated.

5.2 Procedure

The pumping aimed at a constant flow rate which was logged continuously. During the tests the pressure was recorded in totally 29 sections in 14 observation boreholes, both cored and percussion drilled, using the HMS (Hydro Monitoring System).

The boreholes connected to the HMS are fitted with stationary equipment for measuring pressure in the different sections. In some of the observation boreholes the stationary installations were set to log more frequently than then default longterm monitoring frequency.

Appendix 3 show all boreholes and sections involved in these tests and Table 3-1 specifies those which showed a response.

5.3 Data handling

Data from all pressure gauges was corrected with respect to atmospheric pressure and for the observation boreholes converted to groundwater head expressed in metre above sea level in the RT90 national grid elevation system. All data and filed protocols of flow and water level are stored in the site characterisation database (Sicada)

For the observation sections, quality controlled data from the HMS were collected from the SKB database Sicada. The pressure and flow data from the pumping boreholes were collected from the HMS or received from the activity leader in form of .csv, .dat or .txt files.

5.4 Transient analysis and interpretation

5.4.1 General

When possible, both qualitative and quantitative analyses have been carried out in accordance with the methodology descriptions for interference tests, SKB MD 330.003. Standard methods for constant-flow rate tests in an equivalent porous medium were used by the transient analyses and interpretation of the tests.

Transient evaluation of all responding observation sections was performed, both for the flow and recovery period, respectively. All responding observation sections are also included in the response analysis. In the transient evaluation of the responses in the pumping borehole and selected observation sections the models described in /4, 5/ and /7/ respectively was used. The responses in the pumping boreholes were evaluated as single-hole pumping tests according to the methods described in /1/.

In the primary qualitative analyses, data from all observation sections included in each interference test were studied in linear time versus pressure diagrams to deduce the responding sections.

Linear diagrams of pressure versus time are presented in Chapter 6 for each borehole included in the interference tests.

The qualitative evaluation of the dominating transient flow regimes (pseudo-linear, pseudo-radial and pseudo-spherical flow, respectively) and possible outer boundary conditions was mainly based on the drawdown and recovery responses in logarithmic diagrams. In particular, pseudo-radial flow is reflected by a constant (horizontal) derivative in the diagrams, whereas no-flow and constant head boundaries are characterized by a rapid increase and decrease of the derivative, respectively. Based on the qualitative evaluation relevant models were selected for the quantitative transient evaluation.

In the drawdown and recovery diagrams different values on the filter coefficient (step length) by the calculation of the pressure derivative were applied to investigate the effect on the pressure derivative. It is desired to achieve maximum smoothing of the derivative without altering the original shape of the test data.

The quantitative transient analysis was performed by the test analysis software Aqtesolv /10/ that enables both visual and automatic type curve matching. The transient evaluation was carried out as an iterative process of type curve matching and automatic non-linear regression. The transient interpretation of the hydraulic test parameters is in most cases based on the identified pseudo-radial flow regime appearing during the tests and plotted in log-log and lin-log data diagrams.

The analysis from pumping tests in HLX34 was made utilising the software Saphir v 4 /11/.

5.4.2 Pumping boreholes

For the single-hole pumping tests the storativity was calculated using, see Equation (5-1), from SKB (2006) /2/. Firstly, the transmissivity and skin factor were obtained by type curve matching using a fixed storativity value of 10^{-6} according to the instruction SKB MD 320.004. The storativity was then re-calculated from an empirical regression relationship between storativity and transmissivity according to Equation (5-1). The type curve matching was then repeated. In most cases the change of storativity does not significantly alter the transmissivity value in the new type curve matching, but only the estimated skin factor is altered correspondingly. This described way of estimating the storativity is true for all pumping boreholes except for pumping borehole HLX34 which was evaluated based on a constant storativity of $1 \cdot 10^{-4}$.

$$S = 0.0007 \cdot T^{0.5} \quad (5\text{-}1)$$

S = storativity (–)

T = transmissivity (m^2/s)

In addition to the transient analysis, an interpretation based on the assumption of stationary conditions in the pumping boreholes was performed as described in /1/.

The wellbore storage coefficient (C) in the pumping borehole section can be obtained from the parameter estimation of a fictive casing radius, r(c) in an equivalent open test system according to Equation (5-2).

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

The radius of influence at a certain time during the test may be estimated from Jacob's approximation of the Theis' well function according to Equation (5-3):

$$r_i = \sqrt{\frac{2.25 \cdot T \cdot t}{S}} \qquad (5\text{-}3)$$

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

S = storativity estimated from Equation 5-1

r_i = radius of influence at time t (m)

t = time after start of pumping (s)

Furthermore, a 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 5-3.

5.5 Response analysis and estimation of the hydraulic diffusivity

5.5.1 Response analysis

Calculation of the response indices

In responding observation sections the response time (dt_L) and the maximum drawdown (s_p) were calculated. The response time is defined as the time lag after start of pumping until a drawdown response of 0.1 m was observed in the actual observation section. The maximum drawdown does not always occur at stop of pumping, e.g. due to heavy precipitation by the end of the flow period. In such cases the transient analysis is based on the response prior to the disturbance.

The 3D distances between the point of application in the pumping borehole and in the observation borehole sections (r_s) were calculated. These parameters combined with the pumping flow rate (Q_p) are the variables used to calculate the response indices which characterize the hydraulic connectivity between the pumping and the observation section. The calculated hydraulic connectivity parameters are shown in the tables in Chapter 6. The response indices are calculated as follows:

Index 1:

$\mathbf{r_s^2/dt_L}$ = normalised squared distance r_s with respect to the response time lag at s = 0.1 m (m²/s)

Index 2:

$\mathbf{s_p/Q_p}$ = normalised drawdown s_p with respect to the pumping rate [s/m²].

Additionally, a third index was calculated including drawdown and distance. This index is calculated as follows:

Index 2 new:

$\mathbf{(s_p/Q_p)\cdot ln(r_s/r_0)}$ assuming $r_0 = 1$. For the pumped borehole $r_s = e^1$ (i.e. a fictive borehole radius of 2.718).

The classification based on the indices is given as follows:

Index 1 (r_s^2/dt_L)		**Colour code**
$r_s^2/dt_L > 100$ m²/s	Excellent	
$10 < r_s^2/dt_L \leq 100$ m²/s	High	
$1 < r_s^2/dt_L \leq 10$ m²/s	Medium	
$r_s^2/dt_L \leq 1$ m²/s	Low	

Index 2 (s_p/Q_p)		**Colour code**
$s_p/Q_p > 1\cdot 10^5$ s/m²	Excellent	
$3\cdot 10^4 < s_p/Q_p \leq 1\cdot 10^5$ s/m²	High	
$1\cdot 10^4 < s_p/Q_p \leq 3\cdot 10^4$ s/m²	Medium	
$s_p/Q_p \leq 1\cdot 10^4$ s/m²	Low	
$s_p < 0.1$ m	No response	

Index 2 new ($(s_p/Q_p)\cdot ln(r_s/r_0)$)		**Colour code**
$(s_p/Q_p)\cdot ln(r_s/r_0) > 5\cdot 10^5$ s/m²	Excellent	
$5\cdot 10^4 < (s_p/Q_p)\cdot ln(r_s/r_0) \leq 5\cdot 10^5$ s/m²	High	
$5\cdot 10^3 < (s_p/Q_p)\cdot ln(r_s/r_0) \leq 5\cdot 10^4$ s/m²	Medium	
$(s_p/Q_p)\cdot ln(r_s/r_0) \leq 5\cdot 10^3$ s/m²	Low	
$s_p < 0.1$ m	No response	

In some cases it is not clear if the section responds to the pumping or if the drawdown is based on natural processes solely. In uncertain cases, the data sets were regarded all together to better differentiate between these effects. By looking at the pressure responses before and after the pumping period, it may be possible to distinguish between natural fluctuations and those induced by pumping. Furthermore, it should be pointed out, that some of the responses could be caused by the drawdown in adjacent sections above or below the measured section in the same observation borehole.

All observation data are influenced by natural fluctuations of the groundwater level such as tidal effects and long term trends. The pressure changes due to tidal effects are different for the observation boreholes.

5.5.2 Estimation of hydraulic diffusivity

The distances r_s between the pumping borehole and the different observation sections have been calculated as the spherical distance using the co-ordinates for the midpoint of each section as described in Section 3.2. The calculation of the hydraulic diffusivity is based on radial flow according to /6/.

$$T/S = r_s^2/[4 \cdot dt_L \cdot (1 + dt_L/tp) \cdot \ln(1 + tp/dt_L)] \qquad (5\text{-}4)$$

The time lag dt_L is here defined as the time when the pressure response in an observation section is 0.01 m. The pumping time is included as tp. The estimates of the hydraulic diffusivity according to above should be seen as approximate values of the hydraulic diffusivity.

6 Results

6.1 General comments

All pressure data for the observation boreholes presented in this report have been corrected for atmospheric pressure changes by subtraction from the measured (absolute) pressure. The pressure in several of the observation sections included in the interference test was displaying an oscillating behaviour. This is naturally caused by tidal fluctuations. These phenomena have, to some extent, been investigated previously in /3/. It should be observed that no further corrections of the measured drawdown have been made for these interference tests, e.g. due to natural trends, precipitation or tidal effects.

The transient evaluation of the tests were analysed as variable flow rate tests. The nomenclature and symbols used for the results of the single-hole and interference test are according to the Instruction for analysis of single-hole injection- and pumping tests (SKB MD 320.004) and the methodology description for interference tests (SKB MD 330.003), respectively (both are SKB internal controlling documents). Additional symbols used are explained in the text.

Linear plots of pressure versus time for the pumping and observation sections are presented in Figures 6-1 through 6-10. The measured drawdown (s_p) at the end of the flow period and the estimated response time lags (dt_L) in responding observation sections are shown in Tables 6-10 and 6-11, respectively. Test summary sheets for all responding observation borehole sections are presented in Appendix 1. Transient evaluation of the drawdown and recovery period is shown in log-log and lin-log diagram in Appendix 2. The results are also summarized in Table 6-12. The locations of all boreholes are shown in Figure 1-1. Abbreviations of flow regimes and hydraulic boundaries that may appear in the text are listed below.

WBS = Wellbore storage

PRF = Pseudo-radial flow regime

IARF = Infinite acting radial flow

PLF = Pseudo-linear flow regime

PSF = Pseudo-spherical flow regime (including leaky flow)

PSS = Pseudo-stationary flow regime

NFB = No-flow boundary

CHB = Constant head boundary

6.2 Interference test in HLX34

Borehole responses when pumping HLX34 is shown in Figure 6-11 and in the response matrix in Appendix 3. Below results are presented and discussed for the sections which showed a response.

6.2.1 Pumping borehole HLX34

General test data for the pumping test in HLX34 are presented in Table 6-1. The borehole is cased to 9.0 m. The uncased interval of this section is thus c. 9.0–151.8 m.

Table 6-1. General test data for the pumping test in HLX34: 9.0–151.8 m.

General test data			
Pumping borehole	HLX34		
Test type[1)]	Constant rate drawdown and recovery test		
Test section (open borehole/packed-off section):	Open borehole		
Test no	1		
Field crew	SKB		
Test equipment system			
General comment	Interference test		
	Nomenclature	**Unit**	**Value**
Borehole length	L	m	151.8
Casing length	L_c	m	9.0
Test section – secup	Secup	m	9.0
Test section – seclow	Seclow	m	151.8
Test section length	L_w	m	142.8
Test section diameter[2)]	$2 \cdot r_w$	mm	137
Test start (start of flow period)		yymmdd hh:mm	050616 13:20
Packer expanded		yymmdd hh:mm:ss	
Start of flow period		yymmdd hh:mm:ss	050616 13:20:00
Stop of flow period		yymmdd hh:mm:ss	050620 08:11:00
Test stop (stop of flow period)		yymmdd hh:mm	050620 08:11
Total flow time	t_p	min	5,451
Total recovery time	t_F	min	2,794
Pressure data			
Relative pressure in test section before start of flow period	p_i	m	63.5
Relative pressure in test section before stop of flow period	p_p	m	54.7
Relative pressure in test section at stop of recovery period	p_F	m	
Pressure change during flow period (p_i–p_p)	dp_p	m	8.8
Flow data			
Flow rate from test section just before stop of flow period[3)]	Q_p	m^3/s	0.00183
Mean (arithmetic) flow rate during flow period	Q_m	m^3/s	
Total volume discharged during flow period	V_p	m^3	

[1)] Constant Head injection and recovery, Constant Rate withdrawal and recovery or Constant Drawdown and recovery.

[2)] Nominal diameter.

[3)] The flow meter was out of order for the last days and the number given is an estimation of the actual flow.

Comments on the test

The mean flow rate was c. 110 L/min and the duration of the flow period was c. 4 days. A total drawdown during the flow period of 8.77 m was observed (cf. Figure 6-1).

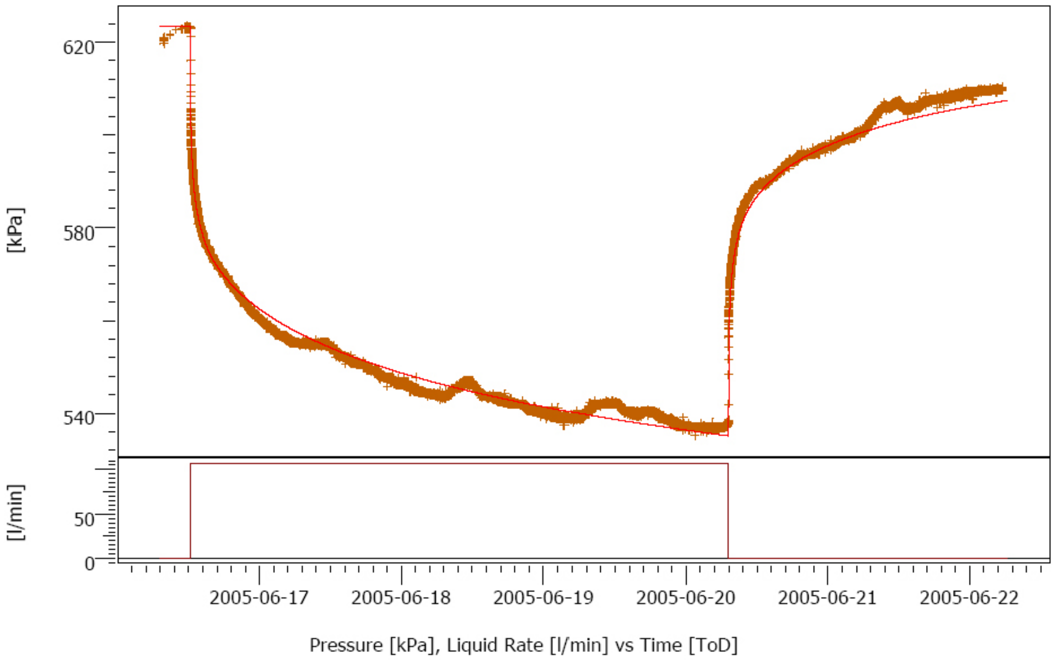


Figure 6-1. *Linear plot of flow rate and pressure versus time in the pumping borehole HLX34.*

Flow regime and calculated parameters

Both drawdown and recovery show a certain double porosity type of behaviour followed by flow along no flow parallel faults. Consistent T and skin were obtained for the respective phases and good match between data and models. A low negative skin of –5 was obtained being indicative for fracture flow.

	Transmissivity (m^2/s)	Assumed storativity based on observation hole results (–)
Drawdown phase	$2.2 \cdot 10^{-4}$	$1.0 \cdot 10^{-4}$
Recovery phase	$1.6 \cdot 10^{-4}$	$1.0 \cdot 10^{-4}$

Selected representative parameters

The selected representative transmissivity is $2.2 \cdot 10^{-4}$ m^2/s derived from the drawdown phase since the parameters provided excellent diagnostic and overall match between measured data and simulated results.

6.2.2 Observation borehole HLX35

Observation section HLX35:1: 65.0–151.8 m

In Figure 6-2, an overview of the pressure response in observation section HLX35:1: 65.0–151.8 m is shown. General test data are presented in Table 6-2.

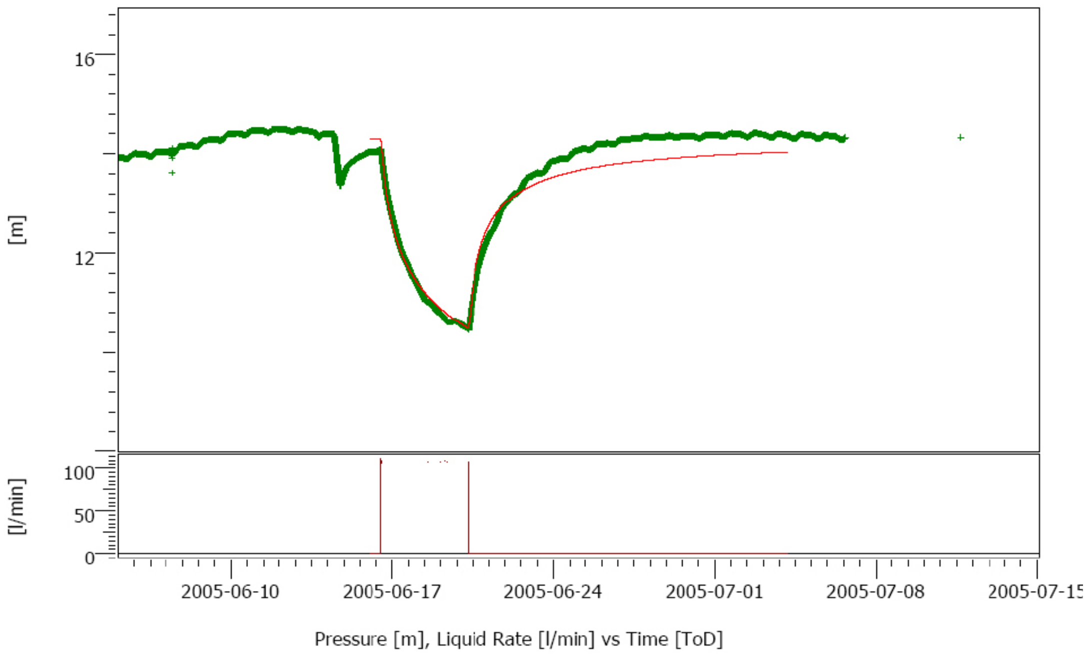


Figure 6-2. *Linear plot of ground water level in section 1 in the observation borehole HLX35 during pumping in borehole HLX34.*

Table 6-2. General test data from the observation section HLX35:1: 65.0–151.8 m during the interference test in HLX34.

Pressure data	Nomenclature	Unit	Value
Hydraulic head in test section before start of flow period	h_i	m.a.s.l.	14.01
Hydraulic head in test section before stop of flow period	h_p	m.a.s.l.	10.52
Hydraulic head in test section at stop of recovery period	h_F	m.a.s.l.	14.43
Hydraulic head change during flow period (h_i–h_p)	dh_p	m	3.49

Flow regime and calculated parameters

Rather consistent T and S were obtained for the drawdown and recovery period respectively and similar good match of the IARF models with the data in log-log.

	Transmissivity (m^2/s)	Storativity (–)
Drawdown phase	$1.3·10^{-4}$	$1.0·10^{-4}$
Recovery phase	$1.0·10^{-4}$	$9.9·10^{-5}$

A better match of the complete test history based on the parameters from the recovery than the drawdown phase was obtained. Although not possible to consitently provide good match on the the lin-lin model for the complete test sequence: a good drawdown match provides too low longterm head during recovery and conversely good recovery match generated too high model head during drawdown.

Selected representative parameters

The selected representative transmissivity is $1.0·10^{-4}$ m^2/s and a storativity of $9.9·10^{-5}$ derived from the recovery phase since the parameters provided a somewhat better overall match between measured data and simulated results.

Observation section HLX35:2: 6.0–64.0 m

In Figure 6-3, an overview of the pressure response in observation section HLX35:2: 6.0–64.0 m is shown. General test data are presented in Table 6-3.

Flow regime and calculated parameters

Rather consistent T and S were obtained for the drawdown and recovery period respectively for the IARF regime.

	Transmissivity (m^2/s)	Storativity (–)
Drawdown phase	$4.2\cdot10^{-4}$	$7.1\cdot10^{-4}$
Recovery phase	$4.5\cdot10^{-4}$	$5.4\cdot10^{-4}$

The recovery phase show a better match between measured data and model, for the diagnostic plot and the complete tests history reconstruction.

Selected representative parameters

The selected representative transmissivity is $4.5\cdot10^{-4}$ m^2/s and a storativity of $5.4\cdot10^{-4}$ derived from the recovery phase since the parameters provided a better overall match between measured data and simulated results.

Table 6-3a. General test data from the observation section HLX35:2: 6.0–64.0 m during the interference test in HLX34.

Pressure data	Nomenclature	Unit	Value
Hydraulic head in test section before start of flow period	h_i	m.a.s.l.	12.04
Hydraulic head in test section before stop of flow period	h_p	m.a.s.l.	11.24
Hydraulic head in test section at stop of recovery period	h_F	m.a.s.l.	11.98
Hydraulic head change during flow period (h_i–h_p)	dh_p	m	0.8

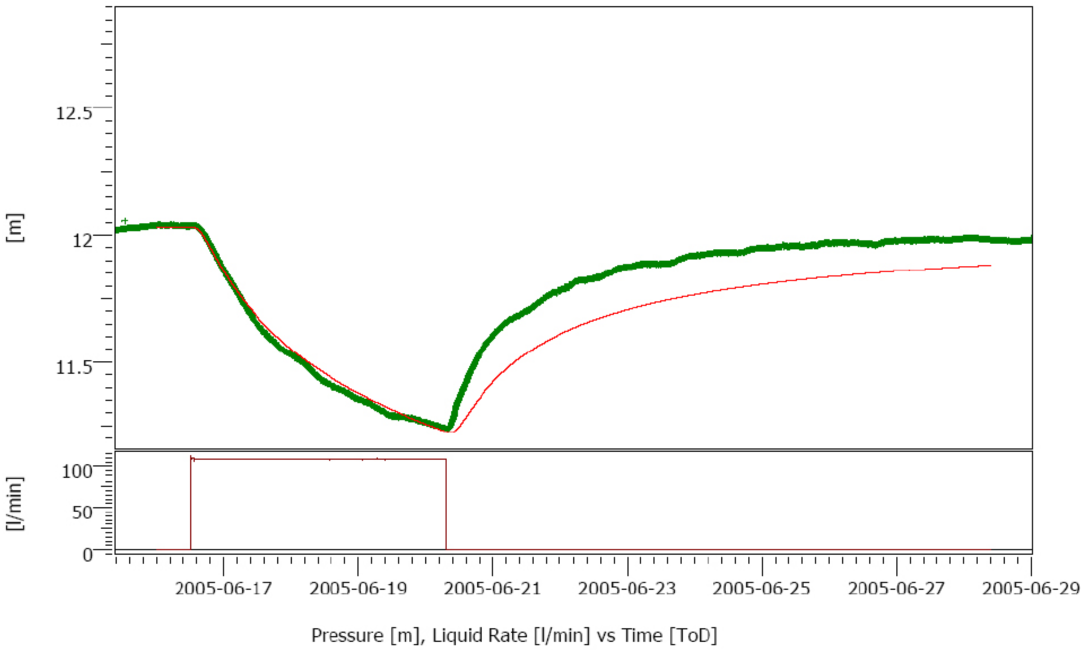


Figure 6-3a. *Linear plot of ground water level in section 2 in the observation borehole HLX35 during pumping in borehole HLX34.*

6.2.3 Observation borehole HLX13

Observation section HLX13 11.78–200.20 m

In Figure 6-3b, an overview of the pressure response in observation section HLX13 is shown. General test data are presented in Table 6-3b.

The head in HLX13 appear respond to the HLX34 pumping but the levels are heavily influenced by the tidal effects and responses due to precipitation events are also observed. There is a more than normal uncertainty in this interpretation due to the disturbed head prior to the test.

However both tidal and precipitation effect are clearly subordinate to the pumping effects during drawdown and large duration of the recovery. An approximate steady state head is obtained during drawdown after half of the pumping period which was modelled as a constant head boundary at 157 m distance. No such boundary is however observed during the recovery.

Table 6-3b. General test data from the observation section HLX13 during the interference test in HLX34.

Pressure data	Nomenclature	Unit	Value
Hydraulic head in test section before start of flow period	h_i	m.a.s.l.	12.54
Hydraulic head in test section before stop of flow period	h_p	m.a.s.l.	11.44
Hydraulic head in test section at stop of recovery period	h_F	m.a.s.l.	12.99
Hydraulic head change during flow period (h_i–h_p)	dh_p	m	1.1

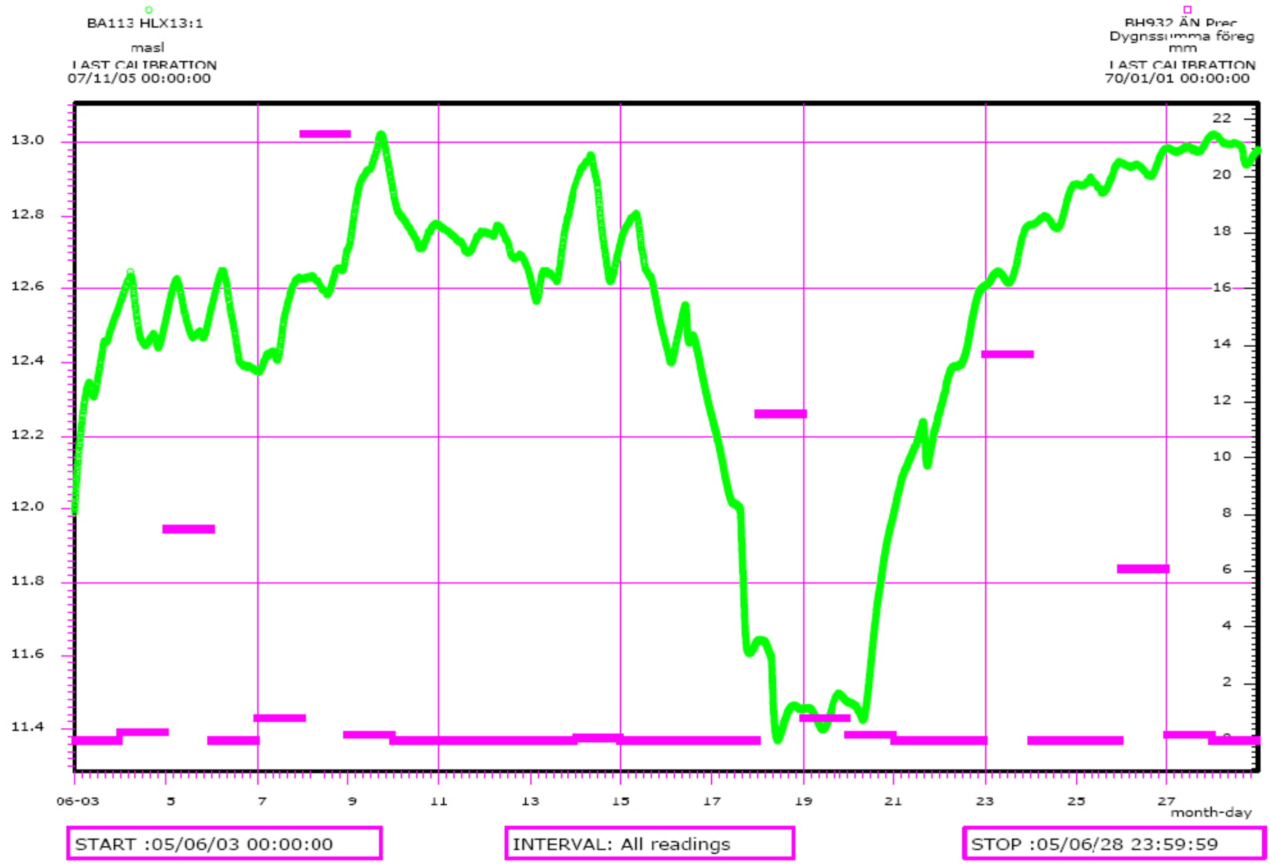


***Figure 6-3b.** Linear plot of hydraulic head (m.a.s.l.) in the observation borehole HLX13 (green line) during pumping in borehole HLX34 and precipitation in mm/d (pink).*

Flow regime and calculated parameters

Consistent T and S were obtained for the drawdown and recovery period respectively and similar match of the models with the data in log-log. It was however not possible to consitently provide good match. the lin-lin model for the complete test sequence: a good drawdown match provides too low longterm head during recovery and conversely good recovery match generated too high model head during drawdown.

Selected representative parameters

The selected representative transmissivity is $1.8 \cdot 10^{-4}$ m^2/s and a storativity of $6.6 \cdot 10^{-5}$ derived from the recovery phase.

6.3 Interference test in HLX37

Borehole responses when pumping HLX37 is shown in Figure 6-12 and in the reponse matrix in Appendix 3. Below results are presented and discussed for the sections which showed a response.

6.3.1 Pumping borehole HLX37

General test data for the pumping test in HLX37 are presented in Table 6-4. The borehole is cased to 12.0 m. The uncased interval of the borehole is thus c. 12.0–199.8 m.

Comments on the test

The test was performed as a constant flow rate pumping test. The flow rate was c. 36 L/min and the duration of the flow period was c. 6 days. A total drawdown during the flow period of 21.5 m and a total recovery at the end of the recovery period of 21.1 m was observed (cf. Figure 6-4).

Flow regime and calculated parameters

During both the flow and recovery period, wellbore storage effects are followed by dominating pseudo-radial flow after c. 70 minutes. At the end of both periods a relatively rapid decrease in the derivatives indicates a possible constant head boundary or transition to pseudo-spherical (leaky) flow.

Selected representative parameters

Transient evaluation was performed by applying the Dougerthy-Babu model to a confined aquifer model. The selected representative transmissivity is $2.2 \cdot 10^{-5}$ m^2/s for an estimated storativity of $3.3 \cdot 10^{-6}$. The parameter values from the flow period are selected as the most representative. The agreement in evaluated parameter values between the flow and recovery period is good.

Table 6-4. General test data for the pumping test in HLX37: 12.0–199.8 m.

General test data			
Pumping borehole	HLX37		
Test type[1)]	Constant rate drawdown and recovery test		
Test section (open borehole/packed-off section):	Open borehole		
Test no	1		
Field crew	SKB		
Test equipment system			
General comment	Interference test		
	Nomenclature	**Unit**	**Value**
Borehole length	L	m	199.8
Casing length	L_c	m	12.0
Test section – secup	Secup	m	12.0
Test section – seclow	Seclow	m	199.8
Test section length	L_w	m	187.8
Test section diameter[2)]	$2 \cdot r_w$	mm	140
Test start (start of flow period)		yymmdd hh:mm:ss	051018 11:34
Packer expanded		yymmdd hh:mm:ss	
Start of flow period		yymmdd hh:mm:ss	051018 11:34:20
Stop of flow period		yymmdd hh:mm:ss	051024 11:06:50
Test stop (stop of flow period)		yymmdd hh:mm	051024 11:06
Total flow time	t_p	min	8,612
Total recovery time	t_F	min	14,184
Pressure data			
Relative pressure in test section before start of flow period	p_i	m	82.2
Relative pressure in test section before stop of flow period	p_p	m	60.7
Relative pressure in test section at stop of recovery period	p_F	m	81.8
Pressure change during flow period (p_i–p_p)	dp_p	m	21.5
Flow data			
Flow rate from test section just before stop of flow period [3)]	Q_p	m^3/s	0.000542
Mean (arithmetic) flow rate during flow period	Q_m	m^3/s	0.0006
Total volume discharged during flow period	V_p	m^3	310

[1)] Constant Head injection and recovery, Constant Rate withdrawal and recovery or Constant Drawdown and recovery.

[2)] Nominal diameter.

[3)] The flow meter was out of order for the last days and the number given is an estimation of the actual flow.

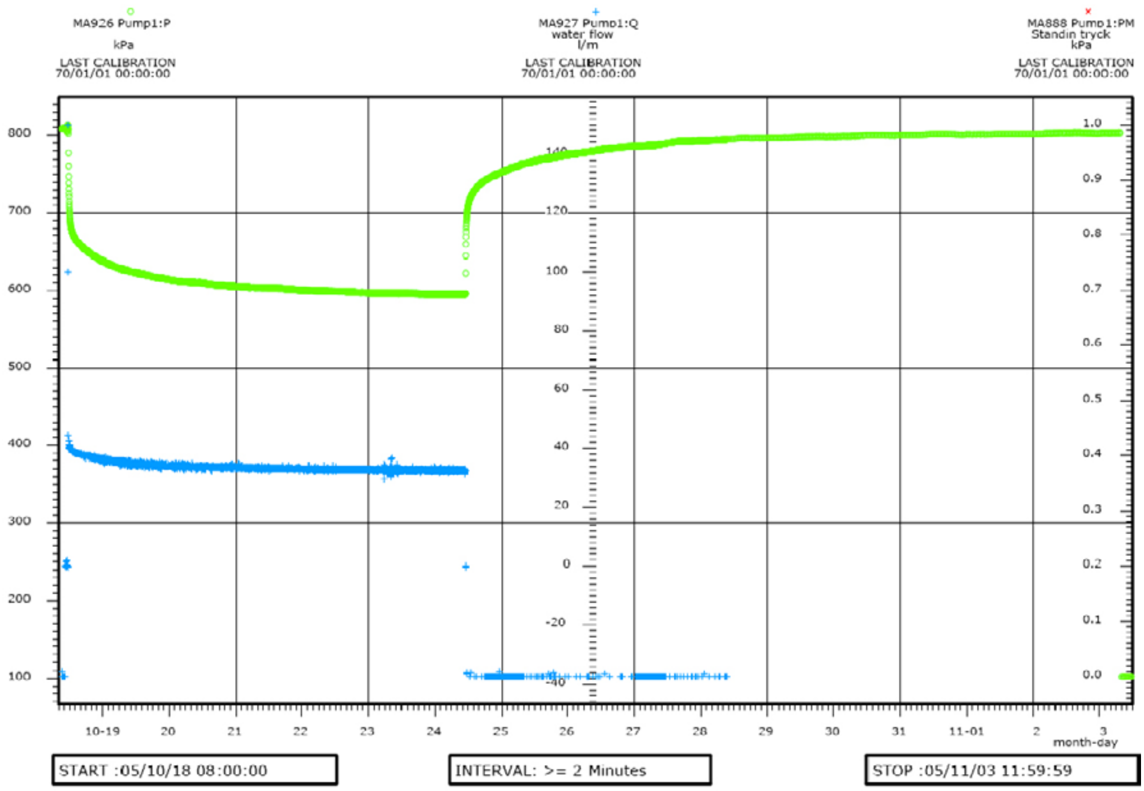


Figure 6-4. *Linear plot of flow rate and pressure versus time in pumping borehole HLX37.*

6.3.2 Observation borehole HLX28

In Figure 6-5 an overview of the pressure response in observation borehole HLX28 is shown. General test data from the observation section HLX28:6.0–154.2 m, are presented in Table 6-5. The borehole is cased to 6.0 m. The uncased interval of this section is thus c. 6.0–154.2 m.

Comments on the test

In this section a clear response is observed. However, tidal oscillations disturb the pressure response from the pumping to a certain degree.

The calculated Index 1 (r_s^2/t_L) is rated as “high”, Index 2 (s_p/Q_p) as “low” and the new Index 2 $(s_p/Q_p)\cdot\ln(r_s/r_0)$ as “medium”.

Table 6-5. General test data from the observation section HLX28: 6.0–154.2 m during the interference test in HLX37.

Pressure data	Nomenclature	Unit	Value
Hydraulic head in test section before start of flow period	h_i	m.a.s.l.	13.7
Hydraulic head in test section before stop of flow period	h_p	m.a.s.l.	12.4
Hydraulic head in test section at stop of recovery period	h_F	m.a.s.l.	13.5
Hydraulic head change during flow period (h_i–h_p)	dh_p	m	1.3

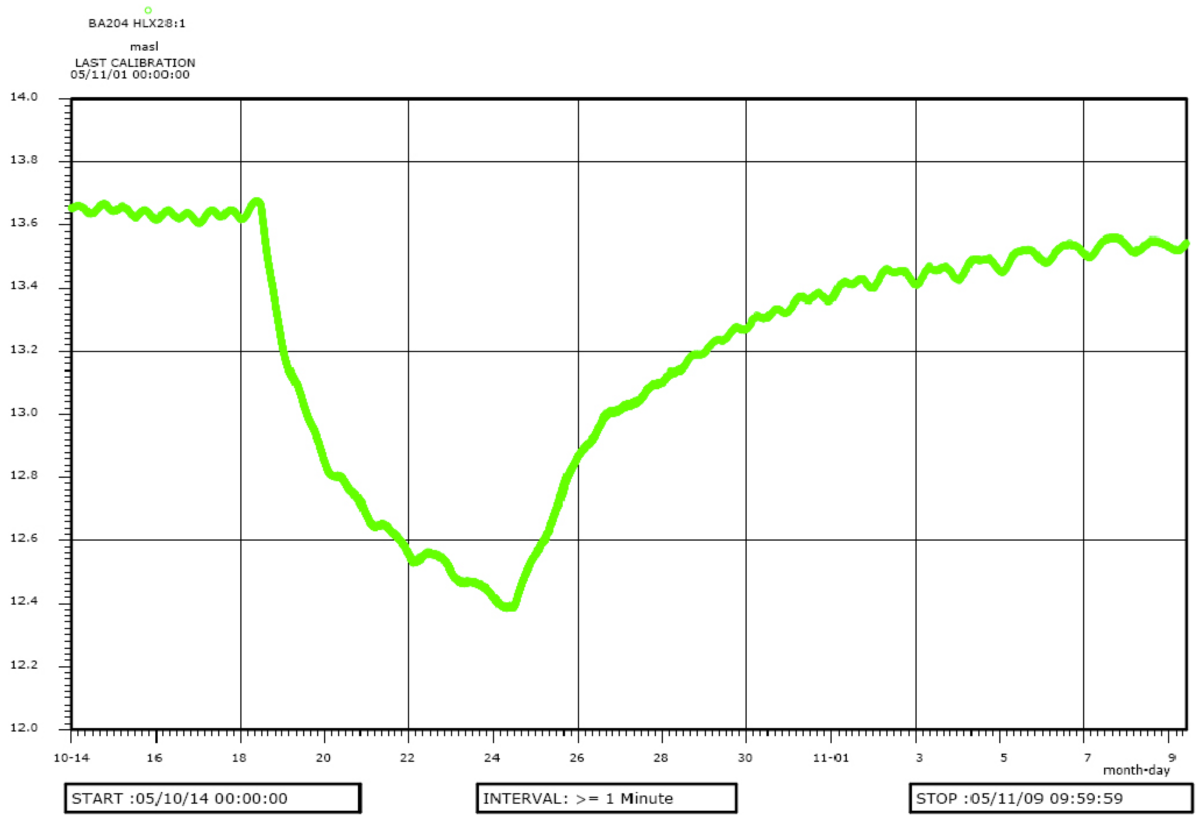


Figure 6-5. *Linear plot of pressure versus time in the observation borehole HLX28 during pumping in borehole HLX37.*

Flow regime and calculated parameters

At the end of both the flow and recovery period pseudo-radial flow is dominating. The flow period is dominated by PRF during c. 1,300–8,500 min and the recovery period during c. 1,300–6,200 min. The early response may possibly indicate another kind of flow regime or alternatively, the presence of an apparent no-flow boundary by the end. The transient evaluation is based on the late time response during both the flow and recovery period. The responses during the flow and recovery period respectively are consistent.

Selected representative parameters

The transient evaluation of the flow period is selected as representative for the test. Transient evaluation was performed by applying the Theis model to a confined aquifer. The selected representative transmissivity value is $1.2 \cdot 10^{-4}$ m^2/s and storativity $1.9 \cdot 10^{-5}$.

6.3.3 Observation borehole HLX32

In Figure 6-6 an overview of the head response in observation borehole HLX32 is shown. General test data from the observation section HLX32:16.0–162.6 m, are presented in Table 6-6. The borehole is cased to 12.3 m. The borehole has a section from 12.3–15.0 m in which no pressure data were recorded.

Comments on the test

Since the tidal oscillations are of the same magnitude as the pressure response from the pumping they strongly disturb the transient evaluation. The calculated Index 1 (r_s^2/t_L) is rated as "low", Index 2 (s_p/Q_p) as "low" and the new Index 2 $(s_p/Q_p) \cdot \ln(r_s/r_0)$ as "low".

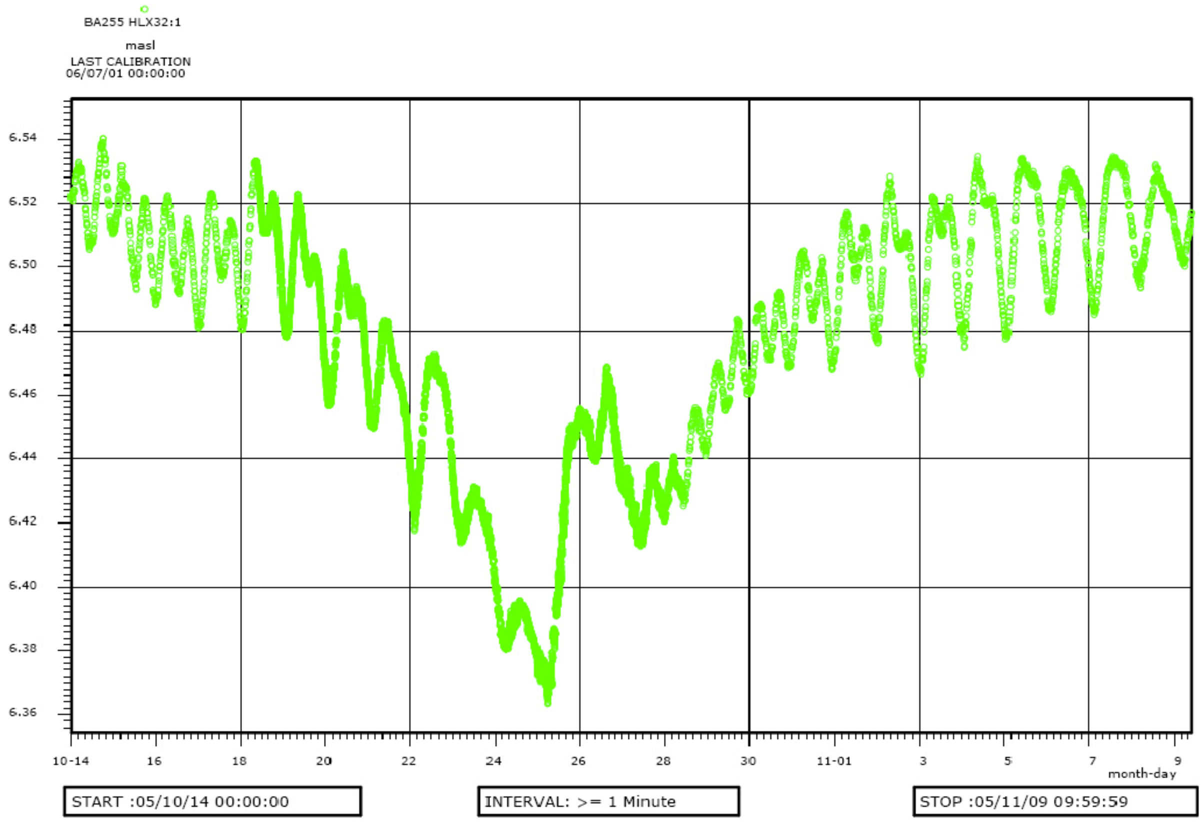


Figure 6-6. *Linear plot of head versus time in the observation borehole HLX32 during pumping in borehole HLX37.*

Table 6-6. General test data from the observation section HLX32: 16.0–162.6 m during the interference test in HLX37.

Pressure data	Nomenclature	Unit	Value
Hydraulic head in test section before start of flow period	h_i	m.a.s.l.	6.5
Hydraulic head in test section before stop of flow period	h_p	m.a.s.l.	6.4
Hydraulic head in test section at stop of recovery period	h_F	m.a.s.l.	6.6
Hydraulic head change during flow period (h_i–h_p)	dh_p	m	0.1

Flow regime and calculated parameters

No certain evaluation of flow regimes can be made for this section. The responses and the evaluated parameters during the flow and recovery period respectively are consistent but very uncertain due to the small head change and influence from tidal effects.

Selected representative parameters

The transient evaluation of the flow period is selected as the most representative for the test. Transient evaluation was performed by applying the Theis' model for a confined aquifer. The selected representative transmissivity is $3.1 \cdot 10^{-4}$ m^2/s and the estimated storativity $8.3 \cdot 10^{-4}$.

6.4 Interference test in HLX42

Borehole responses when pumping HLX42 is shown in Figure 6-13 and in the reponse matrix in Appendix 3. Below results are presented and discussed for the sections which showed a response.

6.4.1 Pumping borehole HLX42

General test data for the pumping test in HLX42 are presented in Table 6-7. The borehole is cased to 9.1 m. The uncased interval of this section is thus c. 9.1–152.6 m.

Table 6-7. General test data for the pumping test in HLX42: 9.1–152.6 m.

General test data			
Pumping borehole	HLX42		
Test type[1)]	Constant rate drawdown and recovery test		
Test section (open borehole/packed-off section):	Open borehole		
Test no	1		
Field crew	SKB		
Test equipment system			
General comment	Interference test		
	Nomenclature	**Unit**	**Value**
Borehole length	L	m	152.6
Casing length	L_c	m	9.1
Test section – secup	Secup	m	9.1
Test section – seclow	Seclow	m	152.6
Test section length	L_w	m	143.5
Test section diameter[2)]	$2 \cdot r_w$	mm	139
Test start (start of flow period)		yymmdd hh:mm	051018 11:34
Packer expanded		yymmdd hh:mm:ss	
Start of flow period		yymmdd hh:mm:ss	051018 11:34:20
Stop of flow period		yymmdd hh:mm:ss	051024 11:06:50
Test stop (stop of flow period)		yymmdd hh:mm	051024 11:06
Total flow time	t_p	min	4,377
Total recovery time	t_F	min	4,204
Pressure data			
Relative pressure in test section before start of flow period	p_i	m	79.0
Relative pressure in test section before stop of flow period	p_p	m	47.0
Relative pressure in test section at stop of recovery period	p_F	m	78.5
Pressure change during flow period (p_i–p_p)	dp_p	m	31.9
Flow data			
Flow rate from test section just before stop of flow period [3)]	Q_p	m^3/s	0.00111
Mean (arithmetic) flow rate during flow period	Q_m	m^3/s	0.00111
Total volume discharged during flow period	V_p	m^3	292

[1)] Constant Head injection and recovery, Constant Rate withdrawal and recovery or Constant Drawdown and recovery.

[2)] Nominal diameter.

[3)] The flow meter was out of order for the last days and the number given is an estimation of the actual flow.

Comments on the test

The test was performed as a constant flow rate pumping test with slightly decreasing flow rate. The mean flow rate was c. 67 L/min and the duration of the flow period was c. 3 days. A total drawdown during the flow period of 32.0 m and a total recovery at the end of the recovery period of 31.5 m was observed (cf. Figure 6-7).

Flow regime and calculated parameters

During both the flow and recovery period, wellbore storage effects are followed by dominating pseudo-radial flow. During the flow period a period of PRF is indicated after c. 100 min to c. 4,000 min. The recovery period displays a period of PRF from c. 300 min to c. 700 min followed by an apparent NFB.

Selected representative parameters

The parameter values estimated from the flow period is selected as the most representative. Evaluation of the flow period was performed by applying the Dougherty-Babu model to a confined aquifer. The selected representative transmissivity value is $4.3 \cdot 10^{-5}$ m²/s for an estimated storativity of $4.6 \cdot 10^{-6}$.

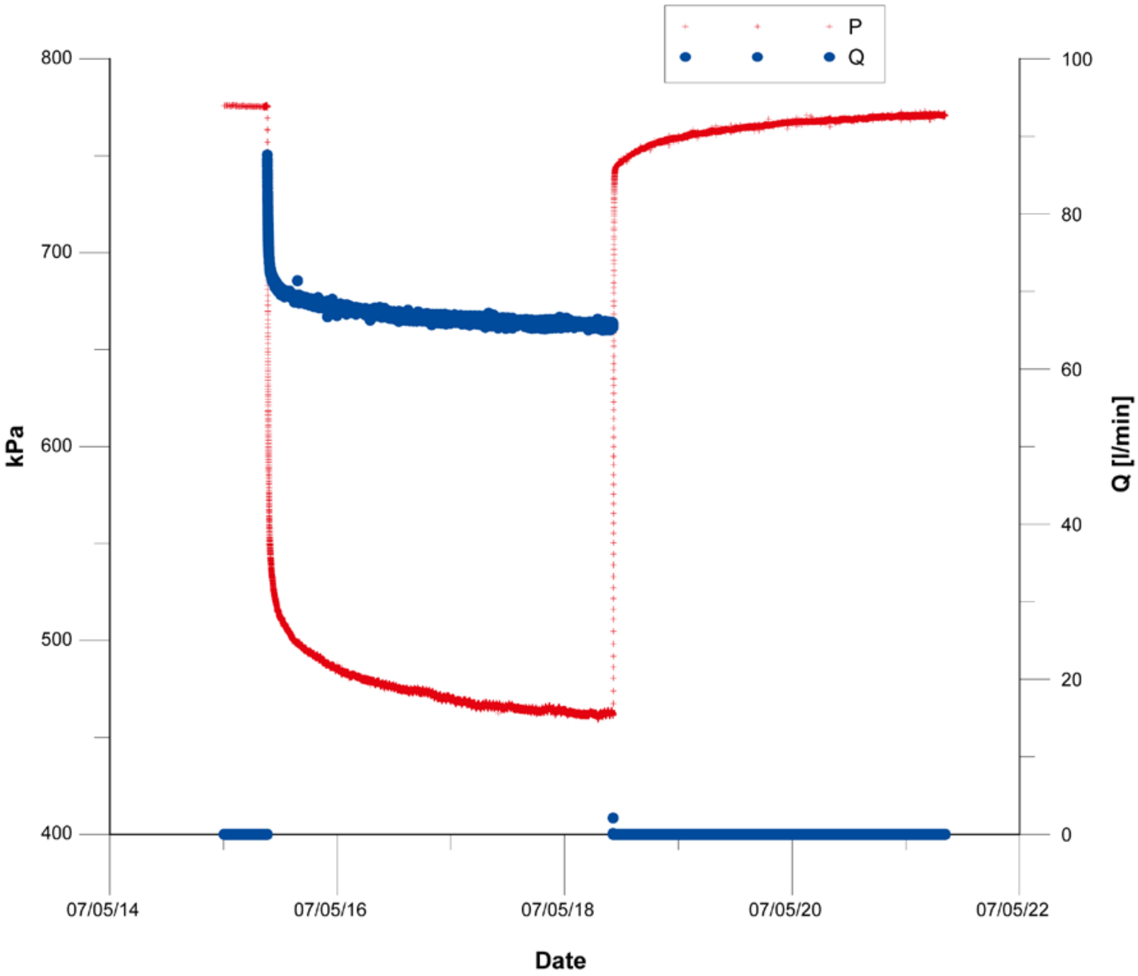


Figure 6-7. *Linear plot of flow rate and pressure versus time in the pumping borehole HLX42.*

6.4.2 Observation borehole KLX16A

Section 1 in this borehole appears to be virtually unaffected by the pumping in HLX42 while sections 2 and 3 show clear responses, cf. Figure 6-8.

Observation section KLX16A:1

Section 1:327.0–433.6 m appears to be virtually unaffected by the pumping in HLX42, cf. Figure 6-8.

Observation section KLX16A:2

In Figure 6-8, an overview of the pressure response in observation section KLX16A:2: 191.0–326.0 m is shown. General test data are presented in Table 6-8.

Table 6-8. General test data from the observation section KLX16A:2 191.0–326.0 m during the interference test in HLX42.

Pressure data	Nomenclature	Unit	Value
Hydraulic head in test section before start of flow period	h_i	m.a.s.l.	8.0
Hydraulic head in test section before stop of flow period	h_p	m.a.s.l.	3.9
Hydraulic head in test section at stop of recovery period	h_F	m.a.s.l.	6.2
Hydraulic head change during flow period (h_i–h_p)	dh_p	m	4.1

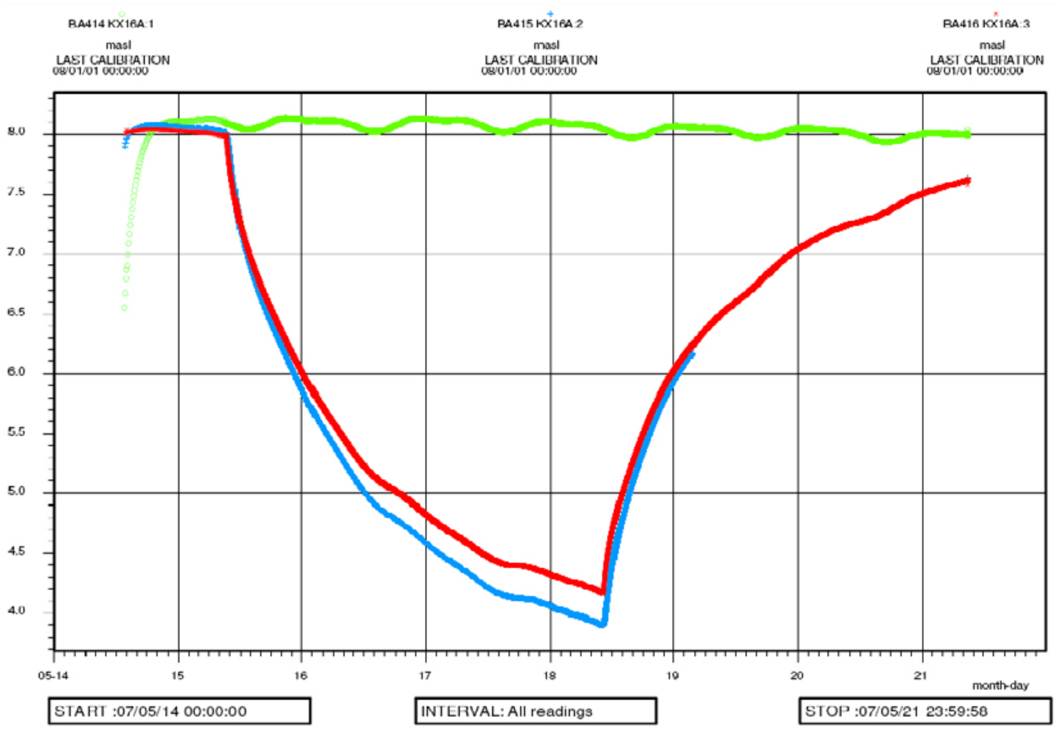


Figure 6-8. *Linear plot of ground water level in the observation borehole KLX16A during pumping in borehole HLX42. Section 1 seems to be unaffected by the pumping in HLX42 while sections 2 and 3 show clear responses.*

Comments on the test

A very clear response form the pumping in HLX42 is shown in this section. No data were available after 2007-05-19 which makes the recovery period short. A total drawdown during the flow period of c. 4.1 m and a total recovery at the end of the recovery period of c. 2.3 m was observed. The calculated Index 1 (r_s^2/t_L) is rated as “high”, Index 2 (s_p/Q_p) as “low” and new Index 2 (s_p/Q_p)·ln(r_s/r_0) as “medium”.

Flow regime and calculated parameters

During both the flow and recovery period a transition to a possible pseudo-radial flow regime is indicated by the end. However, alternative evaluations are possible, e.g. apparent no-flow boundaries after c. 200 min or possibly, pseudo-linear flow. During the flow period the period a PRF is indicated between c. 800 min to c. 4,000 min. The recovery period displays a possible PRF from c. 500 min to c. 800 min. Consistent results of the evaluated parameter values are obtained from the flow and recovery period respectively.

Selected representative parameters

The parameter values estimated from the flow period are selected as the most representative. Transient evaluation was performed by applying the Theis model for a confined aquifer. The selected representative transmissivity value is $6.9 \cdot 10^{-5}$ m^2/s and the estimated storativity $5.1 \cdot 10^{-5}$.

Observation section KLX16A:3

In Figure 6-8, an overview of the pressure responses in observation section KLX16A:3: 11.3–190.0 m is shown. General test data are presented in Table 6-9.

Comments on the test

A very clear response form the pumping in HLX42 is shown in this section. A total drawdown during the flow period of c. 3.8 m and a total recovery at the end of the recovery period of c. 3.4 m was observed. The calculated Index 1 (r_s^2/t_L) is rated as “high”, Index 2 (s_p/Q_p) as “low” and the new Index 2 (s_p/Q_p)·ln(r_s/r_0) as “medium”.

Flow regime and calculated parameters

During both the flow and recovery period a transition to a possible pseudo-radial flow regime is indicated by the end. However, alternative evaluations are possible, e.g. apparent no-flow boundaries after c. 200 min or possibly, pseudo-linear flow. During the flow period a possible PRF is indicated between c. 800 min to c. 4,000 min. The recovery period displays a possible PRF from c. 500 min to c. 1,000 min. Consistent results of the evaluated parameter values are obtained from the flow and recovery period respectively.

Table 6-9. General test data from the observation section KLX16A:3 11.3–190.0 m during the interference test in HLX42.

Pressure data	Nomenclature	Unit	Value
Hydraulic head in test section before start of flow period	h_i	m.a.s.l.	8.0
Hydraulic head in test section before stop of flow period	h_p	m.a.s.l.	4.2
Hydraulic head in test section at stop of recovery period	h_F	m.a.s.l.	7.6
Hydraulic head change during flow period (h_i–h_p)	dh_p	m	3.8

Selected representative parameters

The parameter values estimated from the flow period are selected as the most representative. Transient evaluation was performed by applying the Theis model for a confined aquifer. The selected representative transmissivity is $7.5 \cdot 10^{-5}$ m^2/s and the estimated storativity $9.5 \cdot 10^{-5}$.

6.5 Response analysis

Response analysis including a response matrix (Appendix 3) according to the methodology description for interference tests was made. The estimated response time lags (dt_L) in the responding observation sections during the different interference tests are shown in Table 6-10. The lag times were derived from the drawdown curves in the observation borehole sections at an actual drawdown of 0.1 m. No corrections of the drawdown for natural trends caused by e.g. drought or precipitation have been made. Because of the oscillating behaviour of the measured pressure in some of the observation sections, it was difficult to determine the exact time to reach a 0.1 m drawdown. It was possible, however, to make an approximate estimate from the drawdown curves.

Only observation sections with a presumed, relatively clear, pressure response are included in the response analysis. In Tables 6-10 and 6-11 all observation sections are presented.

The normalized squared distance to the pumping borehole with respect to the time lag was calculated. This parameter is directly related to the hydraulic diffusivity (T/S) of the formation. In addition, the normalized drawdown with respect to the flow rate was calculated and is presented in Table 6-11. From these parameters different response indices were calculated according to Section 5.5.1.

In the figures below, response diagrams showing the distribution of the presumptive responding observation sections are presented. In the diagrams, Index 1 has been plotted versus Index 2 new as defined in Section 5.5.1. Clearly, sections located towards the upper right corner in the diagrams correspond to sections which are well connected to the pumping borehole with high hydraulic diffusivities and distinct responses. On the other hand, sections with delayed and small responses and poorly connected to the pumping sections with lower hydraulic diffusivity are located towards the lower left corner. For the index classification of the responses, see Section 5.5.1.

The following response parameters are used in Tables 6-10 and 6-11 as well as in Figure 6-9:

$r_s^2/dt_L[s = 0.1\ m]$ = normalized squared distance with respect to the time lag (m^2/s).

$dt_L[s = 0.1\ m]$ = time lag after start of pumping (s) at a drawdown of s = 0.1 m in the observation section.

r_s = 3D-distance between the hydraulic point of application (hydr. P.a.) in the pumping borehole and observation borehole (m).

s_p/Q_p = normalized drawdown with respect to the pumping flow rate (s/m^2).

s_p = maximal drawdown in the actual observation borehole/section (m).

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

The interpreted normalized squared distances must be considered as rough estimates for many of the observation sections. The main reason for this fact is, as mentioned above, the difficulty to estimate the time lags due to oscillating pressure. The maximal drawdown is not always at stop of pumping, e.g. due to precipitation or other disturbances by the end of the tests.

Table 6-10. Calculated response lag times and normalized response time lags for the observation sections included in the interference tests.

Pumping borehole	Observation borehole section ID	Section (m)	dt_L[s = 0.1 m] (s)	r_s (m)	r_s^2/dt_L[s = 0.1 m] (m^2/s) Index 1
HLX34	HLX35:1	65.0–151.8	3,549	171	8.25E+00
HLX34	HLX35:2	6.0–64.0	29,021	190	1.24E+00
HLX37	HLX32	16.0–162.6	408,000	511	6.40E–01
HLX37	HLX28	6.0–154.2	8,280	510	3.14E+01
HLX42	KLX16A:1	327.0–433.6	–	–	0
HLX42	KLX16A:2	191.0–326.0	1,680	176	1.84E+01
HLX42	KLX16A:3	11.3–190.0	1,020	135	1.79E+01

Table 6-11. Drawdown and normalized drawdown for the observation sections included in the interference test.

Pumping borehole	Flow rate Q_p (m^3/s)	Observation borehole section ID	Section (m)	s_p (m)	s_p/Q_p (s/m^2) Index 2	$(s_p/Q_p)\cdot\ln(r_s/r_o)$ (s/m^2) Index 2 new
HLX34	1.83E–03	HLX35:1	65.0–151.8	3.59	1,960	1.01E+04
HLX34	1.83E–03	HLX35:2	6.0–64.0	0.80	438	2.29E+03
HLX37	5.42E–04	HLX32	16.0–162.6	0.13	185	1.15E+03
HLX37	5.42E–04	HLX28	6.0–154.2	1.28	2,400	1.50E+04
HLX42	1.11E–03	KLX16A:1	327.0–433.6	–	0	0
HLX42	1.11E–03	KLX16A:2	191.0–326.0	4.11	3,690	1.91E+04
HLX42	1.11E–03	KLX16A:3	11.3–190.0	3.82	3,420	1.68E+04

Furthermore, in some cases the drawdown must be corrected, e.g. due to natural pressure trends, e.g. during draught periods. However, for the actual interference tests no such corrections of the data have been made.

The response diagrams can be used to group observation sections by the strength and lag times of their responses. Observation sections with the most distinct responses can thus be identified. In the interference test in HLX42 only two of three monitored observation sections in KLX16A responded to the pumping.

Figure 6-9 shows the response diagram during the interference test in HLX34, HLX37 and HLX42. A slow and small response was indicated in HLX35:2 during pumping in HLX34, but observation section HLX35:1 shows a more distinct response. In HLX37 the most distinct response occurred in observation borehole HLX28 as reflected by its position towards the upper right corner in the response diagram. In HLX32, a less distinct response was observed as reflected by its location more towards the lower left corner of the diagram. During the interference test in HLX42 observation sections KLX16A:2 and KLX16A:3 show very similar behaviour with distinct responses. In KLX16A:1 no response was indicated.

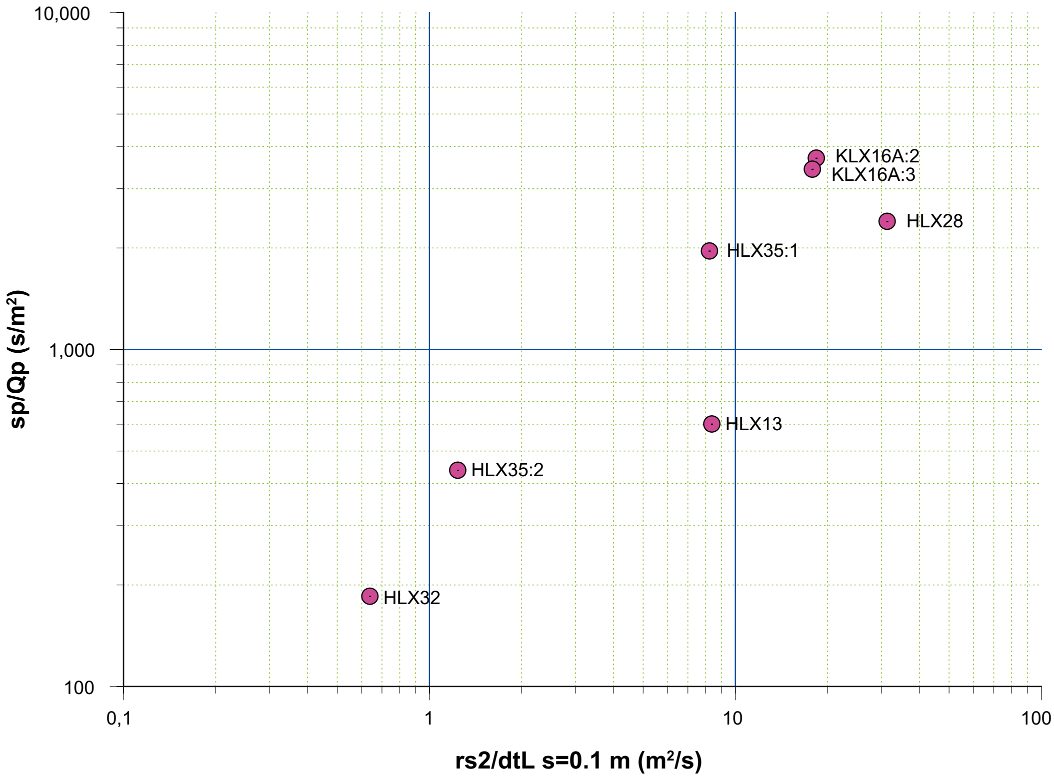


Figure 6-9. *Response diagram showing the responding observation sections during the interference tests in HLX34, HLX37 and HLX42.*

6.6 Estimation of hydraulic diffusivity

The hydraulic diffusivity of the responding observation sections can be estimated from the observed response time lag in the section according to Section 5.5.2. The time lag dt_L is here based on a drawdown s = 0.01 m in the observation section. The estimated time lags in the observation sections during the interference tests in HLX37 and HLX42 are shown in Table 6-12 together with the estimated hydraulic diffusivity T/S (Equation 5-5) of the sections. For comparison, the ratio of the estimated transmissivity and storativity T_o/S_o (measured) from the transient evaluation of the responses in these sections during the interference tests are also presented.

Table 6-12 and Figure 6-10 shows that the estimated hydraulic diffusivities from the time lags in general are similar or slightly higher compared to the ratio of T_o/S_o from the transient evaluation of the test sections, although the statistical basis is weak.

Table 6-12. Estimated response lag times and hydraulic diffusivity for the selected observation sections from the interference tests.

Pumping borehole	Observation borehole	Section (m)	Measured dt_L[s = 0.01 m] (s)	r_s (m)	T/S (m^2/s)	T_o/S_o (m^2/s)
HLX34	HLX13	11.85–200.20	24,540	462	0.74	2.73
HLX34	HLX35:1	65.0–151.8	3,549	171	3.28	1.30
HLX34	HLX35:2	6.0–64.0	29,021	190	0.67	0.33
HLX37	HLX32	16.0–162.6	408,000	511	8.80	6.32
HLX37	HLX28	6.0–154.2	8,280	510	0.78	0.37
HLX42	KLX16A:2	191.0–326.0	1,680	176	1.89	1.35
HLX42	KLX16A:3	11.3–190.0	1,020	135	1.94	0.79

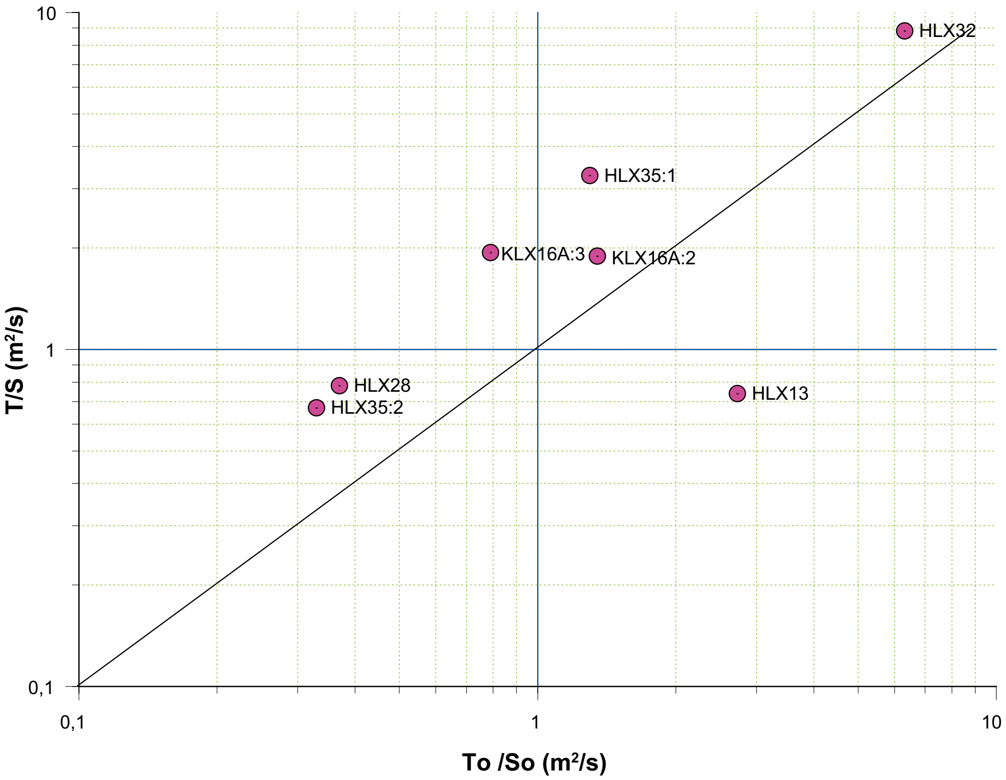


Figure 6-10. *Comparison of estimated hydraulic diffusivity, of observation sections from the interference tests in HLX34, HLX37 and HLX42.*

6.7 Summary of the results of the interference tests

Compilations of measured test data from the interference test are shown in Tables 6-13 and 6-14. In Tables 6-15 and 6-16 calculated hydraulic parameters for the pumping boreholes and the evaluated observation sections are presented.

Responses were detected in observation boreholes as shown in Figure 6-11 for the HLX34 tests, Figure 6-12 for the HLX37 test and Figure 6-13 for the HLX42 test.

Nomenclature used is shown in Table 6-17.

During hydraulic interference tests the estimated transmissivity of observation sections may sometimes be more weighted on the hydraulic properties close to the pumping borehole than on the specific properties adjacent to the actual observation section, particularly at long distances. Furthermore, the estimated transmissivity (and storativity) of certain observation sections with poor hydraulic connection to the pumping borehole may be overestimated from interference tests. This may be the case for section HLX35:2 during pumping in HLX34 and HLX32 during pumping in HLX37, cf. Table 6-16. Both sections have a relatively poor hydraulic connection to the pumping boreholes according to the response diagram in Figure 9 and a lower transmissivity from flow logging /8/ and /9/.

The estimated hydraulic diffusivity of the observation sections based on the response time lags and from the transient evaluation of the interference tests respectively shows a rather good agreement, also at long distances from the pumping borehole.

Table 6-13. Summary of test data from the pumping boreholes during the interference tests.

Pumping borehole ID	Section (m)	Test Type[1)]	h_i (m)	h_p (m)	h_F (m)	Q_p (m^3/s)	Q_m (m^3/s)	V_p (m^3)
HLX34	9.0–151.8	1B	63.5	54.7		1.83E–03		
HLX37	12.0–199.8	1B	82.2	60.7	81.8	5.42E–04	6.0E–04	310
HLX42	9.10–152.6	1B	79.0	47.0	78.5	1.11E–03	1.11E–03	292

Table 6-14. Summary of test data from the observation sections involved in the interference tests.

Pumping borehole ID	Borehole ID	Section (m)	Test Type[1)]	h_i (m.a.s.l.)	h_p (m.a.s.l.)	h_F (m.a.s.l.)
HLX34	HLX35:1	65.0–151.8	2	14.10	10.50	14.40
HLX34	HLX35:2	6.0–64.0	2	12.00	11.20	11.95
HLX37	HLX32	16.0–162.6	2	6.50	6.40	6.60
HLX37	HLX28	6.0–154.2	2	13.70	12.40	13.50
HLX42	KLX16A:2	191.0–326.0	2	8.00	3.90	6.20
HLX42	KLX16A:3	11.3–190.0	2	8.00	4.20	7.60

[1)] 1B: Pumping test-submersible pump, 2: Interference test (observation borehole during pumping in another borehole).

Table 6-15. Summary of calculated hydraulic parameters from the single-hole tests.

Pumping borehole ID	Section (m)	Test type	Q/s (m^2/s)	T_M (m^2/s)	T_T (m^2/s)	ξ (–)	C (m^3/Pa)	S* (–)
HLX34	9.0–151.8	1B	2.08E–04	2.63E–04	1.67E–04	0.8	3.8E–06	1.00E–04
HLX37	12.0–199.8	1B	2.50E–05	3.40E–05	2.20E–05	–5.2	2.2E–06	3.30E–06
HLX42	9.10–152.6	1B	3.40E–05	7.20E–05	4.30E–05	–2.9	3.1E–06	4.60E–06

Table 6-16. Summary of calculated hydraulic parameters from the observation boreholes during the interference tests.

Pumping borehole ID	Observation borehole ID	Section (m)	Test type	T_o (m^2/s)	S_o (–)	T_o/S_o (m^2/s)
HLX34	HLX13		2	1.80E–04	6.60E–05	2.73
HLX34	HLX35:1	65.0–151.8	2	1.30E–04	1.00E–04	1.30
HLX34	HLX35:2	6.0–64.0	2	3.60E–04	1.10E–03	0.33
HLX37	HLX32	16.0–162.6	2	3.10E–04*	8.30E–04*	0.37*
HLX37	HLX28	6.0–154.2	2	1.20E–04	1.90E–05	6.32
HLX42	KLX16A:2	191.0–326.0	2	6.90E–05	5.10E–05	1.35
HLX42	KLX16A:3	11.3–190.0	2	7.50E–05	9.50E–05	0.79

* Uncertain.

Table 6-17. Nomenclature of parameters.

Parameter	Description
Q/s	Specific flow for the pumping/injection borehole.
T_M	Steady state transmissivity from Moye´s equation.
T_T	Transmissivity from transient evaluation of single-hole test.
T_o	Transmissivity from transient evaluation of interference test.
S_o	Storativity from transient evaluation of interference test.
T_o/S_o	Hydraulic diffusivity (m^2/s).
K'/b'	Leakage coefficient from transient evaluation of interference test.
S*	Assumed storativity by the estimation of the skin factor in single-hole tests.
C	Wellbore storage coefficient (only for pumping borehole).
ξ	Skin factor (only for pumping borehole).

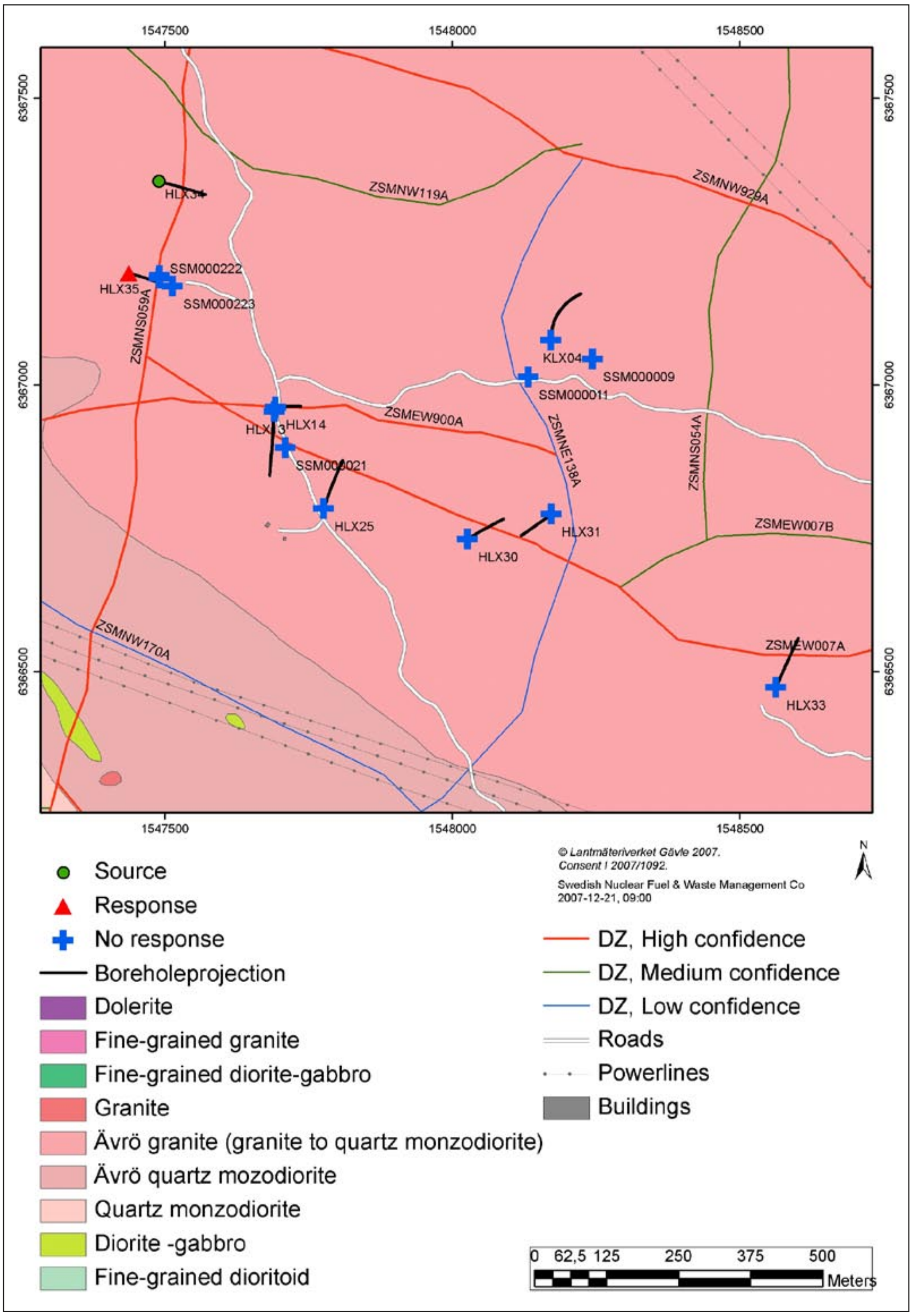


Figure 6-11. *Responses when pumping HLX34.*

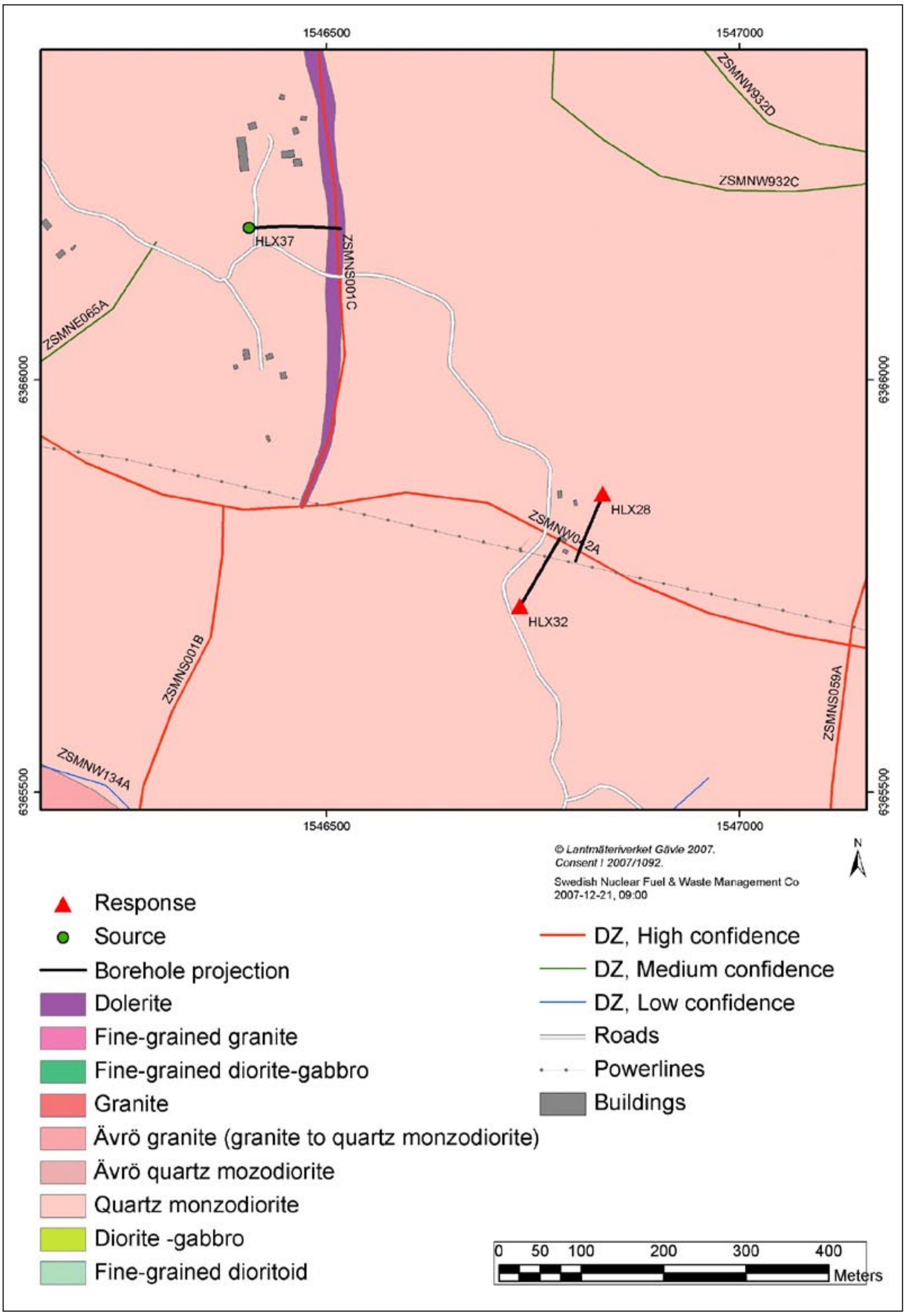


Figure 6-12. *Responses when pumping HLX37.*

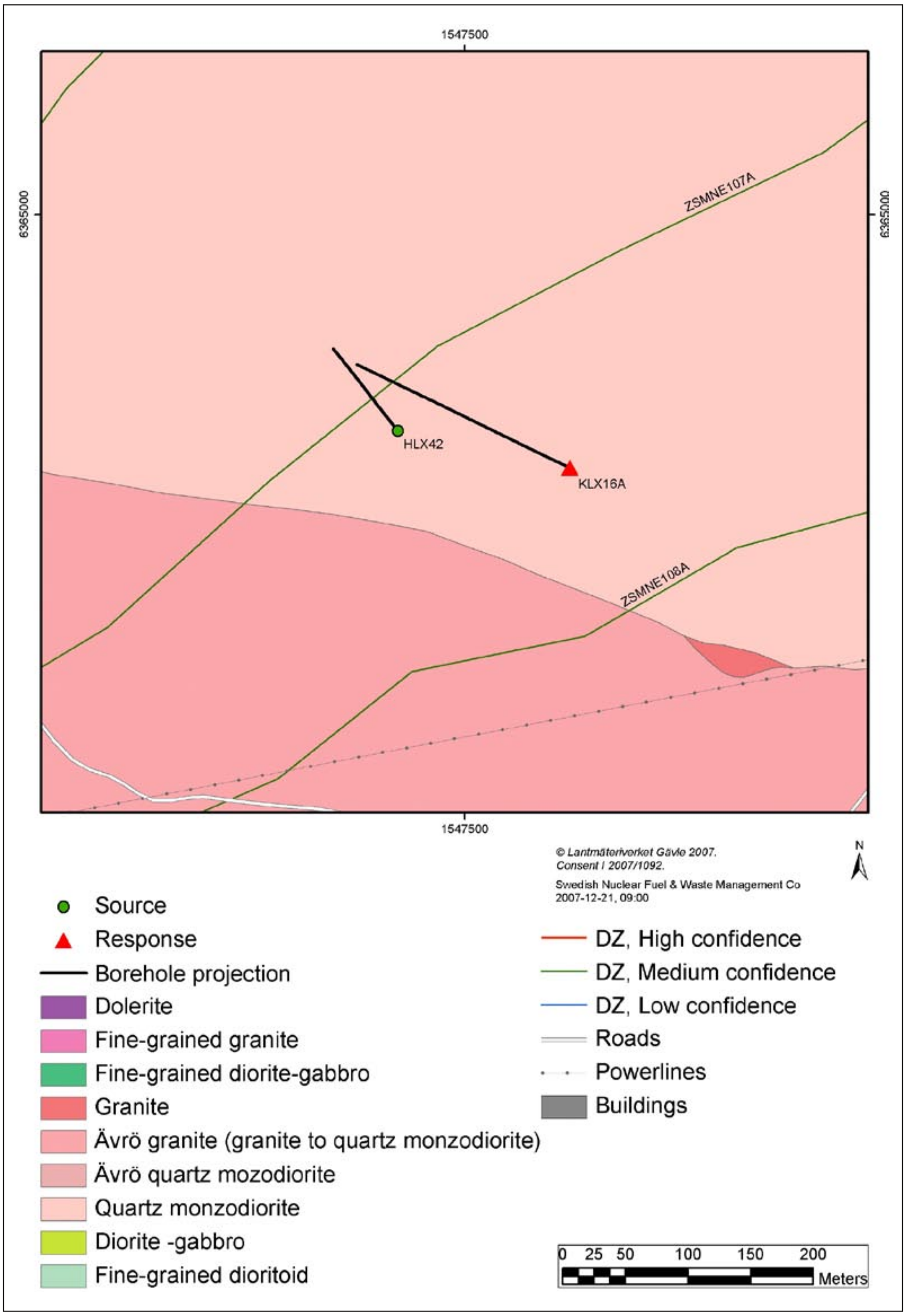


Figure 6-13. *Responses when pumping HLX42.*

7 References

/1/ **Ludvigson J-E, Hansson L, Hjerne C, 2007.** Method evaluation of single-hole hydraulic injection tests at site investigations in Forsmark. SKB P-07-80, Svensk Kärnbränslehantering AB.

/2/ **SKB, 2006.** Preliminary site description. Laxemar subarea – version 1.2. SKB R-06-10, Svensk Kärnbränslehantering AB

/3/ **Ludvigson J-E, Jönsson S, Levén J, 2004.** Forsmark site investigation. Hydraulic evaluation of pumping activities prior to hydro-geochemical sampling in borehole KFM03A – Comparison with results from difference flow logging. SKB P-04-96, Svensk Kärnbränslehantering AB.

/4/ **Dougherty D E, Babu D K, 1984.** Flow to a partially penetrating well in a double-porosity reservoir. Water Resour. Res., 20 (8), 1116–1122.

/5/ **Hantush M S, 1955.** Nonsteady radial flow in an infinite leaky aquifer. Am. Geophys. Union Trans., v. 36, no 1, pp 95–100.

/6/ **Streltsova T D, 1988**. Well testing in heterogeneous formations. Exxon Monograph. John Wiley and sons.

/7/ **Moench A F, 1985.** Transient flow to a large-diameter well in an aquifer with storative semiconfining layers, Water Resources Research, vol. 21, no. 8, pp. 1121–1131.

/8/ **Rohs S, 2006.** Flow logging in boreholes HLX21, HLX35 and HLX38. Subarea Laxemar. Oskarshamn site investigation. SKB P-06-147, Svensk Kärnbränslehantering AB.

/9/ **Rohs S, van der Wall R, Wolf P, 2007.** Flow logging in boreholes HLX14, HLX20, HLX27, HLX28, HLX32, HLX33, HLX37, HLX39 and HLX43. Subarea Laxemar. Oskarshamn site investigation. SKB P-06-319, Svensk Kärnbränslehantering AB.

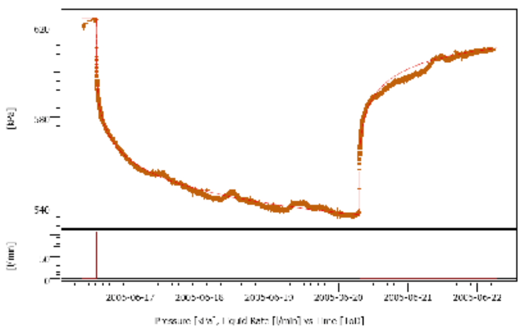
/10/ Aqtesolv v 4 by HydroSolve Inc, USA.

/11/ Saphir v 4 by Kappa Engineering, France.

Test summary sheets

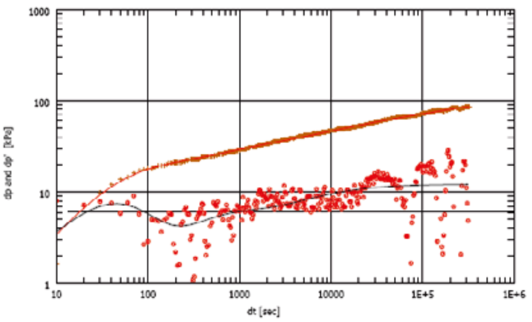
Test Summary Sheet – Pumping borehole HLX34			
Project:	PLU	Test type:	1B
Area:	Oskarshamn	Test no:	1
Borehole ID:	HLX34	Test start:	2005-06-16 13:20
Test section (m):	9.0-158.1	Responsible for test execution:	SKB field crew
Section diameter, $2 \cdot r_w$ (m):	0.137	Responsible for test evaluation:	SKB Mansueto Morosini

Linear plot Q and p

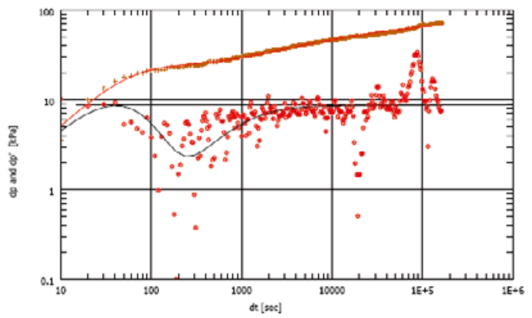


Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa)			
p_i (kPa)	623.2		
p_p (kPa)	537.1	p_F (kPa)	
Q_p (m^3/s)	$1.83 \cdot 10^{-3}$		
tp (min)	5451	t_F (min)	
S^* (-)	$1.0 \cdot 10^{-4}$	S^* (-)	
EC_w (mS/m)			
$Temp_w$(gr C			
Derivative factor	0.1	Derivative factor	0.1
r (m)		r (m)	
Results		**Results**	
Q/s (m^2/s)			
T_M (m^2/s)			
Flow regime:	WBS-> double porosity-> parallel no flow faults	Flow regime:	WBS-> double porosity-> IARF
dt_1 (min)		dt_1 (min)	
dt_2 (min)		dt_2 (min)	
T (m^2/s)	$2.2 \cdot 10^{-4}$	T (m^2/s)	$1.6 \cdot 10^{-4}$
S (-)		S (-)	
K_s (m/s)		K_s (m/s)	
S_s (1/m)		S_s (1/m)	
C (m^3/Pa)	$4.0 \cdot 10^{-6}$	C (m^3/Pa)	$3.0 \cdot 10^{-6}$
C_D (-)		C_D (-)	
ξ (-)	-4.7	ξ (-)	-5.4
T_{GRF}(m^2/s)		T_{GRF}(m^2/s)	
S_{GRF}(-)		S_{GRF}(-)	
D_{GRF} (-)		D_{GRF} (-)	

Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Selected representative parameters.			
dt_1 (min)		C (m^3/Pa)	$4.0 \cdot 10^{-6}$
dt_2 (min)		C_D (-)	
T_T (m^2/s)	$2.2 \cdot 10^{-4}$	ξ (-)	-5
S* (-)	$1.0 \cdot 10^{-4}$		
K_s (m/s)			
S_s (1/m)			

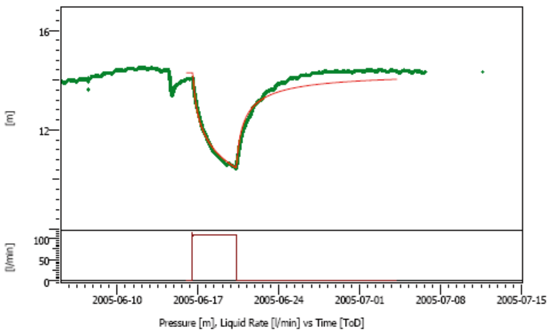
Comments:

Both drawdown and recovery show a certain double porosity type of behaviour followed by flow along no flow parallel faults. Consistent T and skin were obtained for the respective phases and good match between data and models.

Test Summary Sheet – Observation borehole HLX35:1 (pumping borehole HLX34)

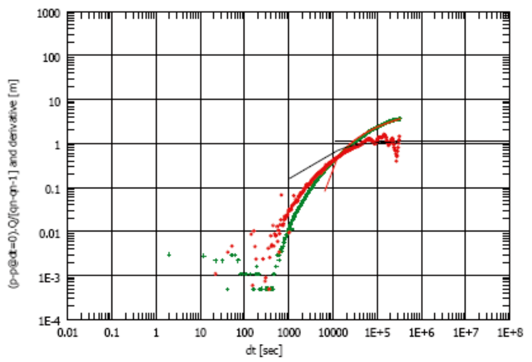
Project:	PLU	Test type:	2
Area:	Oskarshamn	Test no:	1
Borehole ID:	HLX35	Test start:	2005-06-16 13:20
Test section (m):	65.0-151.8	Responsible for test execution:	SKB field crew
Section diameter, $2 \cdot r_w$ (m):	0.140	Responsible for test evaluation:	SKB Mansueto Morosini

Linear plot Q and p

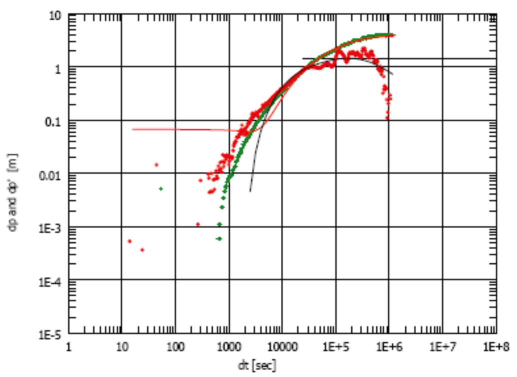


Flow period		Recovery period	
Indata		**Indata**	
h_0 (masl)			
h_i (masl)	14.1		
h_p (masl)	10.5	h_F (masl)	
Q_p (m^3/s)			
tp (min)		t_F (min)	
S^* (-)		S^* (-)	
EC_w (mS/m)			
$Temp_w$(gr C			
Derivative factor	0.1	Derivative factor	0.1
r (m)	171.1	r (m)	171.1
Results		**Results**	
Q/s (m^2/s)			
T_M (m^2/s)			
Flow regime:	IARF	Flow regime:	IARF
dt_1 (min)		dt_1 (min)	
dt_2 (min)		dt_2 (min)	
T (m^2/s)	$1.3 \cdot 10^{-4}$	T (m^2/s)	$1.0 \cdot 10^{-4}$
S (-)	$1.0 \cdot 10^{-4}$	S (-)	$9.9 \cdot 10^{-5}$
K_s (m/s)		K_s (m/s)	
S_s (1/m)		S_s (1/m)	
C (m^3/Pa)		C (m^3/Pa)	
C_D (-)		C_D (-)	
ξ (-)		ξ (-)	
T_{GRF}(m^2/s)		T_{GRF}(m^2/s)	
S_{GRF}(-)		S_{GRF}(-)	
D_{GRF} (-)		D_{GRF} (-)	

Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Selected representative parameters.			
dt_1 (min)		C (m^3/Pa)	
dt_2 (min)		C_D (-)	
T_T (m^2/s)	$1.0 \cdot 10^{-4}$	ξ (-)	
S (-)	$9.9 \cdot 10^{-5}$		
K_s (m/s)			
S_s (1/m)			

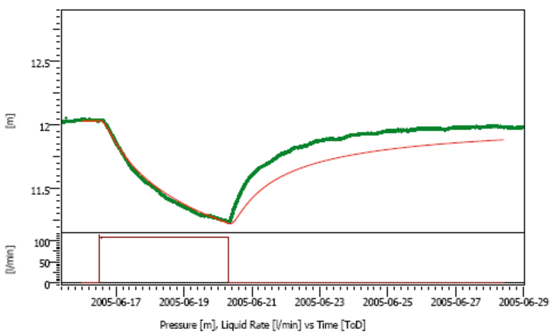
Comments:

Rather consistent T and S were obtained for the drawdown and recovery period respectively and similar good match of the IARF models with the data in log-log. It was however a better match of the complete test history based on the parameters from the recovery than the drawdown phasae. The selected representative transmissivity is $1.0 \cdot 10^{-4}$ m^2/s and a storativity of $9.9 \cdot 10^{-5}$ derived from the recovery phase since the parameters provided a somewhat better overall match between measured data and simulated results.

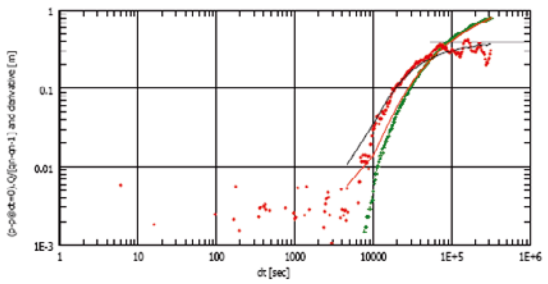
Test Summary Sheet – Observation borehole HLX35:2 (pumping borehole HLX34)

Project:	PLU	Test type:	2
Area:	Oskarshamn	Test no:	1
Borehole ID:	HLX35	Test start:	2005-06-16 13:20
Test section (m):	6.0-64.0	Responsible for test execution:	SKB field crew
Section diameter, $2 \cdot r_w$ (m):	0.140	Responsible for test evaluation:	SKB Mansueto Morosini

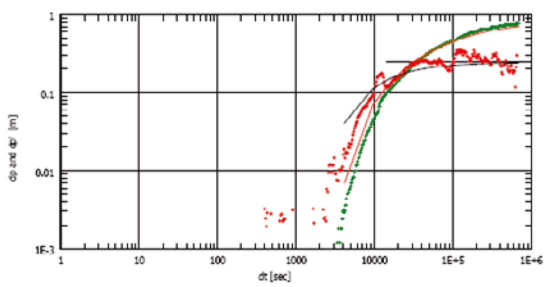
Linear plot Q and p



Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Flow period		**Recovery period**	
Indata		**Indata**	
h_0 (masl)			
h_i (masl)	12.0		
h_p (masl)	11.2	h_F (masl)	
Q_p (m³/s)			
tp (min)		t_F (min)	
S^* (-)		S^* (-)	
EC_w (mS/m)			
$Temp_w$(gr C			
Derivative factor	0.1	Derivative factor	0.1
r (m)	189.7	r (m)	189.7
Results		**Results**	
Q/s (m²/s)			
T_M (m²/s)			
Flow regime:	IARF	Flow regime:	IARF
dt_1 (min)		dt_1 (min)	
dt_2 (min)		dt_2 (min)	
T (m²/s)	$4.2 \cdot 10^{-4}$	T (m²/s)	$4.5 \cdot 10^{-4}$
S (-)	$7.1 \cdot 10^{-4}$	S (-)	$5.4 \cdot 10^{-4}$
K_s (m/s)		K_s (m/s)	
S_s (1/m)		S_s (1/m)	
C (m³/Pa)		C (m³/Pa)	
C_D (-)		C_D (-)	
ξ (-)		ξ (-)	
T_{GRF}(m²/s)		T_{GRF}(m²/s)	
S_{GRF}(-)		S_{GRF}(-)	
D_{GRF} (-)		D_{GRF} (-)	

Selected representative parameters.

dt_1 (min)		C (m³/Pa)	
dt_2 (min)		C_D (-)	
T_T (m²/s)	$4.5 \cdot 10^{-4}$	ξ (-)	
S (-)	$5.4 \cdot 10^{-4}$		
K_s (m/s)			
S_s (1/m)			

Comments:

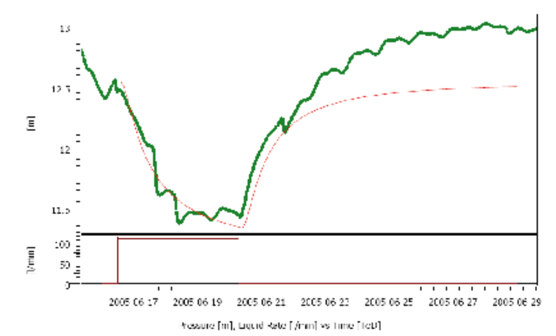
Rather consistent T and S were obtained for the drawdown and recovery period respectively for the IARF regime. The recovery phase show a better match between measured data and model, for the diagnostic plot and the complete tests history reconstruction.

The selected representative transmissivity is $4.5 \cdot 10^{-4}$ m²/s and a storativity of $5.4 \cdot 10^{-4}$ derived from the recovery phase since the parameters provided a better overall match between measured data and simulated results.

Test Summary Sheet – Observation borehole HLX13 (pumping borehole HLX34)

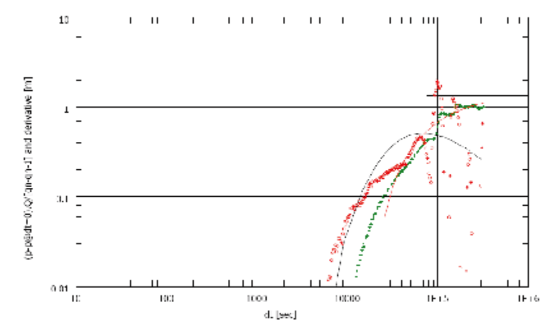
Project:	PLU	Test type:	2
Area:	Oskarshamn	Test no:	1
Borehole ID:	HLX35	Test start:	2005-06-16 13:20
Test section (m):	6.0-64.0	Responsible for test execution:	SKB field crew
Section diameter, $2 \cdot r_w$ (m):	0.140	Responsible for test evaluation:	SKB Mansueto Morosini

Linear plot Q and p

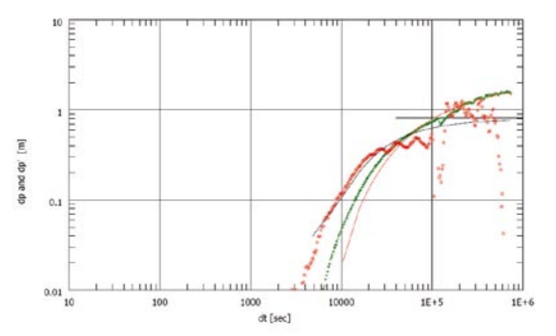


Flow period		Recovery period	
Indata		**Indata**	
h_0 (masl)			
h_i (masl)	12.54		
h_p (masl)	11.44	h_F (masl)	12.99
Q_p (m^3/s)			
tp (min)		t_F (min)	
S^* (-)		S^* (-)	
EC_w (mS/m)			
$Temp_w$(gr C			
Derivative factor	0.1	Derivative factor	0.1
r (m)	462	r (m)	462
Results		**Results**	
Q/s (m^2/s)			
T_M (m^2/s)			
Flow regime:	IARF	Flow regime:	IARF
dt_1 (min)		dt_1 (min)	
dt_2 (min)		dt_2 (min)	
T (m^2/s)	$1.1 \cdot 10^{-4}$	T (m^2/s)	$1.8 \cdot 10^{-4}$
S (-)	$7.5 \cdot 10^{-5}$	S (-)	$6.6 \cdot 10^{-5}$
K_s (m/s)		K_s (m/s)	
S_s (1/m)		S_s (1/m)	
C (m^3/Pa)		C (m^3/Pa)	
C_D (-)		C_D (-)	
ξ (-)		ξ (-)	
T_{GRF}(m^2/s)		T_{GRF}(m^2/s)	
S_{GRF}(-)		S_{GRF}(-)	
D_{GRF} (-)		D_{GRF} (-)	

Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Selected representative parameters.

dt_1 (min)		C (m^3/Pa)	
dt_2 (min)		C_D (-)	
T_T (m^2/s)	$1.8 \cdot 10^{-4}$	ξ (-)	
S (-)	$6.6 \cdot 10^{-5}$		
K_s (m/s)			
S_s (1/m)			

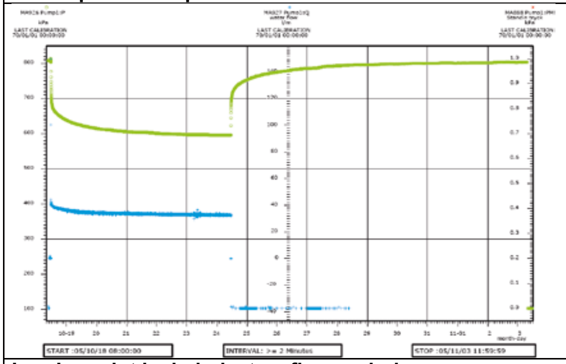
Comments:

The head in HLX13 appear respond to the HLX34 pumping but the levels are heavily influenced by the tidal effects. Responses to precipitation events are also observed. However both tidal and precipitation effect are clearly subordinate to the pumping effects during drawdown and large duration of the recovery. An approximate steady state head is obtained during drawdown after half of the pumping period which was modelled as a constant head boundary at 157m distance. No such boundary is however observed during the recovery.

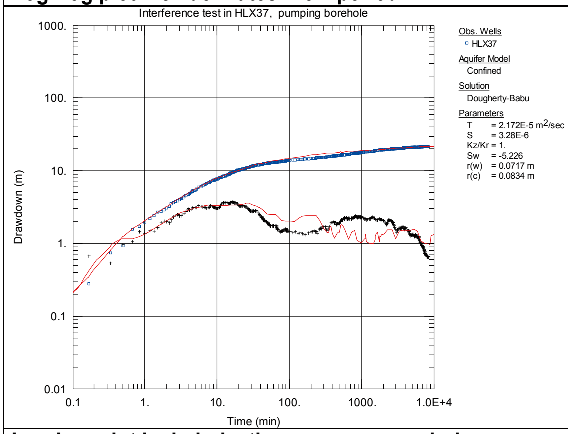
There is a more than normal uncertainty in this interpretation due to the disturbed head prior to the test.

Test Summary Sheet – Pumping borehole HLX37			
Project:	PLU	Test type:	1B
Area:	Oskarshamn	Test no:	1
Borehole ID:	HLX37	Test start:	2005-10-18 11:34:20
Test section (m):	12.0-199.8	Responsible for test execution:	SKB field crew
Section diameter, $2 \cdot r_w$ (m):	0.139	Responsible for test evaluation:	GEOSIGMA AB Jan-Erik Ludvigson

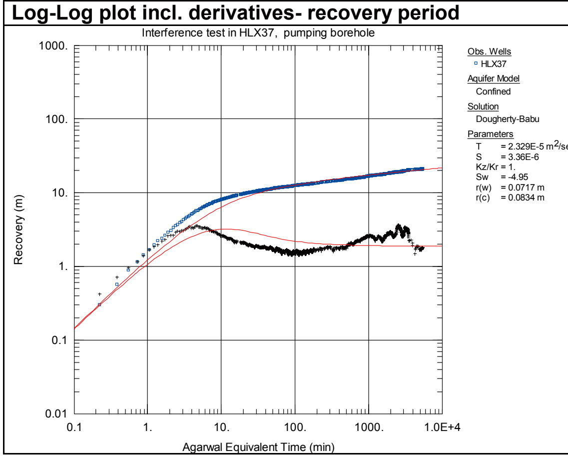
Linear plot Q and p



Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa)			
p_i (kPa)	806.9		
p_p(kPa)	595.7	p_F (kPa)	802.9
Q_p (m^3/s)	$5.42 \cdot 10^{-4}$		
tp (min)	8612	t_F (min)	14184
S^* (-)	$3.3 \cdot 10^{-6}$	S^* (-)	$3.4 \cdot 10^{-6}$
EC_w (mS/m)			
$Temp_w$(gr C			
Derivative factor	0.3	Derivative factor	0.3
r (m)		r (m)	
Results		**Results**	
Q/s (m^2/s)	$2.5 \cdot 10^{-5}$		
T_M (m^2/s)	$3.4 \cdot 10^{-5}$		
Flow regime:	WBS->PRF	Flow regime:	WBS->PRF
dt_1 (min)	70	dt_1 (min)	70
dt_2 (min)	300	dt_2 (min)	400
T (m^2/s)	$2.2 \cdot 10^{-5}$	T (m^2/s)	$2.3 \cdot 10^{-5}$
S (-)		S (-)	
K_s (m/s)		K_s (m/s)	
S_s (1/m)		S_s (1/m)	
C (m^3/Pa)	$2.2 \cdot 10^{-6}$	C (m^3/Pa)	$2.2 \cdot 10^{-6}$
C_D (-)		C_D (-)	
ξ (-)	-5.2	ξ (-)	-4.9
T_{GRF}(m^2/s)		T_{GRF}(m^2/s)	
S_{GRF}(-)		S_{GRF}(-)	
D_{GRF} (-)		D_{GRF} (-)	

Selected representative parameters.			
dt_1 (min)	70	C (m^3/Pa)	$2.2≅10^{-6}$
dt_2 (min)	300	C_D (-)	
T_T (m^2/s)	$2.2 \cdot 10^{-5}$	ξ (-)	-5.2
S* (-)	$3.3 \cdot 10^{-6}$		
K_s (m/s)			
S_s (1/m)			

Comments:

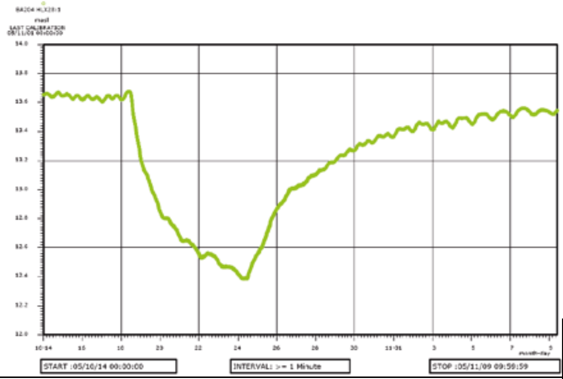
During both the flow and recovery period, wellbore storage effects are followed by dominating pseudo-radial flow after c. 70 minutes. At the end of both periods a relatively rapid decrease in the derivatives may indicate a possible constant head boundary or transition to pseudo-spherical (leaky) flow.

The agreement in evaluated parameter values between the flow and recovery period is good. The parameter values from the flow period are selected as the most representative.

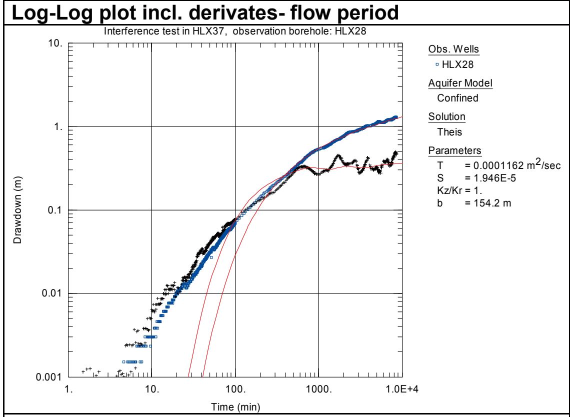
Test Summary Sheet – Observation borehole HLX28 (pumping borehole HLX37)

Project:	PLU	Test type:	2
Area:	Oskarshamn	Test no:	1
Borehole ID:	HLX28	Test start:	2005-10-18 11:34:20
Test section (m):	6.0-154.2	Responsible for test execution:	SKB field crew
Section diameter, $2\cdot r_w$ (m):	0.136	Responsible for test evaluation:	GEOSIGMA AB Jan-Erik Ludvigson

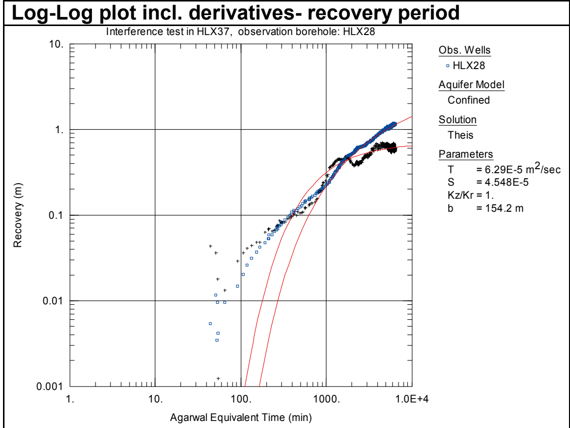
Linear plot Q and p



Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa)			
p_i (kPa)	134.1		
p_p(kPa)	121.5	p_F (kPa)	132.7
Q_p (m^3/s)			
tp (min)		t_F (min)	
S^* (-)		S^* (-)	
EC_w (mS/m)			
$Temp_w$(gr C			
Derivative factor	0.3	Derivative factor	0.3
r (m)	514	r (m)	514
Results		**Results**	
Q/s (m^2/s)			
T_M (m^2/s)			
Flow regime:	PRF	Flow regime:	PRF
dt_1 (min)	1300	dt_1 (min)	1300
dt_2 (min)	8500	dt_2 (min)	6200
T (m^2/s)	$1.2\cdot10^{-4}$	T (m^2/s)	$6.3\cdot10^{-5}$
S (-)	$1.9\cdot10^{-5}$	S (-)	$4.5\cdot10^{-5}$
K_s (m/s)		K_s (m/s)	
S_s (1/m)		S_s (1/m)	
C (m^3/Pa)		C (m^3/Pa)	
C_D (-)		C_D (-)	
ξ (-)		ξ (-)	
T_{GRF}(m^2/s)		T_{GRF}(m^2/s)	
S_{GRF}(-)		S_{GRF}(-)	
D_{GRF} (-)		D_{GRF} (-)	

Selected representative parameters.

dt_1 (min)	1300	C (m^3/Pa)	
dt_2 (min)	8500	C_D (-)	
T_T (m^2/s)	$1.2\cdot10^{-4}$	ξ (-)	
S (-)	$1.9\cdot10^{-5}$		
K_s (m/s)			
S_s (1/m)			

Comments:

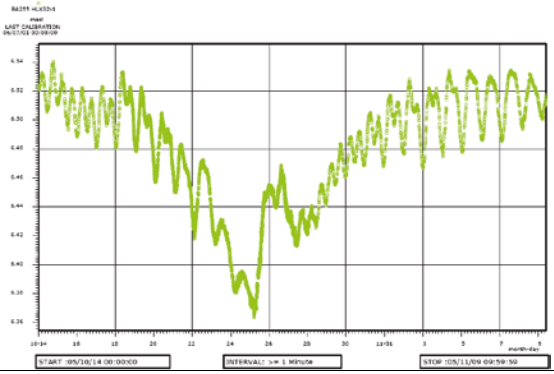
Tidal oscillations may disturb the pressure responses from both the flow and recovery period to a certain degree. At the end of both periods pseudo-radial flow is dominating. The early response may indicate fracture flow or, alternatively, presence of apparent no-flow boundaries by the end.

The transient evaluation is based on the late time response. The agreement in evaluated parameter values between the flow and recovery period is good. The parameter values from the flow period are selected as the most representative.

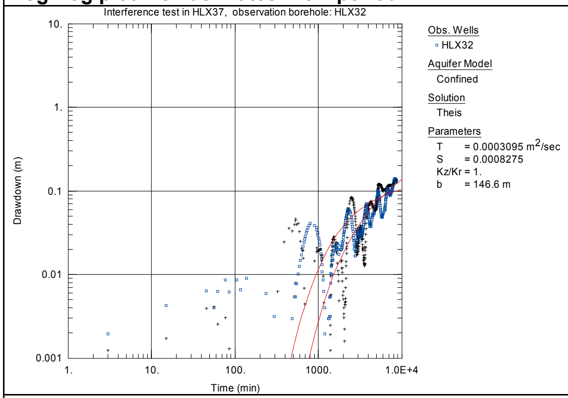
Test Summary Sheet – Observation borehole HLX32 (pumping borehole HLX37)

Project:	PLU	Test type:	2
Area:	Oskarshamn	Test no:	1
Borehole ID:	HLX32	Test start:	2005-10-18 11:34:20
Test section (m):	16.0-162.6	Responsible for test execution:	SKB field crew
Section diameter, $2 \cdot r_w$ (m):	0.140	Responsible for test evaluation:	GEOSIGMA AB Jan-Erik Ludvigson

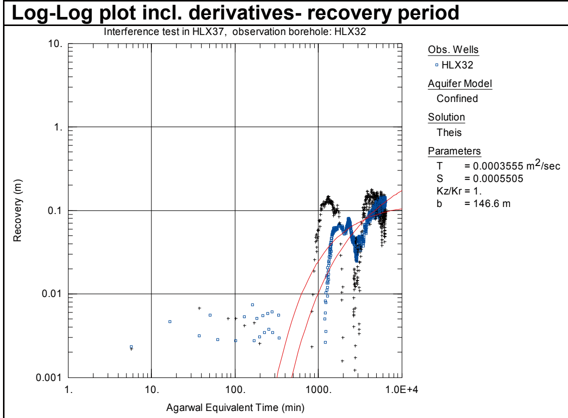
Linear plot Q and p



Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa)			
p_i (kPa)	64.0		
p_p(kPa)	62.7	p_F (kPa)	6.51
Q_p (m^3/s)			
tp (min)		t_F (min)	
S^* (-)		S^* (-)	
EC_w (mS/m)			
$Temp_w$(gr C			
Derivative factor	0.3	Derivative factor	0.3
r (m)	510	r (m)	510
Results		**Results**	
Q/s (m^2/s)			
T_M (m^2/s)			
Flow regime:		Flow regime:	
dt_1 (min)		dt_1 (min)	
dt_2 (min)		dt_2 (min)	
T (m^2/s)	($3.1 \cdot 10^{-4}$)	T (m^2/s)	($3.6 \cdot 10^{-4}$)
S (-)	($8.3 \cdot 10^{-4}$)	S (-)	($5.5 \cdot 10^{-4}$)
K_s (m/s)		K_s (m/s)	
S_s (1/m)		S_s (1/m)	
C (m^3/Pa)		C (m^3/Pa)	
C_D (-)		C_D (-)	
ξ (-)		ξ (-)	
T_{GRF}(m^2/s)		T_{GRF}(m^2/s)	
S_{GRF}(-)		S_{GRF}(-)	
D_{GRF} (-)		D_{GRF} (-)	

Selected representative parameters.

dt_1 (min)		C (m^3/Pa)	
dt_2 (min)		C_D (-)	
T_T (m^2/s)	($3.1 \cdot 10^{-4}$)	ξ (-)	
S (-)	($8.3 \cdot 10^{-4}$)		
K_s (m/s)			
S_s (1/m)			

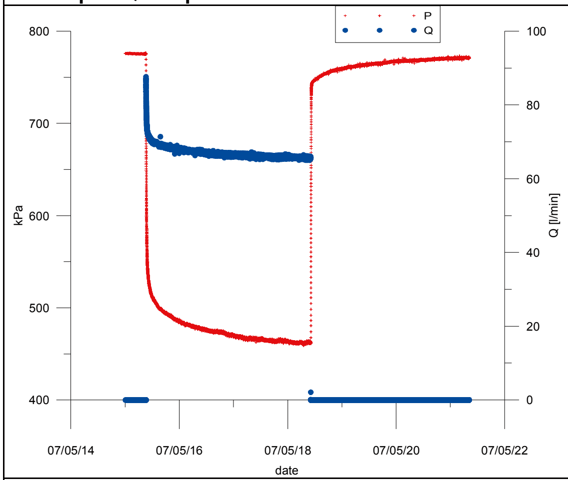
Comments:

Since the tidal oscillations are of the same magnitude as the total pressure response from the pumping they strongly disturb the transient evaluation. No evaluation of flow regimes is possible. Therefore the evaluated parameters are considered as very uncertain in this case, both for the flow and recovery period.

Test Summary Sheet – Pumping borehole HLX42

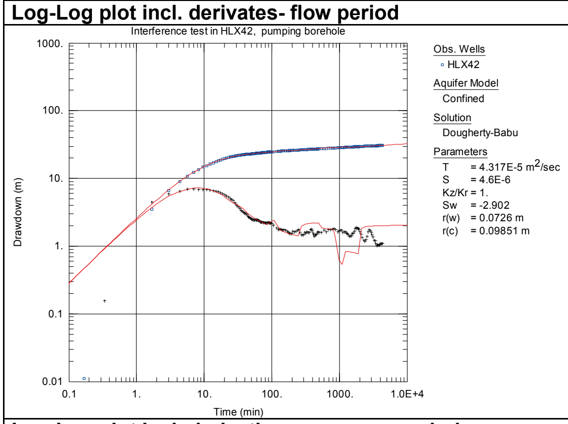
Project:	PLU	Test type:	1B
Area:	Oskarshamn	Test no:	1
Borehole ID:	HLX42	Test start:	2007-05-15 09:17:40
Test section (m):	9.10-152.6	Responsible for test execution:	SKB field crew
Section diameter, $2 \cdot r_w$ (m):	0.0695	Responsible for test evaluation:	GEOSIGMA AB Jan-Erik Ludvigson

Linear plot Q and p

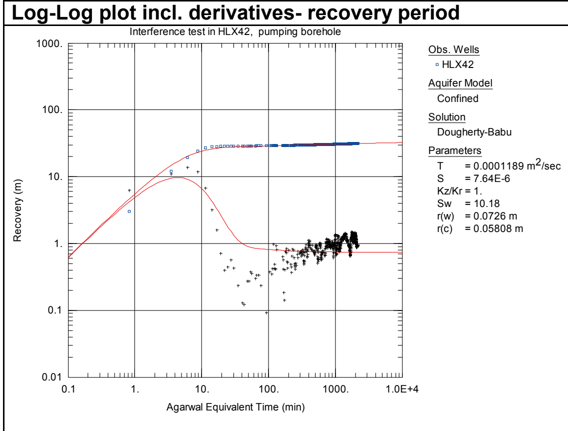


Flow period		**Recovery period**	
Indata		**Indata**	
p_0 (kPa)			
p_i (kPa)	775.2		
p_p(kPa)	461.71	p_F (kPa)	770.7
Q_p (m^3/s)	$1.1 \cdot 10^{-3}$		
t_p (min)	4377	t_F (min)	4204
S^* (-)	$4.6 \cdot 10^{-6}$	S^* (-)	$7.6 \cdot 10^{-6}$
EC_w (mS/m)			
Te_w(^oC)			
Derivative factor	0.4	Derivative factor	0.1
r (m)		r (m)	
Results		**Results**	
Q/s (m^2/s)	$3.4 \cdot 10^{-5}$		
T_M (m^2/s)	$7.2 \cdot 10^{-5}$		
Flow regime:	WBS->PRF	Flow regime:	WBS->PRF ->(NFB)
dt_1 (min)	200	dt_1 (min)	300
dt_2 (min)	4000	dt_2 (min)	700
T (m^2/s)	$4.3 \cdot 10^{-5}$	T (m^2/s)	$1.2 \cdot 10^{-4}$
S (-)		S (-)	
K_s (m/s)		K_s (m/s)	
S_s (1/m)		S_s (1/m)	
C (m^3/Pa)	$3.1 \cdot 10^{-6}$	C (m^3/Pa)	$1.1 \cdot 10^{-6}$
C_D (-)		C_D (-)	
ξ (-)	-2.9	ξ (-)	10.2
T_{GRF}(m^2/s)		T_{GRF}(m^2/s)	
S_{GRF}(-)		S_{GRF}(-)	
D_{GRF} (-)		D_{GRF} (-)	

Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivates- recovery period



Selected representative parameters.			
dt_1 (min)	100	C (m^3/Pa)	$3.1 \cdot 10^{-6}$
dt_2 (min)	4000	C_D (-)	
T_T (m^2/s)	$4.3 \cdot 10^{-5}$	ξ (-)	-2.9
S* (-)	$4.6 \cdot 10^{-6}$		
K_s (m/s)			
S_s (1/m)			

Comments:

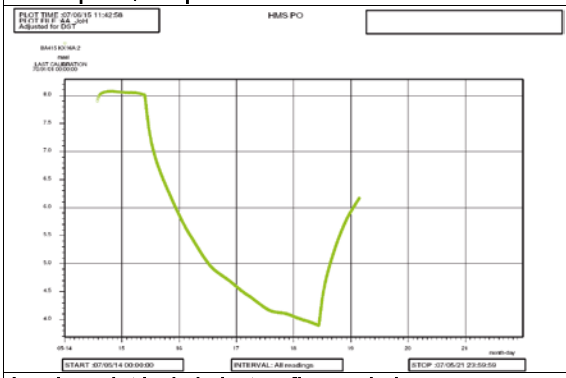
The flow rate slightly decreased during the flow period. During both the flow and recovery period, wellbore storage effects are followed by dominating pseudo-radial flow. During the end of the recovery period effects of an apparent no-flow boundary are weakly indicated.

The test was evaluated as a variable flow rate test. The parameter values estimated from the flow period is selected as the most representative.

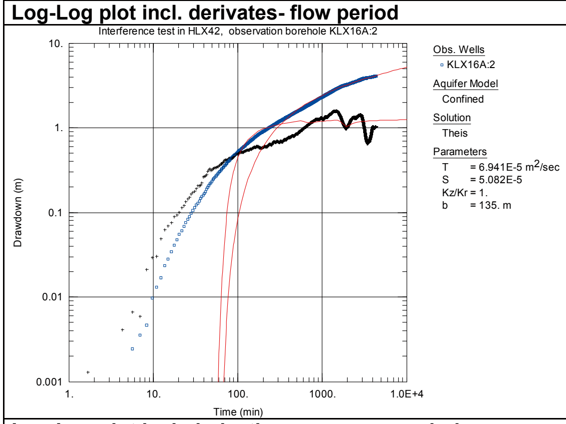
Test Summary Sheet – Observation borehole KLX16A:2 (pumping borehole HLX42)

Project:	PLU	Test type:	2
Area:	Oskarshamn	Test no:	1
Borehole ID:	KLX16A:2	Test start:	2007-05-15 09:17:10
Test section (m):	191.0-326.0	Responsible for test execution:	SKB field crew
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	GEOSIGMA AB Jan-Erik Ludvigson

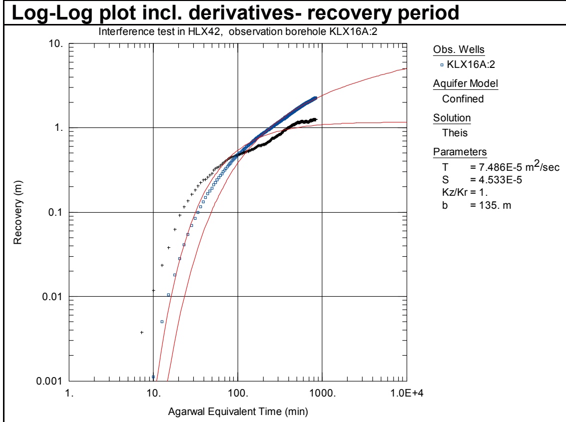
Linear plot Q and p



Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Flow period		**Recovery period**	
Indata		**Indata**	
p_0 (kPa)			
p_i (kPa)	78.6		
p_p(kPa)	38.3	p_F (kPa)	60.5
Q_p (m^3/s)			
t_p (min)		t_F (min)	
S^* (-)		S^* (-)	
EC_w (mS/m)			
Te_w(°C)			
Derivative factor	0.1	Derivative factor	0.1
r (m)	176	r (m)	176
Results		**Results**	
Q/s (m^2/s)			
T_M (m^2/s)			
Flow regime:	PRF	Flow regime:	(PRF)
dt_1 (min)	800	dt_1 (min)	500
dt_2 (min)	4000	dt_2 (min)	800
T (m^2/s)	$6.9 \cdot 10^{-5}$	T (m^2/s)	$7.5 \cdot 10^{-5}$
S (-)	$5.1 \cdot 10^{-5}$	S (-)	$4.5 \cdot 10^{-5}$
K_s (m/s)		K_s (m/s)	
S_s (1/m)		S_s (1/m)	
C (m^3/Pa)		C (m^3/Pa)	
C_D (-)		C_D (-)	
ξ (-)		ξ (-)	
T_{GRF}(m^2/s)		T_{GRF}(m^2/s)	
S_{GRF}(-)		S_{GRF}(-)	
D_{GRF} (-)		D_{GRF} (-)	

Selected representative parameters.

dt_1 (min)	800	C (m^3/Pa)	
dt_2 (min)	4000	C_D (-)	
T_T (m^2/s)	$6.9 \cdot 10^{-5}$	ξ (-)	
S (-)	$5.1 \cdot 10^{-5}$		
K_s (m/s)			
S_s (1/m)			

Comments:

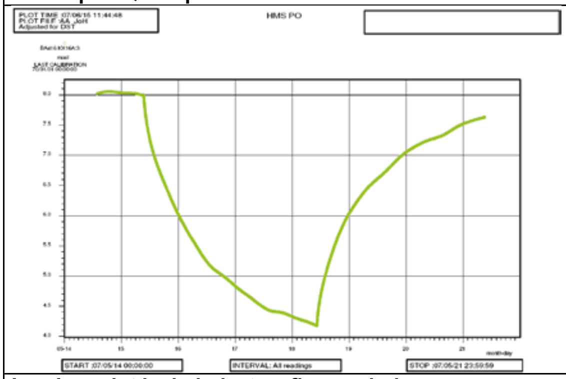
The duration of the recovery period is limited. During both the flow and recovery period transition to a possible pseudo-radial flow regime is indicated by the end. However, alternative evaluations are possible, e.g. an apparent no-flow boundary after c. 200 min of the flow period or pseudo-linear flow.

The transient evaluation is based on the late time response. Consistent results of evaluated parameter values are obtained from the flow and recovery period respectively. The parameter values estimated from the flow period are selected as the most representative.

Test Summary Sheet – Observation borehole KLX16A:3 (pumping borehole HLX42)

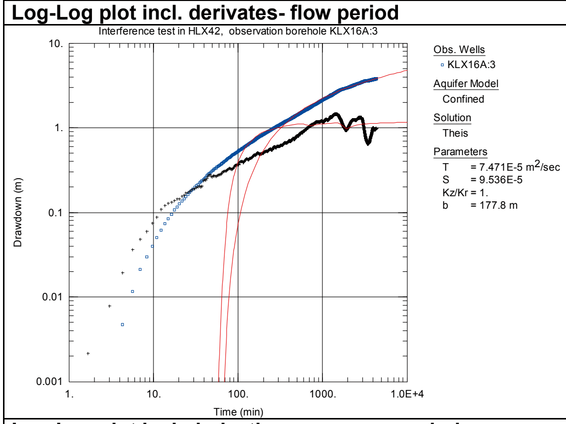
Project:	PLU	Test type:	2
Area:	Oskarshamn	Test no:	1
Borehole ID:	KLX16A:3	Test start:	2007-05-15 09:17:10
Test section (m):	11.25-190.0	Responsible for test execution:	SKB field crew
Section diameter, $2 \cdot r_w$ (m):	0.076	Responsible for test evaluation:	GEOSIGMA AB Jan-Erik Ludvigson

Linear plot Q and p

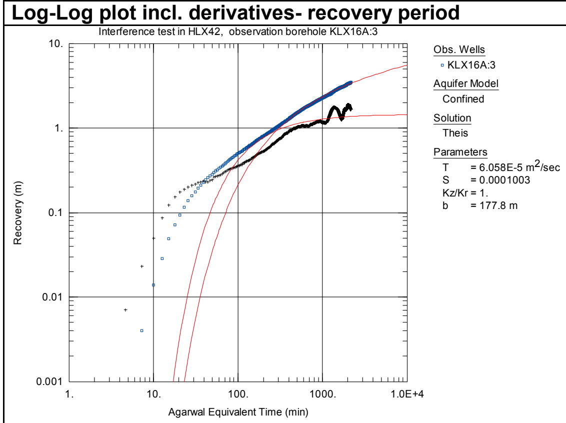


Flow period		Recovery period	
Indata		**Indata**	
p_0 (kPa)			
p_i (kPa)	78.5		
p_p(kPa)	41.0	p_F (kPa)	74.9
Q_p (m^3/s)			
t_p (min)		t_F (min)	
S^* (-)		S^* (-)	
EC_w (mS/m)			
Te_w(°C)			
Derivative factor	0.1	Derivative factor	0.1
r (m)	135	r (m)	135
Results		**Results**	
Q/s (m^2/s)			
T_M (m^2/s)			
Flow regime:	PRF	Flow regime:	(PRF)
dt_1 (min)	800	dt_1 (min)	1500
dt_2 (min)	4000	dt_2 (min)	2000
T (m^2/s)	$7.5 \cdot 10^{-5}$	T (m^2/s)	$6.1 \cdot 10^{-5}$
S (-)	$9.5 \cdot 10^{-5}$	S (-)	$1.0 \cdot 10^{-4}$
K_s (m/s)		K_s (m/s)	
S_s (1/m)		S_s (1/m)	
C (m^3/Pa)		C (m^3/Pa)	
C_D (-)		C_D (-)	
ξ (-)		ξ (-)	
T_{GRF}(m^2/s)		T_{GRF}(m^2/s)	
S_{GRF}(-)		S_{GRF}(-)	
D_{GRF} (-)		D_{GRF} (-)	

Log-Log plot incl. derivates- flow period



Log-Log plot incl. derivatives- recovery period



Selected representative parameters.

dt_1 (min)	800	C (m^3/Pa)	
dt_2 (min)	4000	C_D (-)	
T_T (m^2/s)	$7.5 \cdot 10^{-5}$	ξ (-)	
S (-)	$9.5 \cdot 10^{-5}$		
K_s (m/s)			
S_s (1/m)			

Comments:

During both the flow and recovery period transition to a possible pseudo-radial flow regime occurred by the end. However, alternative evaluations are possible, e.g. an apparent no-flow boundary after c. 200 min of the flow period or pseudo-linear flow.

The transient evaluation is based on the late time response. Consistent results of evaluated parameter values are obtained from the flow and recovery period respectively. The parameter values estimated from the flow period are selected as the most representative.

Appendix 2

Test diagrams

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

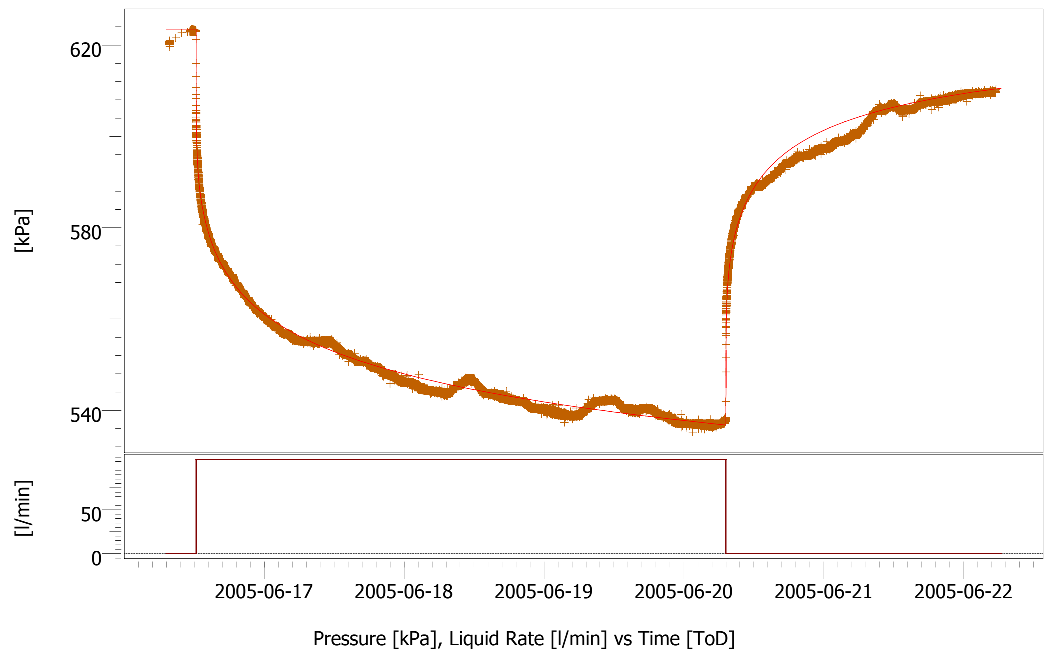
r(w) = borehole radius (m)

r(c) = effective casing radius (m)

r/B = leakage coefficient (s^{-1})

b = thickness of formation (m)

History plot	Dd1
Company Svensk Kärnbränslehantering AB Well HLX34	Field Laxemar Test Name / # Pumping test in HLX34



LX34 pumpingtest_P&Q_050616-050622_AirPcorrected production #1

Rate	107.352 l/min
Rate change	107.352 l/min
P@dt=0	622.895 kPa
Pi	623.496 kPa
Smoothing	0.1

Selected Model

Model Option	Standard Model
Well	Vertical
Reservoir	Two porosity PSS
Boundary	Parallel faults

Main Model Parameters

TMatch	0.0369 1/sec
PMatch	0.0823 1/kPa
C	3.99E-6 m3/Pa
Total Skin	-4.68
T	2.25E-4 m2/s
K	1.58E-6 m/s
Pi	623.496 kPa

Model Parameters

Well & Wellbore parameters (HLX34)

C	3.99E-6 m3/Pa
Skin	-4.68

Reservoir & Boundary parameters

Pi	623.496 kPa
T	2.25E-4 m2/s
K	1.58E-6 m/s
Omega	3.2E-4
Lambda	5.34E-6
S - No flow	44400 m
N - No flow	142 m

Derived & Secondary Parameters

Delta P (Total Skin)	-56.8516 kPa
Delta P Ratio (Total Skin)	-0.655575 Fraction

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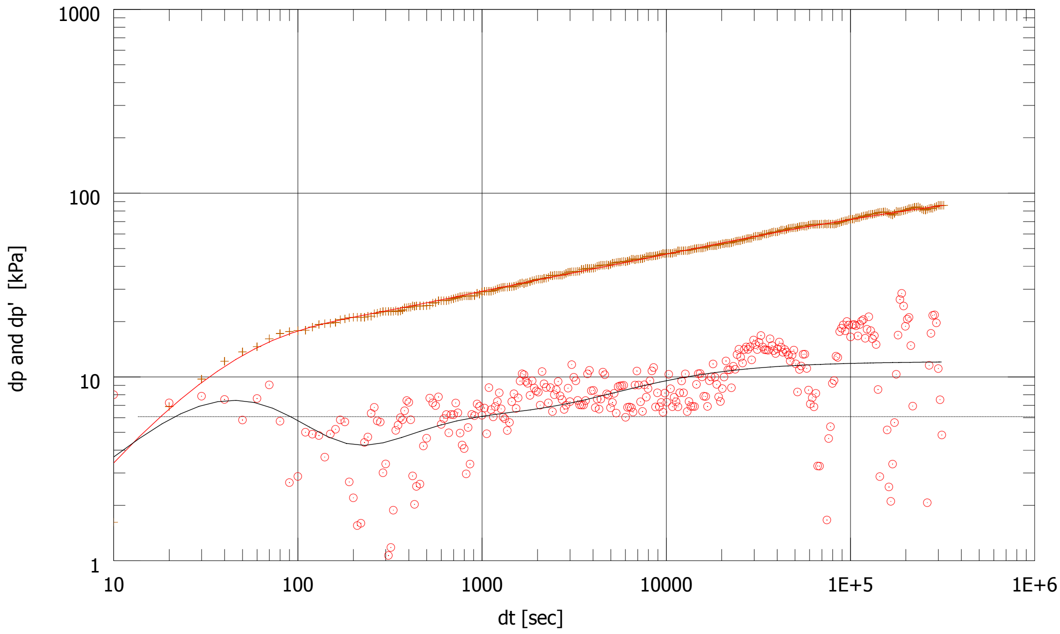
Figure A2-1. *Lin-lin plot of pressure versus time during the pumping test in borehole HLX34 together with evaluated data.*

Log-Log plot	Dd1
Company Svensk Kärnbränslehantering AB Well HLX34	Field Laxemar Test Name / # Pumping test in HLX34



LX34 pumpingtest_P&Q_050616-050622_AirPcorrected production #1

Rate	107.352 l/min
Rate change	107.352 l/min
P@dt=0	622.895 kPa
Pi	623.496 kPa
Smoothing	0.1

Selected Model

Model Option	Standard Model
Well	Vertical
Reservoir	Two porosity PSS
Boundary	Parallel faults

Main Model Parameters

TMatch	0.0369 1/sec
PMatch	0.0823 1/kPa
C	3.99E-6 m3/Pa
Total Skin	-4.68
T	2.25E-4 m2/s
K	1.58E-6 m/s
Pi	623.496 kPa

Model Parameters

Well & Wellbore parameters (HLX34)

C	3.99E-6 m3/Pa
Skin	-4.68

Reservoir & Boundary parameters

Pi	623.496 kPa
T	2.25E-4 m2/s
K	1.58E-6 m/s
Omega	3.2E-4
Lambda	5.34E-6
S - No flow	44400 m
N - No flow	142 m

Derived & Secondary Parameters

Delta P (Total Skin)	-56.8516 kPa
Delta P Ratio (Total Skin)	-0.655575 Fraction

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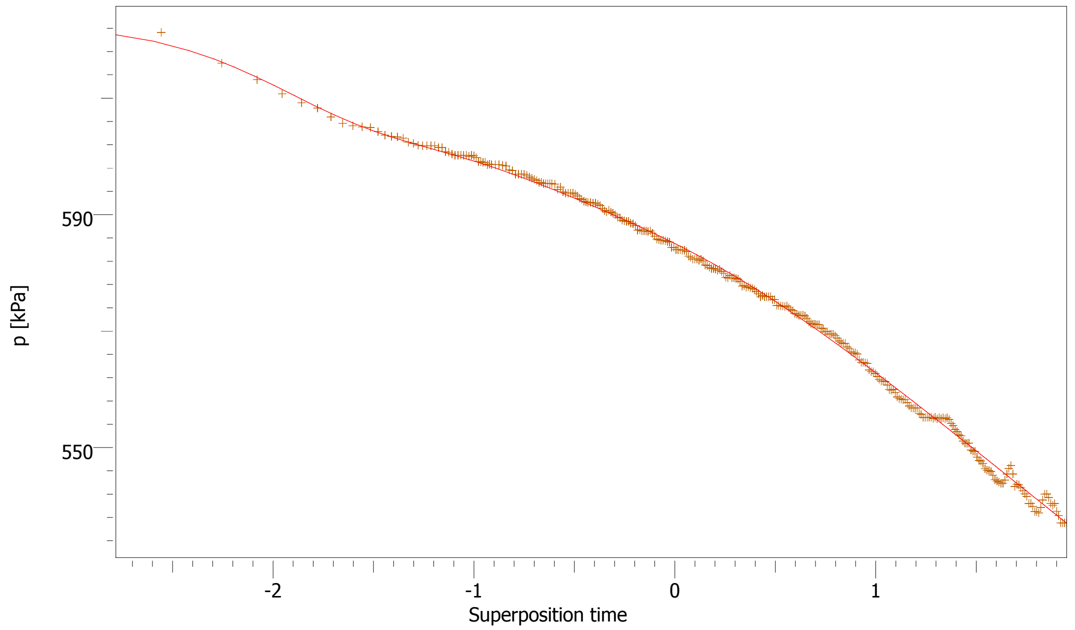
Figure A2-2. *Log-log plot of drawdown and drawdown derivative versus time together with simulated curves in the pumping borehole HLX34.*

Semi-Log plot	Dd1
Company Svensk Kärnbränslehantering AB Well HLX34	Field Laxemar Test Name / # Pumping test in HLX34



LX34 pumpingtest_P&Q_050616-050622_AirPcorrected production #1

Rate	107.352 l/min
Rate change	107.352 l/min
P@dt=0	622.895 kPa
Pi	623.496 kPa
Smoothing	0.1

Selected Model

Model Option	Standard Model
Well	Vertical
Reservoir	Two porosity PSS
Boundary	Parallel faults

Main Model Parameters

TMatch	0.0369 1/sec
PMatch	0.0823 1/kPa
C	3.99E-6 m3/Pa
Total Skin	-4.68
T	2.25E-4 m2/s
K	1.58E-6 m/s
Pi	623.496 kPa

Model Parameters

Well & Wellbore parameters (HLX34)

C	3.99E-6 m3/Pa
Skin	-4.68

Reservoir & Boundary parameters

Pi	623.496 kPa
T	2.25E-4 m2/s
K	1.58E-6 m/s
Omega	3.2E-4
Lambda	5.34E-6
S - No flow	44400 m
N - No flow	142 m

Derived & Secondary Parameters

Delta P (Total Skin)	-56.8516 kPa
Delta P Ratio (Total Skin)	-0.655575 Fraction

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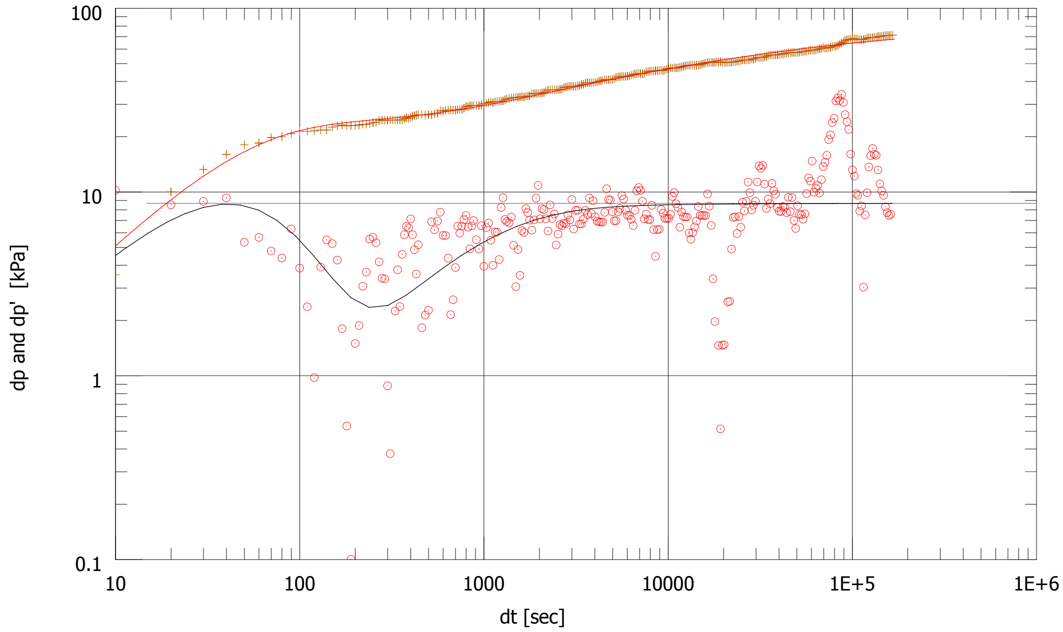
Figure A2-3. *Lin-log plot of drawdown versus time together with simulated curve in the pumping borehole HLX34.*

	Log-Log plot	Bu1
	Company Svensk Kärnbränslehantering AB Well HLX34	Field Laxemar Test Name / # Pumping test in HLX34



HLX34 pumpingtest_P&Q_050616-050622_AirPcorrected build-up #1

Rate	0 l/min
Rate change	107.352 l/min
P@dt=0	538.35 kPa
Pi	615.527 kPa
Smoothing	0.1

Selected Model

Model Option	Standard Model
Well	Vertical
Reservoir	Two porosity PSS
Boundary	Infinite

Main Model Parameters

TMatch	0.0338 1/sec
PMatch	0.0576 1/kPa
C	3.05E-6 m3/Pa
Total Skin	-5.43
T	1.58E-4 m2/s
K	1.1E-6 m/s
Pi	615.527 kPa

Model Parameters

Well & Wellbore parameters (HLX34)

C	3.05E-6 m3/Pa
Skin	-5.43

Reservoir & Boundary parameters

Pi	615.527 kPa
T	1.58E-4 m2/s
K	1.1E-6 m/s
Omega	0.00417
Lambda	2.52E-6

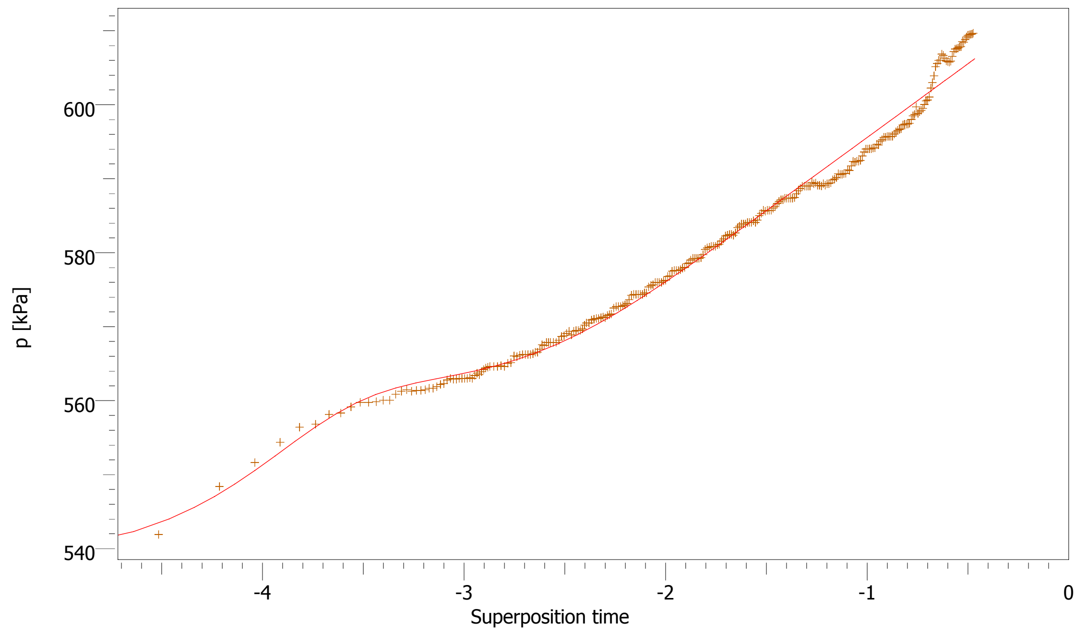
Derived & Secondary Parameters

Delta P (Total Skin)	-94.3639 kPa
Delta P Ratio (Total Skin)	-1.39042 Fraction

Ecrin v4.02.03 HLX34 pumpingtest_P&Q_050616-050622_AirPcorrected 2008-04-02 Page 6/8

Figure A2-4. *Log-log plot of recovery and recovery derivative versus time together with simulated curves in the pumping borehole HLX34*

Semi-Log plot	Bu1
Company Svensk Kärnbränslehantering AB Well HLX34	Field Laxemar Test Name / # Pumping test in HLX34



HLX34 pumpingtest_P&Q_050616-050622_AirPcorrected build-up #1

Rate	0 l/min
Rate change	107.352 l/min
P@dt=0	538.35 kPa
Pi	615.527 kPa
Smoothing	0.1

Selected Model

Model Option	Standard Model
Well	Vertical
Reservoir	Two porosity PSS
Boundary	Infinite

Main Model Parameters

TMatch	0.0338 1/sec
PMatch	0.0576 1/kPa
C	3.05E-6 m3/Pa
Total Skin	-5.43
T	1.58E-4 m2/s
K	1.1E-6 m/s
Pi	615.527 kPa

Model Parameters

Well & Wellbore parameters (HLX34)

C	3.05E-6 m3/Pa
Skin	-5.43

Reservoir & Boundary parameters

Pi	615.527 kPa
T	1.58E-4 m2/s
K	1.1E-6 m/s
Omega	0.00417
Lambda	2.52E-6

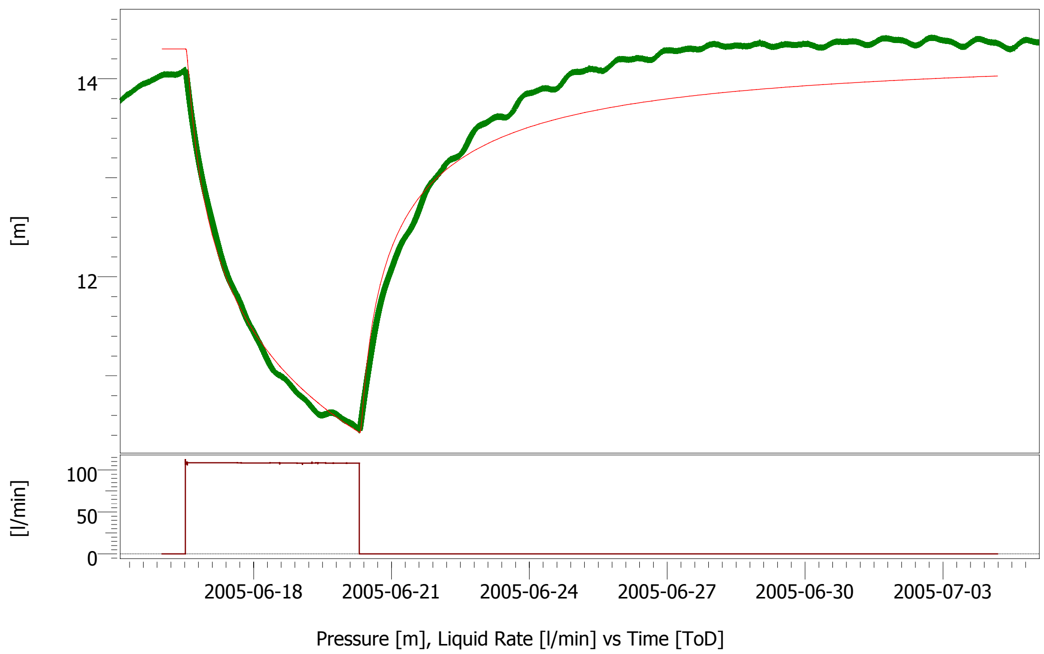
Derived & Secondary Parameters

Delta P (Total Skin)	-94.3639 kPa
Delta P Ratio (Total Skin)	-1.39042 Fraction

Ecrin v4.02.03 HLX34 pumpingtest_P&Q_050616-050622_AirPcorrected 2008-04-02 Page 7/8

Figure A2-5. *Lin-log plot of recovery versus time together with simulated curve in the pumping borehole HLX34.*

History plot	Dd1
Company Svensk Kärnbränslehantering AB Well HLX35:1, obs	Field LAxemar Test Name / # Interferenstest HLX34pump-HLX35obs



HLX35_1obs production #1

Rate	108.161 l/min
Rate change	108.161 l/min
P@dt=0	14.0865 m
Pi	14.3 m
Smoothing	0.1

Selected Model

Model Option	Standard Model
Well	Line source
Reservoir	Homogeneous
Boundary	Infinite

Main Model Parameters

TMatch	4.07E-5 [sec]-1
PMatch	0.442 [m]-1
S	1.04E-4
T	1.27E-4 m2/s
K	1.46E-6 m/s
Pi	14.3 m
Well distance	173 m

Model Parameters

Reservoir & Boundary parameters

Pi	14.3 m
T	1.27E-4 m2/s
K	1.46E-6 m/s
S	1.04E-4

Derived & Secondary Parameters

P @ dt=0	14.1 m
Rinv	1120 m
Test. Vol.	96.8076 MMm3

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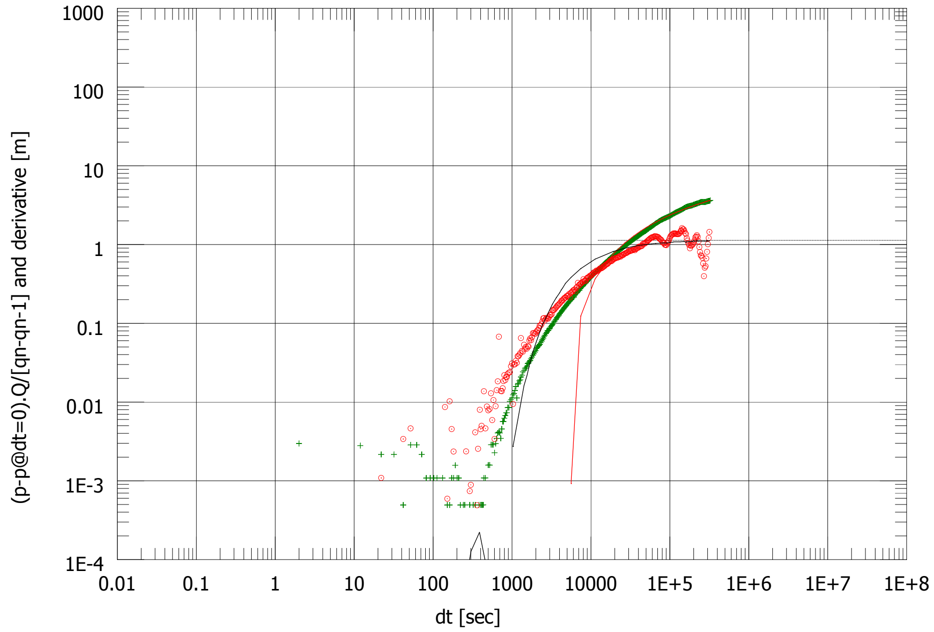
Figure A2-6. *Lin-lin plot of pressure versus time in the observation section HLX35:1 during pumping in HLX34, together with evaluated data.*

Log-Log plot	Dd1
Company Svensk Kärnbränslehantering AB Well HLX35:1, obs	Field LAxemar Test Name / # Interferenstest HLX34pump-HLX35obs



HLX35_1obs production #1

Rate	108.161 l/min
Rate change	108.161 l/min
P@dt=0	14.0865 m
Pi	14.3 m
Smoothing	0.1

Selected Model

Model Option	Standard Model
Well	Line source
Reservoir	Homogeneous
Boundary	Infinite

Main Model Parameters

TMatch	4.07E-5 [sec]-1
PMatch	0.442 [m]-1
S	1.04E-4
T	1.27E-4 m2/s
K	1.46E-6 m/s
Pi	14.3 m
Well distance	173 m

Model Parameters

Reservoir & Boundary parameters

Pi	14.3 m
T	1.27E-4 m2/s
K	1.46E-6 m/s
S	1.04E-4

Derived & Secondary Parameters

P @ dt=0	14.1 m
Rinv	1120 m
Test. Vol.	96.8076 MMm3

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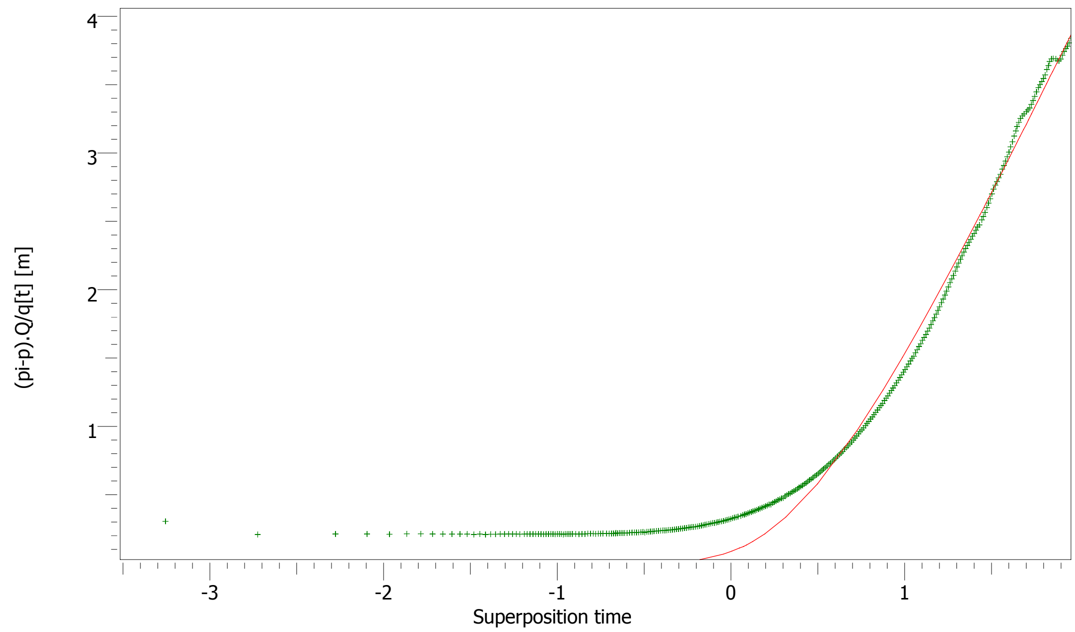
Figure A2-7. *Log-log plot of drawdown and drawdown derivative versus time together with simulated curves in the observation section HLX35:1 during pumping in borehole HLX34.*

SKB	Semi-Log plot	Dd1
	Company Svensk Kärnbränslehantering AB Well HLX35:1, obs	Field LAxemar Test Name / # Interferenstest HLX34pump-HLX35obs



HLX35_1obs production #1

Rate	108.161 l/min
Rate change	108.161 l/min
P@dt=0	14.0865 m
Pi	14.3 m
Smoothing	0.1

Selected Model

Model Option	Standard Model
Well	Line source
Reservoir	Homogeneous
Boundary	Infinite

Main Model Parameters

TMatch	4.07E-5 [sec]-1
PMatch	0.442 [m]-1
S	1.04E-4
T	1.27E-4 m2/s
K	1.46E-6 m/s
Pi	14.3 m
Well distance	173 m

Model Parameters
Reservoir & Boundary parameters

Pi	14.3 m
T	1.27E-4 m2/s
K	1.46E-6 m/s
S	1.04E-4

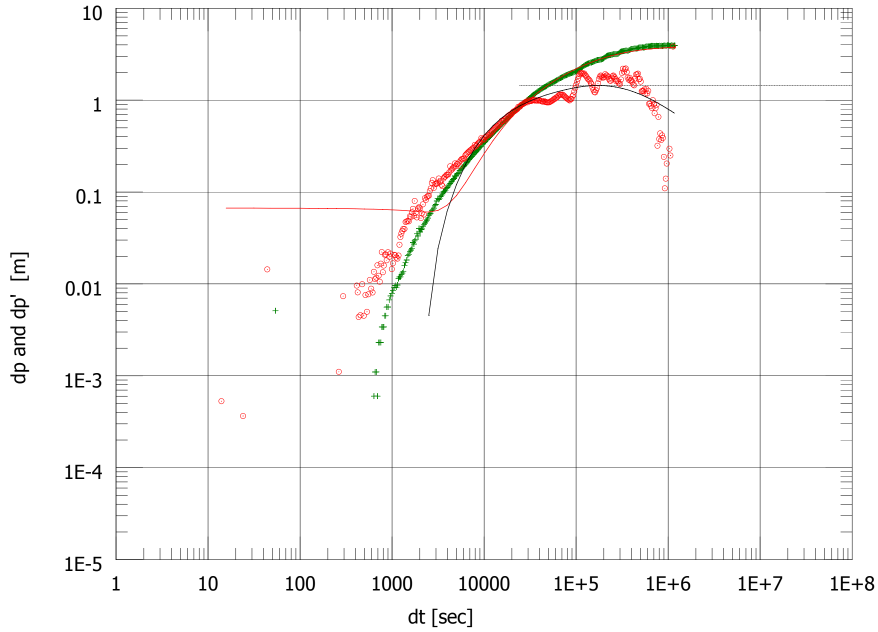
Derived & Secondary Parameters

P @ dt=0	14.1 m
Rinv	1120 m
Test. Vol.	96.8076 MMm3

Ecrin v4.02.02 HLX35_1obs_050616-050622_masl.ks3 2007-01-03 Page 3/8

Figure A2-8. *Lin-log plot of drawdown versus time together with simulated curves in the observation section HLX35:1 during pumping in borehole HLX34.*

Log-Log plot	Bu1
Company Svensk Kärnbränslehantering AB Well HLX35:1, obs	Field LAxemar Test Name / # Interferenstest HLX34pump-HLX35obs



HLX35_1obs build-up #1
Rate 0 l/min
Rate change 108.161 l/min
P@dt=0 10.4513 m
Pi 14.3 m
Smoothing 0.1

Selected Model
Model Option Standard Model
Well Line source
Reservoir Homogeneous
Boundary One fault

Main Model Parameters
TMatch 2.06E-5 [sec]-1
PMatch 0.347 [m]-1
S 1.61E-4
T 9.95E-5 m2/s
K 1.14E-6 m/s
Pi 14.3 m
Well distance 173 m

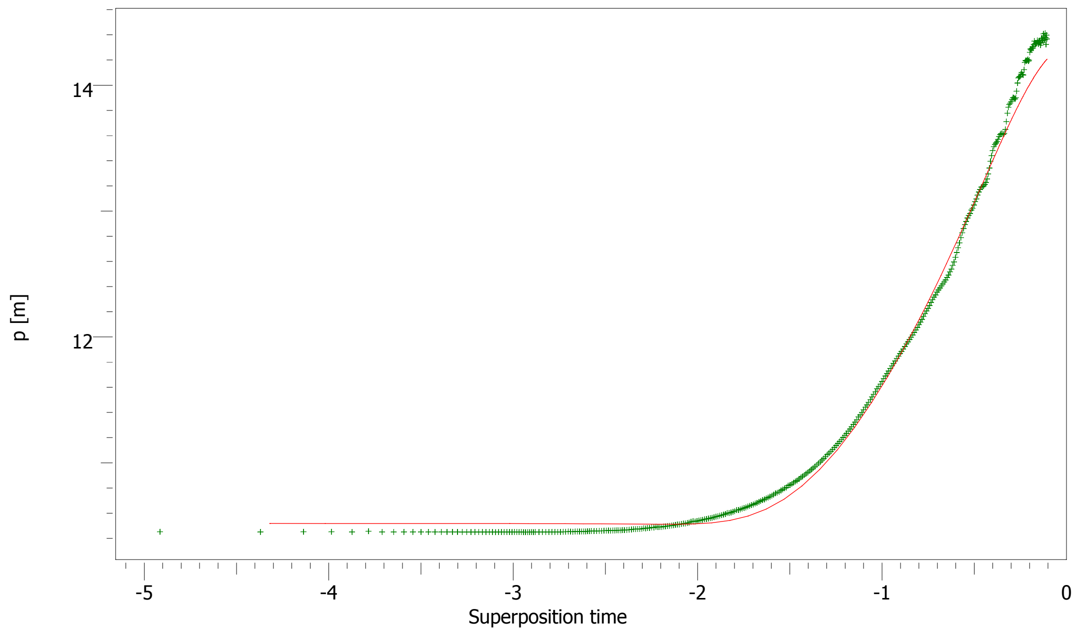
Model Parameters
Reservoir & Boundary parameters
Pi 14.3 m
T 9.95E-5 m2/s
K 1.14E-6 m/s
S 1.61E-4
L - Constant P. 510 m

Derived & Secondary Parameters
P @ dt=0 10.5 m

Ecrin v4.02.02 HLX35_1obs_050616-050622_masl.ks3 2007-01-03 Page 6/8

Figure A2-9. *Log-log plot of recovery and recovery derivative versus time together with simulated curves in the observation section HLX35:1 during pumping in borehole HLX34.*

Semi-Log plot	Bu1
Company Svensk Kärnbränslehantering AB Well HLX35:1, obs	Field LAxemar Test Name / # Interferenstest HLX34pump-HLX35obs



HLX35_1obs build-up #1

Rate	0 l/min
Rate change	108.161 l/min
P@dt=0	10.4513 m
Pi	14.3 m
Smoothing	0.1

Selected Model

Model Option	Standard Model
Well	Line source
Reservoir	Homogeneous
Boundary	One fault

Main Model Parameters

TMatch	2.06E-5 [sec]-1
PMatch	0.347 [m]-1
S	1.61E-4
T	9.95E-5 m2/s
K	1.14E-6 m/s
Pi	14.3 m
Well distance	173 m

Model Parameters
Reservoir & Boundary parameters

Pi	14.3 m
T	9.95E-5 m2/s
K	1.14E-6 m/s
S	1.61E-4
L - Constant P.	510 m

Derived & Secondary Parameters
P @ dt=0 10.5 m

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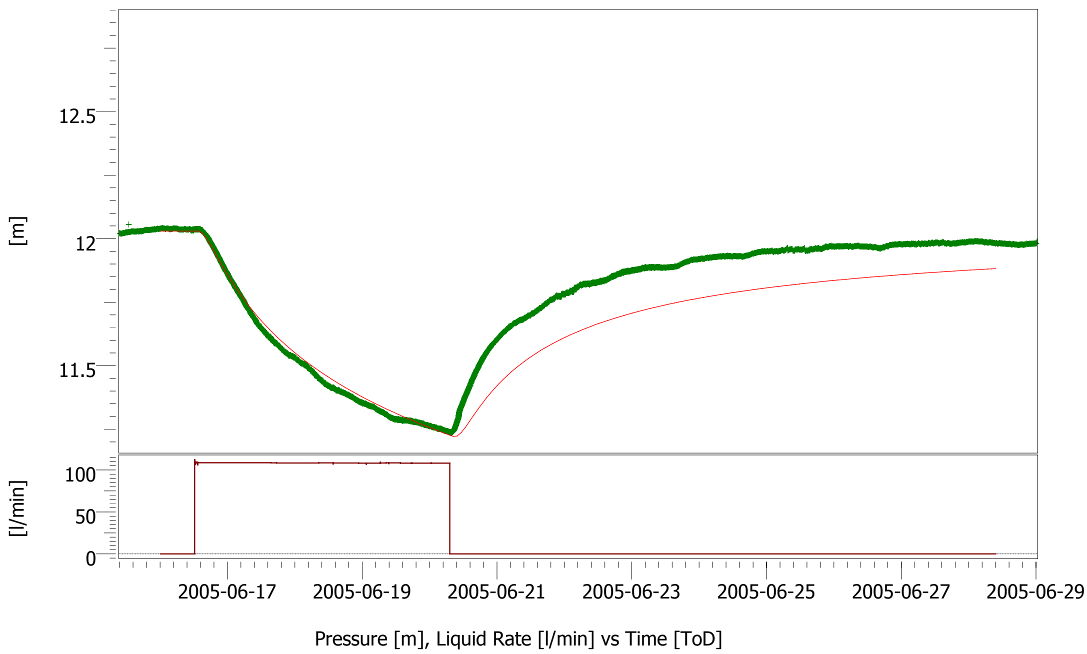
Figure A2-10. *Lin-log plot of recovery versus time together with simulated curves in the observation section HLX35:1 during pumping in borehole HLX34.*

History plot	Dd1
Company Svensk Kärnbränslehantering AB Well HLX35:2	Field Laxemar Test Name / # Interferenstest HLX34-HLX35



HLX35_2obs production #1

Rate	108.161 l/min
Rate change	108.161 l/min
P@dt=0	12.0357 m
Pi	12.03 m
Smoothing	0.1

Selected Model

Model Option	Standard Model
Well	Line source
Reservoir	Homogeneous
Boundary	Infinite

Main Model Parameters

TMatch	9.48E-6 [sec]-1
PMatch	1.26 [m]-1
S	0.00106
T	3.61E-4 m2/s
K	6.22E-6 m/s
Pi	12.03 m
Well distance	190 m

Model Parameters
Reservoir & Boundary parameters

Pi	12.03 m
T	3.61E-4 m2/s
K	6.22E-6 m/s
S	0.00106

Derived & Secondary Parameters

Rinv	590 m
Test. Vol.	271.535 MMm3

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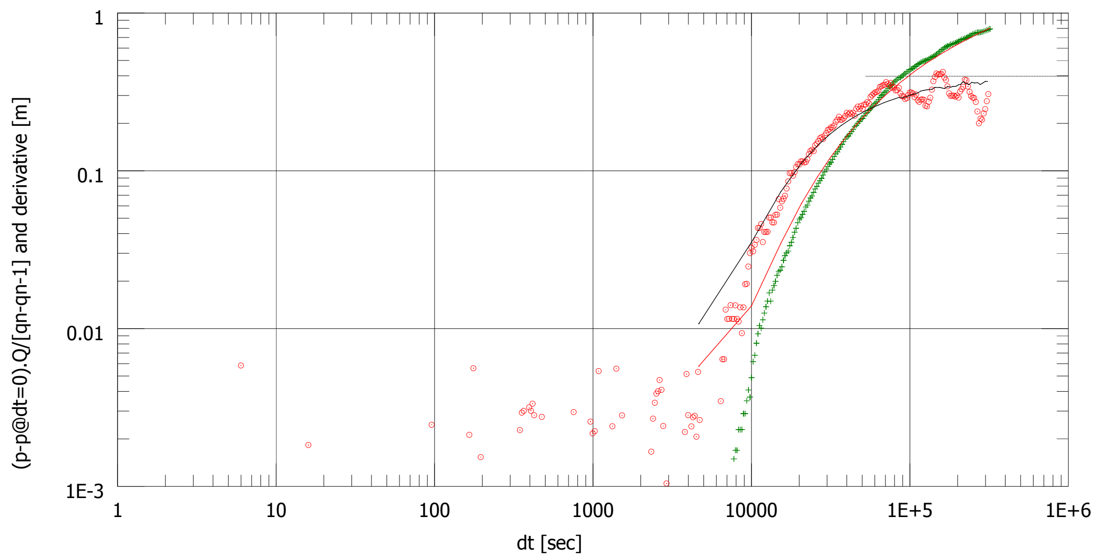
Figure A2-11. *Lin-lin plot of pressure versus time in observation section HLX35:2 during pumping in HLX34, together with evaluated data.*

	Log-Log plot	Dd1
SKB	Company Svensk Kärnbränslehantering AB Well HLX35:2	Field Laxemar Test Name / # Interferenstest HLX34-HLX35



HLX35_2obs production #1
Rate 108.161 l/min
Rate change 108.161 l/min
P@dt=0 12.0357 m
Pi 12.03 m
Smoothing 0.1

Selected Model
Model Option Standard Model
Well Line source
Reservoir Homogeneous
Boundary Infinite

Main Model Parameters
TMatch 9.48E-6 [sec]-1
PMatch 1.26 [m]-1
S 0.00106
T 3.61E-4 m2/s
K 6.22E-6 m/s
Pi 12.03 m
Well distance 190 m

Model Parameters
Reservoir & Boundary parameters
Pi 12.03 m
T 3.61E-4 m2/s
K 6.22E-6 m/s
S 0.00106

Derived & Secondary Parameters
Rinv 590 m
Test. Vol. 271.535 MMm3

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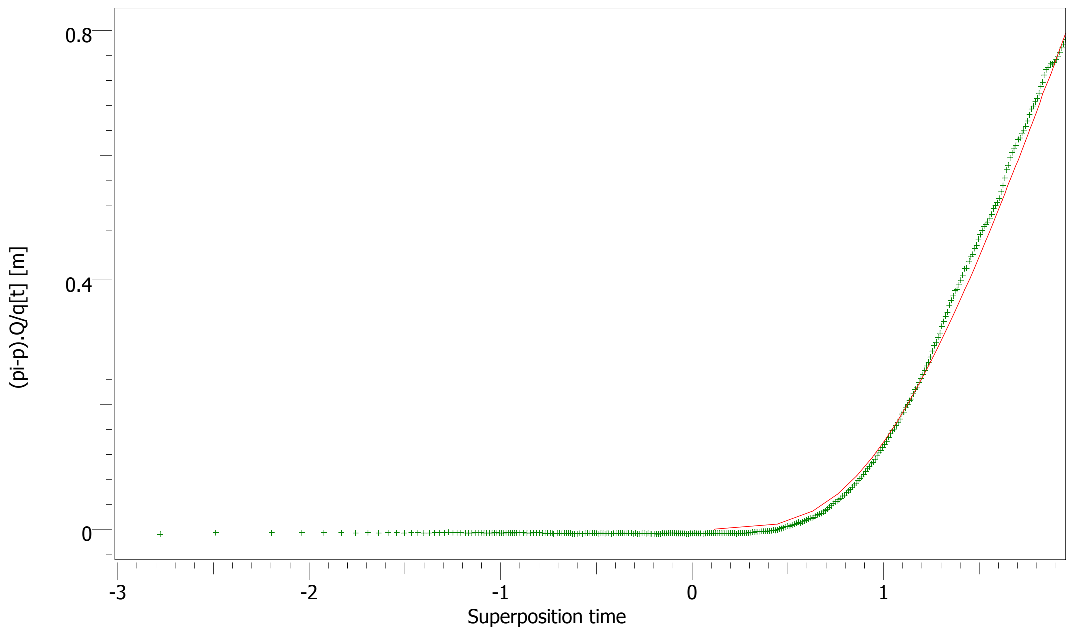
Figure A2-12. *Log-log plot of drawdown and drawdown derivative versus time together with simulated curves in the observation section HLX35:2 during pumping in borehole HLX34.*

Semi-Log plot	Dd1
Company Svensk Kärnbränslehantering AB Well HLX35:2	Field Laxemar Test Name / # Interferenstest HLX34-HLX35



HLX35_2obs production #1
Rate 108.161 l/min
Rate change 108.161 l/min
P@dt=0 12.0357 m
Pi 12.03 m
Smoothing 0.1

Selected Model
Model Option Standard Model
Well Line source
Reservoir Homogeneous
Boundary Infinite

Main Model Parameters
TMatch 9.48E-6 [sec]-1
PMatch 1.26 [m]-1
S 0.00106
T 3.61E-4 m2/s
K 6.22E-6 m/s
Pi 12.03 m
Well distance 190 m

Model Parameters
Reservoir & Boundary parameters
Pi 12.03 m
T 3.61E-4 m2/s
K 6.22E-6 m/s
S 0.00106

Derived & Secondary Parameters
Rinv 590 m
Test. Vol. 271.535 MMm3

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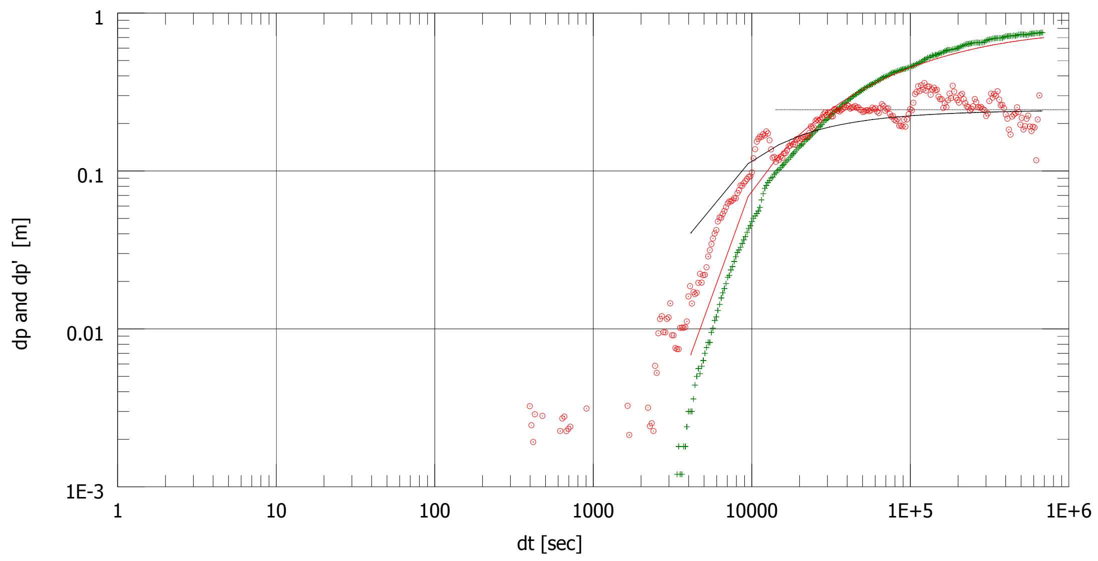
Figure A2-13. *Lin-log plot of drawdown versus time together with simulated curves in the observation section HLX35:2 during pumping in borehole HLX34.*

Log-Log plot	Bu1
Company Svensk Kärnbränslehantering AB Well HLX35:2	Field Laxemar Test Name / # Interferenstest HLX34-HLX35



HLX35_2obs build-up #1
Rate 0 l/min
Rate change 108.161 l/min
P@dt=0 11.2376 m
Pi 12.03 m
Smoothing 0.1

Selected Model
Model Option Standard Model
Well Line source
Reservoir Homogeneous
Boundary Infinite

Main Model Parameters
TMatch 3.53E-5 [sec]-1
PMatch 2.05 [m]-1
S 4.62E-4
T 5.87E-4 m2/s
K 1.01E-5 m/s
Pi 12.03 m
Well distance 190 m

Model Parameters
Reservoir & Boundary parameters
Pi 12.03 m
T 5.87E-4 m2/s
K 1.01E-5 m/s
S 4.62E-4

Derived & Secondary Parameters
Rinv 1670 m
Test. Vol. 944.242 MMm3

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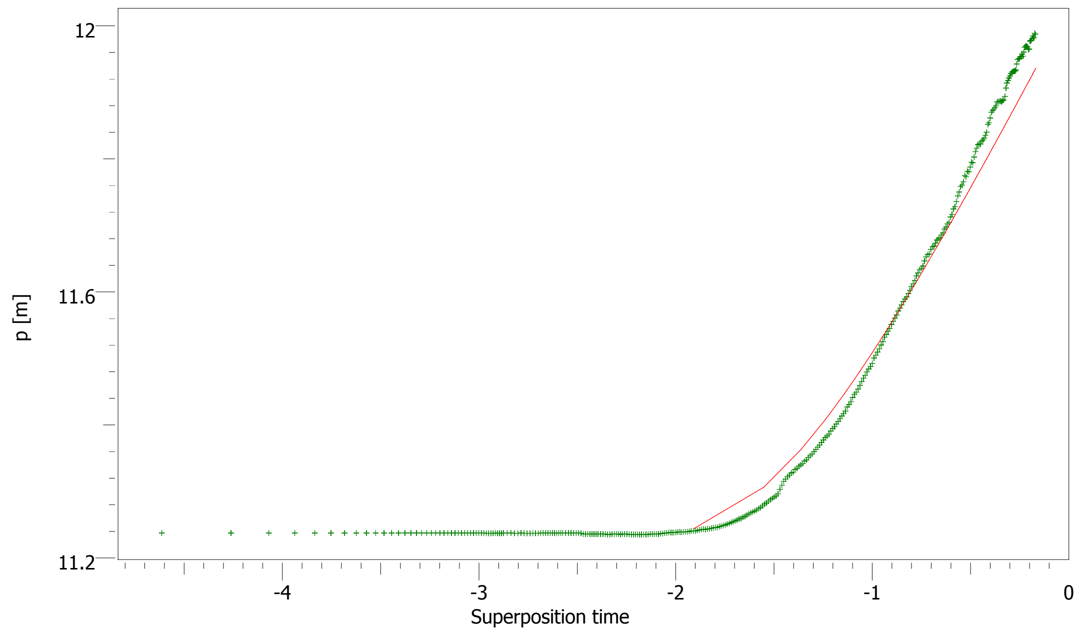
***Figure A2-14.** Log-log plot of recovery and recovery derivative versus time together with simulated curves in the observation section HLX35:2 during pumping in borehole HLX34.*

Semi-Log plot	Bu1
Company Svensk Kärnbränslehantering AB Well HLX35:2	Field Laxemar Test Name / # Interferenstest HLX34-HLX35



HLX35_2obs build-up #1
Rate 0 l/min
Rate change 108.161 l/min
P@dt=0 11.2376 m
Pi 12.03 m
Smoothing 0.1

Selected Model
Model Option Standard Model
Well Line source
Reservoir Homogeneous
Boundary Infinite

Main Model Parameters
TMatch 3.53E-5 [sec]-1
PMatch 2.05 [m]-1
S 4.62E-4
T 5.87E-4 m2/s
K 1.01E-5 m/s
Pi 12.03 m
Well distance 190 m

Model Parameters
Reservoir & Boundary parameters
Pi 12.03 m
T 5.87E-4 m2/s
K 1.01E-5 m/s
S 4.62E-4

Derived & Secondary Parameters
Rinv 1670 m
Test. Vol. 944.242 MMm3

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Figure A2-15. *Lin-log plot of recovery versus time together with simulated curves in the observation section HLX35:2 during pumping in borehole HLX34.*

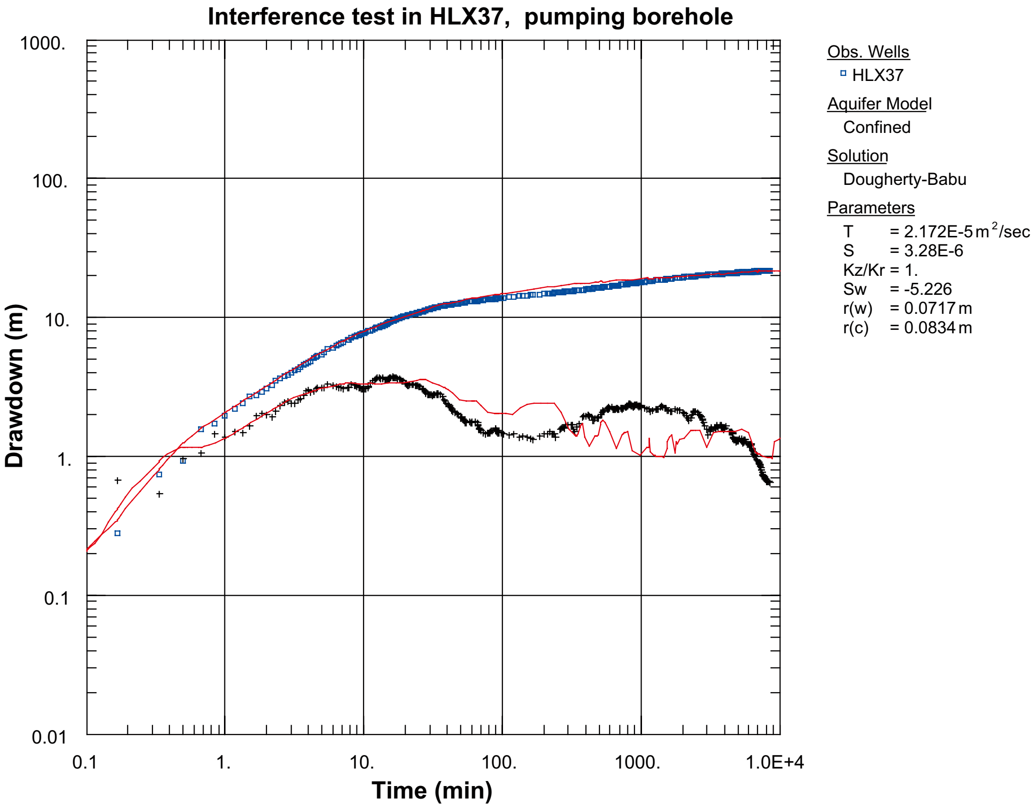


Figure A2-16. *Log-log plot of drawdown (blue □) and drawdown derivative (black +) versus time together with simulated curves (red) in the pumping borehole HLX37.*

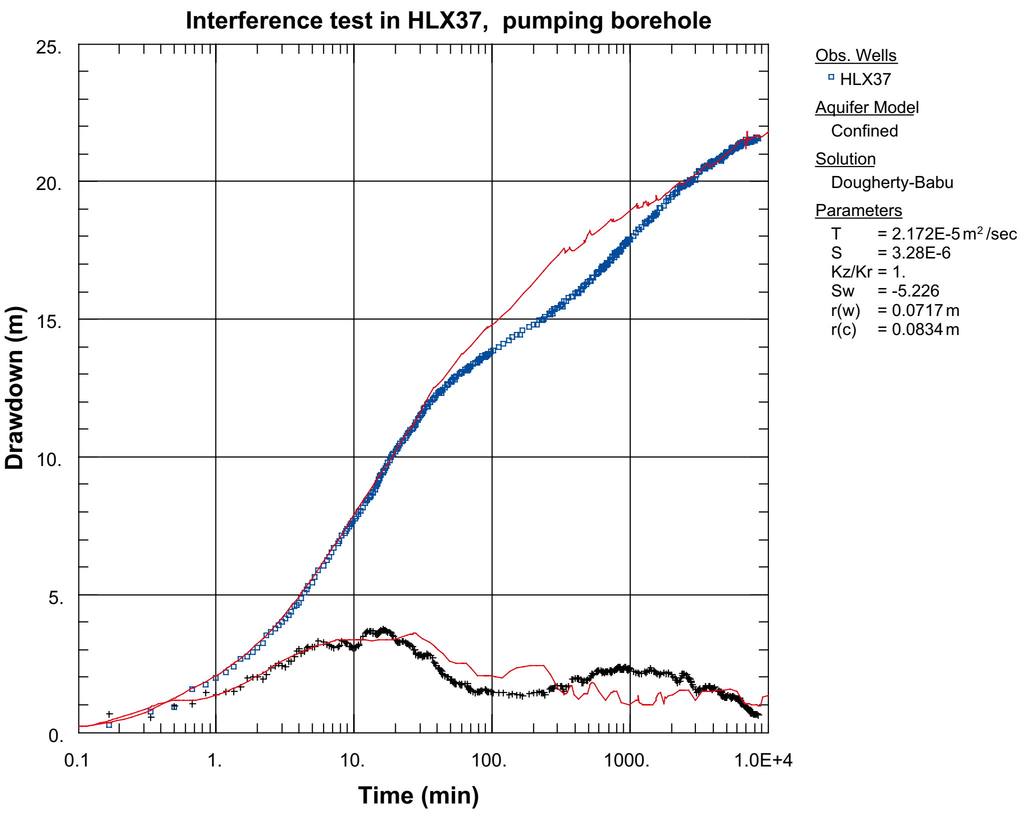


Figure A2-17. *Lin-log plot of drawdown (blue □) and drawdown derivative (black +) versus time together with simulated curves (red) in the pumping borehole HLX37.*

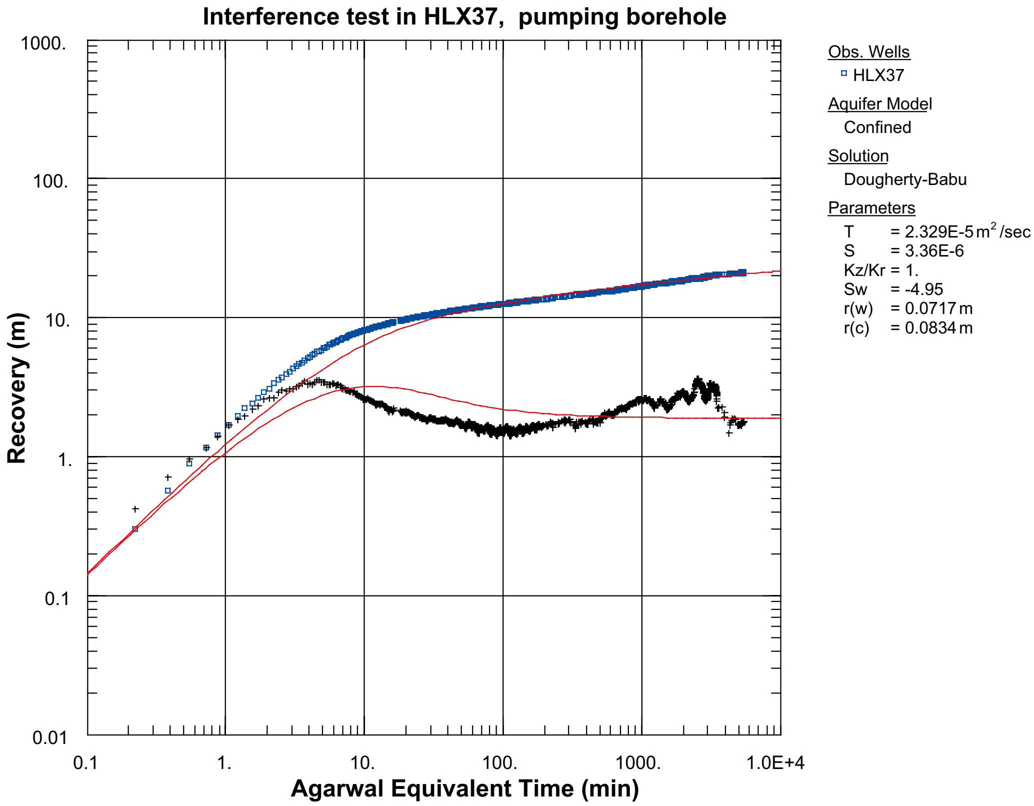


Figure A2-18. Log-log plot of pressure recovery (blue □) and -derivative (black +) versus equivalent time (dte) together with simulated curves (red) in the pumping borehole HLX37.

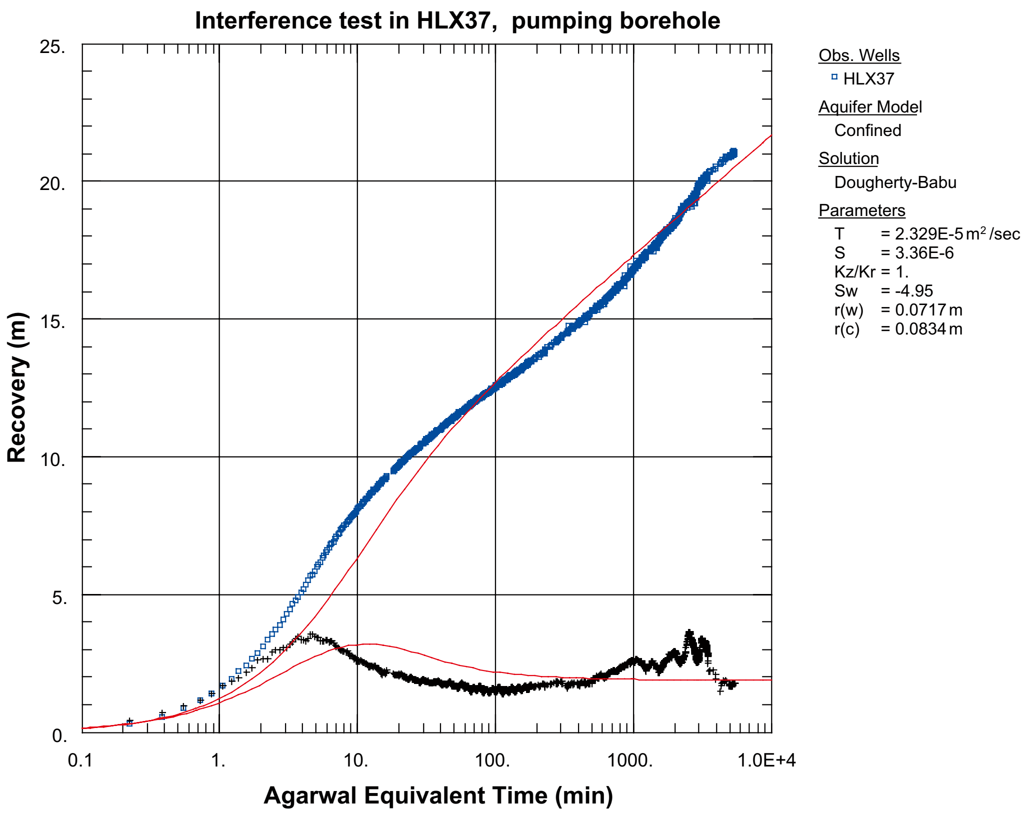


Figure A2-19. Lin-log plot of pressure recovery (blue □) and -derivative (black +) versus equivalent time (dte) together with simulated curves (red) in the pumping borehole HLX37.

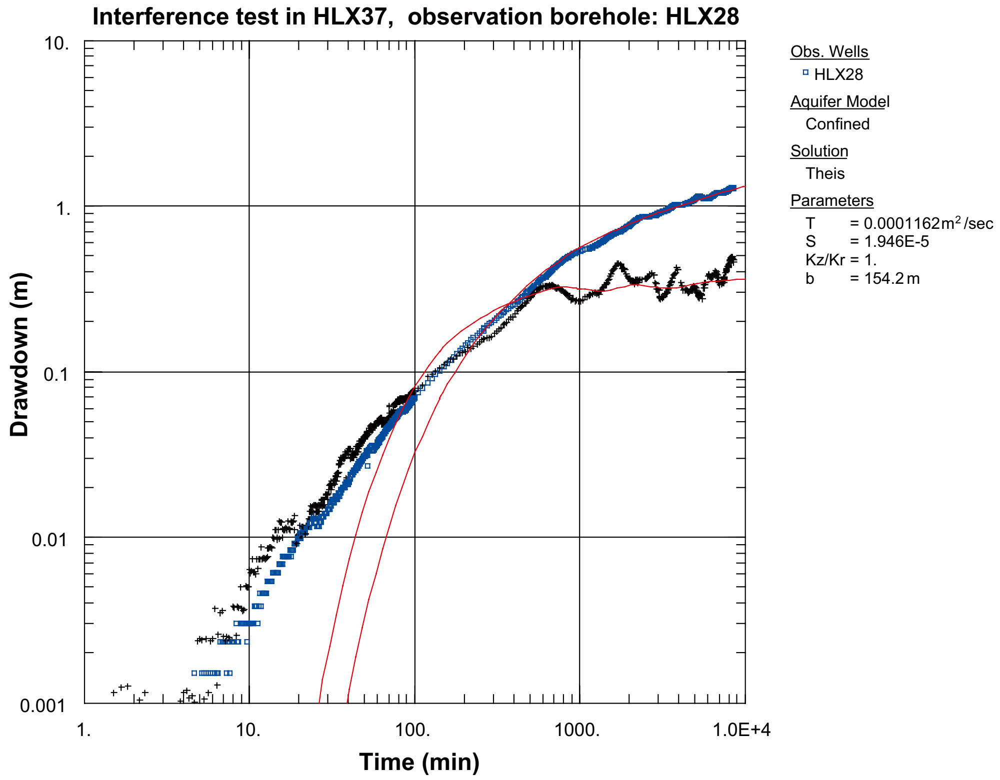


Figure A2-20. *Log-log plot of drawdown (blue □) and drawdown derivative (black +) versus time together with simulated curves (red) in the observation borehole HLX28 during pumping in borehole HLX37.*

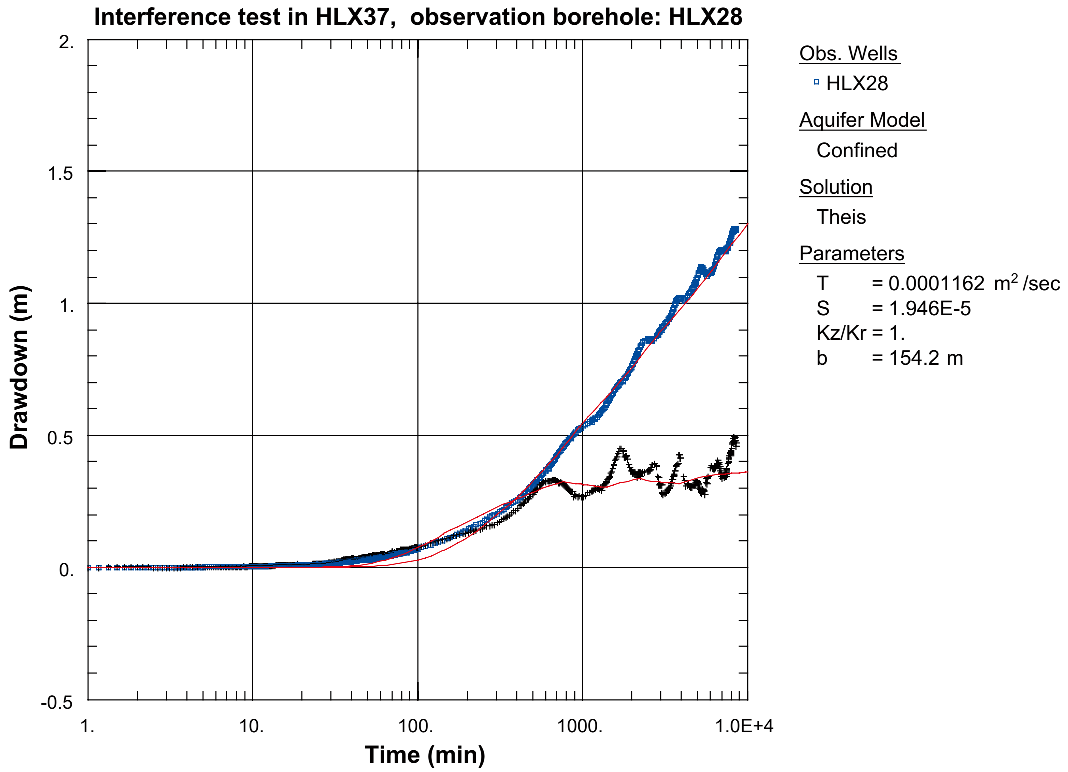


Figure A2-21. *Lin-log plot of drawdown (blue □) and drawdown derivative (black +) versus time together with simulated curves (red) in the observation borehole HLX28 during pumping in borehole HLX37.*

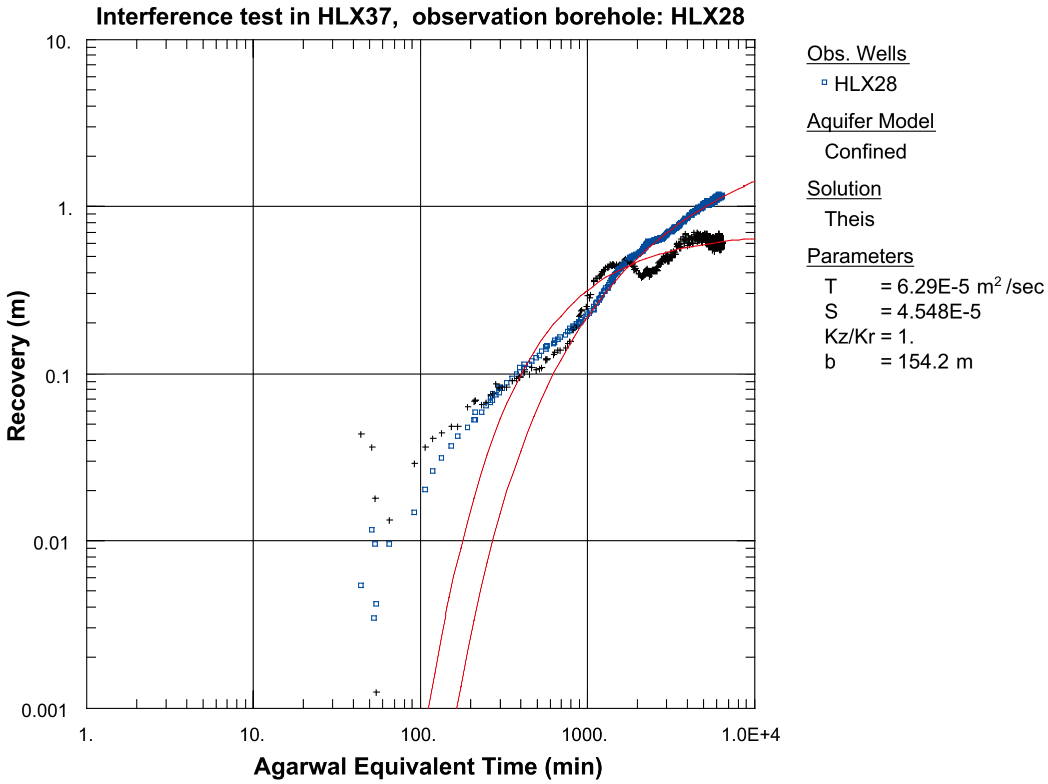


Figure A2-22. *Log-log plot of pressure recovery (blue □) and -derivative (black +) versus equivalent time (dte) together with simulated curves (red) in the observation borehole HLX28 during pumping in borehole HLX37.*

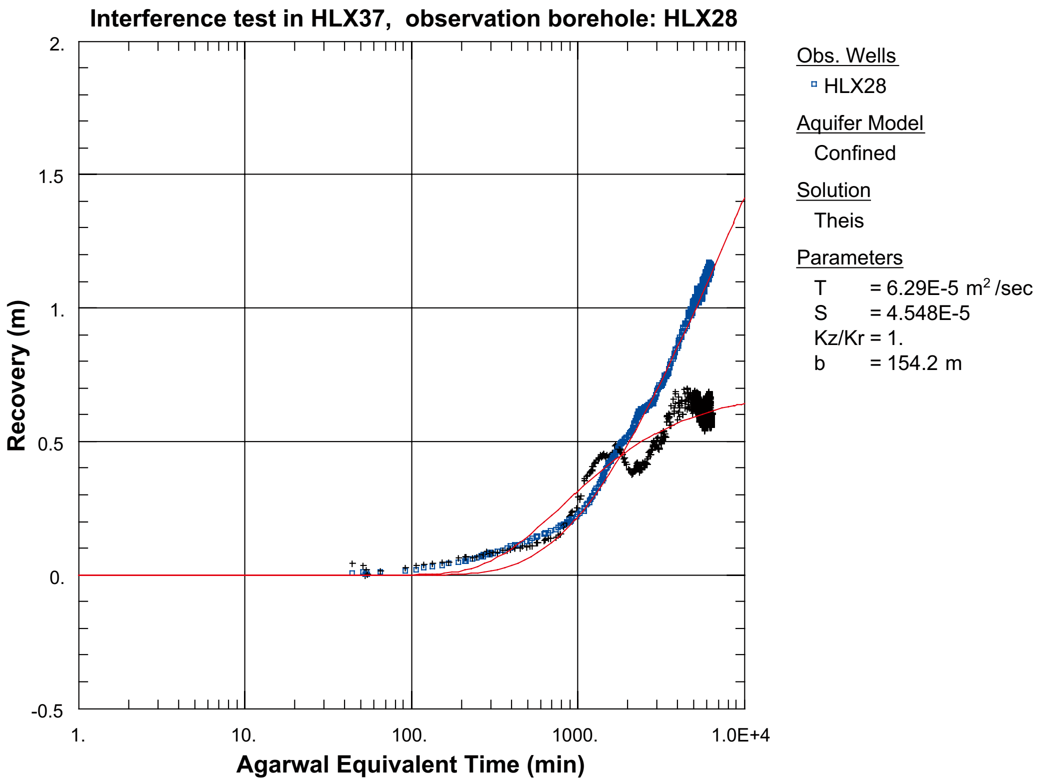


Figure A2-23. *Lin-log plot of pressure recovery (blue □) and -derivative (black +) versus equivalent time (dte) together with simulated curves (red) in the observation borehole HLX28 during pumping in borehole HLX37.*

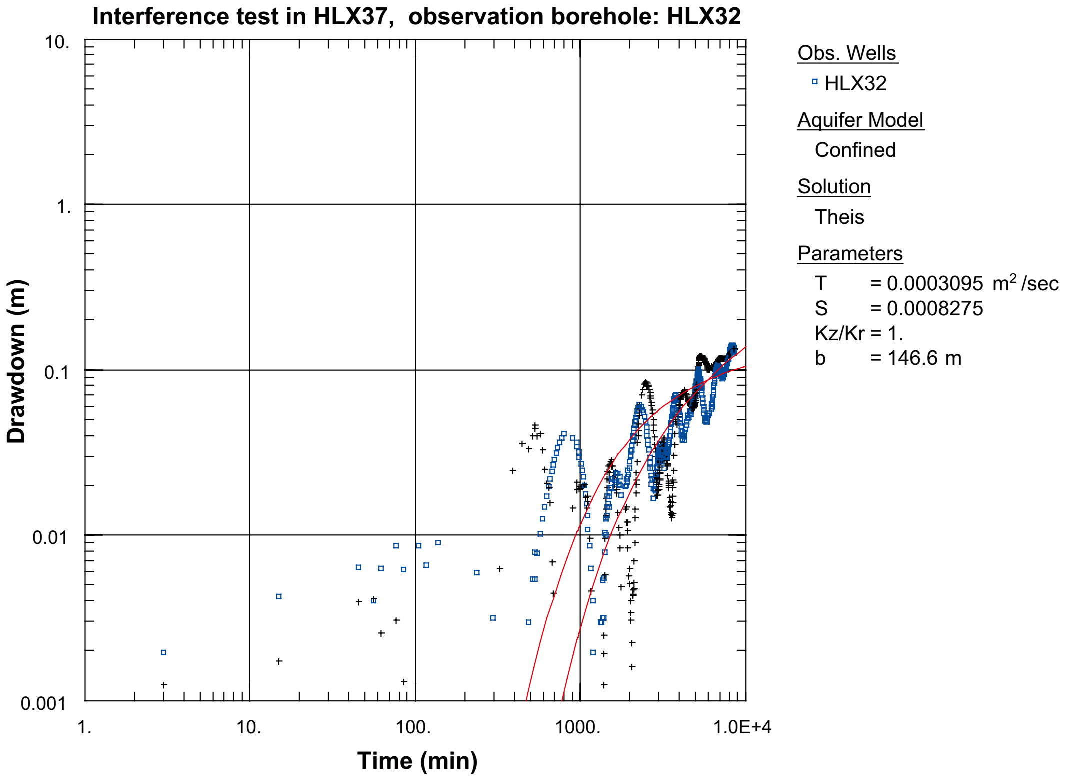


Figure A2-24. *Log-log plot of drawdown (blue □) and drawdown derivative (black +) versus time together with simulated curves (red) in the observation borehole HLX32 during pumping in borehole HLX37.*

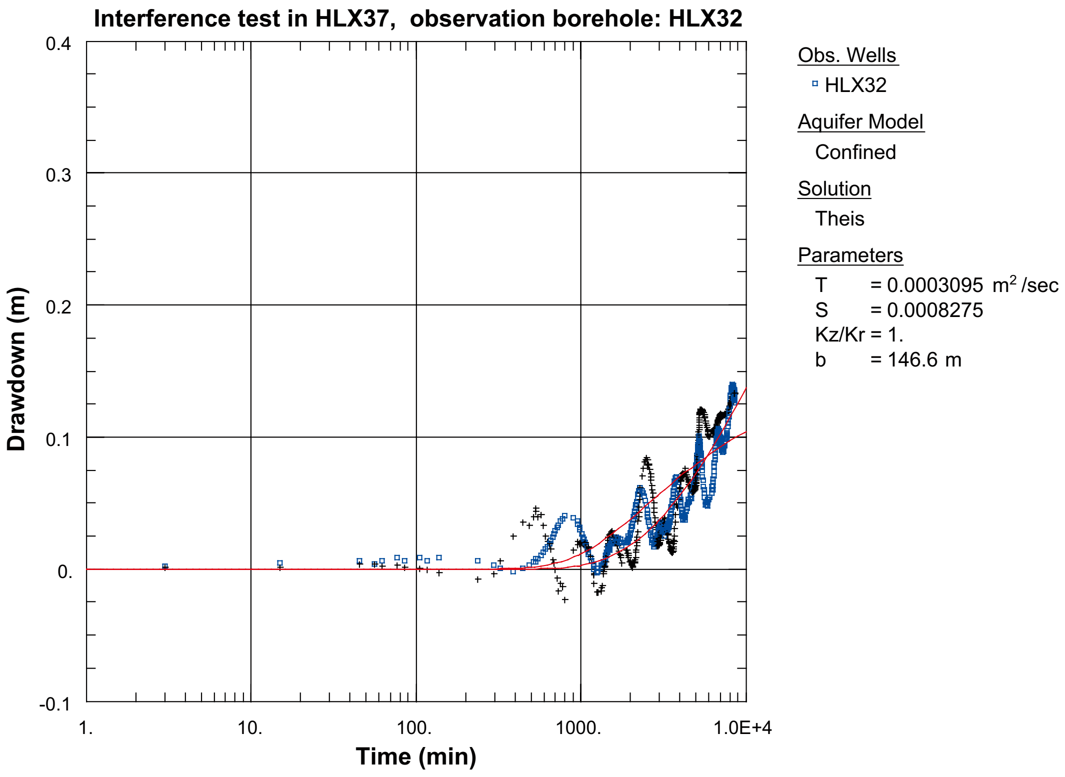


Figure A2-25. *Lin-log plot of drawdown (blue □) and drawdown derivative (black +) versus time together with simulated curves (red) in the observation borehole HLX32 during pumping in borehole HLX37.*

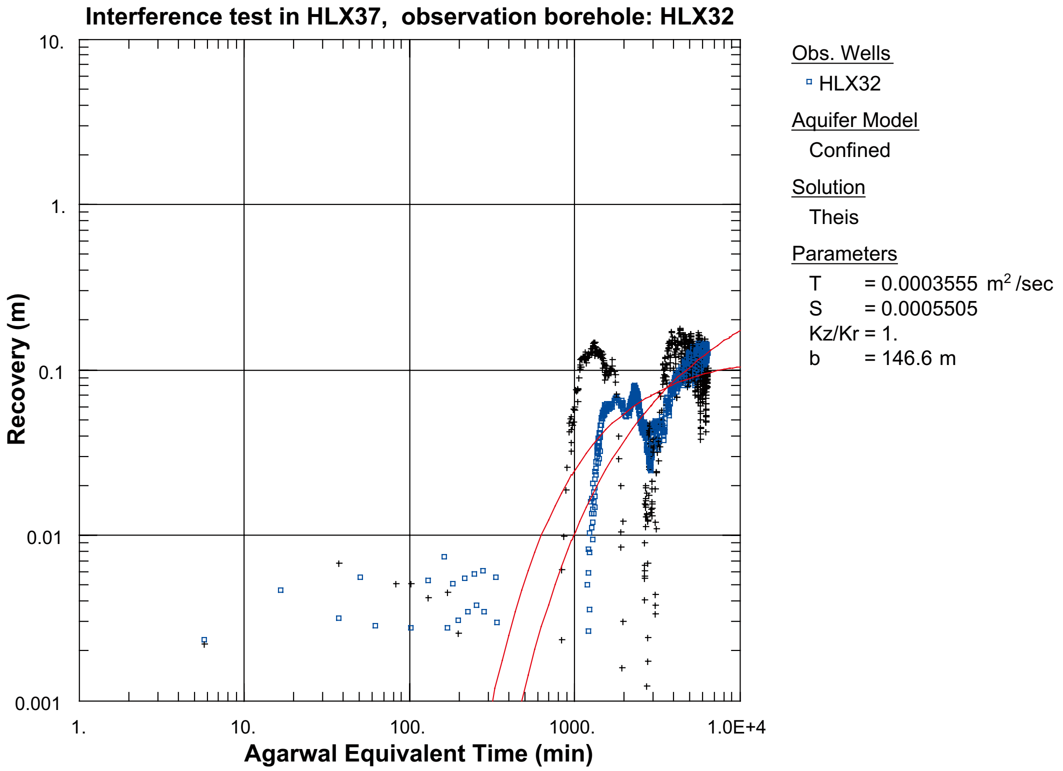


__Figure A2-26.__ Log-log plot of pressure recovery (blue □) and -derivative (black +) versus equivalent time (dte) together with simulated curves (red) in the observation borehole HLX32 during pumping in borehole HLX37.

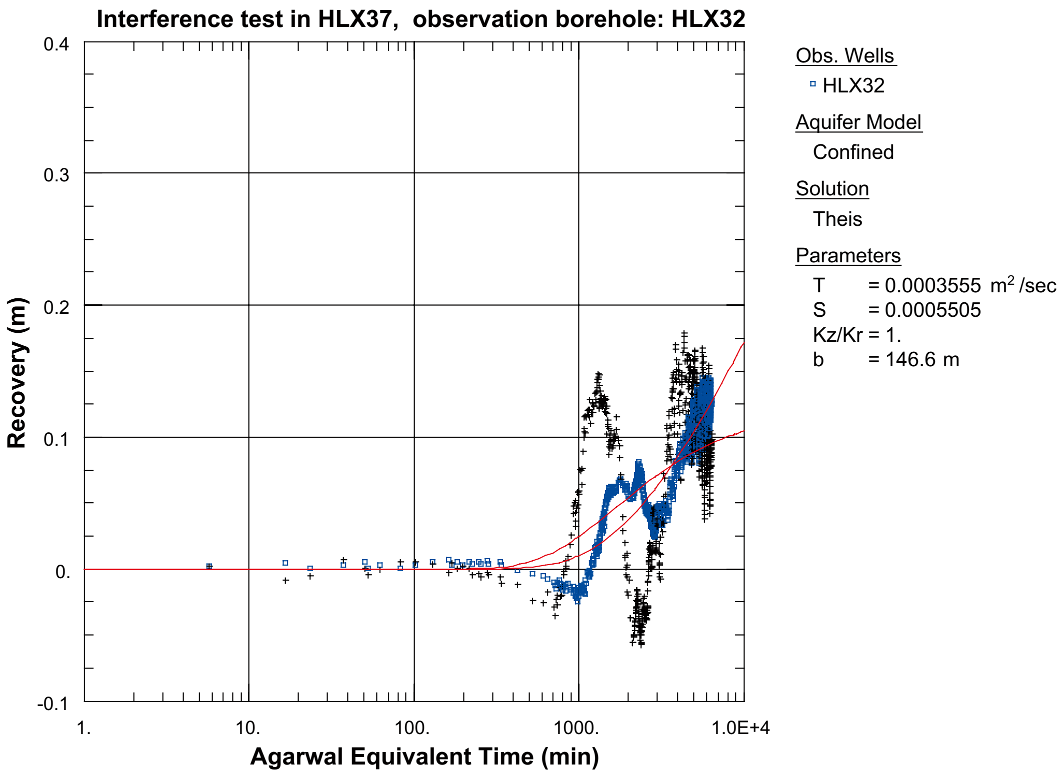


__Figure A2-27.__ Lin-log plot of pressure recovery (blue □) and -derivative (black +) versus equivalent time (dte) together with simulated curves (red) in the observation borehole HLX32 during pumping in borehole HLX37.

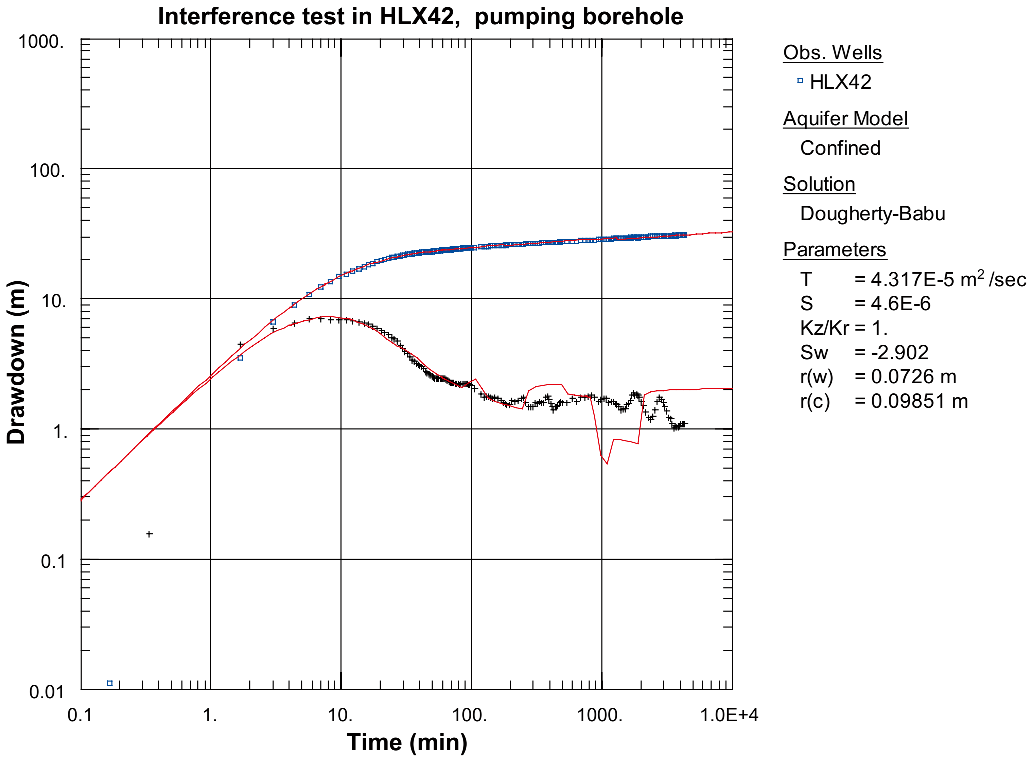


Figure A2-28. *Log-log plot of drawdown (blue □) and drawdown derivative (black +) versus time together with simulated curves (red) in the pumping borehole HLX42.*

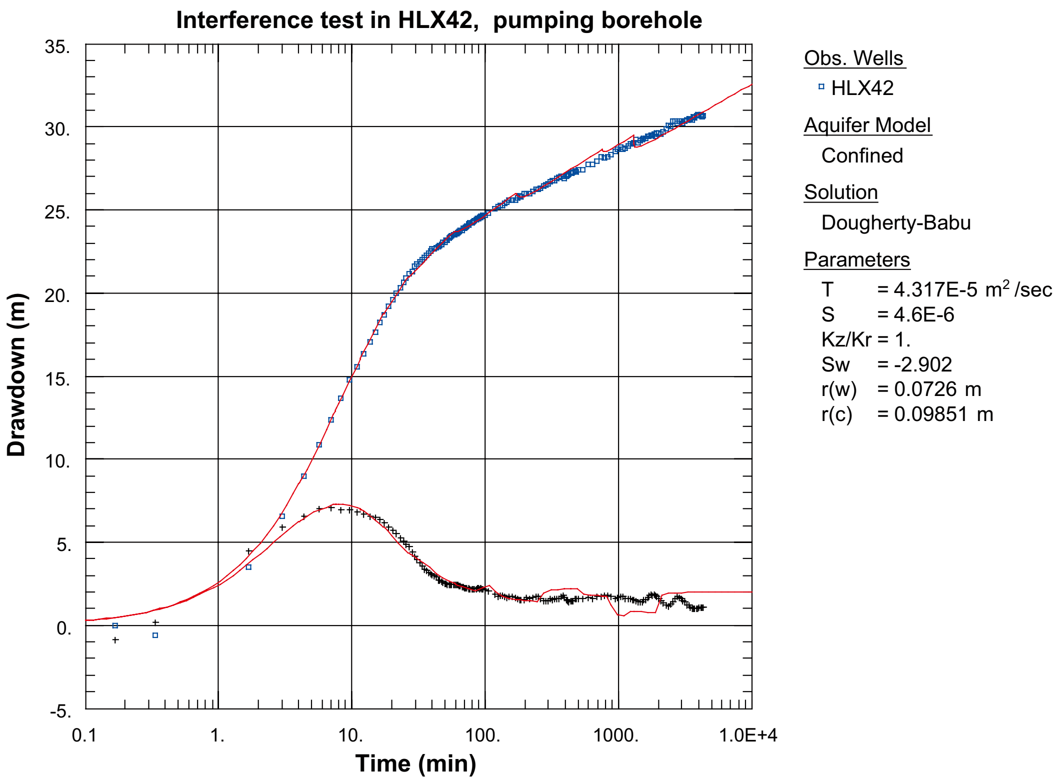


Figure A2-29. *Lin-log plot of drawdown (blue □) and drawdown derivative (black +) versus time together with simulated curves (red) in the pumping borehole HLX42.*

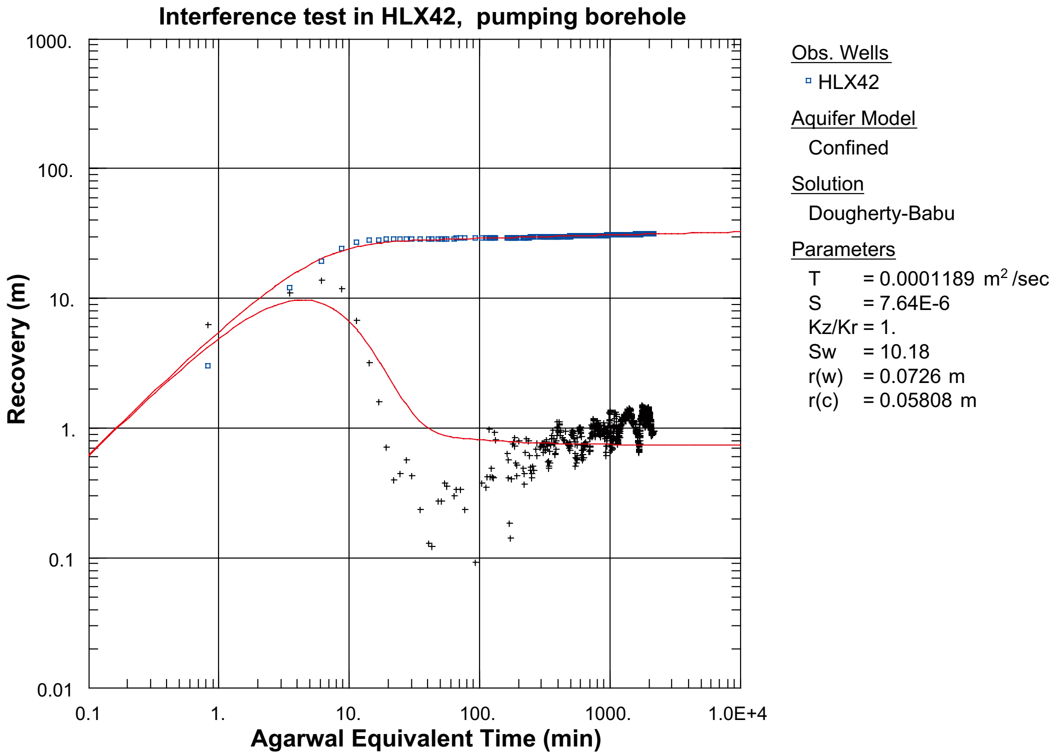


Figure A2-30. *Log-log plot of pressure recovery (blue □) and -derivative (black +) versus equivalent time (dte) together with simulated curves (red) in the pumping borehole HLX42.*

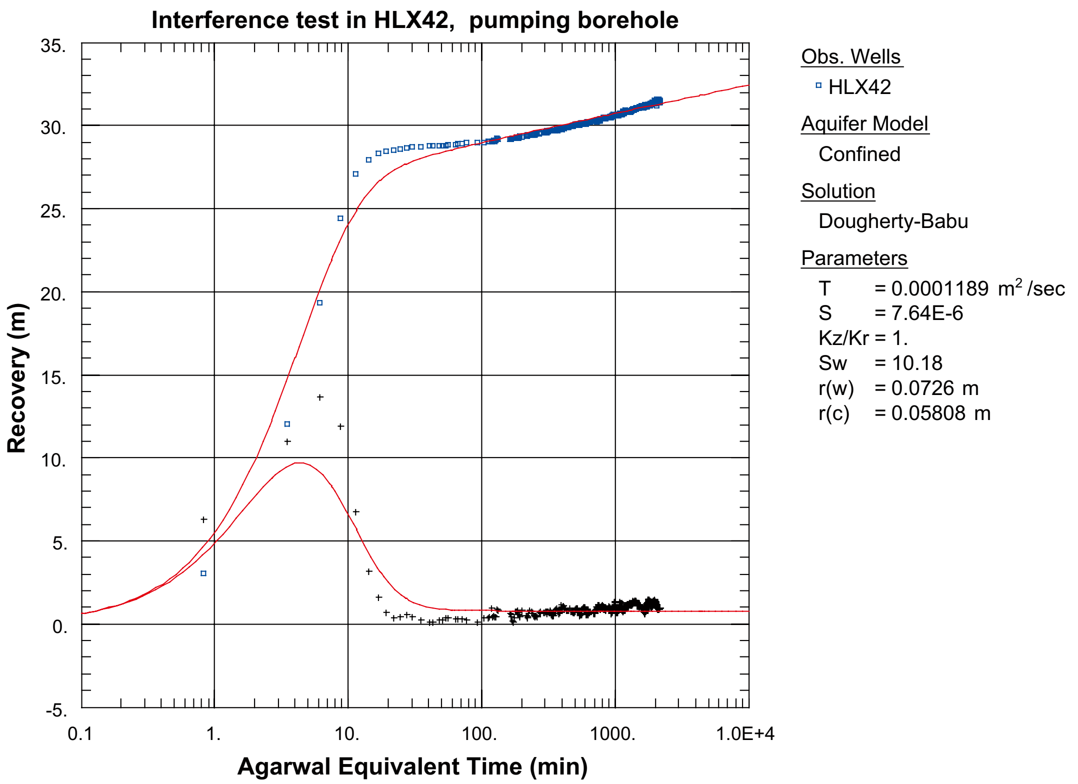


Figure A2-31. *Lin-log plot of pressure recovery (blue □) and -derivative (black +) versus equivalent time (dte) together with simulated curves (red) in the pumping borehole HLX42.*

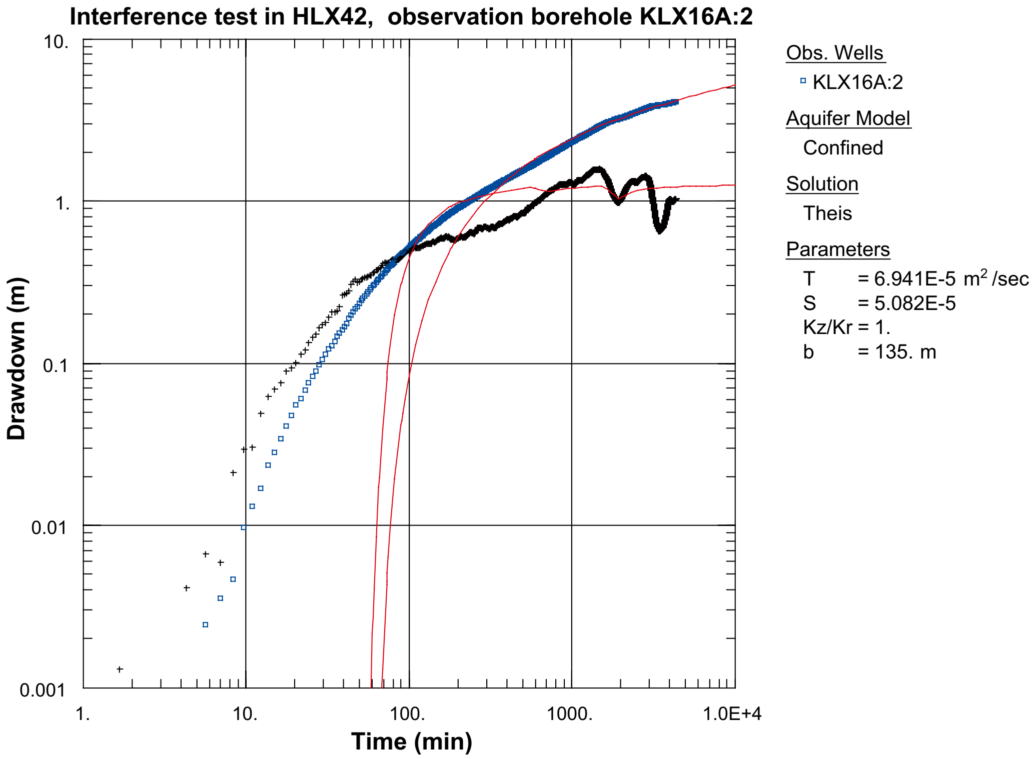


Figure A2-32. *Log-log plot of drawdown (blue □) and drawdown derivative (black +) versus time together with simulated curves (red) in the observation borehole KLX16A, section 2, during pumping in borehole HLX42.*

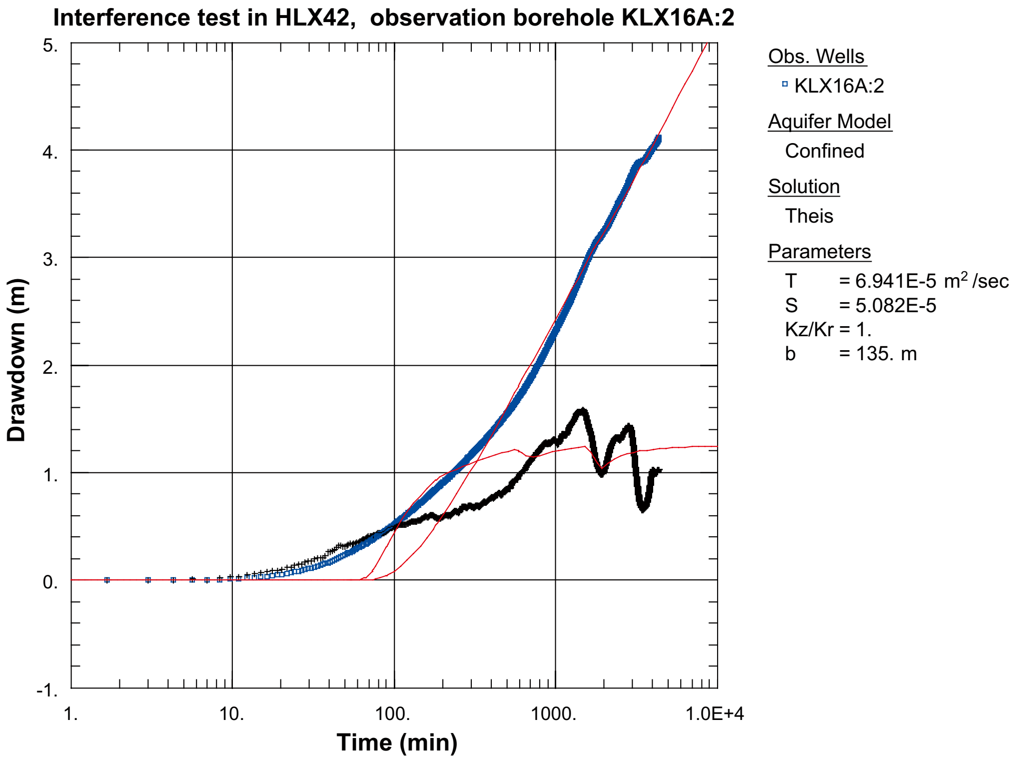


Figure A2-33. *Lin-log plot of drawdown (blue □) and drawdown derivative (black +) versus time together with simulated curves (red) in the observation borehole KLX16A, section 2,during pumping in borehole HLX42.*

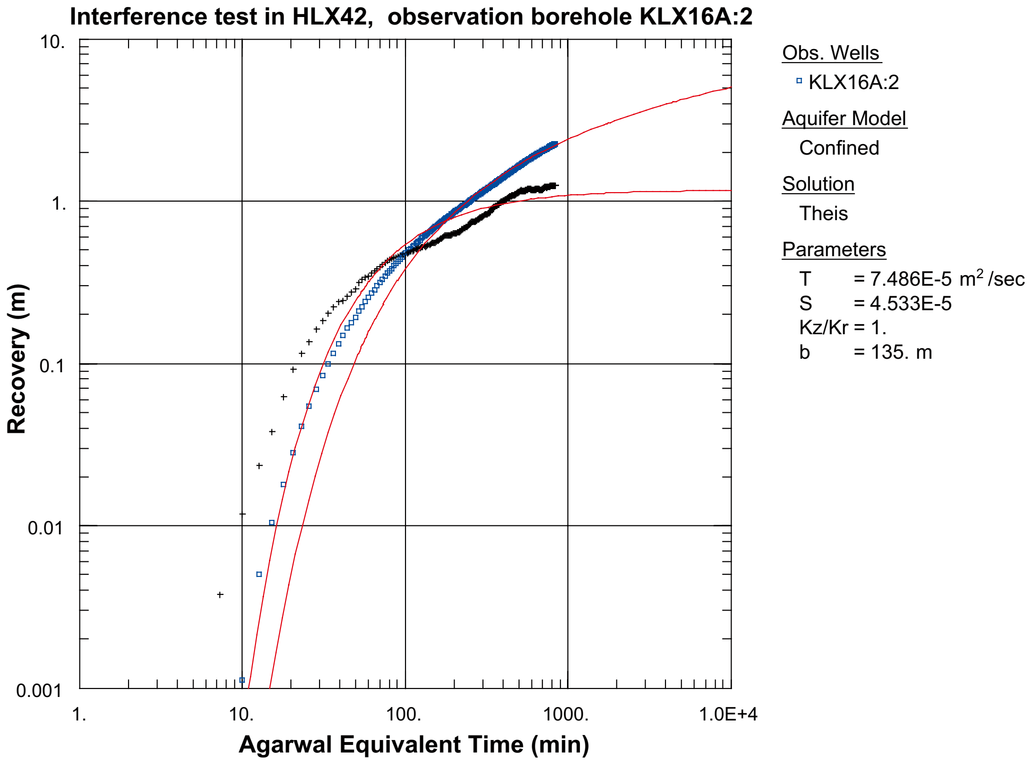


Figure A2-34. *Log-log plot of pressure recovery (blue □) and -derivative (black +) versus equivalent time (dte) in the observation borehole KLX16A, section 2, during pumping in borehole HLX42.*

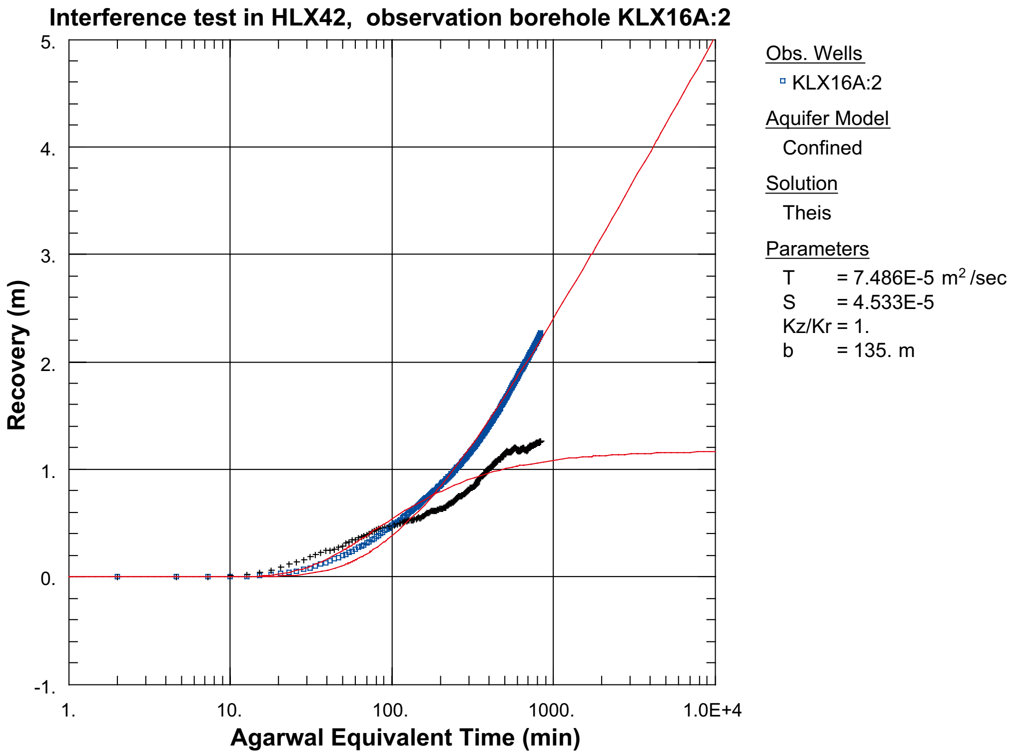


Figure A2-35. *Lin-log plot of pressure recovery (blue □) and -derivative (black +) versus equivalent time (dte) in the observation borehole KLX16A, section 2, during pumping in borehole HLX42.*

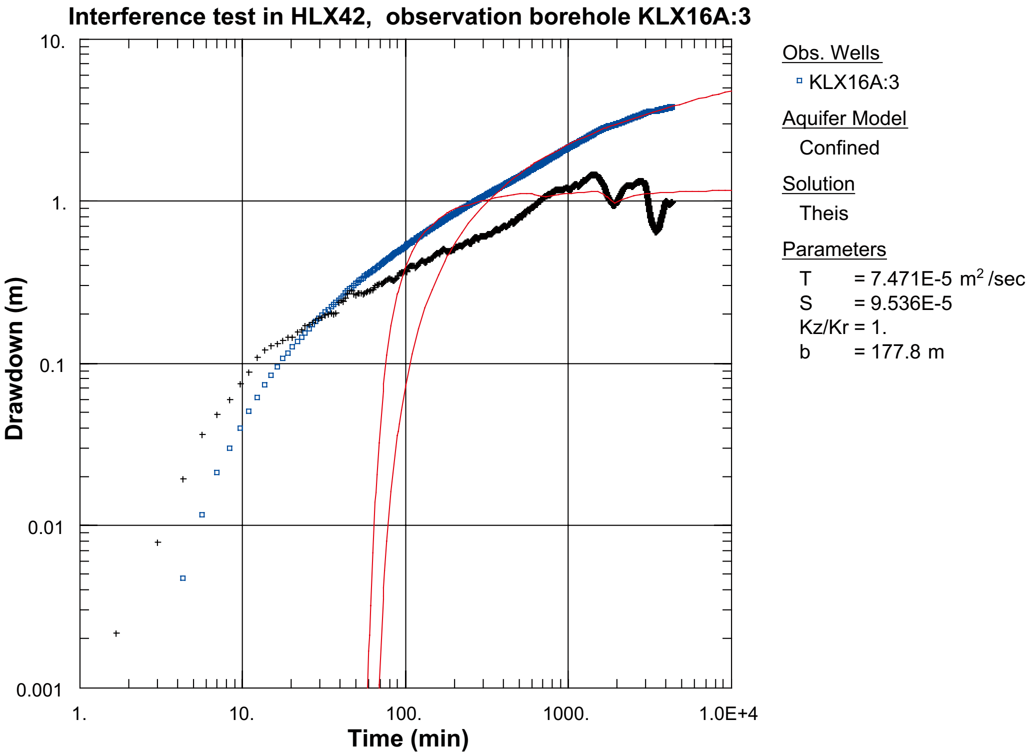


__Figure A2-36.__ Log-log plot of drawdown (blue □) and drawdown derivative (black +) versus time together with simulated curves (red) in the observation borehole KLX16A, section 3, during pumping in borehole HLX42.

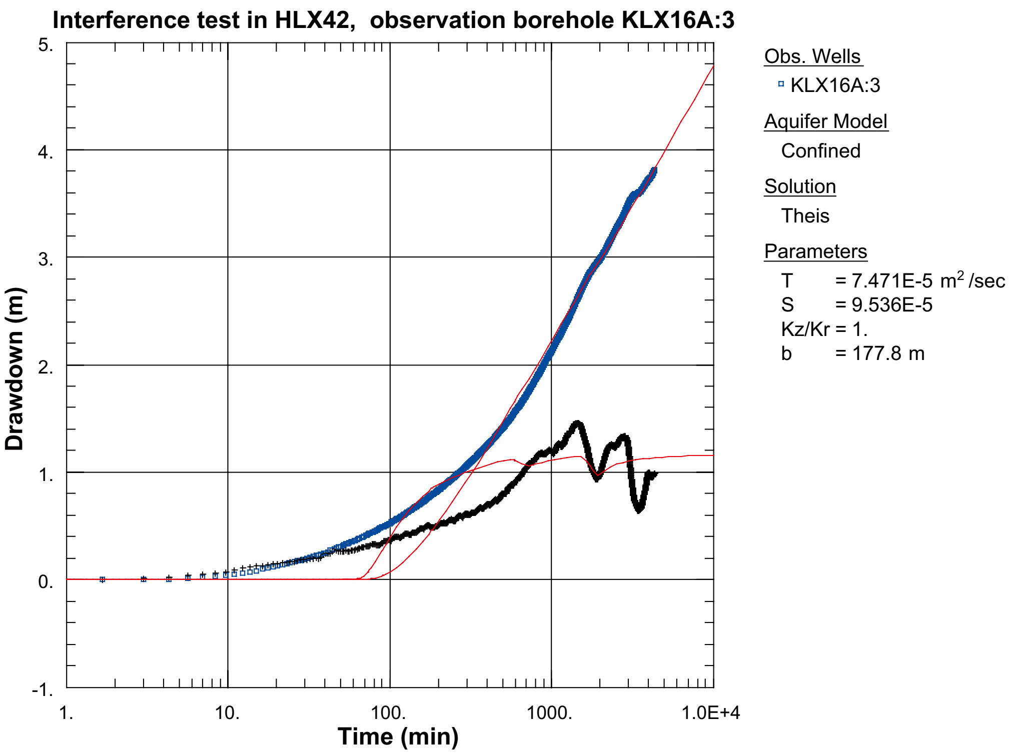


__Figure A2-37.__ Lin-log plot of drawdown (blue □) and drawdown derivative (black +) versus time together with simulated curves (red) in the observation borehole KLX16A, section 3,during pumping in borehole HLX42.

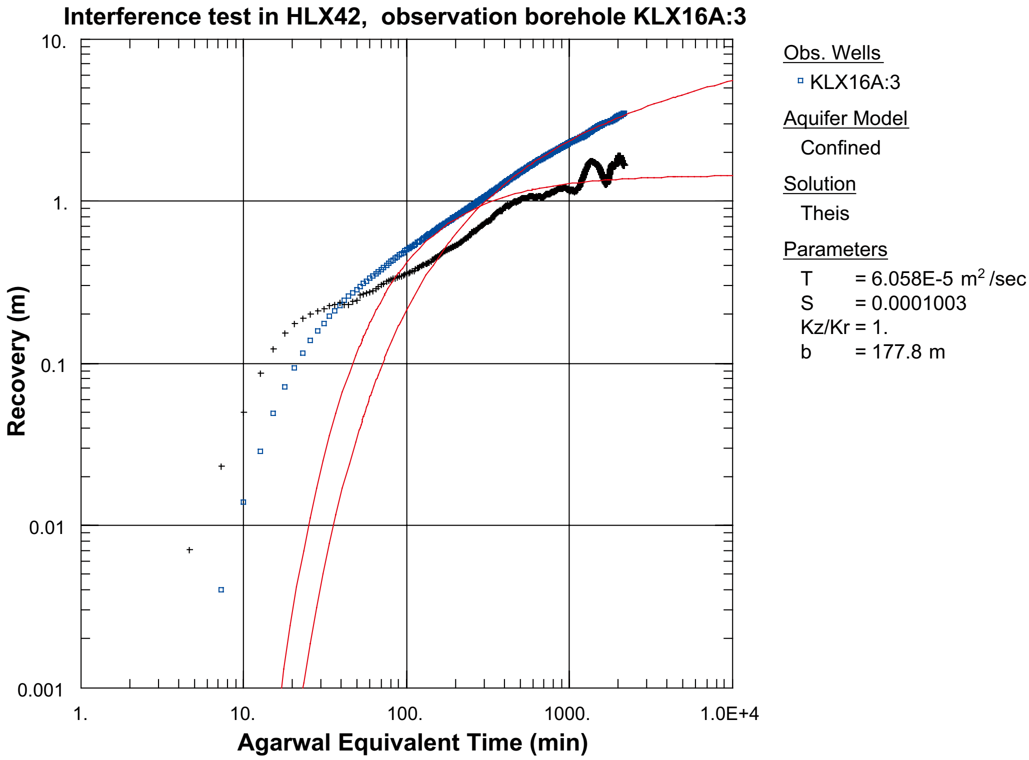


Figure A2-38. *Log-log plot of pressure recovery (blue □) and -derivative (black +) versus equivalent time (dte) in the observation borehole KLX16A, section 3, during pumping in borehole HLX42.*

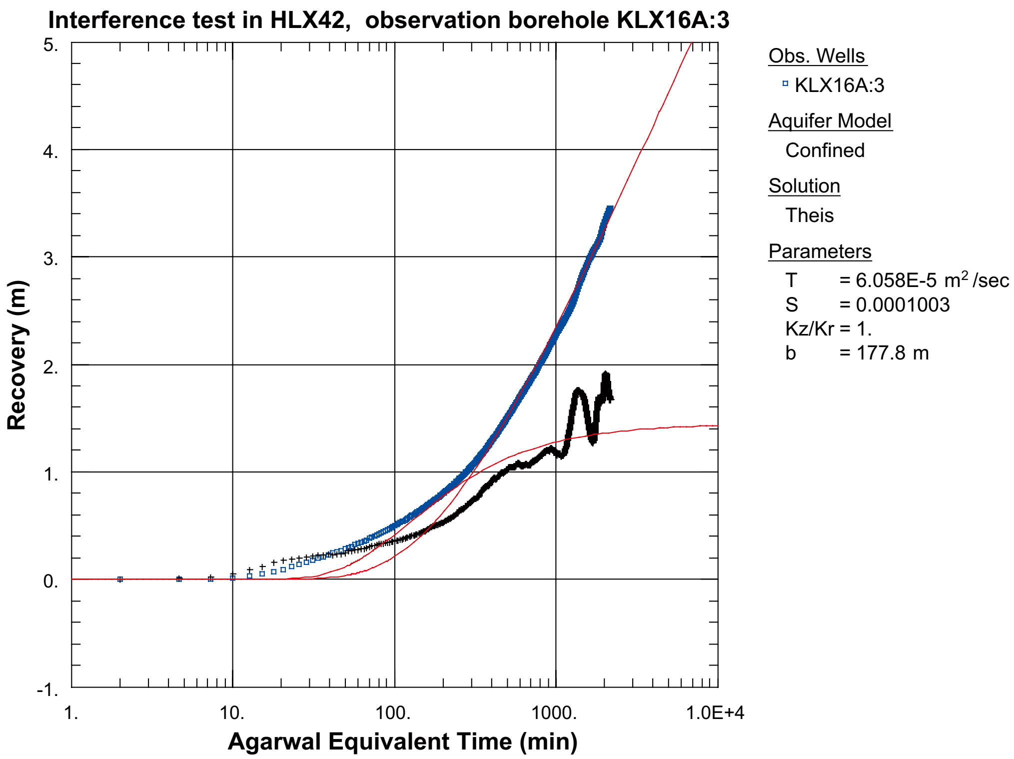
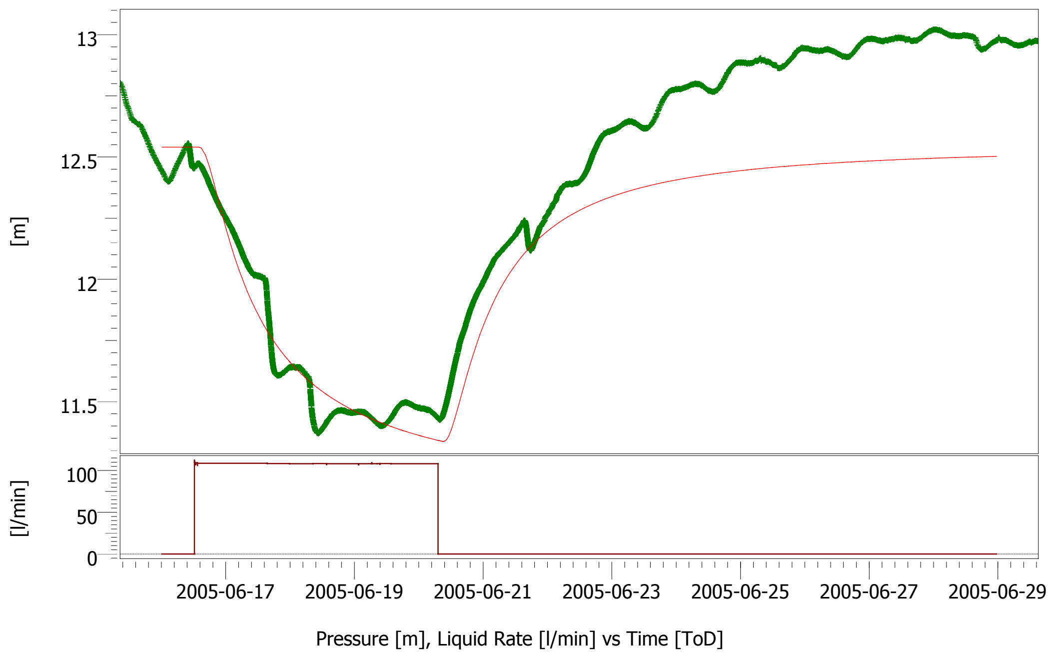


Figure A2-39. *Lin-log plot of pressure recovery (blue □) and -derivative (black +) versus equivalent time (dte) in the observation borehole KLX16A, section 3, during pumping in borehole HLX42.*

History plot		Dd1	
Company	Svensk Kärnbränslehantering AB	Field	Laxemar
Well	HLX13, lp=100m	Test Name / #	Interferenstest HLX34, lp=112m



HLX13obs_HLX34pump production #1

Rate	108.161 l/min
Rate change	108.161 l/min
P@dt=0	12.454 m
Pi	12.54 m
Smoothing	0.1

Selected Model

Model Option	Standard Model
Well	Line source
Reservoir	Homogeneous
Boundary	One fault

Main Model Parameters

TMatch	6.68E-6 [sec]-1
PMatch	0.374 [m]-1
S	7.48E-5
T	1.07E-4 m2/s
K	5.67E-7 m/s
Pi	12.54 m
Well distance	462 m

Model Parameters

Reservoir & Boundary parameters

Pi	12.54 m
T	1.07E-4 m2/s
K	5.67E-7 m/s
S	7.48E-5
L - Constant P.	327 m

Derived & Secondary Parameters

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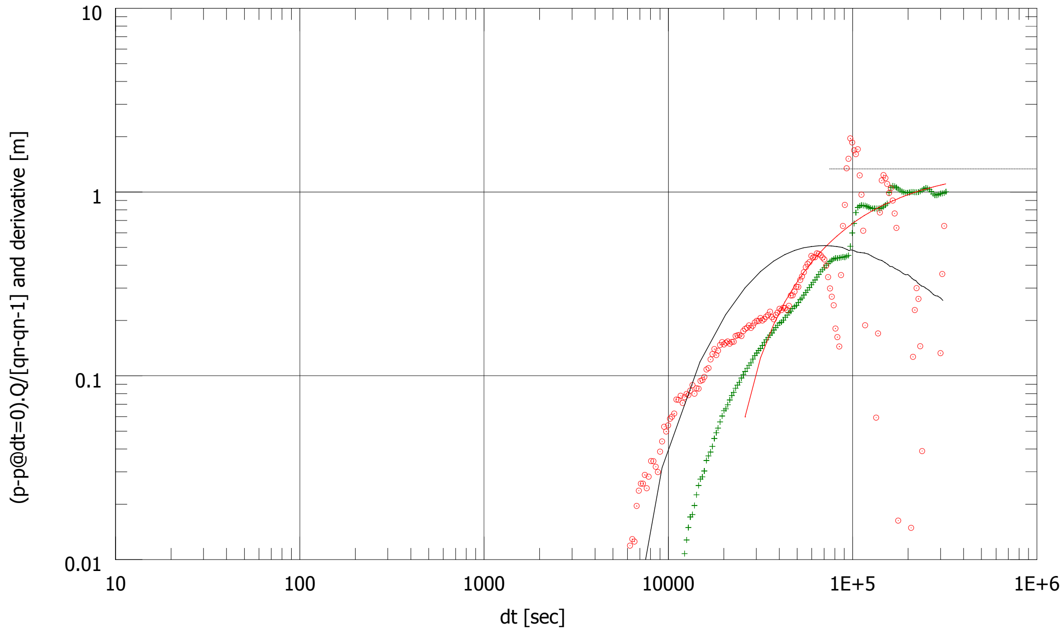
Figure A2-40. *Lin-lin plot of pressure versus time of the drawdown phase in observation borehole HLX13 during the HLX34 pumping test, together with evaluated data.*

Log-Log plot	Dd1
Company Svensk Kärnbränslehantering AB Well HLX13, lp=100m	Field Laxemar Test Name / # Interferenstest HLX34, lp=112m



HLX13obs_HLX34pump production #1

Rate	108.161 l/min
Rate change	108.161 l/min
P@dt=0	12.454 m
Pi	12.54 m
Smoothing	0.1

Selected Model

Model Option	Standard Model
Well	Line source
Reservoir	Homogeneous
Boundary	One fault

Main Model Parameters

TMatch	6.68E-6 [sec]-1
PMatch	0.374 [m]-1
S	7.48E-5
T	1.07E-4 m2/s
K	5.67E-7 m/s
Pi	12.54 m
Well distance	462 m

Model Parameters

Reservoir & Boundary parameters

Pi	12.54 m
T	1.07E-4 m2/s
K	5.67E-7 m/s
S	7.48E-5
L - Constant P.	327 m

Derived & Secondary Parameters

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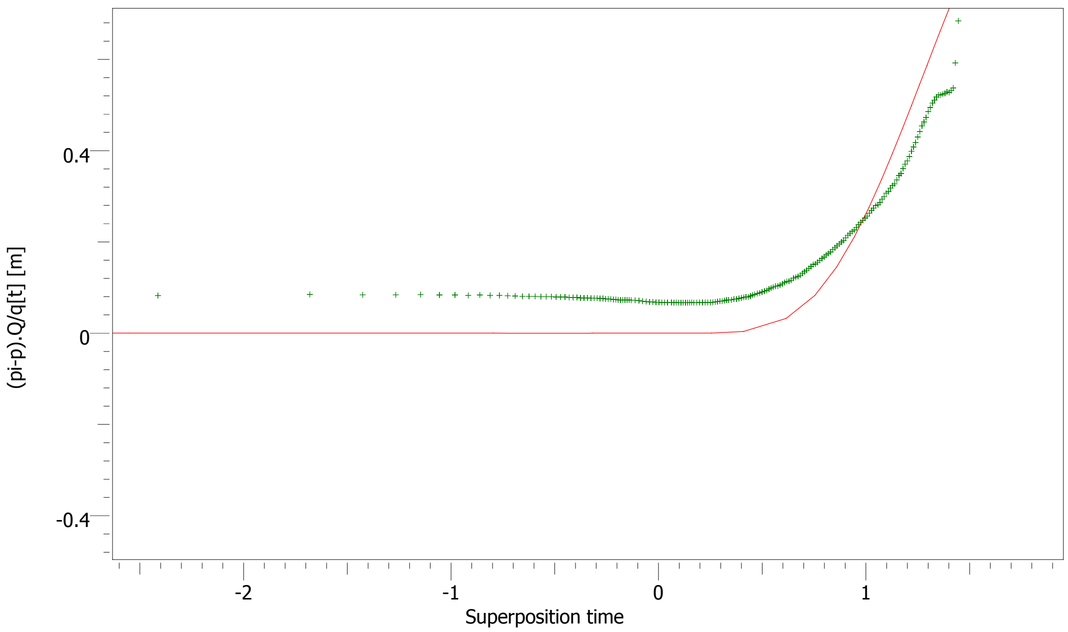
Figure A2-41. *Log-log plot of pressure versus time of the drawdown phase in observation borehole HLX13 during the HLX34 pumping test, together with evaluated data*

Semi-Log plot	Dd1
Company Svensk Kärnbränslehantering AB Well HLX13, lp=100m	Field Laxemar Test Name / # Interferenstest HLX34, lp=112m



HLX13obs_HLX34pump production #1
Rate 108.161 l/min
Rate change 108.161 l/min
P@dt=0 12.454 m
Pi 12.54 m
Smoothing 0.1

Selected Model
Model Option Standard Model
Well Line source
Reservoir Homogeneous
Boundary One fault

Main Model Parameters
TMatch 6.68E-6 [sec]-1
PMatch 0.374 [m]-1
S 7.48E-5
T 1.07E-4 m2/s
K 5.67E-7 m/s
Pi 12.54 m
Well distance 462 m

Model Parameters
Reservoir & Boundary parameters
Pi 12.54 m
T 1.07E-4 m2/s
K 5.67E-7 m/s
S 7.48E-5
L - Constant P. 327 m

Derived & Secondary Parameters

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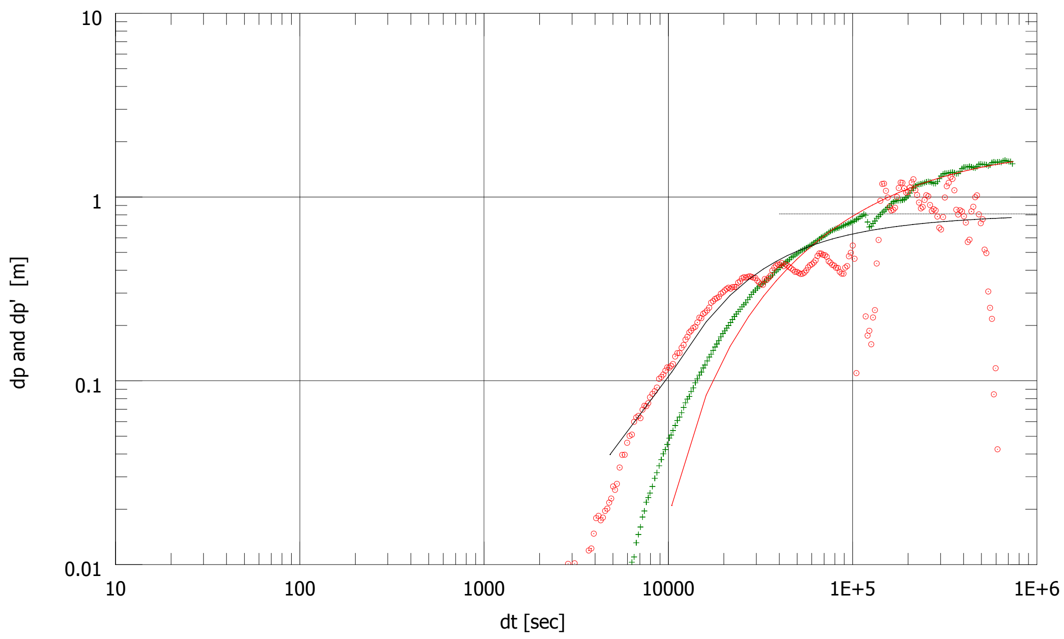
__Figure A2-42.__ Lin-log plot of pressure versus time of the drawdown phase in observation borehole HLX13 during the HLX34 pumping test, together with evaluated data

Log-Log plot	Bu1
Company Svensk Kärnbränslehantering AB Well HLX13, lp=100m	Field Laxemar Test Name / # Interferenstest HLX34, lp=112m



HLX13obs_HLX34pump build-up #1
Rate 0 l/min
Rate change 108.161 l/min
P@dt=0 11.4322 m
Pi 13.2789 m
Smoothing 0.1

Selected Model
Model Option Standard Model
Well Line source
Reservoir Homogeneous
Boundary Infinite

Main Model Parameters
TMatch 1.25E-5 [sec]-1
PMatch 0.618 [m]-1
S 6.59E-5
T 1.76E-4 m2/s
K 9.36E-7 m/s
Pi 13.2789 m
Well distance 462 m

Model Parameters
Reservoir & Boundary parameters
Pi 13.2789 m
T 1.76E-4 m2/s
K 9.36E-7 m/s
S 6.59E-5

Derived & Secondary Parameters
Rinv 2510 m
Test. Vol. 306.612 MMm3

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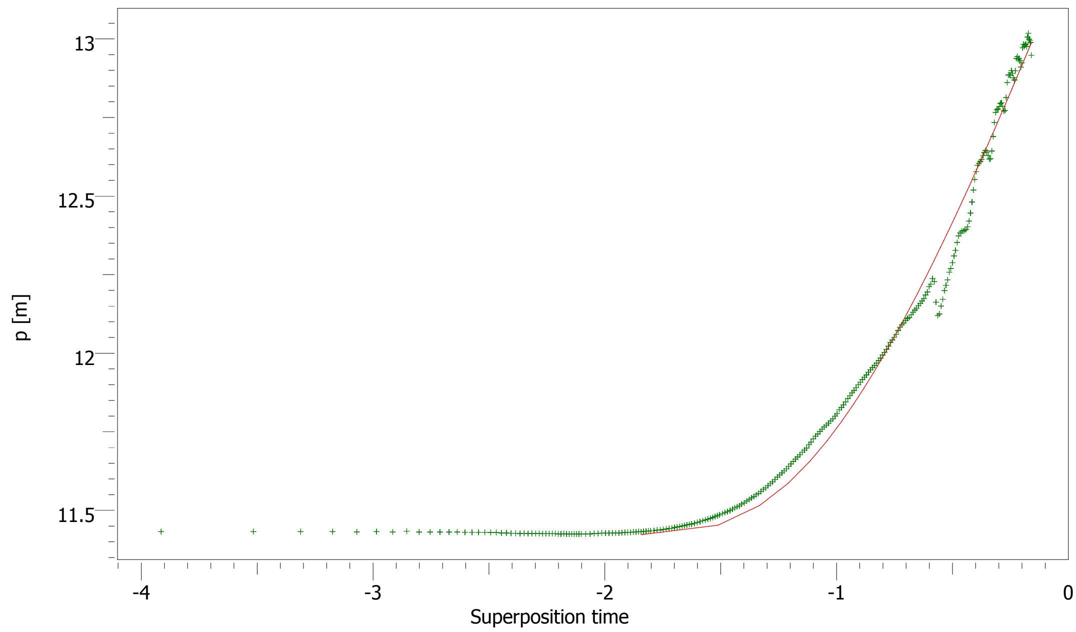
Figure A2-43. *Log-log plot of pressure versus time of the recovery phase in observation borehole HLX13 during the HLX34 pumping test, together with evaluated data.*

Semi-Log plot | Bu1

Company Svensk Kärnbränslehantering AB | Field Laxemar
Well HLX13, lp=100m | Test Name / # Interferenstest HLX34, lp=112m



HLX13obs_HLX34pump build-up #1
Rate 0 l/min
Rate change 108.161 l/min
P@dt=0 11.4322 m
Pi 13.2789 m
Smoothing 0.1

Selected Model
Model Option Standard Model
Well Line source
Reservoir Homogeneous
Boundary Infinite

Main Model Parameters
TMatch 1.25E-5 [sec]-1
PMatch 0.618 [m]-1
S 6.59E-5
T 1.76E-4 m2/s
K 9.36E-7 m/s
Pi 13.2789 m
Well distance 462 m

Model Parameters
Reservoir & Boundary parameters
Pi 13.2789 m
T 1.76E-4 m2/s
K 9.36E-7 m/s
S 6.59E-5

Derived & Secondary Parameters
Rinv 2510 m
Test. Vol. 306.612 MMm3

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Figure A2-44. *Lin-log plot of pressure versus time of the recovery phase in observation borehole HLX13 during the HLX34 pumping test, together with evaluated data.*

Appendix 3

Response matrix

Explanations for the response indices can be found in Chapter 5 of the report:

L = low, M = medium, H = high, E = excellent, 0 = no response; ( ) = uncertain and blank = not measured

	Pumping Hole	**HLX37**			**HLX42**			**HLX34**		
	Section (m.b. ToC)	12.00–199.80			9.10–152.60			9.00–151.80		
	Flow rate (l/min)	36			67			110		
	Drawdown (kPa)	211.20			313.50			623.50		
Observation borehole	**Response indices**	**1**	**2**	**2 new**	**1**	**2**	**2 new**	**1**	**2**	**2 new**
	Section (m)									
HLX13	11.85–200.20							M	L	L
HLX14								(0)	(0)	(0)
HLX25:1-2								0	0	0
HLX30:1-2								0	0	0
HLX31:1-2								0	0	0
HLX33:1-2								0	0	0
KLX04:1-8								0	0	0
HLX26	9–151.2	0	0	0						
HLX27:1	108–164.7	0	0	0						
HLX27:2	6–107	0	0	0						
HLX28	6.00–154.20	H	L	M						
HLX32	12.30–162.60	L	L	L						
KLX16A:1	327.00–433.55				0	0	0			
KLX16A:2	191.00–326.00				H	L	M			
KLX16A:3	11.25–190.00				H	L	M			
HLX35:1	65.00–151.80							M	L	M
HLX35:2	9.00–64.00							L	L	L
HLX36	6.03–199.80	0	0	0						