P-05-78

# Forsmark site investigation

## Hydraulic interference tests

### Boreholes HFM16, HFM19 and KFM02A

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February 2005

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# Abstract

Three short interference tests have been conducted to verify a possible hydraulic connection between the percussion boreholes HFM16 and HFM19 as well as between HFM16 and the cored borehole KFM02A. The hypothesis was that the boreholes should be connected via the highly conductive fracture zone, reflector A2, which is believed to intersect HFM16 at about 60 m along the borehole and KFM02A somewhere between 400 and 520 m along the borehole.

On three separate occasions, interference was generated by means of short-time pumping in the open borehole HFM16. At each pumping occasion the expected pressure responses were registered in three isolated sections in KFM02A. During the last two tests the pressure was also registered in three sections in HFM19. The sections in KFM02A were moved to a new position before the following test, but in HFM19 the sections were unchanged throughout the entire testing period.

The results indicate a clear response in the cored borehole KFM02A. The analyses of the results from the three different interference tests, together with results from previously conducted tests, show that the most important hydraulic connections between the boreholes are found at 416–431 m and at 511–516 m along the borehole. In the observation sections containing these conductive zones, the drawdown was about 0.2 to 0.4 m during the tests which lasted for approximately four to five hours. The response time lag in KFM02A from the start of pumping varied between 40 and 65 min.

In HFM19, a clear response was also obtained, but much weaker than that in KFM02A. All sections in HFM19 shared a very similar drawdown response. Therefore, neither of the previously located anomalies in this borehole seems to have better hydraulic contact with reflector A2 than any of the others. The response time lag for the sections in HFM19 was c 155 min after start of pumping. The total drawdown varied between 0.03 and 0.05 m in these sections.

# Sammanfattning

Tre korta interferenstester har genomförts för att verifiera en möjlig hydraulisk förbindelse mellan hammarborrhålen HFM16 och HFM19 samt mellan HFM16 och kärnborrhål KFM02A. Hypotesen var att hålen skulle vara konnekterade via den högkonduktiva sprickzonen, reflektor A2, som tros skära HFM16 vid ca 60 m borrhålslängd och KFM02A vid mellan ca 400 och 520 m borrhålslängd.

Vid tre tillfällen genererades en interferens genom korttidspumpning av det öppna borrhålet HFM16. Vid varje pumpning registrerades de förväntade tryckresponserna i tre avgränsade sektioner i KFM02A. Under de två sista testerna registrerades trycket även i tre sektioner i HFM19. Sektionerna i KFM02A flyttades inför varje ny test medan sektionerna var oförändrade under hela testperioden i HFM19.

Resultaten påvisar en tydlig respons i kärnborrhål KFM02A. Analysen av resultatet från de tre olika interferenstesterna, tillsammans med resultat från tidigare utförda tester, visar att den viktigaste kontakten mellan hålen återfinns vid 416–431 m samt 511–516 m borrhålslängd. I observationssektionerna som inneslöt dessa intervall var avsänkningen ca 0,2 till 0,4 m under testerna som varade i ungefär fyra till fem timmar. Tidsfördröjningen av responserna varierade mellan 40 och 65 minuter från pumpstart.

I HFM19 erhölls också en tydlig respons, men mycket svagare än den i KFM02A. Alla sektioner i HFM19 hade en mycket likartad avsänkningsrespons. Därför tycks ingen av de tidigare lokaliserade anomalierna i borrhålet ha bättre hydraulisk kontakt med reflektor A2 än någon annan. En tidsfördröjning av responsen på omkring 155 minuter uppmättes i de olika sektionerna i HFM19. Den totala avsänkningen i dessa sektioner varierade mellan 0,03 och 0,05 m.

# Contents

# 1 Introduction

The main purpose of hydraulic interference tests is to get support for interpretations of hydraulic structures in regard to their hydraulic and geometric properties. Furthermore, interference tests may provide information about the hydraulic connectivity and hydraulic boundary conditions for the tested area. Finally, interference tests make up the basis for calibration of numerical models over the tested area.

A series of interference tests were carried out by pumping in the percussion borehole HFM16 and monitoring the pressure response in the cored borehole KFM02A and the percussion borehole HFM19 in order to verify an assumed hydraulic connection between the boreholes. The location of the boreholes within the Forsmark site investigation area is shown in Figure 1-1 together with the seismic reflector A2. This reflector is assumed to have a gentle slope towards south-east and connect the actual boreholes hydraulically. This document reports the results from the interference tests.

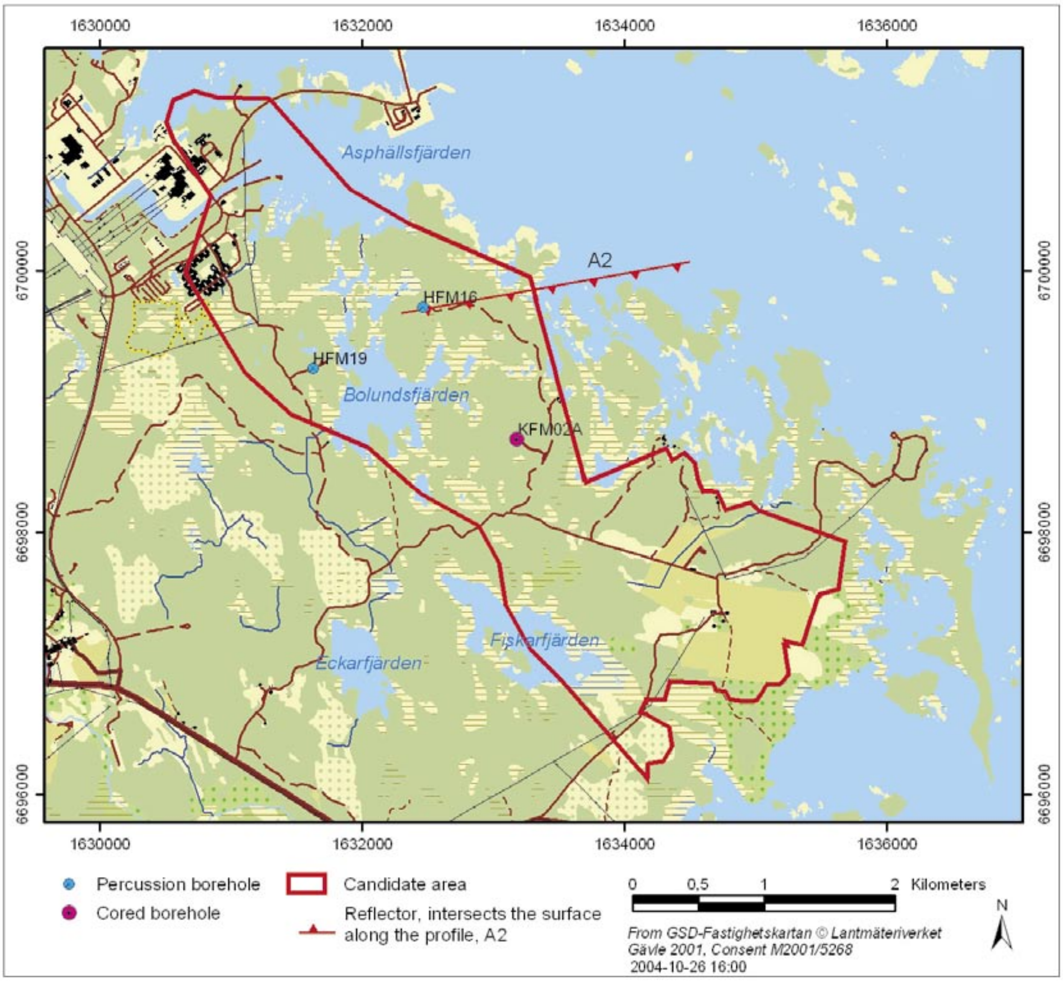



***Figure 1-1.*** *The investigation area at Forsmark including the candidate area selected for more detailed investigations together with the location of boreholes involved in the interference test, as well as the seismic reflector A2.*

From pumping tests and flow logging performed prior to the interference tests, the total transmissivity of the pumping borehole, HFM16, was estimated at $5.3\times10^{-4}$ $m^2/s$ according to /1/. Four separate flow anomalies were identified, at 41.0–41.5 m, 56.0–56.5 m, 58.5–59.5 m and 69.0–69.5 m.

The interference tests were carried out at the end of September to the beginning of October, 2004. The commission was conducted by Geosigma AB within the Forsmark site investigation project.

# 2 Objectives

The main objectives of the interference tests between HFM16, HFM19 and KFM02A were to verify the assumed hydraulic connections between the three boreholes and to roughly estimate the transmissivities of the zone(s) connecting the boreholes. From previous investigations there are reasons to believe that the seismic reflector A2, shown in Figure 2-1, which has turned out to be a highly conductive fracture zone intersecting the percussion borehole HFM16 at c 60 m along the borehole, also intersects KFM02A somewhere in the interval 400–520 m. Furthermore, it is believed that reflector A2 intersects the percussion boreholes HFM13 and HFM19 as well.

In Figure 2-1 the assumed responding boreholes to pumping in HFM16 are shown.

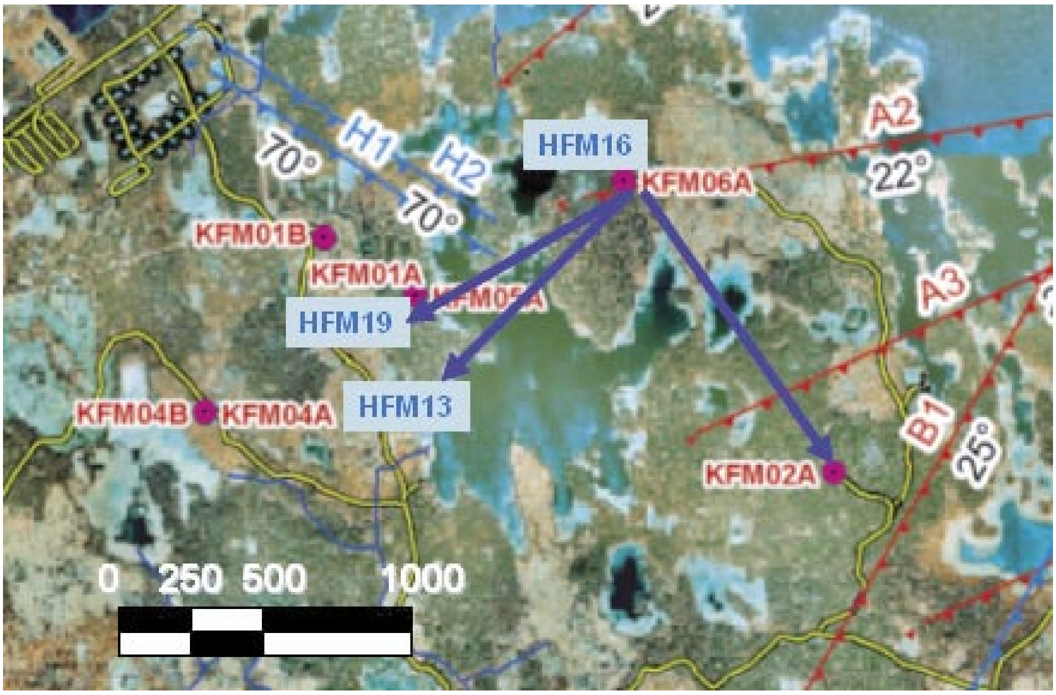



*Figure 2-1. Key map showing the area around percussion borehole HFM16. Arrows indicate the assumed responding boreholes.*

# 3 Scope

## 3.1 Boreholes tested

Technical data of the boreholes tested are shown 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 reported borehole diameter in Table 3-1 refers to the final diameter of the borehole after drilling to full depth. The borehole diameter (measured as the diameter of the drill bit) may decrease along the borehole due to wearing of the drill bit.

The coordinates of the boreholes at ground surface are shown in Table 3-2.

**Table 3-1. Pertinent technical data of the tested boreholes. (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) |
| HFM16 | 3.21 | 0.00–12.02 | 0.160 | –84.22 | 327.96 | Casing ID | 2003-11-10 |
| ” | | 12.02–132.50 | 0.139 | | | Borehole | |
| HFM19 | 3.66 | 0.00–12.04 | 0.160 | –58.10 | 280.91 | Casing ID | 2003-12-18 |
| ” | | 12.04–185.20 | 0.137 | | | Borehole | |
| KFM02A | 7.353 | 0.000–100.140 | 0.200 | –85.385 | 275.764 | Casing ID | 2003-03-12 |
| ” | | 102.000–1,002.440 | 0.077 | | | Borehole | |

**Table 3-2. Coordinates of the tested boreholes. (From SICADA).**

| Borehole data | | |
|---|---|---|
| Bh ID | Northing (m) | Easting (m) |
| HFM16 | 6,699,721.10 | 1,632,466.18 |
| HFM19 | 6,699,257.59 | 1,631,626.93 |
| KFM02A | 6,698,712.501 | 1,633,182.863 |

## 3.2 Tests performed

Three consecutive interference tests (1–3), were generated by a series of short flow periods in HFM16. In KFM02A, the observation sections were moved between the tests in order to identify the most distinct responses in this borehole. The observation sections in HFM19 were not moved between the tests and responses were registered in the same borehole sections during two consecutive tests (test 2 and 3).

The borehole sections involved in the different interference tests are listed in Table 3-3. The times referred to in Table 3-3 are the start and stop times of data logging for the various sections.

The test performance was according to the Geosigma quality plan ("Kvalitetsplan för SKB uppdrag – Undersökning av hydraulisk kontakt mellan Borrhålen HFM16 och KFM02A, Stig Jönsson, 2004-09-23." Geosigma and SKB internal controlling document) and in compliance with the methodology description for interference tests, SKB MD 330.003, Metodbeskrivning för interferenstester (SKB internal controlling document).

The distances between the pumping borehole and the observation borehole sections are shown in Table 3-4. The distances are measured between the hydraulic points of application in the observation borehole sections. In HFM16, the point of application was selected from a point of balance calculation considering the contribution from four different flow anomalies detected in previous single-hole hydraulic tests and flow logging. In the observation boreholes, the points of application were based on the flow anomalies in the sections and their associated transmissivities. The points of application together with the length and transmissivities of the sections from previous tests are presented in Table 3-5. The transmissivities are estimated from previous hydraulic tests in the boreholes, /1, 2, 3, 4/.

**Table 3-3. Configuration of borehole sections during the different interference tests performed in HFM16.**

| Interference tests in HFM16 | | | | | | |
|---|---|---|---|---|---|---|
| **Test #** | **Bh ID** | **Test section (m)** | **Test type[1]** | **Test config** | **Test start date and time (YYYY-MM-DD tt:mm)** | **Test stop date and time (YYYY-MM-DD tt:mm)** |
| 1–3 | HFM16 | 12.02–132.50 | 1B | Open borehole | 2004-09-29 12:00 | 2004-10-26 09:30 |
| 1 | KFM02A | 102–400 | 2 | Above packer | 2004-10-04 13:34 | 2004-10-05 12:29 |
| " | " | 401–521 | 2 | Between packers | 2004-10-04 13:27 | 2004-10-05 12:22 |
| " | " | 522–1,002 | 2 | Below packer | 2004-10-04 13:30 | 2004-10-05 12:25 |
| 2 | KFM02A | 102–459 | 2 | Above packer | 2004-10-05 15:55 | 2004-10-06 08:20 |
| " | " | 460–580 | 2 | Between packers | 2004-10-05 15:46 | 2004-10-06 08:16 |
| " | " | 581–1,002 | 2 | Below packer | 2004-10-05 15:49 | 2004-10-06 08:19 |
| 3 | KFM02A | 102–339 | 2 | Above packer | 2004-10-06 11:24 | 2004-10-07 08:32 |
| " | " | 340–460 | 2 | Between packers | 2004-10-06 11:16 | 2004-10-07 08:26 |
| " | " | 461–1,002 | 2 | Below packer | 2004-10-06 11:19 | 2004-10-07 08:29 |
| 2 | HFM19 | 12–110 | 2 | Above packer | 2004-10-05 12:00 | 2004-10-06 11:59 |
| " | " | 111–150 | 2 | Between packers | 2004-10-05 12:00 | 2004-10-06 11:48 |
| " | " | 151–185.2 | 2 | Below packer | 2004-10-05 12:00 | 2004-10-06 11:55 |
| 3 | HFM19 | 12–110 | 2 | Above packer | 2004-10-06 12:00 | 2004-10-07 09:21 |
| " | " | 111–150 | 2 | Between packers | 2004-10-06 11:51 | 2004-10-07 09:15 |
| " | " | 151–185.2 | 2 | Below packer | 2004-10-06 11:58 | 2004-10-07 09:11 |

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

**Table 3-4. Calculated distances to the observation borehole sections involved in the interference tests in HFM16.**

| Pumping interval in HFM16 | Distance to the point of application in the observation sections during the interference tests. | | | |
|---|---|---|---|---|
| | Bh ID | Section | Distance (m) | Test # |
| 12–132 m | KFM02A | 102–400 m | 1,236 | 1 |
| ” | KFM02A | 401–521 m | 1,298 | 1 |
| ” | KFM02A | 522–1,002 m | 1,299 | 1 |
| ” | KFM02A | 102–459 m | 1,236 | 2 |
| ” | KFM02A | 460–580 m | 1,287 | 2 |
| ” | KFM02A | 581–1,002 m | 1,406 | 2 |
| ” | KFM02A | 102–339 m | 1,236 | 3 |
| ” | KFM02A | 340–460 m | 1,267 | 3 |
| ” | KFM02A | 461–1,002 m | 1,287 | 3 |
| ” | HFM19 | 12–110 m | 1,010 | 2–3 |
| ” | HFM19 | 111–150 m | 1,035 | 2–3 |
| ” | HFM19 | 151–185 m | 1,050 | 2–3 |

**Table 3-5. Point of application in the borehole sections, together with length and estimated transmissivities of the sections from previous tests.**

| Bh ID | Section | Point of application (m below TOC) | Length of section (m) | Transmissivity ($m^2/s$) |
|---|---|---|---|---|
| HFM16 | 12–132 | 56 | 120 | $5.3\times10^{-4}$ |
| KFM02A | 102–400 m | 122 | 298 | $6.0\times10^{-4}$ |
| KFM02A | 401–521 m | 555 | 120 | $4.7\times10^{-6}$ |
| KFM02A | 522–1,002 m | 558 | 480 | $5.4\times10^{-9}$ |
| KFM02A | 102–459 m | 122 | 357 | $3.2\times10^{-4}$ |
| KFM02A | 460–580 m | 513 | 120 | $2.5\times10^{-6}$ |
| KFM02A | 581–1,002 m | 850 | 421 | $3.8\times10^{-9}$ |
| KFM02A | 102–339 m | 122 | 237 | $6.0\times10^{-4}$ |
| KFM02A | 340–460 m | 428 | 120 | $2.5\times10^{-6}$ |
| KFM02A | 461–1,002 m | 513 | 541 | $2.4\times10^{-6}$ |
| HFM19 | 12–110 m | 101 | 98 | $4.0\times10^{-5}$ |
| HFM19 | 111–150 m | 149 | 39 | $1.6\times10^{-5}$ |
| HFM19 | 151–185 m | 176 | 34 | $2.8\times10^{-4}$ |

## 3.3 Equipment check

An equipment check was performed before going to the field and at the site as a simple and fast test to establish the operating status of sensors and other equipment. In addition, calibration constants were implemented and checked.

To check the function of the pressure sensors, the pressure in air was recorded and found to be as expected. Submerged in water, the pressure coincided well, while lowering, with the total head of water.

# 4 Description of equipment

## 4.1 Overview

In the pumping borehole HFM16, a specially designed equipment system, described in Section 5.2, was used. This equipment was installed by personnel from PLU-Forsmark In the observation borehole KFM02A, the PSS (Pipe String System), described in SKB MD 345.101, was employed to lower and install the 120 m long test section at three different positions in the borehole (see Table 3-3). The equipment installed and facilities used to lower the test section in HFM19 consisted of the following parts:

- Packers for isolating the test section.
- Wire to anchor the packers.
- Manual winch for hoisting the packers, mounted on the casing.
- Aluminium rods connected to the packers.
- Nitrogen gas bottle and pressure regulator.
- Tecalan hose for packer pressurizing and pressure distribution to transducers.
- PEM hose connected to Tecalan hose.
- Mini-Troll pressure transducers.

Most of the equipment used in HFM19 is very similar to the compound test system normally referred to as HTHB (Swedish abbreviation for Hydraulic Test System for Percussion Boreholes), described in SKB MD 326.001 (SKB internal controlling document). The HTHB unit is designed for percussion boreholes to perform pumping tests in open boreholes, below a single packer or between double packers in isolated sections of the boreholes, down to a total depth of 200 m. A number of other hydraulic tests can be performed with the HTHB system although not described here. Pumping tests can be conducted, either at a constant hydraulic head or, alternatively, with a constant flow rate.

## 4.2 Measurement sensors

Technical data of the sensors used and estimated data specifications of the test system for pumping tests are given in Table 4-1.

**Table 4-1. Technical data of measurement sensors and estimated specifications of the test system for pumping tests (based on current laboratory and field experiences).**

| Technical specification Parameter | | Unit | Sensor | Test system | Comments |
|---|---|---|---|---|---|
| p-relative | Output signal | mA | Digital | Same as for the sensor | Mini-Troll is a combined sensor and data logger unit |
| (Mini-Troll) | Meas. range | kPa | 0 –206.8 | | |
| | Resolution | kPa | 0.01 | | |
| | Accuracy | kPa | ±0.2 * | | |

*Includes hysteresis, linearity and repeatability

The Mini-Troll pressure loggers used in the observations sections have a measuring range of 0–206.8 kPa and are supplied with a 16-bit A-D converter, cf Table 4-1.

Table 4-2 presents the type and position of pressure sensors in the borehole and the position of the measurement point for each transducer used in the test. Positions are given in metre from the reference point, i.e. top of casing (ToC).

Equipment affecting the wellbore storage coefficient is given in terms of diameter of the submerged item. Position is given as "in section" or "above section" where "section" refers to an isolated test section.

**Table 4-2. Type and position of sensors (from ToC) and equipment that may affect wellbore storage in the pumping section during the different interference tests.**

| Borehole information | | | | | Sensors | | Equipment in test section affecting wellbore storage (WBS) | | |
|---|---|---|---|---|---|---|---|---|---|
| Test # | Bh ID | Test interval (m) | Test configu-ration | Test type[1] | Type | Position[2)] (m b ToC) | Function | Position[3] relative test section | Outer diam (mm) |
| 1–3 | HFM16 | 12–132 | Open borehole | 1B | Absolute pressure | 13 | Transducer wire | In section | 5 |
| | | | | | | 9 | Pump hose | Above section | 60 |
| | | | | | | 9–11.5 | Pump | Above section | 170 |
| 1 | KFM02A | 102–400 | Above packers | 2 | Absolute pressure | 13.0 | Transducer cable | Above section | 9.1 |
| | | | | | | | 2xTecalan hose | Above section | 6 |
| | | | | | | | Aluminium pipe | Above section | 33 |
| | | | | | | | 2xHydraulic hose | Above section | 11.7 |
| 1 | KFM02A | 401–521 | Between packers | 2 | Relative pressure | 16.7 (401) | Transducer cable | In section | 9.1 |
| | | | | | | | 2xTecalan hose | In section | 6 |
| | | | | | | | Aluminium pipe | In section | 33 |
| 1 | KFM02A | 522–1,002 | Below packers | 2 | Relative pressure | 16.3 (522) | | In borehole | |
| 2 | KFM02A | 102–459 | Above packers | 2 | Absolute pressure | 13.0 | Transducer cable | Above section | 9.1 |
| | | | | | | | 2xTecalan hose | Above section | 6 |
| | | | | | | | Aluminium pipe | Above section | 33 |
| | | | | | | | 2xHydraulic hose | Above section | 11.7 |
| 2 | KFM02A | 460–580 | Between packers | 2 | Relative pressure | 18.53 (460) | Transducer cable | In section | 9.1 |
| | | | | | | | 2xTecalan hose | In section | 6 |
| | | | | | | | Aluminium pipe | In section | 33 |
| 2 | KFM02A | 581–1,002 | Below packers | 2 | Relative pressure | 19.5 (581) | | In borehole | |
| 3 | KFM02A | 102–339 | Above packers | 2 | Absolute pressure | 13.0 | Transducer cable | Above section | 9.1 |
| | | | | | | | 2xTecalan hose | Above section | 6 |
| | | | | | | | Aluminium pipe | Above section | 33 |
| | | | | | | | 2xHydraulic hose | Above section | 11.7 |
| 3 | KFM02A | 340–460 | Between packers | 2 | Relative pressure | 19.4 (340) | Transducer cable | In section | 9.1 |
| | | | | | | | 2xTecalan hose | In section | 6 |
| | | | | | | | Aluminium pipe | In section | 33 |
| 3 | KFM02A | 461–1,002 | Below packers | 2 | Relative pressure | 18.52 (461) | | In borehole | |

| Borehole information | | | | | Sensors | | Equipment in test section affecting wellbore storage (WBS) | | |
|---|---|---|---|---|---|---|---|---|---|
| Test # | Bh ID | Test interval (m) | Test configu-ration | Test type[1] | Type | Position[2)] (m b ToC) | Function | Position[3] relative test section | Outer diam (mm) |
| 2–3 | HFM19 | 12–110 | Above packers | 2 | Absolute pressure | 10.4 | 2xPEM hose c 10m | Above section | 32 |
| | | | | | | | 2xTecalan hose | Above section | 8 |
| | | | | | | | Tecalan hose | Above section | 6 |
| | | | | | | | Aluminium rod | Above section | 20 |
| | | | | | | | Steel wire | Above section | 4 |
| 2–3 | HFM19 | 111–150 | Between packers | 2 | Absolute pressure | 10.5 (111) | Tecalan hose | In section | 6 |
| | | | | | | | Tecalan hose | In section | 8 |
| | | | | | | | Aluminium rod | In section | 20 |
| | | | | | | | Steel wire | In section | 4 |
| 2–3 | HFM19 | 151–185.2 | Below packers | 2 | Absolute pressure | 13.1 (151) | | In borehole | |

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

[2)] Distances within parenthesis refer to the distances to the actual pressure measurement point. Pressure changes are then distributed to the transducer via a water-filled tecalan hose.

[3)] Position of equipment that can affect wellbore storage. Position given as "In Section" or "Above Section" or "In borehole".

# 5 Execution

The interference test was performed according to Activity Plan AP PF 400-04-74 (SKB internal controlling document) and Geosigma quality plan ("Kvalitetsplan för SKB uppdrag – Undersökning av hydraulisk kontakt mellan Borrhålen HFM16 och KFM02A, Stig Jönsson, 2004-09-23.", Geosigma and SKB internal controlling document). The test was performed in accordance with the methodology description for interference tests, SKB MD 330.003, (Metodbeskrivning för interferenstester). A simplified response analysis was also made. However, no response matrix was prepared due to the few observation sections available. For the same reason, only one response diagram, (for the third test) was prepared.

The extent of this commission was somewhat limited. For example, the quantitative evaluation only involved the most important sections in KFM02A based on a reduced variety of diagrams and evaluation methods.

## 5.1 Preparations

All sensors included in the test system are calibrated at the Geosigma engineering workshop in Librobäck, Uppsala. Calibration is performed on a yearly basis, or more often if needed. The Mini-Troll transducers employed in the observation boreholes are using the manufacturer's calibration constants that were installed by the manufacturer. Before the tests, function checks and cleaning of equipment were conducted according to the Activity Plan.

## 5.2 Procedure

The interference tests in HFM16 were carried out as a series of short constant flow rate tests followed by pressure recovery periods. The flow periods were approximately 3–5 h long and the subsequent recovery period was measured over-night, see Figures A2-13, A2-14 and A2-15 in Appendix 2. The pressure interference was recorded in three sections in KFM02A and HFM19, respectively (below, above and between packers), during both the flow- and recovery period of the interference tests, see Table 4-2.

The installation of pumping equipment in HFM16 was conducted by personnel from Forsmark site investigation. A large 6" submersible pump was used to provide maximum drawdown. At the top of the borehole the flow rate could be manually adjusted by a control valve, in case the pumping would introduce a too large drawdown. The pump diameter set restrictions to the placement of the pump. It would only fit within the cased part of the borehole which limited the maximum possible drawdown of the groundwater level to c 6–8 m, cf Table 3-1. Because of the flow restriction a flow meter would introduce, the flow rate was measured manually using a 100 L bucket and a stop watch. The flow rate was c 400 L/min. The water intake of the pump was located 11 m below ToC, see Table 4-2.

In HFM19 the packers were lowered using the winch and wire. In addition, aluminium rods were connecting the packers to each other and the upper packer to the surface. This was done as a precaution, in case the section should get stuck and would have to be pulled out with a major force. Two water-filled Tecalan hoses distributed the pressure from the interval below the test section as well as within the test section to the transducers. The Tecalan hoses were connected to a 32 mm diameter PEM-hose approximately 15 m below top of casing. Mini-Troll transducers, a combined pressure transducer and data logger, were then lowered into the PEM-hoses for pressure registration. The Mini-Troll transducers are connected to internal loggers and they were regularly withdrawn from the borehole to download the data into a computer.

In observation borehole KFM02A the monitoring of pressure/water level was carried out using Mini-Troll pressure transducers. For the isolated test section and the section below the packers, the pressure changes were transmitted via water-filled Tecalan hoses to the transducers attached to the pipe string approximately 15 m below top of casing. These transducers were measuring the relative pressure. In the top section, between the water surface and upper packer, an absolute pressure transducer was used.

The Mini-Troll pressure loggers in the observation borehole KFM02A were logging pressure with an interval of 300 s with an extra condition to log as frequently as every 10 s for a pressure difference of at least 0.1 kPa between two consecutive scans. The Mini-Troll transducers are fitted with cables leading up to the surface, where transferring of data into a laptop PC can be conveniently executed at any time. As a backup, the pressure transducers normally used together with the PSS were also installed and connected to the data acquisition system built into the PSS. In the pumping borehole, the logging intervals were similar to the ones in KFM02A. The shortest possible logging frequency was once every 30 seconds. In observation borehole HFM19 the pressure logging was done at a constant rate of once every two minutes. All transducers and logging intervals are summarized in Table 5-1.

Prior to and after the interference tests, manual measurements of groundwater levels were performed in the observation boreholes KFM02A and HFM19 as well as in the pumping borehole HFM16.

**Table 5-1. Logging intervals of the pressure sensors used in the interference tests.**

| Bh ID | Test section | Transducer | Logging interval (s) | condition | Conditional interval (s) |
|---|---|---|---|---|---|
| HFM16 | – | Mini-Troll, absolute | 300 | dP > 0.1 kPa | 30 |
| KFM02A | Top section | Mini-Troll, absolute | 300 | dP > 0.1 kPa | 10 |
| KFM02A | Other sections | Mini-Troll, relative | 300 | dP > 0.1 kPa | 10 |
| HFM19 | All sections | Mini-Troll, absolute | 300 | – | – |

## 5.3 Data handling

Pressure data from both the pumping borehole, HFM16, and the observation boreholes KFM02A and HFM19 were registered and stored by the Mini-Troll transducers. The pressure data were then downloaded to a laptop computer. The software handling the interface between the logger and computer is called Win-Situ. The data files produced by the logger are binary files which are converted by Win-Situ to ordinary text files.

The produced logger files from the boreholes are imported into the evaluation software AQTESOLV and plotted in different diagrams listed in the Instruction for analysis of injection- and single-hole pumping tests (SKB MD 320.004, SKB internal controlling document) and the methodology description for interference tests.

A list of the data files from the data loggers is shown in Appendix 1.

## 5.4 Analyses and interpretation

As mentioned in Section 5.2, the interference tests were performed as constant flow rate tests. Methods for constant-flow tests in an equivalent porous medium were used by the analyses and interpretation of the tests.

The main objective of the interference tests was to verify the assumed hydraulic connectivity between the pumping borehole, HFM16, and the observation boreholes, KFM02A and HFM19. This could firstly be done by a qualitative evaluation of pressure versus time data from the tests. A secondary task was to evaluate selected data from the observation section in KFM02A and make quantitative analyses with regard to transmissivity and storativity.

All available data were used for the primary qualitative analyses. The qualitative analysis is primarily based on time versus pressure diagrams and a response diagram. The qualitative evaluation was made from analyses of log-log diagrams of drawdown data together with the corresponding pressure derivatives versus time. 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 an increase and decrease of the derivative, respectively. Pressure versus time diagrams are presented for all test sections in Appendix 2.

Quantitative evaluation was only undertaken for the responses in the pumping borehole HFM16 according to the methods described in /5/ and for the mid- and lower sections of KFM02A during interference test 3. The transient analysis was performed applying a special version of the test analysis software AQTESOLV that enables both visual and automatic type curve matching. Thus, the quantitative transient evaluation is carried out as an iterative process of type curve matching and automatic non-linear regression.

The transient evaluation in the selected observation sections started by identifying flow regimes (pseudo-linear, pseudo-radial and pseudo-spherical flow, respectively) and possible outer boundary conditions. Different values were applied on the filter coefficient (step length) by the calculation of the pressure derivative to investigate the effect of this coefficient on the derivative. It is desired to achieve maximum smoothing of the derivative without altering the original shape of data.

The quantitative, transient interpretation of the hydraulic parameters (transmissivity and storativity) is normally based on the identified pseudo-radial flow regime during the tests in log-log and lin-log data diagrams. In the tests presented in this report, the pumping time was however too short to reach a pseudo-radial flow regime. A preliminary transient interpretation could still be made. Transient analysis from the observation boreholes was only made for two sections in KFM02A. The sections were chosen based on the results from the preliminary qualitative analyses (response analysis). Furthermore, only the flow period was utilized for transient evaluation.

From the transient analysis of the tests, the different estimates of transmissivity for the actual test were checked and one of them was assessed to be the best representative transmissivity and storativity of the formation.

# 6 Results

## 6.1 Nomenclature and symbols

The nomenclature and symbols used for the results of the interference tests are in agreement with the Instruction for analysis of single-hole injection- and pumping tests (SKB MD 320.004), Version 1.0 (Metodinstruktion för analys av injektions- och enhålspumptester) and the methodology description for interference tests (SKB MD 330.003). Additional symbols used are explained in the text. The nomenclature applied in the AQTESOLV software is explained in the beginning of Appendix 2.

## 6.2 General information

Below, the results from the three interference tests in HFM16 are presented. Each test has its own chapter in the text. Within each chapter the different borehole sections involved in the test and the pertinent results are lined out. Test data diagrams are found in Appendix 2. For tests 1 and 2, only linear overview test data diagrams for the actual borehole sections are presented since no quantitative evaluation was made for these tests. For test 3, linear overview diagrams are firstly presented together with log-log and lin-log diagrams of the responses. In the latter diagrams the evaluation of the tests are displayed.

The type of pressure sensors used in the different observation sections is shown in Table 4-2. The pressure in test section presented in the tables below is calculated based on the actual location of the pressure transducers and the distance to the top of the test section.

The barometric pressure during the interference test period is shown in Figure A2-12 in Appendix 2. Since pressure differences were used and the test periods were short, corrections for variations of the barometric pressure may not be necessary. For absolute pressure sensors, the barometric pressure changes have been subtracted from the absolute pressure when judged necessary and are in such cases described in the text.

No corrections of measured data for changes of tidal fluctuations have been made by the analysis of the data. The precipitation was less than 1 mm per day during the interference test period and was not considered in the analysis.

## 6.3 Interference test 1 in HFM16

The barometric pressure decreased c 1.5 kPa between noon and midnight during the day of the test. Section 401–521 m in KFM02A was open to the atmosphere because the test valve was left open and the gauge pressure (pressure relative to atmospheric pressure) was thus calculated by subtracting the barometric pressure in this section. The top section (102–400 m) in KFM02A and the pumping borehole HFM16 were also open to the atmosphere, and the relative pressure was calculated for these sections as well. Pressure data from the deepest section in KFM02A (522–1,002 m) have not been corrected for changes in barometric pressure because a relative sensor was used in this section, cf Table 4-2.

### 6.3.1 Pumping borehole HFM16: 12–132 m

General test data for the pumping borehole HFM16 (12–132 m), are presented in Tables 6-1, 6-2 and 6-3. An overview of the pressure and flow rate in the pumping borehole HFM16 during interference test 1 is presented in Figure A2-1 in Appendix 2.

**Table 6-1. General test data for interference test 1 in borehole HFM16: 12–132 m.**

| General test data | | | |
|---|---|---|---|
| Pumping borehole | HFM16 (12–132 m) | | |
| Test type[1] | Constant Rate withdrawal and recovery test | | |
| Test section (open borehole/packed-off section): | Open borehole | | |
| Test No | 1 | | |
| Field crew | K. Gokall-Norman, P-T Tammela (GEOSIGMA AB) | | |
| Test equipment system | – | | |
| General comment | Interference test | | |
| | **Nomenclature** | **Unit** | **Value** |
| Borehole length | L | m | 132.50 |
| Casing length | $L_c$ | m | 12.02 |
| Test section– secup | Secup | m | 12.02 |
| Test section– seclow | Seclow | m | 132.50 |
| Test section length | $L_w$ | m | 120.48 |
| Test section diameter[2] | $2×r_w$ | mm | 139 |
| | | | |
| Test start (start of pressure registration) | | yymmdd hh:mm | 040929 12:00 |
| Packer expanded | | yymmdd hh:mm:ss | – |
| Start of flow period | | yymmdd hh:mm:ss | 041004 14:46 |
| Stop of flow period | | yymmdd hh:mm:ss | 041004 19:16 |
| Test stop (stop of pressure registration) | | yymmdd hh:mm | 041026 09:30 |
| Total flow time | $t_p$ | min | 270 |
| Total recovery time | $t_F$ | min | 1,025 |

1) Constant Head injection and recovery or Constant Rate withdrawal and recovery.

2) Nominal diameter.

**Table 6-2. Pressure and groundwater level data during interference test 1 in HFM16.**

| Pressure data, HFM16 (12–132 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Relative pressure in borehole before start of flow period | $p_i$ | kPa | 88.1 |
| Relative pressure in borehole before stop of flow period | $p_p$ | kPa | 42.0 |
| Relative pressure in borehole at stop of recovery period | $p_F$ | kPa | 85.1 |
| Maximum pressure change during flow period | $dp_p$ | kPa | 45.9 |

| Manual groundwater level measurements, HFM16 (12–132 m)<br>Date<br>YYYY-MM-DD | <br>Time<br>tt:mm | <br>Time<br>(min) | GW level<br>(m b. ToC) | <br>(m a s l) |
|---|---|---|---|---|
| 2004-10-04 | 14:32 | –14 | 2.56 | 0.66 |
| 2004-10-04 | 19:14 | 268 | 7.32 | –4.07 |

**Table 6-3. Flow rate data during interference test 1 in HFM16.**

| Flow data, HFM16 (12–132 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Flow rate from test section just before stop of flow period | $Q_p$ | $m^3/s$ | $6.7\times10^{-3}$ |
| Mean (arithmetic) flow rate during flow period | $Q_m$ | $m^3/s$ | $6.7\times10^{-3}$ |
| Total volume discharged during flow period | $V_p$ | $m^3$ | 109 |

### *Comments on the test*

The test was performed as a constant-flow rate pumping test, see Figure A2-1. The flow rate was c 400 L/min and the duration of the flow period was c 4.5 h. The final drawdown was 4.76 m. Pressure recovery was measured for c 17 h.

### *Interpreted flow regimes*

No interpretation of flow regimes has been made for this section.

### *Interpreted parameters*

No transient parameter interpretation has been made for this section.

## 6.3.2 Observation section KFM02A: 102–400 m

General test data from the observation section KFM02A, 102–400 m, is presented in Table 6-4. In Figure A2-2 an overview of the pressure responses in observation borehole KFM02A is shown.

**Table 6-4. Pressure and groundwater level data for observation section KFM02A: 102–400 m.**

| Pressure data, KFM02A (102–400 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Relative pressure in test section before start of flow period | $p_i$ | kPa | 931.8 |
| Relative pressure in test section before stop of flow period | $p_p$ | kPa | 931.8 |
| Relative pressure in test section at stop of recovery period | $p_F$ | kPa | 931.8 |
| Maximal pressure change during flow period | $dp_p$ | kPa | 0.05 |

| Manual groundwater level measurements, KFM02A (102–400 m)<br>Date<br>YYYY-MM-DD | <br>Time<br>tt:mm | <br>Time<br>(min) | GW level<br>(m b. ToC) | <br>(m a s l) |
|---|---|---|---|---|
| 2004-10-04 | 13:13 | –93 | 6.75 | 0.62 |
| 2004-10-04 | 17:37 | 171 | 6.76 | 0.61 |

### *Comments on the test*

No significant response to the pumping in HFM16 can be detected in this observation section, cf Figure A2-2. The potential drawdown during the flow period is less than 0.01 m. The original pressure data gave an impression of an apparent response from pumping. However, this could be fully explained by the change of barometric pressure, cf Figure A2-15.

### *Interpreted flow regimes*

No interpretation of flow regimes has been made for this section.

### *Interpreted parameters*

No transient parameter interpretation has been made for this section.

## 6.3.3 Observation section KFM02A: 401–521 m

Selected pressure data from the observation section KFM02A, 401–521 m, is presented in Table 6-5. An overview of the pressure responses in observation borehole KFM02A is shown in Figure A2-2.

**Table 6-5. Pressure data for observation section KFM02A: 401–521 m.**

| Pressure data, KFM02A (401–521 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Relative pressure in test section before start of flow period | $p_i$ | kPa | 3,856.4 |
| Relative pressure in test section before stop of flow period | $p_p$ | kPa | 3,852.3 |
| Relative pressure in test section at stop of recovery period | $p_F$ | kPa | 3,853.8 |
| Maximal pressure change during flow period | $dp_p$ | kPa | 4.1 |

### *Comments to the test*

The total drawdown during the flow period was c 0.41 m, cf Figure A2-2. A drawdown of c 0.01 m in this section was reached c 50 min after start of pumping in HFM16. Drawdown continued to increase c 150 min after the end of the flow period and there is a total recovery of only c 0.26 m during the entire recovery period of about 17 h. This fact may be due to a natural decreasing trend of the pressure during the test period.

### *Interpreted flow regimes*

No interpretation of flow regimes has been made for this section.

### *Interpreted parameters*

No transient parameter interpretation has been made for this section.

## 6.3.4 Observation section KFM02A: 522–1,002 m

Pressure data from the observation section KFM02A, 522–1,002 m, are presented in Table 6-6. An overview of the pressure responses in observation borehole KFM02A is shown in Figure A2-2.

**Table 6-6. Pressure data for observation section KFM02A: 522–1,002 m.**

| Pressure data, KFM02A (522–1,002 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Relative pressure in test section before start of flow period | $p_i$ | kPa | 5,040.6 |
| Relative pressure in test section before stop of flow period | $p_p$ | kPa | 5,040.7 |
| Relative pressure in test section at stop of recovery period | $p_F$ | kPa | 5,041.0 |
| Maximal pressure change during flow period | $dp_p$ | kPa | –0.13 |

### *Comments on the test*

No significant response to pumping in HFM16 occurred in this section, cf Figure A2-2. An apparent pressure increase occurred in the section during the flow period, but this is due to the fact that a gauge transducer was used. Since the atmospheric pressure fell during the test period, a virtual rise of pressure was introduced in the section which was not in direct contact with the atmosphere and was thus not affected by the change in the atmospheric pressure.

### *Interpreted flow regimes*

No interpretation of flow regimes has been made for this section.

### *Interpreted parameters*

No transient parameter interpretation has been made for this section.

## 6.4 Interference test 2 in HFM16

The barometric pressure was relatively constant during the test and has thus not been corrected for in the observation sections in HFM19 and KFM02A, see Figure A2-15. On the other hand, pressure data from the observation sections are corrected to give values representing the pressure at the top of each test section, depending on the individual transducers. All data from the pumping borehole, HFM16, have though been corrected for changes in the atmospheric pressure to obtain the relative pressure.

### 6.4.1 Pumping borehole HFM16: 12–132 m.

General test data for the open-hole pumping test in HFM16, 12–132 m, is presented in Tables 6-7, 6-8 and 6-9. An overview of the pressure and flow rate in the pumping borehole HFM16 during interference test 2 is presented in Figure A2-3 in Appendix 2.

**Table 6-7. General test data for interference test 2 in borehole HFM16: 12–132 m.**

| General test data | | | |
|---|---|---|---|
| Pumping borehole | HFM16 (12–132 m) | | |
| Test type[1] | Constant Rate withdrawal and recovery test | | |
| Test section (open borehole/packed-off section): | Open borehole | | |
| Test No | 2 | | |
| Field crew | K Gokall-Norman, P-T Tammela (GEOSIGMA AB) | | |
| Test equipment system | – | | |
| General comment | Interference test | | |
| | **Nomenclature** | **Unit** | **Value** |
| Borehole length | L | m | 132.50 |
| Casing length | $L_c$ | m | 12.02 |
| Test section– secup | Secup | m | 12.02 |
| Test section– seclow | Seclow | m | 132.50 |
| Test section length | $L_w$ | m | 120.48 |
| Test section diameter[2] | $2\times r_w$ | mm | 139 |
| | | | |
| Test start (start of pressure registration) | | yymmdd hh:mm | 040929 12:00 |
| Packer expanded | | yymmdd hh:mm:ss | – |
| Start of flow period | | yymmdd hh:mm:ss | 041005 16:48 |
| Stop of flow period | | yymmdd hh:mm:ss | 041005 19:31 |
| Test stop (stop of pressure registration) | | yymmdd hh:mm | 041026 09:30 |
| Total flow time | $t_p$ | min | 163 |
| Total recovery time | $t_F$ | min | 765 |

1) Constant Head injection and recovery or Constant Rate withdrawal and recovery.

2) Nominal diameter.

**Table 6-8. Pressure and groundwater level data during interference test 2 in HFM16.**

| Pressure data, HFM16 (12–132 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Relative pressure in borehole before start of flow period | $p_i$ | kPa | 85.6 |
| Relative pressure in borehole before stop of flow period | $p_p$ | kPa | 44.7 |
| Relative pressure in borehole at stop of recovery period | $p_F$ | kPa | 84.1 |
| Maximal pressure change during flow period | $dp_p$ | kPa | 40.9 |

| Manual groundwater level measurements, HFM16 (12–132 m) Date YYYY-MM-DD | Time tt:mm | Time (min) | GW level (m b. ToC) | (m a s l) |
|---|---|---|---|---|
| 2004-10-05 | 16:46 | –2 | 2.82 | 0.40 |
| 2004-10-05 | 19:29 | 161 | 7.07 | –3.82 |

**Table 6-9. Flow data during interference test 2 in HFM16.**

| Flow data, HFM16 (12–132 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Flow rate from test section just before stop of flow period | $Q_p$ | $m^3/s$ | $6.7\times10^{-3}$ |
| Mean (arithmetic) flow rate during flow period | $Q_m$ | $m^3/s$ | $6.7\times10^{-3}$ |
| Total volume discharged during flow period | $V_p$ | $m^3$ | 66 |

### *Comments on the test*

The test was performed as a constant-flow rate pumping test, see Figure A2-3. The flow rate was c 400 L/min and the duration of the flow period was c 2.5 h. The pressure recovery was measured for almost 13 h.

### *Interpreted flow regimes*

No interpretation of flow regimes has been made for this section.

### *Interpreted parameters*

No transient parameter interpretation has been made for this section.

## 6.4.2 Observation section KFM02A: 102–459 m

General test data from the observation section KFM02A, 102–459 m, during interference test 2 in HFM16 are presented in Table 6-10 and in Figure A2-4 in Appendix 2.

**Table 6-10. Pressure and groundwater level data for observation section KFM02A: 102–459 m.**

| Pressure data, KFM02A (102–459 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Absolute pressure in test secion before start of flow period | $p_i$ | kPa | 1,032.5 |
| Absolute pressure in test section before stop of flow period | $p_p$ | kPa | 1,032.5 |
| Absolute pressure in test section at stop of recovery period | $p_F$ | kPa | 1,032.0 |
| Maximal pressure change during flow period | $dp_p$ | kPa | 0.03 |

| Manual groundwater level measurements, KFM02A (102–459 m)<br>Date<br>YYYY-MM-DD | <br>Time<br>tt:mm | <br>Time<br>(min) | GW level<br>(m b. ToC) | <br>(m a s l) |
|---|---|---|---|---|
| 2004-10-05 | 12:19 | –269 | 6.77 | 0.60 |
| 2004-10-05 | 15:31 | –77 | 6.75 | 0.62 |
| 2004-10-05 | 15:37 | –71 | 6.75 | 0.62 |

### *Comments on the test*

There is no indication of hydraulic connectivity between section 102–459 m in borehole KFM02A and borehole HFM16. The pressure drawdown continues to decrease throughout the recovery period, see Figure A2-4.

### *Interpreted flow regimes*

No interpretation of flow regimes has been made for this section.

### *Interpreted parameters*

No transient parameter interpretation has been made for this section.

### 6.4.3 Observation section KFM02A: 460–580 m

Pressure data from the observation section KFM02A, 460–580 m, are presented in Table 6-11 and in Figure A2-4 in Appendix 2.

**Table 6-11. Pressure data for observation section KFM02A: 460–580 m.**

| Pressure data, KFM02A (460–580 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Relative pressure in test section before start of flow period | $p_i$ | kPa | 4,452.9 |
| Relative pressure in test section before stop of flow period | $p_p$ | kPa | 4,450.7 |
| Relative pressure in test section at stop of recovery period | $p_F$ | kPa | 4,451.5 |
| Maximal pressure change during flow period | $dp_p$ | kPa | 2.16 |

#### *Comments on the test*

A clear response to pumping was detected in this section, see Figure A2-4. The total drawdown during the flow period was c 0.21 m. A drawdown of c 0.01 m was reached c 50 min after the pumping started in HFM16. The drawdown continued to increase c 100 min after the end of the flow period and there was a total recovery of only c 0.08 m during the recovery period of c 13 h duration. This fact may be due to a natural decreasing trend of the pressure during the test period.

#### *Interpreted flow regimes*

No interpretation of flow regimes has been made for this section.

#### *Interpreted parameters*

No transient parameter interpretation has been made for this section.

### 6.4.4 Observation section KFM02A: 581–1,002 m

Pressure data from the observation section KFM02A, 581–1,002 m, during interference test 2 in HFM16 are presented in Table 6-12 and in Figure A2-4 in Appendix 2.

**Table 6-12. Pressure data for observation section KFM02A: 581–1,002 m.**

| Pressure data, KFM02A (581–1,002 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Relative pressure in test section before start of flow period | $p_i$ | kPa | 5,621.4 |
| Relative pressure in test section before stop of flow period | $p_p$ | kPa | 5,620.4 |
| Relative pressure in test section at stop of recovery period | $p_F$ | kPa | 5,620.0 |
| Maximal pressure change during flow period | $dp_p$ | kPa | 0.95 |

#### *Comments on the test*

No indication of hydraulic response in this section can be found. The pressure decreased before the start of the flow period and continued to decrease throughout most of the recovery period. This behaviour is interpreted to be caused primarily by factors other than the pumping in HFM16, probably by natural trends.

### *Interpreted flow regimes*

No interpretation of flow regimes has been made for this section.

### *Interpreted parameters*

No transient parameter interpretation has been made for this section.

## 6.4.5 Observation section HFM19: 12–110 m

Pressure- and groundwater level data from the observation section HFM19, 12–110 m, are presented in Table 6-13. An overview of the pressure is presented in Figure A2-5 in Appendix 2.

**Table 6-13. Pressure and groundwater level data for observation section HFM19: 12–110 m.**

| Pressure data, HFM19 (12–110 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Absolute pressure in test section before start of flow period | $p_i$ | kPa | 170.7 |
| Absolute pressure in test section before stop of flow period | $p_p$ | kPa | 171.0 |
| Absolute pressure in test section at stop of recovery period | $p_F$ | kPa | 170.5 |
| Maximal pressure change during flow period | $dp_p$ | kPa | –0.32 |

| Manual groundwater level measurements, HFM19 (12–110 m)<br>Date<br>YYYY-MM-DD | <br>Time<br>tt:mm | <br>Time<br>(min) | GW level<br>(m b. ToC) | <br>(m a s l) |
|---|---|---|---|---|
| 2004-10-05 | 18:21 | 93 | 3.48 | 0.71 |

### *Comments on the test*

A weak initial response was detected, but c 30 min after start of pumping an unexpected peak in pressure appeared, and the pressure was not back to normal background levels until the end of the flow period. There was no precipitation or sudden change in barometric pressure during the test period that could explain the increased pressure. The drawdown reached a maximum of ca 0.06 m some five hours before the end of the recovery period (total recovery time was c 16 h). After this time, the pressure slowly increased again. The borehole section was probably unaffected by the pumping in HFM16.

### *Interpreted flow regimes*

No interpretation of flow regimes has been made for this section.

### *Interpreted parameters*

No transient parameter interpretation has been made for this section.

### 6.4.6 Observation section HFM19: 111–150 m

Pressure data from the observation section HFM19, 111–150 m, are presented in Table 6-14. An overview of the pressure is presented in Figure A2-5 in Appendix 2.

**Table 6-14. Pressure data for observation section HFM19: 111–150 m.**

| Pressure data, HFM19 (111–150 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Absolute pressure in test section before start of flow period | $p_i$ | kPa | 994.5 |
| Absolute pressure in test section before stop of flow period | $p_p$ | kPa | 994.5 |
| Absolute pressure in test section at stop of recovery period | $p_F$ | kPa | 993.8 |
| Maximal pressure change during flow period | $dp_p$ | kPa | |

#### *Comments on the test*

Test results are very similar to the ones described above from HFM19, 12–110 m.

#### *Interpreted flow regimes*

No interpretation of flow regimes has been made for this section.

#### *Interpreted parameters*

No transient parameter interpretation has been made for this section.

### 6.4.7 Observation section HFM19: 151–185 m

Pressure data from the observation section HFM19, 151–185 m, are presented in Table 6-15. An overview of the pressure is presented in Figure A2-5 in Appendix 2.

**Table 6-15. Pressure data for observation section HFM19: 151–185 m.**

| Pressure data, HFM19 (151–185 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Absolute pressure in test section before start of flow period | $p_i$ | kPa | 1,327.4 |
| Absolute pressure in test section before stop of flow period | $p_p$ | kPa | 1,327.5 |
| Absolute pressure in test section at stop of recovery period | $p_F$ | kPa | 1,326.9 |
| Maximal pressure change during flow period | $dp_p$ | kPa | |

#### *Comments on the test*

Test results are very similar to the ones described above from HFM19, 12–110 m and HFM19, 111–150.

#### *Interpreted flow regimes*

No interpretation of flow regimes has been made for this section.

### *Interpreted parameters*

No transient parameter interpretation has been made for this section.

## 6.5 Interference test 3 in HFM16

The barometric pressure was relatively constant during the test and has thus not been corrected for in any of the observation sections in HFM19 or KFM02A, see Figure A2-15. On the other hand, the pressure data from the observation sections are corrected to give values representing the pressure at the top of each test section, relative or absolute, depending on the individual transducers. All data from the pumping borehole, HFM16, have though been corrected for changes in the atmospheric pressure.

### 6.5.1 Pumping section HFM16: 12–132 m

General test data for the open-hole pumping test in section HFM16, 12–132 m, are presented in Tables 6-16, 6-17 and 6-18. An overview of the pressure and flow rate in the pumping borehole HFM16 during interference test 3 is presented in Figure A2-6 in Appendix 2.

**Table 6-16. General test data for interference test 3 in borehole HFM16: 12–132 m.**

| **General test data** | | | |
|---|---|---|---|
| Pumping borehole | HFM16 (12–132 m) | | |
| Test type[1] | Constant Rate withdrawal and recovery test | | |
| Test section (open borehole/packed-off section): | Open borehole | | |
| Test No | 3 | | |
| Field crew | K. Gokall-Norman, C. Hjerne (GEOSIGMA AB) | | |
| Test equipment system | – | | |
| General comment | Interference test | | |
| | **Nomenclature** | **Unit** | **Value** |
| Borehole length | L | m | 132.50 |
| Casing length | $L_c$ | m | 12.02 |
| Test section– secup | Secup | m | 12.02 |
| Test section– seclow | Seclow | m | 132.50 |
| Test section length | $L_w$ | m | 120.48 |
| Test section diameter[2] | $2{\times}r_w$ | mm | 139 |
| | | | |
| Test start (start of pressure registration) | | yymmdd hh:mm | 040929 12:00 |
| Packer expanded | | yymmdd hh:mm:ss | – |
| Start of flow period | | yymmdd hh:mm:ss | 041006 13:03 |
| Stop of flow period | | yymmdd hh:mm:ss | 041006 17:31 |
| Test stop (stop of pressure registration) | | yymmdd hh:mm | 041026 09:30 |
| Total flow time | $t_p$ | min | 268 |
| Total recovery time | $t_F$ | min | 894 |

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

[2)] Nominal diameter.

**Table 6-17. Pressure and groundwater level data during interference test 3 in HFM16.**

| Pressure data, HFM16 (12–132 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Relative pressure in borehole before start of flow period | $p_i$ | kPa | 84.7 |
| Relative pressure in borehole before stop of flow period | $p_p$ | kPa | 39.2 |
| Relative pressure in borehole at stop of recovery period | $p_F$ | kPa | 82.9 |
| Maximal pressure change during flow period | $dp_p$ | kPa | 45.6 |

| Manual groundwater level measurements, HFM16 (12–132 m)<br>Date<br>YYYY-MM-DD | <br>Time<br>tt:mm | <br>Time<br>(min) | GW level<br>(m b. ToC) | <br>(m a s l) |
|---|---|---|---|---|
| 2004-10-06 | 13:01 | –2 | 2.91 | 0.32 |
| 2004-10-06 | 17:30 | 267 | 7.61 | –4.36 |

**Table 6-18. Flow data during interference test 3 in HFM16.**

| Flow data, HFM16 (12–132 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Flow rate from test section just before stop of flow period | $Q_p$ | $m^3/s$ | $6.7×10^{–3}$ |
| Mean (arithmetic) flow rate during flow period | $Q_m$ | $m^3/s$ | $6.7×10^{–3}$ |
| Total volume discharged during flow period | $V_p$ | $m^3$ | 108 |

### *Comments on the test*

The test was performed as a constant-flow rate pumping test, see Figure A2-6. The flow rate was c 400 L/min and the flow period lasted c 4.5 h. Recovery was measured for c 15 h, although only 4.5 h was used for the transient analyses.

### *Interpreted flow regimes*

No clear interpretation of flow regimes was possible. Nevertheless, a transition to pseudo-radial flow is indicated after c 500 s, both during the flow- and recovery period.

### *Interpreted parameters*

Transient, quantitative interpretation of the flow period of the test is shown in log-log and lin-log diagrams in Figures A2-9 and A2-10. Although no clear pseudo-radial flow regime developed during the test, the interpretation according to the methods described in Section 5.4 is considered fairly unambiguous. The results are shown in the Test Summary Sheet and in Table 6-27 and 6-28 in Section 6.7.

## 6.5.2 Observation section KFM02A: 102–339 m

General test data from the observation section KFM02A, 102–339 m, are presented in Table 6-19.

**Table 6-19. Pressure and groundwater level data for observation section KFM02A: 102–339 m.**

| Pressure data, KFM02A (102–339 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Absolute pressure in test section before start of flow period | $p_i$ | kPa | 1,031.7 |
| Absolute pressure in test section before stop of flow period | $p_p$ | kPa | 1,031.7 |
| Absolute pressure in test section at stop of recovery period | $p_F$ | kPa | 1,031.5 |
| Maximal pressure change during flow period | $dp_p$ | kPa | 0.08 |

| Manual groundwater level measurements, KFM02A (102–339 m)<br>Date<br>YYYY-MM-DD | <br>Time<br>tt:mm | <br>Time<br>(min) | GW level<br>(m b. ToC) | <br>(m a s l) |
|---|---|---|---|---|
| 2004-10-06 | 10:57 | –126 | 6.75 | 0.62 |

### Comments on the test

No clear indication of hydraulic connectivity between section 102–339 m in borehole KFM02A and the pumping borehole HFM16 was observed. The maximal drawdown during the flow period was less than 0.01 m and cannot be distinctively associated with the test activity, see Figure A2-7 in Appendix 2.

### Interpreted flow regimes

No interpretation of flow regimes has been made for this section.

### Interpreted parameters

No transient parameter interpretation has been made for this section.

## 6.5.3 Observation section KFM02A: 340–460 m

Pressure data from the observation section KFM02A, 340–460 m, are presented in Table 6-20 and in Figure A2-7 in Appendix 2.

**Table 6-20. Pressure data for observation section KFM02A: 340–460 m.**

| Pressure data, KFM02A (340–460 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Relative pressure in test section before start of flow period | $p_i$ | kPa | 3,254.9 |
| Relative pressure in test section before stop of flow period | $p_p$ | kPa | 3,252.2 |
| Relative pressure in test section at stop of recovery period | $p_F$ | kPa | 3,253.0 |
| Maximal pressure change during flow period | $dp_p$ | kPa | 2.8 |

### Comments on the test

A clear response to pumping was detected in this section. The total drawdown during the flow period was almost 0.30 m. A drawdown of c 0.01 m was reached approximately 65 min after start of pumping in HFM16. Drawdown continued to increase until c 175 min after the end of the flow period and there was a total recovery of c 0.23 m during the recovery period of c15 h duration.

### *Interpreted flow regimes*

No clear interpretation of flow regimes was possible. The test responses weakly indicated a transition to a possible pseudo-radial flow regime.

### *Interpreted parameters*

An approximate transient interpretation of the short flow period of the test is shown in a log-log diagram in Figure A2-13. Quantitative analysis was only made on the flow period according to the methods described in Section 5.4. Although the flow period was not long enough to obtain a pseudo-radial flow regime the interpretation is considered as approximate. The results are summarized in Table 6-27 and 6-28 in Section 6.7.

## 6.5.4 Observation section KFM02A: 461–1,002 m

Pressure data from the observation section KFM02A, 461–1,002 m, are presented in Table 6-21 and in Figure A2-7 in Appendix 2.

**Table 6-21. Pressure data for observation section KFM02A: 461–1,002 m.**

| Pressure data, KFM02A (461–1,002 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Relative pressure in test section before start of flow period | $p_i$ | kPa | 4,436.4 |
| Relative pressure in test section before stop of flow period | $p_p$ | kPa | 4,432.4 |
| Relative pressure in test section at stop of recovery period | $p_F$ | kPa | 4,434.5 |
| Maximal pressure change during flow period | $dp_p$ | kPa | 4.0 |

### *Comments on the test*

A clear response to pumping was detected in this section. The response is only marginally larger than the one in section 340–460 m and very similar in shape. The maximum drawdown during the flow period was c 0.40 m. A drawdown of c 0.01 m was reached approximately 40 min after the pumping started in HFM16. Drawdown continued to increase c 90 min after the end of the flow period, and there was a total recovery of c 0.31 m during the recovery period of c 15 h duration.

### *Interpreted flow regimes*

No clear interpretation of flow regimes was possible, see previous section.

### *Interpreted parameters*

An approximate transient interpretation of the short flow period of the test is shown in a log-log diagram in Figure A2-14. Quantitative analysis was only made on the flow period. Although the flow period was not long enough to obtain a pseudo-radial flow regime, the interpretation according to the methods described in Section 5.4 is considered approximate. The results are shown in Tables 6-27 and 6-28 in Section 6.7.

### 6.5.5 Observation section HFM19: 12–110 m

General test data from the observation section HFM19, 12–110 m, are presented in Table 6-22 and in Figure A2-8 in Appendix 2.

**Table 6-22. Pressure and groundwater level data for observation section HFM19: 12–110 m.**

| Pressure data, HFM19 (12–110 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Absolute pressure in test section before start of flow period | $P_i$ | kPa | 170.6 |
| Absolute pressure in test section before stop of flow period | $P_p$ | kPa | 170.2 |
| Absolute pressure in test section at stop of recovery period | $p_F$ | kPa | 169.9 |
| Maximal pressure change during flow period | $dp_p$ | kPa | 0.37 |

| Manual groundwater level measurements, HFM19 (12–110 m) | | | GW level | |
|---|---|---|---|---|
| Date YYYY-MM-DD | Time tt:mm | Time (min) | (m b. ToC) | (m a s l) |
| 2004-10-06 | 11:43 | –80 | 3.53 | 0.66 |

#### *Comments on the test*

A weak but clear response was detected in this section in HFM19. The total drawdown was about 0.04 m. The recovery was very slow.

#### *Interpreted flow regimes*

No interpretation of flow regimes has been made for this section.

#### *Interpreted parameters*

No transient parameter interpretation has been made for this section.

### 6.5.6 Observation section HFM19: 111–150 m

Pressure data from the observation section HFM19, 111–150 m, are presented in Table 6-23. An overview diagram of the pressure is shown in Figure A2-8 in Appendix 2.

**Table 6-23. Pressure data for observation section HFM19: 111–150 m.**

| Pressure data, HFM19 (111–150 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Absolute pressure in test section before start of flow period | $p_i$ | kPa | 993.9 |
| Absolute pressure in test section before stop of flow period | $p_p$ | kPa | 993.6 |
| Absolute pressure in test section at stop of recovery period | $p_F$ | kPa | 993.3 |
| Maximal pressure change during flow period | $dp_p$ | kPa | 0.54 |

#### *Comments on the test*

The response was very similar to the one in section HFM19 12–110. A weak but clear response was detected. The total drawdown was about 0.05 m. The recovery was very slow.

### *Interpreted flow regimes*

No interpretation of flow regimes has been made for this section.

### *Interpreted parameters*

No transient parameter interpretation has been made for this section.

### 6.5.7 Observation section HFM19: 151–185 m

Pressure data from the observation section HFM19, 151–185 m, are presented in Table 6-24. An overview diagram of the pressure is shown in Figure A2-8 in Appendix 2.

**Table 6-24. Pressure data for observation section HFM19: 151–185 m.**

| Pressure data, HFM19 (151–185 m) | Nomenclature | Unit | Value |
|---|---|---|---|
| Absolute pressure in test section before start of flow period | $p_i$ | kPa | 1,326.9 |
| Absolute pressure in test section before stop of flow period | $p_p$ | kPa | 1,326.5 |
| Absolute pressure in test section at stop of recovery period | $p_F$ | kPa | 1,326.2 |
| Maximal pressure change during flow period | $dp_p$ | kPa | 0.45 |

### *Comments on the test*

The response was very similar to the ones in the other sections of HFM19. A weak but clear response was detected. The total drawdown was c 0.05 m. The recovery was very slow.

### *Interpreted flow regimes*

No interpretation of flow regimes has been made for this section.

### *Interpreted parameters*

No transient parameter interpretation has been made for this section.

## 6.6 Response analysis

A simplified response analysis according to the methodology description for interference tests (SKB MD 330.003) was made in this case due to the few observation boreholes. A response diagram from all three interference tests is shown in Figure 6-1 below. The response time lags ($dt_L$) in the observation boreholes during the interference tests in HFM16 are shown in Table 6-25a. The time lags were in this case derived from drawdown curves from the observation boreholes at an actual drawdown of 0.01 m.

Only sections that showed a significant response to the pumping have been included in the response analysis and are presented in the response diagram in Figure 6-1. As discussed above, the responses in HFM19 are uncertain. The normalised response time with respect to the distance to the pumping borehole (Index 1), which is inversely related to the hydraulic

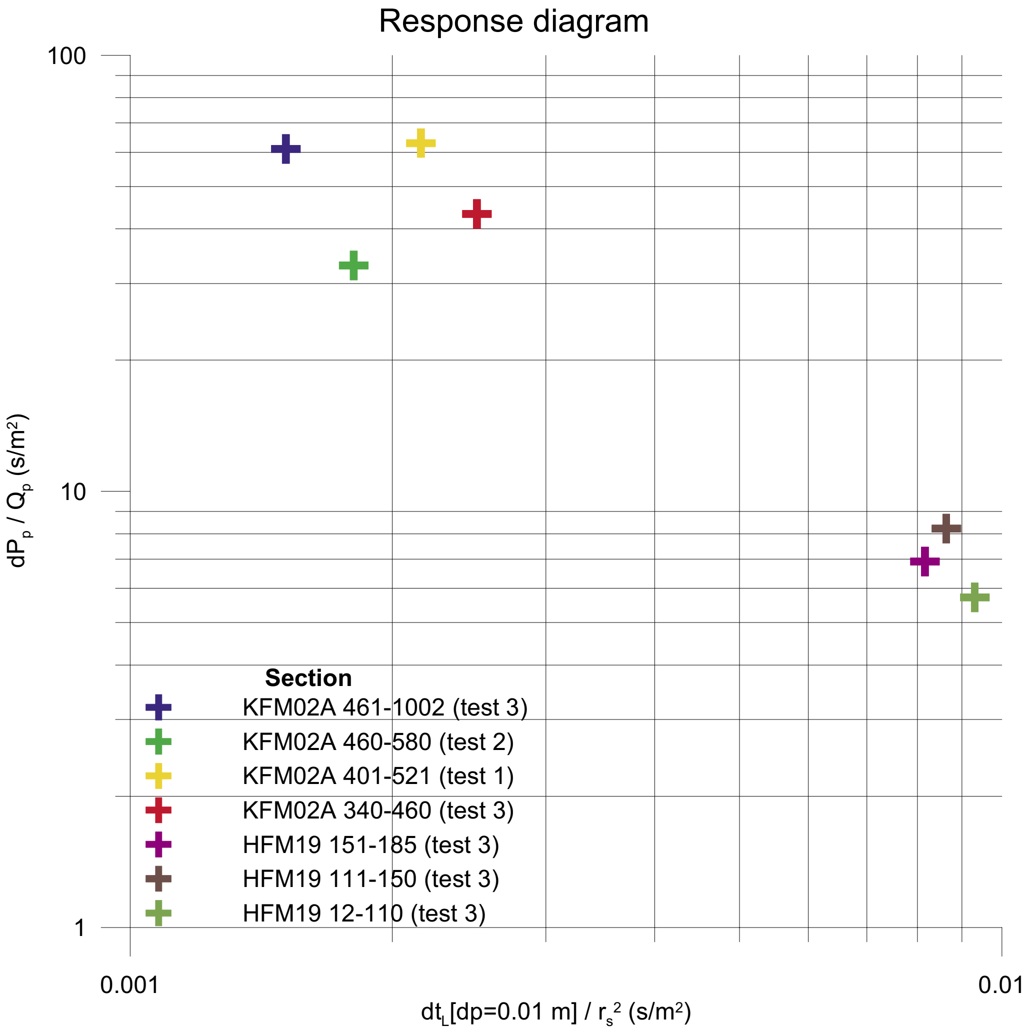



***Figure 6-1.*** *Response diagram for interference tests 1–3 in HFM16.*

diffusivity (T/S) of the formation was calculated. The distances between the boreholes are shown in Table 3-4. In addition, the normalized drawdown with respect to the flow rate (Index 2) was calculated and is presented in Table 6-25b.

By the preparation of Figure 6-1 and Tables 6-25a–b, the parameter definitions described below were used. The responses in HFM19 have been considered only for the third interference test due to the disturbances that occurred in this borehole during the other two tests.

$dt_L$[dp=0.01 m] = time after start of pumping (s) at a drawdown dp = 0.01 m in the observation section

$dt_L$[dp=0.01 m] / $r_s^2$ = normalised response time with respect to the distance $r_s$ (Index 1)

$r_s$ = 3D-distance between the hydraulic points of application (hydr. p.a.) in the pumping borehole and observation section (m)

$dp_p/Q_p$ = normalized drawdown with respect to the flow rate (Index 2)

$dp_p$ = drawdown at stop of pumping in the actual observation section (m)

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

**Table 6-25a. Calculated response time lags and normalized response times (Index 1) for the observation borehole sections during the interference tests in HFM16.**

| Test # | Pumping borehole | Observation borehole | Section (m) | hydr. p.a. (m) | $dt_L$[dp=0.01 m] (s) | $r_s$ (m) | $dt_L$[dp=0.01 m]/$r_s^2$ (s/m²) |
|---|---|---|---|---|---|---|---|
| 1 | HFM16 12–132 m | KFM02A | 401–521 | 461 | 3,500 | 1,274 | $2.16\times10^{-3}$ |
| 2 | HFM16 12–132 m | KFM02A | 460–580 | 520 | 3,000 | 1,289 | $1.81\times10^{-3}$ |
| 3 | HFM16 12–132 m | KFM02A | 340–460 | 428 | 4,000 | 1,265 | $2.50\times10^{-3}$ |
| 3 | HFM16 12–132 m | KFM02A | 461–1,002 | 513 | 2,500 | 1,287 | $1.51\times10^{-3}$ |
| 3 | HFM16 12–132 m | HFM19 | 12–110 | 101 | 9,500 | 1,010 | $9.31\times10^{-3}$ |
| 3 | HFM16 12–132 m | HFM19 | 11–150 | 149 | 9,250 | 1,035 | $8.63\times10^{-3}$ |
| 3 | HFM16 12–132 m | HFM19 | 151–185 | 176 | 9,000 | 1,050 | $8.16\times10^{-3}$ |

**Table 6-25b. Drawdown and normalized drawdown (Index 2) for the observation borehole sections during the interference tests in HFM16.**

| Test # | Pumping borehole | $Q_p$ (m³/s) | Observation borehole | Section (m) | $dp_p$ (m) | $dp_p/Q_p$ (s/m²) |
|---|---|---|---|---|---|---|
| 1 | HFM16 12–132 m | $6.67\times10^{-3}$ | KFM02A | 401–521 | 0.419 | 62.95 |
| 2 | HFM16 12–132 m | $6.67\times10^{-3}$ | KFM02A | 460–580 | 0.220 | 32.98 |
| 3 | HFM16 12–132 m | $6.67\times10^{-3}$ | KFM02A | 340–460 | 0.288 | 43.31 |
| 3 | HFM16 12–132 m | $6.67\times10^{-3}$ | KFM02A | 461–1,002 | 0.407 | 61.04 |
| 3 | HFM16 12–132 m | $6.67\times10^{-3}$ | HFM19 | 12–110 | 0.038 | 5.71 |
| 3 | HFM16 12–132 m | $6.67\times10^{-3}$ | HFM19 | 11–150 | 0.054 | 8.21 |
| 3 | HFM16 12–132 m | $6.67\times10^{-3}$ | HFM19 | 151–185 | 0.046 | 6.90 |

The linear pressure versus time diagrams showing responses to pumping in HFM16 in the different observation sections indicate two different zones or flow anomalies along KFM02A, which are connected to HFM16. This fact is also supported by Figure 6-1. One zone is located in section 401–460 m, and the other one between 460 m and 521 m. This fact also corresponds well to the results from previous tests in KFM02A where conductive sections were found primarily at 416–431 m and 511–516 m, /3, 4/. Other highly conductive zones have been located at more shallow depths, but since there are no clear pressure responses in those parts of the borehole, they are probably not connected to the same fracture zone as in HFM16.

Tables 6-25a and 6-25b are the basis for the response diagram shown in Figure 6-1. In a response diagram, observation sections that are well connected to the pumping section, for instance via fracture zones, are expected to be located in the upper left part of the diagram, i. e. distinct and fast responses. An analysis of this diagram and previous knowledge from KFM02A indicates that the flow anomaly at c 513 m contributes to the largest response in KFM02A. It is likely that this flow anomaly is involved in all of the responding sections in which it is included, i.e. sections 401–521 (test 1), 460–580 (test 2) and 461–1,002 (test 3).

The responses in HFM19 are significant and very similar in all sections, but not as strong as in KFM02A. From previous tests, four different flow anomalies were identified in HFM19. Two anomalies are located in the deepest section (151–185 m) and one in each of the other sections. The weak indication in the response diagram that the deepest section had the strongest response is consistent with the transmissivity data from previous tests, cf Table 3-5.

## 6.7 Summary of interference tests

A compilation of measured test data from the interference tests in HFM16, 12–132 m, is shown in Table 6-26. In Tables 6-27 and 6-28 calculated hydraulic parameters of the formation and borehole from the tests, respectively, are presented. The calculated T-values for HFM16 in Table 6-28 from the transient evaluation correspond well to those from the previous flow logging and pumping tests in this borehole, /1/.

The responses in the observation borehole sections were mainly evaluated qualitatively. For KFM02A, an approximate transient evaluation was though performed for sections 340–460 m and 461–1,002 m from the flow period during interference test 3.

The evaluated, approximate transmissivity from observation sections 340–460 m and 461–1,002 m in KFM02A are significantly higher than the T-values obtained from the injection tests /3/ performed earlier in KFM02A, cf Table 3-5. This fact may possibly be due to that the calculated T-values from the interference tests are more weighted on the hydraulic properties close to the pumping borehole HFM16 because of the long distances between the boreholes and the short test time. Furthermore, the calculated T-values for these sections are uncertain, since no pseudo-radial flow regime developed during the short tests. The calculated T-values for HFM16 and KFM02A are fairly similar.

The lower and upper practical measurement limit for transmissivity for the equipment used, expressed in terms of specific flow (Q/s), is Q/s-L = $3\times10^{-6}$ m²/s and Q/s-U = $1\times10^{-2}$ m²/s for pumping tests.

**Table 6-26. Summary of test data from the interference tests performed between borehole HFM16 and the observation boreholes KFM02A and HFM19 in the Forsmark area.**

| Test # | Pumping borehole ID | Borehole ID | Section (m) | Test Type[1)] | $p_i$ (kPa) | $p_p$ (kPa) | $p_F$ (kPa) | $Q_p$ (m³/s) | $Q_m$ (m³/s) | $V_p$ (m³) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | HFM16 | HFM16 | 12–132 | 1B | 88.1 | 42.0 | 85.1 | $6.7\times10^{-3}$ | $6.7\times10^{-3}$ | 109 |
| 1 | | KFM02A | 102–400 | 2 | 931.8 | 931.8 | 931.8 | | | |
| 1 | | KFM02A | 401–521 | 2 | 3,856.4 | 3,852.3 | 3,853.8 | | | |
| 1 | | KFM02A | 522–1,002 | 2 | 5,040.6 | 5,040.7 | 5,041.0 | | | |
| 2 | HFM16 | HFM16 | 12–132 | 1B | 85.6 | 44.7 | 84.1 | $6.7\times10^{-3}$ | $6.7\times10^{-3}$ | 66 |
| 2 | | KFM02A | 102–459 | 2 | 1,032.5 | 1,032.5 | 1,032.0 | | | |
| 2 | | KFM02A | 460–580 | 2 | 4,452.9 | 4,450.7 | 4,451.5 | | | |
| 2 | | KFM02A | 580–1,002 | 2 | 5,621.4 | 5,620.4 | 5,620.0 | | | |
| 2 | | HFM19 | 12–110 | 2 | 170.7 | 171.0 | 170.5 | | | |
| 2 | | HFM19 | 111–150 | 2 | 994.5 | 994.5 | 993.8 | | | |
| 2 | | HFM19 | 151–185 | 2 | 1,327.4 | 1,327.5 | 1,326.9 | | | |
| 3 | HFM16 | HFM16 | 12–132 | 1B | 84.7 | 39.2 | 82.9 | $6.7\times10^{-3}$ | $6.7\times10^{-3}$ | 108 |
| 3 | | KFM02A | 102–339 | 2 | 1,031.7 | 1,031.7 | 1,031.5 | | | |
| 3 | | KFM02A | 340–460 | 2 | 3,254.9 | 3,252.2 | 3,253.0 | | | |
| 3 | | KFM02A | 461–1,002 | 2 | 4,436.4 | 4,432.4 | 4,434.5 | | | |
| 3 | | HFM19 | 12–110 | 2 | 170.6 | 170.2 | 169.9 | | | |
| 3 | | HFM19 | 111–150 | 2 | 993.9 | 993.6 | 993.3 | | | |
| 3 | | HFM19 | 151–185 | 2 | 1,326.9 | 1,326.5 | 1,326.2 | | | |

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

**Table 6-27. Summary of calculated hydraulic parameters from the single-hole test in HFM16 in the Forsmark area.**

| Pumping borehole ID | Section (m) | Test type | Q/s ($m^2/s$) | $T_M$ ($m^2/s$) | $T_T$ ($m^2/s$) | ζ (–) | C ($m^3/Pa$) | S* (–) |
|---|---|---|---|---|---|---|---|---|
| HFM16 | 12–132 | 1B | $1.44×10^{-3}$ | $1.77×10^{-3}$ | $4.78×10^{-4}$ | –6.97 | – | $5×10^{-5}$ |

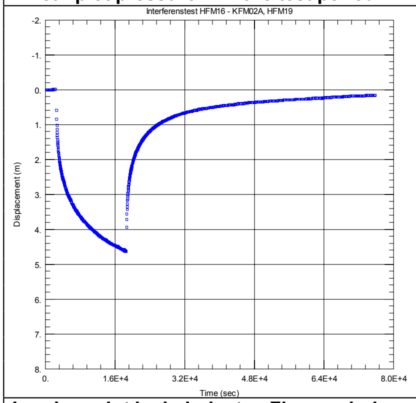
**Table 6-28. Summary of calculated hydraulic parameters from the interference test between HFM16 and KFM02A respectively HFM19 in the Forsmark area.**

| Pumping borehole ID | Observation borehole ID | Section (m) | Test type | $T_o$ ($m^2/s$) | $S_o$ (–) |
|---|---|---|---|---|---|
| HFM16 | KFM02A | 340–460 | 2 | $5.52×10^{-4}$ | $1.84×10^{-5}$ |
| HFM16 | KFM02A | 461–1,002 | 2 | $6.41×10^{-4}$ | $1.41×10^{-5}$ |

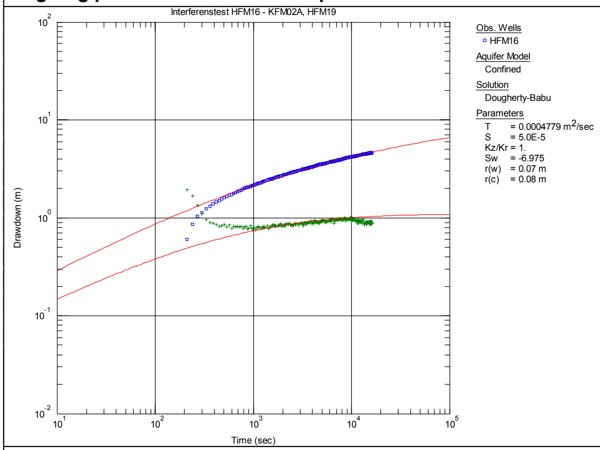
Q/s = specific flow for the pumping/injection borehole,
$T_M$ = steady state transmissivity from Moye´s equation,
$T_T$ = transmissivity from transient evaluation of single-hole test,
$T_o$ = transmissivity from transient evaluation of interference test,
$S_o$ = storativity from transient evaluation of interference test,
S* = assumed storativity by the estimation of the skin factor in single hole tests,
C = wellbore storage coefficient,
ζ = skin factor.

| Test Summary Sheet - Pumping section HFM16: 12-132 m | | | |
|---|---|---|---|
| Project: | PLU | Test type: | 1B |
| Area: | Forsmark | Test no: | 3 |
| Borehole ID: | HFM16 | Test start: | 2004-09-29 12:00 |
| Test section (m): | 12-132 | Responsible for test performance: | GEOSIGMA AB<br>K Gokall-Norman, C Hjerne |
| Section diameter, 2·rw (m): | 0.139 (nominal) | Responsible for test evaluation: | GEOSIGMA AB<br>J-E Ludvigson |

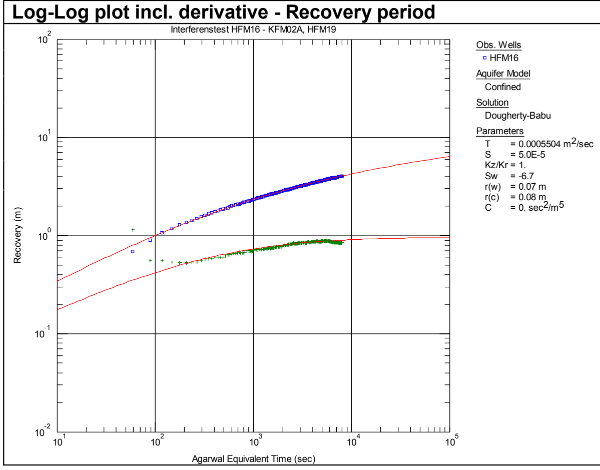
**Linear plot pressure – Entire test period**




**Log-Log plot incl. derivate - Flow period**




**Log-Log plot incl. derivative - Recovery period**




| **Flow period** | | **Recovery period** | |
|---|---|---|---|
| **Indata** | | **Indata** | |
| $p_0$ (kPa) | | | |
| $p_i$ (kPa ) | 84.7 | | |
| $p_p$(kPa) | 39.2 | $p_F$ (kPa ) | 82.9 |
| $Q_p$ ($m^3$/s) | $6.7 \cdot 10^{-3}$ | | |
| tp (s) | 16080 | $t_F$ (s) | 53640 |
| S* | $5.0 \cdot 10^{-5}$ | S* | $5.0 \cdot 10^{-5}$ |
| $EC_w$ (mS/m) | | | |
| $Te_w$(gr C) | | | |
| Derivative fact. | 0.2 | Derivative fact. | 0.2 |
| | | | |
| | | | |
| **Results** | | **Results** | |
| Q/s ($m^2$/s) | $1.44 \cdot 10^{-3}$ | | |
| $T_{Moye}$($m^2$/s) | $1.77 \cdot 10^{-3}$ | | |
| Flow regime: | | Flow regime: | |
| $t_1$ (s) | 1020 | $dt_{e1}$ (s) | 300 |
| $t_2$ (s) | 10200 | $dt_{e2}$ (s) | 6000 |
| $T_w$ ($m^2$/s) | $4.78 \cdot 10^{-4}$ | $T_w$ ($m^2$/s) | $5.50 \cdot 10^{-4}$ |
| $S_w$ (-) | | $S_w$ (-) | |
| $K_{sw}$ (m/s) | | $K_{sw}$ (m/s) | |
| $S_{sw}$ (1/m) | | $S_{sw}$ (1/m) | |
| C ($m^3$/Pa) | | C ($m^3$/Pa) | |
| $C_D$ (-) | | $C_D$ (-) | |
| ξ (-) | -6.97 | ξ (-) | -6.7 |
| | | | |
| $T_{GRF}$($m^2$/s) | | $T_{GRF}$($m^2$/s) | |
| $S_{GRF}$(-) | | $S_{GRF}$(-) | |
| $D_{GRF}$ (-) | | $D_{GRF}$ (-) | |

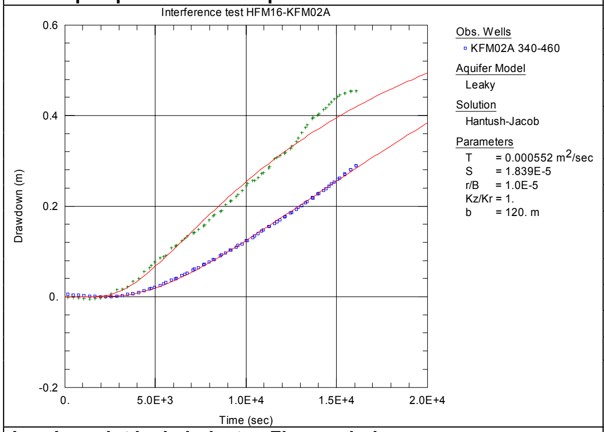
| **Interpreted formation and well parameters.** | | | |
|---|---|---|---|
| Flow regime: | | C ($m^3$/Pa) | |
| $t_1$ (s) | 1020 | $C_D$ (-) | |
| $t_2$ (s) | 10200 | ξ (-) | -6.97 |
| $T_T$ ($m^2$/s) | $4.78 \cdot 10^{-4}$ | | |
| S (-) | | | |
| $K_s$ (m/s) | | | |
| $S_s$ (1/m) | | | |

**Comments**: All pressure data are relative pressure.

Q was considered to be constant throughout the flow period (400 L/min).

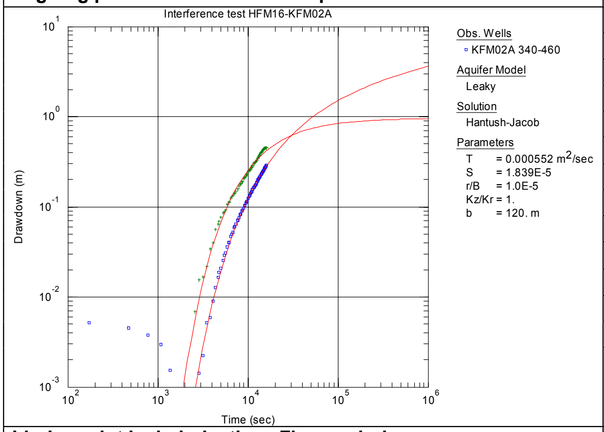
| Test Summary Sheet - Observation section KFM02A: 340-460 m | | | |
|---|---|---|---|
| Project: | PLU | Test type: | 2 |
| Area: | Forsmark | Test no: | 3 |
| Borehole ID: | KFM02A | Test start: | 2004-09-29 12:00 |
| Test section (m): | 340-460 | Responsible for test performance: | GEOSIGMA AB<br>K Gokall-Norman, C Hjerne |
| Section diameter, 2·rw (m): | 0.076 (nominal) | Responsible for test evaluation: | GEOSIGMA AB<br>J-E LudvigsonP |

**Linear plot pressure – Flow period**

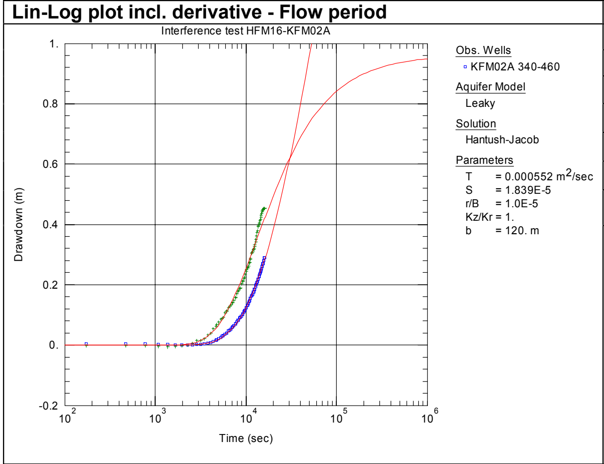



| Flow period | | Recovery period | |
|---|---|---|---|
| **Indata** | | **Indata** | |
| $p_0$ (kPa) | | | |
| $p_i$ (kPa ) | 3254.9 | | |
| $p_p$(kPa) | 3252.2 | $p_F$ (kPa ) | 3253.0 |
| $Q_p$ ($m^3$/s) | $6.7 \cdot 10^{-3}$ | | |
| tp (s) | 16080 | $t_F$ (s) | 53640 |
| S* | - | S* | - |
| $EC_w$ (mS/m) | | | |
| $Te_w$(gr C) | | | |
| Derivative fact. | 0.2 | Derivative fact. | 0.2 |
| | | | |
| | | | |
| **Results** | | **Results** | |
| Q/s ($m^2$/s) | - | | |
| $T_{Moye}$($m^2$/s) | - | | |
| Flow regime: | | Flow regime: | |
| $t_1$ (s) | - | $dt_{e1}$ (s) | - |
| $t_2$ (s) | - | $dt_{e2}$ (s) | - |
| $T_o$ ($m^2$/s) | $5.52 \cdot 10^{-4}$ | $T_w$ ($m^2$/s) | - |
| $S_o$ (-) | $1.84 \cdot 10^{-5}$ | $S_w$ (-) | |
| $K_{sw}$ (m/s) | | $K_{sw}$ (m/s) | |
| $S_{sw}$ (1/m) | | $S_{sw}$ (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. derivate - Flow period**




**Lin-Log plot incl. derivative - Flow period**




| Interpreted formation and well parameters. | | | |
|---|---|---|---|
| Flow regime: | | C ($m^3$/Pa) | |
| $t_1$ (s) | - | $C_D$ (-) | |
| $t_2$ (s) | - | ξ (-) | - |
| $T_o$ ($m^2$/s) | $5.52 \cdot 10^{-4}$ | | |
| $S_o$ (-) | $1.84 \cdot 10^{-5}$ | | |
| $K_s$ (m/s) | | | |
| $S_s$ (1/m) | | | |

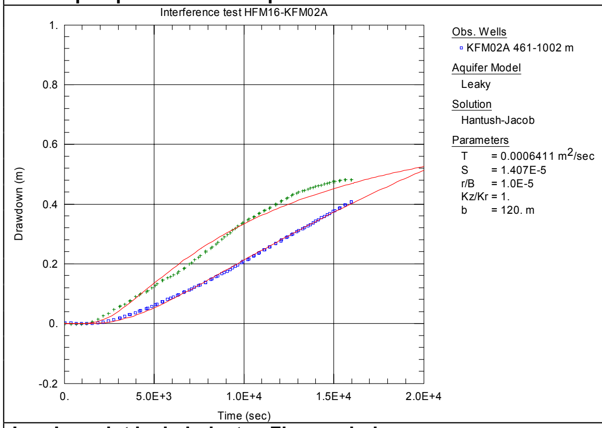
**Comments**: All pressure data are relative pressure.

No pseudo-radial flow regime was developed during the flow period due to the long distance to the pumping borehole HFM16.
An approximate evaluation was made on the first part of the response during the flow period. No evaluation was made on the recovery period.

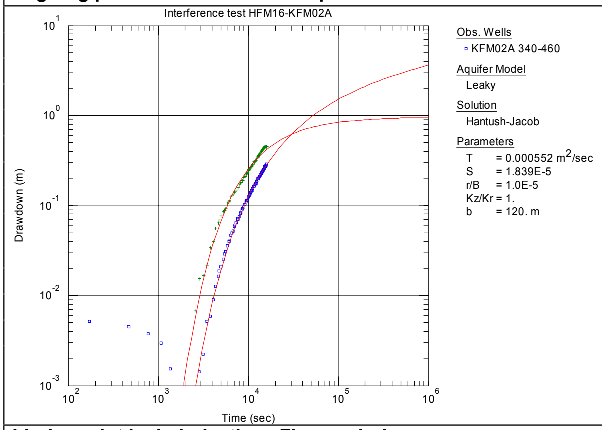
# Test Summary Sheet - Observation section KFM02A: 461-1002 m

| | | | |
|---|---|---|---|
| Project: | PLU | Test type: | 2 |
| Area: | Forsmark | Test no: | 3 |
| Borehole ID: | KFM02A | Test start: | 2004-09-29 12:00 |
| Test section (m): | 461-1002 | Responsible for test performance: | GEOSIGMA AB<br>K Gokall-Norman, C Hjerne |
| Section diameter, 2·rw (m): | 0.076 (nominal) | Responsible for test evaluation: | GEOSIGMA AB<br>J-E Ludvigson |

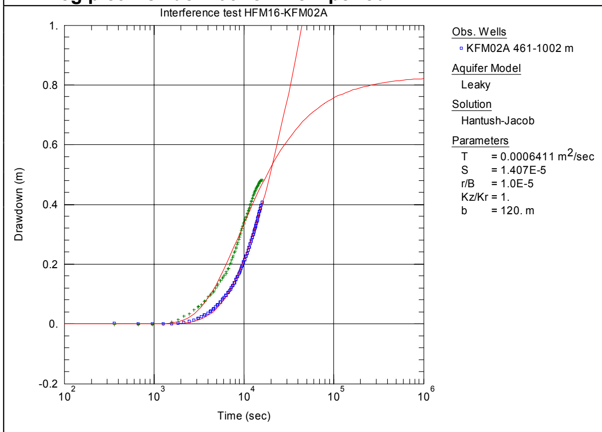
**Linear plot pressure – Flow period**




**Log-Log plot incl. derivate - Flow period**




**Lin-Log plot incl. derivative - Flow period**




| **Flow period** | | **Recovery period** | |
|---|---|---|---|
| **Indata** | | **Indata** | |
| $p_0$ (kPa) | | | |
| $p_i$ (kPa ) | 4436.4 | | |
| $p_p$(kPa) | 4432.4 | $p_F$ (kPa ) | 4434.5 |
| $Q_p$ ($m^3$/s) | $6.7·10^{-3}$ | | |
| tp (s) | 16080 | $t_F$ (s) | 53640 |
| S* | - | S* | - |
| $EC_w$ (mS/m) | | | |
| $Te_w$(gr C) | | | |
| Derivative fact. | 0.2 | Derivative fact. | 0.2 |
| | | | |
| | | | |
| **Results** | | **Results** | |
| Q/s ($m^2$/s) | - | | |
| $T_{Moye}$($m^2$/s) | - | | |
| Flow regime: | | Flow regime: | |
| $t_1$ (s) | - | $dt_{e1}$ (s) | - |
| $t_2$ (s) | - | $dt_{e2}$ (s) | - |
| $T_o$ ($m^2$/s) | $6.41·10^{-4}$ | $T_w$ ($m^2$/s) | - |
| $S_o$ (-) | $1.41·10^{-5}$ | $S_w$ (-) | |
| $K_{sw}$ (m/s) | | $K_{sw}$ (m/s) | |
| $S_{sw}$ (1/m) | | $S_{sw}$ (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) | |
| $S_{GRF}$(-) | | $S_{GRF}$(-) | |
| $D_{GRF}$ (-) | | $D_{GRF}$ (-) | |

**Interpreted formation and well parameters.**

| | | | |
|---|---|---|---|
| Flow regime: | | C ($m^3$/Pa) | |
| $t_1$ (s) | - | $C_D$ (-) | |
| $t_2$ (s) | - | ξ (-) | - |
| $T_o$ ($m^2$/s) | $6.41·10^{-4}$ | | |
| $S_o$ (-) | $1.41·10^{-5}$ | | |
| $K_s$ (m/s) | | | |
| $S_s$ (1/m) | | | |

**Comments**: All pressure data are relative pressure.

No pseudo-radial flow regime was developed during the flow period due to the long distance to the pumping borehole HFM16.
An approximate evaluation was made on the first part of the response during the flow period. No evaluation was made on the recovery period.

# 7 References


/1/ **Ludvigson J-E, Jönsson S, Hjerne C, 2004.** Forsmark site investigation. Pumping tests and flow logging Boreholes KFM06A (0–100 m) and HFM16. SKB P-04-65, Svensk Kärnbränslehantering AB.

/2/ **Ludvigson J-E, Källgården J, Hjerne C, 2004.** Forsmark site investigation. Pumping tests and flow logging – Boreholes HFM17, HFM18 and HFM19. SKB P-04-72, Svensk Kärnbränslehantering AB.

/3/ **Källgården J, Ludvigson J-E, Jönsson J, 2004.** Forsmark site investigation. Single-hole injection tests in borehole KFM02A. SKB P-04-100, Svensk Kärnbränslehantering AB.

/4/ **Rouhiainen P, Pöllänen J, 2004.** Forsmark site investigation. Difference flow logging in borehole KFM02A. SKB P-04-188, Svensk Kärnbränslehantering AB.

/5/ **Almén K-E, Andersson J-E, Carlsson L, Hansson K, Larsson N-Å, 1986.** Hydraulic testing in crystalline rock. A comparative study of single-hole test methods. SKB TR 86-27, Svensk Kärnbränslehantering AB.

/6/ **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.

# Appendix 1

## List of data files

Files are named "logger S/N"_Interferens_"BhID"_"secup"_"seclow"_"YYYYMMDD"_"hhmmss". Interferens is just an internal marker, "logger S/N" is the loggers unique serial number, "BhID" is the name of the borehole, "secup" and "seclow" are the top and bottom of the measured section and last in the file name the datafile start time is given. The data file from the pumping borehole is a little different where only serial number, date of data file start time and BhID are given.

| Bh ID | Test section (m) | Test type[1] | Test no | Test start Date, time YYYY-MM-DD tt:mm:ss | Test stop Date, time YYYY-MM-DD tt:mm:ss | Datafile, start Date, time YYYY-MM-DD tt:mm:ss | Datafile, stop Date, time YYYY-MM-DD tt:mm:ss | Data files of raw and primary data | Content (parameters)[2] | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| HFM16 | 12–132 | 1B | | 2004-09-29 12:00:00 | 2004-10-26 09:30:00 | 2004-09-29 12:00:00 | 2004-10-26 09:30:00 | SN10894 2004-09-29 120000 HFM16.bin | P | Pressure registration in HFM16, 12-132 m for interference |
| KFM02A | 102–400 | 2 | | 2004-10-04 13:34:13 | 2004-10-05 12:21:52 | 2004-10-04 13:34:13 | 2004-10-05 12:29:13 | SN09981_Interferens_KFM02A_102_400_20041004_133413.bin | P | Pressure response to pumping in HFM16 12–132 m. |
| KFM02A | 401–521 | 2 | | 2004-10-04 13:34:13 | 2004-10-05 12:21:52 | 2004-10-04 13:26:52 | 2004-10-05 12:21:52 | SN12572_Interferens_KFM02A_401_521_20041004_132652.bin | P | Pressure response to pumping in HFM16 12–132 m. |
| KFM02A | 522–1,002 | 2 | | 2004-10-04 13:34:13 | 2004-10-05 12:21:52 | 2004-10-04 13:30:29 | 2004-10-05 12:25:29 | SN12115_Interferens_KFM02A_522_1002_20041004_133029.bin | P | Pressure response to pumping in HFM16 12–132 m. |
| KFM02A | 102–459 | 2 | | 2004-10-05 15:55:11 | 2004-10-06 08:18:13 | 2004-10-05 15:55:11 | 2004-10-06 08:23:23 | SN09981_Interferens_KFM02A_102_459_20041005_155511.bin | P | Pressure response to pumping in HFM16 12–132 m. |
| KFM02A | 460–580 | 2 | | 2004-10-05 15:55:11 | 2004-10-06 08:18:13 | 2004-10-05 15:45:41 | 2004-10-06 08:18:13 | SN12572_Interferens_KFM02A_460_580_20041005_154541.bin | P | Pressure response to pumping in HFM16 12–132 m. |
| KFM02A | 581–1,002 | 2 | | 2004-10-05 15:55:11 | 2004-10-06 08:18:13 | 2004-10-05 15:48:42 | 2004-10-06 08:21:08 | SN12115_Interferens_KFM02A_581_1002_20041005_154842.bin | P | Pressure response to pumping in HFM16 12–132 m. |
| KFM02A | 102–339 | 2 | | 2004-10-06 11:23:33 | 2004-10-07 08:26:52 | 2004-10-06 11:23:33 | 2004-10-07 08:32:16 | SN09981_Interferens_KFM02A_102_339_20041006_112333.bin | P | Pressure response to pumping in HFM16 12–132 m. |
| KFM02A | 340–460 | 2 | | 2004-10-06 11:23:33 | 2004-10-07 08:26:52 | 2004-10-06 11:15:52 | 2004-10-07 08:26:52 | SN12572_Interferens_KFM02A_340_460_20041006_111552.bin | P | Pressure response to pumping in HFM16 12–132 m. |
| KFM02A | 461–1,002 | 2 | | 2004-10-06 11:23:33 | 2004-10-07 08:26:52 | 2004-10-06 11:19:03 | 2004-10-07 08:29:48 | SN12115_Interferens_KFM02A_461_1002_20041006_111903.bin | P | Pressure response to pumping in HFM16 12–132 m. |

| Bh ID | Test section (m) | Test type[1] | Test no | Test start Date, time YYYY-MM-DD tt:mm:ss | Test stop Date, time YYYY-MM-DD tt:mm:ss | Datafile, start Date, time YYYY-MM-DD tt:mm:ss | Datafile, stop Date, time YYYY-MM-DD tt:mm:ss | Data files of raw and primary data | Content (parameters)[2] | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| HFM19 | 12–110 | 2 | | 2004-10-05 12:00:00 | 2004-10-06 11:48:00 | 2004-10-05 12:00:00 | 2004-10-06 11:58:51 | SN13784_Interferens_HFM19_12_110_20041005_120000.bin | P | Pressure response to pumping in HFM16 12–132 m. |
| HFM19 | 111–150 | 2 | | 2004-10-05 12:00:00 | 2004-10-06 11:48:00 | 2004-10-05 12:00:00 | 2004-10-06 11:48:00 | SN13661_Interferens_HFM19_111_150_20041005_120000.bin | P | Pressure response to pumping in HFM16 12–132 m. |
| HFM19 | 151–185 | 2 | | 2004-10-05 12:00:00 | 2004-10-06 11:48:00 | 2004-10-05 12:00:00 | 2004-10-06 11:54:35 | SN13787_Interferens_HFM19_151_185_20041005_120000.bin | P | Pressure response to pumping in HFM16 12–132 m. |
| HFM19 | 12–110 | 2 | | 2004-10-06 12:00:15 | 2004-10-07 09:10:45 | 2004-10-06 12:00:15 | 2004-10-07 09:20:41 | SN13784_Interferens_HFM19_12_110_20041006_120015.bin | P | Pressure response to pumping in HFM16 12–132 m. |
| HFM19 | 111–150 | 2 | | 2004-10-06 12:00:15 | 2004-10-07 09:10:45 | 2004-10-06 11:51:00 | 2004-10-07 09:15:02 | SN13661_Interferens_HFM19_111_150_20041006_115100.bin | P | Pressure response to pumping in HFM16 12–132 m. |
| HFM19 | 151–185 | 2 | | 2004-10-06 12:00:15 | 2004-10-07 09:10:45 | 2004-10-06 11:57:31 | 2004-10-07 09:10:45 | SN13787_Interferens_HFM19_151_185_20041006_115731.bin | P | Pressure response to pumping in HFM16 12–132 m. |

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

2) P = Pressure, Q = Flow, Te = Tem□

## 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),
C = well loss constant (set to 0).

### Interference test 1

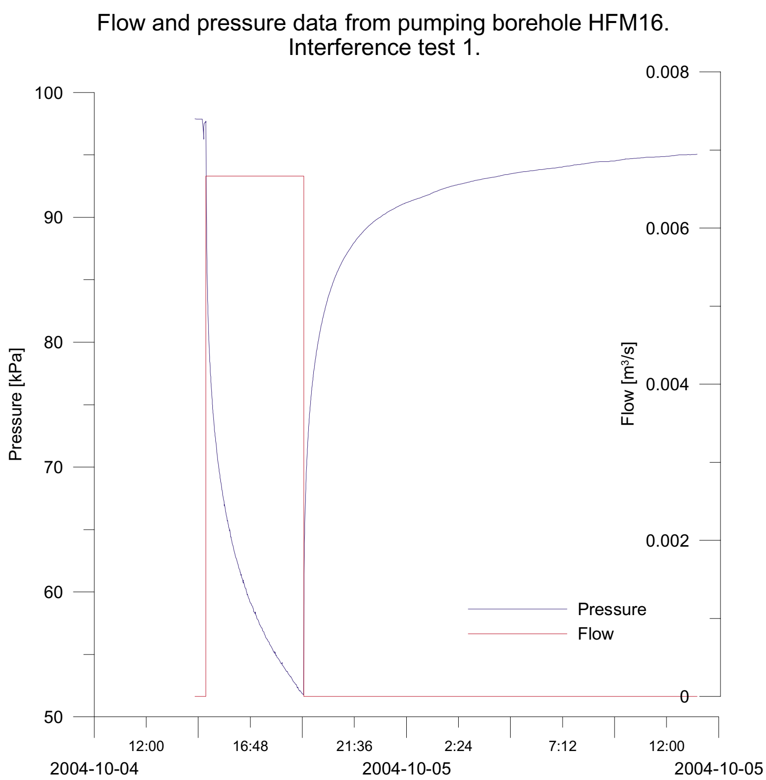



***Figure A2-1.*** *Pressure and flow in HFM16 during interference test 1.*

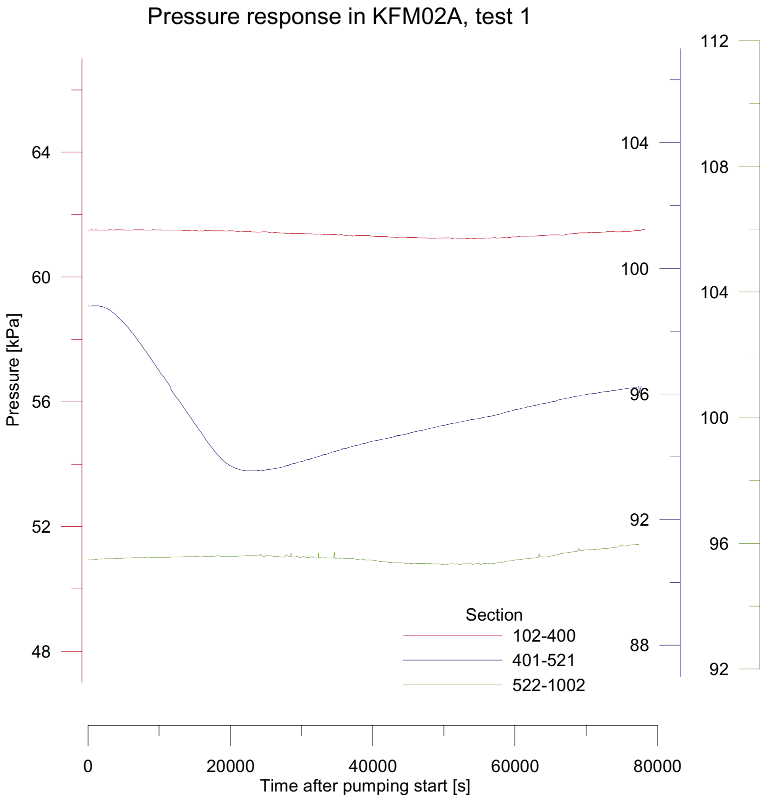



*Figure A2-2.* *Linear plot of pressure versus time in the observation sections in KFM02A during interference test 1.*

## Interference test 2

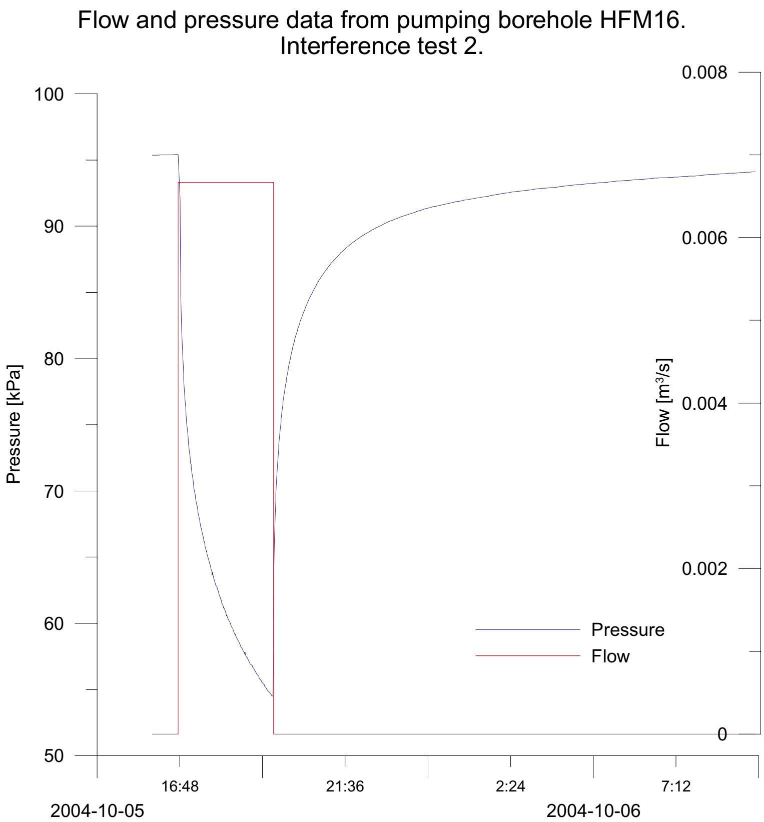



*Figure A2-3.* *Pressure and flow in HFM16 during interference test 2.*

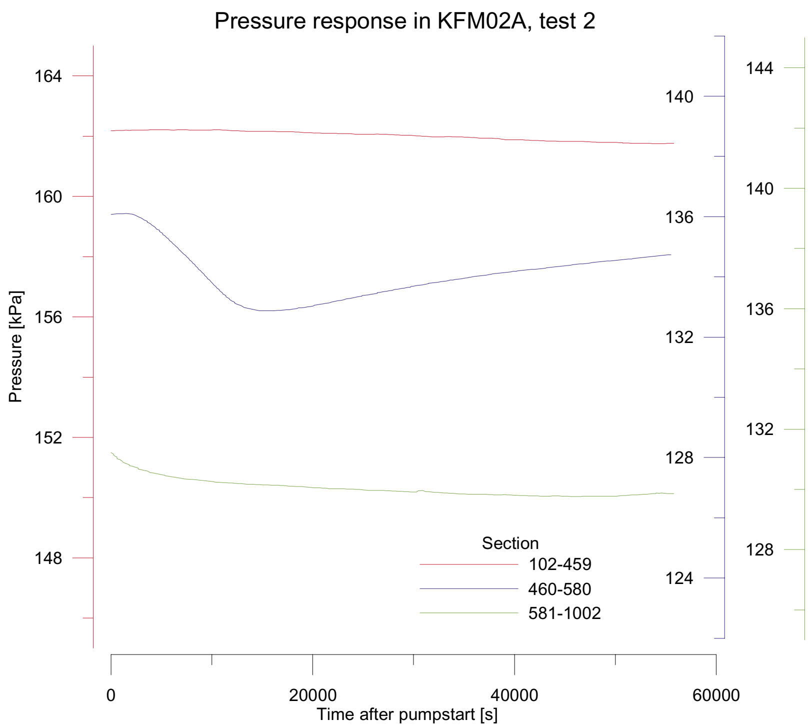



***Figure A2-4.*** *Linear plot of pressure versus time in the observation sections in KFM02A during interference test 2.*

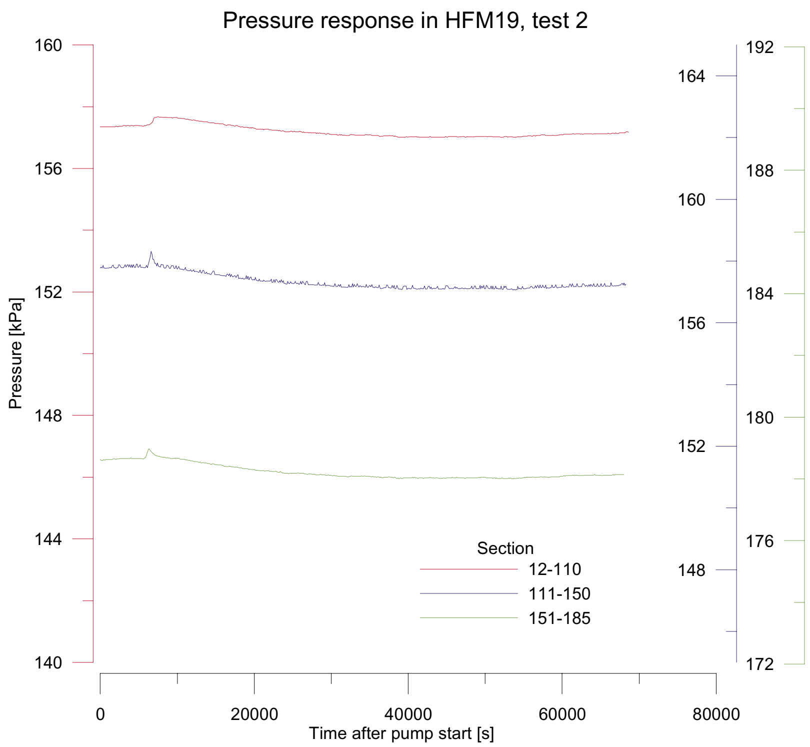



***Figure A2-5.*** *Linear plot of pressure versus time in the observation sections in HFM19 during interference test 2.*

## Interference test 3

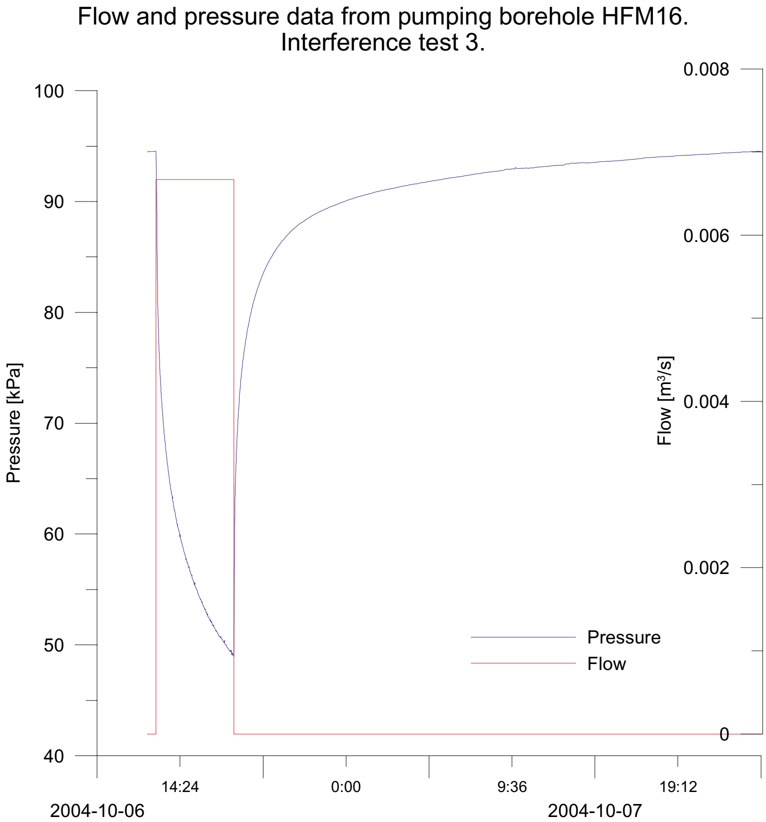



***Figure A2-6.*** *Pressure and flow in HFM16 during interference test 3.*

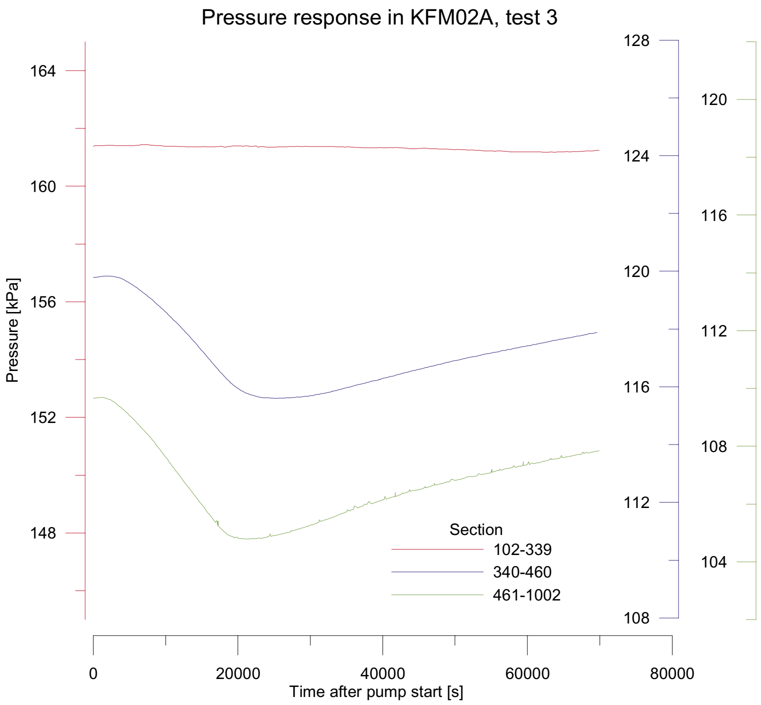



***Figure A2-7.*** *Linear plot of pressure versus time in the observation sections in KFM02A during interference test 3.*

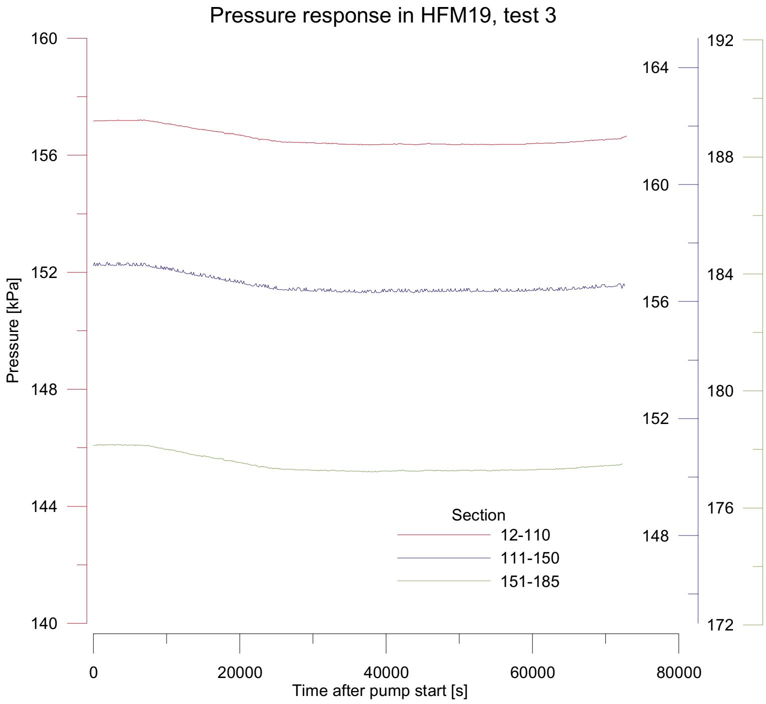



***Figure A2-8.** Linear plot of pressure versus time in the observation sections of HFM19 during interference test 3.*

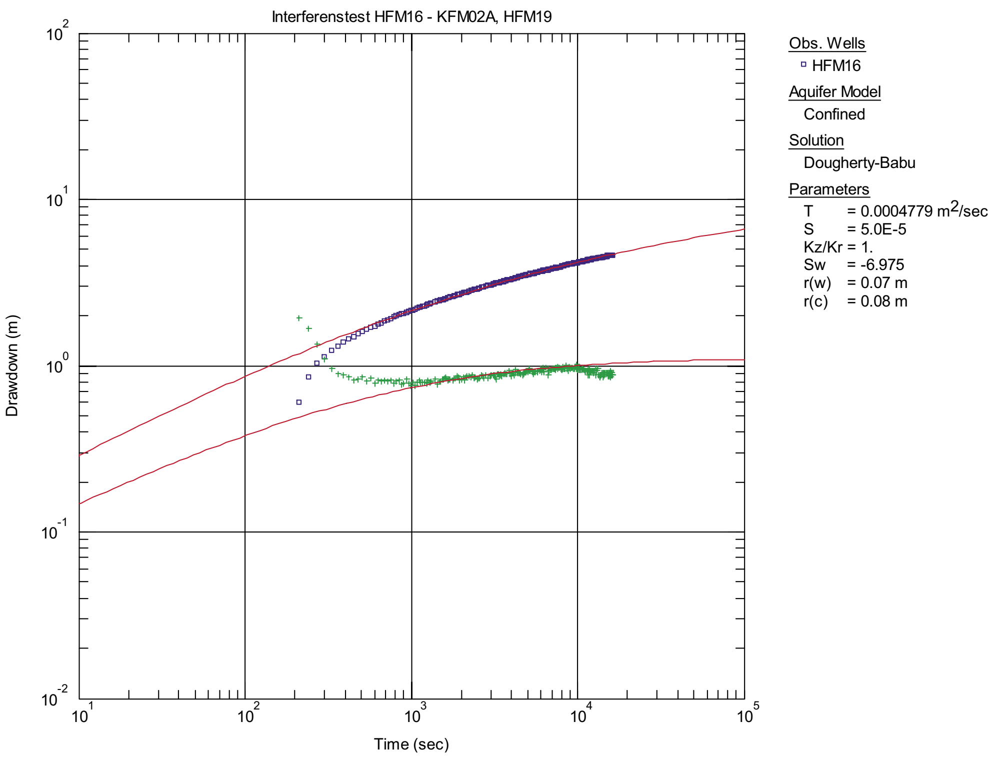



***Figure A2-9.** Log-log plot of drawdown (▫) and drawdown derivative, ds/d(ln t) (+), versus time in HFM16, during interference test 3.*

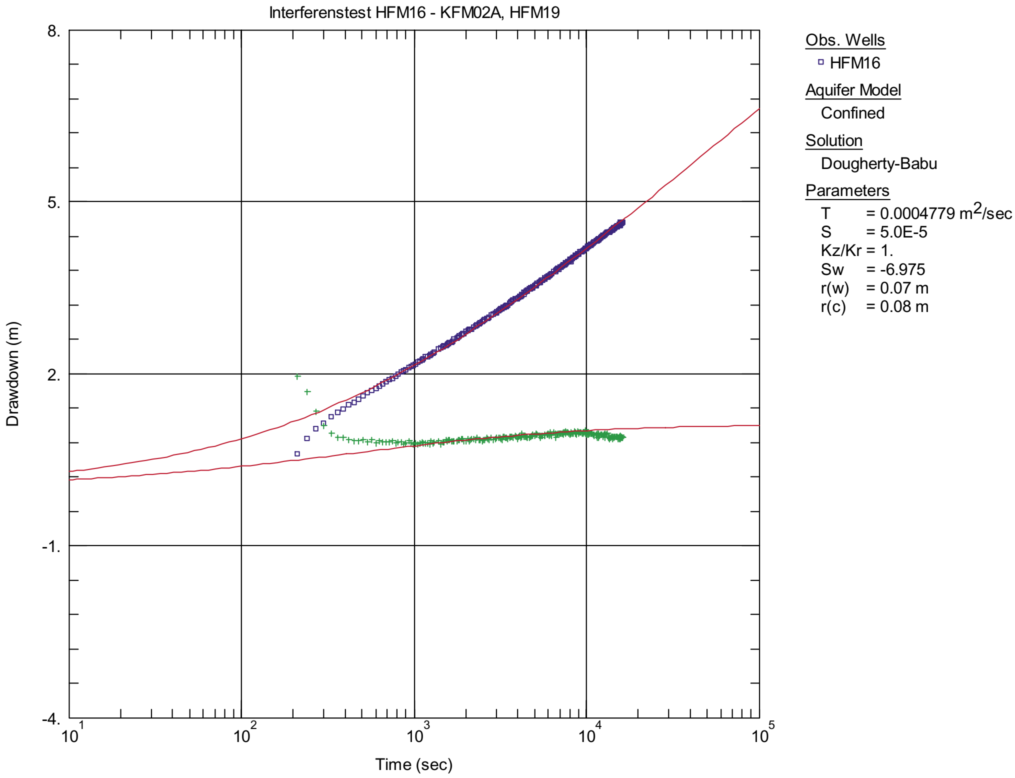



***Figure A2-10.*** *Lin-log plot of drawdown (▫) and drawdown derivative, ds/d(ln t) (+), versus time in HFM16 during interference test 3.*

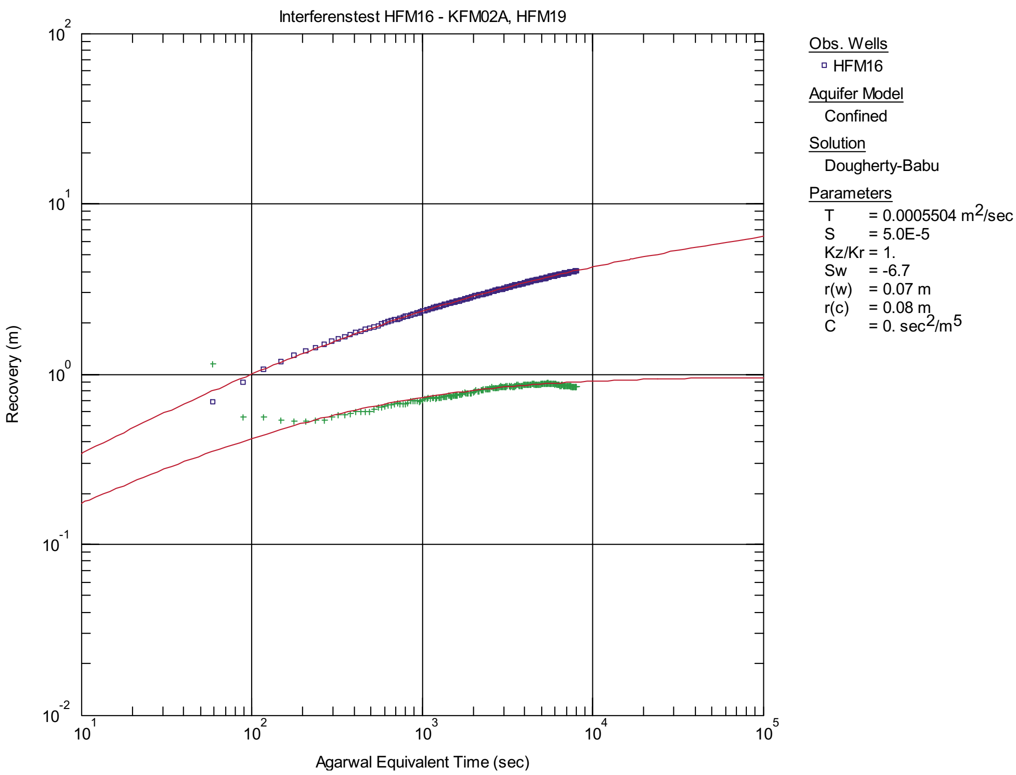



***Figure A2-11.*** *Log-log plot of pressure recovery (▫) and derivative, dsp/d(ln dte) (+), versus equivalent time in HFM16 during interference test 3.*

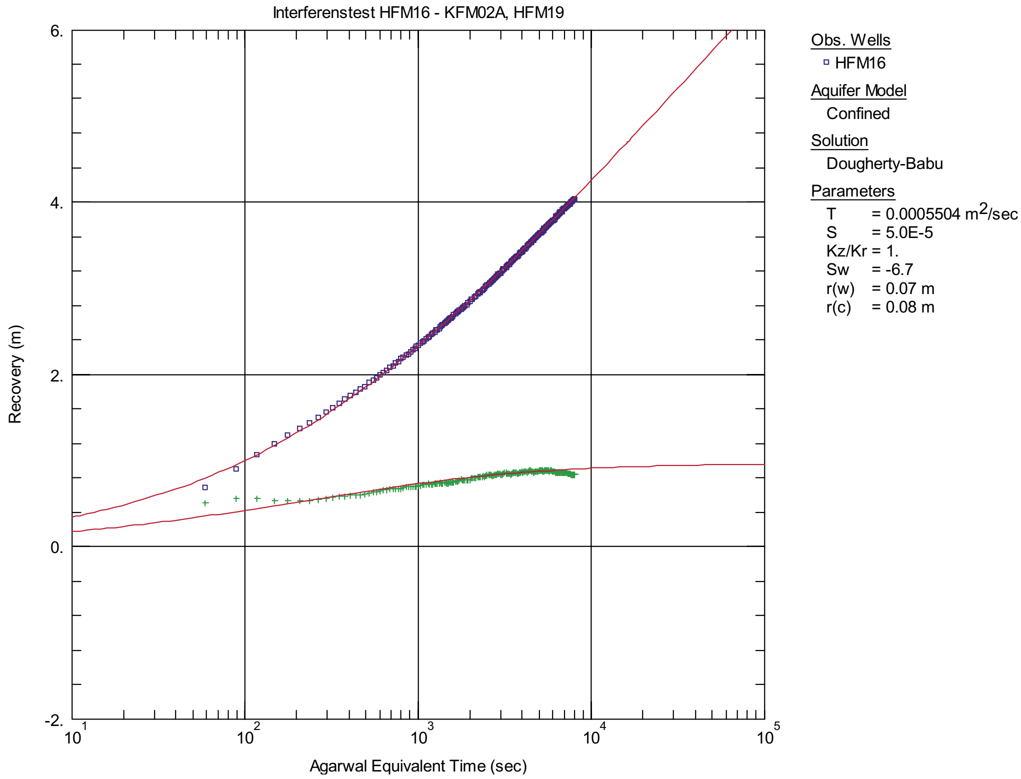



***Figure A2-12.*** *Lin-log plot of pressure recovery (▫) and derivative, dsp/d(ln dte) (+), versus equivalent time in HFM16 during interference test 3.*

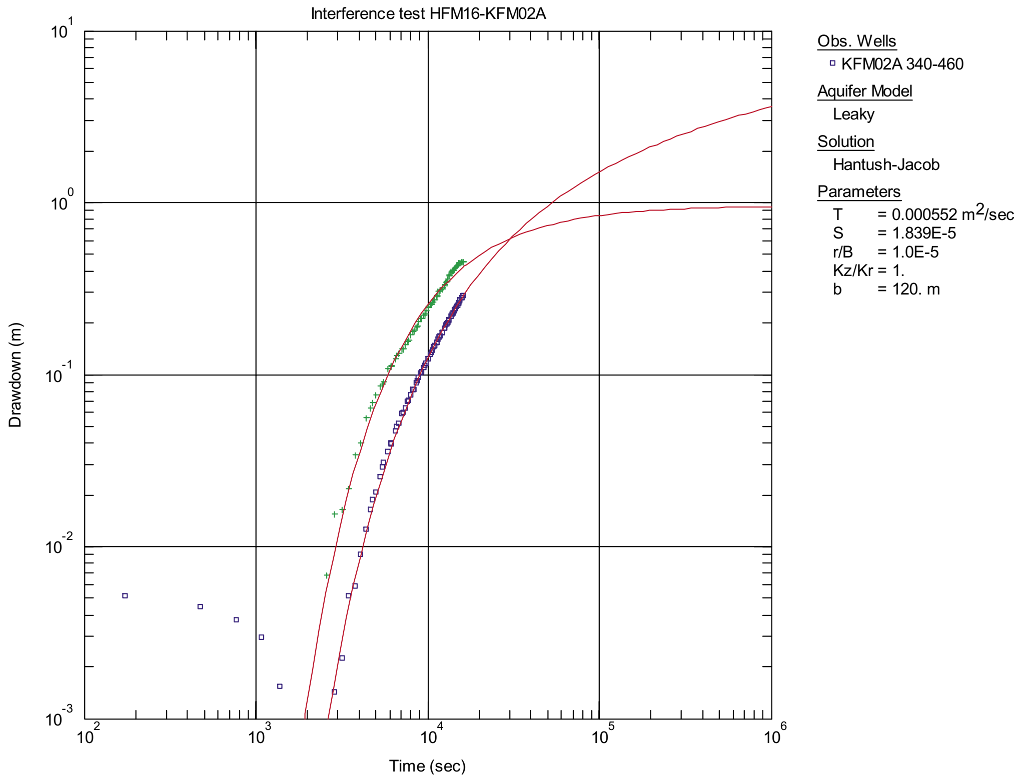



***Figure A2-13.*** *Log-log plot of drawdown (▫) and drawdown derivative, ds/d(ln t) (+), versus time in observation section KFM02A: 340–460 m during interference test 3.*

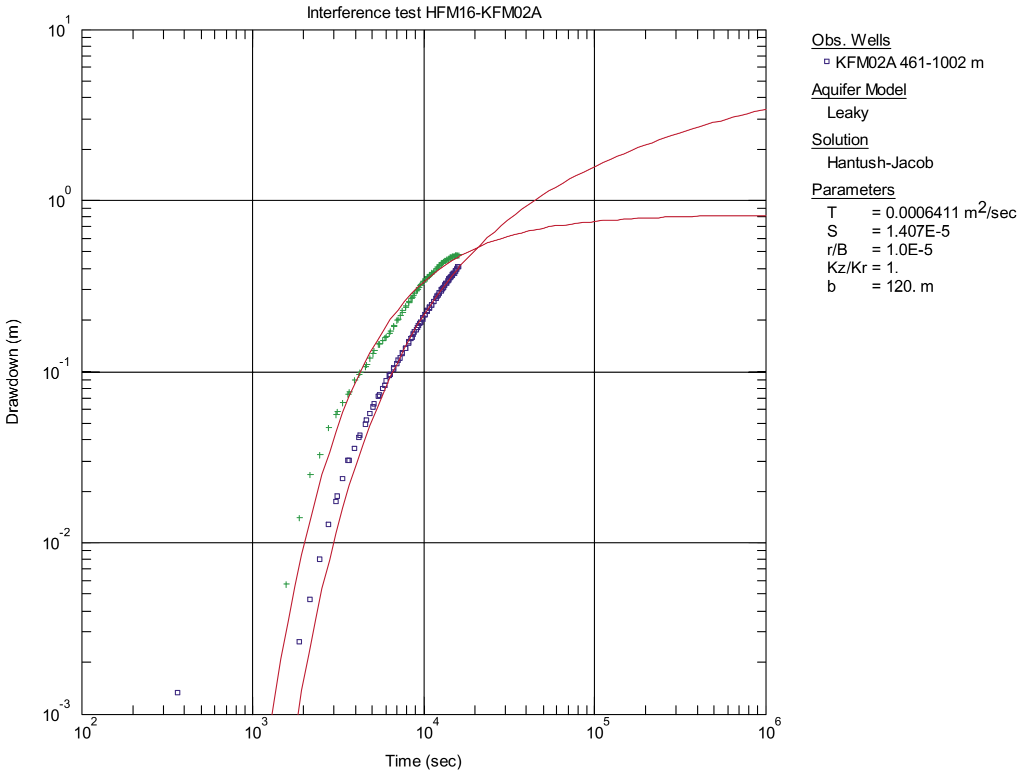



***Figure A2-14.*** *Log-log plot of drawdown (▫) and drawdown derivative, ds/d(ln t) (+), versus time in observation section KFM02A: 461–1,002 m during interference test 3.*

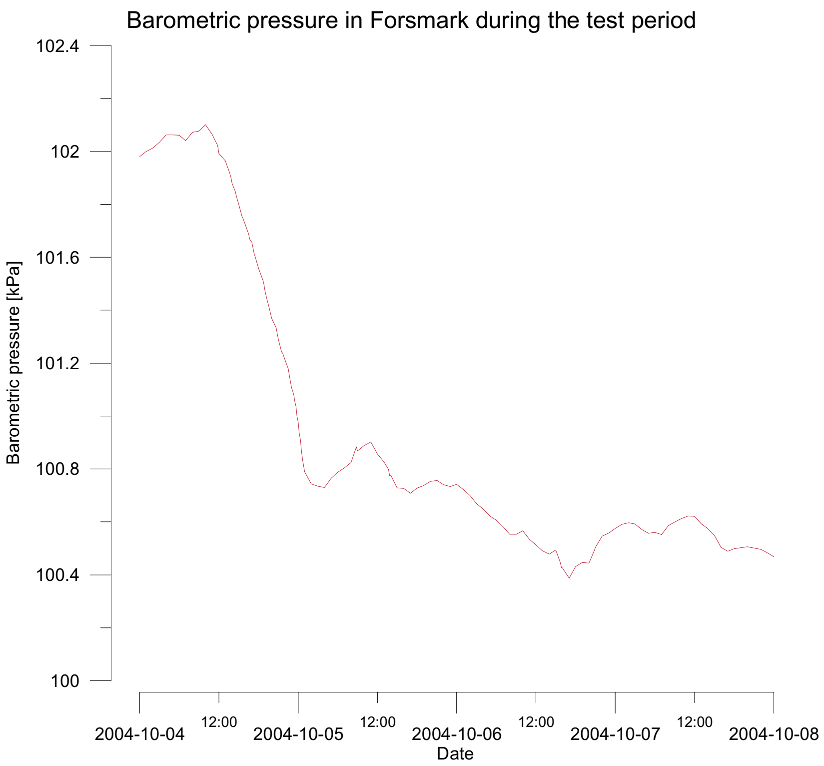



***Figure A2-15.*** *Barometric pressure in the Forsmark area during the test period.*

# Appendix 3

## Result table to SICADA

### *Result table to SICADA for the single-hole test in HFM16*

**plu_s_hole_test_d**

| idcode | start_date | stop_date | secup | seclow | section_no | test_type | formation_ type | start_flow_ period | stop_flow_ period | reference | comments | lp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HFM16 | 2004-10-06 11:23 | 2004-10-07 08:26 | 12.02 | 132.50 | | 1B | 1 | 2004-10-06 13:03 | 2004-10-06 17:31 | | Pressure values are relative air pressure. | |

**cont.**

| flow_rate_ end_qp | value_ type_qp | mean_flow_ rate_qm | q_measl_ _l | q_measl_ _u | tot_volume_vp | dur_flow_ phase_tp | dur_rec_ phase_tf | initial_ head_hi |
|---|---|---|---|---|---|---|---|---|
| 6.6700E–03 | | 6.6700E–03 | | | 1.0700E+02 | 16,080.00 | 53,700.00 | |

**cont.**

| head_at_flow_ end_hp | final_head_hf | initial_press_pi | press_at_flow_ end_pp | final_press_pf | fluid_temp_tew | fluid_elcond_ ecw | fluid_salinity_ tdsw |
|---|---|---|---|---|---|---|---|
| | | 84.70 | 39.20 | 82.90 | | | |

**cont.**

| fluid_salinity_tdswm | reference | comments | lp |
|---|---|---|---|
| | | Pressure values are relative air pressure. | |

## SICADA – description of plu_s_hole_test_d

| SICADA Header | Header | Unit | Explanation |
|---|---|---|---|
| Idcode | Borehole | | ID for borehole |
| Secup | Borehole secup | (m) | Length coordinate along the borehole for the upper limit of the test section |
| Seclow | Borehole seclow | (m) | Length coordinate along the borehole for the lower limit of the test section |
| Test_type | Test type (1–7) | (–) | 1A: Pumping test – wireline eq, 1B: Pumping test-submersible pump, 1C: Pumpingtest-airlift pumping, 2: Interference test, 3□ DIFF-overlapping, 6: Flow logging_Impeller,7: Grain size analysis |
| start_date | Date for test start | YYYY- MM-DD hh::mm | Date for the start of the pumping or injection test (YYYY-MM-DD hh:mm) |
| start_flow_period | Start flow / injection | YYYY- MM-DD hh::mm:ss | Date and time for the start of the pumping or injection period (YYYY-MM-DD hh:mm:ss) |
| stop_flow_period | Start flow / injection | YYYY- MM-DD hh::mm:ss | Date and time for the end of the pumping or injection period (YYYY-M-M DD hh:mm:ss) |
| mean_flow_rate_qm | $Q_m$ | ($m^3$/s) | Arithmetic mean flow rate during flow (pumping/injection) period. |
| flow_rate_end_qp | $Q_p$ | ($m^3$/s) | Flow rate at the end of the flow (pumping/injection ) period. |
| value_type_qp | | | Code for $Q_p$-value; –1 means $Q_p$ < lower measurement limit, 0 means measured value, 1 means $Q_p$ > upper measurement value of flowrate |
| q_measl_l | Qmeasl_L | ($m^3$/s) | Estimated lower measurement limit for flow rate |
| q_measl_u | Qmeasl_U | ($m^3$/s) | Estimated upper measurement limit for flow rate |
| total_volume_vp | $V_p$ | ($m^3$) | Total volume pumped or injected water during the flow period. |
| dur_flow_phase_tp | $t_p$ | (s) | Duration of the flow period. |
| dur_rec_phase_tf | $t_F$ | (s) | Duration of the recovery period. |
| initial_head_hi | $h_i$ | (m) | Hydraulic head in test section at start of the flow period. |
| head_at_flow_end_hp | $h_p$ | (m) | Hydraulic head in test section at stop of the flow period. |
| final_head_hf | $h_F$ | (m) | Hydraulic head in test section at stop of the recovery period.. |
| initial_press_pi | $p_i$ | (kPa ) | Ground water pressure in test section at start of the flow period. |
| press_at_flow_end_pp | $p_p$ | (kPa ) | Ground water pressure in test section at stop of the flow period. |

| SICADA Header | Header | Unit | Explanation |
|---|---|---|---|
| final_press_pf | $p_F$ | (kPa ) | Ground water pressure in test section at stop of the recovery period. |
| fluid_temp_tew | $Te_w$ | (C°) | Me□<br>value) |
| fluid_elcond_ecw | $EC_w$ | (mS/m) | Me□<br>last EC value) |
| fluid_salinity_tdsw | $TDS_w$ | (mg/L) | Calculated total dissolved solids of the borehole fluid in the test section, based on EC-measurement |
| fluid_salinity_tdswn | $TDS_{wn}$ | (mg/L) | Measured total dissolved solids of the borehole fluid in the test section, based on water sampling and chemical analysis |
| reference | references | | SKB report No for reports describing data and evaluation |
| comments | comments | | Short comment to data |

## plu_s_hole_test_ed1

| idcode | start_date | stop_date | secup | seclow | section_no | test_type | formation_type | lp | seclen_class | spec_capacity_q_s | value_type_q_s |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HFM16 | 2004-10-06 11:23 | 2004-10-07 08:26 | 12.02 | 132.50 | | 1B | 1 | 56.00 | | 1.44E–03 | 0 |

## cont.

| transmissivity_tq | value_type_tq | bc_tq | transmissivity_moye | bc_tm | value_type_tm | hydr_cond_moye | formation_width_b | width_of_channel_b | tb |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1.77E–03 | 0 | 0 | 1.47E–05 | 120.00 | | |

## cont.

| l_measl_tb | u_measl_tb | sb | assumed_sb | leakage_factor_lf | transmissivity_tt | value_type_tt | bc_tt | l_measl_q_s | u_measl_q_s | storativity_s | assumed_s |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 4.78E–04 | 0 | 1 | 3.30E–06 | 1.30E–02 | | 5.00E–05 |

**cont.**

| leakage_coeff | hydr_cond_ksf | value_type_ksf | l_measl_ksf | u_measl_ksf | spec_storage_ssf | assumed_ssf | c | cd | skin | dt1 | dt2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | –6.97E+00 | | |

**cont.**

| t1 | t2 | dte1 | dte2 | p_horner | transmissivity_t_nlr | storativity_s_nlr | value_type_t_nlr | bc_t_nlr | c_nlr | cd_nlr | skin_nlr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,020.00 | 10,200.00 | | | | | | | | | | |

**cont.**

| transmissivity_t_grf | value_type_t_grf | bc_t_grf | storativity_s_grf | flow_dim_grf | comment |
|---|---|---|---|---|---|
| | | | | | |

## SICADA – description of plu_s_hole_test_ed1

| SICADA Header | Header | Unit | Explanation |
|---|---|---|---|
| idcode | Borehole | | ID for borehole. |
| secup | Borehole secup | m | Length coordinate along the borehole for the upper limit of the test section. |
| seclow | Borehole seclow | (m) | Length coordinate along the borehole for the lower limit of the test section. |
| test_type | Test type (1–7) | (–) | 1A: Pumpingtest-wireline eq, 1B: Pumpingtest-submersible pump, 1C: Pumpingtest-airlift pumping, 2: Interference test, 3: Injection test, 4: Slug test, 4B: Pulse Test, 5A: Flowlogging-PFL-DIFF_sequential, 5B: Flowlogging-PFL-DIFF_overlapping, 6: Flowlogging-Impeller, 7: Grain size analysis. |
| formation_type | Formation type | (–) | 1: Rock, 2: Soil (Superficial deposits). |
| seclen_class | | (m) | □ differ due to border conditions (e.g borehole end) but is still considdered to be included in the same section length class. |
| start_date | | YYYY-MM-DD hh:mm | Date for the start of the test (YYYY-MM-DD hh:mm). |
| lp | $L_p$ | (m) | Hydraulic point of application for a test section, based on the geometric midpoint of test section or the main point of transmissivity distribution in test section. |
| spec_capacity_q_s | Q/s | $m^2/s$ | Specific capacity, generally estimated from $Q_p$, $s_p$ or $dh_p$. |
| value_type_q_s | | | Code for Q/s; –1 means Q/s < lower measurement limit, 0 means measured value,–1 means Q/s > upper measurement limit. |
| transmissivity_tq | $T_Q$ | $m^2/s$ | Transmissivity, based on Q/s and a function T = f(Q/s), see e.g. Rhén et al (1997) s. 190. The function used should be refered to in "Comments". |
| transmissivity_moye | $T_M$ | $m^2/s$ | Transmissivity ($T_M$ ) based on Moye (1967). |
| value_type_tm | | | Code for $T_M$; –1 means $T_M$ < lower measurement limit, 0 means measured value,–1 means $T_M$ > upper measurement limit. |
| formation_width_b | b | m | Representative aquifer thickness for inferred transmissivity, generally estimated as test section length $L_w$. |
| width_of_channel_b | B | m | Inferred width of formation for evaluated TB. |
| tb | TB | $m^3/s$ | Flow capacity in 1D formation of width B and transmissivity T based on transient evaluation. Considered best estimate from transient evaluation of flow period or recovery period. |
| l_measl_tb | TB-measl-L | $m^3/s$ | Estimated lower measurement limit for evaluated TB. |
| u_measl_tb | TB-measl-L | $m^3/s$ | Estimated upper measurement limit for evaluated TB. |
| sb | SB | m | Storage capacity of 1D formation of width B and storativity S based on transient evaluation. Considered best estimate from transient evaluation of flow period or recovery period. |
| assumed_sb | SB* | m | Assumed storage capacity of 1D formation of width B and storativity S based on transient evaluation. |

| SICADA Header | Header | Unit | Explanation |
|---|---|---|---|
| leakage_factor_lf | $L_f$ | m | Leakage factor. $L_f = (K×b×c_f)^{0.5}$ where K represents the aquifer conditions. $c_f$ = b´/K´ based on 1D linear flow model. Considered best estimate from transient evaluation of flow period or recovery period. |
| transmissivity_tt | $T_T$ | $m^2/s$ | Transmissivity (T) of formation, based on 2D radial flow model. Considered best estimate from transient evaluation of flow period or recovery period. |
| value_type_tt | | | Code for $T_T$; –1 means $T_T$ < lower measurement limit, 0 means measured value, –1 means $T_T$ > upper measurement limit. |
| l_measl_q_s | Q/s-measl-L | $m^2/s$ | Estimated measurement limit for evaluated T ($T_T$, $T_Q$, $T_M$). If estimated T equals Q/s-measl in the table actual T is considered to be equal or less than Q/s-measl. |
| u_measl_q_s | Q/s-measl-U | $m^2/s$ | Estimated measurement limit for evaluated T ($T_T$, $T_Q$, $T_M$). If estimated T equals Q/s-measl in the table actual T is considered to be equal or grater than Q/s-measl. |
| storativity_s | S | (–) | Storativity (Storage coefficient) of formation based on 2D radial flow model. Considered best estimate from transient evaluation of flow period or recovery period. |
| assumed_s | S* | | Assumed storativity of formation based on 2D radial flow model. |
| leakage_koeff | K´/b´ | (1/s) | Leakage coefficient evaluated from 2D radial flow model. K´ = hydraulic conductivity across the aquitard, b´ = water saturated thickness of aquitard (leaky formation). Considered best estimate from transient evaluation of flow period or recovery period. |
| hydr_kond_ksf | $K_{sf}$ | m/s | Hydraulic conductivity of formation, based on 3D spherical flow model. Considered best estimate from transient evaluation of flow period or recovery period. |
| value_type_ksf | | | Code for $K_{Sf}$; –1 means $K_{Sf}$ < lower measurement limit, 0 means measured value, –1 means $K_{Sf}$ > upper measurement limit. |
| l_measl_ksf | $K_S$-measl-L | m/s | Estimated lower measurement limit for evaluated $K_{sf}$. |
| u_measl_ksf | $K_S$-measl-U | m/s | Estimated upper measurement limit for evaluated $K_{sf}$. |
| spec_storage_ss | $S_{sf}$ | 1/m | Specific storage of formation based on 3D spherical flow model. Considered best estimate from transient evaluation of flow period or recovery period. |
| assumed_ss | $S_{sf}$* | 1/m | Assumed specific storage of formation based on 3D spherical flow model. |
| c | C | ($m^3$/Pa) | Wellbore storage coefficient. Considered best estimate from transient evaluation of flow period or recovery period. |
| cd | $C_D$ | (–) | Dimensionless wellbore storage coefficient, $C_D = C×\rho_w×g/(2\pi×S×r_w^2)$. |
| skin | ξ | | Skin factor. Considered best estimate from transient evaluation of flow period or recovery period. |
| dt1 | $dt_1$ | s | Estimated start time after pump/injection start OR recovery start, for the period used for the evaluated parameter. |
| dt1 | $dt_2$ | s | Estimated stop time after pump/injection start OR recovery start, for the period used for the evaluated parameter. |

| SICADA Header | Header | Unit | Explanation |
|---|---|---|---|
| dte1 | $dt_{e1}$ | | Start time for evaluated parameter from start of recovery period. |
| dte2 | $dt_{e2}$ | | Stop time for evaluated parameter from start of recovery period. |
| t1 | $t_1$ | | Start time for evaluated parameter from start of flow period. |
| t2 | $t_2$ | | Stop time for evaluated parameter from start of flow period. |
| p_horner | p* | | Horner extrapolated pressure (used as an estimation of natural pressure of the test section). |
| transmissivity_t_nlr | $T_{ILR}$ | $m^2/s$ | Transmissivity, based on Non Linear Regression of the entire test sequence. |
| storativity_s_nlr | $S_{ILR}$ | (–) | Storativity, based on Non Linear Regression of the entire test sequence. |
| c_nlr | $C_{ILR}$ | ($m^3/Pa$) | Wellbore storage coefficient, based on Non Linear Regression of entire test sequence. |
| cd_nlr | $C_{D,ILR}$ | | Dimensionless wellbore storage coefficient, based on Non Linear Regression of entire test sequence. |
| skin_nlr | $\xi_{NLR}$ | | Skin factor, based on Non Linear Regression of entire test sequence. |
| transmissivity_t_grf | $T_{GRF}$ | $m^2/s$ | Transmissivity, based on the Generalized Radial Flow model (Baker, 1988). Considered best estimate from transient evaluation of flow period or recovery period. |
| storativity_s_grf | $S_{GRF}$ | (–) | Storativity, based on Generalised Radial Flow model. Considered best estimate from transient evaluation of flow period or recovery period. |
| flow_dim_grf | $D_{GRF}$ | (–) | Inferred flow dimension, based on the Generalized Radial Flow model (Barker, 1988). Considered best estimate from transient evaluation of flow period or recovery period. |
| comment | comment | | Comments on the test. |

## Result table to SICADA from the interference test in HFM16

### plu_inf_test_obs_d

| idcode | start_date | stop_date | secup | seclow | section_no | test_type | formation_type | start_flow_period | stop_flow_period |
|---|---|---|---|---|---|---|---|---|---|
| KFM02A | 2004-10-06 11:23 | 2004-10-07 08:26 | 340.00 | 460.00 | | 2 | 1 | 2004-10-06 13:03 | 2004-10-06 17:31 |
| KFM02A | 2004-10-06 11:23 | 2004-10-07 08:26 | 461.00 | 1,002.44 | | 2 | 1 | 2004-10-06 13:03 | 2004-10-06 17:31 |

### cont.

| test_ borehole | test_secup | test_seclow | lp | radial_ distance_rs | shortest_ distance_rt | time_lag_ press_dtl | initial_head_hi |
|---|---|---|---|---|---|---|---|
| HFM16 | 12.02 | 132.50 | 428.00 | 1,267.00 | | 4,000.00 | |
| HFM16 | 12.02 | 132.50 | 513.00 | 1,287.00 | | 2,500.00 | |

### cont.

| head_at_flow_ end_hp | final_head_hf | initial_press_pi | press_at_flow_ end_pp | final_press_pf | fluid_temp_teo | fluid_elcond_ eco |
|---|---|---|---|---|---|---|
| | | 3,254.90 | 3,252.20 | 3,253.00 | | |
| | | 4,436.40 | 4,432.40 | 4,434.50 | | |

### cont.

| fluid_salinity_ tdso | fluid_salinity_ tdsom | reference | comment |
|---|---|---|---|
| | | | Relative pressure. Time lag for 0.01 m |
| | | | Relative pressure. Time lag for 0.01 m |

## SICADA – description of plu_inf_test_obs_d

| SICADA Header | Header | Unit | Explanation |
|---|---|---|---|
| idcode | ID Obs Borehole | | ID for observation borehole. |
| secup | Borehole secup | (m) | Length coordinate along the borehole for the upper limit of observation section. |
| seclow | Borehole seclow | (m) | Length coordinate along the borehole for the lower limit of observation section. |
| start_date | Date for test start | YYYY-M M-DD hh:mm | Date for the start of the pumping/injection test (YYYY-MM-DD hh:mm). |
| stop_date | Date for test stop | YYYY-M M-DD hh:mm | Date for the stop of the pumping/injection test (YYYY-MM-DD hh:mm). |
| test_type | Test type (1–7) | (–) | 1A: Pumping test-wireline eq,1B: Pumping test-submersible pump, 1C: Pumping test-airlift pumping. 2: Interference test. 3: Injection test. 4: Slug test, 4B: Pulse test. 5A: Flowlogging-PFL-DIFF_sequential. 5B Flowlogging-PFL-DIFF_overlapping. 6: Flowlogging Impeller. 7: Grain size analysis. |
| test_borehole | ID. pumped Borehole | (–) | ID for pumped or injected borehole. |
| test_secup | Test secup | (m) | Length coordinate along the borehole for the upper limit of pumped or injected section. |
| test_seclow | Test seclow | (m) | Length coordinate along the borehole for the lower limit of pumped or injected section. |
| start_flow_period | Start flow | YYYY-MM-DD hh:mm:ss | Time for the start of the pumping/injection period (YYYY-MM-DD hh:mm:ss). |
| stop_flow_period | Stop flow | YYYY-MM-DD hh:mm:ss | Time for the stop of the pumping/injection period (YYYY-MM-DD hh:mm:ss). |
| lp | $L_p$ | (m) | Hydraulic point of application for a test section, based on the geometric midpoint of test section or the main point of transmissivity distribution in test section. |
| radial_distance_rs | $r_s$ | (m) | Geometrical distance from point of application in test section to point of application in observation section. |
| shortest_distance_rt | $r_t$ | (m) | Representative hydraulic distance from point of application in test section to point of application in observation section via inferred major conductive features. The actual structural model version shall be reported. |
| time_lag_press_dtl | $dt_L$ | (s) | Time lag for pressure response to reach observation section after start/stop of pumping or injection, based on the first significant response in the observation section. |
| initial_head_hi | $h_i$ | (m) | Hydraulic head in observation section at start of flow period. |
| head_at_flow_end_hp | $h_p$ | (m) | Hydraulic head in observation section at stop of flow period. |
| final_head_hf | $h_F$ | (m) | Hydraulic head in observation section at stop of recovery period. |

| SICADA Header | Header | Unit | Explanation |
|---|---|---|---|
| initial_press_pi | $p_i$ | (kPa) | Groundwater pressure in observation section at start of flow period. |
| press_at_flow_end_pp | $p_p$ | (kPa ) | Groundwater pressure in observation section at stop of flow period. |
| final_press_pf | $p_F$ | (kPa) | Groundwater pressure in observation section at stop of recovery period. |
| fluid_temp_teo | $Te_o$ | (C°) | Measured borehole fluid temperature in the observation section (representative for evaluated parameters). |
| fluid_elcond_eco | $EC_o$ | (mS/m) | Measured electric conductivity of the borehole fluid in the observation section (representative for evaluated parameters). |
| fluid_salinity_tdso | $TDS_o$ | (mg/L) | Calculated total dissolved solids of the borehole fluid in the observation section, based on EC-measurement. |
| fluid_salinity_tdso | $TDS_{om}$ | (mg/L) | Measured total dissolved solids of the borehole fluid in the observation section, based on water sampling and chemical analysis. |
| reference | References | | SKB report No for reports describing data and evaluation. |
| comment | Comments | | Short comment to the evaluated parameters (Optional). |

## plu_inf_test_obs_ed

| idcode | start_date | stop_date | secup | seclow | section_ no | test_ borehole | test_ secup | test_ seclow | formation_ width_b |
|---|---|---|---|---|---|---|---|---|---|
| KFM02A | 2004-10-06 11:23 | 2004-10-07 08:26 | 340.00 | 460.00 | | HFM16 | 12.02 | 132.50 | 120.00 |
| KFM02A | 2004-10-06 11:23 | 2004-10-07 08:26 | 461.00 | 1,002.44 | | HFM16 | 12.02 | 132.50 | 120.00 |

## cont.

| lp | width_of_ channel_b | tbo | l_measl_tbo | u_measl_tbo | sbo | leakage_ factor_lof | transmissivity_ to | value_type_ to | l_measl_to | u_measl_to |
|---|---|---|---|---|---|---|---|---|---|---|
| 428.00 | | | | | | | 5.52E-04 | 0 | | |
| 513.00 | | | | | | | 6.41E-04 | 0 | | |

**cont.**

| storativity_so | leakage_coeff_o | hydr_cond_kosf | l_measl_kosf | u_measl_kosf | spec_storage_sosf | dt1 | dt2 | t1 | t2 | dte1 | dte2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.84E-05 | | | | | | | | 3,000.00 | 10,000.00 | | |
| 1.41E-05 | | | | | | | | 4,000.00 | 10,000.00 | | |

## SICADA – description of plu_inf_test_obs_ed

| SICADA Header | Header | Unit | Explanation |
|---|---|---|---|
| idcode | ID Obs. Borehole | | ID for obsevation borehole |
| secup | Borehole secup | m | Length coordinate along the borehole for the upper limit of the observation section |
| seclow | Borehole seclow | (m) | Length coordinate along the borehole for the lower limit of the observation section |
| start_date | Date for test start | YYYY-MM-DD hh:mm | Date for the start of the interference test (YYYY-MM-DD hh:mm) |
| stop_date | Date for test stop | YYYY-MM-DD hh:mm | Date for the stop of the interference test (YYYY-MM-DD hh:mm) |
| test_borehole | ID- Pumped borehole | (–) | ID for pumped or injected borehole |
| test_secup | | (m) | Length coordinate along the borehole for the upper limit of pumped or injected section |
| test_seclow | | (m) | Length coordinate along the borehole for the lower limit of pumped or injected section |
| formation_width_b | b | m | b: Representative aquifer thickness for inferred transmissivity, generally estimated as observation section length $L_o$ |
| width_of_channel_b | B | m | B: Inferred width of formation for evaluated TB |
| lp | $L_p$ | | Hydraulic point of application for a test section, based on the geometric midpoint of test section or the main point of transmissivity distribution in test section |
| tbo | $TB_o$ | $m^3/s$ | Flow capacity in 1D formation of width B and transmissivity T based on transient evaluation in observation section. Considered best estimate from transient evaluation of flow period or recovery period. |
| l_meas_limit_tbo | TB-measl-L | $m^3/s$ | Estimated lower measurement limit for evaluated TB in observation section. |
| u_meas_limit_tbo | TB-measl-U | $m^3/s$ | Estimated upper measurement limit for evaluated TB in observation section. |
| sbo | $SB_o$ | m | $SB_o$: Storage capacity of 1D formation of width B and storativity S based on transient evaluation in observation section. Considered best estimate from transient evaluation of flow period or recovery period. |

| SICADA Header | Header | Unit | Explanation |
|---|---|---|---|
| leakage_factor_lof | $L_{of}$ | m | Leakage coefficient in observation section evaluated from 2D radial flow model. K´ = hydraulic conductivity across the aquitard, b´ = water saturated thickness of aquitard (leaky formation). Considered best estimate from transient evaluation of flow period or recovery period. |
| transmissivity_to | $T_o$ | $m^2/s$ | Transmissivity of formation in observation section, based on 2D radial flow model. Considered best estimate from transient evaluation of flow period or recovery period. |
| l_measl_to | $T_{o\text{-measl-L}}$ | $m^2/s$ | Estimated lower measurement limit for evaluated $T_o$ in observation section |
| u_measl_to | $T_{o\text{-measl-U}}$ | $m^2/s$ | Estimated upper measurement limit for evaluated $T_o$ in observation section |
| storativity_so | $S_o$ | (–) | Storativity (Storage coefficient) of formation in observation section based on 2D radial flow model. Considered best estimate from transient evaluation of flow period or recovery period. |
| leakage_coeff_o | $(K'/b')_o$ | (l/s) | Leakage coefficient in observation section evaluated from 2D radial flow model. K´ = hydraulic conductivity across the aquitard, b´ = water saturated thickness of aquitard (leaky formation). Considered best estimate from transient evaluation of flow period or recovery period. |
| hydr_kond_kosf | $K_{osf}$ | m/s | Hydraulic conductivity of formation in observation section, based on 3D spherical flow model. Considered best estimate from transient evaluation of flow period or recovery period. |
| l_measl_kosf | $K_{osf\text{-measl-L}}$ | m/s | Estimated lower measurement limit for evaluated $K_{osf}$ in observation section. |
| u_measl_kosf | $K_{osf\text{-measl-U}}$ | m/s | Estimated upper measurement limit for evaluated $K_{osf}$ in observation section. |
| spec_storage_sosf | $S_{osf}$ | 1/m | Specific Storage of formation in observation section, based on 3D spherical flow. Considered best estimate from transient evaluation of flow period or recovery period. |
| dt1 | $dt_1$ | s | Estimated start time after pump/injection start OR recovery start, for the period used for the evaluated parameter |
| dt2 | $dt_2$ | s | Estimated stop time after pump/injection start OR recovery start, for the period used for the evaluated parameter |
| t1 | $t_1$ | s | Start time for evaluated parameter from start of flow period. |
| t2 | $t_2$ | s | Stop time for evaluated parameter from start of flow period. |
| dte1 | $dt_{e1}$ | s | Start time for evaluated parameter from start of recovery period. |
| dte2 | $dt_{e2}$ | s | Stop time for evaluated parameter from start of recovery period. |
| transmissivity_to_nlr | $T_{oNLR}$ | $m^2/s$ | Transmissivity in observation section, based on Non Linear Regression of the entire test sequence. |
| storativity_so_nlr | $S_{oNLR}$ | (–) | Storativity in observation section, based on Non Linear Regression of the entire test sequence. |
| transmissivity_to_grf | $T_{oGRF}$ | $m^2/s$ | Transmissivity in observation section, based on the Generalised Radial Flow model (Baker, 1988). Considered best estimate from transient evaluation of flow period or recovery period. |
| storativity_so_grf | $S_{oGRF}$ | (–) | Storativity in observation section, based on Generalised Radial Flow model. Considered best estimate from transient evaluation of flow period or recovery period. |
| flow_dim_grf_o | $D_{oGRF}$ | (–) | Inferred flow dimension in observation section, based on the Generalised Radial Flow model (Barker, 1988). Considered best estimate from transient evaluation of flow period or recovery period. |
| Comments | Comments | | Short comment to the evaluated parameters (Optional) |