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Forsmark site investigation

Hydrochemical monitoring of percussion– and core drilled boreholes

Results from water sampling and analyses during 2007

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Abstract

The site investigations in Forsmark were completed in June 2007. However, regular hydrochemical sampling and analyses will continue within the ongoing hydrochemical monitoring programme until the site for the planned repository for nuclear waste is selected. The present report documents the third year (2007) of groundwater monitoring in core boreholes and percussion boreholes in Forsmark.

The monitoring programme includes sampling twice a year in boreholes with installed equipment for long-term pressure monitoring, tracer tests and water sampling in packed off borehole sections. The third year comprised sampling of groundwater in 21 borehole sections corresponding to 18 boreholes at the first sampling occasion and seven more sections in four additional boreholes at the next occasion. The number of boreholes in the programme will increase with one more borehole, KFM12A, in 2008 when the borehole installations are completed. The hydrochemical monitoring 2007 yielded groundwater chemistry data in accordance with SKB chemistry class 3 (including the isotopes ^{3}H, δ^{18}O and δD) at the first sampling occasion and SKB chemistry class 5 at the second sampling occasion. An effort was also made to study the processes behind the increase in sulphide concentration that has been observed in many of the investigated borehole sections. A series of three samples was collected from boreholes KFM01D, 429 m borehole length, and KFM08A, 684 m borehole length after 1) the exchange of one tube volume, 2) the exchange of one section volume and 3) the exchange of three section volumes of water. A clear dependence between pumped volume and sulphide concentration was observed in both boreholes representing very high (KFM01D) and somewhat low sulphide concentrations (KFM08A).

The use of Uranine as a tracer in tests prior to and in between chemical sampling occasions caused problems when interpreting and evaluating the hydrochemical monitoring data since it is no longer possible to calculate the flushing water content in the groundwater from several of the borehole sections. Furthermore, short circuiting of groundwater through fracture systems connecting two or more borehole sections was observed in several cases. This was indicated by pressure drawdown in sections other than the pumped ones during pumping. Generally, the groundwater composition (major constituents) has stayed relatively stable since the initial CCC sampling (Complete Chemical Characterisation) in most borehole sections in the cored boreholes. The initial non-marine character of the groundwater in section KFM01D:2 changed though and a significant Littorina contribution was observed from the start of the monitoring programme. However, pressure responses indicate connections in the fracture system between several borehole sections and contamination by water from a more shallow section is probably the cause. The water composition (major constituents) in borehole sections in percussion boreholes, has varied somewhat more, for several reasons: 1) the initial HTHB sampling (HydroTester HammarBorrhål) during pumping tests was conducted at open-hole conditions from the entire borehole and these initial data are not necessarily comparable to data from monitored sections, 2) hydraulic interference tests and large scale tracer tests have affected the groundwater in some percussion boreholes 3) the percussion boreholes intersect large and highly transmissive fracture zones at shallow depths corresponding to the interface between meteoric and brackish water types and pumping may easily cause mixing of different waters.

Sammanfattning

Platsundersökningarna i Forsmark avslutades i juni 2007. Dock kommer regelbunden hydrokemisk provtagning och analys att fortsätta inom det hydrokemiska moniteringsprogrammet till dess platsen för djupförvaret för utbränt kärnbränsle är vald. Denna rapport dokumenterar tredje årets grundvattenmonitering (2007) i kärnborrhål och hammarborrhål i Forsmark.

Moniteringsprogrammet inkluderar provtagning två gånger om året i borrhål med installerad utrustning för långtidsövervakning av tryck, utspädningsmätningar och vattenprovtagning i avgränsade borrhålssektioner. Det tredje året omfattade provtagning i 21 borrhålssektioner motsvarande 18 borrhål vid första provtagningstillfället och ytterligare sju sektioner i fyra nya borrhål vid nästa tillfälle. Antalet borrhål kommer att öka med ett borrhål under 2008 (KFM12A) när borrhålsinstallationerna är slutförda.

Den hydrokemiska moniteringen under 2007 gav grundvattenkemiska data enligt SKB kemiklass 3 (inklusive isotoperna ^{3}H, δ^{18}O och δ^2H) vid det första provtillfället och SKB klass 5 vid det andra tillfället. Ett försök gjordes också att studera processerna som orsakar de ökande halterna av sulfid som observerats i många av borrhålssektionerna. En serie på tre prov togs ut från KFM01D, 429 m borrhålslängd, och KFM08A, 684 m borrhålslängd efter 1) omsättning av en slangvolym, 2) omsättning av en sektionsvolym och 3) omsättning av tre sektionsvolymer. Ett tydligt samband mellan pumpad volym och sulfidkoncentration kunde observeras i båda borrhålen som representerar dels generellt mycket höga (KFM01D), dels ganska låga sulfidkoncentrationer (KFM08A).

Användningen av Uranin som spårämne i olika försök före och mellan de kemiska provtagningstillfällena orsakade problem med tolkning och utvärdering av kemiska data från monitering eftersom det inte längre är möjligt att beräkna spolvatteninnehållet i proven från många av borrhålssektionerna. Vidare observerades i flera fall kontakt via spricksystem mellan två eller fler sektioner. Detta indikerades genom tryckavsänkning i någon/några av de övriga sektionerna vid pumpning i provsektionerna.

Generellt har grundvattensammansättningen (huvudkomponenterna) i de flesta kärnborhål hållit sig relativt stabil alltsedan den första CCC-provtagningen (Complete Chemical Characterisation). Den initialt icke-marina karaktären i sektionen KFM01D:2 har dock förändrats och ett signifikant bidrag av marint Littorinavatten kunde observeras redan vid första moniteringstillfället. Tryckresponser vid pumpning indikerar emellertid att det finns kontakt via sprickor mellan flera borrhålssektioner och orsaken till förändringen är förmodligen kontaminering på grund av inträngande vatten från en sektion ovanför provsektionen.

Vattensammansättningen (huvudkomponenterna) i borrhålssektionerna i hammarborrhålen har varierat mer från provtagningstillfälle till provtagningstillfälle av flera orsaker; 1) Den första HTHB-provtagningen (HydroTester HammarBorrhål) under pumptester utfördes i öppet borrhål från hela borrhålet, och dessa initiala data är inte nödvändigtvis jämförbara med senare data från moniterade borrhålssektioner, 2) hydrauliska interferenstester och storskaliga spårförsök har påverkat vattnet i vissa borrhål och 3) hammarborrhålen korsar i regel stora och mycket transmissiva sprickzoner på djup som motsvarar gränsskiktet mellan färskt ytvatten och bräckt äldre vatten, och pumpning kan lätt orsaka blandning av olika vatten.

Contents

1 Introduction

The investigation phase of the site investigations in Forsmark was finished in June 2007 /1/ but regular sampling and analyses of groundwater will continue within the hydrochemical monitoring programme /2/ at least until the site for the planned repository for nuclear waste is selected. This document reports the performance and results from the hydrochemical monitoring of groundwaters in core boreholes and percussion boreholes during 2007. The work was carried out in accordance with activity plan AP PF 400-07-005. The controlling documents for performing this activity are listed in Table 1-1. Both activity plan and method documents are SKB's internal controlling documents. The field work was performed in June and in October 2007 (with some additional samplings in January 2008).

Original data from the reported activity are stored in the primary database Sicada. Data are traceable in Sicada by the activity plan number (AP PF 400-07-005). Only data in databases are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the database may be revised, if needed. However, such revision of the database will not necessarily result in a revision of this report although the normal procedure is that major data revisions entail a reversion of the P-report. Minor revisions are normally presented as supplements, available at www.skb.se.

The hydrogeochemical monitoring activity performed during 2007 included water sampling and chemical analyses at two occasions (spring and autumn) in the boreholes and borehole sections listed in Table 1-2.

KFM01A, KFM02A and KFM03A are SKB chemistry-type, subvertical, and approximately 1,000 m long, telescopic boreholes, whereas KFM01D, KFM02B, KFM04A, KFM06A, KFM06C, KFM07A, KFM08A, KFM08D, KFM10A and KFM11A are inclined telescopic boreholes of chemistry-type. HFM01, HFM02, HFM04, HFM13, HFM15, HFM16, HFM19, HFM21, HFM27 and HFM32 are percussion boreholes with lengths varying between 99.5 and 221.7 metres. Technical descriptions and designs of the boreholes are presented in /3–21/ and the installations for long-term monitoring of pressures and chemical compositions are described in PIR-04-13/14/27, PIR-05-17/18/20/23/24, PIR-06-02/04/06/25/26/41/42 and PIR-07-09/11/14/38/48/50/51 (all PIR reports are SKB internal documents). The site investigation area in Forsmark as well as the locations of the monitored boreholes is shown in Figure 1-1.

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

Activity plan	Number	Version
Hydrokemiskt övervakningsprogram för hammarborrhål och kärnborrhål under 2007.	AP PF 400-07-005	1.0
Measurement system descriptions	**Number**	**Version**
Mätsystembeskrivning (MSB) – Handhavande del; System för hydrologisk och metrologisk datainsamling. Vattenprovtagning och utspädningsmätning i observationshål.	SKB MD 368.010	1.0

Table 1-2. Boreholes and borehole sections included in the hydro-geochemical monitoring programme for percussion- and core drilled boreholes and corresponding transmissivity values.

Borehole: section	Section [mbl]****	Transmissivity [m^2/s]
KFM01A:5	109.0–130.0	1.0 E–7*
KFM01D:2	429.0–438.0	8.0 E–7*
KFM01D:4	311.0–321.0	2.0 E–7*
KFM02A:3	490.0–518.0	2.1 E–6*
KFM02A:5	411.0–442.0	2.5 E–6*
KFM02B:2	491.0–506.0	3.0 E–5**
KFM02B:4	410.0–431.0	2.0 E–5**
KFM03A:1	969.5–994.5	5.5 E–7*
KFM03A:4	633.5–650.0	2.4 E–6*
KFM04A:4	230.0–245.0	2.0 E–6*
KFM05A:4	254.0–272.0	1.4E–8* (No sampling 2007, low water yield)
KFM06A:3	738.0–748.0	1.2E–7* (No sampling 2007, pump failure)
KFM06A:5	341.0–362.0	3.5 E–6*
KFM06C:3	647.0–666.0	5.3 E–8* (No sampling 2007, high flushing water content)
KFM06C:5	531.0–540.0	1.1 E–6* (No sampling 2007, high flushing water content)
KFM07A:2	962.0–972.0	5.0 E–7*
KFM08A:2	684.0–694.0	1.0 E–6*
KFM08A:6	265.0–280.0	1.0 E–6*
KFM08D:2	825.0–835.0	2.0 E–8** (No sampling 2007, pump failure)
KFM08D:4	660.0–680.0	2.0 E–7**
KFM10A:2	430.0–440.0	3.0 E–5*
KFM11A:2	690.0–710.0	1.0 E–6*
KFM11A:4	446.0–456.0	6.0 E–6*
KFM12A:3	270.0–280.0	1.0 E–6* (No sampling during 2007, no packer installation)
HFM01:2	33.5–45.5	4.0 E–4***
HFM02:2	38.0–48.0	5.9 E–4***
HFM04:2	58.0–66.0	7.9 E–5***
HFM13:1	159.0–173.0	2.9 E–4***
HFM15:1	85.0–95.0	1.0 E–4***
HFM16:2	54.0–67.0	3.5 E–4***
HFM19:1	168.0–182.0	2.7 E–4***
HFM21:3	22.0–32.0	4.0 E–5***
HFM27:2	46.0–58.0	4.0 E–5***
HFM32:3	26.0–31.0	2.3 E–4***

* From injection tests /22–33/.
** From differential flow logging /34, 35/.
*** From flow loggings /36–43/.
**** mbl = metre borehole length.

Figure 1-1. *General overview of the Forsmark site investigation area. Boreholes included in the monitoring program are marked with blue (percussion) and pink (telescopic) infilled circles. Borehole KFM02B is not marked on the map. Its location agrees with KFM02A. The sampling from borehole KFM12A will commence during 2008.*

2 Objective and scope

The long-term hydrogeochemical monitoring programme for percussion drilled and core drilled boreholes aims at creating long time series of data. The main objective is to check the stability of the water composition and observe possible changes. For example, if the initial conditions were disturbed from drilling, a return to natural conditions could occur with changed water composition as a result. The monitoring will also allow identification of possible perturbation effects from other ongoing investigations.

The monitoring programme comprises groundwater sampling twice a year in borehole sections delimited by “permanently” installed packers. In this context “permanently” means that the equipment stays in the borehole for several years unlike other, short-term investigations where the equipment is lifted when the investigation is completed. The number of monitored boreholes will increase with one additional borehole (KFM12A) the next year when the installation work is completed.

The analytical protocol includes sampling and analyses according to SKB chemistry class 3 and 5 as well as field measurements of pH, electric conductivity and temperature. Besides the ordinary programme 2007, additional sampling (SKB class 4) was performed in three sections (two sections in KFM08A and one section in KFM01D) at the second sampling occasion (in the autumn). The objective was to study possible effects from pumping or pumped volume on the sulphide concentration. The sulphide concentration has increased since the initial sampling campaign (CCC) in several boreholes/borehole sections.

3 Borehole history

In order to evaluate the results and understand eventual observed trends in the groundwater composition, it is important to have information about drilling and preceding investigations in each borehole and to understand their implications on the groundwater chemistry. Investigations which are likely to affect subsequent water sampling are injection tests, tracer tests, SWIW-tests, dilution tests and groundwater flow measurements. Besides preceding investigations in a specific borehole/borehole section, on-going activities in nearby situated boreholes, e.g. pumping tests, core drilling and interference tests may also affect the results from water sampling and analyses.

3.1 Cored boreholes

The flushing water contents in the groundwater samples are important information when evaluating chemical data from core drilled boreholes. The dye Uranine was added as a tracer to the flushing water during drilling and is used to calculate the flushing water contents in the groundwater samples. However, Uranine was also used in some of the late investigations in several borehole sections and in several cases the flushing water contents in the samples can not be calculated any longer.

Injection tests with the PSS equipment /22–33/ was conducted in almost all cored boreholes after the initial hydrochemical characterisation campaign. The relatively small water volumes added to the borehole during injection tests were marked with the dye Uranine to the same concentration as the flushing water, i.e. 0.2 mg/L, and the effect on the Uranine concentration in the groundwater should be negligible. Other activities in the cored boreholes (except drilling) with more significant contributions to the concentrations of Uranine and/or trace metals are listed in Table 3-1.

3.2 Percussion boreholes

Flushing water was not used during drilling of percussion boreholes and therefore remaining flushing water is not a problem. However, dilution tests conducted in percussion boreholes prior to chemical sampling may possibly affect the section water. Since the shallow borehole sections in the percussion boreholes generally yield much water and the injected volumes during dilution tests are small, they are not likely to cause significant effects. Interference tests with heavy pumping, on the other hand, are likely to affect the representativity of the samples from percussion boreholes. Such tests, involving pumping in HFM14 located close to HFM15, were conducted both during 2006 and during 2007. All activities performed in the percussion boreholes that might affect the sample quality are listed in Table 3-2.

Table 3-1. Investigations/activities in cored boreholes that might affect the quality of collected water samples.

Borehole [Idcode]	Section [mbl]	Time period [yymmdd]	Activity[1]	Comment	Initial/ background Uranine conc. (mg/L)	Final Uranine concentration (mg/L)
KFM01A	117.7–118.8	041106 to 041108	HY215[2]	Injection of Uranine (0.0013 g), ~1.36 mg/L if the section volume is considered.	0.14 (uncertain)	1.2
	109.0–130.0	050620 to 050712	HY212, HY210[3]	0.0092 g Uranine injected, total volume of injected fluid 1.8205x10^{-5} m^{3}.	–	–
	109.0–130.0	050712	HY231[4]	Injection of high amounts, ~20 g, Uranine due to tracer test.	–	–
	109.0–130.0	050818 to 050819	Pumping[4]	Attempt to reduce Uranine content from HY231 after compleded tracer test.	–	–
	109.0–130.0	061123 to 061201	HY212[6]	0.025 g Amino G Acid injected.	–	–
KFM01D	377.4–378.4	070208 to 070302	HY214[8]	1.04 g Uranine, 0.67 g Cesium and 1.57 g Rubidium was added to the section. Total injected volume of tracer fluid 1.225x10^{-2} m^{3}.	0.18	0.05 Cs 30 µg/L Rb 90 µg/L
	377.4–378.4	070208 to 070302	HY215[8]	Injection of Uranine (0.0017 g), ~1.66 mg/L if the section volume is considered.	0.03	0.94
KFM01D	431.0–432.0	061214 to 070208	HY214[8]	0.95 g Uranine, 0.67 g Cesium and 1.51 g Rubidium was added to the section. Total injected volume of tracer fluid 1.25x10^{-2} m^{3}.	0.07 Cs 3 µg/L Rb 50 µg/L	0.02 Cs 20 µg/L Rb 70 µg/L
	431.0–432.0	061214 to 070208	HY215[8]	Injection of Uranine (0.0016 g), ~1.67 mg/L if the section volume is considered.	0.05	0.89
KFM02A	414.7–417.7	050214 to 050302	HY215, HY214[2]	Natural gradient test, injection of Uranine (0.0020 g) up to ~0.75 mg/L considering section volume. SWIW-test, 1.04 g Uranine and 1.03 g Cesium was added to the section. Total injected volume of tracer fluid 1.140x10^{-2} m^{3}. Rubidium is not used.	0.05 0.014 Cs 4.35 µg/L	0.7 0.031 Cs 74.1µg/L
	411.0–442.0	051116 to 051122	HY212[3]	0.0241 g Uranine injected, total volume of injected fluid 4.862x10^{-5} m^{3}.	–	–
	411.0–442.0	060627 to 060711	HY212, HY210[5]	0.0196 g Uranine injected, total volume of injected fluid 4.225x10^{-5} m^{3}.	–	–
	411.0–442.0	061113 to 061120	HY212[6]	0.021 g Uranine injected, total volume of injected fluid 4.24x10^{-5} m^{3}.	–	0.82
	411.0–442.0	070315 to 070323	HY212, HY210[9]	0.0199 g Uranine injected, total volume of injected fluid 4.270x10^{-5} m^{3}.	–	0.148
	411.0–442.0	070327 to 070403	HY230[9]	75.8 g Rhodamine WT injected, total volume of injected fluid 1.7869 m^{3}.	–	–
	411.0–442.0	070404 to 070413	HY230[9]	125.4 g Uranine, 1.501 g Li, 105 g Cs and 385 g Rb injected. Total volume of injected fluid 2.53 m^{3}.	–	–
KFM02A	511.5–514.5	050302 to 050304	HY215[2]	Injection of Uranine (0.0004 g), ~0.15 mg/L if the section volume is considered.	0.01	0.04
	490.0–518.0	051122 to 051128	HY212[3]	0.0252 g Uranine injected, total volume of injected fluid 5.085x10^{-5} m^{3}.	–	–
	490.0–518.0	060630 to 060707	HY212, HY210[5]	0.0209 g Uranine injected, total volume of injected fluid 4.511x10^{-5} m^{3}.	–	–
	490.0–518.0	061107 to 061113	HY212[6]	0.023 g Uranine injected, total volume of injected fluid 4.53x10^{-5} m^{3}.	–	0.35

KFM02B	408.5–434.0	070327 to 070403	HY230[9]	75.8 g Rhodamine WT injected, total volume of injected fluid 1.7869 m^3 (injected in KFM02A 411.0–442.0).	–	–
KFM02B	408.5–434.0	070404 to 070413	HY230[9]	125.4 g Uranine, 1.501 g Li, 105 g Cs and 385 g Rb injected. Total volume of injected fluid 2.53 m^3 (injected in KFM02A 411.0–442.0).	–	–
KFM03A	643.5–644.5	041214 to 041216	HY215[2]	Injection of Uranine (0.0015), ~1.22 mg/L if the section volume is considered.	0.04	0.8
	643.5–644.5	050107 to 050117	HY214[2]	0.949 g Uranine and 1.03 g Cesium was added to the section. Total injected volume of tracer fluid 1.013x10^{-2} m^3.Rubidium is not used.	0.008 Cs 1.81 µg/L	0.132 Cs 157 µg/L
	633.5–650.0	051118 to 051123	HY212[3]	0.0244 g Uranine injected, total volume of injected fluid 4.920x10^{-5} m^3.	–	–
	633.5–650.0	061113 to 061123	HY212[6]	0.024 g Uranine injected, total volume of injected fluid 4.87x10^{-5} m^3.	–	0.38
KFM03A	986.0–987.0	041119 to 041123	HY215[2]	Injection of Uranine (0.0025 g), ~2.48 mg/L if the section volume is considered.	0.04	2.3
	969.5–994.5	051123 to 051205	HY212[3]	0.0330 g Uranine injected, total volume of injected fluid 6.660x10^{-5} m^3.	–	–
KFM04A	232.0–237.0	060221 to 060223	HY215[2]	Injection of Uranine (0.0019 g), ~0.58 mg/L if the section volume is considered.	0.00	0.006
KFM06A	341.0–362.0	051117 to 051124	HY212[3]	0.0175 g Uranine injected, total volume of injected fluid 3.520x10^{-5} m^3.	–	–
	341.0–362.0	060626 to 060711	HY212, HY210[5]	0.0156 g Uranine injected, total volume of injected fluid 3.377x10^{-5} m^3.	–	–
	341.0–362.0	061106 to 061110	HY212[6]	0.018 g Uranine injected, total volume of injected fluid 3.52x10^{-5} m^3.	–	0.36
KFM06A	738.0–748.0	051124 to 051205	HY212[5]	0.0253 g Uranine injected, total volume of injected fluid 5.100x10^{-5} m^3.	–	–
	738.0–748.0	060630 to 0607007	HY212, HY210[5]	0.0233 g Uranine injected, total volume of injected fluid 5.040x10^{-5} m^3.	–	–
	738.0–748.0	061110 to 061117	HY212[6]	0.026 g Uranine injected, total volume of injected fluid 5.15x10^{-5} m^3.	–	0.45
KFM06C	531.0–540.0	061113 to 061120	HY212[6]	0.0193 g Uranine injected, total volume of injected fluid 3.86x10^{-5} m^3.	–	–
KFM06C	647.0–666.0	061106 to 061113	HY212[6]	0.0251 g Uranine injected, total volume of injected fluid 5.00x10^{-5} m^3.	–	–
KFM08A	410.5–413.5	051125 to 060103	HY214[7]	1.04 g Uranine, 0.74 g Cesium and 1.63 g Rubidium was added to the section. Total injected volume of tracer fluid 1.1x10^{-2} m^3.	0.02 Cs 2 µg/L Rb 40 µg/L	0.15 Cs 160 µg/L Rb 360 µg/L
	410.6–413.5	051125 to 060115	HY215[7]	Injection of Uranine (0.002 g), ~0.94 mg/L if the section volume is considered.	0.01	0.45
KFM10A	430.0–440.0	070625 to 070702	HY210, HY212[6]	0.0197 g Uranine injected, total volume of injected fluid 3.944x10^{-5} m^3.	0.002	0.083
		070706	HY230[10]	60.94 g Ho-DTPA injected, total volume of injected fluid 5.044x10^{-2} m^3.	Ho 0.053 µg/L	Ho 10.2 µg/L

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[1] HY215 = Borehole probe dilution test, natural gradient, HY212 = Dilution test natural gradient, HY210 = Dilution test stressed gradient, HY231 = Tracer injection during tracer tests, HY214 = SWIW-test, HY230 = Radially converging Test Hole.

[2] /44/

[3] /45/

[4] /46/

[5] /47/

[6] /48/

[7] /49/

[8] /50/

[9] /51/

[10] /52/

Table 3-2. Investigations/activities in percussion boreholes that might affect the quality of collected water samples.

Borehole [Idcode]	Section [mbl]	Date [yymmdd]	Activity[1]	Comment
HFM01	33.5–45.5	070625–070702	HY210, HY212[6]	0.020 g Uranine injected, total volume of injected fluid 3.96x10^{-5} m^{3}.
		070706	HY230[6]	19.88 g Eu-DTPA injected, total volume of injected fluid 4.843x10^{-2} m^{3}.
HFM02	38.0–48.0	050621–050712	HY210, HY212[2]	0.3256 g Uranine injected, total volume of injected fluid 6.409x10^{-4} m^{3}.
		050712	HY231[2]	Injection of high amounts, 250 g, Amino G Acid due to tracer test.
		051205–051212	HY212[3]	0.1290 g Uranine injected, total volume of injected fluid 2.600x10^{-4} m^{3}.
		060629–060710	HY210, HY212[4]	0.1426 g Uranine injected, total volume of injected fluid 3.080x10^{-4} m^{3}.
		061127–061201	HY212[5]	0.1574 g Uranine injected, total volume of injected fluid 3.200x10^{-5} m^{3}.
HFM04	58.0–66.0	051116–151122	HY212[3]	0.0129 g Uranine injected, total volume of injected fluid 2.595x10^{-5} m^{3}.
		061107–061114	HY212[5]	0.0151 g Uranine injected, total volume of injected fluid 3.020x10^{-5} m^{3}.
HFM13	159.0–173.0	051206–051212	HY212[3]	0.0216 g Uranine injected, total volume of injected fluid 4.362x10^{-5} m^{3}.
		060628–060711	HY210, HY212[4]	0.0325 g Uranine injected, total volume of injected fluid 7.020x10^{-5} m^{3}.
		061114–061122	HY212[5]	0.0160 g Uranine injected, total volume of injected fluid 3.200x10^{-5} m^{3}.
		070626–070702	HY210, HY212[6]	0.016 g Uranine injected, total volume of injected fluid 3.13x10^{-5} m^{3}.
		070706	HY230[6]	24.89 g Tb-DTPA injected, total volume of injected fluid 5.011x10^{-2} m^{3}.
HFM15	85.0–95.0	050621–050712	HY210, HY212[2]	0.0197 g Uranine injected, total volume of injected fluid 3.870x10^{-5} m^{3}.
		050712	HY231[2]	Injection of high amounts Rhodamine WT, ~180–190 g, due to tracer test.
		051205–051212	HY212[3]	0.0190 g Uranine injected, total volume of injected fluid 3.825x10^{-5} m^{3}.
		060627–060710	HY210, HY212[4]	0.0138 g Uranine injected, total volume of injected fluid 2.989x10^{-5} m^{3}.
		061120–061127	HY212[5]	0.0153 g Uranine injected, total volume of injected fluid 3.060x10^{-5} m^{3}.
		070625–070702	HY210, HY212[6]	0.018 g Uranine injected, total volume of injected fluid 3.57x10^{-5} m^{3}.
		070709	HY230[6]	7.95 g Gd-DTPA injected, total volume of injected fluid 5.181x10^{-2} m^{3}.
		070924–070925	HY230[6]	187.5 g Uranine and 650.8 g Cs injected, total volume of injected fluid 3.677 m^{3}.
HFM16	54.0–67.0	061106–061113	HY212[5]	0.0187 g Uranine injected, total volume of injected fluid 3.740x10^{-5} m^{3}.

HFM19	168.0–182.0	051205–051212	HY212[3]	0.0186 g Uranine injected, total volume of injected fluid 3.750x10^{-5} m^{3}.
		060628–060710	HY210, HY212[4]	0.0169 g Uranine injected, total volume of injected fluid 3.640x10^{-5} m^{3}.
		061117–061127	HY212[5]	0.0186 g Uranine injected, total volume of injected fluid 3.710x10^{-5} m^{3}.
		070626–070702	HY210, HY212[6]	0.244 g Uranine injected, total volume of injected fluid 4.886x10^{-4} m^{3}.
		070709	HY230[6]	166.7 g Dy-DTPA injected, total volume of injected fluid 6.633x10^{-2} m^{3}.
HFM27	46.0–58.0	061124–061201	HY212[5]	0.0180 g Uranine injected, total volume of injected fluid 3.600x10^{-5} m^{3}.
HFM32	26.0–31.0	060626–060707	HY210, HY212[4]	0.0082 g Uranine injected, total volume of injected fluid 1.761x10^{-5} m^{3}.
		061120–061124	HY212[5]	0.0092 g Uranine injected, total volume of injected fluid 1.830x10^{-5} m^{3}.
		070626–070701	HY210, HY212[6]	0.008 g Uranine injected, total volume of injected fluid 1.54x10^{-5} m^{3}.
		070709	HY230[6]	42.60 g ReO_4^- injected, total volume of injected fluid 2.470x10^{-2} m^{3}.

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[1] HY212 = Dilution test natural gradient, HY210 = Dilution test stressed gradient, HY231 = Tracer injection during tracer tests, HY230 = .Radially converging Test Hole.

[2] /46/

[3] /45/

[4] /47/

[5] /48/

[6] /52/

4 Equipment

4.1 Sampling equipment

The monitored boreholes are equipped with straddle packer installations in order to isolate different borehole sections. Each section is connected to the Hydro Monitoring System (HMS) which is a system for pressure monitoring. Outlines of the instrumentation in percussion drilled and telescopic boreholes, respectively, are presented in Figure 4-1.

Twelve identical pump equipments (GEOPUMP UV45) were used to retrieve the water samples from the sampled sections. An outline of the sampling setup is presented in Figure 4-2 and Figure 4-3 shows the lowering of the pump. The water passes through a coarse filter to eliminate large particles that may be present in the water, then via a by-pass tubing through the mini-packer isolating the section and thereafter through the downhole pump on the way to the surface. The flow rate is controlled by varying the capacity of the downhole pump with a voltage regulator at the surface.

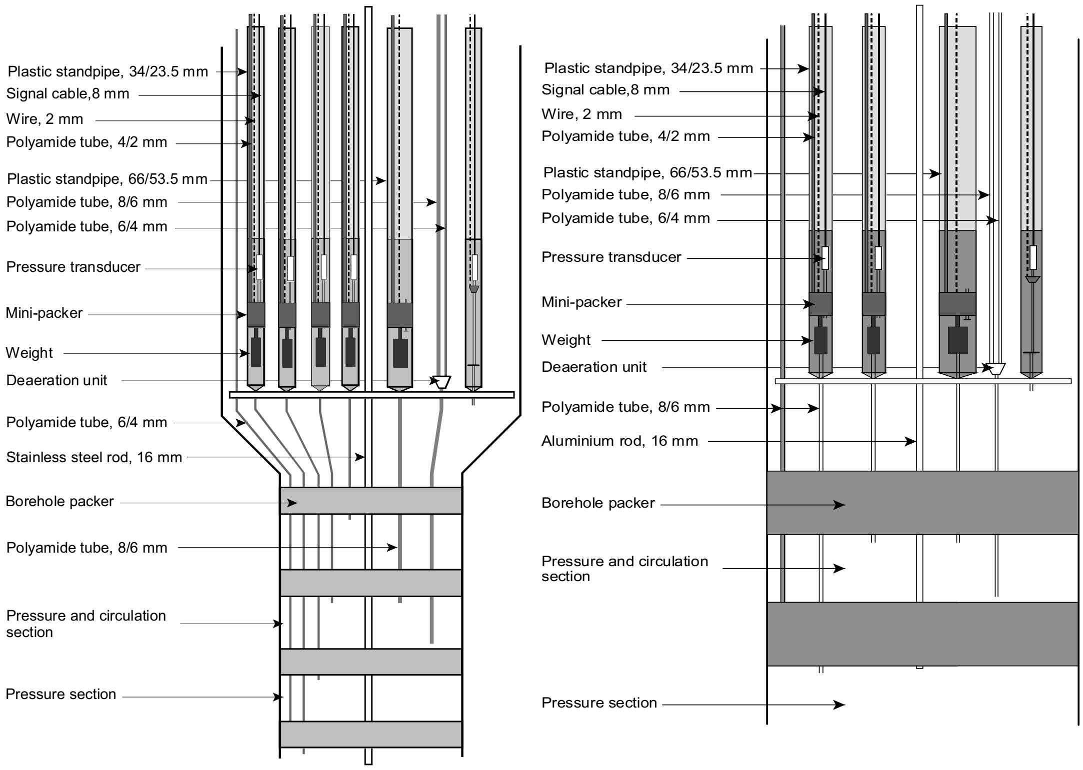


Figure 4-1. *Instrumentation in core boreholes of telescopic type (left) and percussion boreholes (right) including circulation sections.*

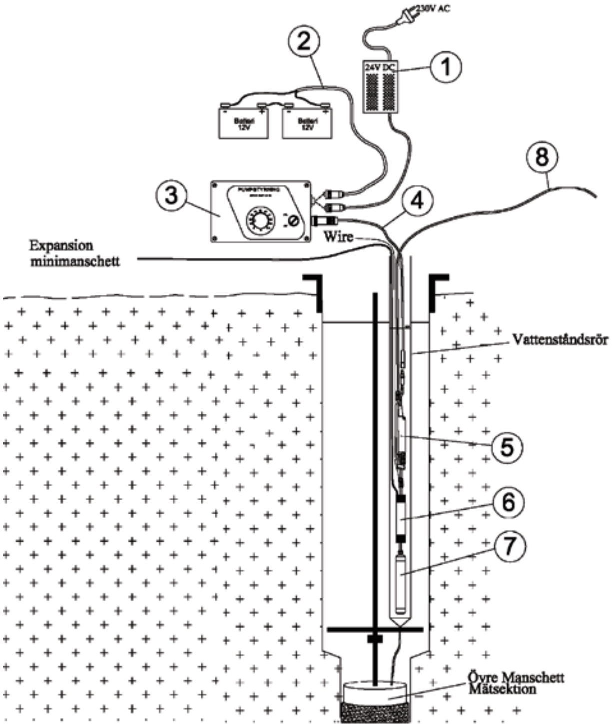


Figure 4-2. *Equipment setup used for sampling of water from circulation sections in monitored percussion drilled and telescopic boreholes. 1) voltage regulator (24 VDC), 2) battery cable (not used), 3) pump regulator, 4) pump cable, 5) pump (GEOPUMP UV 45), 6) small inflatable packer (PU 45), 7) filter (SF 45), 8) 8/6 mm polyamide tube to pump.*

Figure 4-3. *Lowering of equipment in the water stand-pipe in order to pump water from the borehole section. From the bottom; filter, small inflatable packer and pump.*

5 Performance

5.1 General

Monitored boreholes and borehole sections, sampling dates, collected samples and analyses performed are presented in Table 5-1.

Table 5-1. Boreholes, borehole sections, sampling dates, collected samples and analyses performed.

Idcode	Section	Sampling no. 1			Sampling no. 2		
	[mbl]	Date	Sample No.	Analyses	Date	Sample No.	Analyses
HFM01	33.5–45.5	07-04-10	12757	Class 5, options**	07-10-23	12890	Class 5, options
HFM02	38.0–48.0	07-04-11	12761	Class 3 + ^{3}H, ^{2}H,^{18}O	07-10-23	12891	Class 5, options
HFM04	58.0–66.0	07-02-20	12704	Class 3 + ^{3}H, ^{2}H,^{18}O	07-11-01	12912	Class 5, options
HFM13	159.0–173.0	07-04-17	12768	Class 3 + ^{3}H, ^{2}H,^{18}O	07-10-17	12884	Class 5, options
HFM15	85.0–95.0	07-04-12	12763	Class 3 + ^{3}H, ^{2}H,^{18}O	07-10-17	12885	Class 5, options
HFM16	54.0–67.0	07-04-12	12765	Class 3 + ^{3}H, ^{2}H,^{18}O	07-10-23	12892	Class 5, options
HFM19	168.0–182.0	07-04-12	12764	Class 3 + ^{3}H, ^{2}H,^{18}O	07-10-17	12886	Class 5, options
HFM21	22.0–32.0	07-04-10	12758	Class 5, options**	07-10-23	12893	Class 5, options
HFM27	46.0–58.0	07-04-11	12760	Class 3 + ^{3}H, ^{2}H,^{18}O	07-10-26	12896	Class 5, options
HFM32	26.0–31.0	07-04-17	12767	Class 3 + ^{3}H, ^{2}H,^{18}O	07-11-12	12913	Class 5, options
KFM01A	109.0–130.0	07-04-23	12770	Class 3 + ^{3}H, ^{2}H,^{18}O	07-10-19	12885	Class 3***
KFM01D	311.0–321.0	07-04-18	12771	Class 5, options**	07-10-19	12889	Class 3 + ^{3}H, ^{2}H,^{18}O
KFM01D	429.0–438.0	07-04-23	12772	Class 5, options**	07-10-19	12888	Class 3 + ^{3}H, ^{2}H,^{18}O
					08-01-30	12953	Class 4****
					08-01-30	12954	Class 4****
					08-01-30	12955	Class 4****
KFM02A	411.0–442.0	07-02-14	12701	Class 3 + ^{3}H, ^{2}H,^{18}O	07-10-30	12901	Class 3 + ^{3}H, ^{2}H,^{18}O
KFM02A	490.0–518.0	07-02-14	12700	Class 3 + ^{3}H, ^{2}H,^{18}O	07-10-30	12889	Class 5, options
KFM02B	410.0–431.0	–	–	–	07-10-30	12900	Class 5, options
KFM02B	491.0–506.0	–	–	–	07-10-30	12898	Class 5, options
KFM03A	633.5–650.0	07-03-01	12708	Class 3 + ^{3}H, ^{2}H,^{18}O	07-10-15	12850	Class 5, options
KFM03A	969.5–994.5	07-03-02	12711	Class 3 + ^{3}H, ^{2}H,^{18}O	07-10-15	12849	Class 5, options
KFM04A	230.0–245.0	07-04-11	12759	Class 5, options	07-11-01	12911	Class 5, options
KFM06A	341.0–362.0	–	–	–	07-10-26	12897	Class 3 + ^{3}H, ^{2}H,^{18}O
KFM06A	738.0–748.0	–	–	–	–	–	–
KFM06C	531.0–540.0	–	–	–	–	–	–
KFM06C	647.0–666.0	–	–	–	–	–	–
KFM07A*	962.0–972.0	07-03-20	12729	Class 5, options	07-10-26	12895	Class 5, options
KFM08A	265.0–280.0	–	–	–	08-01-22	12946	Class 4****
		–	–	–	08-01-22	12949	Class 4****
		–	–	–	08-01-22	12951	Class 4****+ ^{3}H, ^{2}H,^{18}O
KFM08A	684.0–694.0	–	–	–	08-01-22	12947	Class 4****
		–	–	–	08-01-22	12950	Class 4****
		–	–	–	08-01-22	12952	Class 5, options
KFM08D	660.0–680.0	–	–	–	08-01-22	12948	Class 4****
KFM10A	430.0–440.0	07-04-17	12769	Class 5, options	07-10-17	12883	Class 5, options
KFM11A	446.0–456.0	–	–	–	07-10-09	12829	Class 5, options
KFM11A	680.0–710.0	–	–	–	07-10-09	12831	Class 5, options

* Water “pumped” using nitrogen lifting.

** SKB class 5, with all options except Ra-, Rn-, U- and Th-isotopes.

*** SKB class 3 due to high flushing water content.

**** Water sampling series to investigate HS-concentrations at different stages of pumping. Addition of HS$^-$ to the analytical programme (SKB class 4).

5.2 Water sampling and field measurements

Prior to sampling, the water volume in each section was exchanged at least three times to obtain a representative water sample from the section, except in the section from KFM08D, see Chapter 6. The pumped total volumes from each section prior to sampling are given in Appendix 1. In a few cases, pumping from the sampled test section revealed contact with groundwater from other sections of the same borehole through the fracture system. Information on these short circuiting phenomena is also included in Appendix 1. Short circuiting is indicated by pressure responses in one or more sections other than the pumped ones. Pressure diagrams for each borehole and sampling occasion are given in Appendix 2. The samples for HS^- analyses in KFM01D and KFM08A in January 2008 were collected after 1) exchange of the water in the tube from the water stand-pipe to the section, 2) exchange of one section volume and 3) after exchange of the section volume at least three times.

In addition to sampling of ground water, field measurements of temperature, electric conductivity and pH were conducted. The water pumped from the borehole was led through a measurement cell with probes and electrodes as well as a temperature sensor for measurements of field pH (pH_F), field electrical conductivity (EC_F) and groundwater temperature.

Sample portions intended for analysis of major constituents and trace metals (by ICP technique), DOC, iron (by spectrometry) and nutrient salts were filtered on-line. Disposable 0.4 µm filters were fitted directly to the 6/8 mm polyamide-tube leading the pumped water from the borehole section. During the entire sampling, laboratory gloves were used to minimize the risk of contaminating the samples.

5.3 Water sample treatment and analyses

An overview of sample treatment and analysis routines for major constituents, minor anions, trace metals and isotopes is given in Appendix 3. The routines are applicable independently of sampling method or sampling object.

6 Nonconformities

- The boreholes/borehole sections at drill site 6 (DS6), especially the two sections in KFM06C, showed high flushing water contents at previous sampling occasions /51/. The sections in KFM06A and KFM06C were therefore excluded during spring 2007. At the late sampling occasion in the fall both sections in KFM06C were excluded due to the risk of disturbing on-going interference tests and the lower section in KFM06A (738.0–748.0 m) was excluded due to an early pump failure. There was not enough time available to change the pump and continue with the sampling because of the subsequent interference tests. Special efforts will be made to collect samples from these boreholes during the coming sampling occasion in spring 2008.
- Due to pump failure only the first of three planned samples in section KFM08D:4 (660.0–680.0 m) was collected. The sample was collected after exchange of the tube volume (tube between the test section and its stand pipe), i.e. the sample represents water standing in the section.
- The sampling in some borehole sections in April was performed according to SKB class 5, excluding Ra-, Rn-, U- and Th-isotopes. This in order to get complete background data prior to the subsequent dilution- and tracer tests, which are likely to have effects on the water composition.
- At the sampling occasion in Octobewwr, the sampling in boreholes KFM01A, KFM01D, KFM02A, KFM06A and KFM08A was conducted according to SKB class 3 and not class 5 as planned. The sampling protocol and the reasons behind the changes are given below;

Idcode	Borehole section (m borehole length)	Sampling protocol	Reason for change to class 3
KFM01A	109–130	SKB class 3, no isotope options	High Uranine concentration due to tracer tests and possibly also from intruding flushing water from earlier drilling of boreholes KFM01C and KFM01D.
KFM01D	311–321 429–438	SKB class 3 with ^{3}H, ^{2}H, ^{18}O	High Uranine concentration due to contamination from tracer tests, see Table 3-1. SKB class 5 samples were collected in April.
KFM02A	411–442	SKB class 3 with ^{3}H, ^{2}H, ^{18}O	The borehole section hade been used for tracer tests between KFM02A and KFM02B. High remaining concentrations of Uranine and Rhodamine.
KFM06A	341–362	SKB class 3 with ^{3}H, ^{2}H, ^{18}O	High amount of remaining flushing water from drilling.
KFM08A	265–280	SKB class 3 with ^{3}H, ^{2}H, ^{18}O	High amount of remaining flushing water from drilling.

- The trace element Indium was not analysed in groundwater samples from boreholes HFM01, HFM16 and HFM21, collected in October, due to human error (the analysis was not ordered from the consulted laboratory).

7 Data handling and interpretation

7.1 Water analysis data

The following routines for quality control and data management are generally applied for hydrogeochemical analysis data, independently of sampling method or sampling object.

Several constituents are determined by more than one method and/or laboratory. All analytical results are stored in the Sicada database. The applied hierarchy path "Hydrochemistry/Hydrochemical investigation/Analyses/Water in the database" contains two types of tables, raw data tables and primary data tables (final data tables).

Data on **basic water analyses** are inserted into the raw data tables for further evaluation. The evaluation results in a final reduced data set for each sample. These data sets are compiled in a primary data table named "water composition". The evaluation is based on:

- Comparison of the results from different laboratories and/or methods.
- Calculation of charge balance errors, equation (1). Relative errors within ± 5% are considered acceptable.

$$\text{Relative error}\,(\%) = 100 \times \frac{\sum \text{cations}(\text{equivalents}) - \sum \text{anions}(\text{equivalents})}{\sum \text{cations}(\text{equivalents}) + \sum \text{anions}(\text{equivalents})} \qquad (1)$$

- General expert judgement of plausibility based on earlier results and experience.

All results from special analyses of **trace metals** and **isotopes** are inserted directly into primary data tables. In cases where the analyses are repeated or performed by more than one laboratory, a "best choice" notation will indicate those results which are considered most reliable.

An overview of the data management is given in Figure 7-1.

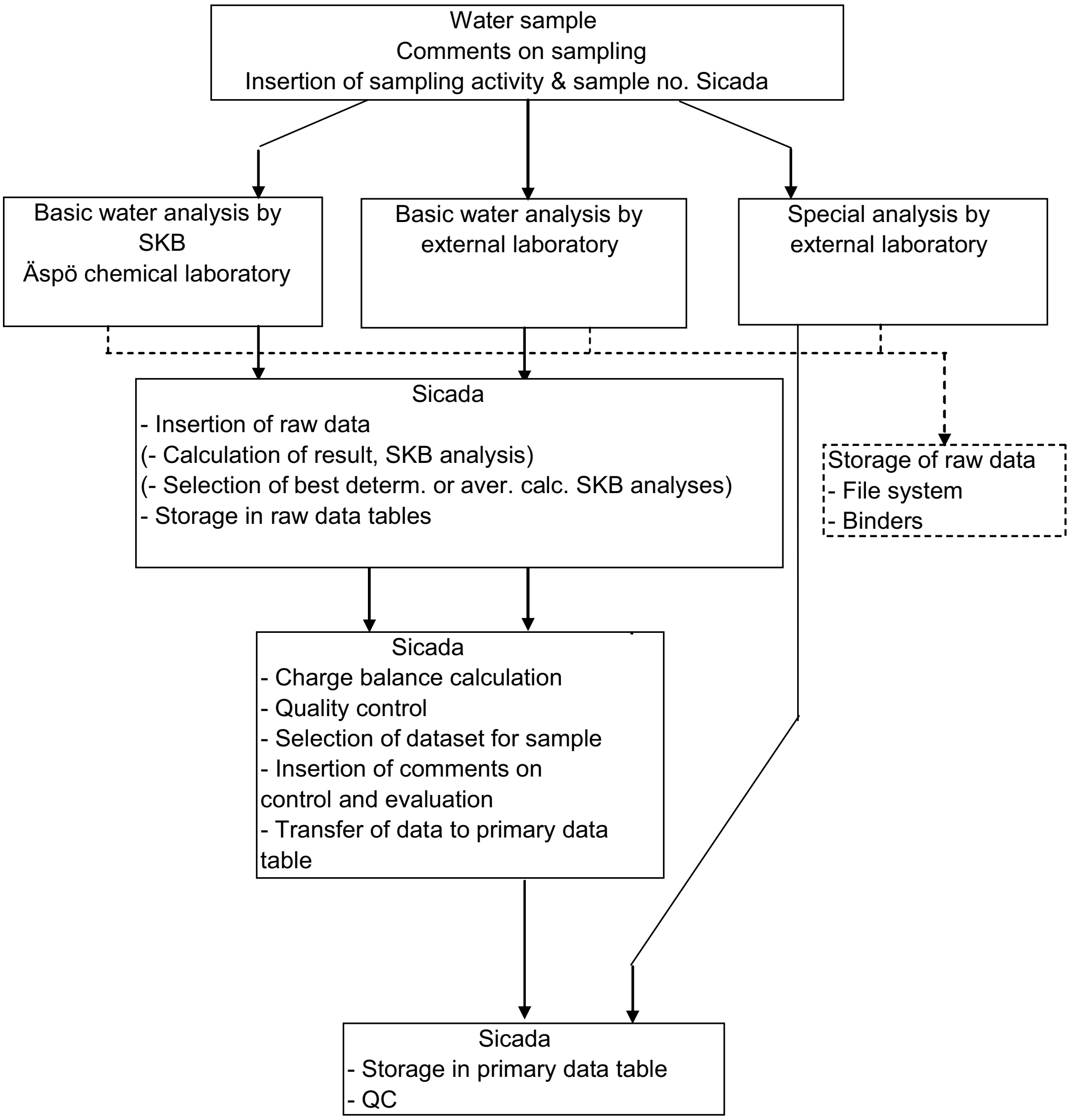


Figure 7-1. *Overview of data management for hydrogeochemical data.*

8 Results

8.1 Water analysis

8.1.1 Basic water analyses

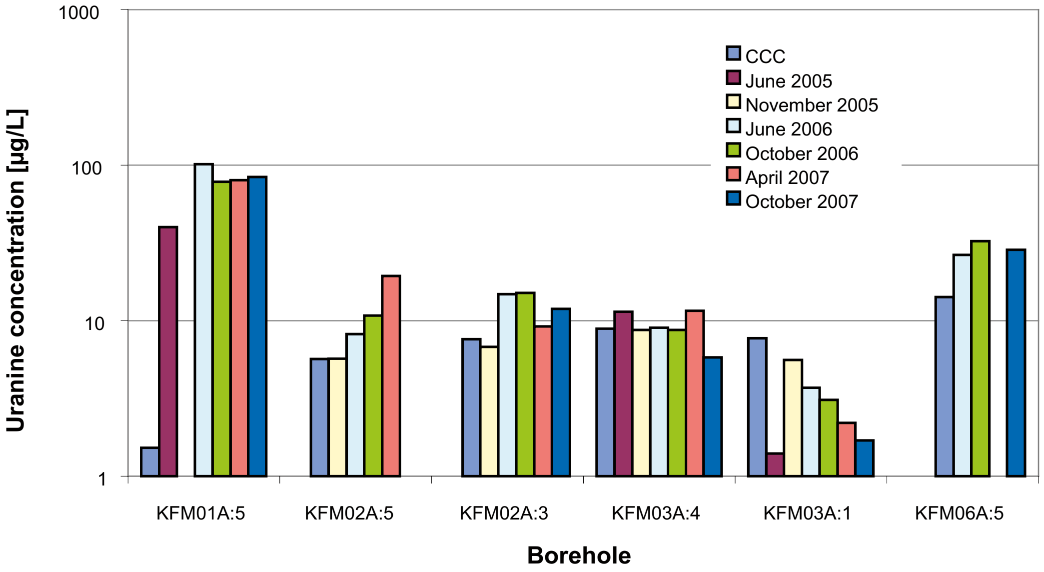
The basic analyses include the major constituents Na, K, Ca, Mg, Fe, Li, Mn, S, Sr, SO_4^{2-}, Cl^-, Si, HCO_3^-, Br^- and F^-. Samples collected according to SKB chemistry class 5 include also P, I^-, HS^-, NH_4^+, NO_2^-, NO_3^-, TOC and DOC. Furthermore, both laboratory data and field measurement data on pH and electrical conductivity (EC) were obtained and the water temperature was recorded in the field.

For samples collected in core drilled telescopic boreholes, the flushing water content is an important parameter. However, since the dye Uranine, which is used to mark the flushing water during drilling, was used also in other investigations, see Tables 3-1 and 3-2, it is not always possible to calculate the amount of flushing water emerging from the drilling of the borehole. Figure 8-1 presents Uranine concentrations in collected samples from hydrochemical monitoring as well as from the initial chemical characterisation in the corresponding section /53–64, 69/. As displayed in the diagram, the Uranine concentration has increased in many borehole sections due to groundwater flow measurements and tracer tests.

The charge balance errors provide an indication of the quality and uncertainty of the analyses of major constituents. The errors did not exceed the acceptable limit of ± 5% in any of the cases. The basic water analysis data and relative charge balance errors are compiled in Appendix 4, Table A4-1.

Chloride concentrations are presented in Figure 8-2 (cored boreholes) and Figure 8-3 (percussion boreholes) together with the initial concentrations from chemical characterisation (core drilled boreholes) /54–64/ or sampling during pumping tests (percussion boreholes) /36–43/. Generally the chloride concentrations were quite stable, especially in core boreholes. Minor increases during 2007 were observed in KFM07A:2, KFM10A:2, HFM01:2 and HFM02:2. In HFM15:1 a relatively large increase was observed from the late sampling occasion in the autumn. This is most likely due to the interference test and the pumping in HFM14 situated close to HFM15.

Some striking changes in the sulphide concentrations have been observed from the groundwater monitoring in boreholes after the initial chemical investigations in the corresponding sections. Table 8-1 presents sulphide concentrations in samples collected during the monitoring programme since the start in 2005 /53, 69/ as well as from initial hydrochemical investigations (CCC) in corresponding borehole sections.



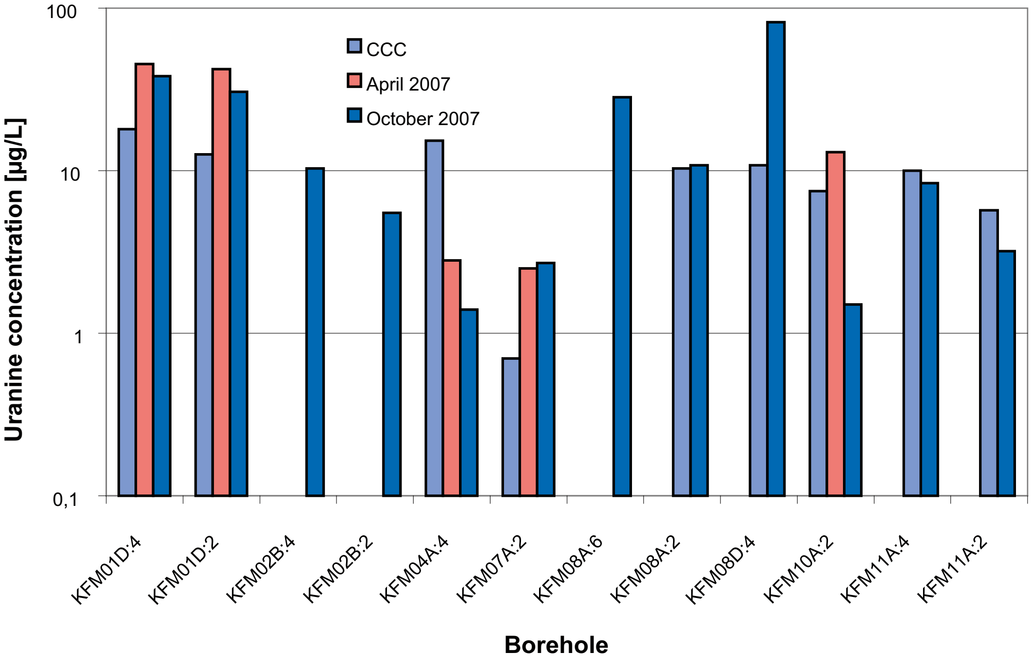
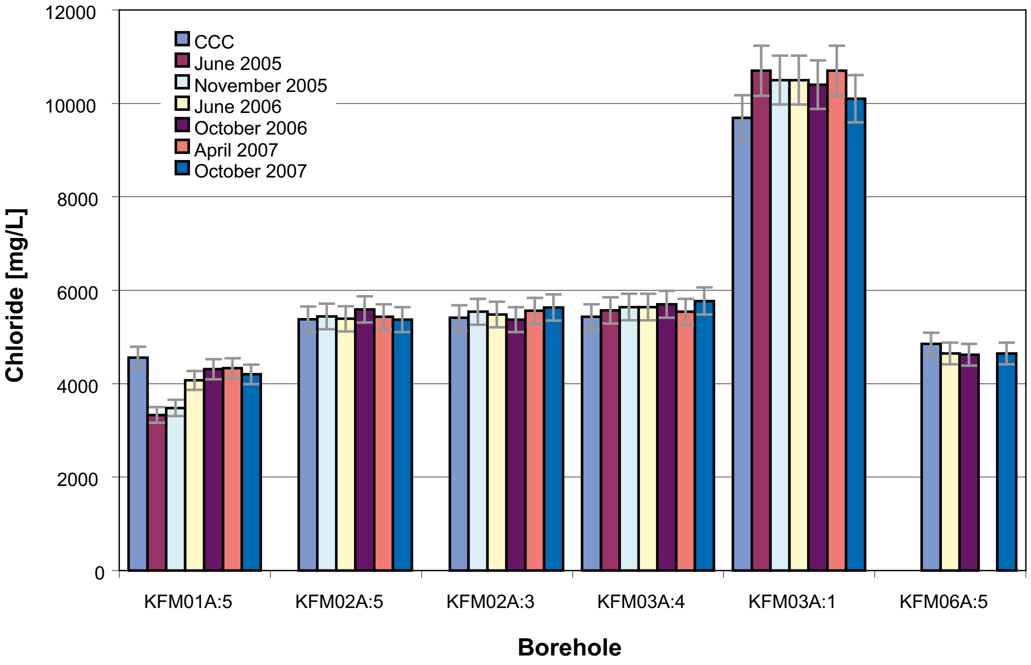


Figure 8-1ab. *Uranine concentrations in water samples from core drilled boreholes included in the hydrochemical monitoring program. The concentrations from the initial chemical characterisations (CCC) in corresponding borehole sections are given for comparison. The nominal Uranine concentration in the drilling water is 200µg/L. Boreholes KFM01A, KFM02A, KFM03A and KFM06A are displayed in Figure 8-1a whereas boreholes KFM01D, KFM02B, KFM04A, KFM07A, KFM08A, KFM08D, KFM10A and KFM11A are presented in Figure 8-1b.*



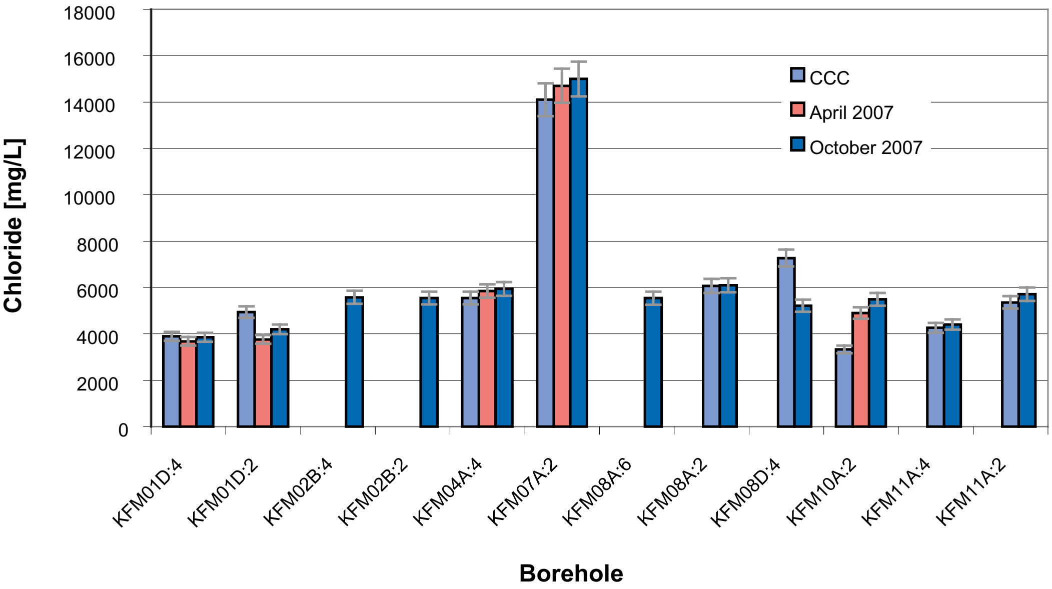


Figure 8-2ab. *Chloride concentrations in samples collected in core boreholes included in the monitoring program. Results from initial hydrochemical characterisations (CCC) are given for comparison. Boreholes KFM01A, KFM02A, KFM03A and KFM06A are displayed in Figure 8-2a whereas boreholes KFM01D, KFM02B, KFM04A, KFM07A, KFM08A, KFM08D, KFM10A and KFM11A are presented in Figure 8-2b*

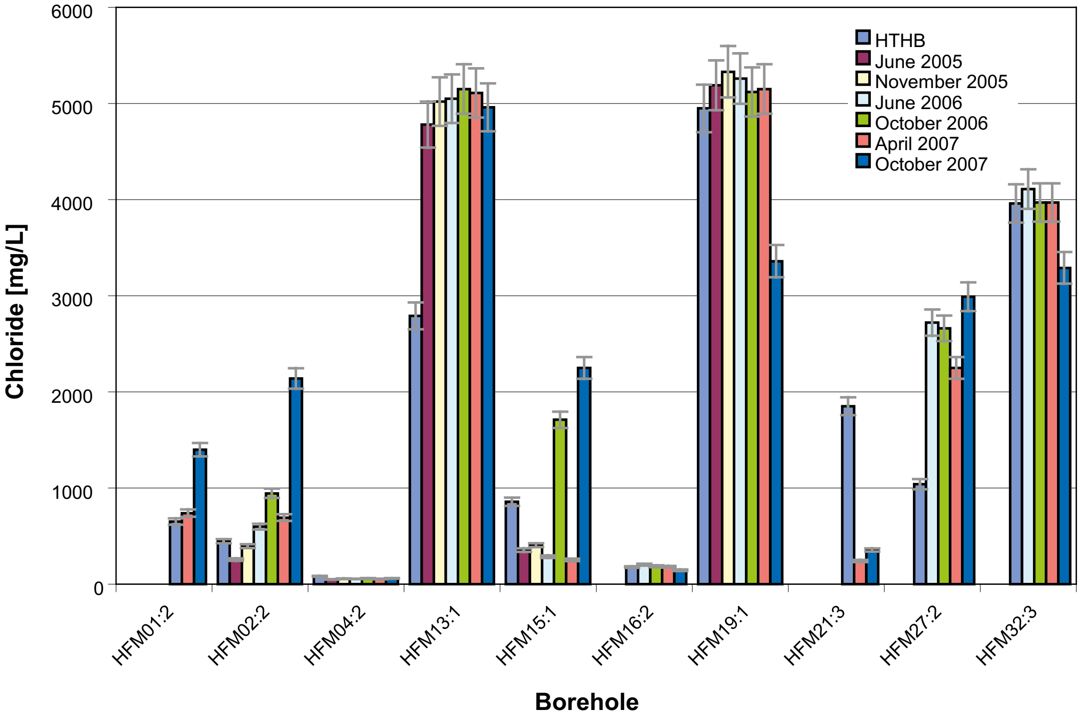


Figure 8-3. *Chloride concentrations in samples collected in percussion boreholes included in the monitoring program. Results from the initial sampling during pumping tests (HTHB) are given for comparison. The initial concentrations are not quite comparable as the early sampling was performed at open hole conditions i.e. affecting the entire borehole, and not from straddle packer isolated sections.*

Table 8-1. Sulphide concentrations in sample series from selected boreholes within the monitoring programme with start in 2005. Available concentrations from previous hydrochemical investigations, CCC, /52–55, 57–59, 61, 62/ are given for comparison.

	CCC	June-05	Oct-05	June-06	Oct-06	April-07	Oct-07	Jan-08:1*	Jan-08:2	Jan-08:3
KFM01A:5	0.014	–	–	–	0.922	–	–	–	–	–
KFM01D:4	0.009	–	–	–	–	0.287	–	–	–	–
KFM01D:2	0.006	–	–	–	–	3.29	–	13.4	1.7	2.38
								6.9**	1.4**	8.1**
KFM02A:5	< 0.002	–	0.058	–	0.129	–	–	–	–	–
KFM02A:3	0.009	–	0.066	0.065	0.167	–	0.219	–	–	–
KFM03A:4	< 0.002	0.133	0.701	–	0.538	–	0.219	–	–	–
KFM03A:1	0.033	–	0.838	–	0.587	–	0.245	–	–	–
KFM06A:5	< 0.002	–	0.614	–	0.108	–	–	–	–	–
KFM07A:2	0.134	–	–	–	–	0.116	0.011	–	–	–
KFM08A:2	0.012	–	–	–	–	–	–	0.19	x	0.025
								x	x	0.010**
KFM08D:4	< 0.006	–	–	–	–	–	–	3.33	–	–
KFM11A:4	0.012	–	–	–	–	–	0.172	–	–	–
KFM11A:2	0.04	–	–	–	–	–	0.145	–	–	–

*Sample series, three samples 1) after exchange of tube volume (tube from borehole section to standpipe) 2) after exchange of section volume and 3) after exchange of at least three times the section volume of water.

**Results from control sample analysed by a second laboratory.

8.1.2 Trace elements (rare earth metals and others)

The analyses of trace elements include Cr, Cu, Co, Ni, Mo, Pb, Zn, Sb, Al, U, Th, B, As, Sc, Cd, Hg, V, Rb, Y, Zr, In, Cs, Ba, La, Hf, Tl, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb as well as Lu and are compiled in Appendix 4, Table A4-2. Due to low natural concentrations and frequent use in different equipment, the risk of contamination is high for common metals like Cr, Cu, Co, Ni, Mo, Zn and Al. The use of Cesium or Cesium together with Rubidium in SWIW-tests might also have contaminated some of the samples. One molybdenum value (sample 12899) is high probably due to contamination. Two samples (12912 and 12913) are considered to be contaminated by aluminium. A sample from HFM15 (Sample 12885) shows a clear contamination by Cesium. The Uranium concentration in section KFM02A:3 continues to be very high /53, 69/ and amounts to 148 µg/L in sample 12899 at the late sampling occasion in October.

8.1.3 Stable and radioactive isotopes

The isotope determinations include the stable isotopes δ^2H, $\delta^{18}O$, $^{10}B/^{11}B$, $\delta^{34}S$, $\delta^{13}C$ and $^{87}Sr/^{86}Sr$ as well as the radioactive isotopes ^3H (TU), ^{14}C (pmC), ^{238}U, ^{234}U, ^{230}Th, ^{226}Ra and ^{222}Rn. All samples were analysed for δD, $\delta^{18}O$ and ^3H, except the sample collected in KFM01A in October and the first samples in the sample series collected in boreholes KFM01D, KFM08A and KFM08D in January 2008. All other isotopes were determined once (SKB class 5 sampling). Available isotope data are compiled in Appendix 4, Table A4-3 and A4-4. Significant changes in the oxygen-18 signature between the two reported sampling occasions were observed in HFM15 and to a minor extent in HFM19 and KFM01D:2.

9 Summary and discussions

Groundwaters from a total of 28 borehole sections in 22 boreholes have been sampled (most of them at two occasions) during 2007. The results and conclusions from the analysis programme are summarised below.

- Uranine has been used as a tracer in tests prior to and in between chemical sampling occasions. This is unfavourable when interpreting and evaluating the hydrochemical data from monitoring since it is no longer possible to calculate the flushing water content in the samples from several of the borehole sections. The increase in Uranine concentration that can be observed in many borehole sections after the initial sampling is rather due to groundwater flow measurements and tracer tests than remaining flushing water. However, Uranine concentrations and flushing water contents are temporary problems as the boreholes will hopefully retain natural groundwater conditions with time.
- Preceding investigations in a specific borehole/borehole section or on-going activities in nearby situated boreholes as pumping tests or interference tests affected the results from hydrochemical monitoring in some boreholes/borehole sections. Furthermore, short circuiting of groundwater through fracture systems connecting two or more borehole sections was observed in some boreholes during pumping.
- Generally, the groundwater composition (major constituents) has stayed relatively stable since the initial CCC sampling in most borehole sections in the cored boreholes. Most of the decrease in chloride concentration during 2005 in section KFM01A:5 turned out to be temporarily and was probably caused by other activities at this drill site at the time. The initial non-marine character of the groundwater in section KFM01D:2 changed and a significant Littorina contribution was observed from the start of the monitoring programme. However, the responses displayed in the pressure diagram from the pumping period indicate connections between several borehole sections, see Appendix 2, and contamination by water from a more shallow sections is probably the cause. The chloride concentration in the deep section KFM03A:1 showed its largest change/increase in June 2005. After this occasion the concentration has decreased somewhat and varies up and down but within the analytical error. It is possible that this borehole section and probably also section KFM07A:2 are sensitive to impacts from pumping due to occurrence of more saline water just underneath them, which may cause at least temporary up-coning of saline water.
- The water composition (major constituents) in borehole sections in percussion boreholes were, however, less stable. There are several reasons for this. 1) The initial HTHB sampling during pumping tests was conducted at open-hole conditions i.e. affecting the entire borehole and these initial data are not necessarily comparable to later data from monitoring in isolated sections of the borehole. This is reflected in results from borehole sections HFM13:1, HFM21:3 and HFM27:2. 2) Previous or ongoing tests like hydraulic interference test and large scale tracer tests have affected some groundwaters. This impact is most obvious in section HFM15:1 this year as well as last year (heavy pumping in the nearby situated HFM14 before the sampling at both occasions /68/). The long pumping period might have had an effect also on other percussion boreholes and core drilled boreholes (e.g. KFM10A and KFM01D). 3) Furthermore, the percussion boreholes intersect large and highly transmissive fracture zones at shallow depths corresponding to the interface between meteoric and brackish water types and pumping may easily cause mixing of different waters.
- Increased sulphide concentrations compared to results from the initial chemical sampling have been observed during groundwater chemical monitoring in some of the boreholes. There seems to be a relation between sulphide concentration and pumped volume. The concentration is high from the start of the pumping but decreases as the pumping continues.

Furthermore, the largest sulphide increase was observed in borehole section KFM01D:2 (having a clearly non-marine groundwater at the initial CCC-sampling). Pumping in the monitored section within the subsequent monitoring programme, however, caused pressure responses in KFM01D:3 and a change in the water composition. The present groundwater in KFM01D:2 show a clear marine Littorina contribution. This mixing of water types may contribute to the sulphide increase. Sulphide production processes are not fully understood and will be further investigated in future special projects.

- The Uranium concentration in section KFM02A:3 continued to be very high and amounted to 148 µg/L at the late sampling occasion in October.

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Appendix 1

Sampling information

Idcode: section	Tube volume [dm³]	Section volume [dm³]	Total volume [dm³]	Pumping time	Flow rate [mL/min]	Pumped volume [dm³]	Sampling date	Sample no.	Pressure responses in other sections of the borehole
HFM01:2	0.1	30	30.1	4h 50 min	400	116	2007-04-10	12757	No
"	"	"	"	7h 21 min	450	198	2007-10-23	12890	No
HFM02:2	0.2	25	25.2	6h 29 min	214	83	2007-04-11	12761	No
"	"	"	"	22h 45 min	100	137	2007-10-23	12891	No
HFM04:2	0.8	20	20.8	5h 4 min	420	128	2007-02-20	12704	No
"	"	"	"	41h 10 min	90	222	2007-11-01	12912	No
HFM13:1	3.6	35	38.6	5h	430	129	2007-04-17	12768	No
"	"	"	"	22h 39 min	350	476	2007-10-17	12884	No
HFM15:1	1.5	25	26.5	4h 3 min	500	122	2007-04-12	12763	No
"	"	"	"	22h 5 min	100	133	2007-10-17	12885	No
HFM16:2	0.7	32.5	33.2	4h 51 min	375	109	2007-04-12	12765	No
"	"	"	"	28h 32 min	140	240	2007-10-23	12892	No
HFM19:1	3.9	35	38.9	4h 58 min	500	149	2007-04-12	12763	No
"	"	"	"	20h 52 min	180	225	2007-10-17	12886	No
HFM21:3	0.1	25	25.1	2h 53 min	500	87	2007-04-10	12758	No
"	"	"	"	22h 16 min	150	200	2007-10-23	12893	No
HFM27:2	0.5	30	30.5	6h 14 min	290	108	2007-04-11	12760	No
"	"	"	"	62h 55 min	80	302	2007-10-26	12896	No
HFM32:3	0.1	12.5	12.6	3h 53 min	500	117	2007-04-17	12767	No
"	"	"	"	1h	1,000	60	2007-11-12	12913	No

Idcode: section	Tube volume [dm^3]	Section volume [dm^3]	Total volume [dm^3]	Pumping-time	Flow rate [mL/min]	Pumped volume [dm^3]	Sampling-date	Sample no.	Pressure responses in other sections of the borehole
KFM01A:5	2.0	21	23.0	67h 5 min	60	242	2007-04-23	12770	No
"	"	"	"	65h 28 min	70	275	2007-10-19	12855	No
KFM01D:2	11.0	9	20.0	66h 43 min	100	400	2007-04-23	12772	Yes; KFM01D:3
"	"	"	"	65h 40 min	80	315	2007-10-19	12888	"
"	"	"	"	1h 1 min	200	12	2008-01-30	12953	"
"	"	"	"	2h 51 min	200	34	2008-01-30	12954	"
"	"	"	"	17h 1 min	350	357	2008-01-31	12955	"
KFM01D:4	7.7	10	17.7	5 h 19 min	200	64	2007-04-18	12771	Yes; KFM01D:5
"	"	"	"	66h	80	317	2007-10-19	12889	"
KFM02A:3	12.7	28	40.7	24h 54 min	420	627	2007-02-14	12700	Unclear, possibly KFM02A:4
"	"	"	"	23h 37 min	100	142	2007-10-30	12899	No
KFM02A:5	10.5	31	41.5	24h 54 min	132	197	2007-02-14	12701	Probably not, unclear
"	"	"	"	23h 20 min	150	210	2007-10-30	12901	No
KFM02B:2	12.8	15	27.8	20h 24 min	150	184	2007-10-30	12898	No
KFM02B:4	10.5	21	31.5	20h 24 min	150	184	2007-10-30	12900	No
KFM03A:1	26.3	25	51.3	48h 41 min	66	193	2007-03-02	12711	Yes; KFM03A:2
"	"	"	"	73h 55 min	70	310	2007-10-15	12849	"
KFM03A:4	16.9	16.5	33.4	23h 2 min	140	193	2007-03-01	12708	No
"	"	"	"	73h 53 min	200	887	2007-10-15	12850	No
KFM04A:4	5.4	15	20.4	2h 26 min	500	73	2007-04-11	12759	No
"	"	"	"	40h 59 min	90	220	2007-11-01	12911	No
KFM06A:3	19.7	10	29.7	–	70	pump-failure	–	no sample	Yes; KFM06A:2
KFM06A:5	8.5	21	29.5	66h 48 min	100	401	2007-10-26	12897	Yes; KFM06A:4
KFM07A:2	26.1	10	36.1	168h 10 min	~20	202	2007-03-20	12729	Yes; KFM07A:1
"	"	"	"	68h 53 min	~20	83	2007-10-26	12895	"
KFM08A:2	18.2	10	28.2	40 min	450	18	2008-01-22	12947	No
"	"	"	"	2h 39 min	200	32	2008-01-22	12950	No
"	"	"	"	6h 15 min	250	94	2008-01-22	12952	No
KFM08A:6	6.4	15	21.4	33 min	250	8	2008-01-22	12946	Yes; KFM08A:7
"	"	"	"	2h 33 min	200	31	2008-01-22	12949	"
"	"	"	"	5h 55 min	200	71	2008-01-22	12951	"
KFM08D:2	18.2	10	28.2	–	20	pump-failure	–	no sample	Unclear, possibly KFM08D:3
KFM08D:4	17.5	20	37.5	1h 48 min	150	16	2008-01-22	12948	Unclear, possibly KFM08D:3
"	"	"	"	–	–	pump failure	–	no sample	"
KFM10A:2	11.0	10	21.0	4h 42 min	500	141	2007-04-17	12769	Yes; KFM10A
"	"	"	"	25h 52 min	200	310	2007-10-17	12883	"
KFM11A:2	18.4	20	38.4	22h 42 min	300	409	2007-10-09	12831	No
KFM11A:4	11.5	10	21.5	22h 29 min	100	135	2007-10-09	12829	No

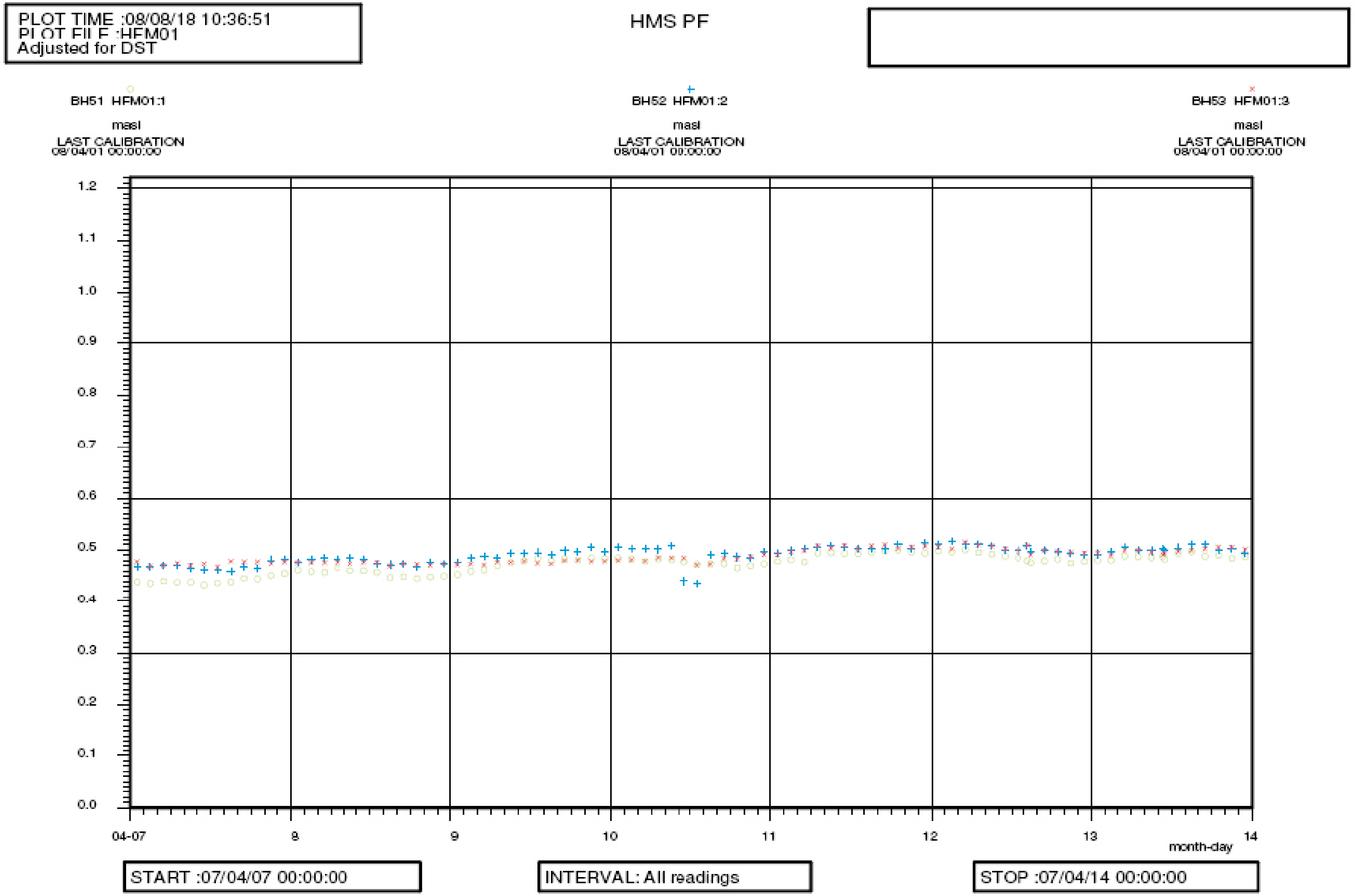

Figure A2-1. *Pumping and minor drawdown in HFM01:2 in April 2007. None of the other sections were affected by the pumping.*

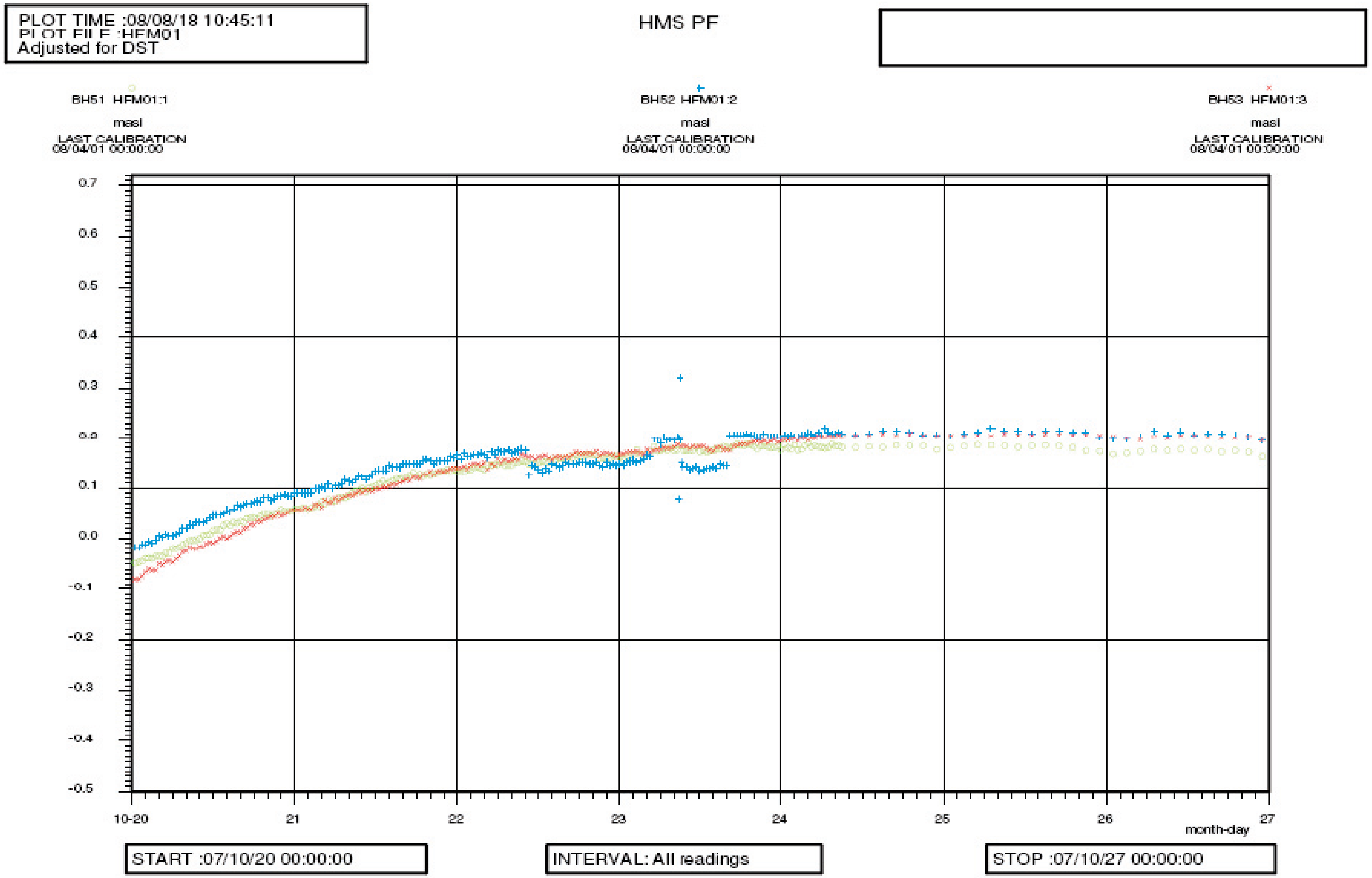

Figure A2-2. *Pumping and drawdown in HFM01:2 in October 2007. None of the other sections were significantly affected by the pumping. The borehole is recovering after interference tests, therefore the initial positive slope.*

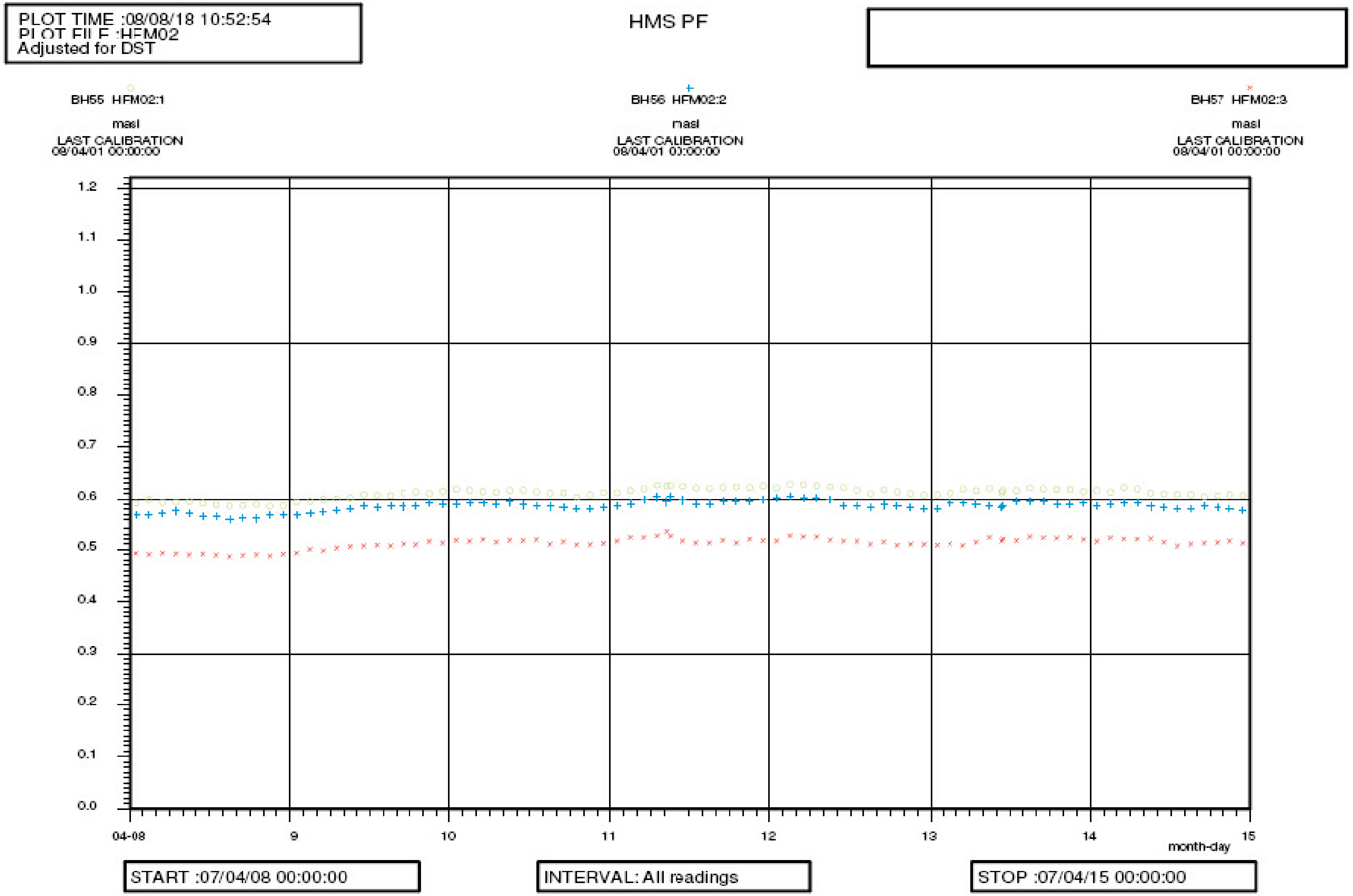

Figure A2-3. *Pumping in HFM02:2 in April 2007. No significant drawdown was observed in any of the borehole sections.*

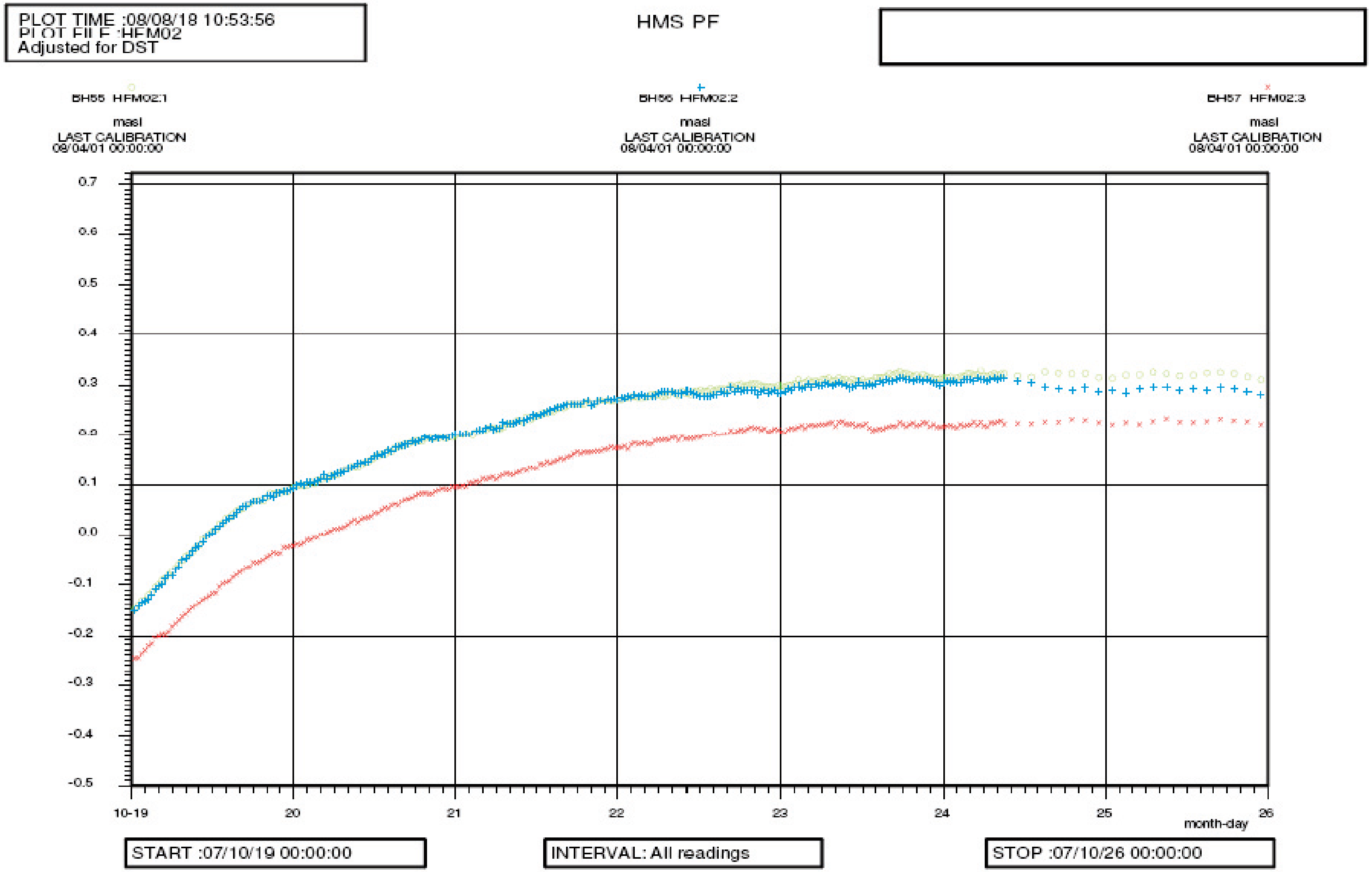

Figure A2-4. *Pumping in HFM02:2 during October 2007. No significant drawdown was observed in any of the borehole sections. The borehole is recovering from interference tests, therefore the initial slope.*

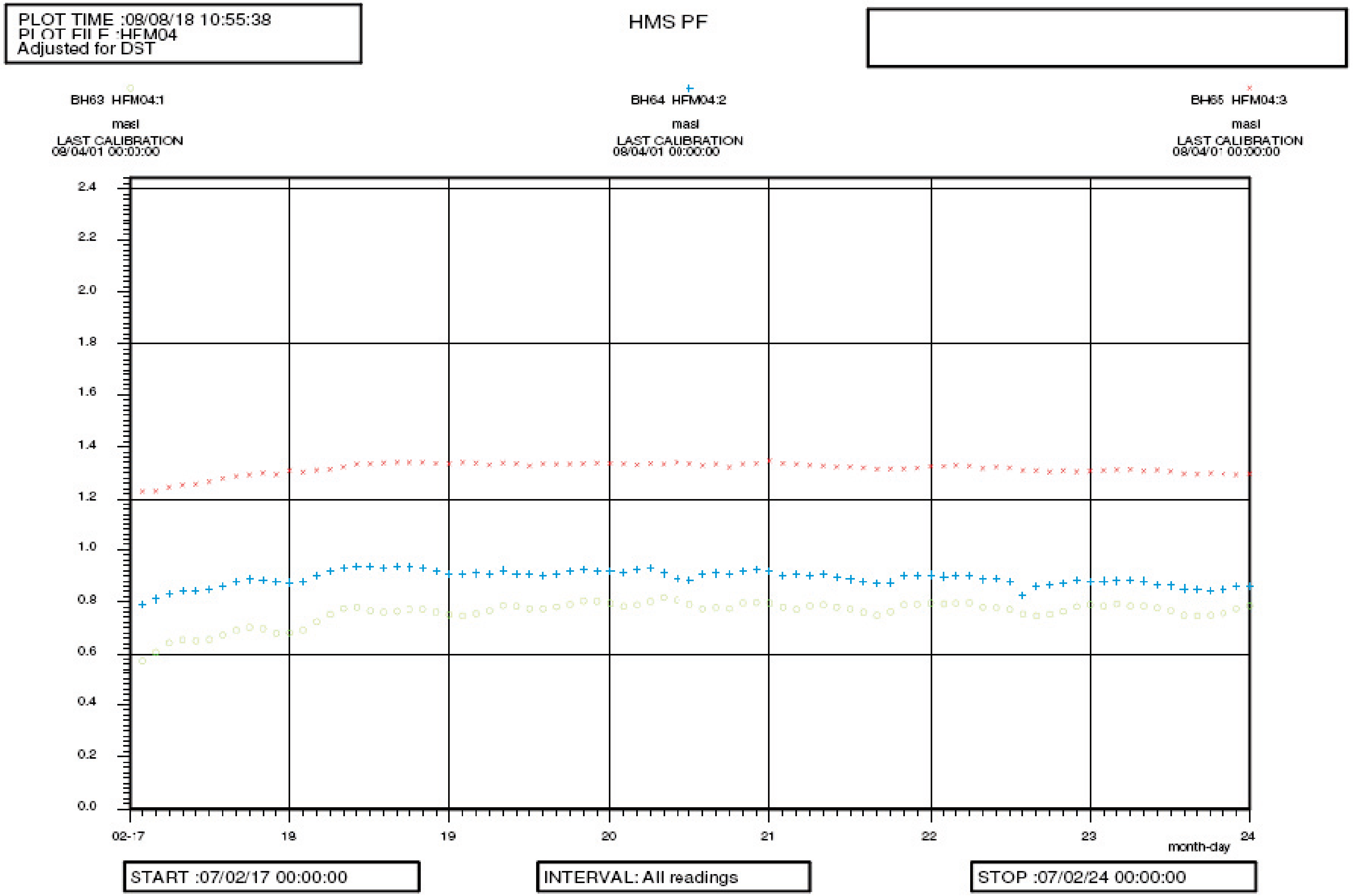

Figure A2-5. *Pumping in HFM04:2 in Februari 2007. No significant drawdown was observed in any of the borehole sections.*

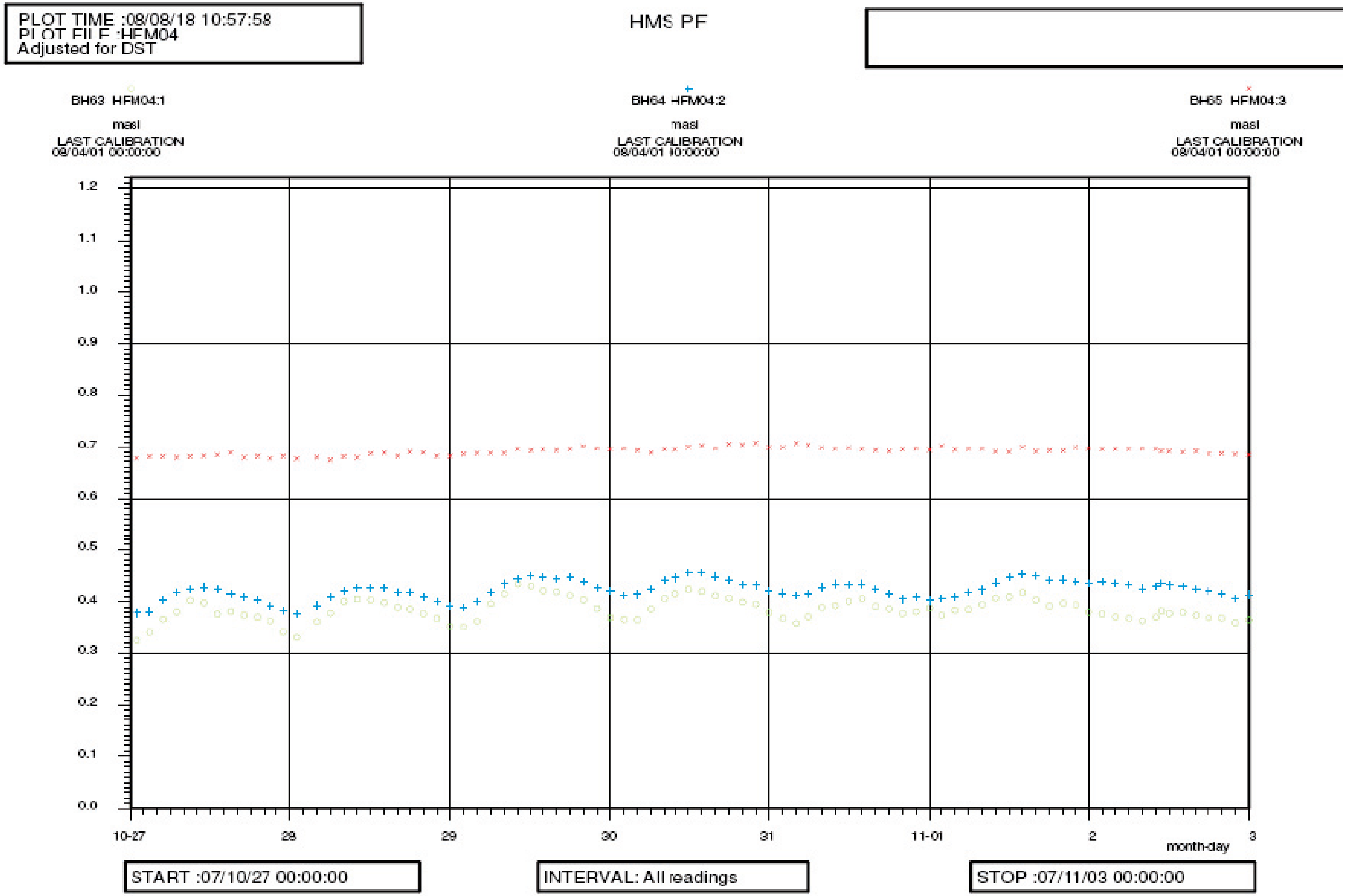

Figure A2-6. *Pumping in HFM04:2 in October 2007. No significant drawdown was observed in any of the borehole sections.*

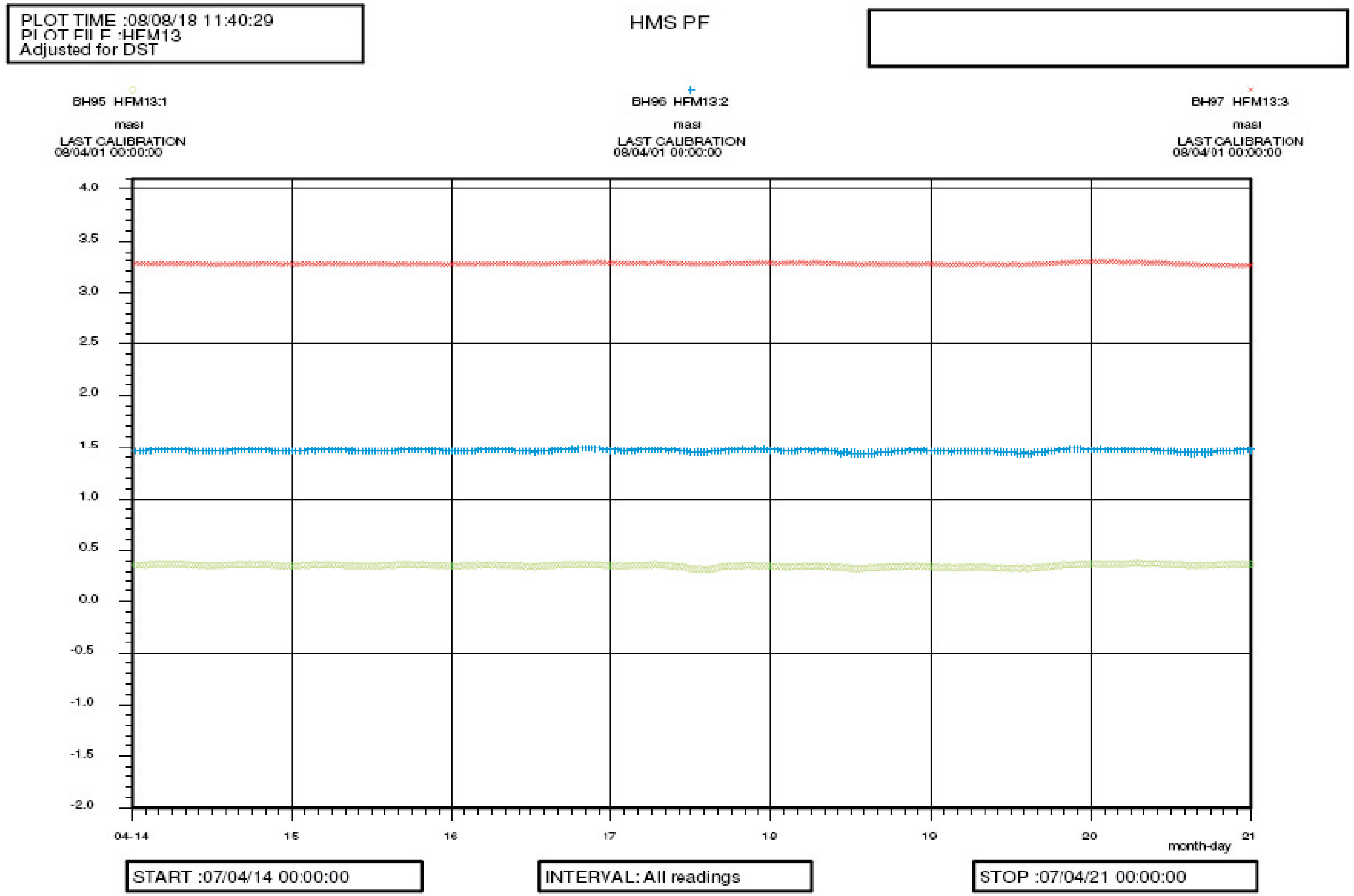

Figure A2-7. *Pumping in HFM13:1 in April 2007. No significant drawdown was observed in any of the borehole sections.*

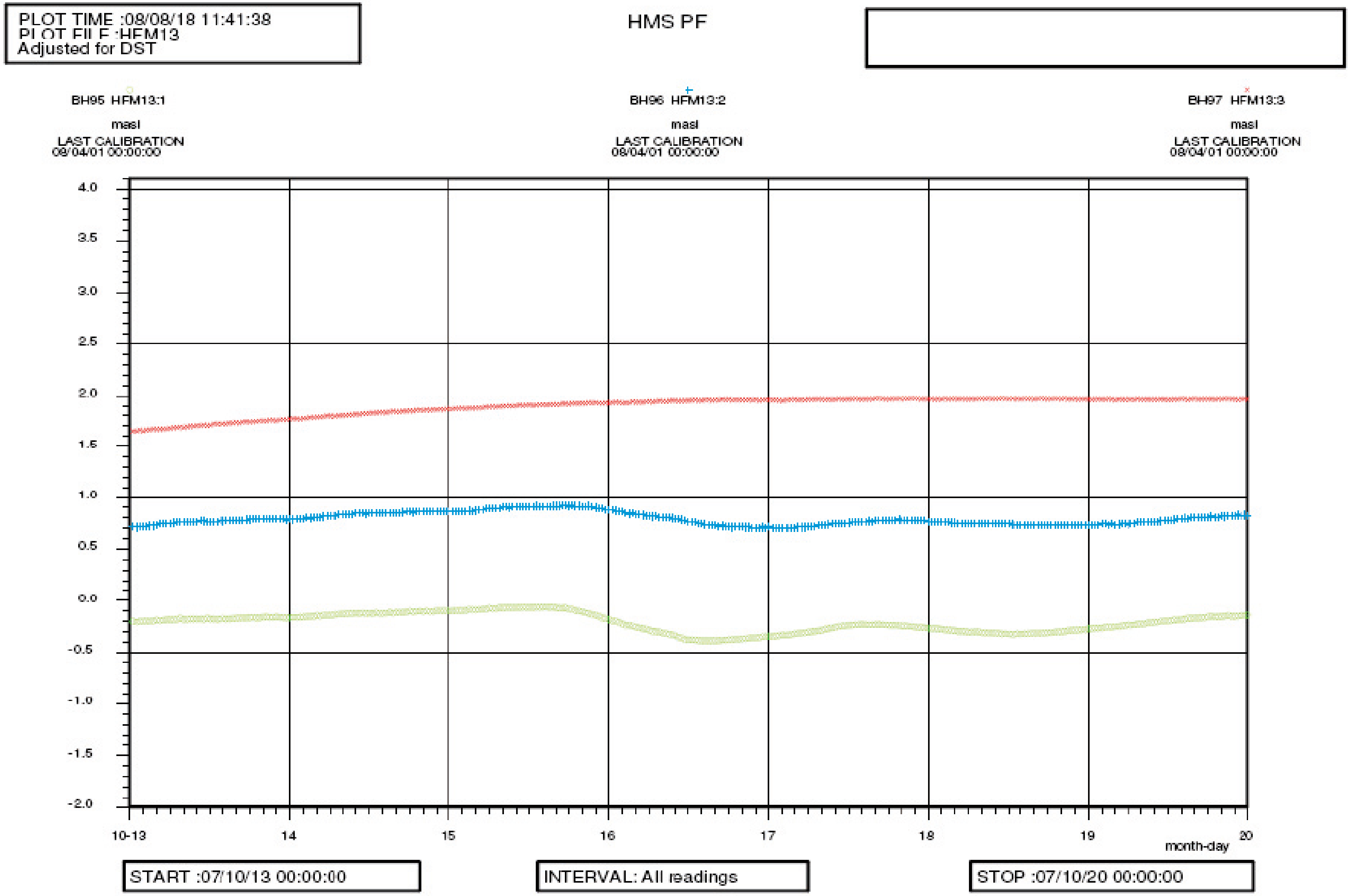

Figure A2-8. *Pumping in HFM13:1 in October 2007. No significant drawdown was observed in any of the borehole sections. The observed pressure variations were not due to the pumping.*

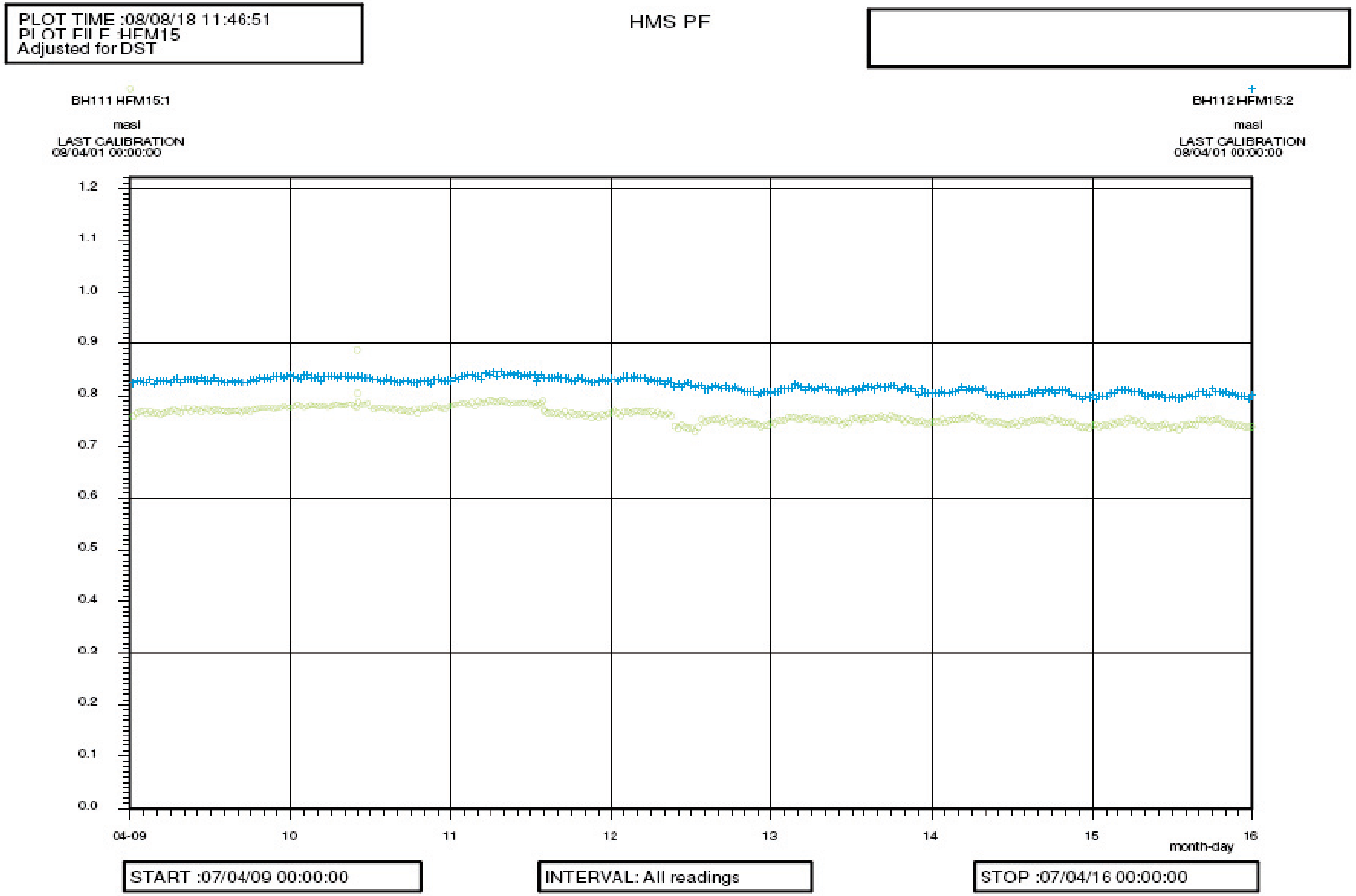

Figure A2-9. *Pumping in HFM15:1 during April 2007. No significant drawdown was observed in any of the borehole sections.*

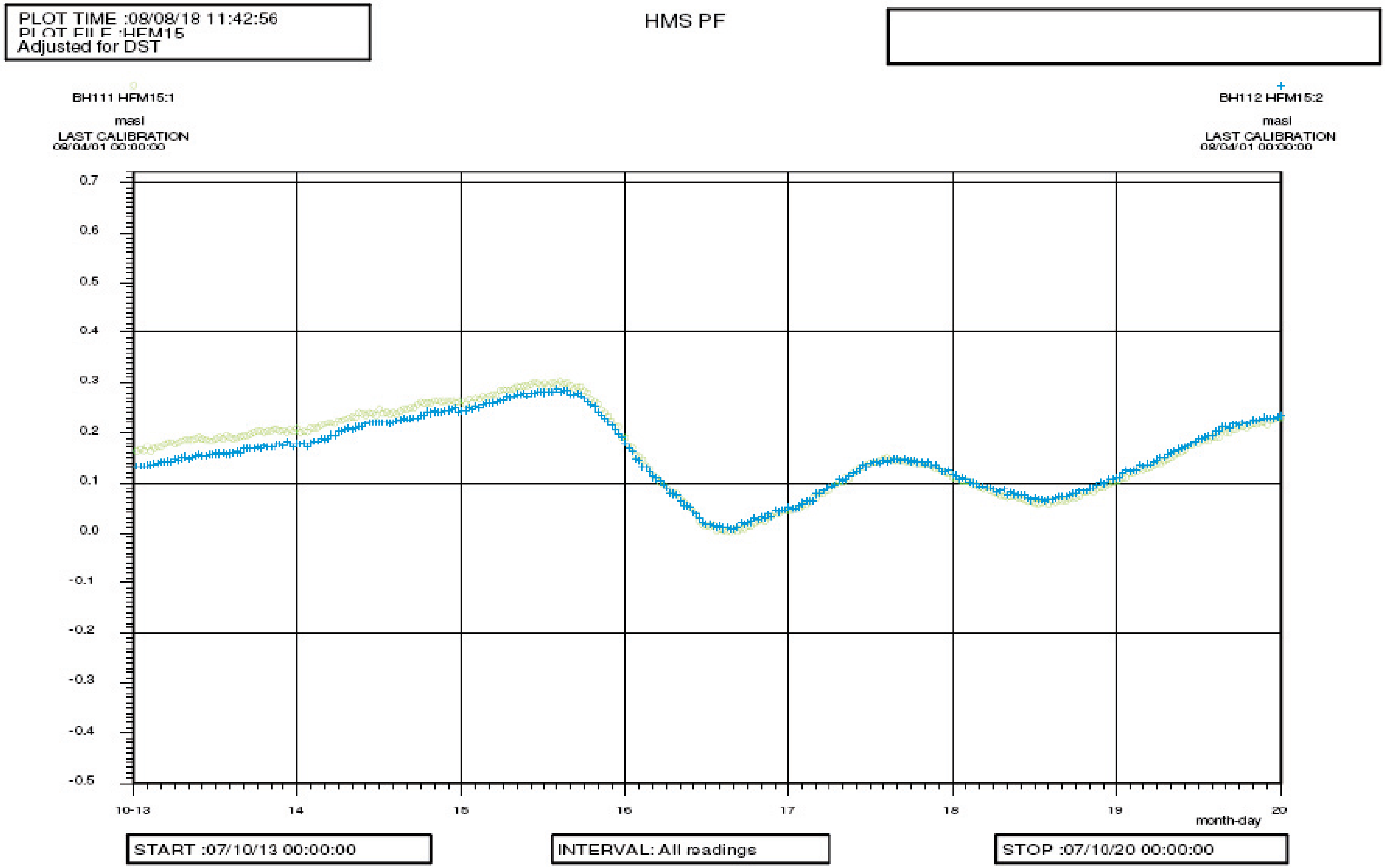

Figure A2-10. *Pumping in HFM15:1 in October 2007. No significant drawdown was observed in any of the borehole sections. The observed pressure variations were not due to the pumping.*

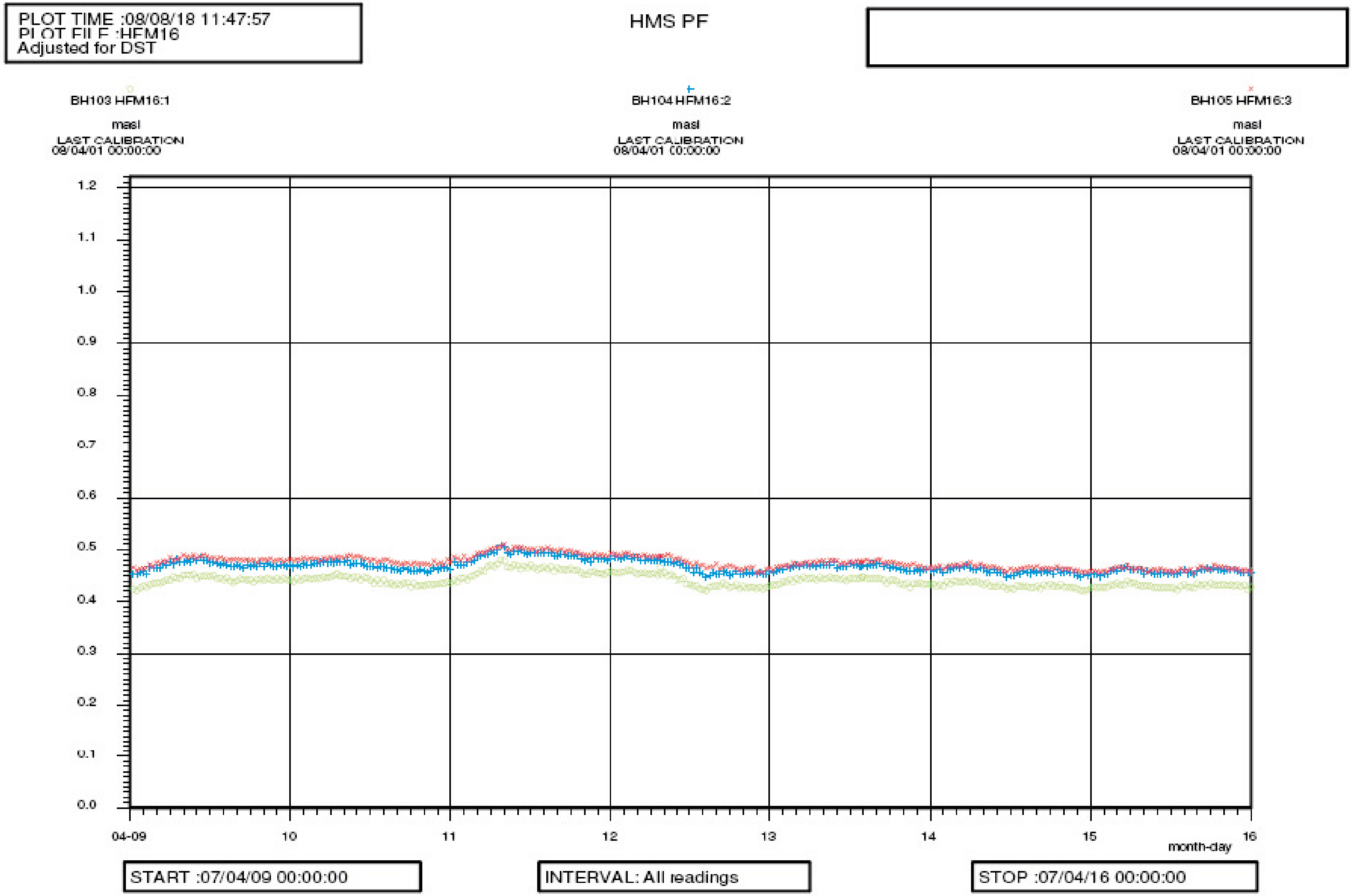

Figure A2-11. *Pumping in HFM16:2 in April 2007. No significant drawdown was observed in any of the borehole sections.*

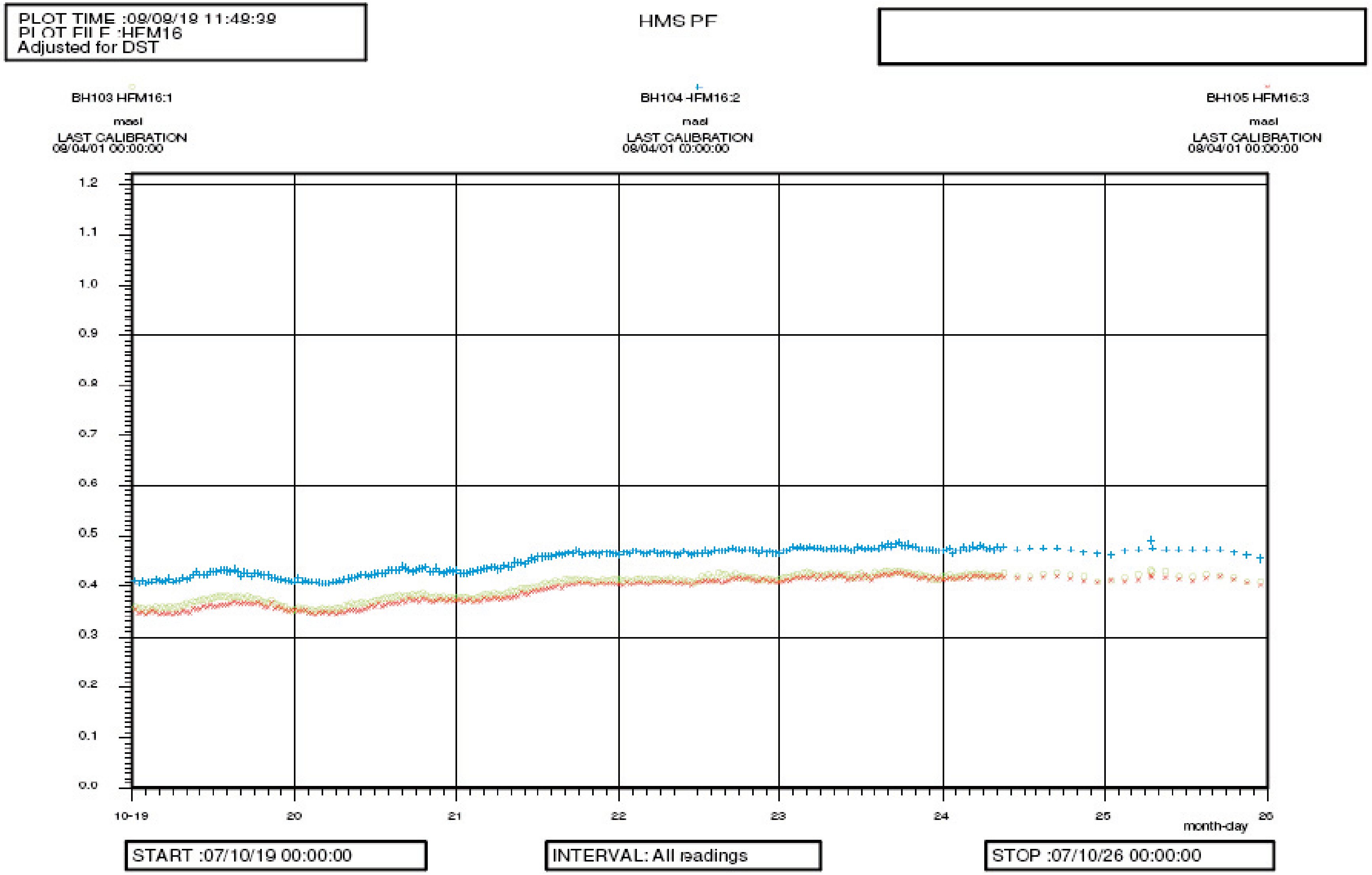

Figure A2-12. *Pumping in HFM16:2 in October 2007. No significant drawdown was observed in any of the borehole sections.*

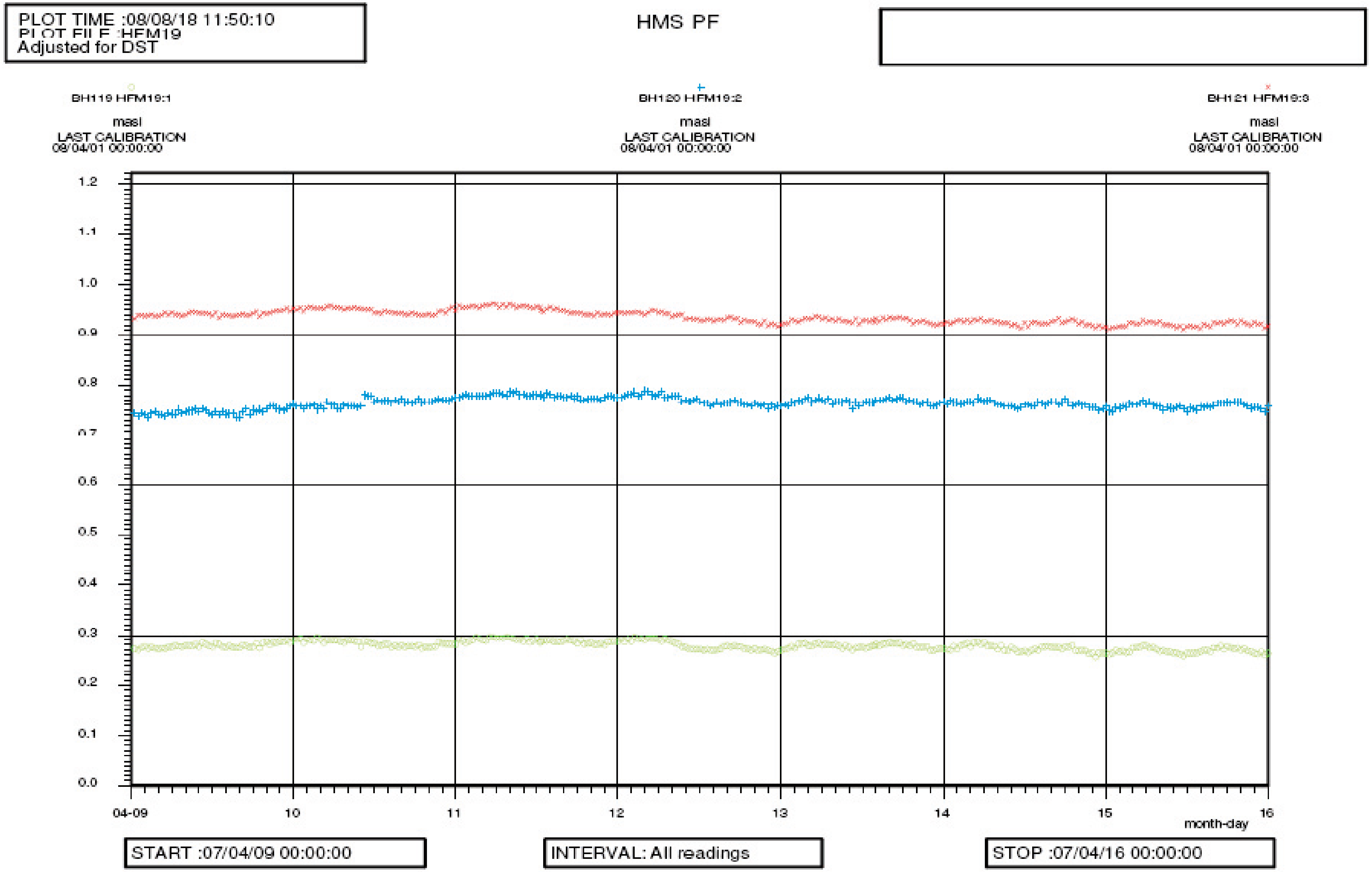

Figure A2-13. *Pumping in HFM19:1 in April 2007. No significant drawdown was observed in any of the borehole sections*

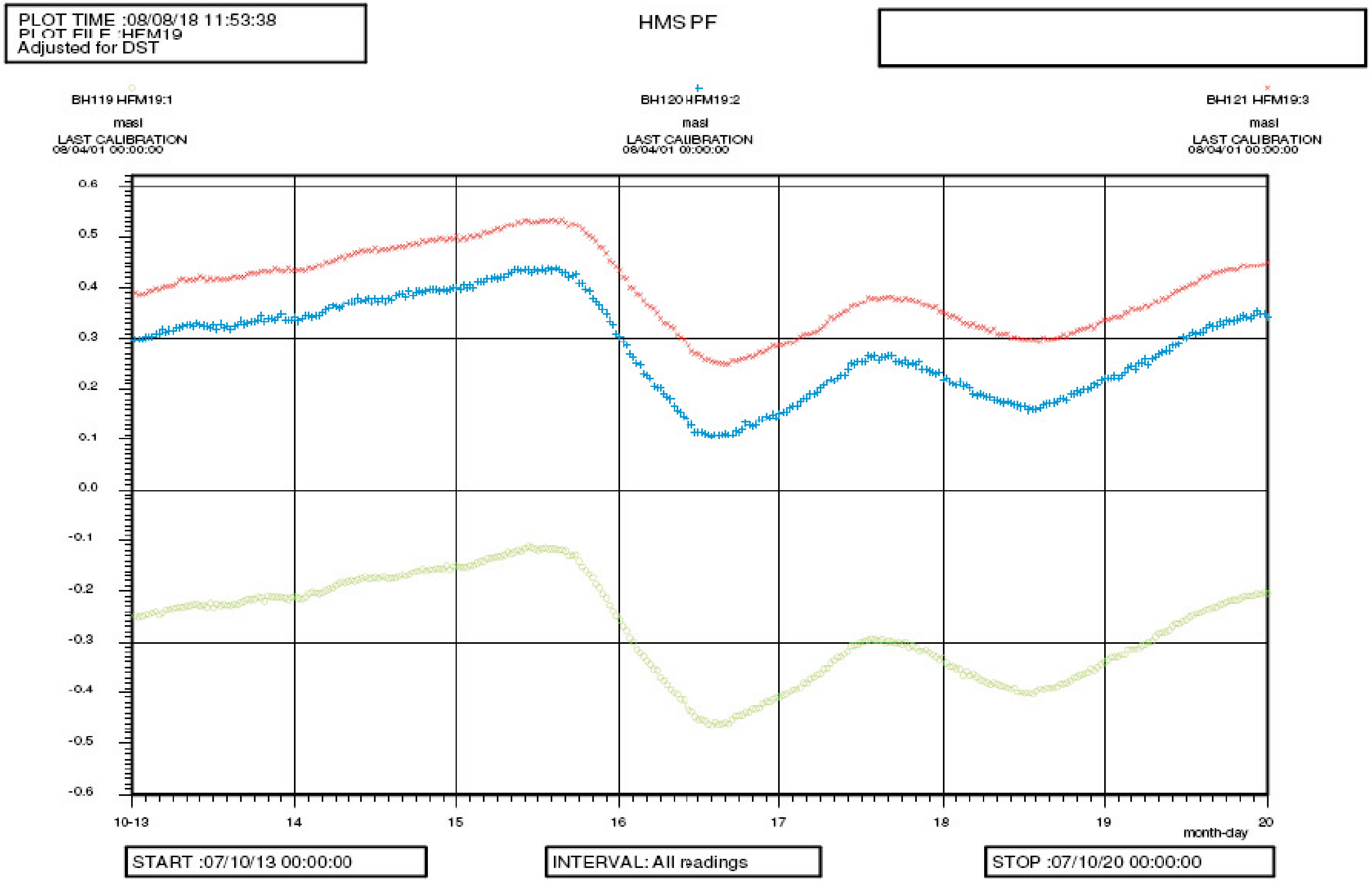

Figure A2-14. *Pumping in HFM19:1 in October 2007. No significant drawdown was observed in any of the borehole sections. The observed pressure variations were not due to the pumping.*

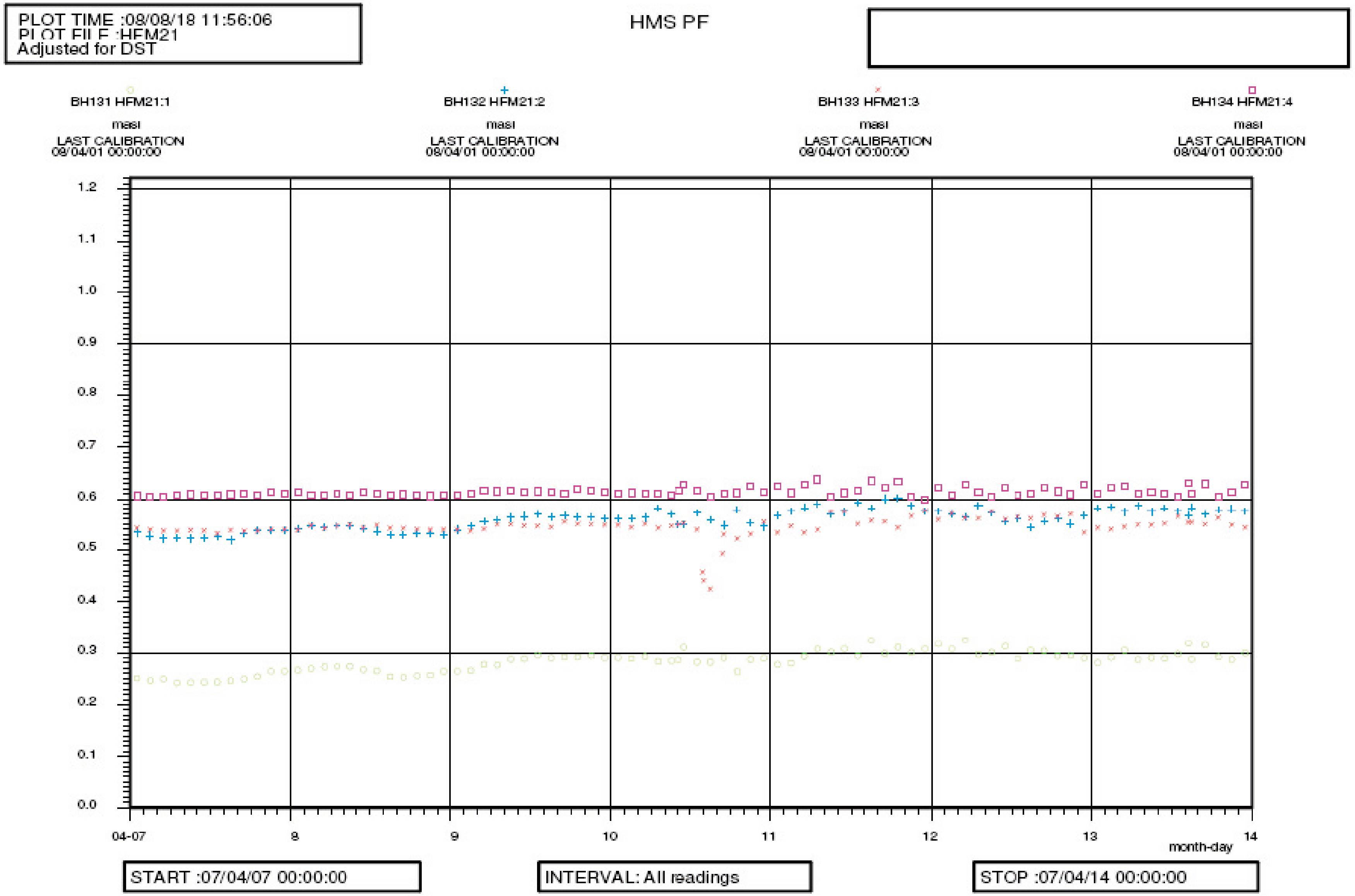

Figure A2-15. *Pumping and drawdown in HFM21:3 in April 2007. None of the other sections were affected by the pumping.*

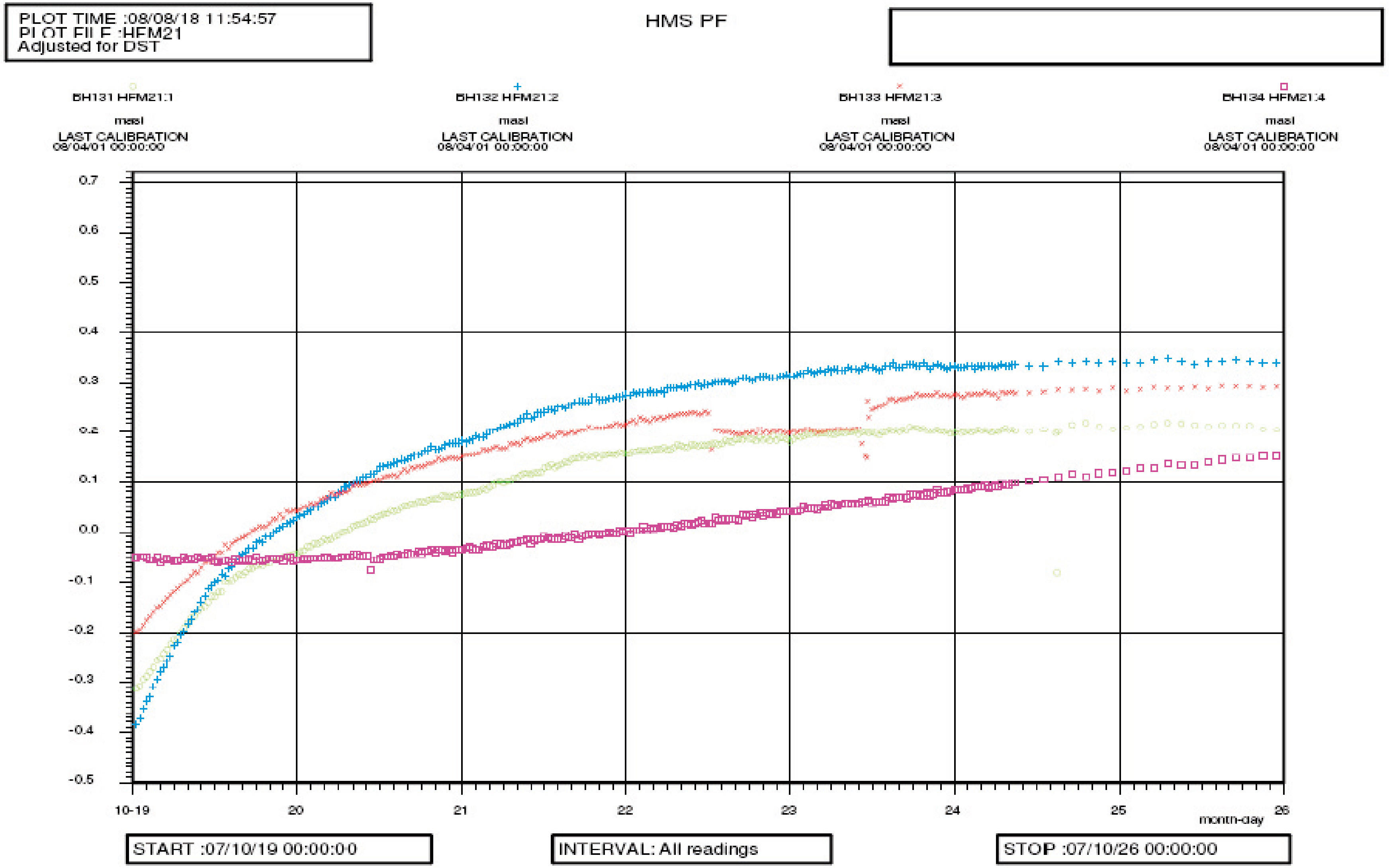

Figure A2-16. *Pumping and drawdown in HFM21:3 in October 2007. None of the other sections were affected by the pumping. The borehole is recovering from interference tests, therefore the initial slope.*

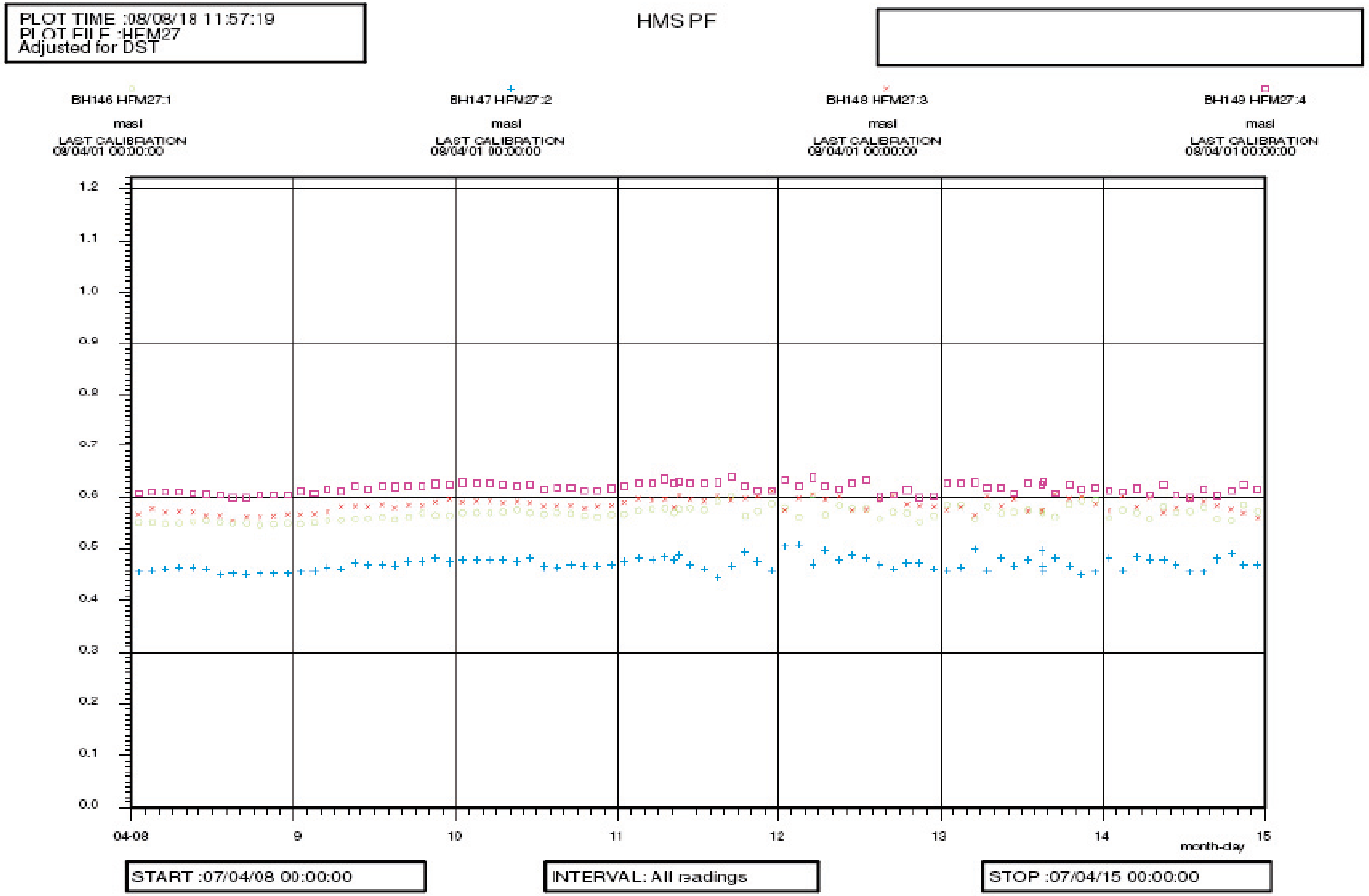

Figure A2-17. Pumping in HFM27:2 in April 2007. No significant drawdown was observed in any of the borehole sections.

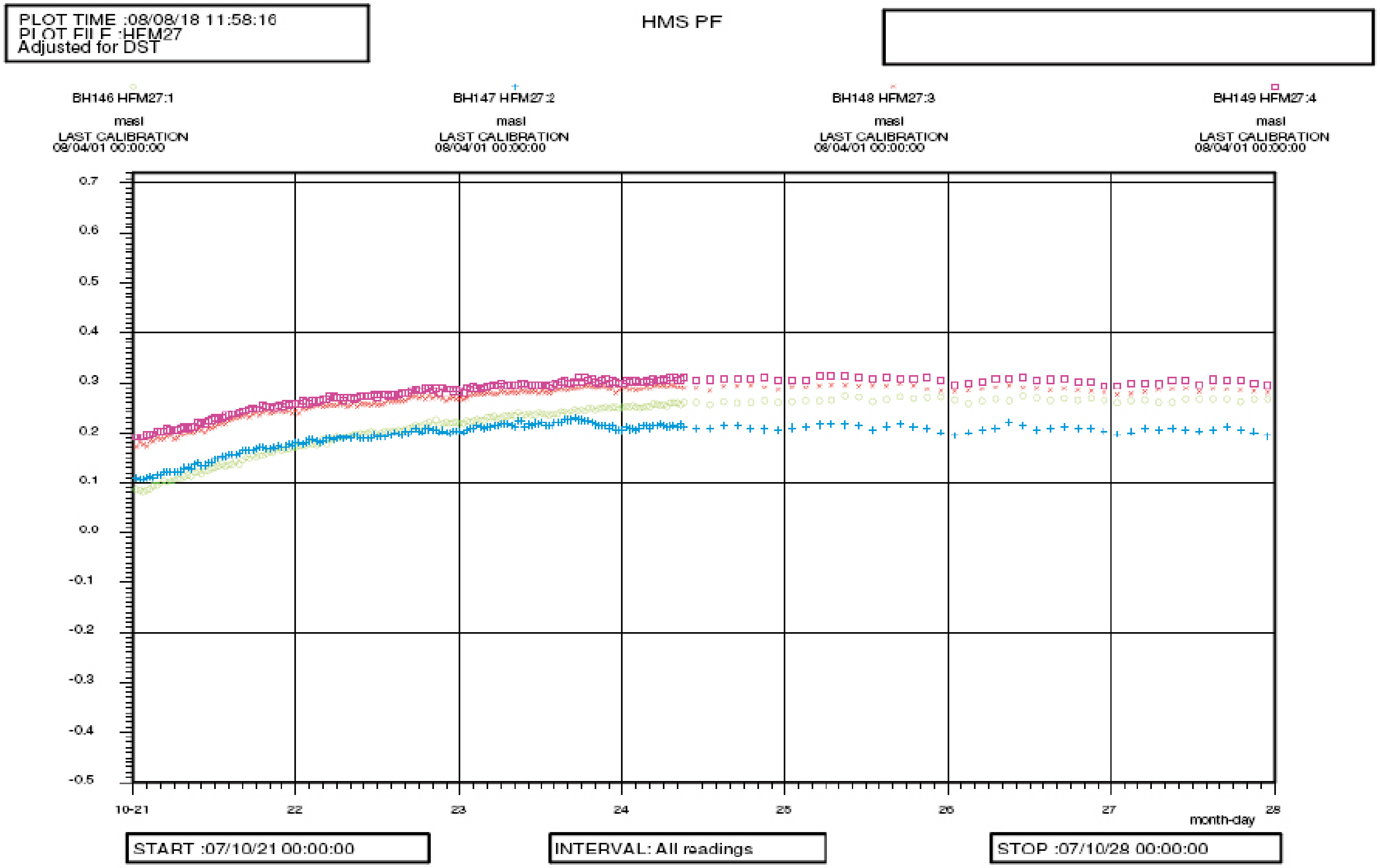

***Figure A2-18.** Pumping in HFM27:2 in October 2007. No significant drawdown was observed in any of the borehole sections.*

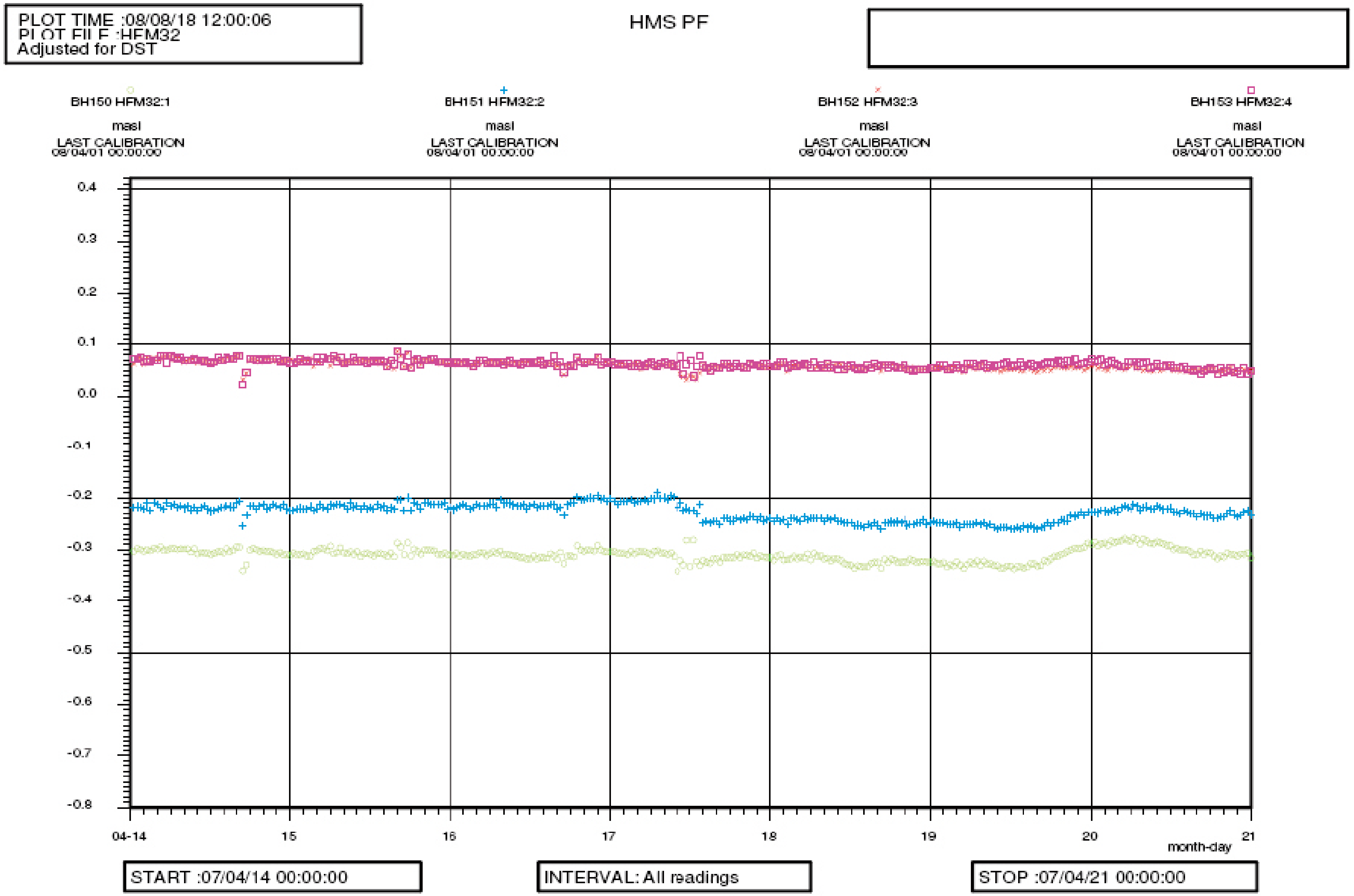

Figure A2-19. *Pumping in HFM32:3 in April 2007. No significant drawdown was observed in any of the borehole sections.*

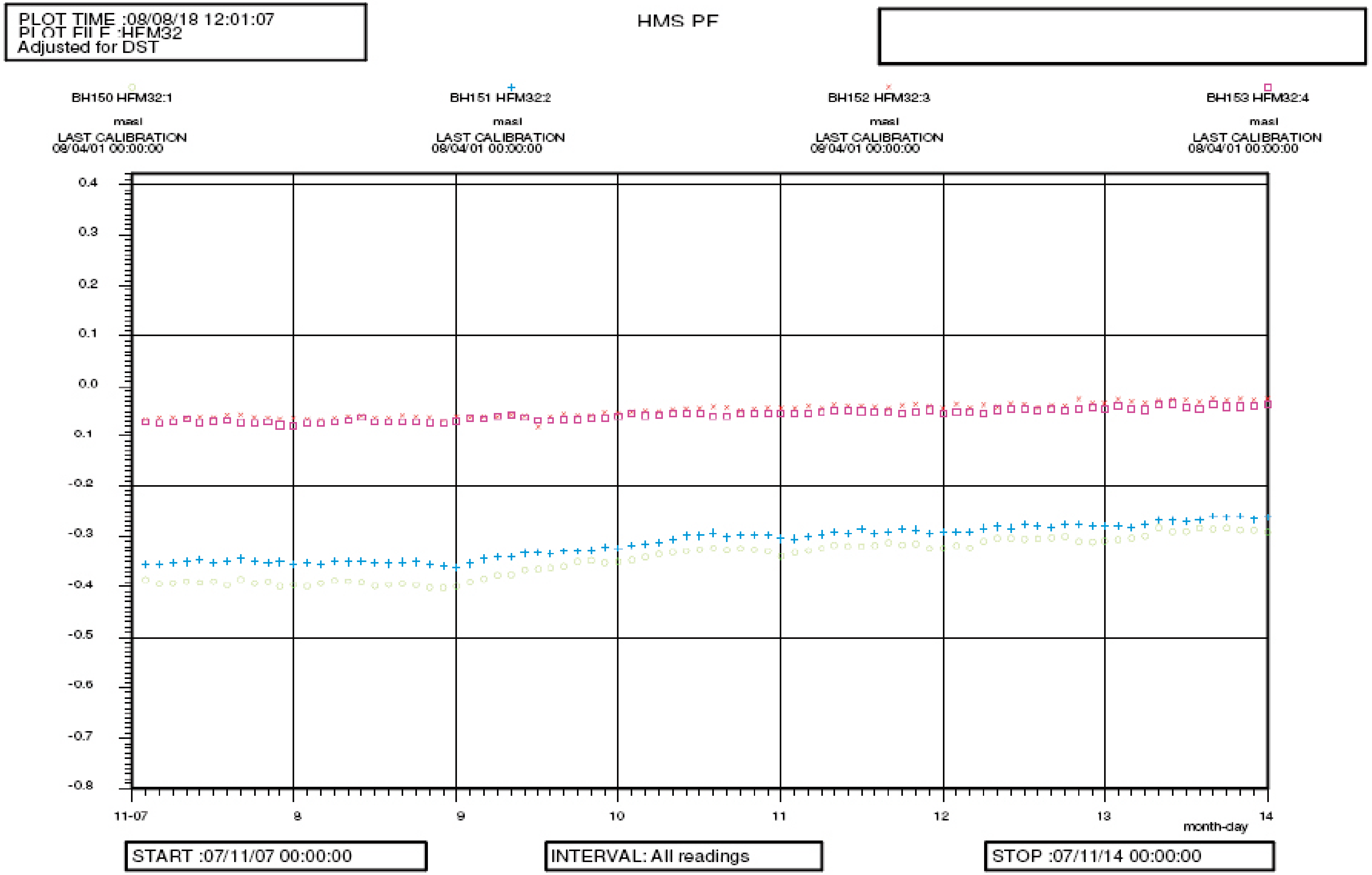

Figure A2-20. *Pumping in HFM32:3 in November 2007. No significant drawdown was observed in any of the borehole sections.*

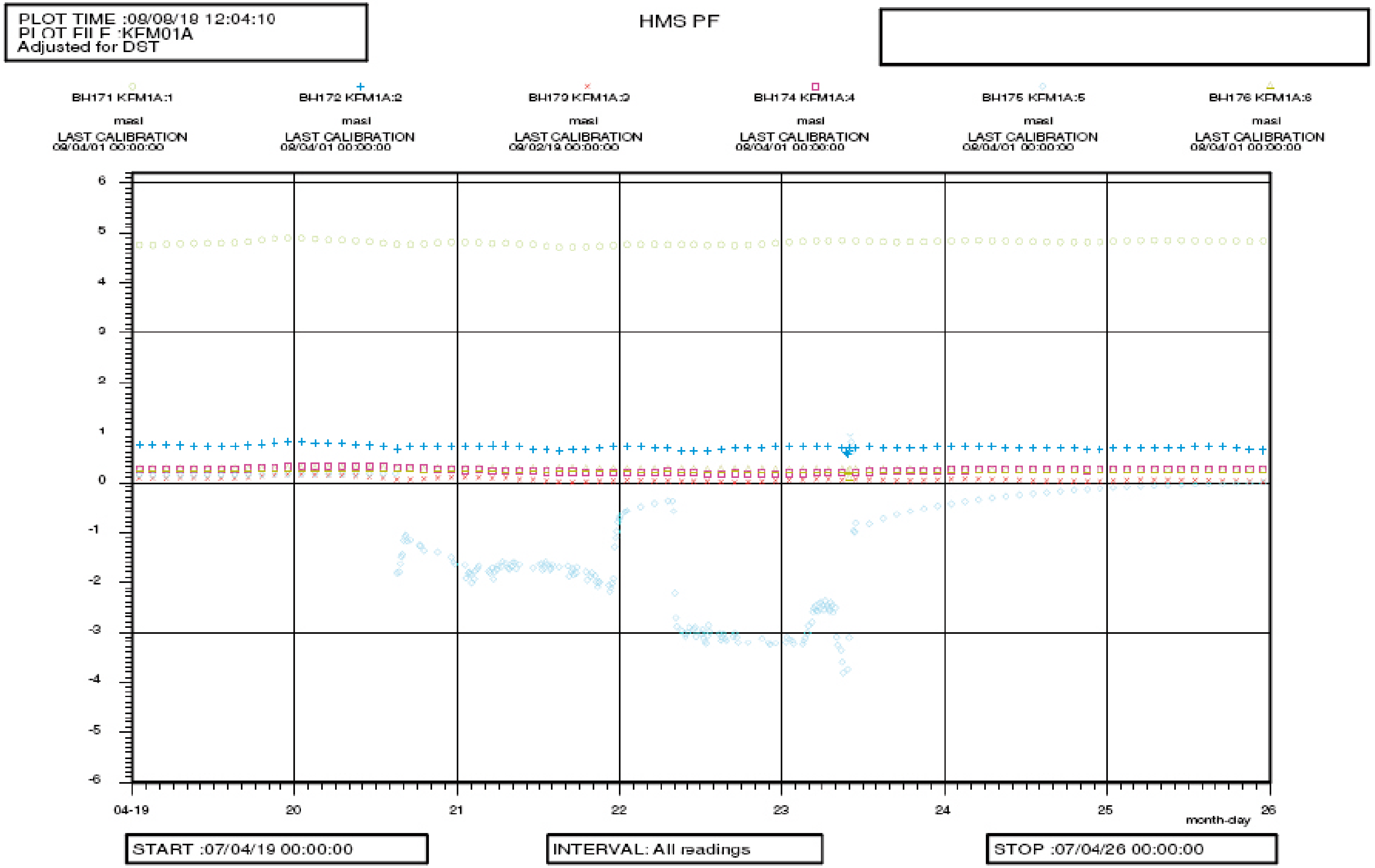

Figure A2-21. *Pumping and drawdown in KFM01A:5 in April 2007. None of the other borehole sections were affected by the pumping.*

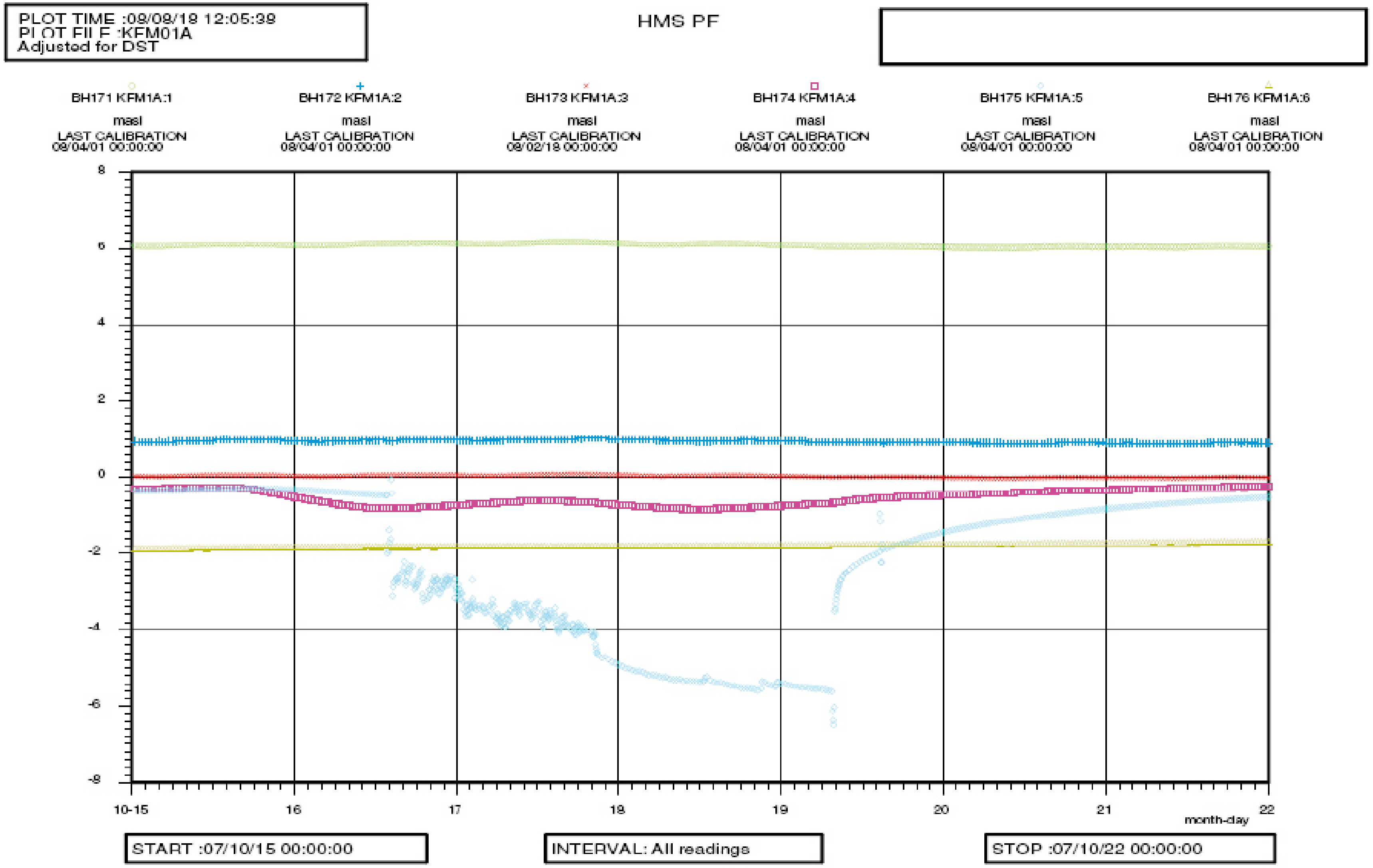

Figure A2-22. *Pumping and drawdown in KFM01A:5 during October 2007. None of the other borehole sections were affected by the pumping.*

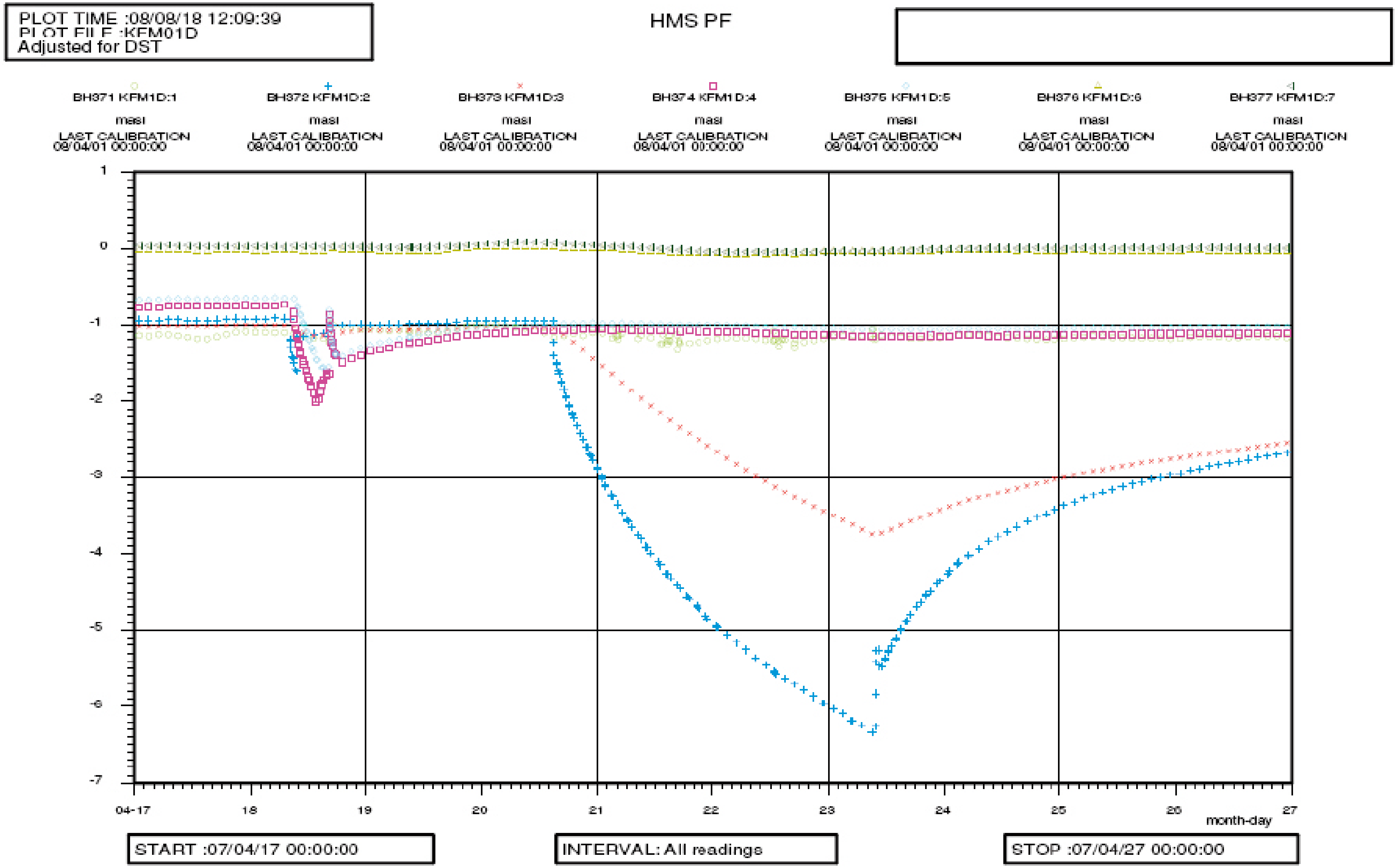

Figure A2-23. *Pumping and drawdown in KFM01D:4 and KFM01D:2 in April 2007. From pumping in KFM01D:4 a response was observed in KFM01D:5 and the pumping in section KFM01D:2 caused a clear response in section KFM01D:3.*

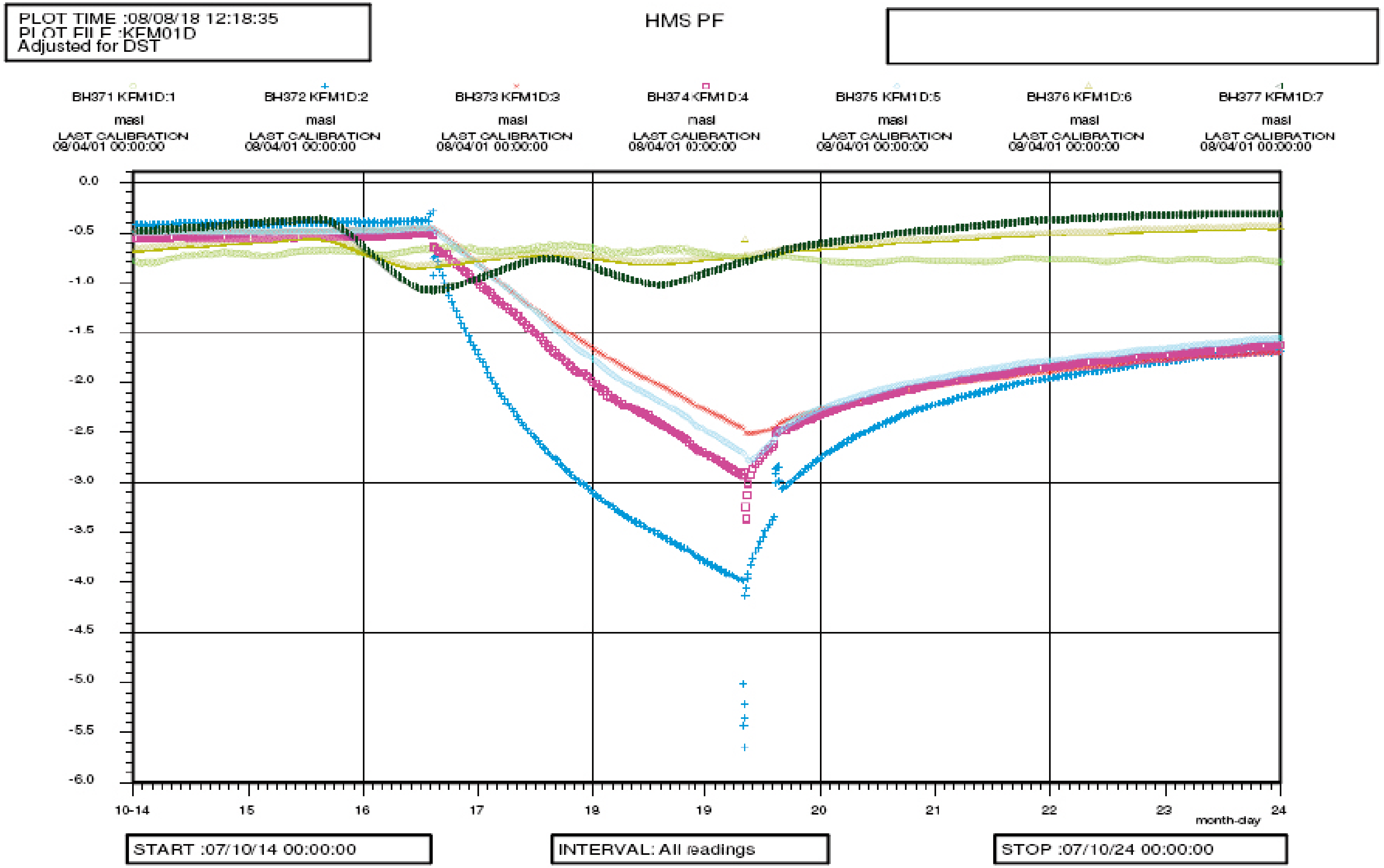

Figure A2-24. *Pumping and drawdown in KFM01D:4 and KFM01D:2 in October 2007. Pumping was performed in both sections at the same time. Information from the previous sampling in April revealed that pumping in KFM01D:4 affects section KFM01D:5 and pumping in KFM01D:2 affects section KFM01D:3.*

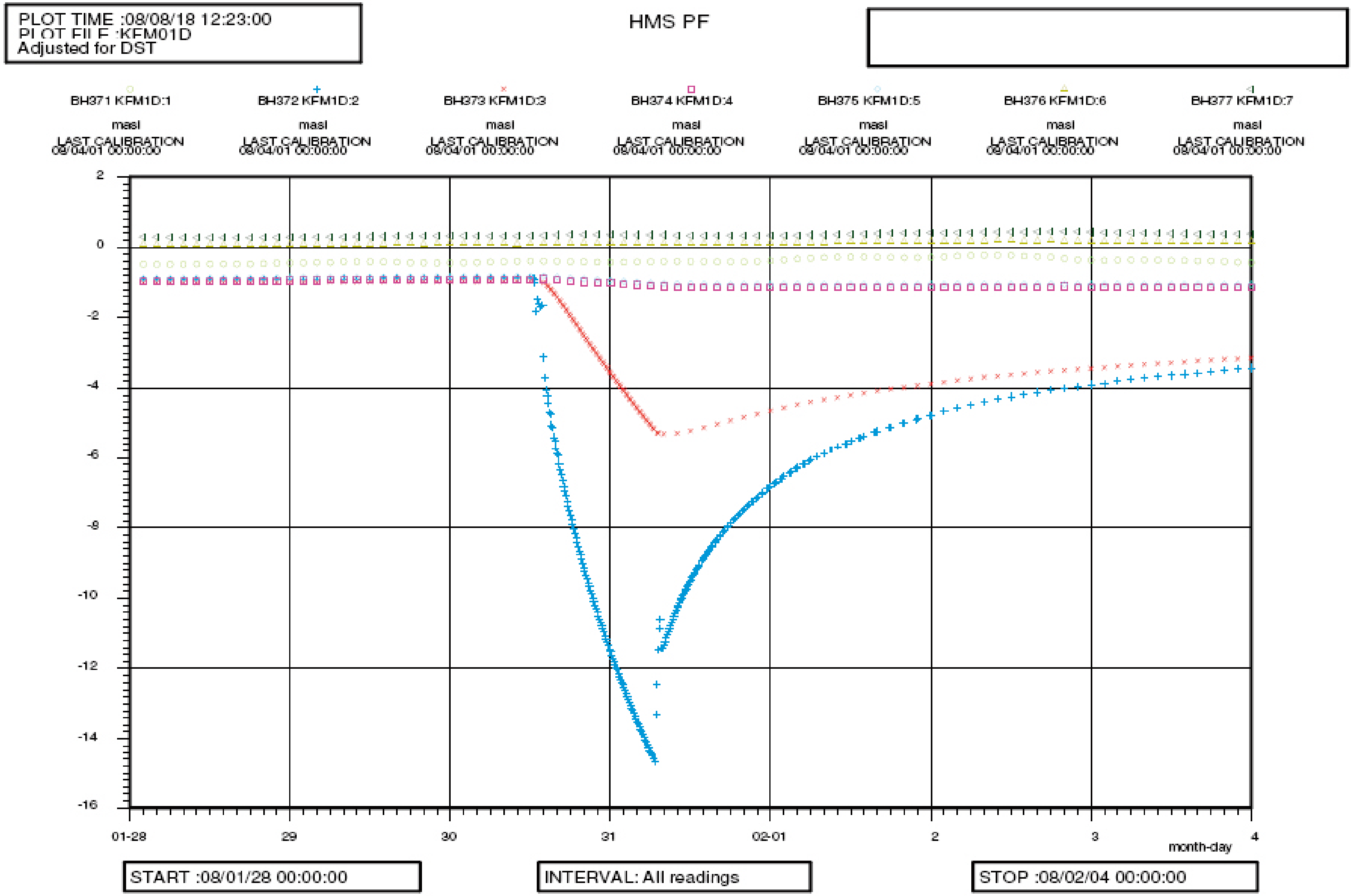

Figure A2-25. *Pumping and drawdown in KFM01D:2 in January 2008. Again a clear effect from the pumping was observed in section KFM01D:3.*

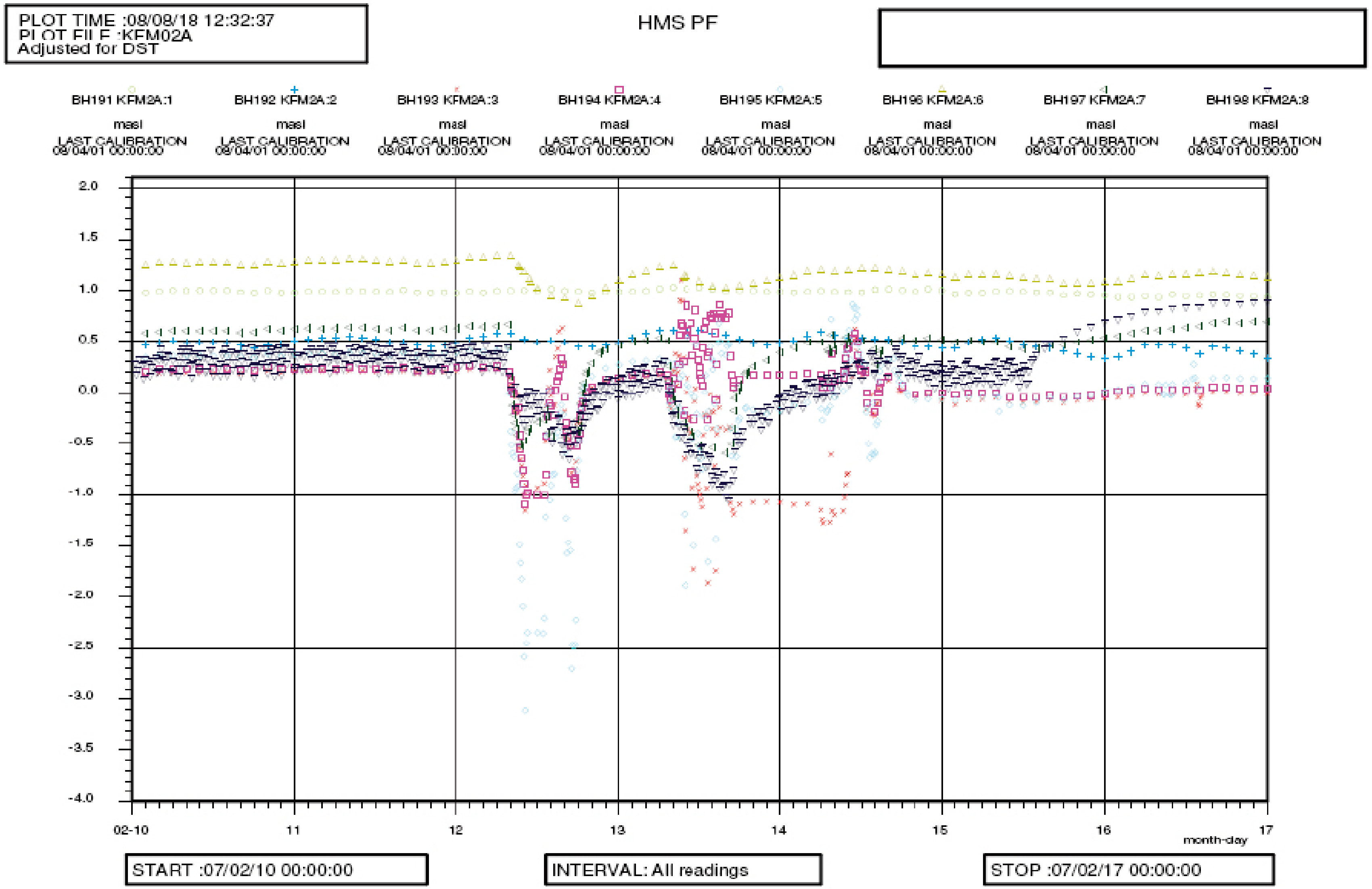

***Figure A2-26.** Pumping and drawdown in KFM02A:3 and KFM02A:5 in February 2007. Pumping was performed in both sections simultaneously. The pressure changes observed in section KFM02A:4 may be caused by the pumping in KFM02A:3. However, the pressure changes observed in sections KFM02A:6, KFM02A:7, KFM02A:8 and KFM02A:9 probably have other reasons.*

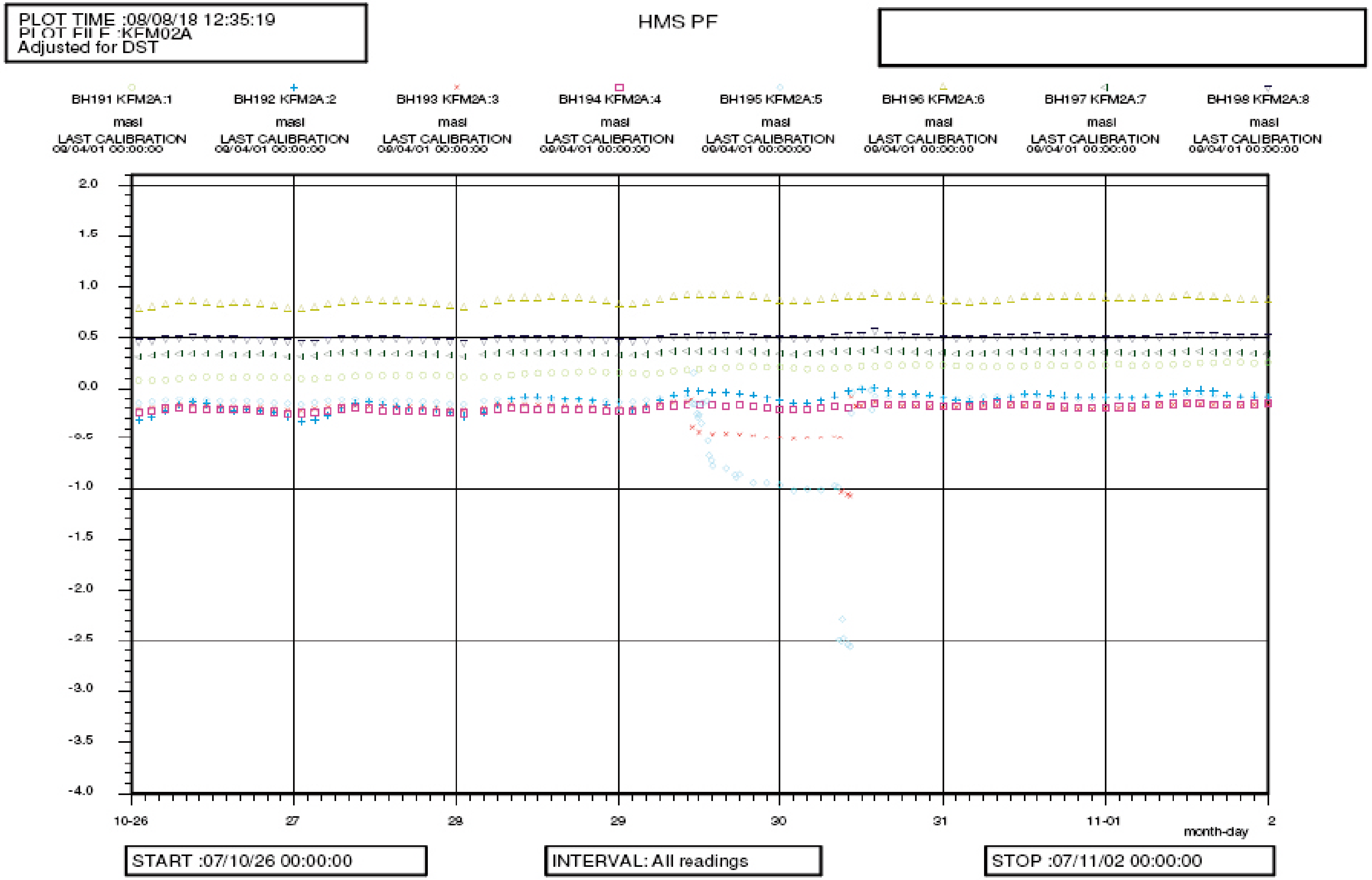

Figure A2-27. *Pumping and drawdown in KFM02A:3 and KFM02A:5 in October 2007. Pumping was performed simultaneously in both sections. None of the other borehole sections were affected by the pumping.*

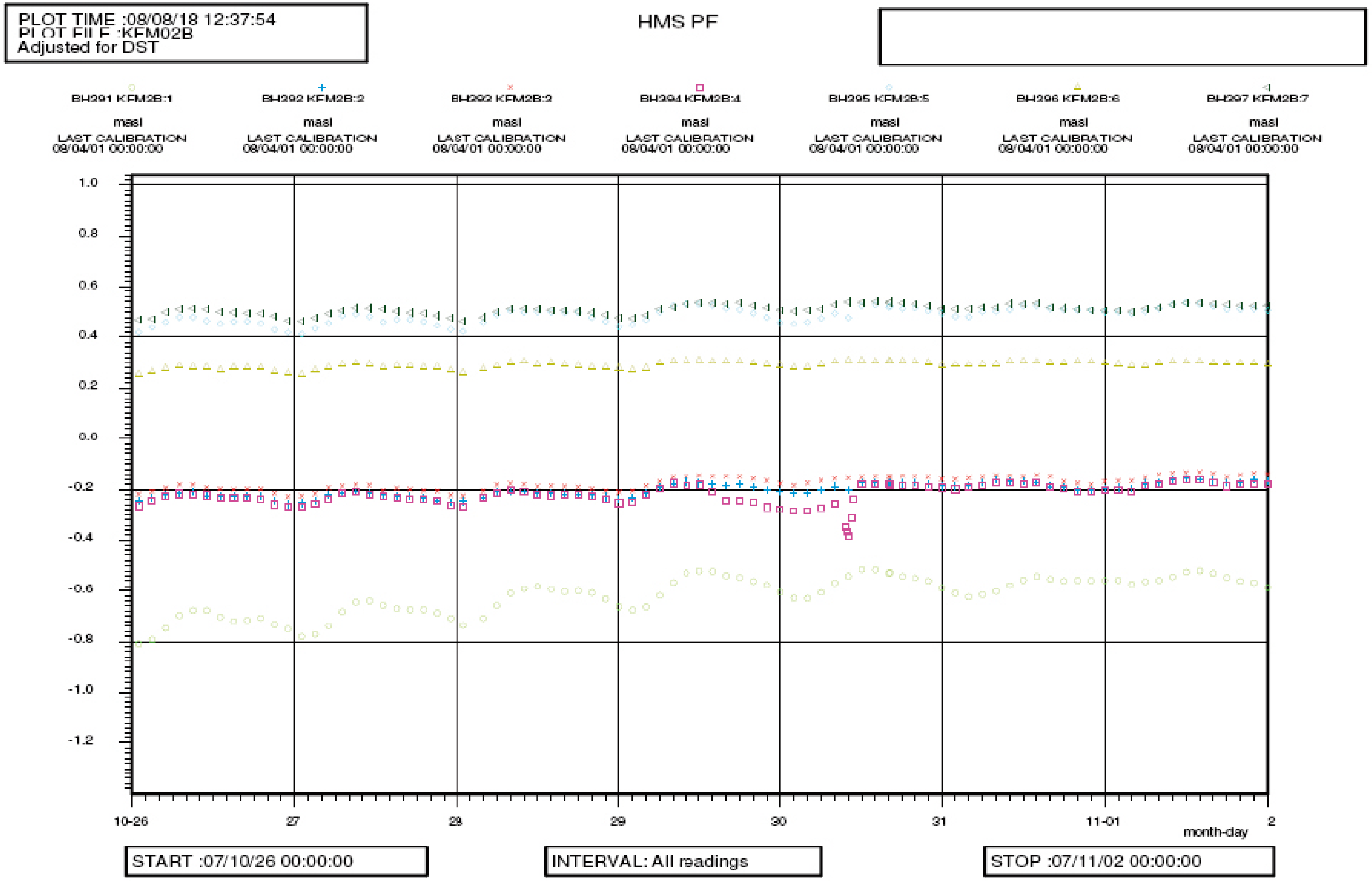

Figure A2-28. *Pumping in KFM02B:2 and KFM02B:4 in October 2007. Section KFM02B:4 showed a pressure response from the pumping in the section. The pressures in the other sections were not significantly affected by the pumping.*

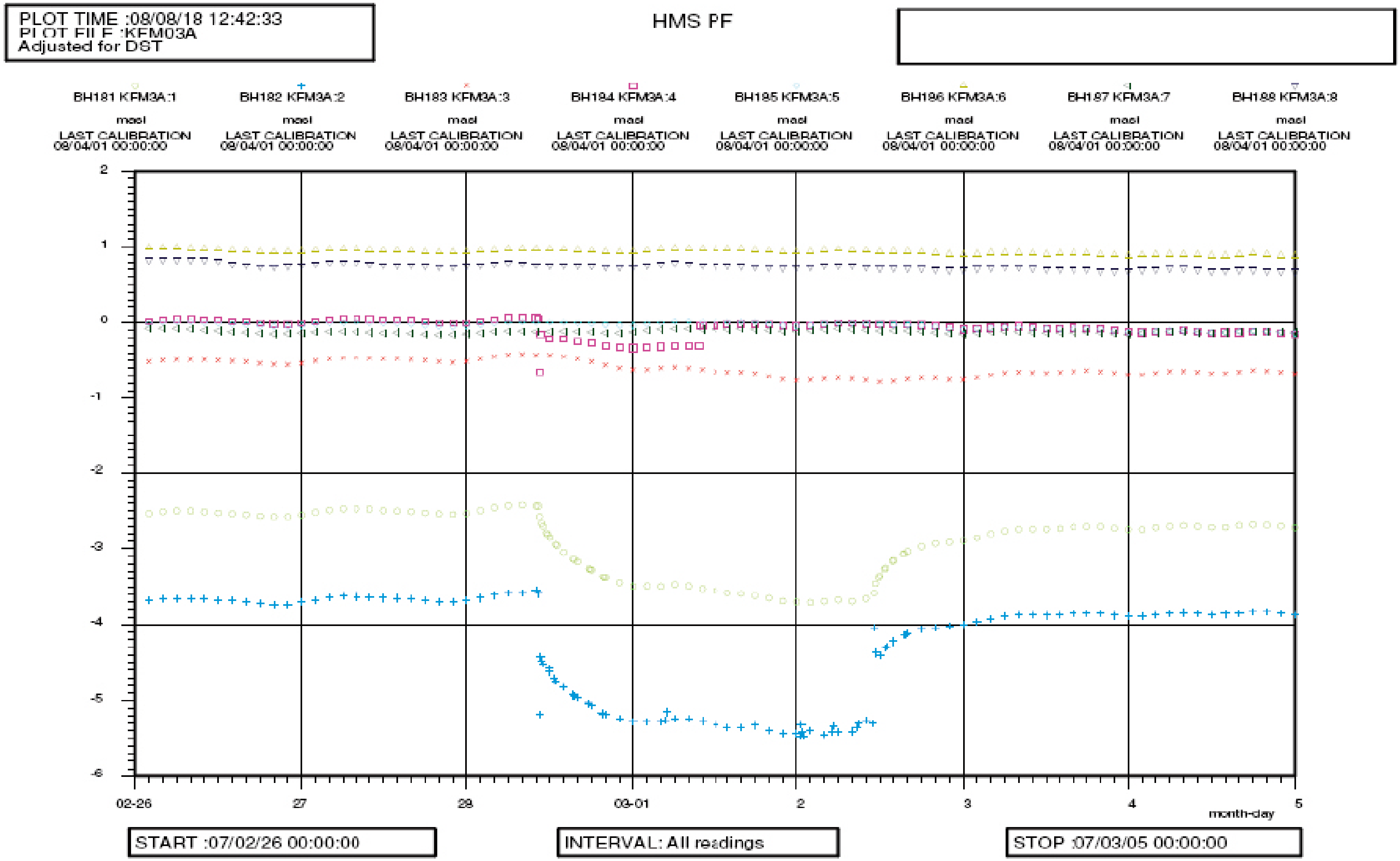

Figure A2-29. *Pumping in KFM03A:1 and KFM03A:4 in February 2007. Initially the pumping was performed in both sections simultaneously. The only response observed (section KFM03A:2) may be caused by a leaking connection in the equipment between sections KFM03A:1 and KFM03A:2 rather than a connected fracture system.*

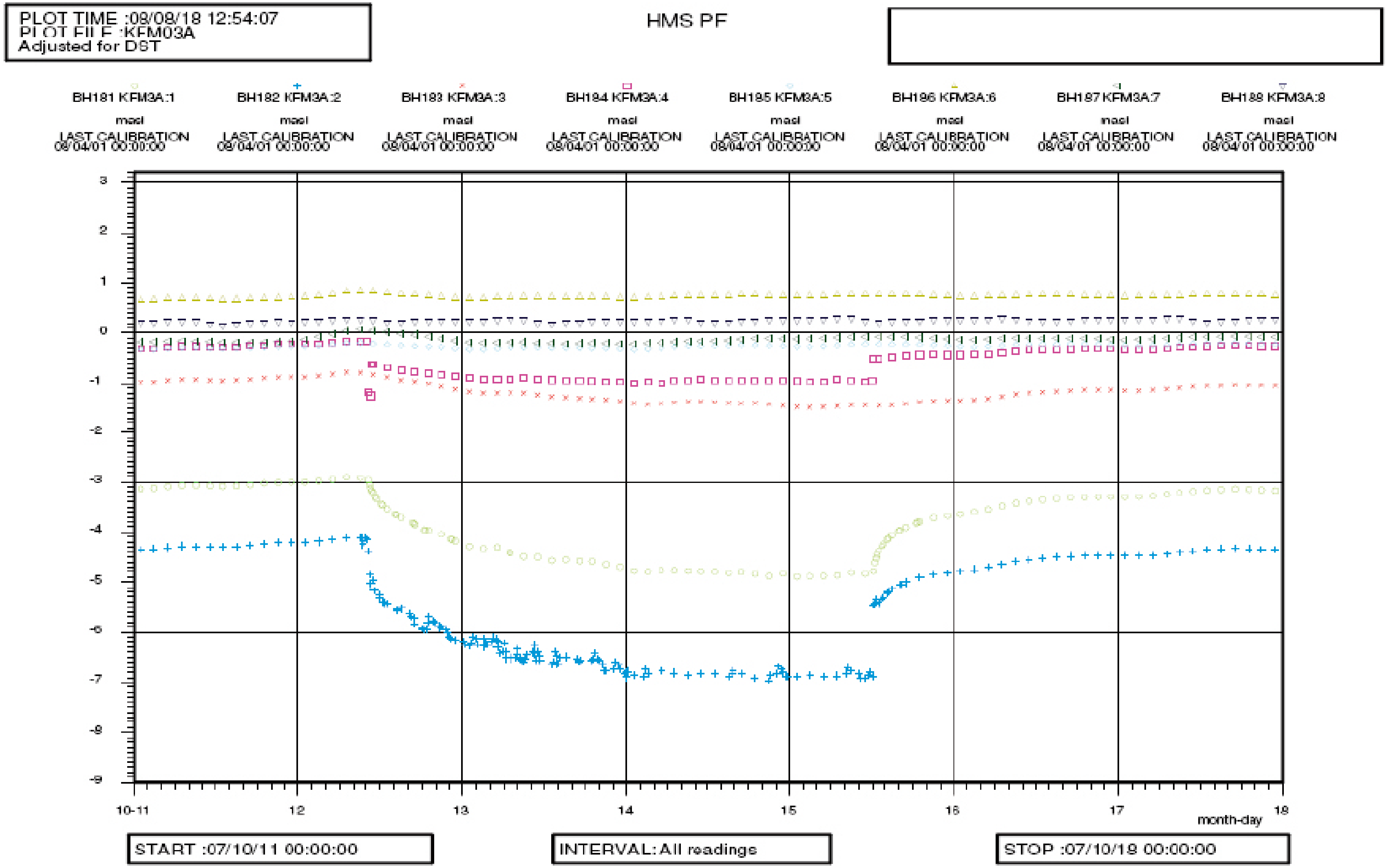

***Figure A2-30.** Pumping and drawdown in KFM03A:1 and KFM03A:4 in October 2007. The pumping was performed in both sections simultaneously. The only response observed (section KFM03A:2) may be caused by a leaking connection in the equipment between the two section rather than a connected fracture system.*

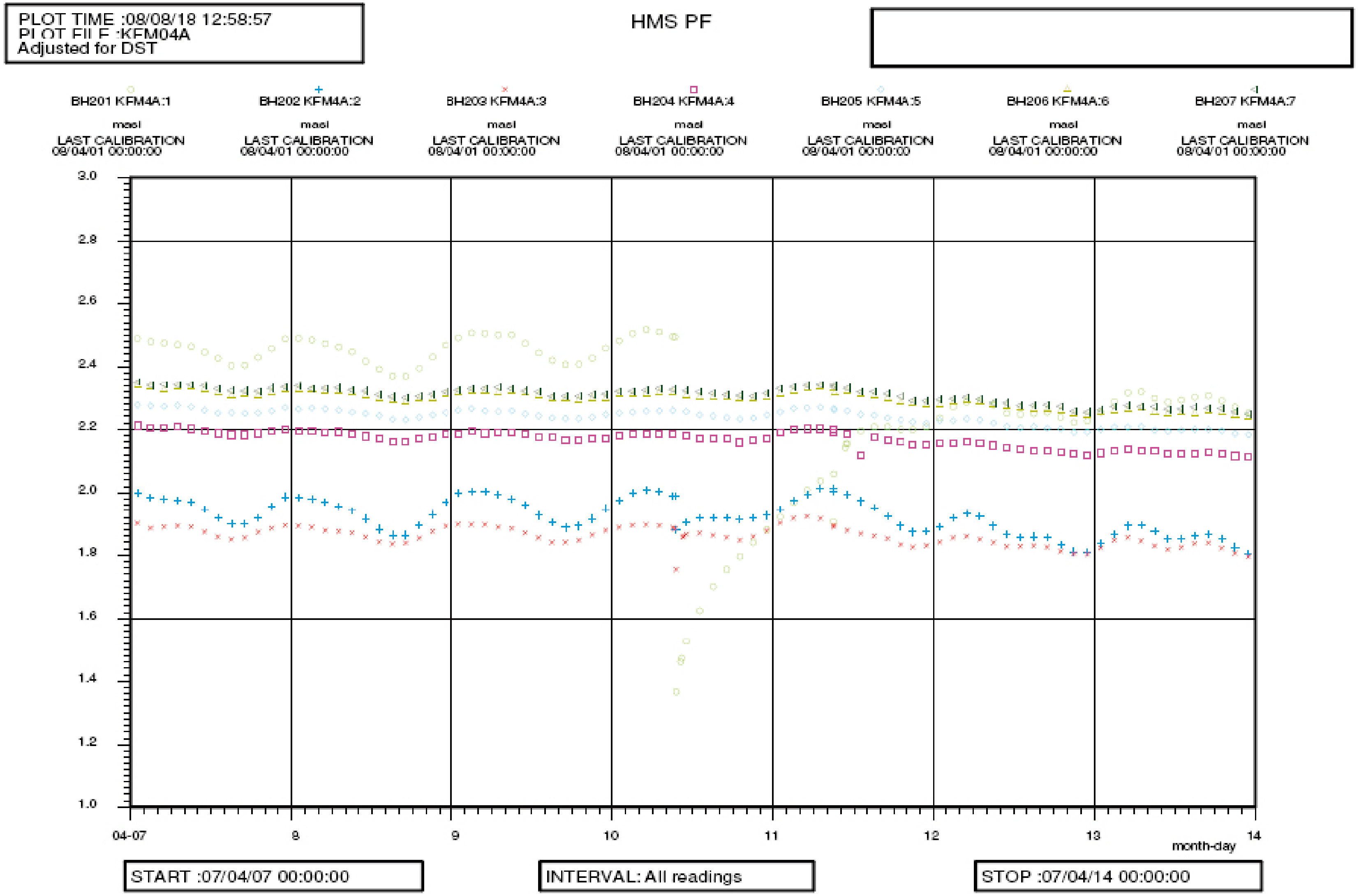

Figure A2-31. *Pumping and drawdown in KFM04A:4 in April 2007. None of the other sections were affected by the pumping.*

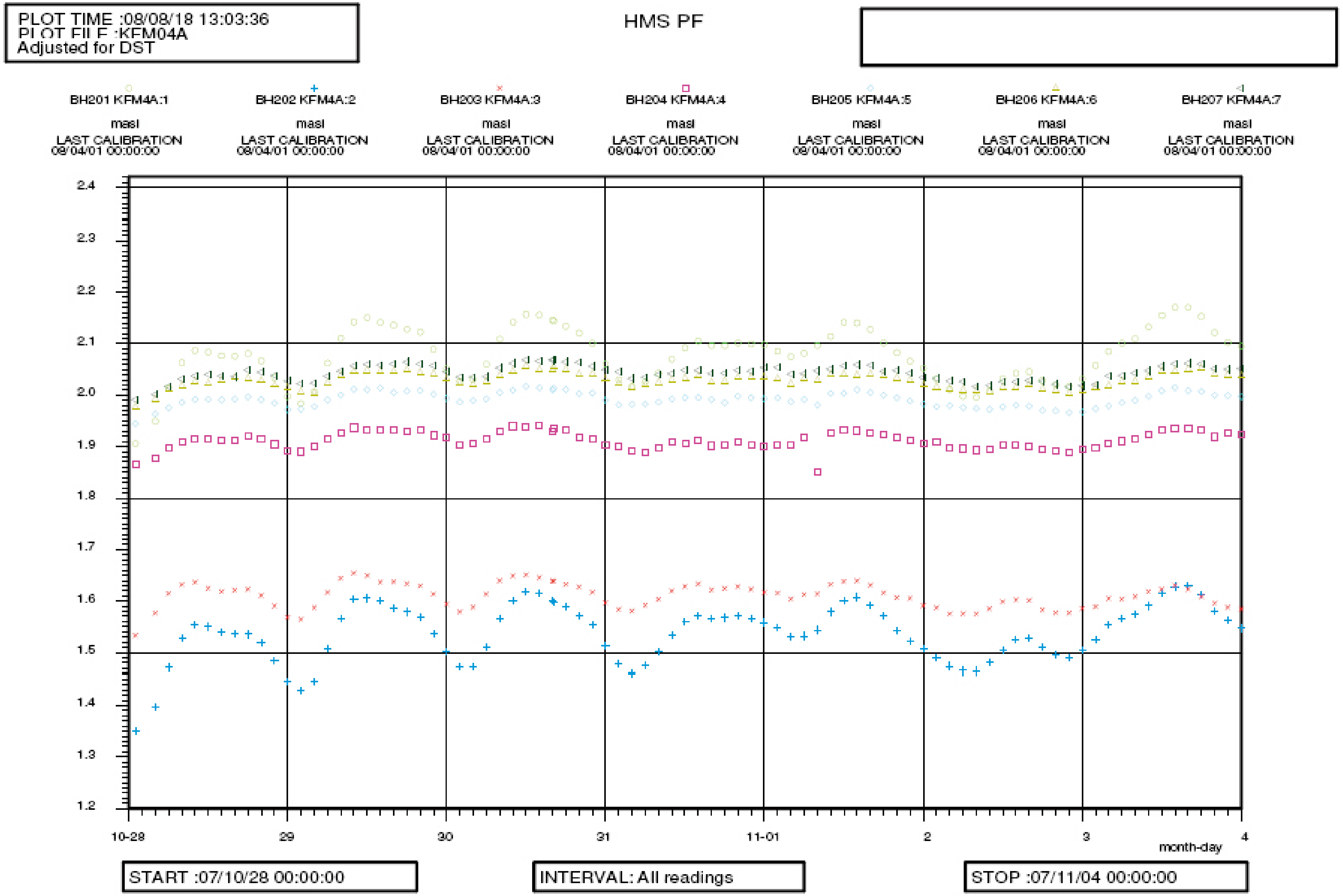

Figure A2-32. *Pumping in KFM04A:4 in October 2007. No significant drawdown was observed in any of the sections.*

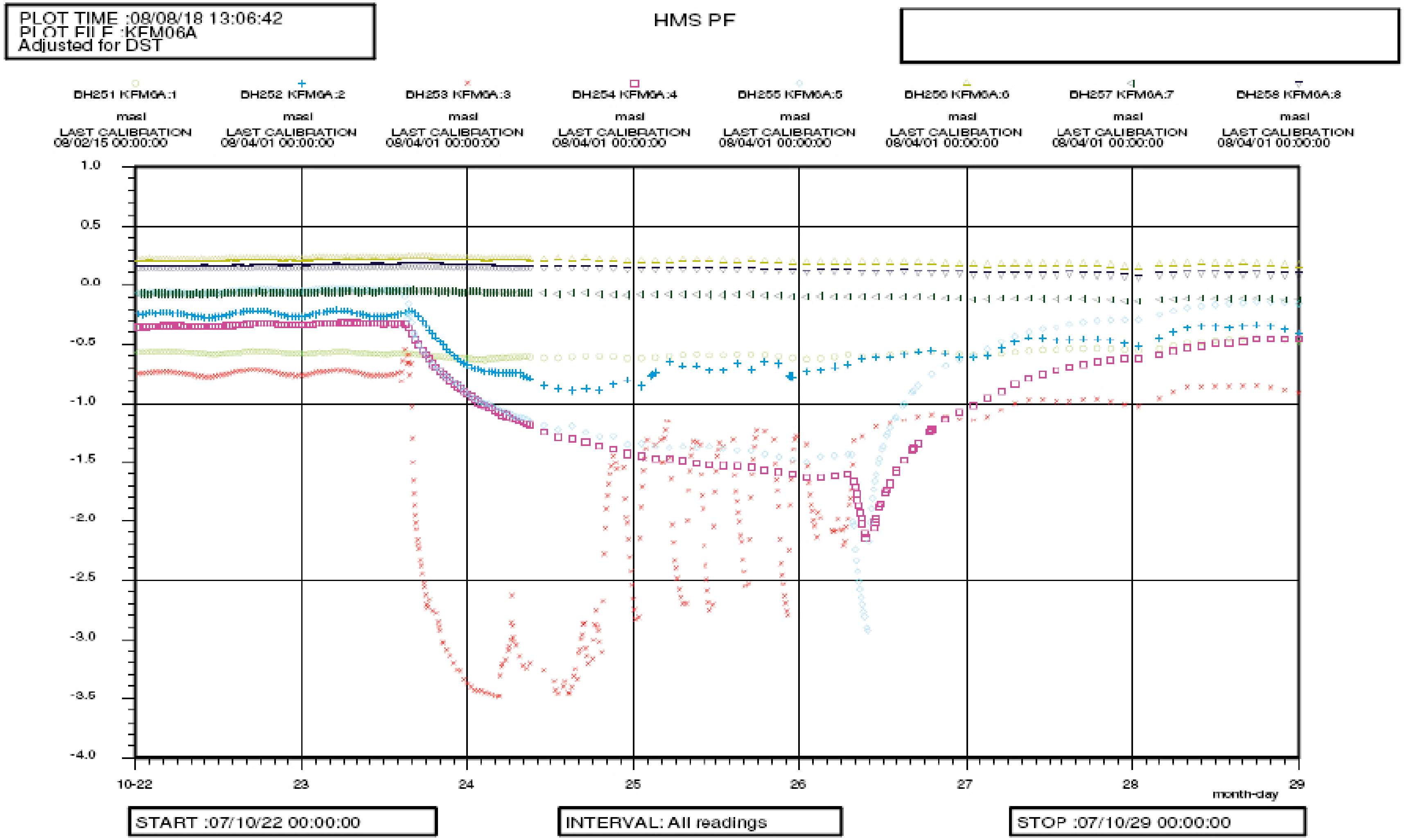

Figure A2-33. *Pumping and drawdown in KFM06A:3 and KFM06A:5 in October 2007. Pumping was performed in both sections simultaneously. Responses to the pumping are observed in sections KFM06A:2 and KFM06A:4. It is likely that the response in KFM06A:2 is due to the pumping in KFM06A:3 and the response in KFM06A:4 is probably due to the pumping in KFM06A:5. However, it can not be ruled out that both KFM06A: and KFM06A:4 are affected by the pumping in KFM06A:3.*

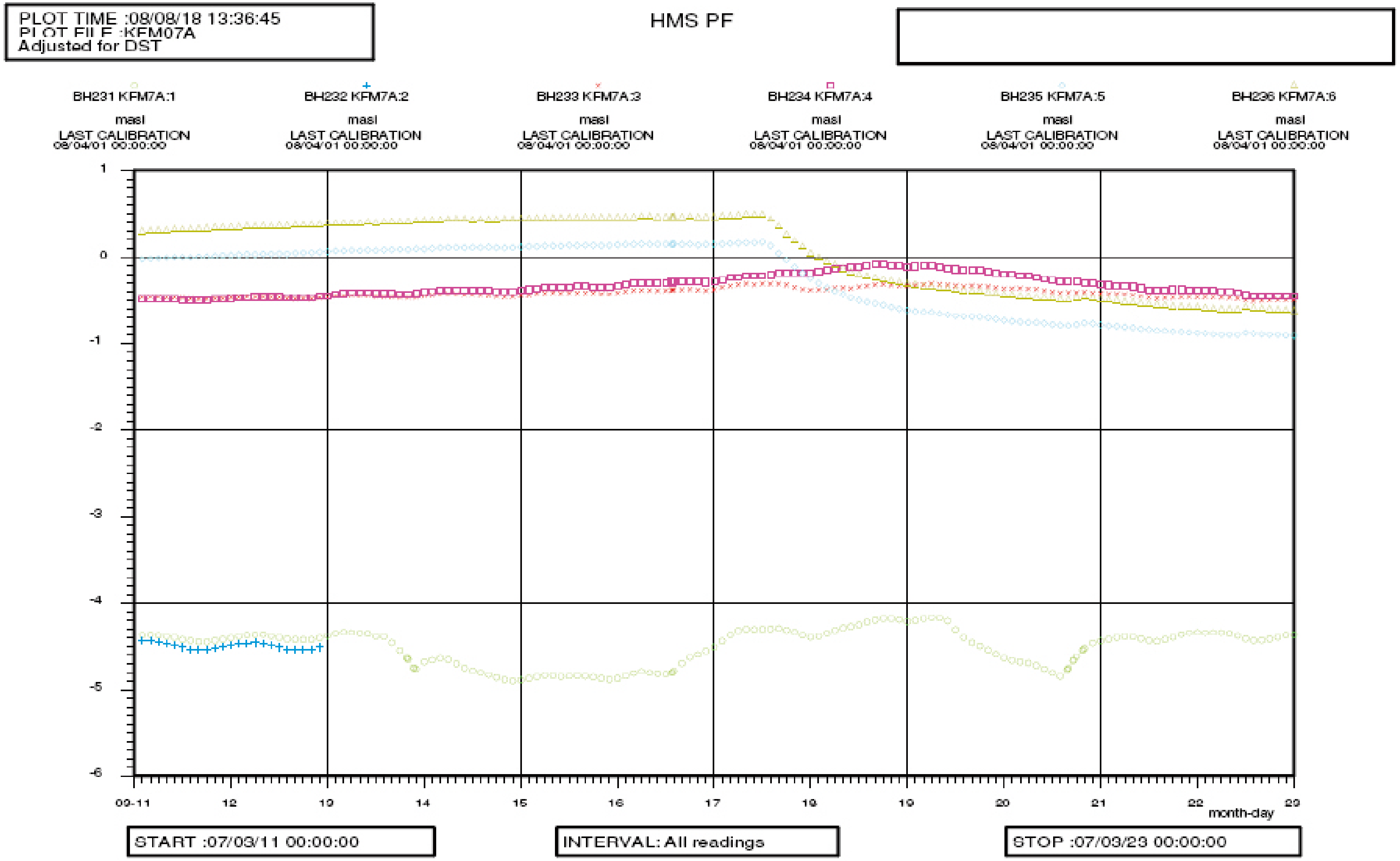

Figure A2-34. *Pumping in KFM07A:2 in March 2007. The logger for the pumped section had to be disconnected in order to allow pumping. Therefore, there is no pressure data recorded from the sampled section itself. A possible effect from pumping in section KFM07A:2 was observed in the deepest section, section KFM07A:1.*

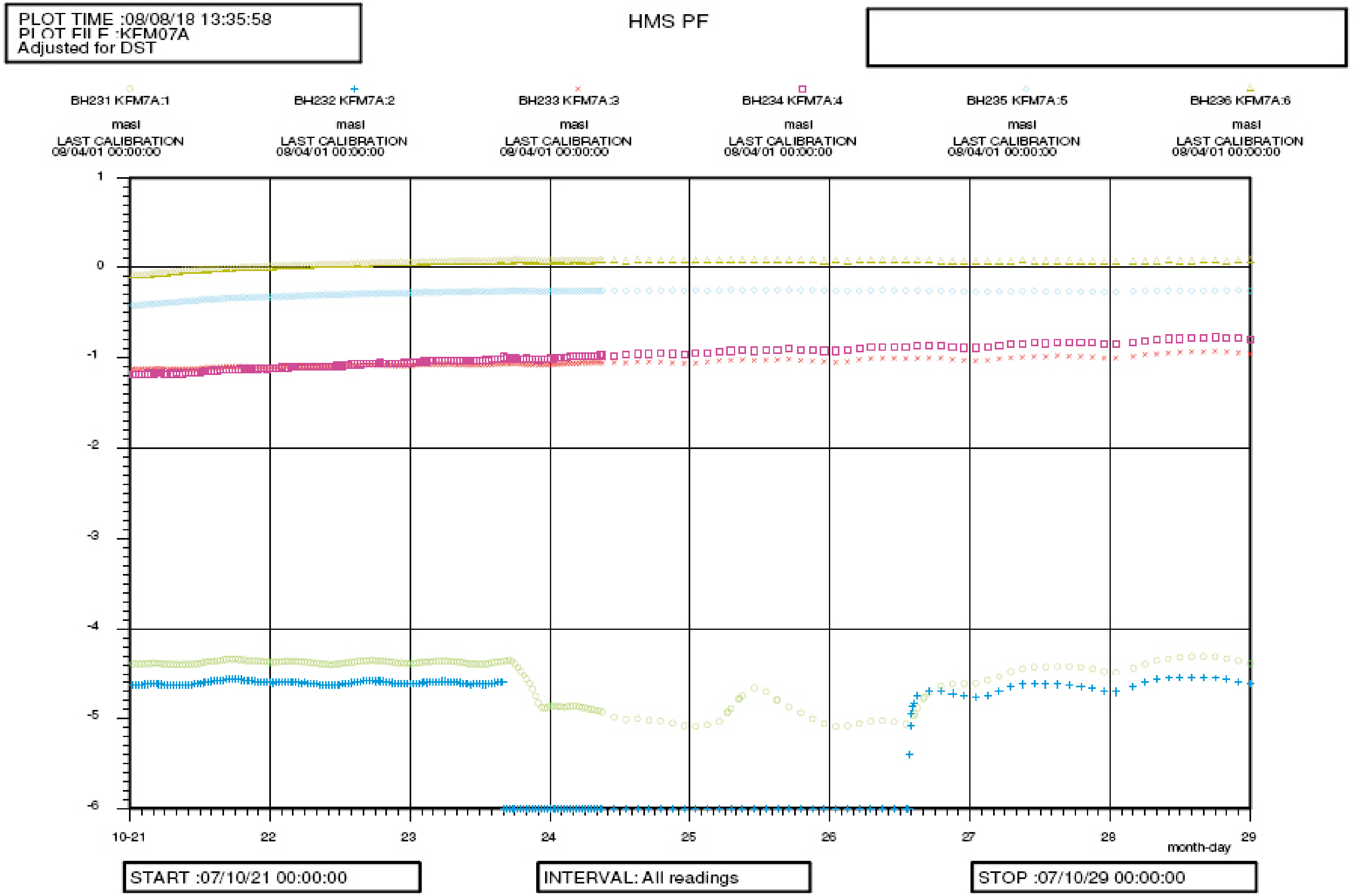

Figure A2-35. *Pumping in KFM07A:2 in October 2007. The logger for the pumped section had to be disconnected in order to allow pumping. Therefore, there is no pressure data recorded from the sampled section itself. A clear effect from pumping in section KFM07A:2 was observed in the deepest section, section KFM07A:1.*

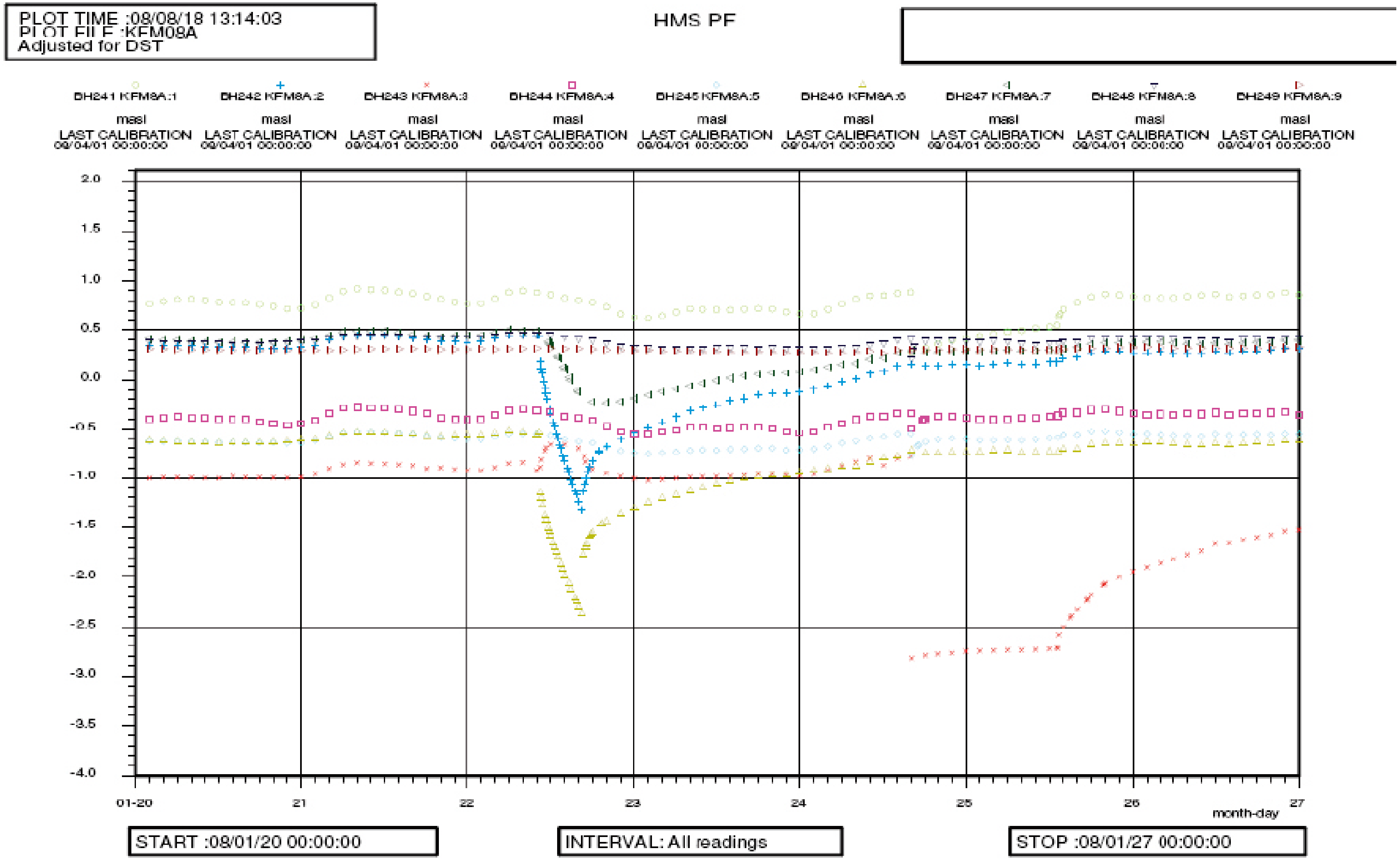

Figure A2-36. *Pumping and drawdown in KFM08A:2 and KFM0A8:6 in January 2008. Pumping was performed in both sections simultaneously. A clear effect from the pumping in KFM08A:6 was observed in KFM08A:7.*

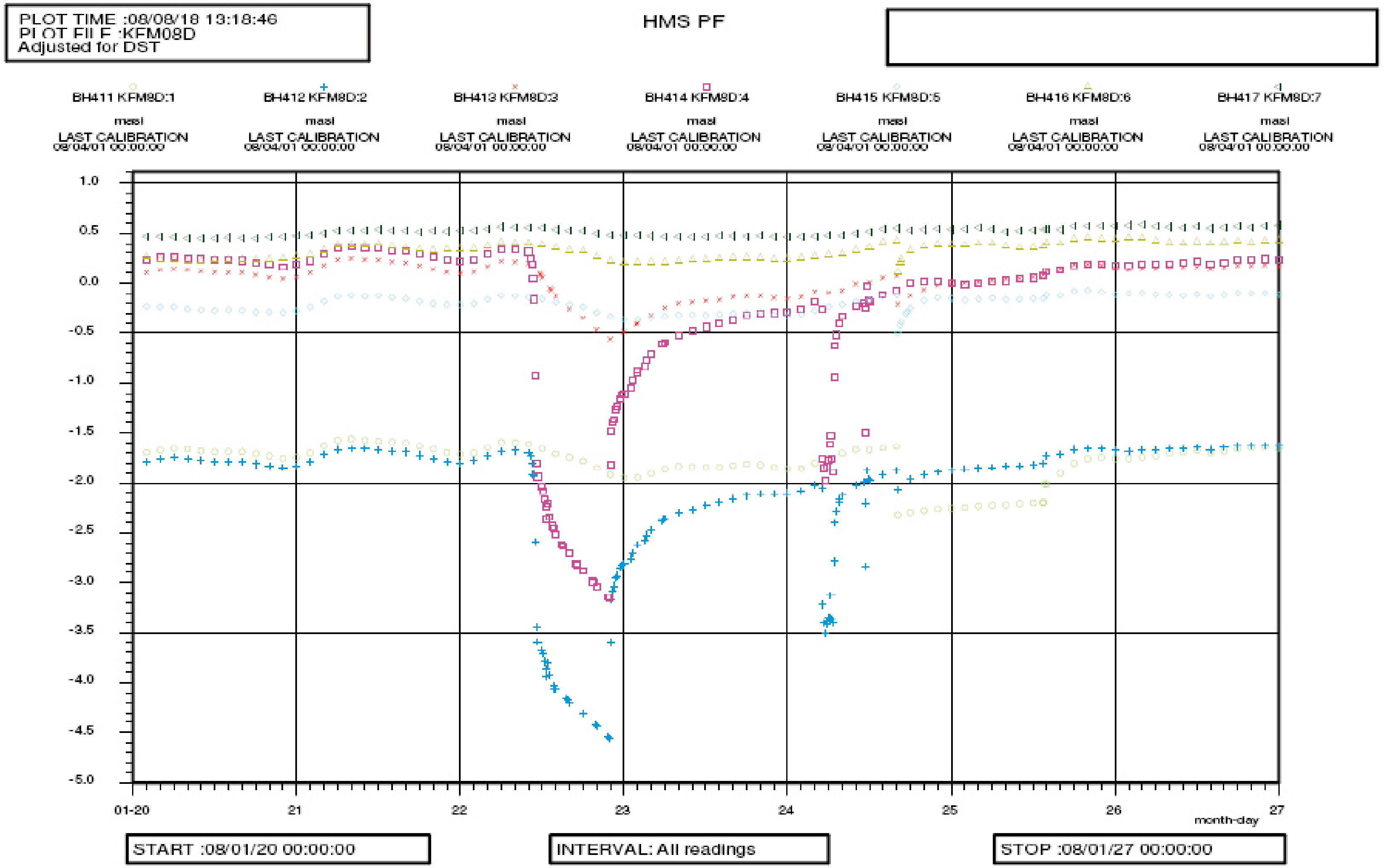

***Figure A2-37.** Pumping and drawdown in KFM08D:2 and KFM08D:4 in January 2008. At first, pumping was performed in both sections simultaneously. The pump in KFM08D:4 was restarted after technical problems but the water yield in KFM08D:2 was found too low to continue pumping. Effects from pumping were observed in section KFM08D:3. However, it is unclear if the drawdown was caused by pumping in KFM08D:2 or KFM08:4 or both.*

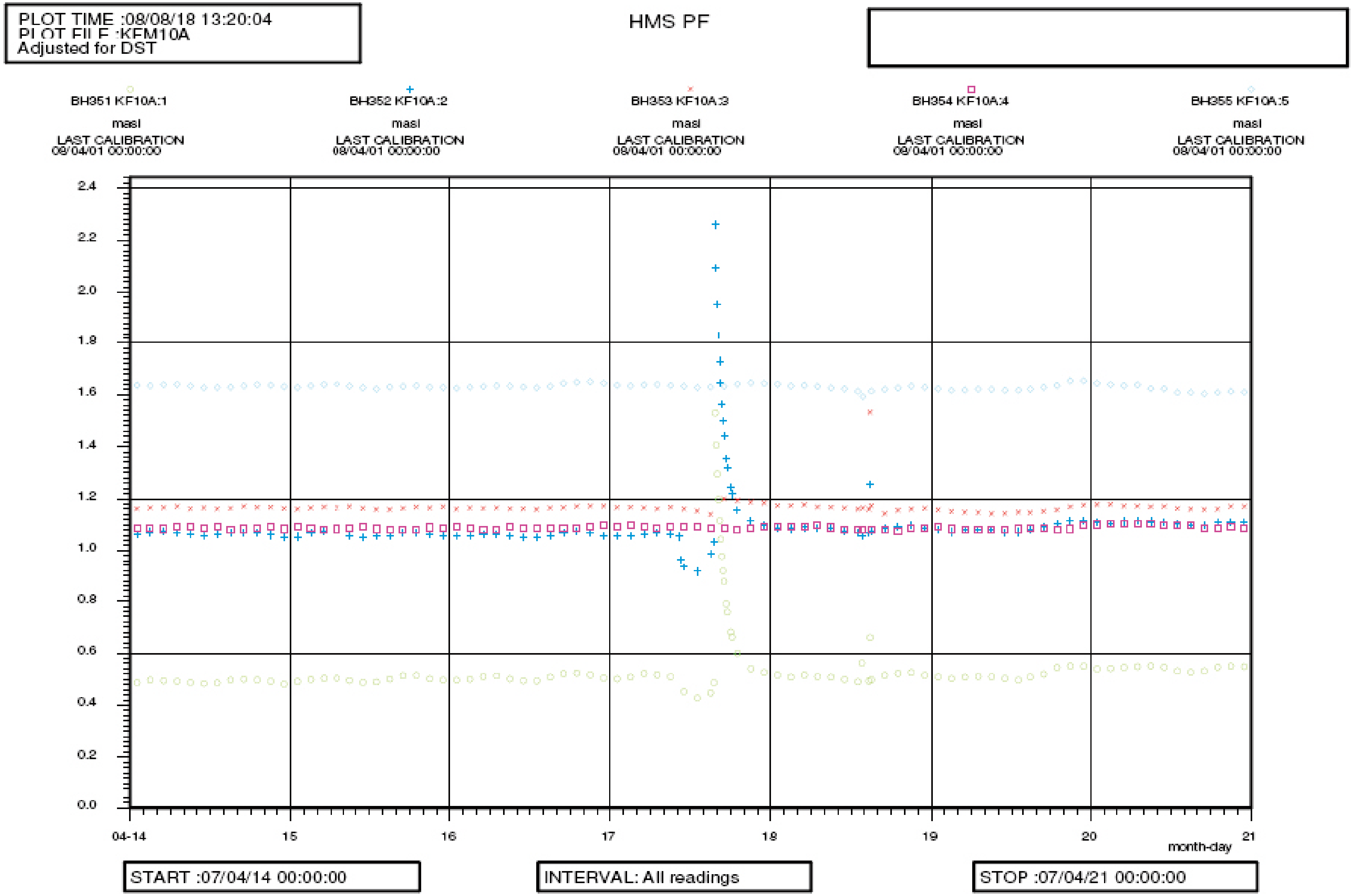

Figure A2-38. *Pumping and drawdown in KFM10A:2 in April 2007. Pressure responses were observed in the deepest section KFM10A:1.*

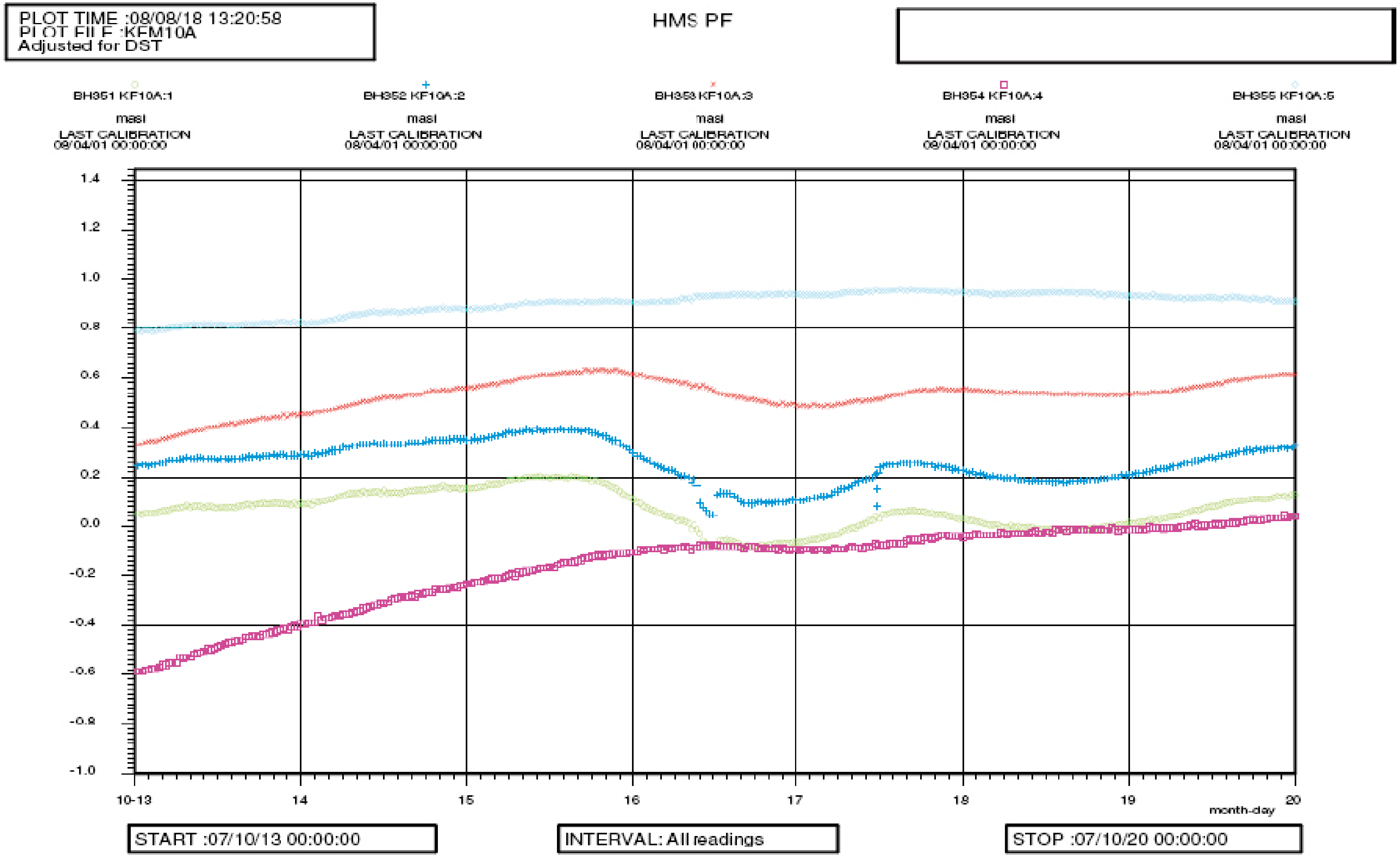

Figure A2-39. *Pumping and drawdown in KFM10A:2 in October 2007. Pressure responses were observed in section KFM10A:2.*

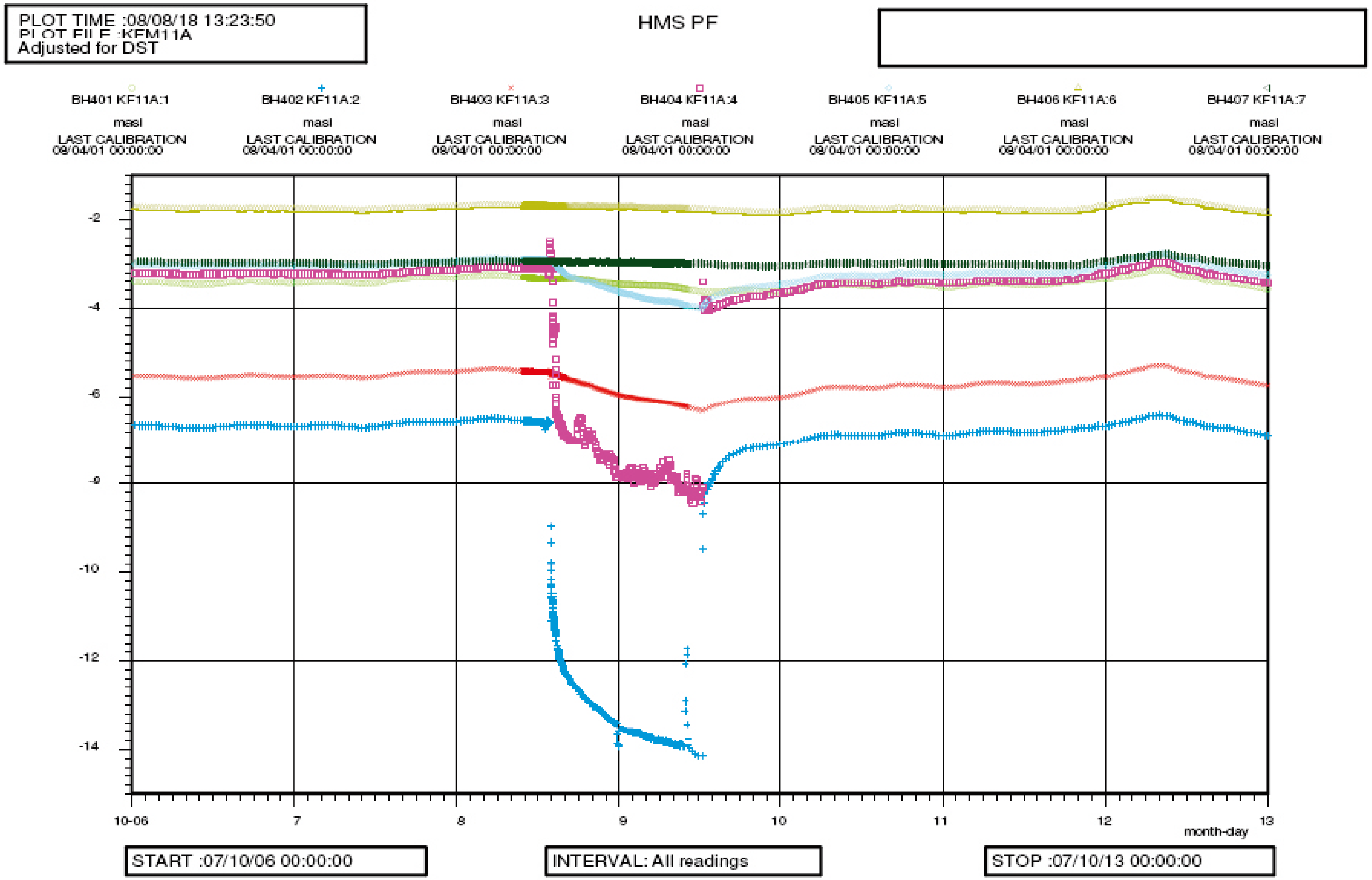

Figure A2-40. Pumping and drawdown in KFM11A:2 and KFM11A:4 in October 2007. Pumping was performed in both sections simultaneously. The responses shown in sections KFM11A:3 and KFM11A:5 are most probably due to pressure changes in the tubing's between the sections.

Appendix 3

Sampling and analytical methods

Table A3-1. Sample handling routines and analytical methods.

Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Analysis within – or delivery time to lab.
Anions 1.	HCO_3 pH(lab) cond (lab)	Plastic	250	Yes (not in the field)	No	Titration Pot. meas, Cond. meas	The same day – maximum 24 hours
Anions 2	Cl, SO_4, Br^-, F^-, I^-	Plastic	100	Yes (not in the field)	No	Titration (Cl^-) IC (Cl^-, SO4, Br^-, F^-) ISE (F^-)	Not critical (month)
	Br, I	Plastic	100	Yes (not in the field)	No	ICP MS	Not critical (month)
Cations, Si and S according to SKB class 3	Na, K, Ca, Mg, S(tot), Si(tot), Li, Sr	Plastic (at low conc. acid washed bottles)	100	Yes (not in the field)	Yes (not in the field, 1 mL HNO_3)	ICP-AES ICP-MS	Not critical (month)
Cations, Si and S according to SKB class 4 and 5	Na, K, Ca, Mg, S(tot), Si(tot), Fe, Mn, Li, Sr	Plastic (Acid washed)	100	Yes (immediately in the field)	Yes (1 mL HNO_3)	ICP-AES ICP-MS	Not critical (month)
Fe(II), Fe(tot)	Fe(II), Fe(tot)	Plastic (Acid washed)	500	Yes	Yes (5 mL HCl))	Spectrophotometry Ferrozine method	As soon as possible the same day
Hydrogen sulphide	HS-	Glass (Winkler)	About 120×2	No	Ev 1 mL 1 M NaOH+ 1 mL 1M ZnAc	Spectrophotometry	Immediately or if conserved, a few days
Environmental metals	Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn	Plastic (Acid washed)	100	Yes	Yes (1 mL HNO_3)	ICP-AES ICP-MS	Not critical (month)
Lantanoids, U, Th and so on	Sc, Rb, Y, Zr, I, Sb, Cs, La, Hf, Tl, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, U, Th	Plastic (Acid washed)	100	Yes	Yes (1 mL HNO_3)	ICP-AES ICP-MS	Not critical (month)
Dissolved organic Carbon, dissolved inorganic Carbon	DOC, DIC	Plastic	250 25	Yes	Frozen, transported in isolated bag	UV oxidation, IR Carbon analysator Shimadzu TOC5000	Short transportation time

Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Analysis within – or delivery time to lab.
Total organic Carbon	TOC	Plastic	250 25	No	Frozen, transported in isolated bag	UV oxidation, IR Carbon analysator Shimadzu TOC5000	Short transportation time
Environmental isotopes	^{2}H, ^{18}O	Plastic	100	No	– –	MS	Not critical (month)
Tritium,	^{3}H (enhanced.)	Plastic (dry bottle)	500 100	No	–	LSC	Not critical (month)
Chlorine-37	Chlorine-37	Plastic		No	–	MS	
Carbon isotopes	^{13}C, ^{14}C	Glass (brown)	100×2	No	–	(A)MS	A few days
Sulphur isotopes	^{34}S	Plastic	500–1,000	Yes	–	Combustion, MS	No limit
Strontium-isotopes	$^{87}Sr/^{86}Sr$	Plastic	100	Yes	–	TIMS	Days or Week
Uranium and Thorium isotopes	^{234}U, ^{235}U, ^{238}U, ^{232}Th, ^{230}Th,	Plastic	50	Nej	–	Alfa spectroscopy	No limit
Boron isotopes	^{10}B	Plastic	100	Yes	Yes (1 mL HNO_3)	ICP – MS	No limit
Radon and Radium isotopes	^{222}Rn, ^{226}Ra	Plastic	500	No	No	LSS	Immediate transport
Dissolved gas (content and composition)	Ar, N_2, CO_2, O_2, CH_4, H_2, CO, C_2H_2, C_2H_4, C_2H_6, C_3H_8	Cylinder of stainless steel	200	No	No	GC	Immediate transport
Colloids	Filter series and fractionation (see below)	Polycarbonate filter	0.45, 0.2 and 0.05 µm	–	N_2 atmosphere	ICP-AES ICP-MS	Immediate transport
Humic and fulvic acids	Fractionation	Frations are collected in plastic bottles	250	–	N_2 atmosphere	UV oxidation, IR (DOC)	Immediate transport
Archive samples with acid	–	Plast (washed in acid)	100×2 **	Yes	Yes (1 mL HNO_3)	–	Storage in freeze container
Archive samples without acid	–	Plastic	250×2 **	Yes	No	–	Storage in freeze container
Carbon isotopes in humic and fulvic acids	^{13}C, ^{14}C (pmc)	DEAE cellulose (anion exchanger)	–	–	–	(A)MS	A few days
Nutrient salt + silicate	NO_2, NO_3, NO_2+NO_3, NH_4, PO_4, SiO_4	Sample tubes, plastic	25×2	Yes (in the field)	No, frozen immediately***	Spectrophotometry	Short transportation time

Component group	**Component/ element**	**Sample container (material)**	**Volume (mL)**	**Filtering**	**Preparation/ Conservation***	**Analysis method**	**Analysis within – or delivery time to lab.**
Total concentrations of Nitrogen and Phosphorous	N-tot, P-tot	Plastic	100	No	No, frozen immediately***	Spectrophotometry	Short transportation time
Particulate Carbon, Nitrogen and Phosphorous	POC, PON, POP	Plastic	1,000	Yes (within 4 h) prepared filters. Blank filters	Filtering, the filters are frozen immediately 2 filters/sample	Elementar-analysator (N, C) own method 990121 (P)	Short transportation time
Chlorophyll	Chlorophyll a, c and pheopigment	Plastic	1,000–2,000	Yes (within 4 h)	Filtering, the filters are frozen immediately	Spectrophotometry Fluorometry	Short transportation time
Oxygen	Dissolved O_2	Winkler, glass	2×ca120	No	Mn (II) reagent Iodide reagent	Spectrophotometry SIS SS-EN 25813	Within 3 days
Archive samples for supplementary radio nuclides		Plastic	5,000	No	50 mL HNO_3	–	Storage in freeze container

* Suprapur acid is used for conservation of samples.

** Minimum number. The number of archive samples can vary depending on the number of similar samples collected at the same occasion.

*** The sample is transported in frozen condition to the laboratory. It is possible that the silicate concentration can change due to polymerisation for this reason.

Abbreviations and definitions:

IC	Ion chromatograph
ISE	Ion selective electrode
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectrometry
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
INAA	Instrumental Neutron Activation Analysis
MS	Mass Spectrometry
TIMS	Thermal Ionization Mass Spectrometer
LSC	Liquid Scintillation Counting
(A)MS	(Accelerator) Mass Spectrometry
GC	Gas Chromatography
LSS	Liquid Scintillation Spectroscopy

Table A3-2. Reporting limits and measurement uncertainties, updated 2008.

Component	Method[1]	Reporting limits (RL), detection limits (DL) or range[2]	Unit	Measurement uncertainty[3]
pH	Potentiometric	3–10	pH unit	±0.1
EC	Electrical Conductivity meas.	1–150 150–10,000	mS/m	5% 3%
HCO_3	Alkalinity titration	1	mg/L	4%
Cl^- Cl^-	Mohr- titration IC	≥ 70 0.5–70	mg/L	5% 8%
SO_4	IC	0.5	mg/L	12%
Br^-	IC	DL 0.2, RL 0.5	mg/L	15%
Br	ICP SFMS	0.001, 0.004, 0.010[4]	mg/L	25%[5]
F^- F^-	IC Potentiometric	DL 0.2, RL 0.5 DL 0.1, RL 0.2	mg/L	13% 12%
I^-	ICP SFMS	0.001, 0.004, 0.010[4]	mg/L	25%[5]
Na	ICP AES	0.1	mg/L	13%
K	ICP AES	0.4	mg/L	12%
Ca	ICP AES	0.1	mg/L	12%
Mg	ICP AES	0.09	mg/L	12%
S(tot)	ICP AES	0.16	mg/L	12%
Si(tot)	ICP AES	0.03	mg/L	14%
Sr	ICP AES	0.002	mg/L	12%
Li	ICP AES	0.004	mg/L	12.2%
Fe	ICP AES	0.02	mg/L	13.3%[6]
Fe	ICP SFMS	0.0004, 0.002, 0.004[4]	mg/L	20%[6]
Mn	ICP AES	0.003	mg/L	12.1%[5]
Mn	ICP SFMS	0.00003, 0.00004, 0.0001[4]	mg/L	53%[6]
Fe(II), Fe(tot)	Spectrophotometry	DL 0.006, RL 0.02	mg/L	0.005 (0.02–0.05 mg/L) 9% (0.05–1 mg/L) 7% (1–3 mg/L)
HS^-	Spectrophotometry, SKB	SKB DL 0.006, RL 0.02	mg/L	25%
HS^-	Spectrophotometry, external laboratory	0.01	mg/L	0.02 (0.01–0.2 mg/L) 12% (> 0.2 mg/L)
NO_2 as N	Spectrophotometry	0.1	µg/L	2%
NO_3 as N	Spectrophotometry	0.2	µg/L	5%
NO_2+NO_3 as N	Spectrophotometry	0.2	µg/L	0.2 (0.2–20 µg/L) 2% (> 20 µg/L)
NH_4 as N	Spectrophotometry, SKB	11	µg/L	30% (11–20 µg/L) 25% (20–50 µg/L) 12% (50–1,200 µg/L)
NH_4 as N	Spectrophotometry external laboratory	0.8	µg/L	0.8 (0.8–20 µg/L) 5% (> 20 µg/L)
PO_4 as P	Spectrophotometry	0.7	µg/L	0.7 (0.7–20 µg/L) 3% (> 20 µg/L)

Component	Method[1]	Reporting limits (RL), detection limits (DL) or range[2]	Unit	Measurement uncertainty[3]
SiO_4	Spectrophotometry	1	µg/L	2.5% (> 100 µg/L)
O_2	Iodometric titration	0.2–20	mg/L	5%
Chlorophyll a, c pheopigment[7]	/1/	0.5	µg/L	5%
PON[7]	/1/	0.5	µg/L	5%
POP[7]	/1/	0.1	µg/L	5%
POC[7]	/1/	1	µg/L	4%
Tot-N[7]	/1/	10	µg/L	4%
Tot-P[7]	/1/	0.5	µg/L	6%
Al,	ICP SFMS	0.2, 0.3, 0.7[4]	µg/L	17.6%[6]
Zn	ICP SFMS	0.2, 0.8, 2[4]	µg/L	15.5, 17.7, 25.5%[6]
Ba, Cr, Mo,	ICP SFMS	0.01, 0.04, 0.1[4]	µg/L	Ba 15%[4], Cr 22%[5] Mo 39%[6]
Pb	ICP SFMS	0.01, 0.1, 0.3[4]	µg/L	15%[6]
Cd	ICP SFMS	0.002, 0.02, 0.5[4]	µg/L	15.5%[6]
Hg	ICP AFS	0.002	µg/L	10.7%[6]
Co	ICP SFMS	0.005, 0.02, 0.05[4]	µg/L	25.9%[6]
V	ICP SFMS	0.005, 0.03, 0.05[4]	µg/L	18.1%[6]
Cu	ICP SFMS	0.1, 0.2, 0.5[4]	µg/L	14.4%[6]
Ni	ICP SFMS	0.05, 0.2, 0.5[4]	µg/L	15.8%[6]
P	ICP SFMS	1, 5, 40[4]	µg/L	16.3%[6]
As	ICP SFMS	0.01 (520 mS/m)	µg/L	59.2%[6]
La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu	ICP SFMS	0.005, 0.02, 0.05[4]	µg/L	20%, 20%, 25%[6]
Sc, In, Th	ICP SFMS	0.05, 0.2, 0.5[4]	µg/L	25%[6]
Rb, Zr, Sb, Cs	ICP SFMS	0.025, 0.1, 0.25[4]	µg/L	15%, 20%, 20%[5], 25%[6]
Tl	ICP SFMS	0.025, 0.1, 0.25[4]	µg/L	14.3%[5 and 6]
Y, Hf	ICP SFMS	0.005, 0.02, 0.05[4]	µg/L	15%, 20%, 20%[5], 25%[6]
U	ICP SFMS	0.001, 0.005, 0.01[4]	µg/L	13.5%, 14.3%, 15.9%[5] 19.1%, 17.9%, 20.9%[6]
DOC	UV oxidation, IR Carbon analysator	0.5	mg/L	8%
TOC	UV oxidation, IR Carbon analysator	0.5	mg/L	10%
δ^2H	MS	2	‰ SMOW[8]	0.9 (one standard deviation)
$\delta^{18}O$	MS	0.1	‰ SMOW[8]	0.1 (one standard deviation)
^3H	LSC	0.8	TU[9]	0.8
$\delta^{37}Cl$	A (MS)	0.2	‰ SMOC[10]	0.2[17]
$\delta^{13}C$	A (MS)	–	‰ PDB[11]	0.3[17]
^{14}C pmc	A (MS)	–	PMC[12]	0.4[17]
$\delta^{34}S$	MS	0.2	‰ CDT[13]	0.4 (one standard deviation)

Component	**Method**[1]	**Reporting limits (RL), detection limits (DL) or range**[2]	**Unit**	**Measurement uncertainty**[3]
$^{87}Sr/^{86}Sr$	TIMS	–	No unit (ratio)[14]	0.00002
$^{10}B/^{11}B$	ICP SFMS	–	No unit (ratio)[14]	–
^{234}U, ^{235}U, ^{238}U, ^{232}Th, ^{230}Th	Alfa spectro-photometry	0.0001	Bq/L[15]	≤ 5% (Counting statistics uncertainty)
^{222}Rn, ^{226}Ra	LSS	0.015	Bq/L	≤ 5% (Counting statistics uncertainty)

1. Many elements may be determined by more than one ICP technique depending on concentration range. The most relevant technique and measurement uncertainty for the concentrations normally encountered in groundwater are presented. In cases where two techniques were frequently used, both are displayed.
2. Reporting limits (RL), generally 10×standard deviation, if nothing else is stated. Measured values below RL or DL are stored as negative values in SICADA (i.e. –RL value and –DL value).
3. Measurement uncertainty reported by the laboratory, generally as ± percent of measured value in question at 95% confidence interval.
4. Reporting limits at electrical cond. 520 mS/m, 1,440 mS/m and 3,810 mS/m respectively.
5. Measurement uncertainty at concentrations 100×RL.
6. Measurement uncertainty at concentrations 10×RL.
7. Determined only in surface waters. PON, POP and POC refers to Particulate Organic Nitrogen, Phosphorous and Carbon, respectively.
8. Per mille deviation[16] from SMOW (Standard Mean Oceanic Water).
9. TU=Tritium Units, where one TU corresponds to a tritium/hydrogen ratio of 10^{-18} (1 Bq/L Tritium = 8.45 TU).
10. Per mille deviation[16] from SMOC (Standard Mean Oceanic Chloride).
11. Per mille deviation[16] from PDB (the standard PeeDee Belemnite).
12. The following relation is valid between pmC (percent modern carbon) and Carbon-14 age: $\text{pmC} = 100 \times e^{((1,950-y-1.03t)/8,274)}$ where y = the year of the C-14 measurement and t = C-14 age.
13. Per mille deviation[16] from CDT (the standard Canyon Diablo Troilite).
14. Isotope ratio without unit.
15. The following expressions are applicable to convert activity to concentration, for uranium-238 and thorium-232: 1 ppm U = 12.4 Bq/kg^{238}U, 1 ppm Th = 3.93 Bq/kg^{232}Th.
16. Isotopes are often reported as per mill deviation from a standard. The deviation is calculated as: $\delta yI = 1,000\times(K_{sample}-K_{standard})/K_{standard}$, where K= the isotope ratio and $^{y}I = {}^{2}H$, ^{18}O, ^{37}Cl, ^{13}C or ^{34}S etc.
17. SKB estimation from duplicate analyses by the contracted laboratory.

Appendix 4

Compilaton of water analysis data

Table A4-1. Water Composition.

Idcode	Secup m	Seclow m	Sample no.	Sampling date	RCB %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO_3^- mg/L	Cl^- mg/L	SO_4^{2-} mg/L	SO4_S mg/L	Br mg/l	F^- mg/L	Si mg/L	Fe mg/L	Fe-tot mg/L	FeII mg/L	Mn mg/L
HFM01	33.50	45.50	12757	2007-04-10	0.65	566	18.0	97.5	29.0	425	739	180	64.3	2.20	2.05	6.55	0.805	0.798	0.794	0.160
HFM01	33.50	45.50	12890	2007-10-23	0.33	857	26.7	186	54.6	381	1,400	246	88.9	5.21	2.05	6.53	0.786	0.790	0.771	0.311
HFM02	38.00	48.00	12761	2007-04-11	–0.06	443	18.5	117	33.9	386	692	115	39.3	2.60	1.70	6.76	–	–	–	–
HFM02	38.00	48.00	12891	2007-10-23	–0.46	1,070	33.7	311	95.4	312	2,140	250	94.4	7.92	1.67	6.76	1.74	1.79	1.80	0.577
HFM04	58.00	66.00	12704	2007-02-20	–1.79	149	6.12	28.6	7.3	392	53	44.1	15.2	0.156	2.00	7.39	–	–	–	–
HFM04	58.00	66.00	12912	2007-11-01	–4.58	143	5.64	29,2	7.5	397	61	45.0	15.0	< 0.2	1.95	6.84	0.344	0.344	0.351	0.078
HFM13	159.00	173.00	12768	2007-04-17	–0.05	1,790	23.9	1,240	202	123	5,110	470	175	21.7	1.33	8.04	–	–	–	–
HFM13	159.00	173.00	12884	2007-10-17	–0.67	1,740	21.6	1,150	196	130	4,960	463	158	21.9	1.31	7.49	3.59	3.500	3.640	2.40
HFM15	85.00	95.00	12763	2007-04-12	–0.57	395	13.5	112	22.5	504	525	98.0	33.8	1.93	1.18	9.25	–	–	–	–
HFM15	85.00	95.00	12885	2007-10-17	–0.11	1,100	31.4	359	92.3	288	2,250	272	98.5	7.11	1.42	6.65	2.81	2.56	2.57	0.726
HFM16	54.00	67.00	12765	2007-04-12	0.26	278	7.35	37.4	9.5	457	181	96.8	34.1	0.690	2.29	6.14	–	–	–	–
HFM16	54.00	67.00	12892	2007-10-23	–1.59	253	6.02	27.5	6.9	448	145	93.0	31.6	0.522	2.46	6.23	0.347	0.374	0.356	0.0740
HFM19	168.00	182.00	12764	2007-04-12	–0.59	2,030	53.7	969	241	128	5,150	530	196	18.9	1.21	6.62	–	–	–	–
HFM19	168.00	182.00	12886	2007-10-17	–0.23	1,470	40.9	581	155	226	3,360	368	141	11.3	1.28	6.85	3.66	3.51	3.49	1.29
HFM21	22.00	32.00	12758	2007-04-10	–2.44	231	13.2	73.7	19.7	450	241	105	36.4	0.792	1.29	8.09	1.02	1.02	1.03	0.190
HFM21	22.00	32.00	12893	2007-10-23	–0.22	343	15.3	77.1	22.8	468	355	154	54.4	1.24	1.45	7.49	0.838	0.855	0.841	0.193
HFM27	46.00	58.00	12760	2007-04-11	–1.63	1,000	34.4	396	103	271	2,250	313	112	8.30	1.30	6.64	–	–	–	–
HFM27	46.00	58.00	12896	2007-10-26	–3.60	1,210	35.5	491	136	249	2,990	332	120	10.5	1.41	6.57	2.90	3.08	3.06	0.896
HFM32	26.00	31.00	12767	2007-04-17	–2.50	1,760	69.4	509	171	191	3,970	389	137	15.5	1.27	5.60	–	–	–	–
HFM32	26.00	31.00	12913	2007-11-12	–3.70	1,480	52.6	388	135	241	3,290	307	109	12.0	1.29	6.13	2.63	2.73	2.63	0.644
KFM01A	109.00	130.00	12770	2007-04-23	–2.99	1,630	24.9	830	141	114	4,330	364	130	16.7	1.46	9.65	–	–	–	–
KFM01A	109.00	130.00	12855	2007-10-19	–0.84	1,760	24.1	765	133	112	4,200	321	128	16.0	1.34	9.60	–	–	–	–
KFM01D	311.00	321.00	12771	2007-04-18	–2.46	1,410	31.2	729	115	288	3,680	212	76.6	16.2	1.61	15.80	3.23	3.31	3.30	0.956
KFM01D	311.00	321.00	12889	2007-10-19	–0.26	1,570	25.9	783	95.8	135	3,850	239	89.5	16.1	1.57	14.20	–	–	–	–
KFM01D	429.00	438.00	12772	2007-04-23	–2.30	1,450	26.6	729	108	274	3,760	142	56.4	16.7	1.18	15.40	0.583	0.615	0.611	0.570
KFM01D	429.00	438.00	12888	2007-10-19	–	1,650	22.0	889	80.8	156	4,200	89.3	X	21.4	1.00	14.90	–	–	–	–
KFM01D	429.00	438.00	12953	2008-01-30	–2.36	1,520	18.0	896	71.8	138	4,200	99.0	32.5	21.6	1.00	13.90	0.0413	–	–	0.364
KFM01D	429.00	438.00	12954	2008-01-30	–3.43	1,460	19.3	915	71.8	125	4,240	93.0	32.5	22.6	1.12	13.90	0.315	–	–	0.432

Idcode	Secup	Seclow	Sample	Li	Sr	I^-	pH	pH_F	DOC	TOC	HS^-	Uranine	ElCond	EC_F	NH_4N	NO_2N	NO_3N	NO_2N/NO_3N	PO_4P	P	Temp.
	m	m	no.	mg/L	mg/L	mg/L			mg/L	mg/L	mg/L	µg/L	mS/m	mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	°C
HFM01	33.50	45.50	12757	0.018	0.547	0.009	7.72	7.54	9.5	9.2	< 0.006	–	322	310	0.261	0.0005	< 0.0003	0.0005	0.0802	0.08020	8.4
HFM01	33.50	45.50	12890	0.026	1.13	0.013	7.56	7.63	7.9	8.2	0.014	–	517	540	1.21	0.0030	0.0005	0.0036	0.0083	0.02080	8.6
HFM02	38.00	48.00	12761	0.019	0.714	–	7.64	7.85	–	–	–	–	288	290	–	–	–	–	–	–	8.1
HFM02	38.00	48.00	12891	0.034	2.02	0.018	7.42	7.02	7.1	7.1	0.026	–	713	708	1.31	0.0005	< 0.0003	0.0004	0.0125	0.02830	8.2
HFM04	58.00	66.00	12704	0.008	0.201	–	7.78	7.75	–	–	–	–	85	88	–	–	–	–	–	–	7.1
HFM04	58.00	66.00	12912	0.008	0.195	0.006	7.63	7.40	8.9	9.1	0.115	–	89	88	0.473	< 0.0002	< 0.0003	< 0.0003	0.0158	0.02510	7.3
HFM13	159.00	173.00	12768	0.064	13.3	–	7.38	7.54	–	–	–	–	1,480	1,450	–	–	–	–	–	–	8.4
HFM13	159.00	173.00	12884	0.051	11.7	0.046	7.29	7.42	1.8	1.8	0.022	–	1,440	1,440	1.43	0.0003	0.0003	0.0000	0.0005	< 0.04	8.4
HFM15	85.00	95.00	12763	0.017	0.649	–	7.22	7.28	–	–	–	–	254	261	–	–	–	–	–	–	8.1
HFM15	85.00	95.00	12885	0.035	2.43	0.017	7.37	7.31	5.7	5.7	0.049	–	744	746	1.69	0.0006	< 0.0003	0.0006	0.0081	0.02010	7.9
HFM16	54.00	67.00	12765	0.012	0.290	–	7.79	7.84	–	–	–	–	145	145	–	–	–	–	–	–	8.3
HFM16	54.00	67.00	12892	0.009	0.217	0.007	7.80	7.62	17	15	0.011	–	132	133	0.665	< 0.0002	< 0.0003	< 0.0003	0.0744	0.09160	8.0
HFM19	168.00	182.00	12764	0.067	7.44	–	7.19	7.26	–	–	–	–	1,520	1,540	–	–	–	–	–	–	8.6
HFM19	168.00	182.00	12886	0.047	4.34	0.019	7.38	7.21	3.7	–	0.937	–	1,030	1,050	1.91	0.0004	0.0392	0.0396	0.0047	0.01120	8.1
HFM21	22.00	32.00	12758	0.017	0.378	0.006	7.54	7.74	7.6	7.4	< 0.006	–	160	160	0.537	0.0003	0.0003	0.0006	0.0088	0.02840	8.0
HFM21	22.00	32.00	12893	0.019	0.420	0.009	7.55	7.81	10	10	0.396	–	207	200	0.494	< 0.0002	0.0005	0.0006	0.0147	0.03450	8.3
HFM27	46.00	58.00	12760	0.037	2.52	–	7.35	7.41	–	–	–	–	752	732	–	–	–	–	–	–	8.1
HFM27	46.00	58.00	12896	0.039	3.10	0.024	7.36	7.56	5.0	5.1	0.052	–	935	951	1.73	0.0003	< 0.0003	< 0.0003	< 0.0005	0.01520	8.3
HFM32	26.00	31.00	12767	0.066	3.51	–	7.18	7.01	–	–	–	–	1,220	1,193	–	–	–	–	–	–	8.1
HFM32	26.00	31.00	12913	0.050	2.42	0.048	7.24	6.95	7.0	8.4	0.173	–	1,020	1,003	1.69	0.0002	< 0.0003	< 0.0003	< 0.0005	0.00636	8.4
KFM01A	109.00	130.00	12770	0.050	6.98	–	7.61	7.85	–	–	–	80.2	1,290	1,324	–	–	–	–	–	–	8.7
KFM01A	109.00	130.00	12855	0.048	6.51	–	7.67	7.59	–	–	–	83.9	1,240	1,322	–	–	–	–	–	–	8.3
KFM01D	311.00	321.00	12771	0.045	6.08	0.043	7.60	7.50	8.0	7.4	0.287	45.4	1,130	1,105	1.02	0.0004	< 0.0003	0.0004	0.0020	0.03840	8.0
KFM01D	311.00	321.00	12889	0.042	7.63	–	7.51	7.59	–	–	–	38.1	1,120	1,140	–	–	–	–	–	–	8.1
KFM01D	429.00	438.00	12772	0.045	6.29	0.041	7.57	7.32	21	14	3.29	42.1	1,140	1,113	0.36	0.0003	< 0.0003	< 0.0003	0.0015	0.01850	8.5
KFM01D	429.00	438.00	12888	0.038	8.98	–	7.58	7.49	–	–	–	30.6	1,200	1,170	–	–	–	–	–	–	8.0
KFM01D	429.00	438.00	12953	0.033	8.99	–	7.27	–	–	–	13.4	32.7	1,230	–	–	–	–	–	–	–	–
KFM01D	429.00	438.00	12954	0.034	9.16	–	7.61	–	–	–	1.77	32.7	1,230	–	–	–	–	–	–	–	–

Idcode	Secup m	Seclow m	Sample no.	Sampling date	RCB %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO_3^- mg/L	Cl^- mg/L	SO_4^{2-} mg/L	SO4_S mg/L	Br mg/l	F^- mg/L	Si mg/L	Fe mg/L	Fe-tot mg/L
KFM01D	429.00	438.00	12955	2008-01-31	–1.19	1,500	14.0	1,100	54.9	86.1	4,380	139.8	47.7	25.2	1.17	15.40	0.111	–
KFM02A	411.00	442.00	12701	2007-02-14	–0.55	1,970	23.7	1,190	206	100	5,430	420	152	26.7	1.33	8.86	–	–
KFM02A	411.00	442.00	12901	2007-10-30	–3.36	1,770	20.9	1,160	199	125	5,370	405	148	22.0	1.13	8.38	–	–
KFM02A	490.00	518.00	12700	2007-02-14	–2.19	2,140	37.2	979	244	125	5,560	489	180	22.2	1.36	6.90	–	–
KFM02A	490.00	518.00	12899	2007-10-30	–4.76	1,940	33.4	1,030	242	134	5,630	494	180	18.9	1.48	6.87	2.01	2.02
KFM02B	410.00	431.00	12900	2007-10-30	–4.53	1,750	27.0	1,190	222	114	5,580	430	159	21.2	1.51	8.84	2.82	2.81
KFM02B	491.00	506.00	12898	2007-10-30	–3.41	2,060	36.0	965	244	134	5,550	506	181	19.6	1.41	8.14	4.43	3.65
KFM03A	633.50	650.00	12708	2007-03-01	–1.07	1,730	19.6	1,540	73.3	28.4	5,540	214	84.0	32.9	1.44	7.83	–	–
KFM03A	633.50	650.00	12850	2007-10-15	–2.52	1,840	16.4	1,480	60.4	21.9	5,770	198	68.9	38.9	1.50	6.50	0.684	0.617
KFM03A	969.50	994.50	12711	2007-03-02	–0.17	2,130	9.00	4,180	10.5	8.1	10,700	48.1	20.6	92.7	1.34	6.19	–	–
KFM03A	969.50	994.50	12849	2007-10-15	2.54	2,360	8.01	3,960	10.3	7.1	10,100	45.8	17.5	101	1.34	5.49	0.352	0.327
KFM04A	230.00	245.00	12759	2007-04-11	–0.21	1,910	25.9	1,480	230	103	5,850	487	172	24.1	1.16	6.73	1.99	2.13
KFM04A	230.00	245.00	12911	2007-11-01	–2.62	1,670	21.4	1,570	240	102	5,940	488	181	28.4	1.07	6.86	2.33	2.35
KFM06A	341.00	362.00	12897	2007-10-26	–2.35	1,410	13.5	1,250	65.5	54.5	4,650	149	56.4	28.2	1.30	6.18	–	–
KFM07A	962.00	972.00	12729	2007-03-20	–0.11	2,960	13.3	5,730	20.4	14.3	14,700	108	40.1	138	1.48	4.09	0.202	0.282
KFM07A	962.00	972.00	12895	2007-10-26	0.50	2,770	11.1	6,180	21.9	28.5	15,000	102	40.3	140	1.23	4.04	< 0.004	0.009
KFM08A	265.00	280.00	12946	2008-01-22	–0.19	1,680	14.1	1,850	22.4	45.4	5,880	65.7	24.2	48.1	1.22	3.65	0.645	–
KFM08A	265.00	280.00	12949	2008-01-22	0.55	1,640	16.2	1,800	35.1	47.8	5,670	78.2	28.6	46.5	1.26	5.16	0.901	–
KFM08A	265.00	280.00	12951	2008-01-22	–0.54	1,600	17.9	1,680	41.7	55.3	5,540	73.5	27.8	44.4	1.25	5.94	1.05	–
KFM08A	684.00	694.00	12947	2008-01-22	0.34	1,710	12.4	2,020	4.3	23.4	6,090	73.4	38.3	49.4	1.23	2.68	< 0.1	–
KFM08A	684.00	694.00	12950	2008-01-22	–0.21	1,680	13.3	1,990	16.1	17.6	6,110	86.8	32.0	50.3	1.37	4.72	0.378	–
KFM08A	684.00	694.00	12952	2008-01-22	0.16	1,710	13.6	1,980	17.4	15.8	6,100	82.7	30.9	51.3	1.23	5.12	0.445	–
KFM08D	660.00	680.00	12948	2008-01-22	0.00	1,660	14.1	1,530	35.7	22.4	5,220	131	65.6	41.3	1.01	6.83	< 0.1	–
KFM10A	430.00	440.00	12769	2007-04-17	–2.46	1,740	35.2	1,040	196	137	4,900	511	187	19.3	1.39	7.61	6.84	7.00
KFM10A	430.00	440.00	12883	2007-10-17	2.29	2,250	31.8	1,190	219	90.8	5,490	516	192	22.6	1.39	7.55	5.95	5.43
KFM11A	446.00	456.00	12829	2007-10-09	0.06	1,400	7.83	1,320	37.9	15.8	4,400	244	90.8	21.6	0.99	5.38	0.534	0.515
KFM11A	690.00	710.00	12831	2007-10-09	2.03	1,910	17.9	1,650	84.1	60.4	5,710	169	61.6	40.3	1.10	6.98	2.15	1.74

Idcode	Secup m	Seclow m	Sample no.	FeII mg/L	Mn mg/L	Li mg/L	Sr mg/L	I^- mg/L	pH	pH_F	DOC mg/L	TOC mg/L	HS^- mg/L	Uranine µg/L	ElCond mS/m	EC_F mS/m	NH_4N mg/L	NO_2N mg/L	NO_3N mg/L
KFM01D	429.00	438.00	12955	–	0.247	0.035	11.6	–	7.52	–	–	–	2.38	25.2	1,260	–	–	–	–
KFM02A	411.00	442.00	12701	–	–	0.054	12.1	–	7.08	7.00	–	–	–	19.4	1,560	1,540	–	–	–
KFM02A	411.00	442.00	12901	–	–	3.350	11.0	–	7.35	7.12	–	–	–	250	1,520	1,516	–	–	–
KFM02A	490.00	518.00	12700	–	–	0.054	8.70	–	6.96	7.01	–	–	–	9.2	1,600	1,597	–	–	–
KFM02A	490.00	518.00	12899	2.01	2.28	0.041	7.25	0.108	7.24	7.14	1.9	1.9	0.219	11.9	1,600	1,590	2.41	0.0002	< 0.0003
KFM02B	410.00	431.00	12900	2.82	2.25	0.133	9.07	0.531	7.28	7.19	1.7	1.7	0.081	10.3	1,590	1,586	2.07	0.0002	< 0.0003
KFM02B	491.00	506.00	12898	3.66	2.22	0.043	7.16	2.86	7.23	7.04	2.3	2.1	0.018	5.5	1,600	1,615	2.45	0.0002	< 0.0003
KFM03A	633.50	650.00	12708	–	–	0.034	18.1	–	7.44	7.52	–	–	–	11.6	1,570	1,555	–	–	–
KFM03A	633.50	650.00	12850	0.609	0.385	0.041	17.8	0.125	7.47	7.61	< 1	< 1	0.219	5.8	1,580	1,587	0.241	< 0.0002	< 0.0003
KFM03A	969.50	994.50	12711	–	–	0.029	48.6	–	7.35	7.45	–	–	–	2.2	2,690	2,610	–	–	–
KFM03A	969.50	994.50	12849	0.311	0.0450	0.038	48.9	0.324	7.87	7.62	< 1	< 1	0.245	1.7	2,630	2,650	0.0576	< 0.0002	< 0.0003
KFM04A	230.00	245.00	12759	2.15	3.15	0.062	15.5	0.058	7.19	6.74	1.7	1.8	< 0.006	2.8	1,680	1,680	1.55	0.0014	< 0.0003
KFM04A	230.00	245.00	12911	2.38	3.39	0.048	13.2	0.068	7.18	6.97	1.3	1.4	0.037	1.4	1,690	1,674	1.50	0.0002	< 0.0003
KFM06A	341.00	362.00	12897	–	–	0.050	13.7	–	7.61	7.85	–	–	–	28.6	1,320	1,344	–	–	–
KFM07A	962.00	972.00	12729	0.252	0.177	0.075	67.9	0.301	8.11	–	1.1	1.0	0.116	2.5	3,650	–	0.0098	–0.0002	< 0.0003
KFM07A	962.00	972.00	12895	< 0.006	0.06700	0.064	54.5	0.405	9.34	–	1.9	2.0	0.011	2.7	3,640	–	0.0253	–0.0002	< 0.0003
KFM08A	265.00	280.00	12946	–	0.153	0.028	23.8	–	8.01	–	–	–	0.055	16.5	1,630	–	–	–	–
KFM08A	265.00	280.00	12949	–	0.313	0.035	22.1	–	7.61	–	–	–	0.094	23.4	1,570	–	–	–	–
KFM08A	265.00	280.00	12951	–	0.427	0.028	21.0	–	7.75	7.89	–	–	0.052	28.3	1,540	1,542	–	–	–
KFM08A	684.00	694.00	12947	–	< 0.02	0.037	25.2	–	10.2	–	–	–	0.190	10.9	1,680	–	–	–	–
KFM08A	684.00	694.00	12950	–	0.154	0.027	24.8	–	8.46	–	–	–	X	11.9	1,690	–	–	–	–
KFM08A	684.00	694.00	12952	–	0.172	0.031	24.5	0.245	8.38	8.21	1.2	1.0	0.025	10.8	1,660	1,661	0.112	< 0.0002	0.0036
KFM08D	660.00	680.00	12948	–	0.239	0.037	18.1	–	8.40	–	–	–	3.33	82.1	1,470	–	–	–	–
KFM10A	430.00	440.00	12769	7.04	1.63	0.062	9.88	0.028	7.41	7.32	2.9	3.2	0.056	13.0	1,450	1,472	1.28	0.0002	< 0.0003
KFM10A	430.00	440.00	12883	5.67	1.70	0.069	11.4	0.040	7.24	7.34	1.8	2.0	0.183	0.8	1,590	1,598	1.30	0.0006	0.0005
KFM11A	446.00	456.00	12829	0.506	0.193	0.052	18.3	0.077	7.77	7.94	1.9	1.8	0.172	8.4	1,260	–	0.139	< 0.0002	< 0.0003
KFM11A	690.00	710.00	12831	1.76	0.763	0.051	20.7	0.136	7.45	6.62	1.3	1.3	0.145	3.2	1,580	–	0.769	< 0.0002	< 0.0003

Idcode	Secup m	Seclow m	Sample no.	NO_2N/NO_3N mg/L	PO_4P mg/L	P mg/L	Temp. °C
KFM01D	429.00	438.00	12955	–	–	–	–
KFM02A	411.00	442.00	12701	–	–	–	8.1
KFM02A	411.00	442.00	12901	–	–	–	8.3
KFM02A	490.00	518.00	12700	–	–	–	8.3
KFM02A	490.00	518.00	12899	< 0.0003	< 0.0005	< 0.04	8.2
KFM02B	410.00	431.00	12900	< 0.0003	< 0.0005	< 0.04	8.4
KFM02B	491.00	506.00	12898	0.0003	< 0.0005	< 0.04	8.1
KFM03A	633.50	650.00	12708	–	–	–	8.1
KFM03A	633.50	650.00	12850	< 0.0003	< 0.0005	< 0.04	8.2
KFM03A	969.50	994.50	12711	–	–	–	8.3
KFM03A	969.50	994.50	12849	< 0.0003	< 0.0005	< 0.04	8.3
KFM04A	230.00	245.00	12759	0.0100	0.0010	< 0.04	8.7
KFM04A	230.00	245.00	12911	0.0003	< 0.0005	< 0.04	8.6
KFM06A	341.00	362.00	12897	–	–	–	–
KFM07A	962.00	972.00	12729	< 0.0003	< 0.0005	< 0.04	–
KFM07A	962.00	972.00	12895	0.0003	0.0018	< 0.04	–
KFM08A	265.00	280.00	12946	–	–	–	–
KFM08A	265.00	280.00	12949	–	–	–	–
KFM08A	265.00	280.00	12951	–	–	–	7.2
KFM08A	684.00	694.00	12947	–	–	–	–
KFM08A	684.00	694.00	12950	–	–	–	–
KFM08A	684.00	694.00	12952	0.0037	0.0006	< 0.04	7.1
KFM08D	660.00	680.00	12948	–	–	–	–
KFM10A	430.00	440.00	12769	< 0.0003	0.0005	0.00597	8.1
KFM10A	430.00	440.00	12883	0.0011	0.0017	< 0.04	8.3
KFM11A	446.00	456.00	12829	< 0.0003	< 0.0005	< 0.005	8.3
KFM11A	690.00	710.00	12831	< 0.0003	< 0.0005	< 0.04	8.2

– = Not analysed

pH_; EC_F = Field measurements of pH and EC

< "value" = value below reporting limit

RCB% = Rel. charge balance error %

x = No result due to analytical problem

SICADA: water_composition

Table A4-2. Trace elements.

Idcode	Secup m	Seclow m	Sample no.	Sampling date	U ug/L	Th ug/L	B ug/L	As ug/L	Sc ug/L	Cd ug/L	Hg ug/L	V ug/L	Rb ug/L	Y ug/L	Zr ug/L	In ug/L	Cs ug/L	Ba ug/L	La ug/L	Hf ug/L	Tl ug/L
HFM01	33.50	45.50	12757	2007-04-10	9.39	0.0267	385	0.10	< 0.05	< 0.002	< 0.002	0.745	9.79	1.43	12.2	< 0.05	0.298	36.0	0.0469	0.162	< 0.005
HFM01	33.50	45.50	12890	2007-10-23	19.0	0.0473	423	0.20	0.0665	< 0.005	< 0.002	0.652	15.9	1.74	3.93	–	0.607	51.1	0.0919	0.0232	< 0.005
HFM02	38.00	48.00	12891	2007-10-23	14.6	< 0.2	431	< 0.5	< 0.4	< 0.02	< 0.002	0.347	21.2	1.73	<10	< 0.05	0.640	131	0.0657	< 0.02	< 0.03
HFM04	58.00	66.00	12912	2007-11-01	2.79	0.0243	189	0.19	0.124	< 0.002	< 0.002	0.883	7.51	1.93	5.98	< 0.05	0.198	31.5	0.102	0.0419	< 0.01
HFM13	159.00	173.00	12884	2007-10-17	16.2	< 0.2	531	< 1	< 0.5	< 0.05	< 0.002	< 0.05	48.3	19.2	< 0.3	< 0.5	2.11	58.7	0.766	< 0.05	< 0.005
HFM15	85.00	95.00	12885	2007-10-17	15.4	< 0.2	381	< 0.5	< 0.4	< 0.02	< 0.002	0.331	24.5	1.45	< 2	< 0.2	891	41.0	0.0485	< 0.02	< 0.03
HFM16	54.00	67.00	12892	2007-10-23	4.97	0.0359	294	1.01	0.0891	< 0.006	0.0028	1.63	5.99	0.886	6.73	–	0.0951	20.6	0.0440	0.0547	< 0.005
HFM19	168.00	182.00	12886	2007-10-17	9.09	< 0.2	457	< 0.5	< 0.4	< 0.02	< 0.002	0.172	30.0	4.66	1.68	< 0.02	1.62	37.6	0.0583	0.0308	< 0.03
HFM21	22.00	32.00	12758	2007-04-10	4.35	< 0.2	187	0.2	< 0.5	< 0.002	< 0.002	0.700	9.09	3.06	7.53	< 0.05	0.210	26.9	0.0687	0.0805	< 0.005
HFM21	22.00	32.00	12893	2007-10-23	7.1	< 0.2	225	0.3	< 0.5	0.0042	< 0.002	0.905	10.2	5.38	4.56	–	0.250	34.5	0.157	0.0276	< 0.005
HFM27	46.00	58.00	12896	2007-10-26	16.4	< 0.2	416	0.632	< 0.4	< 0.02	< 0.002	0.315	24.4	1.82	1.53	< 0.2	0.944	71.9	0.134	< 0.02	< 0.005
HFM32	26.00	31.00	12913	2007-11-12	17.5	< 0.2	646	1.9	< 0.4	< 0.02	< 0.002	0.142	30.8	1.13	0.496	< 0.2	0.805	47.3	0.0554	< 0.02	< 0.005
KFM01D	311.00	321.00	12771	2007-04-18	4.75	0.275	736	0.6	< 0.4	< 0.02	< 0.002	1.23	47.6	6.07	9.53	< 0.2	0.485	294	2.80	1.41	< 0.03
KFM01D	429.00	438.00	12772	2007-04-23	4.34	< 0.2	734	< 0.5	< 0.4	< 0.02	< 0.002	0.663	69.8	12.4	4.01	< 0.2	4.34	314	3.05	0.489	< 0.03
KFM02A	490.00	518.00	12899	2007-10-30	148	< 0.2	588	< 1	< 0.5	< 0.05	< 0.002	0.185	67.2	3.34	< 0.3	< 0.5	1.76	82.9	1.01	< 0.05	< 0.01
KFM02B	410.00	431.00	12900	2007-10-30	16.4	< 0.2	606	< 1	< 0.5	< 0.05	< 0.002	0.0574	85.6	8.91	< 0.3	< 0.5	6.36	87.9	0.797	< 0.05	< 0.01
KFM02B	491.00	506.00	12898	2007-10-30	9.57	< 0.2	600	< 1	< 0.5	< 0.05	< 0.002	0.107	58.6	3.37	< 0.3	< 0.5	1.97	100	0.587	< 0.05	< 0.01
KFM03A	633.50	650.00	12850	2007-10-15	34.6	< 0.2	988	< 1	< 0.5	< 0.05	< 0.002	< 0.05	36.3	0.380	< 0.3	< 0.5	5.41	144	0.369	< 0.05	< 0.005
KFM03A	969.50	994.50	12849	2007-10-15	0.248	< 0.2	895	< 1	0.627	< 0.05	< 0.002	< 0.05	35.1	0.399	< 0.3	< 0.5	0.644	1.080	0.500	< 0.05	< 0.005
KFM04A	230.00	245.00	12759	2007-04-11	27.8	< 0.2	569	< 1	< 0.5	< 0.05	< 0.002	0.0743	39.1	1.42	< 0.3	< 0.5	1.95	94.1	0.296	< 0.05	< 0.005
KFM04A	230.00	245.00	12911	2007-11-01	18.8	< 0.2	549	< 1	< 0.5	0.458	< 0.002	0.0780	37.6	1.29	< 0.3	< 0.5	1.73	81.0	0.225	< 0.05	< 0.01
KFM07A	962.00	972.00	12729	2007-03-20	0.195	< 0.2	735	< 1	0.920	< 0.05	< 0.002	0.0859	36.2	0.600	0.419	< 0.5	0.807	546	< 0.05	< 0.05	< 0.005
KFM07A	962.00	972.00	12895	2007-10-26	0.0122	< 0.2	699	< 1	0.972	< 0.05	< 0.002	< 0.05	40.0	0.447	< 0.3	< 0.5	0.828	496	< 0.05	< 0.1	< 0.005
KFM08A	684.00	694.00	12952	2008-01-22	8.55	< 0.2	709	2.3	< 0.5	< 0.05	< 0.002	< 0.05	31.0	0.226	< 0.3	< 0.5	0.509	364	< 0.05	< 0.05	< 0.1
KFM10A	430.00	440.00	12769	2007-04-17	5.72	< 0.2	622	< 0.5	< 0.4	< 0.02	< 0.002	0.295	37.7	3.18	7.21	< 0.2	0.853	117	0.251	1.92	< 0.03
KFM10A	430.00	440.00	12883	2007-10-17	3.66	< 0.2	757	<1	< 0.5	< 0.05	< 0.002	0.107	54.3	8.66	0.499	< 0.5	1.06	86.0	0.256	< 0.05	< 0.005
KFM11A	446.00	456.00	12829	2007-10-09	0.588	< 0.2	981	< 0.5	< 0.4	< 0.02	< 0.002	0.173	14.1	0.245	0.128	< 0.2	0.636	84.8	0.0780	< 0.02	< 0.03
KFM11A	690.00	710.00	12831	2007-10-09	5.05	< 0.2	808	<1	< 0.5	< 0.05	0.0205	0.0876	24.9	0.325	< 0.3	< 0.5	0.377	191	0.101	< 0.05	< 0.005

Idcode	Secup m	Seclow m	Sample no.	Ce ug/L	Pr ug/L	Nd ug/L	Sm ug/L	Eu ug/L	Gd ug/L	Tb ug/L	Dy ug/L	Ho ug/L	Er ug/L	Tm ug/L	Yb ug/L	Lu ug/L
HFM01	33.50	45.50	12757	0.0968	0.0142	0.0630	0.0281	< 0.05	0.0642	0.0147	0.136	0.0338	0.129	0.0181	0.134	0.0220
HFM01	33.50	45.50	12890	0.188	0.0291	0.155	0.0741	8.67	0.181	0.0415	0.325	0.0761	0.213	0.0268	0.152	0.0254
HFM02	38.00	48.00	12891	0.127	< 0.02	0.0783	0.0278	< 0.02	0.0598	< 0.02	0.126	0.0352	0.124	< 0.02	0.131	< 0.02
HFM04	58.00	66.00	12912	0.220	0.0293	0.156	0.0565	0.0075	0.125	0.0239	0.198	0.0526	0.175	0.0274	0.170	0.0315
HFM13	159.00	173.00	12884	1.50	0.206	1.08	0.420	< 0.05	0.939	0.452	1.26	0.394	1.16	0.159	0.888	0.152
HFM15	85.00	95.00	12885	0.0926	< 0.02	0.0639	0.0300	< 0.02	0.175	0.0291	0.187	0.0562	0.133	< 0.02	0.124	0.107
HFM16	54.00	67.00	12892	0.0963	0.0136	0.0668	0.0258	0.0115	0.0602	0.0116	0.102	0.0300	0.106	0.0163	0.103	0.0241
HFM19	168.00	182.00	12886	0.114	0.0254	0.180	0.157	0.0239	0.464	0.0815	10.6	0.189	0.502	0.0611	0.338	0.150
HFM21	22.00	32.00	12758	0.155	0.0255	0.142	0.0631	0.0079	0.154	0.0293	0.263	0.0687	0.265	0.0380	0.269	0.0454
HFM21	22.00	32.00	12893	0.365	0.0555	0.317	0.127	0.0173	0.307	0.0531	0.483	0.144	0.490	0.0779	0.467	0.0917
HFM27	46.00	58.00	12896	0.208	0.0273	0.134	0.0359	< 0.02	0.0792	< 0.02	0.113	0.0321	0.116	< 0.02	0.117	0.0209
HFM32	26.00	31.00	12913	0.083	< 0.02	0.0525	< 0.02	< 0.02	0.0339	< 0.02	0.0528	< 0.02	0.0612	< 0.02	0.0607	< 0.02
KFM01D	311.00	321.00	12771	4.10	0.485	2.05	0.412	0.0575	0.505	0.0618	0.459	0.111	0.369	0.0414	0.270	0.0410
KFM01D	429.00	438.00	12772	4.93	0.584	2.85	0.692	0.0745	0.976	0.120	0.874	0.212	0.709	0.0803	0.470	0.0701
KFM02A	490.00	518.00	12899	1.57	0.137	0.563	0.0945	< 0.05	0.193	< 0.05	0.172	< 0.05	0.122	< 0.05	0.0894	< 0.05
KFM02B	410.00	431.00	12900	1.35	0.158	0.737	0.227	< 0.05	0.521	0.0891	0.610	0.149	0.452	0.0597	0.284	< 0.05
KFM02B	491.00	506.00	12898	0.794	0.0794	0.351	0.0794	< 0.05	0.152	< 0.05	0.167	< 0.05	0.124	< 0.05	0.0750	< 0.05
KFM03A	633.50	650.00	12850	0.349	< 0.05	0.141	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
KFM03A	969.50	994.50	12849	0.515	< 0.05	0.169	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
KFM04A	230.00	245.00	12759	0.315	0.0731	0.255	< 0.05	< 0.05	0.0519	< 0.05	0.0692	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
KFM04A	230.00	245.00	12911	0.203	< 0.05	0.0740	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
KFM07A	962.00	972.00	12729	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
KFM07A	962.00	972.00	12895	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
KFM08A	684.00	694.00	12952	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
KFM10A	430.00	440.00	12769	0.373	0.0421	0.202	0.056	< 0.02	0.139	0.0229	0.191	0.0580	0.213	0.0278	0.190	0.0295
KFM10A	430.00	440.00	12883	0.435	0.102	0.887	0.659	0.0695	1.62	0.246	1.60	34.8	0.990	0.108	0.529	0.0679
KFM11A	446.00	456.00	12829	0.0776	< 0.02	0.0357	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.104
KFM11A	690.00	710.00	12831	0.116	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05

Idcode	Secup m	Seclow m	Sample no.	Cr ug/L	Cu ug/L	Co ug/L	Ni ug/L	Mo ug/L	Pb ug/L	Zn ug/L	Sb ug/L	Al µg/L
HFM01	33.50	45.50	12757	0.151	1.09	0.0262	0.346	10.1	0.107	1.30	0.0165	2.21
HFM01	33.50	45.50	12890	4.42	0.224	0.210	11.0	11.9	0.0256	3.61	0.0369	2.47
HFM02	38.00	48.00	12891	1.15	< 0.2	< 0.02	1.27	7.59	< 0.1	< 0.8	< 0.1	1.90
HFM04	58.00	66.00	12912	1.73	0.127	0.0353	0.879	4.42	0.0357	0.584	< 0.01	19.8
HFM13	159.00	173.00	12884	< 0.1	< 0.5	< 0.05	< 0.5	4.77	< 0.3	<2	< 0.1	5.56
HFM15	85.00	95.00	12885	4.29	< 0.2	0.0333	1.55	8.49	0.108	< 0.8	< 0.1	4.07
HFM16	54.00	67.00	12892	0.863	0.101	0.0447	0.681	21.8	0.102	1.11	0.018	5.34
HFM19	168.00	182.00	12886	0.169	< 0.2	< 0.02	0.281	5.86	< 0.1	< 0.8	< 0.1	4.31
HFM21	22.00	32.00	12758	0.306	< 0.1	0.0498	0.725	6.06	0.0226	0.238	0.0154	3.19
HFM21	22.00	32.00	12893	0.522	< 0.1	0.0602	0.402	6.64	0.0191	< 0.2	0.0354	4.89
HFM27	46.00	58.00	12896	0.741	< 0.2	0.0393	1.62	6.99	< 0.1	< 0.8	< 0.1	< 0.3
HFM32	26.00	31.00	12913	1.08	< 0.2	0.0627	1.01	10.2	0.111	1.14	< 0.1	47.1
KFM01D	311.00	321.00	12771	1.20	< 0.2	< 0.02	0.421	5.89	0.176	< 0.8	0.112	5.78
KFM01D	429.00	438.00	12772	1.00	< 0.2	< 0.02	< 0.2	0.304	0.158	< 0.8	0.103	7.02
KFM02A	490.00	518.00	12899	1.26	< 0.5	0.648	0.910	122	< 0.3	< 2	< 0.1	< 7
KFM02B	410.00	431.00	12900	0.217	< 0.5	0.193	1.06	8.45	< 0.3	< 2	< 0.1	2.28
KFM02B	491.00	506.00	12898	0.302	< 0.5	0.685	1.59	7.87	< 0.3	< 2	< 0.1	< 0.7
KFM03A	633.50	650.00	12850	0.768	< 0.5	< 0.05	0.847	31.2	< 0.3	< 2	0.119	23.1
KFM03A	969.50	994.50	12849	0.582	< 0.5	< 0.05	< 0.5	11.0	< 0.3	< 2	0.252	18.4
KFM04A	230.00	245.00	12759	0.669	2.18	2.40	2.21	40.4	< 0.3	5.51	0.215	6.28
KFM04A	230.00	245.00	12911	2.13	0.683	2.80	3.83	29.4	< 0.3	2.86	0.130	< 0.7
KFM07A	962.00	972.00	12729	1.56	< 0.5	0.414	0.880	14.2	0.603	9.23	0.344	12.8
KFM07A	962.00	972.00	12895	0.350	< 0.5	< 0.05	0.735	18.5	< 0.3	2.60	1.00	< 0.7
KFM08A	684.00	694.00	12952	0.888	0.563	< 0.05	0.554	31.7	1.54	9.84	0.336	7.32
KFM10A	430.00	440.00	12769	0.405	< 0.2	0.0511	0.285	3.30	0.231	< 0.8	0.115	11.3
KFM10A	430.00	440.00	12883	0.478	< 0.5	< 0.05	1.11	3.16	< 0.3	< 2	< 0.1	13.8
KFM11A	446.00	456.00	12829	1.07	< 0.2	0.134	1.20	15.9	< 0.1	0.974	0.103	30.6
KFM11A	690.00	710.00	12831	4.60	< 0.05	0.0716	2.70	30.9	< 0.3	5.65	0.150	137

– = Not analysed

< "value" = result less than reporting limit

SICADA: trace_elements_1, trace_elements_2

Table A4-3. Isotopes I (H-, O-, B-, S-, Ci- and C-isotopes).

Idcode	Secup m	Seclow m	Sample no	Sampling date	δ^{2}H dev SMOW	^{3}H TU	δ^{18}O dev SMOW	^{10}B/^{11}B no unit	δ^{34}S dev CDT	δ^{13}C dev PDB	^{87}Sr/^{86}Sr no unit	^{14}C pmC	δ^{37}Cl dev SMOC	Cl^{36}_Cl^{35}C^{37} no unit
HFM01	33.50	45.50	12757	2007-04-10	–79.5	6.70	–10.4	0.2381	15.2	–10.47	0.726880	51.38	0.22	–
HFM01	33.50	45.50	12890	2007-10-23	–75.1	4.00	–10.0	0.2351	18.2	–7.79	0.726552	40.23	0.09	–
HFM02	38.00	48.00	12761	2007-04-11	–82.3	7.60	–11.1	–	–	–	–	–	–	–
HFM02	38.00	48.00	12891	2007-10-23	–74.8	3.70	–10.0	0.2366	22.0	–9.07	0.725242	48.70	–0.04	–
HFM04	58.00	66.00	12704	2007-02-20	–85.5	7.90	–11.6	–	–	–	–	–	–	1.60E–013
HFM04	58.00	66.00	12912	2007-11-01	–83.9	9.10	–11.8	0.2383	16.7	–12.19	0.719618	72.28	0.19	–
HFM13	159.00	173.00	12768	2007-04-17	–73.6	1.00	–9.1	–	–	–	–	–	–	–
HFM13	159.00	173.00	12884	2007-10-17	–73.0	1.10	–9.4	0.2367	25.0	–6.10	0.717836	20.32	–0.07	–
HFM15	85.00	95.00	12763	2007-04-12	–84.4	7.60	–11.1	–	–	–	–	–	–	–
HFM15	85.00	95.00	12885	2007-10-17	–74.3	3.90	–9.8	0.2371	23.5	–7.52	0.723519	40.81	–0.03	–
HFM16	54.00	67.00	12765	2007-04-12	–82.7	6.70	–10.7	–	–	–	–	–	–	–
HFM16	54.00	67.00	12892	2007-10-23	–80.6	6.40	–10.9	0.2359	11.5	–10.82	0.719112	56.10	0.26	–
HFM19	168.00	182.00	12764	2007-04-12	–68.5	1.00	–8.3	–	–	–	–	–	–	–
HFM19	168.00	182.00	12886	2007-10-17	–72.3	2.80	–9.4	0.2368	24.5	–8.85	0.722281	46.12	–0.10	–
HFM21	22.00	32.00	12758	2007-04-10	–86.7	9.20	–11.4	0.2388	9.4	–12.80	0.726682	72.28	0.29	–
HFM21	22.00	32.00	12893	2007-10-23	–80.1	8.60	–11.0	0.2367	3.3	–11.69	0.726303	71.13	0.25	–
HFM27	46.00	58.00	12760	2007-04-11	–74.9	2.40	–9.8	–	–	–	–	–	–	–
HFM27	46.00	58.00	12896	2007-10-26	–69.3	1.50	–9.5	0.2362	24.0	–7.46	0.724327	35.32	0.18	–
HFM32	26.00	31.00	12767	2007-04-17	–70.2	–0.80	–8.8	0.2351						–
HFM32	26.00	31.00	12913	2007-11-12	–66.4	1.90	–8.7	0.2358	27.0	–7.35	0.726668	40.74	0.25	–
KFM01A	109.00	130.00	12770	2007-04-23	–81.0	1.46	–10.3	–	–	–	–	–	–	–
KFM01D	311.00	321.00	12771	2007-04-18	–72.4	1.20	–9.5	0.2375	32.4	–15.88	0.722164	65.88	0.10	–
KFM01D	311.50	321.00	12889	2007-10-19	–73.9	1.10	–9.9	–	–	–	–	–	–	–
KFM01D	429.00	438.00	12772	2007-04-23	–73.7	1.50	–9.4	0.2381	38.3	–16.45	0.721946	51.23	0.05	–
KFM01D	429.00	438.00	12888	2007-10-19	–72.2	–0.80	–10.1	–	–	–	–	–	–	–
KFM02A	411.00	442.00	12701	2007-02-14	–77.1	0.90	–10.0	–	–	–	–	–	–	–
KFM02A	411.00	442.00	12901	2007-10-30	–78.6	3.30	–10.4	–	–	–	–	–	–	–
KFM02A	490.00	518.00	12700	2007-02-14	–67.5	–0.80	–8.6	–	–	–	–	–	–	–

Idcode	Secup m	Seclow m	Sample no	Sampling date	δ^2H dev SMOW	^3H TU	$\delta^{18}O$ dev SMOW	$^{10}B/^{11}B$ no unit	$\delta^{34}S$ dev CDT	$\delta^{13}C$ dev PDB	$^{87}Sr/^{86}Sr$ no unit	^{14}C pmC	$\delta^{37}Cl$ dev SMOC	$Cl^{36}\_Cl^{35}C^{37}$ no unit
KFM02A	490.00	518.00	12899	2007-10-30	–66.0	1.70	–8.7	0.2360	24.6	–1.33	0.718326	18.09	–0.01	–
KFM02B	410.00	431.00	12900	2007-10-30	–73.4	–0.80	–9.8	0.2369	24.6	–6.02	0.717524	14.06	0.07	–
KFM02B	491.00	506.00	12898	2007-10-30	–66.2	1.30	–8.7	0.2354	24.7	–5.79	0.718434	18.69	–0.04	–
KFM03A	633.50	650.00	12708	2007-03-01	–86.3	–0.80	–11.4	–	–	–	–	–	–	–
KFM03A	633.50	650.00	12850	2007-10-15	–84.4	1.10	–11.7	0.2351	27.3	xx	0.717462	xx	0.05	–
KFM03A	969.50	994.50	12711	2007-03-02	–99.1	1.80	–13.6	–	–	–	–	–	–	4.10E–014
KFM03A	969.50	994.50	12849	2007-10-15	–99.4	1.60	–13.8	0.2358	31.9	xx	0.717788	xx	0.23	–
KFM04A	230.00	245.00	12759	2007-04-11	–72.3	1.00	–9.3	0.2384	23.8	–6.37	0.717632	15.83	–0.23	–
KFM04A	230.00	245.00	12911	2007-11-01	–69.2	–0.80	–9.3	0.2370	24.3	–4.54	0.717587	16.99	0.03	–
KFM06A	341.00	362.00	12897	2007-10-26	–90.0	0.90	–11.9	–	–	–	–	–	–	–
KFM07A	962.00	972.00	12729	2007-03-20	–87.8	–0.80	–13.0	0.2409	24.0	xx	0.717851	xx	0.39	2.80E–014
KFM07A	962.00	972.00	12895	2007-10-26	–86.2	–0.80	–12.9	0.2399	24.6	–15.85	0.717824	78.90	0.07	–
KFM08A	265.00	280.00	12951	2008-01-22	–91.3	1.80	–12.5	–	–	–	–	–	–	–
KFM08A	684.00	694.00	12952	2008-01-22	–92.2	1.20	–13.0	0.2374	29.2	–12.10	0.718179	xx	0.42	–
KFM10A	430.00	440.00	12769	2007-04-17	–68.2	2.80	–8.6	0.2371	24.1	–8.62	0.719685	29.64	–0.08	–
KFM10A	430.00	440.00	12883	2007-10-17	–70.6	–0.80	–9.1	0.2361	25.2	–5.81	0.718860	22.68	0.06	–
KFM11A	446.00	456.00	12829	2007-10-09	–86.2	2.90	–11.7	0.2355	25.9	xx	0.716240	xx	0.03	–
KFM11A	690.00	710.00	12831	2007-10-09	–80.8	3.50	–11.1	0.2357	39.4	–11.22	0.717151	xx	0.07	–

– = Not analysed

xx = No result due to analytical problems

< "value" = result less than reporting limit

SICADA: isotopes_1

Table A4-4. Isotopes II (U-, Th, Ra- and Rn-isotopes)

Idcode	Secup m	Seclow m	Sample no.	Sampling date	^{238}U mBq/L	^{235}U mBq/L	^{234}U mBq/L	^{230}Th mBq/L	^{232}Th mBq/L	^{226}Ra Bq/L	^{222}Rn Bq/L	^{222}Rn_corr Bq/L
HFM01	33.50	45.50	12890	2007-10-23	226.30	10.31	494.20	0.82	0.39	0.38	80.4	149
HFM02	38.00	48.00	12891	2007-10-23	189.80	6.87	468.70	0.17	0.10	1.00	36.0	72.0
HFM04	58.00	66.00	12912	2007-11-01	37.80	1.42	114.10	2.29	0.76	0.15	274	418
HFM13	159.00	173.00	12884	2007-10-17	191.60	6.84	714.20	0.28	0.22	1.20	648.9	1,123
HFM15	85.00	95.00	12885	2007-10-17	185.90	7.41	469.20	0.36	0.33	0.26	40.6	72.0
HFM16	54.00	67.00	12892	2007-10-23	64.60	2.42	176.30	1.52	0.32	0.07	41.4	83.0
HFM19	168.00	182.00	12886	2007-10-17	110.50	4.47	307.20	0.32	0.25	0.46	108.9	200
HFM21	22.00	32.00	12893	2007-10-23	92.30	4.05	272.00	0.87	0.11	0.14	94.5	201
HFM27	46.00	58.00	12896	2007-10-26	210.30	8.88	567.70	0.25	0.11	1.20	102	248
HFM32	26.00	31.00	12913	2007-11-12	216.30	7.26	550.30	0.27	0.18	0.75	113	225
KFM02A	490.00	518.00	12899	2007-10-30	1,582.00	43.95	3,123.56	0.34	0.17	4.33	1,206	2,463
KFM02B	410.00	431.00	12900	2007-10-30	206.50	8.03	984.40	0.44	0.24	4.12	947	1,986
KFM02B	491.00	506.00	12898	2007-10-30	113.00	4.21	295.70	0.42	0.15	2.04	248	489
KFM03A	633.50	650.00	12850	2007-10-15	459.40	19.06	707.10	0.35	0.24	18.1	1,794	5,008
KFM03A	969.50	994.50	12849	2007-10-15	3.40	0.14	7.70	0.11	0.14	6.50	30.3	82.0
KFM04A	230.00	245.00	12911	2007-11-01	235.80	8.77	624.50	0.36	0.27	1.66	410	612
KFM07A	962.00	972.00	12895	2007-10-26	0.50	< 0.02	1.20	0.41	0.28	14.1	20.5	48.4
KFM08A	684.00	694.00	12952	2008-01-22	104.70	3.70	220.40	0.22	0.16	5.71	231	425
KFM10A	430.00	440.00	12883	2007-10-17	50.40	2.35	135.60	0.60	0.30	1.80	139.9	229
KFM11A	446.00	456.00	12829	2007-10-09	5.30	0.20	13.10	0.29	0.19	2.26	328	696
KFM11A	690.00	710.00	12831	2007-10-09	50.70	1.97	123.80	0.23	0.18	6,913	304	669

A = Results to be reported

< ‘’value’’ = result less than detection limit

SICADA: isotopes_2