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Forsmark site investigation

Hydrochemical monitoring of percussion- and core drilled boreholes

Results from water sampling and analyses during 2006

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April 2007

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Keywords: Forsmark, AP PF 400-06-041, Long-term monitoring, Percussion borehole, Core borehole, Groundwater, Water sampling, Chemical analyses, Isotopes, Uranium, Colloids, Fractionation, Filtration.

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

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

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Abstract

The second year of groundwater sampling (year 2006) within the long-term hydrogeochemical monitoring programme for percussion drilled and core drilled boreholes is completed and is documented in the present report. The 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 second year comprised sampling of groundwater in fifteen borehole sections corresponding to twelve boreholes at the first sampling occasion and two more sections in an additional borehole at the next occasion. At the first sampling occasion, three additional sections (normally not included in the monitoring programme) were sampled in HFM32. The number of boreholes in the programme will increase in the year to come as more boreholes will be equipped with the necessary installations.

Besides the main objective, to obtain long time series of chemical data, the monitoring programme gives a good opportunity to investigate chemical issues arisen from earlier investigations. In connection with the sampling in June 2006 of groundwater from KFM02A at 513 m borehole length, an investigation of uranium oxidation states was also performed /1/. This special study was caused by the exceptionally high uranium concentration observed in the groundwater from this borehole section and also in some other boreholes at Forsmark.

The results constitutes groundwater chemistry data in accordance with SKB chemistry class 3 including the isotopes ^3H , $\delta^{18}\text{O}$ and δD (first sampling) as well as SKB chemistry class 5 (second sampling). Data from the second year suggest that changes in the chemical conditions have occurred in a few boreholes/borehole sections. Generally, however most boreholes show relatively stable water compositions.

Sammanfattning

Andra årets grundvattenprovtagning (år 2006) inom det hydrokemiska programmet för långtidsövervakning av hammarborrhål och kärnborrhål är slutförd och dokumenteras i denna rapport. Programmet omfattar provtagning två gånger om året i borrhål med installerad utrustning för långtidsövervakning av tryck, spår försök och vattenprovtagning i avmanschetterade borrhålssektioner. Andra året omfattade provtagning i 15 borrhålssektioner i 12 borrhål vid första provtagningstillfället och ytterligare två sektioner i ett tillkommande borrhål vid nästa tillfälle. Vid första provtagningstillfället provtogs ytterligare tre sektioner (som normalt inte ingår i monitoringsprogrammet) i HFM32. Antalet borrhål som ingår i monitoringsprogrammet kommer att öka under det kommande året vartefter fler borrhål förses med de nödvändiga installationerna.

Förutom det huvudsakliga syftet, att erhålla långa tidsserier av kemidata, ger monitoringsprogrammet goda möjligheter att undersöka kemiska frågeställningar som uppstått vid tidigare undersökningar. I samband med den provtagning av grundvatten som gjordes vid 513 m borrhålslängd i KFM02A under juni månad 2006, utfördes även en undersökning av uranets oxidationstal /1/. Det som förorsakat denna specialstudie var de exceptionellt höga uranhalterna i denna borrhålssektion samt i några andra borrhål i Forsmark.

Resultaten består av grundvattenkemiska data enligt SKB:s kemiklass 3 med isotop-tillvalen ^3H , $\delta^{18}\text{O}$ och δD (första provtagningstillfället) och SKB:s kemiklass 5 (andra provtagningstillfället). Data från andra året visar att endast ett fåtal borrhål/borrhålssektioner uppvisar förändringar i de kemiska förhållandena. Generellt sett uppvisar borrhålen relativt stabila vattensammansättningar.

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1 Introduction

This document reports performance of and results from the second year (year 2006) of the hydrogeochemical monitoring program for percussion drilled and core drilled boreholes. The sampling programme is one of the activities performed within the site investigation at Forsmark and the work was carried out in accordance with activity plan AP PF 400-06-041. 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 October 2006.

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 400-06-041). 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 the year 2006 included water sampling and chemical analyses 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 KFM06A and KFM06C are inclined telescopic boreholes of chemistry-type. HFM02, HFM04, HFM13, HFM15, HFM16, HFM19, 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 /2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12/ 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 and PIR-06-02/04/06/25/26 (all PIR reports are SKB internal documents). The site investigation area in Forsmark as well as the locations of the monitored boreholes are 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 2006.	AP PF 400-06-041	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 monitoring programme for percussion- and core drilled boreholes during 2006 and corresponding transmissivity values.

Borehole: section	Section borehole length [m]	Transmissivity [m ² /s]
KFM01A:5	109.0–130.0	1.0 E–7*
KFM02A:3	490.0–518.0	2.1 E–6*
KFM02A:5	411.0–442.0	2.5 E–6*
KFM03A:1	969.5–994.5	5.5 E–7*
KFM03A:4	633.5–650.0	2.4 E–6*
KFM06A:3	738.0–748.0	1.2E–7*
KFM06A:5	341.0–362.0	3.5E–6*
KFM06C:3	647.0–666.0	5.3E–8*
KFM06C:5	531.0–540.0	1.1E–6*
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**
HFM27:2	46.0–58.0	4.0 E–5**
HFM32:3	26.0–31.0	2.3 E–4**

* From injection tests /13, 14, 15, 16, 17, 18/.

** From flow loggings /19, 20, 21, 22, 23, 24, 25/.

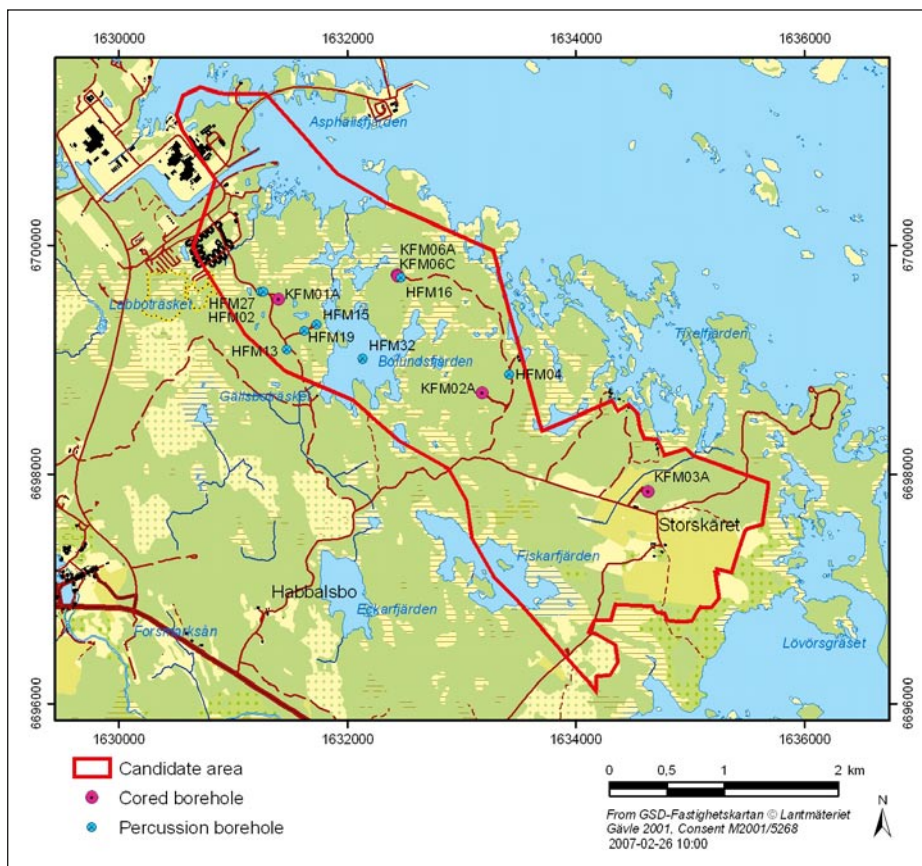


Figure 1-1. General overview over the Forsmark site investigation area. Sampled boreholes within the monitoring program 2006 are marked with blue (percussion) and pink (telescopic) infilled circles.

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 due to that the initial conditions might have been disturbed from drilling. 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 the next year when new borehole installations are completed. Generally, only the so called circulation sections are sampled. These sections are also used for groundwater flow measurements. During the first sampling occasion in 2006 all sections in HFM32 were sampled, i.e. including the non-circulation sections. The main reason for drilling this borehole was to be able to investigate and possibly explain the presence of Littorina sea water in the sediments below Lake Bolundsfjärden. Therefore, knowledge of the chemical composition in samples from several depths along the borehole was desired.

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 2006, a continued uranium study (initiated year 2005 /26/) was performed in KFM02A at 490.0–518.0 m. Due to this, sampling according to SKB class 5 including options was carried out at both sampling occasions (spring and autumn). The uranium study was conducted according to AP PF 400-06-039 (SKB internal controlling document) and is reported in /1/.

3 Background

In order to evaluate the results and understand eventual observed trends in the borehole sections, it is important to know the previous borehole history. Investigations which are likely to affect the water composition are tracer tests, SWIW-tests, dilution test and groundwater flow measurements. Except for investigations in a specific borehole/ borehole section, also on-going activities in nearby situated boreholes, e.g. pumping tests, core drilling and interference tests might be of importance when interpreting the results from water sampling and analyses.

3.1 Cored boreholes

Since the flushing water content is an important parameter when evaluating chemical data from core drilled boreholes, investigations including the use of Uranine (the tracer used for the flushing water during drilling) may obstruct the interpretation of later hydrochemical data.

One activity performed in all cored boreholes after the hydrochemical investigation campaign is injection tests with the PSS equipment /13, 14, 15, 16, 17, 18/. The water added to the borehole during injection tests is marked with the dye Uranine to the same concentration as the flushing water e.i. 0.2 mg/L. These, and other activities performed in the cored boreholes that might affect the sample quality are listed in Table 3-1.

3.2 Percussion boreholes

Flushing water is not used during drilling of percussion boreholes and therefore remaining flushing water is not a problem. Dilution tests conducted in percussion boreholes prior to chemical sampling may though affect the section water. However, since the fractures generally yield much water and the injected volumes during these tests are small, they are not likely to cause significant effects. Furthermore, interference tests with heavy pumping may affect the representativity of the samples from percussion boreholes. During 2006 one interference test was performed that involved pumping in HFM14 situated close to HFM15 /27/. Activities performed in the percussion boreholes that might affect the sample quality are listed in Table 3-2.

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

Borehole [Idcode]	Section [m]	Time period [yyymmdd]	Activity ¹	Comment	Initial/background Uranine conc. (mg/L)	Final Uranine conc. (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 completed tracer test.	–	–
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 74.1 µg/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 .	–	–
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 .	–	–
KFM03A	643.5–644.5	041214 to 041216	HY215 ²	Injection of Uranine (0.0015 g), ~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 .	–	–
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 .	–	–
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 .	–	–
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 060707	HY212, HY210 ⁵	0.0233 g Uranine injected, total volume of injected fluid 5.040x10 ⁻⁵ m ³ .	–	–

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.

² /28/.

³ /29/.

⁴ /30/.

⁵ /31/.

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

Borehole [ldcode]	Section [m]	Date [yymmdd]	Activity ¹	Comment
HFM02	38.0–48.0	050621 to 050712	HY210, HY212 ²	0.3256 g Uranine injected, total volume of injected fluid $6.409 \times 10^{-4} \text{ m}^3$.
		050712	HY231 ²	Injection of high amounts, 250 g, Amino G Acid due to tracer test.
		051205 to 051212	HY212 ³	0.1290 g Uranine injected, total volume of injected fluid $2.600 \times 10^{-4} \text{ m}^3$.
		060629 to 060710	HY210, HY212 ⁴	0.1426 g Uranine injected, total volume of injected fluid $3.080 \times 10^{-4} \text{ m}^3$.
HFM04	58.0–66.0	051116 to 151122	HY212 ³	0.0129 g Uranine injected, total volume of injected fluid $2.595 \times 10^{-5} \text{ m}^3$.
HFM13	159.0–173.0	051206 to 051212	HY212 ³	0.0216 g Uranine injected, total volume of injected fluid $4.362 \times 10^{-5} \text{ m}^3$.
		060628 to 060711	HY210, HY212 ⁴	0.0325 g Uranine injected, total volume of injected fluid $7.020 \times 10^{-5} \text{ m}^3$.
HFM15	85.0–95.0	050621 to 050712	HY210, HY212 ²	0.0197 g Uranine injected, total volume of injected fluid $3.870 \times 10^{-5} \text{ m}^3$.
		050712	HY231 ²	Injection of high amounts Rhodamine WT, ~180–190 g, due to tracer test.
		051205 to 051212	HY212 ³	0.0190 g Uranine injected, total volume of injected fluid $3.825 \times 10^{-5} \text{ m}^3$.
		060627 to 060710	HY210, HY212 ⁴	0.0138 g Uranine injected, total volume of injected fluid $2.989 \times 10^{-5} \text{ m}^3$.
HFM19	168.0–182.0	051205 to 051212	HY212 ³	0.0186 g Uranine injected, total volume of injected fluid $3.750 \times 10^{-5} \text{ m}^3$.
		060628 to 060710	HY210, HY212 ⁴	0.0169 g Uranine injected, total volume of injected fluid $3.640 \times 10^{-5} \text{ m}^3$.
HFM32	26.0–31.0	060626 to 060707	HY210, HY212 ⁴	0.0082 g Uranine injected, total volume of injected fluid $1.761 \times 10^{-5} \text{ m}^3$.

¹ HY212 = Dilution test natural gradient, HY210 = Dilution test stressed gradient, HY231 = Tracer injection during tracer tests.

² /30/.

³ /29/.

⁴ /31/.

4 Equipment

4.1 Sampling equipment

The monitored boreholes are equipped with packer installations in order to isolate different borehole sections. Each section is connected to 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.

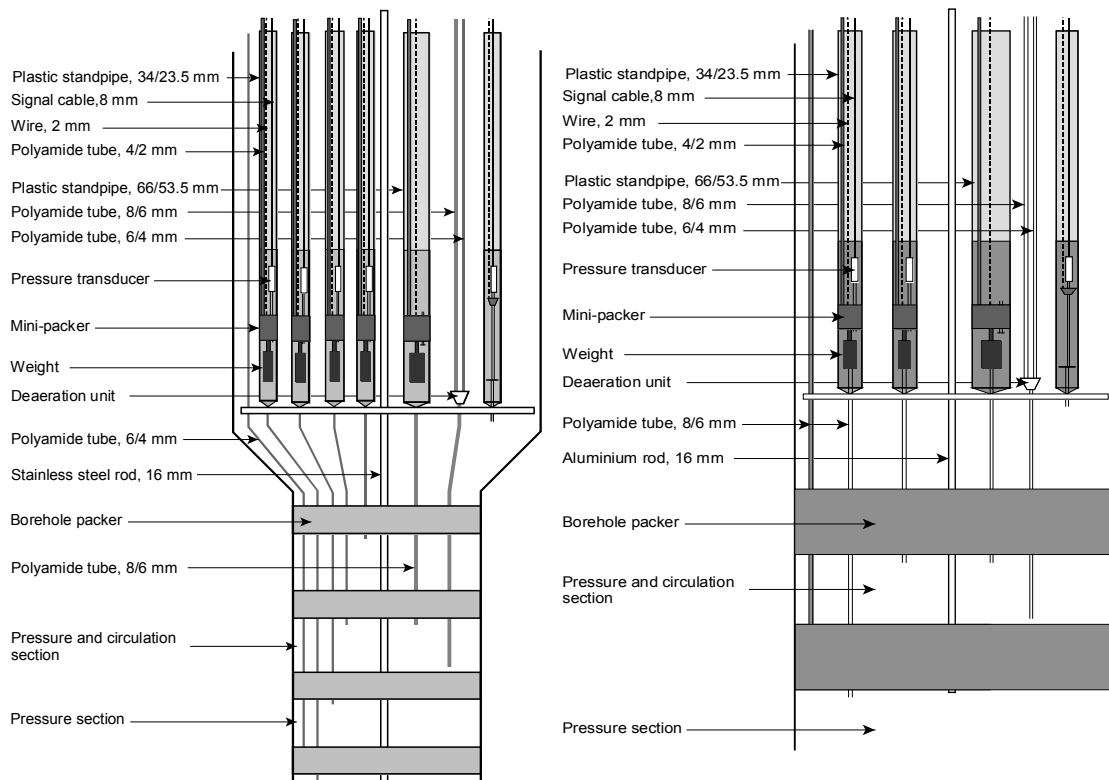


Figure 4-1. Instrumentation in core boreholes (left) and percussion boreholes (right) including circulation sections.

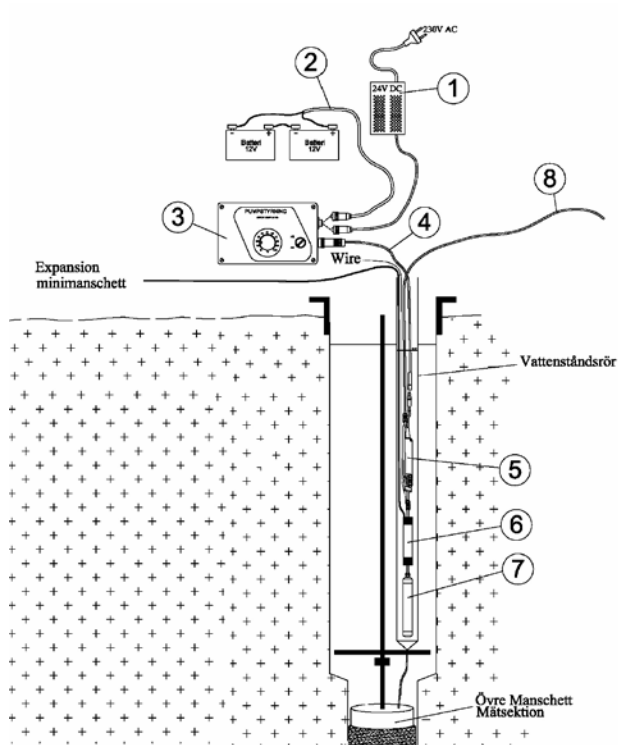


Figure 4-2. Equipment setup used for sampling of water from circulation sections in monitored percussion drilled and telescopic boreholes. 1) voltage regulator (24 VDC), 2) battery cable (not used), 3) pump regulator; 4) pump cable, 5) pump (GEOPUMP UV 45), 6) small inflatable packer (PU 45), 7) filter (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 extent of the analyses are presented in Table 5-1.

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. The pumped total volumes from each section prior to sampling are given in Appendix 1.

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

Idcode	Section [m]	Sampling no. 1			Sampling no. 2		
		Date	Sample no.	Analyses	Date	Sample no.	Analyses
HFM02	38.0–48.0	06-05-30	12282	Class 3 + ³ H, ² H, ¹⁸ O	06-10-17	12503	Class 5, options
HFM04	58.0–66.0	06-05-31	12283	Class 3 + ³ H, ² H, ¹⁸ O	06-10-31	12519	Class 5, options
HFM13	159.0–173.0	06-05-23	12262	Class 3 + ³ H, ² H, ¹⁸ O	06-10-24	12510	Class 5, options
HFM15	85.0–95.0	06-06-13	12309	Class 3 + ³ H, ² H, ¹⁸ O	06-10-24	12511	Class 5, options
HFM16	54.0–67.0	06-05-31	12281	Class 3 + ³ H, ² H, ¹⁸ O	06-10-06	12379	Class 5, options
HFM19	168.0–182.0	06-06-08	12306	Class 3 + ³ H, ² H, ¹⁸ O	05-10-25	12514	Class 5, options
HFM27	46.0–58.0	06-05-30	12280	Class 3 + ³ H, ² H, ¹⁸ O	06-10-17	12506	Class 5, options
HFM32	26.0–31.0	06-05-31	12287	Class 3 + ³ H, ² H, ¹⁸ O	06-10-30	12518	Class 5, options
HFM32*	0–25.0	06-06-01	12286	Class 3 + ³ H, ² H, ¹⁸ O	–	–	–
HFM32*	26.0–31.0	06-06-01	12284	Class 3 + ³ H, ² H, ¹⁸ O	–	–	–
HFM32*	32.0–97.0	06-06-01	12285	Class 3 + ³ H, ² H, ¹⁸ O	–	–	–
HFM32*	98.0–203.0	06-06-01	12288	Class 3 + ³ H, ² H, ¹⁸ O	–	–	–
KFM01A	109.0–130.0	06-06-14	12308	Class 3 + ³ H, ² H, ¹⁸ O	06-10-09	12397	Class 5, options
KFM02A	411.0–442.0	06-06-19	12310	Class 3 + ³ H, ² H, ¹⁸ O	06-10-10	12502	Class 5, options
KFM02A	490.0–518.0	06-06-20	12311	Class 5, options**	06-10-18	12507	Class 5, options
KFM03A	633.5–650.0	06-06-01	12261	Class 3 + ³ H, ² H, ¹⁸ O	06-10-24	12512	Class 5, options
KFM03A	969.5–994.5	06-06-02	12260	Class 3 + ³ H, ² H, ¹⁸ O	06-10-25	12513	Class 5, options
KFM06A	341.0–362.0	06-06-20	12313	Class 3 + ³ H, ² H, ¹⁸ O	06-10-09	12399	Class 5, options***
KFM06A	738.0–748.0	06-06-21	12312	Class 3 + ³ H, ² H, ¹⁸ O	06-10-09	12398	Class 5, options***
KFM06C	531.0–540.0	–	–	–	06-10-10	12500	Class 5 options***
KFM06C	647.0–666.0	–	–	–	06-10-18	12501	Class 3****

*Water “pumped” using nitrogen lifting.

**Class 5, due to Uranium study, /1/.

***No U- and Th-isotopes due to high flushing water content and low capacity at the consulted laboratory.

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

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 in which the electrodes and the thermometer were placed to measure field pH (pH_F), field electric conductivity (EC_F) and groundwater temperature.

Sample portions intended for analysis of major constituents and trace metals (by ICP technique), DOC and iron (by spectrometry) were filtered on-line. Disposable 0.40 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 2. The routines are applicable independently of sampling method or sampling object.

6 Nonconformities

- The sampling protocol for KFM06C:3 in October was reduced to a pure SKB chemistry class 3 sample without any options due to high flushing water content. The pumping of water from the borehole section was problematic due to the low transmissivity. This caused a long pumping period with many pump starts and stops in order to collect the sample.
- Due to low capacity at the consulted laboratory together with high flushing water content in the samples, analyses of U- and Th-isotopes for sections KFM06A:3, KFM06A:5 and KFM06C:5 were not performed.
- The isotope $^{10}\text{B}/^{11}\text{B}$ is missing for groundwaters from boreholes HFM02, HFM04, HFM15, HFM27 and HFM32 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 $\pm 5\%$ are considered acceptable.

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

- 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.

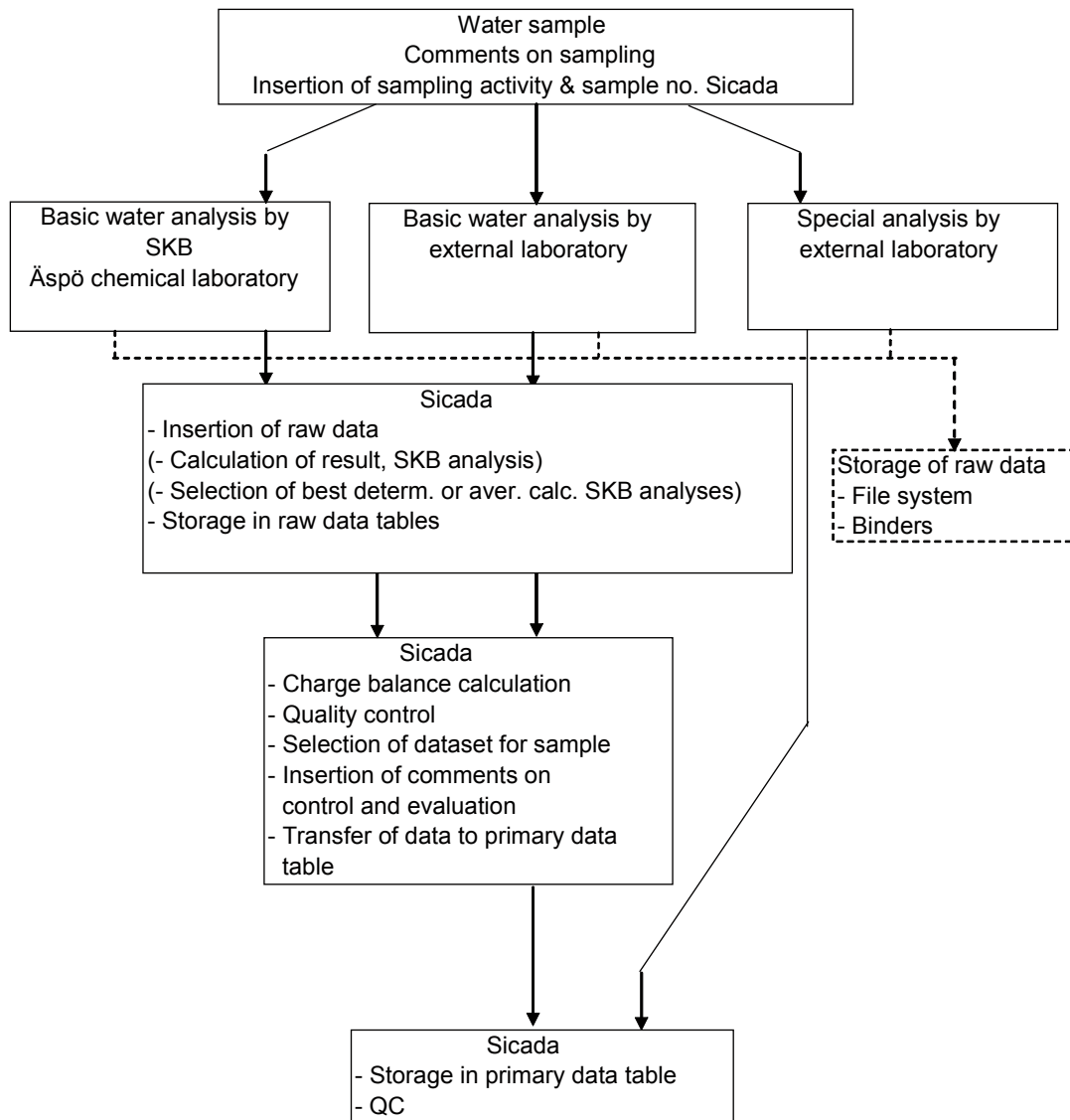


Figure 7-1. Overview of data management for hydrogeochemical data.

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, is used also in other investigations, see Table 3-1, it is in some cases no longer possible to calculate the amount of flushing water emerging from drilling of the borehole. Figure 8-1 shows the Uranine concentrations in the collected samples (data from the previously performed chemical characterisations in the corresponding sections /32, 33, 34, 35/ are presented for comparison). Groundwater flow measurements and tracer tests were performed in KFM01A between the two sampling occasions in 2005 and additional Uranine was introduced in the groundwater. In spite of the high value, the first sampling in June 2005 represents the flushing water content. The increase is most probably due to inflow of flushing water used for core drilling of the nearby situated borehole KFM01B (drilling period 2003-07-29 to 2004-01-15) /36/. The Uranine content in the samples collected during the year 2006 in KFM01A may also be affected by inflow of flushing water from the drilling of KFM01D (drilling period 2005-12-18 to 2006-02-18) /37/.

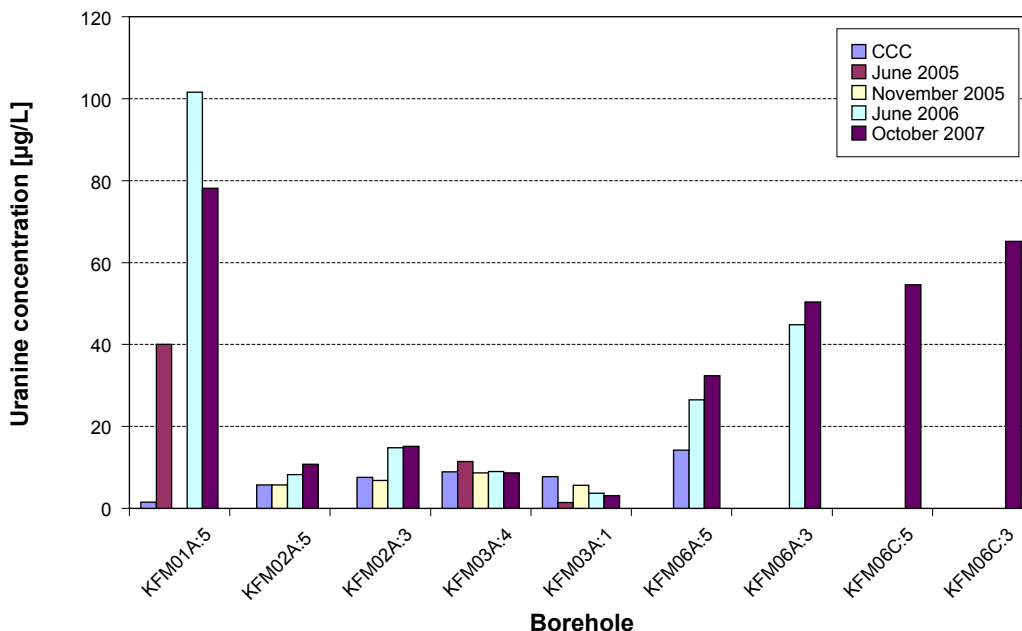


Figure 8-1. Amounts of Uranine in the water samples from the core drilled boreholes within the hydrochemical monitoring program. The initial contents from previous chemical characterisations (CCC) in corresponding borehole sections are given for comparison. The nominal Uranine concentration in the drilling water is about 200 µg/L.

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 $\pm 5\%$ in any of the cases. One sample at each sampling occasion was analysed by a second laboratory. Generally, the difference in concentrations between laboratories/methods for each analysed constituent is less than 10% except for low concentrations close to the detection limits. The basic water analysis data and relative charge balance errors are compiled in Appendix 3, Table A3-1.

Chloride concentrations are presented in Figure 8-2 (cored boreholes) and Figure 8-3 (percussion boreholes) together with earlier results from chemical characterisations with SKB's mobile field laboratory (MFL) in cored boreholes when available /32, 33, 34, 35/ and water samplings conducted during pump test in percussion boreholes /38, 39, 40, 41/.

8.1.2 Trace elements (rare earth metals and others)

The sample collected in section 490.0–518.0 m in KFM02A in June as well as all samples except section 647.0–666.0 m in KFM06C collected in October were analysed for trace elements. The analyses of trace elements include 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 3, Table A3-2.

8.1.3 Stable and radioactive isotopes

The isotope determinations include the stable isotopes $\delta^2\text{H}$, $\delta^{18}\text{O}$, $^{10}\text{B}/^{11}\text{B}$, $\delta^{34}\text{S}$, $\delta^{13}\text{C}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ 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 , $\delta^{18}\text{O}$ and ^3H , except the sample from section 647.0–666.0 m in KFM06C. The other isotopes were determined only for SKB class 5 samples. Available isotope data at the time of reporting are compiled in Appendix 3, Table A3-3 and A3-4.

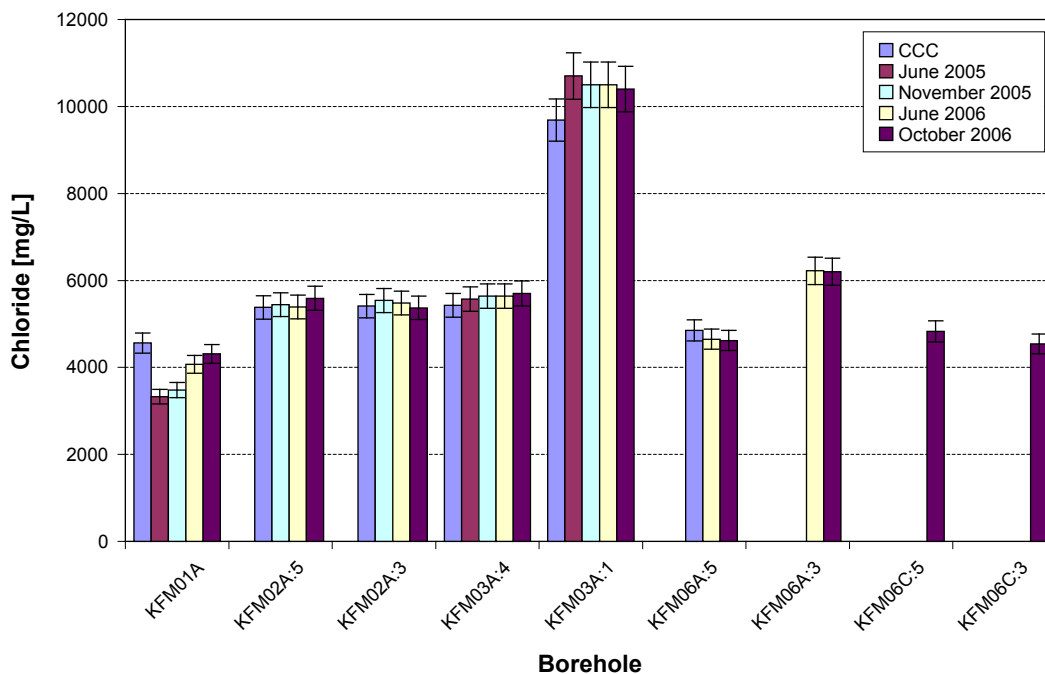


Figure 8-2. Chloride concentrations in samples collected within the monitoring program. Results from earlier chemical characterisations (CCC) are given for comparison.

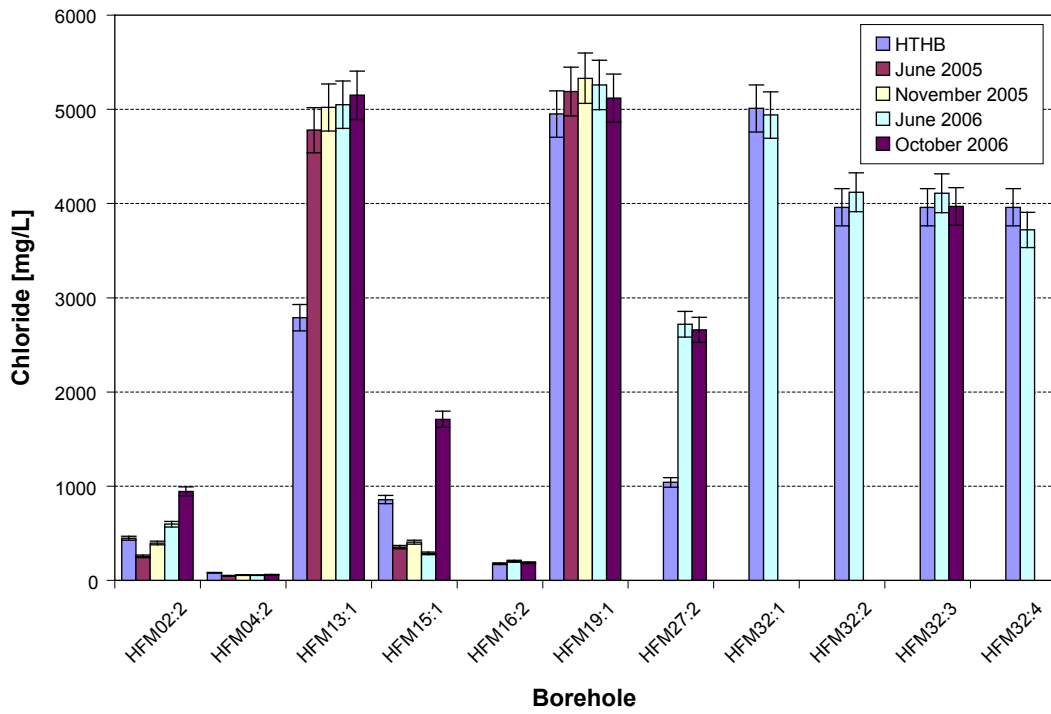


Figure 8-3. Chloride concentrations in samples collected within the monitoring program. Results from earlier sampling at pumping tests (HTHB) are given for comparison. These initial concentrations are not quite comparable as the early sampling was performed at open hole conditions from the entire borehole and not from packed off sections.

9 Summary and discussions

The second year of groundwater sampling within the long-term hydrogeochemical monitoring programme for percussion drilled and core drilled boreholes is completed and 17 borehole sections in 13 boreholes have been sampled (most of them at two occasions). Besides this, three additional sections in HFM32 were sampled outside the monitoring program. The results and conclusions from the analysis programme are summarised below.

- Generally, the changes in Uranine concentration (used to estimate the flushing water content) originating from drilling since the initial investigations in the core drilled boreholes are small. Where an increase in Uranine concentration is seen, the increased concentration in the borehole water most probably originates from ground water flow measurements and does not represent an increase in flushing water content. One exception is borehole KFM01A. The increased flushing water content is most probably explained by two factors discussed in the report from 2005 of the hydrochemical monitoring program /26/. The two factors being core drilling of the nearby situated borehole KFM01B /37/ and ground water flow measurements and tracer tests /30/.
- The previously observed decrease in chloride concentration in the fractures at 113–119 m KFM01A from last year's samplings seems now to have recovered to the same level as during the hydrochemical investigation. Since the decrease most probably was due to flushing water intrusion from drilling KFM01C, the now increased chloride concentration may suggest that the contribution of flushing water is less than before.
- The steep increase in chloride concentration in HFM15 between the sampling conducted in June and the one performed in October is most probably a result of the hydraulic interference test in July with heavy pumping during a long period in the nearby situated HFM14.
- HFM02 shows increased chloride concentrations. The fracture in HFM02 is connected to borehole HFM01. HFM01 has been used as pumphole for a interference test in 2005 /42/ and as source of flushing water for drilling KFM01B–D /36, 37/. These activities may partly explain the increase in chloride concentration in HFM02.
- Except for the conditions accounted for in the text above, only minor changes in the water composition are observed in the boreholes.

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Sampling information and field measurements

Idcode: section	Pumping		Pumped volume [dm ³]	Sampling Date			Field measurements			Sample no.
	Start	Stop			Start	Stop	Date	Start	Stop	
HFM02:2	2006-05-30 09:06	2006-05-30 17:52	158	2006-05-30	17:36	17:50	2006-05-30	17:30	17:35	12282
HFM02:2	2006-10-16 14:02	2006-10-17 14:05	300	2006-10-17	13:30	14:03	2006-10-17	13:20	13:26	12503
HFM04:2	2006-05-29 10:30	2006-05-31 07:23	819	2006-05-31	07:12	07:22	2006-05-31	07:08	07:11	12283
HFM04:2	2006-10-31 07:06	2006-10-31 13:02	135	2006-10-31	12:23	13:01	2006-10-31	12:15	12:21	12519
HFM13:1	2006-05-22 11:02	2006-05-23 07:30	280	2006-05-23	07:11	07:25	2006-05-23	07:25	07:30	12262
HFM13:1	2006-10-23 15:19	2006-10-24 09:10	214	2006-10-24	08:39	09:09	2006-10-24	08:30	08:39	12510
HFM15:1	2006-06-12 16:50	2006-06-13 07:37	290	2006-06-13	07:19	07:36	2006-06-13	07:10	07:15	12309
HFM15:1	2006-10-23 16:00	2006-10-24 09:43	300	2006-10-24	09:18	09:42	2006-10-24	08:59	09:10	12511
HFM16:2	2006-05-29 09:25	2006-05-31 07:02	832	2006-05-31	06:51	07:01	2006-05-31	06:45	06:50	12281
HFM16:2	2006-10-05 16:54	2006-10-06 07:50	295	2006-10-06	07:10	07:49	2006-10-06	07:00	07:10	12379
HFM19:1	2006-06-07 14:49	2006-06-08 11:09	777	2006-06-08	10:46	11:08	2006-06-08	10:38	10:45	12306
HFM19:1	2006-10-24 16:56	2006-10-25 10:32	149	2006-10-25	09:58	10:29	2006-10-25	09:50	09:57	12514
HFM27:2	2006-05-30 09:02	2006-05-30 17:34	270	2006-05-30	17:20	17:32	2006-05-30	17:14	17:19	12280
HFM27:2	2006-10-16 14:06	2006-10-17 14:15	313	2006-10-17	13:35	14:14	2006-10-17	13:30	13:34	12506
HFM32:1	2006-05-31 14:44	2006-06-01 15:30	44	2006-06-01	15:00	15:30	–	–	–	12288
HFM32:2	2006-05-31 14:44	2006-06-01 15:30	43	2006-06-01	15:00	15:30	–	–	–	12285
HFM32:3	2006-05-31 10:36	2006-05-31 15:46	161	2006-05-31	15:39	15:45	2006-05-31	15:30	15:38	12287
HFM32:3	2006-05-31 14:44	2006-06-01 15:30	45	2006-06-01	15:00	15:30	–	–	–	12284
HFM32:3	2006-10-30 10:18	2006-10-30 13:10	77	2006-10-30	12:37	13:10	2006-10-30	12:30	12:37	12518
HFM32:4	2006-05-31 14:44	2006-06-01 15:30	39	2006-06-01	15:00	15:30	–	–	–	12286
KFM01A:5	2006-06-12 08:22	2006-06-14 08:05	195	2006-06-14	07:40	08:03	2006-06-14	07:30	07:38	12308
KFM01A:5	2006-10-06 17:45	2006-10-09 08:08	262	2006-10-09	06:58	08:06	2006-10-09	06:50	06:57	12397
KFM02A:3	2006-06-16 08:45	2006-06-26 17:40	1,494	2006-06-20	08:20	08:53	2006-06-20	08:15	08:20	12311

Idcode: section	Pumping Start	Stop	Pumped volume [dm³]	Sampling Date	Start	Stop	Field measurements Date	Start	Stop	Sample no.
KFM02A:3	2006-10-17 13:11	2006-10-18 08:03	102	2006-10-18	07:26	08:00	2006-10-18	07:20	07:26	12507
KFM02A:5	2006-06-16 08:45	2006-06-19 10:40	426	2006-06-19	10:17	10:39	2006-06-19	10:10	10:16	12310
KFM02A:5	2006-10-06 17:20	2006-10-10 14:17	627	2006-10-10	13:54	14:15	2006-10-10	13:47	13:54	12502
KFM03A:1	2006-05-22 14:30	2006-06-02 06:32	216	2006-06-02	06:17	06:28	2006-06-02	06:28	06:31	12260
KFM03A:1	2006-10-23 10:32	2006-10-25 08:33	172	2006-10-25	07:10	08:32	2006-10-25	06:50	07:10	12513
KFM03A:4	2006-05-22 14:20	2006-06-01 15:38	432	2006-06-01	15:16	15:37	2006-06-01	15:05	15:15	12261
KFM03A:4	2006-10-23 10:32	2006-10-24 10:37	195	2006-10-24	10:05	10:33	2006-10-24	09:57	10:04	12512
KFM06A:3	2006-06-19 13:20	2006-06-21 08:09	138	2006-06-21	07:25	08:08	2006-06-21	07:00	07:24	12312
KFM06A:3	2006-10-06 16:59	2006-10-09 10:25	220	2006-10-09	09:07	10:23	2006-10-09	08:55	09:07	12398
KFM06A:5	2006-06-19 13:55	2006-06-20 08:07	182	2006-06-20	07:53	08:06	2006-06-20	07:48	07:53	12313
KFM06A:5	2006-10-06 16:59	2006-10-09 09:54	183	2006-10-09	09:09	09:53	2006-10-09	09:00	09:08	12399
KFM06C:3	2006-10-06 16:45	2006-10-18 10:30	approx. 100	2006-10-10/18*	10:25	10:29	–	–	–	12500
KFM06C:5	2006-10-06 16:45	2006-10-10 10:45	259	2006-10-10	10:04	10:43	2006-10-10	09:50	10:02	12501

*Prolonged sampling due to several pumpstart and pumpstop. Sampling stated 2006-10-10 and ended 2006-10-18.

Sampling and analytical methods

Table A2-1. 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	No	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 ⁻ , SO ₄ , 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 (1mL 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	Yes	Ev 1 mL 1 M NaOH+ 1 mL 1 M 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 analyser 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	$\delta^2\text{H}$, $\delta^{18}\text{O}$	Plastic	100	No	–	MS	Not critical (month)
Tritium	^3H (enhanced.)	Plastic (dry bottle)	500	No	–	LSC	
Chlorine-37	^{37}Cl	Plastic	100	No	–	ICP MS	Not critical (month)
Carbon isotopes	^{13}C , pmC	Plastic (HDPE)	100×2	No	–	(A)MS	A few days
Sulphur isotopes	^{34}S	Plastic	500–1,000	No	–	Combustion, MS	No limit
Strontium-isotopes	$^{87}\text{Sr}/^{86}\text{Sr}$	Plastic	100	No	–	TIMS	Days or week
Uranium and Thorium isotopes	^{234}U , ^{235}U , ^{238}U , ^{232}Th , ^{230}Th ,	Plastic	50 1,000	No	–	Chemical separat. Alfa/gamma spectrometry	No limit
Boron isotopes	$^{10}\text{B}/^{11}\text{B}$	Plastic	100	Yes	Yes (1 mL HNO_3)	ICP – MS	No limit
Radon and Radium isotopes	^{222}Rn , ^{226}Ra	Plastic	500–1,000	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	Polycarbonate filter	0.4, 0.2 and 0.05 μm	–	Ar atmosphere	ICP-AES ICP-MS	Immediate transport
Fractionation; Humic and fulvic acids, inorganic constituents	<1,000 D >1,000 D but <5,000 D >5,000 D	Fractions 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

Component group	Component/element	Sample container (material)	Volume (mL)	Filtering	Preparation/Conservation*	Analysis method	Analysis within – or delivery time to lab.
Nutrient salt + silicate	NO ₂ , NO ₃ , NO ₂ +NO ₃ , NH ₄ , PO ₄ , SiO ₄	Sample tubes, plastic	25×2 250	No	No, frozen immediately***	Spectrophotometry	Short transportation time
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×ca 120	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
LSS	Liquid Scintillation Spectrometry
(A)MS	(Accelerator) Mass Spectrometry
GC	Gas Chromatography

Table A2-2. Reporting limits and measurement uncertainties.

Component	Method	Reporting limits or range	Unit	Measurement uncertainty ²	“Total” uncertainty ³
HCO ₃	Alkalinity titration	1	mg/L	4%	<10%
Cl ⁻	Mohr-titration	>70	mg/L	5%	<10%
Cl ⁻	IC	1–100		6%	10%
SO ₄	IC	1	mg/L	10%	15%
Br ⁻	IC	0.2	mg/L	9%	20%
Br ⁻	ICP	0.001		15%	
F ⁻	IC	0.1	mg/L	10%	20%
F ⁻	Potentiometric	–		–	
I ⁻	ICP	0.001	mg/L	15%	20%
Na	ICP	0.1	mg/L	4%	10%
K	ICP	0.4	mg/L	6%	15%
Ca	ICP	0.1	mg/L	4%	10%
Mg	ICP	0.09	mg/L	4%	10%
S(tot)	ICP	0.160	mg/L	21%	15%
Si(tot)	ICP	0.03	mg/L	4%	15%
Sr	ICP	0.002	mg/L	4%	15%
Li	ICP	0.2 ¹ 2	mg/L	10%	20%
Fe	ICP	0.4 ¹ 4	mg/L	6%	10%
Mn	ICP	0.03 ¹ 0.1	µg/L	8%	10%
Fe(II), Fe(tot)	Spectrophotometry	0.02 (DL=0.005 mg/L)	mg/L	15% (>30 µg/L)	20%
HS ⁻	Spectrophotometry	SKB 0.03 (DL=0.02)	mg/L	10%	30%
NO ₂ as N	Spectrophotometry	0.1	µg/L	2%	20%
NO ₃ as N	Spectrophotometry	0.2	µg/L	5%	20%
NO ₂ +NO ₃ as N	Spectrophotometry	0.2	µg/L	0.2 (0.2–20 µg/L) 2% (>20 µg/L)	20%
NH ₄ as N	Spectrophotometry	0.8 50 (SKB)	µg/L	0.8 (0.8–20 µg/L) 5% (>20 µg/L) 20%	20%
PO ₄ as P	Spectrophotometry	0.7	µg/L	0.7 (0.7–20 µg/L) 3% (>20 µg/L)	20%
SiO ₄	Spectrophotometry	1	µg/L	3% (>200 µg/L)	–
O ₂	Iodometric titration	0.2–20	mg/L	5%	–
Chlorophyll a, c pheopigment ⁴	See Table A1-2	0.5	µg/L	5%	–
PON ⁴	See Table A1-2	0.5	µg/L	5%	–
POP ⁴	See Table A1-2	0.1	µg/L	5%	–
POC ⁴	See Table A1-2	1	µg/L	4%	–
Tot-N ⁴	See Table A1-2	10	µg/L	4%	–
Tot-P ⁴	See Table A1-2	0.5	µg/L	6%	–
Al, Zn	ICP	0.2	µg/L	12%	20% ⁵
Ba, Cr, Mo, Pb	ICP	0.01	µg/L	7–10%	20% ⁵
Cd, Hg	ICP	0.002	µg/L	9 resp 5%	20% ⁵
Co, V	ICP	0.005	µg/L	8 resp 5%	20% ⁵
Cu	ICP	0.1	µg/L	8%	20% ⁵
Ni	ICP	0.05	µg/L	8%	20% ⁵
P	ICP	1	µg/L	6%	10%
As	1CP	0.01	µg/L	20%	Correct order of size (low conc.)

Component	Method	Reporting limits or range		Unit	Measurement uncertainty ²	“Total” uncertainty ³
La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb	ICP	0.0051	0.05	µg/L	10%	Correct order of size (low conc.)
Sc, In, Th	ICP	0.05 ¹	0.5	µg/L	10%	Correct order of size (low conc.)
Rb, Zr, Sb, Cs, Tl	ICP	0.025 ¹	0.25	µg/L	10%	Correct order of size (low conc.)
Y, Hf	ICP	0.005 ¹	0.05	µg/L	10%	Correct order of size (low conc.)
U	ICP	0.001 ¹	–	µg/L	12%	Correct order of size (low conc.)
DOC	See Table A1-1	0.5		mg/L	8%	30%
TOC	See Table A1-1	0.1		mg/L	10%	30%
δ ² H	MS	2		‰ SMOW ⁵	1‰	–
δ ¹⁸ O	MS	0.1		‰ SMOW ⁵	0.2‰	–
³ H	LSC	0.8 eller 0.1		TU ⁶	0.8 eller 0.1	Correct order of size
³⁷ Cl	ICP MS	0.2‰ (20 mg/L)		‰ SMOC ⁷	–	–
δ ¹³ C	A (MS)	–		‰ PDB ⁸	–	–
¹⁴ C pmc	A (MS)	–		PMC ⁹	–	–
δ ³⁴ S	MS	0.2‰		‰ CDT ¹⁰	0.3‰	–
⁸⁷ Sr/ ⁸⁶ Sr	TIMS	–		No unit (ratio) ¹¹	–	–
¹⁰ B/ ¹¹ B	ICP MS	–		No unit (ratio) ¹¹	–	–
²³⁴ U, ²³⁵ U, ²³⁸ U, ²³² Th, ²³⁰ Th	Alfa spectr.	0.0005		Bq/L ¹²	5%	–
²²² Rn, ²²⁶ Rn	LSS	0.03		Bq/L	5%	–

- Reporting limits at salinity ≤ 0.4% (520 mS/m) and ≤ 3.5% (3,810 mS/m) respectively.
- Measurement uncertainty reported by consulted laboratory, generally 95% confidence interval.
- Estimated total uncertainty by experience (includes effects of sampling and sample handling).
- Determined only in surface waters and near surface groundwater.
- Per mille deviation¹³ from SMOW (Standard Mean Oceanic Water).
- TU = Tritium Units, where one TU corresponds to a Tritium/hydrogen ratio of 10⁻¹⁸ (1 Bq/L Tritium = 8.45 TU).
- Per mille deviation¹³ from SMOC (Standard Mean Oceanic Chloride).
- Per mille deviation¹³ from PDB (the standard PeeDee Belemnite).
- 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.
- Per mille deviation¹³ from CDT (the standard Canyon Diablo Troilite).
- Isotope ratio without unit.
- The following expressions are applicable to convert activity to concentration, for uranium-238 and thorium-232: 1 ppm U = 12.4 Bq ppm Th = 3.93 Bq/kg²³²Th.
- Isotopes are often reported as per mill deviation from a standard. The deviation is calculated as:

$$\delta\text{‰} = 1,000 \times (K_{\text{sample}} - K_{\text{standard}}) / K_{\text{standard}}$$
where K = the isotope ratio and ‰ = ²H, ¹⁸O, ³⁷Cl, ¹³C or ³⁴S etc.

Compilation of water analysis data

March 2007

Table A3-1. 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	SO ₄ _S mg/L	Br mg/l	F ⁻ mg/L	Si mg/L	Fe mg/L	Fe-tot mg/L	Fell mg/L	Mn mg/L	Li mg/L
HFM02	38	48	12282	2006-05-30	-1.5	405	16.1	95.6	28.4	397	597	104	39.4	2.08	1.85	7.14	-	-	-	-	0.016
HFM02	38	48	12503	2006-10-17	0.2	566	21.2	149	44.7	374	945	155	52.3	3.65	1.79	6.36	0.826	0.834	0.819	0.268	0.02
HFM04	58	66	12283	2006-05-31	-0.8	150	6.1	31.4	7.9	389	54.9	42.6	16.3	<0.2	2.02	7.73	-	-	-	-	0.009
HFM04	58	66	12519	2006-10-31	-1.46	152	6.28	30.1	7.4	393	58.9	44.9	15.3	0.241	2.05	6.9	0.337	0.351	0.335	0.0788	0.01
HFM13	159	173	12262	2006-05-23	-0.19	1,760	20.7	1,230	207	124	5,050	462	185	19.8	1.28	8.57	-	-	-	-	0.052
HFM13	159	173	12510	2006-10-24	-1.12	1,700	23.5	1,250	214	126	5,150	431	174	21.8	1.27	7.89	3.31	3.62	3.62	2.29	0.055
HFM15	85	95	12309	2006-06-13	1.45	307	9.47	84.9	12.9	481	286	94.6	36.7	0.965	2.04	8.57	-	-	-	-	0.013
HFM15	85	95	12511	2006-10-24	1.16	869	23.1	329	69.6	317	1,710	255	91.5	6.62	1.45	7.56	2.31	2.31	2.3	0.833	0.03
HFM16	54	67	12281	2006-05-31	-1.21	276	7.16	45.8	10.6	466	204	95.1	35.2	0.78	2.45	6.41	-	-	-	-	0.011
HFM16	54	67	12379	2006-10-06	0.18	281	7.17	37.6	9	446	187	101	36.3	0.754	2.66	6.71	0.356	0.595	0.594	0.0901	0.009
HFM19	168	182	12306	2006-06-08	0.18	2,080	55.3	1,010	262	120	5,260	538	205	17.7	1.17	6.97	-	-	-	-	0.069
HFM19	168	182	12514	2006-10-25	-1.64	1,950	51.3	947	253	145	5,120	521	202	20.1	1.14	6.41	4.29	4.44	4.46	1.93	0.061
HFM27	46	58	12280	2006-05-30	-1.67	1,130	34.4	512	134	235	2,720	347	142	9.2	1.21	7.02	-	-	-	-	0.04
HFM27	46	58	12506	2006-10-17	-2.86	1,080	36.9	474	125	247	2,660	347	122	9.79	1.3	6.39	2.64	2.81	2.77	0.847	0.039
HFM32	0	25	12286	2006-06-01	-1.42	1,650	58.9	535	166	196	3,720	340	138	13.5	1.1	6.18	-	-	-	-	0.057
HFM32	26	31	12287	2006-05-31	-1.41	1,840	60.3	568	190	183	4,110	388	161	14.8	1.2	6.07	-	-	-	-	0.061
HFM32	26	31	12284	2006-06-01	-1.71	1,830	61.1	556	190	188	4,100	388	160	14.7	1.2	5.96	-	-	-	-	0.063
HFM32	26	31	12518	2006-10-30	-3.76	1,690	65.7	502	173	195	3,970	374	132	15.6	1.23	5.3	3.57	3.8	3.79	0.919	0.061
HFM32	32	97	12285	2006-06-01	-1.09	1,810	55.7	602	186	174	4,120	360	145	15.1	1.21	6.34	-	-	-	-	0.064
HFM32	98	203	12288	2006-06-01	0.74	1,900	18	1,070	190	98.5	4,940	365	142	18.4	1.2	7.74	-	-	-	-	0.067

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	SO ₄ _S mg/L	Br mg/l	F ⁻ mg/L	Si mg/L	Fe mg/L	Fe-tot mg/L	Fell mg/L	Mn mg/L	Li mg/L
KFM01A	109	130	12308	2006-06-14	-2.15	1,540	23.8	818	126	152	4,070	271	106	14.8	1.34	8.6	-	-	-	-	0.05
KFM01A	109	130	12397	2006-10-09	-0.53	1,720	27.1	857	154	118	4,310	391	140	18.4	1.4	9.78	0.437	0.443	0.436	0.791	0.053
KFM02A	411	442	12310	2006-06-19	-0.15	1,960	23.4	1,220	201	97	5,390	415	161	21.1	1.51	8.72	-	-	-	-	0.061
KFM02A	411	442	12502	2006-10-10	-1.35	1,920	23.8	1,280	201	95.7	5,590	502	158	22.6	1.39	8.51	1.64	1.73	1.74	1.87	0.06
KFM02A	490	518	12311	2006-06-20	-1.14	2,150	37.8	1,010	243	125	5,480	493	193	22.4	1.46	7.11	1.84	1.85	1.84	2.44	0.061
KFM02A	490	518	12507	2006-10-18	-0.23	2,100	38.1	1,020	252	129	5,370	437	178	22	1.55	6.66	1.88	1.98	1.97	2.33	0.054
KFM03A	633.5	650	12261	2006-06-01	0.27	1,870	17.7	1,560	75.5	26.9	5,640	214	85.2	32.8	1.35	7.76	-	-	-	-	0.03
KFM03A	633.5	650	12512	2006-10-24	-0.40	1,870	19.8	1,540	74.9	30.1	5,700	216	77.9	34.3	1.38	7.23	0.829	0.843	0.838	0.478	0.032
KFM03A	969.5	994.5	12260	2006-06-02	0.64	2,100	8.84	4,200	11	7.84	10,500	47.7	27	99.2	1.34	6.04	-	-	-	-	0.023
KFM03A	969.5	994.5	12513	2006-10-25	-0.50	2,050	10.4	4,040	10.6	10.9	10,400	44.8	17.9	99.2	1.32	5.99	0.615	0.665	0.656	0.0645	0.019
KFM06A	341	362	12313	2006-06-20	-0.63	1,470	18	1,280	83	64.3	4,650	185	72.4	25.3	1.3	6.75	-	-	-	-	0.061
KFM06A	341	362	12399	2006-10-09	0.88	1,540	18.9	1,280	81.8	60.9	4,620	186	69	31.9	1.34	6.86	2.33	2.46	2.39	0.82	0.06
KFM06A	738	748	12312	2006-06-21	1.70	1,750	12.5	2,120	31.8	28.6	6,220	109	42	44.1	1.28	7.82	-	-	-	-	0.046
KFM06A	738	748	12398	2006-10-09	1.30	1,690	13	2,130	31.8	24	6,200	115	43.1	48.6	1.22	7.67	0.892	0.942	0.923	0.461	0.046
KFM06C	531	540	12500	2006-10-10	0.64	1,650	16.1	1,310	98.7	69	4,830	280	103	26.4	1.11	5.92	0.843	0.893	0.886	0.874	0.054
KFM06C	647	666	12501	2006-10-10	-0.26	1,420	15.7	1,280	77.2	96.8	4,540	139	53.4	30.6	1.08	6.99	-	-	-	-	0.04

-- = Not analysed.

pH_F; EC_F = Field measurements of pH and Electrical conductivity.

< "value" = below reporting limit.

RCB % = Rel. charge balance error %.

SICADA: water_composition.

Table A3-1. Cont.

Idcode	Secup m	Seclow m	Sample no.	Sr mg/L	I ⁻ mg/L	pH	pH_F	DOC mg/L	TOC mg/L	HS ⁻ mg/L	Uranine µg/L	EC mS/m	EC_F mS/m	NH ₄ N mg/L	NO ₂ N mg/L	NO ₃ N mg/L	NO ₂ N/NO ₃ N mg/L	PO ₄ P mg/L	P mg/L	Temp °C
HFM02	38	48	12282	0.55	-	7.68	7.71	-	-	-	-	267	270	-	-	-	-	-	-	8.1
HFM02	38	48	12503	0.89	0.012	7.60	7.59	8.6	8.6	0.031	-	371	369	0.774	<0.0002	<0.0003	<0.0003	0.0052	0.0348	-
HFM04	58	66	12283	0.2	-	7.73	7.76	-	-	-	-	87.9	88.1	-	-	-	-	-	-	7.2
HFM04	58	66	12519	0.2	0.006	7.69	7.69	8.8	8.7	0.055	-	86.8	87.5	0.441	0.0005	<0.0003	0.0005	0.0613	0.027	7.0
HFM13	159	173	12262	11.9	-	7.39	7.30	-	-	-	-	1,490	1,530	-	-	-	-	-	-	7.9
HFM13	159	173	12510	12.2	0.043	7.32	7.33	1.9	2.2	0.005	-	1,480	1,500	1.5	<0.0002	0.0006	0.0006	0.0005	<0.04	8.1
HFM15	85	95	12309	0.35	-	7.43	7.00	-	-	-	-	177	177	-	-	-	-	-	-	9.0
HFM15	85	95	12511	2.03	0.017	7.34	7.45	7.3	6.9	0.095	-	598	605	1.66	<0.0002	<0.0003	<0.0003	<0.0005	0.023	8.3
HFM16	54	67	12281	0.31	-	7.72	7.84	-	-	-	-	157	160	-	-	-	-	-	-	7.4
HFM16	54	67	12379	0.29	0.009	7.78	7.75	13	13	0.011	-	147	148	0.238	<0.0002	0.0032	0.0033	0.0672	0.0673	8.6
HFM19	168	182	12306	7.05	-	6.83	6.83	-	-	-	-	1,570	1,570	-	-	-	-	-	-	-
HFM19	168	182	12514	6.66	0.034	6.96	7.13	5.8	4.4	1.46	-	1,700	1,710	2.35	<0.0002	<0.0003	<0.0003	<0.0005	<0.04	7.1
HFM27	46	58	12280	3.29	-	7.39	7.26	-	-	-	-	883	887	-	-	-	-	-	-	8.2
HFM27	46	58	12506	3.14	0.018	7.35	7.32	4.6	4.7	0.02	-	842	851	0.7	0.0006	0.0007	0.0013	0.0015	0.0135	-
HFM32	0	25	12286	3.5	-	7.20	-	-	-	-	-	1,160	-	-	-	-	-	-	-	11.1
HFM32	26	31	12287	3.65	-	7.11	7.10	-	-	-	-	1,270	1,270	-	-	-	-	-	-	10.7
HFM32	26	31	12284	3.68	-	7.11	-	-	-	-	-	1,260	-	-	-	-	-	-	-	10.2
HFM32	26	31	12518	3.24	0.045	7.12	7.12	3.5	3.6	0.08	-	1,210	1,200	2.08	0.0004	<0.003	0.0005	0.0005	0.0075	7.0
HFM32	32	97	12285	4.2	-	7.15	-	-	-	-	-	1,280	-	-	-	-	-	-	-	10.4
HFM32	98	203	12288	10	-	7.45	-	-	-	-	-	1,470	-	-	-	-	-	-	-	11.8
KFM01A	109	130	12308	7.04	-	7.20	7.32	-	-	-	-	1,210	1,280	-	-	-	-	-	-	11.4
KFM01A	109	130	12397	7.15	0.047	7.61	7.54	3.6	2.7	0.922	78.1	1,310	1,340	1.13	0.0002	0.0006	0.0009	0.0012	<0.005	7.9
KFM02A	411	442	12310	12.2	-	7.40	7.46	-	-	-	8.2	1,560	1,640	-	-	-	-	-	-	9.3
KFM02A	411	442	12502	12.5	0.095	7.44	7.42	1.5	1.8	0.129	10.9	1,570	1,600	1.73	0.0005	<0.0003	0.0006	0.0008	<0.04	8.9
KFM02A	490	518	12311	8.79	0.091	7.16	7.19	1.5	1.5	0.065	6.8	1,600	1,620	2.77	<0.0002	0.0022	0.0023	<0.0005	<0.04	-

Idcode	Secup m	Seclow m	Sample no.	Sr mg/L	I ⁻ mg/L	pH	pH_F	DOC mg/L	TOC mg/L	HS ⁻ mg/L	Uranine µg/L	EC mS/m	EC_F mS/m	NH ₄ N mg/L	NO ₂ N mg/L	NO ₃ N mg/L	NO ₂ N/NO ₃ N mg/L	PO ₄ P mg/L	P mg/L	Temp °C
KFM02A	490	518	12507	8.69	0.091	7.25	7.09	2.2	1.9	0.167	14.8	1,600	1,600	2.69	0.0003	<0.003	0.0005	0.0005	<0.04	8.1
KFM03A	633.5	650	12261	17.4	–	7.54	7.59	–	–	–	8.7	1,590	1,630	–	–	–	–	–	–	10.4
KFM03A	633.5	650	12512	17.7	0.112	7.43	7.48	1.2	1.3	0.538	9.0	1,570	1,560	0.37	<0.0002	<0.0003	<0.0003	<0.0005	<0.04	8.7
KFM03A	969.5	994.5	12260	48	–	7.16	7.18	–	–	–	3.7	2,270	2,380	–	–	–	–	–	–	8.0
KFM03A	969.5	994.5	12513	48.6	0.339	7.11	7.15	1.8	1.7	0.587	3.1	2,500	2,610	0.166	0.0003	0.0003	0.0007	<0.0005	<0.04	7.1
KFM06A	341	362	12313	13.2	–	7.55	7.40	–	–	–	26.5	1,350	1,400	–	–	–	–	–	–	–
KFM06A	341	362	12399	14.1	0.139	7.38	7.37	2	1.9	0.108	32.5	1,350	1,390	0.582	0.0009	0.0012	0.002	0.0011	<0.005	7.4
KFM06A	738	748	12312	23	–	7.57	7.60	–	–	–	22.4	1,720	1,720	–	–	–	–	–	–	10.8
KFM06A	738	748	12398	23.9	0.202	7.42	7.41	1.8	2	0.368	25.2	1,740	1,730	0.287	0.0004	<0.0003	0.0005	0.0024	<0.04	7.4
KFM06C	531	540	12500	13.8	0.083	7.45	7.41	1.6	1.8	0.064	54.7	1,410	1,460	0.568	0.0004	<0.0003	0.0005	0.0007	<0.005	8.6
KFM06C	647	666	12501	13.9	–	7.49	–	–	–	–	65.3	1,310	–	–	–	–	–	–	–	–

– = Not analysed.

pH_F; EC_F = Field measurements of pH and Electrical conductivity.

< "value" = below reporting limit.

RCB % = Rel. charge balance error %.

SICADA: water_composition.

Table A3-2. 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	Ce ug/L	Pr ug/L
HFM02	38	48	12503	2006-10-17	17.6	<0.02	315	0.16	<0.05	<0.003	<0.002	0.641	11.4	1.61	4.41	<0.05	0.374	85.1	0.0379	0.0241	<0.005	0.0765	0.011
HFM04	58	66	12519	2006-10-31	2.94	0.0319	190	0.18	<0.05	<0.002	<0.002	0.81	8.35	1.85	5.29	<0.05	0.212	33.4	0.0977	0.0421	<0.005	0.2	0.0288
HFM13	159	173	12510	2006-10-24	16.3	<0.2	578	<10	<0.5	<0.05	0.0027	0.189	45.7	17.4	<0.3	<0.5	1.83	72.4	0.727	<0.05	<0.05	1.28	0.173
HFM15	85	95	12511	2006-10-24	19.9	<0.2	329	<0.5	<0.4	<0.02	<0.002	0.492	21.2	1.43	3.06	<0.2	0.619	95.6	0.108	0.0205	<0.03	0.157	0.0255
HFM16	54	67	12379	2006-10-06	7.32	0.0355	336	4.49	<0.05	<0.009	<0.002	1.53	6.29	0.72	<10	<0.05	0.207	27.9	0.031	0.0427	<0.005	0.064	0.0087
HFM19	168	182	12514	2006-10-25	3.22	<0.2	493	<10	<0.5	<0.05	0.0027	0.233	40	2.38	<0.3	<0.5	1.65	65.2	0.0964	<0.05	<0.05	0.147	<0.05
HFM27	46	58	12506	2006-10-17	20.7	<0.2	387	1.18	<0.4	<0.02	<0.002	0.329	23.6	1.56	1.21	<0.2	0.875	84.4	0.0876	<0.02	<0.03	0.14	<0.02
HFM32	26	31	12518	2006-10-30	41	<0.2	641	2.3	<0.4	<0.02	0.0053	0.237	37.8	0.893	0.317	<0.2	1.08	61.4	0.0705	<0.02	<0.03	0.0833	<0.02
KFM01A	109	130	12397	2006-10-09	2.58	<0.2	744	<0.5	<0.4	<0.02	<0.002	0.102	57.8	16.3	<10	<0.2	0.95	189	1.48	<0.02	<0.03	2.01	0.257
KFM02A	411	442	12502	2006-10-10	31.3	<0.2	695	<1	<0.5	<0.05	<0.002	0.163	61	7.69	<0.3	<0.5	4.76	79.3	0.871	<0.05	<0.05	1.06	0.143
KFM02A	490	518	12311	2006-06-20	137	<0.2	603	<1	<0.5	0.0522	<0.002	0.249	61.4	2.77	<0.3	<0.5	1.86	77.6	0.762	<0.05	<0.05	0.953	0.0921
KFM02A	490	518	12507	2006-10-18	143	<0.2	612	<10	<0.5	<0.05	<0.002	0.156	62	3.45	<0.3	<0.5	1.65	86.2	1.04	<0.05	<0.05	1.45	0.124
KFM03A	633.5	650	12512	2006-10-24	49.5	<0.2	1,040	23.4	<0.5	<0.05	<0.002	0.086	43.1	0.522	<0.3	<0.5	8.92	161	0.462	<0.05	<0.05	0.499	<0.05
KFM03A	969.5	994.5	12513	2006-10-25	0.683	<0.2	931	<20	0.704	<0.05	0.0022	0.188	35.3	0.8	<0.3	<0.5	0.447	1,080	1.11	<0.05	<0.05	1.38	0.111
KFM06A	738	748	12398	2006-10-09	2.18	<0.2	844	1.04	<0.5	<0.1	<0.002	0.223	34.1	0.624	<0.3	<0.5	1.07	337	0.308	<0.05	<0.05	0.262	<0.05
KFM06A	341	362	12399	2006-10-09	24	<0.2	938	<30	<0.4	<0.07	<0.002	0.155	33.8	0.72	0.135	<0.2	0.966	210	0.253	<0.02	<0.03	0.344	0.0329
KFM06C	531	540	12500	2006-10-10	44.4	<0.2	1,020	<0.5	<0.4	<0.02	<0.002	0.151	31.2	1.16	<0.1	<0.2	1.26	103	0.0916	<0.02	<0.03	0.101	<0.02

– = Not analysed.

< "value" = below reporting limit.

SICADA: trace_elements_1, trace_elements_2.

Table A3-2. Cont.

Idcode	Secup m	Seclow m	Sample no.	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	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
HFM02	38	48	12503	0.06	0.0274	<0.005	0.0705	0.0155	0.132	0.0377	0.137	0.0213	0.148	0.0273	0.208	<0.1	0.0238	0.202	8.77	0.482	<0.2	0.0302	1.89
HFM04	58	66	12519	0.137	0.0541	<0.005	0.123	0.025	0.202	0.0541	0.18	0.0279	0.185	0.0327	0.215	<0.1	0.0198	0.295	4.01	0.224	0.477	0.0176	6.24
HFM13	159	173	12510	0.886	0.3	<0.05	0.736	0.131	1.05	0.284	0.948	0.121	0.674	0.115	0.283	<0.5	<0.05	0.529	4.46	1.59	3.78	<0.1	3
HFM15	85	95	12511	0.112	0.0362	<0.02	0.0857	<0.02	0.138	0.0365	0.119	<0.02	0.113	<0.02	0.175	<0.2	<0.02	<0.2	7.68	0.48	<0.8	<0.1	3.49
HFM16	54	67	12379	0.0478	0.0155	<0.005	0.0384	0.0079	0.0735	0.0201	0.0756	0.0115	0.075	0.0157	0.141	0.254	0.0478	0.293	36	0.0631	4.98	0.0196	1.97
HFM19	168	182	12514	0.102	<0.05	<0.05	0.0896	<0.05	0.118	<0.05	0.132	<0.05	0.108	<0.05	0.829	<0.5	<0.05	1.26	2.03	1.08	<2	<0.1	2.06
HFM27	46	58	12506	0.0868	0.0288	<0.02	0.0602	<0.02	0.0944	0.0285	0.0985	<0.02	0.0996	0.0222	0.683	<0.2	0.0495	2.04	7.57	0.684	1.16	<0.1	62.5
HFM32	26	31	12518	0.0431	<0.02	<0.02	0.0271	<0.02	0.0477	<0.02	0.045	<0.02	0.035	<0.02	0.322	<0.2	0.185	0.391	32.2	0.771	<0.8	<0.1	1.48
KFM01A	109	130	12397	1.38	0.365	0.0253	0.859	0.127	1.08	0.301	0.945	0.101	0.541	0.0827	0.258	1	0.0368	0.286	12.8	0.192	<0.8	<0.1	5.7
KFM02A	411	442	12502	0.592	0.139	<0.05	0.349	0.0656	0.486	0.126	0.389	<0.05	0.264	<0.05	0.475	1.19	0.434	0.52	28.6	0.492	<2	<0.1	4.76
KFM02A	490	518	12311	0.334	0.0681	<0.05	0.169	<0.05	0.148	<0.05	0.114	<0.05	0.0843	0.078	0.437	<0.5	0.881	1.39	48.1	<0.3	<2	<0.1	11.1
KFM02A	490	518	12507	0.473	0.0917	<0.05	0.195	<0.05	0.157	<0.05	0.137	<0.05	0.0878	<0.05	0.35	<0.5	0.781	0.8	78.4	2.12	<2	<0.1	7.26
KFM03A	633.5	650	12512	0.18	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.54	<0.5	<0.05	0.515	37.1	1.6	<2	<0.1	5.34
KFM03A	969.5	994.5	12513	0.428	0.0622	<0.05	0.0608	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.513	<0.5	<0.05	7.06	12.7	2.12	8.53	0.133	14.8
KFM06A	738	748	12398	0.0978	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.238	1.26	<0.05	0.585	453	0.505	<2	0.152	3.84
KFM06A	341	362	12399	0.133	0.0286	<0.02	0.0366	<0.02	0.0358	<0.02	0.0342	<0.02	0.0279	<0.02	0.363	1.14	1.25	1.14	267	0.207	1.92	0.172	8.42
KFM06C	531	540	12500	0.0363	<0.02	<0.02	0.0202	<0.02	0.0295	<0.02	0.0335	<0.02	0.0292	<0.02	0.22	1.05	0.291	1.5	66.3	0.197	1.56	0.14	4.37

-- = Not analysed.

< "value" = below reporting limit.

SICADA: trace_elements_1, trace_elements_2.

Table A3-3. Isotopes I (H-, O-, B-, S-, Cl- and C-isotopes).

Idcode	Secup m	Seclow m	Sample no	Sampling date	$\delta^2\text{H}$ dev SMOW	^3H TU	$\delta^{18}\text{O}$ dev SMOW	$^{10}\text{B}/^{11}\text{B}$ no unit	$\delta^{34}\text{S}$ dev CDT	$\delta^{13}\text{C}$ dev PDB	$^{87}\text{Sr}/^{86}\text{Sr}$ no unit	^{14}C pmC	$\delta^{37}\text{Cl}$ dev SMOC
HFM02	38	48	12282	2006-05-30	-82	6.4	-11.1	-	-	-	-	-	-
HFM02	38	48	12503	2006-10-17	-78.5	xxx	-10.6	-	22.6	-10.74	0.725077	59.87	0.22
HFM04	58	66	12283	2006-05-31	-85.8	7.8	-11.8	-	-	-	-	-	-
HFM04	58	66	12519	2006-10-31	-86	xxx	-11.5	-	19.2	-12.45	0.719818	73.89	0.34
HFM13	159	173	12262	2006-05-23	-73.5	0.9	-9.5	-	-	-	-	-	-
HFM13	159	173	12510	2006-10-24	-68.1	xxx	-9.2	0.2367	26	-5.74	0.717835	17.16	0.27
HFM15	85	95	12309	2006-06-13	-83.1	6.7	-11.4	-	-	-	-	-	-
HFM15	85	95	12511	2006-10-24	-76	xxx	-9.9	-	23	-9.10	0.722582	41.39	-0.22
HFM16	54	67	12281	2006-05-31	-81.1	6.7	-11.1	-	-	-	-	-	-
HFM16	54	67	12379	2006-10-06	-81.1	4.9	-10.9	0.2367	12.4	-10.9	0.719348	54.42	0.24
HFM19	168	182	12306	2006-06-08	-63.7	<0.8	-8.3	-	-	-	-	-	-
HFM19	168	182	12514	2006-10-25	-65.0	xxx	-8.2	0.2336	24.1	-6.92	0.722318	38.96	0.24
HFM27	46	58	12280	2006-05-30	-73.5	1.7	-9.6	-	-	-	-	-	-
HFM27	46	58	12506	2006-10-17	-74.0	xxx	-9.5	-	25.9	-7.65	0.724032	32.23	0.05
HFM32	0	25	12286	2006-06-01	-72.0	1.2	-9.1	-	-	-	-	-	-
HFM32	26	31	12287	2006-05-31	-71.0	<0.8	-8.9	-	-	-	-	-	-
HFM32	26	31	12284	2006-06-01	-70.2	<0.8	-9.0	-	-	-	-	-	-
HFM32	26	31	12518	2006-10-30	-65.7	xxx	-8.7	-	28.3	-6.76	0.726837	25.92	0.29
HFM32	32	97	12285	2006-06-01	-71.9	<0.8	-9.1	-	-	-	-	-	-
HFM32	98	203	12288	2006-06-01	-80.7	<0.8	-10.2	-	-	-	-	-	-
KFM01A	109	130	12308	2006-06-14	-80.8	1.5	-10.7	-	-	-	-	-	-
KFM01A	109	130	12397	2006-10-09	-76.9	1	-10.3	0.2347	26.8	-9.41	0.72064	26.57	-0.01
KFM02A	411	442	12310	2006-06-19	-78.6	1.1	-10.2	-	-	-	-	-	-
KFM02A	411	442	12502	2006-10-10	-77.0	1	-10.1	0.2316	25.7	-5.81	0.717106	10.69	-0.02
KFM02A	490	518	12311	2006-06-20	-67.7	0.8	-8.7	0.2385	25	-5.68	0.718269	15.89	-0.02
KFM02A	490	518	12507	2006-10-18	-67.0	xxx	-8.6	0.2365	26.6	-5.56	0.718296	17.94	-0.17

Idcode	Secup m	Seclow m	Sample no	Sampling date	$\delta^2\text{H}$ dev SMOW	^3H TU	$\delta^{18}\text{O}$ dev SMOW	$^{10}\text{B}/^{11}\text{B}$ no unit	$\delta^{34}\text{S}$ dev CDT	$\delta^{13}\text{C}$ dev PDB	$^{87}\text{Sr}/^{86}\text{Sr}$ no unit	^{14}C pmC	$\delta^{37}\text{Cl}$ dev SMOC
KFM03A	633.5	650	12261	2006-06-01	-85.9	<0.8	-11.5	-	-	-	-	-	-
KFM03A	633.5	650	12512	2006-10-24	-81.0	xxx	-11.4	0.2368	26.9	xx	0.717525	xx	0.20
KFM03A	969.5	994.5	12260	2006-06-02	-99.7	<0.8	-13.8	-	-	-	-	-	-
KFM03A	969.5	994.5	12513	2006-10-25	-99.1	xxx	-13.6	0.2377	30.9	xx	0.717769	xx	0.35
KFM06A	341	362	12313	2006-06-20	-85.9	1.1	-11.5	-	-	-	-	-	-
KFM06A	341	362	12399	2006-10-09	-81.9	1.1	-11.5	0.237	28	-10.2	0.717342	30.55	-0.05
KFM06A	738	748	12312	2006-06-21	-81.9	1.6	-11.7	-	-	-	-	-	-
KFM06A	738	748	12398	2006-10-09	-86.3	1.1	-11.7	0.2325	29.8	xx	0.717429	xx	0.05
KFM06C	531	540	12500	2006-10-10	-81.9	0.9	-10.9	0.2346	26	-10.39	0.717582	30.10	0.04

- = Not analysed.

xx = No result due to analytical problems.

xxx = No result due to problem with the postal service.

< "value" = below reporting limit.

SICADA: isotopes_1.

Table A3-4. 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
HFM02	38	48	12503	2006-10-17	184	7.3	438	0.2	0.2	0.46	26.2
HFM04	58	66	12519	2006-10-31	36	1.5	110	1.1	0.3	0.14	113
HFM13	159	173	12510	2006-10-24	205	7	750	0.3	< 0.24	1.01	102
HFM15	85	95	12511	2006-10-24	228	8.9	492	0.4	0.2	0.51	12.4
HFM16	54	67	12379	2006-10-06	92.87	3.05	256.6	0.6	0.15	0.06	20
HFM19	168	182	12514	2006-10-25	39	1.7	107	0.8	0.4	0.81	18.2
HFM27	46	58	12506	2006-10-17	233.5	9.16	602.8	0.61	0.45	1.1	97
HFM32	26	31	12518	2006-10-30	140.4	16.24	1,043	0.34	0.12	1.0	63
KFM01A	109	130	12397	2006-10-09	34	1.4	78	0.3	0.3	3.20	206
KFM02A	411	442	12502	2006-10-10	390	15.3	1,440	1.1	0.7	2.4	402
KFM02A	490	518	12311	2006-06-20	1,740	–	3,520	0.76	–	0.53	1,910
KFM02A	490	518	12507	2006-10-18	1,755	68	3,529	1.4	0.8	3.3	1,430
KFM03A	633.5	650	12512	2006-10-24	603	21.6	911	0.2	0.2	13.6	1,240
KFM03A	969.5	994.5	12513	2006-10-25	6	0.5	15	0.2	0.1	9.2	6.5
KFM06A	738	748	12398	2006-10-09	–	–	–	–	–	3.9	22
KFM06A	341	362	12399	2006-10-09	–	–	–	–	–	2.0	23
KFM06C	531	540	12500	2006-10-10	–	–	–	–	–	2.5	178

– = Not analysed.

SICADA: isotopes_2.