

Forsmark site investigation

Sampling and analyses of groundwater in percussion drilled boreholes and shallow monitoring wells at drillsite DS2

**Results from the percussion boreholes
HFM04, HFM05, KFM02A (borehole
section 0–100 m) and the monitoring
wells SFM0004 and SFM0005**

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April 2003

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Keywords: groundwater, early water sampling after drilling, chemical analyses, isotope determinations, AP PF 400-02-39, AP PF 400-02-36, Field notes No 60, 63 and 72.

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

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1 Introduction

This document reports performance of and results from two activities: "Sampling of percussion boreholes after drilling" and "Sampling of water in monitoring wells", performed within the site investigation at Forsmark /1/. The work was conducted according to the activity plans AP PF 400-02-39 and AP PF 400-02-36 (SKB internal controlling documents). The report presents groundwater-chemical data from:

- 1) percussion drilled boreholes in hard rock at drillsite DS2 /2/, below referred to as "percussion boreholes", including section 0–100 m of the telescopic drilled borehole KFM02A /3/, and
- 2) monitoring wells drilled in the soil layer at drillsite DS2 /4/, below referred to as "monitoring wells". Observe that, in this report, "soil" is used synonymously to overburden, i.e. all material covering the bedrock.

The data were obtained during the period November 2002 – December 2002.

1.1 Percussion boreholes

Borehole KFM02A is the second deep (1002.45 m) telescopic borehole drilled at the site investigations in the Forsmark area. The location of the borehole is shown in Figure 1-1. The borehole section 0–100 m is percussion drilled, and today cased with a stainless steel casing with the internal diameter 200 mm, whereas section 100–1002.5 m is core drilled with a diameter of c. 77 mm.

The percussion boreholes HFM04 and HFM05 as well as the monitoring wells SFM0004 and SFM0005 were drilled at relatively short distances from the telescopic borehole KFM02A, see Figure 1-2. Borehole HFM05 was drilled with the primary purpose to serve as a supply well for the flushing water needed for drilling the core drilled part of borehole KFM02A. Borehole HFM05 is like the telescopic borehole KFM02A of the so called SKB chemical type, see method descriptions MD 620.003 (Method description for drilling cored boreholes) and 610.003 (Method description for percussion drilling). A borehole being of SKB chemical type entails cleaning procedures of all in-hole equipment to be used in the borehole during and after drilling according to level 2 in the cleaning instructions in MD 600.004 (Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning).

Borehole HFM04 was drilled primarily as a monitoring well for groundwater levelling in the shallow part of the bedrock. However, also for this borehole, cleaning according to level 2 in MD 600.004 was applied in order to let this borehole serve as a reserve flushing water well.

Basic borehole information is given in Table 1-1 below. The designs of the boreholes are presented in Appendix 1. A map showing the locations of the boreholes at drillsite DS2, depth of dominating water bearing fracture zones and chloride concentrations is presented in Figure 1-2.

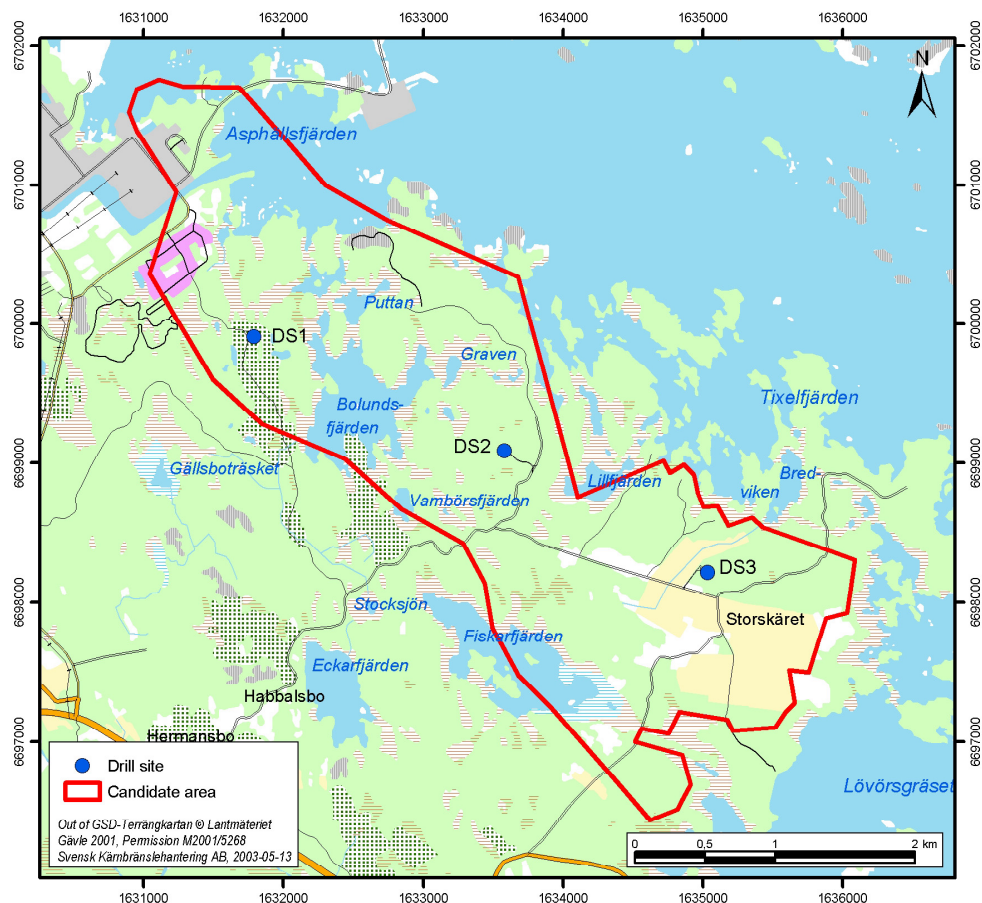


Figure 1-1. The investigation area at Forsmark (approximately the area inside the black square) including the candidate area selected for more detailed investigations. Drillsites DS1–3 are marked with blue circles.

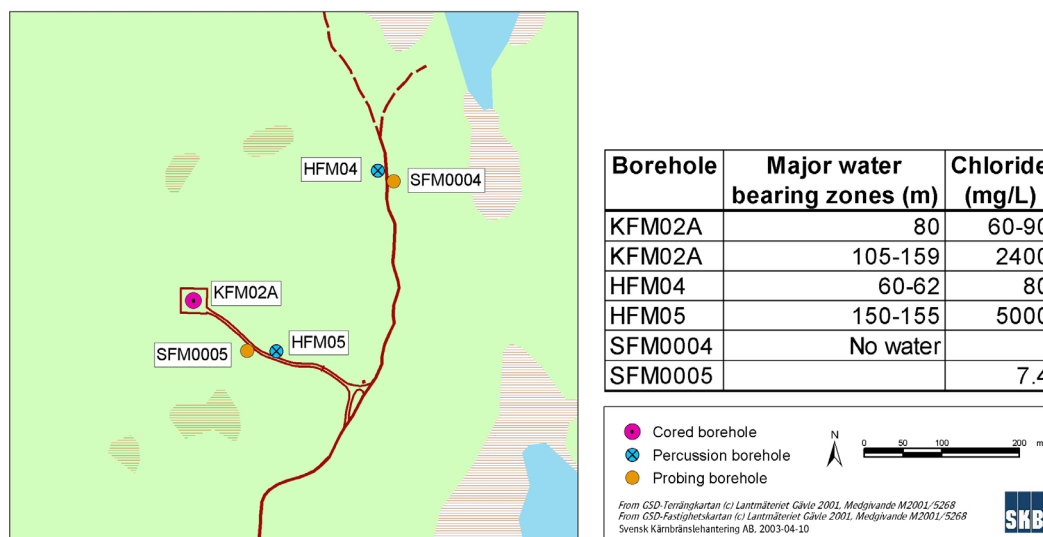


Figure 1-2. Locations of percussion boreholes and monitoring wells in connection with the telescopic borehole KFM02A at drillsite DS2, water bearing zones and typical chloride concentrations. The location of HFM05 was chosen in order to hit a relatively deep (ca 150 m) possible water bearing zone, in order to increase the possibility of obtaining groundwater with a low TOC-concentration.

Table 1-1. Borehole information, percussion boreholes at drillsite DS2.

| Borehole | Date of completion | Length | Water bearing sections (length along borehole, m) | Comment |
|----------|--------------------|--------------------------|---|--|
| HFM04 | 2002-05-03 | 221.7 | 60–62 | |
| HFM05 | 2002-05-21 | 200.1 | 150–155 | Source of flushing water for core drilling the cored part of KFM02A |
| KFM02A | 2002-06-10 | Borehole section 0–100 m | 80 | Later on a casing was installed and gap grouted, sealing off water inflow in this part of the borehole |

Sampling of KFM02A, HFM04 and HFM05 was accomplished a short time after drilling, in connection with pumping tests and flow logging carried out within the programme for hydrogeological investigations /5/. The pumping test and water sampling in the percussion drilled part (section 0–100 m) of the telescopic borehole KFM02A was performed after the first drilling step, when the borehole diameter was approximately 165 mm. Boreholes HFM04 and HFM05, which both have a diameter of 140 mm or a few millimetres less, were pumped, flow logged and sampled at the same campaign with a time separation between the individual boreholes of a few days, see Table 4-1. In borehole HFM04 no other borehole tests were carried out prior to the hydrotest/water sampling campaign. This was not the case in HFM05 where geophysics logging, BIPS-logging and radar logging were performed before the hydrotest and water sampling.

1.2 Monitoring wells

The designs of the monitoring wells are shown in Appendix 1. A map showing the locations of the wells at drillsite DS2 is presented in Figure 1-2.

The first sampling of groundwater in the monitoring wells SFM0004 and SFM0005 was performed a short time after installation of the well equipment (screen, riser pipes, sand filter and bentonite sealings, see Appendix 1) and after conditioning of the wells (pumping to renew the water volume in the borehole and to obtain clean groundwater representative for the soil formation). The monitoring well SFM0004 did not yield any measurable amount of water at that occasion. The monitoring wells were hydraulically characterized by slug testing, although performed after the groundwater sampling /6/.

Starting in May 2003, groundwater sampling in the monitoring wells will be part of a long-term sampling programme, in which sampling will be performed four times a year, see also Chapter 6.

Basic borehole information is given in Table 1-2.

Table 1-2. Borehole information, monitoring wells at drillsite DS2.

| Monitoring well | Date of completion | Length (m) | Comment |
|------------------------|---------------------------|-------------------|--|
| SFM0004 | 2002-12-03 | 5.4 | Acid leached HDPE-pipes. Dry hole. |
| SFM0005 | 2002-12-10 | 2.4 | Well intended for environmental control. Acid leached HDPE-pipes. |

2 Objective and scope

2.1 Groundwater sampling in percussion boreholes

Sampling and analysis of groundwater from boreholes HFM04, HFM05 and KFM02A (0–100 m) was performed in order to:

- Check the suitability of HFM05 to serve as a supply well for the flushing water needed for drilling the cored part of the telescopic borehole KFM02A. Pumping capacity and water quality are critical parameters when assessing the suitability of a potential flushing water well.
- Gain data on the groundwater composition of so called “first strike” groundwater, i.e. groundwater sampled before the impact of short circuiting between fractures of different hydrogeochemical character has become significant.
- Obtain groundwater-chemical data from the shallow part of the bedrock (to approximately 200 m depth) at drillsite DS2.

Of primary interest in this activity was to investigate if the groundwater in borehole HFM05 was of sufficient quality to be used as flushing water for drilling the cored part of telescopic borehole KFM02A. Core drilling of a 1000 m long borehole will consume 1000 m³ or more flushing water. As borehole KFM02A is of SKB chemistry type, the content of organic components in the flushing water should be low, preferably below 5 mg/L. The reason for this is that introduction of hydrocarbons may affect the microbiological flora in the borehole, which, consequently, would obstruct a reliable characterization of the in situ microbiological conditions.

Sampling and analysis was performed according to the SKB class 3 procedure /1/.

2.2 Groundwater sampling in monitoring wells

Sampling and analyses of groundwater in the monitoring wells was performed in order to:

- Study possible changes in groundwater-chemical composition due to drilling of KFM02A. The drilling may also result in groundwater level fluctuations in the near-surrounding of the telescopic borehole.
- Control possible groundwater contamination (especially in the near-situated well SFM0005) due to unintentional spillage of oil products during the drilling activities in KFM02A. SFM0005 is included in the environmental control programme for drillsite DS2.
- Obtain data that can enhance the understanding of processes at the interface between the geosphere and the near-surface ecosystem.

The only monitoring well at drillsite DS2 yielding groundwater (at least so far) SFM0005 has up to now been sampled only once. In the future, sampling will be repeated with a frequency of four times per year in order to estimate the size of the natural variations of the groundwater-chemical composition in the soil aquifer. It is not the purpose to study the size and nature of seasonal variations. This would require a much more frequent sampling programme.

Sampling and analysis of groundwater from monitoring wells in soil are performed according to SKB surface water sampling class 5.

3 Equipment

3.1 Sampling equipment used in percussion boreholes

The sampling in boreholes HFM04, HFM05 and KFM02A (section 0–100 m) was performed in connection with hydraulic tests with the HTHB (HydroTester för HammarBorrhål) pump & packer equipment described in SKB MD 326.001 (Mätsystembeskrivning för hydrotestutrustning för hammarborrhål – HTHB). The equipment allows pumping from packed off sections in boreholes of diameter 165 mm and 140 mm (\pm a few millimetres) using a single- or double packer system. The in-hole equipment includes a packer system, a measurement tube, an enclosed pump, and a combined pressure sensor and data logger. An overview of the HTHB equipment is given in Figure 3-1 below.

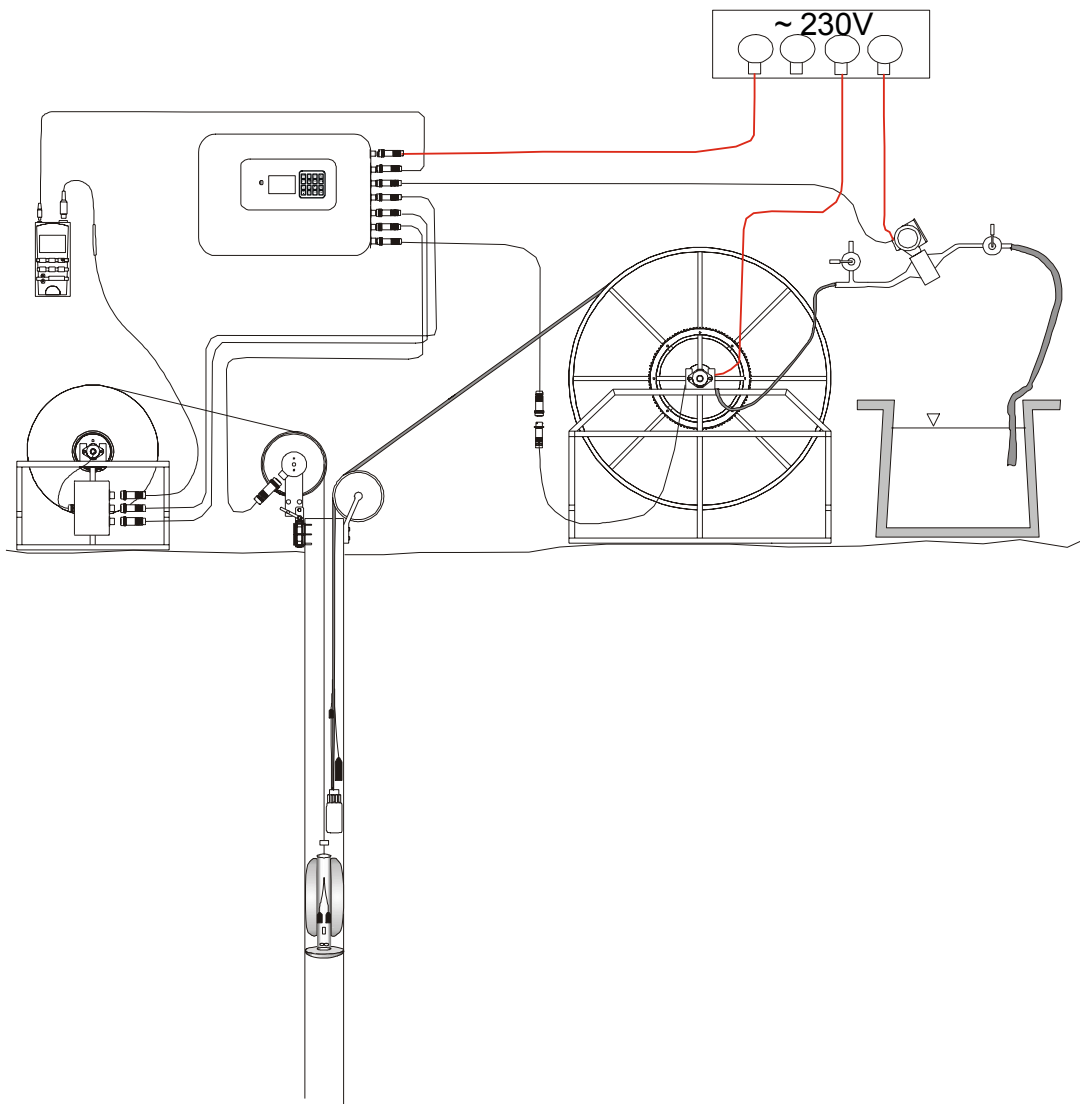


Figure 3-1. The HTHB (HydroTester för HammarBorrhål) equipment, configured for pumping at “open hole” conditions in combination with flow logging.

3.2 Sampling equipment used in monitoring wells

Sampling of “near-surface” groundwater in monitoring wells was performed using the equipment described below:

- A Grundfors MP1 pump, (diameter = 48mm) enclosed in a cover of acid proof stainless steel, stainless steel quick couplings, and PEH-tubings of dimension 10/8 mm.
- A simple flow through measurement cell made of a 10 L plastic bucket with a lid, a pH-meter, and an electric conductivity meter. No oxygen meter was used in the cell.

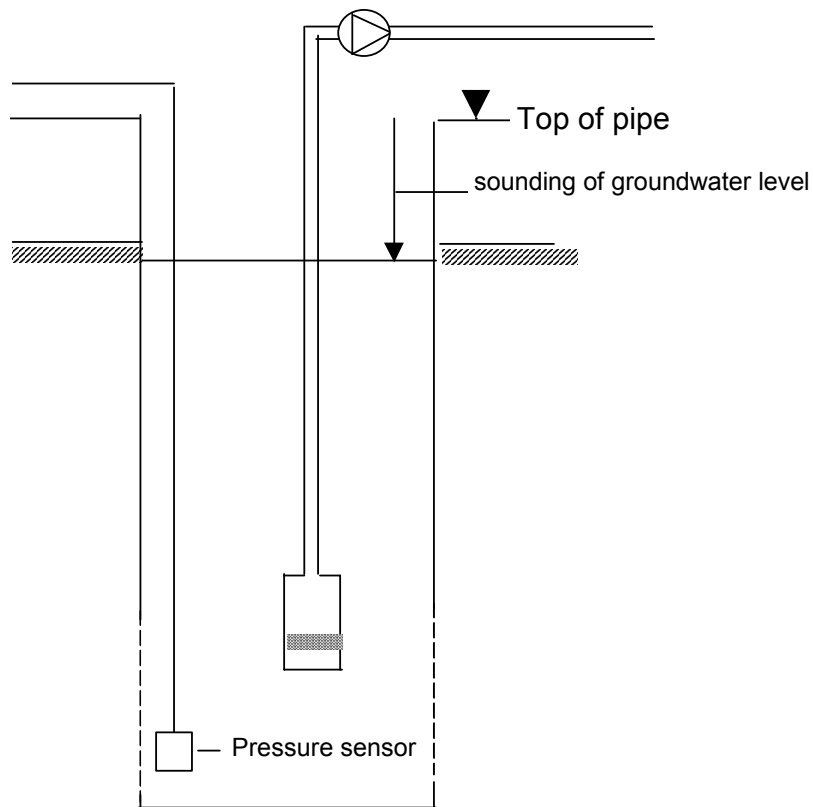


Figure 3-2. Installation in monitoring well, pump and pressure sensor.

4 Performance

4.1 Performance of sampling and measurements

Sampling of the percussion boreholes at drillsite DS2 was performed according to activity plan AP PF 400-02-39 (SKB internal controlling document) following the method described in SKB MD 423.002 (Metodbeskrivning för vattenprovtagning i hammarborrhål efter borrning).

The sampling was carried out in the following succession: KFM02A, HFM04, and finally HFM05. Generally, pumping was performed during 10 hours, and samples were collected twice during the pumping period. Table 4-1 displays the pumping times and sampling occasions during the pumping tests.

Sampling and analyses was performed according to SKB class 3, and isotope determinations were performed in the last sample collected for each borehole and sampling occasion. Total organic carbon (TOC) was determined in samples from HFM05 to investigate its suitability as a source for flushing water. The components iron, manganese, hydrogen-sulphide and iodide are not included in class 3 and therefore not determined.

Sampling of the monitoring wells at drillsite DS2 was performed according to Activity Plan AP PF 400-02-36 (SKB internal controlling document). The wells have been sampled only once, so far. The water volume in the pipe was renewed three times before the water sample was collected. Measurements in the flow through cell were performed during pumping. Table 4-2 illustrates the pumping times and sampling occasions during the pumping tests.

Table 4-1. Pumping times and sampling occasions in percussion boreholes at drillsite DS2.

| Borehole | Section | Pump start | Pump stop | Sampl. Time | Comments |
|----------|----------|--------------|--------------|--|--|
| HFM04 | 30–221.7 | 021210 10:32 | 021210 20:47 | 021210 11:45 021210 15:00 021210 20:45 | Sampling & analyses, class 3 |
| HFM05 | 25–200.1 | 021219 10:48 | 021219 20:48 | 021219 11:35 021219 15:45 021219 20:25 | Sampling & analyses, class 3 |
| KFM02A | 18–100.4 | 021129 9:30 | 021129 19:34 | 021129 10:00 021129 15:50 | Ack. Volume 1.95 m ³ Ack. Volume 24.8 m ³ Sampling & analyses, class 3 |

Table 4-2. Pumping times and sampling occasions in monitoring wells at drillsite DS2.

| Borehole | Pump start | Pump stop | Sampl. Time | Comments |
|----------|------------|-----------|-------------|---|
| SFM0004 | – | – | – | The well was dry at the sampling occasion. |
| SFM0005 | – | – | 2002-12-16 | Sampling & analyses class 5 incl. surface water options |

4.2 Sample treatment and chemical analyses

An overview of sample treatment and analysis routines is given in Appendix 2. The routines are applicable independent of sampling method or sampling object.

4.3 Data handling

The field measurement data were manually registered directly in the SICADA table “hydrogeol_field_measurement” as soon as possible after performance of the field work.

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

Several components are determined by more than one method and/or laboratory. Moreover, control analyses by an independent laboratory are performed as a standard procedure on each fifth or tenth collected sample.

All analytical results were 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 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. The analyses are repeated if a large disparity is noted (generally more than 10 %).
- Calculation of charge balance errors. Relative errors within ± 5 % are considered acceptable (in surface waters ± 10 %).

$$\text{Rel. Error (\%)} = 100 \times \frac{(\sum \text{cations(equivalents)} - \sum \text{anions(equivalents)})}{(\sum \text{cations(equivalents)} + \sum \text{anions(equivalents)})}$$

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

All results from “biochemical” components and special analyses of trace metals and isotopes are inserted directly in primary data tables. In those 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 4-1.

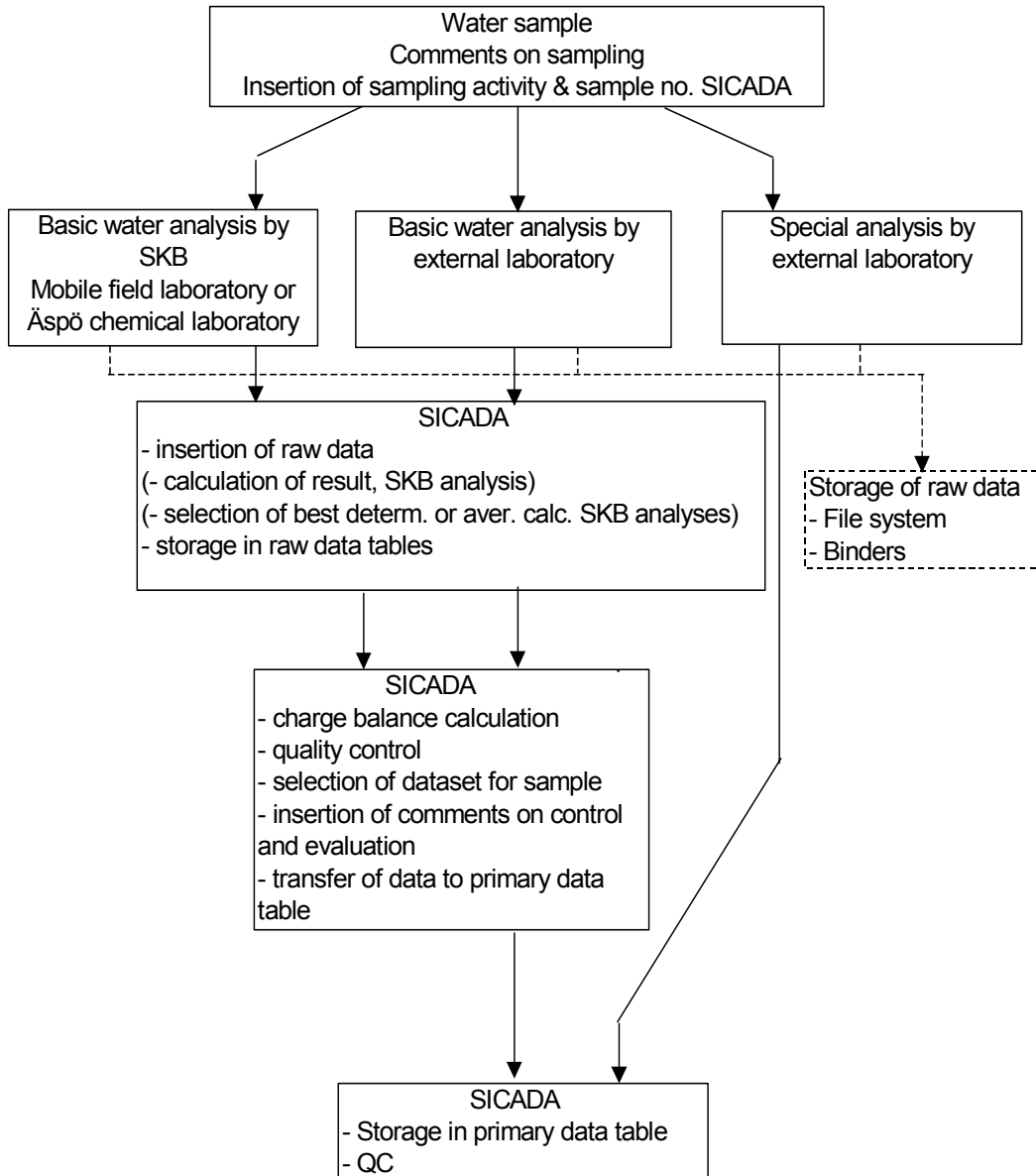


Figure 4-1. Overview of data management for hydrogeochemical data.

5 Results

5.1 Analysis results from HFM04, HFM05 and KFM02A

The analytical data from the percussion boreholes including the percussion drilled part of KFM01A are presented in Appendix 3 and 4.

Samples were collected at least three times during the pumping test, and the water composition of the respective samples do not differ considerably. However, the last sample in each series should be regarded as the one most representative.

The concentration of Total Organic Carbon (TOC) in the samples collected in HFM05 was found to be in the range 2.3–2.6 mg/L. These values were considered as low enough to accept HFM05 as supply well for the flushing water needed for drilling the core drilled part of KFM02A without further measures.

5.2 Analysis results from SFM0005

The analytical data from the monitoring well SFM0005 is presented in Appendix 3, 4, 5 and 6. The sampling and analyses of the near surface groundwater are performed according to SKB surface water sampling class 5 which also includes surface water components, see Appendix 6. Sampling has been performed at only one occasion. Some of the results from isotope analyses have not yet been reported from the consulted laboratories and are therefore not included in the present report.

5.3 Quality of the analyses

Comparison between results from different laboratories and methods indicates that the agreement is acceptable in most cases. Generally, the difference in concentrations between each controlled component is less than 10 %.

The charge balance errors give an indication of the quality and uncertainty of the analyses of the major components. The relative charge balance errors are calculated for the selected sets of data, see Appendix 3. The errors do not exceed ± 3 % in any of the nine cases, which is a quite satisfactory result.

6 Future work

6.1 Percussion boreholes

The initial sampling of percussion boreholes at drillsite DS2 (reported here), performed according to the SKB class 3 procedure, will in the future be repeated on a regular basis in a long-term monitoring programme. The programme will include a selection of boreholes, and samples will be collected regularly twice a year from one or two packed off sections in each borehole. Sampling and analysis within the frame of the monitoring programme will be performed according to the SKB class 5 procedure /1/.

6.2 Monitoring wells

The two monitoring wells at drillsite DS2 reported here are all situated close to the deep borehole KFM02A. Early this year (2003), a number of "not drillsite connected" monitoring wells have been drilled within or close to the candidate area. Some of them are intended for groundwater sampling and chemical analyses.

A sampling programme (activity plan) is being written, which includes the "drill site connected" wells as well as the new "not drill site connected" hydrogeochemistry wells (totally 16 wells). This new programme for near-surface groundwater will be connected to the surface water sampling programme. Sampling in the wells will be performed four times during 2003, at the same campaigns as for the sampling of surface water in the area of investigation. The sampling times during 2003 and early in 2004 as well as types of analytical procedures applied are presented in Table 6-1.

Tabell 6-1. Sampling times during 2003/early 2004 and types of analytical procedures applied in shallow monitoring wells.

| | | | | | | |
|--------------|-------------|---------------------|---------------------------------|-------------|---------------------|-------------|
| Year | 2003 | 2003 | 2003 | 2003 | 2003 | 2003 |
| Month | March | April | May | Juni | July | August |
| Week* | | | 19 (SKB class 5) test run | | 28 (SKB class 3) | |
| Year | 2003 | 2003 | 2003 | 2003 | 2004 | 2004 |
| Month | September | October | November | December | January | February |
| Week* | | 42 (SKB class 5) | | | 3 (SKB class 3) | |

* Week numbers when sampling of monitoring wells is planned to be performed

The programme will probably continue for several years according to this structure.

7 References

- /1/ **SKB, 2001.** Generellt genomförande program för platsundersökningar. SKB R-01-10, Svensk Kärnbränslehantering AB.
- /2/ **Claesson L-Å, Nilsson G, 2003.** Forsmark site investigation. Drilling of a flushing water well, HFM05, and one groundwater monitoring well, HFM04, at drillsite DS2. SKB P-03-51, Svensk Kärnbränslehantering AB.
- /3/ **Claesson L-Å, Nilsson G, 2003.** Forsmark site investigation. Drilling of the telescopic borehole KFM02A at drillsite DS2. SKB P-03-52, Svensk Kärnbränslehantering AB.
- /4/ **Claesson L-Å, Nilsson G, 2003.** Forsmark site investigation. Drilling of groundwater monitoring wells SFM0004 and SFM0005 in soil at drillsite DS2. SKB P-03-50, Svensk Kärnbränslehantering AB.
- /5/ **Ludvigsson J-E, Svensson T, 2003.** Forsmark site investigation. Pumping tests and flow logging. Boreholes KFM02A (0–100 m), HFM04 and HFM05. SKB P-03-34, Svensk Kärnbränslehantering AB.
- /6/ **Werner K, Johansson P-O, 2003.** Forsmark site investigation. Slugtests in observation wells in soil. SKB P-03-46, Svensk Kärnbränslehantering AB.

Designs of boreholes and monitoring wells

Figure 1. KFM02A

Figure 2. HFM04

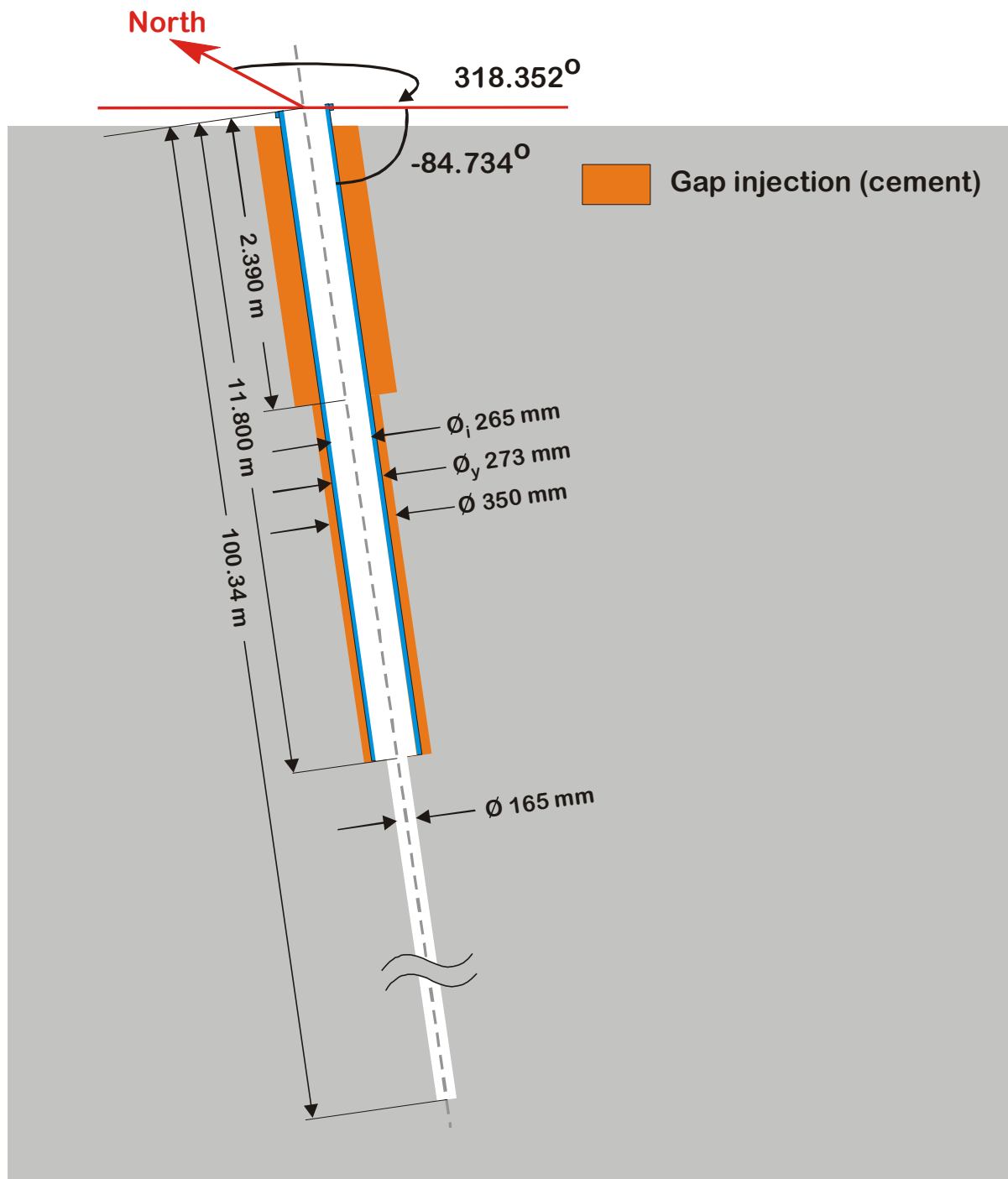
Figure 3. HFM05

Figure 4. SFM0004

Figure 5. SFM0005

Technical data

Borehole KFM02A

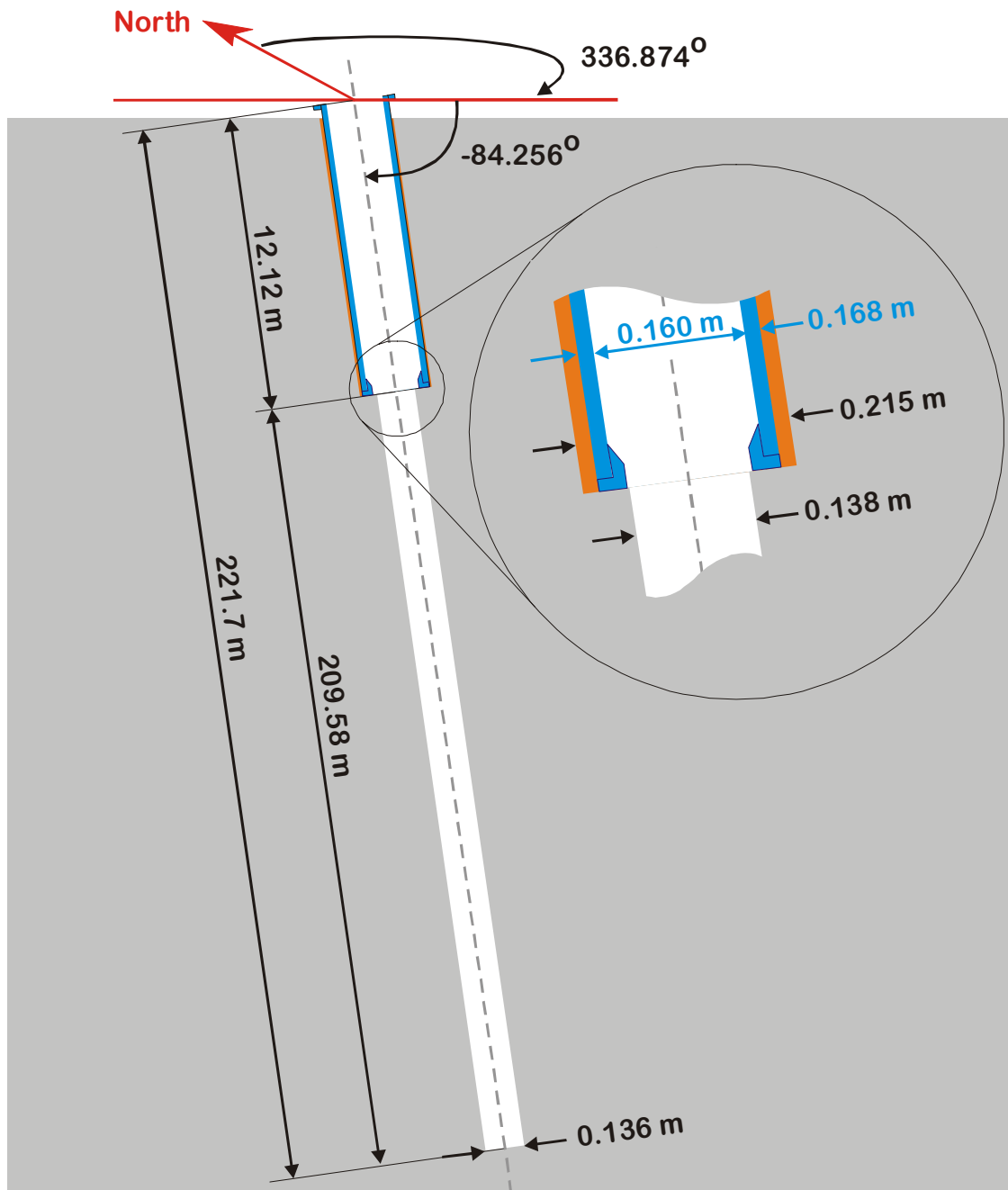


Drilling reference point

Northing: 6698712.501 (m), RT90 2,5 gon V 0:-15
Easting: 1633182.863 (m), RT90 2,5 gon V 0:-15
Elevation: 7.353 (m), RHB 70

Technical data

Borehole HFM 04



Drilling reference point

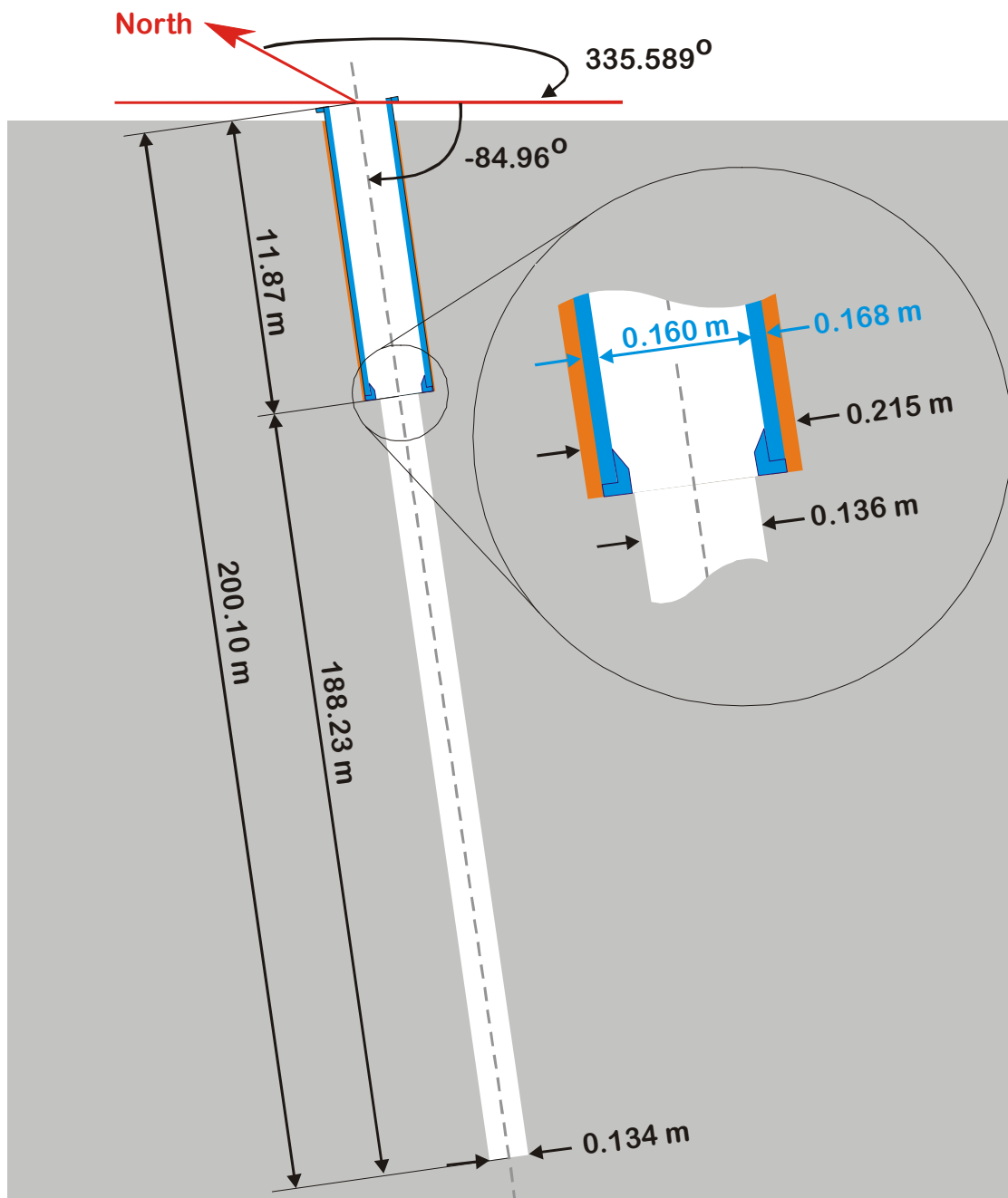
Northing: 6698878.968 (m), RT90 2,5 gon V 0:-15
 Easting: 1633420.733 (m), RT90 2,5 gon V 0:-15
 Elevation: 3.873 (m), RHB 70

Drilling period

Drilling start date: 2002-11-19
 Drilling stop date: 2002-12-03

Technical data

Borehole HFM 05

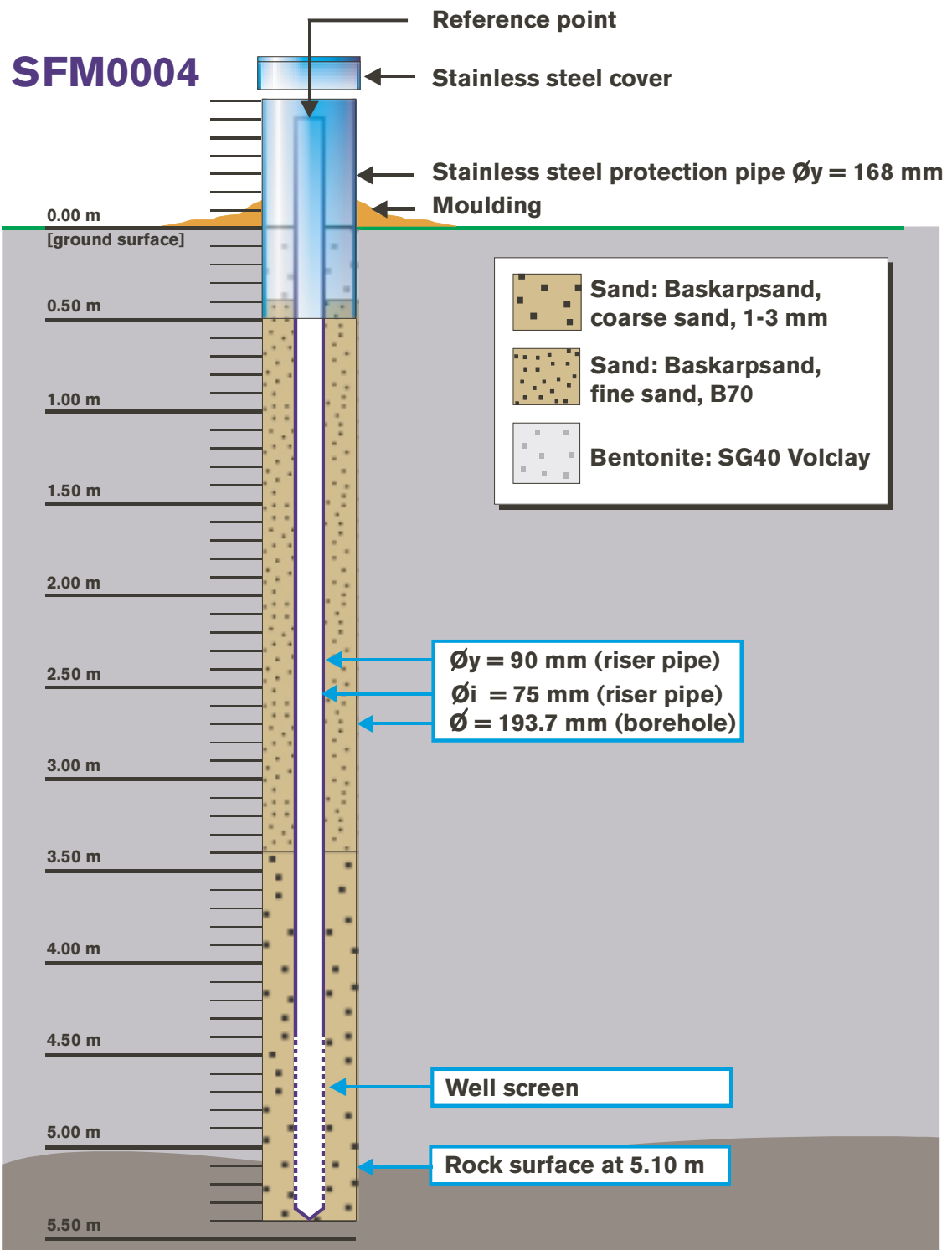


Drilling reference point

Northing: 6698647.275 (m), RT90 2,5 gon V 0:-15
Easting: 1633289.721 (m), RT90 2,5 gon V 0:-15
Elevation: 7.672 (m), RHB 70

Drilling period

Drilling start date: 2002-12-04
Drilling stop date: 2002-12-17

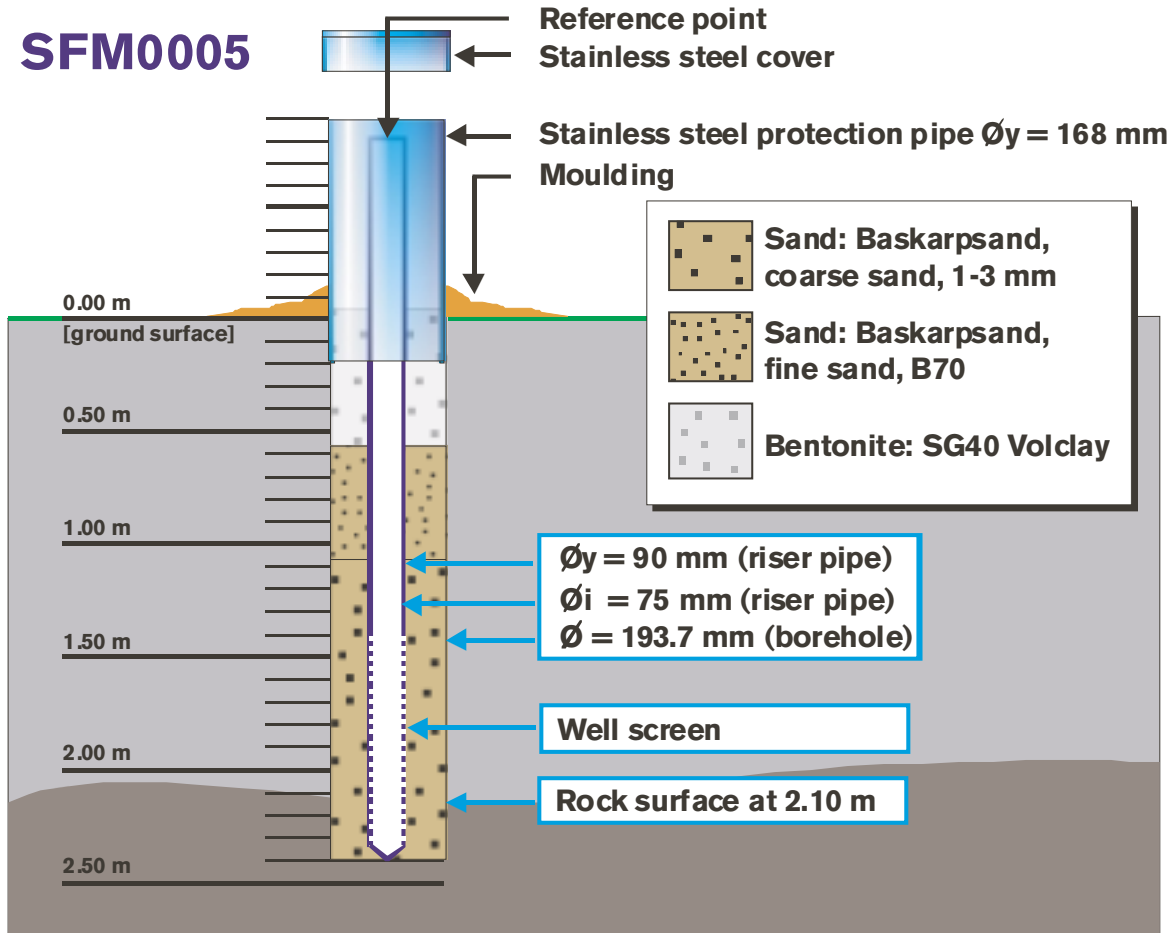


Installation date:
2002-12-03

Reference point

Northing: 6698865.757 (m), RT90 2.5 gon V 0:-15
 Easting: 1633441.208 (m), RT90 2.5 gon V 0:-15
 Elevation: 4.143 (m), RHB 70

SFM0005



Installation date:

2002-12-10

Reference point

Northing: 6698647.552 (m), RT90 2.5 gon V 0:-15

Easting: 1633252.184 (m), RT90 2.5 gon V 0:-15

Elevation: 6.801 (m), RHB 70

Appendix 2

Table A2-1. Overview of general sample handling routines and analysis methods.

| Component group | Component/element | Sample container (material) | Volume (mL) | Filtering | Preparation/Conservation* | Analysis method | Laboratory**** | 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 | Mobile field lab. Alcontrol | 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 ⁻) | Åspö:s chemistry lab. Alcontrol | Not critical (month) |
| | Br, I | Plastic | 100 | Yes (not in the field) | No | ICP MS | Paavo Ristola OY SGAB Analytica, | 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 | SGAB Analytica, SLU, Umeå | 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 | SGAB Analytica, SLU, Umeå | Not critical (month) |
| Fe(II), Fe(tot) | Fe(II), Fe(tot) | Plastic (Acid washed) | 500 | Yes | Yes (5 mL HCl)) | Spectrophotometry Ferrozine method | Mobile field lab. | 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 | Alcontrol Åspö:s chemistry lab. | Immediately or if conserved, a few days |
| Nutrient salts | NO ₂ , NO ₃ +NO ₂ , NH ₄ , PO ₄ | Plastic | 250 | No | No | Spectrophotometry | Åspö:s chemistry lab. Alcontrol | Maximum 24 hours |
| Environmental metals | Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn | Plastic | 100 | Yes | Yes (1 mL HNO ₃) | ICP-AES ICP-MS | SGAB Analytica, Alcontrol | Not critical (month) |

| Component group | Component/element | Sample container (material) | Volume (mL) | Filtering | Preparation/Conservation* | Analysis method | Laboratory**** | Analysis within - or delivery time to lab. |
|--|--|-----------------------------|-----------------------|-----------|-------------------------------------|---|---|--|
| 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 | 100 | Yes | Yes (1 mL HNO ₃) | ICP-AES ICP-MS | SGAB Analytica, Alcontrol | 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 | Paavo Ristola OY Dept. of System ecology, SU | Short transportation time |
| Total organic Carbon | TOC | Plastic | 250 25 | No | Frozen, transported in isolated bag | UV oxidation, IR Carbon analysator Shimadzu TOC5000 | Paavo Ristola OY Dept. of System ecology, SU | Short transportation time |
| Environmental isotopes | ² H, ¹⁸ O | Plastic | 100 | No | - - | MS | IFE | Not critical (month) |
| Tritium, | ³ H (enhanced.) | Plastic (dry bottle) | 500 | No | - | LSC | Univ. Of Waterloo | Not critical (month) |
| Chlorine-37 | Chlorine-37 | Plastic | 100 | No | - | ICP MS | | |
| Carbon isotopes | ¹³ C, ¹⁴ C | Glass (brown) | 100×2 | No | - | (A)MS | Univ. Of Waterloo | A few days |
| Sulphur isotopes | ³⁴ S | Plastic | 500 –1000 | Yes | - | Combustion, ICP MS | IFE | No limit |
| Strontium-isotopes | ⁸⁷ Sr/ ⁸⁶ Sr | Plastic | 100 | Yes | - | TIMS | IFE | Days or Week |
| Uranium and Thorium isotopes | ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³² Th, ²³⁰ Th, | Plastic | 50 | Nej | - | Chemical separat. Alfa/gamma spectrometry | IFE | No limit |
| Boron isotopes | ¹⁰ B | Plastic | 100 | Yes | Yes (1 mL HNO ₃) | ICP – MS | SGAB Analytica | No limit |
| Radon and Radium isotopes | ²²² Rn, ²²⁶ Ra | Plastic | 500 | No | No | EDA, RD-200 | IFE | Immediate transport |
| Dissolved gas (content and composition) | Ar, N ₂ , CO ₂ , O ₂ , CH ₄ , H ₂ , CO, C ₂ H ₂ , C ₂ H ₄ , C ₂ H ₆ , C ₃ H ₈ | Cylinder of stainless steel | 200 | No | No | GC | Paavo Ristola OY | 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 | SGAB Analytica | Immediate transport |

| Component group | Component/element | Sample container (material) | Volume (mL) | Filtering | Preparation/Conservation* | Analysis method | Laboratory**** | Analysis within - or delivery time to lab. |
|---|----------------------------------|--|-------------|-----------|------------------------------|------------------------|----------------------------------|--|
| Humic and fulvic acids | Fractionation | Fractions are collected in plastic bottles | 250 | - | N ₂ atmosphere | UV oxidation, IR (DOC) | Paavo Ristola OY | 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 | DEAE cellulose (anion exchanger) | - | - | - | (A)MS | The Ångström laboratory, Uppsala | A few days |

* Suprapur acid is used for conservation of samples.

** Minimum number, the number of archive samples can vary depending on how many similar samples that are collected at the same occasion.

**** Full name and address is given in Table A1-5.

Table A2-2. Sample handling routines and analysis methods for supplementary analyses in near surface groundwater samples (Monitoring wells/soil pipes).

| Component group | Component/element | Sample container (material) | Volume (mL) | Filtering | Preparation/Conservation* | Analysis method | Laboratory**** | Analysis within - or delivery time to lab. |
|--|---|-----------------------------|-------------|--|--|---|---------------------------------------|--|
| Nutrient salt + silicate | NO ₂ , NO ₃ , NO ₂ +NO ₃ , NH ₄ , PO ₄ , SiO ₂ | Sample tubes, plastic | 25×2 | Yes (in the field) | No, frozen immediately*** | Spectrophotometry | Dept. of System ecology, SU | Short transportation time |
| Total concentrations of Nitrogen and Phosphorous | N-tot, P-tot | Plastic | 100 | No | No, frozen immediately*** | Spectrophotometry | Dept. of System ecology, SU | Short transportation time |
| Particulate Carbon, Nitrogen and Phosphorous | POC, PON, POP | Plastic | 1000 | 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) | Dept. of System ecology, SU | Short transportation time |
| Chlorophyll | Chlorophyll a, c and pheopigment | Plastic | 1000-2000 | Yes (within 4 h) | Filtering, the filters are frozen immediately | Spectrophotometry Fluorometry | Dept. of System ecology, SU | Short transportation time |
| Oxygen | Dissolved O ₂ | Winkler, glass | 2×ca 120 | No | Mn (II) reagent Iodide reagent | Spectrophotometry SIS SS-EN 25813 | Dept. of System ecology, SU Alcontrol | Within 3 days |
| Archive samples for supplementary radio nuclides | | Plastic | 5000 | 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 how many similar samples that are 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.

**** Full name and address is given in Table A1-5.

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 |
| LSC | Liquid Scintillation Counting |
| (A)MS | (Accelerator) Mass Spectrometry |
| GC | Gas Chromatography |

Table A2-3. Reporting limits and measurement uncertainties.

| Component | Method | Reporting limits or range | Unit | Measurement uncertainties ³ | "Total" uncertainties ⁴ |
|---------------------------------------|-----------------------|--|------|--|------------------------------------|
| HCO ₃ | Alkalinity titration | 1 | mg/L | 4 % | Time delay affects the results |
| Cl ⁻ Cl ⁻ | Mohr- titration IC | > 70 1 – 100 | mg/L | 5 % 6 % | <10 % 20 % |
| SO ₄ | IC | 1 | mg/L | 10 % | 20 % |
| Br ⁻ Br ⁻ | IC ICP | 0.2 0.001 | mg/L | 9 % 15 % | 30 % |
| F ⁻ F ⁻ | IC Potentiometric | 0.1 - | mg/L | 10 % - | 20 % |
| I ⁻ | ICP | 0.001 | mg/L | 15 % | 20 % |
| Na | ICP | 0.1 | mg/L | 4 % | 10 % |
| K | ICP | 0.4 | mg/L | 6 % | 20 % |
| Ca | ICP | 0.1 | mg/L | 4 % | 10 % |
| Mg | ICP | 0.09 | mg/L | 4 % | 10 % |
| S(tot) | ICP | 0.160 | mg/L | 21 % | 20 % |
| Si(tot) | ICP | 0.03 | mg/L | 4 % | 15 % |
| Sr | ICP | 0.002 | mg/L | 4 % | 10 % |
| Li | ICP | 0.2 ¹ 2 ² | mg/L | 10 % | 20 % |
| Fe | ICP | 0.4 ¹ 4 ² | mg/L | 6 % | 10 % |
| Mn | ICP | 0.03 ¹ 0.1 ² | µg/L | 8 % | 10 % |
| Fe(II), Fe(tot) | Spectrophotometry | 0.02 (DL=0.005 mg/L) | mg/L | 22 % | 30 % |
| HS ⁻ | Spectrophotometry | SKB 0.03 (DL=0.002) Alcontrol (DL= 0.003) | mg/L | 20 % | 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 % |

| Component | Method | Reporting limits or range | Unit | Measurement uncertainties ³ | "Total" uncertainties ⁴ |
|--|-------------------------|--------------------------------------|------------|--|------------------------------------|
| PO ₄ as P | Spectrophotometry | 0.7 | µg/L | 0.7 (0.7-20 µg/L) 3 % (> 20 µg/L) | 20 % |
| SiO ₂ | Spectrophotometry | 1 | µg/L | 3 % (>200 µg/L) | |
| O ₂ | Jodometrische titration | | mg/L | | |
| Chlorophyll a, c pheopigment ⁶ | See table A1-2 | 0.5 | µg/L | 5 % | |
| PON ⁶ | See table A1-2 | 0.5 | µg/L | 5 % | |
| POP ⁶ | See table A1-2 | 0.1 | µg/L | 5 % | |
| POC ⁶ | See table A1-2 | 1 | µg/L | 4 % | |
| Tot-N ⁶ | See table A1-2 | 10 | µg/L | 4 % | |
| Tot-P ⁶ | 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 | ICP | 0.01 | µg/L | 20 % | Correct order of size |
| La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb | ICP | 0.005 ¹ 0.05 ² | µg/L | 10 % | Correct order of size |
| Sc, In, Th | ICP | 0.05 ¹ 0.5 ² | µg/L | 10 % | Correct order of size |
| Rb, Zr, Sb, Cs, Tl | ICP | 0.025 ¹ 0.25 ² | µg/L | 10 % | Correct order of size |
| Y, Hf | ICP | 0.005 ¹ 0.05 ² | µg/L | 10 % | Correct order of size |
| U | ICP | 0.001 ¹ - | µg/L | 12 % | Correct order of size |
| DOC, DIC | See table A1-1 | 0.1 | Mg/L | 20 % | 50 % |
| TOC | See table A1-1 | 0.1 | Mg/L | 20 % | 50 % |
| ² H | MS | 2 | ‰ dev SMOW | 1.0 ‰ | |
| ¹⁸ O | MS | 0.1 | ‰ dev SMOW | 0.2 ‰ | |

| Component | Method | Reporting limits or range | Unit | Measurement uncertainties ³ | "Total" uncertainties ⁴ |
|--|------------------|---|---------|--|------------------------------------|
| ³ H | LSC | 0.8 eller 0.1 | TU | 0.8 | Correct order of size |
| ³⁷ Cl | ICP MS | 0.2 ‰ (20 mg/L) | SMOC | - | |
| ¹³ C | A (MS) | - | PDB | - | |
| ¹⁴ C pmc | A (MS) | - | PMC | - | Correct order of size |
| ³⁴ S | ICP MS | 0.2 ‰ | | 0.3 ‰ | |
| ⁸⁷ Sr/ ⁸⁶ Sr | TIMS | - | No unit | <±0.000020 | |
| ¹⁰ B/ ¹¹ B | ICP MS | - | No unit | - | |
| ²³⁴ U, ²³⁵ U, ²³⁸ U, ²³² Th, ²³⁰ Th, ²²² Rn, ²²⁶ Ra | Alfa spectr. LSC | 0.1 (²³⁴ U, ²³⁸ U, ²²⁶ Ra) 0.3 (²³⁵ U) 0.05 (²³² Th, ²³⁰ Th) | Bq/L | 0.05 Bq/L | Correct order of size |

¹ Salt ≤ 0.4 ‰ (520 mS/m)

² Salt ≤ 3.5 ‰ (3810 mS/m)

³ Measurement uncertainty reported by consulted laboratory

⁴ "Total" uncertainty estimated by experience (includes sampling and sample handling)

⁵ Valid for surface water samples collected by metal free "Ruttner sampler", filtered and acidified in the field. The risk of contamination varies depending on sampling method.

⁶ Determined only in surface waters and near surface groundwater

Table A2-4. Consulted laboratories, full name and address.

| |
|--|
| Äspö waterchemical laboratory (SKB) Mobile field laboratory, Forsmark (SKB) |
| Inainööritoimisto Paavo Ristola Oy Teollisuus-ja Voimalaitoskemia Rajantorantie 8, C-talo 01600 Vantaa FINLAND |
| Dept. of System ecology Stockholm University 10691 Stockholm |
| Analytica AB Aurorum 10 977 75 Luleå (Nytorpsvägen 16 Box 511 183 25 Täby) |
| Environmental Isotope Laboratory Dep. Of earth sciences University of Waterloo Waterloo, Ontario N2L 3G1 CANADA |
| Institutt for energiteknik (IFE) Insituttveien 18 P.O Box 40 2027 Kjeller NORGE |
| Alcontrol Nordic AB Box 905 531 19 Lidköping |
| The Ångström laboratory Box 534 Se-751 21 Uppsala |
| Environmental research laboratory (SLU), Luleå |
| Alcontrol Box 1083 581 10 Linköping |

Water Composition

| Idcode | Secup m | Seclow m | Sample no, | Date | Time | Charge Bal % | Na mg/L | K mg/L | Ca mg/L | Mg mg/L | HCO ₃ mg/L | Cl mg/L | SO ₄ mg/L | SO ₄ S mg/L | Br mg/l | F ⁻ mg/L | Si mg/L | Fe mg/L | Mn mg/L | Li mg/L | Sr mg/L |
|---------|------------|-------------|---------------|------------|-------------|-----------------|------------|-----------|------------|------------|--------------------------|------------|-------------------------|---------------------------|------------|------------------------|------------|------------|------------|------------|------------|
| HFM04 | 30 | 221,7 | 4399 | 2002-12-10 | 11:45:00 AM | -0,30 | 169 | 6,68 | 27,6 | 6,9 | 390 | 72,0 | 44,7 | 16,1 | 0,32 | 1,82 | 6,30 | - | - | -0,01 | 0,20 |
| HFM04 | 30 | 221,7 | 4400 | 2002-12-10 | 3:00:00 PM | -0,36 | 167 | 6,57 | 28,3 | 7,0 | 390 | 71,4 | 43,7 | 16,0 | 0,27 | 1,64 | 6,40 | - | - | -0,01 | 0,21 |
| HFM04 | 30 | 221,7 | 4401 | 2002-12-10 | 8:45:00 PM | -1,50 | 167 | 6,57 | 28,9 | 7,2 | 388 | 81,4 | 49,6 | 16,0 | 0,28 | 1,85 | 6,40 | - | - | -0,01 | 0,21 |
| HFM05 | 25 | 200,1 | 4433 | 2002-12-19 | 11:35:00 AM | -0,42 | 1830 | 42,4 | 805 | 212 | 110 | 4650 | 309 | 101 | 19,0 | 0,43 | 6,00 | - | - | 0,05 | 5,90 |
| HFM05 | 25 | 200,1 | 4434 | 2002-12-19 | 3:45:00 PM | 0,04 | 1800 | 42,2 | 781 | 207 | 115 | 4500 | 307 | 100 | 18,9 | 0,44 | 6,10 | - | - | 0,04 | 5,68 |
| HFM05 | 25 | 200,1 | 4435 | 2002-12-19 | 8:25:00 PM | -0,08 | 1740 | 41,2 | 749 | 199 | 122 | 4340 | 299 | 97,3 | 22,0 | 0,57 | 6,10 | - | - | 0,04 | 5,42 |
| KFM02A | 18 | 100,4 | 4398 | 2002-11-29 | 10:00:00 AM | 0,44 | 168 | 6,46 | 34,2 | 7,8 | 378 | 84,4 | 53,9 | 17,0 | 0,28 | 1,90 | 6,40 | - | - | 0,01 | 0,25 |
| KFM02A | 18 | 100,4 | 4397 | 2002-11-29 | 3:50:00 PM | -1,12 | 148 | 8,35 | 30,8 | 7,3 | 381 | 63,0 | 48,1 | 13,9 | 0,24 | 1,91 | 6,00 | - | - | 0,01 | 0,23 |
| SFM0005 | - | 2,4 | 4432 | 2002-12-16 | 11:00:00 AM | 2,28 | 5,8 | 1,87 | 85,6 | 5,4 | 260 | 7,40 | 13,6 | 4,84 | 0,05 | 0,35 | 3,80 | 0,043 | 0,030 | 0,00 | 0,11 |

- = Not analysed

x = No result due to sampling problems

xx = No result due to analytical problems

- "value" = result less than detection limit

ChargeBal % = Relative charge balance error %

SICADA: water_composition, 021210-030301

| Idcode | Secup m | Seclow m | Sample no, | pH | TOC mg/L | HS ⁻ mg/L | I ⁻ mg/L | DOC mg/L |
|---------|------------|-------------|---------------|-----|-------------|-------------------------|------------------------|-------------|
| HFM04 | 30 | 221,7 | 4399 | 8,0 | 9,1 | - | - | - |
| HFM04 | 30 | 221,7 | 4400 | 7,9 | 9,4 | - | - | - |
| HFM04 | 30 | 221,7 | 4401 | 8,0 | 9,6 | - | - | - |
| HFM05 | 25 | 200,1 | 4433 | 7,5 | 2,3 | - | - | - |
| HFM05 | 25 | 200,1 | 4434 | 7,4 | 2,5 | - | - | - |
| HFM05 | 25 | 200,1 | 4435 | 7,4 | 2,6 | - | - | - |
| KFM02A | 18 | 100,4 | 4398 | 8,0 | - | - | - | - |
| KFM02A | 18 | 100,4 | 4397 | 7,9 | - | - | - | - |
| SFM0005 | - | 2,4 | 4432 | 7,5 | 12,0 | -0,03 | 0,01 | - |

- = Not analysed

x = No result due to sampling problems

xx = No result due to analytical problems

- "value" = result less than detection limit

ChargeBal % = Relative charge balance error %

SICADA: water_composition, 021210-030301

| Idcode | Secup m | Seclow m | Sample no | Date | Time | D dev SMOW | Tr TU | O-18 dev SMOW | ¹⁰ B/ ¹¹ B no unit | S-34 dev CDT | Cl-37 dev SMOC | C-13 dev PDB | ⁸⁷ Sr/ ⁸⁶ Sr no unit | C-14 pmc | AGE_BP years |
|---------|------------|-------------|--------------|------------|-------------|---------------|----------|------------------|---|-----------------|-------------------|-----------------|---|-------------|-----------------|
| HFM04 | 30.00 | 221.70 | 4399 | 2002-12-10 | 11:45:00 AM | -84,5 | A | -11,7 | - | 14,9 | A | A | 0,719883 | A | - |
| HFM04 | 30.00 | 221.70 | 4400 | 2002-12-10 | 3:00:00 PM | -83,9 | A | -11,7 | - | 14,9 | A | A | 0,719784 | A | - |
| HFM04 | 30.00 | 221.70 | 4401 | 2002-12-10 | 8:45:00 PM | -84,6 | A | -11,7 | - | 14,8 | A | A | 0,719787 | A | - |
| HFM05 | 25.00 | 200.10 | 4433 | 2002-12-19 | 11:35:00 AM | -78,2 | -0,8 | -10,2 | 0,24 | 24,6 | A | A | 0,718978 | A | - |
| HFM05 | 25.00 | 200.10 | 4434 | 2002-12-19 | 3:45:00 PM | -78,1 | -0,8 | -10,2 | 0,24 | 24,5 | A | A | 0,719056 | A | - |
| HFM05 | 25.00 | 200.10 | 4435 | 2002-12-19 | 8:25:00 PM | -75,0 | -0,8 | -10,3 | 0,24 | 24,6 | A | A | 0,719068 | A | - |
| KFM02A | 18.00 | 100.40 | 4398 | 2002-11-29 | 10:00:00 AM | -82,1 | 11,2 | -11,4 | 0,24 | 13,9 | A | A | 0,719865 | A | - |
| KFM02A | 18.00 | 100.40 | 4397 | 2002-11-29 | 3:50:00 PM | -83,0 | 10,6 | -11,4 | 0,24 | 15,4 | A | A | 0,720510 | A | - |
| SFM0005 | - | - | 4432 | 2002-12-16 | 11:00:00 AM | -84,3 | 11,0 | -12,0 | 0,24 | - | A | A | - | A | - |

- = Not analysed

A = results will be reported later

x = No result due to sampling problems

xx = No result due to analytical problems

Trace elements

| Idcode | Sample no. | Date | Time | Ba ug/L | Al ug/L | As ug/L | Cd ug/L | Cr ug/L | Cu ug/L | Co ug/L | Hg ug/L | Ni ug/L | Zn ug/L | Pb ug/L | V ug/L | Mo ug/L |
|---------|------------|------------|-------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|--------|---------|
| SFM0005 | 4432 | 2002-12-16 | 11:00:00 AM | 65,1 | 39,1 | - | 0,019 | 0,427 | 3,47 | 0,191 | -0,002 | 1,79 | 1,42 | 0,133 | 0,313 | 0,743 |

- = Not analysed

x = No result due to sampling problems

xx = No result due to analytical problems

- "value" = result less than detection limit

SICADA: trace_elements, 021210-030301

Compilation April 2003

Biochemical components

Appendix 6

| Idcode | Sample no. | Date | Time | NH ₄ N mg/L | NO ₂ N mg/L | NO ₃ N+NO ₂ N mg/L | N_Tot mg/L | P_Tot mg/L | PO ₄ P mg/L | POP mg/L | PON mg/L | SiO ₂ Si mg/L | POC mg/L | TOC mg/L | DOC mg/L | DIC mg/L | O ₂ mg/L |
|---------|------------|------------|-------------|---------------------------|---------------------------|---|---------------|---------------|---------------------------|-------------|-------------|-----------------------------|-------------|-------------|-------------|-------------|------------------------|
| SFM0005 | 4432 | 2002-12-16 | 11:00:00 AM | 0,0125 | 0,00166 | 0,04101 | - | - | 0,00516 | 20,5 | 0,0340 | 2,81 | 0,65 | 12,0 | - | - | 5,23 |

- = Not analysed

x = No result due to sampling problems

xx = No result due to analytical problems

- "value" = result less than detection limit