

Forsmark site investigation

Hydrochemical monitoring of near surface groundwaters

Results from sampling of five shallow soil monitoring wells, one BAT pipe and three private wells, July 2005–April 2006

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November 2006

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Keywords: Shallow groundwater, Chemical analyses, Shallow soil monitoring well, Stand pipe, BAT-filter tip, BAT-sampler, Private wells, Water composition, Major constituents, Trace elements, Nutrient salts, Isotopes, Drinking water quality, AP PF 400-05-080.

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.

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Abstract

The present report documents the first year of the hydrochemical monitoring programme for near surface groundwaters in Forsmark comprising the sampling period July 2005 to April 2006. Sampling and analyses of water from a total of five shallow soil monitoring wells, three private wells, and one BAT-pipe is performed four times a year. The objectives are to characterise near surface groundwaters down to the bedrock, understand natural variations and identify eventual changes in the water composition due to other activities in the area. The sampling objects are mainly located within the prioritised target area at the Forsmark site.

The activity included field measurements of redox potential (ORP), pH, dissolved oxygen, electrical conductivity and water temperature, as well as chemical analyses of major constituents, nutrient salts, trace metals and isotopes.

Sammanfattning

Rapporten dokumenterar första året av det hydrokemiska övervakningsprogrammet för ytnära grundvatten i Forsmark och omfattar provtagningsperioden juli 2005 till april 2006. Provtagning och analys av vatten från totalt sex jordborrhål varav ett av dem utrustat med BAT filterspets och tre privata brunnar utförs vid fyra tillfällen per år. Syftet är karakterisera ytnära grundvatten ner till berggrunden, förstå naturliga variationer och identifiera eventuella förändringar i vattensammansättningen på grund av övriga aktiviteter i området. Provpunkterna är huvudsakligen lokaliserade inom prioriterat område för ett eventuellt djupförvar.

Aktiviteten omfattade fältmätningar av redox potential (ORP), pH, löst syre, elektrisk konduktivitet och vattentemperatur samt kemiska analyser av huvudkomponenter, närsalter, organiska kolföreningar, spårmetaller och isotoper.

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1 Introduction

This document reports performance and results from the first year of the hydrochemical monitoring programme for near surface groundwaters, which is one of the activities performed within the site investigation in Forsmark /1/. The work was conducted according to the activity plan and method documentations listed in Table 1-1. Both activity plan and method descriptions are SKB's internal controlling documents. The report presents hydrochemical data from shallow soil monitoring wells, a pipe equipped with a BAT-filter tip (special sampling system described in Section 4.3) and private wells. The obtained data from the activity are reported in the SICADA database and are traceable by the activity plan number.

All the different sampling objects (soil monitoring wells and private wells) are listed and described in Chapter 2 and a map showing their location is presented in Figure 2-1.

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

Activity plan	Number	Version
Hydrokemiskt övervakningsprogram för ytnära grundvatten, juni 2005 till juni 2006.	AP PF 400-05-080	1.0
Method descriptions	Number	Version
Metodbeskrivning för ytvattenprovtagningar vid platsundersökningar.	SKB MB 900.004	2.0
Mätsystembeskrivning för YSI. Multiparametersystem för vattenmätningar.	SKB MD 910.003	1.0
Provtagning och provhantering.	SKB MD 452.001	3.0

2 Sampling objects

The monitoring programme for near surface groundwater includes six selected monitoring wells/stand pipes of the following types:

1. Stand pipe (made of HDPE) located close to the drill sites, SFM0001, see Appendix 1 for design, Figure A1-1.
2. Double stand pipes (made of HDPE), where one of the pipes is equipped with a permanently installed sensor for logging the groundwater pressure, SFM0032, SFM0037 and SFM0049. The other pipe is intended to collect water samples for chemical analyses, see Appendix 1 for design, Figure A1-2.
3. Stand pipe located in Lake Bolundsfjärden, SFM0023, where the pipe is installed in the sediment below the water layer. The pipe is made of ordinary, non-stainless iron, see Appendix 1 for design, Figure A1-3.
4. Pipe with BAT-filter tip, SFM0051, as described in Section 4.3.

For pipe types 1) to 3), the positions of the filter/screen part, and for type 4) the position of the BAT-filter tip, correspond to the upper and lower section limits (SECUP and SECLOW) in the SICADA database. The section limits refer to the top of the stand pipe (Top Of Casing or TOC). Furthermore, three private wells are included in the monitoring programme.

The locations of the different sampling objects are shown in Figure 2-1 and listed in Table 2-1. Total depths and filter/screen depths, as well as coordinates for the different stand pipes, are given in Appendix 1 together with outlines of the different pipe types.

Table 2-1. List of sampling objects, type of sampling and type of object.

Idcode	Comments on sampled object	Type*
SFM0001	Stand pipe connected to drill site	A
SFM0023	Stand pipe in sediment below water surface	C
SFM0032	Double-pipe for chemistry	B
SFM0037	Double-pipe for chemistry	B
SFM0049	Double-pipe for chemistry	B
SFM0051	BAT-system, drill site 1	D

* Code used to distinguish between different types of soil monitoring wells/stand pipes included in the monitoring programme, see Table 5-1 and Appendix 1.

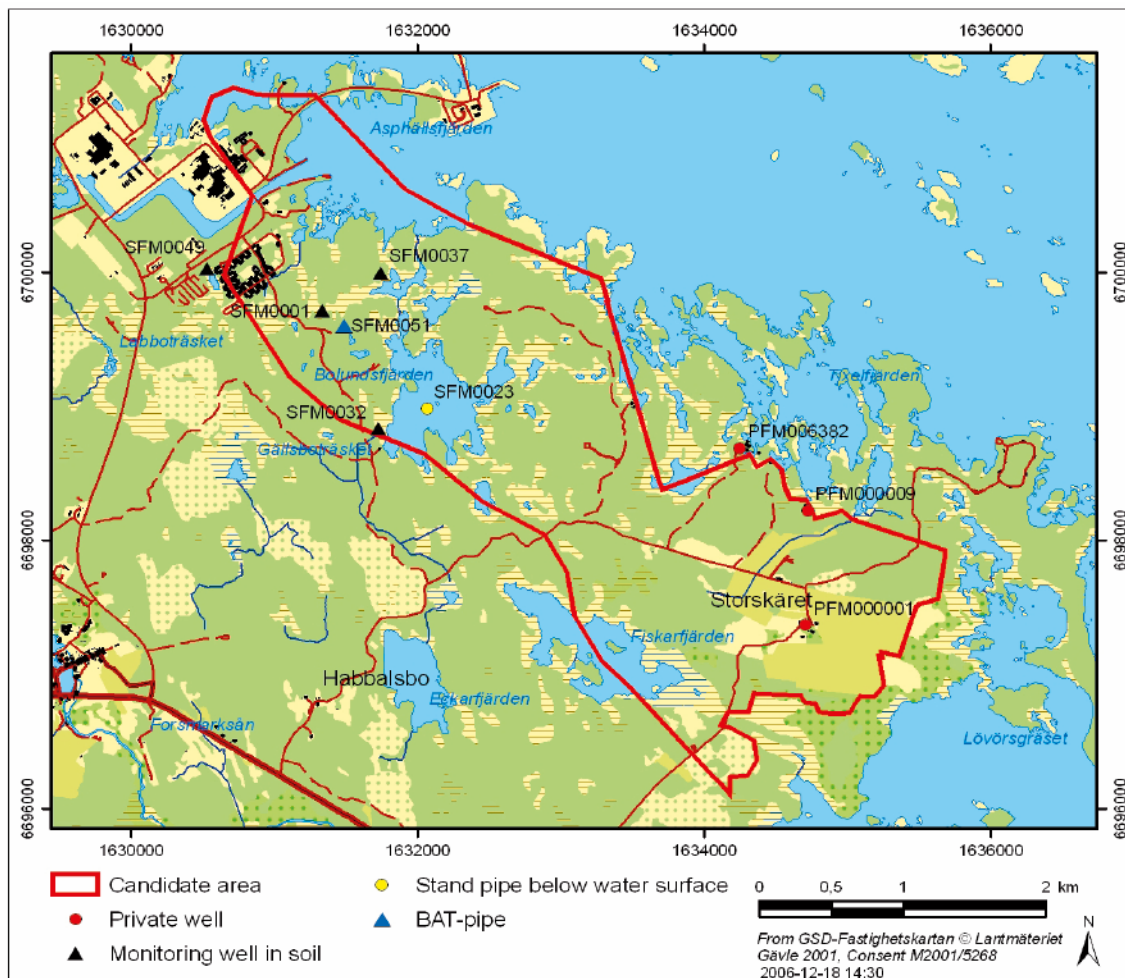


Figure 2-1. Location of sampling objects in the monitoring program for near surface groundwater, including different types of soil monitoring wells and private wells. The well SFM0051 is equipped with a BAT-filter tip installation.

3 Objectives and scope

Near surface groundwaters are investigated in order to increase the understanding of processes that occur at the interface between the geosphere and the near surface ecosystem. Furthermore, sampling and analyses of groundwaters from shallow monitoring wells may be used to identify discharge areas.

The completed two year long extensive sampling campaign in order to characterise near surface groundwaters in different types of environments within the candidate area /2/ was followed by a reduced monitoring programme which started in July 2005. This programme includes sampling four times per year in five soil monitoring wells (stand pipes) and one pipe equipped with a BAT-filter tip, all in the prioritised north-western part of the candidate area. Furthermore, three private wells are included to check the drinking water quality (sampled once during the year).

The sampling of private wells is mainly performed in order to obtain initial information on the drinking water quality and to monitor eventual changes in the water composition during the site investigation period. The private well data are of limited use for the chemical modelling as they are more or less affected by human activities. However, some additive information on the salinity distribution in the candidate area may be gained.

Besides the general objectives, the soil monitoring wells that are located in the vicinity of the drill sites are also monitored in order to identify eventual changes in the water composition due to drilling activities. The changes may be caused either by altered hydraulic conditions or, however more unlikely, by contamination from fuel or lubricants for example.

The activity implies water sampling for chemical analysis as well as direct measurements in the field of parameters such as ORP (redox potential), pH, dissolved oxygen, electrical conductivity and water temperature. The analytical protocol includes major constituents, nutrient salts, silica, carbon species as well as isotopes and trace metals, see Tables 5-1 and 5-2.

4 Equipment

4.1 Sampling equipment

Groundwater samples from the shallow soil monitoring wells/stand pipes and natural wells were collected using four online pumping setups, each one consisting of a submersible electrical pump (12 V, Awimex) connected to a 10–20 m long polyamide-tube (Tecalán) of 8 mm diameter. The inner metal part of the pumps was coated with Teflon. Manually operated electrical regulators (powered by 12 V, 7 Ah cells) were used to adjust the water flow to a maximum of 1 litre/minute. Disposable filters (Millipore, 0.45 μm , $\text{Ø} = 22 \text{ mm}$) were fitted directly to the tube from the pump when collecting the sample portions for trace metals and ferrous iron. A separate sampling set-up was used for the stand pipe in the lake Bolundsfjärden, as this pipe was made from ordinary iron, in order to minimise the risk to contaminate other samples.

4.2 Multi-parameter sondes

Field measurements were performed with two multi-parameter sondes (YSI 6600 EDS and YSI 600 QS). A terminal (YSI 650 MDS) is connected to each sonde through a cable for logging data, Figure 4-1. Calibration of the sondes was conducted according to the measurement system description SKB MD 910.003, see Table 1-1. The measured parameters in near surface groundwaters included pH, water temperature, oxygen, ORP (redox potential) as well as electrical conductivity and were conducted in a simple flow-through cell constructed from a plastic bottle. The upper part of the bottle fitted tightly to the sonde and had a narrow outlet for the circulating water.

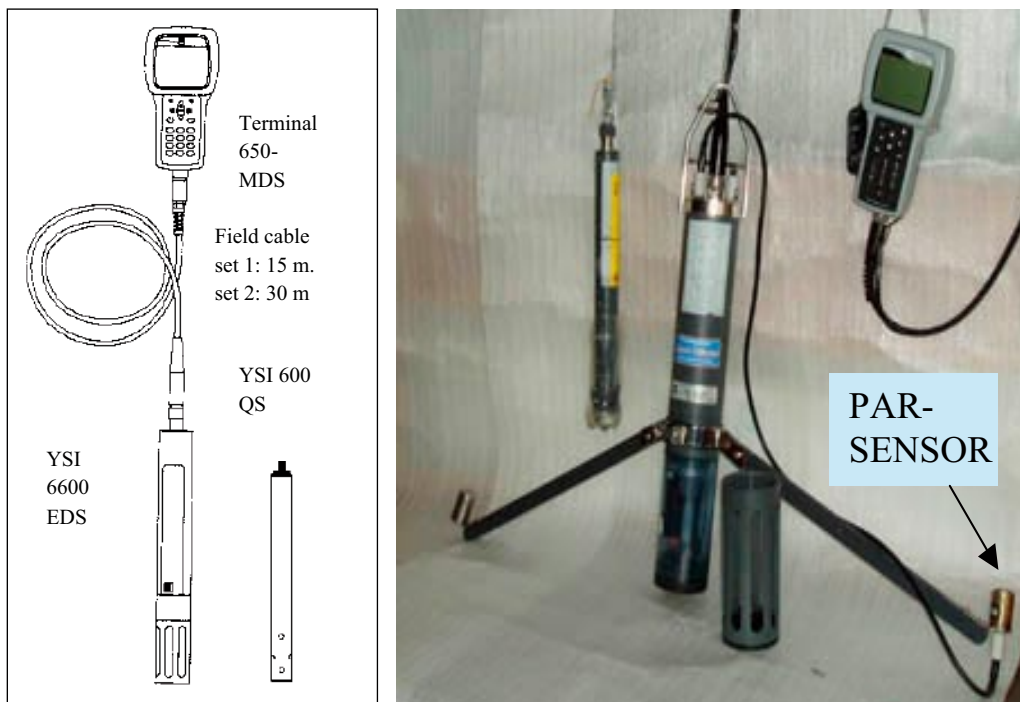


Figure 4-1. Details of the measurement sonde.

4.3 BAT-equipment

Water sampling in the stand pipe equipped with a BAT-filter tip was performed by a GeoN BAT-type groundwater sampler. The sampler carries an evacuated and hermetically closed glass sample container (500 mL) and a vial. The vial is fitted with a cap with a rubber disc, similar to the disc in the filter tip. The needle of the sampler, which is “double-ended”, penetrates through the two rubber discs, thus connecting the filter tip to the vial cap, see Figure 4-2. Due to the vacuum in the vial, water will be sucked from the aquifer, through the filter and the needle, into the vial.

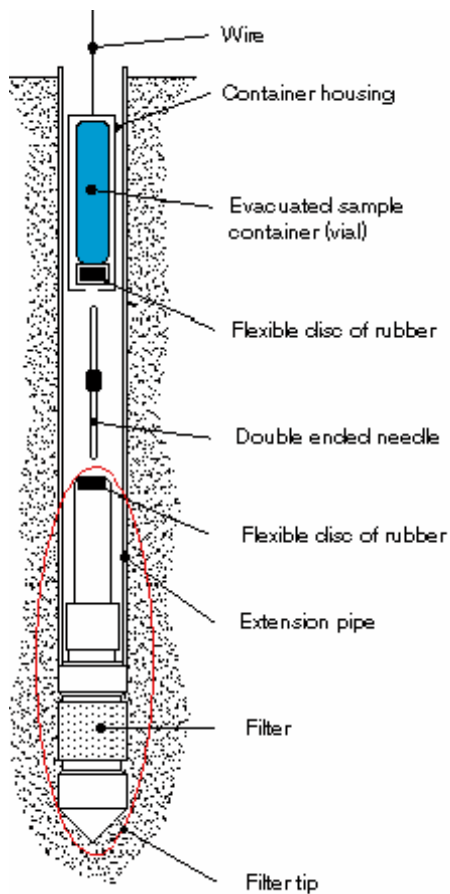


Figure 4-2. Outline of BAT-sampler system and the BAT-filter tip.

5 Performance

5.1 Sampling programme

Sampling scheme

The sampling scheme for the sampling programme is given in Table 5-1. Bottles filled and analysis performed according to the different SKB chemical classes (class 3 and class 5, respectively) are summarised in Table 5-2. Omitted sampling objects and the reasons for deviation from the sampling scheme are given in Table 5-2.

Presampling preparations

Prior to the sampling campaign, sample bottles were cleaned, labelled and packed in insulated boxes/bags according to established routines (SKB MD 452.001, see Table 1-1). Acid additions were made in advance in the bottles intended for trace metal analyses. The different pumping setups were washed and rinsed with deionised water before use and all parts of equipment were kept well protected in plastic bags or in tight containers. The disposable filters (Millipore, 0.45 µm, Ø = 22 mm) were rinsed with deionised water and placed in plastic bags to prevent contamination. Calibration of the sonde was performed according to the measurement system description SKB MD 910.003.

Sampling and measurements

The groundwater sampling procedure as described below was generally applied in groundwater pipes and wells, except for the BAT-pipes and the drilled private wells where the water was collected directly from the tap.

Table 5-1. Sampling scheme July 2005–April 2006.

Year	Month	Week	Sampling object*	Sampling and analysis class and options
2005	July	28	Shallow monitoring wells, A, B	SKB class 5
			Shallow monitoring wells, C	SKB class 3 and isotopes
			BAT-pipe, D	SKB class 5
2005	October	40	Shallow monitoring wells, A, B	SKB class 5
			Shallow monitoring wells, C	SKB class 3 and isotopes
			Private wells	Drinking water
			BAT-pipe, D	SKB class 5
2006	January	4	Shallow monitoring wells, A, B	SKB class 5
			Shallow monitoring wells, C	SKB class 3 and isotopes
			BAT-pipe, D	SKB class 5
2006	April	16	Shallow monitoring wells, A, B	SKB class 5
2006	May	18	BAT-pipe, D	SKB class 5

*The sampling object types A, B, C and D are defined in Table 2-1.

Table 5-2. Sample portions/bottles and preparation procedures for class 3 and class 5 /1/.

Bottle volym (mL)	Number of bottles	SKB label	Components	Preparation	Filling instructions
125	1	Red	ICP; cations and S, Si	Acid addition (1 mL conc. HNO ₃) Filtering with syringe/0.45 µm	Fill up
100	1	Green	Br, I		Fill up
250	2	Green	Alkalinity, pH, Electric conductivity Anions (Br, SO ₄ , Cl, F)	–	Fill up
25	4	Green	Ammonia, NO _x , Silicate	Filtering with syringe/0.45 µm filter	
100	1	Green	Tot-N, Tot-P	–	Fill 80% of the volume
50	1	Green	TOC	–	Fill 80% of the volume
50	2	Green	DIC/DOC	Filtering with syringe/0.45 µm filter	Fill 80% of the volume
500	1	Green	Tritium	–	Flow over x 3
100	1	Green	Deuterium, O-18	–	Fill up from bottom
Winkler bottles	2	Green	HS	1 ml 1M ZnAc + 1 ml 1M NaOH and mix	Flow over x 3
100 ¹	1	Red	ICP; cations and S, Si, Br, I, trace metals, ¹⁰ B/ ¹¹ B	Acid addition (1 mL conc. HNO ₃) Filtering with 0.45 µm filter	Fill up
250	1	Red	Fe(II)/Fetot	Acid addition (2.5 mL conc. HCl) Filtering with 0.45 µm filter	Fill up

¹ Same bottle as the first SKB class 3 one. Analyses of trace metals Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn, Sc, Rb, Y, Zr, Sb, Cs, La, Hf, Ti, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, U, Th.

Class 3 and 5 
 Class 5 

First, the groundwater level in the pipe was established by sounding and the water volume of the pipe was calculated. The pump with its tubing was lowered carefully in order to prevent dirt from entering the pipe. The water inlet of the submersible pump (Awimex) was lowered to the filter/screen section of the pipe or just above. Pumping was then performed at a maximum flow rate of one litre per minute. The pumped water was disposed of at least 10 m away from the sampling object where it infiltrated back into the ground. The pumping phases were as follows:

- *Exchange of water volume in pipe and tubes:* The water volume was exchanged three to five times (depending on the exchange/recovery time) prior to the actual sampling.
- *Sampling:* All sample bottles, except the ones with added acid, were rinsed three times with pumped water. Disposable filters were used for filtration of water portions for trace metals, Fe(+II) and DOC/DIC. The filters were fitted directly on the outlet tube from the pump. Each filter was rinsed with sample water (approx. 30 mL) before the sample portion/filtrate was collected. The bottles containing acid were the last ones to be filled in order to prevent acid contamination in the other sample portions. Disposable plastic gloves were used during the sampling. The samples were transported back from the field in insulated bags.
- *Field measurement:* A flow-through cell was connected to the pumping setup and measurements were performed with the sonde (YSI 600 QS). The results were recorded when the electrodes and sensors in the flow-through cell showed stable values (minimum 10 minutes). A judgement of the plausibility of the values was made in the field and accepted values were noted in the field protocol.

Table 5-3. List of collected samples during the period July 2005 to July 2006 and reasons for sampling failures.

Id code	Name	Week/year					Sum (X)
		28/05	40/05	4/06	16/06	29/06	
Sondes							
YSI 600 QS		X	X	X	X	X	
Soil wells							
SFM 0001	Drill site 1	X	X	X	X	X	5
SFM 0023	Bolundsfjärden	X	X	X	A	X	4
SFM 0032	SV - Bolundsfjärden	X	X	X	X	X	5
SFM 0037	N - Bolundsfjärden	X	X	X	X	X	5
SFM 0049	Bostadsområdet	X	X	X	X	X	5
Private wells							
PFM 000001	–		X				1
PFM 000009	–		X				1
PFM 006382	Tixelfjärden		X				1
Sum (X)		5	8	5	4	5	27

X = Collected sample.

A = No sample, due to no access, weak ice.

Sampling performance using BAT-system

Sampling of the BAT-filter tip pipe followed the sampling scheme for the ordinary shallow soil wells with a few days delay. The approximate time to fill one 500 mL container in SFM0051 was 15 minutes.

A total of four sample containers were filled from the BAT-pipe in order to obtain enough water for the analyses. The use of the sample volumes and the analyses performed are listed in Table 5-4.

5.2 Sample handling and analyses

Measurements/analyses of $pH_{(lab)}$, electrical conductivity_(lab) and alkalinity as well as spectrophotometric analyses of total iron and ferrous iron (Fe+II) were conducted immediately at the site in the mobile field laboratory. An overview of sample treatment and analytical routines for major constituents, minor anions, trace metals and isotopes is given in Appendix 3. The routines are applicable independent of sampling method or type of sampling object.

Table 5-4. Sample containers and analyses.

Sample container no.	Analyses and determinations		Total volume
1	Chloride, bromide, fluoride and sulphate by IC. (200 mL)	Alkalinity titr, pH and EC. (150 mL)	δ^2H , $\delta^{18}O$ (100 mL) 450 mL
2	Tritium (500 mL)		Approx. 500 mL
3	Fe (+II), (Fe(tot)) (50 mL)	Major constituents, trace elements, $^{10}B/^{11}B$, U-isotopes by ICP AES/MS (125 mL)	5 mL of HCl was added to the container prior to sampling. 175 mL

5.3 Data handling

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 $\pm 5\%$ are considered acceptable (in surface waters $\pm 10\%$).

$$rel.error(\%) = 100 \times \frac{\sum cation(equivalents) - \sum anions(equivalents)}{\sum cation(equivalents) + \sum anion(equivalents)}$$

- 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 into 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 5-1.

5.4 Nonconformities

Two nonconformities occurred during the time period concerned.

- Weak ice on Lake Bolundsfjärden in April made it impossible to reach stand pipe SFM0023 and therefore there is no collected sample in spring.
- By mistake, trace element analyses were not requested from the consulted laboratory at the first sampling occasion in July. Therefore these data are missing.

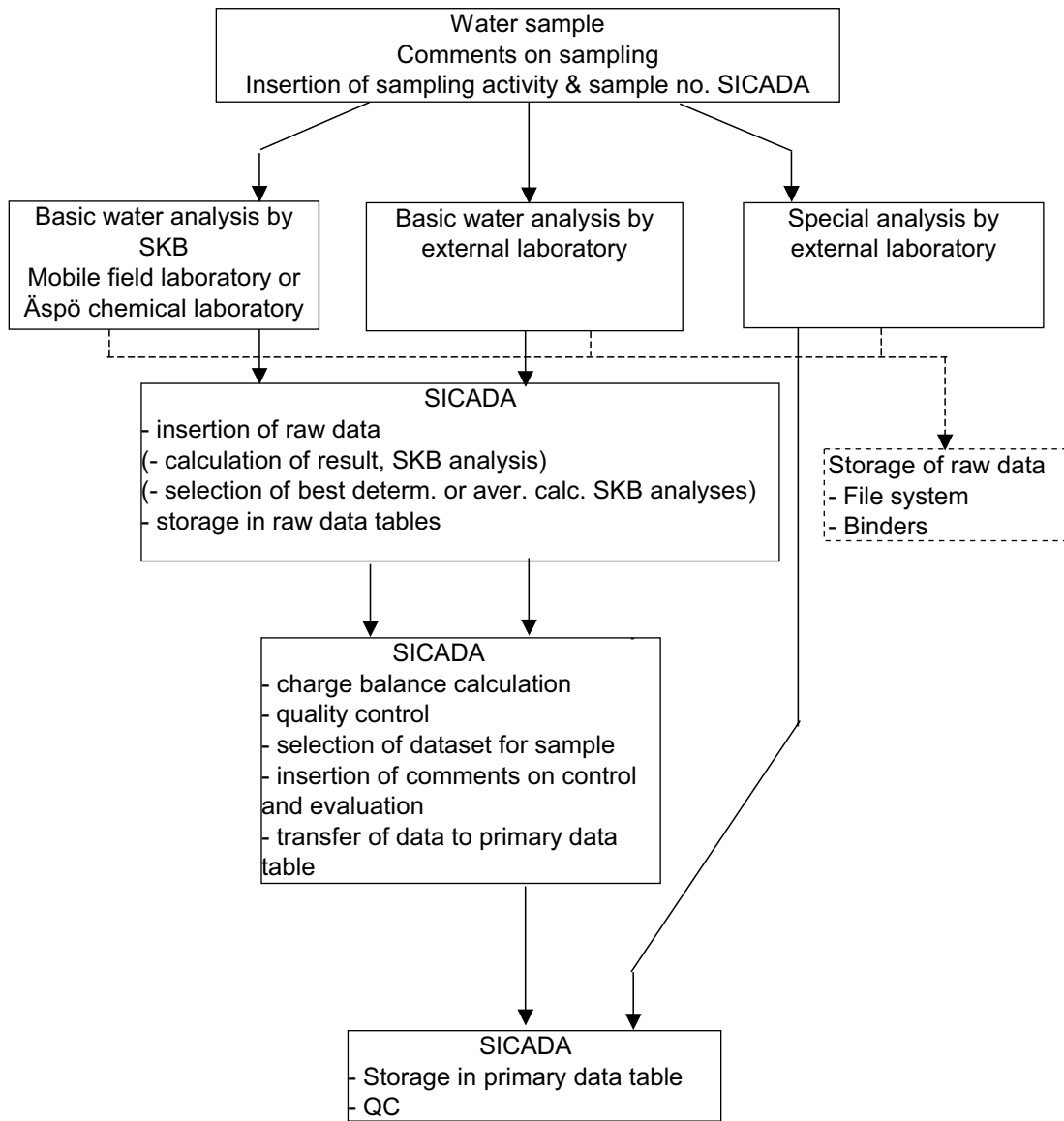


Figure 5-1. Overview of data management for hydrochemical data.

6 Results

6.1 Field measurements

The results from the field measurements on pH, electrical conductivity, dissolved oxygen, water temperature and redox potential (ORP) are presented in Appendix 3.

pH-measurement

Field measurements of pH are plotted against the corresponding laboratory values in Figure 6-1. Some deviation is reasonable considering the change of water temperature, change of pressure and the time delay prior to the laboratory measurement. However, in a few cases, the disagreement seems to be greater than expected.

Electrical conductivity

Electrical conductivity field values are plotted versus corresponding laboratory values in Figure 6-2 and show good agreement.

Dissolved oxygen

The measurements of dissolved oxygen were checked in April 2005 by comparison to results from laboratory analyses /2/. This control showed that, generally, the field measurement values were somewhat higher, especially at oxygen concentrations below 4 mg/L. Field measurements of dissolved oxygen are presented in Appendix 3.

ORP-measurements and redox conditions

ORP-measurements (Oxidising-Reducing Potential) have been conducted using the multi-purpose measurement sonde. The recorded ORP-values should be used with great caution and merely considered as an indication of the redox conditions in the waters. Measured ORP-values are presented in Appendix 3.

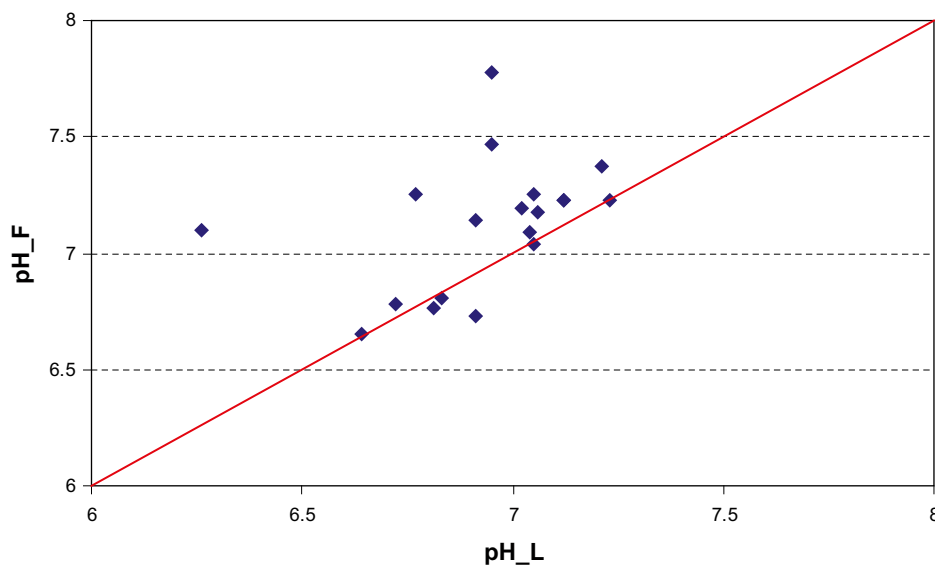


Figure 6-1. Field-pH (pH_F) values versus laboratory-pH (pH_L) values. Field-pH and laboratory-pH values are measured at prevailing water temperature and at 25°C respectively.

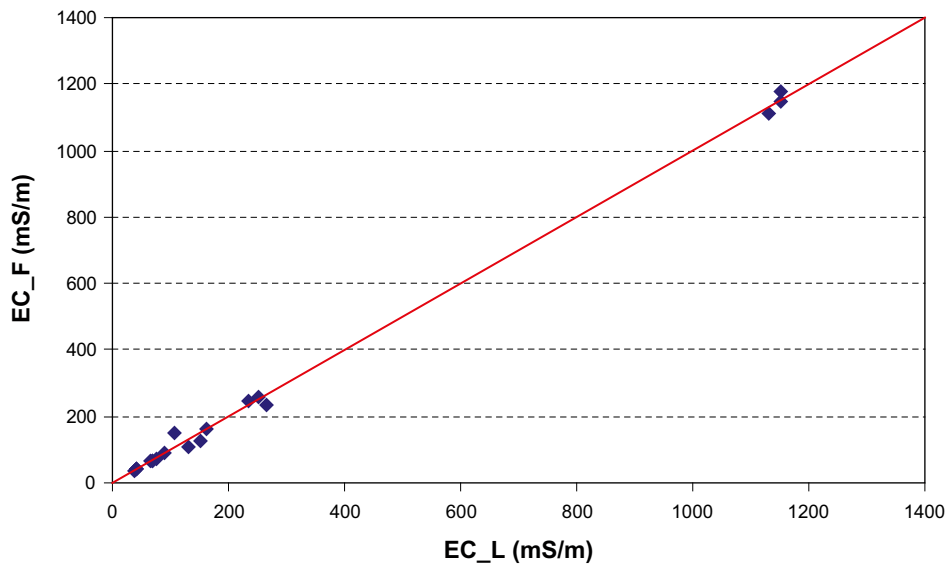


Figure 6-2. Electrical conductivity (25°C). Field measurements (EC_F) versus laboratory values (EC_L).

6.2 Water analyses

Basic components

The basic water analyses include the major constituents Na, K, Ca, Mg, Sr, S, SO_4^{2-} , Cl^- , Si and HCO_3^- as well as the minor constituents Fe, Li, Mn, Br, F, I and HS^- . Furthermore, batch measurements of pH and electrical conductivity are included. The basic water analysis data are compiled in Appendix 4, Table A4-1.

The charge balance errors give an indication of the quality and uncertainty of the analyses of major constituents. The errors exceed the acceptance limit $\pm 5\%$ slightly in two cases out of 23 samples. Furthermore, duplicate analyses by a second laboratory or another method are conducted regularly for some of the analysed constituents. Comparison between results from different laboratories and/or methods shows that the agreement is acceptable in most cases (within $\pm 10\%$).

The chloride concentrations are plotted against the corresponding electrical conductivity values in Figure 6-3 as a rough check and the data agree well with a thought regression line.

The bromide analyses are often uncertain, for example the detection limit of bromide by ion chromatography ($< 0.2 \text{ mg/L}$) is often too high for fresh waters. Therefore, duplicate analyses by ICP (bromine) have been performed on most samples. Selected bromide/bromine values for each sample are plotted against the corresponding chloride concentrations in Figure 6-4 as a consistency check.

Sulphate by ion chromatography and sulphate calculated from total sulphur by ICP are compared in Figure 6-5 showing a satisfactory agreement.

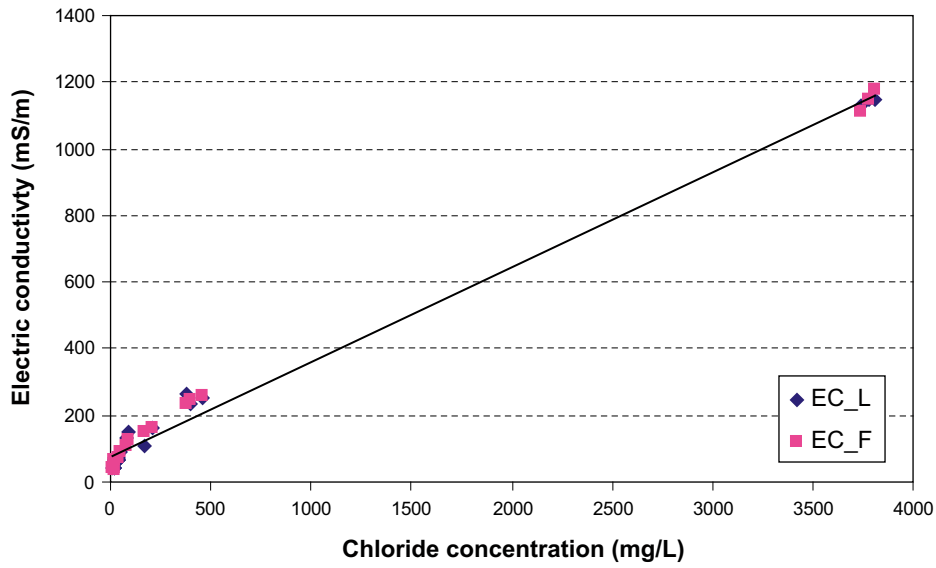


Figure 6-3. Electrical conductivity values versus chloride concentrations. EC_L = Laboratory value, EC_F = Field value.

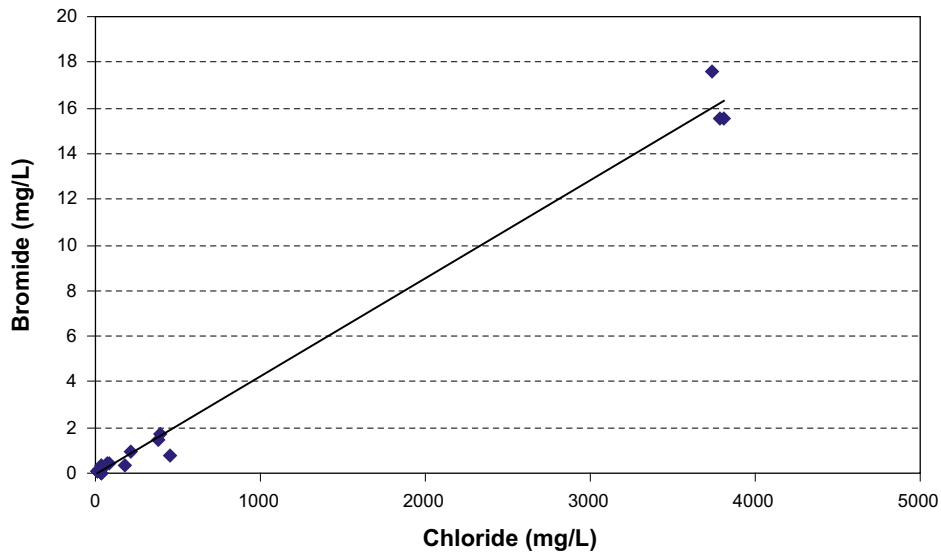


Figure 6-4. Bromide concentrations versus chloride concentrations. Bromide concentrations below the detection limit (< 0.2 mg/L) are plotted as zero (IC-method).

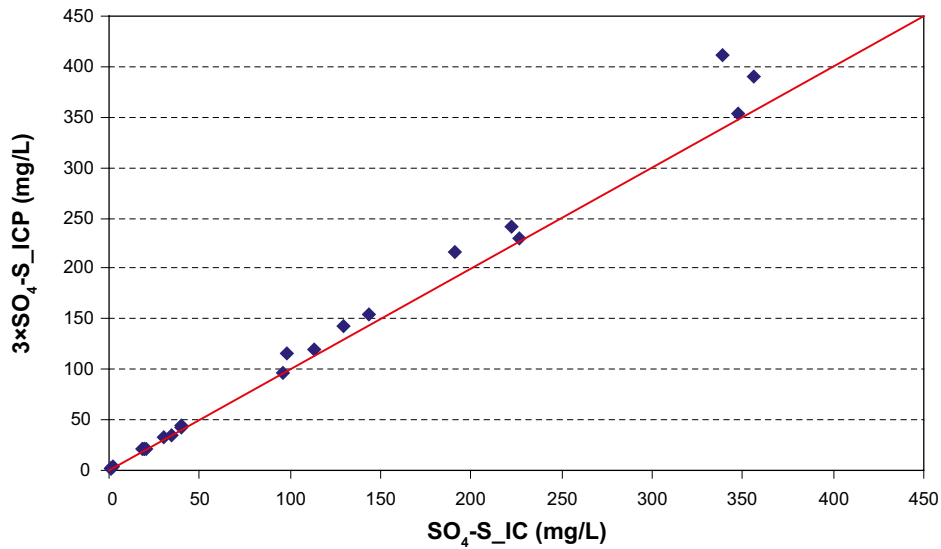


Figure 6-5. Sulphate (SO₄ by IC) versus sulphate calculated from total sulphur (3xSO₄-S) by ICP.

Total silicon concentrations by ICP, and SiO₄ as silicon concentrations (SiO₄-Si) by spectrophotometry, are compared in Figure 6-6. Also here the values diverge, but somewhat higher total silicon concentrations may be expected/explained.

The iron concentrations determined by ICP-AES (total Fe) and by spectrophotometry (Fe(+II) and Fe-tot) are compared in Figure 6-7. The total iron concentrations determined by ICP agree well with the results obtained by spectrophotometry.

Drinking water quality (private wells)

Data on drinking water quality parameters/components for the investigated private wells are presented in Appendix 4, Table A4-2.

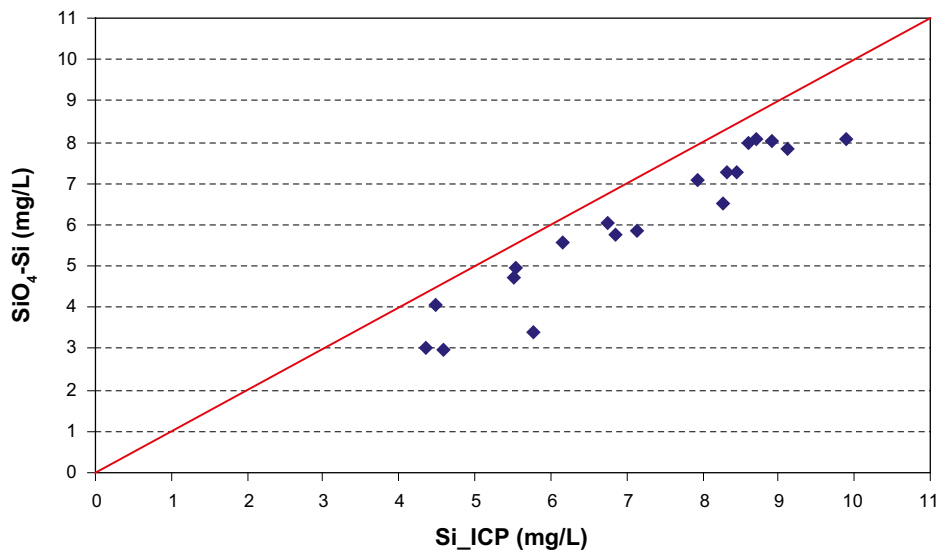


Figure 6-6. SiO₄-Si determined by spectrophotometry versus total Si analysed by ICP.

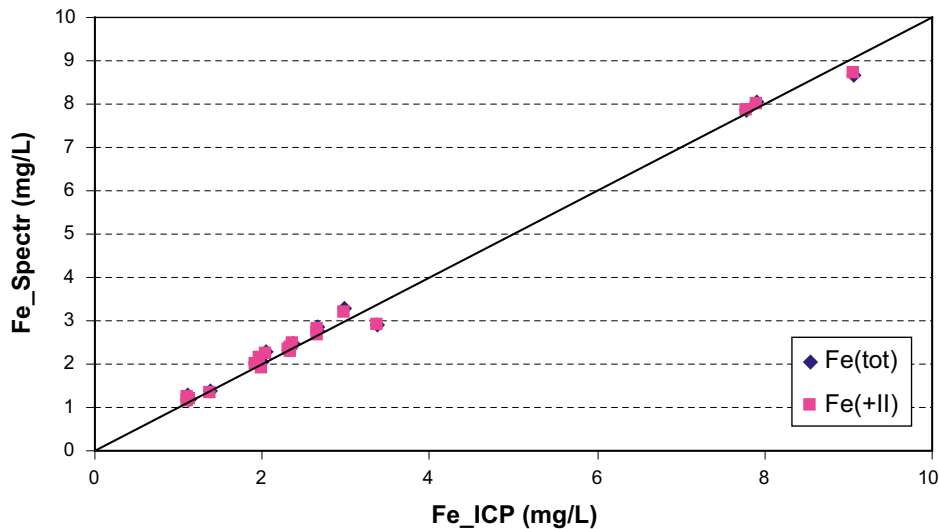


Figure 6-7. Comparison of iron concentrations obtained by ICP and by spectrophotometry (Fetot and FeII).

Surface water supplements

Shallow groundwater analysis includes the surface water supplements/options $\text{NH}_4\text{-N}$, $\text{NO}_2\text{-N}$, $\text{NO}_3\text{-N}+\text{NO}_2\text{-N}$, $\text{NO}_3\text{-N}$, tot-N, tot-P, $\text{PO}_4\text{-P}$, TOC, DOC and DIC. The analytical data are compiled in Appendix 4, Table A4-3. The DIC values should be used with care and bicarbonate values (by alkalinity titration) are considered more reliable.

The concentrations of the different nitrogen, phosphorous and carbon compounds are expected to show seasonal variation depending on decomposition processes and the presence of oxygen. However, this variation is more pronounced in surface waters than in the present shallow groundwaters. Figure 6-8 show the variations of total nitrogen, ammonium and phosphate in the sampled groundwaters.

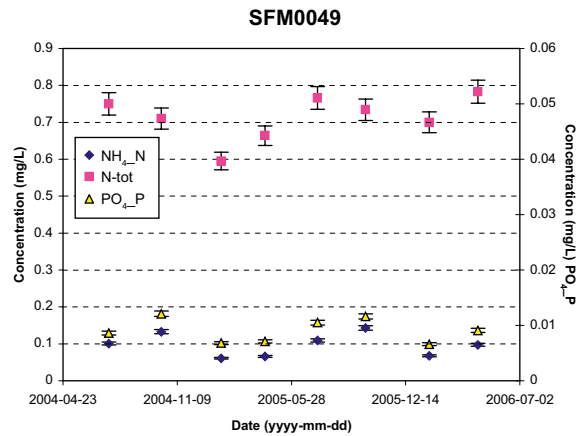
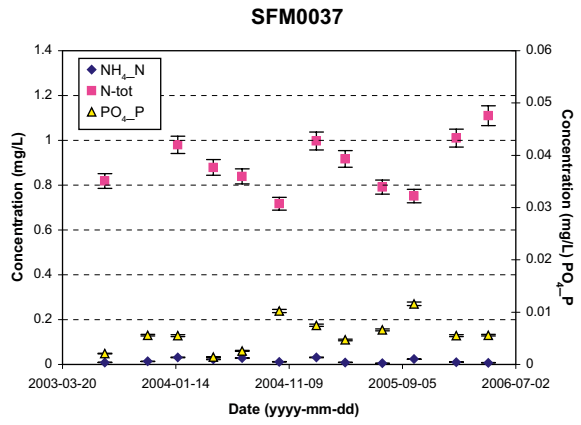
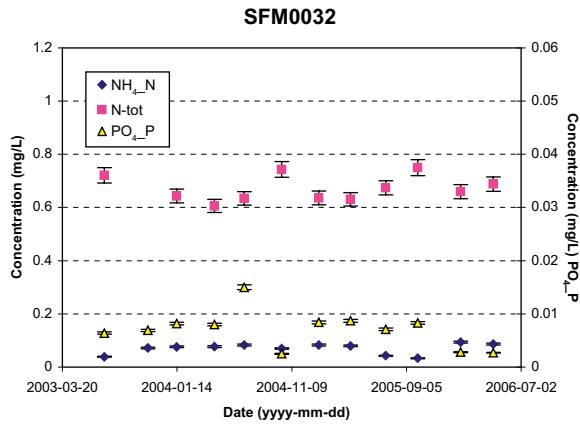
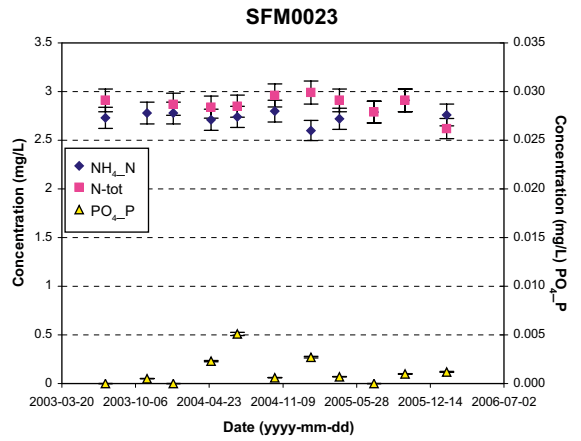
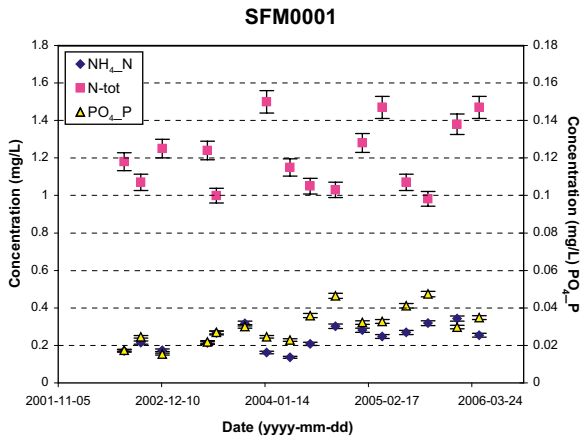
Trace metals

The analyses of trace and rare earth elements include Al, As, Sc, Cd, Cr, Cu, Co, Hg, Ni, Zn, Pb, V, U, Th, Rb, Y, Zr, Mo, In, Sb, Cs, Ba, La, Hf, Tl, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu. From the sampling conducted in January 2006 the element Nb are included (by special request). The trace element data are compiled in Appendix 4, Table A4-5 and A4-6.

These elements are generally present at low concentrations in the groundwater and the risk for contamination is high. Especially data on common metals such as Al, Cr, Cu, Co, Ni and Zn must be used with caution. Generally, the borehole data conform well but outliers exist.

Isotopes

Isotope determinations include the stable isotopes δD , $\delta^{18}\text{O}$ and $^{10}\text{B}/^{11}\text{B}$ as well as the radioactive isotope Tr (TU). The isotope data are compiled in Appendix 4, Table A4-4.



Figures 6-8. Ammonium, total nitrogen and phosphate concentrations versus sampling date. Note that phosphate concentrations refer to the secondary Y-axis.

7 Summary and discussion

The chemical investigation routines for near surface waters are well established after more than three years of field work, reporting and data administration. This first year of the long-term hydrochemical monitoring programme, that succeeded the previous more extensive two year long characterisation campaign for near surface waters, has passed without any major nonconformities or surprises.

The main experiences and conclusions from near surface water sampling and analyses since July 2005 are summarised below:

- The statements/findings regarding the character of the near surface waters after this third year of sampling and analyses remain unchanged.
- The ORP measurements seem to reflect the redox situation in the near surface waters. However, due to high measurement uncertainty, the actual ORP-values should be used with caution.
- Some trace element data from soil pipes SFM0001 and SFM0051 show deviating high values most likely due to contamination. The elements concerned are aluminium, copper, nickel and zinc. Soil pipe SFM0051 is equipped with a BAT filter tip but this condition was rather expected to prevent than to cause contamination, and the results from this pipe are hard to explain.

8 References

- /1/ **SKB, 2001.** Generellt genomförande program för platsundersökningar. SKB R-01-10 (in Swedish), Svensk Kärnbränslehantering AB.
- /2/ **Nilsson A-C, Borgiel M, 2005.** Forsmark site investigation. Sampling and analyses of near surface groundwaters. Results from sampling of shallow soil monitoring wells, BAT pipes, a natural spring and private wells, May 2003–April 2005. SKB P-05-071, Svensk Kärnbränslehantering AB.

Sampling objects; coordinates and installation designs

Table A-1. Sampling object coordinates, depth to the upper (Secup) and lower (Seclow) limits of the filter sections and total depths.

Sampling object* Id code	Coordinates (RT90-RHB70)**			Depths		
	Northing (m)	Easting (m)	Elevation (m.a.s.l.)	Secup*** (m)	Seclow*** (m)	Depth**** (m)
SFM0001	6699713	1631335	1.1	3.95	4.95	4.95
SFM0023	6698983	1632064	1.1	4.42	5.42	5.42
SFM0032	6698838	1631726	1.6	3	4	5
SFM0037	6699992	1631744	1.5	2	3	4
SFM0049	6700028	1630533	4	4	5	6
SFM0051	6699600	1631488	2.2	5.02	5.18	5.27
PFM000001	6697373	1634709	–	45	–	–
PFM000009	6698227	1634724	–	70	–	–
PFM006382	6698691	1634249	–	–	–	–

* The designs of the different types (A, B and C) of monitoring wells/stand pipes are presented in Figures A1-1 to A1-3. Typ D = BAT filter tip installation is described in Section 4.3.

** Northing, easting and elevation for the reference point TOC (Top of Casing).

*** SECUP = length from TOC to filter/screen part of the pipe (upper section limit).

*** SECLow = length from TOC to end of filter/screen part of the pipe (lower section limit).

**** Length/depth of casing/pipe from TOC.

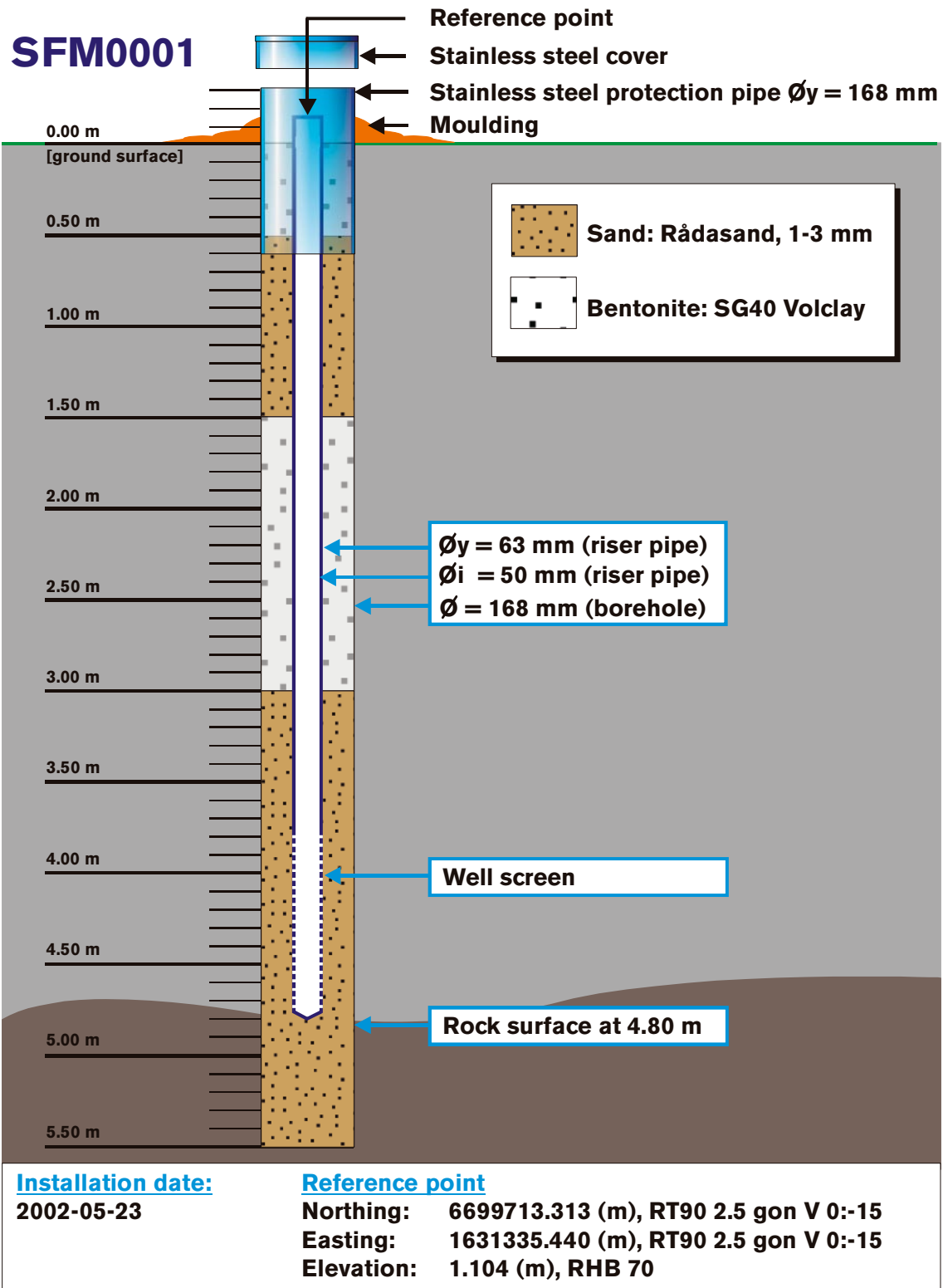


Figure A1-1. Design of an A-type, drill site connected shallow soil monitoring well (SFM0001). The filter/screen section is placed at the bottom of the pipe. Note that all length information given in the database SICADA refers to the reference point as zero point.

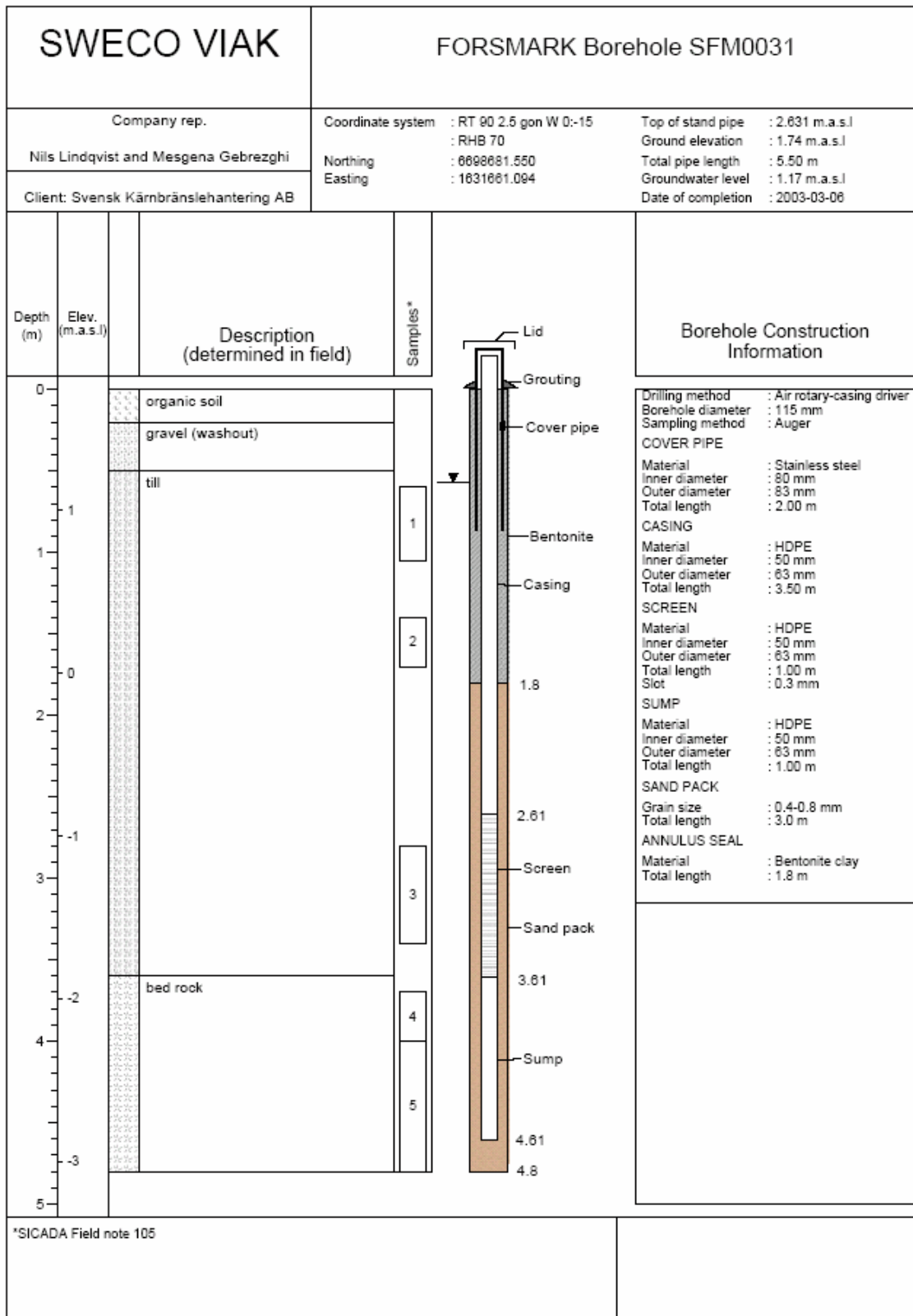


Figure A1-2. Design of a B-type, double stand pipe for sampling of water. The filter section is placed one metre up from the bottom of the pipe. Note that all length information given in the database SICADA refers to Top Of Casing as zero point.

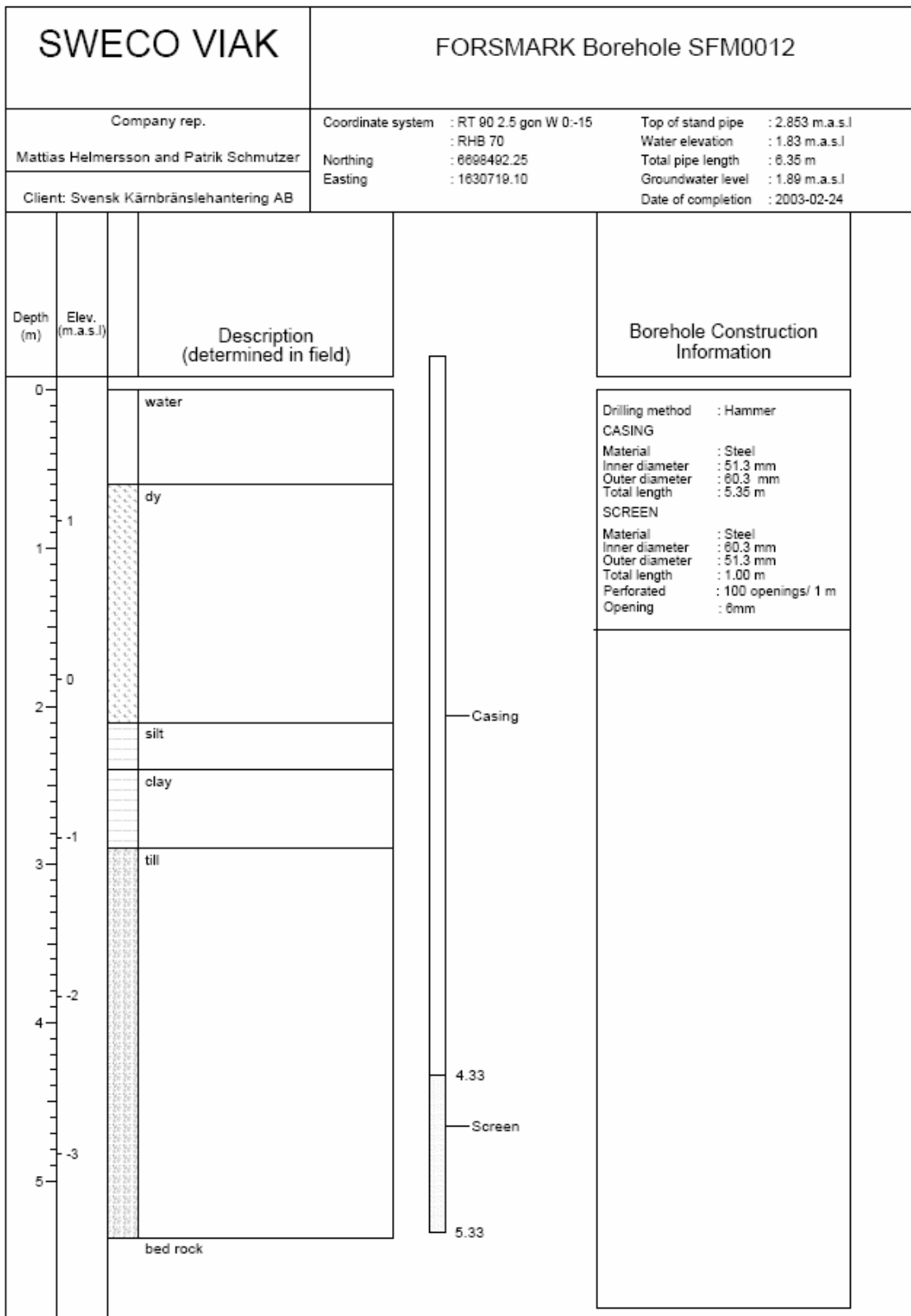


Figure A1-3. Design of a C-type, stand pipe in sediment layer below open water. Note that all length information given in the database SICADA refers to Top Of Casing as zero point.

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	Yes (not in the field)	No	Titration Pot. meas, Cond. meas	The same day – maximum 24 hours
Anions 2	Cl, SO ₄ , Br ⁻ , F ⁻ , I ⁻	Plastic	100	Yes (not in the field)	No	Titration (Cl ⁻) IC (Cl ⁻ , 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 (1 mL HNO ₃)	ICP-AES ICP-MS	Not critical (month)
Fe(II), Fe(tot)	Fe(II), Fe(tot)	Plastic (Acid washed)	250	Yes	Yes (2.5 mL HCl)	Spectrophotometry Ferrozine method	As soon as possible the same day
Hydrogen sulphide	HS ⁻	Glass (Winkler)	About 120×2	No	1 mL 1M NaOH+ 1 mL 1M ZnAc	Spectrophotometry	Immediately or if conserved, a few days
Environmental metals	Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn	Plastic (Acid washed)	100	Yes	Yes (1 mL HNO ₃)	ICP-AES ICP-MS	Not critical (month)
Lantanoids, U, Th and so on	Sc, Rb, Y, Zr, I, Sb, Cs, La, Hf, Ti, 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	100 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 analyser Shimadzu TOC5000	Short transportation time
Environmental isotopes	² H, ¹⁸ O	Plastic	100	No	–	MS	Not critical (month)
Tritium,	³ H (enhanced.)	Plastic (dry bottle) Plastic	500 100	No	–	LSC	Not critical (month)
Chlorine-37	Chlorine-37	–	–	No	–	MS	–
Carbon isotopes	¹³ C, ¹⁴ C	Glass (brown)	100x2	No	–	(A)MS	A few days
Sulphur isotopes	³⁴ S	Plastic	500–1,000	Yes	–	Combustion, MS	No limit
Strontium-isotopes	⁸⁷ Sr/ ⁸⁶ Sr	Plastic	100	Yes	–	TIMS	Days or week
Uranium and Thorium isotopes	²³⁴ U, ²³⁸ U, ²³⁰ Th	Plastic	1,000	Nej	–	Chemical separat. Alfa/gamma spectrometry	No limit
Boron isotopes	¹⁰ B	Plastic	100	Yes	Yes (1 mL HNO ₃)	ICP – MS	No limit
Radon and Radium isotopes	²²² Rn, ²²⁶ Ra	Plastic	1,000	No	No	EDA, RD-200	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	Immediate transport
Colloids	Filter series and fractionation (see below)	Polycarbonate filter	0.45, 0.2 and 0.05 µm	–	N ₂ atmosphere	ICP-AES ICP-MS	Immediate transport
Humic and fulvic acids	Fractionation	Fractions are collected in plastic bottles	250	–	N ₂ atmosphere	UV oxidation, IR (DOC)	Immediate transport
Archive samples with acid	–	Plast (washed in acid)	100x2**	Yes	Yes (1 mL HNO ₃)	–	Storage in freeze container
Archive samples without acid	–	Plastic	250x2**	Yes	No	–	Storage in freeze container
Carbon isotopes in humic and fulvic acids	¹³ C, ¹⁴ C (pmc)	DEAE cellulose (anion exchanger)	–	–	–	(A)MS	A few days
Nutrient salt + silicate	NO ₂ , NO ₃ , NO ₂ +NO ₃ , NH ₄ , PO ₄ , SiO ₄	Sample tubes, plastic	25x2	Yes (in the field)	No, frozen immediately***	Spectrophotometry	Short transportation time

Component group	Component/element	Sample container (material)	Volume (mL)	Filtering	Preparation/conservation*	Analysis method	Analysis within – or delivery time to lab.
Total concentrations of Nitrogen and Phosphorous	N-tot, P-tot	Plastic	100	No	No, frozen immediately***	Spectrophotometry	Short transportation time
Particulate Carbon, Nitrogen and Phosphorous	POC, PON, POP	Plastic	1,000	Yes (within 4 h) prepared filters. Blank filters	Filtering, the filters are frozen immediately 2 filters/sample	Elementar-analysator (N, C) own method 990121 (P)	Short transportation time
Chlorophyll	Chlorophyll a, c and pheopigment	Plastic	1,000–2,000	Yes (within 4 h)	Filtering, the filters are frozen immediately	Spectrophotometry Fluorometry	Short transportation time
Oxygen	Dissolved O ₂	Winkler, glass	2×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
(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 = 0.002)	mg/L	10%	30% (low conc.)
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	Jodometric 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%

Component	Method	Reporting limits or range		Unit	Measurement uncertainty ²	"Total" uncertainty ³
As	ICP	0.01		µg/L	20%	Correct order of size (low conc.)
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	–
³⁷ Cl	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 ¹³	5%	–
²²² Rn, ²²⁶ Rn	LSC	0.03		Bq/L	5%	–

¹ Reporting limits at salinity ≤ 0.4‰ (520 mS/m) and ≤ 3.5‰ (3,810 mS/m) respectively.

² Measurement uncertainty reported by consulted laboratory, generally 95% confidence interval.

³ Estimated total uncertainty by experience (includes effects of sampling and sample handling).

⁴ Determined only in surface waters and near surface groundwater.

⁵ Per mille deviation¹³ from SMOW (Standard Mean Oceanic Water).

⁶ TU = Tritium Units, where one TU corresponds to a Tritium/hydrogen ratio of 10⁻¹⁸ (1 Bq/L Tritium = 8.45 TU).

⁷ Per mille deviation¹³ from SMOC (Standard Mean Oceanic Chloride).

⁸ Per mille deviation¹³ from PDB (the standard PeeDee Belemnite).

⁹ The following relation is valid between pmC (percent modern carbon) and Carbon-14 age:

$$\text{pmC} = 100 \times e^{((1.950 - y - 1.031) / 8.274)}$$

where y = the year of the C-14 measurement and t = C-14 age.

¹⁰ Per mille deviation¹³ from CDT (the standard Canyon Diablo Troilite).

¹¹ Isotope ratio without unit.

¹² The following expressions are applicable to convert activity to concentration, for uranium-238 and thorium-232:

$$1 \text{ ppm U} = 12.4 \text{ Bq/kg}^{238}\text{U}$$

$$1 \text{ ppm Th} = 3.93 \text{ Bq/kg}^{232}\text{Th}$$

¹³ Isotopes are often reported as per mill deviation from a standard. The deviation is calculated as:

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

Appendix 3

Field measurements

Idcode	Start_date	Stop_date	Sampling depth (m)	Water temp. (°C)	pH	EC (mS/m)	Salinity (%)	ORP (mV)	O ₂ diss. (mg/L)	Oxygen (%)	Atm. pressure (mm)	GWL (m)
PFM000001	2005-10-05 13:03	2005-10-05 13:05	45	10.0	6.88	125.9	0.6	-39	1.19	10.6	1,027	-
PFM000009	2005-10-05 13:23	2005-10-05 13:25	70	6.8	7.55	1,349	7.8	-105	4.11	35.4	1,027	-
PFM006382	2005-10-05 11:38	2005-10-05 11:40	18	10.3	6.8	247.8	1.3	-22	1.16	10.5	1,029	-
SFM0001	2005-07-12 13:07	2005-07-12 14:27	4.1	7.2	7.23	235.7	1.2	-113	0.33	2.8	-	1.00
SFM0001	2005-10-04 17:45	2005-10-04 18:23	4.1	8.7	7.37	259.7	1.4	-106	0.49	4.2	1,028	1.20
SFM0001	2006-01-25 13:40	2006-01-25 14:50	4.1	6.0	7.23	248.4	1.3	-27	2.68	21.7	1,011	0.65
SFM0001	2006-04-20 15:25	2006-04-20 16:00	4.1	4.7	7.18	161.3	0.8	-72	0.28	2.2	1,002	0.45
SFM0023	2005-07-14 08:39	2005-07-14 09:23	4.3	13.3	7.25	1,150	6.6	-187	0.21	2.1	761.0	0.89
SFM0023	2005-10-06 08:15	2005-10-06 09:08	4.3	13.4	7.78	1,109	6.3	-267	1.17	11.6	1,025	0.90
SFM0023	2006-01-27 11:30	2006-01-27 12:08	4.3	4.3	7.47	1,176	6.6	-136	1.8	14.5	1,018	0.69
SFM0032	2005-07-12 16:48	2005-07-12 19:42	3.0	11.2	7.04	67.9	0.3	-135	0.24	2.2	766	1.57
SFM0032	2005-10-04 19:11	2005-10-04 19:47	3.0	10.7	7.1	64.6	0.3	-103	0.53	4.8	1,026	1.58
SFM0032	2006-01-24 20:00	2006-01-24 21:20	3.0	4.8	7.25	73.6	0.4	-75	3.19	24.9	1,009	1.07
SFM0032	2006-04-19 20:13	2006-04-19 21:00	2.1	3.2	7.23	67.9	0.3	-83	0.39	2.9	1,003	0.96
SFM0037	2005-07-13 10:22	2005-07-13 11:07	2.4	11.5	6.73	128.2	0.6	-132	0.17	1.6	760.1	1.94
SFM0037	2005-10-05 17:17	2005-10-05 18:07	3.0	10.2	7.14	148.6	0.8	-103	0.65	5.8	1,025	2.26
SFM0037	2006-01-25 16:00	2006-01-25 17:05	3.0	3.7	7.19	105.7	0.5	-71	2.16	16.4	1,012	1.16
SFM0037	2006-04-20 10:35	2006-04-20 11:45	1.9	2.9	7.09	88.6	0.4	-79	0.19	1.4	1,002	0.90
SFM0049	2005-07-12 10:38	2005-07-12 11:18	4.1	13.5	6.76	39.0	0.2	-139	0.06	0.6	769.4	1.91
SFM0049	2005-10-04 12:25	2005-10-04 13:30	4.1	12.1	6.78	39.4	0.2	-112	0.34	3.2	1,029	2.18
SFM0049	2006-01-24 13:00	2006-01-24 14:20	4.1	2.8	6.81	40.9	0.2	-17	1.25	9.3	1,016	1.72
SFM0049	2006-04-19 17:16	2006-04-19 18:32	4.0	2.1	6.65	39.7	0.2	-77	0.24	1.8	1,005	1.53

Compilation of water analysis data

Table A4-1. Water Composition. Compilation, November 2006.

Idcode	Secup m	Seclow m	Date yyyy-mm-dd	Sample no.	RCB %	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
SFM0001	3.95	4.95	2005-07-12	8942	-1.62	325	21.1	97.7	45.0	542	378	191	72.4	1.43	0.72
SFM0001	3.95	4.95	2005-10-04	8982	-0.55	404	24.7	95.6	50.4	597	456	227	76.6	0.731	1.35
SFM0001	3.95	4.95	2006-01-25	12040	0.31	336	21.6	122	58.1	596	395	222	80.6	1.71	0.63
SFM0001	3.95	4.95	2006-04-20	12228	-0.60	188	17.0	93.5	35.9	443	213	144	51.7	0.908	0.58
SFM0023	4.42	5.42	2005-07-14	8943	-3.72	1,550	71.1	527	169	160	3,780	339	137	15.5	0.91
SFM0023	4.42	5.42	2005-10-06	8983	-3.94	1,540	69.0	502	161	173	3,740	347	118	17.6	0.83
SFM0023	4.42	5.42	2006-01-27	12039	-5.24	1,520	58.8	503	171	177	3,810	356	130	15.5	1.06
SFM0032	3	4	2005-07-12	8939	2.67	23.4	6.04	113	9.4	365	20.9	30.0	10.7	0.155	0.54
SFM0032	3	4	2005-10-04	8981	2.29	22.2	5.56	113	8.8	361	20.2	34.1	11.3	0.049	0.75
SFM0032	3	4	2006-01-24	12041	4.63	35.1	5.89	124	10.6	371	35.4	39.7	15.0	0.208	0.71
SFM0032	3	4	2006-04-19	12226	2.56	24.3	5.42	116	9.4	357	24.3	39.6	14.2	0.168	0.72
SFM0037	2	3	2005-07-13	8940	1.62	108	12.9	134	33	561	87.4	98.3	38.4	0.442	0.64
SFM0037	2	3	2005-10-05	8979	-0.64	143	13.7	132	32.7	561	174	96.3	32.2	0.316	1.07
SFM0037	2	3	2006-01-25	12038	1.30	77.0	8.2	126	25.8	402	76.9	130	47.4	0.406	0.66
SFM0037	2	3	2006-04-20	12227	1.38	50.9	7.27	114	19.1	341	47.8	113	40.0	0.247	0.69
SFM0049	4	5	2005-07-12	8941	4.53	12.7	2.94	65.8	5.0	210	16.8	0.97	0.95	0.077	0.26
SFM0049	4	5	2005-10-04	8980	2.55	12.0	1.95	67.7	4.9	220	16.5	1.79	1.44	0.055	0.41
SFM0049	4	5	2006-01-24	12071	4.26	12.6	2.55	70.4	5.5	222	19.1	0.85	0.84	0.072	0.26
SFM0049	4	5	2006-04-19	12225	3.69	11.5	2.66	69.8	5.4	229	14.6	0.56	0.72	0.062	0.26
SFM0051	5.02	5.18	2005-07-21	8944	4.99	17.9	5.40	136	8.4	381	41.3	18.8	7.34	-0.2	0.46
SFM0051	5.02	5.18	2005-10-03	8984	0.89	17.0	5.28	124	7.9	386	37.5	19.0	7.16	0.319	0.68
SFM0051	5.02	5.18	2006-01-24	12073	5.16	16.1	4.63	125	7.5	357	30.1	19.1	7.30	-0.2	0.55
SFM0051	5.02	5.18	2006-05-02	12224	2.03	15.5	4.90	121	7.8	350	36.0	20.3	7.34	-0.2	0.54

Table A4-1. Cont.

Idcode	Secup m	Seclow m	Date yyyy-mm-dd	Sample no.	Si mg/L	Fe mg/L	Fe(tot) mg/L	Fe(+II) mg/L	Mn mg/L	Li mg/L	Sr mg/L	pH (lab)	EC (lab) mS/m	HS- mg/L	I- mg/L
SFM0001	3.95	4.95	2005-07-12	8942	8.45	2.05	2.28	2.26	0.239	0.019	0.385	7.23	162	0.068	0.012
SFM0001	3.95	4.95	2005-10-04	8982	8.61	1.92	2.07	2.01	0.213	0.022	0.418	7.21	250	0.014	0.015
SFM0001	3.95	4.95	2006-01-25	12040	9.88	3.37	2.90	2.89	0.289	0.021	0.500	7.12	234	0.075	0.012
SFM0001	3.95	4.95	2006-04-20	12228	7.94	2.66	2.74	2.68	0.215	0.014	0.337	7.06	264	0.073	0.005
SFM0023	4.42	5.42	2005-07-14	8943	5.78	-	-	-	1.53	0.059	3.78	6.77	1,150	-	0.059
SFM0023	4.42	5.42	2005-10-06	8983	4.36	-	-	-	1.44	0.056	3.55	6.95	1,130	-	-
SFM0023	4.42	5.42	2006-01-27	12039	4.59	-	-	-	1.23	0.050	3.54	6.95	1,150	0.035	0.058
SFM0032	3	4	2005-07-12	8939	8.31	1.96	2.15	2.15	0.200	0.007	0.188	7.05	68.7	0.050	0.010
SFM0032	3	4	2005-10-04	8981	8.91	2.32	2.33	2.34	0.241	0.007	0.183	6.26	69.5	0.568	0.011
SFM0032	3	4	2006-01-24	12041	8.26	2.33	2.41	2.40	0.297	0.008	0.220	7.05	74.8	0.051	0.009
SFM0032	3	4	2006-04-19	12226	6.75	2.37	2.47	2.50	0.202	0.006	0.188	7.12	66.7	0.112	0.002
SFM0037	2	3	2005-07-13	8940	9.12	2.98	3.28	3.20	0.285	0.014	0.395	6.91	88.9	0.113	0.005
SFM0037	2	3	2005-10-05	8979	8.71	2.66	2.86	2.81	0.284	0.016	0.391	6.91	106	0.124	0.006
SFM0037	2	3	2006-01-25	12038	7.14	2.33	2.37	2.29	0.235	0.013	0.320	7.02	130	0.164	0.009
SFM0037	2	3	2006-04-20	12227	5.53	1.99	2.07	1.90	0.197	0.007	0.252	7.04	152	0.130	0.002
SFM0049	4	5	2005-07-12	8941	5.52	1.13	1.19	1.17	0.145	< 0.004	0.082	6.81	39.5	0.356	0.005
SFM0049	4	5	2005-10-04	8980	4.47	1.12	1.27	1.26	0.127	< 0.004	0.081	6.72	41.0	0.160	0.005
SFM0049	4	5	2006-01-24	12071	6.84	1.10	1.20	1.12	0.100	< 0.004	0.090	6.83	40.5	0.197	0.010
SFM0049	4	5	2006-04-19	12225	6.16	1.37	1.40	1.35	0.150	< 0.004	0.087	6.64	40.0	0.310	< 0.005
SFM0051	5.02	5.18	2005-07-21	8944	10.5	9.07	8.69	8.70	0.314	0.012	0.179	7.43	68.5	-	-
SFM0051	5.02	5.18	2005-10-03	8984	8.73	7.91	8.04	7.99	0.275	0.006	0.168	7.17	67.6	-	-
SFM0051	5.02	5.18	2006-01-24	12073	9.50	7.78	7.85	7.84	0.267	0.006	0.200	7.61	68.8	-	-
SFM0051	5.02	5.18	2006-05-02	12224	9.87	7.37	7.32	7.20	0.255	0.006	0.173	7.17	64.3	-	-

< "value" = result below detection or reporting limit.

RCB % = Relative charge balance error %.

EC = Electrical conductivity.

SICADA: water_composition.

Table A4-2. Drinking water quality. Compilation, November 2006.

Id code	Date	Kbact no/100 mL	Microbes no/100 mL	Ecoli no/100 mL	Temp. _Field (°C)	Smell _Lab	Sediment /mud	Colour (number)	pH_L	Temp_pH (°C)	Alk mg/L	EC_L mS/m	Ca mg/L	Cl mg/L	COD mg/L
PFM000001	2005-10-05	19	127,000	1	10	Week	No	40	7.5	25	620	110	170	58	6
PFM000009	2005-10-05	< 1	220,000	< 1	6.8	Week	No	49	7.4	25	170	1,410	900	4,900	12
PFM006382	2005-10-05	< 1	46,000	< 1	10.3	No smell	No	81	7.0	25	170	990	200	610	14

Table A4-2. Cont.

Id code	Date	Cu mg/L	F mg/L	Fe mg/L	Hardness _German	K mg/L	Mg mg/L	Mn mg/L	Na mg/L	NH ₄ _N mg/L	NH ₄ mg/L	NO ₃ _N mg/L	NO ₃ mg/L	NO ₂ _N mg/L	NO ₂ mg/L	PO ₄ _P mg/L	PO ₄ mg/L	SO ₄ mg/L
PFM000001	2005-10-05	< 0.02	0.8	4	32.0	40	34	0.4	40	4.5	5.8	< 0.1	< 0.44	< 0.002	< 0.01	< 0.005	< 0.02	110
PFM000009	2005-10-05	< 0.02	1	7.8	170.0	26	190	1.1	1,700	1.4	1.8	< 0.1	< 0.44	< 0.002	< 0.01	< 0.005	< 0.02	300
PFM006382	2005-10-05	< 0.02	0.6	1.5	37.0	13	38	0.11	270	0.038	0.05	< 0.1	< 0.44	< 0.002	< 0.01	< 0.005	< 0.02	130

Explanations:

Kbact Number of coliform bacteria.

Ecoli Number of escherichia coli bacteria at 35°C.

Sediment Ocular inspection of sediment.

EC_L Electric conductivity.

< "value" = value below reporting limit.

Table A4-3. Surface water supplements. Compilation, November 2006.

Id code	Secup m	Seclow m	Date	Sample no.	NH₄-N mg/L	NO₂-N mg/L	NO₃-N+NO₂-N mg/L	NO₃-N mg/L	N-tot mg/L	P-tot mg/L	PO₄-P mg/L	SiO₂-Si mg/L	TOC mg/L	DOC mg/L	DIC mg/L
SFM0001	3.95	4.95	2005-07-12	8942	0.269	0.0002	0.0006	-	1.07	0.046	0.0412	7.28	22.9	23.6	96.2
SFM0001	3.95	4.95	2005-10-04	8982	0.319	0.0003	-0.0002	-0.0003	0.982	0.056	0.0474	8	20.2	20.2	107
SFM0001	3.95	4.95	2006-01-25	12040	0.343	0.001	0.0012	-0.0003	1.38	0.048	0.0298	8.05	29.8	30.1	109
SFM0001	3.95	4.95	2006-04-20	12228	0.255	0.0006	0.0013	0.0007	1.47	0.043	0.0348	7.1	36.1	36	84.5
SFM0023	4.42	5.42	2005-07-14	8943	2.79	-0.0002	-0.0002	-	2.79	0.04	-0.0005	3.41	4.4	4	20.4
SFM0023	4.42	5.42	2005-10-06	8983	2.91	0.0006	0.0022	0.0016	2.91	0.01	0.001	3.01	3.6	4.2	10.3
SFM0023	4.42	5.42	2006-01-27	12039	2.76	0.0007	0.0012	0.0005	2.62	0.017	0.0012	2.96	3.1	3.6	15.9
SFM0032	3	4	2005-07-12	8939	0.0431	0.0002	0.0005	-	0.674	0.014	0.0071	7.27	19.2	19.5	68.8
SFM0032	3	4	2005-10-04	8981	0.0331	0.0003	0.0004	-0.0003	0.75	0.015	0.0083	8.02	21.4	21.8	65.4
SFM0032	3	4	2006-01-24	12041	0.0942	0.0003	0.0006	0.0003	0.66	0.017	0.0028	6.5	17.8	17.9	68.9
SFM0032	3	4	2006-04-19	12226	0.0865	0.0005	0.0004	-0.0003	0.688	0.015	0.0027	6.04	18.3	18.2	68.7
SFM0037	2	3	2005-07-13	8940	0.0051	0.0004	0.0008	-	0.791	0.024	0.0066	7.85	21.1	21.4	100
SFM0037	2	3	2005-10-05	8979	0.0238	0.0004	0.0005	-0.0003	0.752	0.021	0.0116	8.08	18.9	19.6	98.8
SFM0037	2	3	2006-01-25	12038	0.0107	0.0008	0.0011	0.0003	1.01	0.058	0.0055	5.84	28.9	29.4	72.4
SFM0037	2	3	2006-04-20	12227	0.0076	0.0005	0.0009	0.0004	1.11	0.027	0.0056	4.95	31.9	30.9	67.4
SFM0049	4	5	2005-07-12	8941	0.109	-0.0002	0.0003	-	0.766	0.016	0.0105	4.72	20.9	20.6	40.8
SFM0049	4	5	2005-10-04	8980	0.143	-0.0002	-0.0002	-0.0003	0.734	0.017	0.0116	4.05	18.8	19.2	42.5
SFM0049	4	5	2006-01-24	12071	0.0678	0.0003	0.0005	-0.0003	0.7	0.023	0.0066	5.77	18.3	18.4	44.7
SFM0049	4	5	2006-04-19	12225	0.0975	0.0008	0.0006	-0.0003	0.783	0.019	0.0091	5.55	17.7	16.8	46.6

< "value" = below reporting limit

SICADA: biochemistry_supplements

Table A4-4. Isotopes I. Compilation, November 2006.

Id code	Secup m	Seclow m	Date	Sample no.	¹⁰B/¹¹B	δ D (‰ SMOW)	Tritium (TU)	δ¹⁸O (‰ SMOW)
SFM0001	3.95	4.95	2005-07-12	8942	–	–73	12.2	–10.6
SFM0001	3.95	4.95	2005-10-04	8982	–	–81.1	11.3	–10.4
SFM0001	3.95	4.95	2006-01-25	12040	0.2408	–75.4	7.9	–10.6
SFM0001	3.95	4.95	2006-04-20	12228	0.2392	–84.3	11.6	–11.7
SFM0023	4.42	5.42	2005-07-14	8943	–	–66.5	2.4	–9
SFM0023	4.42	5.42	2005-10-06	8983	–	–74.5	2.7	–8.8
SFM0023	4.42	5.42	2006-01-27	12039	0.2383	–67.8	2.8	–8.9
SFM0032	3	4	2005-07-12	8939	–	–79.6	9.2	–11.7
SFM0032	3	4	2005-10-04	8981	–	–83.6	13.3	–11.3
SFM0032	3	4	2006-01-24	12041	0.2408	–84.3	11.5	–12.1
SFM0032	3	4	2006-04-19	12226	0.2417	–87.4	9.8	–12.1
SFM0037	2	3	2005-07-13	8940	–	–67	12.7	–10.2
SFM0037	2	3	2005-10-05	8979	–	–80.1	13.6	–10
SFM0037	2	3	2006-01-25	12038	0.2434	–82	9.2	–11.7
SFM0037	2	3	2006-04-20	12227	0.2427	–89.3	10.9	–12.2
SFM0049	4	5	2005-07-12	8941	–	–65.8	13	–8.8
SFM0049	4	5	2005-10-04	8980	–	–70.3	12.9	–8.8
SFM0049	4	5	2006-01-24	12071	0.2422	–77.3	11.6	–10.3
SFM0049	4	5	2006-04-19	12225	0.2424	–85	11.5	–11.4
SFM0051	5.02	5.18	2005-07-21	8944	–	–85.7	11.6	–12.2
SFM0051	5.02	5.18	2005-10-03	8984	–	–90.4	9.9	–12.2
SFM0051	5.02	5.18	2006-01-24	12073	0.2488	–86.4	10.8	–12.3
SFM0051	5.02	5.18	2006-05-02	12224	0.2449	–84.6	9.3	–12

SICADA: Isotopes_1.

Table A4-5. Trace metals I. Compilation, November 2006.

Idcode	Secup m	Seclow m	Date	Sample no.	Al µg/L	As µg/L	Cd µg/L	Cr µg/L	Cu µg/L	Co µg/L	Hg µg/L	Nb µg/L	Ni µg/L	Zn µg/L	Pb µg/L	V µg/L	Mo µg/L	Ba µg/L	B µg/L
SFM0001	3.95	4.95	2005-10-04	8982	44.5	1.1	0.005	0.391	0.174	0.227	0.005	-	0.634	0.873	0.255	2.05	2.13	76.2	-
SFM0001	3.95	4.95	2006-01-25	12040	38.6	1.2	0.025	0.48	37.6	0.504	0.004	0.136	0.954	90.6	0.182	1.86	1.12	74.9	381
SFM0001	3.95	4.95	2006-04-20	12228	43.8	-	0.005	0.437	0.411	0.201	<0.002	-	1.4	1.09	0.167	1.77	0.847	48.3	-
SFM0032	3	4	2005-10-04	8981	79.2	0.7	<0.002	0.419	<0.1	0.086	0.005	-	0.66	1.26	0.094	2.35	1.36	50	-
SFM0032	3	4	2006-01-24	12041	44.2	1	0.003	0.373	0.534	0.207	0.004	0.0891	0.699	2.09	0.124	1.66	2.49	54.7	46.7
SFM0032	3	4	2006-04-19	12226	56.1	-	0.003	0.209	0.229	0.07	<0.002	-	0.443	0.767	0.083	1.62	1.62	50.1	-
SFM0037	2	3	2005-10-05	8979	32.2	0.6	0.003	0.533	0.156	0.099	0.005	-	0.561	0.848	0.284	2.44	0.774	107	-
SFM0037	2	3	2006-01-25	12038	93.2	0.29	0.008	0.514	0.716	0.095	<0.002	0.101	1.11	0.908	0.198	3.01	0.852	76.8	119
SFM0037	2	3	2006-04-20	12227	45.9	-	0.006	0.422	0.671	0.066	<0.002	-	0.935	0.554	0.062	1.92	1.36	67.1	-
SFM0049	4	5	2005-10-04	8980	90.2	0.3	<0.002	0.25	<0.1	0.056	0.005	-	0.316	3.81	0.283	0.713	<0.05	24.6	-
SFM0049	4	5	2006-01-24	12071	29.5	<0.1	<0.002	0.283	1.52	0.252	0.003	0.0442	0.504	33.5	0.14	0.479	0.148	28.4	<10
SFM0049	4	5	2006-04-19	12225	73.3	-	0.005	0.24	0.138	0.068	<0.002	-	0.355	0.358	0.399	1.07	0.071	28.7	-
SFM0051	5.02	5.18	2005-07-21	8944	904	1.33	0.07	43.1	3.78	0.979	<0.002	-	24.2	22.1	1.52	4.01	1.36	89.3	-
SFM0051	5.02	5.18	2005-10-03	8984	243	1.5	0.018	6.79	3.72	0.277	0.006	-	5.57	13.9	0.836	2.94	1.23	87.6	-
SFM0051	5.02	5.18	2006-01-24	12073	286	1.9	0.018	1.57	4.61	0.298	0.005	0.230	4.09	24.9	0.699	2.99	1.38	82.5	21.8
SFM0051	5.02	5.18	2006-05-02	12224	143	-	0.016	11.9	0.873	0.323	<0.002	-	7.24	2.75	0.558	2.35	1.2	86	-

< "value" = below reporting limit.

SICADA: trace_elements_1.

Table A4-6. Trace metals II. Compilation, November 2006.

Idcode	Secup m	Seclow m	Date	Sample no.	U µg/L	Th µg/L	Sc µg/L	Rb µg/L	Y µg/L	Zr µg/L	In µg/L	Sb µg/L	Cs µg/L	La µg/L	Hf µg/L	Ti µg/L
SFM0001	3.95	4.95	2005-10-04	8982	4.36	0.115	0.0918	5.22	1.51	7.01	<0.05	0.0532	0.0458	1.62	0.082	<0.005
SFM0001	3.95	4.95	2006-01-25	12040	3.59	0.174	0.135	3.96	2.38	5.91	<0.05	0.0713	<0.03	2.09	0.094	<0.005
SFM0001	3.95	4.95	2006-04-20	12228	2.66	0.247	0.127	2.94	2.89	4.43	-	0.0701	<0.03	2.82	0.085	<0.005
SFM0032	3	4	2005-10-04	8981	3.27	0.154	0.0671	1.87	2.2	4.44	<0.05	0.0478	<0.03	1.65	0.08	0.0095
SFM0032	3	4	2006-01-24	12041	5.43	0.0703	0.0731	1.72	2.1	4.36	<0.05	0.0327	<0.03	1.91	0.077	0.0058
SFM0032	3	4	2006-04-19	12226	5.23	0.08	0.0631	1.61	1.5	4.23	-	0.0297	<0.03	1.24	0.078	<0.005
SFM0037	2	3	2005-10-05	8979	7.14	0.137	0.112	4.34	2.09	5.95	<0.05	0.0729	<0.03	1.44	0.105	<0.005
SFM0037	2	3	2006-01-25	12038	5.49	0.176	0.132	2.26	3.02	<10	<0.05	0.0771	<0.03	1.93	0.106	<0.005
SFM0037	2	3	2006-04-20	12227	7.87	0.237	0.126	1.97	3.49	3.35	-	0.0729	<0.03	2.13	0.093	<0.005
SFM0049	4	5	2005-10-04	8980	0.158	0.113	0.0828	3.26	0.864	0.415	<0.05	0.0242	<0.03	1.32	0.013	0.0083
SFM0049	4	5	2006-01-24	12071	0.225	0.0658	<0.05	2.35	0.689	0.299	<0.05	0.0482	<0.03	1.15	0.008	0.0093
SFM0049	4	5	2006-04-19	12225	0.168	0.127	0.0568	2.77	0.895	0.458	-	0.0496	<0.03	1.46	0.012	<0.005
SFM0051	5.02	5.18	2005-07-21	8944	1.2	0.641	0.364	3.35	2.27	1.61	<0.05	0.222	0.141	2.36	0.09	<0.03
SFM0051	5.02	5.18	2005-10-03	8984	0.815	0.25	0.19	2.12	1.18	5.93	0.075	0.0766	0.0502	0.949	0.065	0.0056
SFM0051	5.02	5.18	2006-01-24	12073	0.933	0.326	0.196	2.17	1.25	7.25	0.131	0.0984	0.0815	1.25	0.081	0.0061
SFM0051	5.02	5.18	2006-05-02	12224	0.91	0.183	0.0923	1.66	0.843	5.09	-	0.309	0.0436	0.562	0.071	0.0054

Table A4-6. Cont.

Idcode	Secup m	Seclow m	Date	Sample no.	Tl µg/L	Ce µg/L	Pr µg/L	Nd µg/L	Sm µg/L	Eu µg/L	Gd µg/L	Tb µg/L	Dy µg/L	Ho µg/L	Er µg/L	Tm µg/L	Yb µg/L	Lu µg/L
SFM0001	3.95	4.95	2005-10-04	8982	< 0.005	3.85	0.351	1.35	0.233	0.024	0.258	< 0.05	0.222	0.048	0.132	0.0179	0.124	0.022
SFM0001	3.95	4.95	2006-01-25	12040	< 0.005	5.33	0.471	1.85	0.345	0.051	0.385	0.052	0.319	0.067	0.205	0.0272	0.188	0.03
SFM0001	3.95	4.95	2006-04-20	12228	< 0.005	6.54	0.624	2.54	0.486	0.062	0.509	0.071	0.438	0.088	0.277	0.0382	0.251	0.042
SFM0032	3	4	2005-10-04	8981	0.0095	1.95	0.369	1.46	0.266	0.031	0.316	< 0.05	0.293	0.067	0.198	0.0273	0.186	0.034
SFM0032	3	4	2006-01-24	12041	0.0058	1.92	0.406	1.68	0.262	0.039	0.287	< 0.05	0.217	0.051	0.155	0.0228	0.149	0.027
SFM0032	3	4	2006-04-19	12226	< 0.005	1.23	0.26	1.08	0.189	0.03	0.218	0.03	0.192	0.045	0.151	0.0213	0.153	0.026
SFM0037	2	3	2005-10-05	8979	< 0.005	2.59	0.318	1.34	0.252	0.026	0.293	< 0.05	0.283	0.067	0.201	0.0315	0.204	0.042
SFM0037	2	3	2006-01-25	12038	< 0.005	3.5	0.468	1.89	0.373	0.055	0.423	0.063	0.395	0.091	0.278	0.0406	0.267	0.043
SFM0037	2	3	2006-04-20	12227	< 0.005	3.86	0.513	2.2	0.473	0.064	0.531	0.079	0.532	0.12	0.389	0.0549	0.398	0.06
SFM0049	4	5	2005-10-04	8980	0.0083	2.49	0.305	1.1	0.205	0.023	0.195	< 0.05	0.153	0.031	0.0806	0.0116	0.077	0.012
SFM0049	4	5	2006-01-24	12071	0.0093	1.91	0.254	0.925	0.16	0.023	0.139	< 0.05	0.106	0.022	0.0617	0.0085	0.056	0.008
SFM0049	4	5	2006-04-19	12225	< 0.005	2.56	0.33	1.26	0.232	0.034	0.21	0.029	0.162	0.031	0.0931	0.0137	0.089	0.016
SFM0051	5.02	5.18	2005-07-21	8944	< 0.03	4.77	0.574	2.09	0.401	0.062	0.375	0.056	0.327	0.066	0.187	0.0288	0.211	0.037
SFM0051	5.02	5.18	2005-10-03	8984	0.0056	2.01	0.235	0.842	0.165	0.019	0.167	< 0.05	0.161	0.033	0.102	0.0159	0.148	0.03
SFM0051	5.02	5.18	2006-01-24	12073	0.0061	2.47	0.258	0.987	0.194	0.045	0.227	< 0.05	0.163	0.038	0.116	0.0169	0.12	0.024
SFM0051	5.02	5.18	2006-05-02	12224	0.0054	1.19	0.144	0.614	0.119	0.023	0.128	0.018	0.126	0.028	0.0961	0.0154	0.135	0.027

< "value" = below reporting limit.

SICADA: trace_elements_2.