P-06-308

Oskarshamn site investigation

Complete chemical characterisation in KLX08

Results from four investigated borehole sections: 197.0–206.6 m, 396.0–400.9 m, 476.0–485.6 m, 609.0–618.5 m

Anette Bergelin, Kersti Nilsson, Anna Lindquist, Pia Wacker
Geosigma AB

August 2008

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 250, SE-101 24 Stockholm
Tel +46 8 459 84 00

ISSN 1651-4416
SKB P-06-308

Oskarshamn site investigation

Complete chemical characterisation in KLX08

Results from four investigated borehole sections: 197.0–206.6 m, 396.0–400.9 m, 476.0–485.6 m, 609.0–618.5 m

Anette Bergelin, Kersti Nilsson, Anna Lindquist, Pia Wacker
Geosigma AB

August 2008

Keywords: Groundwater, Measurements on line, In situ sampling, Measurements in situ, Redox potential, Dissolved gas, Humic and fulvic acids, Colloids, Microbes, Chemical analyses, Isotope determinations, AP PS 400-05-047.

Abstract

Complete chemical characterisation has been conducted in four sections, 197.0–206.6, 396.0–400.9, 476.0–485.6 and 609.0–618.5 m, of borehole KLX08. This is the most extensive chemical investigation method performed in core drilled boreholes. The method entails pumping, measurements on-line and regular water sampling for chemical analyses in isolated borehole sections during approximately three weeks per section at a flow rate of between 50 and 200 mL/min.

The results obtained include on-line measurements of redox potential, pH, dissolved oxygen, electrical conductivity and water temperature in the borehole section together with chemical analyses of major constituents, trace metals and isotopes as well as gas content and composition. Furthermore, inorganic and organic colloids (humic and fulvic acids) were investigated.

The water composition was stable during the pumping and sampling periods in all of the sections. The chloride concentrations were approximately 13 mg/L (197.0–206.6 m), 15 mg/L (476.0–485.6 m), 1,500 mg/L (476.0–485.6 m) and 2,000 mg/L (609.0–618.5 m). Enhanced concentrations of ^{3}H were found in some of the groundwater samples from section 476.0–485.6 m. The reason for this was contamination with de ionised water containing ^{3}H. The water was part of the hydraulic pumping system.

Stable redox potentials are reported for the borehole electrodes in sections 197.0–206.6 m and 396.0–400.9 m (–266 and –245 mV respectively). In sections 476.0–485.6 m and 609.0–618.5 m, the redox electrodes did not reach stable and agreeing values within the measurement period.

The content of inorganic colloids in the water was very low or nonexistent with respect to Si and Mn. The presence of colloidal Al and Fe is uncertain since contamination and precipitation have to be considered. The organic constituents were present mainly as fulvic acids and possibly other low molecular weight organic acids (citric acid, oxalic acid, etc) in section 476.0–485.6 m. In sections 197.0–206.6 m and 396.0–400.9 m, fractions with molecular weights above 5,000 D were observed in addition to the low molecular species.

Sammanfattning

Fullständig kemikarakterisering har utförts i de fyra borrhålssektionerna 197,0–206,6, 396,0–400,9, 476,0–486,6 och 609,0–618,5 m av borrhålet KLX08. Metoden är den mest omfattande kemiska undersökningsmetoden för kärnborrhål. Den innebär pumpning, mätning on-line och regelbunden vattenprovtagning för kemiska analyser i avgränsade borrhålssektioner under cirka tre veckor per sektion och vid ett pumpflöde på mellan 50 och 200 mL/min.

Resultaten från den fullständiga kemikarakteriseringen av sektionerna 197,0–206,6, 396,0–400,9, 476,0–486,6 och 609,0–618,5 m omfattar mätningar on-line av redoxpotential, pH, löst syre, elektrisk konduktivitet och vattentemperatur i borrhålssektionen liksom kemiska analyser av huvudkomponenter, spårelement och isotoper. Vidare undersöktes gasmängd och sammansättning, oorganiska kolloider samt humus- och fulvosyror i grundvattnet.

Vattensammansättningen var stabil under hela pump- och provtagningsperioderna i alla borrhålssektionerna. Kloridkoncentrationerna uppgick till cirka 13 mg/L (197,0–206,6 m), 15 mg/L (396,0–400,9 m), 1 500 mg/L (476,0–486,6 m) och 2 000 mg/L (609,0–618,5 m). Förhöjda koncentrationer av ^{3}H uppmättes i några av grundvattenproverna från sektion 476,0–485,6 m. Orsaken till detta var kontaminering med avjoniserat vatten innehållande ^{3}H. Vattnet ingick i det hydrauliska pumpsystem som användes.

Stabila redoxpotentialer uppmättes av borrhålselektroderna för sektionerna 197,0–206,6 m och 396,0–400,9 m (–266 respektive –245 mV). I sektionerna 476,0–485,6 m och 609,0–618.5 m uppnådde inte redox elektroderna stabila och överensstämmande värden under mätperioden.

Förekomsten av oorganiska kolloider befanns vara mycket låg eller obefintlig vad gäller Si och Mn. Förekomsten av kolloidalt Al och Fe är osäker då kontaminering och utfällning kan påverka resultatet. De organiska komponenterna förelåg huvudsakligen som fulvosyror eller andra lågmolekylära organiska syror (citronsyra, oxalsyra) i sektionen 476,0–485,6 m. I sektionerna 197,0–206,6 m och 396,0–400,9 m observerades förutom den lågmolekylära fraktionen även fraktioner med högre molekylär vikt.

Contents

Appendices attached on CD

1 Introduction

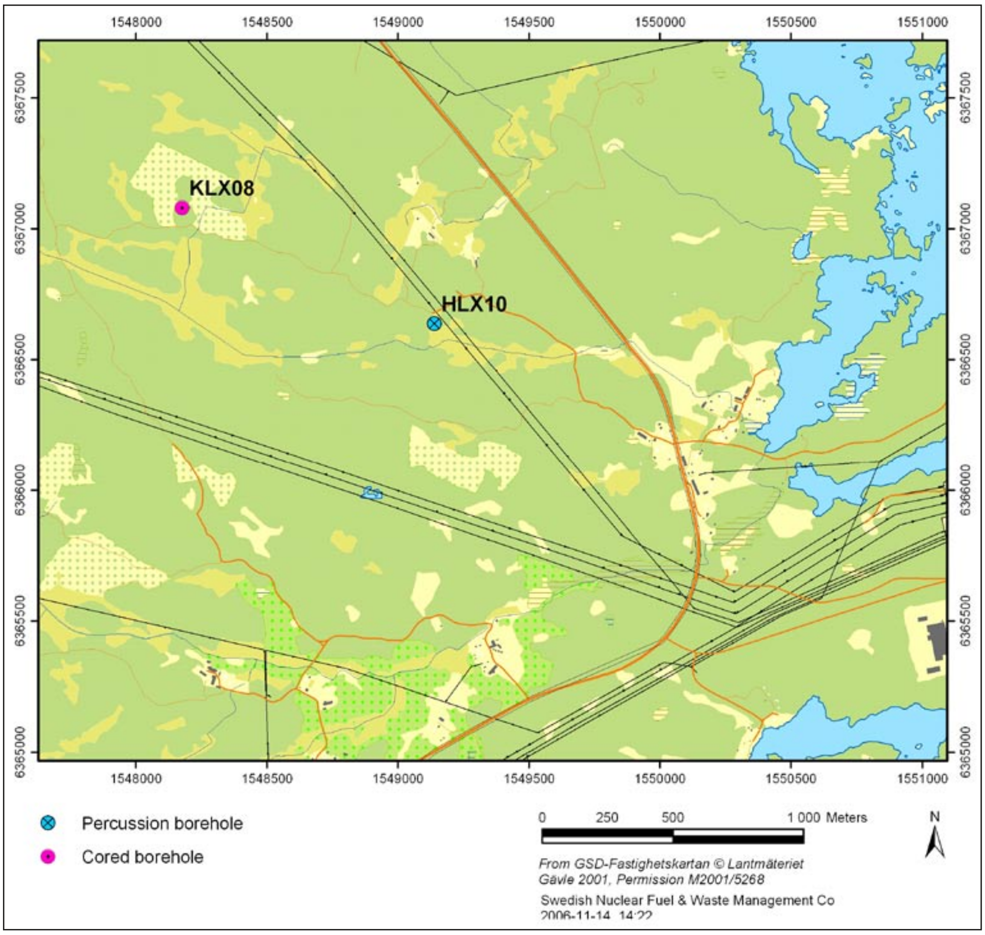
This document reports performance of and results from the activity *Complete hydrochemical characterisation* in the cored borehole KLX08 performed within the site investigation at Oskarshamn /1/. The work was conducted according to the activity plan AP PS 400-05-047. The report presents hydrogeochemical data from field work carried out during November 2005 to July 2006.

The controlling documents for the activity are listed in Table 1-1. The activity plan, the method description and the measurement system descriptions constitute SKB's internal controlling documents. The obtained data from the activity are reported to the SICADA database and are traceable by the activity plan number. Sampling for microbe studies, based on the activity plan AP PS 400-05-047, was also performed within the present activity. The microbe investigations is reported in a separate primary data report /2/.

Borehole KLX08 is a 1,000.4 m long telescopic borehole drilled at Laxemar and inclined 60° from the horizontal plane. The interval 0–100 m is percussion drilled with a diameter of 200 mm and the interval 100–1,000.4 m is core drilled with a diameter of 76 mm. The percussion borehole HLX10 served as the source of flushing water for the drilling of KLX08. The locations of KLX08 and HLX10 are shown in Figure 1-1. The borehole design of KLX08 is presented in Appendix 1. The borehole is of the so-called SKB chemical-type, see method descriptions MD 620.003 (Method description for drilling cored boreholes) and MD 610.003 (Method description for percussion drilling). A SKB chemical-type borehole requires that cleaning procedures are carried out on all downhole equipment to be used in the borehole, both during and after drilling, according to level 2 in the cleaning instructions outlined in MD 600.004 (Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning).

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

Activity plan	**Number**	**Version**
Fullständig kemikaraktärisering med mobilt fältlaboratorium i KLX08.	AP PS 400-05-047	1.0
Method description	**Number**	**Version**
Metodbeskrivning för fullständig kemikaraktärisering med mobilt fältlaboratorium.	SKB MD 430.017	2.0
Measurement system descriptions		
Instruktion för rengöring av borrutrustning och viss markbaserad utrustning.	SKB MD 600.004	1.0
Mätsystembeskrivningar för mobil kemienhet allmän del, slangvagn, borrhålsutrustning, mobil ytChemmac och dataapplikation.	SKB MD 434.004 SKB MD 434.005 SKB MD 434.006 SKB MD 434.007 SKB MD 434.018	1.0 1.0 1.0 1.0 1.0
Mätsystembeskrivning för kolloidfiltreringssystem	SKB MD 431.045	In progress
Mätsystembeskrivning för uppkoncentrering av humus- och fulvosyror.	SKB MD 431.044	1.0
Mätsystembeskrivning för fraktionering av humus- och fulvosyror.	SKB MD 431.043	1.0
Instructions		
Provtagning och analys-kemilaboratorium	SKB MD 452.001-019	–



From GSD-Fastighetskartan © Lantmäteriet
Gävle 2001, Permission M2001/5268

Swedish Nuclear Fuel & Waste Management Co
2006-11-14 14:22

Figure 1-1. *Locations of the core drilled borehole KLX08 and the percussion borehole HLX10 within the site investigation at Oskarshamn.*

2 Objectives and scope

Complete chemical characterisation is the most extensive chemical investigation method performed in coredrilled boreholes. The method is carried out in order to obtain as complete information as possible about the groundwater chemical conditions in individual water-bearing fractures or local minor fracture zones. Considerable effort is made to obtain representative samples from a limited rock volume. Careful pumping and continuous control of the pressure in the sampled borehole section, as well as above the section, is maintained in order to minimise the risk of mixing with ground waters from other fracture systems.

The analytical programme was carried out according to SKB chemistry class 4 and class 5 including all options /1/. Furthermore, pH, redox potential (Eh) and water temperature were measured in flow-through cells downhole as well as at the ground surface. The flow-through cell at the surface also measured electrical conductivity and dissolved oxygen. Samples were collected in situ in the borehole sections for determination of colloids, gas content and composition, microbe content and their characterisation. Fractionation of organic acids and inorganic species was performed in order to investigate size distribution (DOC and ICP analyses) and enrichment of organic acids was conducted in order to determine $\delta^{13}C$ and pmC in organic constituents.

3 Background

3.1 Flushing water history

The core drilling of the 1,000.4 m long borehole consumed 991 m^3 of flushing water and the volume of returned water pumped from the borehole by air-lift pumping during drilling was 2,547 m^3.

Uranine was added automatically to the tank with flushing water that supplies flushing water to the drilling head. The Uranine concentration in the flushing water and returned water was checked regularly and a total of 125 samples of each sample type were analysed. The Uranine concentrations in the flushing water and in the returned water are presented in Figure 3-1. A water budget, presenting the amount of Uranine added to the borehole via the flushing water and the estimated amount recovered in the return water, is given in Table 3-1.

The Uranine budget in Table 3-1 suggests that flushing water has been lost to the borehole and the adjacent host bedrock during drilling.

More detailed information on the flushing water and drilling can be obtained from the drilling report /3/.

Table 3-1. Amount of Uranine added to KLX08 via the flushing water during core drilling and the amount recovered from the contemporary air-lift pumping.

Uranine	(g)
Added, calculated from the average Uranine concentration added and the total volume of flushing water.	187
Recovered, estimated from the average Uranine concentration recovered and the total volume of returned water.	47

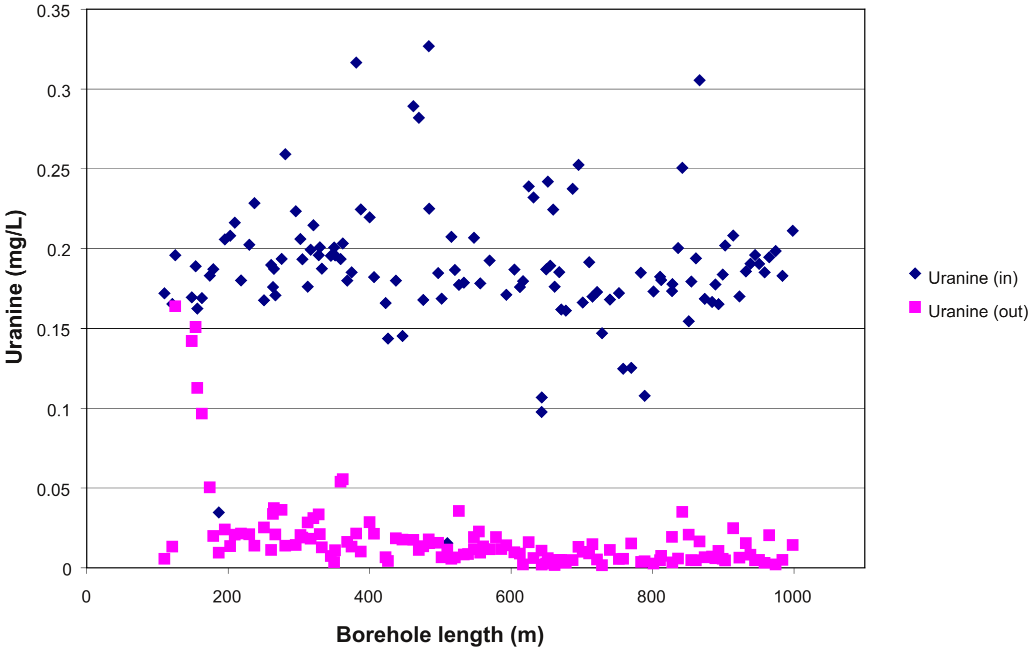


Figure 3-1. Uranine concentrations in the flushing water and in the recovered water versus borehole length.

3.2 Previous activities in the borehole

KLX08 is an SKB chemistry-type core borehole intended for *Complete chemical characterisation*. Only activities that are necessary in order to select borehole sections are carried out in the borehole prior to the chemistry campaign. The more downhole equipment used in the borehole, the greater is the risk of contamination and affects on, for example, the in situ microbiological conditions. The activities/investigations performed in KLX08 prior to the chemistry campaign are listed in Table 3-2 below.

3.3 Choice of borehole sections

The differential flow logging /6/ revealed several water-bearing zones (> 10,000 mL/h) in the shallow part of the borehole between 100 and 230 m. Furthermore, four sections with water yield above 10,000 mL/h were identified below 230 m and several fracture zones with flow rates just below 10,000 mL/h. A deep zone was identified at 852 m borehole length and a probable zone was indicated at 771 m. The interesting fracture zones with a probable water yield large enough to allow water sampling are listed in Table 3-3. The two upper fracture zones have flow rates above the criteria for water sampling, while the third section is located at the planned repository depth and the flow of water is from the borehole into the fracture. The fourth fracture zone represents the deeper part of the borehole. However, since the deeper part of the borehole appeared to contain high amounts of flushing water /3/, the deeper fracture zone at 852 m borehole length was replaced by the section at 399 m borehole length.

The differential flow logs for the relevant parts of the borehole are given in Appendix 2 and the corresponding pictures from BIPS-logging (Borehole Image Processing System) are presented in Appendix 3.

Table 3-2. Activities performed in KLX08 prior and in connection to the chemical characterisation.

Activity	Date of completion	Length or section (m)	Comment
Percussion drilling	2005-01-24	0–100.33	
Core drilling	2005-06-13	100.33–1,000.41	
Hydrochemical logging	2005-07-12	0–990	/4/
Nitrogen lifting of water column	2005-09-24	0–1,000.4 0–995 0–990	Three separate liftings were performed.
BIPS-logging	2005-06-27 2005-09-08 2005-09-27	197–303 12–987.3 100–987.25	/5/
Differential flow logging	2005-10-25	100.9–987.0	/6/
Geophysical logging	2005-10-27	101.1–988.9	/7/

Table 3-3. Selected fractured/fracture zones identified from the differential flow logging of KLX08.

Section	Borehole length (m)	Flow (mL/h)	Comments
1	198	> 10,000	
2	479	> 10,000	
3	615	< 10,000	Planned repository depth, water flowing from the borehole into the fracture
4	852	< 10,000	Deep fracture zone
5	399 465 771	> 10,000 < 10,000 < 10,000	Optional sections

4 Equipment

4.1 The mobile field laboratory

The mobile field laboratories used by SKB for water sampling and downhole measurements consist of a laboratory unit, a hose unit with downhole equipment and a Chemmac measurement system, Figure 4-1; the system is presented schematically in Figure 4-2. It is also possible to include a separate unit for computer work (MYC). The different parts of the system are described in the SKB internal controlling documents SKB MD 434.004, 434.005, 434.006, 434.007 and SKB MD 433.018 (Mätsystembeskrivningar för mobil kemienhet allmän del, slangvagn, borrhålsutrustning, mobil ytChemmac och dataapplikation).

The Chemmac measurement facilities include communication systems, measurement application and flow-through cells with electrodes and sensors at the ground surface (surface Chemmac) and downhole (borehole Chemmac).

The downhole equipment comprises inflatable packers, pump, borehole Chemmac and the in situ sampling unit (PVP), allowing measurement (borehole Chemmac) and sampling in situ in the borehole section (PVP sampling unit). The four sampled portions of groundwater collected with the PVP sampling unit maintain the pressure from the borehole section when raised to the surface. The portions are used for colloid and gas analysis and microbe investigations.

The mobile units used for the investigation of borehole KLX08 consisted of the hose unit S2, the laboratory unit L2 and the computer unit MYC 2. The equipments used for colloid filtration, enrichment of humic and fulvic acids and fractionation of humic and fulvic acids are described below.

***Figure 4-1.** The mobile units used at KLX08; from left container for collecting the water from the borehole, laboratory unit, hose unit with downhole equipment and a unit for computer work.*

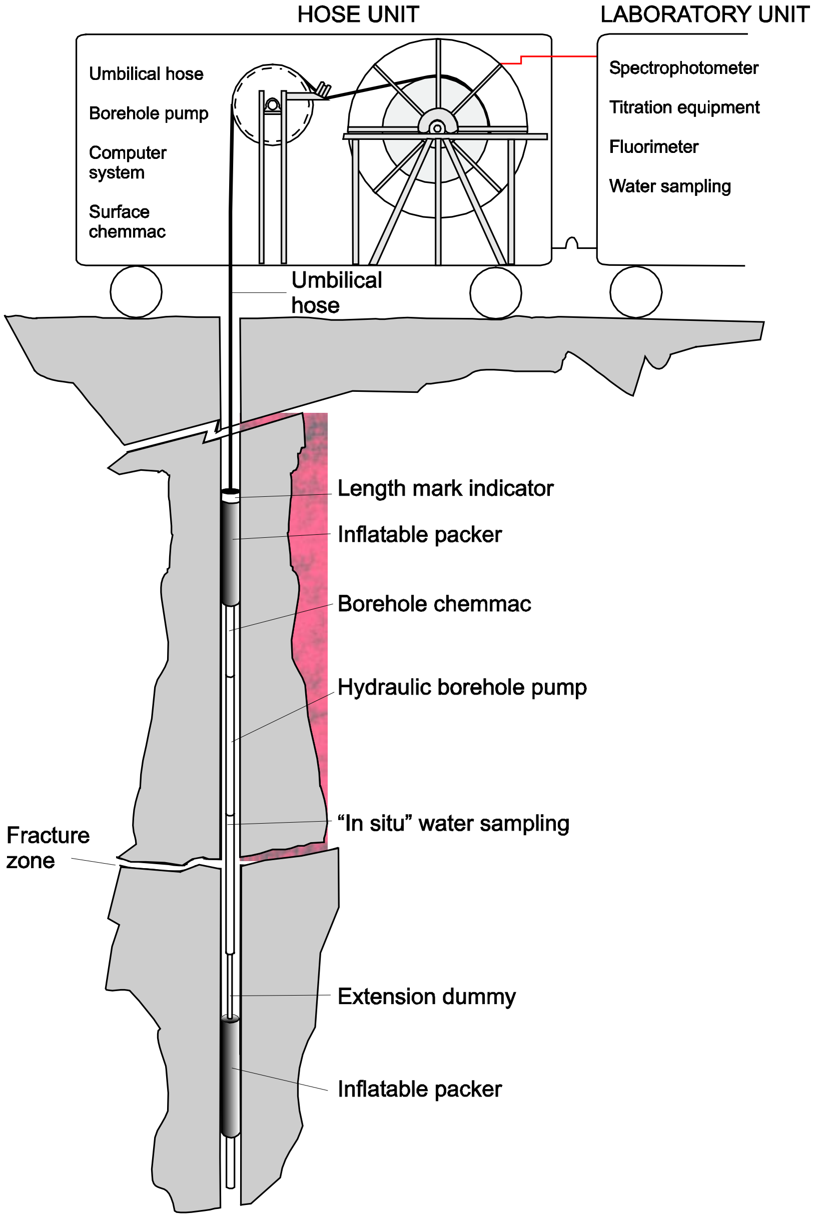


Figure 4-2. *The mobile laboratory including laboratory unit, hose unit and downhole equipment. The configuration of the downhole units in the borehole can be varied depending on desired section length. However, the in situ water sampler must always be positioned first in the sample water path.*

4.2 Colloid filtering equipment

The equipment is adapted to the sample containers (PVB) from the PVP water sampling unit. The colloid filtering equipment consists of holders for two PVB-containers, a separated tube and valve system for water and gas, a filter holder package for five filters, and a collecting container. The pore sizes of the five connected filters are 0.4, 0.4, 0.2, 0.05 and 0.05 µm. The equipment is described in SKB MD 431.045 (Mätsystembeskrivning för kolloidfiltreringssystem, handhavandedel (SKB internal controlling document to be published)). Figure 4-3 shows the equipment setup.

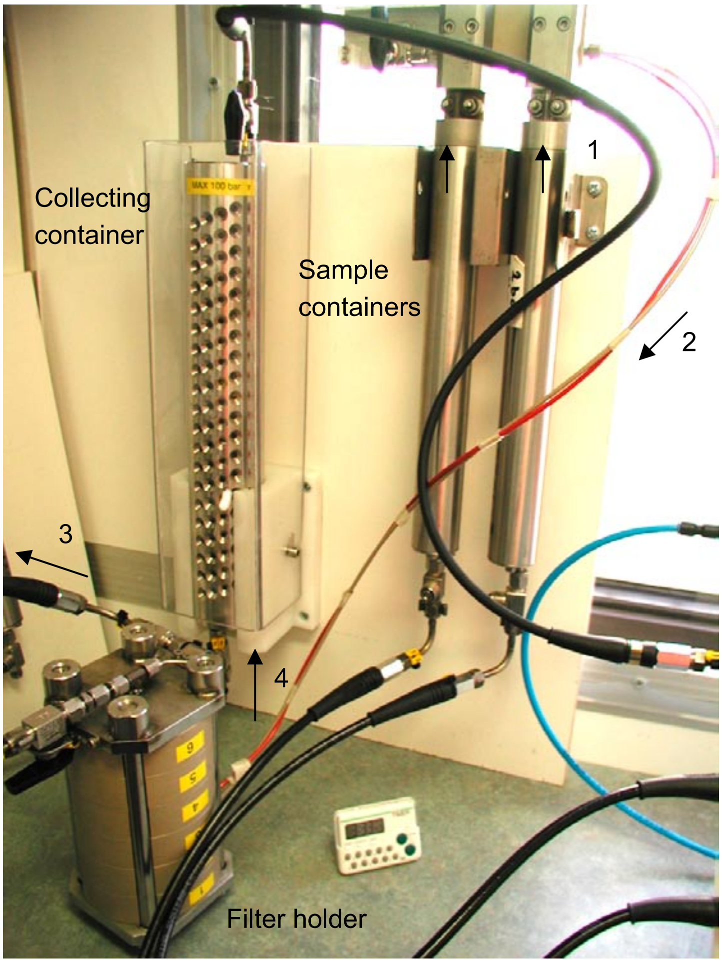


Figure 4-3. The colloid filtering equipment including the sample containers, the filter holder package and the collecting container. The black arrows, 1 to 4, show the flow direction of the sample water through the system.

The major equipment features are:

- Filtering is performed in a closed system under an argon atmosphere, thus avoiding the risk of iron precipitation due to contact between the groundwater sample and air.
- Filtering is performed at a pressure similar to that of the groundwater in the borehole section. The system is adjusted to create a pressure difference between the inlet of the filter package and the outlet side. The pressure difference drives the sample water through the filters.
- The design of the sample containers, and the mounting with the outlet at the top, prevents migration of larger particles that may clog the filters. Furthermore, clogging is prevented by the first two filters with pore sizes 0.4 µm which are mounted parallel to each other.

Disadvantages/drawbacks that may cause modifications of the equipment later on are:

- The sample volume is limited to a maximum of 2×190 mL.
- The PVB sample containers are made of stainless steel which may contaminate the samples. An improvement could be to use Teflon coating on the insides of the cylindrical containers.

4.3 Equipment for enrichment of humic and fulvic acids

Enrichment of humic and fulvic acids is conducted in order to collect enough material to determine $\delta^{13}C$ and pmC (percent modern carbon) on organic constituents in the groundwater. The equipment for enrichment includes a porous column filled with an anion exchanger (DEAE-cellulose) and a textile filter with a well-defined pore size. The textile filter is placed inside the column in order to prevent the ion exchange resin from diffusing through the column. The equipment and performance is described in SKB MD 431.044 (Mätsystembeskrivning för uppkoncentrering av humus- ch fulvosyror, SKB internal controlling document). Figure 4-4 shows the equipment setup. Since the ion exchange resin in the column creates a counter-pressure, which disturbs the water flow through the surface Chemmac, a pump was used for pumping a portion of the outlet water through the column (approximately 2.4 L/hour).

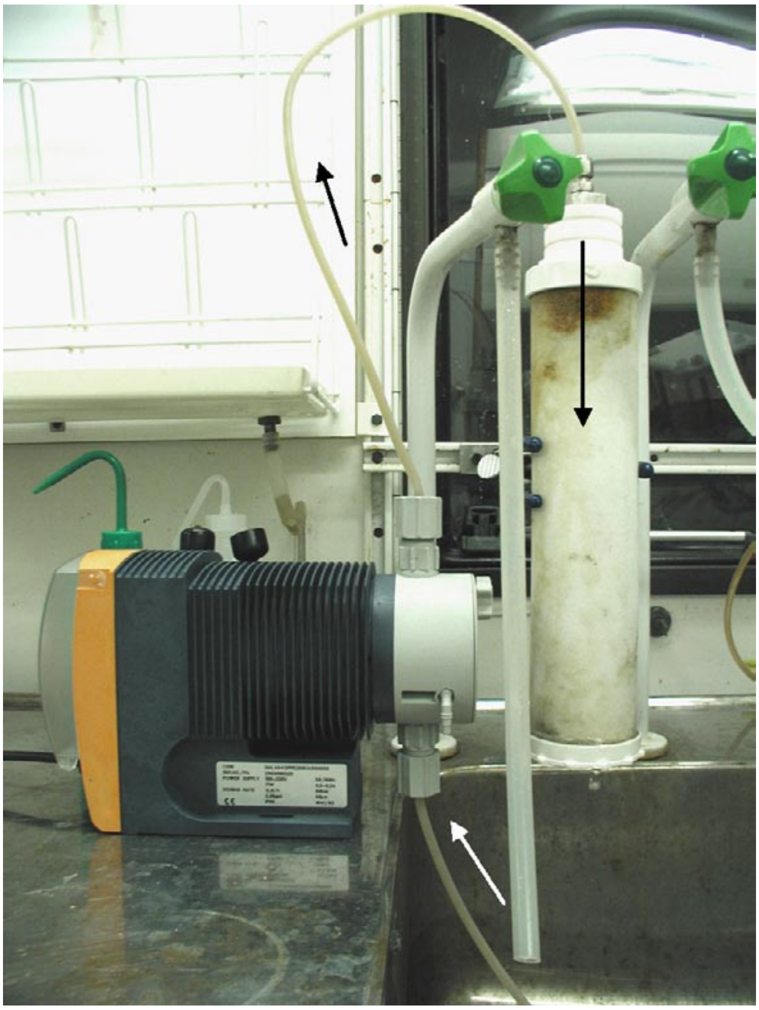


Figure 4-4. *The ion exchange column. The arrows show the water flow direction.*

4.4 Equipment for fractionation of humic and fulvic acids

The equipment consists of membrane filters with a defined cut-off (pore size), a membrane pump, flexible tubing and vessels. Generally, one water sample from each section is filtered through two filters with different pore sizes (1,000 D and 5,000 D, D=Dalton, 1 D=1 g/mol). The equipment and performance are described in SKB MD 431.043 (Mätsystembeskrivning för fraktionering av humus- och fulvosyror, SKB internal controlling document). Figure 4-5 shows the equipment setup and Figure 4-6 schematically describes the function of a membrane.

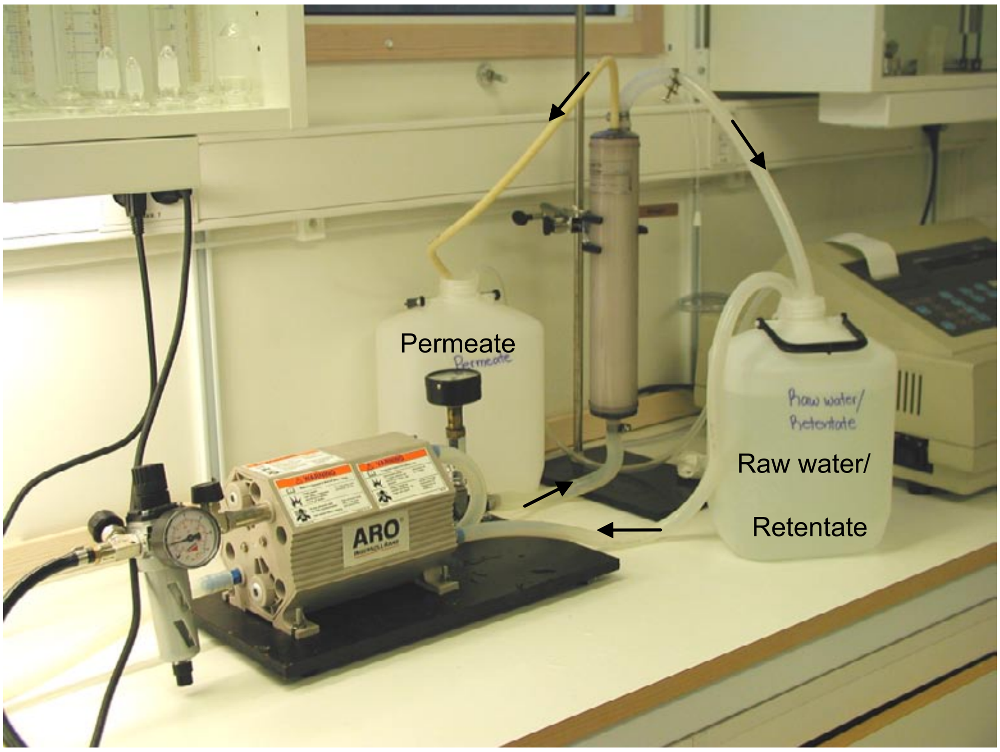


Figure 4-5. Equipment for fractionation of humic and fulvic acids.

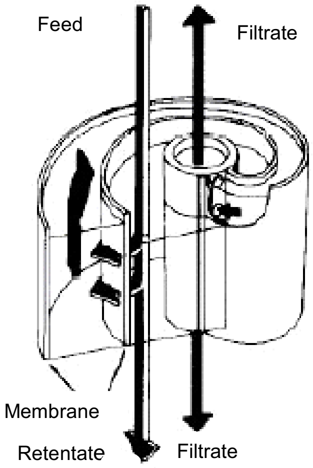


Figure 4-6. Outline of membrane filter with water flow directions.

5 Performance

5.1 General

Chemical characterisation in borehole KLX08 was conducted according to activity plan AP PS 400-05-047 following the method described in SKB MD 430.017 (Metodbeskrivning för fullständig karakterisering med mobilt fältlaboratorium). Table 5-1 gives an overview of the investigation sequence in KLX08.

Table 5-1. Investigation sequence in KLX08.

Start date/ Stop date	Section (m)	Comment
2005-11-22/ 2006-12-20	197.00–206.65	Pumped volume = 6.3 m^3 Flow rate approx. 180 mL/min
2006-01-03/ 2006-01-17	476.00–485.65	Pumped volume = 4.0 m^3 Flow rate approx. 40–200 mL/min Interrupted investigation
2006-01-17/ 2006-02-01	610.00–619.65	Pumped volume = 4.3 m^3 Flow rate approx. 200 mL/min Interrupted investigation
2006-02-02/ 2006-03-07	396.00–400.87	Pumped volume = 6.1 m^3 Flow rate approx. 150–190 mL/min
2006-03-08/ 2006-03-28	0–1,000.41	Clean-up pumping Pumped volume = 2,068 m^3 Flow rate approx. 77–84 L/min
2006-03-30/ 2006-04-03	610.00–619.62	Interrupted investigation
2006-04-03/ 2006-04-25	476.00–485.62	Pumped volume = 5.8 m^3 Flow rate approx. 200–250 mL/min Interrupted investigation
2006-05-03/ 2006-05-09 2006-05-09/ 2006-05-17	599.27–1,000.41 473.37–1,000.41	Clean-up pumping Pumped volume = 356 m^3 Flow rate approx. 15–23 L/min
2006-05-18/ 2006-06-27	476.00–485.62	Pumped volume = 9.5 m^3 Flow rate approx. 200 mL/min
2006-06-27/ 2006-07-27	609.00–618.51	Pumped volume = 5.2 m^3 Flow rate approx. 70–150 mL/min

The investigation started in section 197.0–206.6 m followed by section 476.0–485.6 m. Due to high flushing water content, the pumping was interrupted in the latter section and the equipment was lowered to section 610.0–619.6 m. However, also in this section the flushing water content was high and the pumping was interrupted. Following this, section 396.0–400.9 m was investigated successfully with a flushing water content of 1.2%. Clean-up pumping was performed from the entire borehole 2006-03-08 to 2006-03-28 but sections 610.0–619.6 m and 476.0–485.6 m still showed high flushing water content. An additional clean-up pumping was therefore performed 2006-05-03 to 2006-05-17. The investigations in sections 476.0–485.6 m and 609.0–618.5 m could then be carried out with flushing water contents of 5% and 11%, respectively. The total pumped volume during the clean-up pumping was 2,424 m^3.

5.2 Overview of field work procedure

A short chronological summary of the different steps that constitute chemical characterisation of groundwater in a borehole section is given below. Preparations before the downhole equipment is lowered in the borehole include:

- Cleaning of the inside of the umbilical hose (the sample water channel) with de-ionised and de-oxygenated water. Finally, the sample water channel is filled with de-ionised and de-oxygenated water prior to lowering.
- Cleaning and preparation of the four sample containers (PVB) belonging to the in situ water sampling unit (PVP). The containers are cleaned on the outside using 70% denatured ethanol and on the inside using chlorine dioxide. One of the containers is used for microbe sampling and sterile conditions are desirable. The containers are purged with nitrogen gas and a small nitrogen gas pressure is maintained in the containers. The magnitude of the pressure depends on the depth of the section to be sampled.
- Calibration of the pH and redox electrodes in the borehole Chemmac.

The different downhole units are assembled during lowering of the equipment in the borehole and the following steps are taken:

- The outside of the umbilical hose is cleaned with 70% denatured ethanol (SKB MD 600.004).
- Calibration of the umbilical hose length is conducted at least once for each borehole. For this, a length mark detector unit (caliper) is mounted together with the downhole equipment. The length mark detector indicates length calibration marks milled into the borehole wall at almost every 50 m along the borehole. At each indication, a reading is made of the corresponding length mark on the umbilical hose. The correct distance to each length mark is obtained from the SICADA database.

When the pump is started and the packers are inflated at the desired positions in the borehole, a pumping and measurement period begins. Typical measures taken and activities carried out during this period are:

- Calibration of the pH and redox electrodes as well as the electrical conductivity and oxygen sensors in the surface Chemmac is conducted when the pumped water from the borehole section has reached the surface.
- Careful attention is paid to ensure that the packed off section is well isolated from the rest of the borehole. A significant drawdown in the section during pumping is one indication that the section is properly sealed off. Leakage would cause pumping of water from the borehole column above and/or below the packers and not only from the fracture zone of interest. However, the drawdown in the borehole section must not be too large, because the greater the drawdown, the larger the bedrock volume affected by the pumping and the risk of mixing with groundwater from other shallower and/or deeper fracture systems increases.

The pumping flow rate is adjusted depending on the flow yield from the fracture or fracture zone (to between 50 and 300 mL/min) and maintained more or less constant during the pumping and measurement period.

- Water samples are collected regularly once or twice a week during the pumping period. Changes in water composition are monitored by pH and conductivity measurements and by immediate analyses (pH, Uranine, chloride, alkalinity, ammonium, ferrous and total iron).
- Enrichment of humic and fulvic acids is conducted for as long time as possible in each section. The time needed depends on the organic carbon concentration in the water and the flow rate through the ion-exchanger. Generally, a period of at least two weeks is needed to collect the amount of carbon required to determine $\delta^{13}C$ and pmC.
- Fractionation of humic and fulvic acids, as well as inorganic species to determine the size distribution, is performed at the end of the pumping period.
- A decision when to terminate the sampling work in the section is made during a suitable stage of the pumping and measurement period. The investigation might be prolonged if the concentration of flushing water exceeds 1% or if the redox potential measurements have not reached stable values. A final SKB Class 5 sample including all options is collected the day before termination.

Completion of the investigation in the section and lifting of the downhole equipment entails:

- Collection of in situ samples prior to lifting the equipment. The valves to the PVB sampling containers in the borehole section are opened in order to rinse the system and fill the containers. After a few hours the valves are closed and the water sample portions for analyses of colloids, dissolved gases and microbes are secured.
- Following stopping of the borehole pump and deflation of the packers, the equipment is lifted and the different downhole units are dismantled.
- Calibration of the electrodes in the borehole Chemmac and surface Chemmac.

Performance in the investigated borehole sections

The following sections (5.2.1–5.2.9) shortly describe the performance in each section. The main activities are presented in the events tables together with SKB sample numbers of the corresponding water samples. Due to high amounts of flushing water the investigations were interrupted twice and the borehole was subjected to clean-up pumping.

5.2.1 Performance in section 197.0–206.6 m

The chemical characterisation in section 197.0–206.6 m was performed using the following configuration of the downhole equipment in the borehole. From the top: umbilical hose, length mark detector, borehole Chemmac, upper packer, borehole pump, in situ water sampler (PVP), and lower packer, see Appendix 4. The pressures above and within the section were measured by the borehole Chemmac unit and the PVP water sampling unit, respectively.

The pumping flow rate was about 180 mL/min and the drawdown approximately 0 m at the end of the measurement period. Diagrams showing the pressures above and within the borehole section and the flow rate during the pumping/measurement period are presented in Appendix 5. The events during the investigation are listed in Table 5-2.

Table 5-2. Events during the pumping/measurement period in section 197.0–206.6 m.

Date	Event	Sample no.
051121	Calibration of borehole Chemmac	
051122	**Lowering of downhole equipment S2 (197.00–206.65 m)**	
	Start of Chemmac measurements	
	Defective magnet valve in the driving water pump	
	Stop of borehole pump	
	Exchange of magnet valve	
	Start of borehole pump	
051123	Calibration of surface Chemmac	
	Water sampling: Uranine	10639
051124	Lost contact with the borehole equipment, low water flow from the borehole pump	
	Stop of borehole pump	
	Lifting	
	Cleaning of contacts in the multi-connection	
	Exchange of borehole pump	
	Lowering of downhole equipment S2 (197.00–206.65 m)	
	Start of borehole pump and Chemmac measurements	
051125	Water sampling: SKB class 2	10640
051128	Water sampling: SKB class 2; pH, electrical conductivity, alkalinity, chlorinity, anions and Uranine	10641
	Clogged up non-return valve in the borehole pump	
	Stop of borehole pump	
	Lifting	
	Cleaning of the non-return valve	
	Lowering of downhole equipment (197.00–206.65 m)	
	Start of borehole pump and Chemmac measurements	
051130	Water sampling: SKB class 2; pH, electrical conductivity, alkalinity, chlorinity, anions and Uranine	10642
051201	Water sampling: SKB class 4	10643
051205	Water sampling: SKB class 5	10644
051206	Connection of computer network	
051208	Water sampling: SKB class 4	10645
051209	Water sampling: Uranine	10646
	Humic and fulvic acids; enrichment start	
	Restart of measurement application due to connection of network	
051212	Water sampling: SKB class 5	10647
	Restart of measurement application due to alarm	
051215	Water sampling: SKB class 4	10648
051216	Humic and fulvic acids; fractionation	10649
051219	Water sampling: SKB class 5, all options	10649
	Humic and fulvic acids; enrichment stop	10649
	Water sampling: SKB class 5, control sample. Density measurement	10650
	PVP-sampler: opening of valve at 17:26	
051220	Calibration of borehole and surface Chemmac.	
	PVP-sampler: closure of valve at 07:16	
	Sampling for microbes and dissolved gases	10649
	Cancelled colloid filtration due to defective equipment	
	End of Chemmac measurements	
	Raising equipment	

5.2.2 Interrupted investigation in section 476.0–485.6 (1) m

Table 5-3. Events during the pumping/measurement period in section 476.0–485.6 (1) m.

Date	Event	Sample no.
060102	Calibration of borehole Chemmac	
060103	**Lowering of downhole equipment S2 (476.00–485.65 m)**	
060104	Calibration of surface Chemmac	
060105	Water sampling: SKB class 2; pH, electrical conductivity, alkalinity, chlorinity and Uranine	10730
060109	Water sampling: Uranine	10731
060110	Water sampling: SKB class 4	10732
060111	Water sampling: Uranine	10733
060112	Water sampling: SKB class 4	10734
060113	Driving pump exchanged, due to leakage of oil	
060116	Water sampling: Uranine	10735
060117	Oxygen meter; cleaning and exchange of membrane, calibration	
	Interrupted investigation due to large amounts of flushing water	
	End of Chemmac measurement	
060201	Calibration of borehole Chemmac	
060202	Calibration of surface Chemmac	

5.2.3 Interrupted investigation in section 610.0–619.6 (1) m

Table 5-4. Events during the pumping/measurement period in section 610.0–619.65 (1) m.

Date	Event	Sample no.
060102	Calibration of borehole Chemmac	
060104	Calibration of surface Chemmac	
060117	**Lowering of downhole equipment (610.00–619.65 m)**	
060118	Water sampling: Uranine	10736
060119	Water sampling: Uranine	10739
060123	Water sampling: Uranine	10737
060124	Water sampling: SKB class 2; pH, electric conductivity, alkalinity, chlorinity, anions and Uranine	10738
060127	Water sampling: SKB class 2; pH, electrical conductivity, alkalinity, chlorinity and Uranine	10740
	Interrupted investigation due to large amounts of flushing water	
050201	**End of Chemmac measurements**	
	Raising equipment	
	Calibration of borehole Chemmac	
060202	Calibration of surface Chemmac	

5.2.4 Performance in section 396.0–400.9 m

The chemical characterisation in section 396.0–400.9 m was performed using the following configuration of the downhole equipment in the borehole. From the top: umbilical hose, length mark detector, borehole Chemmac, upper packer, borehole pump, in situ water sampler (PVP), and lower packer, see Appendix 4. The pressures above and within the section were measured by the borehole Chemmac unit and the PVP water sampling unit, respectively.

The pumping flow rate was about 150–190 mL/min and the inflow approximately 0.4 m at the end of the measurement period. Diagrams showing the pressures above and within the borehole section and the flow rate during the pumping/measurement period are presented in Appendix 5. The events during the investigation are listed in Table 5-5.

Table 5-5. Events during the pumping/measurement period in section 396.0–400.9 m.

Date	Event	Sample no.
060201	Calibration of borehole Chemmac	
060202	**Lowering of downhole equipment (396.00–400.87 m)**	
060202	Calibration of surface Chemmac	
	Start of Chemmac measurements	
060203	Water sampling: SKB class 2	10741
060207	Water sampling: SKB class 5	10794
060209	Water sampling: SKB class 4	10795
060210	Humic and fulvic acids; enrichment start	
060213	Low water flow from borehole pump (120 mL/min)	
060214	Water sampling: SKB class 5	10742
	Surface Chemmac temporary not in use due to exchange of electrode holder	
060217	Water sampling: SKB class 4	10743
060220	Water sampling: SKB class 5	10744
060220	Leakage of oil from the driving pump	
060221	Humic and fulvic acids; fractionation 1 kD	10746
060222	Humic and fulvic acids; fractionation 5 kD	10746
060223	Water sampling: SKB class 4	10745
060227	Water sampling: SKB class 5	10746
	An SKB class 5 control sample was not collected due to low water flow (35 mL/min)	
	PVP-sampler: opening of valve at 17:00	
060228	PVP-sampler: closure of valve at 06:40	
	Sampling for microbes and dissolved gases, however, the PVB containers were not sent for analysis due to small volumes of sampled water in two PVBs and low pressure in one PVB.	
	Sampling for colloids, one PVB container. Only the results from the second sampling occasion with two PVB containers are reported.	
	End of Chemmac measurements	
	Raising equipment	
	Calibration of borehole Chemmac	
	Prolonged measurement due to defective PVP equipment	
	Lowering of downhole equipment (369.00–400.87 m)	
060301	Calibration of surface Chemmac	
060306	Water sampling: SKB class 5, all options	10747
	Water sampling: SKB class 5, control sample	10748
	Humic and fulvic acids; enrichment stop	
	PVP-sampler: opening of valve at 17:30	
060307	PVP sampler: closure of valve at 06:11	
	Sampling for colloids, microbes and dissolved gases	10747
	End of Chemmac measurements	
	Raising equipment	
	Calibration of borehole Chemmac	
	Calibration of surface Chemmac	
060308–060328	Clean-up pumping (0–1,000.41 m) Water sampling: SKB class 1; Electrical conductivity and Uranine	10868, 10870, 10871, 10884, 10890, 10898, 10901, 10903, 10904, 10908, 10923, 10933, 10934, 10939

5.2.5 Interrupted investigation in section 610.0–619.6 (2) m

Table 5-6. Events during the pumping/measurement period in section 610.0–619.6 (2) m.

060329	Calibration of borehole Chemmac
060330	**Lowering of downhole equipment (610.00–619.62 m)**
060331	Calibration of surface Chemmac
060403	**End of chemmac measurements**
	Raising equipment from 610.00–619.62 to 476.00–485.62 m

5.2.6 Interrupted investigation in section 476.0–485.6 (2) m

Table 5-7. Events during the pumping/measurement period in section 476.0–485.6 (2) m.

060329	Calibration of borehole Chemmac	
060331	Calibration of surface Chemmac	
060403	**Raising equipment from 610.00–619.62 to 476.00–485.62 m**	
060404	Water sampling: SKB class 2; pH, electrical conductivity, alkalinity, chlorinity and Uranine	10750
060406	Water sampling: SKB class 4.	10954
060408	Defective spring in borehole pump	
060413	Water sampling: SKB class 1; Uranine	10955
060412	**Raising equipment**	
	Exchanged borehole pump	
	Lowering of downhole equipment (476.00–485.62 m)	
060418	Water sampling: SKB class 4	10956
060420	Water sampling: SKB class 2; pH, electrical conductivity, alkalinity, chlorinity and Uranine	10957
060424	Water sampling: SKB class 2; pH, electrical conductivity, alkalinity, chlorinity and Uranine	10958
	Interrupted investigation due to large amounts of flushing water	
060425	**Raising of equipment**	
	Calibration of borehole Chemmac	
	Calibration of surface Chemmac	
060503–060517	Clean-up pumping (599.27–1,000.41 m and 473.37–1,000.41 m) Water sampling: SKB class 1; Electrical conductivity and Uranine	11015-26 and 11027–11028, 11045–11056

5.2.7 Performance in section 476.0–485.6 (3) m

The chemical characterisation in section 476.0–485.6 m was performed using the following configuration of the downhole equipment in the borehole. From the top: umbilical hose, length mark detector, borehole Chemmac, upper packer, borehole pump, in situ water sampler (PVP), and lower packer, see Appendix 4. The pressures above and within the section were measured by the borehole Chemmac unit and the PVP water sampling unit, respectively.

The pumping flow rate was about 200 mL/min and the drawdown approximately 1.2 m at the end of the measurement period. Diagrams showing the pressures above and within the borehole section and the flow rate during the pumping/measurement period are presented in Appendix 5. The events are listed in Table 5-8.

Table 5-8. Events during the pumping/measurement period in section 476.0–485.6 (3) m.

060518	Calibration of borehole Chemmac	
060519	**Lowering of downhole equipment S2 (476.00–485.62 m)**	
060522	Water sampling: SKB class 4	10959
	No connection with PVP equipment	
	Calibration of surface Chemmac	
060523	Calibration of oxygen meter	
060524	Water sampling: SKB class 4	11087
	Low water flow due to leakage of water in borehole pump	
060529	**Raising equipment**	
	Exchange of borehole pump and PVP	
	Lowering of downhole equipment S2 (476.00–485.62 m)	
060530	Water sampling: SKB class 5	11094
	No electric power supply due to thunderstorm	
060531	**Raising equipment**	
	Low water flow due to defect spring in borehole pump. Exchange of borehole pump	
	Lowering of downhole equipment S2 (476.00–485.62 m)	
060601	Water sampling: SKB class 4	11088
	Humis and fulvic acids; enrichment start	
060607	Water sampling: SKB class 5	11115
060609	Water sampling: SKB class 4	11118
060612	Water sampling: SKB class 5	11143
060612	Humic and fulvic acids; fractionation 1 kD	11183
060613	Humic and fulvic acids; fractionation 5 kD	11183
060615	Water sampling: SKB class 4	11158
060619	Water sampling: SKB class 5	11159
060621	Water sampling: SKB class 4	11178
060626	Water sampling: SKB class 5, all options	11183
	Water sampling: SKB class 5, control sample	11160
	Humic and fulvic acids; enrichment stop	
	PVP-sampler: opening of valve at 12:18	
060627	PVP-sampler: closure of valve at 06:37	
	Sampling for colloids, microbes and dissolved gases	11183
	End of Chemmac measurements	
	Raising equipment	
	Calibration of borehole Chemmac	
	Calibration of surface Chemmac	
061128	A 250 ml archive sample with SKB number 11087 (new SKB number 11540) are sent to University of Waterloo in Canada for re-analysis of ^{3}H.	11540
061227	A 250 ml archive sample with SKB number 11087 (new SKB number 11548) are sent to a laboratory in Krakow, Poland, for analysis of ^{3}H.	11548
070202	A 250 ml sample of deionised water from the tank for the driving water pump and hydraulic borehole pump is analysed for ^{3}H at CLAB (laboratory at SKB).	11685
070207	A 250 ml sample of deionised water from the tank supplying the smaller tank for the driving water pump and hydraulic borehole pump is analysed for ^{3}H at CLAB (laboratory at SKB).	11686

5.2.8 Performance in section 609.0–618.5 (3) m

The chemical characterisation in section 609.0–618.5 m was performed using the following configuration of the downhole equipment in the borehole. From the top: umbilical hose, length mark detector, borehole Chemmac, upper packer, borehole pump, in situ water sampler (PVP), and lower packer, see Appendix 4. The pressures above and within the section were measured by the borehole Chemmac unit and the PVP water sampling unit, respectively.

The pumping flow rate was about 70–150 mL/min and the drawdown approximately 0.3 m at the end of the measurement period. Diagrams showing the pressures above and within the borehole section and the flow rate during the pumping/measurement period are presented in Appendix 5. The events during the investigation are listed in Table 5-9.

Table 5-9. Events during the pumping/measurement period in section 609.0–618.5 (3) m.

060627	Calibration of borehole Chemmac	
060628	**Lowering of downhole equipment S2 (609.00–618.51 m)**	
	Calibration of surface Chemmac, Addition of an oxygen electrode after the swivel in S2 for comparison with the oxygen electrode in MYC2. Manual readings.	
060629	Water sampling: SKB class 2	11205
060630	Water sampling: Uranine	11207
060703	Water sampling: SKB class 4	11211
060706	Water sampling: SKB class 4	11216
	Loss of contact with borehole Chemmac	
060710	Water sampling: SKB class 4	11218
060712	**Raising equipment**	
	Re-calibration of oxygen electrode in MYC2	
	Disconnection and repair of borehole Chemmac	
	Lowering of downhole equipment S2 (609.00–618.51 m)	
060713	Low water flow caused by leakage in swivel, repair	
060714	Water sampling: SKB class 4	11219
060717	Water sampling: SKB class 5	11222
060720	Water sampling: SKB class 4	11229
060724	Water sampling: SKB class 5	11226
060725	Defrosting of cooling equipment in S2	
060726	Water sampling: SKB class 5, all options	11228
	Water sampling: SKB class 5, control sample	11227
060726	PVP-sampler: opening of valve at 15:25	
060727	PVP-sampler: closure of valve at 06:06	
	Sampling for colloids and dissolved gases	11228
	End of Chemmac measurements	
	Raising equipment	
	Calibration of surface Chemmac	

5.3 Water sampling, sample treatment and analyses

The pumped water from the borehole section is led from the hose unit into the laboratory unit where sampling and sample filtration is carried out. Filtration of sample portions is performed on-line by connecting the filter holders directly to the water outlet. A water sample is defined as groundwater collected during one day and consists of several sample portions, labelled with the same sample number.

An overview of sample treatment and analysis methods is given in Appendix 10. The routines are applicable independently of sampling method or type of sampling object.

5.4 Collection of in situ water samples

The in situ water sampling was conducted successfully in sections 476.0–485.6 and 609.0–618.5 m. The microbe investigation in section 609.0–618.5 m was cancelled due to summer vacation. There was no filtration of colloids in section 197.0–206.6 m due to defective equipment. The investigation in section 396.0–400.9 m was prolonged and a second in situ sample collected, since two of the PVB containers were malfunctioning.

All of the PVB containers were quality controlled before use; this procedure includes disassembling of the container, thorough cleaning, reassembling and measurement of piston friction. The filled PVB containers were packed together with ice packs in insulated bags and sent to the laboratories by express delivery service immediately after sampling.

The purpose of each sample portion is given in Table 5-10.

5.5 Colloid filtration

Colloid filtration was performed in three of the investigated sections, 396.0–400.9 m, 476.0–485.6 m and 609.0–618.5 m. In section 197.0–206.6 m, the performance was cancelled due to defective equipment. The method for sampling of colloids in groundwater entails filtering the groundwater through a series of connected filters in a closed system under an argon atmosphere. The pressure in the system is maintained at the same level as the pressure in the sampled borehole section. The intention is that colloids should be collected on the different filters (descending pore sizes) according to their sizes. Two of the four sample portions collected in situ in each borehole section are used for colloid filtration. Data on performance of the filtration runs are given in Table 5-11.

A leakage test of the system at 10 bars was also done prior to the sampling in order to eliminate the risk of leakage. If no leakage was detected, the system was dried and assembled.

Each filtration results in five filter samples (two 0.4 µm, one 0.2 µm and two 0.05 µm filter pore sizes) and two water samples (water in and water out). All samples were sent for ICP analyses (major constituents and common trace metals).

Table 5-10. Collection and purpose of in-situ water sample portions.

Sample portion no.	Section 197.0–206.6 m 2006-12-20	Section 396.0–400.9 m 2006-03-07	Section 476.0–485.6 m 2006-06-27	Section 609.0–618.5 m 2006-07-27
1	Dissolved gas (Paavo Ristola)	Dissolved gas (Paavo Ristola)	Dissolved gas (Paavo Ristola)	Dissolved gas (Paavo Ristola)
2	Microbes (MICANS)	Microbes (MICANS)	Microbes (MICANS)	–
3	–	Colloids	Colloids	Colloids
4	–	Colloids	Colloids	Colloids

Table 5-11. Colloid filtration, data on performance.

Section/date	Entering pressure [bar]	Max. differential pressure over filter package [bar]	Temp. [°C]	Filtering time [min]	Filtered volume [ml]	Comments
396.0–400.9 m /20060307	~34	3.9	~11	148	286	Leakage test prior to filtration. No leakage was noticed.
476.0–485.6 m /20060627	~41	10.2	~19	59	160*	Leakage test prior to filtration. No leakage was noticed.
609.0–618.5 m /20060727	~53	4.4	~16	35	314	Leakage test prior to filtration. No leakage was noticed.

* Only one PVB container was filtered.

5.6 Enrichment of humic and fulvic acids

Enrichment of humic and fulvic acids was conducted in order to collect enough material to determine $\delta^{13}C$ and pmC in organic constituents in the groundwater. The method is described in SKB MD 431.044 (Mätsystembeskrivning för uppkoncentrering av humus- och fulvosyror). The enrichment method entails collection of organic acids on an ion exchanger, eluation of the resin and evaporation of the resulting solution. The dry residue is used for isotope determination and a minimum amount of 10 mg organic carbon is needed. In addition to organic material, the residue also contains sodium hydroxide from the eluation. The sample is acidified in order to prevent the formation of carbon dioxide. No enrichment was performed in section 609.0–618.5 m because of the high flushing water content.

Estimations of total duration and water volume through the ion exchanger are given in Table 5-12.

5.7 Fractionation of humic and fulvic acids

Humic and fulvic acids were fractionated with respect to molecular weight using an ultrafiltration technique. The method is described in SKB MD 431.043 (Mätsystembeskrivning för fraktionering av humus- och fulvosyror, SKB internal controlling document).

Fractionation of humic and fulvic acids were made on samples from sections 197.0–206.6, 396.0–400.9 and 476.0–485.6 m. For section 609.0–618.5 m, the fractionation was excluded due to the high content of remaining flushing water.

Sampled water from the investigated sections was first filtered through a 0.45 µm filter and then filtered through membrane filters with cut-off sizes of 1,000 D and 5,000 D, respectively. The initial water volume, prior to filtration, was approximately 5 litres. The final retentate and permeate volumes following the filtration runs were approximately 1 and 4 litres, respectively, which gave an enrichment factor of five in the retentate.

Table 5-12. Enrichment time and water volume through the ion exchanger.

Borehole section [m]	Duration of enrichment [days]	Volume through ion exchanger [L]
197.0–206.6	11	670
396.0–400.9	21	1,100
476.0–485.6	21	1,200

Water samples were collected from the retentate and the permeate as well as from the untreated groundwater. Each sample was analysed for dissolved organic carbon (DOC), major constituents and common trace metals. The analyses of metal ions should indicate if metals such as Al, Si, Mn and Fe exist as colloidal species.

5.8 Nonconformities

The Complete chemical characterisation in KLX08 has been conducted according to the SKB internal controlling documents AP PS 400-05-047 and SKB MD 430.017 with the following deviations and remarks:

- The readings from the oxygen electrodes were not reliable. The cause might be defective electrodes or insufficient calibration routines.
- The colloid filtration in section 197.0–206.6 m was cancelled due to defective equipment.
- No control sample (an additional SKB class 5 sample) was taken in section 396.0–400.9 m since the water flow was too low. The cause was a defective driving pump.
- The in situ sampling in section 396.0–400.9 m was repeated since two of the PVB containers were not completely filled with water and were unable to maintain section pressure during raising of the equipment.
- The investigations in sections 476.0–485.6 m and 609.0–618.5 m were interrupted twice due to high flushing water content. The borehole was pumped for clean-up at two occasions; see Table 5-5 and Table 5-7.
- During the investigation in section 476.0–485.6 m, there was a leakage of de ionised water from the hydraulic borehole pump, which resulted in deionised water mixing with the sampled groundwater from the section. The deionised water contained ^{3}H and gave enhanced concentrations in some of the water samples from this section (Figure 7-18 and Appendix 11).
- The investigation in section 476.0–485.6 m was prolonged with one week in order to reach low and stable values from the redox electrodes.
- The fractionation and enrichment of humic and fulvic acids was cancelled in section 609.0–618.5 m due to high flushing water content.
- The allowed upper limit for flushing water content, 1%, was exceeded in all of the sections. In sections 197.0–206.6 m and 396.0–400.9 m, it was just above the limit (average 1.5% and 1.2%, respectively) and in sections 476.0–485.6 m and 609.0–618.5 it was about 5% and 11%, respectively.
- Some equipment malfunctions were encountered during the investigation:
  - defective driving water pump and borehole pump,
  - loss of connection with the multi-tube and the borehole- and surface Chemmac,
  - defective PVB containers,
  - defective colloid filtration equipment.

6 Data handling and interpretation

6.1 Chemmac measurement data

The processing of Chemmac data are described in SKB MD 434.007-02 (Mätsystembeskrivning för Chemmac mätsystem, SKB internal controlling document, in progress).

6.1.1 Data file types and calculation software

The on-line measurements in a borehole section produce the following types of raw data files:

- Calibration files from calibration measurements (*.CRB) and corresponding comment files (*.CI). The files are used for calculation of calibration constants (pH and Eh) and the calibration factor (electrical conductivity). For surface Chemmac ten *.CRB and ten *.CI files are produced, and for borehole Chemmac six *.CRB and six *.CI files.
- Raw data file containing the logged measurements from the borehole section and the surface (*K.MRB) as well as a corresponding comment file (*.MI). The logged voltage values need to be converted to pH and Eh values (also in mV) using the calibration constants obtained from calibration.
- Measurement file including equipment and environment parameters (*O.MRB), such as power consumption in the downhole Chemmac unit and temperature inside the hose unit.

The original raw data files listed above are stored in the SICADA file archive. Furthermore, the files are re-calculated and evaluated to obtain pH and redox potential values and to correct the electrical conductivity values using the specially designed calculation software (Hilda). The resulting files containing calculated and evaluated values as well as comments on the performance are:

- A file **constants.mio* containing all the calculated calibration constants (one constant for each electrode in each buffer solution). The file is stored in the SICADA file archive and is useful in order to follow the development of single electrodes.
- A file **measurements.mio* containing the calculated and evaluated measurement values (pH, redox potential, electrical conductivity and water temperature). The data from the file are exported to the data tables “redox” and “ph_cond” in SICADA. As the file also contains some measured parameters that are not included in the tables mentioned above (e.g. pressure registrations) the complete file is also stored in the SICADA file archive.
- A file **comments.mio* containing comments on the field work and the calculation/evaluation. The comments in the file are imported as activity comments in SICADA.

6.1.2 Calculations and evaluation of pH and redox potential

The redox potential is measured by three electrodes at the surface and three in the borehole section. In addition, pH is measured by two electrodes at the surface and two in the borehole section. The registrations by the redox and the pH electrodes are logged each hour during a measurement period of approximately three weeks and a calibration is performed before and after the measurement period. The treatment of the raw data includes the following steps:

- Calculation and choice of calibration constants.
- Calculation of one pH and one redox potential sequence for each electrode (i.e. three or six redox electrodes and two or four pH electrodes).
- Determination of representative pH and redox potential values as well as estimated measurement uncertainties for the investigated borehole section.

One calibration constant is selected for each electrode using one of the following alternatives:

- Case 1: Calculation of the average calibration constant value and the standard deviation. The initial and the final calibration measurements results in four constants for each redox electrode (in pH 4 and pH 7 buffer solutions) and six constants for each pH electrode (in pH 4, 7 and 10 buffer solutions).
- Case 2: The calibration constant obtained from the initial calibration measurement at pH 7 is selected since it is closest to the pH of the borehole water. This alternative is chosen if the calibration constants obtained in the different buffers show a large variation in value (generally a difference larger than 20 mV between the highest and the lowest value). The standard deviation is calculated in the same way as in Case 1.
- Case 3: If the final calibration constants turn out to be very different (more than 20 mV) from the initial constants, a linear drift correction is needed. The reason is most often a drift in the reference electrode. The values and standard deviations are calculated for the initial and the final calibration constants separately and a linear correction is made between the selected initial and the selected final constant. The higher of the two standard deviation values is used in the estimation of the total measurement uncertainty.

The values in the measurement raw data file are converted to pH and Eh measurement sequences for each pH and redox electrode using the calibration constant selected as stated above.

The next step is to choose a logging occasion in a stable part of the measurement period and select a representative result for each electrode. The average values are calculated for each electrode group in order to obtain one representative value of redox potential, pH (borehole Chemmac) and pH (surface Chemmac), respectively. Obviously erroneous electrodes are omitted. The corresponding total measurement uncertainties are estimated using the standard deviations of the calibration constants and the standard deviations of the Eh and the pH values obtained by the different sets of electrodes. It is useful to evaluate pH at the surface and pH in the borehole section separately, since pH in the pumped water might differ from the pH measured in the borehole section. This is due to changing gas pressure conditions and its effects on the carbonate system.

Factors considered when evaluating the measurement uncertainties in pH and redox potential (Eh) values are:

- Difference in calibration constants for each electrode and calibration/buffer solution.
- Drift in calibration constants between the initial and the final calibration.
- Stability in voltage value during the final part of the on-line measurement. A successful measurement shows no tendency of a slope.
- Agreement between the different pH and redox electrodes on the surface and in the down-hole borehole Chemmac.
- Number of electrodes showing reasonable agreement. Obviously erroneous electrodes are excluded from the calculation.

6.2 Water analysis data

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

Some components are determined by more than one method and/or laboratory. Moreover, duplicate analyses by an independent laboratory are performed as a standard procedure on each fifth or tenth collected sample. All analytical results are stored in the SICADA database. The applied hierarchy path “Hydrochemistry/Hydrochemical investigation/Analyses/Water in the database” contains two types of tables, raw data tables and primary data tables (final data tables).

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

Comparison of the results from different laboratories and/or methods. The analyses are repeated if a large disparity is noted (generally more than 10%).

Calculation of charge balance errors according to the equation below. Relative errors within ± 5% are considered acceptable (in surface waters ± 10%).

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

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

All results from *special analyses of trace metals and isotopes* are inserted directly into primary data tables. In 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 6-1.

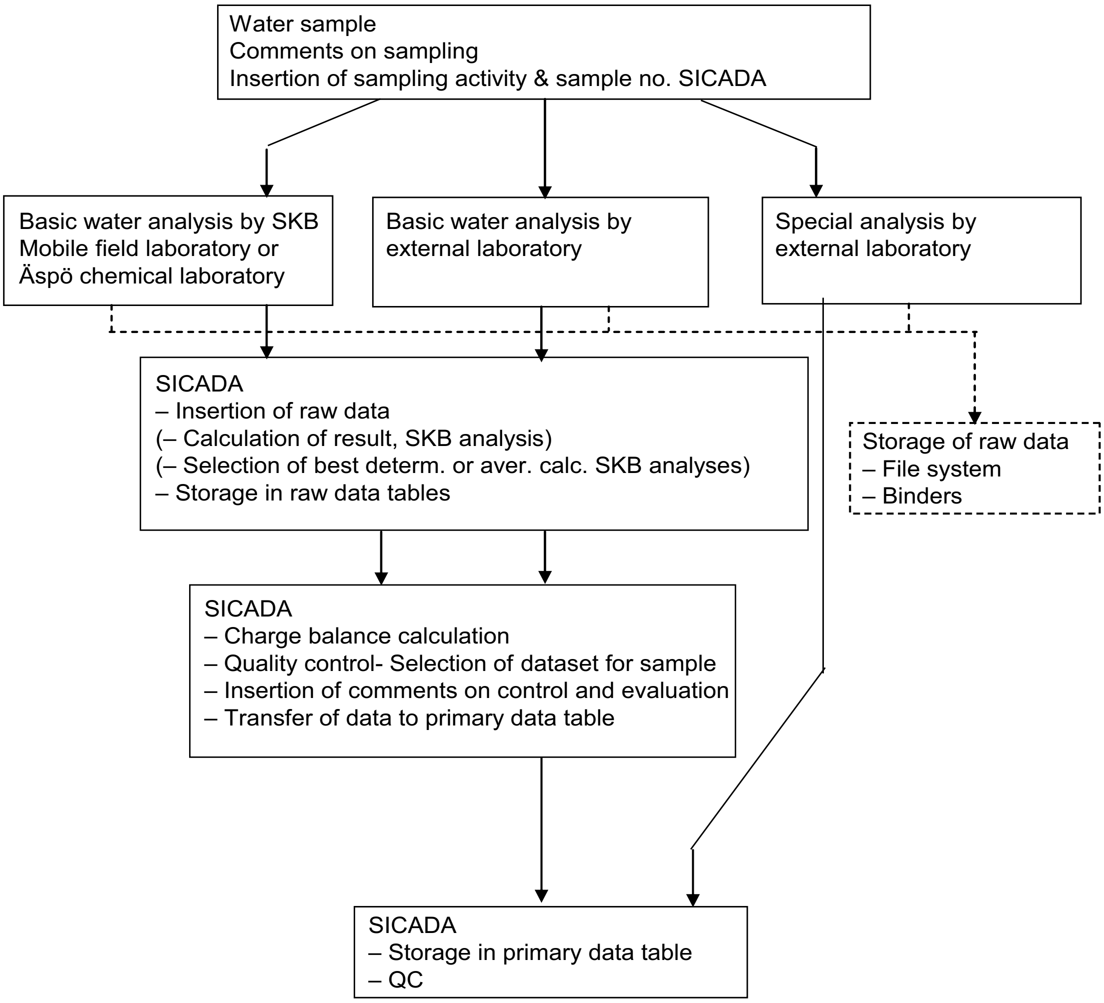


Figure 6-1. *Overview of data management for hydrogeochemical data.*

6.3 Data from special sampling methods

Special sampling methods include collection of in situ samples (colloid filtration and dissolved gases), enrichment and fractionation of humic and fulvic acids.

Separate sampling activities, methods and sample numbers are defined for data on dissolved gases, colloids, fractions of humic and fulvic acids and δ^{13}C and pmC determined on organic constituents. All analytical data are subjected to quality control and stored in the SICADA database.

6.3.1 Colloid filtration

The concentration of the colloid portion caught on each filter is calculated with the assumption that the water volume coming out in the collecting container is equal to the volume going into the system. This is not quite true as up to ten millilitres will be left in cavities in the filter holder package, in the tubing and in valves. A small volume of about 0.01 to 0.06 mL is left in each filter after the filtration and its content of the different elements is included in the analysis. The measurement uncertainty of each colloid concentration is calculated from the "sum" of the measurement uncertainties of the filter analyses and estimated volume error (volume passing through the filters) according to the equation below:

$$U = \sqrt{\left(\frac{1}{V^2} \cdot (\Delta m)^2 + \frac{m^2}{V^4}(\Delta V)^2\right)}$$

where

U = measurement uncertainty [µg/L],

V = water volume through the system [L],

ΔV = estimated volume error, 0.010 L,

m = amount on filter [µg],

Δm = measurement uncertainty of the filter analysis, 20% [µg].

The calculated results from the colloid filtration, filters, are stored in SICADA. The results from water samples are directly inserted into the primary data tables in SICADA.

6.3.2 Dissolved gases

The results of the gas analyses are stored in the primary data tables in SICADA without processing or interpretation.

6.3.3 Enrichment of humic and fulvic acids

The pmC and δ^{13}C values for enriched organic acids are stored in SICADA without processing or interpretation.

6.3.4 Fractionation of humic and fulvic acids

The concentrations of organic and inorganic constituents in the retentate and permeate are re-calculated to concentrations of each fraction of carbon and metal ions with molecular weight lower or higher than the cut-off size of the filter. This is done using mass balance equations as described in SKB MD 431.043, (Mätsystembeskrivning för fraktionering av humus- och fulvosyror). Comparison of the four concentration values from the two filters results in values for three fractions i.e. < 1,000 D, 1,000 – 5,000 D and > 5,000 D.

7 Results

7.1 Chemmac measurements

The redox potentials in borehole Chemmac were negative in all of the four investigated sections. The reducing conditions in the borehole are consistent with the presence of iron as ferrous iron (Fe(+II)). The redox potentials in surface Chemmac were in general less negative than those for borehole Chemmac, which has also been frequently observed in previous measurements. Even traces of oxygen can affect the redox electrodes and give less negative or positive redox values.

The oxygen measurement values were above zero in all sections despite re-calibrations and change of membranes. In section 609.0–618.5 m an additional oxygen probe was placed directly after the swivel in the hose unit (S2) for comparison with the existing probe in the surface Chemmac (MYC-unit), in order to assess the reliability of the oxygen probes. The readings of the hose unit probe gave consistently lower values. This difference could be caused by oxygen intrusion. However, a more plausible explanation is inaccurate oxygen readings. To remediate this, deoxygenated water should be used to verify electrode readings in the low measurement range. In addition, calibration with a reference gas should be considered.

The measurement data sequences were evaluated in order to obtain one representative value each of redox potential, pH, electric conductivity and dissolved oxygen as described in section 6.1. Data were selected (marked with an arrow) from a part of the measurement sequences where the electrodes show the most stable values. The measurement sequences of Eh, pH, electrical conductivity, dissolved oxygen and water temperature are plotted versus time in Appendices 6 to 9. The evaluated results from the measurements in the four investigated sections are given in Table 7-1.

The redox potentials in section 197.0–206.6 m show stable and negative values (except for the platinum electrode in surface Chemmac, which was slightly positive). The redox potentials from the borehole Chemmac were selected as representative values since, in general, redox measurements tend to be biased towards more positive redox potentials rather than the opposite.

The redox potentials in section 396.0–400.9 m were negative and stable before the interruption of the measurements. An average value of the redox potentials in borehole Chemmac was selected.

Table 7-1. Evaluated results from the Chemmac measurements in KLX08.

Borehole section [m]	Electrical conductivity* [mS/m]	pH (borehole chemmac)**	pH (surface chemmac)**	Eh ** [mV]	Dissolved oxygen*** [mg/L]
197.0–206.6	49.8 ± 1.5	8.1 ± 0.1	8.4 ± 0.2	–266 ± 8 B	0.10
396.0–400.9	45.2 ± 1.4	8.0 ± 0.1	8.3 ± 0.2	–245 ± 24 B	0.06
476.0–485.6	525 ± 16	7.6 ± 0.2	8.1 ± 0.3	–210 ± 52 B	0.18
609.0–618.5	642 ± 19	8.4 ± 0.2	8.4 ± 0.3	–239 ± 11 C	0.06

* The electrical conductivity is measured between 0–10,000 mS/m with a total uncertainty of 3%.

** Evaluated result and measurement uncertainty calculated as described in section 7.1.

*** Measurement interval 0–15 mg/L, resolution and measurement uncertainty ± 0.001 mg/L.

B Only values from borehole Chemmac have been used in the calculation.

C The calculation is based on the carbon electrode in surface Chemmac.

In section 476.0–485.6 m, the redox potentials were negative, but not stable or consistent amongst electrodes. An average value of the redox potentials in borehole Chemmac was selected. The resulting redox potential is uncertain, but the lower redox potential of the carbon electrode is considered more likely than those obtained from the gold- and platinum electrodes.

During the Chemmac measurements in section 609.0–618.5 m there were some equipment malfunctions. The contact was lost with borehole Chemmac after over one week of measurements. The response from the carbon electrode in the surface Chemmac was selected as the representative redox potential for this section, supported by the carbon electrode values and the decreasing values of the gold- and platinum electrodes in the borehole Chemmac.

The pH electrodes at the ground surface and in the borehole were consistent and stable, except in section 476.0–485.6 m, where the pH electrodes in borehole Chemmac gave a slightly lower value (7.6 ± 0.2 compared to 8.1 ± 0.3).

7.2 Water analyses

7.2.1 Basic water analyses

The basic water analyses include the major constituents Na, K, Ca, Mg, S, Sr, SO_4^{2-}, Cl^-, Si and HCO_3^- as well as the minor constituents Fe, Li, Mn, DOC, F^-, I, HS^- and NH_4^+. Furthermore, batch measurements of pH (lab-pH) and electrical conductivity (lab-EC) are included. Another important parameter is the flushing water content in each sample. The basic water analysis data and relative charge balance errors are compiled in Appendix 11, Table A11-1. Existing batch measurement values of pH and electrical conductivity are compared with the corresponding on-line Chemmac measurement values in Appendices 6 to 9.

The charge balance errors give an indication of the quality and uncertainty of the analyses of major constituents. The errors exceeded ± 5% in one sample, no. 11160 from section 476.0–485.6 m, which was the control sample analysed by an independent laboratory. The reason for the discrepancy was probably too low results from the calcium and sodium determinations. A comparison between results from different laboratories and methods shows that the agreement is acceptable in most cases. Generally, the difference in concentrations between laboratories/methods for each analysed constituent is less than 10%.

The flushing water contents in the sample series collected from the borehole sections are presented in Figure 7-1 and Figure 7-2. The flushing water content should not exceed 1% in order for a sample to be considered representative for the groundwater of the sampled fracture zone. This condition was almost met for samples collected in sections 197.0–206.6 m and 396.0–400.6 m with contents of 1.3% and 1.1%, respectively. However, in sections 476.0–486.6 m and 609.0–618.5 m, the flushing water content was 5 and 11% respectively. The flushing water content is calculated using the average Uranine concentration in the added flushing water during core drilling.

The concentration levels of sodium, calcium and chloride are presented in Figures 7-3 to 7-6. The concentrations of all major constituents remained more or less constant during the pumping and sampling periods.

The iron concentrations determined by ICP-AES (total Fe) and by spectrophotometry (Fe(+II) and Fe-tot) are compared in Figures 7-7 to 7-10. The total iron concentrations determined by ICP agree reasonably well with the results obtained by spectrophotometry.

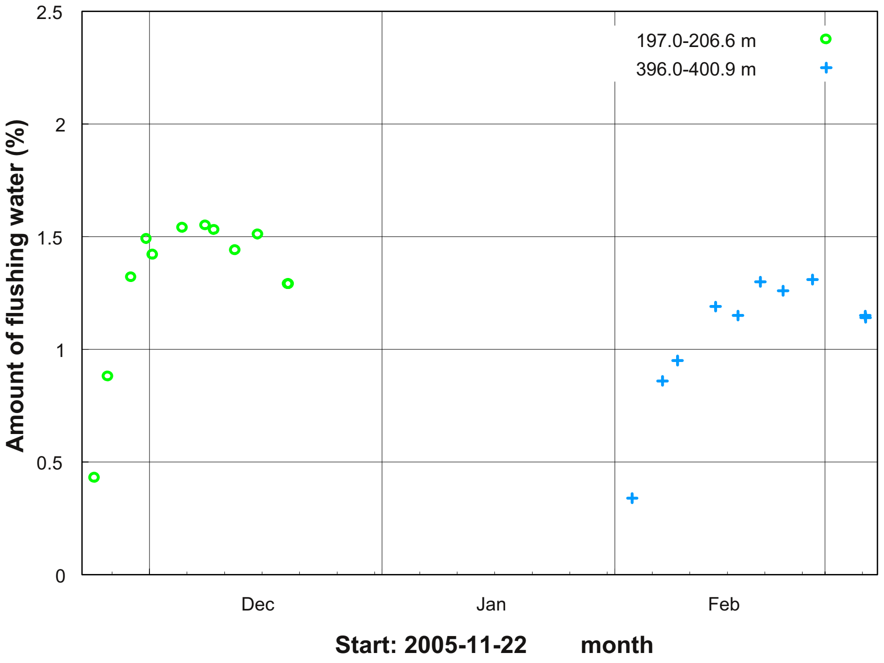


Figure 7-1. Flushing water content in the sample series collected during pumping in borehole sections 197.0–206.6 m and 396.0–400.9 m.

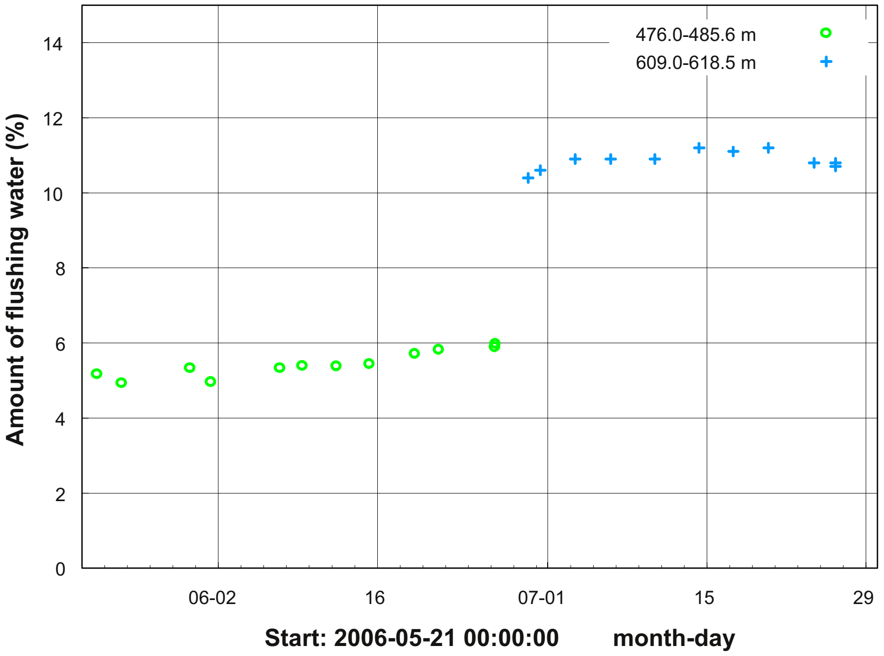


Figure 7-2. Flushing water content in the sample series collected during pumping in borehole sections 476.0–485.6 and 609.0–618.5 m.

Sulphate analysed by ion chromatography (IC) is compared to sulphate determined as total sulphur by ICP-AES in Figures 7-11 to 7-14. The sulphate concentrations remained constant during all of the investigation sequences. The IC results are somewhat lower than the ICP results in all of the sections. With the exception of three samples in section 396.0–400.9 m, the differences are within the analytical error. For the three differing samples, differences may be due to the presence of other sulphur species than sulphate, although experience has shown that ICP measurements may be more reliable since the variation between the samples in a time series often is smaller.

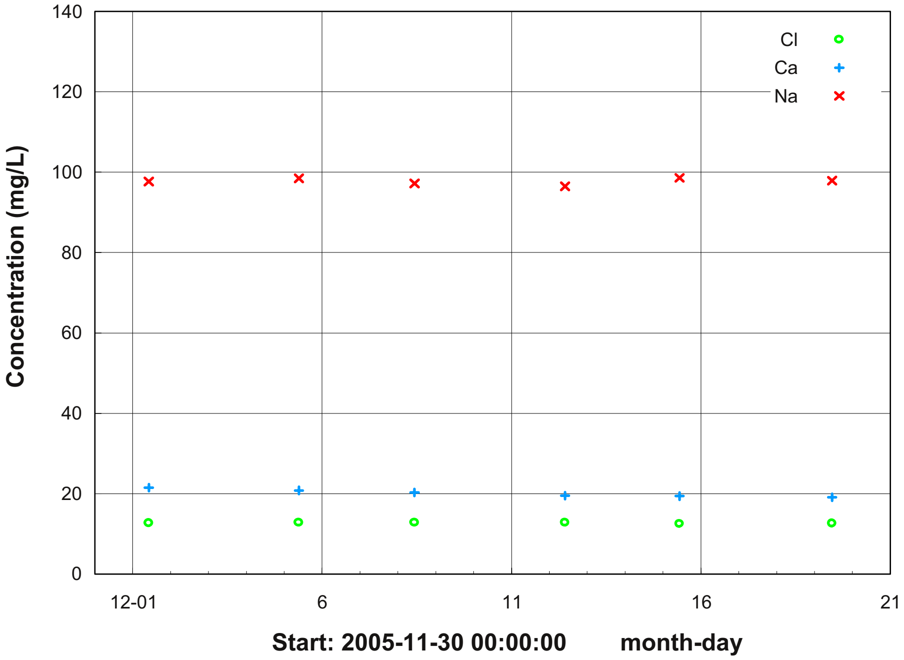


***Figure 7-3.** Sodium, calcium and chloride concentration trends from sample series at 197.0–206.6 m.*

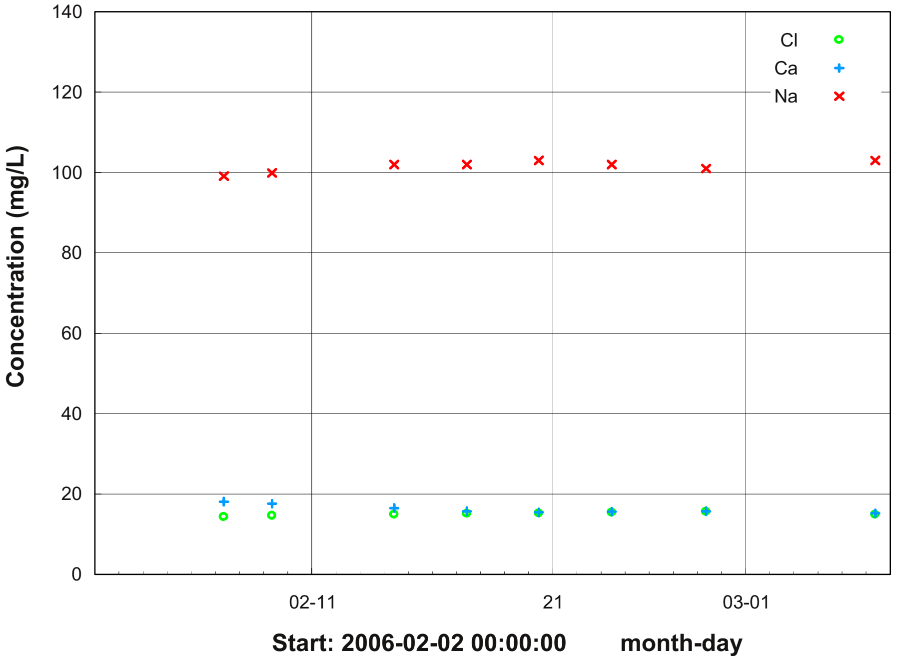


***Figure 7-4.** Sodium, calcium and chloride concentration trends from sample series at 396.0–400.9 m.*

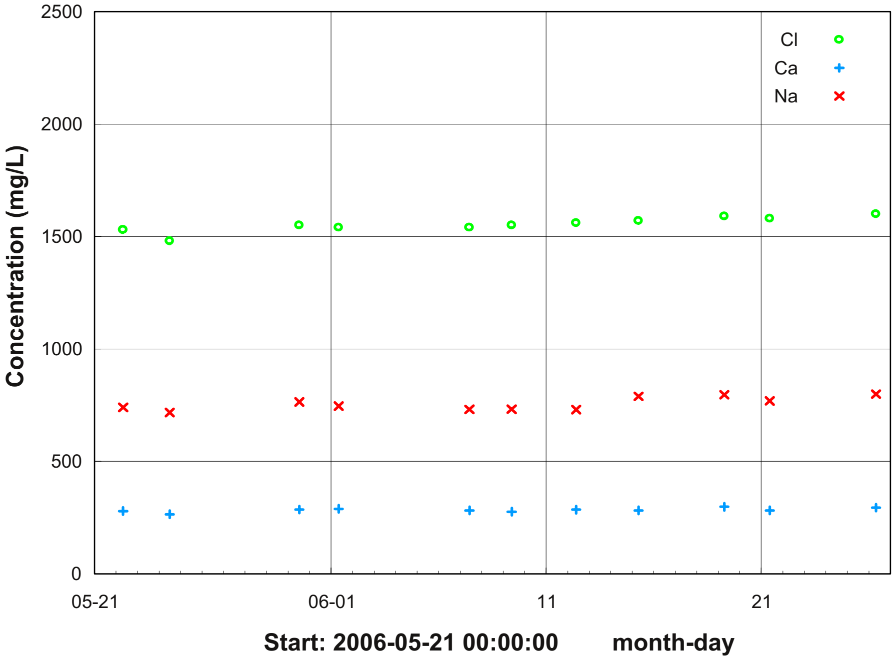


Figure 7-5. Sodium, calcium and chloride concentration trends from sample series at 476.0–485.6 m.

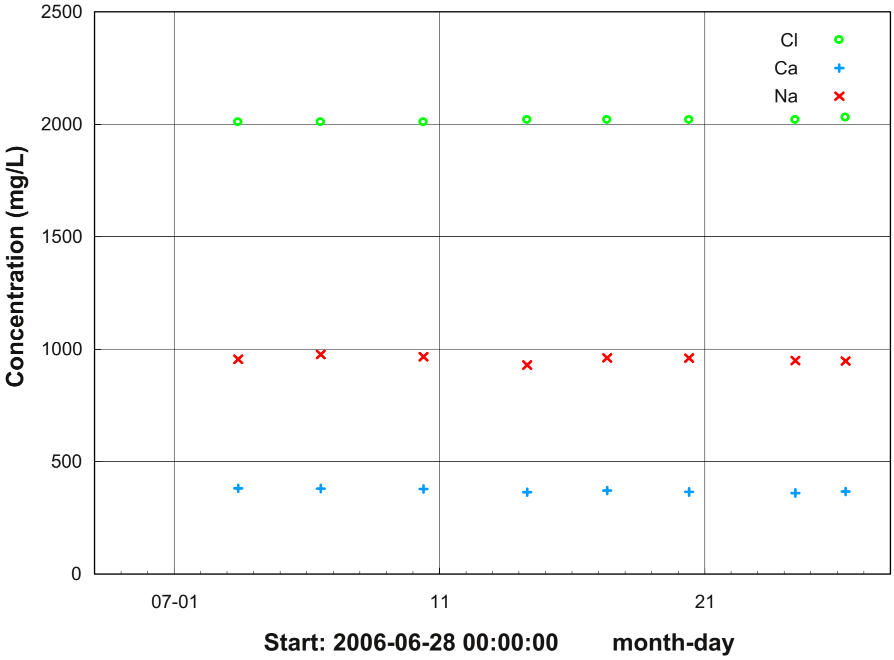


Figure 7-6. Sodium, calcium and chloride concentration trends from sample series at 609.0–618.5 m.

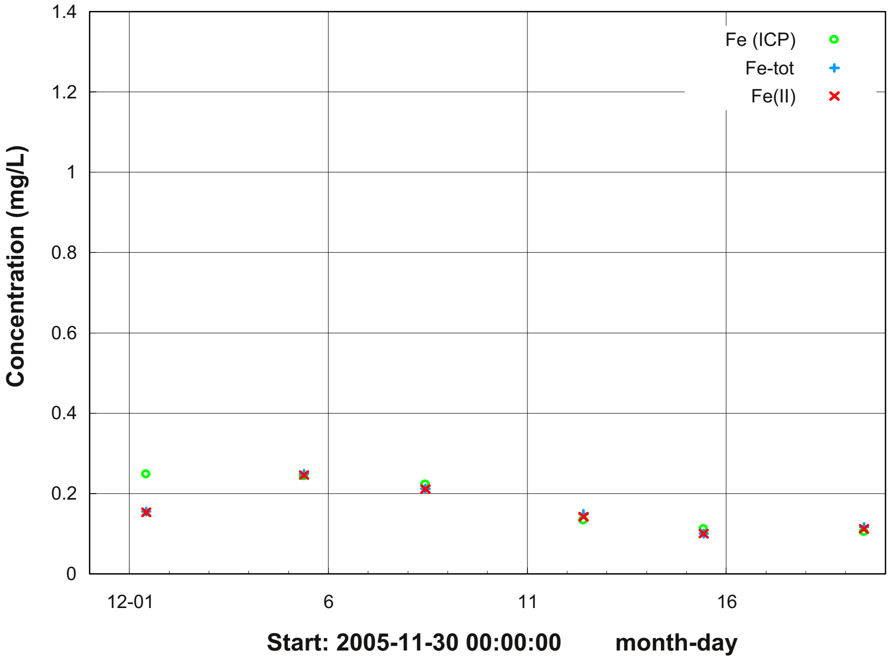


Figure 7-7. Comparison of iron concentrations obtained by ICP-AES and spectrophotometry from borehole section 197.0–206.6 m.

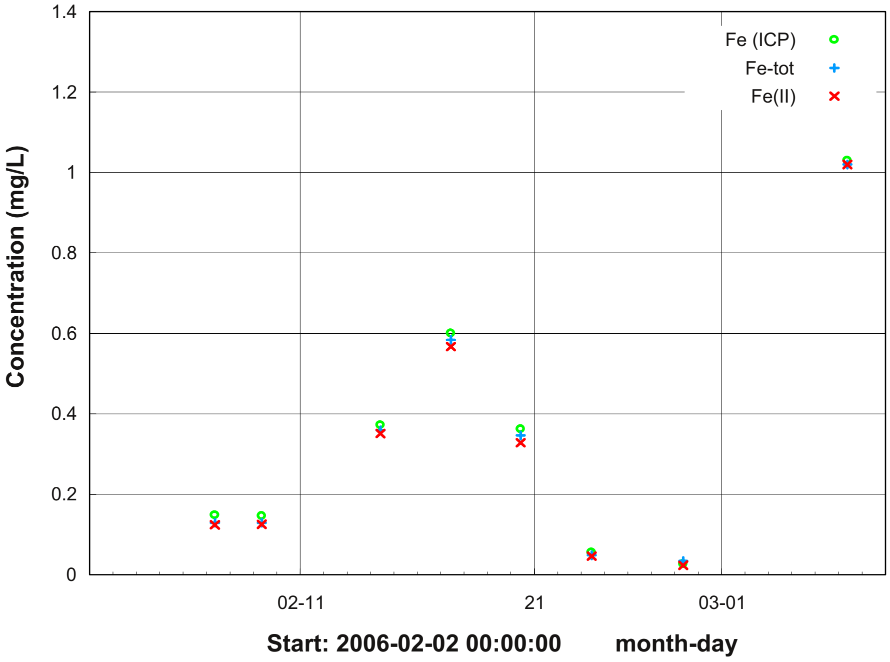


Figure 7-8. Comparison of iron concentrations obtained by ICP-AES and spectrophotometry from borehole section 396.0–400.9 m.

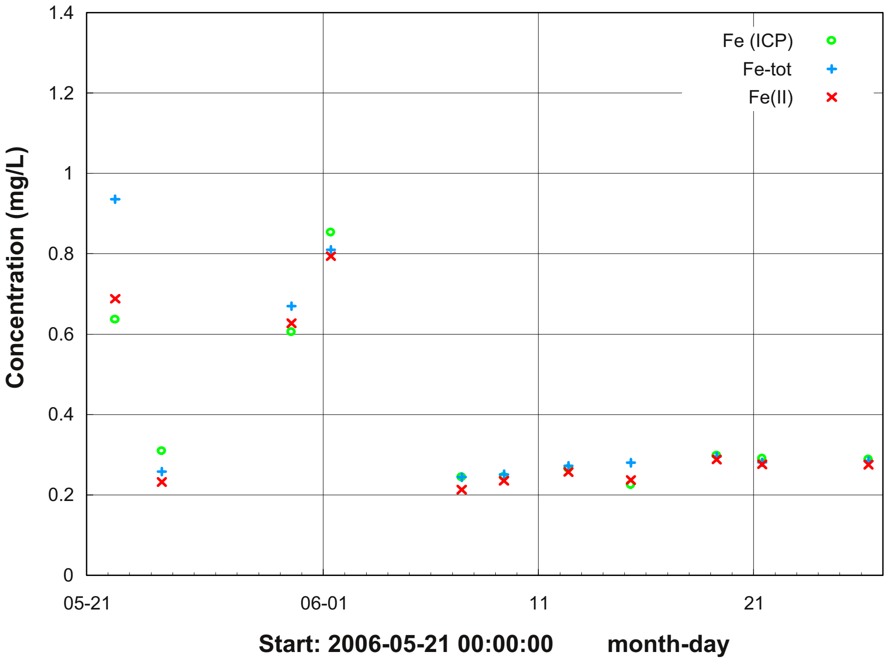


Figure 7-9. *Comparison of iron concentrations obtained by ICP-AES and spectrophotometry from borehole section 476.0–485.6 m.*

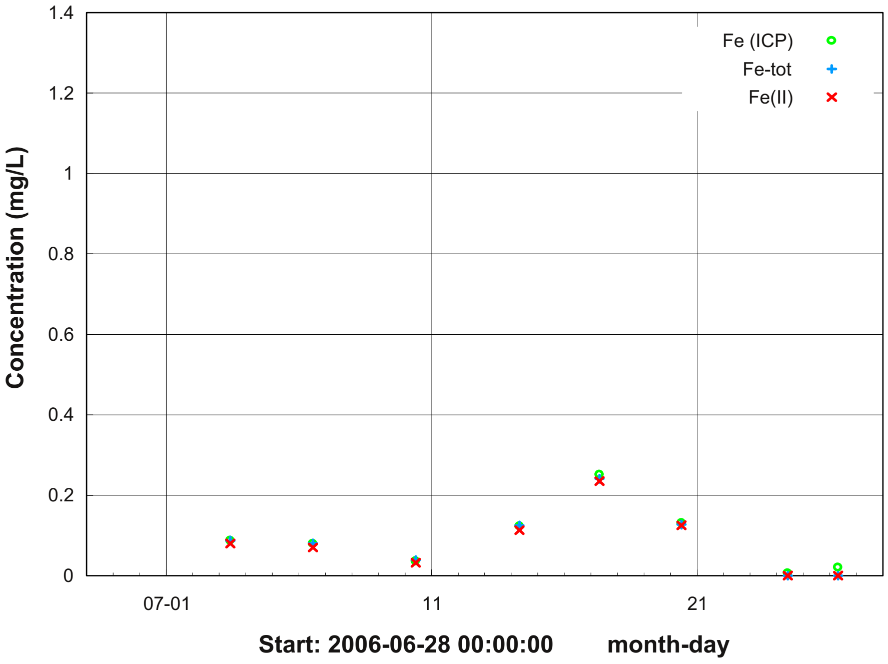


Figure 7-10. *Comparison of iron concentrations obtained by ICP-AES and spectrophotometry from borehole section 609.0–618.5 m.*

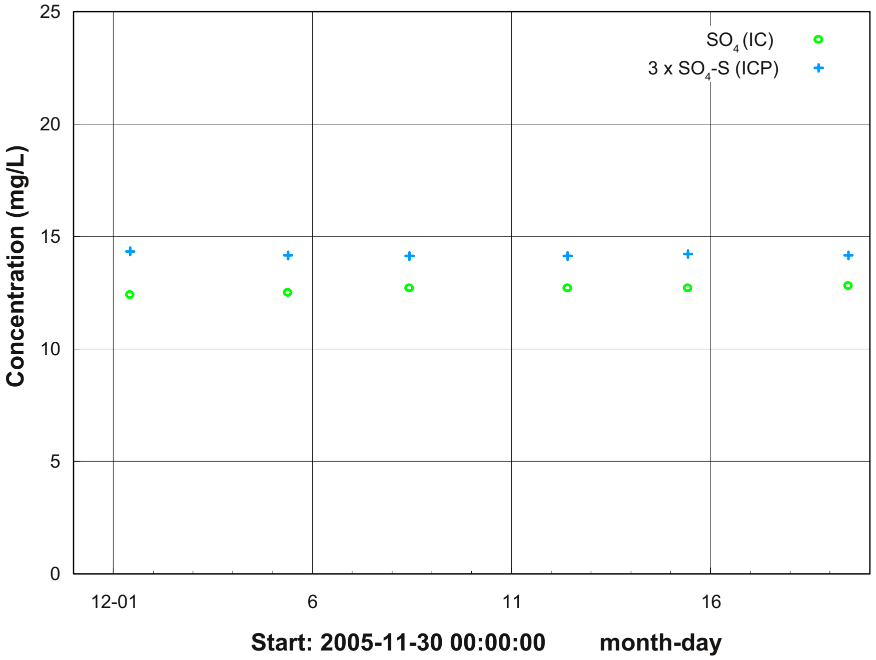


Figure 7-11. *Sulphate (SO_4 by IC) to total sulphate calculated from total sulphur ($3\times SO_4$-S by ICP) versus date. Samples collected in section 197.0–206.6 m.*

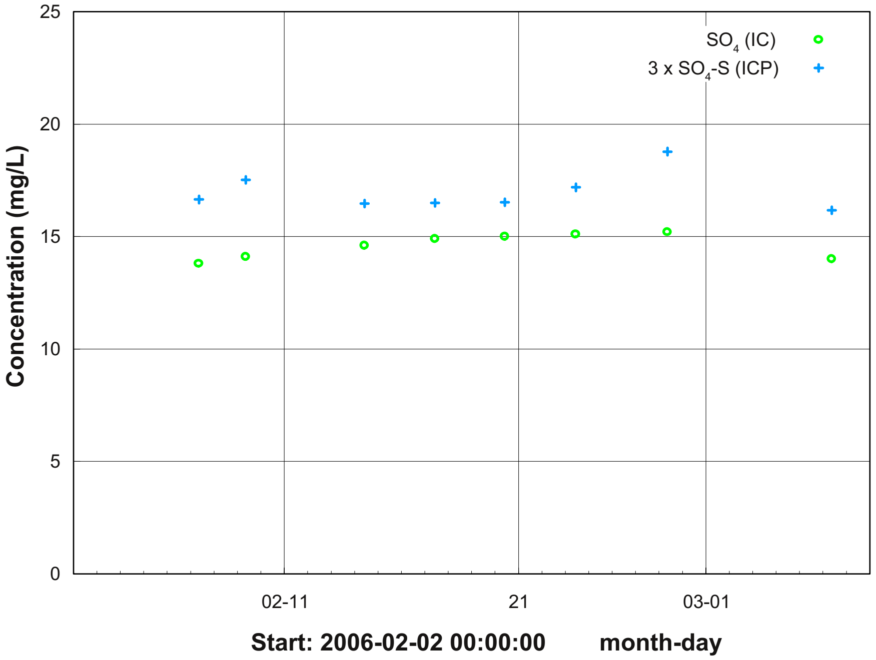


Figure 7-12. *Sulphate (SO_4 by IC) to total sulphate calculated from total sulphur ($3\times SO_4$-S by ICP) versus date. Samples collected in section 396.0–400.9 m.*

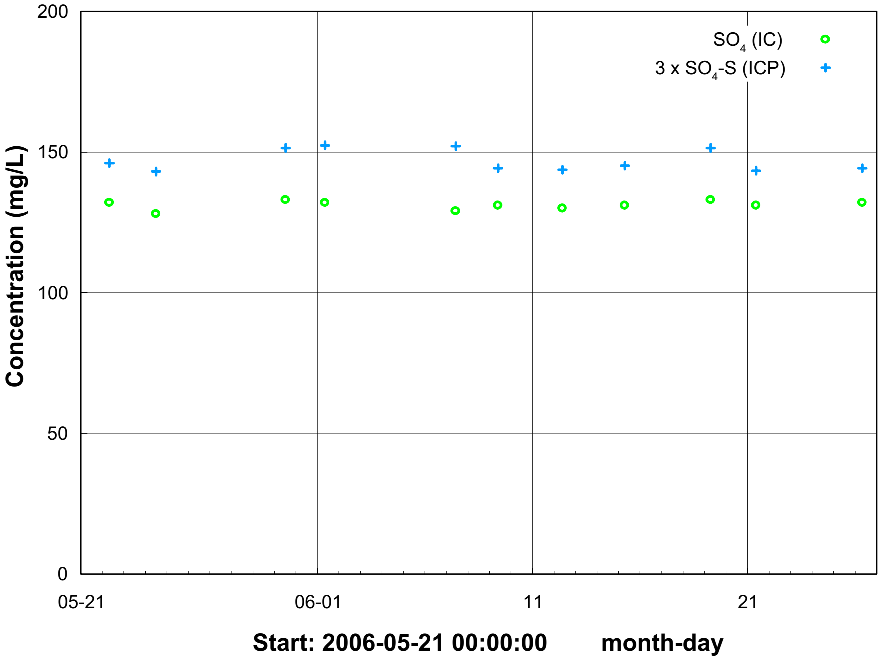


Figure 7-13. Sulphate (SO_4 by IC) to total sulphate calculated from total sulphur (3×SO_4-S by ICP) versus date. Samples collected in section 476.0–485.6 m.

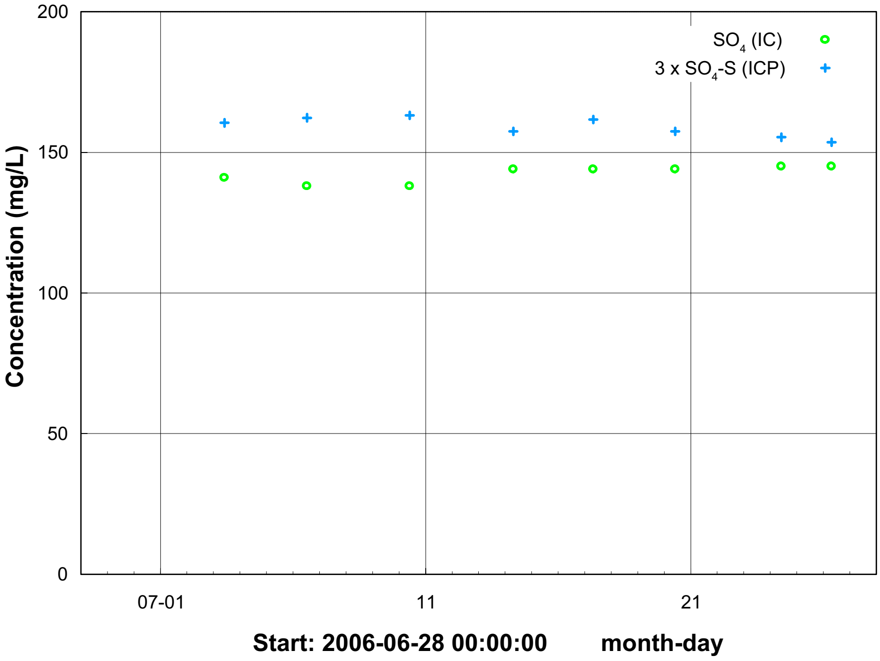


Figure 7-14. Sulphate (SO_4 by IC) to total sulphate calculated from total sulphur (3×SO_4-S by ICP) versus date. Samples collected in section 609.0–618.5 m.

The chloride concentrations are plotted versus the corresponding electrical conductivity values in Figure 7-15. The plot gives a rough check of the data. As shown, the data from the borehole sections agree well with the regression line obtained by earlier data from the Äspö Hard Rock Laboratory.

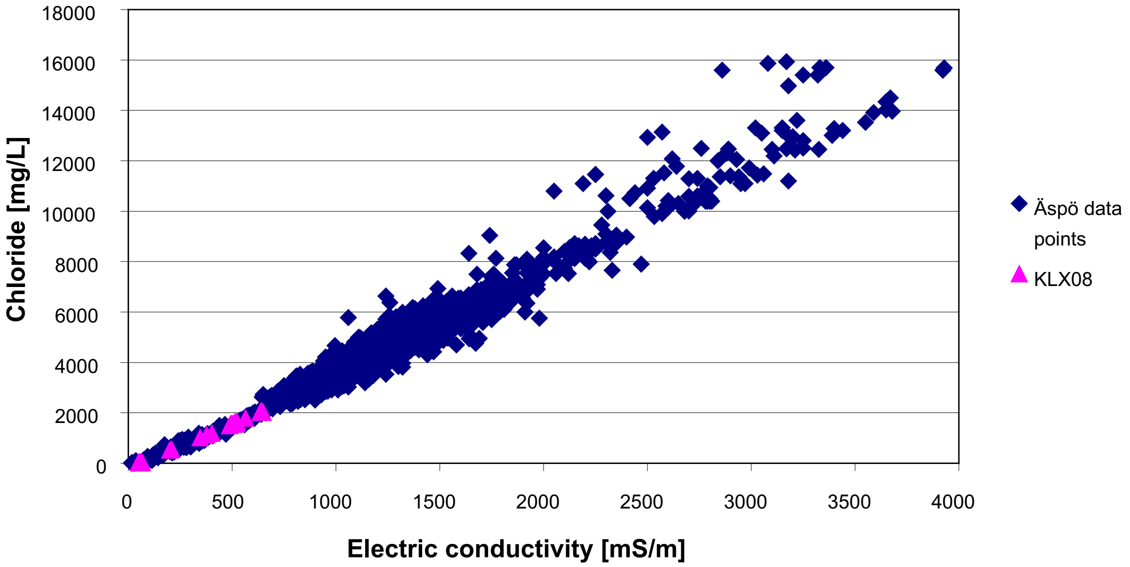


Figure 7-15. *Chloride concentration versus electrical conductivity. Data from earlier investigations at the Äspö Hard Rock Laboratory are used to show the linear relationship. The data from KLX08 do not deviate from a thought regression line.*

7.2.2 Trace elements (rare earth metals and others)

The analyses of trace and rare earth metals include U, Th, As, Sc, Cd, Hg, V, Rb, Y, Zr, In, Cs, Ba, La, Hf, Tl, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu. Commonly occurring metals, such as Cu, Zn, Pb and Mo are not included in the analysis programme due to contamination considerations. The trace element data are compiled in Appendix 11, Table A11-2.

7.2.3 Stable and radioactive isotopes

The isotope determinations include the stable isotopes δ^{2}H, δ^{18}O, ^{10}B/^{11}B, δ^{34}S, δ^{13}C and ^{87}Sr/^{86}Sr as well as the radioactive isotopes ^{3}H (TU), ^{14}C (pmC), ^{238}U, ^{234}U, ^{230}Th, ^{226}Ra and ^{222}Rn. Isotope data are compiled in Appendix 11, Tables A11-3 and A11-4. The B-isotope ratio is given as ^{10}B/^{11}B (the result reported from the consulting laboratory)1.

The ^{3}H and δ^{18}O results are presented in Figures 7-16 to 7-19. The δ^{18}O ratios remained stable during the sampling periods. The ^{3}H content was greatly enhanced in some of the samples from section 476.0–485.6 m (Figure 7-18 and Appendix 12). The reason for this was contamination from de ionised water containing ^{3}H that originated from the hydraulic pumping system. Furthermore, the ^{3}H content was above the detection limit (0.8 TU) in all samples except for two samples in section 609.0–618.5 m. Normally, concentrations below or slightly above the detection limit is expected in deep groundwater and it cannot be excluded that contamination might have occurred in additional samples.

δ^{13}C and pmC were determined both in inorganic carbon (hydrogen carbonate) and in organic constituents. The results are presented in Table 7-2. Enrichment of organic carbon was necessary in order to collect enough organic material. In section 609.0–618.5 m, the alkalinity was too low for determination of δ^{13}C and pmC and the enrichment of organic carbon was cancelled due to the high flushing water content.

---

[1] The notation according to international standard for environmental isotopes is ^{11}B/^{10}B, i.e. (1/^{10}B/^{11}B).

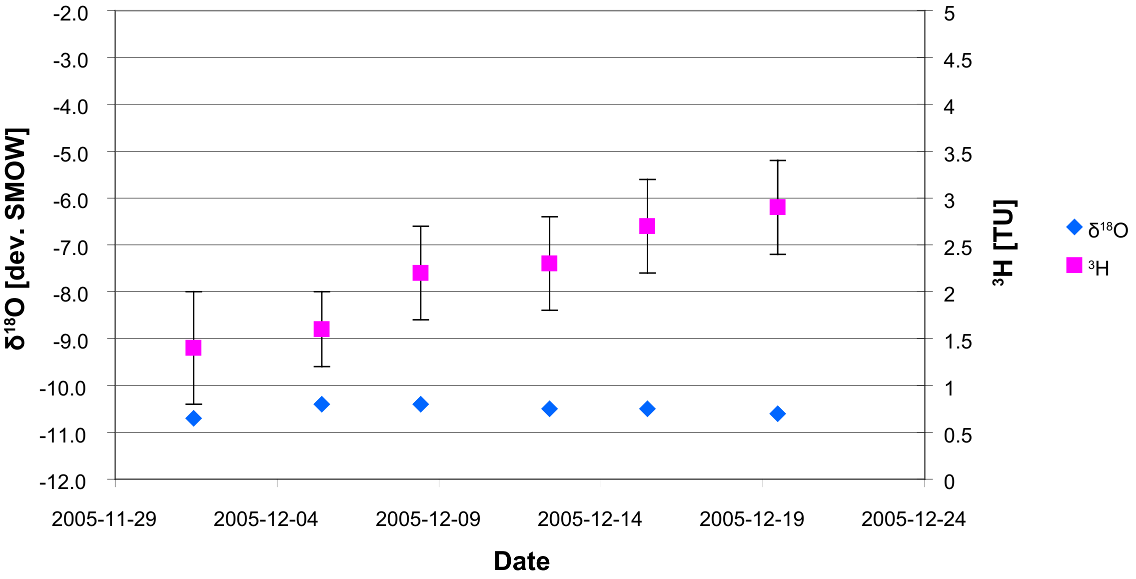


Figure 7-16. ^{3}H and δ^{18}O (‰ SMOW) data versus sampling date, section 197.0–206.6 m.

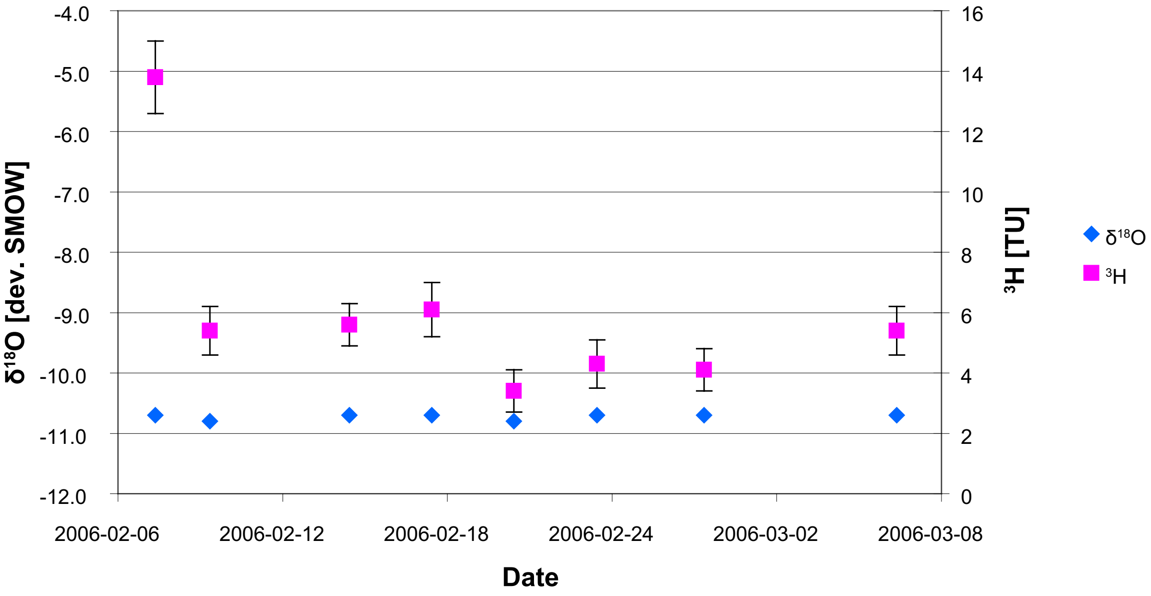


Figure 7-17. ^{3}H and δ^{18}O (‰ SMOW) data versus sampling date, section 396.0–400.9 m.

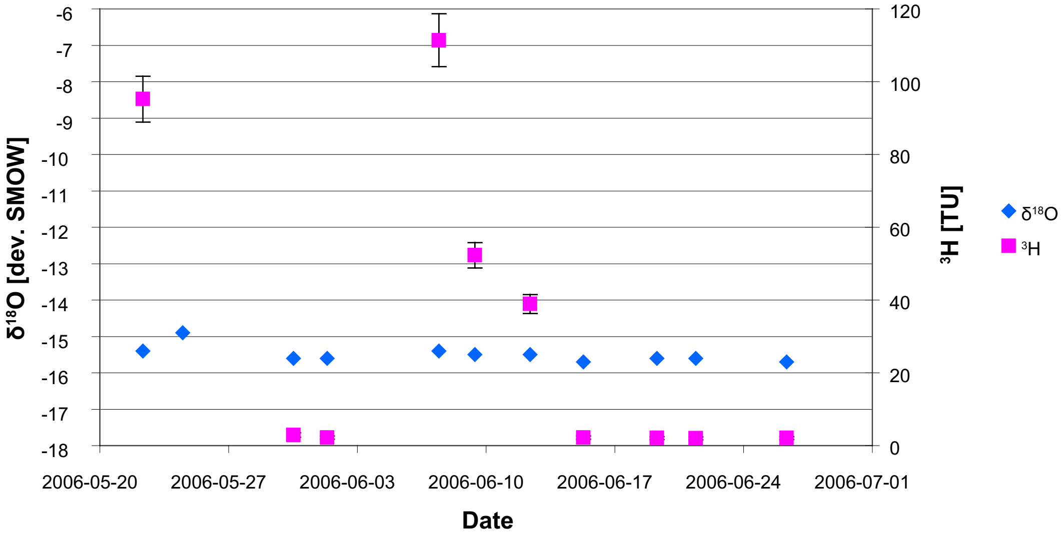


Figure 7-18. ^{3}H and δ^{18}O (‰ SMOW) data versus sampling date, section 476.0–485.6 m. The result for SKB number 11087 (756.6 TU), sampled 2006-05-24, has been omitted in the Figure.

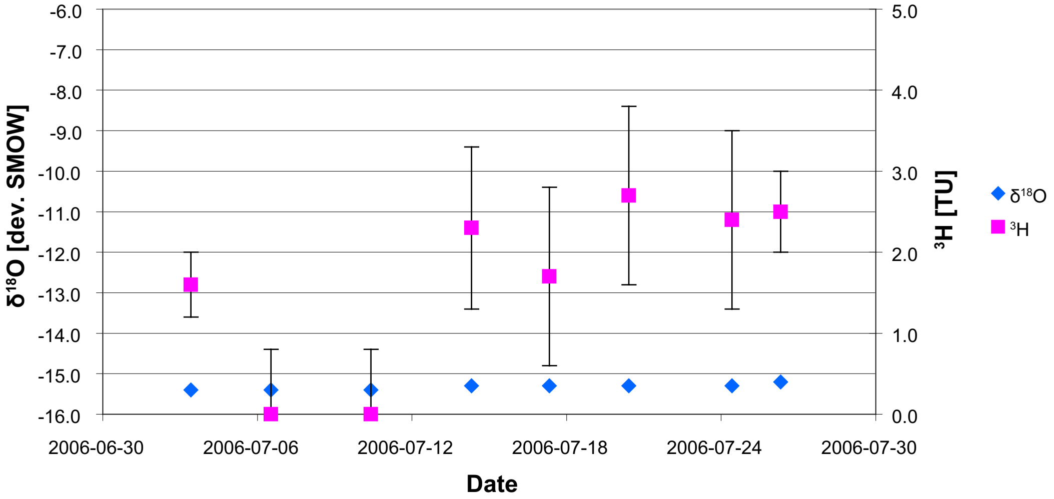


Figure 7-19. ^{3}H and δ^{18}O (‰ SMOW) data versus sampling date, section 609.0–618.5 m.

Table 7-2. Inorganic and organic δ^{13}C and pmC.

Borehole section (m)	Inorg. δ^{13}C (dev PDB)	Org. δ^{13}C (dev PDB)	Inorg. pmC	Org. pmC
197.0–206.6	–17.58	–26.7	63.0	83.7
396.0–400.9	–17.8	–26.8	66.3	89.9
476.0–485.6	–15.7	–27.8	32.1	64.6

7.3 Dissolved gas

Sampling for gas was performed in sections 197.0–206.6, 396.0–400.9, 476.0–485.6 and 609.0–618.5 m. The analyses of dissolved gases include argon (Ar), helium (He), nitrogen (N_2), carbon dioxide (CO_2), carbon monoxide (CO) methane (CH_4), oxygen (O_2), hydrogen (H_2), ethane (C_2H_6), ethene (C_2H_4), ethyne (C_2H_2), propane (C_3H_8) and propene (C_3H_6). The gas data are compiled in Appendix 11, Table A11-5.

Total gas content in the groundwater as well as the detected oxygen content is given in Table 7-3. The oxygen content indicates air leakage into the purging system at the consulted laboratory. The air leakage which affects the analysis results may be corrected, assuming that the oxygen content is zero, by removing the air effect (nitrogen, oxygen and argon).

The two analysed samples from section 609.0–618.5 m differed in gas content and nitrogen concentration (see Table 7-3 and Figure 7-20) due to leakage of nitrogen into the PVB container when purging sample number 2 at the consulting laboratory. The gas composition of the four different borehole sections is compared in Figure 7-20 and Figure 7-21.

Table 7-3. Total content of dissolved gas.

	Section 197.0–206.6 m	Section 396.0–400.9 m	Section 476.0–485.6 m	Section 609.0–618.5 m sample 1*	Section 609.0–618.5 m sample 2
Total gas content [mL/L]	60	40	63	62	220
Oxygen content [mL/L]	0.54	0.04	0.2	0.036	0.22

* "Best choice" in SICADA.

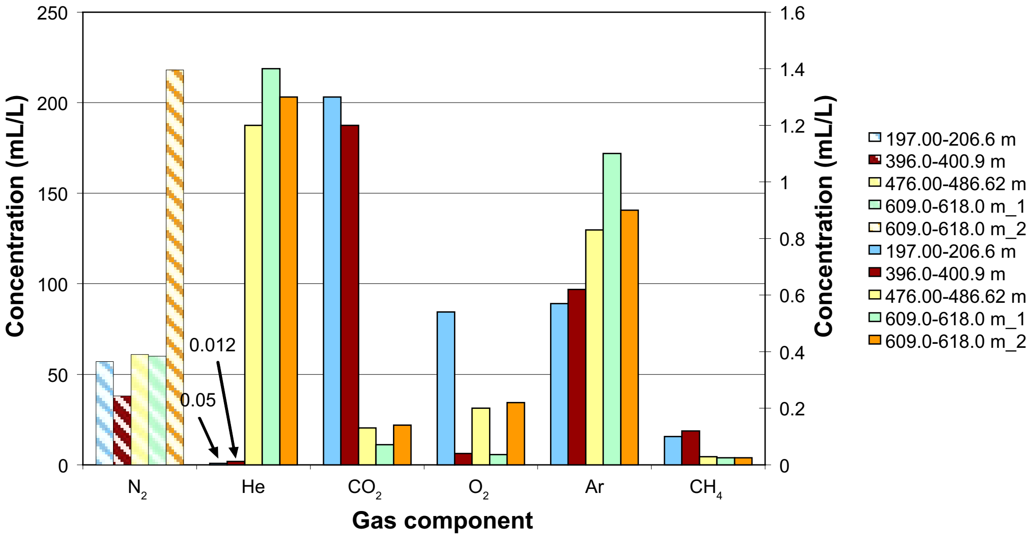


Figure 7-20. *Gas components of high concentrations (N_2, He, CO_2, O_2, Ar and CH_4) in samples collected in KLX08 using the in situ sampling equipment. Striped and non-striped bars refer to the scales on left and right axis, respectively.*

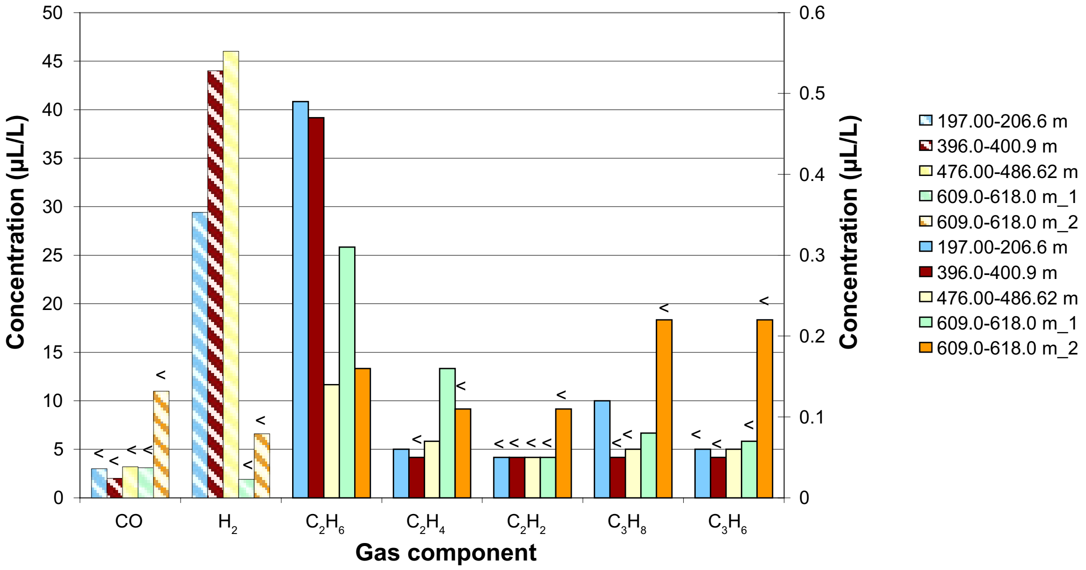


Figure 7-21. *Gas components of low concentrations (CO, H_2, C_2H_6, C_2H_4, C_2H_2, C_3H_8 and C_3H_6) in samples collected in KLX08 using the in situ sampling equipment. Striped and non- striped bars refer to the scales on left and right axis, respectively. The < sign indicates a level below detection limit.*

7.4 Inorganic colloids

The presence of inorganic colloids was investigated by two different methods. One method was colloid filtration through a series of connected filters of different pore sizes. A second method was fractionation/ultra filtration using cylindrical membrane filters with a cut-off of 1,000 D and 5,000 D, respectively. The results from the two methods are difficult to compare quantitatively but a qualitative agreement is identified.

7.4.1 Inorganic colloids – colloid filtration

The results from the colloid filtration performed in sections 396.0–400.9, 476.0–486.6 and 609.0–618.5 m are presented in Figures 7-22 to 7-33. The colloid filtration was cancelled in section 197.0–206.6 due to equipment malfunction.

The bars in the diagrams represent amounts (µg) of aluminium, iron, silicon and manganese entering the filter package, collected on each filter and present in the collecting container. The amounts are calculated assuming that the water volume coming out in the collecting container is equal to the volume going into the system. This is not quite the case as up to ten millilitres will be left in cavities in the filter holder package, in the tubing and in valves. Further, a small volume of about 0.01 to 0.06 mL is left in each filter after the filtration and the salt content of this volume is included in the analysis. The presented input amounts, in the diagrams below, represent the sample taken on-line at the surface just before opening the PVB containers for sampling.

The concentrations in blank samples (rinsing water), PVB containers, collecting container and pumped groundwater are given in Table 7-4. The remaining water in the PVB containers after filtration was possibly contaminated by aluminium and iron. The evaluation is complicated for iron since precipitation and/or contamination have to be considered.

In section 396.0–400.9 m, the iron concentration in the outgoing water is much lower than the amount detected in the collecting container after passing the filters despite that almost nothing is detected on the filters. This could be caused by precipitation of iron after passing the filtering system, possibly in the collecting container.

Results of colloid filtering experiment, using water sample from section 396.0-400.9 m

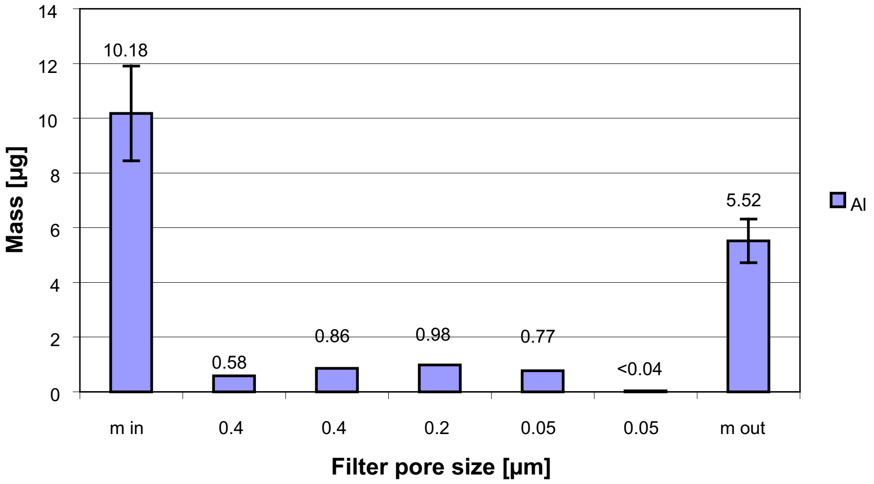


***Figure** 7-22. Amount of aluminium entering the filter system (m in), in the filters and in the collecting container (m out).*

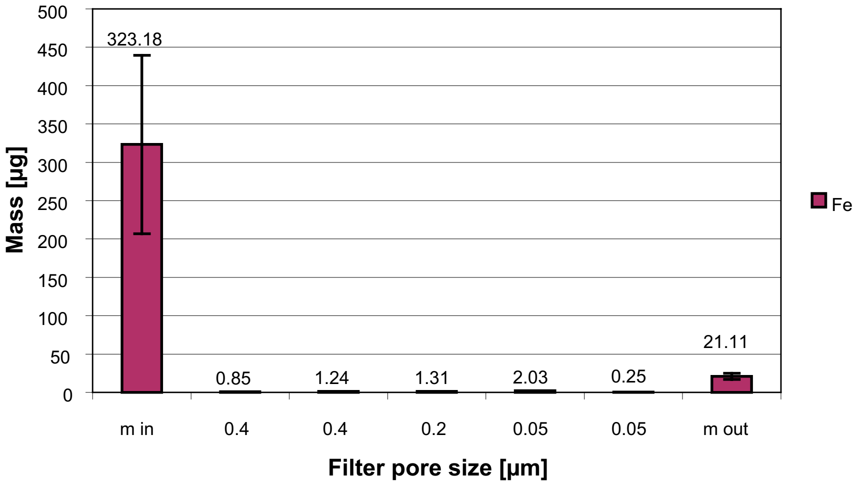


***Figure** 7-23. Amount of iron entering the filter system (m in), in the filters and in the collecting container (m out).*

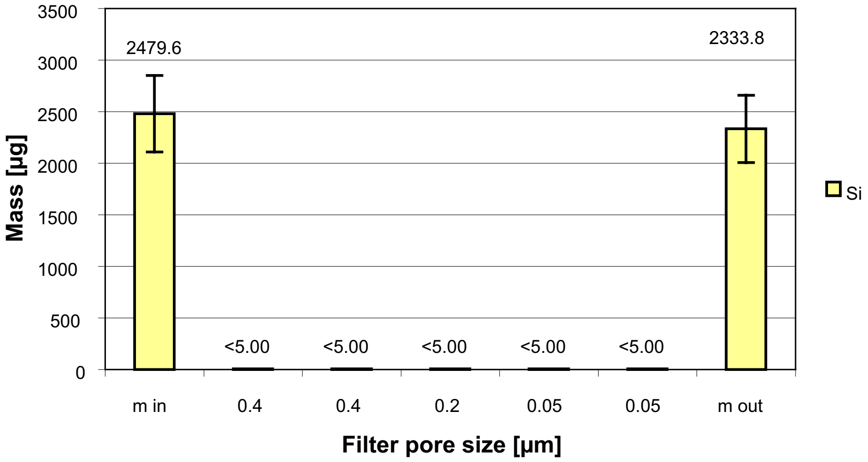


***Figure** 7-24. Amount of silicon entering the filter system (m in), in the filters and in the collecting container (m out).*

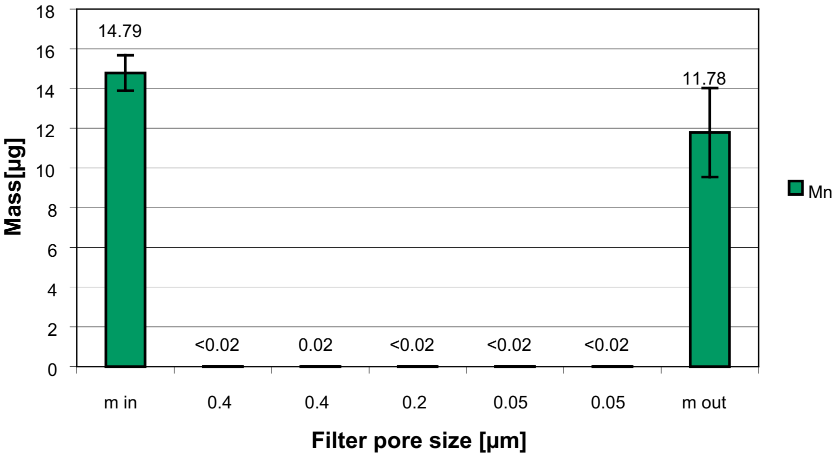


Figure7-25. Amount of manganese entering the filter system (m in), in the filters and in the collecting container (m out).

Results of colloid filtering experiment, using water sample from section 476.0-486.6 m

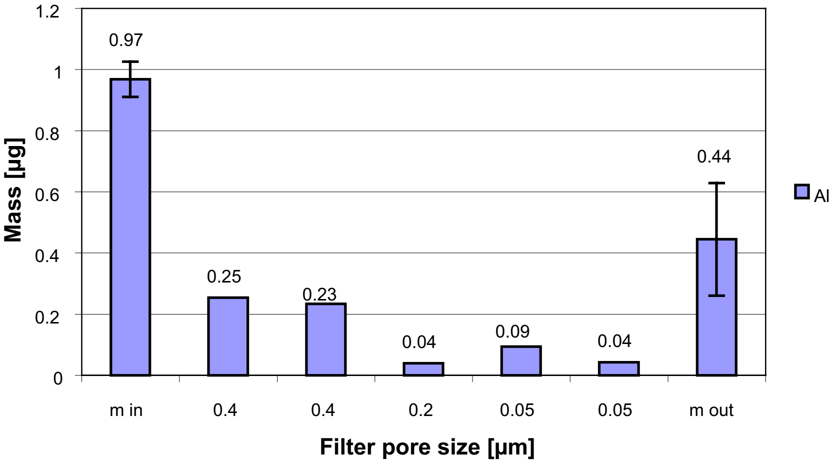


Figure 7-26. Amount of aluminium entering the filter system (m in), in the filters and in the collecting container (m out).

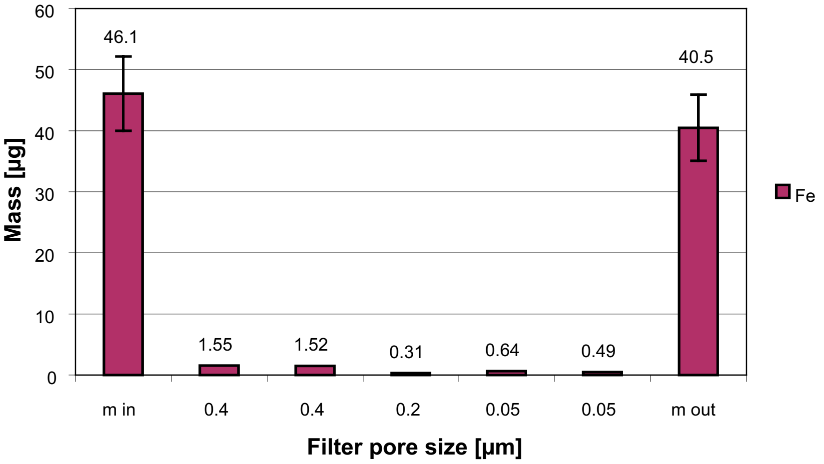


Figure 7-27. Amount of iron entering the filter system (m in), in the filters and in the collecting container (m out).

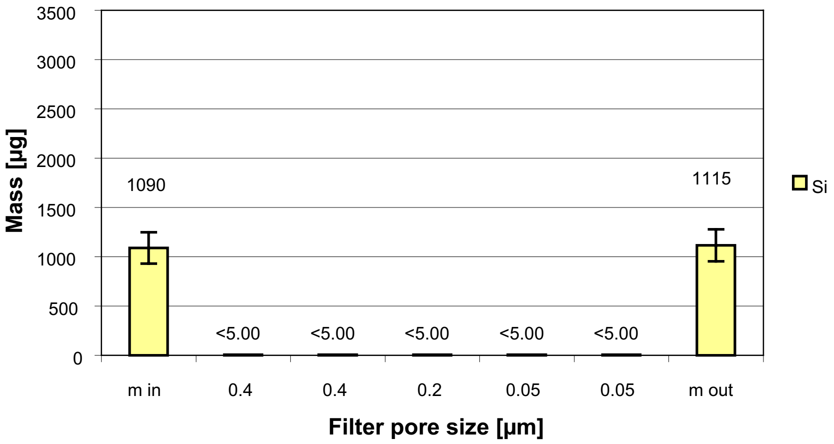


Figure 7-28. *Amount of silicon entering the filter system (m in), in the filters and in the collecting container (m out).*

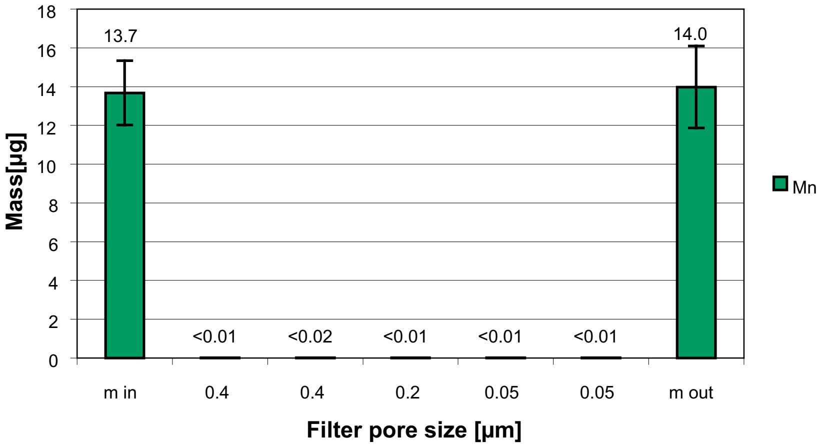


Figure 7-29. *Amount of manganese entering the filter system (m in), in the filters and in the collecting container (m out).*

Results of colloid filtering experiment, using water sample from section 609.0-618.5 m

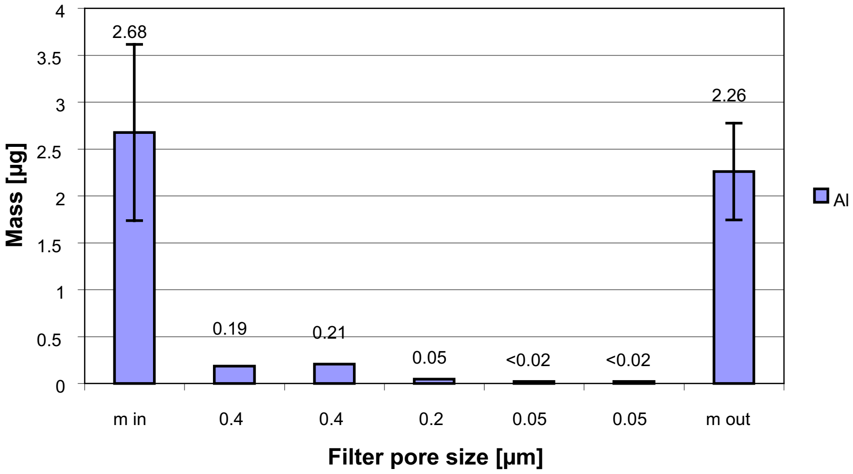


Figure 7-30. *Amount of aluminium entering the filter system (m in), in the filters and in the collecting container (m out).*

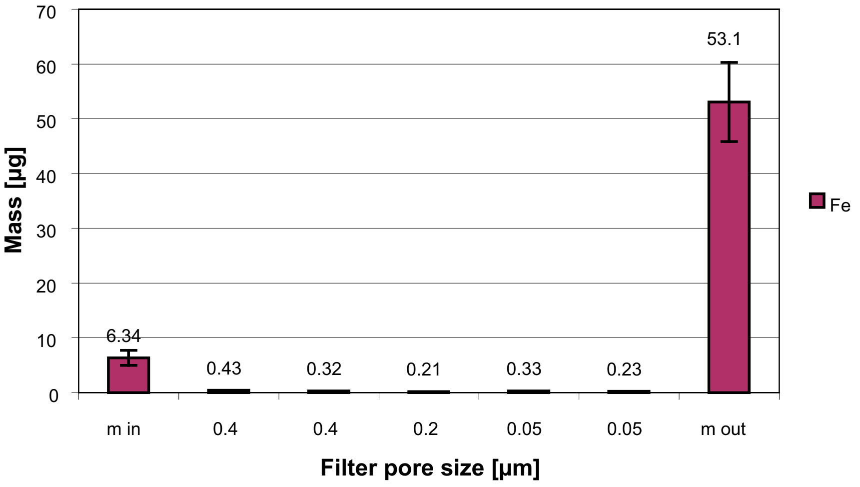


Figure 7-31. *Amount of iron entering the filter system (m in), in the filters and in the collecting container (m out).*

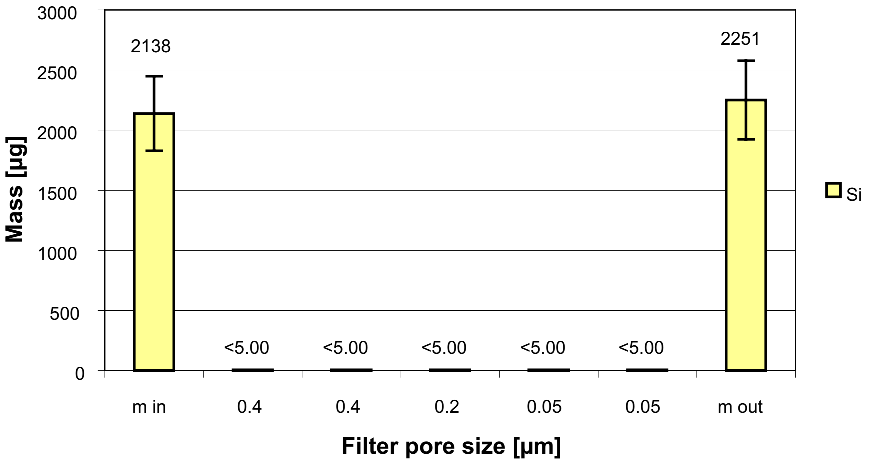


Figure 7-32. *Amount of silicon entering the filter system (m in), in the filters and in the collecting container (m out).*

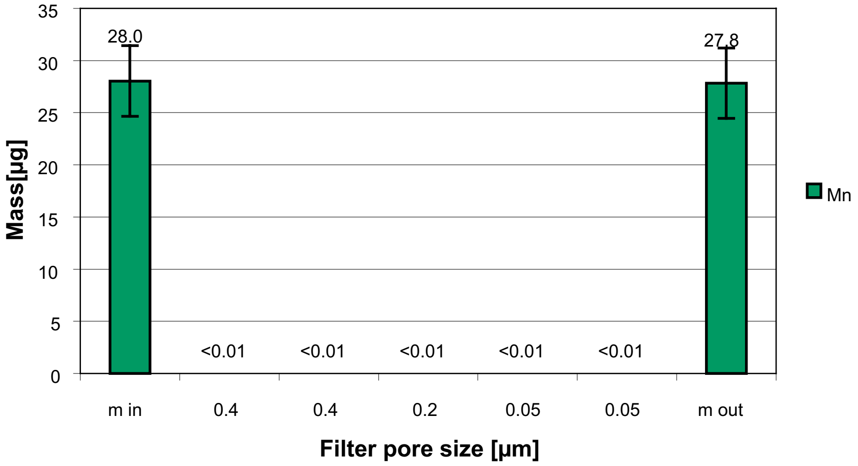


Figure 7-33. *Amount of manganese entering the filter system (m in), in the filters and in the collecting container (m out).*

Table 7-4. Concentrations in blank water, remaining water in PVB container, collected output water from filter system and pumped water that has not passed the filter system.

Section m	Sample origin	Al µg/L	Fe mg/L	Si mg/L	Mn µg/L	Ca mg/L	S mg/L
396.0–400.9	Blank, deionised water	0.667	0.0016	< 0.03	< 0.03	< 0.1	< 0.2
	Blank, leakage test	2.73	0.0058	0.272	8.45	< 0.1	< 0.2
	Pumped water (alt. input conc.)	35.6	1.13	8.67	51.7	15.3	5.56
	Rest volume PVB (input conc.)	149 554	0.482 2.44	8.76 10.1	43.2 73.8	17.7 15.1	5.74 5.46
	Collecting container	19.3	0.0738	8.16	41.2	14.6	5.69
476.0–486.6	Blank, deionised water	0.367	0.0018	0.0476	0.0439	< 0.1	< 0.2
	Blank, leakage test	1.34	0.014	0.0872	20.9	< 0.2	< 0.3
	Pumped water (alt. input conc.)	6.05	0.288	6.81	85.5	294	48.5
	Rest volume PVB (input conc.)	798 733	3.33 3.05	9.25 8.21	174 119	312 317	49.4 50.6
	Collecting container	2.78	0.253	6.97	87.4	308	48.5
609.0–618.5	Blank, deionised water	6.96	0.006	< 0.03	0.172	< 0.1	0.245
	Blank, leakage test	2.96	0.01	0.0778	10.1	0.136	0.194
	Pumped water (alt. input conc.)	8.52	< 0.0202	6.81	89.3	367	51.2
	Rest volume PVB (input conc.)	790 1,550	1.73 3.71	8.34 9.69	123 145	372 370	51.3 51.9
	Collecting container	7.2	0.169	7.17	88.6	374	52.4

Blank, leakage test = remaining water in the PVB container after filtration of blank sample/de-ionised water.

Pumped water = sample collected at the surface and not in situ in the borehole section.

Rest volume PVB = remaining water in the PVB container after filtration of sample.

Collecting container = water that has passed the filter system.

On the other hand, in section 609.0–618.5 m, the iron concentration in the outgoing water is much higher than in the incoming water and there is no iron detected on the filters. This indicates that the outgoing water is contaminated with iron after passing the filtering system, maybe in the collecting container.

Analysis of blank filters showed that the contribution of aluminium, iron, silica and manganese from filters were insignificant for section 476.0–486.6 m. In the other two sections, aluminium and iron were present on the filters in amounts < 0.08 µg and < 0.2 µg, respectively.

Filter analyses of silica and manganese as well as calcium and sulphur (not presented in the figures) show values below the detection limits.

The following may be concluded from the colloid filtration results:

- The amounts present as colloidal iron in sections 396.0–400.9 m and 609.0–618.5 m are somewhat difficult to evaluate since the output amount plus the amount collected on filters does not balance the input amount. The reasons for this are contamination and/or precipitation in the PVB containers.
- Low amounts of the investigated metals are detected on the filters.

7.4.2 Inorganic colloids – fractionation

Besides the DOC analyses, the samples from fractionation experiments were also analysed by ICP. The determined elements were; Ca, Fe, K, Mg, Na, S, Si, Al, Ba, Cd, Co, Cr, Cu, Hg, Li, Mn, Mo, Ni, P, Pb, Sr, V and Zn. Only Fe (iron), Si (silicon), Ca (calcium), S (sulphur), Al (aluminium) and Mn (manganese) were considered important as colloid species.

The results presented in Table 7-5 to Table 7-7 were calculated using mass balance equations. Silicon and calcium exist mainly as species (associated or non-associated with humic and fulvic acids) with a molecular weight less than 1,000 D (g/mol). Such species are too small to be referred to as colloids. Small fractions of sulphur with molecular weight more than 5,000 D were observed in sections 396.0–400.9 m and 476.0–485.6 m. Besides a low molecular fraction in section 396.0–400.9 m, high molecular species (> 5,000 D) of aluminium is observed, while in sections 197.0–206.6 m and 476.0–485.6 m, aluminium is predominantly present as low molecular species. The results for manganese and iron are uncertain since precipitation might have occurred before or during filtering. The results for iron in sections 396.0–400.9 m and 476.0–485.6 m were excluded because of possible precipitation during collection of the water sample (before the filtering process).

The blanks (de-ionised water collected after passing through the washed filters) showed insignificant concentrations of iron, silicon, calcium, aluminium, manganese, calcium and sulphur.

Fractionation was excluded in section 609.0–618.5 m due to a high content of flushing water.

Table 7-5. Inorganic fractions (< 1,000 D, 1,000 D to 5,000 D and > 5,000 D) in section 197.0–206.6 m.

Fraction	Fe [mg/L]	Si [mg/L]	Al [µg/L]	Mn [µg/L]	Ca [mg/L]	S [mg/L]
< 1,000 D	0.0014 ± 0.0005	7 ± 1	6.9 ± 1.1	58 ± 7	16 ± 2	3.8 ± 1.3
< 5,000 D	0.006 ± 0.001	7.1 ± 1.3	8.0 ± 1.1	59 ± 7	17 ± 3	4.4 ± 0.8
> 1,000 D but < 5,000 D	0.009 ± 0.001	–	0.8 ± 0.2	–	0.6 ± 0.4	0.4 ± 0.2
> 5,000 D	0.006 ± 0.001	–	–	3.0 ± 2.1	–	–
Adsorption 1,000 D	0.009 ± 0.004	–	–	21 ± 12	–	–
Adsorption 5,000 D	0.022 ± 0.005	–	–	18 ± 16	–	–

– = Below detection limit

Table 7-6. Inorganic fractions (< 1,000 D, 1,000 D to 5,000 D and > 5,000 D in section 396.0–400.9 m.

Fraction	Si [mg/L]	Al [µg/L]	Mn [µg/L]	Ca [mg/L]	S [mg/L]
< 1,000 D	8.0 ± 1.1	9.5 ± 1.4	41 ± 6	14 ± 2	4.1 ± 1.9
< 5,000 D	7.7 ± 1.1	10.4 ± 2.0	35 ± 5	13 ± 2	4.6 ± 1.0
> 1,000 D but < 5,000 D	–	2.6 ± 1.2	–	0.8 ± 0.5	0.5 ± 0.3
> 5,000 D	–	8.7 ± 1.6	–	–	0.6 ± 0.3
Adsorption 1,000 D	–	–	22 ± 12	–	–
Adsorption 5,000 D	–	–	30 ± 12	–	–

– = Below detection limit

Table 7-7. Inorganic fractions (< 1,000 D, 1,000 D to 5,000 D and > 5,000 D in section 476.0–485.6 m.

Fraction	Si [mg/L]	Al [µg/L]	Mn [µg/L]	Ca [mg/L]	S [mg/L]
< 1,000 D	6.3 ± 0.9	4.9 ± 0.9	83 ± 12	264 ± 32	43.4 ± 0.9
< 5,000 D	6.3 ± 0.9	3.0 ± 0.7	33 ± 5	255 ± 31	44.4 ± 0.9
> 1,000 D but < 5,000 D	–	–	–	–	1.0 ± 0.2
> 5,000 D	–	–	–	–	1.1 ± 0.2
Adsorption 1,000 D	–	–	–	–	2.6 ± 1.4
Adsorption 5,000 D	–	2.4 ± 1.3	56 ± 14	–	–

– = Below detection limit

7.5 Humic and fulvic acids – fractionation

The results from fractionation of organic acids in sections 197.0–206.6, 396.00–400.9 and 476.0–485.6 m are summarised in Table 7-8. The water in section 476.0–485.6 m contains mainly a fraction of organic acids with a molecular weight less than 1,000 D, which consist of fulvic acids and possibly other low molecular weight organic acids such as citric acid and oxalic acid. However, in sections 197.0–206.6 m and 396.0–400.9 m there is a fraction of organic acids with molecular weight above 1,000 D but less than 5,000 D. The water in section 396.0–400.9 m consists of organic acids with molecular weights from less than 1,000 D to above 5,000 D.

The results from the 1,000 D and 5,000 D filters were consistent for all sections.

Fractionation of organic acids was not performed in section 609.0–618.5 m due to high flushing water content.

Table 7-8. Summary of fractionation results in KLX08.

Section Fraction	197.0–206.6 m DOC [mg/L]	396.0–400.9 m DOC [mg/L]	476.0–485.6 m DOC [mg/L]
< 1,000 D	2.7 ± 0.4	2.4 ± 0.3	1.9 ± 0.2
> 1,000 D but < 5,000 D	2.9 ± 0.3	1.4 ± 0.4	0.49 ± 0.09
> 5,000 D	–	3.3 ± 0.5	0.2 ± 0.1
Adsorption 1,000 D	1.7 ± 1.1	–	–
Adsorption 1,000 D	–	–	–

– = Below detection limit

8 Summary

The Complete chemical characterisation in KLX08 was, on the whole, performed successfully.

The main conclusions from the experimental results are:

- An upper limit for the allowed flushing water content in a representative water sample is set to 1%. This condition was almost met in sections 197.0–206.6 m (1.3%) and 396.0–400.6 m (1.1%). However, in sections 476.0–486.6 and 609.0–618.5 m, the flushing water content was 5 and 11%, respectively.
- The quality of the water analyses is generally high, based on comparison between results from different laboratories, methods and acceptable charge balance errors. The relative errors are all within ± 5% with one exception.
- The major constituents show stable concentrations during the pumping/sampling period which indicates that no mixing occurred with water from other fracture systems with different water compositions.
- The salinity concentrations indicate that two different water systems have been investigated; the chloride concentrations range from 13–15 mg/L in sections 197.0–206.6 and 396.0–400.9 m to 1,500–2,000 mg/L in sections 476.0–485.6 and 609.0–618.5 m.
- Greatly enhanced ^{3}H concentrations were found in some samples from section 476.0–485.6 m due to contamination from de ionised water containing ^{3}H in the hydraulic pumping system. In general for all investigated borehole sections, the concentrations of ^{3}H can be considered slightly enhanced, indicating that contamination of additional samples cannot be excluded.
- The redox potential measurements from the borehole Chemmac in sections 197.0–206.6 m and 396.0–400.9 m appear to be of good quality. The three electrodes (gold, glassy carbon and platinum) reached stable and consistent values (–266 and –245 mV respectively). The redox electrodes at the surface gave stable but less negative values. In sections 476.0–485.6 m and 609.0–618.5 m the obtained redox potentials were not stabilised and the electrodes were disagreeing. Therefore, the reported redox potential values (–210 and –239 mV) for these sections should be considered uncertain.
- The results from colloid filtering and fractionation using ultra-filtration indicate that the content of silicon and manganese colloids in the groundwater is low or non-existent. The evaluation is more complicated for iron and aluminium since possible contamination and/or precipitation have to be considered.
- The organic constituents are present as fulvic acids and possibly other low molecular weight organic acids (citric and oxalic acids) in sections 197.0–206.65 m, 396.0–400.9 m and 476.0–485.6 m. In the two former sections there are also equivalent concentrations of organic acids with molecular weight above 1,000 D and 5,000 D.

9 References

/1/ **SKB, 2001.** Site investigations. Investigation methods and general execution programme. SKB TR-01-29, Svensk Kärnbränslehantering AB.

/2/ **Pedersen K, 2007.** Oskarshamn site investigation. Microorganisms in groundwater from borehole KLX08- number, viability and metabolic diversity. Results from sections 197.0–206.7, 396.0–400.9 and 476.0–485.6 m. SKB P-07-59, Svensk Kärnbränslehantering AB.

/3/ **Ask H, Morosini M, Samuelsson L-E, Ekström L, Häkansson N, 2006.** Drilling of cored borehole KLX08. Oskarshamn site investigation. SKB P-06-222. Svensk Kärnbränslehantering AB.

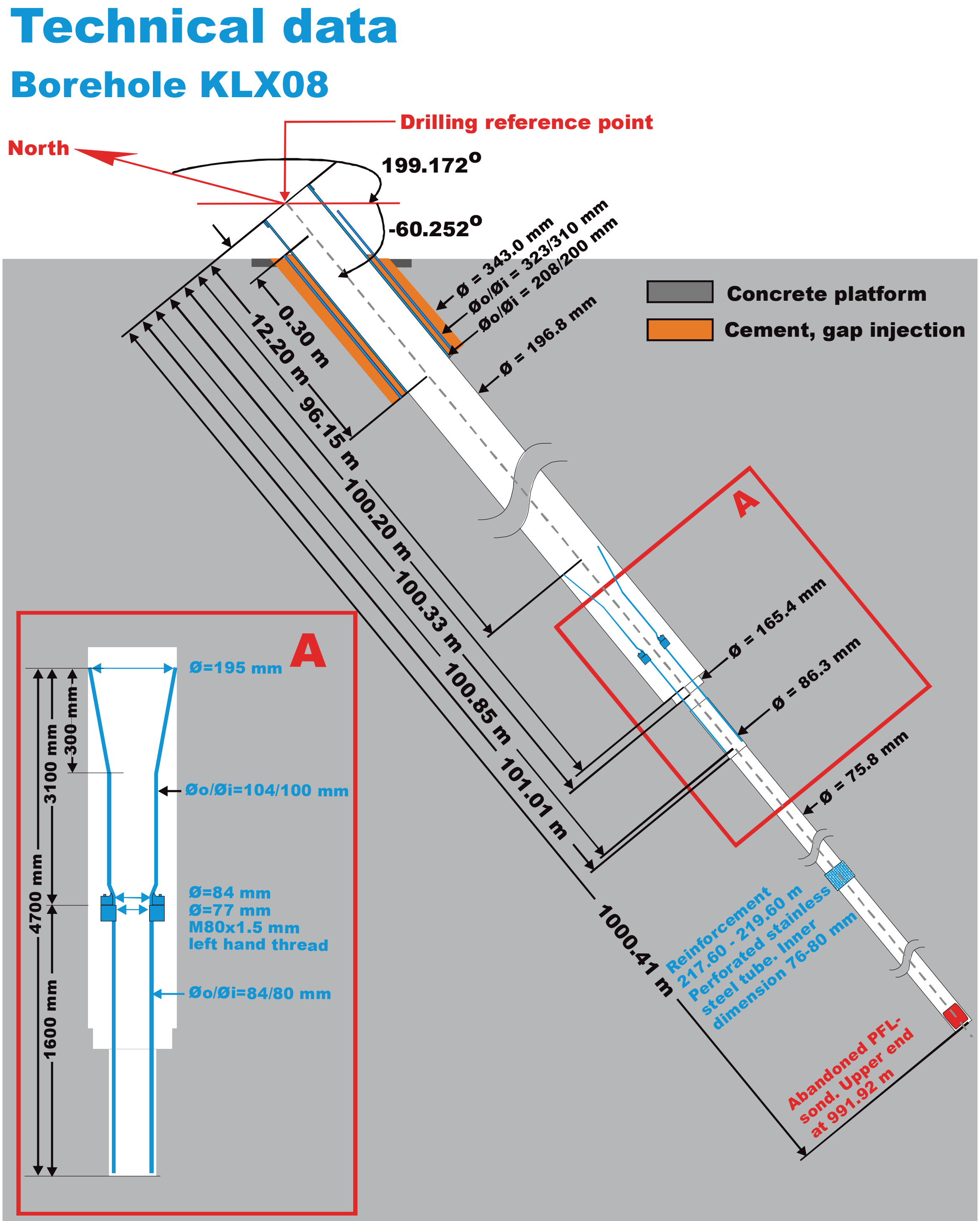
/4/ **Berg C, 2005.** Oskarshamn site investigation. Hydrochemical logging in KLX08. SKB P-05-230, Svensk Kärnbränslehantering AB.

/5/ **Gustafsson J, Gustafsson C, 2006.** Oskarshamn site investigation. RAMAC, BIPS and deviation logging in boreholes KLX08, HLX30 and HLX33. SKB P-05-240, Svensk Kärnbränslehantering AB.

/6/ **Sokolnicki M, Pöllänen J, 2006.** Oskarshamn site investigation. Difference flow logging of borehole KLX08. Subarea Laxemar. SKB P-05-267, Svensk Kärnbränslehantering AB.

/7/ **Nielsen U T, Ringgaard J, 2005.** Oskarshamn site investigation. Geophysical borehole logging in boreholes KLX08, HLX30, HLX31 and HLX33. SKB P-05-270, Svensk Kärnbränslehantering AB.

Design of cored borehole KLX08



Drilling reference point

Northing: 6367079.10 (m), RT90 2,5 gon V 0:-15

Easting: 1548176.71 (m), RT90 2,5 gon V 0:-15

Elevation: 24.31 (m), RHB 70

Drilling period

Drilling start date: 2005-01-12

Drilling stop date: 2005-06-13

Ver 2005-11-07

Results from differential flow logging in KLX08

Laxemar, borehole KLX08
Flow rate, caliper and single point resistance

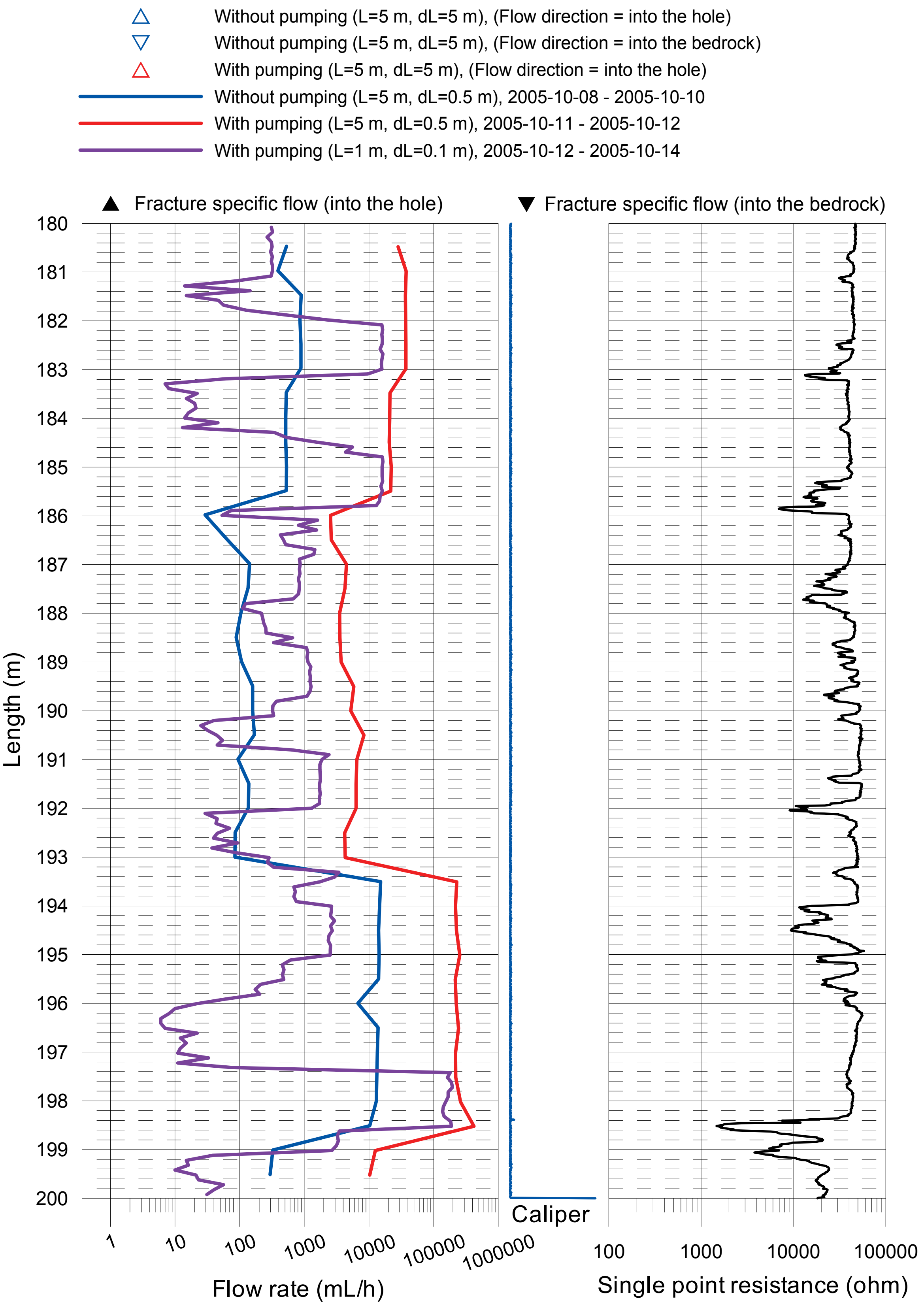


Figure A2-1a. *Borehole KLX08: Differential flow measurements from 180-200 m including the water bearing fracture zone at approximately 198 m /5/.*

Results from differential flow logging in KLX08

Laxemar, borehole KLX08
Flow rate, caliper and single point resistance

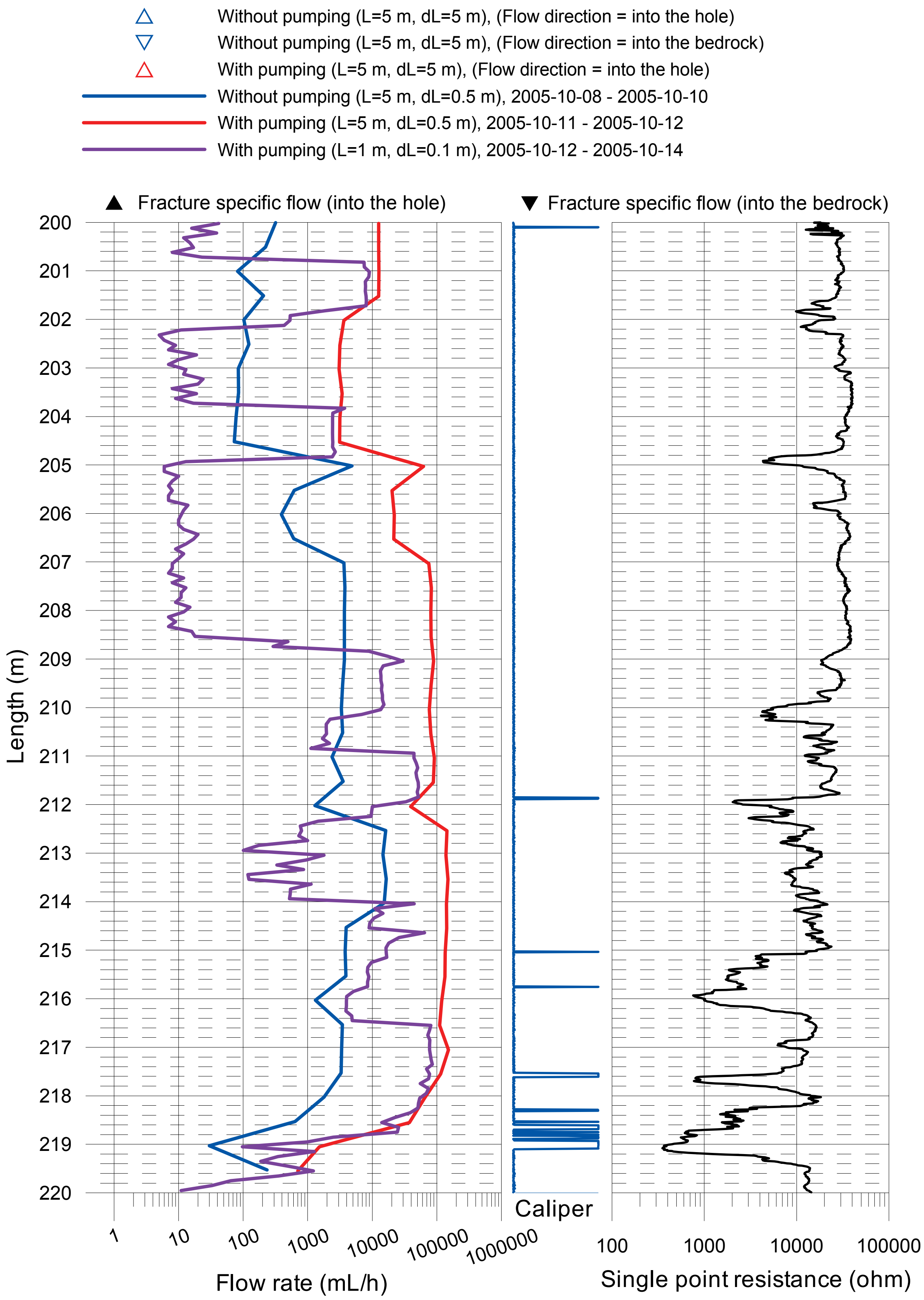


Figure A2-1b. Borehole KLX08: Differential flow measurements from 200-220 m including the water bearing fracture zones at approximately 201 and 205 m /5/.

Appendix 2

Results from differential flow logging in KLX08

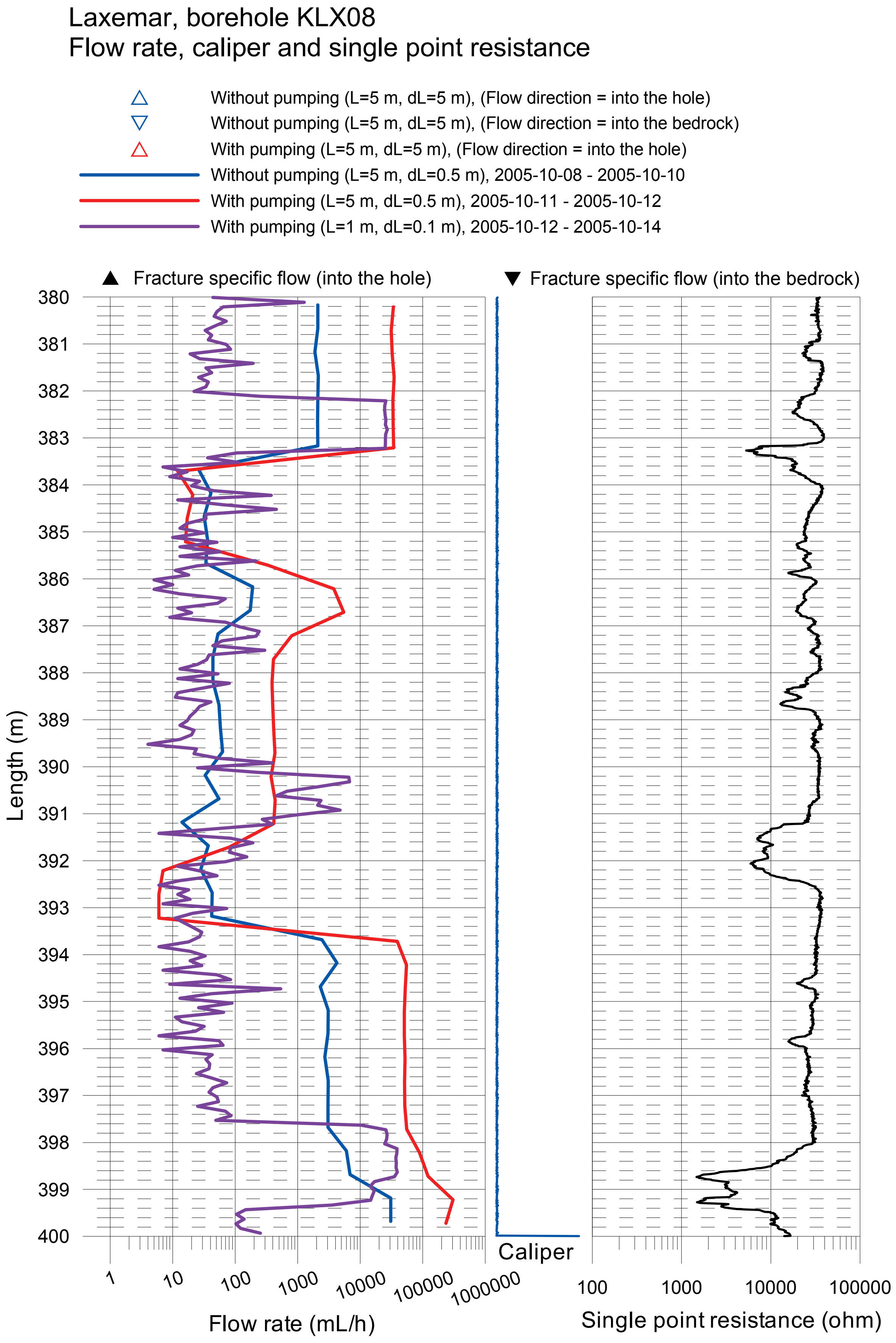


Figure A2-2. Borehole KLX08: Differential flow measurements from 380-400 m including the water bearing fracture zone at approximately 399 m /5/.

Results from differential flow logging in KLX08

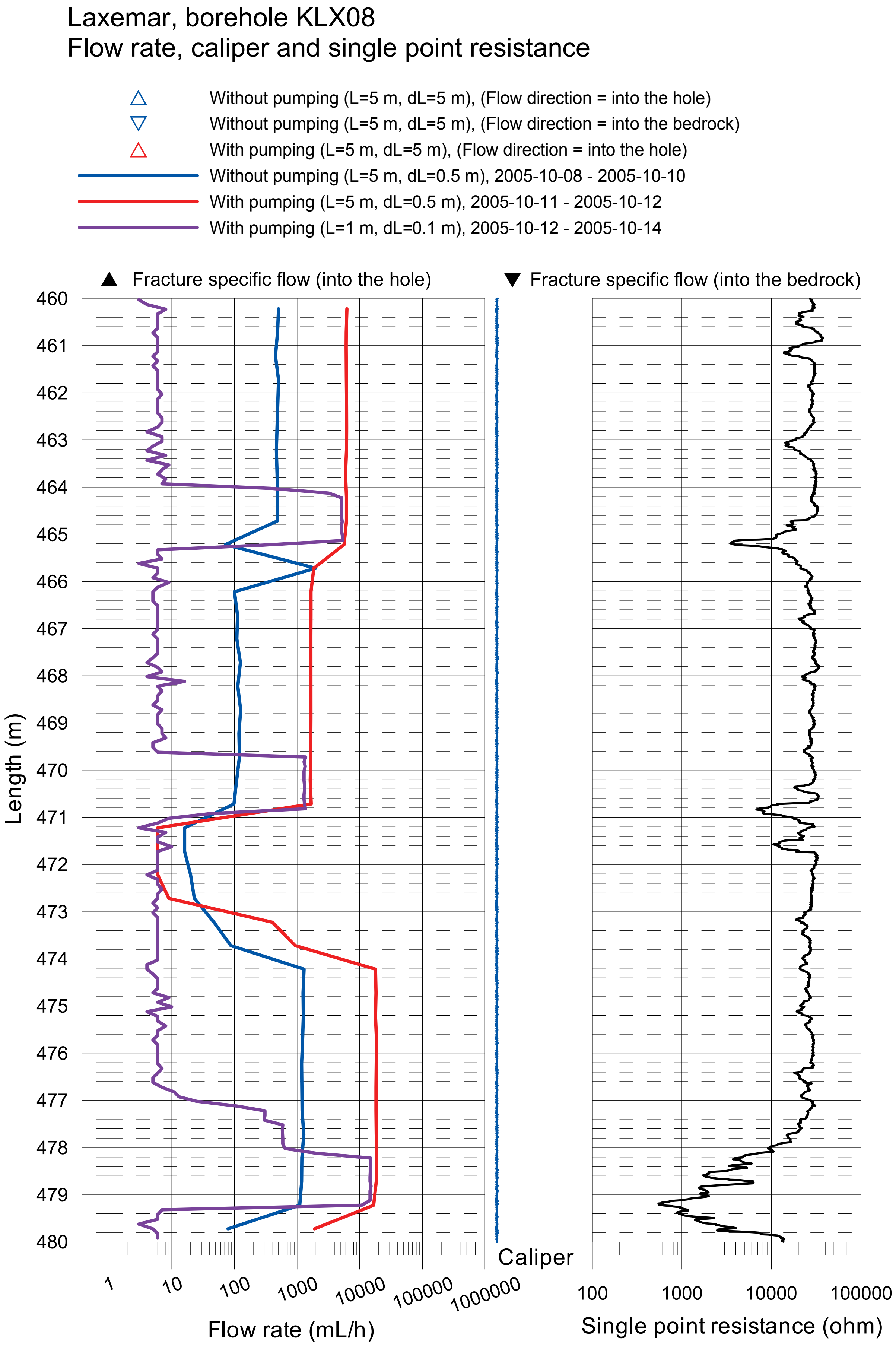


Figure A2-3. Borehole KLX08: Differential flow measurements from 460-480 m including the water bearing fracture zone at approximately 479 m /5/.

Results from differential flow logging in KLX08

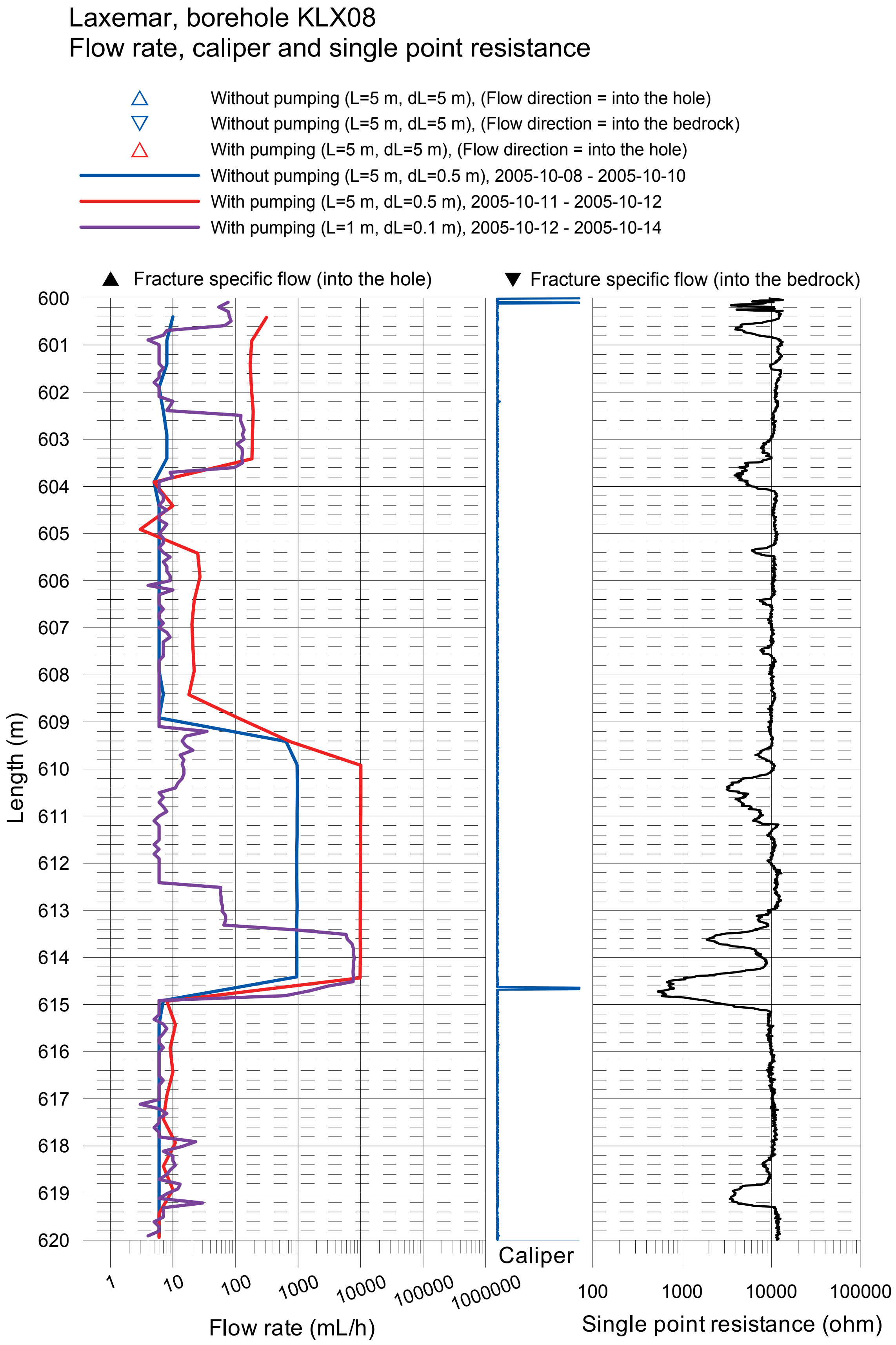


Figure A2-4. *Borehole KLX08: Differential flow measurements from 600-620 m including the water bearing fracture zone at approximately 614 m /5/.*

Selected images from BIPS logging in KLX08

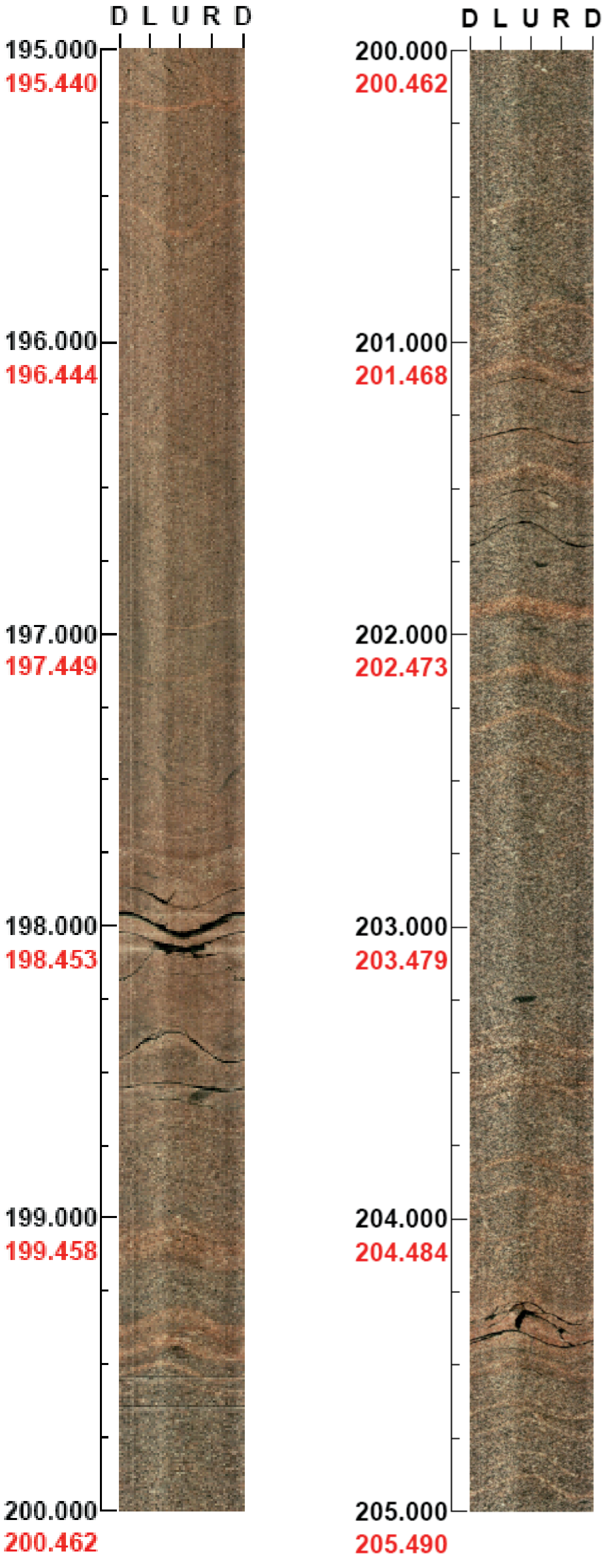


Figure A3-1. *Borehole KLX08: selected BIPS logging image from 195.4 to 205.5 m including the water bearing fractures at 198 and 205 m. The non-adjusted length is marked with black and the adjusted true length is marked with red /4/.*

Selected images from BIPS logging in KLX08

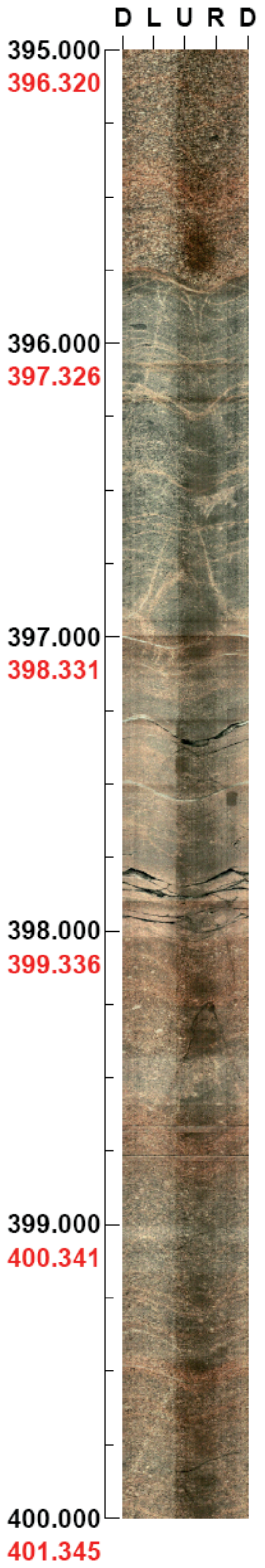


Figure A3-2. *Borehole KLX08: selected BIPS logging image from 396.3 to 401.3 m including the water bearing fracture at 399 m. The non-adjusted length is marked with black and the adjusted true length is marked with red /4/*

Selected images from BIPS logging in KLX08

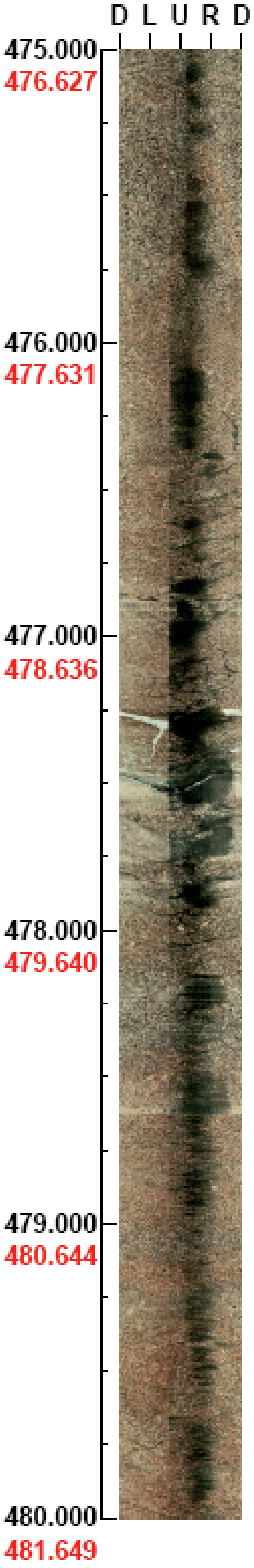


Figure A3-3. *Borehole KLX08: selected BIPS logging image from 476.6 to 481.6 m including the water bearing fracture at 479 m. The non-adjusted length is marked with black and the adjusted true length is marked with red /4/*

Appendix 3

Selected images from BIPS logging in KLX08

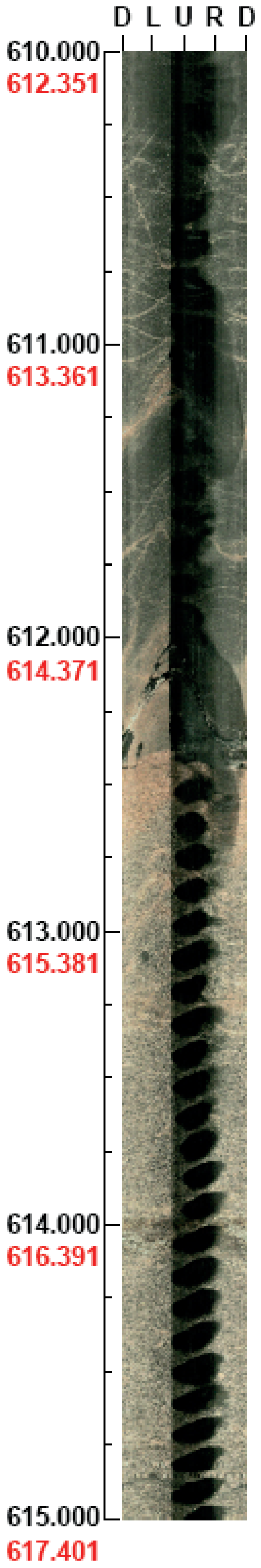
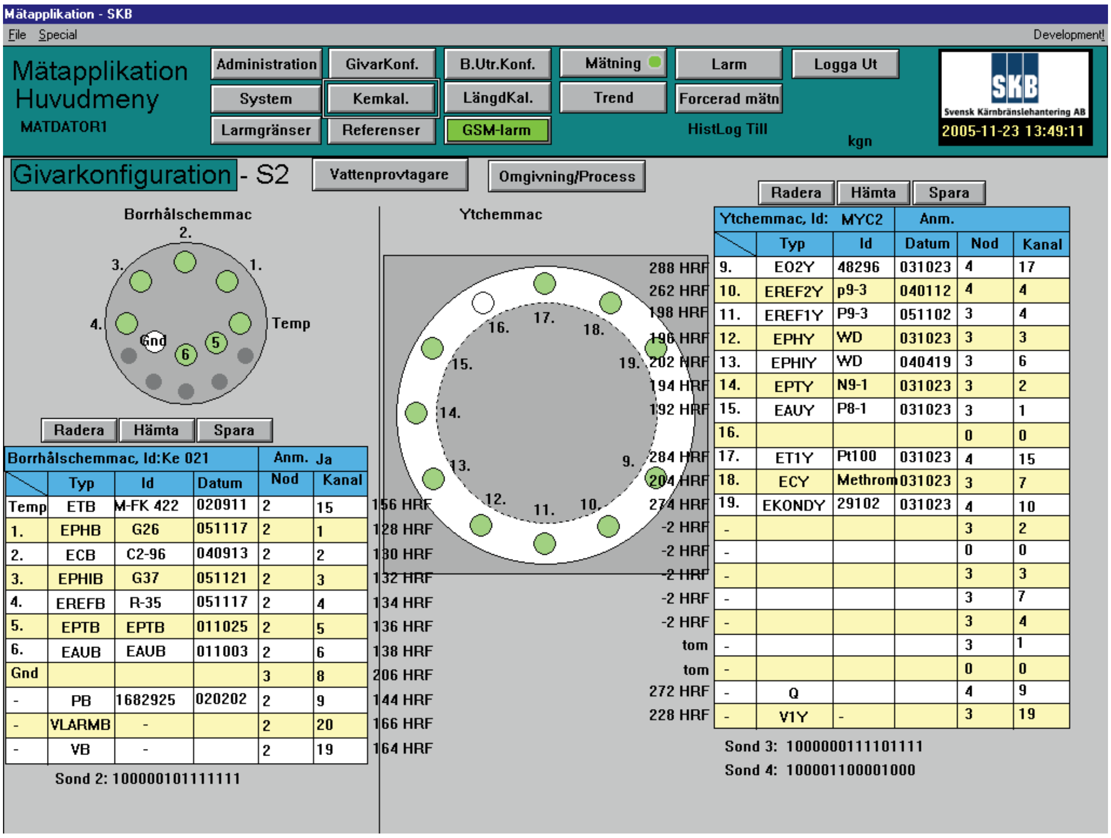


Figure A3-4. *Borehole KFM08: selected BIPS logging image from 612.4 to 617.4 m including the water bearing fracture at 614 m. The non-adjusted length is marked with black and the adjusted true length is marked with red /4/*

Appendix 4

Measurement information, KLX08

Section 197.0-206.6 m



Borrhålschemmac, Id:Ke 021				Anm. Ja	
	Typ	Id	Datum	Nod	Kanal
Temp	ETB	M-FK 422	020911	2	15
1.	EPHB	G26	051117	2	1
2.	ECB	C2-96	040913	2	2
3.	EPHIB	G37	051121	2	3
4.	EREFB	R-35	051117	2	4
5.	EPTB	EPTB	011025	2	5
6.	EAUB	EAUB	011003	2	6
Gnd				3	8
-	PB	1682925	020202	2	9
-	VLARMB	-		2	20
-	VB	-		2	19

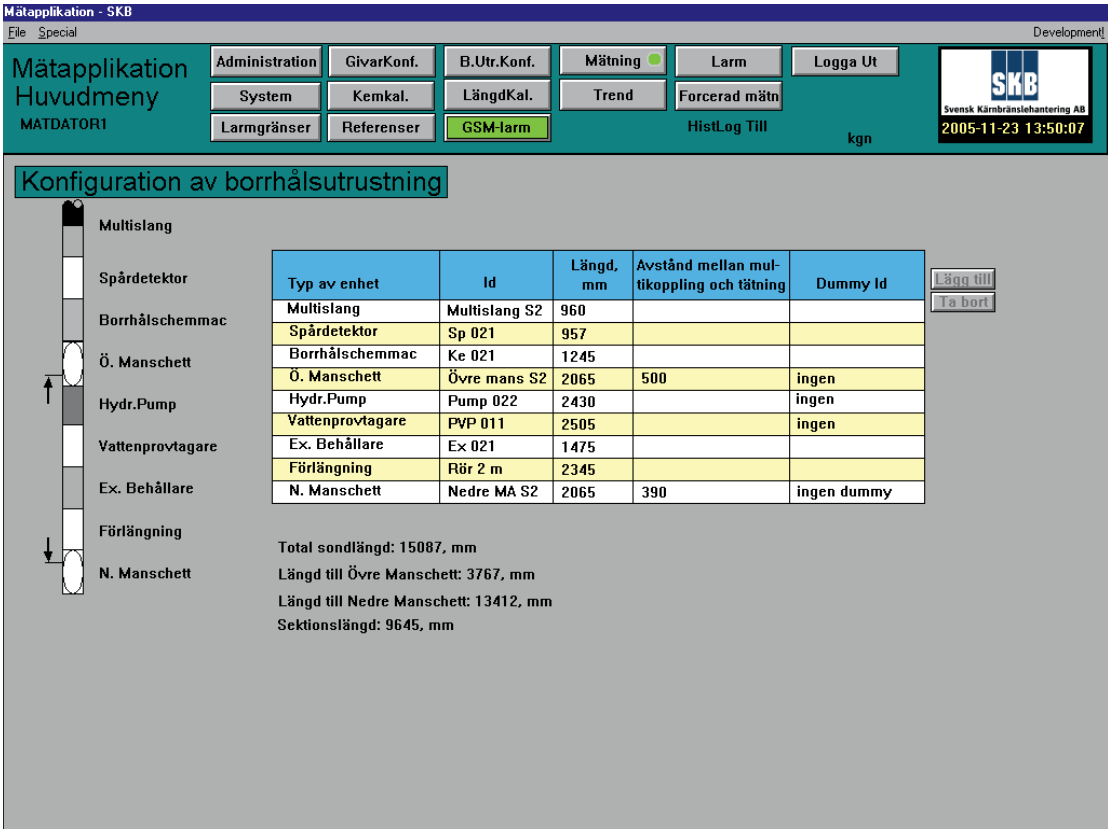
Sond 2: 100000101111111

Ytchemmac, Id: MYC2			Anm.		
	Typ	Id	Datum	Nod	Kanal
9.	EO2Y	48296	031023	4	17
10.	EREF2Y	p9-3	040112	4	4
11.	EREF1Y	P9-3	051102	3	4
12.	EPHY	WD	031023	3	3
13.	EPHIY	WD	040419	3	6
14.	EPTY	N9-1	031023	3	2
15.	EAUY	P8-1	031023	3	1
16.				0	0
17.	ET1Y	Pt100	031023	4	15
18.	ECY	Methrom	031023	3	7
19.	EKONDY	29102	031023	4	10
-				3	2
-				0	0
-				3	3
-				3	7
-				3	4
-				3	1
-				0	0
-	Q			4	9
-	V1Y	-		3	19

Sond 3: 1000000111101111

Sond 4: 100001100001000

Figure A4-1. *Electrode configuration, section 197.0-206.6 m.*



Typ av enhet	Id	Längd, mm	Avstånd mellan multikoppling och tätning	Dummy Id
Multislang	Multislang S2	960		
Spårdetektor	Sp 021	957		
Borrhålschemmac	Ke 021	1245		
Ö. Manschett	Övre mans S2	2065	500	ingen
Hydr.Pump	Pump 022	2430		ingen
Vattenprovtagare	PVP 011	2505		ingen
Ex. Behållare	Ex 021	1475		
Förlängning	Rör 2 m	2345		
N. Manschett	Nedre MA S2	2065	390	ingen dummy

Total sondlängd: 15087, mm

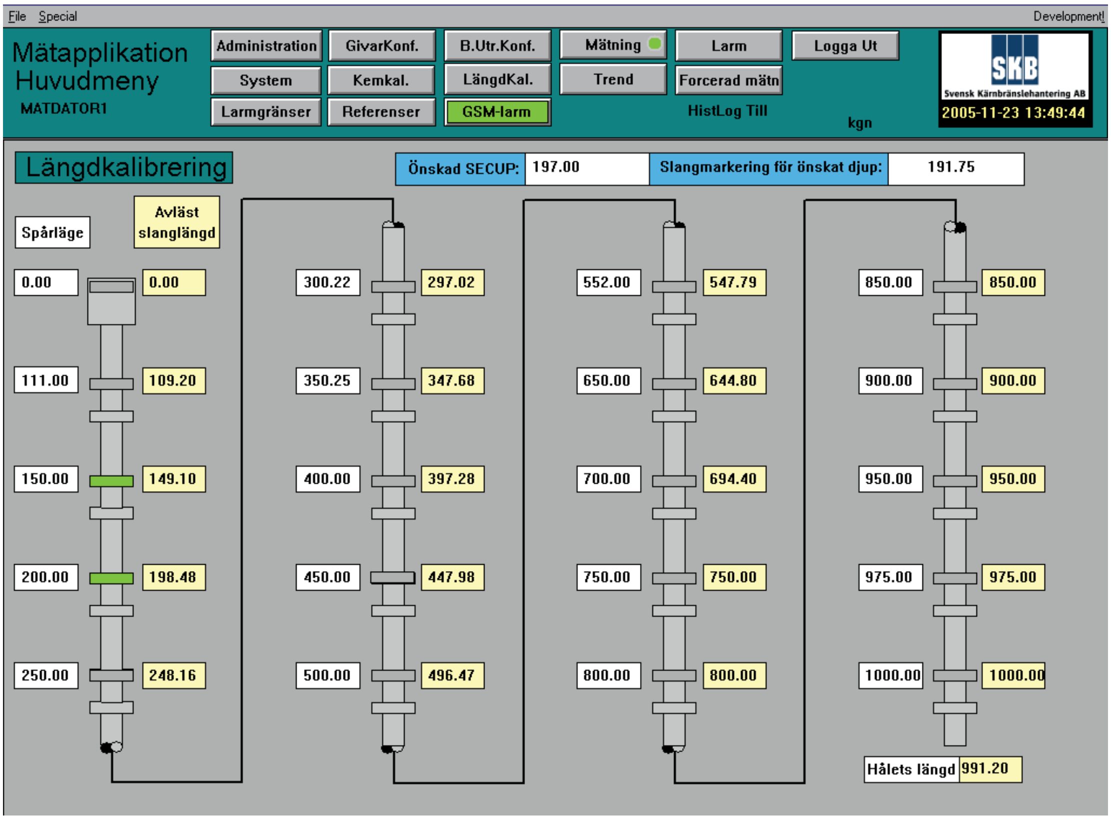
Längd till Övre Manschett: 3767, mm

Längd till Nedre Manschett: 13412, mm

Sektionslängd: 9645, mm

Figure A4-2. *Configuration of downhole equipment, section 197.0-206.6 m.*

Measurement information, KLX08



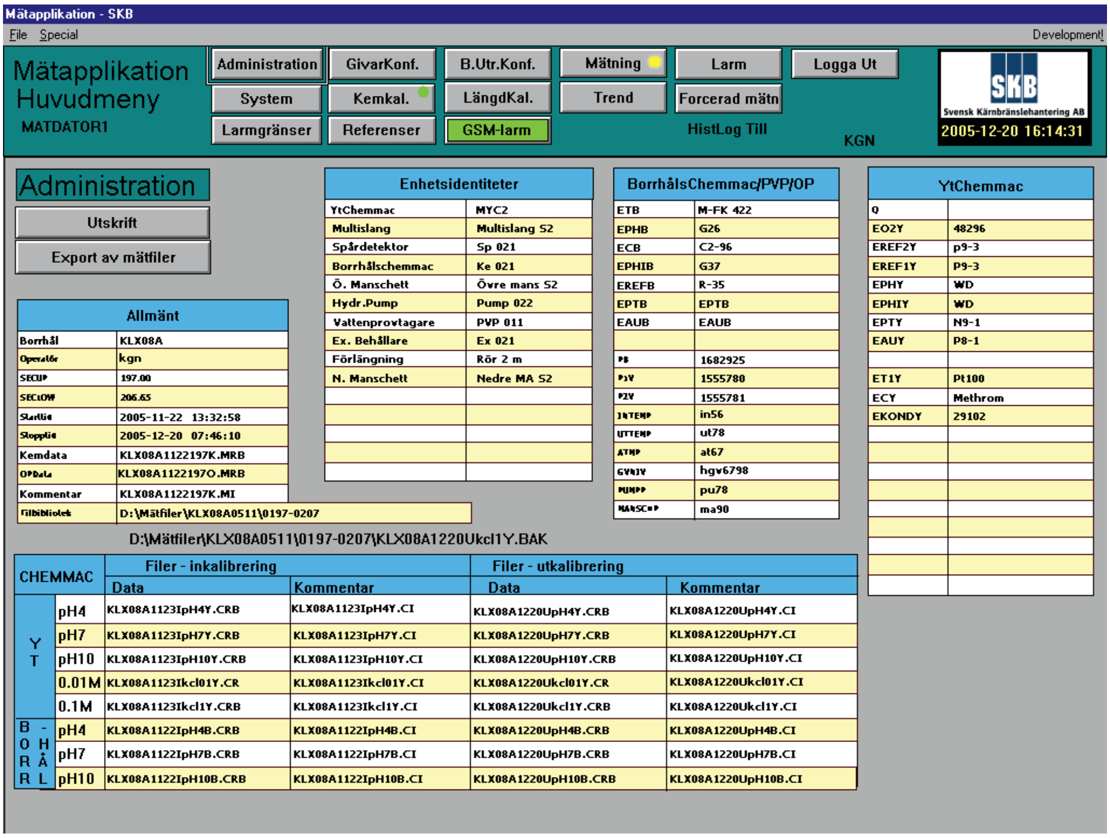
Önskad SECUP: 197.00

Slangmarkering för önskat djup: 191.75

Spårläge	Avläst slanglängd
0.00	0.00
111.00	109.20
150.00	149.10
200.00	198.48
250.00	248.16
300.22	297.02
350.25	347.68
400.00	397.28
450.00	447.98
500.00	496.47
552.00	547.79
650.00	644.80
700.00	694.40
750.00	750.00
800.00	800.00
850.00	850.00
900.00	900.00
950.00	950.00
975.00	975.00
1000.00	1000.00

Hålets längd 991.20

Figure A4-3. Length calibration, section 197.0-206.6 m.



Allmänt	
Borrhål	KLX08A
Operatör	kgn
SECUP	197.00
SECLOW	206.65
Starttid	2005-11-22 13:32:58
Stopptid	2005-12-20 07:46:10
Kemdata	KLX08A1122197K.MRB
OPData	KLX08A1122197O.MRB
Kommentar	KLX08A1122197K.MI
Filbibliotek	D:\Mätfiler\KLX08A0511\0197-0207

Enhetsidentiteter	
YtChemmac	MYC2
Multislang	Multislang S2
Spårdetektor	Sp 021
Borrhålschemmac	Ke 021
Ö. Manschett	Övre mans S2
Hydr.Pump	Pump 022
Vattenprovtagare	PVP 011
Ex. Behållare	Ex 021
Förlängning	Rör 2 m
N. Manschett	Nedre MA S2

BorrhålsChemmac/PVP/OP	
ETB	M-FK 422
EPHB	G26
ECB	C2-96
EPHIB	G37
EREFB	R-35
EPTB	EPTB
EAUB	EAUB
PB	1682925
P1V	1555780
P2V	1555781
INTEMP	in56
UTTEMP	ut78
ATMP	at67
GVNIV	hgv6798
PUMPP	pu78
MANSCHP	ma90

YtChemmac	
Q	
EO2Y	48296
EREF2Y	p9-3
EREF1Y	P9-3
EPHY	WD
EPHIY	WD
EPTY	N9-1
EAUY	P8-1
ET1Y	Pt100
ECY	Methrom
EKONDY	29102

D:\Mätfiler\KLX08A0511\0197-0207\KLX08A1220Ukcl1Y.BAK

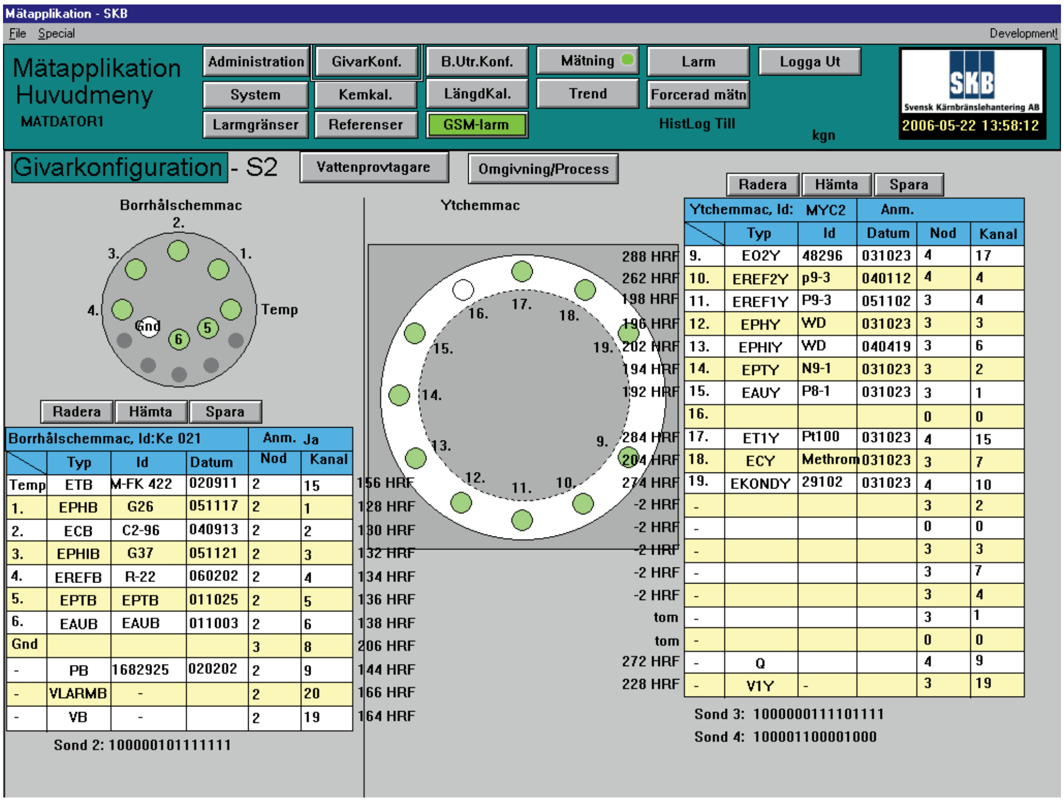
CHEMMAC		Filer - inkalibrering		Filer - utkalibrering	
		Data	Kommentar	Data	Kommentar
YT	pH4	KLX08A1123IpH4Y.CRB	KLX08A1123IpH4Y.CI	KLX08A1220UpH4Y.CRB	KLX08A1220UpH4Y.CI
	pH7	KLX08A1123IpH7Y.CRB	KLX08A1123IpH7Y.CI	KLX08A1220UpH7Y.CRB	KLX08A1220UpH7Y.CI
	pH10	KLX08A1123IpH10Y.CRB	KLX08A1123IpH10Y.CI	KLX08A1220UpH10Y.CRB	KLX08A1220UpH10Y.CI
	0.01M	KLX08A1123Ikcl01Y.CR	KLX08A1123Ikcl01Y.CI	KLX08A1220Ukcl01Y.CR	KLX08A1220Ukcl01Y.CI
	0.1M	KLX08A1123Ikcl1Y.CRB	KLX08A1123Ikcl1Y.CI	KLX08A1220Ukcl1Y.CRB	KLX08A1220Ukcl1Y.CI
BORR-HÅL	pH4	KLX08A1122IpH4B.CRB	KLX08A1122IpH4B.CI	KLX08A1220UpH4B.CRB	KLX08A1220UpH4B.CI
	pH7	KLX08A1122IpH7B.CRB	KLX08A1122IpH7B.CI	KLX08A1220UpH7B.CRB	KLX08A1220UpH7B.CI
	pH10	KLX08A1122IpH10B.CRB	KLX08A1122IpH10B.CI	KLX08A1220UpH10B.CRB	KLX08A1220UpH10B.CI

Figure A4-4. Administration, section 197.0-206.6 m.

Measurement information, KLX08

Section 396.0-400.9 m The measurement information from this section is missing.

Section 476.0-485.6 m



Borrhålschemmac, Id:Ke 021				Anm. Ja	
	Typ	Id	Datum	Nod	Kanal
Temp	ETB	M-FK 422	020911	2	15
1.	EPHB	G26	051117	2	1
2.	ECB	C2-96	040913	2	2
3.	EPHIB	G37	051121	2	3
4.	EREFB	R-22	060202	2	4
5.	EPTB	EPTB	011025	2	5
6.	EAUB	EAUB	011003	2	6
Gnd				3	8
-	PB	1682925	020202	2	9
-	VLARMB	-		2	20
-	VB	-		2	19

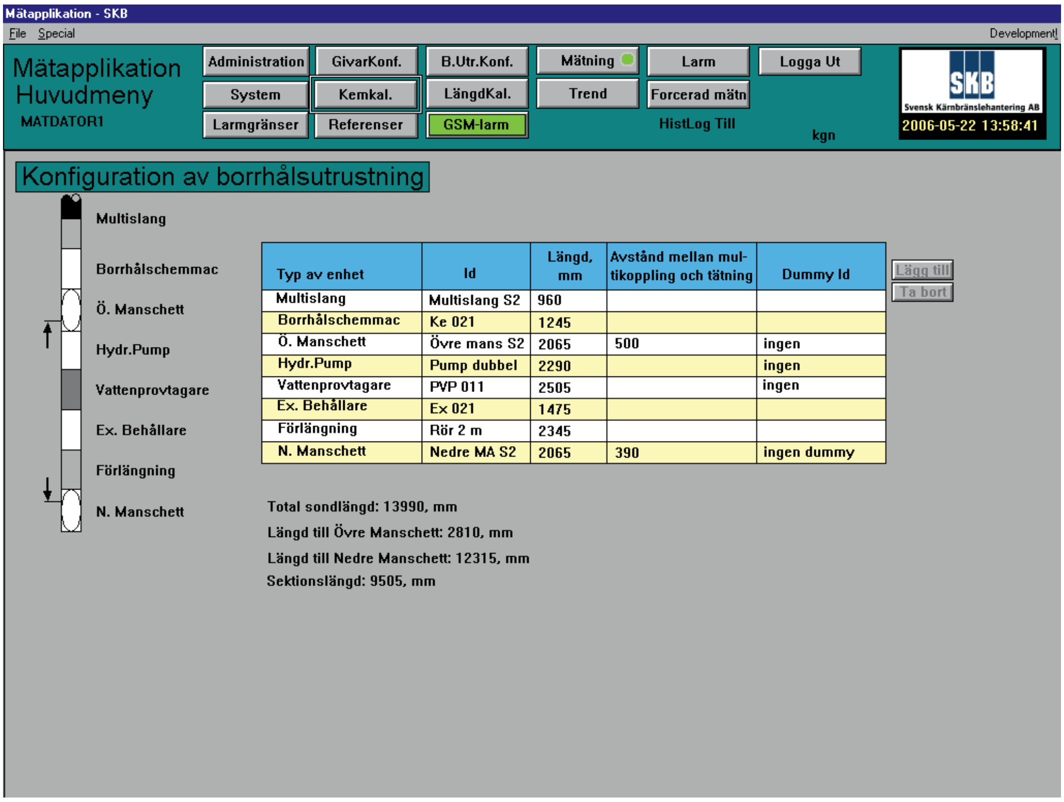
Sond 2: 100000101111111

Ytchemmac, Id:	MYC2		Anm.		
	Typ	Id	Datum	Nod	Kanal
9.	EO2Y	48296	031023	4	17
10.	EREF2Y	p9-3	040112	4	4
11.	EREF1Y	P9-3	051102	3	4
12.	EPHY	WD	031023	3	3
13.	EPHIY	WD	040419	3	6
14.	EPTY	N9-1	031023	3	2
15.	EAUY	P8-1	031023	3	1
16.				0	0
17.	ET1Y	Pt100	031023	4	15
18.	ECY	Methrom	031023	3	7
19.	EKONDY	29102	031023	4	10
-				3	2
-				0	0
-				3	3
-				3	7
-				3	4
-				3	1
-				0	0
-	Q			4	9
-	V1Y	-		3	19

Sond 3: 1000000111101111

Sond 4: 100001100001000

Figure A4-9. Electrode configuration, section 476.0-485.6 m.



Typ av enhet	Id	Längd, mm	Avstånd mellan multikoppling och tätning	Dummy Id
Multislang	Multislang S2	960		
Borrhålschemmac	Ke 021	1245		
Ö. Manschett	Övre mans S2	2065	500	ingen
Hydr.Pump	Pump dubbel	2290		ingen
Vattenprovtagare	PVP 011	2505		ingen
Ex. Behållare	Ex 021	1475		
Förlängning	Rör 2 m	2345		
N. Manschett	Nedre MA S2	2065	390	ingen dummy

Total sondlängd: 13990, mm

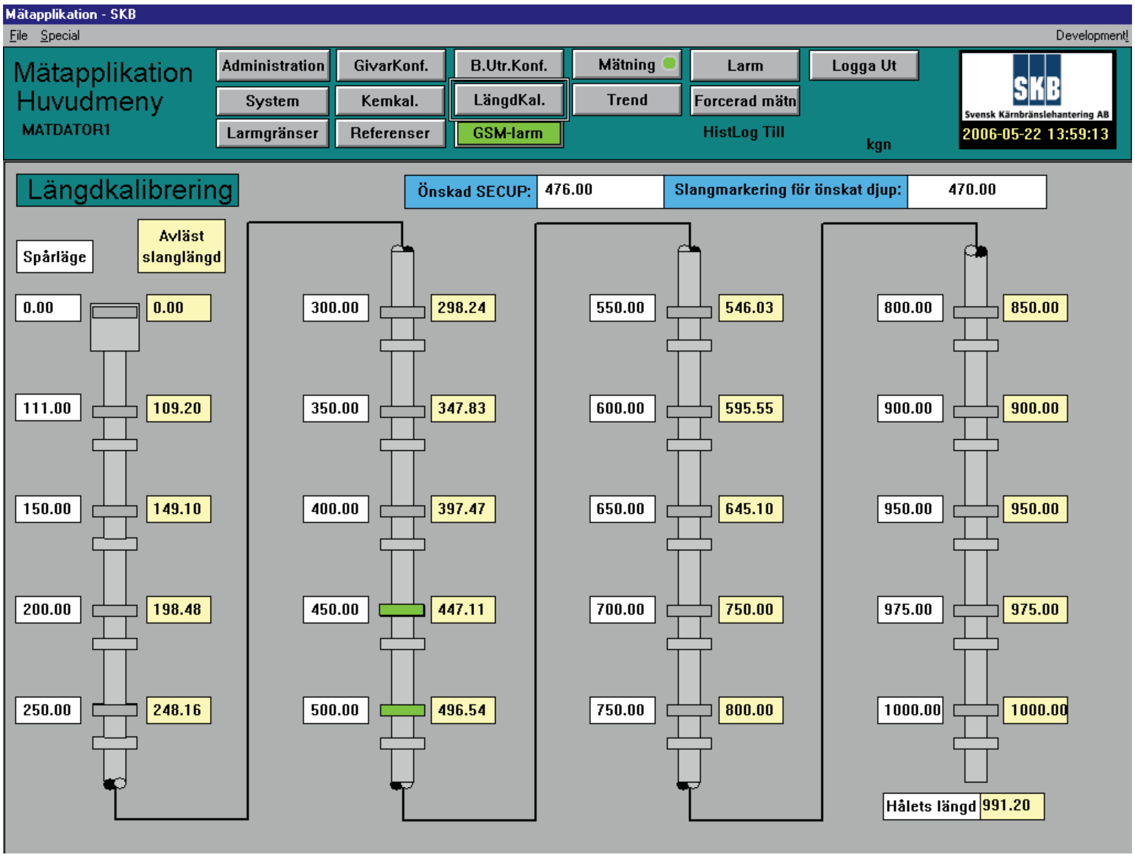
Längd till Övre Manschett: 2810, mm

Längd till Nedre Manschett: 12315, mm

Sektionslängd: 9505, mm

Figure A4-10. Configuration of downhole equipment, section 476.0-485.6 m.

Measurement information, KLX08



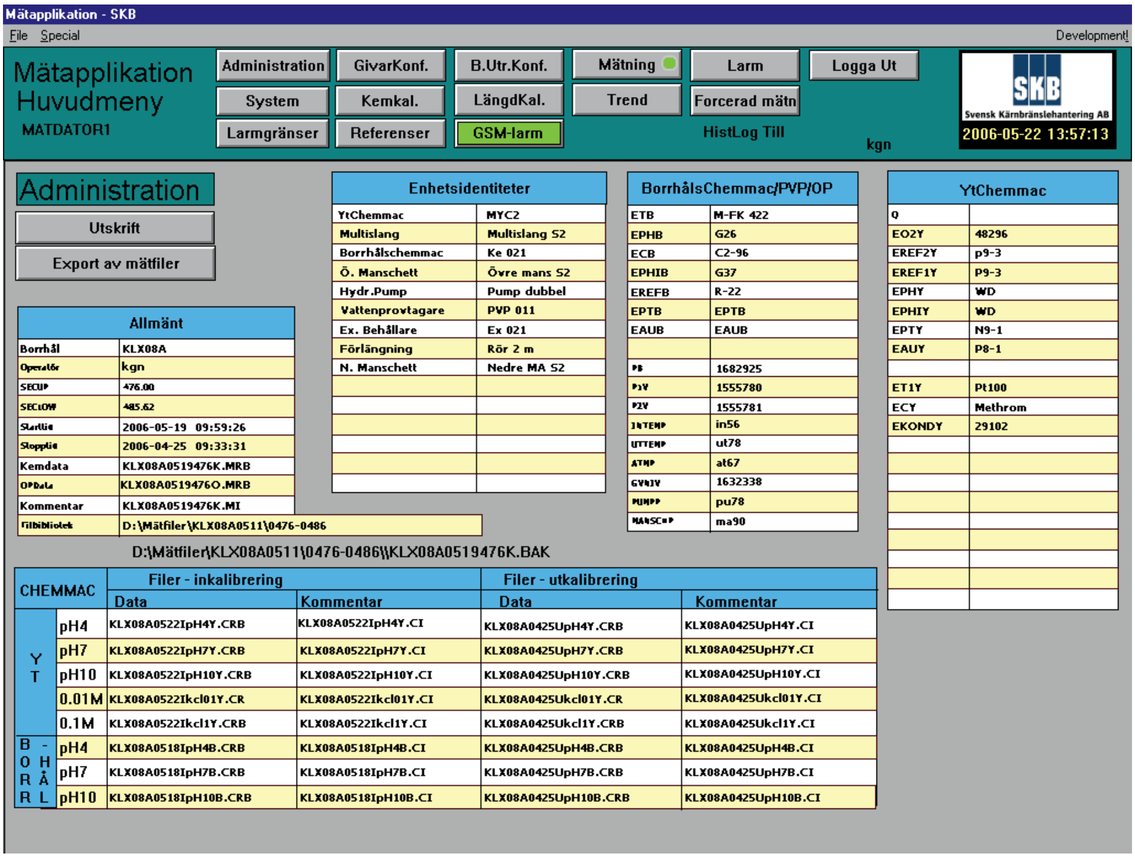
Önskad SECUP: 476.00

Slangmarkering för önskat djup: 470.00

Spårläge	Avläst slanglängd
0.00	0.00
111.00	109.20
150.00	149.10
200.00	198.48
250.00	248.16
300.00	298.24
350.00	347.83
400.00	397.47
450.00	447.11
500.00	496.54
550.00	546.03
600.00	595.55
650.00	645.10
700.00	750.00
750.00	800.00
800.00	850.00
900.00	900.00
950.00	950.00
975.00	975.00
1000.00	1000.00

Hålets längd 991.20

Figure A4-11. Length calibration, section 476.0-485.6 m.



Allmänt	
Borrhål	KLX08A
Operatör	kgn
SECUP	476.00
SECLOW	485.62
Starttid	2006-05-19 09:59:26
Stopptid	2006-04-25 09:33:31
Kemdata	KLX08A0519476K.MRB
OPData	KLX08A0519476O.MRB
Kommentar	KLX08A0519476K.MI
Filbibliotek	D:\Mätfiler\KLX08A0511\0476-0486

D:\Mätfiler\KLX08A0511\0476-0486\\KLX08A0519476K.BAK

Enhetsidentiteter	
YtChemmac	MYC2
Multislang	Multislang S2
Borrhålschemmac	Ke 021
Ö. Manschett	Övre mans S2
Hydr.Pump	Pump dubbel
Vattenprovtagare	PVP 011
Ex. Behållare	Ex 021
Förlängning	Rör 2 m
N. Manschett	Nedre MA S2

BorrhålsChemmac/PVP/OP	
ETB	M-FK 422
EPHB	G26
ECB	C2-96
EPHIB	G37
EREFB	R-22
EPTB	EPTB
EAUB	EAUB
PB	1682925
P1V	1555780
P2V	1555781
INTEMP	in56
UTTEMP	ut78
ATMP	at67
GVNIV	1632338
PUMPP	pu78
MANSCHP	ma90

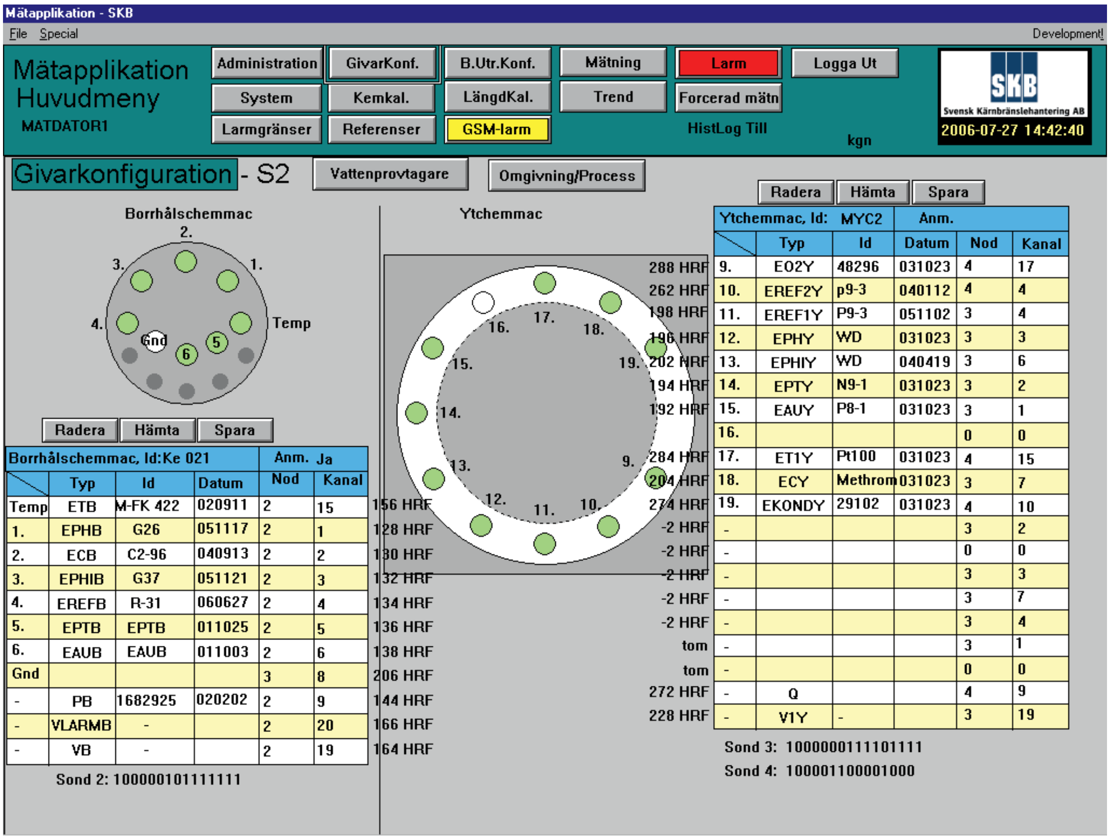
YtChemmac	
Q	
EO2Y	48296
EREF2Y	p9-3
EREF1Y	P9-3
EPHY	WD
EPHIY	WD
EPTY	N9-1
EAUY	P8-1
ET1Y	Pt100
ECY	Methrom
EKONDY	29102

CHEMMAC		Filer - inkalibrering		Filer - utkalibrering	
		Data	Kommentar	Data	Kommentar
YT	pH4	KLX08A0522IpH4Y.CRB	KLX08A0522IpH4Y.CI	KLX08A0425UpH4Y.CRB	KLX08A0425UpH4Y.CI
	pH7	KLX08A0522IpH7Y.CRB	KLX08A0522IpH7Y.CI	KLX08A0425UpH7Y.CRB	KLX08A0425UpH7Y.CI
	pH10	KLX08A0522IpH10Y.CRB	KLX08A0522IpH10Y.CI	KLX08A0425UpH10Y.CRB	KLX08A0425UpH10Y.CI
	0.01M	KLX08A0522Ikcl01Y.CR	KLX08A0522Ikcl01Y.CI	KLX08A0425Ukcl01Y.CR	KLX08A0425Ukcl01Y.CI
	0.1M	KLX08A0522Ikcl1Y.CRB	KLX08A0522Ikcl1Y.CI	KLX08A0425Ukcl1Y.CRB	KLX08A0425Ukcl1Y.CI
BORR-HÅL	pH4	KLX08A0518IpH4B.CRB	KLX08A0518IpH4B.CI	KLX08A0425UpH4B.CRB	KLX08A0425UpH4B.CI
	pH7	KLX08A0518IpH7B.CRB	KLX08A0518IpH7B.CI	KLX08A0425UpH7B.CRB	KLX08A0425UpH7B.CI
	pH10	KLX08A0518IpH10B.CRB	KLX08A0518IpH10B.CI	KLX08A0425UpH10B.CRB	KLX08A0425UpH10B.CI

Figure A4-12. Administration, section 476.0-485.6 m.

Measurement information, KLX08

Section 609.0-618.5 m



Borrhålschemmac, Id:Ke 021 Anm. Ja

	Typ	Id	Datum	Nod	Kanal
Temp	ETB	M-FK 422	020911	2	15
1.	EPHB	G26	051117	2	1
2.	ECB	C2-96	040913	2	2
3.	EPHIB	G37	051121	2	3
4.	EREFB	R-31	060627	2	4
5.	EPTB	EPTB	011025	2	5
6.	EAUB	EAUB	011003	2	6
Gnd				3	8
-	PB	1682925	020202	2	9
-	VLARMB	-		2	20
-	VB	-		2	19

Sond 2: 100000101111111

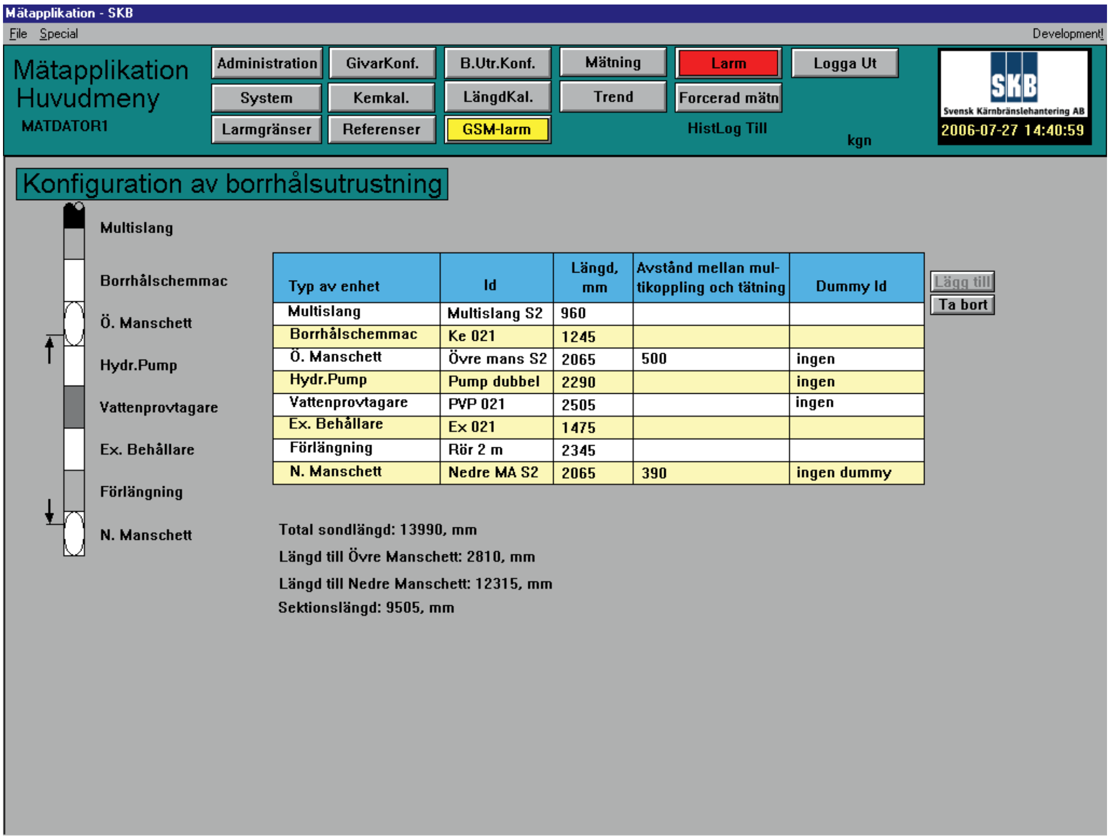
Ytchemmac, Id: MYC2 Anm.

	Typ	Id	Datum	Nod	Kanal
9.	EO2Y	48296	031023	4	17
10.	EREF2Y	p9-3	040112	4	4
11.	EREF1Y	P9-3	051102	3	4
12.	EPHY	WD	031023	3	3
13.	EPHIY	WD	040419	3	6
14.	EPTY	N9-1	031023	3	2
15.	EAUY	P8-1	031023	3	1
16.				0	0
17.	ET1Y	Pt100	031023	4	15
18.	ECY	Methrom	031023	3	7
19.	EKONDY	29102	031023	4	10
-				3	2
-				0	0
-				3	3
-				3	7
-				3	4
-				3	1
-				0	0
-	Q			4	9
-	V1Y	-		3	19

Sond 3: 1000000111101111

Sond 4: 100001100001000

Figure A4-13. Electrode configuration, section 609.0-618.5 m.



Typ av enhet	Id	Längd, mm	Avstånd mellan multikoppling och tätning	Dummy Id
Multislang	Multislang S2	960		
Borrhålschemmac	Ke 021	1245		
Ö. Manschett	Övre mans S2	2065	500	ingen
Hydr.Pump	Pump dubbel	2290		ingen
Vattenprovtagare	PVP 021	2505		ingen
Ex. Behållare	Ex 021	1475		
Förlängning	Rör 2 m	2345		
N. Manschett	Nedre MA S2	2065	390	ingen dummy

Total sondlängd: 13990, mm

Längd till Övre Manschett: 2810, mm

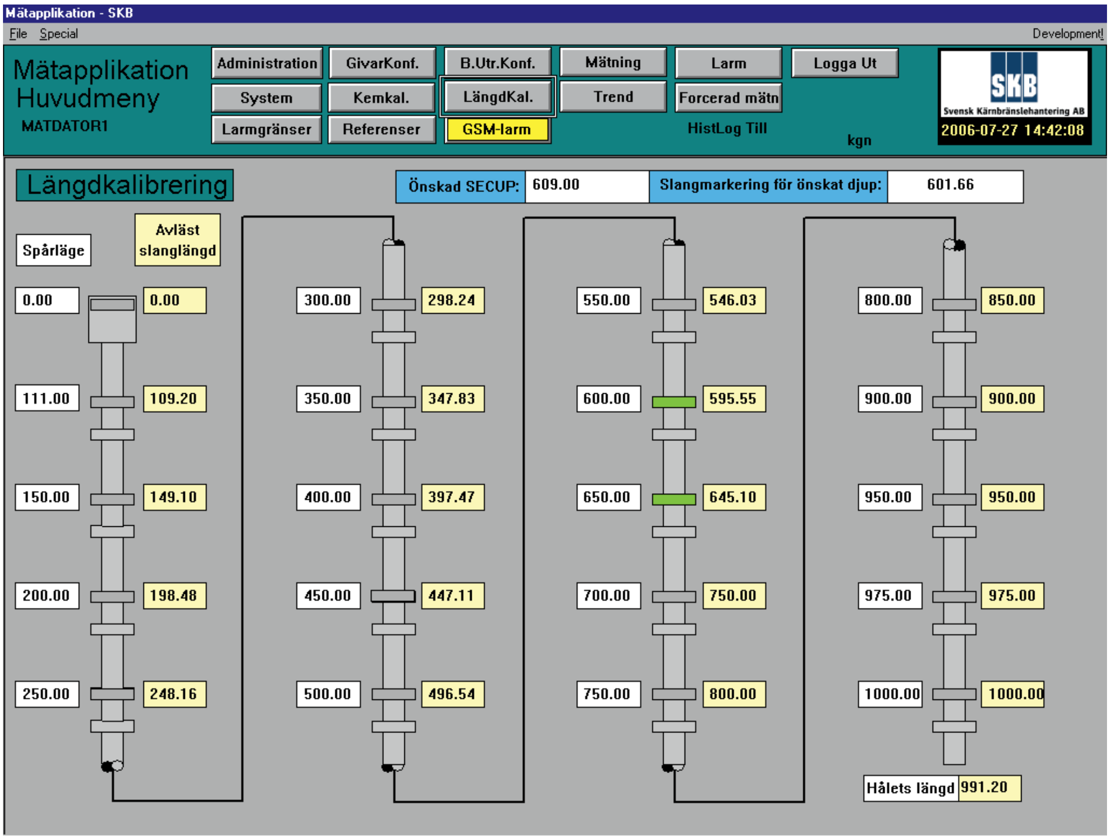
Längd till Nedre Manschett: 12315, mm

Sektionslängd: 9505, mm

Figure A4-14. Configuration of downhole equipment, section 609.0-618.5 m.

Appendix 4

Measurement information, KLX08



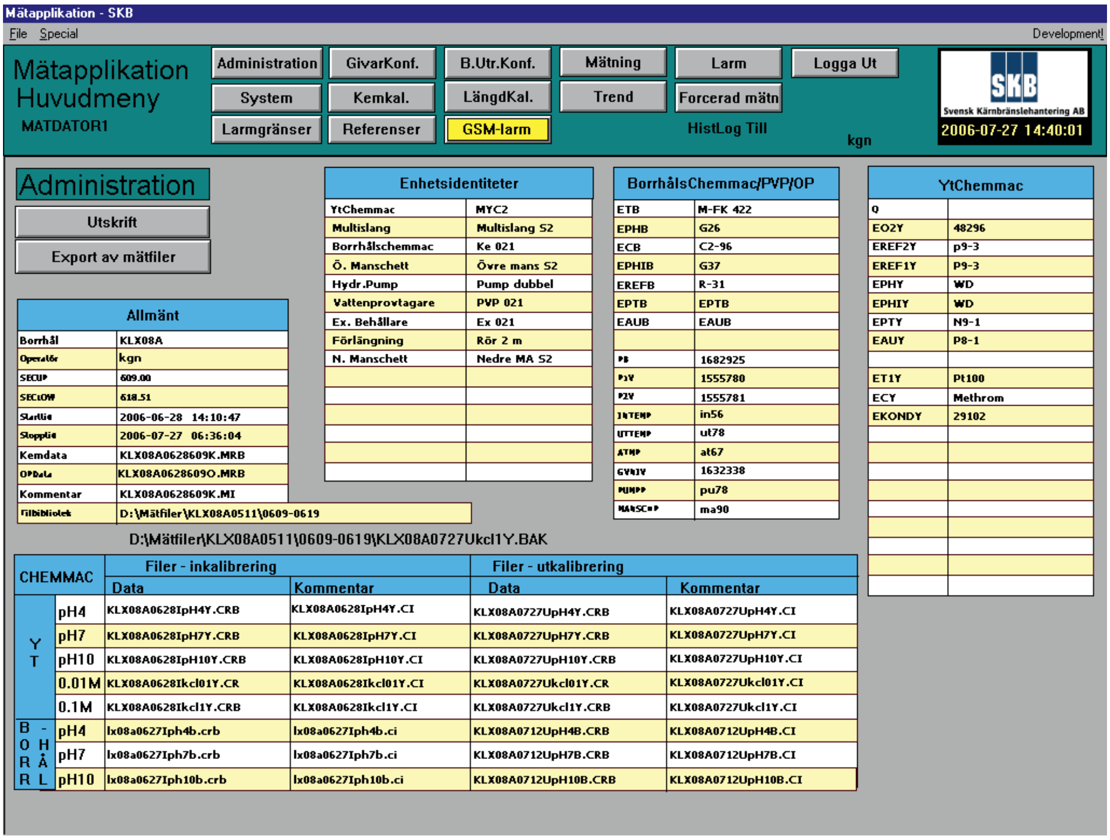
Önskad SECUP: 609.00

Slangmarkering för önskat djup: 601.66

Spårläge	Avläst slanglängd
0.00	0.00
111.00	109.20
150.00	149.10
200.00	198.48
250.00	248.16
300.00	298.24
350.00	347.83
400.00	397.47
450.00	447.11
500.00	496.54
550.00	546.03
600.00	595.55
650.00	645.10
700.00	750.00
750.00	800.00
800.00	850.00
900.00	900.00
950.00	950.00
975.00	975.00
1000.00	1000.00

Hålets längd 991.20

Figure A4-15. *Length calibration, section 609.0-618.5 m.*



Allmänt	
Borrhål	KLX08A
Operatör	kgn
SECUP	609.00
SECLOW	618.51
Starttid	2006-06-28 14:10:47
Stopptid	2006-07-27 06:36:04
Kemdata	KLX08A0628609K.MRB
OPData	KLX08A0628609O.MRB
Kommentar	KLX08A0628609K.MI
Filbibliotek	D:\Mätfiler\KLX08A0511\0609-0619

Enhetsidentiteter	
YtChemmac	MYC2
Multislang	Multislang S2
Borrhålschemmac	Ke 021
Ö. Manschett	Övre mans S2
Hydr.Pump	Pump dubbel
Vattenprovtagare	PVP 021
Ex. Behållare	Ex 021
Förlängning	Rör 2 m
N. Manschett	Nedre MA S2

BorrhålsChemmac/PVP/OP	
ETB	M-FK 422
EPHB	G26
ECB	C2-96
EPHIB	G37
EREFB	R-31
EPTB	EPTB
EAUB	EAUB
PB	1682925
P1V	1555780
P2V	1555781
INTEMP	in56
UTTEMP	ut78
ATMP	at67
GVNIV	1632338
PUMPP	pu78
MANSCHP	ma90

YtChemmac	
Q	
EO2Y	48296
EREF2Y	p9-3
EREF1Y	P9-3
EPHY	WD
EPHIY	WD
EPTY	N9-1
EAUY	P8-1
ET1Y	Pt100
ECY	Methrom
EKONDY	29102

D:\Mätfiler\KLX08A0511\0609-0619\KLX08A0727Ukcl1Y.BAK

CHEMMAC		Filer - inkalibrering		Filer - utkalibrering	
		Data	Kommentar	Data	Kommentar
YT	pH4	KLX08A0628IpH4Y.CRB	KLX08A0628IpH4Y.CI	KLX08A0727UpH4Y.CRB	KLX08A0727UpH4Y.CI
	pH7	KLX08A0628IpH7Y.CRB	KLX08A0628IpH7Y.CI	KLX08A0727UpH7Y.CRB	KLX08A0727UpH7Y.CI
	pH10	KLX08A0628IpH10Y.CRB	KLX08A0628IpH10Y.CI	KLX08A0727UpH10Y.CRB	KLX08A0727UpH10Y.CI
	0.01M	KLX08A0628Ikcl01Y.CR	KLX08A0628Ikcl01Y.CI	KLX08A0727Ukcl01Y.CR	KLX08A0727Ukcl01Y.CI
	0.1M	KLX08A0628Ikcl1Y.CRB	KLX08A0628Ikcl1Y.CI	KLX08A0727Ukcl1Y.CRB	KLX08A0727Ukcl1Y.CI
BORR - HÅL	pH4	lx08a0627Iph4b.crb	lx08a0627Iph4b.ci	KLX08A0712UpH4B.CRB	KLX08A0712UpH4B.CI
	pH7	lx08a0627Iph7b.crb	lx08a0627Iph7b.ci	KLX08A0712UpH7B.CRB	KLX08A0712UpH7B.CI
	pH10	lx08a0627Iph10b.crb	lx08a0627Iph10b.ci	KLX08A0712UpH10B.CRB	KLX08A0712UpH10B.CI

Figure A4-16. *Administration, section 609.0-618.5 m.*

Flow and pressure measurements in KLX08

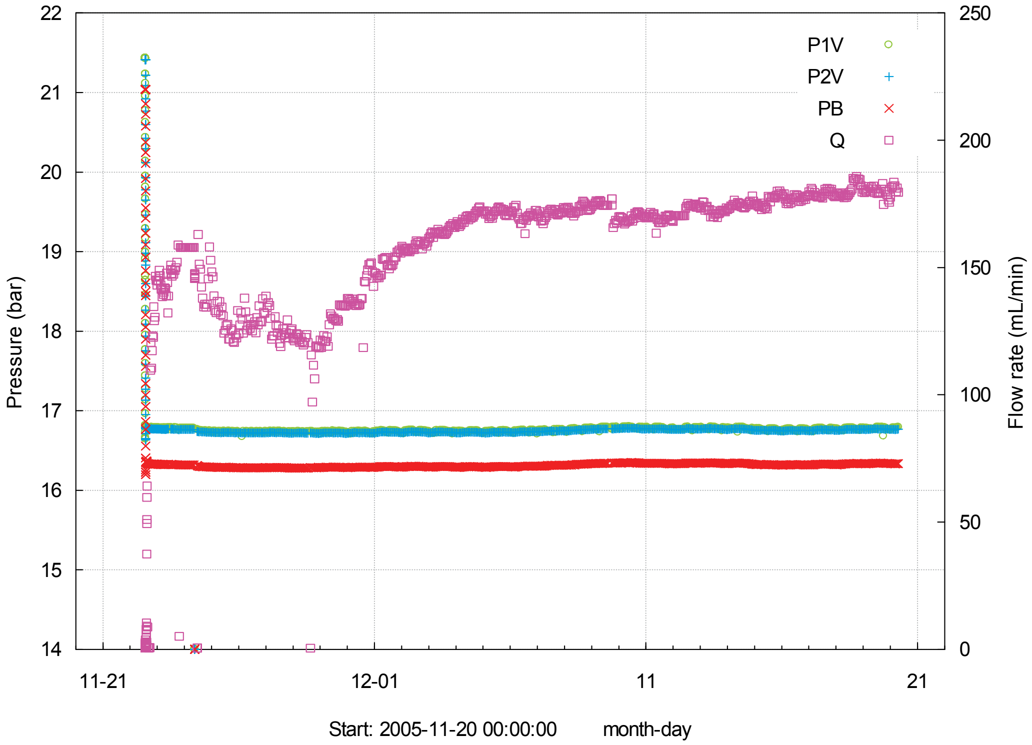


Figure A5-1. *Pressure (P1V, P2V and PB) and flow rate (Q) measurements in borehole section 197.0-206.6 m. The P1V and P2V pressure sensors are placed in the in situ sampling unit and measure the pressure in the section. PB is the sensor in the borehole Chemmac and measures the pressure above the section.*

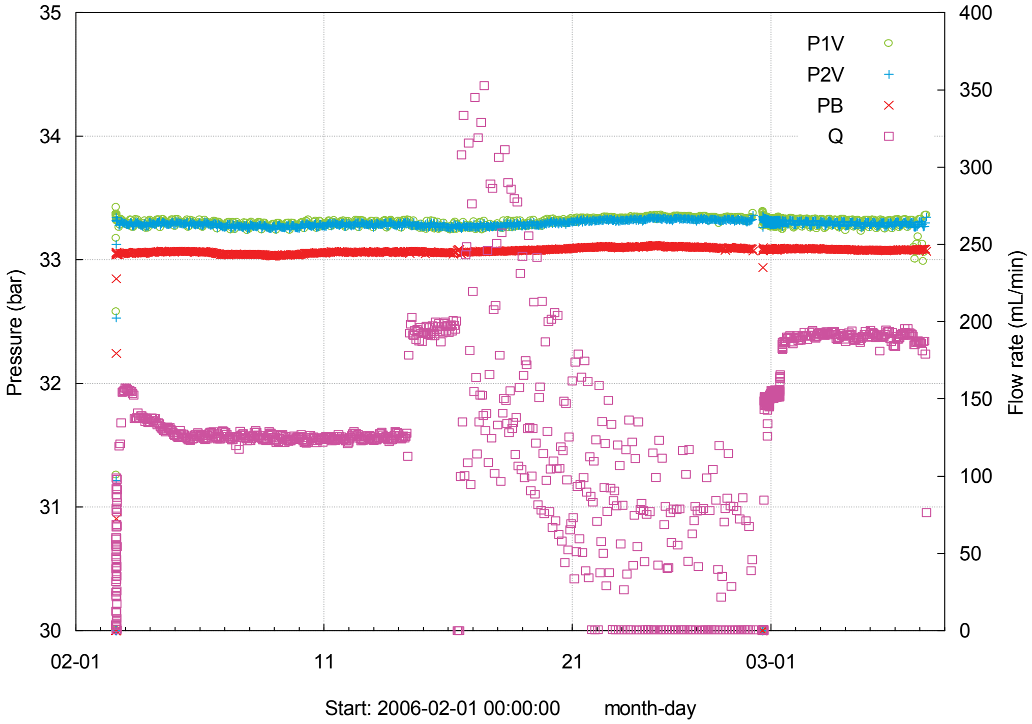


Figure A5-2. *Pressure (P1V, P2V and PB) and flow rate (Q) measurements in borehole section 396.0-400.9 m. The P1V and P2V pressure sensors are placed in the in situ sampling unit and measure the pressure in the section. PB is the sensor in the borehole Chemmac and measures the pressure above the section.*

Flow and pressure measurements in KLX08

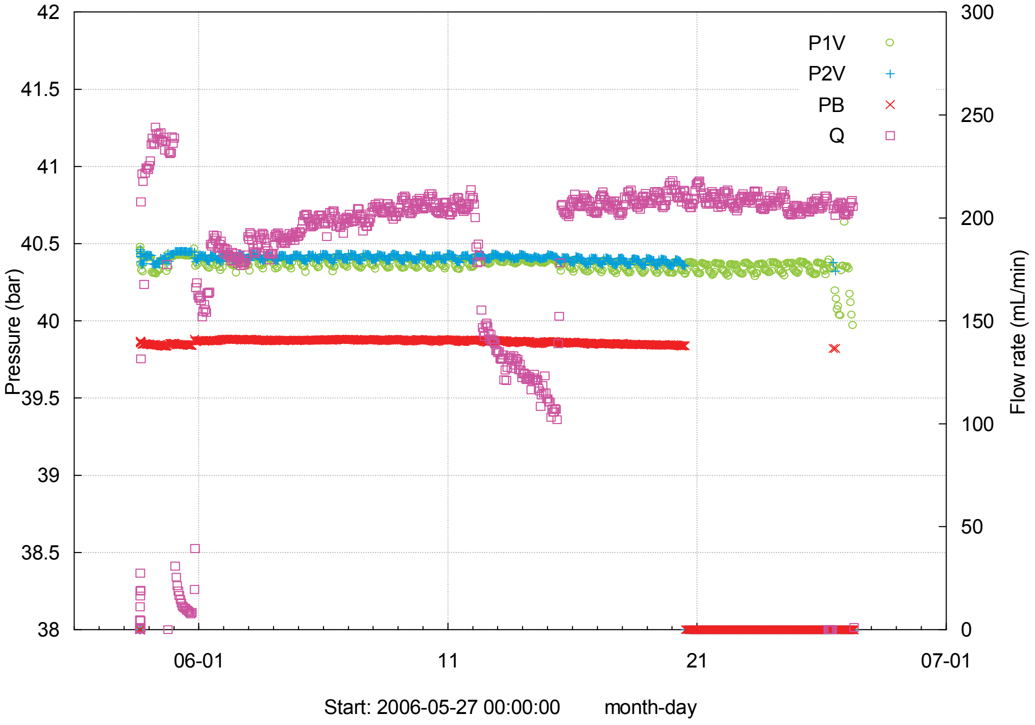


Figure A5-3. *Pressure (P1V, P2V and PB) and flow rate (Q) measurements in borehole section 476.0-485.6 m. The P1V and P2V pressure sensors are placed in the in situ sampling unit and measure the pressure in the section. PB is the sensor in the borehole Chemmac and measures the pressure above the section.*

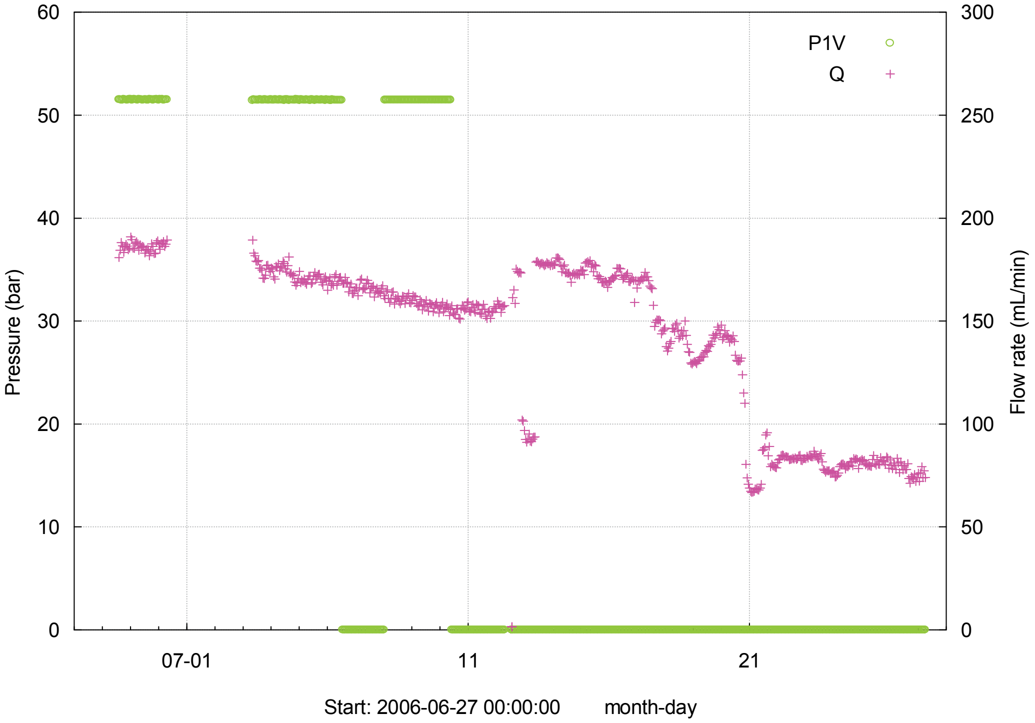


Figure A5-4. *Pressure (P1V) and flow rate (Q) measurements in borehole section 609.0-618.5 m. The P1V pressure sensor is placed in the in situ sampling unit and measures the pressure in the section. Values for P2V and PB are missing due to loss of communication with borehole Chemmac.*

Chemmac measurements in KLX08, section 197.0-206.6 m

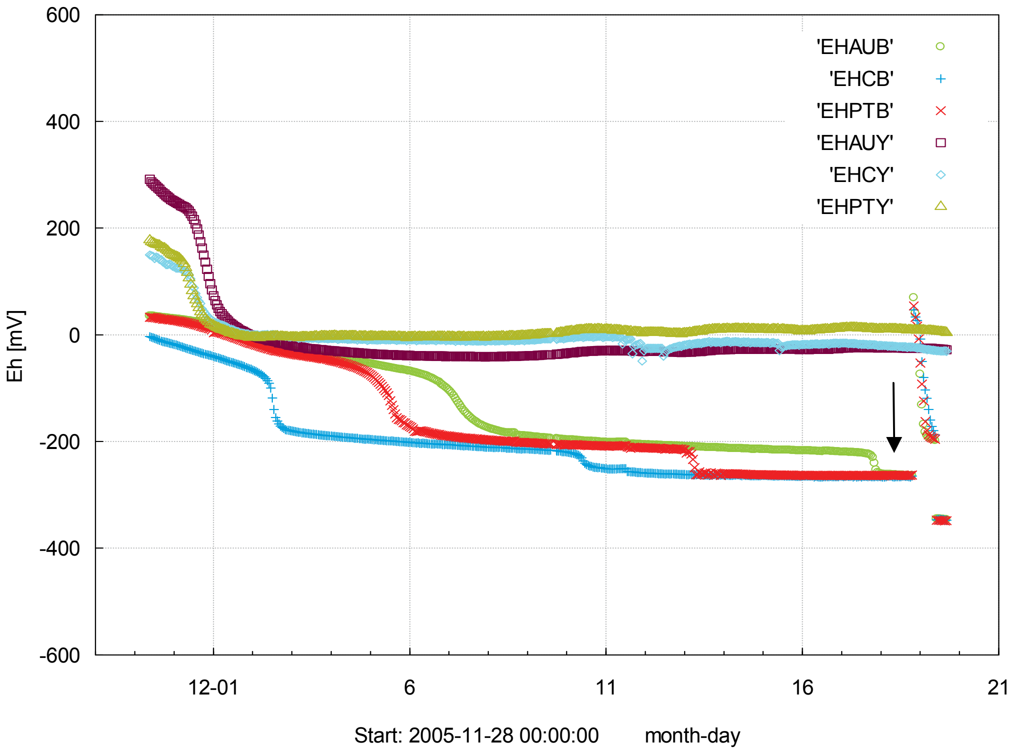


Figure A6-1. *Redox potential measurements (Eh) by gold, glassy carbon and platinum electrodes in the borehole section (EHAUB, EHCB and EHPTB) and at the surface (EHAUY, EHCY and EHPTY). The arrow show the chosen representative Eh values for the borehole section.*

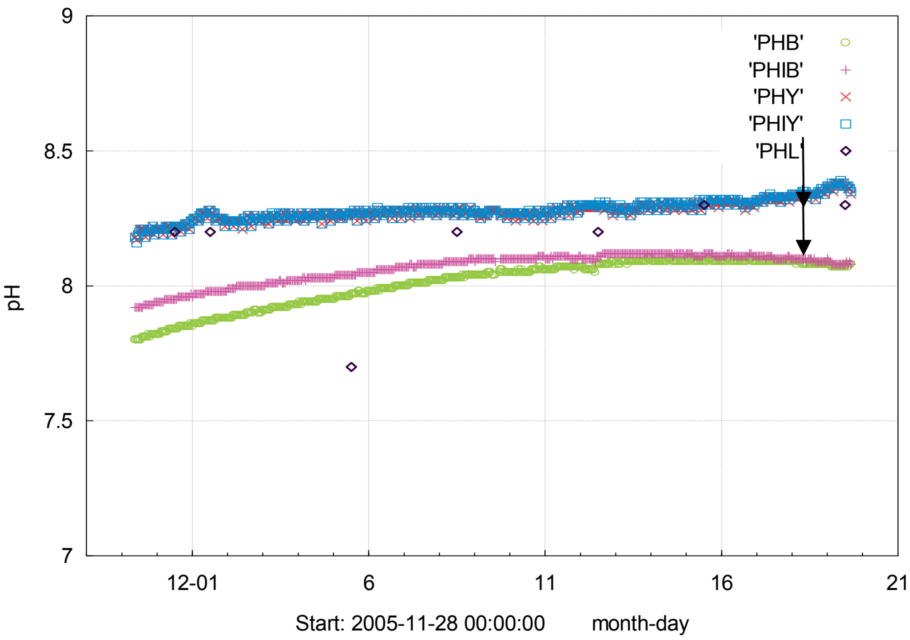


Figure A6-2. *Measurements of pH by two glass electrodes in the borehole section (PHB and PH1B) and two glass electrodes at the surface (PHY and PHIY). The laboratory pH in each collected sample (PHL) is given for comparison. The arrows show the chosen representative pH values for the borehole section.*

Chemmac measurements in KLX08, section 197.0-206.6 m

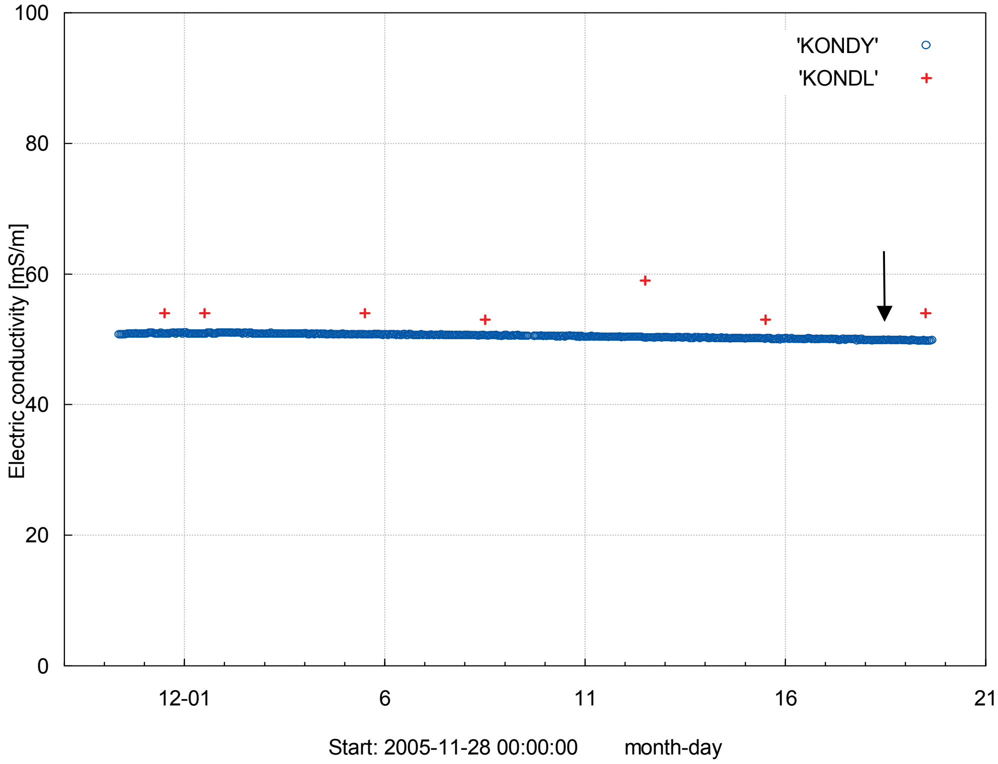


Figure A6-3. *Electrical conductivity measurement in the surface measurement cell (KONDY). The laboratory conductivity in each collected sample (KONDL) is given for comparison. The arrow shows the chosen representative electric conductivity value for the borehole section.*

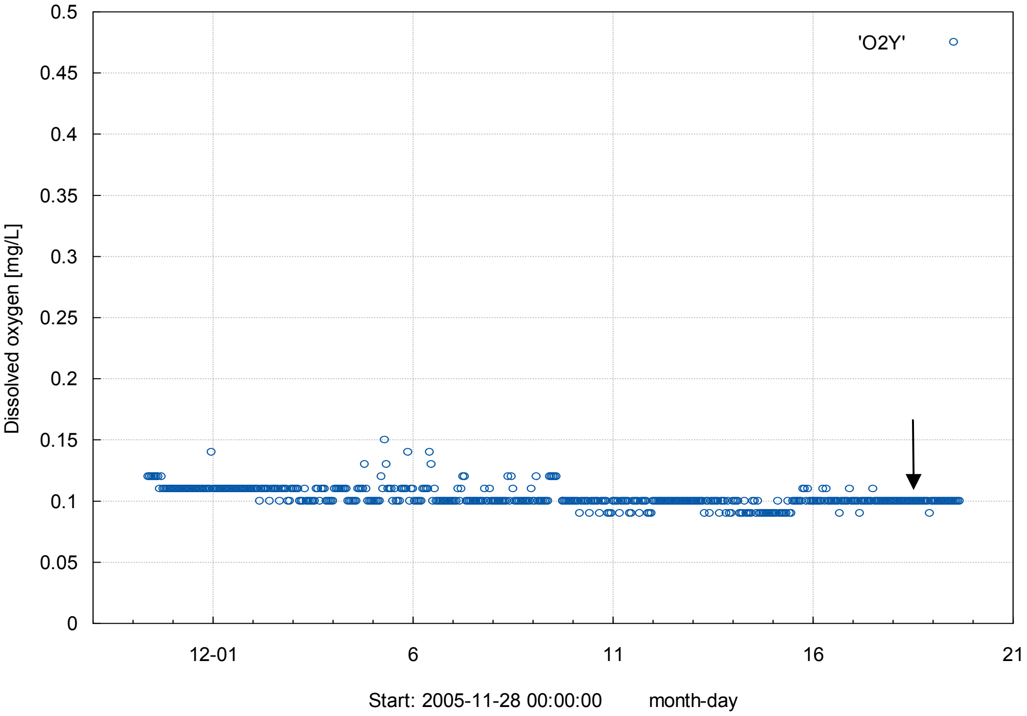


Figure A6-4. *Dissolved oxygen measurement (O2Y) in the surface measurement cell. The arrow shows the chosen representative value for dissolved oxygen in the borehole section.*

Chemmac measurements in KLX08, section 197.0-206.6 m

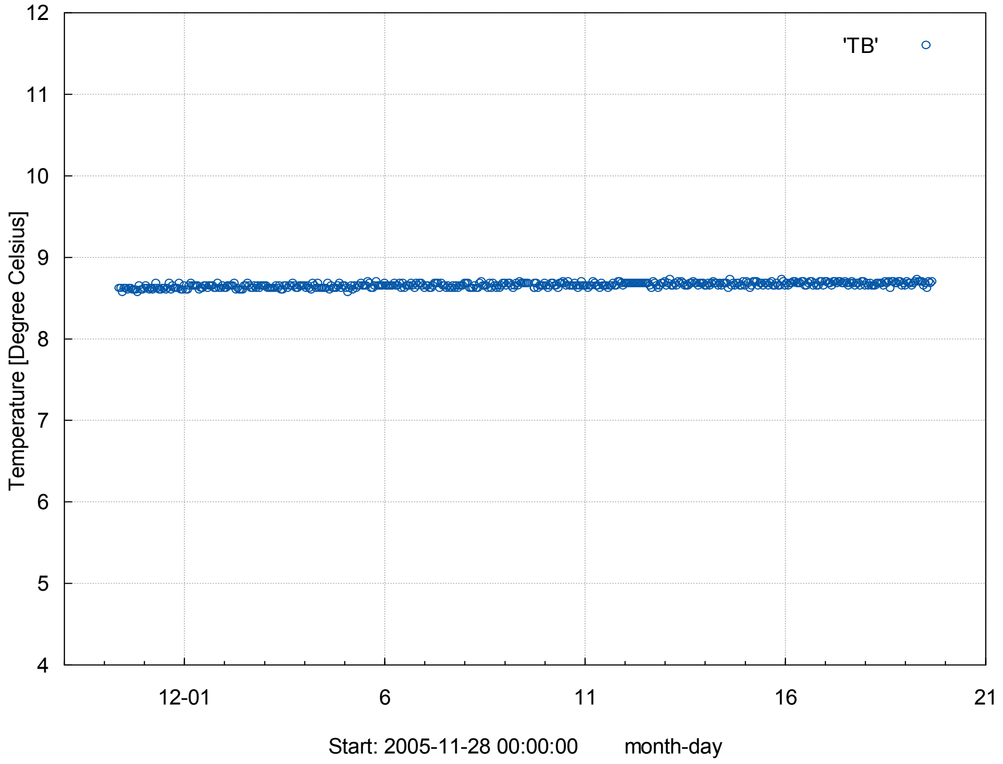


Figure A6-5. *Temperature of the groundwater in the borehole section (TB).*

Chemmac measurements in KLX08, section 396.0-400.9 m

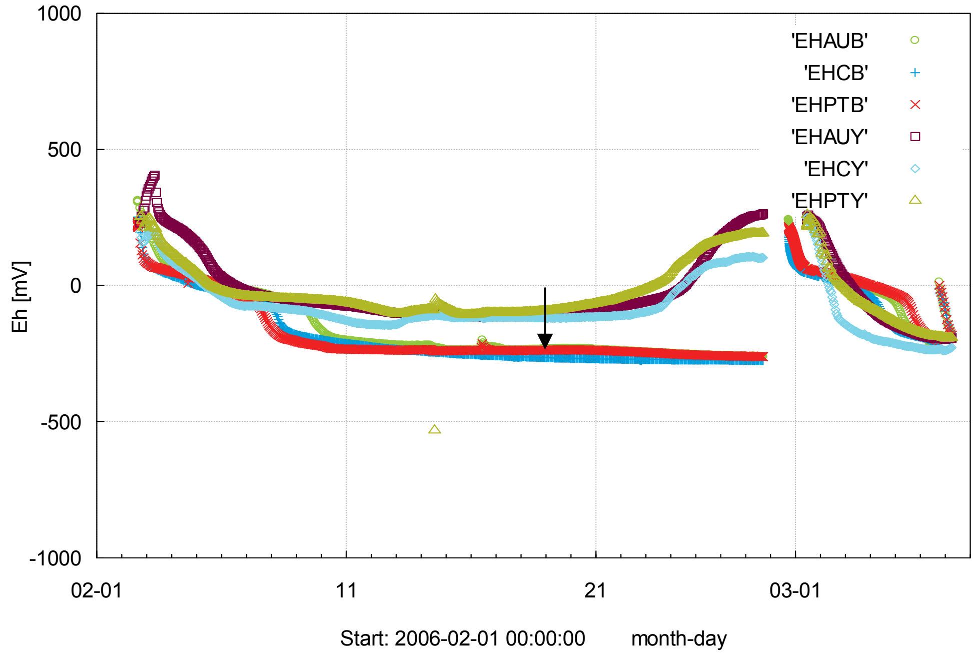


Figure A7-1. *Redox potential measurements (Eh) by gold, glassy carbon and platinum electrodes in the borehole section (EHAUB, EHCB and EHPTB) and at the surface (EHAUY, EHCY and EHPTY). The arrow shows the chosen representative Eh values for the borehole section.*

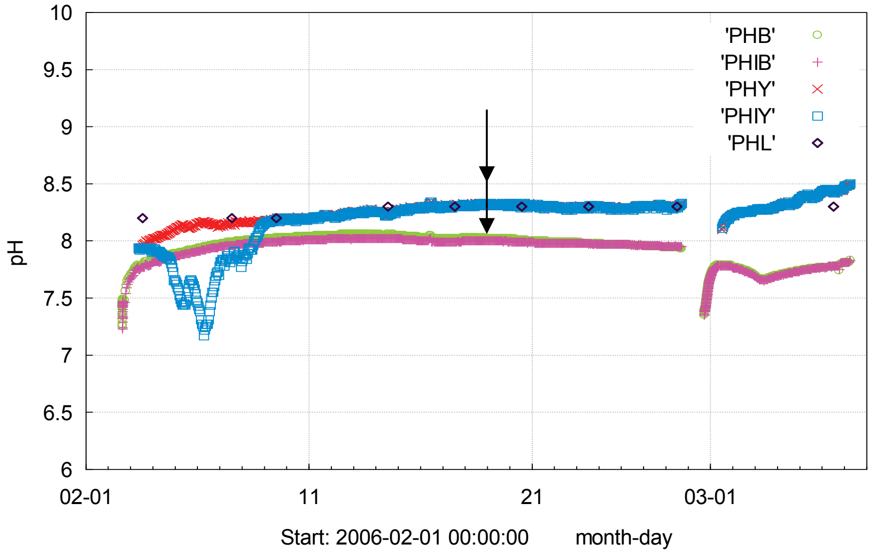


Figure A7-2. *Measurements of pH by two glass electrodes in the borehole section (PHB and PH1B) and two glass electrodes at the surface (PHY and PHIY). The laboratory pH in each collected sample (PHL) is given for comparison. The arrow shows the chosen representative pH values for the borehole section.*

Chemmac measurements in KLX08, section 396.0-400.9 m

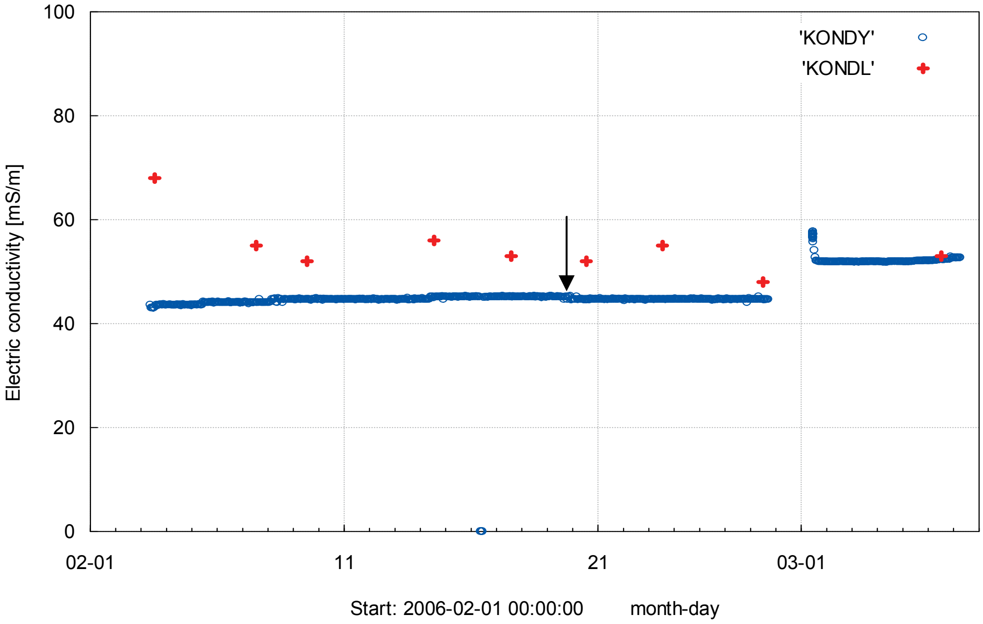


Figure A7-3. *Electrical conductivity measurement in the surface measurement cell (KONDY). The laboratory conductivity in each collected sample (KONDL) is given for comparison. The arrow shows the chosen representative electric conductivity value for the borehole section.*

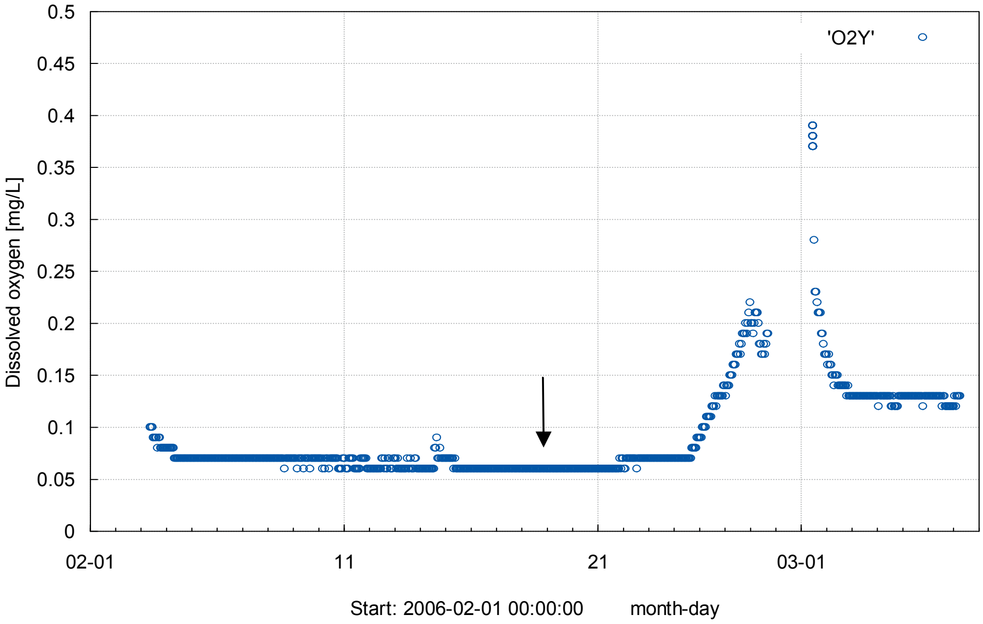


Figure A7-4. *Dissolved oxygen measurement (O2Y) in the surface measurement cell. The arrow shows the chosen representative value for dissolved oxygen in the borehole section.*

Chemmac measurements in KLX08, section 396.0-400.9 m

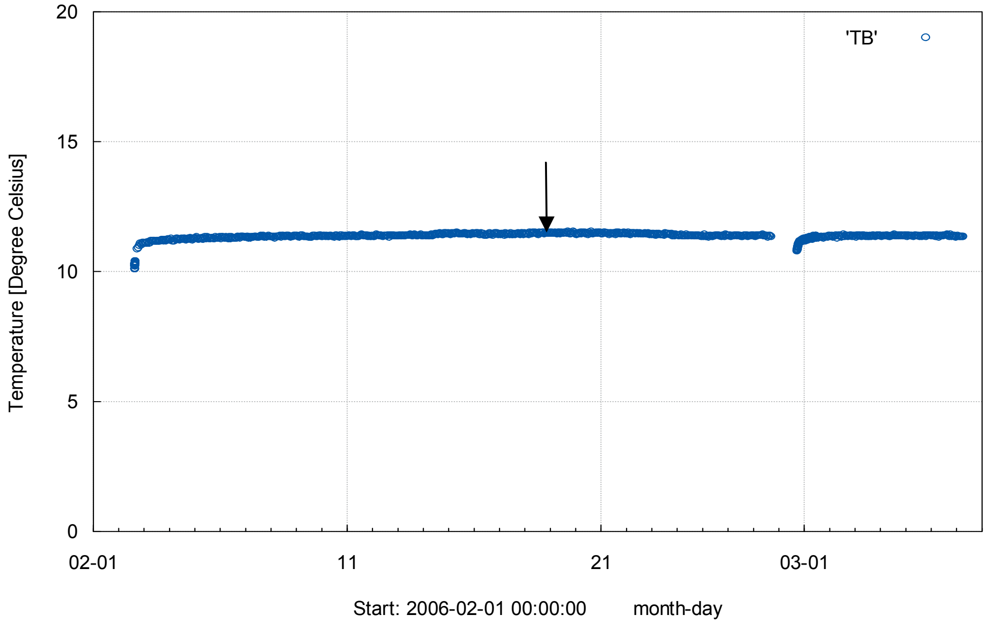


Figure A7-5. *Temperature of the groundwater in the borehole section (TB).*

Chemmac measurements in KLX08, section 476.0-485.6 m

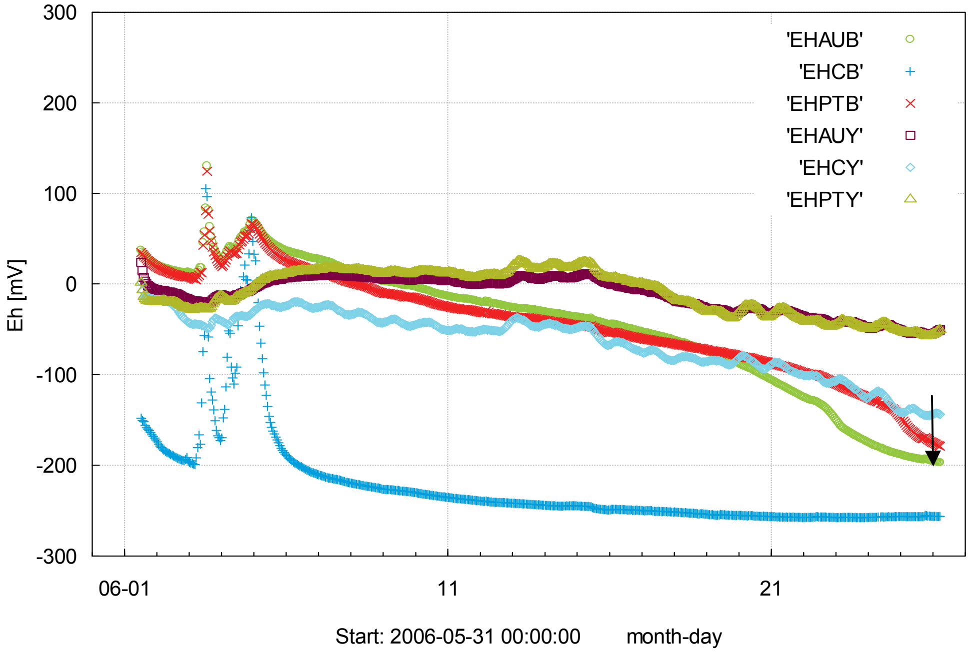


Figure A9-1. *Redox potential measurements (Eh) by gold, glassy carbon and platinum electrodes in the borehole section (EHAUB, EHCB and EHPTB) and at the surface (EHAUY, EHCY and EHPTY). The arrow shows the chosen representative Eh values for the borehole section.*

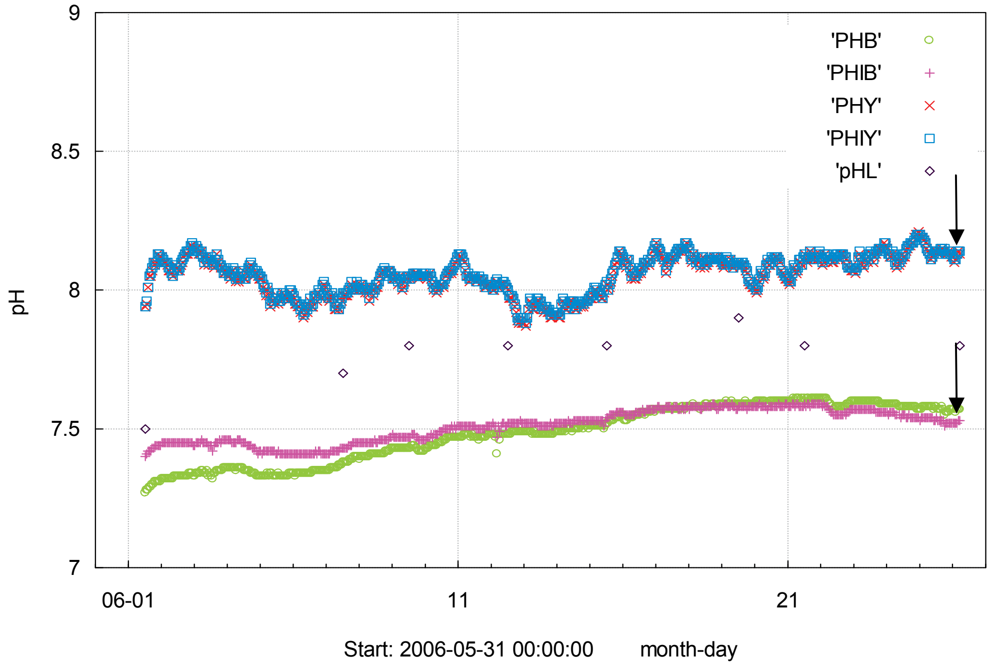


Figure A9-2. *Measurements of pH by two glass electrodes in the borehole section (PHB and PH1B) and two glass electrodes at the surface (PHY and PHIY). The laboratory pH in each collected sample (PHL) is given for comparison. The arrows show the chosen representative pH values for the borehole section.*

Chemmac measurements in KLX08, section 476.0-485.6 m

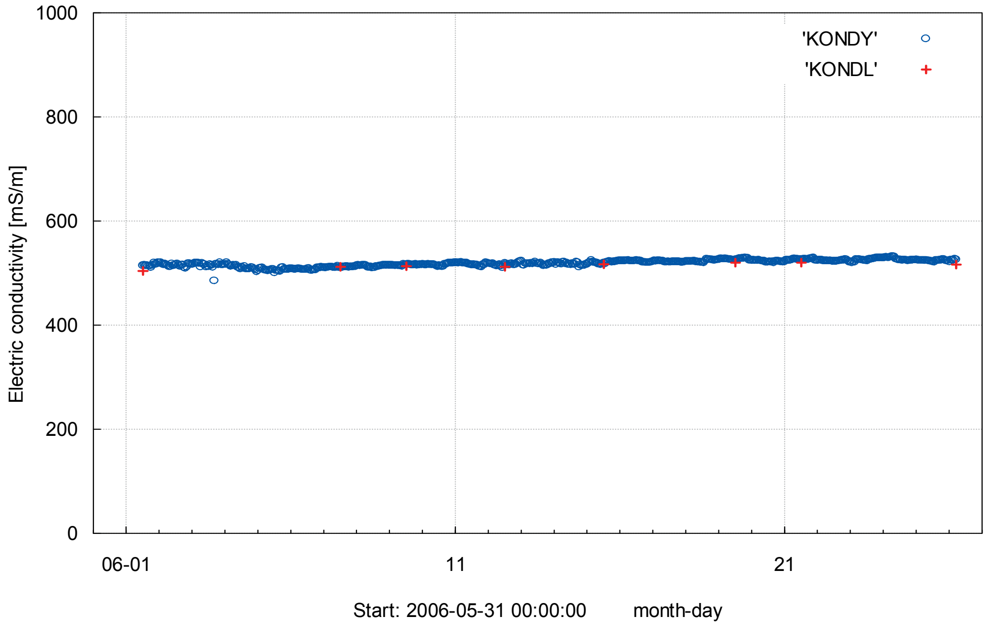


Figure A9-3. *Electrical conductivity measurement in the surface measurement cell (KONDY). The laboratory conductivity in each collected sample (KONDL) is given for comparison. The arrow shows the chosen representative electric conductivity value for the borehole section.*

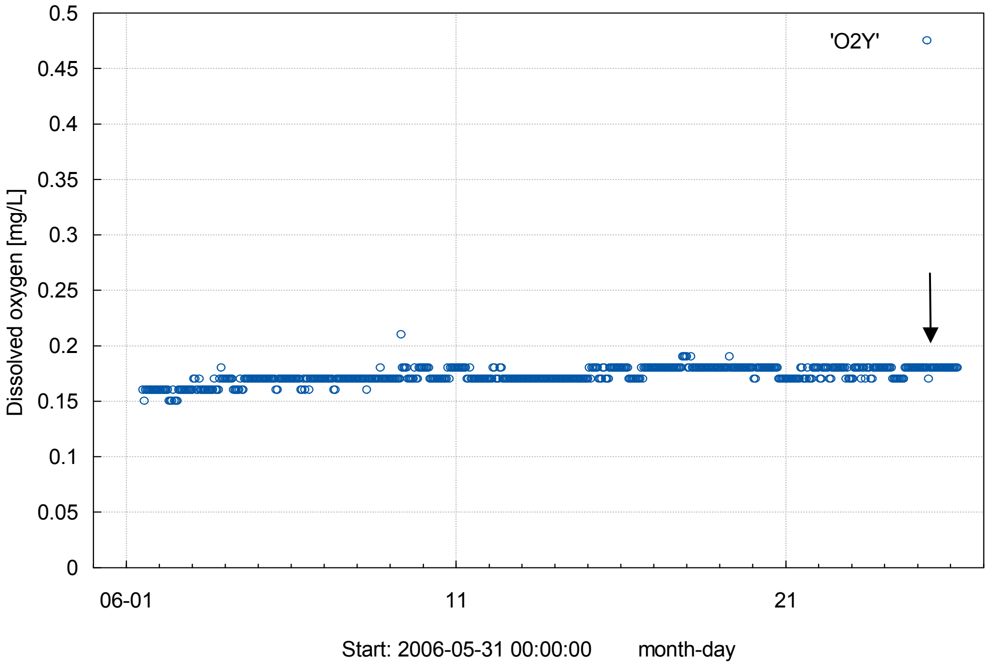


Figure A9-4. *Dissolved oxygen measurement (O2Y) in the surface measurement cell. The arrow shows the chosen representative value for dissolved oxygen in the borehole section.*

Chemmac measurements in KLX08, section 476.0-485.6 m

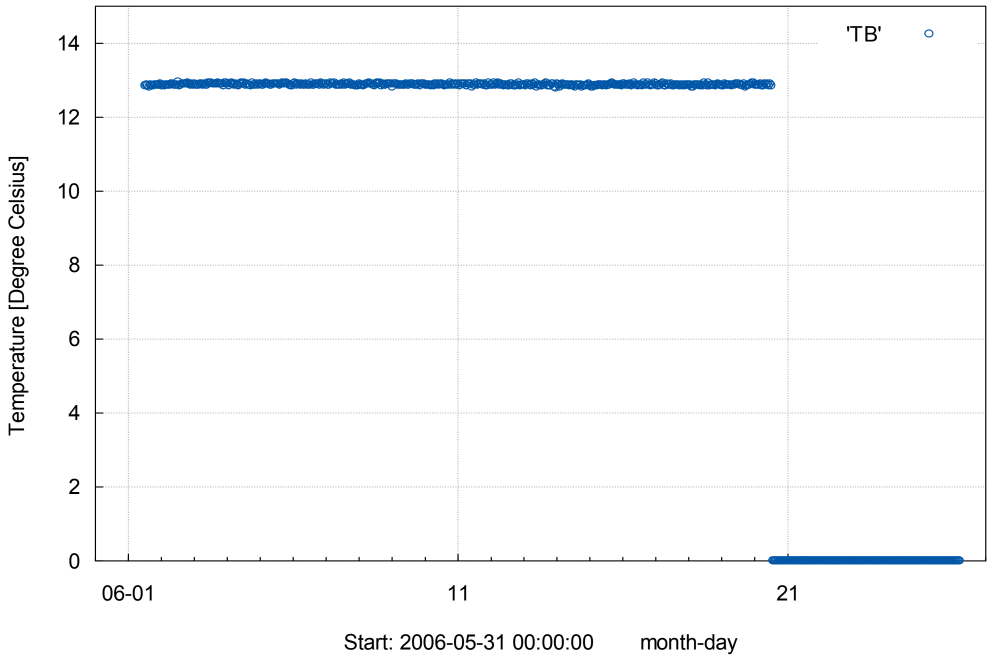


Figure A9-5. *Temperature of the groundwater in the borehole section (TB).*

Chemmac measurements in KLX08, section 609.0-618.5 m

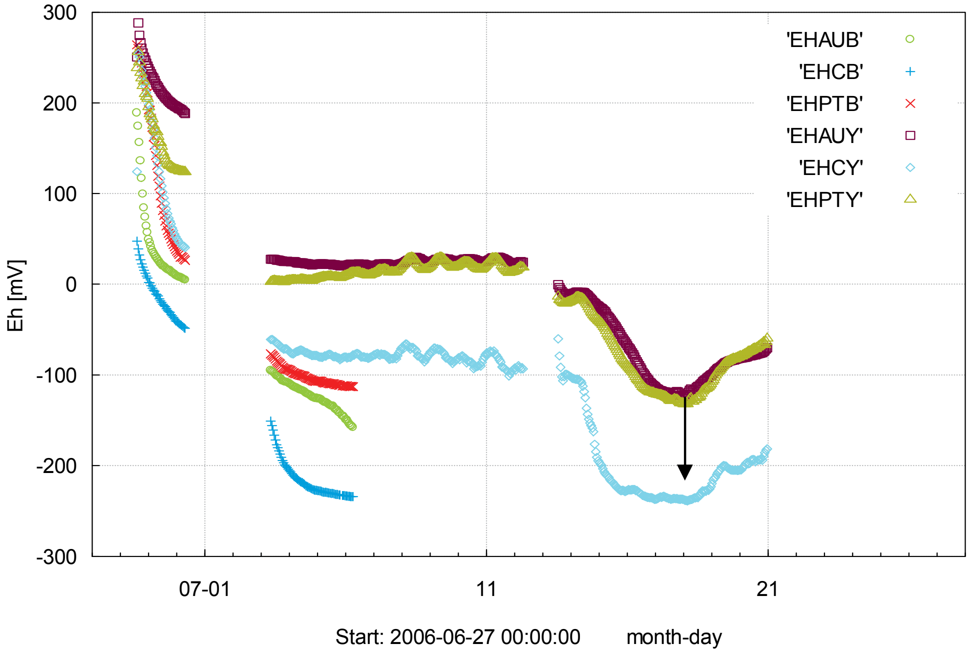


Figure A9-1. *Redox potential measurements (Eh) by gold, glassy carbon and platinum electrodes in the borehole section (EHAUB, EHCB and EHPTB) and at the surface (EHAUY, EHCY and EHPTY). The arrow shows the chosen representative Eh values for the borehole section.*

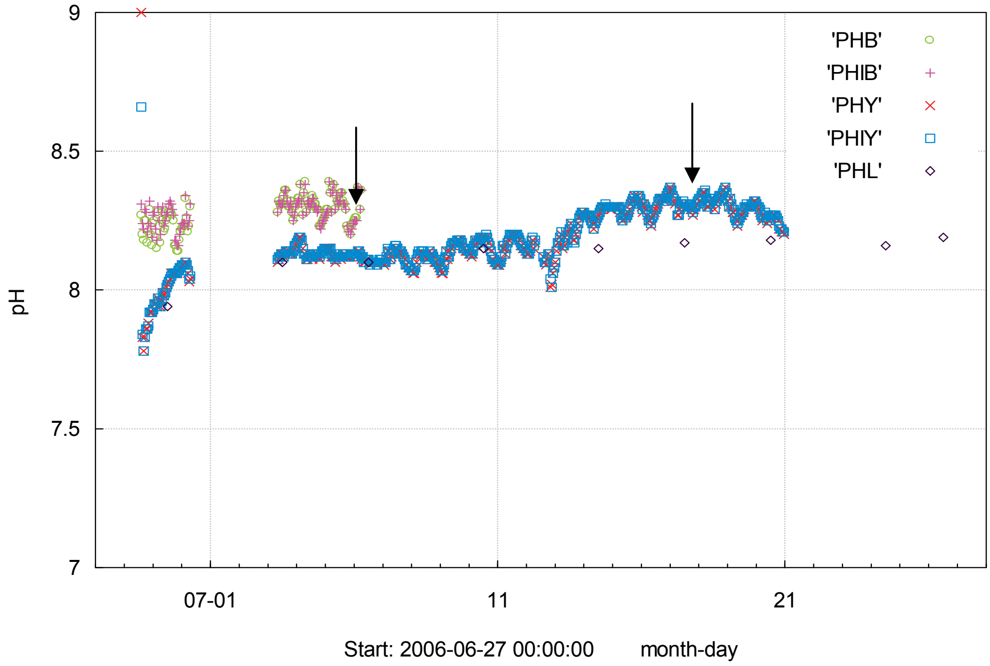


Figure A9-2. *Measurements of pH by two glass electrodes in the borehole section (PHB and PH1B) and two glass electrodes at the surface (PHY and PHIY). The laboratory pH in each collected sample (PHL) is given for comparison. The arrows show the chosen representative pH values for the borehole section.*

Chemmac measurements in KLX08, section 609.0-618.5 m

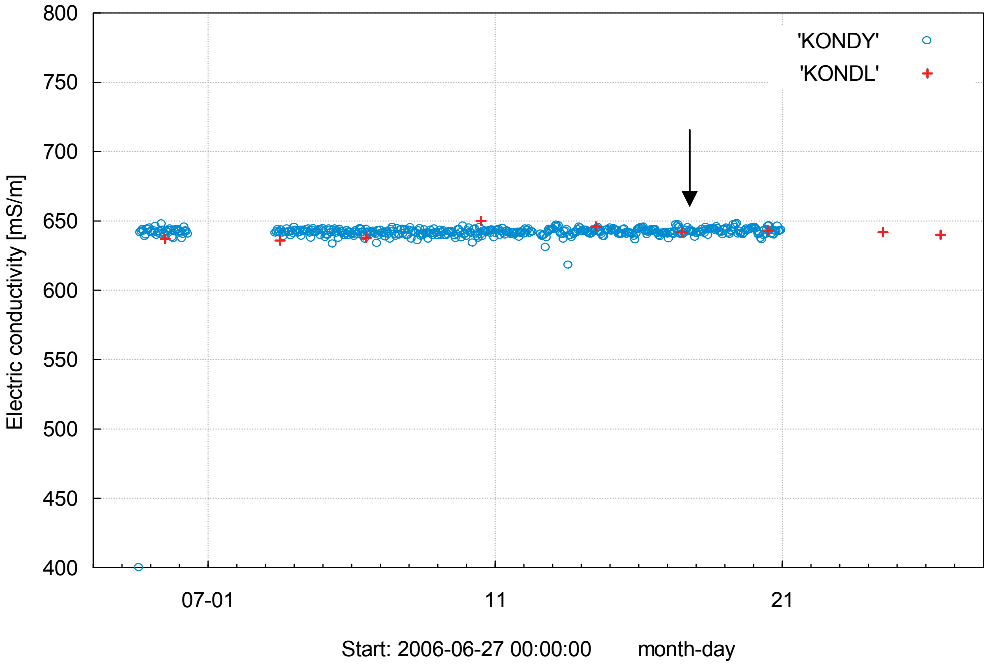


Figure A9-3. *Electrical conductivity measurement in the surface measurement cell (KONDY). The laboratory conductivity in each collected sample (KONDL) is given for comparison. The arrow shows the chosen representative electric conductivity value for the borehole section.*

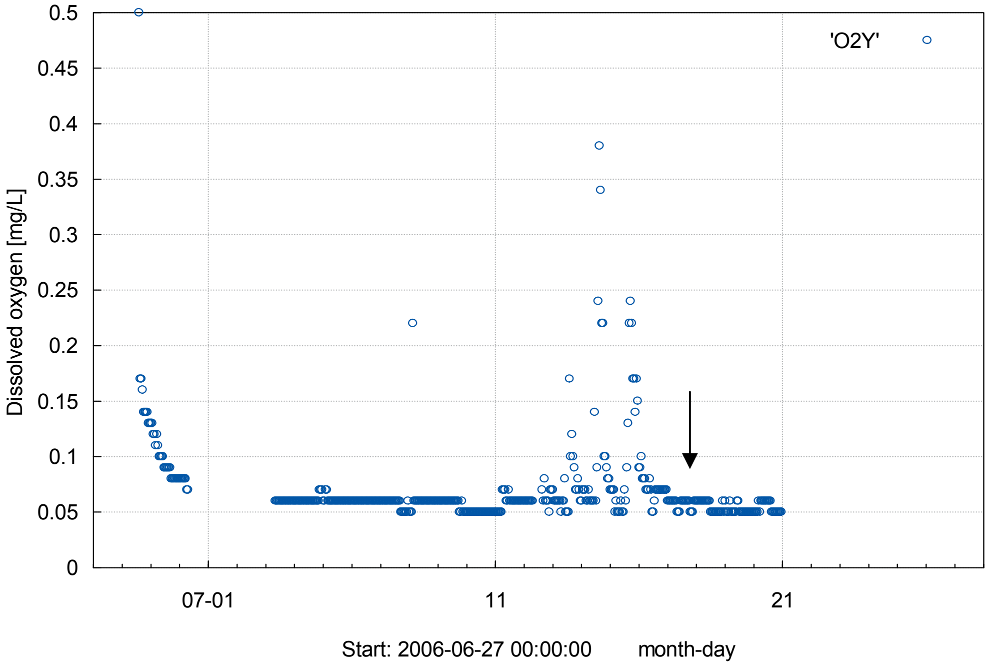


Figure A9-4. *Dissolved oxygen measurement (O2Y) in the surface measurement cell. The arrow shows the chosen representative value for dissolved oxygen in the borehole section.*

Chemmac measurements in KLX08, section 609.0-618.5 m

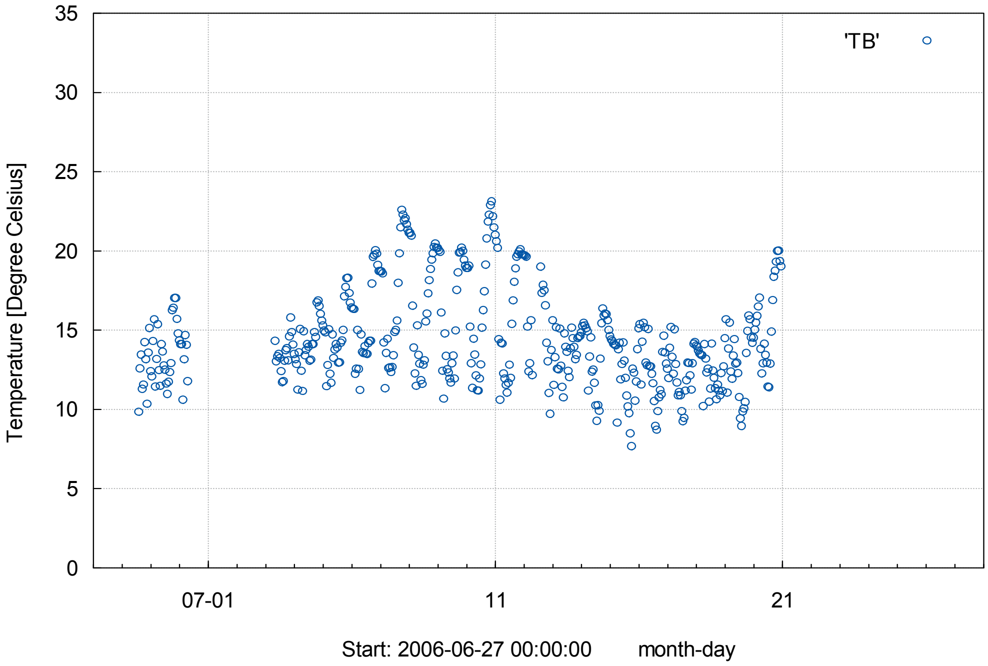


Figure A9-5. *Temperature of the groundwater in the borehole section (TB).*

Appendix 10

Sampling and analysis methods

Table A10-1. Sample handling routines and analysis methods

Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Analysis within - or delivery time to lab.
Drill water	Uranine	Glass (brown)	100	No	No	Spectrofluorometry	-
Anions	HCO_3^- pH (lab) cond. (lab)	Plastic	250	No	No	Titration Pot. meas, Cond. meas.	The same day – maximum 24 hours
	Cl^-, SO_4^{2-}, Br^-, F^-	Plastic	250	Yes (not in the field)	No	Titration (Cl^-) IC (Cl^-, SO_4^{2-}, Br^-, F^-) ISE (F^-)	Not critical (month)
	Br**, I	Plastic	100	Yes	No	ICP MS	Not critical (month)
Cations etc.	Na, K, Ca, Mg, S(tot), Si(tot), Fe, Mn, Li, Sr	Plastic (acid washed)	100	Yes	Yes (1 mL HNO_3)	ICP AES ICP MS	Not critical (month)
Fe(II), Fe(tot)	Fe(II), Fe(tot)	Plastic-PEH (acid washed)	500	Yes	Yes (5 mL HCl)	Spectrophotometry Ferrozine method	As soon as possible the same day
Hydrogen sulphide	HS^-	Glass (Winkler)	About 120×2	Yes	1 mL 1 M NaOH+ 1 mL 1M ZnAc	Spectrophotometry	Immediately or if conserved, a few days
Nutrient salts	NO_2-N, NO_3-N+NO_2-N, PO_4-P	Plastic	250	Yes	Frozen, transported in isolated bag	Spectrophotometry	Short transportation time
	NH_4-N	Plastic cylinder	50	Yes	No	Spectrophotometry	Maximum 24 hours
Environmental metals etc.	Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn, In	Plastic	100	Yes	Yes (1 mL HNO_3)	ICP AES ICP MS	Not critical (month)
Lanthanoids, U, Th, etc.	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	Not critical (month)

Appendix 10

Sampling and analysis methods

Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Analysis within - or delivery time to lab.
Dissolved organic Carbon	DOC	Plastic	250	Yes	Frozen, transported in isolated bag	UV oxidation, IR Carbon analyzer Shimadzu TOC5000	Short transportation time
Total organic Carbon	TOC	Plastic	250	No	Frozen, transported in isolated bag	UV oxidation, IR Carbon analyzer Shimadzu TOC5000	Short transportation time
Environmental isotopes	$\delta^{2}H$, $\delta^{18}O$	Plastic	100	No	- -	MS	Not critical (month)
Tritium,	^{3}H (enhanced.)	Plastic (dry bottle)	500	No	-	LSC	Not critical (month)
Chlorine-37	$\delta^{37}Cl$	Plastic	500	No	-	ICP MS	Not critical (month)
Carbon isotopes	$\delta^{13}C$, pmC (^{14}C)	Glass (brown)	100×2	No	-	(A)MS	A few days
Sulphur isotopes	$\delta^{34}S$	Plastic	1000	No	-	Combustion, ICP MS	No limit
Strontium-isotopes	$^{87}Sr/^{86}Sr$	Plastic	100	No	-	TIMS	Days or Week
Uranium and Thorium isotopes	^{234}U, ^{235}U, ^{238}U, ^{232} Th, ^{230}Th,	Plastic (HDPE)	1000	No	-	Chemical separat. Alfa spectroscopy	No limit
Boron isotopes	$^{10}B/^{11}B$	Plastic	100	Yes	Yes (1 mL HNO_3)	ICP MS	No limit
Radon and Radium isotopes	^{222}Rn, ^{226}Ra	Plastic (HDPE)	1000	No	No	LSS	Immediate transport
Dissolved gas (content and composition)	Ar, He, N_2, CO_2, O_2, CH_4, H_2, CO, C_2H_6, C_2H_4, C_2H_2, C_3H_8 , C_3H_6	Cylinder of stainless steel	200	No	No	GC	Immediate transport

Appendix 10

Sampling and analysis methods

Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Analysis within - or delivery time to lab.
Colloids	Filter series and fractionation (Analysis of cations and environmental metals)	Polycarbonate filters	0.4, 0.2 and 0.05 µm	-	Ar atmosphere	ICP AES ICP MS	Immediate transport
Humic and fulvic acids, fractionation	DOC	Fractions are collected in plastic bottles	250	-	N$_2$ atmosphere	UV oxidation, IR Carbon analyzer Shimadzu TOC5000	Immediate transport
	(Analysis of cations and environmental metals)	Plastic (acid washed bottles)	100	Yes	Yes (1 mL HNO$_3$)	ICP AES ICP MS	Not critical (month)
Carbon isotopes in humic and fulvic acids	δ^{13}C, pmC (^{14}C)	DEAE cellulose (anion exchanger)	-	-	-	(A)MS	A few days
Density	Density	Plastic	250	No	-	Pycnometer	-
Archive samples with acid	-	Plastic (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

* Suprapur acid is used for conservation of samples.

** Control of IC result

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

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
TIMS	Thermal Ionization Mass Spectrometry
LSS	Liquid Scintillation Spectroscopy
GC	Gas Chromatography

Sampling and analysis methods

Table A10-2. Reporting limits and measurement uncertainties

Component	Method	Detection limit	Reporting limit or range	Unit	Measurement uncertainty[2]	"Total" uncertainty[3]
HCO_3^-	Alkalinity titration	0.2	1	mg/L	4 %	<10 %
pH	Pot. Meas.	-	-	-	5%	-
Cond.	Cond. Meas.	0.02	1	mS/m	4%	-
Cl^-	Mohr titration	5	70	mg/L	5 %	<10 %
Cl^-	IC	0.2	0.5		6 %	10 %
SO_4^{2-}	IC	0.2	0.5	mg/L	6 %	15 %
Br^-	IC	0.2	0.7	mg/L	9 %	20 %
Br^-	ICP	-	0.001 – 0.010[1]		15 %	
F^-	IC	0.2	0.6	mg/L	10 %	20 %
F^-	ISE	-	-		-	-
I^-	ICP	-	0.001 – 0.010[1]	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	10 %	15 %
Si(tot)	ICP	-	0.03	mg/L	4 %	15 %
Sr	ICP	-	0.002	mg/L	4 %	15 %
Li	ICP	-	0.2 - 2[1]	µg/L	10 %	20 %
Fe	ICP	-	0.4-4[1]	µg/L	6 %	10 %
Mn	ICP	-	0.03-0.1	µg/L	8 %	10 %
Component	**Method**	**Detection limit**	**Reporting limit or range**	**Unit**	**Measurement uncertainties[2]**	**"Total" uncertainty[3]**

Appendix 10

Sampling and analysis methods

Fe(II), Fe(tot)	Spectro-photometry	5	20	µg/L	15 % (>30 µg/L)	20 %
HS^-	Spectro-photometry	2	30-200 200-500	µg/L	18 % 30 µg/L	20 %
NO_2-N	Spectro-photometry	-	0.1-20 >20	µg/L	0.1 µg/L 2 %	15 %
NO_2-N +NO_3-N	Spectro-photometry	-	0.2-20 >20	µg/L	0.2 µg/L 2.5 %	15 %
NH_4-N	Spectro-photometry	-	0.5-20 >20	µg/L	0.5 µg/L 2.4 %	15 %
PO_4-P	Spectro-photometry	-	0,5-20 >20	µg/L	0.4 µg/L 2.2 %	15 %
Al, Zn	ICP	-	0.2-0.7	µg/L	12 %	20 %
Ba, Cr, Mo Pb	ICP	-	0.01-0.3	µg/L	7-10 %	20 %
Cd, Hg	ICP	-	0.002-0.5	µg/L	5-9 %	20 %
Co, V	ICP	-	0.005-0.05	µg/L	5-8 %	20 %
Cu	ICP	-	0.1-0.5	µg/L	8 %	20 %
Ni	ICP	-	0.05-0.5	µg/L	8%	20 %
P	ICP	-	1-40	µg/L	6 %	15 %
As	ICP	-	0.01-0.5	µg/L	20 %	Within the same size (low conc.)
La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Y, Hf	ICP	-	0.005-0.05	µg/L	10 %	Within the same size (low conc.)
Sc, In, Th	ICP	-	0.05-0.5	µg/L	10 %	Within the same size (low conc.)
Component	**Method**	**Detection limit**	**Reporting limit or range**	**Unit**	**Measurement uncertainties**[2]	**”Total” uncertainty**[3]

Sampling and analysis methods

Rb, Zr, Sb, Cs, Tl	ICP	-	0.025-0.25	µg/L	10 %	Within the same size (low conc.)
U	ICP	-	0.001-0.01	µg/L	12 %	Within the same size (low conc.)
DOC	See Tab. A10-1	-	0.5	mg/L	8 %	30 %
TOC	See Tab. A10-1	-	0.5	mg/L	10 %	30 %
δ^{2}H	MS	-	2	‰ SMOW[4]	1.0 ‰	-
δ^{18}O	MS	-	0.1	‰ SMOW[4]	0.2 ‰	-
^{3}H	LSC	-	0.8 or 0.1	TU[5]	0.8 or 0.1 TU	-
δ^{37}Cl	ICP MS	-	0.2 ‰ (20 mg/L)	‰ SMOC[6]	-	-
δ^{13}C	A (MS)	-	>20 mg carbon	‰ PDB[7]	-	-
pmC (^{14}C)	A (MS)	-	>20 mg carbon	pmC[8]	-	-
δ^{34} S	ICP MS	-	0.2 ‰	‰ CDT[9]	0.2 ‰	-
^{87}Sr/^{86}Sr	MS	-	-	No unit (ratio)[10]	0.000020	-
^{10}B/^{11}B	ICP MS	-	-	No unit (ratio)[10]	0.0020	-
^{234}U, ^{235}U, ^{238}U, ^{232}Th, ^{230}Th	Alfa spectr.	-	0.05	Bq/L[13]	0.05 Bq/L	Right order of magnitude
^{222}Rn, ^{226}Ra	LSS	-	0.1	Bq/L	0.05 Bq/L	

Appendix 10

Sampling and analysis methods

1. Reporting limits at salinity ≤ 0.4 % (520 mS/m) and ≤ 3.5 % (3810 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. Per mill deviation[11] from SMOW (Standard Mean Oceanic Water).
5. TU=Tritium Units, where one TU corresponds to a Tritium/hydrogen ratio of 10^{-18} (1 Bq/L Tritium = 8.45 TU).
6. Per mill deviation[11] from SMOC (Standard Mean Oceanic Chloride).
7. Per mill deviation[11] from PDB (the standard PeeDee Belemnite).
8. The following relation is valid between pmC (percent modern carbon) and Carbon-14 age: $\text{pmC} = 100 \times e^{((1950-y-1.03t)/8274)}$
   where y = the year of the C-14 measurement and t = C-14 age
9. Per mill deviation[12] from CDT (the standard Canyon Diablo Troilite).
10. Isotope ratio without unit.
11. The following expressions are applicable to convert activity to concentration, for uranium-238 and thorium-232:
    1 ppm U = 12.4 Bq/kg ^{238}U
    1 ppm Th = 3.93 Bq/kg ^{232}Th
12. Isotopes are often reported as per mill deviation from a standard. The deviation is calculated as:
    $\delta^{y}I = 1000 \times (K_{sample} - K_{standard})/K_{standard}$, where K= the isotope ratio and $^{y}I = {}^{2}H$, ^{18}O, ^{37}Cl, ^{13}C or ^{34}S etc.

Table A11-1. Water Composition

Idcode	Secup m	Seclow m	Sample no.	Sampling date	Charge Bal %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO_3^- mg/L	Cl^- mg/L	SO_4^{2-} mg/L	SO_4-S mg/L	Br^- mg/l	F^- mg/L	Si mg/L	Fe mg/L	Fe-tot mg/L	Fe(II) mg/L	Mn mg/L	Li mg/L
KLX08	197.00	206.65	10639	2005-11-23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	197.00	206.65	10640	2005-11-25	-	-	-	-	-	298	12.8	12.3	-	<0.2	2.49	-	-	-	-	-	-
KLX08	197.00	206.65	10641	2005-11-28	-	-	-	-	-	300	12.8	12.5	-	<0.2	2.60	-	-	-	-	-	-
KLX08	197.00	206.65	10642	2005-11-30	-	-	-	-	-	306	12.5	12.3	-	<0.2	2.68	-	-	-	-	-	-
KLX08	197.00	206.65	10643	2005-12-01	0.05	97.7	3.61	21.5	4.5	305	12.7	12.4	4.78	<0.2	2.66	7.69	0.248	0.155	0.153	0.102	0.017
KLX08	197.00	206.65	10644	2005-12-05	0.48	98.5	3.53	20.8	4.2	301	12.8	12.5	4.72	<0.2	2.62	6.32	0.243	0.249	0.246	0.0952	0.017
KLX08	197.00	206.65	10645	2005-12-08	-0.15	97.2	3.52	20.3	4.2	300	12.8	12.7	4.71	<0.2	2.64	7.61	0.223	0.212	0.211	0.0910	0.017
KLX08	197.00	206.65	10646	2005-12-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	197.00	206.65	10647	2005-12-12	-0.67	96.5	3.29	19.5	4.0	298	12.8	12.7	4.71	<0.2	2.62	7.56	0.133	0.149	0.142	0.0875	0.017
KLX08	197.00	206.65	10648	2005-12-15	0.13	98.6	3.50	19.4	4.0	298	12.5	12.7	4.74	<0.2	2.65	7.60	0.112	0.100	0.100	0.0856	0.017
KLX08	197.00	206.65	10649	2005-12-19	0.02	97.9	3.43	19.1	3.9	296	12.6	12.8	4.72	0.047	2.53	7.66	0.104	0.117	0.112	0.0854	0.016
KLX09	197.00	206.65	10650	2005-12-19						297	12.6	12.8	-	<0.2	2.55	-	-	0.121	0.119	-	-
KLX08	396.00	400.87	10741	2006-02-03	-	-	-	-	-	287	12.6	-	-	-	-	-	-	-	-	-	-
KLX08	396.00	400.87	10794	2006-02-07	-0.15	99.1	2.82	18.1	3.2	287	14.3	13.8	5.55	<0.2	2.46	8.52	0.148	0.129	0.124	0.0697	0.018
KLX08	396.00	400.87	10795	2006-02-09	-0.76	99.9	2.75	17.6	3.0	289	14.6	14.1	5.84	<0.2	2.45	8.45	0.146	0.129	0.125	0.0658	0.018
KLX08	396.00	400.87	10742	2006-02-14	-0.82	102	2.61	16.5	2.7	291	14.9	14.6	5.49	<0.2	2.50	8.56	0.372	0.359	0.351	0.0572	0.020
KLX08	396.00	400.87	10743	2006-02-17	-1.28	102	2.47	15.7	2.4	290	15.1	14.9	5.50	<0.2	2.54	8.47	0.600	0.584	0.567	0.0503	0.019
KLX08	396.00	400.87	10744	2006-02-20	-0.70	103	2.49	15.4	2.4	287	15.2	15.0	5.51	<0.2	2.49	8.40	0.362	0.346	0.328	0.0475	0.019
KLX08	396.00	400.87	10745	2006-02-23	-1.12	102	2.44	15.6	2.4	286	15.4	15.1	5.73	<0.2	2.48	8.34	0.0551	0.048	0.046	0.0304	0.019
KLX08	396.00	400.87	10746	2006-02-27	-1.93	101	2.56	15.7	2.5	287	15.6	15.2	6.26	<0.2	2.57	8.30	0.0266	0.034	0.023	0.0227	0.019
KLX08	396.00	400.87	10747	2006-03-06	-1.01	103	2.38	15.2	2.3	290	14.9	14.0	5.39	<0.2	2.57	8.54	1.03	1.02	1.02	0.0530	0.019
KLX08	396.00	400.87	10748	2006-03-06	-	-	-	-	-	289	14.9	14.0	-	<0.2	2.57	-	-	1.03	1.03	-	-
KLX08	476.00	485.65	10730	2006-01-05	-	-	-	-	-	182	501	-	-	-	-	-	-	-	-	-	-
KLX08	476.00	485.65	10731	2006-01-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	476.00	485.65	10732	2006-01-10	0.78	524	5.12	176	8.2	95.1	1,000	92.4	32.7	4.76	2.09	6.53	0.599	0.563	0.554	0.147	0.094
KLX08	476.00	485.65	10733	2006-01-11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	476.00	485.65	10734	2006-01-12	1.10	569	4.99	203	8.3	82.2	1,110	97.6	35.1	5.28	2.07	6.80	0.544	0.519	0.512	0.141	0.108
KLX08	476.00	485.65	10735	2006-01-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	0.00	1,000.41	10868	2006-03-08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	0.00	1,000.41	10870	2006-03-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

- = Not analysed
< ”value” = result less than detection limit
ChargeBal % = Rel. charge balance error %
SICADA: water_composition

Table A11-1. Water Composition

Idcode	Secup m	Seclow m	Sample no.	Sampling date	Sr mg/L	I^- mg/L	pH	DOC mg/L	TOC mg/L	HS^- mg/L	Drill water %	ElCond mS/m	NH_4-N mg/L	NO_2-N mg/L	NO_3-N mg/L	NO_2-N+NO_3-N mg/L	PO_4-P mg/L	P mg/L	Density g/mL
KLX08	197.00	206.65	10639	2005-11-23	-	-	-	-	-	-	0.43	-	-	-	-	-	-	-	-
KLX08	197.00	206.65	10640	2005-11-25	-	-	8.19	-	-	-	0.88	53.2	-	-	-	-	-	-	-
KLX08	197.00	206.65	10641	2005-11-28	-	-	8.19	-	-	-	1.32	54.2	-	-	-	-	-	-	-
KLX08	197.00	206.65	10642	2005-11-30	-	-	8.21	-	-	-	1.49	53.5	-	-	-	-	-	-	-
KLX08	197.00	206.65	10643	2005-12-01	0.313	0.006	8.22	7.9	-	0.002	1.42	53.8	0.0984	<0.0002	0.0005	0.0006	0.0169	0.0236	-
KLX08	197.00	206.65	10644	2005-12-05	0.307	0.002	7.72	7.7	7.6	0.003	1.54	54.1	0.1110	<0.0002	0.0005	0.0005	0.0155	-	-
KLX08	197.00	206.65	10645	2005-12-08	0.300	0.006	8.24	7.3	-	0.002	1.55	53.2	0.1190	<0.0002	0.0007	0.0008	0.0159	-	-
KLX08	197.00	206.65	10646	2005-12-09	-	-	-	-	-	-	1.53	-	-	-	-	-	-	-	-
KLX08	197.00	206.65	10647	2005-12-12	0.288	0.002	8.28	7.9	7.6	0.003	1.44	58.8	0.1050	<0.0002	<0.0003	0.0003	0.0149	0.0190	-
KLX08	197.00	206.65	10648	2005-12-15	0.289	0.006	8.29	7.5	-	<0.002	1.51	53.2	0.0984	0.0004	0.0003	0.0006	0.0154	-	-
KLX08	197.00	206.65	10649	2005-12-19	0.286	0.002	8.29	7.7	7.6	0.004	1.29	53.2	0.0944	0.0007	0.0006	0.0013	0.0149	0.0179	0.9962
KLX09	197.00	206.65	10650	2005-12-19	-	-	8.32	-	-	0.005	1.29	53.8	0.0959	-	-	-	-	-	-
KLX08	396.00	400.87	10741	2006-02-03	-	-	8.17	-	-	-	0.34	67.5	-	-	-	-	-	-	-
KLX08	396.00	400.87	10794	2006-02-07	0.286	0.010	8.22	-	-	0.053	0.86	55.0	0.0864	0.0002	0.0037	0.0039	0.0060	0.0261	0.9966
KLX08	396.00	400.87	10795	2006-02-09	0.281	0.012	8.25	-	-	0.052	0.95	55.2	0.0735	0.0003	<0.0003	<0.0003	0.0199	-	-
KLX08	396.00	400.87	10742	2006-02-14	0.273	0.010	8.31	-	-	0.008	1.19	55.7	0.0796	0.0002	<0.0003	0.0003	0.0221	0.0286	-
KLX08	396.00	400.87	10743	2006-02-17	0.266	0.012	8.32	-	-	0.005	1.15	52.9	0.0603	0.0004	0.0004	0.0008	0.0204	-	-
KLX08	396.00	400.87	10744	2006-02-20	0.262	0.012	8.28	-	-	<0.002	1.30	51.9	0.0746	0.0003	<0.0003	<0.0003	0.0204	0.0272	-
KLX08	396.00	400.87	10745	2006-02-23	0.256	0.017	8.27	-	-	<0.002	1.26	54.6	0.0746	0.0002	0.0030	0.0032	0.0212	-	-
KLX08	396.00	400.87	10746	2006-02-27	0.258	0.015	8.30	-	-	<0.002	1.31	47.6	0.0687	<0.0002	0.0171	0.0172	0.0210	0.0257	0.9964
KLX08	396.00	400.87	10747	2006-03-06	0.261	0.008	8.32	-	-	0.037	1.15	53.1	0.0568	0.0002	0.0003	0.0005	0.0193	0.0346	0.9970
KLX08	396.00	400.87	10748	2006-03-06	-	-	8.35	-	-	0.035	1.14	52.9	0.0587	-	-	-	-	-	-
KLX08	476.00	485.65	10730	2006-01-05	-	-	7.95	-	-	-	16.2	199	-	-	-	-	-	-	-
KLX08	476.00	485.65	10731	2006-01-09	-	-	-	-	-	-	21.4	-	-	-	-	-	-	-	-
KLX08	476.00	485.65	10732	2006-01-10	2.98	0.049	7.88	4.5	-	0.008	20.2	346	0.0707	<0.0002	<0.0003	<0.0003	0.0009	-	-
KLX08	476.00	485.65	10733	2006-01-11	-	-	-	-	-	-	20.3	-	-	-	-	-	-	-	-
KLX08	476.00	485.65	10734	2006-01-12	3.44	0.055	7.85	3.9	-	0.011	20.8	378	0.0643	0.0003	<0.0003	0.0005	0.0017	-	-
KLX08	476.00	485.65	10735	2006-01-16	-	-	-	-	-	-	20.1	565	-	-	-	-	-	-	-
KLX08	0.00	1,000.41	10868	2006-03-08	-	-	-	-	-	-	0.12	50.2							

- = Not analysed
< ”value” = result less than detection limit
ChargeBal % = Rel. charge balance error %
SICADA: water_composition

Table A11-1. Water Composition

Idcode	Secup m	Seclow m	Sample no.	Sampling date	Charge Bal %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO_3^- mg/L	Cl^- mg/L	SO_4^{2-} mg/L	SO_4-S mg/L	Br^- mg/l	F^- mg/L	Si mg/L	Fe mg/L	Fe-tot mg/L	Fe(II) mg/L	Mn mg/L	Li mg/L
KLX08	0.00	1,000.41	10871	2006-03-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	0.00	1,000.41	10884	2006-03-13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	0.00	1,000.41	10890	2006-03-14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	0.00	1,000.41	10898	2006-03-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	0.00	1,000.41	10901	2006-03-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	0.00	1,000.41	10903	2006-03-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	0.00	1,000.41	10904	2006-03-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	0.00	1,000.41	10908	2006-03-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	0.00	1,000.41	10923	2006-03-22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	0.00	1,000.41	10933	2006-03-23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	0.00	1,000.41	10934	2006-03-24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	0.00	1,000.41	10939	2006-03-27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	476.00	485.62	10750	2006-04-04	-	-	-	-	-	194	533	-	-	-	-	-	-	-	-	-	-
KLX08	476.00	485.62	10954	2006-04-06	-	-	-	-	-	80.8	1,180	102	-	6.19	2.36	-	-	0.649	0.649	-	-
KLX08	476.00	485.62	10955	2006-04-13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	476.00	485.62	10956	2006-04-18	-	-	-	-	-	37.3	1,520	120	-	7.16	2.19	-	-	0.433	0.403	-	-
KLX08	476.00	485.62	10957	2006-04-20	-	-	-	-	-	35.6	1,540	-	-	-	-	-	-	-	-	-	-
KLX08	476.00	485.62	10958	2006-04-24	-	-	-	-	-	35.1	1,530	-	-	-	-	-	-	-	-	-	-
KLX08	476.00	485.62	10959	2006-05-22	-0.08	740	3.08	279	6.9	34.8	1,530	132	48.7	7.60	2.53	7.27	0.636	0.936	0.688	0.0946	0.143
KLX08	476.00	485.62	11087	2006-05-24	-0.38	717	3.08	265	6.6	34.0	1,480	128	47.7	7.40	2.75	7.01	0.309	0.258	0.232	0.0897	0.137
KLX08	476.00	485.62	11094	2006-05-30	0.71	764	3.21	286	7.2	34.1	1,550	133	50.5	7.95	2.55	7.37	0.605	0.670	0.627	0.0961	0.150
KLX08	476.00	485.62	11088	2006-06-01	0.36	746	3.61	289	7.2	33.2	1,540	132	50.8	7.88	2.53	7.21	0.853	0.810	0.794	0.105	0.148
KLX08	476.00	485.62	11115	2006-06-07	-0.75	731	3.01	282	6.9	32.4	1,540	129	50.7	7.60	2.63	6.98	0.244	0.244	0.213	0.0936	0.145
KLX08	476.00	485.62	11118	2006-06-09	-1.20	732	3.05	276	6.7	33.5	1,550	131	48.1	7.67	2.61	6.93	0.245	0.251	0.235	0.0910	0.146
KLX08	476.00	485.62	11143	2006-06-12	-1.06	730	3.11	285	6.7	32.2	1,560	130	47.9	7.63	2.58	6.93	0.265	0.272	0.257	0.0888	0.146
KLX08	476.00	485.62	11158	2006-06-15	1.16	789	3.74	282	6.8	32.0	1,570	131	48.4	7.98	2.63	6.76	0.225	0.280	0.237	0.0933	0.149
KLX08	476.00	485.62	11159	2006-06-19	1.55	796	3.52	298	6.8	32.0	1,590	133	50.5	7.88	2.68	7.04	0.298	0.295	0.288	0.0877	0.165
KLX08	476.00	485.62	11178	2006-06-21	0.00	769	3.73	282	6.8	32.7	1,580	131	47.8	7.87	2.64	7.06	0.290	0.281	0.276	0.0873	0.157
KLX08	476.00	485.62	11160	2006-06-26	-11.88	620	3.00	210	5.8	32.3	1,590	130	45.0	7.65	2.55	5.10	0.220	0.284	0.278	0.0640	0.140

- = Not analysed
< ”value” = result less than detection limit
ChargeBal % = Rel. charge balance error %
SICADA: water_composition

Table A11-1. Water Composition

Idcode	Secup m	Seclow m	Sample no.	Sampling date	Sr mg/L	I^- mg/L	pH	DOC mg/L	TOC mg/L	HS^- mg/L	Drill water %	ElCond mS/m	NH_4-N mg/L	NO_2-N mg/L	NO_3-N mg/L	NO_2-N+NO_3-N mg/L	PO_4-P mg/L	P mg/L	Density g/mL
KLX08	0.00	1,000.41	10870	2006-03-09	-	-	-	-	-	-	1.16	55.4							
KLX08	0.00	1,000.41	10871	2006-03-10	-	-	-	-	-	-	1.63	56.7							
KLX08	0.00	1,000.41	10884	2006-03-13	-	-	-	-	-	-	2.49	60.2							
KLX08	0.00	1,000.41	10890	2006-03-14	-	-	-	-	-	-	2.66	60.1							
KLX08	0.00	1,000.41	10898	2006-03-15	-	-	-	-	-	-	2.90	62.0							
KLX08	0.00	1,000.41	10901	2006-03-16	-	-	-	-	-	-	2.95	62.4							
KLX08	0.00	1,000.41	10903	2006-03-17	-	-	-	-	-	-	3.15	63.3							
KLX08	0.00	1,000.41	10904	2006-03-20	-	-	-	-	-	-	3.15	67.5							
KLX08	0.00	1,000.41	10908	2006-03-21	-	-	-	-	-	-	3.29	67.9							
KLX08	0.00	1,000.41	10923	2006-03-22	-	-	-	-	-	-	3.28	68.5							
KLX08	0.00	1,000.41	10933	2006-03-23	-	-	-	-	-	-	3.34	68.2							
KLX08	0.00	1,000.41	10934	2006-03-24	-	-	-	-	-	-	3.48	70.6							
KLX08	0.00	1,000.41	10939	2006-03-27	-	-	-	-	-	-	3.32	71.6							
KLX08	476.00	485.62	10750	2006-04-04	-	-	7.81	-	-	-	4.33	209	-	-	-	-	-	-	-
KLX08	476.00	485.62	10954	2006-04-06	-	-	7.74	-	-	0.051	10.5	402	0.0476	-	-	-	-	-	-
KLX08	476.00	485.62	10955	2006-04-13	-	-	-	-	-	-	16.5	-	-	-	-	-	-	-	-
KLX08	476.00	485.62	10956	2006-04-18	-	-	7.88	-	-	0.015	16.5	496	0.0561	-	-	-	-	-	-
KLX08	476.00	485.62	10957	2006-04-20	-	-	7.89	-	-	-	16.3	501	-	-	-	-	-	-	-
KLX08	476.00	485.62	10958	2006-04-24	-	-	7.90	-	-	-	16.1	508	-	-	-	-	-	-	-
KLX08	476.00	485.62	10959	2006-05-22	5.19	0.052	7.84	4.0	-	0.008	5.17	498	0.0217	0.0002	0.0003	0.0005	0.0035	-	-
KLX08	476.00	485.62	11087	2006-05-24	4.95	0.046	7.89	6.4	-	0.007	4.93	488	0.0185	0.0003	<0.0003	0.0003	0.0030	-	-
KLX08	476.00	485.62	11094	2006-05-30	5.46	0.056	7.51	2.8	3.4	0.007	5.33	493	0.0223	0.0002	<0.0003	<0.0003	0.0004	0.0171	0.9991
KLX08	476.00	485.62	11088	2006-06-01	5.23	0.061	7.48	2.7	-	0.005	4.96	504	0.0072	<0.0002	<0.0003	<0.0003	0.0020	-	-
KLX08	476.00	485.62	11115	2006-06-07	5.11	0.056	7.75	2.7	2.7	<0.002	5.33	512	0.0461	0.0003	<0.0003	0.0004	0.0069	0.0152	-
KLX08	476.00	485.62	11118	2006-06-09	5.16	0.056	7.83	2.8	-	0.002	5.39	513	0.0687	0.0002	<0.0003	0.0004	0.0081	0.0134	-
KLX08	476.00	485.62	11143	2006-06-12	5.18	0.056	7.83	2.9	2.8	0.004	5.38	512	0.0528	0.0002	<0.0003	0.0004	0.0057	0.0182	
KLX08	476.00	485.62	11158	2006-06-15	5.41	0.066	7.80	2.6	-	<0.002	5.44	517	0.0236	<0.0002	<0.0003	<0.0003	0.0030	-	-
KLX08	476.00	485.62	11159	2006-06-19	5.51	0.062	7.85	2.5	2.6	<0.002	5.71	520	0.0273	<0.0002	<0.0003	<0.0003	0.0030	0.0149	-
KLX08	476.00	485.62	11178	2006-06-21	5.42	0.066	7.85	2.5	-	<0.002	5.82	520	0.0249	<0.0002	<0.0003	<0.0003	0.0028	-	-

- = Not analysed
< ”value” = result less than detection limit
ChargeBal % = Rel. charge balance error %
SICADA: water_composition

Table A11-1. Water Composition

Idcode	Secup m	Seclow m	Sample no.	Sampling date	Charge Bal %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO_3^- mg/L	Cl^- mg/L	SO_4^{2-} mg/L	SO_4-S mg/L	Br^- mg/l	F^- mg/L	Si mg/L	Fe mg/L	Fe-tot mg/L	Fe(II) mg/L	Mn mg/L	Li mg/L
KLX08	476.00	485.62	11183	2006-06-26	1.35	799	3.88	294	6.9	32.3	1,600	132	48.1	7.98	2.70	6.81	0.288	0.284	0.275	0.0855	0.154
KLX08	610.00	619.65	10736	2006-01-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	610.00	619.65	10739	2006-01-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	610.00	619.65	10737	2006-01-23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	610.00	619.65	10738	2006-01-24	-	-	-	-	-	31.8	1,620	114	-	8.00	2.05	-	-	-	-	-	-
KLX08	610.00	619.65	10740	2006-01-27	-	-	-	-	-	30.9	1,620	-	-	-	-	-	-	-	-	-	-
KLX08	610.00	619.62	10749	2006-03-31	-	-	-	-	-	24.3	-	-	-	-	-	-	-	-	-	-	-
KLX08	610.00	619.62	10948	2006-04-03	-	-	-	-	-	25.5	1,770	-	-	-	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11015	2006-05-03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11016	2006-05-03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11017	2006-05-04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11018	2006-05-04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11019	2006-05-05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11020	2006-05-05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11021	2006-05-06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11022	2006-05-06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11023	2006-05-07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11024	2006-05-07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11025	2006-05-07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11026	2006-05-08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11027	2006-05-09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11028	2006-05-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11045	2006-05-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11046	2006-05-11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11055	2006-05-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11056	2006-05-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11047	2006-05-11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11048	2006-05-12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

- = Not analysed
< ”value” = result less than detection limit
ChargeBal % = Rel. charge balance error %
SICADA: water_composition

Table A11-1. Water Composition

Idcode	**Secup m**	**Seclow m**	**Sample no.**	**Sampling date**	**Sr mg/L**	**I$^-$ mg/L**	**pH**	**DOC mg/L**	**TOC mg/L**	**HS$^-$ mg/L**	**Drill water %**	**ElCond mS/m**	**NH$_4$-N mg/L**	**NO$_2$-N mg/L**	**NO$_3$-N mg/L**	**NO$_2$-N+NO$_3$-N mg/L**	**PO$_4$-P mg/L**	**P mg/L**	**Density g/mL**
KLX08	476.00	485.62	11160	2006-06-26	4.60		7.84	-	-	0.011	5.98	516	0.0274	-	-	-	-	-	-
KLX08	476.00	485.62	11183	2006-06-26	5.45	0.068	7.87	2.7	2.7	0.008	5.89	513	0.0284	<0.0002	<0.0003	<0.0003	0.0031	0.0114	0.9991
KLX08	610.00	619.65	10736	2006-01-18	-	-	-	-	-	-	31.8	-	-	-	-	-	-	-	-
KLX08	610.00	619.65	10739	2006-01-19	-	-	-	-	-	-	34.3	-	-	-	-	-	-	-	-
KLX08	610.00	619.65	10737	2006-01-23	-	-	-	-	-	-	36.2	-	-	-	-	-	-	-	-
KLX08	610.00	619.65	10738	2006-01-24	-	-	7.89	-	-	-	37.0	518	-	-	-	-	-	-	-
KLX08	610.00	619.65	10740	2006-01-27	-	-	8.02	-	-	-	37.8	524	-	-	-	-	-	-	-
KLX08	610.00	619.62	10749	2006-03-31	-	-	7.59	-	-	-	31.1	555	-	-	-	-	-	-	-
KLX08	610.00	619.62	10948	2006-04-03	-	-	7.65	-	-	-	26.3	565	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11015	2006-05-03	-	-	-	-	-	-	0.57	49.2	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11016	2006-05-03	-	-	-	-	-	-	0.07	51.7	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11017	2006-05-04	-	-	-	-	-	-	9.50	232	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11018	2006-05-04	-	-	-	-	-	-	10.1	234	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11019	2006-05-05	-	-	-	-	-	-	10.0	238	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11020	2006-05-05	-	-	-	-	-	-	10.2	243	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11021	2006-05-06	-	-	-	-	-	-	9.95	246	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11022	2006-05-06	-	-	-	-	-	-	9.93	245	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11023	2006-05-07	-	-	-	-	-	-	9.95	248	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11024	2006-05-07	-	-	-	-	-	-	9.92	252	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11025	2006-05-08	-	-	-	-	-	-	9.82	255	-	-	-	-	-	-	-
KLX08	599.27	1,000.41	11026	2006-05-08	-	-	-	-	-	-	9.77	262	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11027	2006-05-09	-	-	-	-	-	-	6.00	138	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11028	2006-05-10	-	-	-	-	-	-	7.88	185	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11045	2006-05-10	-	-	-	-	-	-	7.55	181	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11046	2006-05-11	-	-	-	-	-	-	7.81	182	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11055	2006-05-16	-	-	-	-	-	-	9.20	207	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11056	2006-05-17	-	-	-	-	-	-	9.48	204	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11047	2006-05-11	-	-	-	-	-	-	8.23	196	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11048	2006-05-12	-	-	-	-	-	-	8.38	194	-	-	-	-	-	-	-

- = Not analysed
< ”value” = result less than detection limit
ChargeBal % = Rel. charge balance error %
SICADA: water_composition

Table A11-1. Water Composition

Idcode	Secup m	Seclow m	Sample no.	Sampling date	Charge Bal %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO$_3^-$ mg/L	Cl$^-$ mg/L	SO$_4^{2-}$ mg/L	SO$_4$-S mg/L	Br$^-$ mg/l	F$^-$ mg/L	Si mg/L	Fe mg/L	Fe-tot mg/L	Fe(II) mg/L	Mn mg/L	Li mg/L
KLX08	473.37	1,000.41	11049	2006-05-12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11050	2006-05-13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11051	2006-05-14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11052	2006-05-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11053	2006-05-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11054	2006-05-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	609.00	618.51	11205	2006-06-29	-	-	-	-	-	19.8	2,030	-	-	-	-	-	-	-	-	-	-
KLX08	609.00	618.51	11207	2006-06-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	609.00	618.51	11211	2006-07-03	0.79	955	5.98	381	8.4	20.2	2,010	141	53.5	9.85	2.40	7.16	0.0870	0.087	0.080	0.0898	0.194
KLX08	609.00	618.51	11216	2006-07-06	1.50	976	5.87	380	9.1	20.1	2,010	138	54.1	9.55	2.40	7.26	0.0793	0.080	0.070	0.0954	0.178
KLX08	609.00	618.51	11218	2006-07-10	1.04	966	5.83	378	8.9	20.3	2,010	138	54.4	9.55	2.35	7.19	0.0360	0.039	0.032	0.0880	0.171
KLX08	609.00	618.51	11219	2006-07-14	-1.02	929	5.74	364	8.7	20.2	2,020	144	52.5	10.7	2.40	7.43	0.123	0.125	0.113	0.0859	0.178
KLX08	609.00	618.51	11222	2006-07-17	0.38	961	5.87	371	9.0	20.1	2,020	144	53.9	10.3	2.35	7.68	0.251	0.241	0.235	0.0897	0.188
KLX08	609.00	618.51	11229	2006-07-20	0.11	960	6.18	365	8.1	20.6	2,020	144	52.5	10.1	2.45	7.09	0.131	0.127	0.125	0.0855	0.173
KLX08	609.00	618.51	11226	2006-07-24	-0.47	949	6.39	360	8.0	20.6	2,020	145	51.8	10.4	2.60	6.84	0.0062	<0.005	<0.005	0.0787	0.174
KLX08	609.00	618.51	11227	2006-07-26	-	-	-	-	-	20.1	2,030	141	-	10.3	2.25	-	-	0.040	0.015	-	-
KLX08	609.00	618.51	11228	2006-07-26	-0.46	947	5.91	367	8.0	20.5	2,030	145	51.2	10.6	2.25	6.81	0.0202	<0.005	<0.005	0.0893	0.174

- = Not analysed
< ”value” = result less than detection limit
ChargeBal % = Rel. charge balance error %
SICADA: water_composition

Table A11-1. Water Composition

Idcode	Secup m	Seclow m	Sample no.	Sampling date	Sr mg/L	I^- mg/L	pH	DOC mg/L	TOC mg/L	HS^- mg/L	Drill water %	ElCond mS/m	NH_4-N mg/L	NO_2-N mg/L	NO_3-N mg/L	NO_2-N+NO_3-N mg/L	PO_4-P mg/L	P mg/L	Density g/mL
KLX08	473.37	1,000.41	11049	2006-05-12	-	-	-	-	-	-	8.60	193	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11050	2006-05-13	-	-	-	-	-	-	8.45	195	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11051	2006-05-14	-	-	-	-	-	-	8.84	199	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11052	2006-05-15	-	-	-	-	-	-	9.10	203	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11053	2006-05-15	-	-	-	-	-	-	9.25	206	-	-	-	-	-	-	-
KLX08	473.37	1,000.41	11054	2006-05-16	-	-	-	-	-	-	9.37	208	-	-	-	-	-	-	-
KLX08	609.00	618.51	11205	2006-06-29	-	-	7.94	-	-	-	10.4	637	-	-	-	-	-	-	-
KLX08	609.00	618.51	11207	2006-06-30	-	-	-	-	-	-	10.6	-	-	-	-	-	-	-	-
KLX08	609.00	618.51	11211	2006-07-03	6.83	0.083	8.10	1.8	-	0.007	10.9	636	0.0256	-	-	-	-	-	-
KLX08	609.00	618.51	11216	2006-07-06	6.88	0.083	8.10	1.7	-	0.010	10.9	638	0.0283	-	-	-	-	-	-
KLX08	609.00	618.51	11218	2006-07-10	6.77	0.080	8.15	1.9	-	0.008	10.9	650	0.0230	<0.0002	<0.0003	<0.0003	0.0048	-	-
KLX08	609.00	618.51	11219	2006-07-14	6.89	0.088	8.15	1.8	-	0.004	11.2	646	0.0231	<0.0002	<0.0003	<0.0003	<0.0046	0.0156	-
KLX08	609.00	618.51	11222	2006-07-17	7.11	0.097	8.17	1.7	1.8	0.009	11.1	642	0.0248	<0.0002	<0.0003	<0.0003	0.0044	0.0152	-
KLX08	609.00	618.51	11229	2006-07-20	6.94	0.095	8.18	1.7	-	0.005	11.2	643	0.0265	<0.0002	<0.0003	<0.0003	0.0062	-	-
KLX08	609.00	618.51	11226	2006-07-24	6.85	0.095	8.16	1.8	1.9	0.003	10.8	642	0.0332	<0.0002	<0.0003	<0.0003	0.0025	-	-
KLX08	609.00	618.51	11227	2006-07-26	-	-	8.19	-	-	0.002	10.8	640	0.0318	-	-	-	-	-	-
KLX08	609.00	618.51	11228	2006-07-26	6.75	0.100	8.19	1.8	1.7	0.010	10.7	640	0.0357	<0.0002	<0.0003	<0.0003	0.0024	-	0.9996

- = Not analysed
< ”value” = result less than detection limit
ChargeBal % = Rel. charge balance error %
SICADA: water_composition

Table A11-2. Trace elements

Idcode	Secup m	Seclow m	Sample no.	Sampling date	U μg/L	Th μg/L	As μg/L	Sc μg/L	Cd μg/L	Hg μg/L	V μg/L	Rb μg/L	Y μg/L	Zr μg/L	In μg/L	Cs μg/L	Ba μg/L	La μg/L	Hf μg/L	Tl μg/L	Ce μg/L
KLX08	197.00	206.65	10644	2005-12-05	0.981	<0.02	0.217	<0.05	0.0030	<0.002	1.27	6.46	0.0125	0.741	<0.05	0.372	35.0	0.0077	0.0059	<0.005	0.0102
KLX08	197.00	206.65	10647	2005-12-12	0.927	<0.02	0.210	<0.05	0.0035	<0.002	1.13	6.48	0.0121	0.784	<0.05	0.363	30.8	0.0079	0.0068	<0.005	0.0111
KLX08	197.00	206.65	10649	2005-12-19	0.928	<0.02	0.220	<0.05	0.0029	<0.002	1.19	6.53	0.0122	0.780	<0.05	0.358	32.4	0.0074	0.0068	<0.005	0.0102
KLX08	396.00	400.87	10794	2006-02-07	0.366	<0.02	0.12	<0.05	<0.002	<0.002	1.14	5.27	0.130	0.635	<0.05	0.253	39.2	0.107	0.0059	<0.005	0.136
KLX08	396.00	400.87	10742	2006-02-14	0.348	<0.02	0.23	<0.05	<0.002	<0.002	1.16	4.98	0.126	0.609	<0.05	0.218	43.8	0.100	0.0067	<0.005	0.122
KLX08	396.00	400.87	10744	2006-02-20	0.386	<0.02	0.19	<0.05	<0.002	<0.002	1.11	4.84	0.133	0.652	<0.05	0.195	45.3	0.0823	0.0680	<0.005	0.113
KLX08	396.00	400.87	10746	2006-02-27	0.397	<0.02	0.21	<0.05	0.0291	<0.002	1.40	4.83	0.121	0.586	<0.05	0.223	39.6	0.0662	0.0057	<0.005	0.0909
KLX08	396.00	400.87	10747	2006-03-06	0.397	<0.02	0.22	<0.05	0.0344	0.0023	1.12	4.74	0.129	0.638	<0.05	0.185	47.8	0.0804	0.0067	<0.005	0.1100
KLX08	476.00	485.62	11094	2006-05-30	0.0545	<0.04	2.4	<0.1	0.0127	<0.002	0.130	8.45	0.0322	<0.06	<0.1	0.523	68.0	<0.01	<0.01	<0.01	<0.01
KLX08	476.00	485.62	11115	2006-06-07	0.0255	<0.04	1.6	<0.1	0.0171	<0.002	0.133	7.97	0.0282	<0.06	<0.1	0.505	64.5	<0.01	<0.01	<0.01	<0.01
KLX08	476.00	485.62	11143	2006-06-12	0.0224	<0.04	<0.1	<0.1	0.0055	<0.002	0.170	8.11	0.0289	0.0677	<0.1	0.479	65.3	<0.01	<0.01	<0.01	<0.01
KLX08	476.00	485.62	11159	2006-06-19	0.0289	<0.08	<1	<0.2	<0.008	<0.002	0.127	8.86	0.0892	<0.1	<0.25	0.515	66.1	<0.02	<0.02	<0.02	<0.02
KLX08	476.00	485.62	11183	2006-06-26	0.0267	0.0644	<1	<0.1	0.0088	<0.002	0.167	8.63	0.0313	0.157	<0.1	0.538	70.7	<0.01	<0.01	<0.01	<0.01
KLX08	609.00	618.51	11222	2006-07-17	0.0133	<0.2	<0.5	<0.4	0.0273	<0.002	0.0477	11.9	0.0281	<0.1	<0.2	0.626	92.8	<0.02	<0.02	<0.03	<0.02
KLX08	609.00	618.51	11226	2006-07-24	0.0212	<0.2	<0.5	<0.4	<0.02	<0.002	0.100	15.7	0.0412	<0.1	<0.2	0.677	84.6	<0.02	<0.02	0.026	<0.02
KLX08	609.00	618.51	11228	2006-07-26	0.0280	<0.2	<0.5	<0.4	<0.02	<0.002	0.107	18.8	0.0408	0.174	<0.2	0.944	84.0	<0.02	<0.02	<0.03	<0.02

- = Not analysed
A = Results will be reported later
x = No result due to sampling problems
xx = No result due to analytical problems
< ”value” = result less than detection limit
SICADA: trace_elements

Table A11-2. Trace elements

Idcode	Secup m	Seclow m	Sample no.	Sampling date	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
KLX08	197.00	206.65	10644	2005-12-05	<0.005	0.0060	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
KLX08	197.00	206.65	10647	2005-12-12	<0.005	0.0119	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
KLX08	197.00	206.65	10649	2005-12-19	<0.005	0.0123	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
KLX08	396.00	400.87	10794	2006-02-07	0.0153	0.141	0.0164	0.0072	0.0168	<0.005	0.0147	<0.005	0.0121	<0.005	0.0130	<0.005
KLX08	396.00	400.87	10742	2006-02-14	0.0148	0.114	0.0150	0.0065	0.0179	<0.005	0.0143	<0.005	0.0119	<0.005	0.0148	<0.005
KLX08	396.00	400.87	10744	2006-02-20	0.0134	0.116	0.0159	0.0062	0.0164	<0.005	0.0138	<0.005	0.0145	<0.005	0.0153	<0.005
KLX08	396.00	400.87	10746	2006-02-27	0.0112	0.139	0.0123	0.0052	0.0144	<0.005	0.0133	<0.005	0.0125	<0.005	0.0149	<0.005
KLX08	396.00	400.87	10747	2006-03-06	0.0137	0.0987	0.0108	0.0066	0.0172	<0.005	0.0154	<0.005	0.0137	<0.005	0.0172	<0.005
KLX08	476.00	485.62	11094	2006-05-30	<0.01	0.0600	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
KLX08	476.00	485.62	11115	2006-06-07	<0.01	0.0548	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
KLX08	476.00	485.62	11143	2006-06-12	<0.01	0.0119	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
KLX08	476.00	485.62	11159	2006-06-19	<0.02	0.0981	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
KLX08	476.00	485.62	11183	2006-06-26	<0.01	0.0176	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.012
KLX08	609.00	618.51	11222	2006-07-17	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
KLX08	609.00	618.51	11226	2006-07-24	<0.02	0.0244	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
KLX08	609.00	618.51	11228	2006-07-26	<0.02	0.0331	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

- = Not analysed
A = Results will be reported later
x = No result due to sampling problems
xx = No result due to analytical problems
< ”value” = result less than detection limit
SICADA: trace_elements

Table A11-3. Isotopes I (H-, O-, B-, S-, Cl- and C-isotopes)

Idcode	Secup m	Seclow m	Sample no	Sampling date	δ^{2}H dev SMOW	^{3}H TU	δ^{18}O dev SMOW	^{10}B/^{11}B no unit	δ^{34}S dev CDT	δ^{13}C dev PDB	^{87}Sr/^{86}Sr no unit	^{14}C pmC	AGE_BP years	δ^{37}Cl dev SMOC
KLX08	197.00	206.65	10640	2005-11-25	-76.0	2.3	-10.3	-	-	-	-	-	-	-
KLX08	197.00	206.65	10643	2005-12-01	-76.0	1.4	-10.7	-	-	-	-	-	-	-
KLX08	197.00	206.65	10644	2005-12-05	-76.5	1.6	-10.4	0.2409	40.9	-17.44	0.715750	62.69	3,697	0.32
KLX08	197.00	206.65	10645	2005-12-08	-76.1	2.2	-10.4	-	-	-	-	-	-	-
KLX08	197.00	206.65	10647	2005-12-12	-76.0	2.3	-10.5	0.2404	38.7	-17.55	0.715761	63.50	3,594	0.31
KLX08	197.00	206.65	10648	2005-12-15	76.1	2.7	-10.5	-	-	-	-	-	-	-
KLX08	197.00	206.65	10649	2005-12-19	-76.2	2.9	-10.6	0.2403	39.4	-17.58	0.715766	63.00	3,658	0.23
KLX08	396.00	400.87	10794	2006-02-07	-76.4	13.8	-10.7	0.2417	33.7	-17.75	0.715798	66.04	3,279	0.23
KLX08	396.00	400.87	10795	2006-02-09	-76.2	5.4	-10.8	-	-	-	-	-	-	-
KLX08	396.00	400.87	10742	2006-02-14	-76.0	5.6	-10.7	0.2417	33.9	-17.77	0.715846	65.64	3,327	0.17
KLX08	396.00	400.87	10743	2006-02-17	-77.2	6.1	-10.7	-	-	-	-	-	-	-
KLX08	396.00	400.87	10744	2006-02-20	-76.7	3.4	-10.8	0.2420	31.1	-17.80	0.715867	65.57	3,336	0.63
KLX08	396.00	400.87	10745	2006-02-23	-76.8	4.3	-10.7	-	-	-	-	-	-	-
KLX08	396.00	400.87	10746	2006-02-27	-76.1	4.1	-10.7	0.2416	29.1	-18.04	0.715861	63.69	3,570	0.38
KLX08	396.00	400.87	10747	2006-03-06	-76.4	5.4	-10.7	0.2406	32.7	-17.79	0.715856	66.27	3,250	0.34
KLX08	476.00	485.65	10732	2006-01-10	-98.2	1.7	-13.6	-	-	-	-	-	-	-
KLX08	476.00	485.65	10734	2006-01-12	-102.7	1.9	-14.0	-	-	-	-	-	-	-
KLX08	476.00	485.62	10956	2006-04-18	-109.4	-	-15.1	-	-	-	-	-	-	-
KLX08	476.00	485.62	10959	2006-05-22	-115.1	95.2	-15.4	-	-	-	-	-	-	-
KLX08	476.00	485.62	11087	2006-05-24	-111.9	756.6	-14.9	-	-	-	-	-	-	-
KLX08	476.00	485.62	11540	2006-05-24	-	710.3	-	-	-	-	-	-	-	-
KLX08	476.00	485.62	11548	2006-05-24	-	757	-	-	-	-	-	-	-	-
KLX08	476.00	485.62	11094	2006-05-30	-115.2	2.9	-15.6	0.2364	15.5	-15.70	0.715724	32.09	9,076	0.03
KLX08	476.00	485.62	11088	2006-06-01	-115.2	2.2	-15.6	-	-	-	-	-	-	-
KLX08	476.00	485.62	11115	2006-06-07	-117.4	111.4	-15.4	0.2371	15.6	xx	0.715673	xx	xx	0.03
KLX08	476.00	485.62	11118	2006-06-09	-117.1	52.3	-15.5	-	-	-	-	-	-	-
KLX08	476.00	485.62	11143	2006-06-12	-114.0	38.9	-15.5	0.2373	15.4	xx	0.715676	xx	xx	0.05
KLX08	476.00	485.62	11158	2006-06-15	-115.1	2.2	-15.7	-	-	-	-	-	-	-

- = Not analysed
A = results will be reported later
xx = No result due to analytical problems
< ”value” = result less than detection limit
SICADA: isotopes_1_t

Table A11-3. Isotopes I (H-, O-, B-, S-, Cl- and C-isotopes)

Idcode	Secup m	Seclow m	Sample no	Sampling date	δ^2H dev SMOW	^3H TU	$\delta^{18}O$ dev SMOW	$^{10}B/^{11}B$ no unit	$\delta^{34}S$ dev CDT	$\delta^{13}C$ dev PDB	$^{87}Sr/^{86}Sr$ no unit	^{14}C pmC	AGE_BP years	$\delta^{37}Cl$ dev SMOC
KLX08	476.00	485.62	11159	2006-06-19	-117.0	2.1	-15.6	0.2354	17.0	xx	0.715664	xx	xx	0.05
KLX08	476.00	485.62	11178	2006-06-21	-116.1	2.0	-15.6	-	-	-	-	-	-	-
KLX08	476.00	485.62	11183	2006-06-26	-116.1	2.1	-15.7	0.2367	16.4	xx	0.715668	xx	xx	0.16
KLX08	609.00	618.51	11205	2006-06-29	-115.4	1.2	-15.4	-	-	-	-	-	-	-
KLX08	609.00	618.51	11211	2006-07-03	-115.4	1.6	-15.4	-	-	-	-	-	-	-
KLX08	609.00	618.51	11216	2006-07-06	-115.1	<0.8	-15.4	-	-	-	-	-	-	-
KLX08	609.00	618.51	11218	2006-07-10	-113.1	<0.8	-15.4	-	-	-	-	-	-	-
KLX08	609.00	618.51	11219	2006-07-14	-114.2	2.3	-15.3	-	-	-	-	-	-	-
KLX08	609.00	618.51	11222	2006-07-17	-114.4	1.7	-15.3	0.2388	13.3	xx	0.715550	xx	xx	0.10
KLX08	609.00	618.51	11229	2006-07-20	-113.6	2.7	-15.3	-	-	-	-	-	-	-
KLX08	609.00	618.51	11226	2006-07-24	-112.7	2.4	-15.3	0.2383	13.2	xx	0.715565	xx	xx	0.09
KLX08	609.00	618.51	11228	2006-07-26	-112.9	2.5	-15.2	0.2377	13.2	xx	0.715561	xx	xx	0.10

- = Not analysed
A = results will be reported later
xx = No result due to analytical problems
< ”value” = result less than detection limit
SICADA: isotopes_1_t

Table A11-4. Isotopes II (U-, Th, Ra- and Rn-isotopes)

Idcode	Secup m	Seclow m	Sample no.	Sampling date	^{238}U mBq/L	^{235}U mBq/L	^{234}U mBq/L	^{232}Th mBq/L	^{230}Th mBq/L	^{226}Ra Bq/L	^{222}Rn Bq/L
KLX08	197.00	206.65	10644	2005-12-05	13.4	-	37.4	-	0.7	0.030	68.6
KLX08	197.00	206.65	10647	2005-12-12	12.3	-	31.3	-	0.2	0.040	66
KLX08	197.00	206.65	10649	2005-12-19	11.4	-	33.0	-	0.2	0.021	97
KLX08	197.00	206.65	10650	2005-12-19	10.3	-	30.3	-	0.4	0.016	89
KLX08	396.00	400.87	10794	2006-02-07	4.2	-	12.5	-	<0.3	0.023	80
KLX08	396.00	400.87	10742	2006-02-14	4.9	-	12.0	-	0.4	0.020	112
KLX08	396.00	400.87	10744	2006-02-20	4.5	-	12.5	-	<0.2	<0.015	58
KLX08	396.00	400.87	10746	2006-02-27	4.8	-	12.6	-	<0.2	0.035	77
KLX08	396.00	400.87	10747	2006-03-06	4.8	-	13.8	-	<0.2	<0.015	53
KLX08	396.00	400.87	10748	2006-03-06	4.8	-	12.0	-	<0.3	0.015	44
KLX08	476.00	485.62	11094	2006-05-30	0.84	-	2.27	-	<0.5	<0.015	91
KLX08	476.00	485.62	11115	2006-06-07	0.52	-	1.43	-	<0.5	<0.015	81
KLX08	476.00	485.62	11143	2006-06-12	0.28	-	0.97	-	<0.5	<0.015	100
KLX08	476.00	485.62	11159	2006-06-19	<0.73	-	0.86	-	0.18	<0.015	99
KLX08	476.00	485.62	11160	2006–06–26	0.51	-	1.7	-	0.64	<0.015	71
KLX08	476.00	485.62	11183	2006-06-26	0.41	-	1.3	-	<0.25	0.0319	72
KLX08	609.00	618.51	11222	2006-07-17	<0.14	<0.07	0.79	0.16	0.28	<0.015	27
KLX08	609.00	618.51	11226	2006-07-24	0.25	<0.07	0.42	<0.16	<0.28	0.060	27
KLX08	609.00	618.51	11228	2006-07-26	0.14	<0.07	0.71	<0.16	<0.28	<0.015	28

- = Not analysed
A = Results will be reported later
x = No result due to sampling problems
xx = No result due to analytical problems
< ”value” = result less than detection limit
SICADA: u_th_isotope_t, ra_rn_isotope_t

Table A11-5. Dissolved gases

Idcode	Secup m	Seclow m	Sample no.	Sampling date	Ar mL/L	He mL/L	N_2 mL/L	CO_2 mL/L	CH_4 mL/L	O_2 mL/L	H_2 µL/L	CO µL/L	C_2H_6 µL/L	C_2H_4 µL/L	C_2H_2 µL/L	C_3H_8 µL/L	C_3H_6 µL/L	DISS_GAS mL/L H_2O
KLX08	197.00	206.65	10649	2005-12-20	0.57	0.005	57	1.3	0.10	0.54	29.4	<3.0	0.49	0.06	<0.05	0.12	<0.06	60
KLX08	396.00	400.87	10747	2006-03-07	0.62	0.012	38	1.2	0.12	0.04	44	<2.0	0.47	<0.05	<0.05	<0.05	<0.05	40
KLX08	476.00	486.62	11183	2006-06-27	0.83	1.2	61	0.13	0.029	0.20	46	<3.2	0.14	0.07	<0.05	<0.06	<0.06	63
KLX08	609.00	618.51	11228	2006-07-27	1.1	1.4	60	0.071	0.025	0.036	<1.9	<3.1	0.31	0.16	<0.05	0.08	0.07	62
KLX08	609.00	618.51	11228	2006-07-27	0.90	1.3	218	0.14	0.025	0.22	<6.6	<11	0.16	<0.11	<0.11	<0.22	<0.22	220

- = Not analysed
A = Results will be reported later
x = No result due to sampling problems
xx = No result due to analytical problems
< ”value” = result below detection limit
SICADA: Dissolved_gases

Appendix 12

Tritium concentrations in section 476.0-485.6 m

Background

Enhanced tritium (^3H) concentrations (Table A12-1) were detected in several water samples from section 476.0-485.6 m in borehole KLX08. The enhanced concentrations coincided with losses of water flow due to worn o-rings in the borehole pump, Figure A12-1. The pumping system is of a hydraulic type and deionised water is used in the confined system that constitutes the driving water pump at the ground surface and the borehole pump in the borehole. Leakage of deionised water in the borehole pump caused by worn o-rings would result in a dilution of the borehole water that is pumped to the surface and enhanced ^3H concentrations (Figure A12-2). Analyses for ^3H of the deionised water confirmed this hypothesis.
Loss of water flow (Q) and deionised water in the tank for the driving water pump occurred on the 29th of May and the 15th of June.

The deionised water was collected from the nearby nuclear power plant, OKG (Oskarshamns Kärnkraft Grupp).

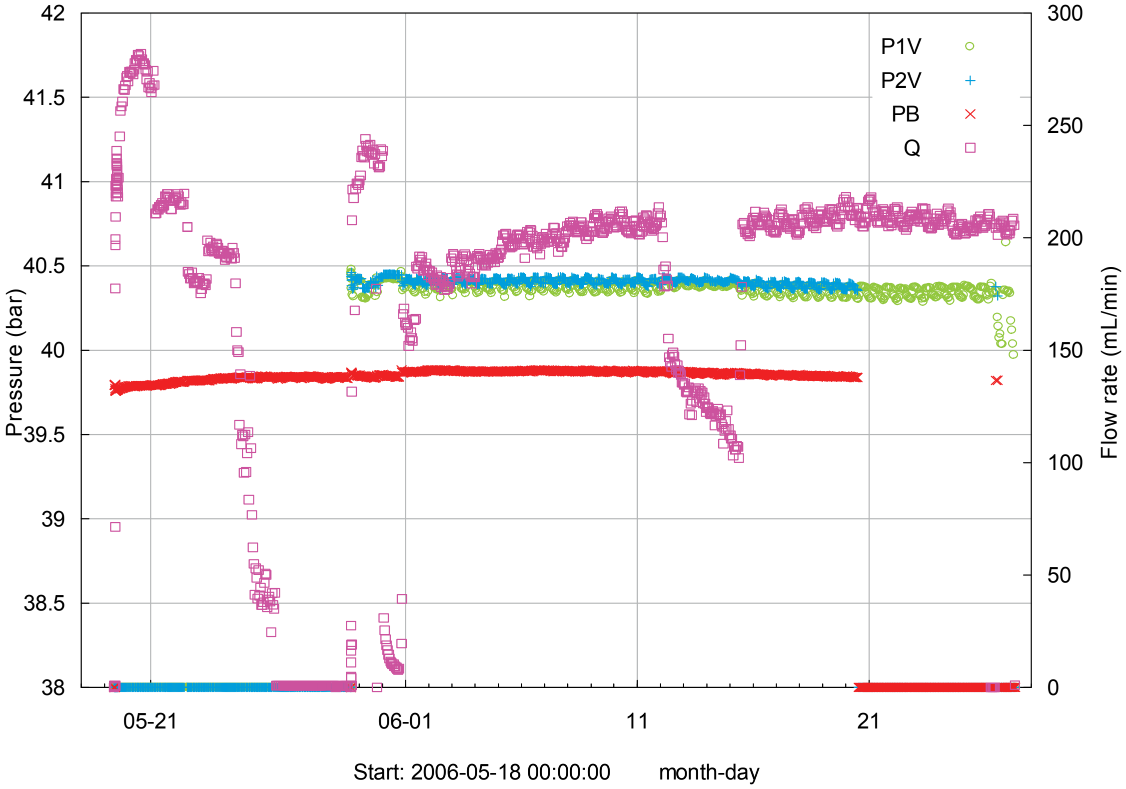


Figure A12-1. *Pressure (P1V, P2V and PB) and flow rate (Q) measurements in borehole section 476.0-485.6 m. The P1V and P2V pressure sensors are placed in the in situ sampling unit and measure the pressure in the section. PB is the sensor in the borehole Chemmac and measure the pressure above the section.*

Tritium concentrations in section 476.0-485.6 m

Hydraulic pumping system

Water from the borehole section is pumped to the mobile field laboratory by the hydraulic borehole pump. The borehole pump is operated by the driving water pump at the ground surface. The water tank for the driving water pump holds about 40 litres of deionised water. Furthermore, a hydro fore containing 150 litres of deionised water is used is used for pressurising the inflatable packers in the borehole as well as for filling the driving water tank. Deionised water is also used in the mobile field laboratory for laboratory purposes (cleaning, dilution).

The deionised water is normally separated from the borehole water in the borehole pump; however, when the o-rings are worn deionised water can pass and dilute the borehole water that is pumped to the mobile field laboratory. The water that is pumped to the surface is collected in containers and let out in the nearby Östersjön.

Results

Table A12-1 shows the ^{3}H concentrations in samples from section 476.0-485.6 m in KLX08. Enhanced concentrations are detected a few days before a loss of water flow on the 29th of May and on the 15th of June. Two independent laboratories confirmed the results for sample 11087.

The deionised water from the driving water tank and the hydro fore was analysed for ^{3}H using a liquid scintillation detector, the results are given in Table A12-2.

Figure A12-2 shows the chloride and ^{3}H concentrations for water samples in section 476.0-485.6 m. The chloride concentrations decrease when the ^{3}H concentrations increase, which is interpreted as a dilution of the borehole water.

Table A12-1. *Detected ^{3}H concentrations in water samples from section 476.0-485.6 m, KLX08.*

SKB number	Sampling date	Tr (TU)
10959	2006-05-22	95.2
11087	2006-05-24	756.6
11094	2006-05-30	2.9
11088	2006-06-01	2.2
11115	2006-06-07	111.4
11118	2006-06-09	52.3
11143	2006-06-12	38.9
11158	2006-06-15	2.2
11159	2006-06-19	2.1
11178	2006-06-21	2.0
11183	2006-06-26	2.1

Table A12-2. *Detected ^{3}H concentrations in deionised water from the water tank for the driving pump and from the hydro fore.*

SKB number	Sampling date	Time	Concentration (Bq/kg)	Concentration (TU)	Sample
11685	2007-02-02	16:00-16:05	375	3100	Driving water tank
11686	2007-02-07	10:40-10:45	210	1800	Hydro fore

Tritium concentrations in section 476.0-485.6 m

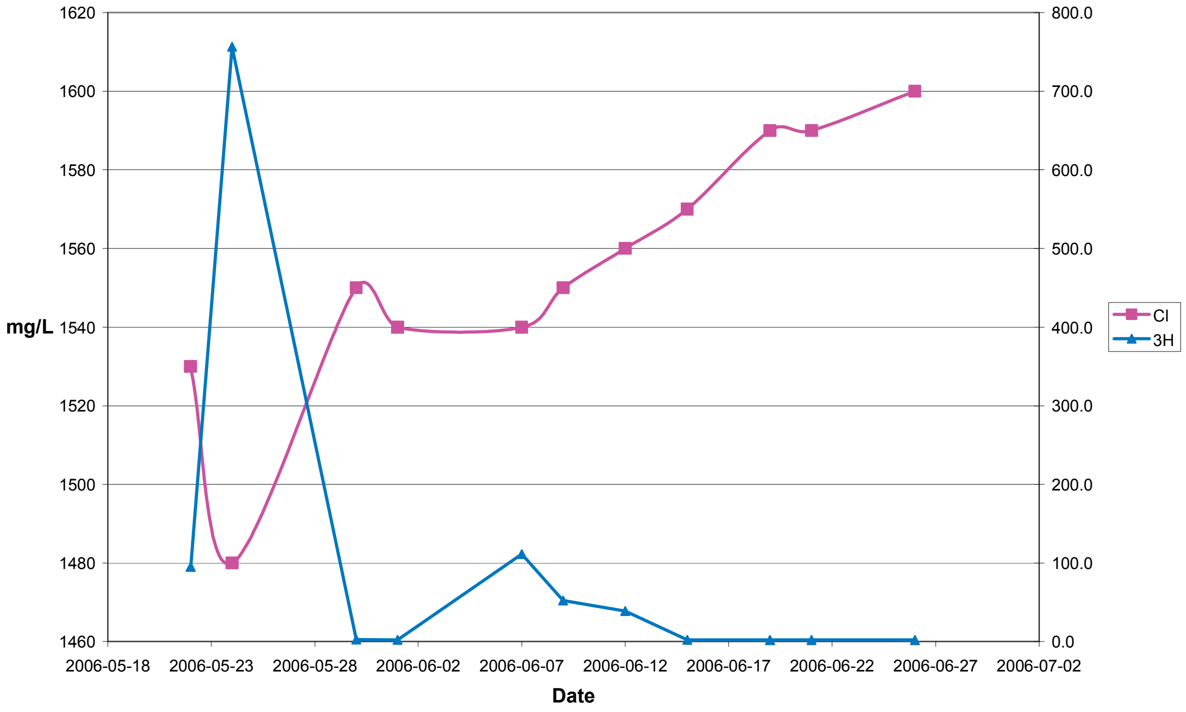


Figure A12-2. *Chloride and ^{3}H concentration in water samples from section 476.0-485.6 m, KLX08.*

Conclusions

The deionised water containing ^{3}H was never in direct contact with the borehole itself, but the water was confined in the borehole pump and pumped to the surface container. The limit for radiation protection is 500 Bq/kg; the concentrations detected in the driving water tank and hydro fore were below that limit.