

**P-04-299**

## **Oskarshamn site investigation**

### **Hydrochemical logging in KLX03A**

Cecilia Berg, Pia Wacker  
Geosigma AB

November 2004

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*Keywords:* Core drilled borehole, Groundwater, Water sampling, Chemical analyses.

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

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## Abstract

*Hydrochemical logging*, or so called tube sampling, has been performed in the core drilled borehole KLX03A. The method is a fast and simple sampling technique for obtaining information about the chemical composition of the water along an open borehole. The equipment consists of an approximately 1,000 m long polyamide tube divided into units of 50 m.

The water content in each tube unit constituted one sample. Every other sample, starting with the uppermost tube unit, was analysed according to SKB chemistry class 3 (no options included). Samples for isotope determination were collected at the time of sampling and stored in a freezer (tritium and carbon isotopes in a refrigerator);  $\delta^{18}\text{O}$ , deuterium,  $^{10}\text{B}$ , tritium,  $\delta^{37}\text{Cl}$  and  $^{87}\text{Sr}$  from odd-numbered tube units and  $\delta^{34}\text{S}$  and carbon isotopes from even-numbered tube units.

The content of flushing water remaining in the borehole after drilling was quite high along the borehole. The maximum amount of flushing water was found at approximately 700 m where it was 60%. The relative charge balance error exceeded the acceptable limit of  $\pm 5\%$  in two out of ten samples, no 7780 and 7794.

# Sammanfattning

*Hydrokemisk loggning*, eller så kallad slangprovtagning, har utförts i det kärnborrade borrhålet KLX03A. Metoden är snabb och enkel att använda för att erhålla information om den kemiska sammansättningen hos grundvattnet längs ett öppet borrhål. Utrustningen består av en cirka 1 000 meter lång polyamidslang uppdelad i enheter om vardera 50 meter.

Innehållet i en slangenhet utgör ett prov. Varannan slangenhet, med start från den översta, analyserades enligt SKB kemiklass 3 (exklusive tillval). Prover för bestämning av isotoptillvalen togs ut vid provtagningstillfället och sparades i frys (tritium och kolisotoper i kylskåp);  $\delta^{18}\text{O}$ , deuterium,  $^{10}\text{B}$ , tritium,  $\delta^{37}\text{Cl}$  och  $^{87}\text{Sr}$  ur udda enheter,  $\delta^{34}\text{S}$  och kolisotoper ur jämna enheter.

Halten kvarvarande spolvatten i borrhålet efter borring var relativt hög. Den högsta spolvattenhalten uppmättes omkring 700 m där halten var strax över 60%. Det relativa felet i jonbalansen översteg den acceptabla nivån  $\pm 5\%$  i två av de tio analyserade proverna, nummer 7780 och 7794.

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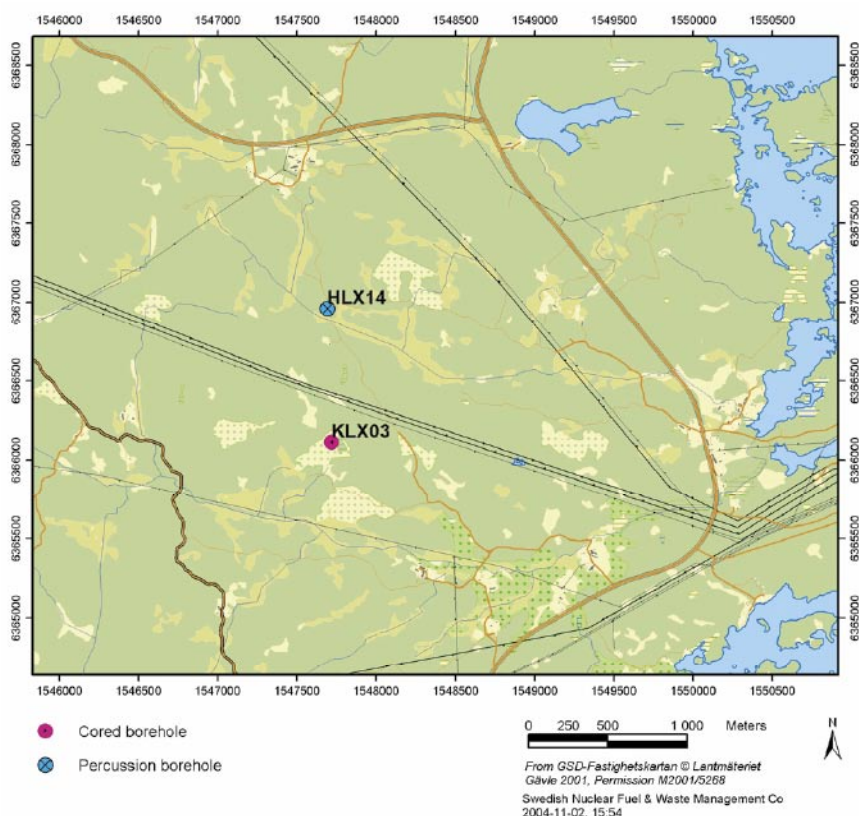
# 1 Introduction

This document reports the performance and results from *Hydrochemical logging* in borehole KLX03A. The *Hydrochemical logging* is one of the activities performed within the site investigation at Oskarshamn /1/. The work was carried out in accordance with activity plan SKB PS 400-04-079 (SKB internal controlling document). The controlling documents for the performance of this activity are listed in Table 1-1. The data is reported to SICADA in field note no Simpevarp 472.

**Table 1-1. SKB internal controlling documents for the performance of the activity.**

Activity plan	Number	Version
Hydrokemisk loggning i KLX03	AP PS 400-04-079	1.0
Method descriptions	Number	Version
Metodbeskrivning för hydrokemisk loggning	SKB MD 422.001	1.0

Borehole KLX03A is a 1000.42 m long telescopic borehole, drilled within the site investigation in the Oskarshamn area. The borehole KLX03A is of a so called SKB chemical type. A borehole of SKB chemical type implies cleaning procedures of all equipment used in the borehole during and after the drilling. The percussion borehole HLX14 served as the source of flushing water for the drilling of KLX03A. The locations of KLX03A and HLX14 are shown in Figure 1-1.



**Figure 1-1.** Locations of the core drilled borehole KLX03A and the supply well HLX14 within the site investigation in the Oskarshamn area.

## 2 Objective and scope

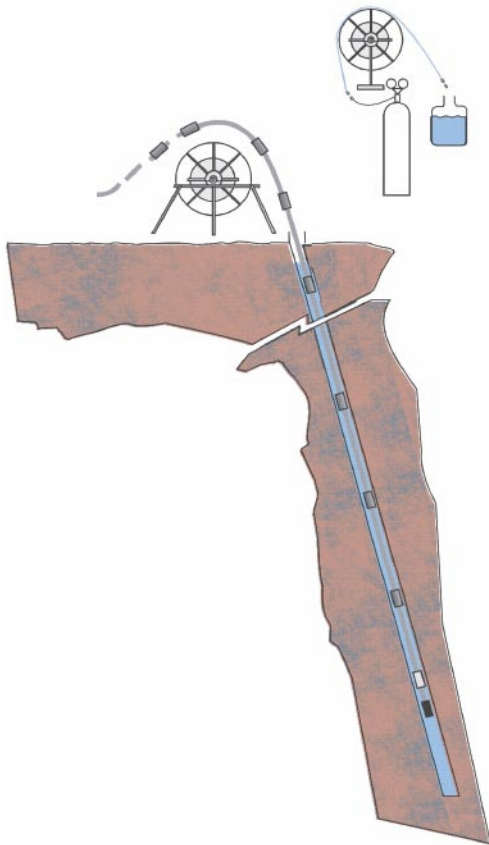
*Hydrochemical logging* was performed in order to obtain an overview of the chemical composition of the water along the open borehole KLX03A. The technique used for sampling is fast and simple, even at great depth.

The analysis program was carried out according to SKB chemistry class 3 except for optional isotopes. Sample portions intended for isotope analyses were collected at the time of sampling, but have not been analysed. The samples are stored in a freezer at SKB (except the samples collected for determination of tritium and carbon isotopes; these samples were stored in a refrigerator) until further notice. If samples from the activity are analysed for isotopes, the results from those analyses will be presented in a separate report.

### 3 Sampling equipment

For the *Hydrochemical logging* an approximately 1000 m long polyamide tube, divided into units of 50 m, was used. The equipment is described in the method description, see Table 1-1.

A schematic picture of the equipment used for the *Hydrochemical logging* is shown in Figure 3-1. The tube units are connected using couplings. The length of each tube unit is given in Table 3-1. The first tube lowered down the borehole has a non-return valve at the bottom to prevent water outflow while lifting the tube units. The external and internal diameters of the tube units are 10 and 8 mm, respectively. The water content in each tube unit constitutes one sample, and the volume of each sample is approximately two and a half litres. At the lower end of the tube array, a weight is added in order to stretch the array and thereby prevent fastening.



**Figure 3-1.** Equipment for Hydrochemical logging in boreholes. At the lower end of the tube array there is a check valve and a weight connected. Each tube unit is 50 m long.



**Table 3-1. Length of tube units used for the Hydro-chemical logging in KLX03A.**

<b>Unit</b>	<b>Length (m)</b>
1	49.71
2	50.01
3	49.77
4	49.28
5	50.08
6	49.97
7	49.85
8	49.87
9	49.57
10	49.72
11	49.67
12	50.25
13	50.62
14	49.70
15	49.20
16	49.22
17	49.30
18	49.63
19	49.62
20	49.87
Sum:	994.91
Couplings:	2.812
Weight:	0.817
Total tube length:	998.539

## 4 Performance

### 4.1 Hydrochemical logging

The *Hydrochemical logging* in KLX03A was performed on September 21, 2004 .

The lowering of the tube units started at 11:10. The tubes were lowered down the borehole at a rate of about five metres/minute. The equipment was lowered to a depth of 990 meter, i.e. the length of the borehole subtracted by 10 m, in order to avoid sedimentation of drilling debris at the bottom of the borehole, and thereby decrease the risk of fastening. The lifting of the tubes started at 15:31, and the last tube unit was retrieved at 17:00. The tube unit at the top of the tube array was lowered to 40 m of its length. This resulted in a not completely filled tube unit. Pressurized nitrogen gas was used to empty the tube units and the water samples were portioned into sample bottles. Each tube unit represents one sample.

The ground water levels before and after completed logging were 9.60 m and 9.17 m, respectively, measured from the top of the casing.

### 4.2 Sample treatment and chemical analysis

An overview of sample treatment and analysis routines is given in Appendix 1. The routines are applicable irrespectively of sampling object or sampling method.

An overview showing the samples obtained at the logging occasion is given in Table 4-1. Sample portions intended for isotope analyses were collected at the sampling occasion but not sent for analysis. These samples are stored in a freezer at SKB (except the sample collected for tritium determination which is stored in refrigerator). The collected samples intended for isotope analysis may be sent for analysis, and in that case, the results will be presented in a separate report. The data from the *Hydrochemical logging* are stored in the database SICADA in field note no Simpevarp 472. The SKB sample numbers are 7778–7797.

**Table 4-1. Overview of samples collected at the Hydrochemical logging in KLX03A. Filled cells represent collected samples. Dark (blue) filling represents samples sent for analyses, light (yellow) filling represents samples collected and stored in a freezer (tritium and carbon isotopes in a refrigerator) and dashed (purple) cells represent archive samples.**

Sample information			Collected sample portions										Archive	
Tube unit	Length (m)	SKB no	Cond, pH, alk.	Major comp.	Ura- nine	An- ions	$^3\text{H}$	$\delta^2\text{H}$ $\delta^{18}\text{O}$	$\delta^{37}\text{Cl}$	$^{10}\text{B}$	$^{87}\text{Sr}$	$\delta^{34}\text{S}$	Carbon isotopes	Filtered 2x250 mL
1	0-40	7778					ω	ж	ж					
2	90	7779												
3	140	7780												
4	190	7781												
5	240	7782												
6	290	7783												
7	340	7784												
8	390	7785												
9	440	7786												
10	490	7787												
11	540	7788												
12	590	7789												
13	640	7790												
14	690	7791												
15	740	7792												
16	790	7793												
17	840	7794												
18	890	7795												
19	940	7796												
20	990	7797												

ω Partly filled with sample water from tube unit 2.  
ж Filled with sample water from tube unit 2.

The uppermost tube unit was not completely filled, see section 4.1. All other tube units seemed, by visual inspection, to be fully filled with sample water; only small bubbles of gas was observed during lifting. Over-pressure was observed in the tubes from section 690–740 m down to the bottom of the borehole. The highest pressure occurred in the lowest tube unit, section 940–990 m. Due to the lack of water in the first tube unit, see above, archive samples from the second tube unit was not obtained. Water intended for archive samples in the second unit were used to fill sample bottles for analyses of anions,  $\delta^2\text{H}$  and  $\delta^{18}\text{O}$ ,  $\delta^{37}\text{Cl}$ ,  $^{10}\text{B}/^{11}\text{B}$  from the first section (0–40 m).

### 4.3 Data handling

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

All analytical results were stored in the SICADA database. The applied hierarchy path “Hydrochemistry/Hydrochemical investigation/Analyses/Water in the database” contains two types of tables, raw data tables and primary data tables (final data tables).

Data from *basic water analyses* are inserted into raw data tables for further evaluation. The evaluation results in a final data set for each sample. These data sets are compiled in a primary data table named “water\_composition”. The evaluation is based on:

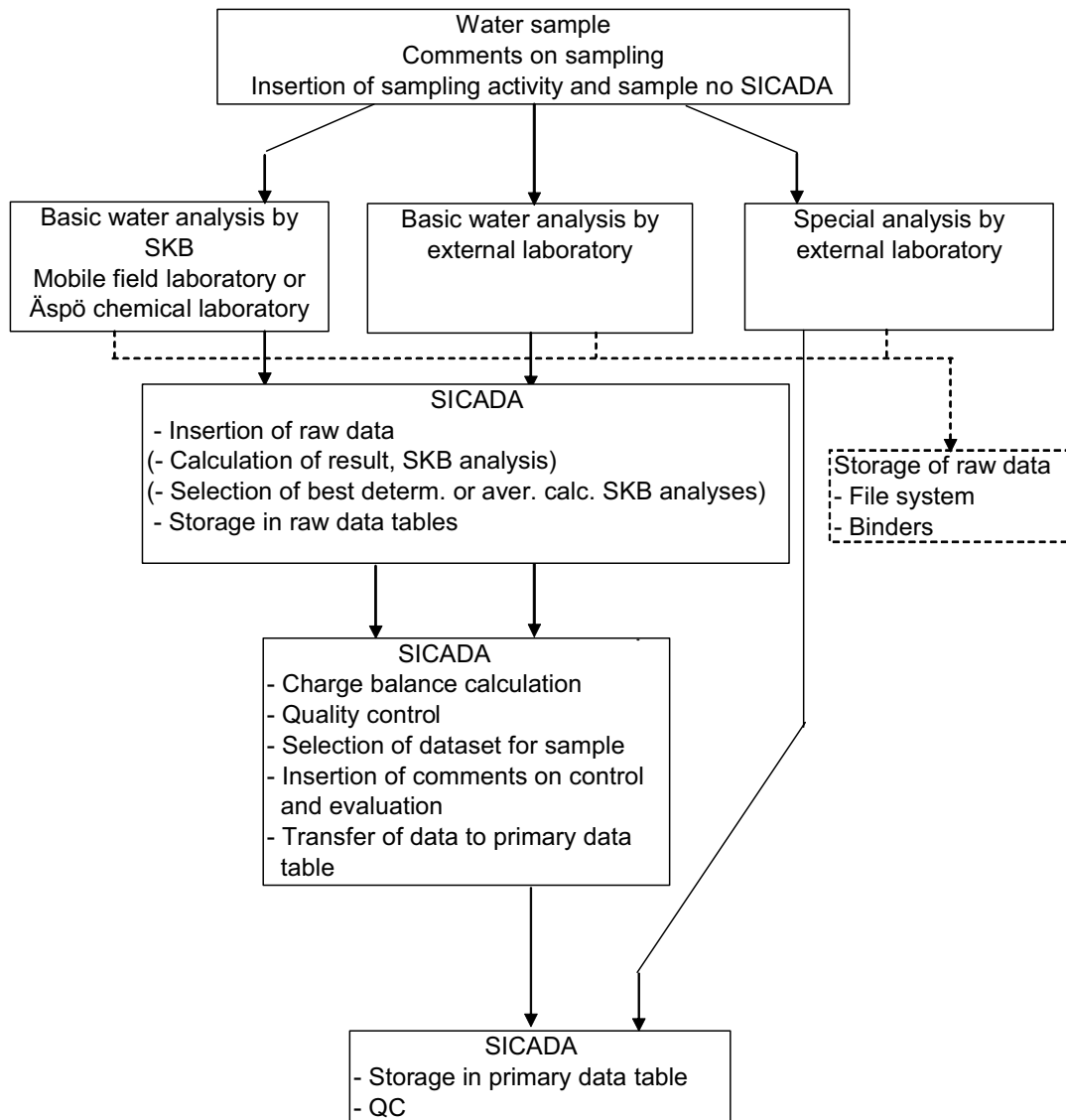
- Comparison of the results from different laboratories and/or methods. The analyses are repeated if a large disparity is noted (generally more than 10%).
- Calculation of charge balance errors. Relative errors within  $\pm 5\%$  are considered acceptable (in surface waters  $\pm 10\%$ ).

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

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

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

An overview of the data management is given in Figure 4-1.



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

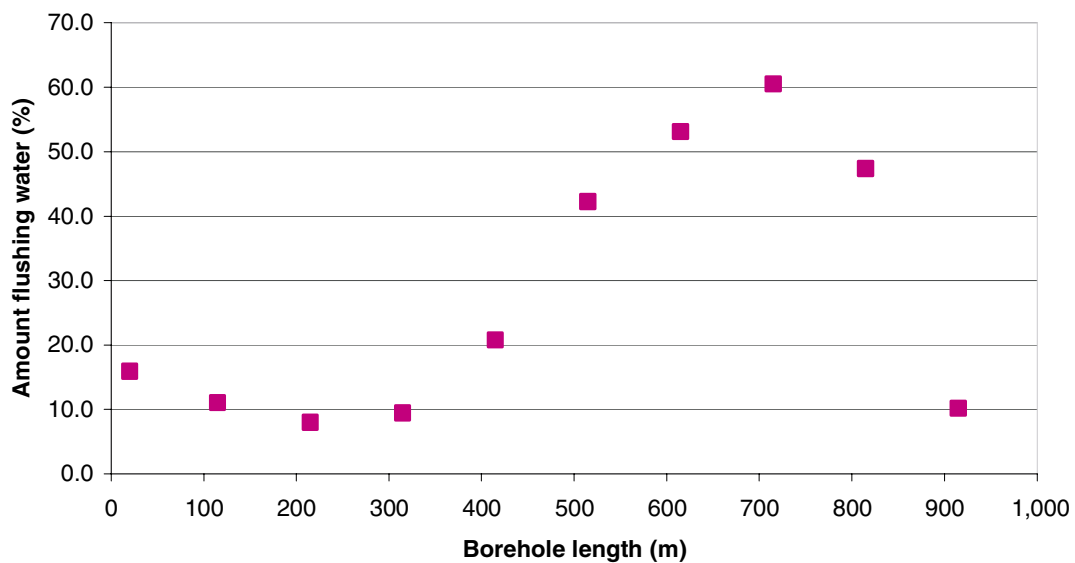
#### 4.4 Nonconformities

The activity was performed without any deviations from the controlling documents for the activity.

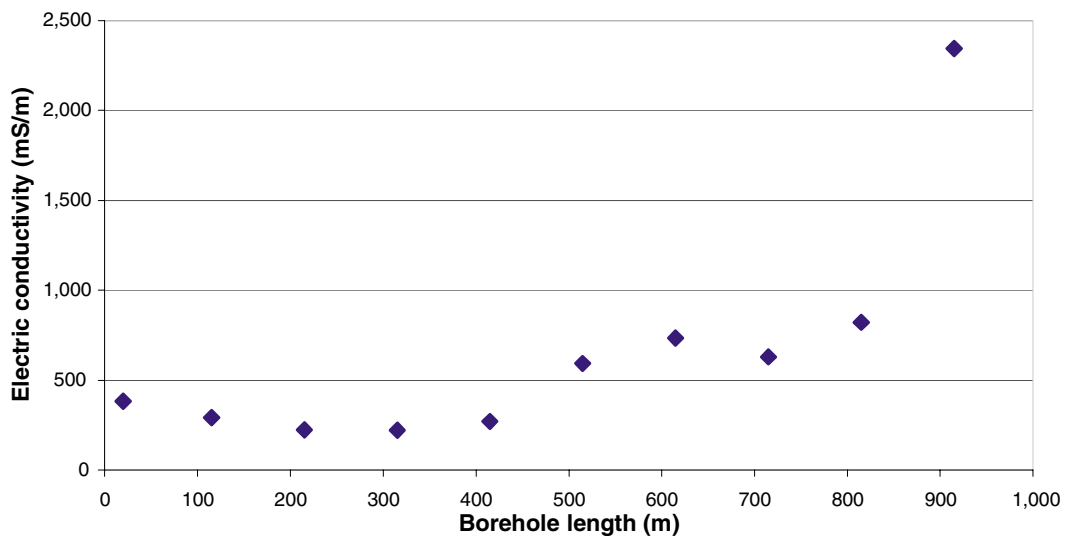
# 5 Results

## 5.1 Analysis results

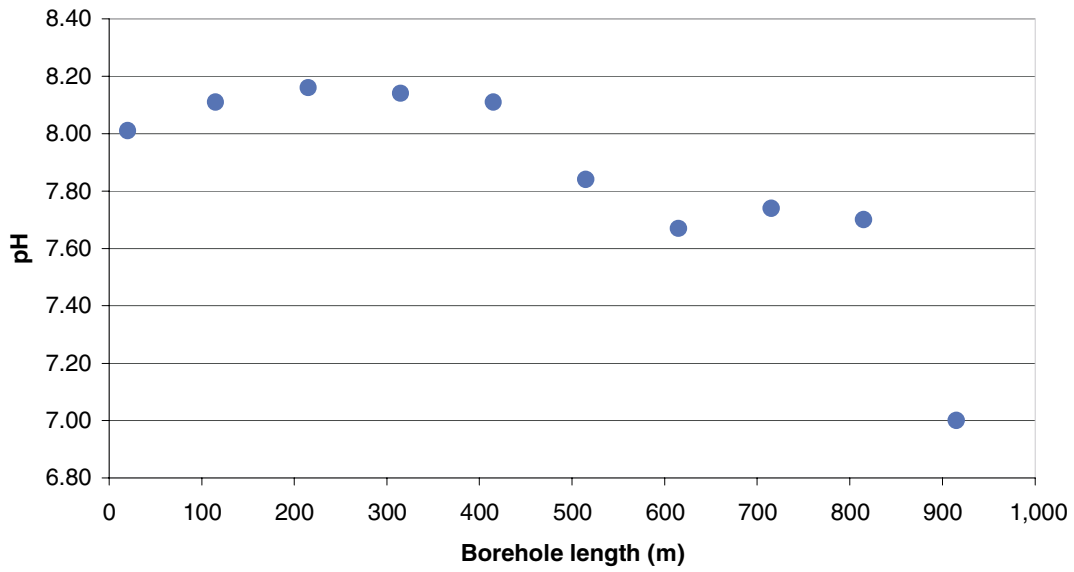
Results from the chemical analysis are given in Appendix 2. Diagrams showing the flushing water content and the electric conductivity along the borehole, at the time of the *Hydrochemical logging*, are presented in Figures 5-1 and 5-2. Results from analyses of pH, hydrogen carbonate ( $\text{HCO}_3^-$ ), some of the major constituents (Na, Ca and Cl<sup>-</sup>) and sulphate ( $\text{SO}_4^{2-}$ ) are shown in Figures 5-3 to 5-6, respectively. Results are plotted for the mid-length of each tube unit. For example, the first tube is plotted at 20 m.



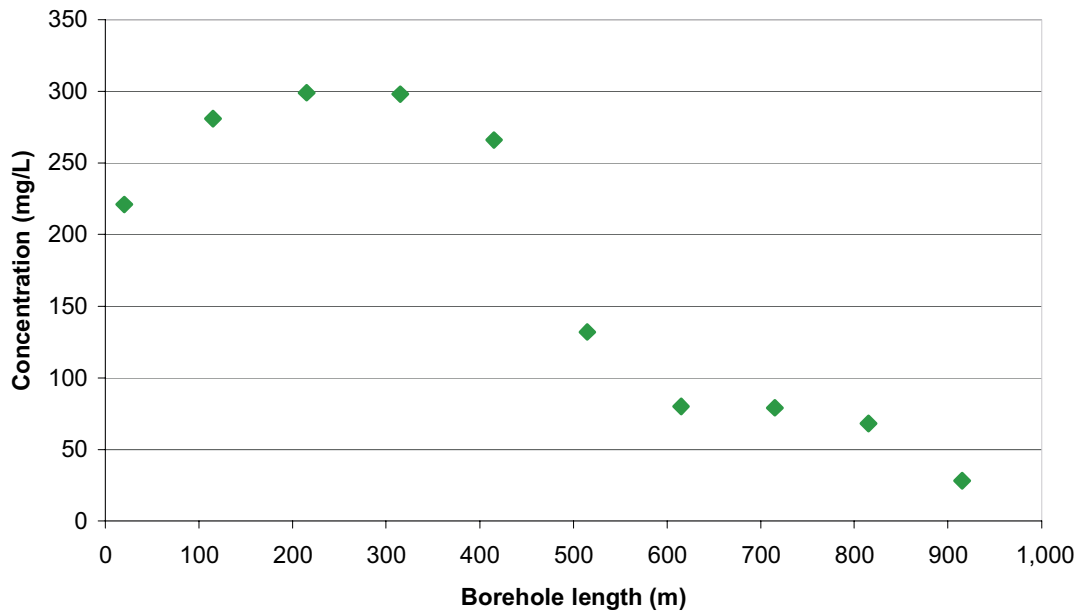
**Figure 5-1.** Amount of flushing water remaining at different borehole lengths at the time of the *Hydrochemical logging* in KLX03A.



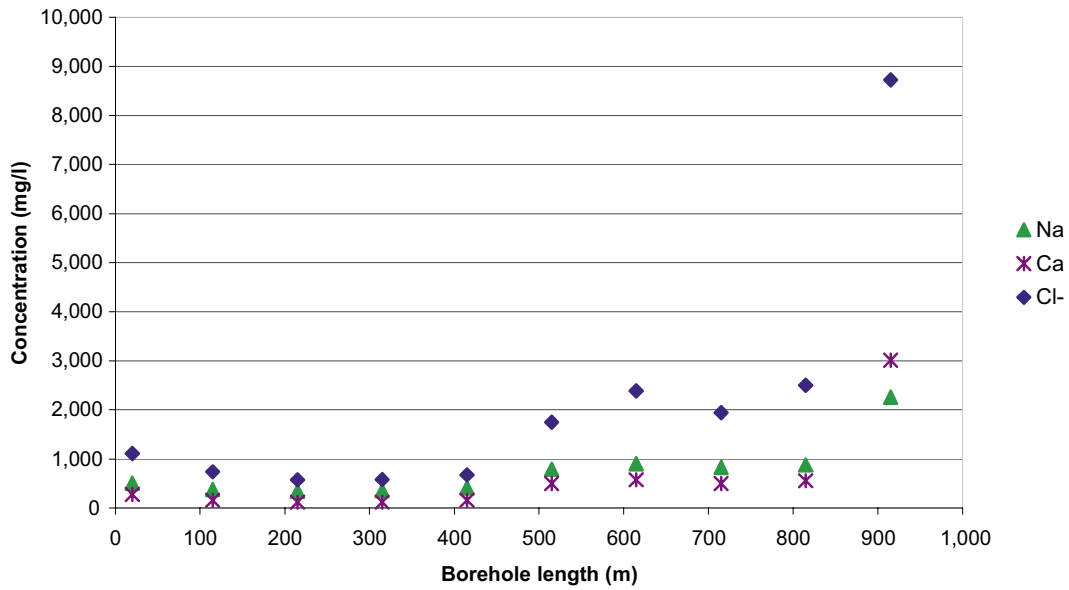
**Figure 5-2.** Electric conductivity values along the borehole KLX03A obtained from the *Hydrochemical logging*.



*Figure 5-3. Results from pH measurements obtained from the Hydrochemical logging in KLX03A.*

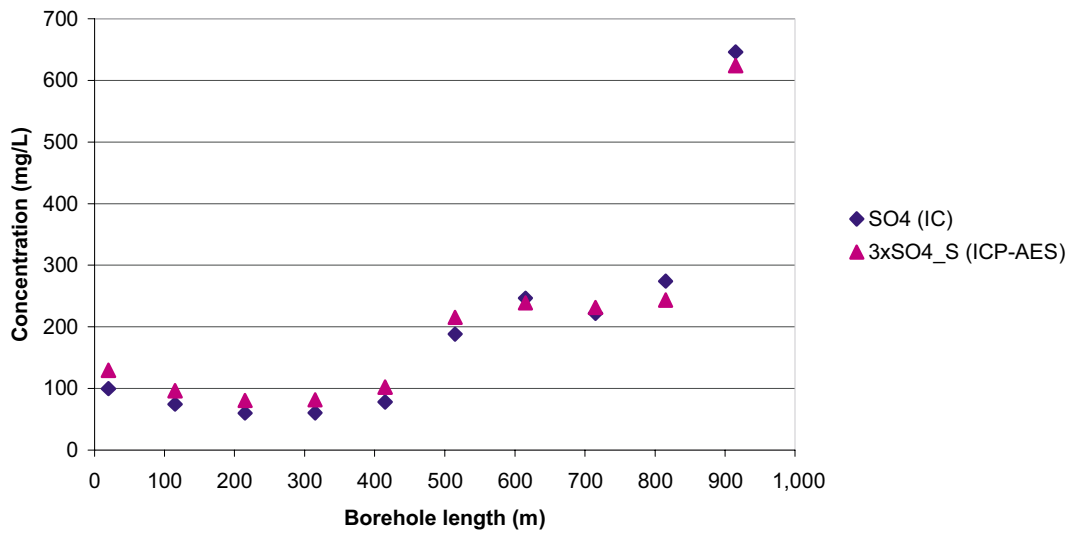


*Figure 5-4. Results from hydrogen carbonate ( $\text{HCO}_3^-$ ) analysis of water samples obtained from Hydrochemical logging in KLX03A.*



**Figure 5-5.** Results from analysis of the constituents Na, Ca and Cl- in water samples obtained from Hydrochemical logging in KLX03A.

Sulphate ( $\text{SO}_4^{2-}$ ) analysed by using ion chromatography (IC) is compared with sulphate determined as total sulphur using inductively coupled plasma atomic emission spectrometry (ICP-AES) in Figure 5-6. The values obtained from ICP-AES are somewhat higher than from IC for most samples. The two results from the lowest parts of the borehole show the opposite, with IC results somewhat higher than the ICP-AES results.



**Figure 5-6.** Sulphate (IC) compared to total sulphur (ICP-AES).



## 5.2 Quality of the analyses

The charge balance errors give an indication of the quality and uncertainty of the analyses of major constituents. The relative charge balance errors were calculated for the selected sets of data, see Appendix 2. If the relative errors are within  $\pm 5\%$  they are considered acceptable. The errors did exceed 5% in two out of ten cases, samples no 7780 and 7794.

## 6 Conclusions

At the *Hydrochemical logging* in KLX03A, the following chemical conditions were found:

- The amount of remaining flushing water at the time of the *Hydrochemical logging* was high. The maximum was found at about 700 m where it was just above 60%. Below 700 m, there was a steep decrease to an amount of about 10% in the deepest section.
- The charge balance error, giving an indication of the quality and uncertainty of the analyses, exceeded the acceptable level in two cases, samples 7780 and 7794.
- The electric conductivity and the chloride concentration increased only slightly down the borehole, with a few small dips in concentration, except from 800 to 900 m where a steep increase was observed. The highest values were 2340 mS/m and 8720 mg/L, respectively (both values from the deepest part measured along the borehole).
- Due to the high content of remaining flushing water in parts of the borehole, it may be necessary to carry out extra “clean-up” pumping in order to obtain representative samples during forthcoming water sampling activities.

## 7 References

- /1/ **SKB, 2001.** Generellt genomförande program för platsundersökningar.  
SKB R 01-10, Svensk Kärnbränslehantering AB.

## Sampling and analysis methods

Table A1-1. Overview of general sample handling routines and analysis methods.

Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Laboratory***	Analysis within – or delivery time to lab.
Anions 1	HCO <sub>3</sub> pH(lab) cond (lab)	Plastic	250	Yes (not in the field)	No	Titration Pot. meas, Cond. meas	Åspö's chemistry lab.	The same day – maximum 24 hours
Anions 2	Cl, SO <sub>4</sub> , Br <sup>-</sup> , F <sup>-</sup> , I <sup>-</sup>	Plastic	100	Yes (not in the field)	No	Titration (Cl <sup>-</sup> ) IC (Cl <sup>-</sup> , SO <sub>4</sub> , Br <sup>-</sup> , F <sup>-</sup> ) ISE (F <sup>-</sup> )	Åspö's chemistry lab.	Not critical (month)
Cations, Si and S according to SKB class 3	Na, K, Ca, Mg, S(tot), Si(tot), Li, Sr	Plastic (at low conc. acid washed bottles)	100	Yes (not in the field)	Yes (not in the field, 1 mL HNO <sub>3</sub> )	ICP-AES ICP-MS	Analytica AB	Not critical (month)
Environmental isotopes	<sup>2</sup> H, <sup>18</sup> O	Plastic	100	No	–	MS	IFE	Not critical (month)
Tritium,	<sup>3</sup> H (enhanced.)	Plastic (dry bottle) Plastic	500	No	–	LSC	Univ. Of Waterloo	Not critical (month)
Chlorine-37	Chlorine-37		100	No	–	ICP MS		
Carbon isotopes	<sup>13</sup> C, <sup>14</sup> C	Glass (brown)	100x2	No	–	(A)MS	Univ. Of Waterloo	A few days
Sulphur isotopes	<sup>34</sup> S	Plastic	500–1000	Yes	–	Combustion, ICP MS	IFE	No limit
Strontium-isotopes	<sup>87</sup> Sr/ <sup>86</sup> Sr	Plastic	100	Yes	–	TIMS	IFE	Days or Week
Boron isotopes	<sup>10</sup> B	Plastic	100	Yes	Yes (1 mL HNO <sub>3</sub> )	ICP – MS	Analytica AB	No limit
Archive samples without acid	–	Plastic	250x2 **	Yes	No	–	–	Storage in freeze

\* Suprapur acid is used for conservation of samples.

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

\*\*\* Full name and address is given in Table A1-2.

**Abbreviations and definitions:**

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

**Table A1-2. Consulted laboratories, full name and address.**

---

**Äspö waterchemical laboratory (SKB)**

Analytica AB  
Aurorum 10  
977 75 Luleå  
(Nytorpsvägen 16  
Box 511  
183 25 Täby)

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Environmental Isotope Laboratory  
Dep. Of earth sciences  
University of Waterloo  
Waterloo, Ontario  
N2L 3G1 CANADA

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Institutt for energiteknik (IFE)  
Instituttveien 18  
P.O Box 40  
2027 Kjeller  
NORGE

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The Ångström laboratory  
Box 534  
Se-751 21 Uppsala

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# Appendix 2

## Water composition

Compilation November 2004.

ldcode	Secup m	Seclow m	Sample no	Charge Bal %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO <sub>3</sub> <sup>-</sup> mg/L	Cl <sup>-</sup> mg/L	SO <sub>4</sub> <sup>2-</sup> mg/L	SO <sub>4</sub> <sup>-S</sup> mg/L	Br <sup>-</sup> mg/L	F <sup>-</sup> mg/L	Si mg/L	Fe mg/L	Mn mg/L
KLX03A	0	40	7778	-2.6	502	5.72	278	7.0	221.0	1,110	99.5	43.0	11.10	3.25	5.77	1.130	0.189
KLX03A	40	90	7779	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX03A	90	140	7780	-6.2	377	4.21	157	6.0	281.0	741	74.7	32.1	7.65	3.60	5.99	0.971	0.134
KLX03A	140	190	7781	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX03A	190	240	7782	-4.4	341	3.89	119	5.6	299.0	575	59.7	26.8	5.50	2.95	6.01	0.972	0.120
KLX03A	240	290	7783	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX03A	290	340	7784	-3.2	352	4.22	122	5.9	298.0	580	60.4	27.2	5.80	3.30	6.84	1.720	0.143
KLX03A	340	390	7785	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX03A	390	440	7786	0.7	408	5.01	160	6.4	266.0	675	78.1	34.1	6.24	2.90	6.17	1.120	0.141
KLX03A	440	490	7787	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX03A	490	540	7788	3.1	791	8.93	499	9.2	132.0	1,750	188	71.8	18.00	2.30	6.37	2.250	0.246
KLX03A	540	590	7789	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX03A	590	640	7790	-3.9	900	10.9	576	10.6	79.7	2,390	247	79.6	27.30	1.90	6.08	1.800	0.268
KLX03A	640	690	7791	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX03A	690	740	7792	0.2	829	11.2	501	10.5	79.4	1,950	222	77.1	20.50	2.20	5.94	0.641	0.225
KLX03A	740	790	7793	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX03A	790	840	7794	-7.3	879	11.4	554	11.0	68.4	2,500	274	81.1	27.50	1.90	8.31	4.930	0.258
KLX03A	840	890	7795	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX03A	890	940	7796	-2.6	2,260	11.7	3,010	4.6	28.1	8,720	646	208.0	112.00	2.10	7.29	11.100	0.383
KLX03A	940	990	7797	-	-	-	-	-	-	-	-	-	-	-	-	-	-

- = Not analysed
- A = results will be reported later
- x = No result due to sampling problems
- xx = No result due to analytical problems
- xxx = Stored in freezer/refrigerator
- < = result below detection limit
- ChargeBal % = Relative charge balance error %

Li mg/L	Sr mg/L	pH	Drill_water %	EiCond mS/m	$\delta^2\text{H}$ dev SMOW	$\delta^{18}\text{O}$ dev SMOW	$^3\text{H}$ TU	$\delta^{37}\text{Cl}$ dev SMOC	$^{10}\text{B}/^{11}\text{B}$ no unit	$^{87}\text{Sr}/^{86}\text{Sr}$ no unit	$\delta^{34}\text{S}$ dev CDT	$\delta^{13}\text{C}$ dev PDB	$^{14}\text{C}$ pMC
0.0762	4.96	8.01	15.9	382	xxx	xxx	xxx	xxx	xxx	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	xxx	xxx	xxx
0.050	2.84	8.11	11.0	292	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
-	-	-	-	-	-	-	-	-	-	-	xxx	xxx	xxx
0.0456	2.16	8.16	8.0	224	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
-	-	-	-	-	-	-	-	-	-	-	xxx	xxx	xxx
0.0517	2.20	8.14	9.5	222	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
-	-	-	-	-	-	-	-	-	-	-	xxx	xxx	xxx
0.0552	2.91	8.11	20.8	269	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
-	-	-	-	-	-	-	-	-	-	-	xxx	xxx	xxx
0.117	8.94	7.84	42.2	592	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
-	-	-	-	-	-	-	-	-	-	-	xxx	xxx	xxx
0.134	10.20	7.68	53.1	734	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
-	-	-	-	-	-	-	-	-	-	-	xxx	xxx	xxx
0.125	9.00	7.74	60.5	629	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
-	-	-	-	-	-	-	-	-	-	-	xxx	xxx	xxx
0.136	9.88	7.70	47.4	822	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
-	-	-	-	-	-	-	-	-	-	-	xxx	xxx	xxx
0.368	53.30	7.01	10.2	2,340	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
-	-	-	-	-	-	-	-	-	-	-	xxx	xxx	xxx

- = Not analysed

A = results will be reported later

x = No result due to sampling problems

xx = No result due to analytical problems

xxx = Stored in freezer/refrigerator

< = result below detection limit

ChargeBal % = Relative charge balance error %