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Oskarshamn site investigation
Hydrochemical logging in KLX09

Cecilia Berg, Elin Gustavsson
Geosigma AB

February 2006

Svensk Kärnbränslehantering AB

Swedish Nuclear Fuel
and Waste Management Co
Box 5864

SE-102 40 Stockholm Sweden

Tel 08-459 84 00

+46 8 459 84 00

Fax 08-661 57 19

+46 8 661 57 19



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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 KLX09. 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 (options excluded). 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 ($\delta^2\text{H}$), tritium (^3H), ^{10}B , $\delta^{37}\text{Cl}$ and ^{87}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 low; below 3% in all samples except in the lowest section (770–820 m) where it was approximately 12%. The relative charge balance error did not exceed the acceptable limit of $\pm 5\%$ in any of the nine analysed samples.

Sammanfattning

Hydrokemisk loggning, eller så kallad slangprovtagning, har utförts i det kärnborrade borrhålet KLX09. 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 m lång polyamidslang uppdelad i enheter om vardera 50 m.

Innehållet i en slangenhet utgör ett prov. Varannan slangenhet, med start från den översta, analyserades enligt SKB kemiklass 3 (exklusive alla tillval). Prover för bestämning av isotoptillvalen togs ut vid provtagningstillfället och sparades i frys (tritium och kolisotoper i kylskåp); $\delta^{18}\text{O}$, deuterium ($\delta^2\text{H}$), tritium (^3H), ^{10}B , $\delta^{37}\text{Cl}$ och ^{87}Sr ur udda enheter, $\delta^{34}\text{S}$ och kolisotoper ur jämna enheter.

Halten kvarvarande spolvatten i borrhålet efter avslutad borrning var låg; under tre procent i alla sektioner utom den lägsta (770–820 m) där den var cirka 12 %. Det relativa felet i jonbalansen översteg inte den acceptabla nivån av $\pm 5\%$ i något av de nio analyserade proverna.

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1 Introduction

This document reports the performance and results from *Hydrochemical logging* in borehole KLX09. 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 400-05-081 (SKB internal controlling document). The controlling documents for the performance of this activity are listed in Table 1-1. The data is reported to the database SICADA.

Borehole KLX09 is an 880.38 m long borehole, drilled within the site investigation in the Oskarshamn area. The percussion borehole HLX20 served as the source of flushing water for the drilling of KLX09. The location of KLX09 and HLX20 is shown in Figure 1-1.

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

Activity plan	Number	Version
Hydrokemisk loggning i KLX09	AP PS 400-05-081	1.0
Method descriptions	Number	Version
Metodbeskrivning för hydrokemisk loggning	SKB MD 422.001	1.0

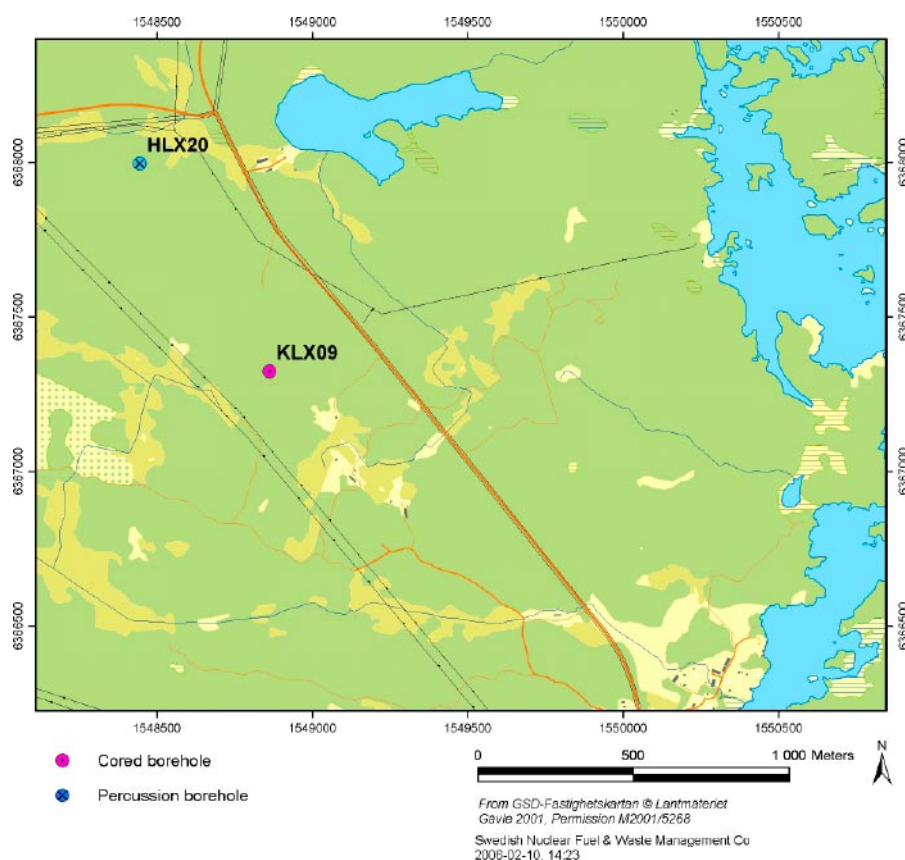


Figure 1-1. Location of the core drilled borehole KLX09 and the percussion borehole HLX20 within the site investigation in the Oskarshamn area.

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 KLX09. 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 are 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 1,000 m long polyamide tube, composed of units of 50 m length was used. The equipment is described in the method description (Table 1-1).

A schematic illustration of the equipment used for the *Hydrochemical logging* is given in Figure 3-1. The tube units are connected using couplings. The external and internal diameters of the tube units are 10 and 8 mm, respectively. 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 water content in each tube unit constitutes one sample, and the volume of each sample is approximately two and a half litres. A weight and a non-return valve are mounted at the lower end of the tube array to keep it stretched in the borehole and to prevent water outflow when the equipment is lifted to the ground surface.

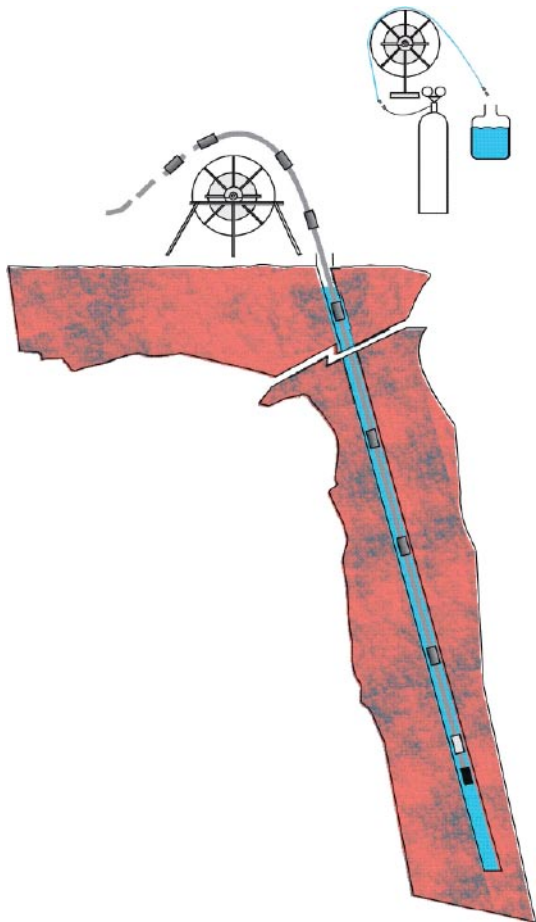


Figure 3-1. Equipment for Hydrochemical logging in boreholes. At the lower end of the tube array there is a check valve and a weight connected. Each tube unit is 50 m long.

4 Performance

4.1 Hydrochemical logging

The *Hydrochemical logging* in KLX09 was performed on December 15, 2005.

The lowering of the tube units started at 08:37. The tubes were lowered down the borehole at a rate of about five m/minute. The equipment was lowered to a depth of 870 m down the borehole, in order to avoid possible sedimentation of drilling debris at the bottom of the borehole, and thereby decrease the risk of get caught. The lifting of the tubes started at 12:43, and the last tube unit was retrieved at 14:50. The tube unit at the top of the tube array was lowered to 20 m of its length. This resulted in a tube unit almost empty of water from the upper most section. 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.

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 a 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. The SKB sample numbers are 10583 and 10586–10602.

There was only a small portion of water in the upper most tube unit. All other tube units seemed, by visual inspection, to be fully filled with sample water; only small bubbles of gas was observed during lifting. Due to the lack of water in the first tube unit, only the bottles for uranine and major components could be filled from the upper most section. Water intended for archive samples in the second unit were used to fill up sample bottles for the analyses mentioned above from the first section (0–20 m).

Table 4-1. Overview of samples collected at the Hydrochemical logging in KLX09. Filled cells represent collected samples. Blue (dark) filling represents samples sent for analyses, yellow (light) filling represents samples collected and stored in a freezer (tritium and carbon isotopes in a refrigerator) and purple (dashed) cells represent archive samples.

Sample information			Collected sample portions											Archive
Tube unit	Length [m]	SKB no.	Cond., pH, alk.	Major Comp.	Uranine	Anions	³ H	δ ² H δ ¹⁸ O	δ ³⁷ Cl	¹⁰ B	⁸⁷ Sr	δ ³⁴ S	C-isotopes	Filtered 2×250 mL
1	0-20	10583		ж)	ж)									
2	70	10586												
3	120	10587												
4	170	10588												
5	220	10589												
6	270	10590												
7	320	10591												
8	370	10592												
9	420	10593												
10	470	10594												
11	520	10595												
12	570	10596												
13	620	10597												
14	670	10598												
15	720	10599												
16	770	10600												
17	820	10601												
18	870	10602												

ж) Partly filled with sample water from tube unit 2.

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.

4.4 Nonconformities

The activity was performed without any deviations from the controlling documents for the activity that can affect the results.

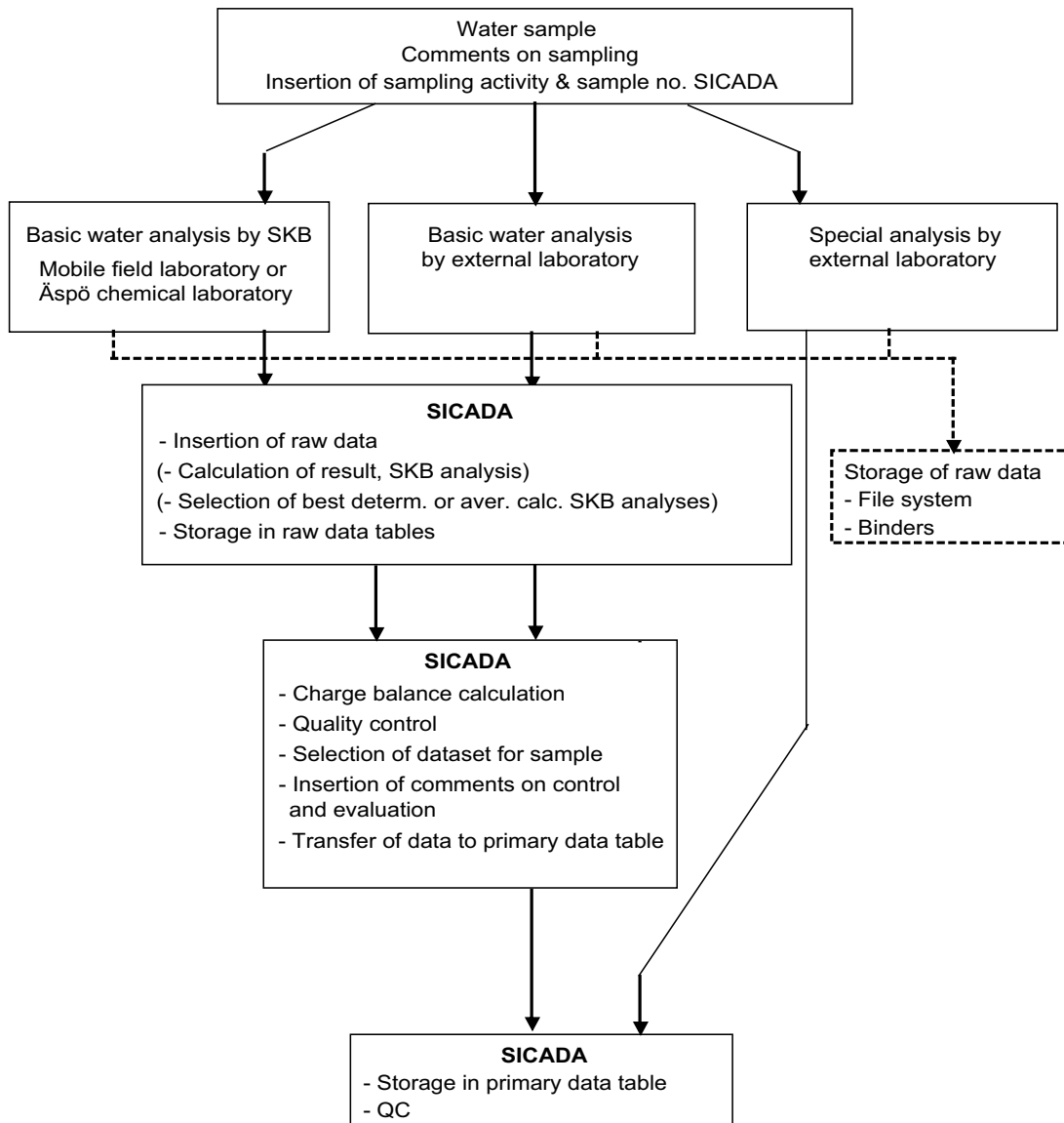


Figure 4-1. Overview of data management for hydrogeochemical data.

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, some of the major constituents (Na, Ca and Cl⁻) and sulphate (SO₄²⁻) are shown in Figures 5-3 to 5-5, respectively. Results are plotted for the mid-length of each tube unit. For example, the first tube is plotted at 10 m.

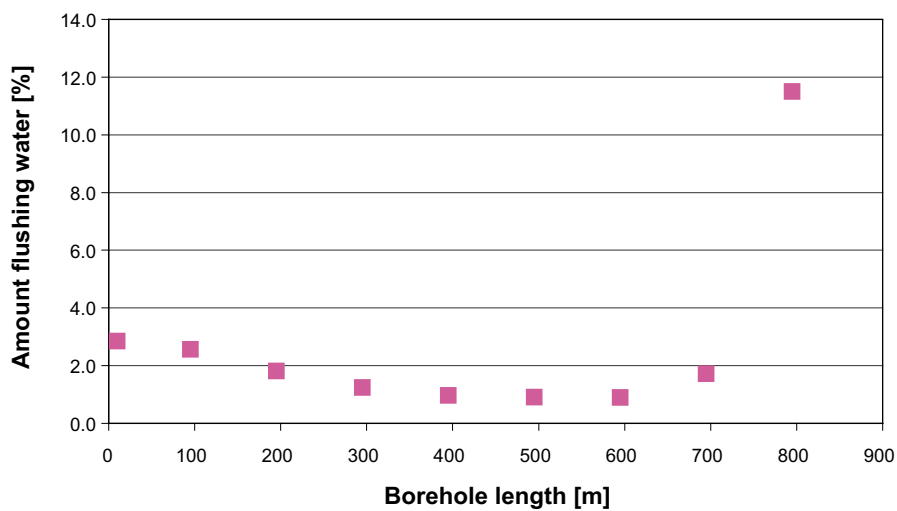


Figure 5-1. Amount of flushing water remaining at different borehole lengths at the time of the *Hydrochemical logging* in KLX09.

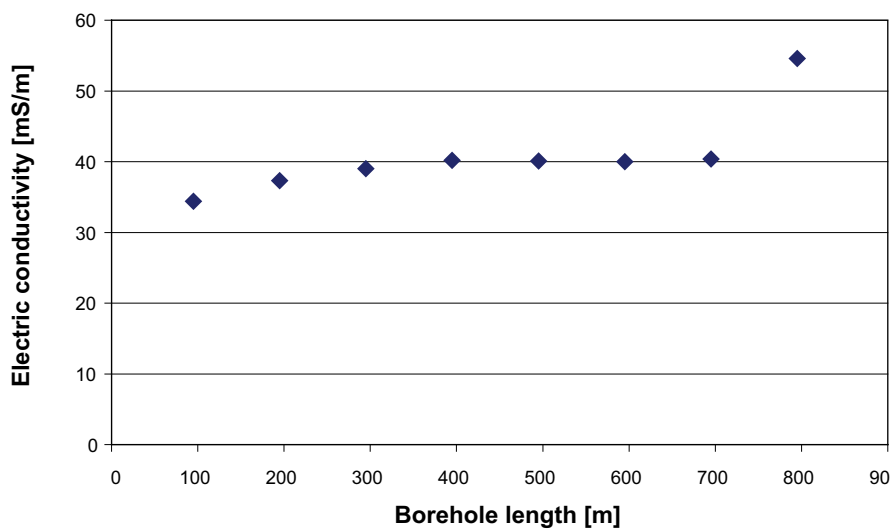


Figure 5-2. Electric conductivity values along the borehole KLX09 obtained from the *Hydrochemical logging*.

Sulphate (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 total sulphur values determined by ICP-AES are higher than the sulphate concentration determined by IC in all samples, and especially evident in the samples from the upper most sections. If sulphate were to be the only component containing sulphur the values should correspond (i.e. three times the total sulphur value should equal the sulphate concentration).

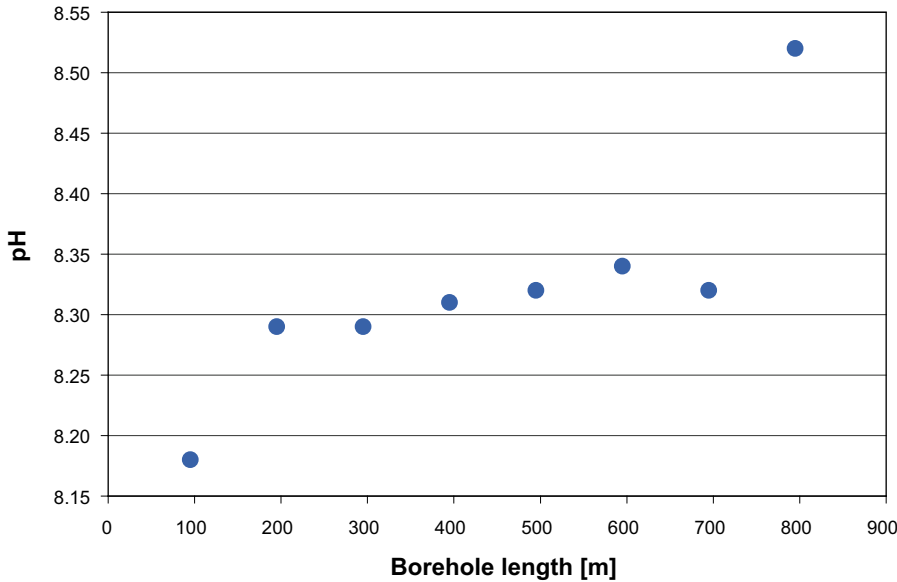


Figure 5-3. Results from pH measurements obtained from the Hydrochemical logging in KLX09.

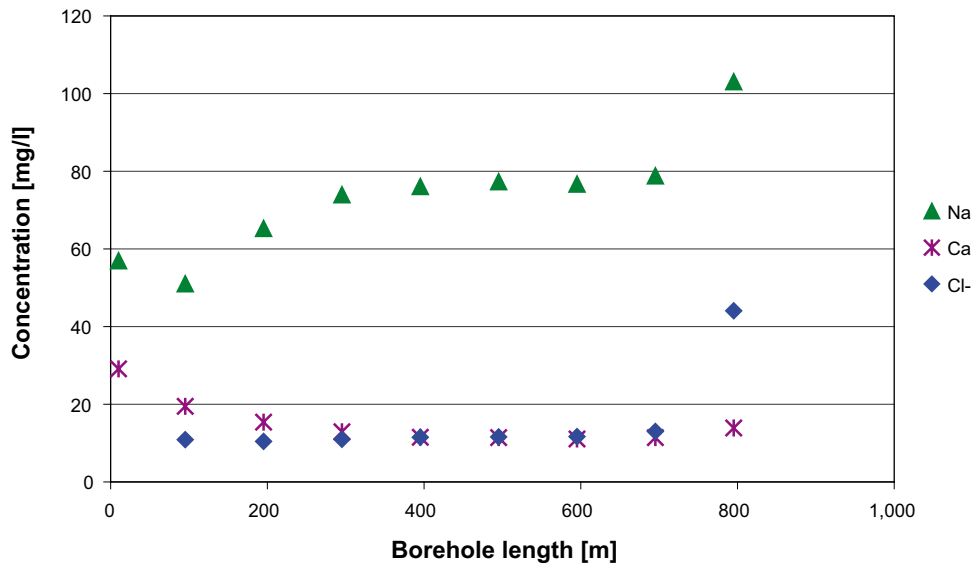


Figure 5-4. Results from analysis of the constituents Na, Ca and Cl⁻ in water samples obtained from Hydrochemical logging in KLX09.

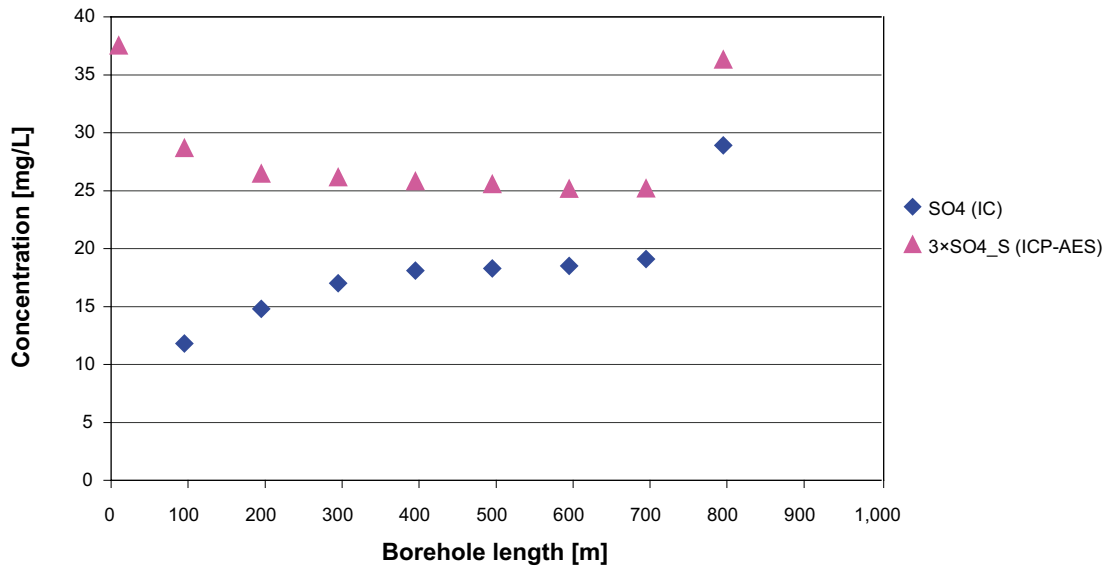


Figure 5-5. Sulphate (IC) compared to total sulphur (ICP-AES), results from the hydrochemical logging in KLX09.

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 not exceed 5% in any of the nine cases.

6 Conclusions

At the *Hydrochemical logging* in KLX09, the following chemical conditions were found:

- The amount of remaining flushing water at the time of the *Hydrochemical logging* was low throughout the entire borehole (below 3% in all samples except the lowest sampled section, 770–820 m, where the uranine content was about 12%).
- The charge balance error, giving an indication of the quality and uncertainty of the analyses, did not exceed the acceptable level in any case.

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 ₃ pH(lab) cond (lab)	Plastic	250	No	No	Titration Pot. meas, Cond. meas	Äspö's chemistry lab.	The same day – maximum 24 hours
Anions 2	Cl ⁻ , SO ₄ ²⁻ , Br ⁻ , F ⁻	Plastic	250	Yes (in connection with analysis)	No	Titration (Cl ⁻) IC (Cl ⁻ , SO ₄ , Br ⁻ , F ⁻) ISE (F ⁻)	Äspö'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	Yes (1 mL HNO ₃)	ICP-AES ICP-MS	Analytica AB	Not critical (month)
Environmental isotopes	² H, ¹⁸ O	Plastic	100	No	–	MS	IFE	Not critical (month)
Tritium,	³ H (enhanced.)	Plastic (dry bottle)	500	No	–	LSC	Univ. of Waterloo	Not critical (month)
Chlorine-37	Chlorine-37	Plastic	500	No	–	ICP MS	Univ. of Waterloo	Not critical (month)
Carbon isotopes	¹³ C, ¹⁴ C	Glass (brown), or plastic	100x4	No	–	(A)MS	Univ. of Waterloo The Ångström laboratory, Uppsala	A few days
Sulphur isotopes	³⁴ S	Plastic	1,000	No	–	Combustion, ICP MS	IFE	No limit
Strontium-isotopes	⁸⁷ Sr/ ⁸⁶ Sr	Plastic	100	No	–	TIMS	IFE	Days or Week
Boron isotopes	¹⁰ B	Plastic	100	Yes	Yes (1 mL HNO ₃)	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 chromatography
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)

Environmental Isotope Laboratory

Dep. Of earth sciences

University of Waterloo

Waterloo, Ontario

N2L 3G1 CANADA

Institutt for energiteknik (IFE)

Insituttveien 18

P.O Box 40

2027 Kjeller

NORGE

The Ångström laboratory

Box 534

Se-751 21 Uppsala

Appendix 2

Water composition

Compilation February 2006

Idcode	Secup m	Seclow m	Sample no.	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	Mn mg/L	Li mg/L	Sr mg/L	pH
KLX09	0	20	10583		56.9	1.84	29.1	4.6	-	-	-	12.5	-	-	6.22	0.12	0.076	0.022	0.38	-
KLX09	20	70	10586		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX09	70	120	10587	-3.87	51.0	1.77	19.5	4.1	172	10.9	11.6	9.55	<0.2	2.81	6.66	0.06	0.060	0.011	0.243	8.18
KLX09	120	170	10588		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX09	170	220	10589	-1.64	65.2	1.77	15.4	3.3	186	10.4	14.8	8.82	<0.2	3.18	7.11	0.072	0.047	0.012	0.222	8.29
KLX09	220	270	10590		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX09	270	320	10591	-0.97	73.9	1.66	12.9	2.8	194	11.0	17.0	8.71	<0.2	3.44	7.24	0.067	0.040	0.012	0.209	8.29
KLX09	320	370	10592		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX09	370	420	10593	-1.54	76	1.7	11.5	2.5	196	11.5	18.1	8.60	<0.2	3.54	7.15	0.066	0.036	0.011	0.199	8.31
KLX09	420	470	10594		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX09	470	520	10595	-1.11	77.3	1.71	11.4	2.4	197	11.6	18.3	8.52	<0.2	3.57	7.23	0.061	0.037	0.012	0.200	8.32
KLX09	520	570	10596		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX09	570	620	10597	-1.45	76.6	1.71	11.1	2.4	196	11.7	18.5	8.38	<0.2	3.58	7.10	0.065	0.036	0.013	0.198	8.34
KLX09	620	670	10598		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX09	670	720	10599	-0.95	78.4	1.74	11.4	2.4	197	13.0	19.1	8.39	<0.2	3.58	7.08	0.115	0.037	0.012	0.203	8.32
KLX09	720	770	10600		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX09	770	820	10601	0.01	103	2.57	13.9	2.5	198	44.1	28.9	12.1	<0.2	3.88	8.09	0.649	0.037	0.019	0.250	8.52
KLX09	820	870	10602		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Idcode	Secup m	Seclow m	Sample no.	Drill_water %	EiCond mS/m	$\delta^2\text{H}$ dev SMOW	$\delta^{18}\text{O}$ dev SMOW	^3H 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}C pMC
KLX09	0	20	10583	2.85	-	-	-	-	-	-	-	-	-	-
KLX09	20	70	10586	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX09	70	120	10587	2.56	34.4	xxx	xxx	xxx	xxx	xxx	-	-	-	-
KLX09	120	170	10588	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX09	170	220	10589	1.81	37.3	xxx	xxx	xxx	xxx	xxx	-	-	-	-
KLX09	220	270	10590	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX09	270	320	10591	1.24	39.0	xxx	xxx	xxx	xxx	xxx	-	-	-	-
KLX09	320	370	10592	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX09	370	420	10593	0.97	40.2	xxx	xxx	xxx	xxx	xxx	-	-	-	-
KLX09	420	470	10594	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX09	470	520	10595	0.90	40.1	xxx	xxx	xxx	xxx	xxx	-	-	-	-
KLX09	520	570	10596	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX09	570	620	10597	0.89	40.0	xxx	xxx	xxx	xxx	xxx	-	-	-	-
KLX09	620	670	10598	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX09	670	720	10599	1.71	40.4	xxx	xxx	xxx	xxx	xxx	-	-	-	-
KLX09	720	770	10600	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX09	770	820	10601	11.5	54.6	xxx	xxx	xxx	xxx	xxx	-	-	-	-
KLX09	820	870	10602	-	-	-	-	-	-	-	-	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 %