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Oskarshamn site investigation

Hydrochemical logging in KLX05

Cecilia Berg, Geosigma AB

November 2005

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 author 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 KLX05. 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 except for ^{10}B). 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), $\delta^{37}\text{Cl}$ 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 quite high in the deeper sections. The maximum amount of flushing water was approximately 67%, sampled at the bottom of the borehole. The relative charge balance error exceeded the acceptable limit of $\pm 5\%$ ($-10, 16\%$) in one out of ten analysed samples, no 10208 from the section at 0–40 m along the borehole.

Sammanfattning

Hydrokemisk loggning, eller så kallad slangprovtagning, har utförts i det kärnborrade borrhålet KLX05. 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 förutom ^{10}B). Prover för bestämning av isoptillvalen togs ut vid provtagningstillfället och sparades i frys (tritium och kolisotoper i kylskåp); $\delta^{18}\text{O}$, deuterium ($\delta^2\text{H}$), tritium (^3H), $\delta^{37}\text{Cl}$ och ^{87}Sr ur udda enheter, $\delta^{34}\text{S}$ och kolisotoper ur jämna enheter.

Halten kvarvarande spolvatten i borrhålet efter borrning var ganska hög i de djupare sektionerna. Den högsta spolvattenhalten uppmättes till omkring 67 % i botten på borrhålet. Det relativa felet i jonbalansen översteg den acceptabla nivån av $\pm 5\%$ ($-10,16\%$) i ett av tio analyserade prover, nummer 10208 från sektion 0–40 m längs borrhålet.

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1 Introduction

This document reports the performance and results from hydrochemical logging in borehole KLX05. 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 400-05-003 (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 KLX05 is a 1,000.16 m long telescopic borehole, drilled within the site investigation in the Oskarshamn area. The percussion borehole HLX10 served as the source of flushing water for the drilling of KLX05. The location of KLX05 and HLX10 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 KLX05	AP PS 400-05-003	1.0
Method descriptions	Number	Version
Metodbeskrivning för hydrokemisk loggning	SKB MD 422.001	1.0

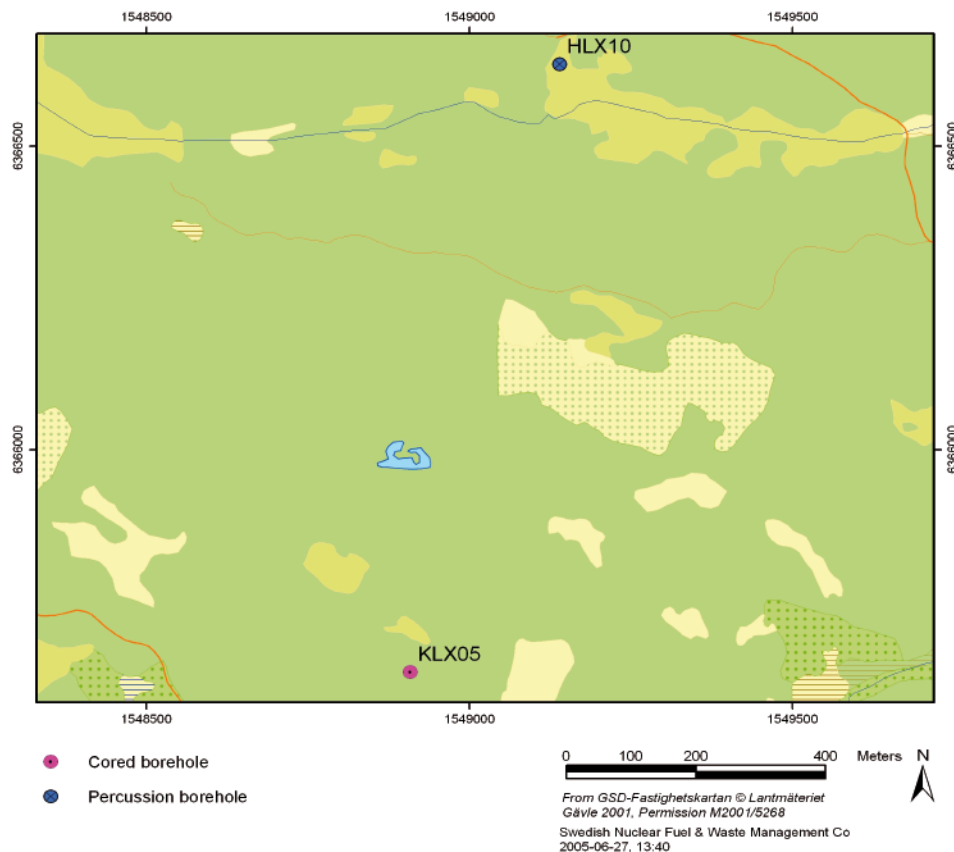


Figure 1-1. Location of the core drilled borehole KLX05 and the percussion borehole HLX10 within the site investigation in the Oskarshamn area.

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 KLX05. 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 except for ^{10}B , see Section 4.4. 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 1,000 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.

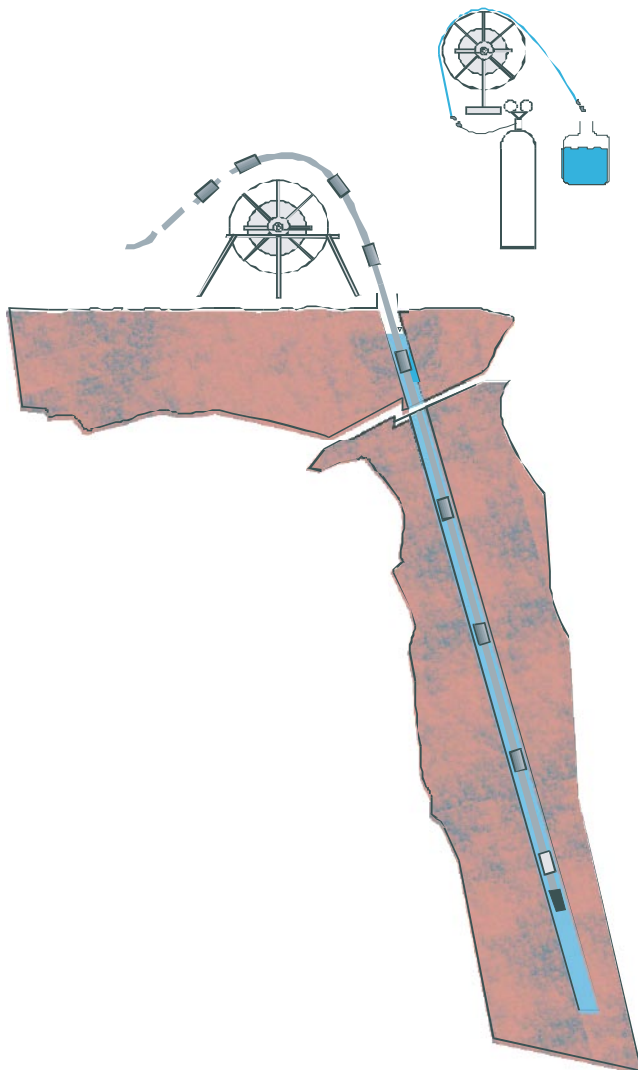


Figure 3-1. Equipment for hydrochemical logging in boreholes. At the lower end of the tube array there is a check valve and a weight connected. Each tube unit is 50 m long.

Table 3-1. Length of tube units used for the hydrochemical logging in KLX05.

Unit	Length (m)
1	49.71
2	50.08
3	49.77
4	49.28
5	49.97
6	50.01
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	49.22
16	49.20
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 KLX05 was performed on April 6, 2005.

The lowering of the tube units started at 08:55. The tubes were lowered down the borehole at a rate of about five metres/minute. The equipment was lowered to a depth of 990 m, 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 12:39, and the last tube unit was retrieved at 13:55. 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 level before the hydrochemical logging was 8.04 m 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, except ^{10}B samples see, Section 4.4. 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. The SKB sample numbers are 10208–10227.

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. 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 $\delta^2\text{H}/\delta^{18}\text{O}$, $\delta^{37}\text{Cl}$, $^{10}\text{B}/^{11}\text{B}$ and ^{87}Sr from the first section (0–40 m).

Table 4-1. Overview of samples collected at the hydrochemical logging in KLX05. 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	Uranine	An-ions	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 40	10208					Ж	Ж	Ж	Ж				
2	90	10209												
3	140	10210												
4	190	10211												
5	240	10212												
6	290	10213												
7	340	10214												
8	390	10215												
9	440	10216												
10	490	10217												
11	540	10218												
12	590	10219												
13	640	10220												
14	690	10221												
15	740	10222												
16	790	10223												
17	840	10224												
18	890	10225												
19	940	10226												
20	990	10227												

Ж 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.

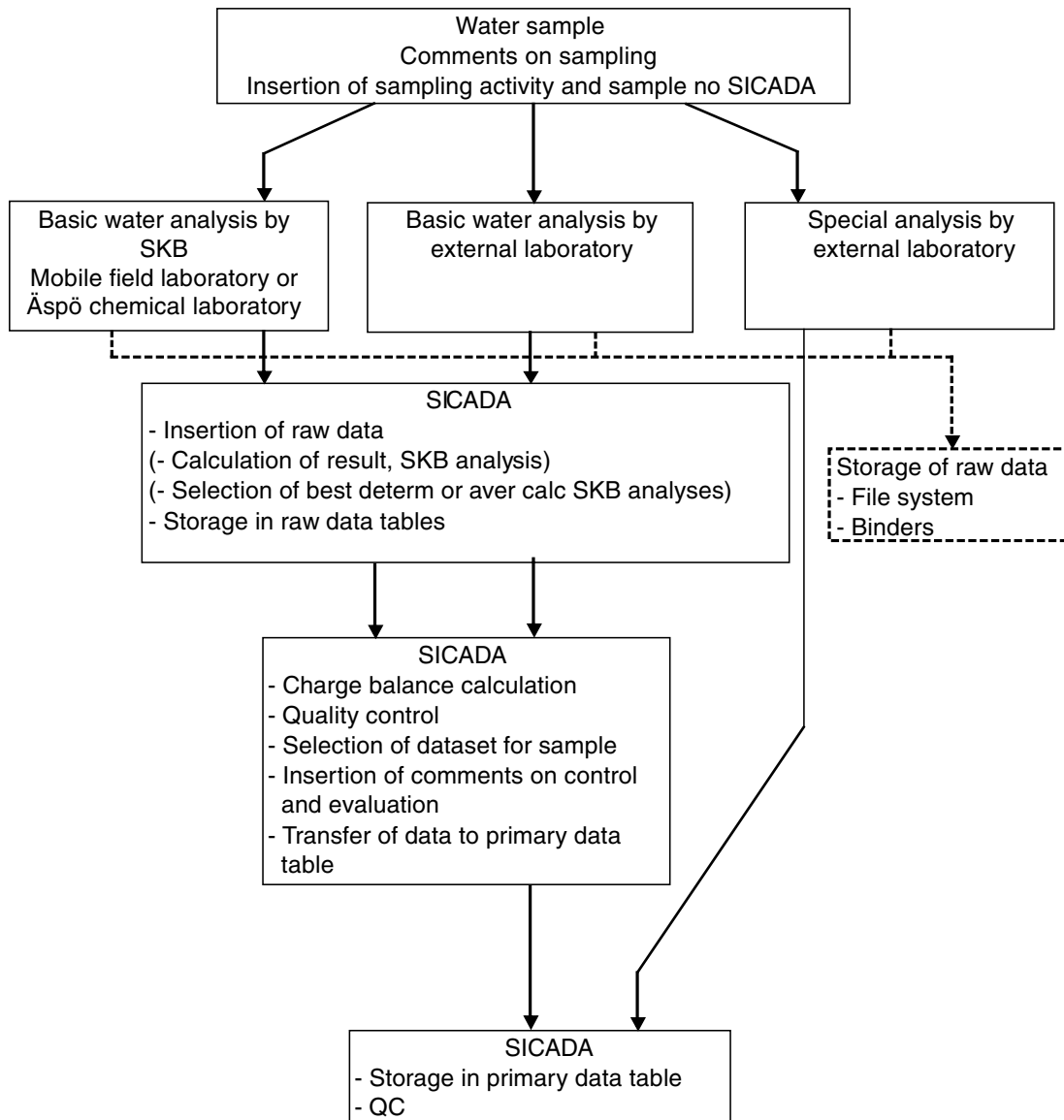


Figure 4-1. Overview of data management for hydrogeochemical data.

4.1 Nonconformities

The activity was performed without any deviations from the controlling documents for the activity that can affect the results. One deviation from the AP PS 400-05-003 can be mentioned; samples collected for ¹⁰B analyses was sent and analysed at the consulted laboratory.

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 20 m.

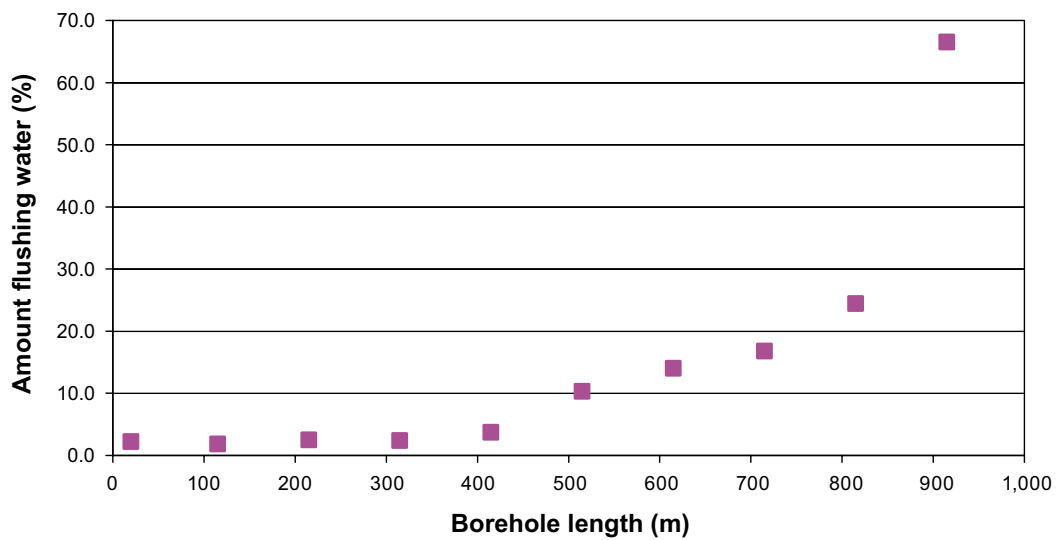


Figure 5-1. Amount of flushing water remaining at different borehole lengths at the time of the hydrochemical logging in KLX05.

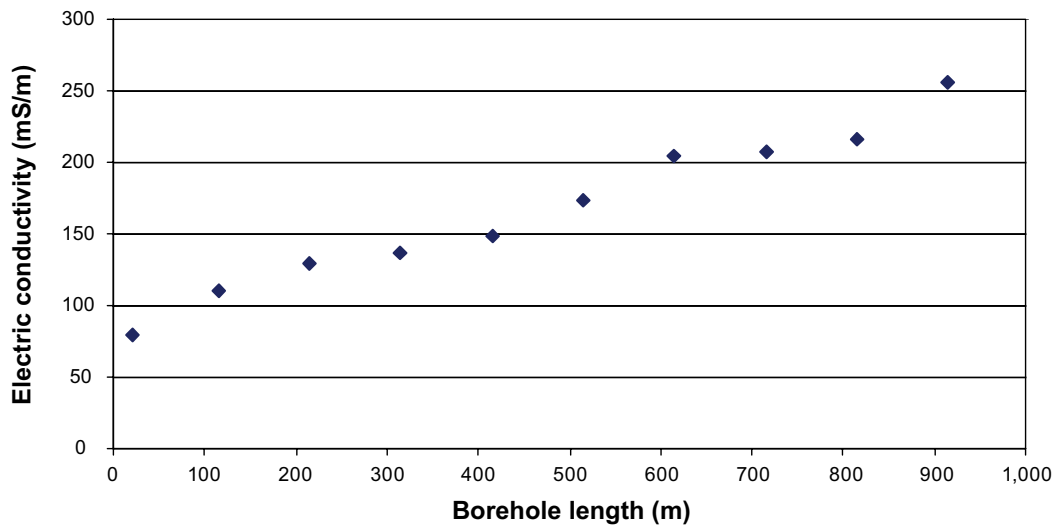


Figure 5-2. Electric conductivity values along the borehole KLX05 obtained from the hydrochemical logging.

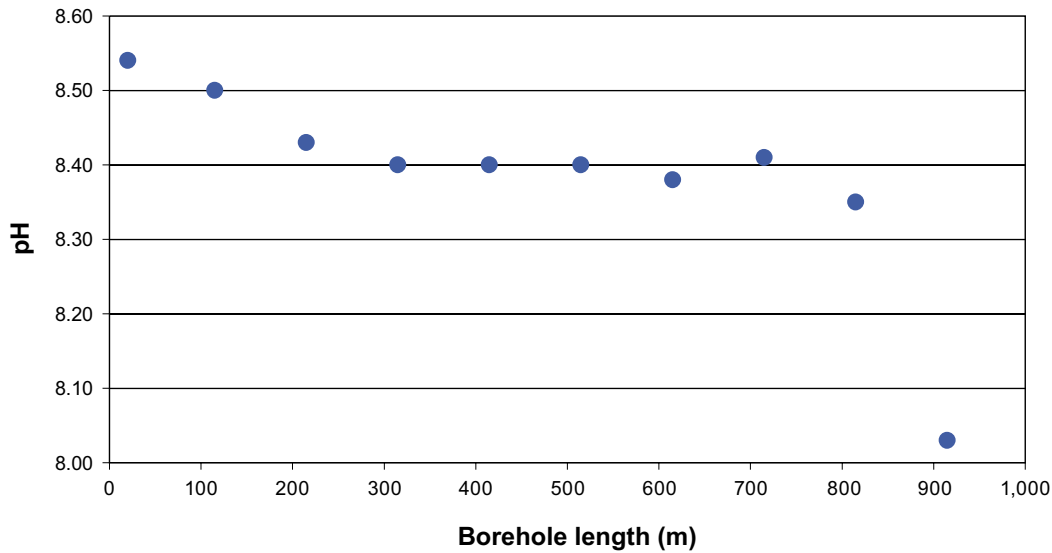


Figure 5-3. Results from pH measurements obtained from the hydrochemical logging in KLX05.

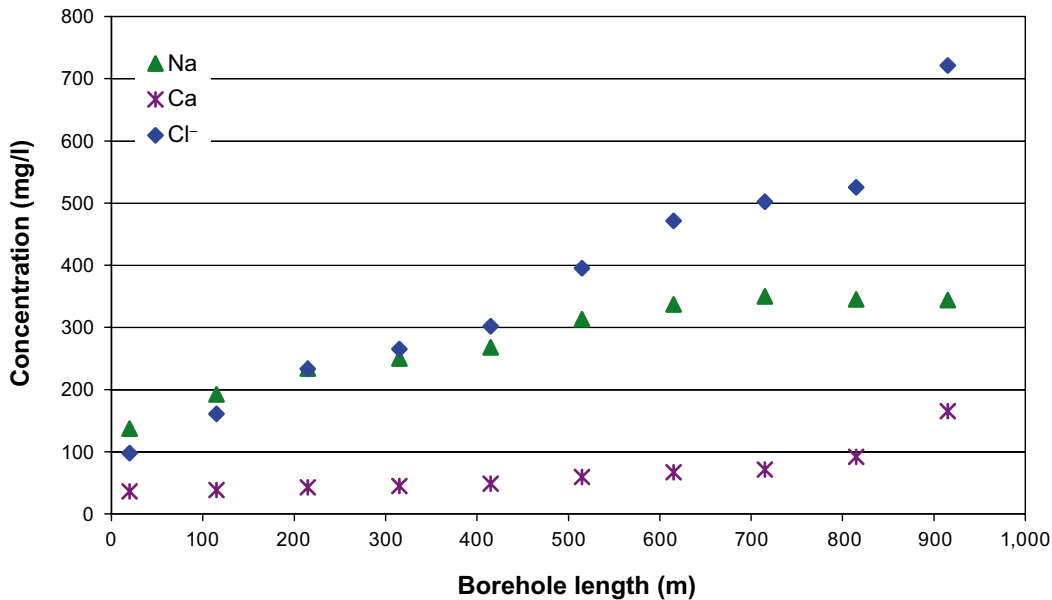


Figure 5-4. Results from analysis of the constituents Na, Ca and Cl⁻ in water samples obtained from hydrochemical logging in KLX05.

Sulphate (SO₄²⁻) 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 5-5. The values obtained from ICP-AES are higher than the value from IC in all samples.

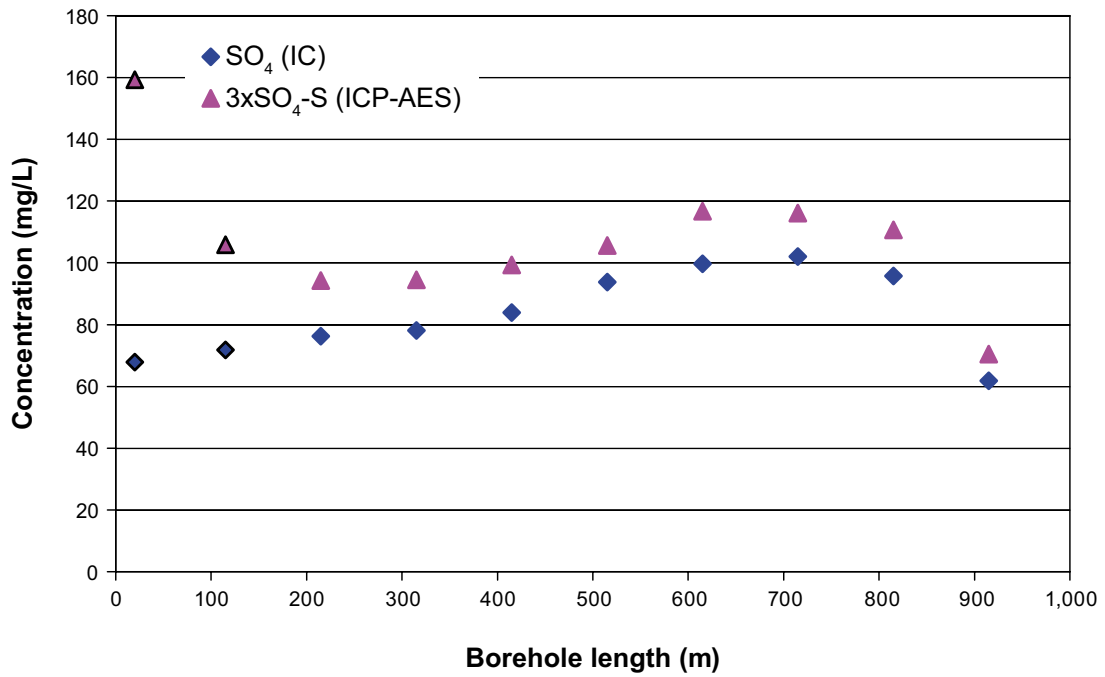


Figure 5-5. Sulphate (IC) compared to total sulphur (ICP-AES). Results with outlines are not QC-marked in SICADA.

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% ($-10, 16\%$) in one out of ten cases, no 10208 from the section at 0–40 m along the borehole.

6 Conclusions

At the hydrochemical logging in KLX05, the following chemical conditions were found:

- The amount of remaining flushing water at the time of the hydrochemical logging was low the first 450 m along the borehole, below 5%. From 500 to 850 m the amount increased from approximately 10 to 25%. The maximum was found at the bottom of the borehole where it was about 65% of remaining flushing water.
- The charge balance error, giving an indication of the quality and uncertainty of the analyses, exceeded the acceptable level one case, sample 10208. The sample was collected from the uppermost sections, 0–40 m, in the borehole.
- The electric conductivity and the chloride concentration increased only slightly down the borehole. The highest values were 260 mS/m and 720 mg/L, respectively (both values from the deepest part measured along the borehole i.e section 940–990 m).

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	Åspö's chemistry lab	The same day – maximum 24 hours
Anions 2	Cl, SO ₄ , Br ⁻ , F ⁻ , I ⁻	Plastic	250	Yes (not in the field)	No	Titration (Cl ⁻) IC (Cl ⁻ , SO ₄ , Br ⁻ , F ⁻) ISE (F ⁻)	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 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)	100×2	No	–	(A)MS	Univ Of Waterloo	A few days
Sulphur isotopes	³⁴ S	Plastic	500–1,000	No	–	Combustion, ICP MS	The Ångström laboratory, Uppsala	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	250×2**	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)
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 July 2005

Idcode	Secup	Secup	Secup	Sample	Charge	Na	K	Ca	Mg	HCO ₃ ⁻	Cl ⁻	SO ₄ ²⁻	SO ₄ -S	Br ⁻	F ⁻	Si	Fe	Mn	Li	Sr	pH	
	m	m	m	no	Bal%	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		
KLX05	0	40	10208		-10.16	137	3.97	36.3	6.8	246	97.9	67.9*	53.1*	0.575	4.45	9.66	0.746	0.056	0.022	0.331	8.54	
KLX05	40	90	10209																			
KLX05	90	140	10210		-1.36	192	3.99	38.4	7.9	266	161	71.8*	35.3*	1.68	4.00	8.51	0.655	0.150	0.027	0.521	8.50	
KLX05	140	190	10211																			
KLX05	190	240	10212		0.17	234	4.01	42.5	8.5	265	233	76.2	31.4	<0.2	3.80	7.55	0.446	0.142	0.028	0.660	8.43	
KLX05	240	290	10213																			
KLX05	290	340	10214		-0.06	250	4.11	44.6	8.5	263	265	78.1	31.5	<0.2	3.65	7.21	0.356	0.156	0.034	0.713	8.40	
KLX05	340	390	10215																			
KLX05	390	440	10216		-0.36	268	4.22	48.8	8.2	258	302	83.9	33.1	<0.2	3.80	6.91	0.402	0.159	0.032	0.798	8.40	
KLX05	440	490	10217																			
KLX05	490	540	10218		0.07	313	4.72	59.6	7.8	232	395	93.8	35.2	<0.2	4.10	6.61	0.390	0.152	0.034	1.10	8.40	
KLX05	540	590	10219																			
KLX05	590	640	10220		-1.30	337	4.95	67.2	7.6	208	471	99.7	38.9	<0.2	3.28	6.46	0.315	0.142	0.04	1.24	8.39	
KLX05	640	690	10221																			
KLX05	690	740	10222		-1.67	350	4.95	71.3	7.4	205	502	102	38.7	<0.2	5.30	6.36	0.397	0.134	0.038	1.29	8.41	
KLX05	740	790	10223																			
KLX05	790	840	10224		0.06	345	5.30	91.5	6.6	188	525	95.7	36.9	<0.2	1.50	6.53	0.540	0.138	0.036	1.75	8.35	
KLX05	840	890	10225																			
KLX05	890	940	10226		-0.51	344	7.18	165	3.9	115	721	61.8	23.5	9.50	4.10	6.74	0.607	0.167	0.027	3.29	8.03	
KLX05	940	990	10227																			

Compilation July 2005

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
KLX05	0	40	10208	2.17	79.7	xxx	xxx	xxx	xxx	0.238	xxx	-	-	-
KLX05	40	90	10209	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX05	90	140	10210	1.84	110	xxx	xxx	xxx	xxx	0.238	xxx	-	-	-
KLX05	140	190	10211	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX05	190	240	10212	2.46	130	xxx	xxx	xxx	xxx	0.237	xxx	-	-	-
KLX05	240	290	10213	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX05	290	340	10214	2.37	137	xxx	xxx	xxx	xxx	0.236	xxx	-	-	-
KLX05	340	390	10215	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX05	390	440	10216	3.65	148	xxx	xxx	xxx	xxx	0.236	xxx	-	-	-
KLX05	440	490	10217	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX05	490	540	10218	10.3	174	xxx	xxx	xxx	xxx	0.236	xxx	-	-	-
KLX05	540	590	10219	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX05	590	640	10220	14.0	204	xxx	xxx	xxx	xxx	0.235	xxx	-	-	-
KLX05	640	690	10221	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX05	690	740	10222	16.8	207	xxx	xxx	xxx	xxx	0.235	xxx	-	-	-
KLX05	740	790	10223	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX05	790	840	10224	24.4	216	xxx	xxx	xxx	xxx	0.236	xxx	-	-	-
KLX05	840	890	10225	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX05	890	940	10226	66.5	256	xxx	xxx	xxx	xxx	0.238	xxx	-	-	-
KLX05	940	990	10227	-	-	-	-	-	-	-	-	xxx	xxx	xxx

- = Not analysed

A = results will be reported later

x = No result due to sampling problems

xxx = No result due to analytical problems

xxx = Stored in freezer/refrigerator

< = result below detection limit

Charge Bal % = Relative charge balance error %