

Oskarshamn site investigation

Hydrochemical logging in KLX08

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September 2005

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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 KLX08. 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 below 10% down to approximately 500 m. From 500 m and down the content increased, ending with a maximum value of 59% in section 890–940 m. The relative charge balance error did not exceed the acceptable limit of $\pm 5\%$ in any of the ten analysed samples.

Sammanfattning

Hydrokemisk loggning, eller så kallad slangprovtagning, har utförts i det kärnborrade borrhålet KLX08. 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 borrhning var under tio procent de första 500 metrarna, för att sedan öka till den högst uppmätta halten av 59 % i den lägst provtagna sektionen i borrhålet (890–940 m). Det relativa felet i jonbalansen översteg inte den acceptabla nivån av $\pm 5\%$ i något av de tio analyserade proverna.

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1 Introduction

This document reports the performance and results from hydrochemical logging in borehole KLX08. 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 AP PS 400-05-055 (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 KLX08 is a 1,000.41 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 KLX08. The location of KLX08 and HLX10 is shown in Figure 1-1.

The borehole KLX08 is of the so called SKB chemical type; see method descriptions MD 620.003 (Method description for drilling cored boreholes) and 610.003 (Method description for percussion drilling). A SKB chemical type of borehole requires cleaning procedures of all equipment to be used in the borehole, during and after drilling, according to level 2 in the cleaning instructions in MD 600.004 (Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning).

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

Activity plan	Number	Version
Hydrokemisk loggning i KLX08	AP PS 400-05-055	1.0
Method descriptions	Number	Version
Metodbeskrivning för hydrokemisk loggning	SKB MD 422.001	1.0

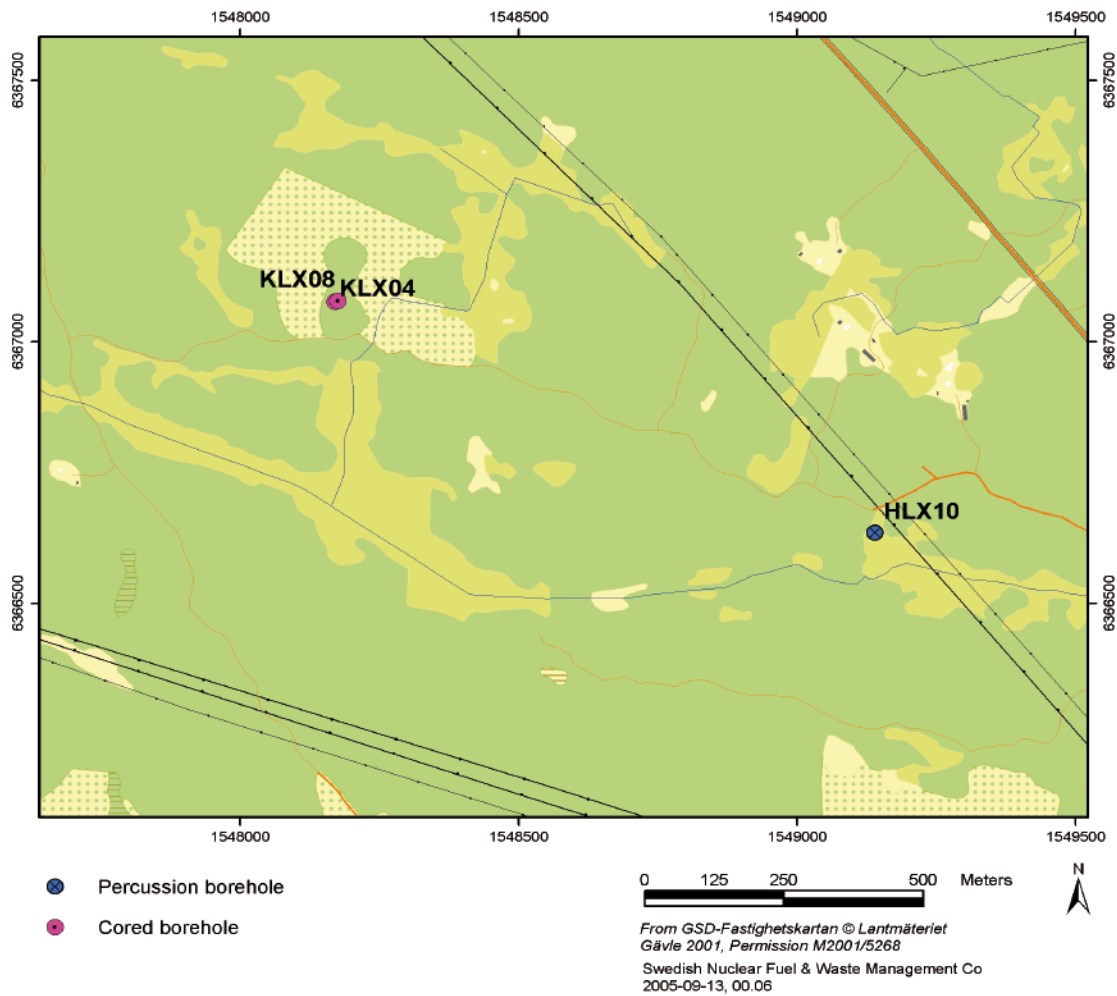


Figure 1-1. Location of the core drilled borehole KLX08 and the percussion borehole HLX10 as well as the nearby situated core drilled borehole KLX04 within the site investigation in the Oskarshamn area.

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 KLX08. 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 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 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. At the lower end of the tube array, a weight is added in order to stretch the array and thereby prevent fastening.

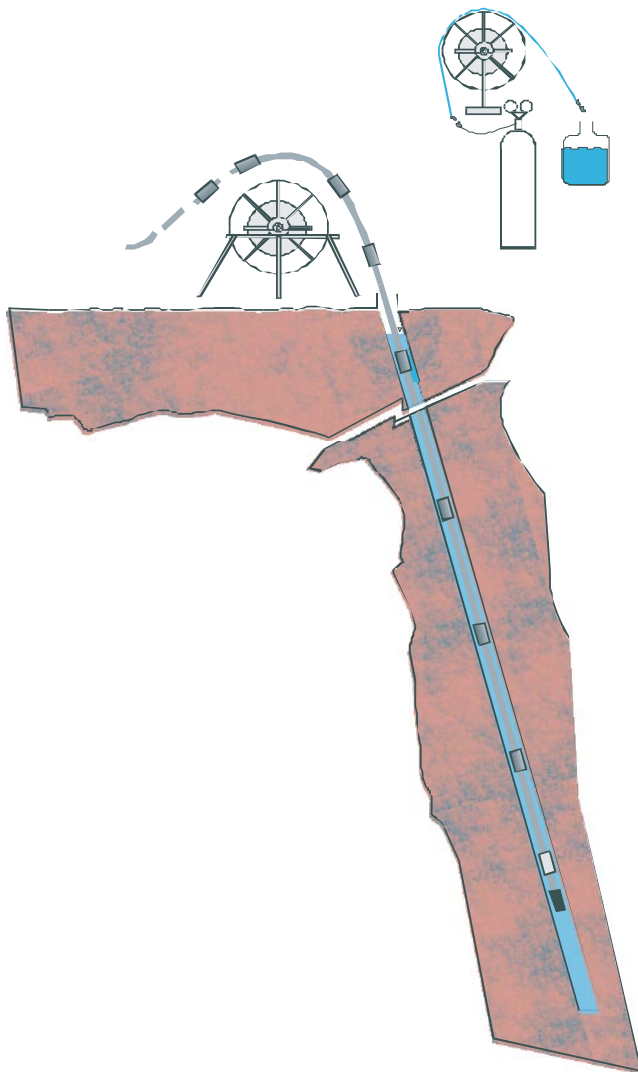


Figure 3-1. Equipment for hydrochemical logging in boreholes. At the lower end of the tube array there is a check valve and a weight connected. Each tube unit is 50 m long.

4 Performance

4.1 Hydrochemical logging

The hydrochemical logging in KLX08 was performed on July 12, 2005.

The lowering of the tube units started at 08:46. The tubes were lowered down the borehole at a rate of about five metres/minute. The equipment was lowered to a length of 990 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 fastening. The lifting of the tubes started at 12:25, and the last tube unit was retrieved at 13:40. 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 and after the hydrochemical logging was 13.83 and 13.87 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. The SKB sample numbers are 10408–10427.

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, bottles for isotope analysis of ^{10}B and ^{87}Sr from the upper most section as well as archive samples from the second tube unit were not collected. Water intended for archive samples in the second unit were used to fill sample bottles for analyses of ^3H , $\delta^2\text{H}/\delta\text{O}18$ and $\delta^{37}\text{Cl}$ from the first section (0–40 m).

Table 4-1. Overview of samples collected at the hydrochemical logging in KLX08.
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	10408					⌘	⌘	⌘					
2	90	10409												
3	140	10410												
4	190	10411												
5	240	10412												
6	290	10413												
7	340	10414												
8	390	10415												
9	440	10416												
10	490	10417												
11	540	10418												
12	590	10419												
13	640	10420												
14	690	10421												
15	740	10422												
16	790	10423												
17	840	10424												
18	890	10425												
19	940	10426												
20	990	10427												

⌘ 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.

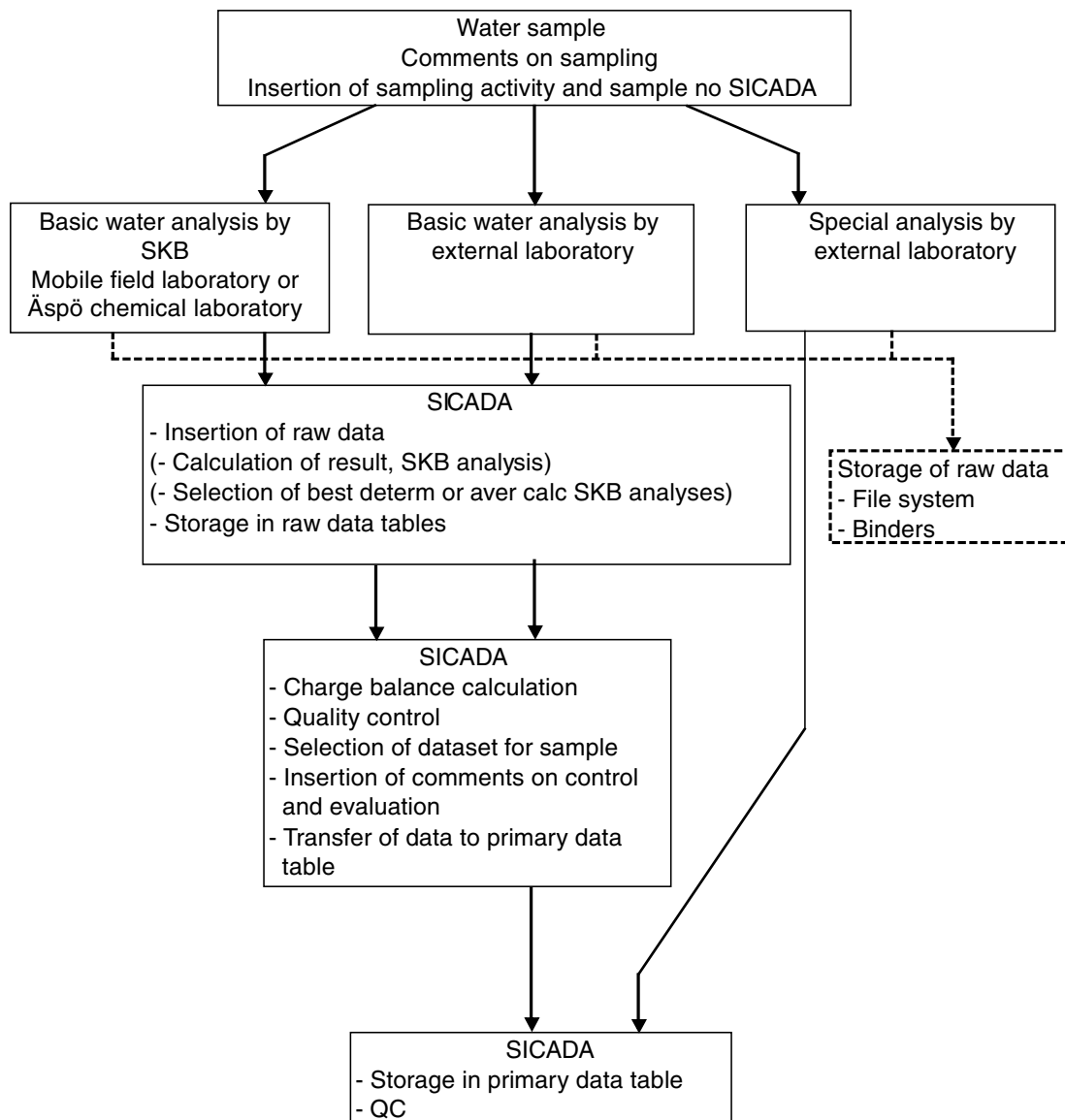


Figure 4-1. Overview of data management for hydrogeochemical data.

4.4 Nonconformities

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

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 (SO_4^{2-}) 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.

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 5-5. 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 first six samples. 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).

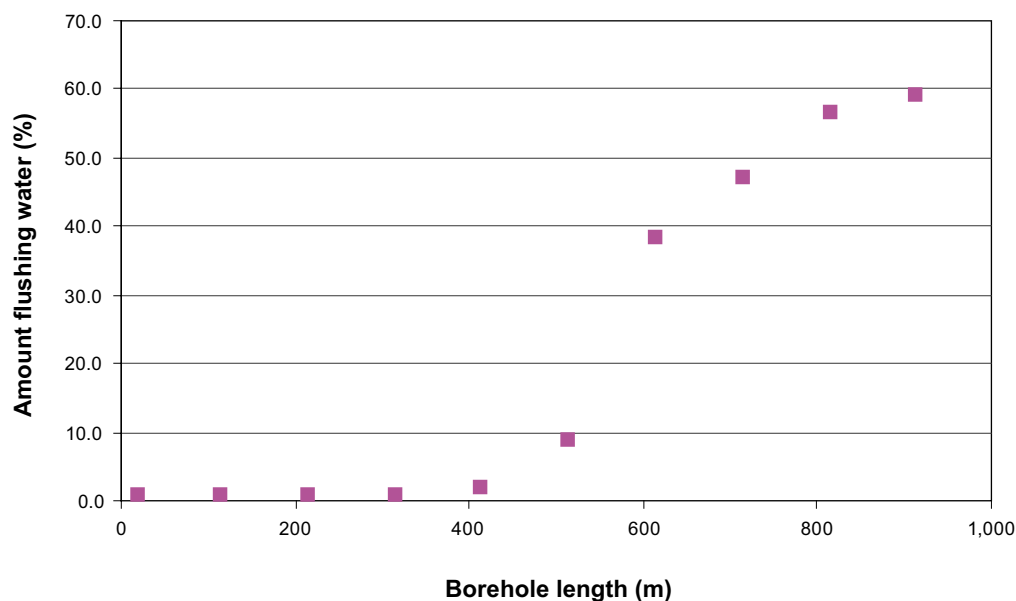


Figure 5-1. Amount of flushing water remaining at different borehole lengths at the time of the hydrochemical logging in KLX08.

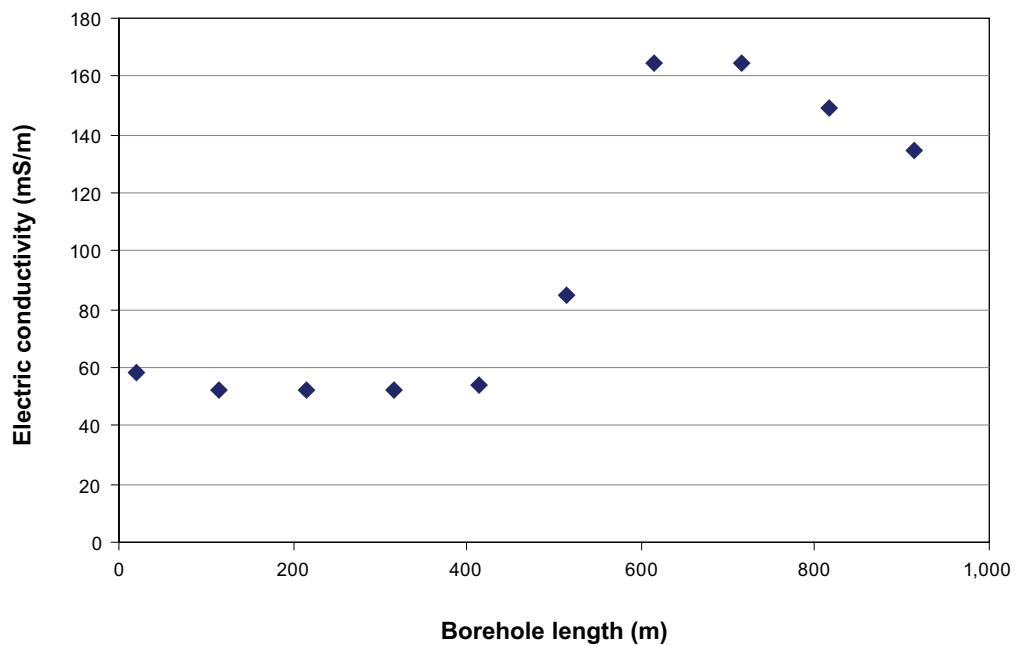


Figure 5-2. Electric conductivity values along the borehole KLX08 obtained from the hydrochemical logging.

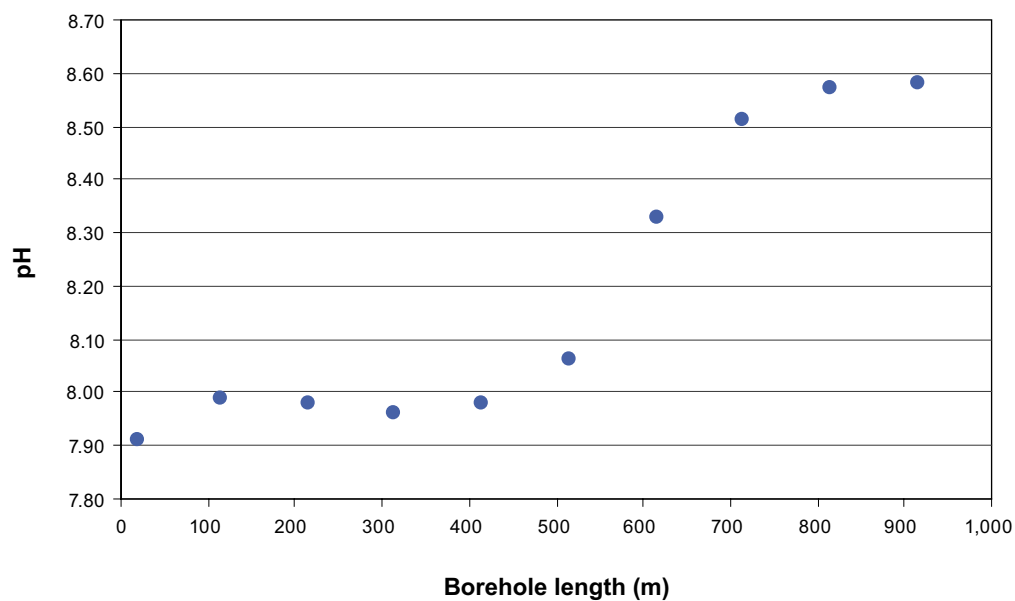


Figure 5-3. Results from pH measurements obtained from the hydrochemical logging in KLX08.

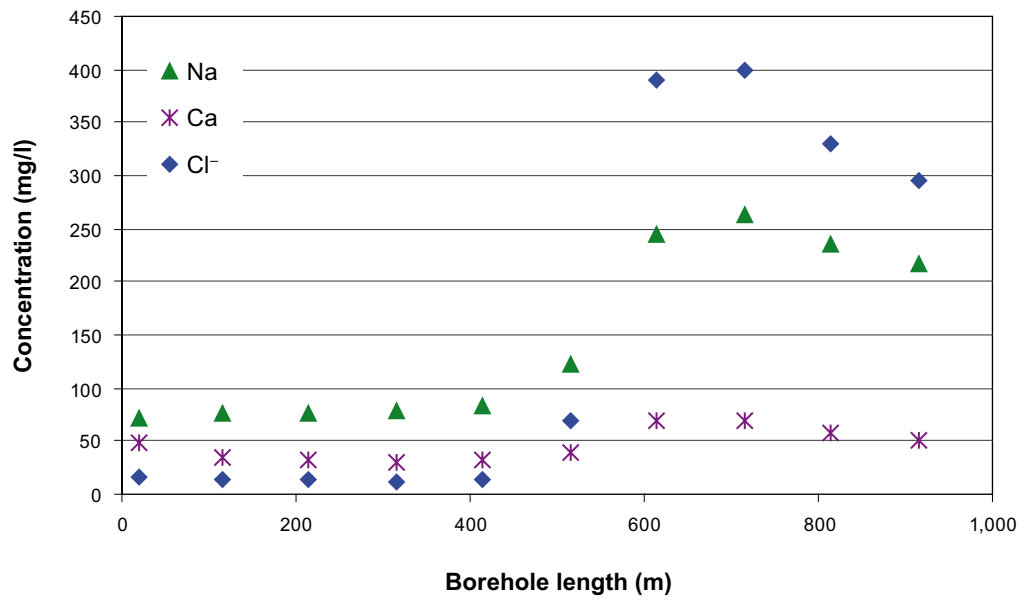


Figure 5-4. Results from analysis of the constituents Na, Ca and Cl⁻ in water samples obtained from hydrochemical logging in KLX08.

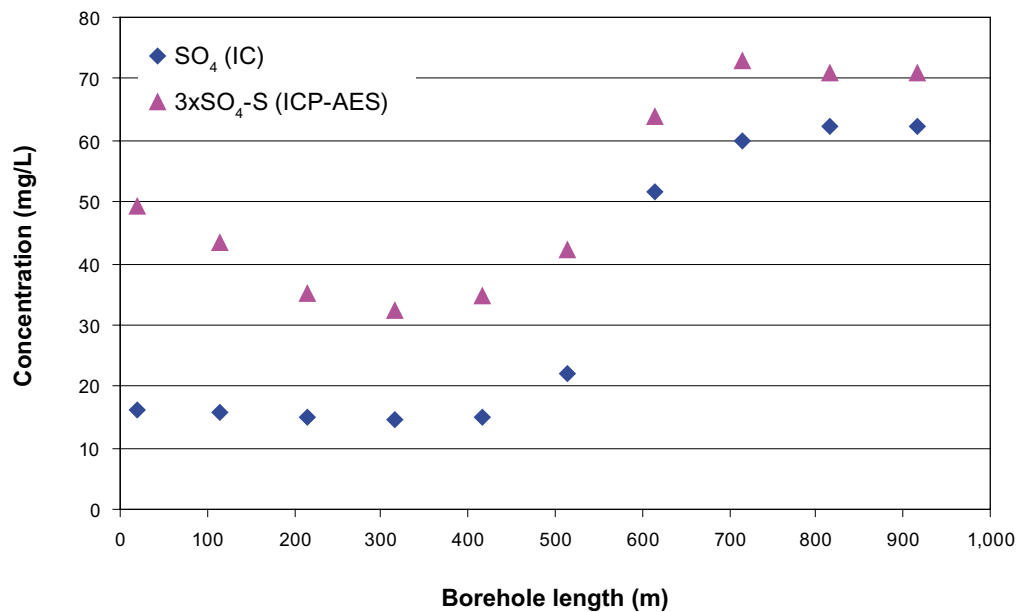


Figure 5-5. Sulphate (IC) compared to total sulphur (ICP-AES), results from the hydrochemical logging in KLX08.

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 ten cases.

6 Conclusions

At the hydrochemical logging in KLX08, the following chemical conditions were found:

- The amount of remaining flushing water at the time of the hydrochemical logging was relatively low the first 500 m along the borehole, below 10%. From 500 m and to the bottom the amount increased, reaching approximately 60% in the lowest section.
- The charge balance error, giving an indication of the quality and uncertainty of the analyses, did not exceed the acceptable level in any case.
- The highest value of electric conductivity and chloride concentration was found in section 690–740 m. The values were 165 mS/m and 399 mg/L, respectively.

7 References

- /1/ **SKB, 2001.** Generellt genomförandeprogram 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	100	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 The Ångström laboratory, Uppsala	A few days
Sulphur isotopes	³⁴ S	Plastic	500–1,000	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	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

Water composition

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Idcode	Secup m	Secup 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
KLX08	0	40	10408	3.61	76.1	3.17	48.3	7.2	266	16.3	16.0	16.4	< 0.2	2.29	8.00	0.420	0.177	0.013	0.499	7.91
KLX08	40	90	10409	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	90	140	10410	-1.75	75.6	3.29	35.7	7.1	276	14.7	15.6	14.5	< 0.2	2.19	8.18	0.277	0.155	0.013	0.402	7.99
KLX08	140	190	10411	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	190	240	10412	-3.22	76.2	3.31	31.4	6.8	287	12.9	14.9	11.7	< 0.2	2.13	8.24	0.284	0.153	0.013	0.383	7.98
KLX08	240	290	10413	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	290	340	10414	-1.97	79.6	3.39	30.4	6.6	288	12.2	14.5	10.8	< 0.2	2.10	8.31	0.399	0.158	0.013	0.390	7.96
KLX08	340	390	10415	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	390	440	10416	-1.5	83.5	3.49	32.4	6.4	294	14.4	14.9	11.5	< 0.2	2.21	8.07	0.565	0.159	0.014	0.396	7.98
KLX08	440	490	10417	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	490	540	10418	2.07	123	4.21	39.2	5.8	284	68.3	22.2	14.0	0.73	2.44	7.38	0.434	0.150	0.021	0.569	8.06
KLX08	540	590	10419	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	590	640	10420	-2.82	244	7.32	68.4	5.7	184	391	51.5	21.3	3.15	2.89	5.78	0.337	0.119	0.043	1.11	8.33
KLX08	640	690	10421	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	690	740	10422	-0.71	263	8.46	68.3	5.3	169	399	59.8	24.3	3.66	3.160	5.08	0.227	0.089	0.045	1.11	8.51
KLX08	740	790	10423	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	790	840	10424	-0.09	235	8.67	57.5	5.1	172	329	62.1	23.6	3.33	3.23	4.87	0.270	0.081	0.039	0.845	8.57
KLX08	840	890	10425	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KLX08	890	940	10426	-0.69	218	8.97	51.5	5.2	177	295	62.3	23.7	2.77	3.23	4.75	0.294	0.080	0.035	0.743	8.58
KLX08	940	990	10427	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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Idcode	Secup	Secow	Sample	Drill_water	EiCond	$\delta^2\text{H}$	$\delta^{18}\text{O}$	^3H	$\delta^{37}\text{Cl}$	$^{10}\text{B}/^{11}\text{B}$	$^{87}\text{Sr}/^{86}\text{Sr}$	$\delta^{34}\text{S}$	$\delta^{13}\text{C}$	^{14}C
m	m	m	no	%	mS/m	dev SMOW	dev SMOW	TU	dev SMOC	no unit	no unit	dev CDT	dev PDB	pmC
KLX08	0	40	10408	0.71	57.5	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX08	40	90	10409	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX08	90	140	10410	0.60	51.6	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX08	140	190	10411	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX08	190	240	10412	0.58	51.9	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX08	240	290	10413	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX08	290	340	10414	0.84	52.4	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX08	340	390	10415	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX08	390	440	10416	1.73	53.5	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX08	440	490	10417	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX08	490	540	10418	8.94	85.3	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX08	540	590	10419	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX08	590	640	10420	38.2	165	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX08	640	690	10421	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX08	690	740	10422	47.1	165	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX08	740	790	10423	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX08	790	840	10424	56.3	149	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX08	840	890	10425	-	-	-	-	-	-	-	-	xxx	xxx	xxx
KLX08	890	940	10426	59.0	135	xxx	xxx	xxx	xxx	xxx	xxx	-	-	-
KLX08	940	990	10427	-	-	-	-	-	-	-	-	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
Charge Bal % = Relative charge balance error %