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# TECHNICAL REPORT

# 86-17

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## Analysis of groundwater from deep boreholes in Klipperas

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ANALYSIS OF GROUNDWATER FROM DEEP BOREHOLES IN KLIPPERÅS

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September 22, 1986

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

A list of other reports published in this series during 1986 is attached at the end of this report. Information on KBS technical reports from 1977-1978 (TR 121), 1979 (TR 79-28), 1980 (TR 80-26), 1981 (TR 81-17), 1982 (TR 82-28), 1983 (TR 83-77), 1984 (TR 85-01) and 1985 (TR 85-20) is available through SKB.

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Deep Boreholes in Klipperås**

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Stockholm, 1986-09-22

## SUMMARY

Groundwater from three boreholes in granitic rock at an investigation site in Klipperås has been sampled and analysed. This is part of a larger program of geological, geophysical and hydrogeological investigations aimed at finding a suitable site for a high level radioactive waste repository.

Water-bearing levels in the boreholes down to the deepest at 777 m were selected. Prior to sampling, the water-bearing level is isolated between packer sleeves. The water is then pumped to the surface where sensitive parameters such as redox potential, pH, sulphide and oxygen content are measured electrochemically on the flowing water in a system isolated from the air. Water, filter and gas samples are sent to several laboratories for further analysis.

During the site investigations in Klipperås a new mobile field laboratory was introduced with the capability to measure certain sensitive parameters such as Eh and pH downhole and to perform rapid, on site analyses of several other groundwater constituents.

The present report is a presentation of the results of the groundwater analyses. The reliability of the results is discussed but there is no evaluation in relation to geology and hydrogeology. This report presents the basic results from the groundwater analyses to be further evaluated by experts in different fields.

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# 1 INTRODUCTION

Groundwater from three core drilled boreholes in Klipperås: Kl 1, Kl 2 and Kl 9 has been sampled and analyzed. The sampling levels have been chosen on the basis of hydrological measurements in the boreholes.

All field work has been carried out by personnel from Industrins Processkonsult AB (IPK). The sampling in Klipperås has been carried out in a period of transition between old and new technology.

One level - 406 m - has been sampled in Kl 1. The first sampling there was carried out in Nov.-Dec. 1983 using the old technique (KBS TK 83-44 and 83-70). The results of the chemical water analyses exhibited an abnormally large variation. A more recent reanalysis of two frozen samples has shed doubt on the correctness of the previous analyses for a number of the parameters. The analyses are therefore not reported here. In June 1985, sampling was repeated at the same level, but now with new technology, i.e. new measuring equipment, automatic recording of the measured values and chemical analyses in our own computer-equipped field laboratory (to be published as SKB TR 86-16).

Kl 2 was sampled for the first time in Oct.-Dec. 1984. Five levels were sampled on this occasion: 326, 623, 741, 761 and 777 m. At the four greatest depths, it was found that drilling water admixture was around 5% and did not decrease during sampling. The work was therefore interrupted after a relatively short time at each level. The measured values have been recorded automatically with the computer unit, Chemmac, which recorded the measured values in units of one-half mV. In order to permit all the measurement results to be treated uniformly, the measured values in the filed computer tables have been divided by two. The chemical analyses were performed in the field laboratory, where the analysis results were calculated manually and recorded on test reports. In May 1985, a new sampling was carried out, this time at 860 m and with the new equipment. At this level as well, such high concentrations of drilling water were found that the sampling was interrupted after a week or so.

Kl 9 was sampled during Aug.-Sept. 1985. Only the 696 m level was investigated. New technology was used throughout.

Control analyses are performed about once a week by AB IVL, Stockholm, to verify the results of the field laboratory. A number of laboratories are used for special analyses (see Sections 6-8).

The present report consists mainly of a presentation of the results of the groundwater analyses. The reliability of the results is subjected to some scrutiny. No further evaluation in relation to geology or hydrology is made here, but the material in the report will be further analyzed by experts in different fields.

The geology and hydrology of the study area are described in KBS TR 86-06 and 86-08.

The fracture mineralogy at the Klipperås study site has been investigated by E-L Tullborg (SKB TR 86-10). The relations between the chemical and isotopical composition of the groundwater and the fracture minerals are described in that work.

The importance of groundwater composition in relation to final disposal of radioactive waste is discussed in the final report KBS-3, Volume 2 and 3 (Final storage of Spent Nuclear Fuel - KBS-3; 2 Geology Volume and 3 Barriers Volume) Stockholm, May 1983.

The previously used sampling equipment is described in KBS TR 83-44 and a description of the new mobile field laboratory will be presented in the technical report SKB TR 86-16.



## 2 SAMPLING

The sampled boreholes are core-drilled with a diameter of 56 mm. K1 1 and K1 2 are virtually vertical while K1 9 slopes about 60°. Normally, borehole length is given in the tables, but the corresponding vertical depth is also indicated in Tables 1-2.

Before sampling starts in a borehole, it is first cleaned by means of gas-lift pumping three times with compressed nitrogen. Gas-lift pumping is repeated prior to each new sampling sequence in a borehole.

The sampling equipment (see Section 2.2) is lowered to the level selected for water sampling and is allowed to work there for 3-4 days before sampling starts. Successive sampling for at least 8-9 days makes it possible to follow changes in the composition of the water, which can be due to activities in the borehole and/or changing conditions in the rock.

The changes may be due to many factors. They may, for example, derive from drilling water or accidental contamination during the drilling procedure. Slowly declining Eh values may be due to the fact that there was adsorbed oxygen on the surface of the sampling equipment (hose, probe etc.). An example of changes due to natural causes is the fact that several aquifers with different composition can be tapped during the pumping procedure.

In interpreting the analysis results, it is important to know whether the water is subject to external influence or whether the results stem from unaffected groundwater. The sampling periods are therefore made longer than before in order that stable conditions can be achieved.

### 2.1 DRILLING WATER

Drilling water used in the core drilling of the sampling holes is taken from percussion boreholes within the study area and is filtered through mechanical filters of cellulose material (18 CMC 3-2), which separate particles with a diameter greater than 5 µm. The drilling water can penetrate into fractures in the rock and

contaminate the groundwater. In order to get rid of the drilling water to as great an extent as possible, the borehole is gas-lift-pumped both before the hydrological survey and immediately prior to installation of the sampling equipment.

The drilling water for K1 2 and K1 9 was marked with  $0.5 \text{ g/m}^3$  of uranine AP (Na fluorescein,  $\text{C}_{20}\text{H}_{10}\text{Na}_2\text{O}_5$ ) in order to permit traces of drilling water in the sampled waters to be traced. The amount of drilling water found in the analyzed water is reported in Tables 1-2. The measured uranine content in K1 1 only shows the background. It is calculated as "Drilling water" in order to facilitate comparison with other concentrations.

## 2.2 SAMPLING EQUIPMENT

The sampling zone is 5 m long and is sealed off by 1 m wide rubber packers that are expanded to a pressure that is 0.7-0.8 MPa above the groundwater pressure. During sampling of some deeper levels, the measuring zone is only sealed off by an upper packer. This is the case in K1 1, 406 m and in K1 2, 761, 777 and 860 m. The sampling equipment consists of a 2 m long measuring probe and a 3 m long pump. The water intake is thus 5 m below the upper packer. Given borehole lengths refer to the upper packer. The pump, which is made of steel and equipped with teflon seals, has a maximum capacity of 0.12 l/stroke and can pump 200-250 ml/min (about 300 l/d). The water flow is often lower than the pump capacity (Tables 1 and 2), which is due to the fact that the hydraulic conductivity of the rock limits the flow. A schematic illustration of sampling pump, packers and probe is shown in Figure 2-1.

The water is pumped through the probe and then through polyamide hose up to the ground surface, where it goes directly into a measuring chamber located in a refrigerator. The temperature of the refrigerator is approximately the same as that of the pumped-up water. The temperature, pH, pS and redox potential of the water are registered both in the probe and in the measuring chamber. The conductivity and oxygen content of the water are measured in the measuring chamber. A detailed description of the sampling equipment is provided in SKB TR 86-16.

In the measurements in K1 1 during Nov.-Dec. 1983, the probe had not yet been put into use.

## 2.3 SAMPLING FOR LABORATORY ANALYSES AND FREEZING

Sampling is performed via a filter cartridge (Pall/Ultrapor  $0.45 \mu\text{m}$ ) and a PVC hose immediately after the water has passed through the refrigerator (2.2). The sample bottles, which are made of uncoloured polyethylene, are filled from the bottom via a poly-

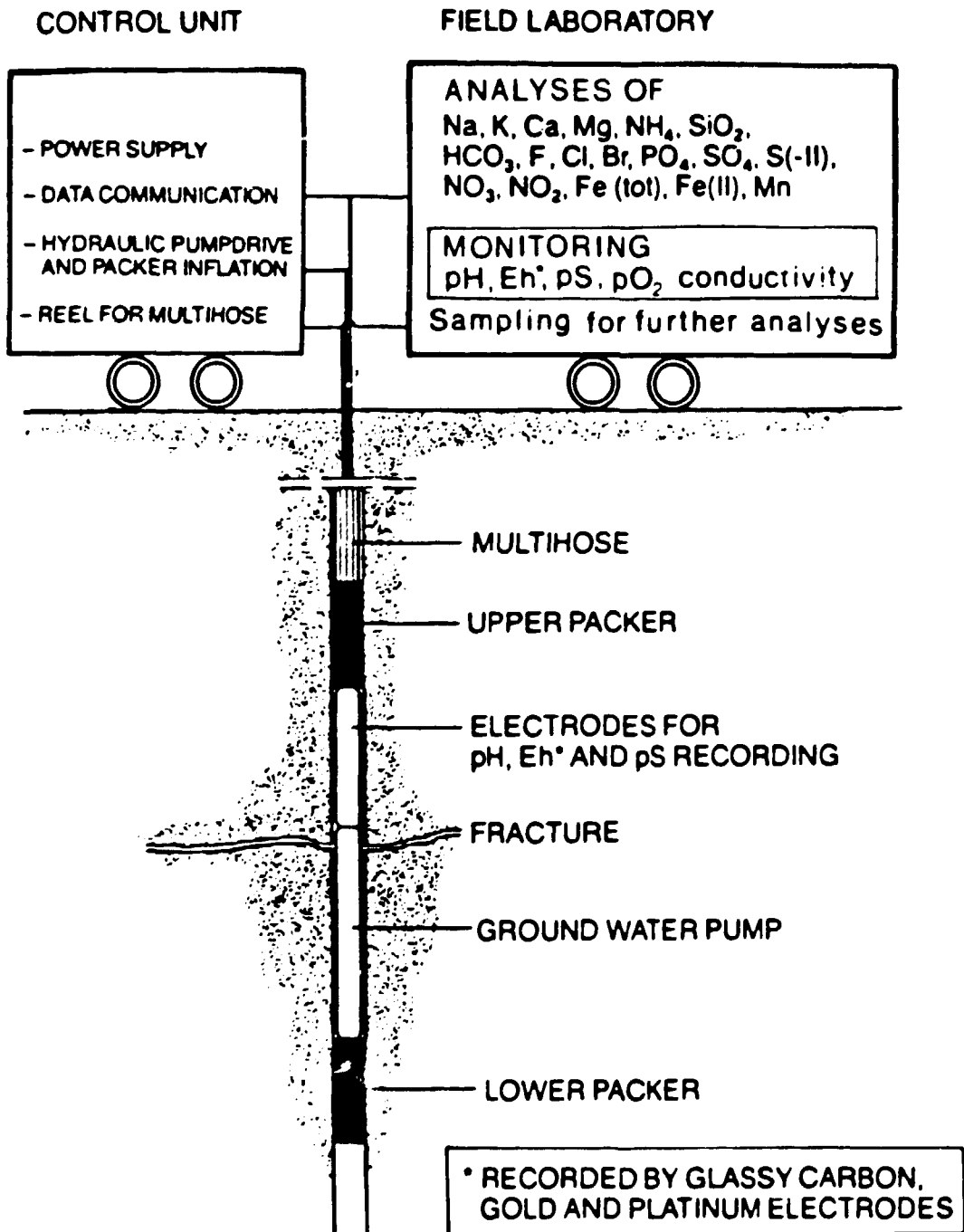


Figure 2-1

ethylene tube. Unpreserved and acid-preserved reference samples are frozen and kept in cold storage to permit supplementary analyses. For the analyses presented in Table 8-16, as well as for the frozen samples, a couple of bottles of water are allowed to overflow before the brim-filled bottle is sealed. The water that is analyzed in the field laboratory is not bottled.

### 2.3.1 Sampling number

Each sampling occasion is assigned a unique sampling number, which is the same for all samples taken during a 24-hour period. The number, which is given in Tables 1-2, is indicated on each individual sample bottle by means of printed and different-coloured labels. Red labels are used for acid-preserved samples intended for metal analysis (1 ml concentrated hydrochloric acid (super-pure) per 100 ml sample).

### 3 AUTOMATICALLY RECORDED MEASUREMENTS

The measurements of the water's redox properties and pH are reported in Tables 4-7 and the  $E^0$  values obtained from the field calibrations are reported in Table 3. pH and conductivity recorded simultaneously in laboratory analyses are presented in Tables 8 and 11.

Conductivity and dissolved oxygen are only recorded at the surface. From 1984 onwards Eh, pH and pS are recorded both at the bottom and at the surface. Glassy carbon, platinum and gold electrodes are used for the Eh measurements. A detailed description of the older measuring equipment is provided in KBS TR 83-44 and of the new equipment in SKB TR 86-16.

#### 3.1 CALIBRATION

All calibration solutions, except the one used for the conductivity cell, are prepared freshly from concentrate from ampoules and deaerated purified water (ion exchanger). In the calibration procedure, the solutions are circulated through the measuring chamber. Bottom probe and surface electrodes are calibrated separately.

For calibration of the pH electrodes, three buffer solutions are prepared with pH 4, 7 and 10. Quinhydrone is added to the buffer solutions with pH 4 and 7 for simultaneous calibration of the Eh electrodes. For calibration of the sulphide electrode, alkaline solutions are prepared that are 0.01 and 0.05 molar with respect to sulphide ion. Recording during the calibration is done automatically. Calculated  $E^0$  values are presented in Table 3.

The oxygen probe is calibrated against air-saturated purified water (ion exchanger) and the conductivity cell against 0.01 and 0.1 mol/l KCl.

## 3.2 MEASUREMENT

At least one value per hour is recorded automatically with the aid of a computer.

It takes some time after each calibration before the water in the measuring chambers is representative of the borehole water and then before the Eh and pS values have stabilized. Values measured 72 hours after calibration are reported for K1 2, 761 m. In other cases, more than a week has passed between calibration and reporting of results. Values resulting from samplings that have obviously failed due to operating disturbances in the field are not reported.

### 3.2.1 Temperature measurement

The temperature is measured in the measuring chambers in order to permit calibration and calculation of the electrode potentials. Only the temperature measured in the bottom probe is representative of the groundwater. It is reported in Tables 4 and 6.

### 3.2.2 Measurement of pH, pS and Eh

The pH and pS measurements are presented in Tables 4 and 6 and the Eh measurements in Tables 5 and 7. pH measurements (surface) simultaneous with the laboratory analyses are also presented in Tables 8 and 11. The electrodes are normally cleaned in connection with calibration. The system normally needs to be undisturbed about one week before the Eh and pS values approach stable levels. The pH value normally stabilizes much faster. Periods with very rapid potential fluctuations are not reported in the tables.

### 3.2.3 Oxygen measurement with probe

The oxygen probe should be calibrated more often than is possible with respect to other electrodes. The quality of the measured oxygen concentrations is therefore always difficult to judge. In this case, however, the values have been considered to be so uncertain that they have not been reported.

## 4 MAIN COMPONENTS OF THE WATER

The analysis results are presented in Tables 8-13 - pH, conductivity, organic carbon and silicon in Tables 8 and 11, metal ions in Tables 9 and 12, anions and ammonium in Tables 10 and 13. pH and conductivity marked with "y" are recorded in the measuring chamber simultaneously with sampling for laboratory analyses.

The chemical analyses confirm that conditions within the sampling area are uniform. Conductivity varies between 23 and 38 mS/m. The sodium concentration is higher than the calcium concentration in the deep water from Kl 9 and in Kl 2, 741 m and 860 m. The opposite situation prevails in the shallower waters from Kl 2, 326 m and Kl 1, 406 m - as well as in the intervening levels (761 m and 777 m) in Kl 2. In Kl 1, the chloride ions dominate, while bicarbonate dominates in all other waters.

### 4.1 LABORATORY ANALYSES

Starting in 1984, the analyses have primarily been carried out in the mobile field laboratory. Control analysis of approximately one sample per week has been carried out at AB IVL in Stockholm.

Bromide and the redox-sensitive parameters ion(II), nitrite, sulphide and sulphate have only been analyzed in the field laboratory and aluminium, lithium, strontium, iodide and organic carbon (TOC) only by IVL.

The following analysis methods have been used:

- pH and conductivity. Values marked with "b" and "y" in Tables 8 and 11 have been recorded automatically from the in-situ probe ("b") and the measuring chambre in field laboratory ("y") before it has come into contact with the air (see Section 3). The control analyses, which were performed in accordance with Swedish Standard (SS), are marked with "1".
- Metal ions. In the field laboratory, sodium and potassium are determined by means of ion chromatography, calcium and magnesium titrimetrically in accordance with SS, iron and manga-

nese spectrophotometrically - iron with ferrozine and manganese with periodate oxidation. At IVL, all metals are determined by means of atomic absorption spectrophotometry.

- Fluoride, chloride, bromide and sulphate have been determined in the field laboratory by means of ion chromatography, while IVL has determined chloride titrimetrically in accordance with Mohr (SS) and fluoride by means of potentiometric titration (SS).
- Nutrients and sulphide photometrically in accordance with SS.
- Silicon has been determined at IVL by means of atomic absorption, while the field laboratory has determined  $\text{SiO}_2$  photometrically (yellow silicon molybdate complex).
- Bicarbonate has been determined titrimetrically as alkalinity at pH 5.4 in accordance with SS.
- TOC has been determined with a carbon analyzer from Astro.
- Iodide has been determined photometrically by means of the "Leuco Crystal Violet Method".

## 4.2 SAMPLING

The water samples are taken through a valve immediately after the refrigerator (2.2). All sampling water passes a filter cartridge with a pore diameter of  $0.45 \mu\text{m}$  before it is sampled except in sampling for determination of iron and manganese where a polycarbonate membrane ( $0.4 \mu\text{m}$ ) is used as from July 1985. Analysis of the particulate matter (Table 14) shows that a considerable portion of the iron can consist of small particles, which can be smaller than  $0.4 \mu\text{m}$ .

## 4.3 TRANSPORT OF SAMPLES

Samples to the control laboratory are packed in specially made cases. The cases are mailed "express" on the afternoon of the sampling day and delivered to the laboratory the following morning. No samples were sent on Fridays or Saturdays, since the samples could then not be taken care of by the laboratory until the following Monday.



## 5 ASSESSMENT OF ANALYSIS RESULTS

The judgement below is given only from an analytical viewpoint based on available information on the analyses - double values, scatter and previous experience. Evaluation of the results from other viewpoints will be performed in connection with their use by experts within different fields.

In general, it can be said that the measurements with the new in-situ probe, as well as the analyses in the mobile field laboratory, have succeeded beyond expectation.

### 5.1 AUTOMATIC RECORDINGS

Equilibrium is achieved in the in-situ probe faster than at the surface, which is probably because there is adsorbed oxygen in lines etc. that affects the water during its transport to the surface. After a few days' pumping, the differences have generally been evened out, and after a longer period of measurement, the agreement between in-situ ("b") and the surface ("y") is very good, as is shown in Tables 4-7. Obviously incorrect results are not reported.

#### 5.1.1 pH and conductivity

The pH of all waters is around 8. The highest value, pH 8.7, was measured in the deepest water (K1 2, 860 m).

There is a small difference between pH measured at the in-situ and at the surface, which is probably due to differences in the carbon dioxide balance. Laboratory verifications show good agreement with the values recorded at the surface.

### 5.1.2 Redox potential

The redox potential was measured simultaneously with platinum, gold and glassy carbon electrodes placed in the in-situ probe and in the measuring chamber at the surface. All Eh values are approximately -300 mV. The good agreement between the measurements makes it probable that they reflect the actual state of the water. Observe, however, the unusually high contamination with drilling water at the deeper levels in Kl 2. The extent of contamination with drilling water in Kl 1 is not known (2.1).

### 5.1.3 pS

The pS value depends on total content of sulphide and pH. However, at low sulphide contents the sulphide electrode measures Eh instead of pS. Therefore pS has to be compared to Eh. It is recommended that the laboratory values of sulphide content are used first hand.

### 5.1.4 Measurement of conductivity

The conductivity measurements (Tables 8 and 11) have been consistently stable and exhibit good agreement with the control analysis in Kl 2, 860 m (Table 14).

## 5.2 **MOBILE FIELD LABORATORY**

In the field laboratory, double analyses are performed of all analysis parameters. Approximately once a week samples are sent to AB IVL in Stockholm for control analysis of the stable ions. Iron(II), sulphate, sulphide, bromide and nitrite are only analyzed in the field laboratory and TOC, strontium, aluminium and lithium only at IVL.

The analyses where the results of the field laboratory and the control laboratory do not agree are commented on below. For the sake of continuity in the measurement series, the results of the field laboratory are given unless otherwise specified.

### 5.2.1 Potassium

The concentration is uniformly low, around 1 mg/l. For Kl 9, IVL's analyses are consistently 0.1-0.2 mg/l lower than the mobile laboratory's.

### 5.2.2 Calcium and magnesium

The determination is performed titrimetrically with EDTA in the field laboratory. In the analysis, both the sum of calcium and magnesium and calcium alone are determined. The latter analysis is the more difficult of the two. Magnesium is determined as the difference between the two results.

The scatter in the analysis results is relatively great and the largest relative deviation from the control laboratory is found, naturally enough, in the magnesium concentration. If the mole sum (Ca + Mg) is considered, the scatter is acceptable and the agreement with the control laboratory good.

### 5.2.3 Iron

The colorimetric determination in the field laboratory shows that the dissolved iron is present as ferrous iron, i.e. iron(II). The control analysis of the total concentration performed by means of atomic absorption spectrophotometry shows good agreement in Kl 9, but gives roughly twice the value in Kl 1 and Kl 2. The analyses of particulate matter (Table 14) show that a considerable portion of the particulate iron in Kl 1 and Kl 2 is present in the form of particles smaller than 0.4  $\mu\text{m}$ .

One explanation for the difference in the analysis results is that the particulate matter has not been completely dissolved in the colorimetric analysis. This assumption is confirmed by the unusually great scatter in the results from the field laboratory. The analyses are performed in acid solution, but the sample has not been heat-treated in an autoclave, as is prescribed in Swedish Standard. In other words, the scatter could be due to the fact that a varying portion of the particulate iron has been undissolved during the analysis, owing to the fact that the sample has been acidified for varying lengths of time prior to the analysis.

Another explanation for the scatter in the results could be the column filter (0.45  $\mu\text{m}$ ) that has been used for all sample water in the field laboratory. The same filter is used a couple of days in succession, and the longer it is used the more particles with pore diameter less than 0.45  $\mu\text{m}$  can be assumed to be retained in the filter. In order to avoid this source of error, water for iron and manganese analysis has been filtered through a polycarbonate membrane with a pore diameter of 0.4  $\mu\text{m}$  since July 1985.

### 5.2.4 Fluoride

In the ion chromatographic analysis, the fluoride peak comes right at the beginning of the chromatogram and is therefore difficult to evaluate. In cases of poor agreement, IVL's results are therefore reported.

**5.2.5 Ammonium and nitrate**

The concentrations are too low for the ion chromatograph. IWL's results have therefore been reported. As of 85-08-23 (419), the field laboratory also analyzes ammonium photometrically in accordance with Swedish Standard.

## 6 PARTICULATE MATTER

For determination of the chemical composition of the particulate matter, the water has been filtered through three membrane filters of polycarbonate with successively decreasing pore size - nominal pore diameter 0.4, 0.2 and 0.05  $\mu\text{m}$ . Scandlab in Sollentuna has determined aluminium, calcium, iron, manganese, silicon and sulphur on the membranes. The results are reported as  $\mu\text{g/l}$  of filtered sample in Table 14.

## 7 ISOTOPE ANALYSIS

Isotope analysis of light elements in the water is performed primarily in order to permit calculations of the age and origin of the water. The heavy radioactive elements are determined because the natural background levels are of great interest for the SKB project.

The analyses were performed at the following laboratories: Laboratory for Isotope Geology, Stockholm (see Section 7.1 and 7.2), Department of Physical Geography, Uppsala University (see Section 7.3), Studsvik Energiteknik, Nyköping (see Section 7.4).

### 7.1 TRITIUM

Owing to its short half-life (about 12 years), tritium is an important isotope in hydrological studies. The amount of tritium in the atmosphere has increased drastically due to experiments with nuclear fission. However, the results are becoming increasingly difficult to interpret the longer the weapons tests continue. At the sampling in Kl 1 during December 1983, the tritium concentration lay at or below the detection limit. When the samplings were resumed in June 1985, 6-7 TU tritium was measured.

The results of sampling in Kl 1 and Kl 2 are presented in the Table below. The tritium concentration is given in the unit TU, which is the number of tritium atoms per  $10^{18}$  hydrogen atoms.

## Isotopes of hydrogen, oxygen and sulphur

Bore-hole	Length m	Date sampling	D o/oo	Tr TU	O-18 o/oo	O-18* o/oo	S-34 o/oo
K1 1	406	83-11-30	-85.7	3		-11.96	
K1 1	406	83-12-02		3			
K1 1	406	83-12-06	-86.3	3		-12.02	
K1 1	406	83-12-08		3			
K1 1	406	83-12-12	-86.5			-12.11	
K1 1	406	83-12-13					7.0
K1 1	406	83-12-14		3			
K1 1	406	83-12-15		3			9.0
K1 1	406	85-06-26		7			
K1 1	406	85-06-29			-11.90		
K1 1	406	85-07-01		6			
K1 2	326	84-12-06			-12.35		
K1 2	326	84-12-10		3			
K1 2	741	84-11-06		13	-11.31		
K1 2	751	84-10-18		25			
K1 9	696	85-08-19		3			
K1 9	696	85-08-29		2			
K1 9	696	85-09-03			-11.93		

## 7.2

## CARBON ISOTOPES

The determination was used for dating by means of the carbon-14 method. The water's contents of carbon dioxide and carbonate have to be concentrated prior to the determination. It is of the utmost importance that the concentrate not be contaminated by carbon-containing chemicals or by contact with air.

The age determination is reported in the Table below as "age BP" and the age after correction for carbon-13 content as "age BP, corr".

## Groundwater age

Bore-hole	Length m	Date sampling	Age BP year	Age BP corr	C-13 o/oo
K1 1	406	83-12-06	28375	28500	-17.0
K1 9	696	85-09-03	30795	30295	-15.7

### 7.2.1 Sample preparation

A polyethylene barrel holding 130 l and filled from the start with nitrogen is filled with water. Hydrochloric acid is added in order to break down carbonates in the water to carbon dioxide. A nitrogen gas stream is then used to drive the carbon dioxide over to a wash bottle containing carbonate-free sodium hydroxide.

### 7.3 DEUTERIUM, OXYGEN AND SULPHUR

The analyses provide information on the age of the water and on the climatic conditions prevailing at the time of infiltration (see the table in Section 7.1).

The concentrations in the table of Section 7.1 refer to deviations in per mill from SMOW (Standard Mean Oceanic Water).

### 7.4 URANIUM, THORIUM, RADIUM AND RADON

The natural concentration of these elements in the groundwater is of great interest to the project. The analyses are reported in Table 15. The concentrations for U, Ra and Rn are given in Bq/l. The following relationships apply: 39.4  $\mu\text{g}$  U per Bq,  $2.71 \times 10^{-5}$   $\mu\text{g}$  Ra-226 per Bq,  $1.76 \times 10^{-10}$   $\mu\text{g}$  Rn-222 per Bq.



## 8 GAS ANALYSIS

In the samples from Kl 1 and Kl 2, nitrogen, oxygen, hydrogen, carbon dioxide, helium, argon and methane were determined in the gas that spontaneously leaves the water on passage through a Horst bottle. AGA SpecialGas, Lidingö, performed the analyses.

### Gas analysis

Bore-hole	Length m	Date sampling	Water- vol l	Gas- vol ml	N2 %	O2 %	H2 %	CO2 %	He %	Ar %	CH4 %
Kl 1	406	83-12-07	9	105	94.5			.03	.30		
Kl 1	406	83-12-15			96.8			.03	.21		
Kl 1	406	85-06-29	1	205	97.2	.12	.002	.01	.07	.08	.016
Kl 2	326	84-12-09			96.0	.10	.050	.10	.22	1.40	.120

Besides the gas phase's percentage content of the analyzed gases, the table below also shows the amount of water that has passed through the Horst bottle and the gas volume obtained. The concentrations cannot be related directly to the water volume, since the conditions of degassing are uncertain.

Table 1

Bore-hole	Length m	Depth m	Date	Sampling No	W. flow ml/min	Drilling water, %			
KL01	0406	0398	83-11-23	1001	52.0				
			83-11-24	1002	46.0				
			83-11-29	1003					
			83-11-30	1004					
			83-12-01	1005					
			83-12-02	1006					
			83-12-05	1007					
			83-12-06	1008					
			83-12-07	1009					
			83-12-08	1010	50.0				
			83-12-12	1011					
			83-12-13	1012	45.0				
			83-12-14	1013					
			83-12-15	1014					
			85-06-17	1156	45.5				
			85-06-17	1157					
			85-06-18	1158	25.0				
			85-06-22	1160	35.0				
			85-06-23	1161	28.0	.03			
			85-06-25	1162	26.0				
			85-06-25	1163	32.0	.02			
			85-06-26	1164	20.0	.02			
			85-06-27	1165	30.0	.02			
			KL09	0696	0581	85-08-13	1170	203.0	.01
						85-08-14	1171	207.0	
						85-08-15	1172	202.0	
						85-08-16	1173	208.0	
85-08-18	1174	195.0							
85-08-18	1175	194.0							
85-08-19	1176	194.0							
85-08-20	1177	188.0							
85-08-21	1178	186.0							
85-08-22	1178	185.0				.01			
85-08-23	1179	180.0							
85-08-26	1182	205.0							
85-08-27	1183	205.0							
85-08-28	1184	197.0							
85-08-29	1185	204.0							
85-08-30	1186	203.0							
85-09-02	1188	202.0				.01			
85-09-03	1189	200.0							
85-09-04	1190	202.0							
85-09-05	1191	195.0							

Bore-hole	Length m	Depth m	Date	Sampling No	W. flow ml/min	Drilling water, %
KL02	0326	0320	84-11-15	1099	47.0	5.32
			84-11-16	1100	54.0	1.81
			84-11-17	1101	50.0	1.83
			84-11-19	1103	47.0	1.42
			84-11-20	1104	43.0	1.32
			84-11-21	1105	44.0	1.27
			84-11-22	1106	43.0	1.24
			84-11-24	1108	40.0	1.20
			84-11-26	1110	41.0	1.16
			84-11-27	1111	45.0	1.15
			84-11-28	1112	43.0	1.13
			84-11-29	1113	45.0	1.13
			84-11-30	1114	43.0	1.12
			84-12-03	1117	52.0	1.10
			84-12-04	1118	48.0	1.11
			84-12-05	1119	48.0	1.09
			84-12-06	1120	41.0	1.08
			84-12-07	1121	43.0	1.08
			KL02	0741	0727	84-10-25
84-10-26	1082	71.0				6.44
84-10-27	1083	76.0				6.86
84-10-28	1084	73.0				7.69
84-10-29	1085	71.0				7.21
84-10-30	1086	73.0				7.18
84-10-31	1087	76.0				7.01
84-11-01	1088	74.0				6.97
84-11-02	1089	75.0				6.90
84-11-03	1090	75.0				7.06
84-11-04	1091	73.0				6.60
84-11-05	1092	72.0				6.47
84-11-06	1093	71.0				5.99
KL02	0761	0746	84-10-11	1069	170.0	5.32
			84-10-12	1070	165.0	3.15
			84-10-13	1071	175.0	4.29
			84-10-14	1072	175.0	4.74
			84-10-15	1073	172.0	6.02
			84-10-16	1074	172.0	6.87
			84-10-17	1075	173.0	4.78
			84-10-18	1076	170.0	5.23
			84-10-19	1077	170.0	5.09
			KL02	0777	0762	84-10-08
84-10-09	1067	170.0				4.20
84-10-22	1078	186.0				4.56
84-10-23	1079	187.0				4.39
84-10-24	1080	187.0				5.01
KL02	0860	0843	85-05-20	1150		4.54
			85-05-21	1151	79.0	
			85-05-22	1152	84.0	4.17
			85-05-23	1153	80.0	3.80
			85-06-05	1155		3.50

E<sup>o</sup>-values (mV) obtained from the field calibrations

Bore-hole	Calibr date	Used until or from	pH. b	pH. y	C. b	Pt. b	Au. b	C. y	Pt. y	Au. y	C. y es	pS. b	pS. y
KL01	83-11-22			435				254	254				- 860
	83-12-19	11-23		435				254	251				- 860
	85-06-13		206	380	179	207	198	256	256	258	221	- 656	- 902
	85-07-03	06-20	213	373	193	191	193	262	262	265	233	- 663	- 894
KL02	84-10-05		28		392	392	392						- 998
	84-10-09	11-13		366				270	269	273	208		- 915
	84-12-13	11-14	18	370	404	401	402	266	267	269	248	-1009	- 504
	85-05-09	05-23	21	384	394	391	390	252	251	251	211	-1028	- 893
	85-05-29		-114		389	389	391						- 847
KL09	85-08-09		17	379	382	382	385	259	259	259	240	-1052	- 895
	85-09-06	08-22	25	369	386	386	386	266	266	267	268	-1025	- 890

FIELD MEASUREMENT - Temp, pH and pS  
(b = bottom, y = surface)

Bore-hole	Length m	Datum	K1	Temp, b oC	pH, b	pH, y	pS, b	pS, y			
KL01	0406	83-11-30	08 04			8 42		11 27			
		83-12-01	08 06			8 47		11 38			
		83-12-02	06 35			8 45		11 45			
		83-12-05	08 45			8 45		11 18			
		83-12-06	08 10			8 43		11 03			
		83-12-07	07 57			8 50		10 96			
		83-12-08	08 12			8 48		10 96			
		83-12-09	10 10			8 48		10 95			
		83-12-12	08 15			8 45		10 71			
		83-12-13	08 17			8 50		10 53			
		83-12-14	08 00			8 53		10 63			
		83-12-15	07 58			8 49		10 51			
		83-12-16	06 53			8 53		10 38			
		83-12-19	07 53			8 48		10 28			
		85-06-24	08 12			12 20		8 35	11 92		
		85-06-25	08 12			12 20		8 51	11 62		
		85-06-26	08 25			12 21		8 51	11 65		
		85-06-27	08 25			12 21		8 57	11 64		
		85-06-28	09 21			12 22	8 15	8 60	5 62	11 68	
		85-06-29	08 21			12 22	8 07	8 60	5 65	11 68	
		85-06-30	08 21			12 21	8 12	8 57	5 47	11 60	
		85-07-01	08 21			12 22	8 12	8 60	5 40	11 62	
		85-07-02	08 21			12 21	8 22	8 65	5 14	11 79	
		KI 09	0696	85-08-23	08 00		14 94	7 50	8 04	13 38	12 00
				85-08-24	08 00		14 94	7 52	8 05	13 33	12 03
				85-08-25	08 00		14 95	7 55	8 02	13 21	12 03
				85-08-26	08 00		14 95	7 59	8 04	13 09	12 05
				85-08-27	08 00		14 95	7 70	8 04	12 77	12 03
				85-08-28	08 02		14 95	7 78	8 07	12 53	12 07
				85-08-29	08 00		14 95	7 78	8 03	12 46	12 00
85-08-30	08 18				14 95	7 62	8 07	12 79	12 05		
85-08-31	08 18				14 95	7 60	8 06	12 81	12 00		
85-09-01	08 18				14 96	7 60	8 03	12 80	12 04		
85-09-02	08 13				14 96	7 59	8 07	12 80	12 11		
85-09-03	08 13				14 96	7 60	8 07	12 82	12 13		
85-09-04	08 13				14 96	7 60	8 04	12 84	12 11		
85-09-05	08 13				14 95	7 60	8 06	12 84	12 12		

FIELD MEASUREMENT - Eh  
 (Bottom. y = surface)

Bore-hole	Length m	Datum	K1	Eh-C. b mV	Eh-Pt. b mV	Eh-Au. b mV	Eh-C. y mV	Eh-Pt. y mV	Eh-Au. y mV	Eh-C. y ex. mV		
K101	0406	83-11-30	08 04				-179					
		83-12-01	08 06				-217					
		83-12-02	06 35				-232					
		83-12-05	08 45				-300					
		83-12-06	08 10				-303					
		83-12-07	07 57				-308					
		83-12-08	08 12				-308	-389				
		83-12-09	10 10				-306	-335				
		83-12-12	08 15				-310	-283				
		83-12-13	08 17				-313	-295				
		83-12-14	08 00				-312	-271				
		83-12-15	07 58				-313	-289				
		83-12-16	06 53				-315	-305				
		83-12-19	07 53				-312	-305				
		85-06-24	08 12				-244	-285			-154	
		85-06-25	08 12				-309	-303			-222	
		85-06-26	08 25				-314	-311			-252	
		85-06-27	08 25				-318	-314			-308	
		85-06-28	09 21			-311	-195	-223	-318	-316	-230	-319
		85-06-29	08 21			-304	-197	-265	-319	-318	-236	-323
85-06-30	08 21			-306	-273	-295	-320	-319	-295	-327		
85-07-01	08 21			-305	-288	-299	-320	-320	-296	-330		
85-07-02	08 21			-309	-303	-312	-320	-321	-297	-329		
K109	0696	85-08-23	08 00		-197	-217	-213	-35	-126		-111	
		85-08-24	08 00		-202	-268	-218	-186	-213		-134	
		85-08-25	08 00		-207	-274	-224	-213	-223		-149	
		85-08-26	08 00		-211	-280	-272	-221	-273		-187	
		85-08-27	08 00		-220	-297	-292	-278	-281		-207	
		85-08-28	08 02		-228	-324	-322	-281	-284		-256	
		85-08-29	08 00		-273	-340	-333	-284	-287		-281	
		85-08-30	08 18		-268	-283	-276	-285	-289		-287	
		85-08-31	08 18		-268	-274	-271	-287	-291		-289	
		85-09-01	08 18		-270	-274	-271	-287	-290		-289	
		85-09-02	08 13		-271	-274	-271	-287	-291		-291	
		85-09-03	08 13		-273	-276	-273	-287	-290		-292	
		85-09-04	08 13		-274	-276	-274	-287	-291		-293	
		85-09-05	08 13		-275	-278	-274	-287	-290		-294	

FIELD MEASUREMENT - Temp, pH and pS  
 (b = bottom, y = surface)

Bore-hole	Length m	Datum	K1	Temp. b oC	pH. b	pH. y	pS. b	pS. y
KL02	0326	84-11-16	08 00	11 31	7 76	8 16	9 66	10 94
		84-11-17	08 00	11 31	7 71	8 12	9 73	11 17
		84-11-18	08 00	11 31	7 71	8 13	9 83	11 51
		84-11-19	08 00	11 32	7 68	8 14	9 92	11 80
		84-11-20	08 00	11 32	7 67	8 09	10 05	11 89
		84-11-21	08 00	11 33	7 66	8 06	10 08	11 93
		84-11-22	07 00	11 32	7 65	8 07	10 15	11 98
		84-11-23	08 00	11 32	7 65	8 04	10 17	12 00
		84-11-24	08 00	11 33	7 64	8 00	10 22	11 97
		84-11-25	08 00	11 32	7 64	7 97	10 20	11 93
		84-11-26	08 00	11 33	7 63	7 99	10 22	11 96
		84-11-27	08 00	11 33	7 63	8 12	10 22	12 11
		84-11-28	08 46	11 33	7 62	8 06	10 36	12 00
		84-11-29	08 00	11 33	7 62	8 03	10 49	11 97
		84-11-30	08 00	11 34	7 62	8 03	10 51	11 97
		84-12-01	08 00	11 34	7 61	8 05	10 66	11 99
		84-12-02	08 00	11 33	7 61	8 07	10 66	12 03
		84-12-04	08 00	11 34	7 60	8 08	10 58	11 98
		84-12-05	08 00	11 34	7 60	8 12	10 66	12 03
		84-12-07	08 00	11 34	7 59	8 11	10 77	11 98
		84-12-08	08 00	11 34	7 60	8 04	10 79	11 90
		84-12-09	08 00	11 34	7 60	8 07	10 77	11 95
		84-12-10	08 00	11 34	7 60	8 11	10 77	11 99
84-12-11	08 00	11 34	7 60	8 12	10 75	11 99		
KL02	0623	84-11-08	08 00	15 49	7 91	7 69	9 13	12 48
		84-11-09	08 00	15 50	7 99	7 73	8 94	11 78
		84-11-10	08 00	15 51	8 02	7 86	8 82	11 49
		84-11-11	08 00	15 51	8 04	7 88	8 78	11 32
		84-11-12	12 00	15 51	8 05	7 90	8 69	11 29
		84-11-13	08 00	15 52	8 04	8 04	8 69	11 30
		84-11-14	07 00	15 53	8 03	7 96	8 75	11 05
KL02	0741	84-10-27	08 00	17 19	8 04	7 97	10 17	11 82
		84-10-28	08 00	17 20	8 06	8 11	9 91	11 62
		84-10-29	08 00	17 20	8 09	8 16	9 63	11 47
		84-10-30	08 00	17 21	8 11	8 15	9 39	11 32
		84-10-31	08 00	17 20	8 14	8 11	9 16	11 24
		84-11-01	08 00	17 21	8 15	8 17	8 99	11 26
		84-11-01	15 00	17 21	8 16	8 12	8 96	11 21
		84-11-02	08 00	17 22	8 16	8 19	8 87	11 30
		84-11-03	08 00	17 21	8 17	8 24	8 73	11 29
		84-11-04	08 00	17 22	8 17	8 24	8 70	11 30
		84-11-05	08 00	17 21	8 17	8 24	8 63	11 28
		84-11-06	08 00	17 22	8 16	8 24	8 56	11 27
KL02	0761	84-10-12	08 00	17 51	7 94	7 94	11 43	13 33
		84-10-13	08 00	17 51	7 87	7 98	11 55	13 25
		84-10-14	08 00	17 51	7 86	7 96	11 53	13 25
		84-10-15	08 00	17 52	7 91	8 01	11 41	13 13
		84-10-16	08 00	17 53	7 96	8 04	11 25	13 08
		84-10-17	08 00	17 54	8 02	7 99	11 08	13 00
		84-10-18	08 00	17 53	8 08	8 03	10 92	12 96
		84-10-19	08 00	17 54	8 11	8 02	10 78	12 87
KL02	0777	84-10-21	08 00	17 77	8 13	8 11	10 60	12 92
		84-10-22	08 00	17 78	8 17	8 15	10 45	12 85
		84-10-23	15 00	17 77	8 18	8 11	10 38	12 72
		84-10-24	11 00	17 78	8 18	8 13	10 29	12 68
KL02	0860	85-05-18	08 44	18 88	7 93	8 43	12 58	12 07
		85-05-19	08 44	18 88	8 01	8 56	12 48	11 76
		85-05-20	08 44	18 88	8 07	8 58	12 30	11 34
		85-05-21	08 44	18 88	8 11	8 63	12 17	11 33
		85-05-22	08 56	18 89	8 15	8 72	12 06	11 24
		85-05-23	08 22	18 88	8 12	8 73	12 10	11 08

FIELD MEASUREMENT - Eh  
 (bottom. y = surface)

Bore-hole	Length m	Datum	t	Eh-C. b mV	Eh-Pt. b mV	Eh-Au. b mV	Eh-C. y mV	Eh-Pt. y mV	Eh-Au. y mV	Eh-C. y ex. mV		
KL02	0326	84-11-16	08 00	-339	-347	-345	-316	-353	-281	-314		
		84-11-17	08 00	-335	-343	-340	-304	-323	-276	-310		
		84-11-18	08 00	-330	-340	-336	-288	-300	-272	-306		
		84-11-19	08 00	-326	-336	-332	-265	-280	-270	-302		
		84-11-20	08 00	-321	-331	-325	-259	-280	-269	-301		
		84-11-21	08 00	-321	-327	-322	-258	-280	-271	-300		
		84-11-22	07 00	-318	-323	-317	-258	-279	-273	-300		
		84-11-23	08 00	-318	-319	-314	-258	-279	-276	-300		
		84-11-24	08 00	-317	-316	-311	-261	-280	-277	-302		
		84-11-25	08 00	-317	-314	-310	-260	-278	-277	-304		
		84-11-26	08 00	-319	-313	-309	-259	-280	-277	-305		
		84-11-27	08 00	-319	-312	-308	-261	-279	-274	-302		
		84-11-28	08 46	-311	-306	-302	-260	-281	-277	-305		
		84-11-29	08 00	-305	-298	-296	-260	-282	-276	-307		
		84-11-30	08 00	-307	-297	-297	-260	-282	-276	-309		
		84-12-01	08 00	-298	-287	-287	-261	-282	-278	-310		
		84-12-02	08 00	-301	-287	-288	-261	-282	-275	-310		
		84-12-04	08 00	-303	-289	-288	-262	-282	-274	-311		
		84-12-05	08 00	-303	-287	-287	-263	-284	-269	-310		
		84-12-07	08 00	-300	-283	-285	-262	-283	-268	-312		
		84-12-08	08 00	-300	-282	-283	-264	-285	-270	-314		
		84-12-09	08 00	-302	-284	-285	-263	-284	-265	-314		
		84-12-10	08 00	-303	-284	-286	-263	-284	-266	-313		
		84-12-11	08 00	-303	-285	-286	-263	-284	-263	-313		
		KL02	0623	84-11-08	08 00	-352	-357	-360	-254	-274	-257	-326
				84-11-09	08 00	-358	-365	-367	-294	-344	-274	-323
				84-11-10	08 00	-352	-369	-369	-295	-360	-279	-341
				84-11-11	08 00	-362	-370	-370	-301	-362	-281	-347
84-11-12	12 00			-364	-371	-372	-303	-357	-280	-351		
84-11-13	08 00			-365	-371	-371	-306	-353	-275	-349		
84-11-14	07 00			-363	-370	-369	-310	-351	-278	-353		
KL02	0741	84-10-27	08 00	-311	-327	-313	-265	-348	-273	-307		
		84-10-28	08 00	-320	-321	-315	-275	-367	-281	-318		
		84-10-29	08 00	-328	-322	-318	-281	-376	-287	-325		
		84-10-30	08 00	-337	-325	-321	-289	-382	-292	-328		
		84-10-31	08 00	-345	-328	-325	-289	-386	-294	-333		
		84-11-01	08 00	-350	-332	-330	-289	-387	-296	-338		
		84-11-01	15 00	-351	-333	-331	-293	-386	-296	-341		
		84-11-02	08 00	-354	-337	-336	-290	-386	-294	-343		
		84-11-03	08 00	-357	-342	-351	-291	-386	-294	-347		
		84-11-04	08 00	-359	-354	-358	-292	-386	-295	-348		
		84-11-05	08 00	-361	-359	-363	-296	-384	-292	-351		
		84-11-06	08 00	-362	-364	-368	-297	-383	-294	-353		
		KL02	0761	84-10-12	08 00	-282	-199	-240	-245	-270	19	-33
84-10-13	08 00			-284	-249	-263	-252	-275	61	-146		
84-10-14	08 00			-288	-268	-272	-254	-278	-159	-213		
84-10-15	08 00			-293	-280	-281	-258	-281	-144	-276		
84-10-16	08 00			-298	-290	-289	-259	-282	-169	-288		
84-10-17	08 00			-303	-299	-297	-261	-285	-246	-296		
84-10-18	08 00			-308	-307	-304	-261	-285	-255	-300		
84-10-19	08 00			-311	-313	-309	-262	-287	-262	-302		
KL02	0777			84-10-21	08 00	-314	-320	-315	-261	-285	-266	-300
		84-10-22	08 00	-317	-325	-320	-263	-286	-270	-303		
		84-10-23	15 00	-318	-328	-322	-265	-288	-274	-305		
		84-10-24	11 00	-319	-329	-323	-265	-288	-276	-307		
KL02	0860	85-05-18	08 44	-200	-240	-235	-231	-246		-178		
		85-05-19	08 44	-242	-284	-297	-296	-310		-242		
		85-05-20	08 44	-278	-291	-306	-309	-314		-359		
		85-05-21	08 44	-291	-298	-311	-316	-317	-249	-340		
		85-05-22	08 56	-297	-296	-313	-323	-325	-309	-337		
		85-05-23	08 22	-297	-295	-306	-329	-327	-317	-337		



## KLIPPERASEN - Field parameters and sundries

Bore-hole	Length m	Date	pH.y	Cond. y mS/m	Cond. lab mS/m	TOC mg/l	Si mg/l
KL01	0406	85-06-23		28 8			4 1
		85-06-25	8 2	30 2			4 1
		85-06-25	8 3	31 0	30 9	3 7	4 2
		85-06-26	8 3	31 6			4 4
		85-06-27	8 4	31 8			4 3
		85-07-02			32 5		4 3
		85-07-02					
KL09	0696	85-08-14	7 9	22 9	23 0	5	9 6
		85-08-15	7 9	22 9			9 7
		85-08-16	7 9	22 9			9 7
		85-08-17	7 9	23 0			9 7
		85-08-18	7 9	23 0			10 0
		85-08-19	7 9	23 0	22 9	5	9 8
		85-08-20	7 9	23 0			10 0
		85-08-21	8 0	23 0			10 0
		85-08-23	8 0	22 9			10 0
		85-08-26	8 0	23 0			10 0
		85-08-27	8 0	23 0	22 9	1 2	9 7
		85-08-28	8 0	23 0			9 9
		85-08-29	8 0	23 0			9 9
		85-08-30	8 0	23 0			9 9
		85-09-02	8 0	23 0	22 8	5	
		85-09-03	8 0	23 0			9 6
		85-09-04	8 0	23 0			10 0
		85-09-05	8 0	23 0			10 0

## KLIPPERASEN - Metal ions

Bore-hole	Length m	Date	Na mg/l	K mg/l	Li mg/l	Ca mg/l	Mg mg/l	Sr mg/l	Al mg/l	Mn mg/l	Fe. tot mg/l	Fe2+ mg/l	
KL01	0406	85-06-23	45	9		14	2.6			05	013	012	
		85-06-25	46	9		14	2.2			04	021	021	
		85-06-25	46	1.1	01	14	2.6	28	01	04	016	012	
		85-06-26	47	9		14	2.3			03	006	002	
		85-06-27	48	9		14	2.3			04	010	007	
		85-07-02	48	1.1	01	15		35	04	03			
KL09	0696	85-08-14	15	1.1	015	28	2		021	03	074	066	
		85-08-15	16	1.4							084	071	
		85-08-16	16	1.4							03	071	063
		85-08-17	16									077	069
		85-08-18	16	1.2								081	071
		85-08-19	16	1.3	020				024	03	080		
		85-08-20								03	085	079	
		85-08-21	16	1.2		29	3			04	088	082	
		85-08-23	16	1.2		28	3				092	094	
		85-08-26	15	1.3		29	3				04	092	087
		85-08-27	15	1.3	002	29	3		025	04	100	096	
		85-08-28	16	1.3		29	3			03	098	097	
		85-08-29	16	1.3		29	3			04	096	092	
		85-08-30	16	1.3		29	3			04	096	094	
		85-09-02	16	1.1	001	29	3			05	098	082	
		85-09-03	16	1.0		30	2			04	098	091	
		85-09-04	15	1.0		29	3			04	092	085	
		85-09-05	15	1.0		30	2			04	090	082	

## KLIPPERASEN - Anions + NH4-N

Bore-hole	Length m	Date	HCO3 mg/l	Cl mg/l	F mg/l	Br mg/l	I mg/l	PO4-P mg/l	SO4 mg/l	S-2. mg/l	NO2-N mg/l	NO3-N mg/l	NH4-N mg/l
KLO1	0406	85-06-23	73		3 3	32			001 2 3	01	001		
		85-06-25	77		3 6	34			001 2 3	01	001		
		85-06-25	78		3 8	38		006	001 1 8	15	001	005	01
		85-06-26	80			39			001 1 5	11	001		
		85-06-27	80			40			001 1 3	13	001		
		85-07-02	79		3 9			008		09			
		85-08-14	119		3 6			002		4 4	01	001	01
85-08-15	120							4 5	01	001			
85-08-16	120							4 4	01	001			
85-08-17	120							4 1	01	001			
85-08-18	120							4 1	01	001			
85-08-19	119		3 5			002	003		01	001	01	01	
85-08-20	121							4 0	01	001			
85-08-21	120		3 2					4 5	01	001			
85-08-23	119		3 2					4 4	01	001			
85-08-26	120							4 4	01			01	
85-08-27	120		3 2			002	003	4 4	01	001	04	01	
85-08-28	120		3 1					4 3	02	001		01	
85-08-29	120		2 9					4 1	02			01	
85-08-30	120		3 0		05			4 0	02	001		01	
85-09-02	121		2 9		05	002	001	3 9	01	001	02	01	
85-09-03	121				05			4 0	01	001		01	
85-09-04	121		3 0		04			4 3	01	001		02	
85-09-05	119		3 1		05			4 4	01	001		02	

## KLIPPERASEN - Field parameters and sundries

Bore-hole	Length m	Datum	pH.y	Cond. y mS/m	Cond. lab mS/m	TOC mg/l	Si mg/l		
KL02	0326	84-11-15	7.6	25.5					
		84-11-16	7.6	27.1		11.0			
		84-11-17	7.6	27.7					
		84-11-19	7.6	27.9					
		84-11-20	7.6	27.8		3.0			
		84-11-21	7.6	27.9			7.0		
		84-11-22	7.6	28.0		2.0			
		84-11-24	7.6	28.0					
		84-11-26	7.6	28.1			7.3		
		84-11-27	7.5	28.2			8	7.9	
		84-11-28	7.5	28.1				7.5	
		84-11-29	7.5	28.1				7.6	
		84-11-30	7.5	28.1				7.8	
		84-12-03	7.5	28.1				7.6	
		84-12-04	7.5	28.1			1.2	7.6	
		84-12-05	7.5	28.2				7.4	
		84-12-06	7.5	28.2			2.0	7.5	
		84-12-07	7.5	28.1				7.6	
		KL02	0741	84-10-25	8.6	20.6			3.3
				84-10-26					3.4
84-10-27	7.9			24.0			3.8		
84-10-28	7.9			25.0			3.8		
84-10-29	8.0			24.3			4.2		
84-10-30	8.0			24.8			3.8		
84-10-31	8.0			25.2			4.0		
84-11-01	8.1			25.5			12.0	4.0	
84-11-02	8.1			25.8				4.3	
84-11-03	8.1			26.2				4.1	
84-11-04	8.1			26.5				4.5	
84-11-05	8.1			26.8				4.4	
84-11-06	8.1			27.0			12.0	4.4	
KL02	0761			84-10-11					2.8
		84-10-12					2.8		
		84-10-13					2.8		
		84-10-14					2.7		
		84-10-15					2.7		
		84-10-16					2.5		
		84-10-17					2.5		
		84-10-18	8.0	20.4			2.4		
		84-10-19	8.0	20.5			2.6		
		KL02	0777	84-10-08					
84-10-09									
84-10-22	8.1			20.7			3.0		
84-10-23	8.1			20.8			2.6		
84-10-24							2.6		
KL02	0860	85-05-20					3.9		
		85-05-21	8.6	34.0	33.5	5.3	3.8		
		85-05-22	8.6	35.0			4.9		
		85-05-23	8.6	36.6			5.0		
		85-06-05	8.7	38.5			4.9		

## KLIPPERASEN - Metal ions

Bore-hole	Length m	Datum	Na mg/l	K mg/l	Li mg/l	Ca mg/l	Mg mg/l	Sr mg/l	Al mg/l	Mn mg/l	Fe <sub>2</sub> tot mg/l	Fe <sub>2</sub> <sup>+</sup> mg/l	
KL02	0326	84-11-15	19	1.6		29.0	2.0			25			
		84-11-16				30.0	2.0		17	14	212	209	
		84-11-17	29	1.5		31.0	1.0						
		84-11-19	29			31.0	1.2				07	231	217
		84-11-20	29	1.5		31.0	2.0		07	06	06	230	200
		84-11-21	29	1.3		31.0	2.0				06	171	176
		84-11-22	29	1.0			31.0	1.0		08	05		
		84-11-24					31.0	1.0				203	162
		84-11-26	33	8		30.0	2.0				05	145	138
		84-11-27	28	9		31.0	1.0			09	05	147	141
		84-11-28	27	9		31.0	1.0				05	133	130
		84-11-29	29	1.1		31.0	1.0				06	140	134
		84-11-30	31	1.1		31.0	1.0				06	130	123
		84-12-03	26				31.0	1.0			05	128	125
		84-12-04	24	1.1			31.0	1.0		08	05	126	126
		84-12-05	26				31.0	1.0		09	05	107	102
		84-12-06	27	1.1			30.0	1.0		07	04	105	102
84-12-07					31.0	1.0			04	092	088		
KL02	0741	84-10-25	14	2.0		23.0	4.0			88	199	151	
		84-10-26				18.0	4.0				113	107	
		84-10-27	27	2.0		17.0	3.0				27		
		84-10-28	28	1.1		16.0	2.0						
		84-10-29	34	1.4		16.0	2.0				17	088	079
		84-10-30	36	2.0		16.0	1.0				16		
		84-10-31	35	1.8		16.0	1.0				16		
		84-11-01	35	1.6		16.0	1.0		15		14	058	048
		84-11-02	38	1.1		16.0	1.0				12	045	039
		84-11-03					16.0	1.0			13	045	038
		84-11-04	39	1.6		16.0	1.0				11	068	067
		84-11-05	41	1.8		16.0					11		
		84-11-06	41	1.5		16.0	1.0		15		10	060	059
KL02	0751	84-10-11				23.0	5.0			85	430	410	
		84-10-12	11	3.1		23.0	4.0			77	365	365	
		84-10-13										435	445
		84-10-14	12	3.0		23.0	4.0				73	430	430
		84-10-15	13	3.3		23.0	4.0				72	405	410
KL02	0777	84-10-16	13	3.4		23.0	4.0			69	340	320	
		84-10-17	13	3.3		22.0	4.0			63	310	285	
		84-10-18	13	2.5		22.0	4.0				57	350	345
		84-10-19	13	3.1		22.0	4.0				60	259	253
		84-10-08	9	2.2		24.0	5.5				1.10		
84-10-09	9	2.0		24.0	5.5				94				
84-10-22	15	3.1		23.0	4.0				54				
84-10-23					22.0	4.0					209	201	
84-10-24	16	3.1		22.0	4.0				51	173	159		
KL02	0860	85-05-20	57	1.6		8.4	1.9				11	043	031
		85-05-21	59	1.7	02	8.6	1.8	16	09		10	050	045
		85-05-22	63	1.6		8.3	1.8				10	043	041
		85-05-23	65	1.6		8.2	1.8				07	042	037
		85-06-05	72	1.4		7.9	1.9				06	060	045

## KLIPPERASEN - Anions + NH4-N

Bore-hole	Length m	Datum	HCO3 mg/l	Cl mg/l	F mg/l	Br mg/l	I mg/l	PO4-P mg/l	SO4 mg/l	S-2. mg/l	NO2-N mg/l	NO3-N mg/l	NH4-N mg/l		
KL02	0326	84-11-15	113	14	3 5	08			8	21					
		84-11-16	130	15	2 8		010		4	15					
		84-11-17	132								14				
		84-11-19	132	16	2 9	09			2	11					
		84-11-20	132	16	2 9		010			07					
		84-11-21	138			02			2	10		001	02	02	
		84-11-22	138	17	2 9	05	010		1	09					
		84-11-24													
		84-11-26	139	16	2 9	13			1	08		001		08	
		84-11-27	135	16	2 8	12	010		1	08					
		84-11-28	137	17	2 9	12			1	06		001	01	08	
		84-11-29	135	17	2 8	12			1	06					
		84-11-30	135	17	2 5	13				002	1	05			
		84-12-03	137	16					002	1	04				
		84-12-04	136	16				010	002		07				
		84-12-05	134	17					002		05	001	02	08	
		84-12-06	134	18				010			07				
84-12-07	132	18					002		02						
KL02	0741	84-10-25	102	8	2 9	01			1 1	04					
		84-10-26	102	14	3 6	08			1	08					
		84-10-27	97	15	4 0	09			1	33					
		84-10-28	97	19	4 2	10			1	31					
		84-10-29	98	20	4 3	13			1	26					
		84-10-30	97	20	4 7	17			1	24					
		84-10-31	98	21	4 4	17			1	27					
		84-11-01	97	22	4 6	18	002	001	1	39		001	02	03	
		84-11-02	97	23	4 4	19			1	41					
		84-11-03	97								41				
		84-11-04	97	24	4 1	20				2	40				
		84-11-05	99	23	4 1	21				1					
		84-11-06	99	25	4 7			002	001		36	001	02	01	
KL02	0761	84-10-11	107	6	2 0				8	04					
		84-10-12	106	6		02			8	04					
		84-10-13		6	2 1	03			6						
		84-10-14	106	7	1 9	04			6	03					
		84-10-15	105	6	2 0	03			5						
KL02	0777	84-10-16	106	7	2 3	02			5	04					
		84-10-17	106	8	2 7	04			4	05					
		84-10-18	106	7	2 5	04			3	05					
		84-10-19	105	7	2 4	02			2	05					
		84-10-08	105	6	1 3	02			2 4						
84-10-09	107	6	1 9	03			1 5								
84-10-22	103	8	2 7	05			1	05							
84-10-23	103	8	2 8	05			2	05							
84-10-24	103	8	2 9	03			2	05							
KL02	0860	85-05-20	106	37	5 4	25			1 6	15	001				
		85-05-21	103	37	5 4	25	012	002	1 6	15	001	10	02		
		85-05-22	102	49	5 8	35			1 5	14	001				
		85-05-23	101	51	5 3	42			1 5	12	001				
		85-06-05	97	53	4 8	48			1 3	11	001				

## PARTICULATE MATTER - Chemical composition

Line- hole	Length m	Date sampling	Filter um	Al.p ug/l	Ca.p ug/l	Fe.p ug/l	Mn.p ug/l	Si.p ug/l	S.p ug/l	Fe-tot ng/l	Fe(II) ng/l
AL01	406	85-06-27	05	34.3	20.6	100.6	4	41.6	24.5		
			20	1	5.5	1.3	2	3	9.5	105	100
			40	2	6.5	15.3	2	5.1	9.8	105	096
AL02	326	84-11-27	05	58.4	5.4	20.9	1.0	10.2	33.5		
			05	28.7	6.3	2	1.6	2.0	14.7		
			20	< 1	3.6	6	< 2	< 1	< 1		
			40	3.8	6.8	3	2	1.7	2.5		
AL02	860	85-05-23	05	3.2	6.2	5.3	1	7.5	11.0		
			20	9	4.0	4	1	2.2	6.8	043	002
			40	5.5	4.2	25.6	2	15.9	6.5	043	002
AL09	696	85-08-15	05	3	9.9	3	1	3.2	11.0		
			05	3	4.9	3	1	1.3	6.1		
			20	4	4	< 1	1	2	1.1	067	067
			40	7	3.7	5	1	2.6	6.5	067	067
AL09	696	85-09-05	05	1	7.2	< 1	1	1.4	4.5		
			05	2	8.0	3.1	1	5	9.5		
			20	1	4.6	3	1	3	2.5	086	086
			40	2	1.3	< 1	1	4	1.1	087	019

## Uranium, thorium, radium and radon

Bore-hole	Length m	Date sampling	U Bq/l	Th ug/l	Ra-226 Bq/l	Rn-222 Bq/l
KL01	406	83-12-01	(7.2 ± 3.6)E-3	<1.5 E-2	(6.03 ± 0.34)E-2	1590 ± 50
KL01	406	83-12-06	(1.60 ± 0.32)E-2	<1.6 E-2	(8.14 ± 0.24)E-2	1640 ± 50
KL01	406	85-06-29	(4.4 ± 0.7)E-2	(4.1 ± 1.6)E-3	(7.25 ± 0.20)E-2	252 ± 50
KL02	326	84-12-10	(7.0 ± 1.1)E-2	(1.0 ± 1.8)E-3	(2.87 ± 0.10)E-1	2710 ± 50
KL09	696	85-09-03	(1.43 ± 0.05)E-2	(5.9 ± 3.8)E-3	(6.3 ± 0.3)E-2	221 ± 5



# List of SKB reports

## Annual Reports

1977-78

TR 121

### **KBS Technical Reports 1 - 120.**

Summaries. Stockholm, May 1979.

1979

TR 79-28

### **The KBS Annual Report 1979.**

KBS Technical Reports 79-01 - 79-27.

Summaries. Stockholm, March 1980.

1980

TR 80-26

### **The KBS Annual Report 1980.**

KBS Technical Reports 80-01 - 80-25.

Summaries. Stockholm, March 1981.

1981

TR 81-17

### **The KBS Annual Report 1981.**

KBS Technical Reports 81-01 - 81-16.

Summaries. Stockholm, April 1982.

1982

TR 82-28

### **The KBS Annual Report 1982.**

KBS Technical Reports 82-01 - 82-27.

Summaries. Stockholm, July 1983.

1983

TR 83-77

### **The KBS Annual Report 1983.**

KBS Technical Reports 83-01 - 83-76

Summaries. Stockholm, June 1984.

1984

TR 85-01

### **Annual Research and Development Report 1984**

Including Summaries of Technical Reports Issued during 1984. (Technical Reports 84-01 - 84-19)  
Stockholm June 1985.

1985

TR 85-20

### **Annual Research and Development Report 1985**

Including Summaries of Technical Reports Issued during 1985. (Technical Reports 85-01-85-19)  
Stockholm May 1986.

## Technical Reports

1986

TR 86-01

**I: An analogue validation study of natural radionuclide migration in crystalline rock using uranium-series disequilibrium studies**

**II: A comparison of neutron activation and alpha spectroscopy analyses of thorium in crystalline rocks**

JAT Smellie, Swedish Geological Co. A B MacKenzie and RD Scott, Scottish Universities Research Reactor Centre

February 1986

TR 86-02

**Formation and transport of americium pseudocolloids in aqueous systems**

U Olofsson

Chalmers University of Technology, Gothenburg, Sweden

B Allard

University of Linköping, Sweden

March 26, 1986

TR 86-03

**Redox chemistry of deep groundwaters in Sweden**

D Kirk Nordstrom

US Geological Survey, Menlo Park, USA

Ignasi Puigdomenech

Royal Institute of Technology, Stockholm, Sweden

April 1, 1986

TR 86-04

**Hydrogen production in alpha-irradiated bentonite**

Trygve Eriksen

Royal Institute of Technology, Stockholm, Sweden

Hilbert Christensen

Studsvik Energiteknik AB, Nyköping, Sweden

Erling Bjergbakke

Risø National Laboratory, Roskilde, Denmark

March 1986

TR 86-05

**Preliminary investigations of fracture zones in the Brändan area, Finnsjön study site**

Kaj Ahlbom, Peter Andersson, Lennart Ekman,

Erik Gustafsson, John Smellie,

Swedish Geological Co, Uppsala

Eva-Lena Tullborg, Swedish Geological Co, Goteborg

February 1986

TR 86-06

**Geological and tectonical description of the Klipperås study site**

Andrzej Olkiewicz  
Vladislav Stejskal  
Swedish Geological Company  
Uppsala, June 1986

TR 86-07

**Geophysical investigations at the Klipperås study site**

Stefan Sehlstedt  
Leif Stenberg  
Swedish Geological Company  
Luleå, July 1986

TR 86-08

**Hydrogeological investigations at the Klipperås study site**

Bengt Gentschein  
Swedish Geological Company  
Uppsala, June 1986

TR 86-09

**Geophysical laboratory investigations on core samples from the Klipperås study site**

Leif Stenberg  
Swedish Geological Company  
Luleå, July 1986

TR 86-10

**Fissure fillings from the Klipperås study site**

Eva-Lena Tullborg  
Swedish Geological Company  
Göteborg, June 1986

TR 86-11

**Hydraulic fracturing rock stress measurements in borehole Gi-1, Gideå Study Site, Sweden**

Bjarni Bjarnason and Ove Stephansson  
Division of Rock Mechanics,  
Luleå University of Technology, Sweden  
April 1986

TR 86-12

**PLAN 86— Costs for management of the radioactive waste from nuclear power production**

Swedish Nuclear Fuel and Waste Management Co  
June 1986

TR 86-13

**Radionuclide transport in fast channels in crystalline rock**

Anders Rasmuson, Ivars Neretnieks  
Department of Chemical Engineering  
Royal Institute of Technology, Stockholm  
March 1985

TR 86-14

**Migration of fission products and actinides in compacted bentonite**

Börje Torstenfelt  
Department of Nuclear Chemistry, Chalmers  
University of Technology, Göteborg  
Bert Allard  
Department of water in environment and society, Linköping university, Linköping  
April 24, 1986

TR 86-15

**Biosphere data base revision**

Ulla Bergström, Karin Andersson, Björn Sundblad, Studsvik Energiteknik AB,  
Nyköping  
December 1985

TR 86-16

**Site investigation—equipment for geological, geophysical, hydrogeological and hydrochemical characterization**

Karl-Erik Almén, SKB, Stockholm  
Olle Andersson, IPA-Konsult AB, Oskarshamn  
Bengt Fridh, Bengt-Erik Johansson,  
Mikael Sehlstedt, Swedish Geological Co. Malå  
Kenth Hansson, Olle Olsson, Swedish Geological Co. Uppsala  
Göran Nilsson, Swedish Geological Co. Luleå  
Peter Wikberg, Royal Institute of Technology, Stockholm