P-04-136

Forsmark site investigation

Undisturbed pore water sampling and permeability measurements with BAT filter tips

Soil sampling for pore water analyses

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June 2004

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Keywords: Forsmark, AP PF 400-03-28, Field note no Forsmark 107, BAT filter tips, Pore water sampling, Soil sampling, Permeability measurements, Pore water content.

Abstract

BAT-type filter tips were installed for pore water sampling and measurements of hydraulic conductivity. Furthermore, soil samples were taken for analyses of pore water in the laboratory. The laboratory tests were carried out at two different laboratories, Institute of Geological Sciences, University of Bern, and at SWECO´s soil laboratory, with partly different methods.

Hydraulic conductivity tests were performed in three filter tips placed in till at three different locations within the candidate area at depths approximately 5 to 6 m below ground. The estimated hydraulic conductivities were 4×10^{-8}, 4×10^{-9}, and 9×10^{-9} m/s. From grain size analyses, the tills at these locations have in earlier investigations been classified as sandy till, clayey, sandy, silty till, and boulder clay, respectively. The values are considered low compared with results from slug tests in nearby monitoring wells at approximately the same depths (1 to 3 orders of magnitude lower).

The soil samples for pore water analyses were taken in boulder clay at a depth of 4.6–5.2 m below ground. The mean chloride concentrations of the samples analysed at Institute of Geological Sciences and SWECO were 585 and 736 mg/l, respectively.

The results of the water analyses from the sampling in the BAT-type filter tips are presented separately /4/.

Sammanfattning

Filterspetsar av BAT-typ installerades för provtagning av porvatten och för mätning av hydraulisk konduktivitet. Jordprover togs också ut för laboratorieanalys av porvatten. Laboratorieanalyserna utfördes vid två olika laboratorier med delvis olika metodik, Institute of Geological Sciences, Universitetet i Bern, och SWECO´s jordlaboratorium.

Mätning av den hydrauliska konduktiviteten utfördes i tre filterspetsar placerade i finkornig morän. De uppmätta hydrauliska konduktiviteterna var 4 x 10^{-8}, 4 x 10^{-9}, och 9 x 10^{-9} m/s. Moränen på respektive plats har utifrån kornstorleksanalyser klassats som sandig morän, lerig, sandig, siltig morän och moränlera. De erhållna värden bedöms som låga i jämförelse med resultaten från slugtester i närbelägna grundvattenrör på ungefär motsvarande djup (1–3 tiopotenser lägre).

Jordproverna för porvattenanalys togs i moränlera på ett djup av 4,6–5,2 m under markytan. Medelvärdena för kloridhalterna för analyserna vid Institute of Geological Sciences och SWECO var 585 respektive 736 mg/l.

Resultaten för vattenanalyserna från provtagningen i BAT-spetsarna redovisas separat /4/.

Contents

1 Introduction

This document reports the methodology and results of installation of BAT-type filter tips, permeability measurements and soil water sampling by these tips, and soil sampling for pore water analyses in the Forsmark area during April 2003. The work is one of the activities performed in the site investigation at Forsmark and is a part of the investigation of the hydrogeology of the Quaternary deposits in the area. The work was carried out in accordance with activity plan SKB PF 400-03-28. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	Number	Version
Ostörd porvattenprovtagning och permeabilitetsbestämning med BAT-spetsar samt provtagning av jordprover för analys av porvatten	AP PF 400-03-28	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för jordborrning	SKB MD 630.003	1.0
Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning	SKB MD 600.004	1.0
Instruktion för användning av kemiska produkter och material vid borrning och undersökning	SKB MD 600.006	
Inmätning och avvägning av objekt	SKB MD 110.001	1.0

The location of the boreholes and installed BAT-type filter tips is shown in Figure 1-1 and the x-, y- and z- coordinates are given in Table 1-2. The data of the present activity is stored in SKB´s database SICADA, field note no Forsmark 107.

Table 1-2. Coordinates and type of boreholes and installations.

Borehole	X	Y	Z	Type
SFM0050	6699601.50	1631487.50	3.009	Filter tip for hydraulic conductivity test.
SFM0051	6699600.00	1631488.00	2.183	Filter tip for water sampling.
SFM0052	6698517.90	1633589.70	1.030	Filter tip for hydraulic conductivity test.
SFM0053	6698515.97	1633589.70	0.958	Filter tip for water sampling.
SFM0054	6697068.43	1634793.37	4.408	Filter tip for hydraulic conductivity test.
SFM0055	6697068,55	1634792,70	6,611	Borehole for soil sampling.
SFM0056	6697068.43	1634791.67	3.897	Filter tip for water sampling.

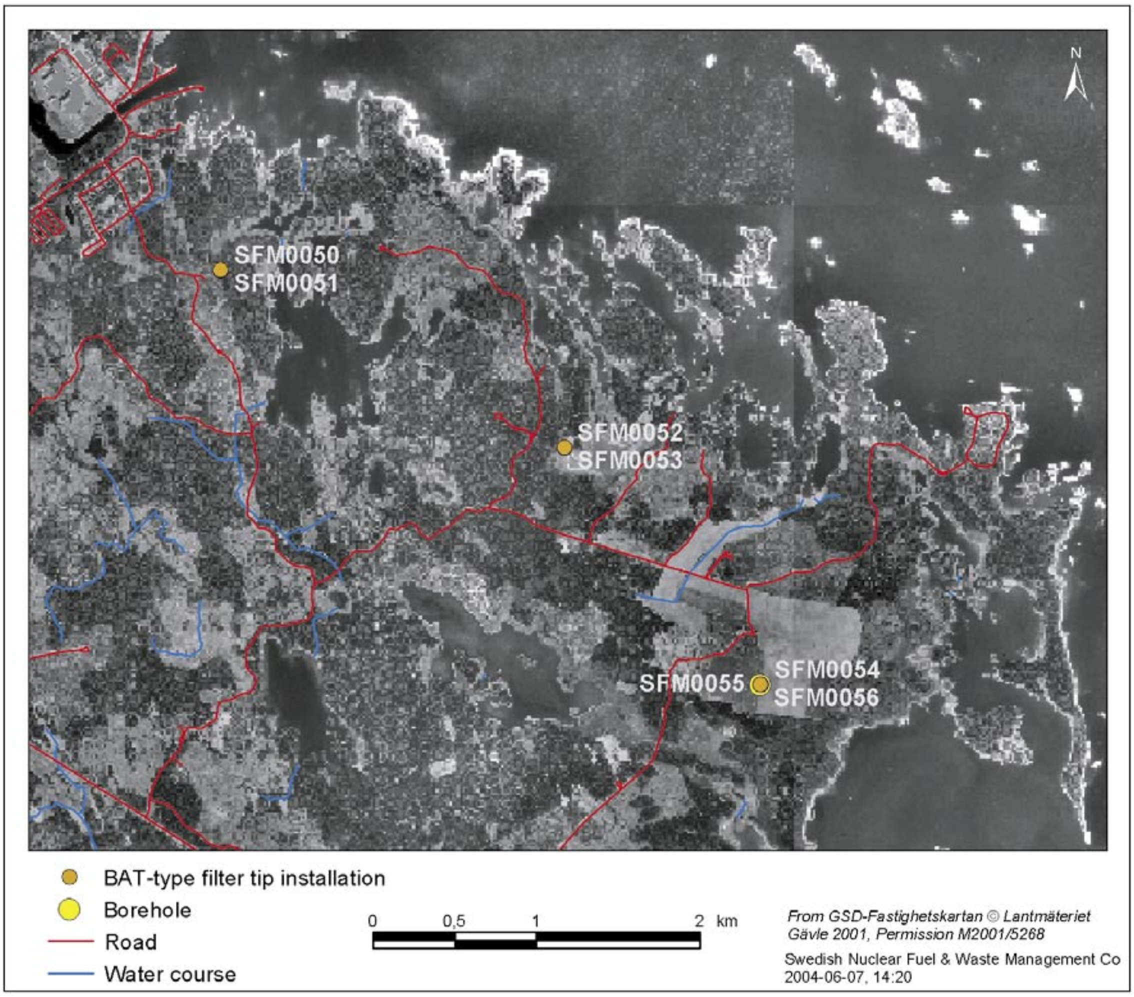


Figure 1-1. *Location of the boreholes and BAT installations.*

2 Objective and scope

The overall objective of the site investigations at Forsmark is described in /1/ and /2/. The specific objective of the present study is to obtain information on pore water chemistry and additional data on the hydraulic conductivity of the till in the candidate area. Three different methods for pore water sampling were to be tested and the results compared.

The soil sampling in SFM0051 was performed within the activity AP PF 400-02-12 "Jordartskartering vid Forsmark, 2002–2003". Profile descriptions are stored in SKB´s database SIDACA, field note no Forsmark 153, and are also presented in /3/. No analyses of grain size distribution have been performed, but the samples are stored to enable future analyses. In SFM0055 soil sampling was performed for pore water analysis at Institute of Geological Sciences, University of Bern, and at the soil laboratory at SWECO VBB.

The results of the analyses of the water sampled by the installed filter tips are presented separately in /4/.

3 Equipment

3.1 Description of equipment/interpretation tools

The weight sounding and auger drilling, soil sampling, and installation of the GeoN BAT-type filter tips were performed with a track driven drilling rig, GeoMachine GM 100 GTT (Figure 3-1).

Figure 3-1. *Drilling rig GeoMachine GM 100 GTT.*

The water sampling in the filter tips was performed by the GeoN BAT-type groundwater sampler and the hydraulic conductivity measurements were performed by the GeoN BAT-type permeameter. In Figure 3-2 the principles of the permeameter equipment are illustrated. The principles for the water sampling are the same but usually the filter diameter is larger as well as the sample container /5/.

A thorough description of the principles of the BAT system is given in /6/.

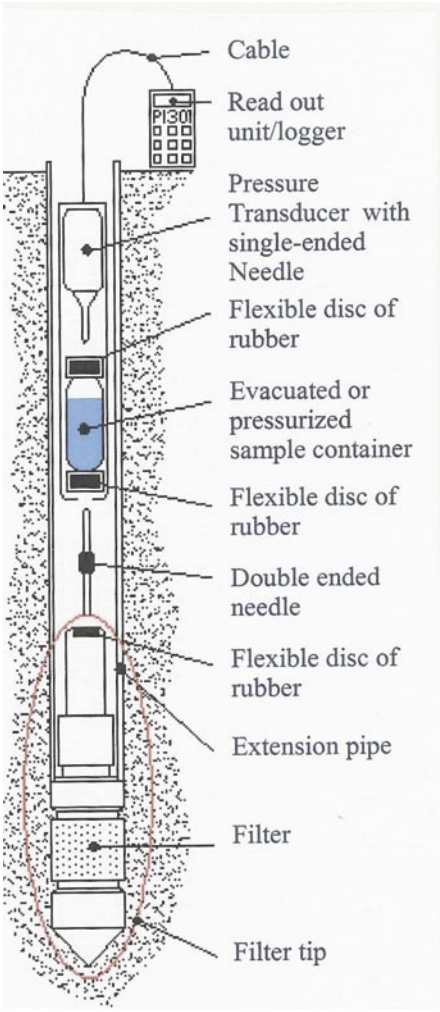


Figure 3-2. *GeoN BAT-type permeameter equipment.*

4 Execution

4.1 General

The drilling and soil sampling were performed according to SKB MD 630.003, version 1.0 and Activity Plan PF FM 400-03-28 (SKB internal documents). The field work included sounding, drilling, soil sampling, installation of GeoN BAT-type filter tips for measurement of hydraulic conductivity and for water sampling, sampling of a first set of water samples by the installed filter tips, and surveying of boreholes and filter tip installations. The content of chloride in the pore water of the soil samples from SFM0055 was analyzed and the hydraulic conductivities were calculated from the permeameter tests in SFM0050, SFM0052 and SFM0054.

4.2 Preparations

In the preparation stage, service and function checks of all equipment were conducted. It was checked that type of fuel, oil and grease was in accordance with SKB´s instructions for chemical products used for drill work (SKB MD 600.006, version 1.0) and for cleaning of equipment (SKB MD 600.004, version 1.0).

The calibration and function check of the equipment for measurements of hydraulic conductivity were carried out by GeoN.

4.3 Execution of field work

The installation of the BAT-type filter tips for measurement of hydraulic conductivity was performed by weight sounding (Ø: 32 mm) while the filter tips for pore water sampling were installed by auger drilling (Ø: 100 mm). The soil sampling in SFM0051 and SFM0055 was performed by auger drilling (Ø: 100 mm).

The soil samples taken in SFM0055, at a depth of 4.6–5.2 m below ground, for pore water analyses were immediately packed in airtight heavy-duty PE-bags.

The key constituents of the GeoN BAT-type equipment for water sampling and measurement of hydraulic conductivity are a filter tip (pore size: 20 micron), an adapter pipe, and an evacuated or pressurized sample container, see Figure 3-2. The filter tip and the sample container are sealed with flexible rubber discs. During the sampling and tests, a connection is established between the filter tip and the sample container by a double ended needle /6/.

The hydraulic conductivity tests were performed by GeoN. The tests can be conducted either as an inflow test or an outflow test /6/. In the inflow test the sample container is filled with gas (partly evacuated) while in the outflow test the container is partly filled with water and partly with compressed air. In SFM0050 and SFM0052 inflow tests were conducted while in SFM0054 both inflow and outflow tests were performed.

4.4 Data handling/post processing

Minutes of the following items have been collected by the activity leader for quality control and filing:

- Activity journals.
- Cleaning of equipment.
- Installation of groundwater monitoring wells and pore pressure devices.
- Discrepancy reports.

Data from soil and water sampling, installation of filter tips and the surveying are reported in Excel files for storage in SKB´s database SICADA (field note no Forsmark 107). During the hydraulic conductivity tests pressure data were automatically recorded. These data were also delivered for filing.

4.5 Analyses and interpretations

4.5.1 Hydraulic conductivity

The hydraulic conductivity test starts with a measurement of the equilibrium pore water pressure in the soil. The initial pressure in the gas/water container is chosen based on the type of test to be performed and the equilibrium pore water pressure. The container is lowered down inside the adapter pipe and temperature equilibrium should be reached before the container is connected to the filter tip by the double ended needle. After connection the change in the pressure in the container is automatically recorded.

The pressure change in the container is analyzed by the falling head theory as defined by Hvorslev /7/:

$$q = FK\,(p_1 - p_0) \tag{1}$$

where q = flow rate (m^3/s), F = flow factor, K = hydraulic conductivity (m/s), p_1 = equilibrium pore pressure (m H_2O), and p_0 = initial pressure in container (m H_2O).

The condition of continuity requires:

$$dV = -\,qdt \tag{2}$$

where dV = volume change (m^3) and dt = time interval (s).

The pressure/volume relationship of the gas filled container can be defined by Boyle´s-Mariottes law:

$$p_0V_0 = p_tV_t \tag{3}$$

where V_0 = initial volume in test container (m^3), p_t = pressure at time t, and V_t = volume at time t.

By combining equations 1-3, the hydraulic conductivity can be derived according to the following expression:

$$K = p_0 V_0/Ft\ [1/p_1 p_0 - 1/p_1 p_t + 1/p_1^2 (\ln p_0 p_1/p_0 * p_t/p_1 p_t)] \quad (4)$$

For a more thorough description of method and interpretation see /6/.

4.5.2 Pore water analysis

The procedure for determination of the chloride concentration in pore water at Institute of Geological Sciences, University of Bern, is described in Appendix 3.

The procedure at SWECO´s soil laboratory for the analysis of the chloride content in the pore water of the soil sample from SFM0055 was as follows:

- weighing in of 5 sub samples of approximately 10 g each,
- addition of 100 ml de-ionized water per sample,
- vibration of the samples for approximately 1 hour followed by settlement of the soil,
- filtration and analysis of the water phase for chloride by ion-chromatography,
- drying of the solid phase for 24 h in 105°C,
- calculation of chloride concentration as mg/kg dry soil.

The obtained chloride concentrations were then recalculated to concentrations in the original pore water expressed as mg/l.

4.6 Nonconformities

The installation of the water sampling filter tip in borehole SFM0055 failed due to a broken adapter pipe. The installation was pulled out. A new installation was made in SFM0056.

The inflow test for determination of the hydraulic conductivity in SFM0054 did not give satisfactory results. The reason for this was probably that the filter tip was not fully water saturated. The filter tip was saturated by an outflow test.

5 Results

5.1 Drilling, soil sampling and installation of filter tips

The location of the boreholes and the installed GeoN BAT-type filter tips is presented in Figure 1-1 and Table 1-2. Profiles with all data are presented in Appendix 1 and photographs of installations are shown in Appendix 4. All filter tips are placed in till below the groundwater level and also below the present sea water level.

5.2 Hydraulic conductivity

The hydraulic conductivity is calculated by GeoN´s software based on equations 1 to 4 in Section 4.5.1. The pressure data recorded in the field are presented in Appendix 2 together with the calculated values of the hydraulic conductivity for each time interval.

Up to 24 values of hydraulic conductivity are calculated for each test. The final interpretation aims at evaluation of which part of the test that gives the best estimate of the hydraulic conductivity. For the inflow tests the last part of the test often gives the best estimate, while the most representative values from an outflow test usually are obtained in the middle part of the test. Due to a probable incomplete saturation of the filter tip in SFM0054, the initial K-values of the outflow test are considered not to be representative. However, the values stabilize at the end of the test (see Appendix 2).

The best estimates of the hydraulic conductivity are presented in Table 5-1.

Table 5-1. Best estimates of hydraulic conductivity.

Borehole	Hydraulic conductivity (m/s)	Type of test
SFM0050	4.0-4.3 x 10^{-8}	Inflow test
SFM0052	4.0 x 10^{-9}	Inflow test
SFM0054	8.5-8.8 x 10^{-9}	Outflow test

The hydraulic conductivity values are considerably lower (1 to 3 orders of magnitude) than the values obtained from slug tests performed in nearby groundwater monitoring wells with screens at approximately the same depth as the filter tips /8, 9/.

The results of the pore water analyses of the soil sample from SFM0055 performed at University of Bern are presented in Appendix 3. The mean chloride concentration was 585 mg/l.

The pore water analyses performed at SWECO´s soil laboratory of a soil sample from the same borehole and depth gave for 5 sub-samples 738, 716, 684, 750, and 793 mg/l, respectively. The mean concentration was 736 mg/l.

All results presented are stored in SKB´s database SICADA, field note no Forsmark 107.

6 References

/1/ **SKB, 2001**. Platsundersökningar. Undersökningsmetoder och generellt genomförande program. SKB R-01-10. Svensk Kärnbränslehantering AB. (In Swedish.)

/2/ **SKB, 2001.** Program för platsundersökning vid Forsmark. SKB R-01-42. Svensk Kärnbränslehantering AB. (In Swedish.)

/3/ **Hedenström A, Sohlenius G, Albrecht J, 2004.** Forsmark site investigation. Stratigraphical and analytical data from auger drillings and pits. P-04-111. Svensk Kärnbränslehantering AB.

/4/ **Borgiel M, Nilsson A-C, 2004.** Forsmark site investigation. Sampling and analyses of near surface groundwater. Results from shallow monitoring wells in soil, BAT filter tips, springs, and private wells, May 2003 to May 2004. SKB P-report in progress. Svensk Kärnbränslehantering AB.

/5/ **www.geonordic.se**

/6/ **Thorstensson B-A, 1984.** A new system for ground water monitoring. Ground Water Monitoring Review, Fall issue.

/7/ **Hvorslev M J, 1951.** Time lag and soil permeability in ground-water observations. Bull. 26, Waterways Experiment Station, U.S. Army Corps of Engineers, Vicksburg, MS.

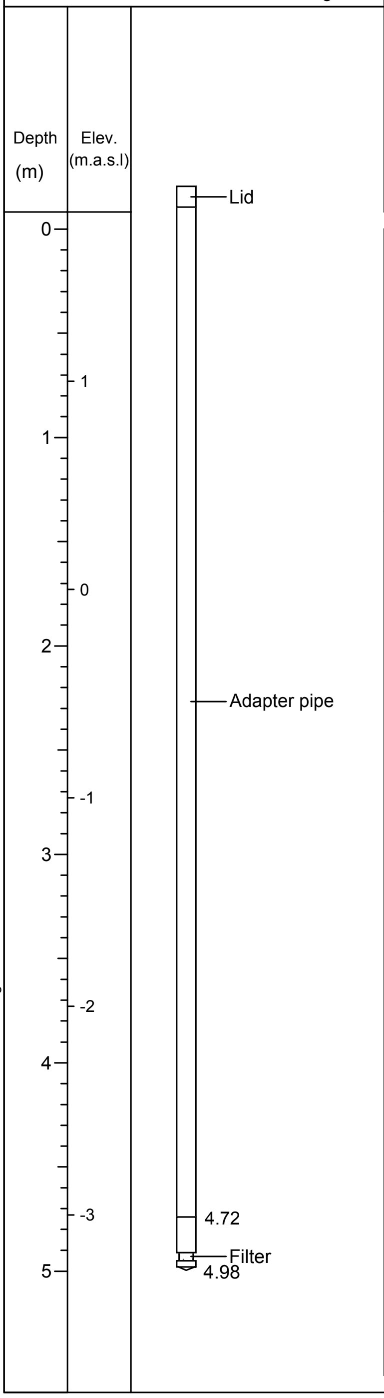
/8/ **Werner K, Johansson P-O, 2003.** Forsmark site investigation. Slug tests in groundwater monitoring wells in soil. SKB P-03-65. Svensk Kärnbränslehantering AB.

/9/ **Werner K, 2004.** Forsmark site investigation. Supplementary slug tests in groundwater monitoring wells in soil. SKB P-04-140. Svensk Kärnbränslehantering AB.

Appendix 1

Profiles of boreholes and filter tip installations

SWECO VIAK	FORSMARK BAT Permeameter SFM0050
Company rep. Nils Lindqvist and Mesgena Gebrezghi	Coordinate system : RT 90 2.5 gon W 0:-15 : RHB 70 Northing : 6699601.50 Easting : 1631487.50
Client: Svensk Kärnbränslehantering AB	Top of stand pipe : 3.009 m.a.s.l Ground elevation : 1.73 m.a.s.l Total pipe length : 6.265 m Groundwater level : - Date of completion : 2003-04-11



Well Construction Information

Drilling method : Weight
Borehole diameter : 32 mm

ADAPTER PIPE

Material : Stainless steel
Inside diameter : 25.6 mm
Outer diameter : 33.7 mm
Total length : 6.00 m

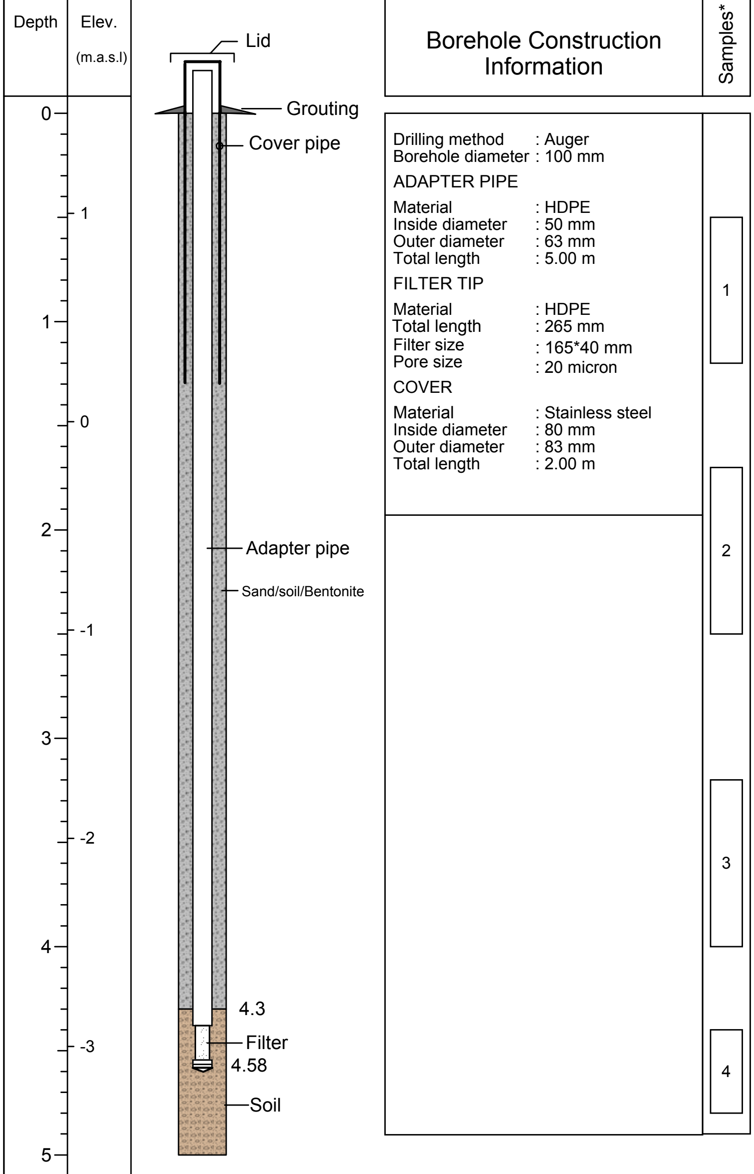
FILTER TIP

Material : HDPF
Filter size : 30*40 mm
Pore size : 20 micro
Total length : 265 mm

05-24-2004 P:\1113\1133510000 SKB Bat-tester\Quicklog\SFM0050.bor

SWECO VIAK	FORSMARK BAT Groundwater sampler SFM0051

Company rep.				
Nils Lindqvist and Mesgena Gebrezghi	Coordinate system	: RT 90 2.5 gon W 0:-15	Top of stand pipe	: 2.183 m.a.s.l
		: RHB 70	Ground elevation	: 1.48 m.a.s.l
	Northing	: 6699600.00	Total pipe length	: 5.265 m
Client: Svensk Kärnbränslehantering AB	Easting	: 1631488.00	Date of completion	: 2003-04-11



Borehole Construction Information

Drilling method : Auger
Borehole diameter : 100 mm

ADAPTER PIPE

Material : HDPE
Inside diameter : 50 mm
Outer diameter : 63 mm
Total length : 5.00 m

FILTER TIP

Material : HDPE
Total length : 265 mm
Filter size : 165*40 mm
Pore size : 20 micron

COVER

Material : Stainless steel
Inside diameter : 80 mm
Outer diameter : 83 mm
Total length : 2.00 m

*SICADA Field note 107

SWECO VIAK

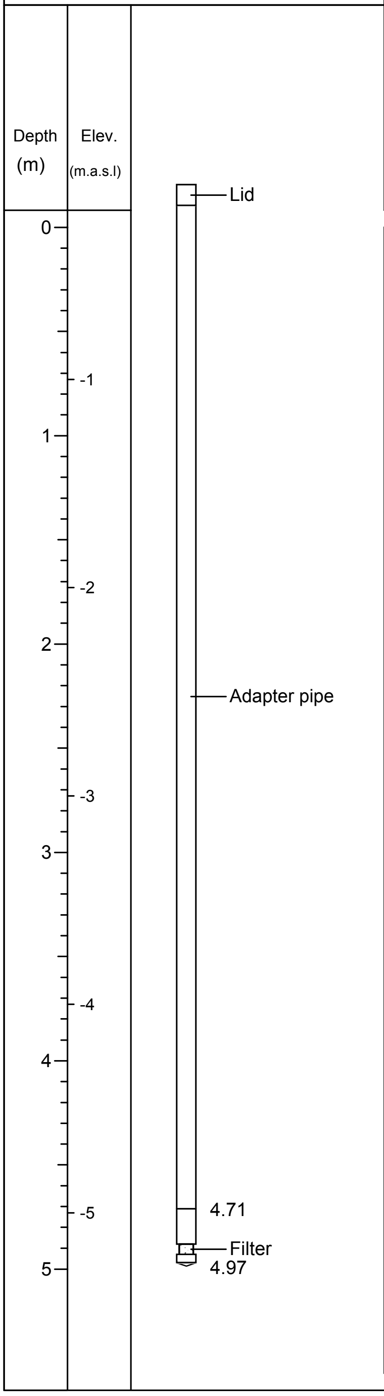
FORSMARK
BAT Permeameter SFM0052

Company rep.

Nils Lindqvist and Mesgena Gebrezghi

Client: Svensk Kärnbränslehantering AB

Coordinate system	: RT 90 2.5 gon W 0:-15	Top of stand pipe	: 1.030 m.a.s.l
	: RHB 70	Ground elevation	: -0.27 m.a.s.l
Northing	: 6698517.90	Total pipe length	: 6.265 m
Easting	: 1633589.70	Date of completion	: 2003-04-15



Well Construction Information

Drilling method : Weight
Borehole diameter : 32 mm

ADAPTER PIPE

Material : Stainless steel
Inside diameter : 25.6 mm
Outer diameter : 33.7 mm
Total length : 6.00 m

FILTER TIP

Material : HDPE
Total length : 265 mm
Filter size : 30*40 mm
Pore size : 20 micron

SWECO VIAK

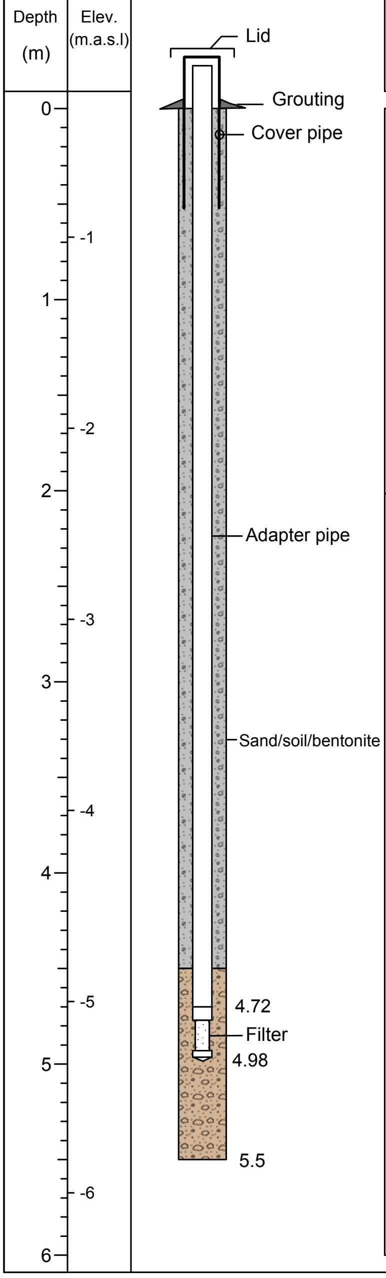
FORSMARK
BAT Groundwater sampler SFM0053

Company rep.

Nils Lindqvist and Mesgena Gebrezghi

Client: Svensk Kärnbränslehantering AB

Coordinate system	: RT 90 2.5 gon W 0:-15	Top of stand pipe	: 0.958 m.a.s.l
	: RHB 70	Ground elevation	: -0.33 m.a.s.l
Northing	: 6698515.97	Total pipe length	: 6.265 m
Easting	: 1633589.70	Date of completion	: 2003-04-15



Borehole Construction Information

Drilling method	: Auger
Borehole diameter	: 100 mm
COVER PIPE	
Material	: Stainless steel
Inside diameter	: 80 mm
Outer diameter	: 83 mm
Total length	: 2.00 m
ADAPTER PIPE	
Material	: HDPE
Inside diameter	: 50 mm
Outer diameter	: 63 mm
Total length	: 6.00 m
FILTER TIP	
Material	: HDPE
Total length	: 265 mm
Filter size	: 165*40 mm
Pore size	: 20 micron

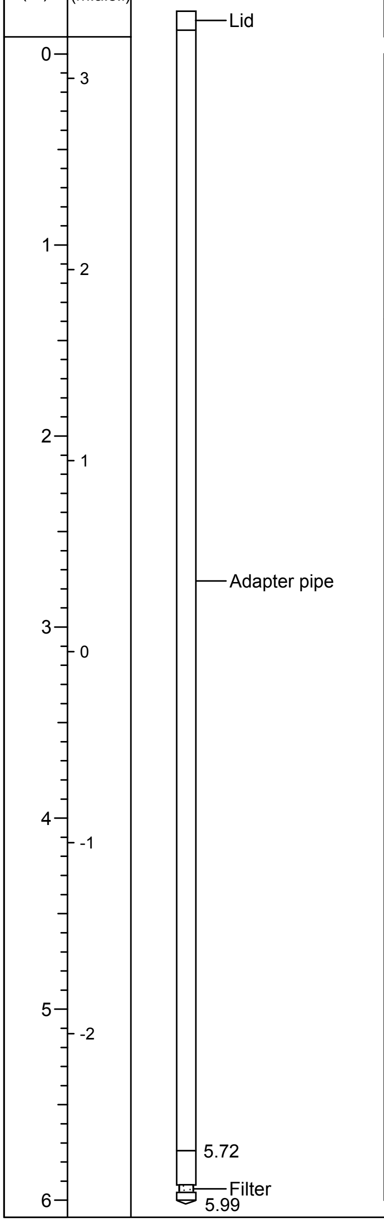
SWECO VIAK

FORSMARK
BAT Permeameter SFM0054

Company rep.	
Mattias Helmersson and Patrik Schmutzer	
Client: Svensk Kärnbränslehantering AB	

Coordinate system	: RT 90 2.5 gon W 0:-15	Top of stand pipe	: 4.408 m.a.s.l
	: RHB 70	Ground elevation	: 3.128 m.a.s.l
Northing	: 6697068.43	Total pipe length	: 7.265 m
Easting	: 1634793.37	Date of completion	: 2003-04-16

Depth (m)	Elev. (m.a.s.l)



Borehole Construction Information

Drilling method	: Weight
Borehole diameter	: 32 mm

ADAPTER PIPE

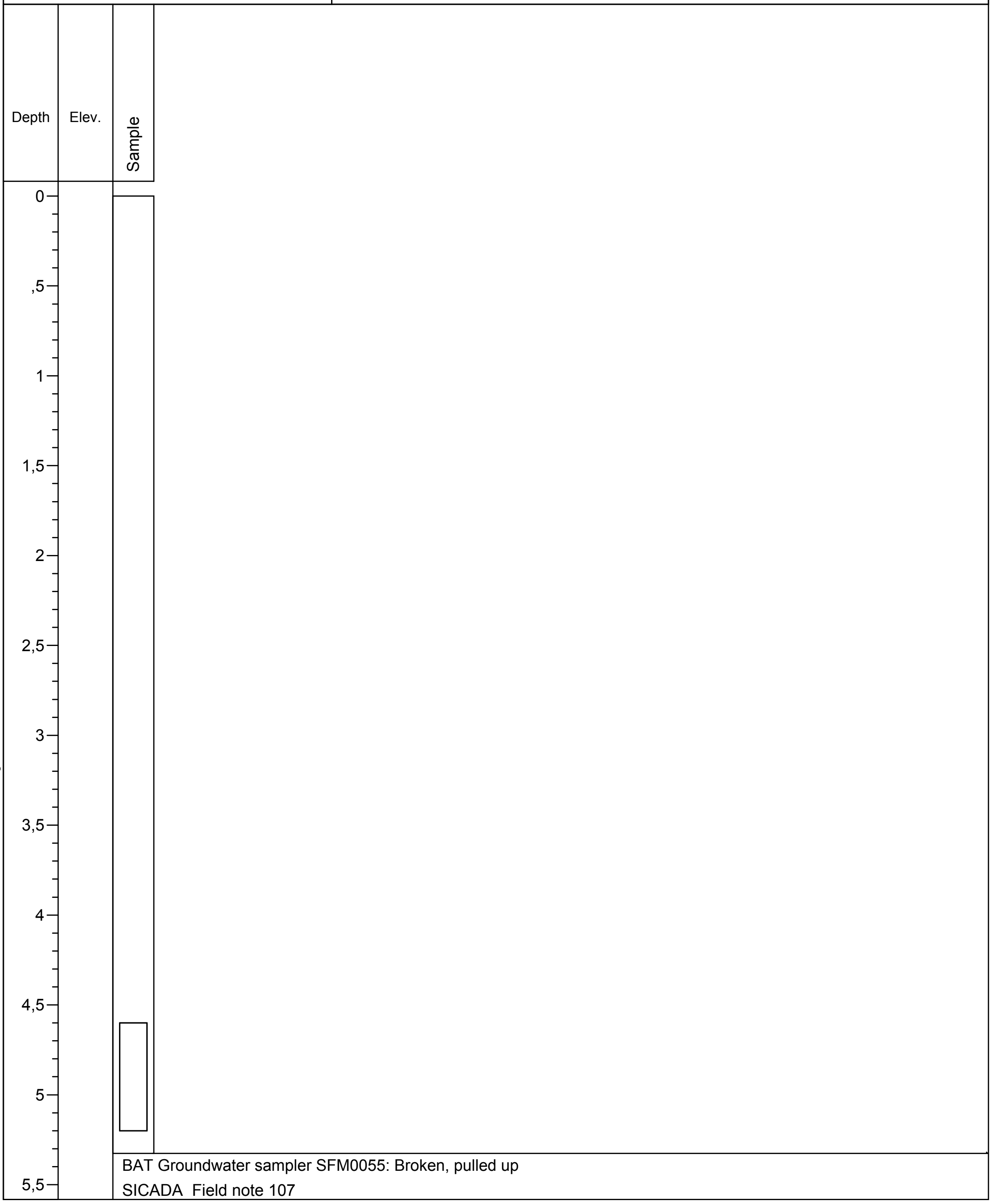
Material	: Stainless steel
Inside diameter	: 25.6 mm
Outer diameter	: 33.7 mm
Total length	: 7.00 m

FILTER TIP

Material	: HDPE
Total length	: 265 mm
Filter size	: 40*30 mm
Pore size	: 20 micro

SWECO VIAK	FORSMARK BAT Groundwater sampler SFM0055

Company rep.				
Nils Lindqvist and Mesgena Gebrezghi	Coordinate system	: RT 90 2.5 gon W 0:-15	Top of stand pipe	: -
		: RHB 70	Ground elevation	: 3.13 m.a.s.l
	Northing	: 6697068.55	Total pipe length	: -
	Easting	: 1634791.70	Groundwater level	: -
Client: Svensk kärnbränslehantering AB			Date of completion	: 2003-04-16

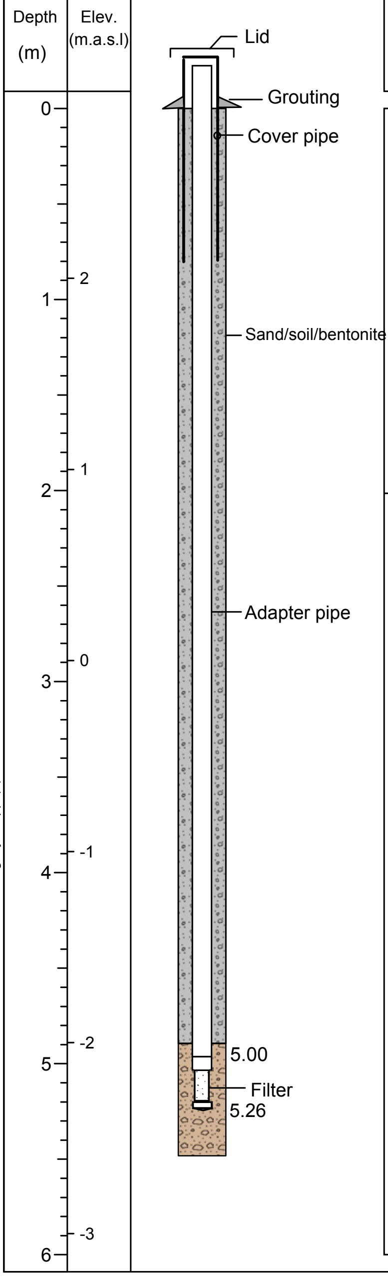


BAT Groundwater sampler SFM0055: Broken, pulled up
SICADA Field note 107

05-17-2004 P:\1113\1133505 000 SKB Jordborr\Dokumentation\Quicklog\SFM0055.bor

SWECO VIAK	FORSMARK BAT Groundwater sampler SFM0056

Company rep.	Coordinate system	: RT 90 2.5 gon W 0:-15	Top of stand pipe	: 3.897 m.a.s.l
Nils Lindqvist and Mesgena Gebrezghi		: RHB 70	Ground elevation	: 2.89 m.a.s.l
	Northing	: 6697068.43	Total pipe length	: 6.265 m
Client: Svensk Kärnbränslehantering AB	Easting	: 1634791.67	Date of completion	: 2003-04-15



Borehole Construction Information

Drilling method	: Auger
Borehole diameter	: 100 mm
COVER PIPE	
Material	: Stainless steel
Inside diameter	: 80 mm
Outer diameter	: 83 mm
Total length	: 2.00 m
ADAPTER PIPE	
Material	: HDPE
Inside diameter	: 50 mm
Outer diameter	: 63 mm
Total length	: 6.00 m
FILTER TIP	
Material	: HDPE
Filter size	: 165*40 mm
Pore size	: 20 micron
Total length	: 265 mm

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Appendix 2

Data from the hydraulic conductivity tests – pressure for each time interval and calculated hydraulic conductivity

Permeability test SFM0050

```
     B A T   PI 301   PERMEABILITY TEST

Test point         : SFM0050
Date  (MM.DD.YY)   : 04.29.03
Time  (HH:MM)            : 08:45
Flow type          : IN
Filter type        (mm)  : 40/30
Test container vol       (ml)   : 35
EXT cylinder vol         (ml)   : 0.50
Liquid start level       (m)    : 0.19
Initial gas vol    (ml)  : 35.50
Container x-area         (cm2) : 1.96
Static pore pressure     (mH2O)       : 4.65
Initial test pressure    (mH2O)       : -8.66
Init liquid vol    (ml)  : 0
```

Time	Pressure	Permeability
HH:MM:SS	m H2O	cm/s
00:00:00	-8.66	
00:00:59	-8.23	3.89E-06
00:01:42	-7.81	3.78E-06
00:02:12	-7.38	3.98E-06
00:02:35	-6.96	4.05E-06
00:02:53	-6.53	4.05E-06
00:03:09	-6.11	4.00E-06
00:03:22	-5.68	3.97E-06

00:03:34	-5.26	3.82E-06
00:03:45	-4.83	3.87E-06
00:03:55	-4.40	3.96E-06
00:04:03	-3.98	3.95E-06
00:04:11	-3.55	3.81E-06
00:04:19	-3.13	3.80E-06
00:04:26	-2.70	3.91E-06
00:04:33	-2.28	4.01E-06
00:04:39	-1.85	4.10E-06
00:04:45	-1.42	4.01E-06
00:04:51	-1.00	3.96E-06
00:04:57	-0.57	4.12E-06
00:05:03	-0.15	4.26E-06
00:05:08	0.28	4.28E-06
00:05:14	0.70	4.08E-06
00:05:20	1.13	4.08E-06
00:05:27	1.55	4.44E-06
00:05:34	1.98	

Final calculated permeability value : 4.44E-06

Permeability test SFM0052

B A T PI 301 PERMEABILITY TEST

Test point : SFM0052

Date (MM.DD.YY) : 04.29.03

Time (HH:MM) : 11:55

Flow type : IN

Filter type (mm) : 40/30

Test container vol (ml) : 35

EXT cylinder vol (ml) : 0.50

Liquid start level (m) : 0.19

Initial gas vol (ml) : 35.50

Container x-area (cm2) : 1.96

Static pore pressure (mH2O) : 5.35

Initial test pressure (mH2O) : -8.78

Init liquid vol (ml) : 0

Time	Pressure	Permeability
HH:MM:SS	m H2O	cm/s
00:00:00	-8.78	
00:04:54	-8.33	5.86E-06
00:05:22	-7.88	7.82E-07
00:08:01	-7.42	4.84E-07
00:11:39	-6.97	4.08E-07
00:14:26	-6.52	4.13E-07
00:16:46	-6.07	4.09E-07
00:18:46	-5.62	4.11E-07
00:20:28	-5.16	4.14E-07

00:21:55	-4.71	4.09E-07
00:23:17	-4.26	3.99E-07
00:24:34	-3.81	3.95E-07
00:25:43	-3.36	3.97E-07
00:26:48	-2.90	4.00E-07
00:27:47	-2.45	3.80E-07
00:28:43	-2.00	
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-

Final calculated permeability value : 3.80E-07

Permeability test SFM0054

B A T PI 301 PERMEABILITY TEST

Test point : SFM0054

Date (MM.DD.YY) : 04.29.03

Time (HH:MM) : 10:51

Flow type : OUT

Filter type (mm) : 40/30

Test container vol (ml) : 35

EXT cylinder vol (ml) : 0.50

Liquid start level (m) : 0.29

Initial gas vol (ml) : 15.50

Container x-area (cm2) : 1.96

Static pore pressure (mH2O) : 6.00

Initial test pressure (mH2O) : 20.92

Init liquid vol (ml) : 20

Time	Pressure	Permeability
HH:MM:SS	m H2O	cm/s
00:00:00	20.92	
00:00:32	20.44	7.52E-06
00:00:33	19.96	8.03E-06
00:00:34	19.49	8.54E-06
00:00:35	19.01	9.12E-06
00:00:36	18.53	9.80E-06
00:00:37	18.05	1.06E-05
00:00:38	17.58	1.14E-05
00:00:39	17.10	1.22E-05

00:00:40	16.62	1.33E-05
00:00:41	16.14	1.45E-05
00:00:42	15.67	1.57E-05
00:00:43	15.19	9.78E-06
00:00:44	14.71	5.11E-06
00:00:47	14.23	3.30E-06
00:00:53	13.76	2.13E-06
00:01:02	13.28	1.46E-06
00:01:18	12.80	1.12E-06
00:01:43	12.32	9.56E-07
00:02:16	11.85	8.82E-07
00:02:57	11.37	8.57E-07
00:03:44	10.89	8.49E-07
00:04:38	10.41	8.55E-07
00:05:42	9.94	8.60E-07
00:06:55	9.46	1.03E-06
00:08:22	8.98	

Final calculated permeability value : 1.03E-06

Appendix 3

Institute of Geological Sciences, University of Geological Sciences. SKB Site Investigations: CL-determination on pore water of a glacial till

University of Bern
Institute of Geological Sciences
Rock-Water Interaction

SKB SITE INVESTIGATIONS:

CL-DETERMINATION IN PORE WATER OF A GLACIAL TILL

ANALYSIS REPORT COVER NOTE

The chloride concentration of pore water of a glacial till was assessed by aqueous extraction of the till sample. The till sample arrived in an incoherent state with water floating in the tightly sealed PE-bag. This prevented a determination of a bulk density value by a conventional displacement method.

The water content was determined on 3 subsamples by drying the samples at 105°C, aqueous extraction tests were performed on 4 subsamples at a solid:liquid ratio of 1:1, and the grain density was analysed by He-pycnometry on 2 subsamples. The results of all analytical data are given in the table below.

The Cl concentration of the pore water was calculated according to

$$Cl\left[\frac{mass}{Vol._{PW}}\right] = Cl_{AqEx}\left[\frac{mass}{kg_{Rock}}\right] \bullet \frac{(1-n_{WC})\bullet \rho_{Grain}}{n_{WC}}$$

where PW = pore water, AqEx = aqueous extract, n_{WC} = water-loss porosity, and ρ_{Grain} = grain density.

In this calculation it is assumed that all water lost from the sample at 105°C is accessible for Cl. This might not be true for *in situ* conditions where some of this water is also bound on the clay surfaces. The Cl-accessible porosity (or Cl geochemical porosity) is thus smaller than the water-loss porosity. The Cl concentration calculated with the water-loss porosity thus represents a minimum Cl concentration of the *in situ* pore water. However, the texture of the sample and its incoherent state upon arrival here in the laboratory suggest that the ratio of Cl-accessible porosity to water-loss porosity is close to unity and the calculated Cl concentration might be too low by about 10% to 20%.

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Till sample: Analytical Data

Analysis	Units	Subsample				Till Sample
		For 1	For 2	For 3	For 4	Average
grain density	g/cm^3	2.68		2.69		2.685
weight loss at 105°C, 72h	%	11.36	11.09	10.56		
weight-loss porosity	%	25.6	25.1	24.1		24.9
Cl aqueous extract	mg/l	75	71	73	70	72.3
Cl pore water	mg/kg_{H2O}	584		618		585 [1)]

[1)] calculated from average values of water-loss porosity, grain density and Cl-content in aqueous extract solutions

Bern, 2nd June 2003

Dr. H.N. Waber
RWI, Uni Bern

Appendix 4

Photographs of all BAT-type filter tip installations

Filter tip installations SFM0050 and SFM0051

Before

After

Filter tip installations SFM0052 and SFM0053

Before

After

Filter tip installations SFM0054 and SFM0056

Before

After