P-04-94

Forsmark site investigation

Drilling of a monitoring well, HFM16, at drilling site DS6.

Lars-Åke Claesson, Mirab Mineral Resurser AB
Göran Nilsson, GNC AB

May 2004

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

ISSN 1651-4416
SKB P-04-94

Forsmark site investigation

Drilling of a monitoring well, HFM16, at drilling site DS6.

Lars-Åke Claesson, Mirab Mineral Resurser AB
Göran Nilsson, GNC AB

May 2004

Keywords: AP PF 400-03-79, Field note no Forsmark 216, Percussion drilling, Monitoring well, DS6.

Summary

A borehole in solid rock, HFM16, was drilled at drilling site DS6 using percussion drilling technique. The borehole was primarily aimed both as a flushing water well for the planned core drilling at the drilling site and as a monitoring well during disturbed (pumped) and undisturbed conditions. Due to a too high TOC-value (Total Organic Content) the borehole was though rejected as a flushing water well, and will instead be used for monitoring of the groundwater level and for groundwater sampling. A third objective with the borehole was to investigate a lineament north of the drilling site.

Borehole HFM16, which was drilled during the period November 4th to 11th, 2003, is 132.5 m long, inclined c 84 degrees to the horizontal plane and has a diameter of c140 mm. A single fracture at 41 m yielded 480 L/min, whereas an inflow of about 600 L/min was recorded from a flat-dipping fracture zone at 59–61 m.

A lineament is striking WSW-ENE just north-west of drilling site DS6. Besides, a reflection seismic reflector is interpreted to intersect the ground surface close to DS6. So far, it has neither been possible to confirm that borehole HFM06 penetrates any of these structures, nor to corroborate whether the lineament and the reflector represent the same structure.

Sammanfattning

Ett hammarborrhål, HFM16, har borrats vid borrplats BP6. Borrhålet var ursprungligen avsett att användas både som spolvattenbrunn vid kärnborrningen vid borrplats BP6 och som moniteringsbrunn vid såväl störda (under pumpning) som ostörda förhållanden.
Ett alltför högt innehåll av organiska ämnen i grundvattnet medförde dock att en annan brunn kommer att användas för spolvattenförsörjningen, och att HFM16 endast används för monitering av grundvattennivåer och för grundvattenprovtagning. Ett tredje syfte med HFM16 var att undersöka ett lineament strax norr om borrplatsen.

HFM16 borrades under perioden 4:e till 11:e November 2003. Borrhålet är 132,5 m långt, är ansatt ca 84° mot horisontalplanet och är borrat med diametern 140 mm. En enskild spricka vid ca 41 m gav ett inflöde av ca 480 L/min, medan en sprickzon mellan 59 och 61 m gav ca 600 L/min.

Ett lineament stryker i VSV-ONO-lig riktning ca 160 m nordväst om borrplats BP6. Vidare har en reflektionsseismiskt indikerad reflektor tolkats skära markytan nära borrplatsen. Det är osäkert om borrhål HFM16 penetrerar någon av dessa strukturer eller inte. Det är vidare möjligt att lineamentet och reflektorn representerar en och samma struktur. Inte heller detta går dock i nuläget att avgöra.

Contents

1	**Introduction**	7
2	**Objective and scope**	11
3	**Equipment**	13
3.1	Drilling system	13
3.2	Gap injection technique and equipment	14
3.3	Equipment for deviation measurements	14
3.4	Equipment for measurements and sampling during drilling	14
4	**Execution**	15
4.1	Preparations	15
4.2	Mobilization	15
4.3	Drilling and measurements during drilling of borehole HFM16	15
	4.3.1 Drilling through the overburden	16
	4.3.2 Gap injection	16
	4.3.3 Percussion drilling in solid rock	16
	4.3.4 Sampling and measurements during drilling	17
4.4	Finishing off work	18
4.5	Data handling	18
4.6	Environmental control	18
4.7	Nonconformities	18
5	**Results**	19
5.1	Design of the percussion drilled borehole HFM16	19
5.2	Consumables used up in HFM16	21
5.3	Well Cad presentations	21
5.4	Hydrogeology	24
	5.4.1 Observations during drilling	24
	5.4.2 Hydraulic response	26
References		28

1 Introduction

SKB performs site investigations to locate a deep repository for high level radioactive waste /1/. The investigations are performed in two Swedish municipalities: Östhammar and Oskarshamn. The investigation area in Östhammar /2/ is situated close to the nuclear power plant at Forsmark, see Figure 1-1.

Drilling is one important activity within the scope of the site investigations, rendering geoscientific characterization of the bedrock down to and beyond repository depth possible. Three main types of boreholes are produced: core drilled boreholes, percussion drilled boreholes in bedrock and boreholes drilled through unconsolidated soil. The initial phase of the investigations includes drilling of three, c 1000 m deep boreholes inside the candidate area, at drilling sites DS1, DS2 and DS3, see Figure 1-1. These boreholes were succeeded by a fourth 1000 m borehole, starting at drilling site DS4 outside the candidate area, and inclined towards this. A fifth 1000 m borehole has recently been completed at drilling site DS5. During drilling at DS5, preparations were made at drilling site DS6 for a sixth deep borehole, which is planned to be finished during the summer 2004. The locations of drilling sites DS4, DS5 and DS6 are shown in Figure 1-1.

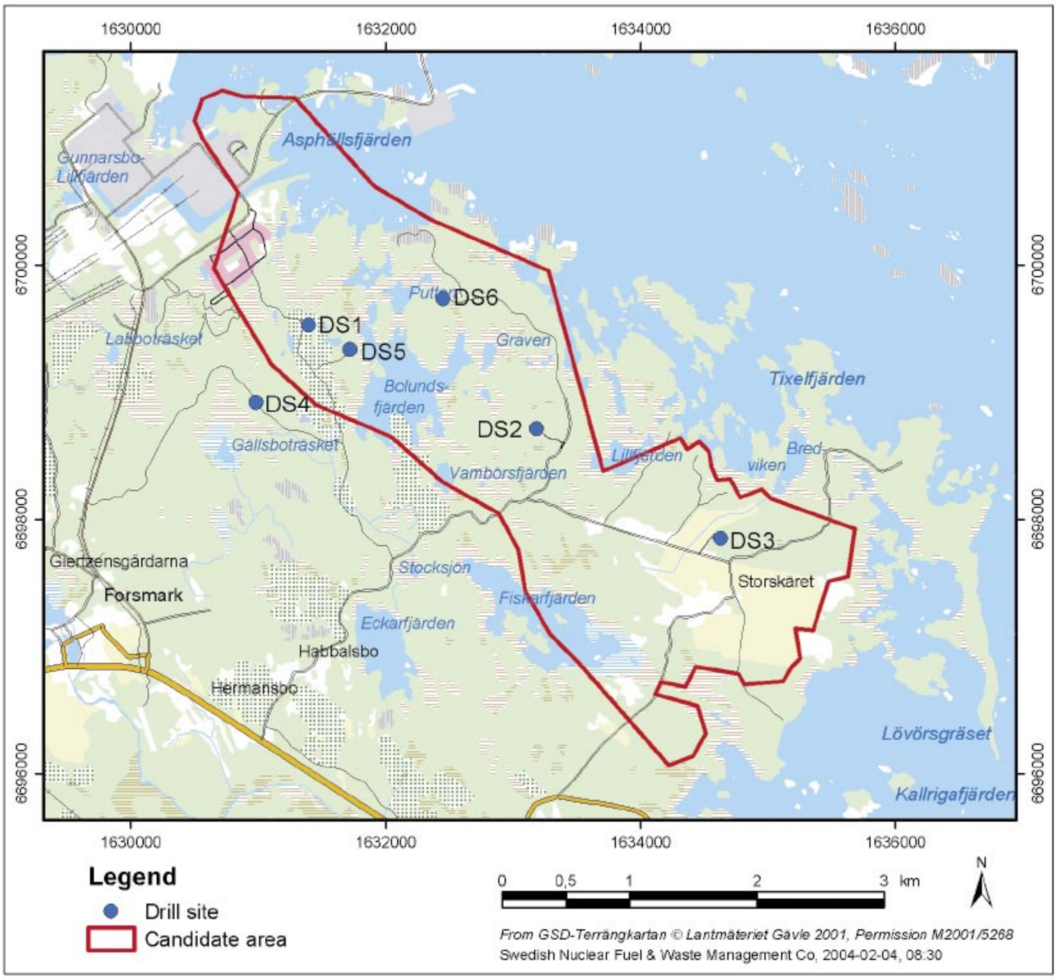


Figure 1-1. The investigation area at Forsmark including the candidate area selected for more detailed investigations. Drilling sites DS1–6 are marked with blue dots.

All mentioned drilling sites also incorporate percussion drilled boreholes in bedrock and in soil. During the continued investigations, several additional drilling sites for deep core drilled boreholes will be established. Some of the drilling sites are planned to surve as the collaring point for two or more deep or semi-deep (500–700 m) boreholes.

At drilling site DS6, a 1000 m long inclined telescopic borehole, KFM06A, is planned to be drilled. "Telescopic" implies that the upper 100 m of the borehole is percussion drilled and the remaining part, in this case 100–1000 m, is core drilled. The percussion drilled part is already accomplished. Core drilling is planned to start in May, 2004, and is to be finished during the summer 2004. However, prior to drilling KFM06A, a short (100 m) core drilled borehole, KFM06B, will be drilled quite close to KFM06A to compensate for the missing drill core in the percussion drilled part of this borehole. Results from both KFM06A and KFM06B will be presented in /3/. Additional cored boreholes may later be drilled at DS6 during the site investigations.

Besides borehole KFM06A, drilling site DS6 is also hosting a percussion borehole in solid rock, HFM16, with the borehole length 132.5 m, and a percussion borehole through the soil layer, SFM0021. Drilling of the latter is reported in /4/. The positions of the three currently existing boreholes at drilling site DS6 are displayed in Figure 1-2.

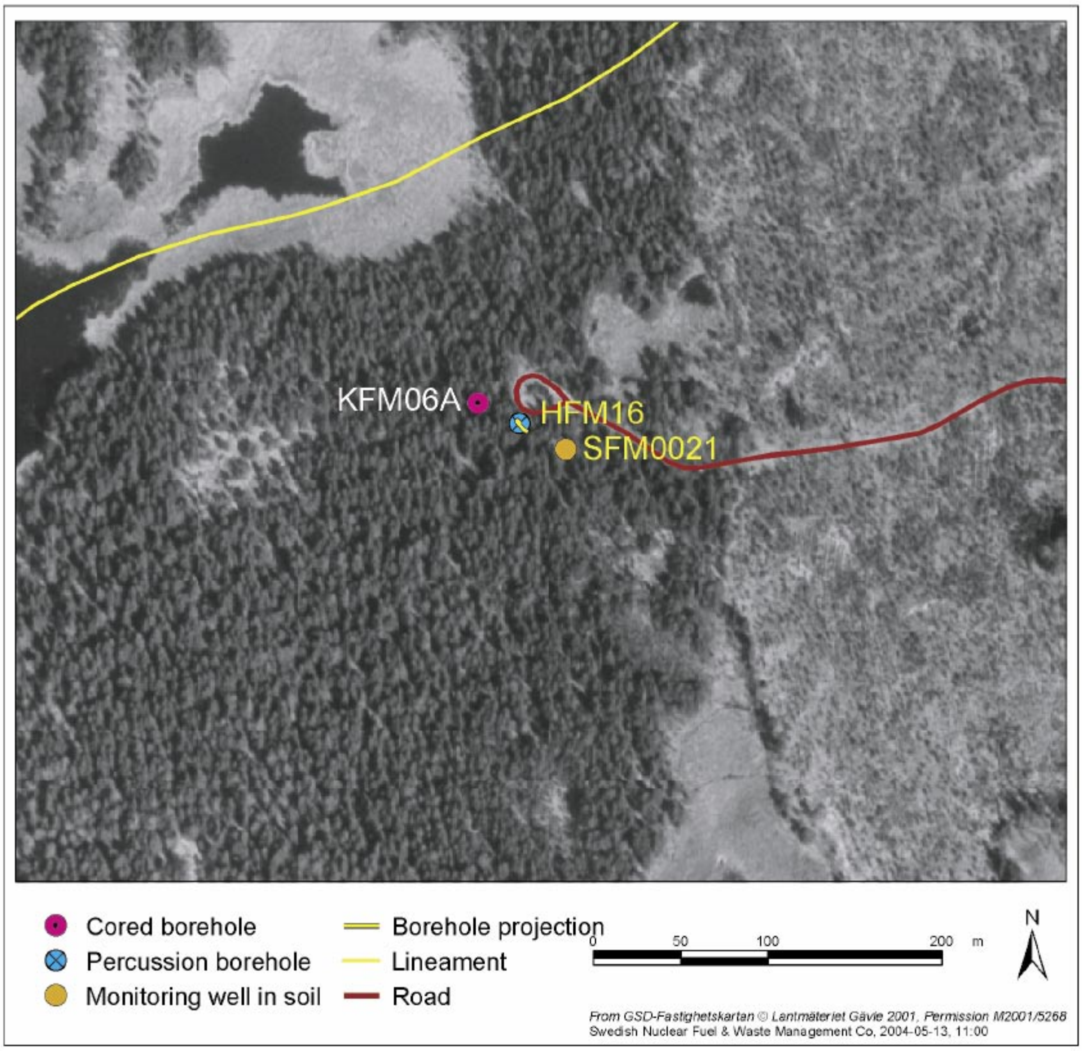


Figure 1-2. *Borehole locations at drilling site DS6.*

In the present report, performance of and results from drilling HFM16 are presented. The report also treats investigations made during and immediately after drilling and the results obtained.

Sven Andersson in Uppsala AB was contracted for the drilling commission. Support was provided from SKB-personnel regarding measurements and tests during drilling.

Drilling and measurements were carried out during the period November 4th to 11th, 2003, in compliance with Activity Plan AP PF 400-03-79, Version 1.0 (SKB internal controlling document). The Activity Plan refers to MD 610.003, Version 1.0, Method Description for Percussion Drilling (SKB internal controlling document).

2 Objective and scope

When drilling many of the deep cored boreholes at the SKB site investigations, so called telescopic drilling technique is applied, entailing that the upper 100 m of the borehole are percussion drilled with a large diameter (≥ 200 mm), whereas the borehole section 100–1000 m is core drilled with a diameter of approximately 76–77 mm.

Core drilling demands injection of relatively large amounts of flushing water through the drilling pipe string and drill bit for cooling the latter and for transportation of drill cuttings from the borehole bottom to the ground surface. At the SKB site investigations, an air-lift pump is installed in the upper, large-diameter part of the telescopic drilled borehole in order to augment the recovery of flushing water and drill cuttings. During the entire core drilling period (comprising about three months when drilling a 1000 m borehole), the air-lift pumping and, to a lesser extent, the injection of flushing water, affects the groundwater levels and, possibly, the groundwater-chemical composition near the deep borehole. To enable observation of groundwater level fluctuations due to the deep drilling operations, monitoring wells are drilled.

However, borehole HFM16 was drilled with multiple aims. Firstly, the borehole was intended to account for supply of the clean flushing water needed for drilling the deep cored borehole KFM06A (and possibly other core drilled boreholes at DS6). A too high TOC-value (Total Organic Content) amounting to 13 mg/L, however disqualified HFM16 as a flushing water well. Secondly, the borehole was intended to be used as a monitoring well, enabling long-term study of groundwater levels and groundwater-chemical composition. A third objective was to characterize a lineament striking WSW-ENE just north-west of the drilling site, see Figure 1-2.

The soil borehole SFM0021 at drilling site DS6 was drilled with the purposes of monitoring the groundwater level in the soil layer and for groundwater sampling.

Borehole HFM16 is of so called SKB chemical type, implying that the borehole is prioritized for hydrogeochemical and bacteriological investigations. The practical consequence of this is that all DTH (Down The Hole)-equipment used during and/or after drilling must undergo severe cleaning procedures, see Section 4.1.

One criterion for determining the position of borehole HFM16 was to locate it within the expected radius of influence of groundwater-level drawdown due to air-lift pumping during core drilling at drilling site DS6. Borehole SFM0021 was drilled for monitoring purposes before drilling site DS6 was selected and prepared for deep drilling. Its position turned out to be suitable also for monitoring of possible groundwater fluctuations related to the deep drilling at DS6.

Data gained during monitoring of undisturbed conditions will be part of the characterization of the groundwater conditions of the shallow part of the bedrock and of the soil layers. Monitoring during the percussion and core drilling operations at drilling site DS6 is primarily part of the environmental control program for the drilling operations. However, also these data may be used for basic hydraulic characterization.

After completion of drilling and borehole investigations at DS6, boreholes HFM16 and SFM0021 will be used for long-term groundwater level monitoring and groundwater sampling.

3 Equipment

Drilling of percussion borehole HFM16 at DS6 was carried out with a Nemek 407 RE DTH percussion drilling machine (Figure 3-1) supplied with various accessory equipment. In this chapter short descriptions are given of the drilling system and the technique and equipment for gap injection of the borehole casing. Besides, the instrumentation used for deviation measurements performed after completion of drilling as well as the equipment used for measurements and sampling during drilling are briefly described.

3.1 Drilling system

The drilling machine is equipped with separate engines for transportation and power supplies. Water and drill cuttings were discharged from the borehole by means of an Atlas-Copco XRVS 455 Md 27 bars diesel compressor. The air-operated DTH drilling hammer was of type Secoroc 5", descended in the borehole by a Driconeq 76 mm pipe string.

All DTH-components were cleaned with a Kärcher HDS 1195 high-capacity steam cleaner.

Figure 3-1. *The Nemek 407 percussion drilling machine employed for drilling the percussion borehole HFM16 at drilling site DS6. Water and drill cuttings are discharged to the container. The snap-shot illustrates steam-cleaning of drilling pipes.*

3.2 Gap injection technique and equipment

In order to prevent surface water and shallow groundwater to infiltrate into deeper parts of the borehole, the normal procedure is to grout the gap between the borehole wall and the casing pipe with cement. The cement application may be performed by different technical approaches and equipment. Two variants of gap injection with cement are illustrated in Figure 3-2. In HFM16 only the borehole packer technique was applied.

3.3 Equipment for deviation measurements

Deviation measurements in HFM16 were performed with a Reflex EZ-shot (magnetic) camera. Azimuth and dip were measured every third metre. The coordinates for the collaring point and the measured values from the EZ-shot instrument were used for calculating the coordinates for every measured point along the borehole.

3.4 Equipment for measurements and sampling during drilling

Flow measurements during drilling were conducted using measuring vessels of different sizes and a stop watch. Drilling penetration rate was measured with a carpenter's rule and a stop watch. Samples of soil and drill cuttings were collected in sampling pots and groundwater in small bottles. The electrical conductivity of the groundwater was measured by a Kemotron 802 field measuring devise.

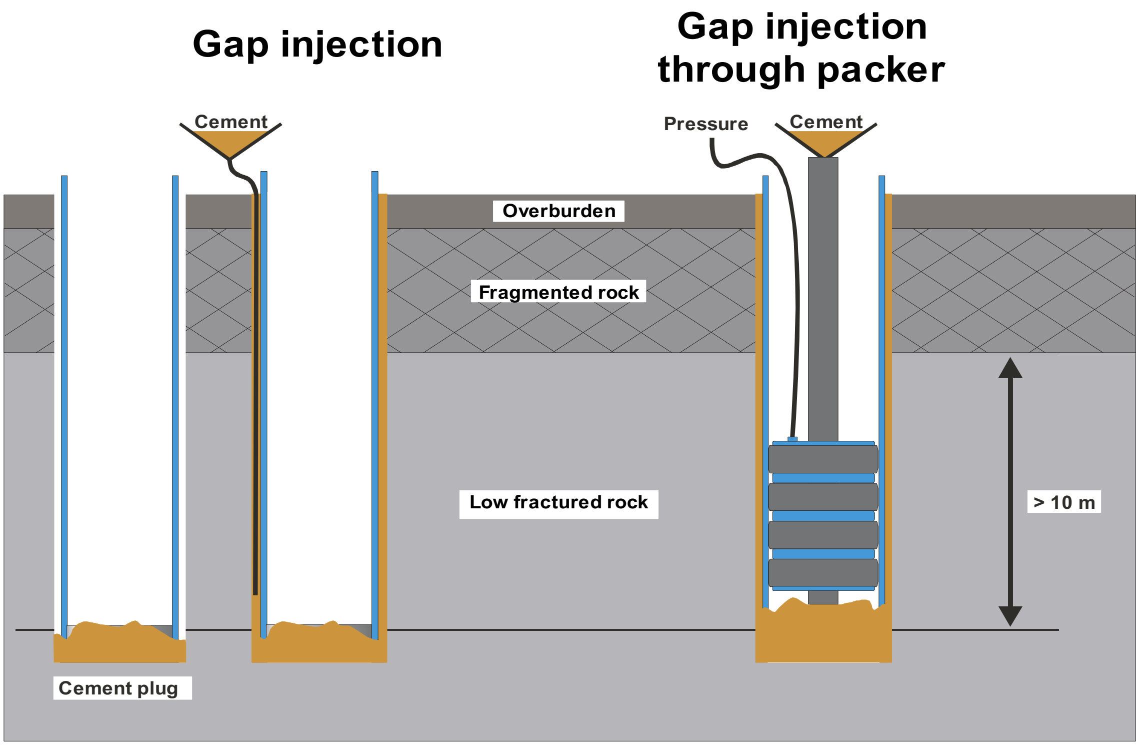


Figure 3-2. Gap injection technique. In order to grout the gap between the borehole wall and the casing, different systems may be used. To the left, filling up a cement-water mixture with a flexible hose is shown. To the right, injection is performed through a borehole packer.

4 Execution

Drilling of borehole HFM16 followed SKB MD 610.003 (Method Description for Percussion Drilling), including the following items:

- preparations,
- mobilization, including lining up the machine and measuring the position,
- drilling, measurements, and sampling during drilling,
- finishing off work,
- deviation measurements,
- data handling,
- environmental control.

4.1 Preparations

The preparations included the Contractor's service and function control of his equipment. The machinery was obliged to be supplied with fuel, oil and grease exclusively of the types stated in SKB MD 600.006, Version 1.0 (Method Instruction for Chemical Products and Materials). Finally, part of the equipment was cleaned in accordance with SKB MD 600.004, Version 1.0 (Method Instruction for Cleaning Borehole Equipment and certain Ground-based Equipment) at level two, used for SKB boreholes of chemical type (the remaining part of the equipment was cleaned on-site). SKB MD 600.004 and SKB MD 600.006 are both SKB internal controlling documents.

4.2 Mobilization

Mobilization onto and at the site started with preparation of the drilling site and transport of drilling and accessory equipment to site. The mobilization also comprised, on-site cleaning of all DTH-equipment at level two according to SKB MD 600.004, lining up the machine and final function control.

4.3 Drilling and measurements during drilling of borehole HFM16

For drilling through the overburden and 9 m into solid bedrock, a TUBEX- system (an ODEX-variant) was applied (Figure 4-1).

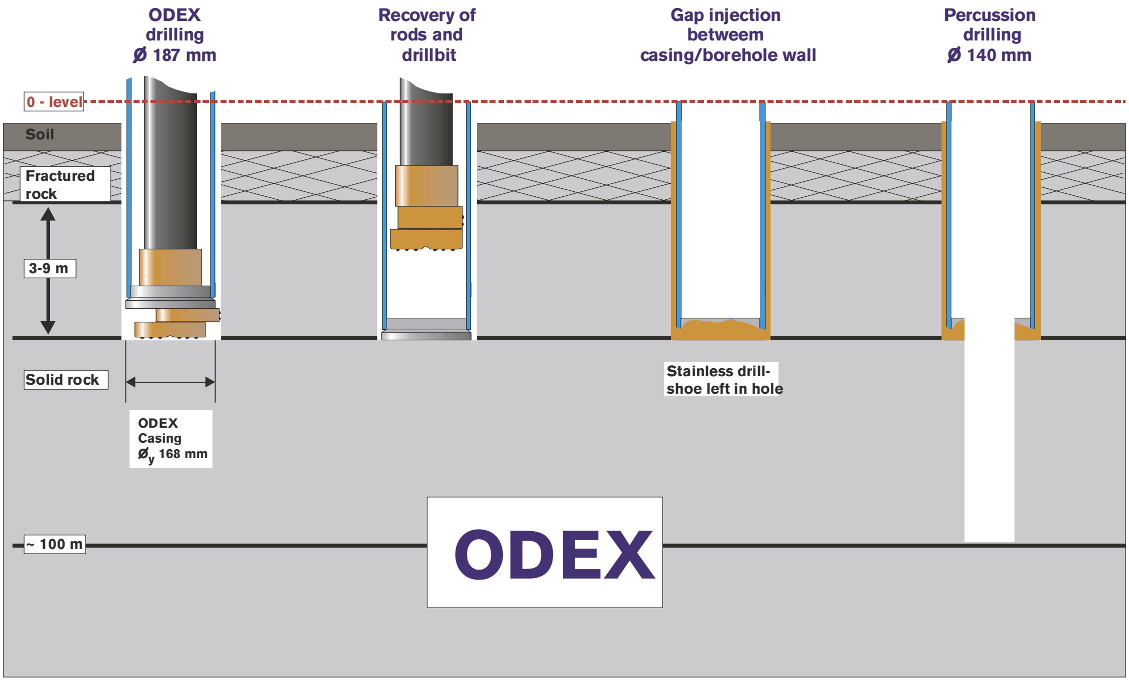


Figure 4-1. The different steps included in the performance of the percussion drilled borehole HFM16.

4.3.1 Drilling through the overburden

TUBEX is a system for simultaneous drilling and casing driving. The method is based on a system with a pilot bit and an eccentric reamer, which produces a borehole slightly larger than the external diameter of the casing tube. This enables the casing tube to follow the drill bit down the hole. In the Ejector-TUBEX system, the design of the discharge channels for the flushing medium, in this case compressed air, is such that the oxygen and oil contamination of the penetrated soil layers is reduced compared to conventional systems.

4.3.2 Gap injection

When the casing string had been firmly installed in borehole HFM16, the narrow gap between the borehole wall and the external wall of the casing was grouted with a cement/water-mixture according to the borehole packer technique illustrated in Figure 3-2.

4.3.3 Percussion drilling in solid rock

After the casing was set, drilling could continue and was now performed to the full borehole length with conventional percussion drilling. Before start of drilling, the diameter of the drill bit was measured. In this last drilling step, the initial borehole diameter (approximately the same as the drill bit diameter) is normally 140 mm, see Figure 4-1. However, a diameter decrease of about 1 mm/100 m drilling length is to be expected when drilling in the rock types prevailing in the Forsmark area. For boreholes deeper then 100 m, the drill bit normally has to be grinded.

4.3.4 Sampling and measurements during drilling

During drilling, a sampling and measurement program was carried out, which included:

- Collecting one soil sample per metre drilling length. Analysis and results are reported in /5/.
- Collecting one sample per 3 m drilling length of drill cuttings from the bedrock (Figure 4-2). Each major sample consists of three individual minor samples collected at every metre borehole length, stored in one plastic box marked with a sample number. As far as possible, mixing of the three individual samples was avoided. A first description of the material was made on-site including the mineral content and rock structure, which gave a preliminary classification of the rock type. These samples were later examined more thoroughly and interpreted together with a BIPS-log (so called Boremap mapping) /6/.
- Measurements of the penetration rate (one measurement per 20 cm drilling length). The time needed for the drill bit to sink 20 cm was recorded manually in a paper record.
- Performing one observation of discharged groundwater flow rate (if any) and water colour per 20 cm drilling length and a measurement of the flow rate at each major flow change observed. The measured values were noted in a paper record.
- Measurements of the electrical conductivity of the groundwater (if any) at every 3 m drilling length (noted in a paper record).

The results from the third and fourth items were used as supporting data for the Boremap mapping mentioned above. The last item gave on-site information about hydraulic and hydrogeochemical characteristics of the penetrated aquifers at the respective drilling sites.

Figure 4-2. *Sampling of drill cuttings from the penetrated bedrock.*

4.4 Finishing off work

Finishing off work included rinsing of the borehole from drill cuttings by a "blow out" with the compressor at maximum capacity during 30 min. By measuring the flow rate of the discharged groundwater, a rough estimate of the water yielding capacity of the borehole at maximum drawdown was achieved. The drilling pipes were then retrieved from the hole, and the diameter of the drill bit was measured. A deviation survey of the borehole completed the measurement programme during and immediately after drilling. The borehole was secured by a stainless steel lockable cap, mounted on the casing flange, which finishes off the casing. Finally, the equipment was removed, the site cleaned and a joint inspection made by representatives from SKB and the Contractor, to ensure that the site had been satisfactorily restored.

4.5 Data handling

Minutes with the following headlines: Activities, Cleaning of equipment, Drilling, Borehole, Percussion drilling penetration rate, Deliverance of field material, and Discrepancy report were collected by the Activity Leader, who made a control of the information, and had it stored in the SKB database SICADA /7/.

4.6 Environmental control

A programme according to the SKB routine for environmental control was complied with throughout the activity. A checklist was filled in and signed by the Activity Leader and finally filed in the SKB archive.

4.7 Nonconformities

No departures from the Activity Plan were made.

5 Results

All data were stored in the SICADA database inder field note no Forsmark 216 /7/. Below, a summary of the data acquired is presented.

5.1 Design of the percussion drilled borehole HFM16

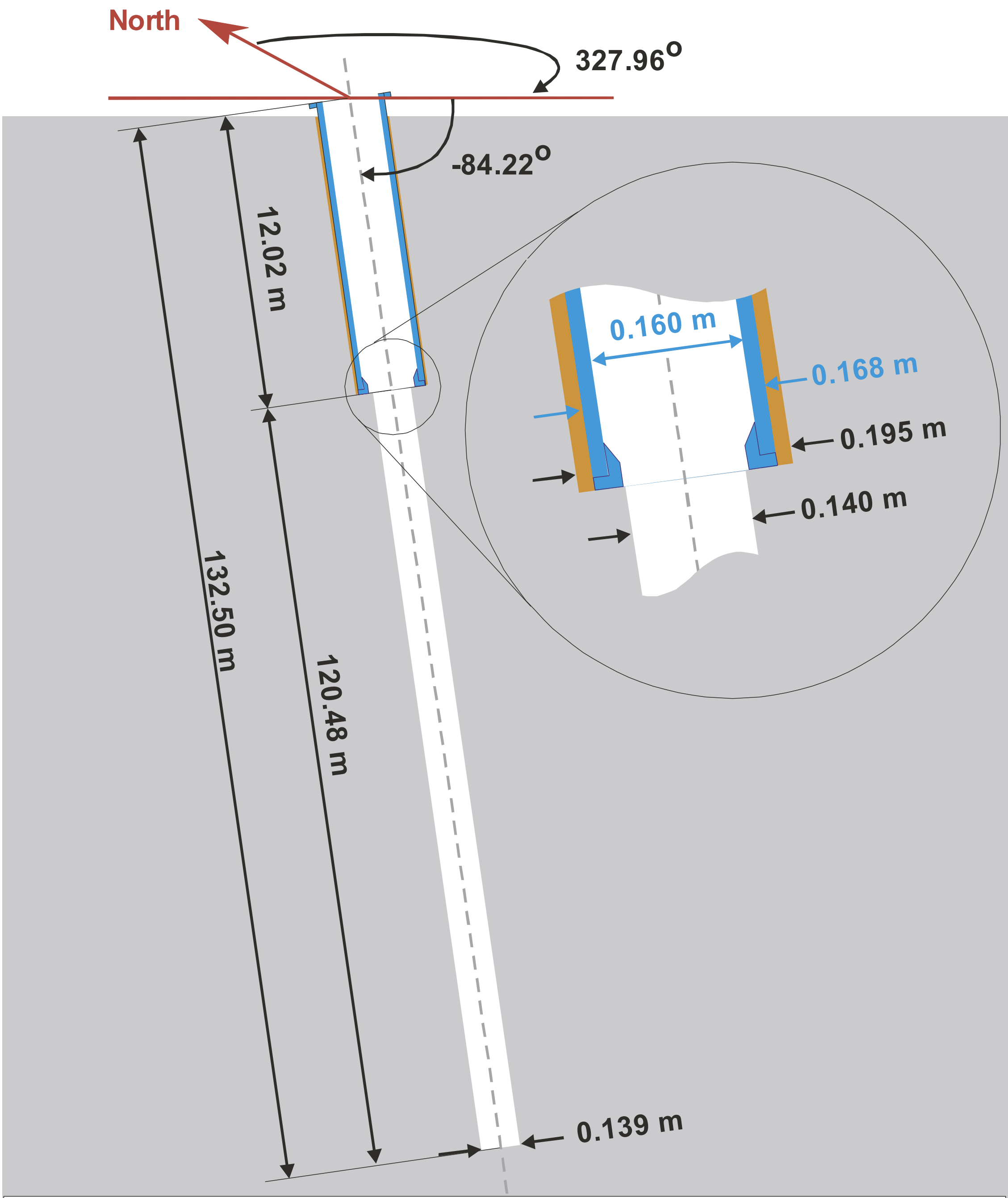
Administrative, geometric, and technical data for HFM16 are presented in Table 5-1. The technical design of the borehole is illustrated in Figure 5-1.

Table 5-1. Administrative, geometric and technical data for borehole HFM16.

Parameter	HFM16
Drilling period	From 2003-11-04 to 2003-11-11
Borehole inclination (collaring point)	–84.22° (– = downwards)
Borehole bearing	327.96°
Borehole length	132.50 m
Borehole diameter	From 0.00 m to 12.02 m: 0.195 m
	From 12.02 m to 132.50 m: decreasing from 0.140 m to 0.139 m
Casing length	12.02 m
Casing diameter	Øo/Øi = 168 mm/160 mm to 12.02 m
	Øo/Øi = 168 mm/146 mm between 12.00 and 12.02 m
Drill bit diameter	Start of drilling: 0.140 m End of drilling: 0.139 m
Collaring point coordinates (system RT90 2.5 gon V/ RHB70)	Northing: 6699721.10 m Easting: 1632466.18 m Elevation: 3.21 m.a.s.l.

Technical data

Borehole HFM16



Drilling reference point		
Northing:	6699721.10	(m), RT90 2,5 gon V 0:-15
Easting:	1632466.18	(m), RT90 2,5 gon V 0:-15
Elevation:	3.21	(m.a.s.l.), RHB 70
Drilling period		
Drilling start date:	2003-11-04	
Drilling stop date:	2003-11-10	

Figure 5-1. *Technical data for borehole HFM16.*

5.2 Consumables used up in HFM16

The amount of oil products consumed in the borehole during drilling, and grout used for gap injection of the respective casings is reported in Tables 5-2 and 5-3. The cement was of low alkalic type, consisting of microsilica (920-D) and white cement (Aalborg Portland CEM I, 52.5N).

Regarding contamination risks, albeit some amounts of hammer oil and compressor oil reach the borehole, they are, on the other hand, continuously retrieved due to the permanent air flushing during drilling. After completion of drilling, only minor remainders of the products are left in the borehole.

Table 5-2. Oil consumption.

Borehole ID	Hammer oil Preem Hydra 46	Compressor oil Schuman 46
HFM16	2 L	Not detected

Table 5-3. Consumption of cement grouting.

Borehole ID	Casing length	Cement volume (Aalborg Portland Cement/microsilica)	Grouting method
HFM16	12.02 m	25/11 kg	Borehole packer

5.3 Well Cad presentations

Technical as well as geoscientific results achieved during drilling are presented in the so called Well Cad plot in Figure 5-2.

The deviation measurements made in borehole HFM16 indicate that the end (bottom) point of HFM16 deviates approximately 0.1 m upwards and 11.7 m to the right compared to an imagined straight line following the dip and strike of the borehole collaring point (inclination –84.22° and bearing 327.96°).

At 41.0–41.2 m, a highly permeable single fracture occurred, yielding 480 L/min. In section 59–61 m, a significant fracture zone is revealed by the penetration rate curve. A groundwater inflow of 600 L/min was observed from this zone.

Also in sections 65–66 m and 69–71 m, high penetration rates were observed, which may indicate fracture zones. However, these sections did not yield measurable amounts of water during drilling. The accumulated inflow of water, 1200 L/min, from the entire borehole when flushing it after drilling, could indicate opening up of the different fracture zones, possibly due to retrieval of drill cuttings and/or unconsolidated fracture material.

Title PERCUSSION DRILLED BOREHOLE HFM16

Svensk Kärnbränslehantering AB

Site	FORSMARK	**Coordinate System**	RT90-RHB70
Borehole	HFM16	**Northing [m]**	6699721.10
Diameter [mm]	139	**Easting [m]**	1632466.18
Length [m]	132.50	**Elevation [m.a.s.l.]**	3.21
Bearing [°]	327.96	**Drilling Start Date**	2003-11-04 07:00:00
Inclination [°]	-84.22	**Drilling Stop Date**	2003-11-11 16:00:00
Date of mapping	2004-05-11 15:31:00	**Plot Date**	2004-05-12 08:11:56

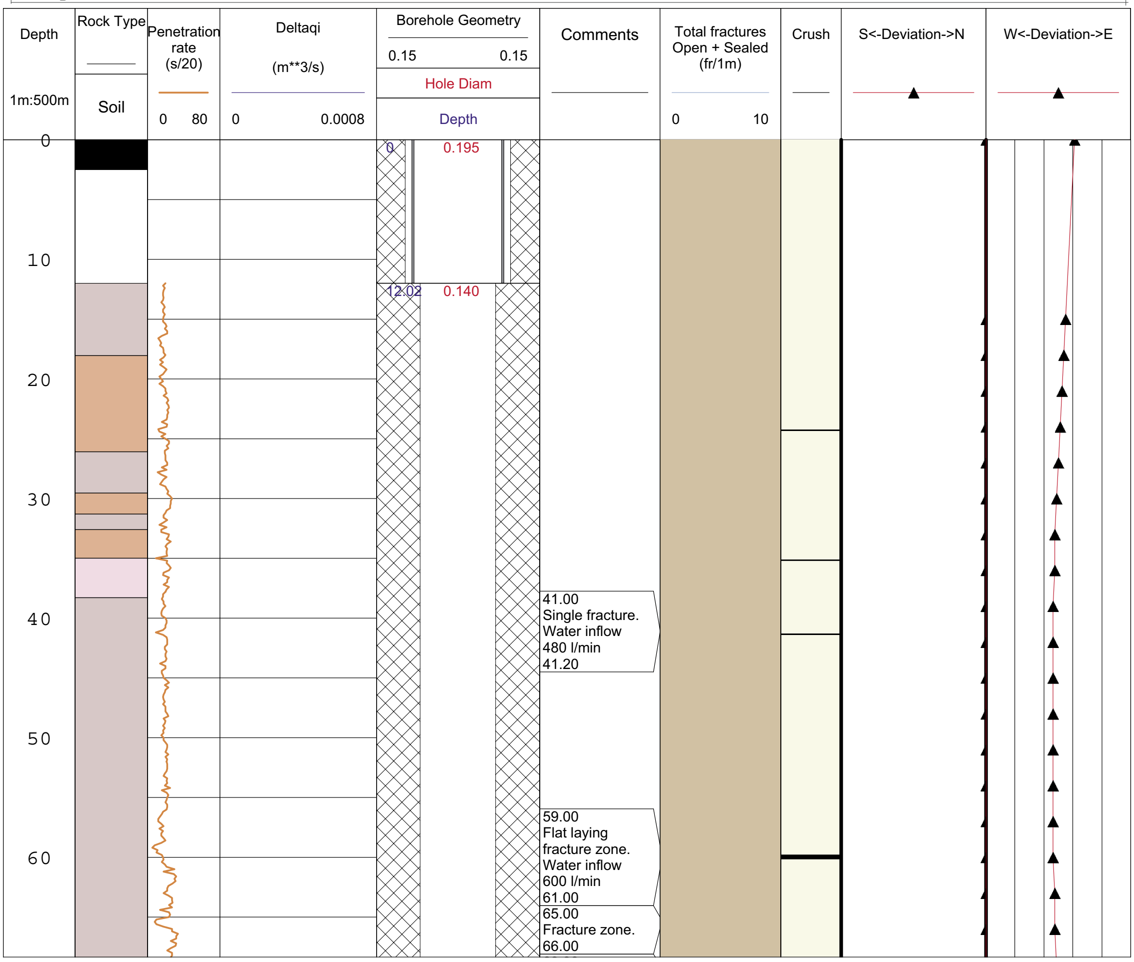
ROCKTYPE FORSMARK

- **Granite, fine- to medium-grained**
- **Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained**
- **Granite to granodiorite, metamorphic, medium-grained**
- **Amphibolite**

SOIL

- **Soil**

Script Name



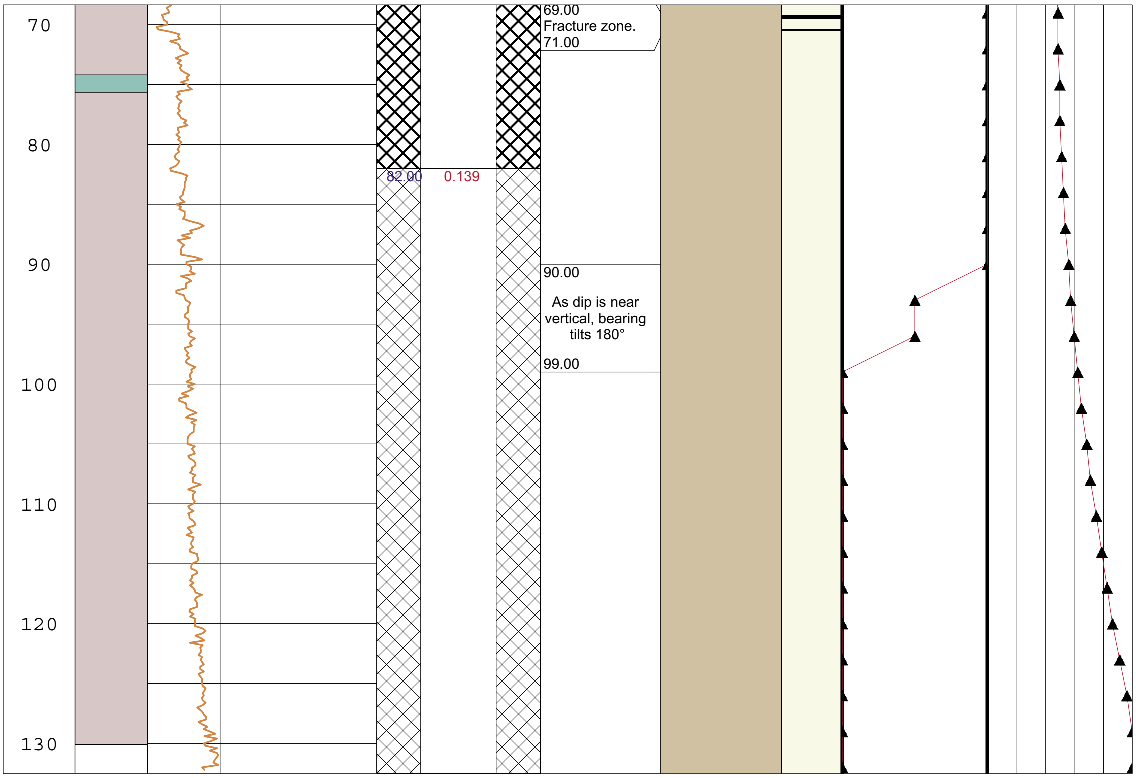


__Figure 5-2.__ Technical and geoscientific data acquired during drilling of borehole HFM16.

5.4 Hydrogeology

5.4.1 Observations during drilling

During drilling of borehole HFM16, the accumulated water flow rate increased to about 1800 L/min during a period where the drilling length increased from c 65 m to 80 m (Figures 5-3 and 5-4). This is the highest inflow of water seen so far during the investigations in the Forsmark area. The flow rate then decreased to about 1200 L/min, possibly indicating that a minor aquifer close to the borehole was emptied, whereupon steady-state conditions ensued. It must however also be underlined, that the flow rate measurements are impaired by a relatively large degree of inaccuracy due to the huge flow rate.

The electrical conductivity indicates a relatively fresh water inflow at 41 m, cf Figure 5-3. The increasing trend in electrical conductivity from 65 m to end of drilling indicates either additional inflows versus depth with a higher salinity or that the continuous pumping results in emptying of the fresh-water aquifer, entailing that more saline water reaches the borehole by up-coning.

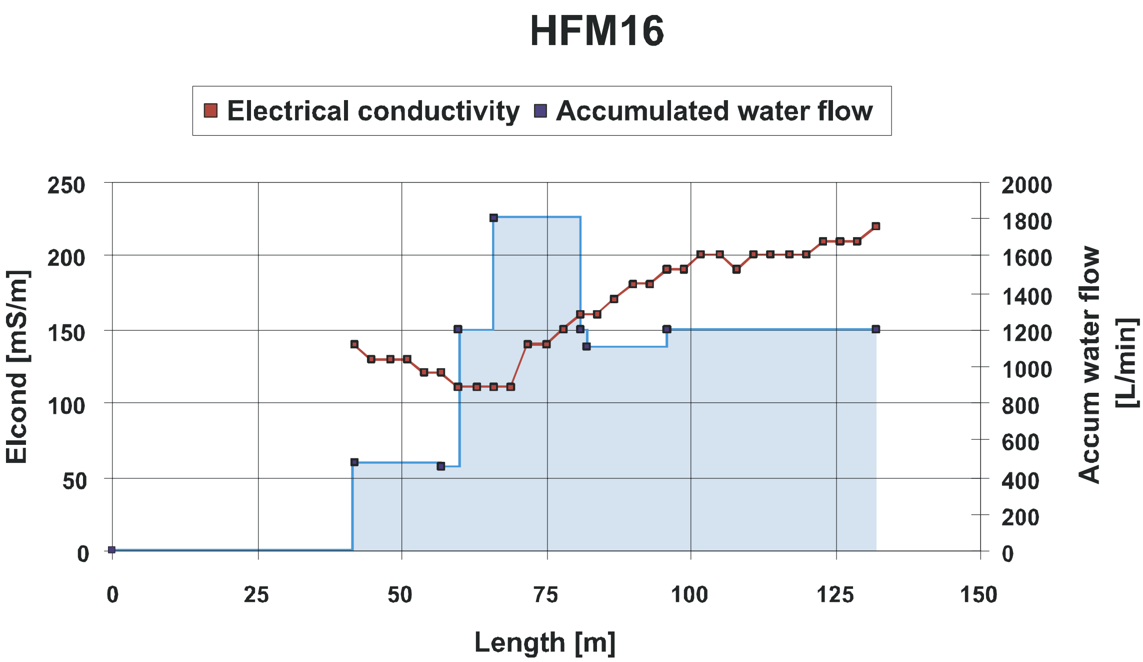


Figure 5-3. Electrical conductivity and accumulated groundwater flow rate versus drilling length in HFM16.

Figure 5-4. *Discharged groundwater (c 1800 L/min) during drilling of borehole HFM16.*

5.4.2 Hydraulic response

During percussion drilling of section 0–100 m of borehole KFM06A (situated close to HFM16, see Figure 1-2), performed after completed drilling of HFM16, open fractures were penetrated and hydraulic responses observed in HFM16, see Figure 5-5).

A link of water-bearing structures between boreholes HFM16 and the percussion drilled part of KFM06A (illustrated with blue schlieren in Figure 5-5) is therefore obvious. In Figure 5-5 this flat-dipping structure is extended to a presumed fracture zone, indicated by a lineament striking WSW-ESE c 160 m north-west of drilling site DS6, see Figure 1-2. Figure 5-5 thereby illustrates a preliminary, simplified interpretation of the structural situation associated with the drilling site. However, if the fracture zone is dipping steeply, neither borehole HFM16 nor the percussion drilled part of KFM06A may have intersected the zone. In this case the extension of the deep water-bearing structure encountered in the two boreholes is uncertain.

If the above mentioned lineament represent the same structure as the A2 reflector, cf Figure 5-6, interpreted from a reflection seismic survey to strike WSW-ENE, dip flatly towards ESE, and to intersect the ground surface close to drilling site DS6, cannot be verified with the information available to-day, but represents one of several possible interpretations.

The shallow, highly fractured, but not water yielding section occurring in both HFM16 and KFM06A (grey schlieren in Figure 5-5), is interpreted as being of the same nature as observed in outcrops at drilling site DS5, as well as in several boreholes at drilling sites DS1–DS4. A significant characteristic of these sections is low water yielding capacity, although the rock is highly fractured and altered. A possible explanation to the low water yielding capacity may be, that part of the fracture system is filled with fine-grained, low-conductive sediments, a phenomenon observed in outcrops, boreholes and rock cuts at different locations within the Forsmark investigation area.

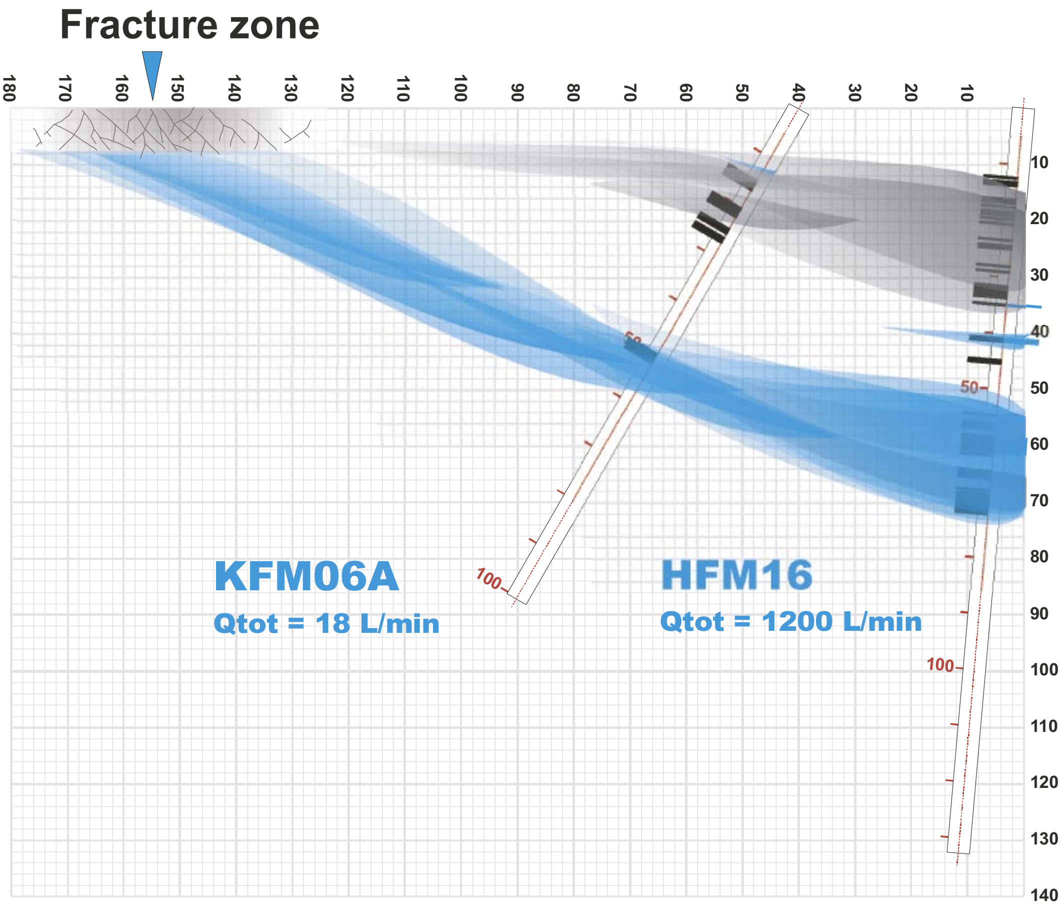


***Figure 5-5.** Tentative, simplified interpretation of the structural conditions in the shallow part of the bedrock at drilling site DS6.*

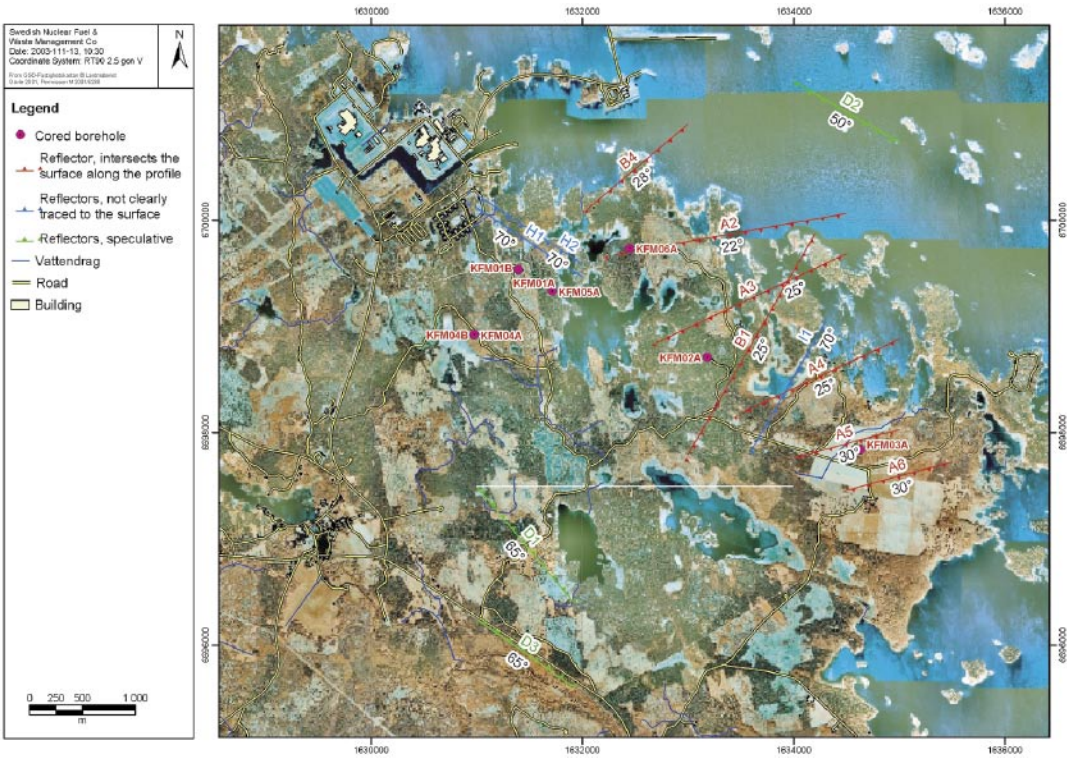


***Figure 5-6.** Reflectors interpreted from a reflection seismic survey in the Forsmark area.*

References

/1/ **SKB, 2001.** Site investigations. Investigation methods and general execution programme. SKB TR-01-29, Svensk Kärnbränslehantering AB.

/2/ **SKB, 2001**. Execution programme for the initial site investigations at Forsmark. SKB P-02-03, Svensk Kärnbränslehantering AB.

/3/ **SKB, 2004.** Claesson, L-Å & Nilsson, G. Forsmark site investigation. Drilling of the telescopic borehole KFM06A at drilling site DS6. SKB P-report in progress, Svensk Kärnbränslehantering AB.

/4/ **SKB, 2003.** Johansson, P-O. Forsmark: Drilling and sampling in soil. Installation of ground water monitoring wells and surface water level gauges. SKB P-03-64, Svensk Kärnbränslehantering AB.

/5/ **SKB, 2003.** Sohlenius, G. & Rudmark, L. Forsmark. Forsmark site investigation. Mapping of unconsolidated Quaternary deposits 2002–2003. Stratigraphical and analytical data. SKB P-03-14. Svensk Kärnbränslehantering AB.

/6/ **SKB, 2004.** Nordman, C. Forsmark. Boremap mapping of percussion borehole HFM16–18. SKB P-report in progress. Svensk Kärnbränslehantering AB.

/7/ **SICADA.** Field Note No Forsmark 216.