P-07-98

Oskarshamn site investigation

Drilling of cored borehole KLX18A

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June 2007

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Keywords: Core drilling, Bedrock, Measurement while drilling, Flushing water monitoring, Water sampling, Wireline measurements, Air-lift pumping, Telescope hole.

Abstract

Borehole KLX18A is located in the Laxemar subarea. Drilling was made between February and May 2006 as a part of the site investigation for a possible repository for spent nuclear fuel in Oskarshamn municipality, Sweden. KLX18A was the fifteenth deep cored borehole within the site investigation in Oskarshamn.

KLX18A was core drilled to a length of 611.28 metres with N-size (76 mm) equipment. The uppermost section, to the length of 99.93 metres, was constructed as a telescopic section with an inner nominal diameter of 200 mm.

No water inflow could be measured over the entire length of the telescopic section during percussion drilling.

Five successful pumping tests were performed in KLX18A with wireline equipment. The resulting transmissivities (T_M) varied between 1.2×10^{-7} and 7.8×10^{-6} m^2/s. The most transmissive section was between 312 and 611 metres.

Continuous monitoring of drilling parameters and flushing water parameters with the drilling monitoring system was conducted throughout the core drilling phase in KLX18A.

Four water samples for chemical analysis were collected during the core drilling of KLX18A.

An air-lift pumping test in the telescopic section performed when borehole KLX18A was core drilled to its full length gave a transmissivity (T_M) of 1.9×10^{-5} m^2/s.

Lithologically the core is being dominated by Ävrö granite with minor portions of diorite/gabbro or fine-grained diorite-gabbro.

Red staining with weak to medium intensity occurs sporadically to ca 490 metres. Below 490 metres length the presence of red staining is very rare. Sections with red staining are indicated as "oxidized" in Appendix 1.

The average fracture frequency over the entire core drilled section expressed as open fractures is 2.15 (fractures/metre).

Sammanfattning

Borrhål KLX18A ligger inom delområde Laxemar. Borrningen utfördes mellan februari och maj 2006 som ett led i platsundersökningen för ett möjligt djupförvar för använt kärnbränsle i Oskarshamns kommun. KLX18A var det femtonde djupa kärnborrhålet inom platsundersökningen i Oskarshamn.

KLX18A kärnborrades med borrstorlek N (76 mm) till 611,28 meters borrad längd. Den övre delen av hålet, från markytan till 99,93 meter, utfördes som en teleskopdel med cirka 200 mm inre diameter.

Inget vatteninflöde kunde uppmätas över hela teleskopdelen vid hammarborrningen.

Fem lyckade pumptester med wireline-baserad mätutrustning utfördes. De uppmätta transmissiviteterna (T_M) varierade mellan $1,2 \times 10^{-7}$ och $7,8 \times 10^{-6}$ m^2/s. Den mest transmissiva sektionen var mellan 312 och 611 meter.

Kontinuerliga mätningar av borrningsparametrar och spolvattenparametrar via DMS (drilling monitoring system) gjordes under hela kärnborrningsfasen i KLX18A.

Fyra vattenprover för kemisk analysering togs i samband med borrning i KLX18A.

En mammutpumpning i teleskopdelen som gjordes när kärnborrningen i KLX18A utförts till full längd gav en transmissivitet (T_M) på $1,9 \times 10^{-5}$ m^2/s.

Litologiskt domineras kärnan av Ävrögranit med mindre inslag av diorit/gabbro eller finkorning diorit-gabbro.

Rödfärgning med svag till måttlig intensitet förekommer sporadiskt ner till borrad längd 490 meter. Nedanför 490 meter är förekomsten av rödfärgning mycket sällsynt. Sektioner med rödfärgning är angivna som ”oxiderade” i bilaga 1.

Den genomsnittliga sprickfrekvensen över hela borrkärnan uttryckt som öppna sprickor är 2,15 (sprickor/meter).

Contents

1 Introduction

SKB, the Swedish Nuclear Fuel and Waste Management Company, performs site investigations in order to evaluate the feasibility of locating a deep repository for spent nuclear fuel /1/. The investigations are performed in two Swedish municipalities: Östhammar and Oskarshamn. Borehole KLX18A is located in the central part of the Laxemar subarea of the investigation area in Oskarshamn /2/.

Drilling and investigations in boreholes are fundamental activities in order to facilitate characterisation of rock and groundwater properties at depth. KLX18A was the fifteenth deep cored borehole within the Oskarshamn site investigation. The location of the core drilled borehole and the water source, HLX14 in the Laxemar subarea is shown in Figure 1-1.

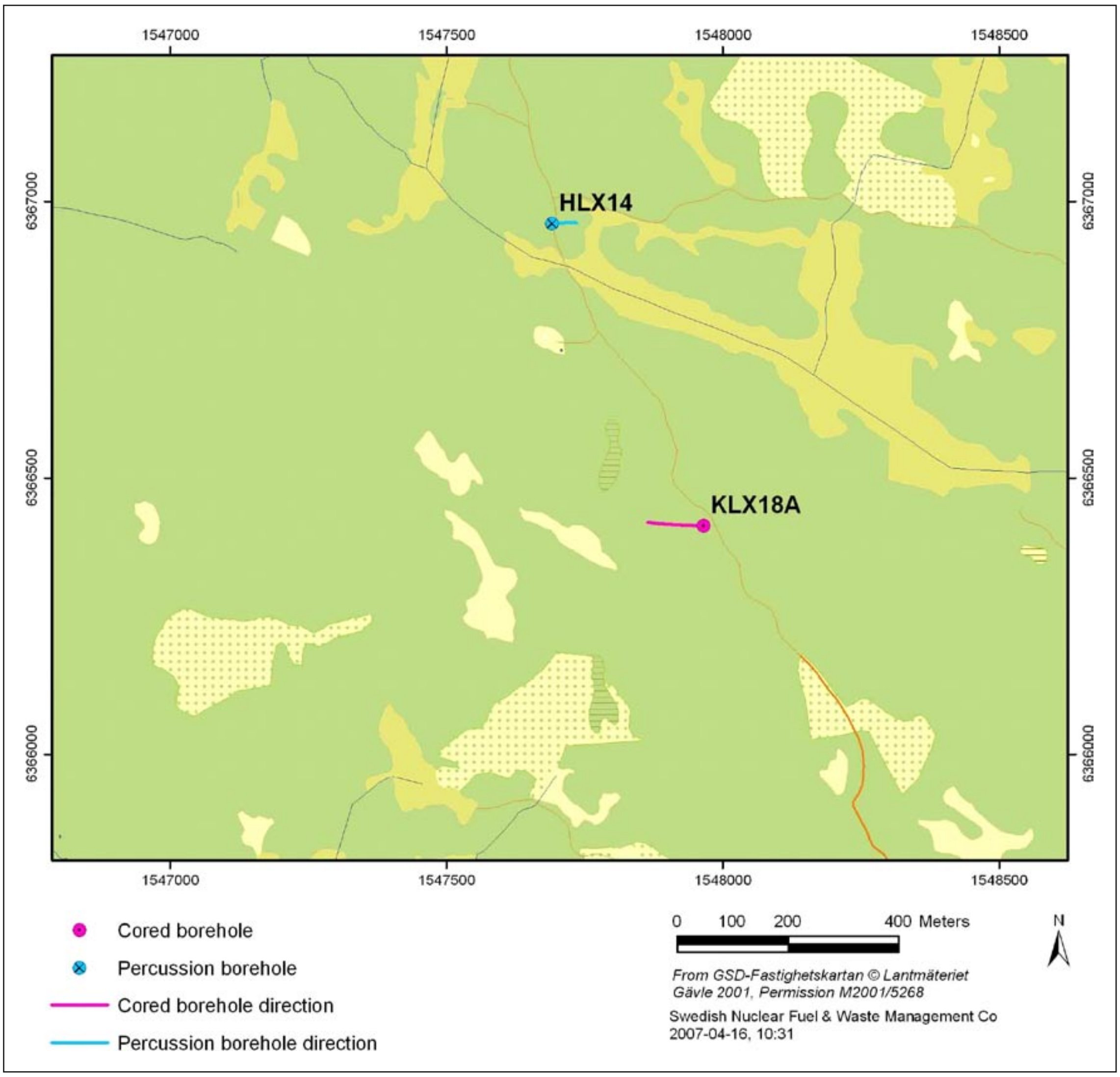


Figure 1-1. *Location of the cored borehole KLX18A and the water source, percussion borehole HLX14 in the Laxemar subarea.*

The drilling of KLX18A and all related on-site operations were performed according to a specific activity plan (AP PS 400-06-011), which in turn refers to a number of method descriptions, see Table 1-1.

The activity plans and method descriptions are SKB internal documents.

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

Activity plan	Number	Version
Kärnborrning KLX18A*	AP PS 400-06-011*	1.0*
Method descriptions	**Number**	**Version**
Metodbeskrivning för kärnborrning	SKB MD 620.003	1.0
Metodbeskrivning för hammarborrning	SKB MD 610.003	2.0
Metodbeskrivning för hydrauliska enhålstester	SKB MD 321.003	1.0
Metodbeskrivning för registrering och provtagning av spolvattenparametrar samt borrkax under kärnborrning	SKB MD 640.001	1.0
Metodbeskrivning för vattenprovtagning, pumptest och tryckmätning i samband med wireline-borrning	SKB MD321.002	1.0
Mätsystembeskrivning för längdmarkering (spårfräsning)	SKB MD620.009	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 undersökningar	SKB MD 600.006	1.0
Instruktion för borrplatsanläggning	SKB MD 600.005	1.0
Instruktion för spolvattenhantering	SKB MD 620.007	1.0
Instruktion för kvalitetssäkring av DMS data, Oskarshamn	SKB MD 640.008	1.0
Instruktion för utsättning och ansättning av hammar och kärnborrhål	SKB MD 600.002	1.0
Instruktion för längdkalibrering vid undersökningar i kärnborrhål	SKB MD 620.010	2.0
Instruktion för hantering och provtagning av borrkärna	SKB MD 143.007	1.0
Metodbeskrivning för krökningsmätning av hammar- och kärnborrhål	SKB MD 224.001	1.0
Instruktion för miljökontroll av ytvattten, ytnära grundvatten och mark vid borrning och pumpning i berg	SKB MD 300.003	2.0

* Two amendments to the activity plan exists.

2 Objective and scope

This report will describe the methods employed and the results achieved during the drilling of borehole KLX18A. A number of related activities, such as wireline hydraulic tests, water sampling and monitoring of drilling parameters that were performed in conjunction with drilling will also be reported here.

The main reason for drilling the borehole was to gain geological information and facilitate further investigation at depth in the central part of the Laxemar subarea. The decision for the location of KLX18A is given in SKB id no 1049176, dated 2006-01-17.

The hole was constructed as a "telescope hole", which means that the upper, normally, 100 metre section of the hole has a wider diameter than the deeper core drilled part of the hole.

A notification (SKB id 1047829, 2005-12-15) to the Regional Authorities was sent in accordance with the Environmental Code. Information of the final coordinates and details regarding the return water handling was submitted to the Regional Authorities on 2006-01-17, SKB id no 1049196.

3 Overview of the drilling method

3.1 The SKB telescope drilling method

In brief, the telescope drilling method is based on the construction of a larger diameter hole (200 mm diameter) to a length of normally 100 m followed by a N-size (76 mm diameter) cored section to full length. The larger diameter section can either be percussion drilled or reamed with a percussion bit after core drilling of a pilot hole.

The main purpose of the upper large diameter section is to improve the removal of water from the hole by air-lift pumping in order to minimize the intrusion of foreign substances (flushing water and cuttings) to the surrounding bedrock. It also enables the use of submersible pumps for tests and to facilitate the installation of multi-packer systems for ground water pressure recordings.

After drilling 0–100 m, equipment for air-lift pumping is installed in the borehole. The air-lift pumping will create a pressure drawdown and help remove water and cuttings while core drilling between 100 m and full planned length, see Figure 3-1. The effect of drawdown is dependent on the depth and capacity of major groundwater conductors.

During the core drilling phase several measurements and sampling exercises are performed through the drilling monitoring system (DMS), wireline tests for hydraulic purposes and sampling for water chemistry.

After the core drilling is completed to full length, depth reference slots are reamed in the borehole wall and a conical guide of stainless steel is installed between the telescope part and the deeper core drilled part, see Figure 3-2.

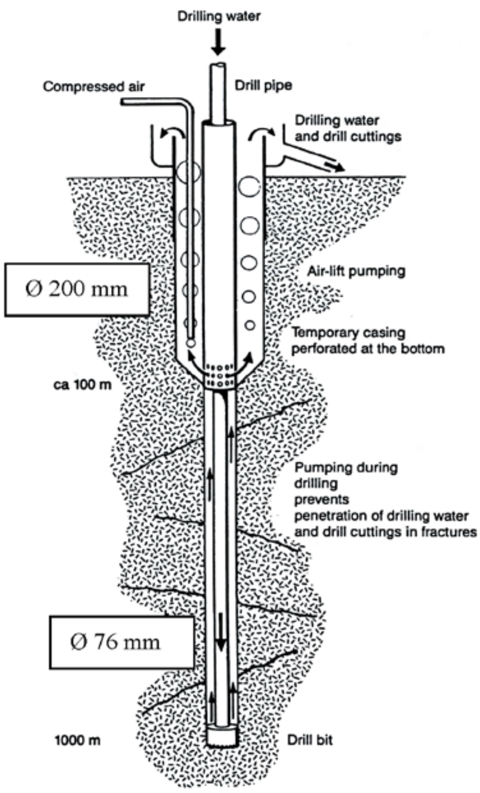


__Figure 3-1.__ A sketch of the telescopic drilling method with air-lift pumping for retrieval of drilling water and cuttings.

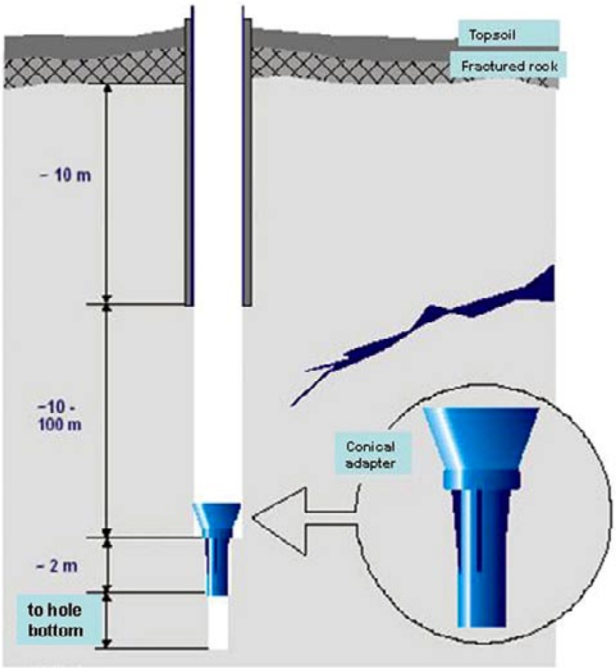


Figure 3-2. Installation of the conical guide.

3.1.1 The flushing water system

The handling of flushing water includes a source of water with a submersible pump, tanks and air-lift pumps for raising the water from the bottom of the telescope part to surface. The return water is led to settling containers before discharge, see Figure 3-3.

Nitrogen gas is bubbled through the drilling water to remove dissolved oxygen. This is done to avoid introduction of oxygen to the formation water and thereby disturbing the virgin chemical properties.

In order to monitor possible mixing of formation and drilling water, a tracer dye (uranine) is added to the drilling water to a fixed concentration, see Figure 3-4.

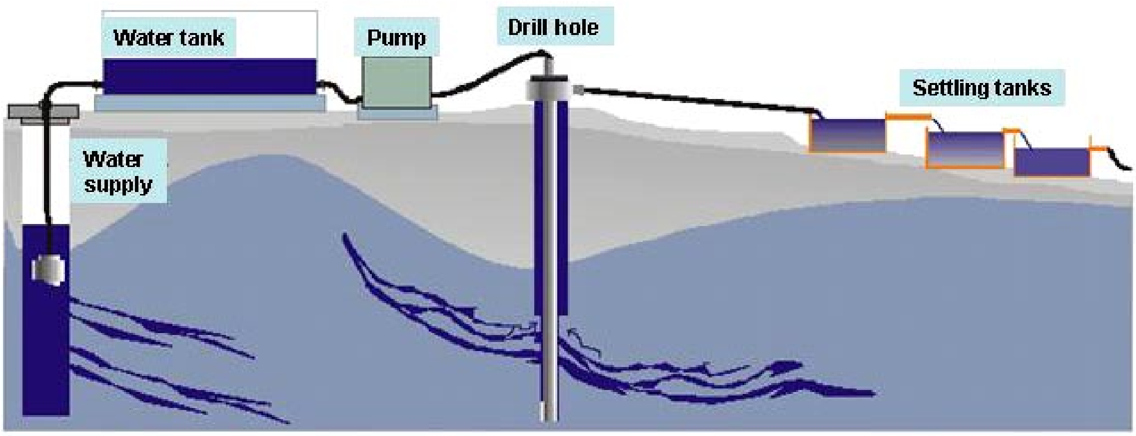


Figure 3-3. The flushing water system from source to discharge point.

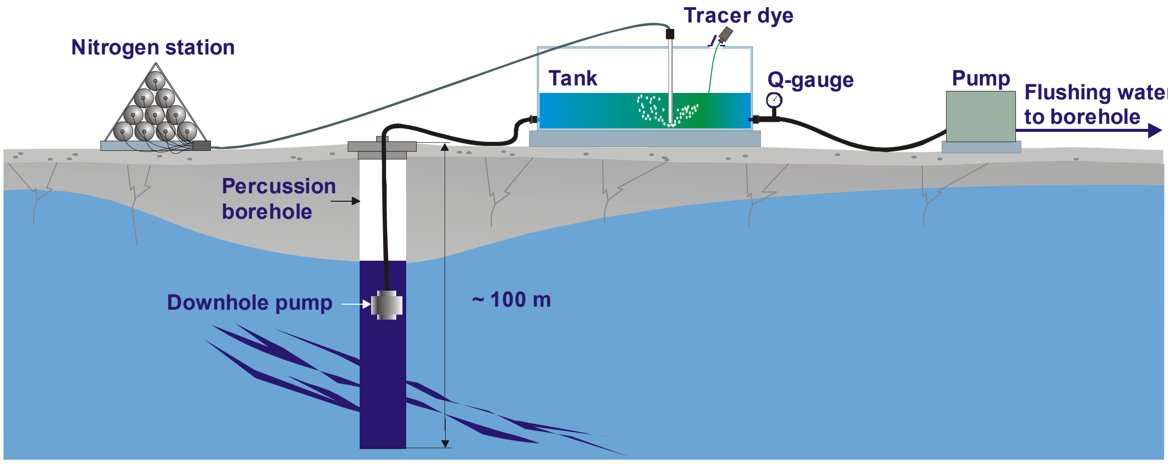


Figure 3-4. Schematic drawing of the preparation of flushing water. Uranine is added to the water as a tracer dye. Nitrogen is bubbled through the water to remove dissolved oxygen.

3.2 Measurements and sampling during drilling

3.2.1 Percussion drilling

Drill cuttings are collected for every metre during the percussion drilling. A preliminary geological logging of the cuttings is done on site. During the preliminary logging notes are made on the dominating lithology, size and shape of the cutting or any other noticeable geological feature. The magnetic susceptibility of the cuttings samples are measured with hand held equipment. Small cups of return water are taken systematically of the return water. The water colour and intensity are noted as indications on degree of rock oxidation and clay content. The return water flow (i.e. the amount of water driven up by compressed air) is measured when noticeable changes in flow occur. The drill penetration rate during percussion drilling is either logged automatically (most common) or manually.

3.2.2 Core drilling

The sampling and measurements during the core drilling phase of KLX18A consisted of:

- Wireline measurements.
- Air-lift pumping and recovery tests.
- Water sampling at the surface.
- The drilling monitoring system.

Wireline measurements and water sampling

The measurements and the sampling are made in the borehole with a wireline based equipment. Pumping tests are evaluated according to Moye /3/ and are normally performed for every 100 metres of drilled length. Sampling of water for chemical analysis is done in conjunction with the pumping tests where feasible. The wireline tests are done in accordance with SKB Method Description MB 321.002, SKB internal document.

NB Measurement of absolute pressure were not done in KLX18A following an internal decision, (SKB id 1044856, internal document).

Air-lift pumping with evaluation of drawdown

Air-lift pumping with evaluation of drawdown is done with 300 metres intervals, nominally at 400 metres and full drilled length. The actual levels are adapted to when changes of drill bit, or some other reason to raise the drill stem, occur. The test is normally based on the drawdown phase.

- The test cycle is started with air-lift pumping in the telescopic section.
- Drilling or other related activities such as rinsing of drill cuttings can occur prior to lifting the stem. This means that an inflow of water through the drill stem can occur during the initial stages of the test cycle.
- After the stem has been removed the air-lift pumping continues between 30 minutes and two hours to achieve stable conditions.
- The air-lift pumping is stopped.
- The recovery of the water table in the telescopic section is monitored.

Water sampling at the surface

Water samples of flushing and return water, i.e. the water entering and returning from the borehole at the surface, are taken at 10 to 20 metre intervals of drilled length for analysis of drilling water content (percentage of water with uranine tracer content) and electrical conductivity.

Drilling monitoring system (DMS)

Drilling is monitored on-line by continuous registration of drill rig parameters (logged every centimetre of bit penetration) and flushing water parameters (logged every 10 seconds). The data is compiled into a database called drilling monitoring system (DMS).

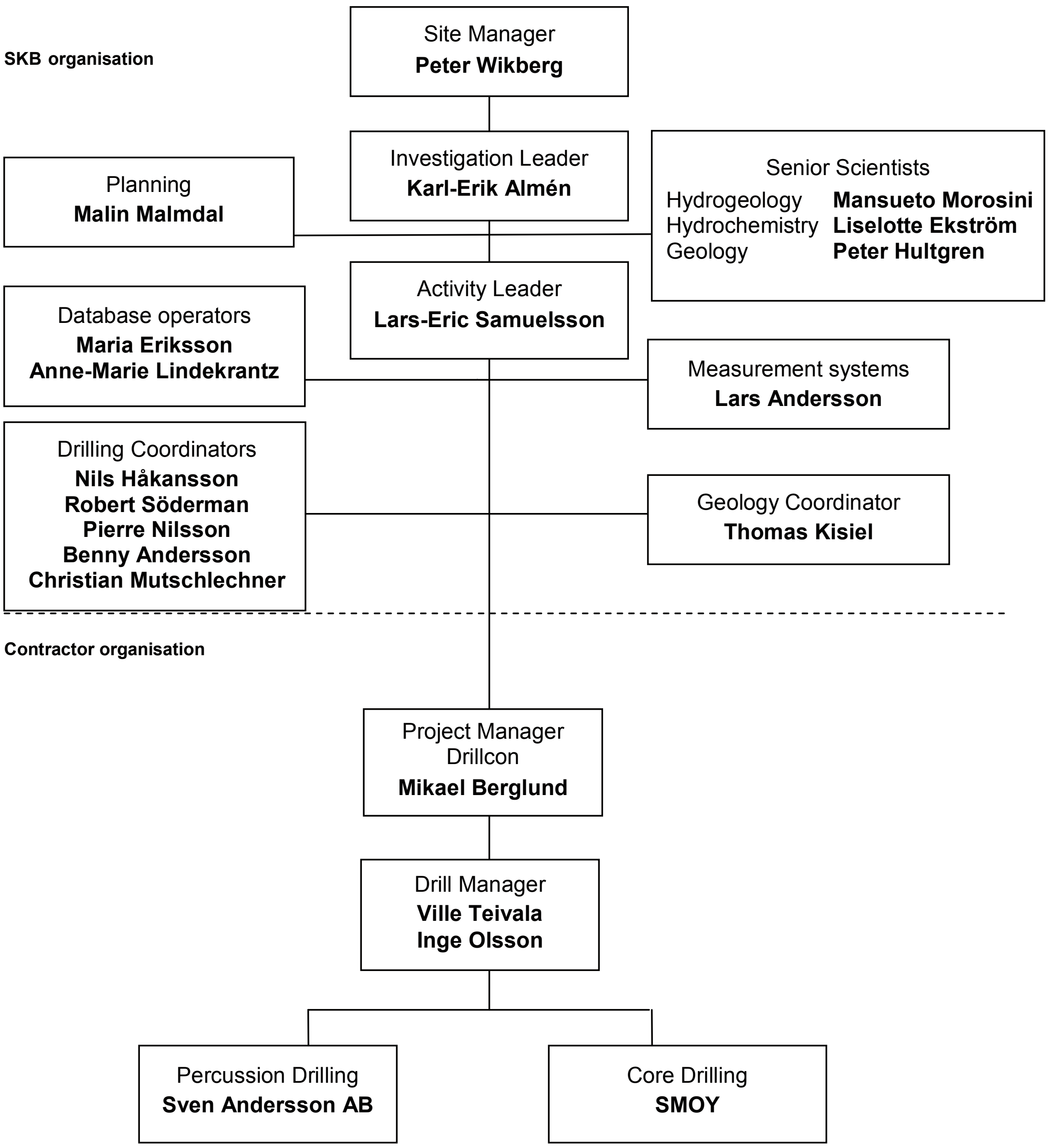
4 Contractors and equipment

4.1 Contractors

The main contractor for drilling was Drillcon Core AB, with subcontractor for core-drilling Suomen Malmi OY (SMOY) and subcontractor for percussion drilling Sven Andersson AB.

An overview of the organisation for the drilling activity is given in Table 4-1.

Table 4-1. Drill activity organisation.



4.2 Percussion drilling equipment

The equipment used in KLX18A was a Comacchio MC1500 percussion drill rig with an Atlas Copco XRVS 455 Md air compressor. Overburden drilling was made with NO-X 280 mm equipment. The down-the-hole hammer was a Secoroc 165 mm for the pilot borehole and the drill rods were Driqoneq 114 mm. Reamings were done with Secoroc DTH-hammers for 200 or 250 mm diameter. The casings utilized were 208×4 mm (SS 2343, stainless) and 323×11 mm (non stainless). The casing dimensions are presented here as outer diameter × thickness.

4.3 Core drilling equipment

Core drilling in KLX18A was made with a Diamec U8 APC Atlas Copco fully hydraulic machine fitted with a modern and environmentally adapted diesel engine. The drilling was done with N-size, i.e. giving a borehole of 76 mm diameter. The core barrel was of the type AC Corac N3/50, a triple-tube wireline equipment which gives a core diameter of 50.2 mm. The rods were of type NT. Directional drilling was not made in KLX18A.

The drill rig was fitted with a diesel power generator of 175 kW which would give a capacity for drilling to a depth of ca 1,500 m with N-size drilling.

4.3.1 Measurements with wireline probe

The wireline probe has been developed by SKB. With this equipment water sampling, pump tests and measurements of absolute pressure in a borehole section can be made without having to lift the drill stem.

Measurements are made as specified in method description SKB MD 321.002, SKB internal document.

The principal components are:

- an inflatable packer,
- pressure gauges for the test section and for the packer,
- a water sampler,
- a submersible pump (placed in the upper part of the drill stem),
- a flow meter (placed at the ground surface).

The probe is lowered through the drill stem into position at the drill bit. The test section is between the lower end of the packer and the bottom of the borehole, see Figure 4-2.

Before the pumping tests are made leakage tests of the drill string are done.

Hydraulic tests performed during drilling are generally affected to some degree by disturbances caused by the drilling operations. Transients from changes in pressure, temperature and salinity might affect the hydraulic response curves.

Pumping tests

The wireline probe is emplaced at the bottom of the drill stem. A submersible pump (Grundfoss MP1 or equivalent) is lowered into the upper part of the drill stem at a length of about 40 m. The test section is hydraulically connected to the drill stem by opening a valve at a predetermined pressure. This creates a passage between the test section and the water column in the drill stem. The packer remains expanded during the entire test. Water is pumped from the drill stem and the pressure in the test section and packer are recorded in a data logger. The pumped surface flow rate is recorded in a data logger on the ground surface. The pressure gauge (or pressure

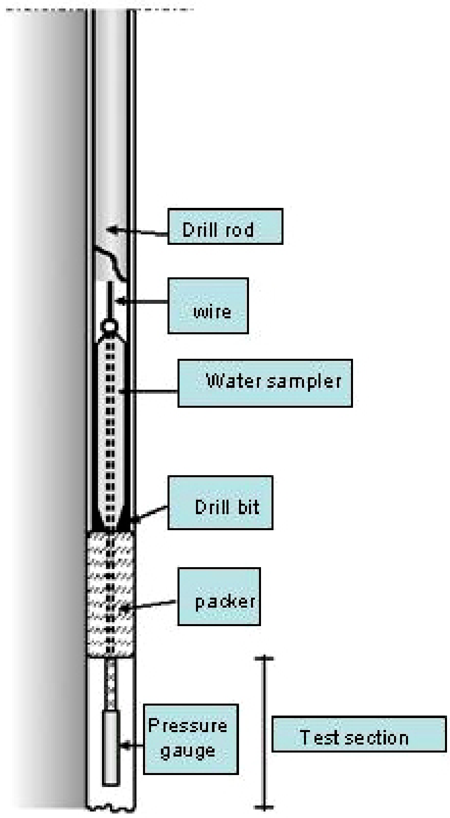


Figure 4-2. *The wireline probe and its emplacement in the hole.*

transducer) is situated 1.10 m below the lower end of the packer. The test consists of a pressure drawdown phase and a recovery phase. Typically the pumping time is three hours with a recovery phase of the same duration. However, the duration is sometimes adapted to the hydraulic situation of the tested section. The tests are normally carried out in sections of about 100 m length.

Water sampling

The equipment for water sampling is the same as for the pumping tests. The water volume in the section is removed at least three times by pumping water out of the drill stem. The water in the test section is then replaced by formation water and a sample is collected. The wireline probe, with the sampling unit containing a maximum volume of 5 litres, is subsequently brought to the surface.

Pumping tests and water sampling are normally performed as an integrated activity. The aim is to characterize the hydrochemistry as well as the hydrology in the bedrock when the conditions are least affected by hydraulic short circuiting in the borehole.

Absolute pressure measurement

No measurements of absolute pressure were done in KLX18A.

4.3.2 Drilling monitoring system

During the core drilling phase continual monitoring was made of several measurement-while-drilling (MWD) parameters and flushing water parameters. The data is compiled into the DMS database. The procedure for data handling and quality assurance is given in method description SKB MD 640.008 (SKB internal document).

The drill rig (MWD) parameters include:

- Rotational pressure (bar).
- Bit force (kN).
- Flush water flow in (L/min).
- Water pressure at bit (kPa).
- Rotation (rpm).
- Penetration rate (cm/min).

The flushing water parameters include:

- Water level in the telescope part of the borehole (kPa).
- Oxygen level of flushing water (mg/L).
- Flow of flushing (ingoing) and return (outgoing) water (L/min).
- Electrical conductivity of flushing and return water (mS/m).
- Barometric pressure (kPa).

Data from on-line monitoring of flushing water parameters were stored on two different logging units (CR10 and CR23). A separate logging unit was used for the measurement-while-drilling (MWD) dataset. The data from the loggers was downloaded either continuously (CR10 and CR23) or by diskette or CD-ROM to the DMS database.

4.3.3 Deviation measurements

Two types of deviation measurements were made:

- Measurements to keep track on the borehole orientation (primarily the dip) were made twice with the magnetometer/accelerometer method Reflex EZ-AQ/EMS, also called "Easy-shot".
- Final measurements, along the entire length of the borehole after the drilling was completed, was made with two methods, Flexit and Maxibor. The Maxibor (Reflex MAXIBOR™) is a non-magnetic, optical method. The Flexit instrument (Flexit SmartTool) is based on magnetometer/accelerometer measurements. All final deviation measurements, i.e. both Maxibor and Flexit, were made both up and down the borehole in KLX18A.

4.3.4 Equipment for reaming reference slots

In order to establish accurate and similar depth references for the various measurements that will be performed in the borehole, reference slots are reamed in the borehole wall.

The equipment has been developed by SKB and consists of a reaming tool that can be fitted to conventional drilling rods for 56 and 76 mm drilling equipment. The reaming tool is operated hydraulically from the surface, so that the cutters expand when the water pressure is increased.

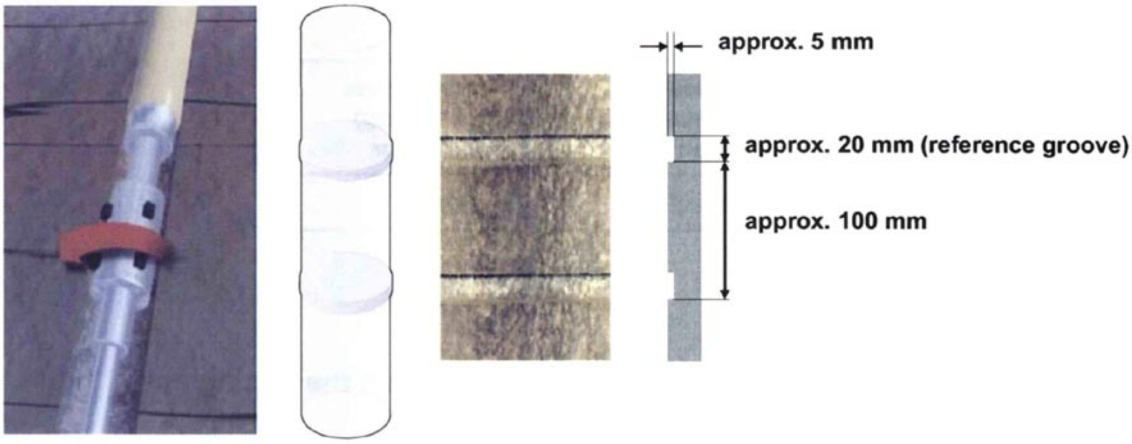


Figure 4-3. *The equipment for reaming of reference slots. To the left, the reaming tool with openings for the cutters is shown. The resulting reference slots are illustrated in the three pictures to the right.*

5 Execution and results

The original data and results are stored in the SICADA database. Only the datasets in the database will be used for further interpretation and modelling. The data is traceable in SICADA by the Activity Plan number, AP PS 400-06-011.

5.1 Summary of KLX18A drilling

A technical summary of the drilling of KLX18A is given in Table 5-1. A graphical presentation of the borehole after completion is given in Figure 5-1. A summary of drilling progress and borehole measurements is given in Table 5-2 and chronological summary is presented in Table 5-3.

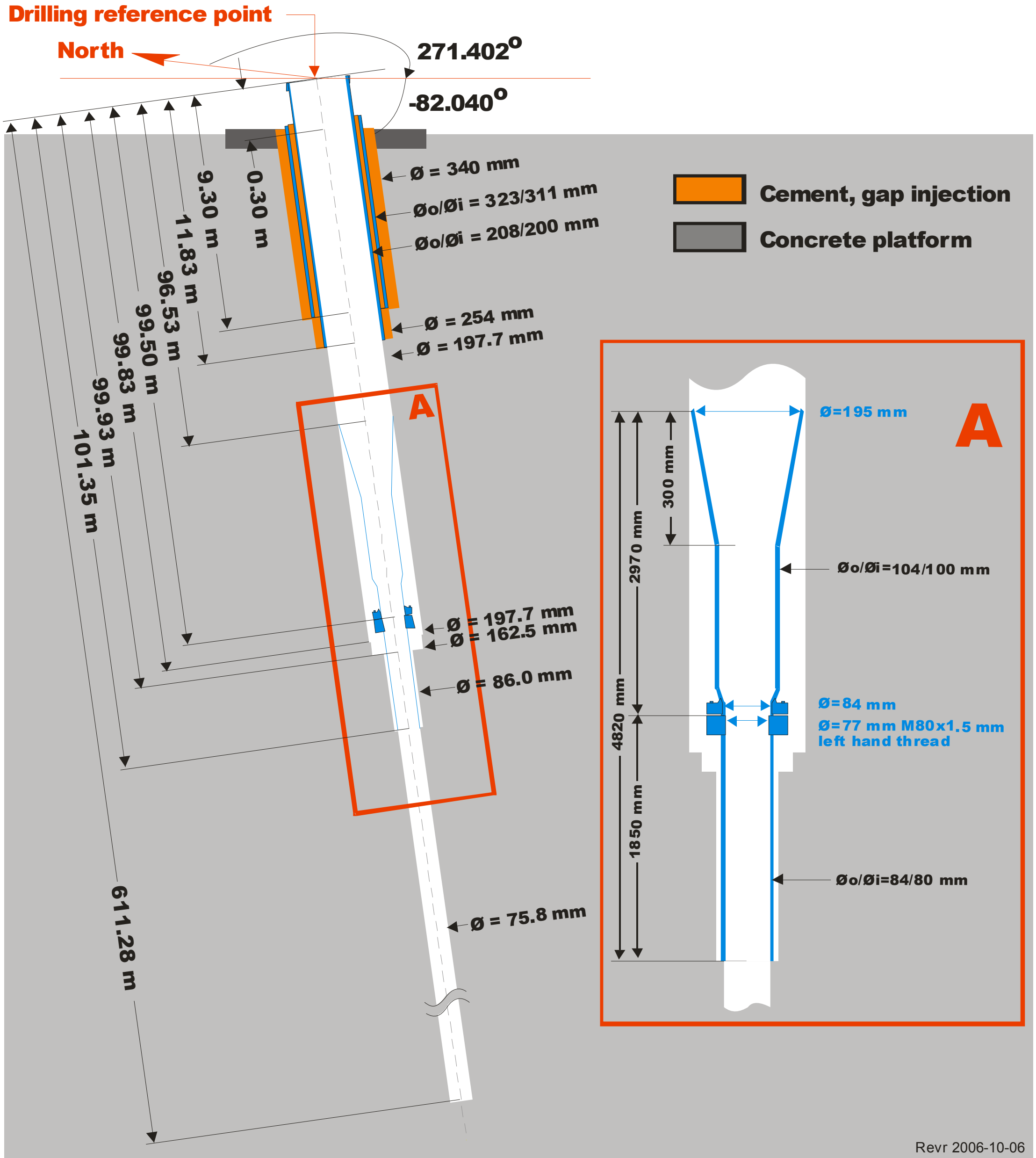
Further descriptions of the percussion drilling of the telescopic section 0–99.93 metres and the measurements performed during this phase are given in Section 5.2. The core drilling between 99.93–611.28 metres is further described in Section 5.3. Results from hydrogeological and hydrogeochemical measurements during core drilling are presented in Section 5.4. Drilling progress over time is further reported in Section 5.5 “Drilling monitoring results”.

Table 5-1. KLX18A Technical summary.

General	Technical
Name of hole: KLX18A	*Percussion drill rig:* Comacchio MC1500
Location: Laxemar, Oskarshamn Municipality, Sweden	*Percussion hole length:* 99.83 m (diam 197.7 mm) 99.93 m (diam 162.5 mm)
Contractor for drilling: Drillcon AB	*Core drill rig:* U8 APC Atlas Copco *Core drill dimension:* N-size (76 mm)
Subcontractor percussion drilling: Sven Andersson AB	*Cored interval:* 99.93–611.28 m *Diamond bits used*: 7
Percussion drill start date: February 15, 2006	*Average bit life:* 73 metres
Completion date: February 21, 2006	*Position KLX18A (RT90 RH70) at top of casing:* N 6366413.39 E 1547966.35 Z 21.01 (m.a.s.l.)
Subcontractor core drilling: Suomen Malmi OY (SMOY)	*Azimuth (0–360)/Dip (0–90):* 271.40/–82.04
Core drill start date: March 29, 2006	*Position KLX18A (RT90 RH70) at 611.28 m length:* N 6366419.89 E 1547864.24 Z –581.60 (m.a.s.l.)
Completion date: May 2, 2006	*Azimuth (0–360)/Dip (0–90):* 278.11/–79.69

Technical data

Borehole KLX18A



Drilling reference point

Northing: 6366413.39 (m), RT90 2,5 gon V 0:-15

Easting: 1547966.35 (m), RT90 2,5 gon V 0:-15

Elevation: 21.01 (m), RHB 70

Drilling period

Drilling start date: 2006-02-15

Drilling stop date: 2006-05-02

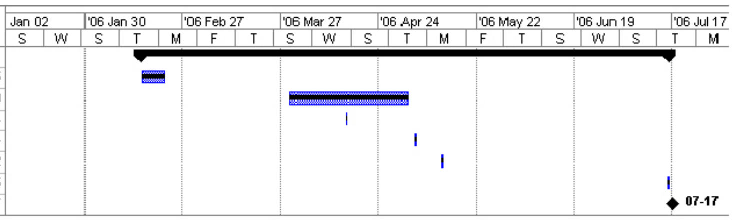
Figure 5-1. *Technical data from KLX18A.*

Table 5-2. Summary of core drilling progress and borehole measurements in KLX18A.

bh metres	Drilled length, pumping tests and water sampling	Airlift pumping with evaluation of drawdown and/or recovery	Deviation measurement	Miscellaneous
100	060329 Pumping test in the telescopic section 11.83-100.80 m. Water flow approximately 1 L/min at 23 m drawdown.			
200			060405 180 m Dip -80.3	
300	060407 Pumping test 102.00-242.35 m. Water sample. 060413 Pumping test 239.94-313.73 m. Water flow 0.2 L/min at 16 m drawdown. No water sample.	060414 Airlift pumping 11.83-346.54 m. No drillstem in borehole.		
400			060421 420 m Dip -80.0	
500	060424 Pumping test 312.00-488.06 m. Water flow 3.5 L/min at 18 m drawdown. No water sample.			
600	060505 Pumping test 471.00-611.28 m. Water flow 1.5 L/min at 19 m drawdown. Water sample.	060511 Airlift pumping 11.83-611.28 m. No drillstem in borehole.	060504 Final measurements with Maxibor. Two measurements with runs both up and down. 060515 Final measurement with Flexit. Two measurements with runs both up and down.	060502 KLX18A core drilling completed at 611.28 m. 060505-060508 Pumping test 312.00-611.28 m. Water flow 5 L/min at 18 m drawdown. Water sample. 060514, 18 and 24 Nitrogen flushing with drill stem lowered to 611 m length.

Table 5-3. Chronological summary of main drilling events in KLX18A.

ID		Aktivitet	Start
1	✓	**First activity starts**	**Wed 06-02-15**
2	✓	Percussion drilling	Wed 06-02-15
3	✓	Core drilling	Wed 06-03-29
4	✓	Recovery test	Fri 06-04-14
5	✓	Maxibor measurement	Thu 06-05-04
6	✓	Length calibration marks	Fri 06-05-12
7	✓	Recovery test	Sat 06-07-15
8	✓	Last activity ends	Mon 06-07-17



5.2 Drilling, measurements and results in the telescopic section 0–99.93 m

Drilling, reaming and grouting (gap injection) were made from February 15 to 21, 2006.

5.2.1 Preparations

A cement pad for emplacement of drill rig, fuel container and compressor was built.

Cleaning of all DTH (down-the-hole) equipment was done with a high-capacity steam cleaner.

5.2.2 Drilling and casing installation

The construction of the upper telescope section (0–99.93 metres) of KLX18A was made in steps as shown in Figure 5-2 and described below.

Drilling was done by Sven Andersson AB and consisted of the following items:

- Drilling was made to 9.30 metres length with NO-X 280 mm equipment. This gave a hole diameter of 343 mm and left a casing (323/310 mm diameter) to a length of 9.30 metres.
- Inner supportive casing for guidance for the drill string was mounted.
- A pilot percussion hole was drilled to a depth of 99.93 metres. The diameter at full length was 162.5 mm.
- Deviation measurement was attempted but results were not obtained due to malfunctioning equipment.
- Reaming to diameter 254 mm was done from 9.30 to 11.83 metres
- Stainless casing of 208×4 mm was installed from 0 to 11.83 metres.
- Casing grouting (gap injection) with low alkali cement based concrete (420 litres) was made for both sets of casing. The outer casing was cut along the ground surface.
- After the concrete had hardened, the hole was reamed from 11.83 to 99.83 metres. The diameter at full length was 197.7 mm. The borehole was rinsed and flushed to remove concrete and water. No test of the tightness of the concrete seal (casing grouting) was made, see Section 5.9.

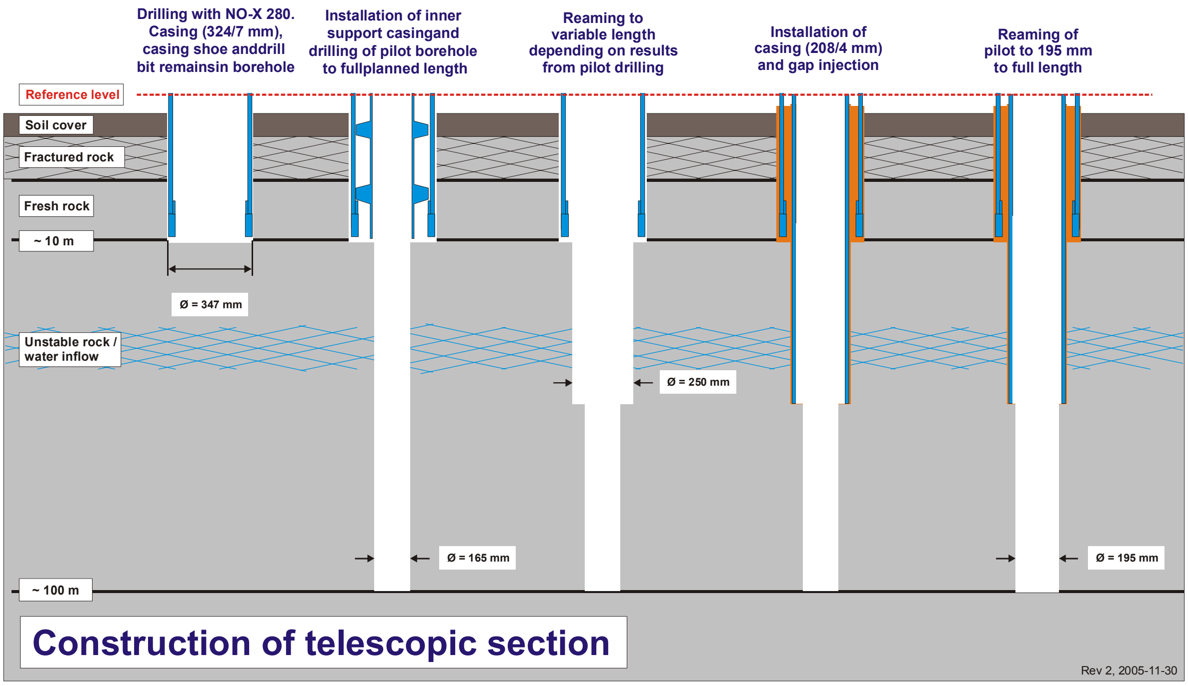


Figure 5-2. Construction of the telescopic section. The cement for casing grouting is introduced between the casing and the rock wall. The drill bit acts as a barrier so that cement does not enter the pilot hole.

5.2.3 Measurements and sampling during drilling of the telescopic section

Sampling and measurements done during drilling of the telescopic section included:

- The percussion drilling progress was monitored by a contracted geologist. Drill cuttings samples were collected every metre and a preliminary geological logging including measurement of magnetic susceptibility was made.
- Penetration rate (expressed as seconds per 20 cm) was recorded automatically and observation of changes in water flow was noted.

The preliminary geological results with penetration rate and magnetic susceptibility as measured on the cuttings are presented in Figure 5-3.

The depth to bedrock from top of casing was 2.3 metres. The soil depth (ground surface to rock) was 2.0 metres.

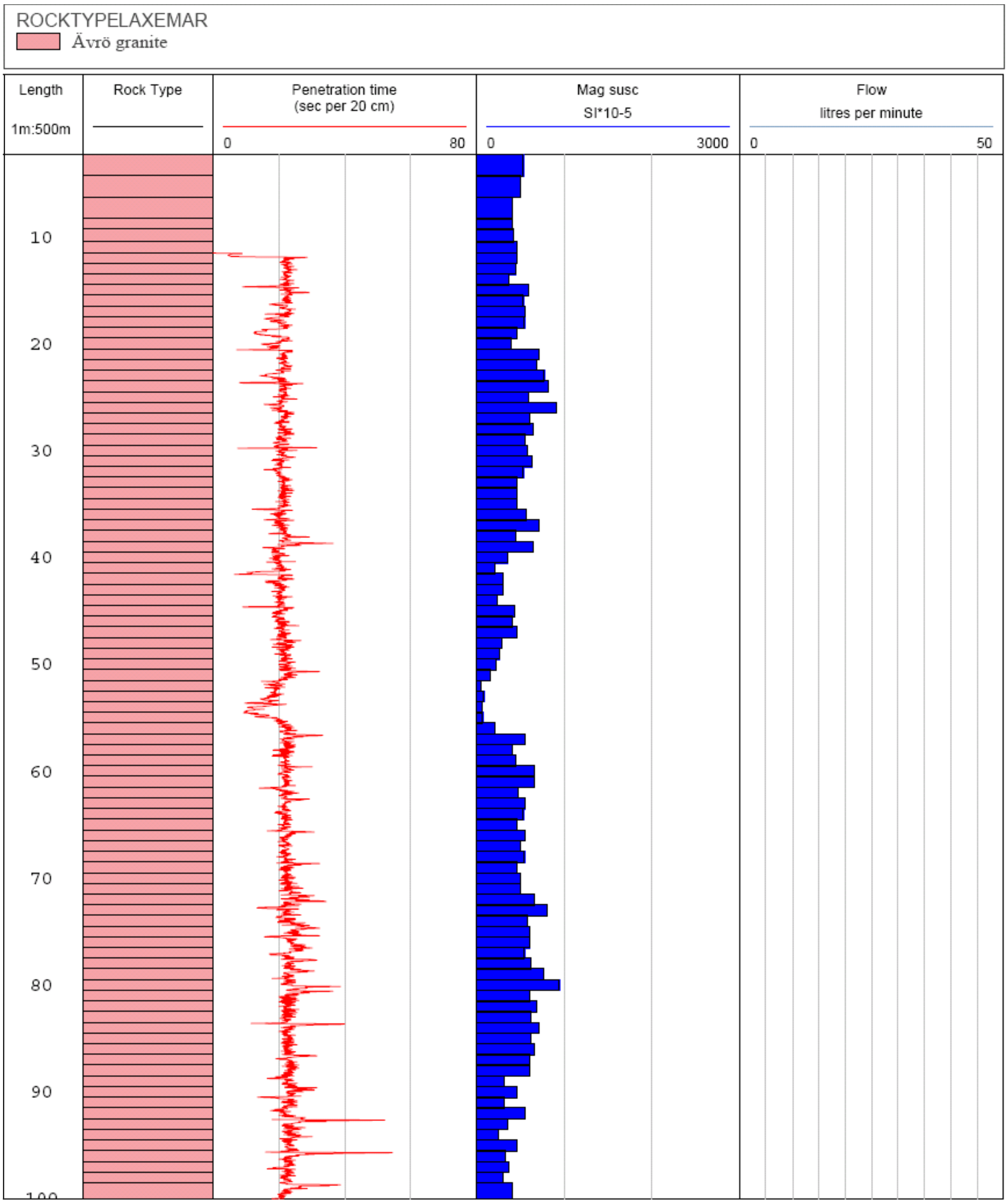


Figure 5-3. Preliminary geological results based on logging of drill cuttings and penetration rate from percussion drilling of KLX18A.

Hydrogeological observations during percussion drilling

No water inflow could be measured over the entire length of the telescopic section.

5.2.4 Hydrogeological measurements in the telescopic section

In the telescopic section of KLX18A a pumping test was performed in open borehole. The result is shown in Table 5-4 below and graphically in Appendix 5. The pumping phase was 11 h and 40 min, and the recovery phase was 13 h and 10 min.

No water samples were collected in the telescopic section in KLX18A.

5.3 Core drilling KLX18A 99.93–611.28 m

Core drilling in KLX18A was conducted between March 29 and May 2, 2006.

The main work in KLX18A after drilling the telescopic section consisted of the following steps:

- preparations for core drilling,
- flushing and return water handling,
- core drilling including directional drilling and deviation measurements,
- borehole completion including risk assessment of the borehole wall stability.

Measurements and results from wireline tests and drilling monitoring are given in Sections 5.4 and 5.5.

5.3.1 Preparations

The preparations for core drilling started on March 22, 2006 and consisted of installation of air-lift pumping equipment and supportive casing for alignment of the core drill rods, see Figure 5-4.

The installation of supportive casing was done in steps:

- An outer casing with a diameter of 98/89 mm, fitted with fins to align with the diameter of the percussion drilled borehole was installed.
- Equipment for air-lift pumping was installed and a discharge header was fitted to collect the return water.
- Drilling was made between 99.93 and 100.80 m with T-86 equipment. An inner supportive casing with diameter 84/77 mm was installed to 100.80 m.

The supportive casings have a perforated section between 99.20 and 99.60 metres length so that water from the borehole can be lead to the air-lift pumping system outside the supportive casings. A pressure meter for monitoring of the water level was emplaced at a length of 90 metres.

Table 5-4. Results from pumping test in KLX18A, 11.83–100.80 m.

Tested section [m]	Q/s [m²/s]	T_M [m²/s]	Comments
11.83–100.80	$7.8 \cdot 10^{-7}$	$8.8 \cdot 10^{-7}$	Pumping test without wireline probe in open borehole. The tested section consists of the uncased telescopic part from 11.83 to 99.93 and the 86 mm diameter core drilled part from 99.93 to 100.80 m.

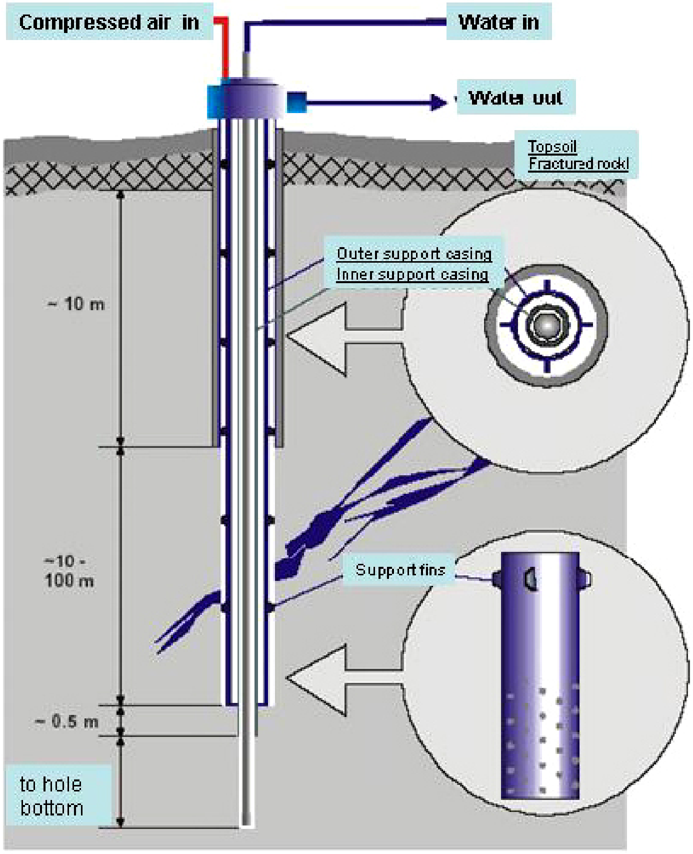


Figure 5-4. In the telescopic part of the drill hole a temporary installation is made with casing tubes for support and alignment and equipment for air-lift pumping. In the uppermost part the return water discharge header is mounted. The water discharge is led to the settling containers.

5.3.2 Flushing and return water handling

The flushing water source was percussion borehole HLX14, see also Sections 5.4.2 and 5.5. The location of the water source, borehole HLX14 is shown in Figure 1-1.

Treatment of the flushing water before introduction into the boreholes consisted of removal of oxygen by nitrogen flushing and addition of the fluorescent tracer uranine. The water is also treated with ultraviolet light in order to reduce the microbial content. The flushing and return water handling and the emplacement of related monitoring equipment in KLX18A is shown in Figure 5-5.

The targeted content for uranine in the flushing water was 0.20 mg/L and the actual average uranine content was 0.199 mg/L, see also Figure 5-9 and Section 5.4.2.

The return water from drilling was led to a series of sedimentation containers in order to collect cuttings before infiltration to the ground, see also Section 5.8.

5.3.3 Drilling, directional drilling and deviation measurements KLX18A

Core drilling with T-86 equipment giving an 86 mm diameter hole was done from 99.93 to 100.80 m in KLX18A.

Core drilling with N-size (76 mm) triple-tube, wireline equipment was conducted from 100.80 m to the final length of 611.28 m in KLX18A.

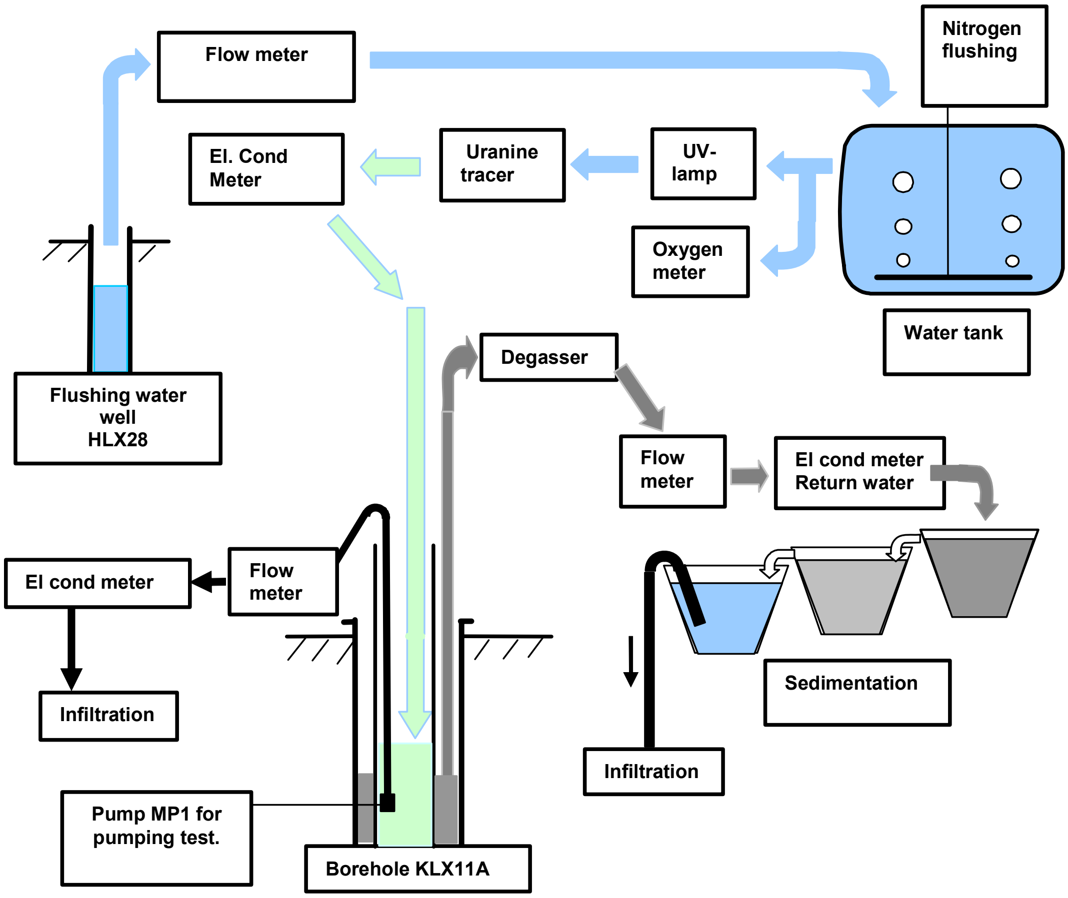


Figure 5-5. The flushing and return water handling and the emplacement of related monitoring equipment in KLX18A.

The core diameters and intervals for different drilling dimensions or method of directional drilling are given in Table 5-6.

Measurements of borehole deviation are made for two purposes:

- Monitoring of drilling progress.
- Measurements at full drilled length for final calculation of borehole deviation.

The core drilling progress was followed by deviation measurements with the Easy-Shot method twice along the borehole. The results from these measurements are not stored in the Sicada database but are given in a summary fashion in Table 5-2.

Table 5-6. Core diameters, borehole diameters and drilling dimensions during core drilling in KLX18A.

Core diameter (mm)	Borehole diameter (mm)	Interval (m drilled length)	Drilling dimension or directional drilling method	Comment
72.0	86	99.93–100.80	T–86	
50.2	86	100.80–101.35	N and T-86	Reamed to 86 mm diameter
50.2	76	101.35–611.28	N	

Two individual measurements were done with the Flexit method for the final evaluation of the borehole deviation in KLX18A. The Flexit tool was run both up and down the borehole from 0 to 609 metres. In addition two runs with the Maxibor instrument were performed between 0 and 606 metres. The final deviation file in KLX18A is calculated based on the measurements given in Table 5-7 together with the surveyed bearing and inclination of the top-of-casing. The calculations are made according to routines specified in the SICADA database and general expert judgement. Further comment on the method for calculation of final borehole deviation is given in /4/.

Horizontal and vertical plots of the results of the calculated deviation covering the entire length of borehole KLX18A are given in Appendix 4.

Core losses were noted in the Boremap mapping, see Section 5.6, at the intervals given in Table 5-8.

A total of seven drill bits were used for KLX18A, see Figure 5-6.

Table 5-7. Measurements used for borehole deviation calculation in KLX18A.

Deviation measurement method	Used for calculation of bearing/inclination	Interval from (m)	Interval to (m)	Sicada database activity ID
Maxibor	bearing	117	606	13112106
Flexit	bearing	117	606	13120581
Flexit	inclination	3	606	13120581
Maxibor	bearing	117	606	13141039
Flexit	bearing	117	606	13141042
Flexit	inclination	3	606	13141042

Table 5-8. Core losses noted in KLX18A.

From (m)	To (m)	Core loss length (m)	Comment
285.62	285.81	0.19	missing core piece
289.07	289.98	0.91	missing core piece
404.10	404.15	0.05	mechanical

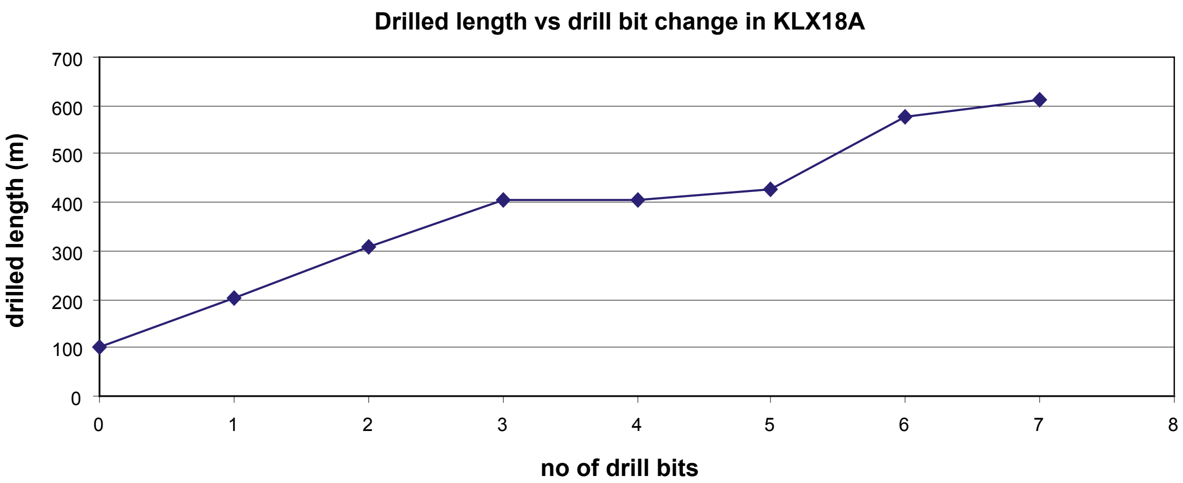


***Figure 5-6.** Drill bit changes during core drilling in KLX18A.*

Further results from drill monitoring i.e. drill penetration rate and various measurements will be presented in Section 5.5 "Drilling monitoring results" and in Appendix 1.

5.3.4 Borehole wall risk assessment, stabilisation and completion

Borehole wall risk assessment and stabilisation

A borehole wall assessment was prepared on May 29, 2006, SKB id no 1055396, SKB internal document.

The main drilling events that have influence on the risk assessment are summarized as follows:

- Diamond drilling completed at 611.28 metres.
- Flushing and brushing with high water pressure on the borehole wall was done along intervals as given in Table 5-9. The selection of the intervals to rinse was based mainly on study of the drill core. The flush and brush tool is shown in Figure 5-7.
- The steel dummy was lowered without any problems along the entire length of the borehole (to 611 metres). The probe is designed so that it will run smoothly along the borehole if the curvature does not exceed 0.1°/metre.
- Downhole operations consisting of deviation measurements, milling of reference grooves and flushing of the borehole with nitrogen gas was made without stability problems.
- BIPS logging for final risk assessment was done to full drilled length.

The overall assessment was that the probability for rock fallout was low in the borehole.

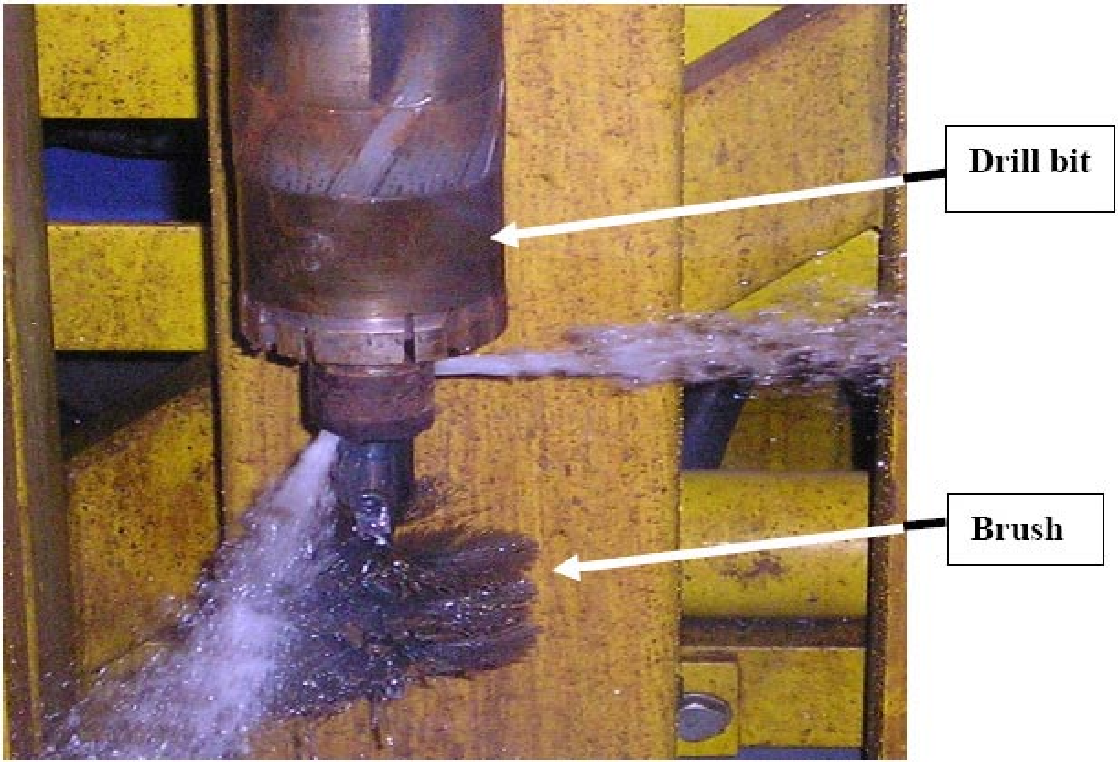


Figure 5-7. *The water flushing and rotating steel brush tool. The tool is lowered into the drill stem and can be seen in place just below the drill bit. During operating the drill string is moved up and down to remove loose rock fragments from the borehole wall.*

Table 5-9. Borehole sections that were mechanically rinsed by water flushing and rotating steel brush.

From (bh length m)	To (bh length m)
106	110
114	116
121.5	124.5
138	139
143	144
165	169
227.5	228.5
243	244
266.5	268.5
284	291
309	311
331.5	332.5
348	350
365.5	366.5
369	372
375	380
402	404
419	420
423	427
429	430
432	435
448	450
476	477
478.5	479.5
480	483
484	489
492	494
540	541

Borehole completion

Reaming of depth reference slots was done at the drilled lengths shown in Table 5-10. The depth reference slots are used for depth calibration of down-hole equipment for subsequent investigations in the hole. The presence of the depth reference slots have been confirmed by caliper log measurements.

Table 5-10. Depth reference slots (m) in KLX18A.

110.00	400.00
150.00	450.00
200.00	500.00
250.00	550.00
300.00	602.00
350.00	

The air lift pumping equipment and the inner supportive casing in the telescopic section were removed.

The borehole was reamed from 100.8 to 101.35 m with T-86 equipment. A steel conical guide was installed in KLX18A between 96.53 and 101.35 m. The conical guide tapers from an inner diameter of 195 mm to 77 mm.

The length of the holes was rinsed by flushing with nitrogen gas at times given in Table 5-11.

The boreholes were secured by mounting of lockable steel caps fastened to the concrete pad. All equipment was removed, the site cleaned and inspected by representatives from SKB and the contractor to ensure that the site had been satisfactorily restored.

5.4 Hydrogeological and hydrochemical measurements and results 99.93–611.28 m

The performed measurements, as already outlined in Tables 5-2 and 5-3, can be summarized as follows.

Measurements and sampling with wireline equipment:

- Five successful pumping tests were conducted at various intervals, see Section 5.4.1.
- Four water samples were taken, see Section 5.4.2.

Two air-lift pumping tests with evaluation of drawdown and/or recovery phase were made, for results see Section 5.4.3

Hydraulic responses in near-by boreholes from drilling in KLX18A are commented in Section 5.4.4.

5.4.1 Hydrogeological results from wireline measurements

Results from the wireline tests in KLX18A are presented in Table 5-12 and Figure 5-8.

The pumping tests were evaluated with steady-state assumption in accordance with Moye /3/. The flow rate at the end of the drawdown phase was used for calculating the transmissivity (T_M) and the specific capacity (Q/s), where Q is the flow rate and s is the drawdown.

A total of eleven tests were performed in KLX18A, and five achieved sufficiently stable conditions for calculating pseudo steady-state transmissivity and hydraulic conductivity. The reason behind the failed tests was mainly leakage between the casing and the tested section caused by a malfunctioning check valve. The leakage in the wireline probe was taken care of by mechanical adjustment of the check valve on 2006-05-04.

Table 5-11. Nitrogen gas flushing in KLX18A. (time is given in local time including daylight saving time i.e. GMT +2).

Date	Time	Interval (m)
060514	08.12	11.83–611.28
060514	09.05	11.83–611.28
060514	09.57	11.83–611.28
060514	11.09	11.83–611.28
060518	08.00–10.00	11.83–611.28
060518	08.00–10.00	11.83–611.28
060524	10.37	11.83–611.28

Table 5-12. Pumping tests with wireline probe in KLX18A.

Tested section [m]	Q/s [m²/s]	T_M [m²/s]	Comments
102.00–242.35	$6.1\cdot10^{-6}$	$7.4\cdot10^{-6}$	At c. 01:50 the flow rate increases from c. 6.2 L/min to c. 9 L/min, causing a pressure drop in the casing but not in the test section or in the drill string.
			The graphs indicate a leakage between casing and the test section. However, the drill water content of the water sample is low. The packer pressure is OK and an examination of the wire line probe did not indicate a leakage.
239.94–313.73	$9.6\cdot10^{-8}$	$1.2\cdot10^{-7}$	The low flow is not sufficient to generate pseudo steady state conditions. The water table rises in the test section during the pumping phase, the pump stop is clearly seen however.
			The initial pressure, h_i, is read at time t_i = 16:22, and the pressure at pump stop, h_p, at time t = 19:30.
			Pressure in casing during transient recovery phase is unaffected by pumping test.
312.00–488.06	$3.5\cdot10^{-6}$	$4.8\cdot10^{-6}$	Short test, but pseudo steady state.
			Pressure in casing during transient recovery phase is unaffected by pumping test.
471.00–611.28	$1.3\cdot10^{-6}$	$1.7\cdot10^{-6}$	Reduced flow by the end of the pumping phase. Evaluated test period 17:43–23:50, due to reduced flow.
			Leakage in the wireline probe was stopped on 2006-05-04.
312.00–611.28	$5.3\cdot10^{-6}$	$7.8\cdot10^{-6}$	Pressure in casing during transient recovery phase is unaffected by pumping test. NB In order to detect possible hydraulic responses between the modelled horizontal deformation zone "M1" this pumping test lasted three days.

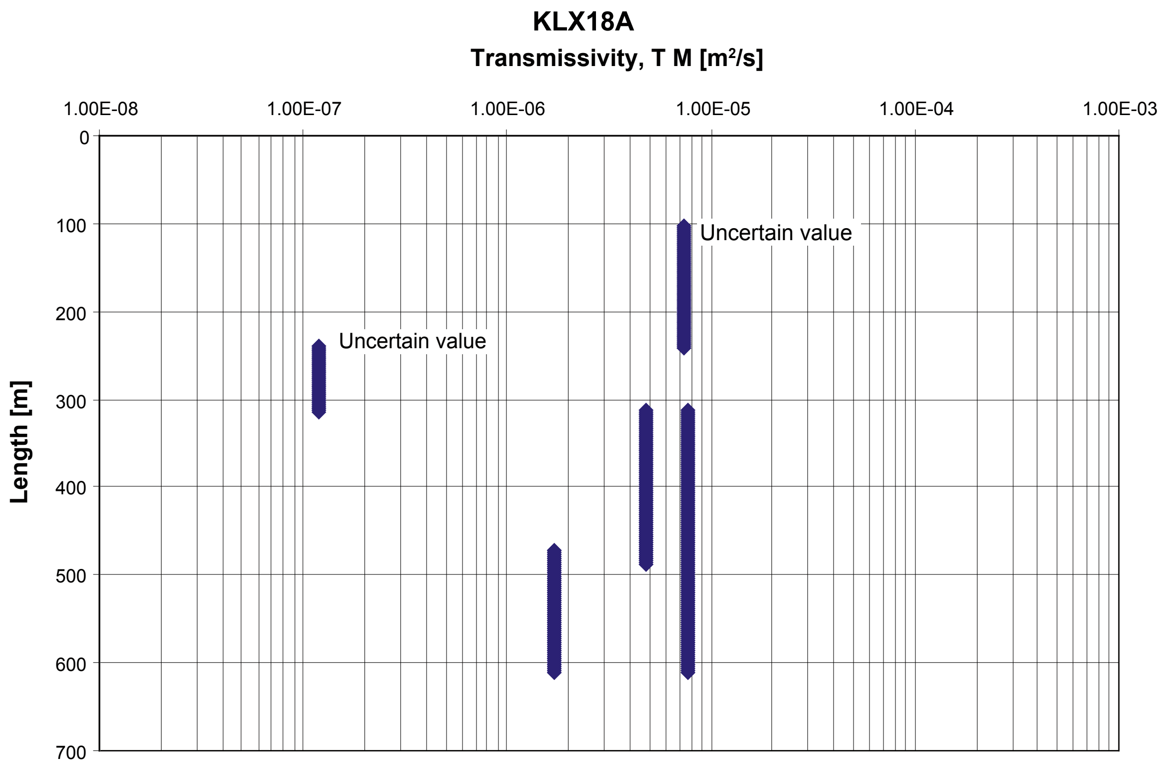


Figure 5-8. *Transmissivity from wireline pumping tests in KLX18A versus borehole length.*

Borehole KLX18A was forecast to penetrate a possible horizontal deformation zone "M1" at ca 500 m drilled length. Great care was therefore taken already at the preliminary mapping stage to identify possible candidates for the modelled structure "M1", see also Section 5.6. The most likely candidate was an interval with increased fracture frequency between 480 and 490 m drilled length. The final wireline pumping test from 312.00 to 611.28 m was prolonged to three full days of pumping in order to record any possible hydraulic responses in near-by boreholes, see also Section 5.4.4.

The plots from the pumping tests are given in Appendix 5.

The start and stop times for the interval used for evaluation of the pumping tests are given in Table 5-13.

5.4.2 Hydrochemistry

Four water samples were collected in connection with core drilling in KLX18A. Time and length for the samples are given in Table 5-14.
Sampling and analysis were performed according to the SKB classes specified in Table 5-14. The samples were collected at the drill site as soon as possible after the sampling occasion and prepared and conserved at the Äspö laboratory. The samples were stored in refrigerator until the drilling of the borehole was completed.

Sample 10994 was discarded due to a probable leakage in the wireline probe during sampling and it was decided not to analyse this sample for isotopes.

Sample 11043 was not analysed for isotopes since it had a relatively high amount of drilling water, see Table 5-15. Sample 11044 was taken from a similar section and had a low amount of drilling water. The latter sample was therefore selected for analysis of isotopes.

The drilling water content is a measure of the amount of uranine tracer in the return water. A low percentage of drilling water implies that the amount of pristine formation water is high in the sample i.e. low amount of the uranine-spiked flushing water.

Collected isotope bottles from the samples 10994 and 11043 are stored in freezer at the Äspö laboratory. Samples for tritium and carbon isotopes are stored in a refrigerator at the same facility.

Table 5-13. Evaluated test periods.

Tested section	Start (YYYY-MM-DD HH:MM)*		Stop (YYYY-MM-DD HH:MM)*	
102.00–242.35	2006-04-07	17:42	2006-04-08	01:50
239.94–313.73	2006-04-12	16:22	2006-04-12	19:30
312.00–435.65	2006-04-24	17:06	2006-04-24	17:48
471.00–611.28	2006-05-04	17:43	2006-05-04	23:50
312.00–611.28	2006-05-05	13:08	2006-05 07	07:30

* Times are given in local time i.e. including daylight saving time

Table 5-14. Sample dates and length during core drilling in KLX18A.

Sample number	Borehole	Date	Test section, length (m)	SKB chemistry class
10966	KLX18A	2006-04-08	102.00–242.35	3 (and all option isotopes)
10994	KLX18A	2006-04-22	312.00–435.65	3 (isotope options not included)
11043	KLX18A	2006-05-05	471.00–611.28	3 (isotope options not included)
11044	KLX18A	2006-05-08	312.00–611.28	3 (and all option isotopes)

Table 5-15. Analytical results from water chemistry sampling.

Borehole	Sample no	Date	From m	To m	Drill water %	pH	Conductivity mS/m	Cl mg/l
KLX18A	10966	2006-04-08	102.00	242.35	16.70	8.23	70.5	60.7
KLX18A	10994	2006-04-22	312.00	435.65	2.95	7.47	458.0	1,360.0
KLX18A	11043	2006-05-05	471.00	611.28	17.60	7.47	378.0	1,080.0
KLX18A	11044	2006-05-08	312.00	611.28	1.31	8.07	426.0	1,260.0

Archive samples have been collected for all the samples mentioned in Table 5-5. The samples are stored in a freezer at the Äspö laboratory.

Selected analytical results from KLX18A are given in Table 5-15. A complete record of analytical results is given in Appendix 2.

The percussion drilled borehole HLX14 was used as water source during the drilling of KLX18A.

No water samples were collected from HLX14 in connection with the drilling of KLX18A. However, water samples have been collected from HLX14 at earlier occasions to ensure that the water quality is sufficient for serving as a source for core drilling. The results from those analyses were reported in conjunction with core drilling of borehole KLX03 /5/.

A further account on analytical method, chemistry class 3 and quality is given in Appendix 3.

Sampling of uranine tracer content and electrical conductivity

From KLX18A, a total of 66 samples for uranine content and electrical conductivity in flushing and returning water were taken along the borehole.

The results are shown graphically in Figure 5-9. All the samples were analysed for uranine content and electrical conductivity at the Äspö laboratory.

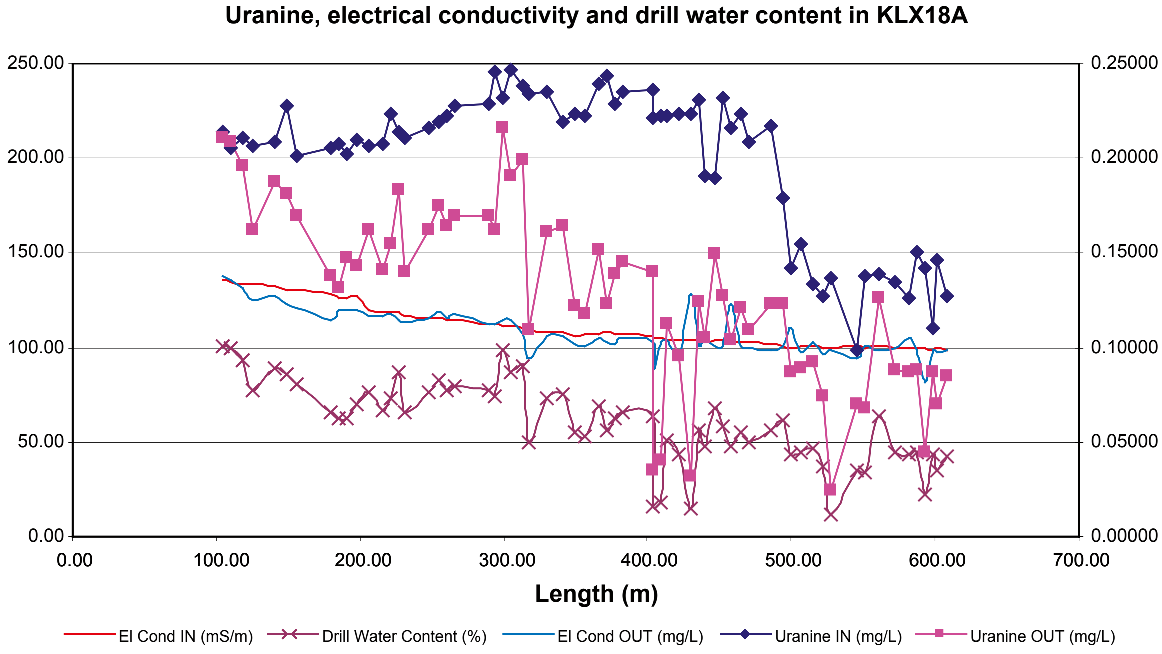


Figure 5-9. *The uranine concentration and electrical conductivity of flushing water (IN) and returning water (OUT) in KLX18A. The drill water content in the returning water is also shown.*

The calculated average uranine content for the whole borehole is 0.199 mg/l. This value has also been used for further calculations of the drill water content in the samples collected after drilling. However, for the samples collected during drilling (i.e the samples in this report), the drill water content for each sample is based on the average uranine content in the flushing water samples up to the time of sampling.

Monitoring of the electrical conductivity in the flushing and return water is also made via the drilling monitoring system, see Section 5.5.

5.4.3 Results from air-lift pumping with evaluation of drawdown and/or recovery

One air-lift pumping tests was conducted during drilling, and one additional test was conducted after the borehole was drilled to full depth. The execution of the tests varies in detail as drilling or other related activities such as cleaning and flushing of drill cuttings may occur prior to lifting the stem.

The steady state transmissivity, T_M, was calculated according to Moye, 1967 /3/, as well as the specific capacity, $Q/_s$. The results are shown in Table 5-16, and stored in the SICADA database as "recovery tests" (code HY050). The tested section is here defined as the section between the lower end of the grouted casing and the borehole bottom.

The plots from the drawdown and recovery tests are given in Figures 5-10 and 5-11.

The tested section 11.83–346.54 m (Figure 5-10) starts with air-lift pumping being performed together with drilling related activities. This is indicated by water being pumped into the borehole (water flow in). The drilling is subsequently stopped and the drill stem removed from the borehole. The "flow in" is reduced to zero when drilling stops. Towards the middle of the day only the air-lift pumping is being performed in the borehole, thereby creating a more stable drawdown period.

The air-lift pumping in the deeper section, 11.83–611.28 m, consists of a pumping sequence that is undisturbed by drilling related activities, see Figure 5-11.

Times for the drawdown phases are given in Table 5-16 and shown graphically in Figures 5-10 and 5-11. Within the drawdown phase a period with as stable flow conditions as possible is selected for test evaluation.

5.4.4 Hydraulic responses in near-by boreholes.

Hydraulic responses from drilling activities in a borehole are created by the drawdown from air-lift pumping during core drilling and from flushing or rinsing the borehole with nitrogen gas (i.e. lifting the water with nitrogen gas). Percussion drilling of the telescopic section also constitutes an air-lift pumping from a hydrogeological point of view.

Table 5-16. Results from airlift pumping in KLX18A.

Tested section [m]	Flow rate [L/min]	Drawdown [m]	Q/s [m²/s]	T_M [m²/s]	Comments
11.83–346.54	14	55	$4.2\cdot10^{-6}$	$6.2\cdot10^{-6}$	Q derives from accumulated volumes of water in and out 11:45–15:05. Q = ΣV/dt
11.83–611.28	29	39	$1.2\cdot10^{-5}$	$1.9\cdot10^{-5}$	Q derives from accumulated volumes of water out 06:08–10:07 local time (05:08–9:07 SNT). Q = ΣV/dt.

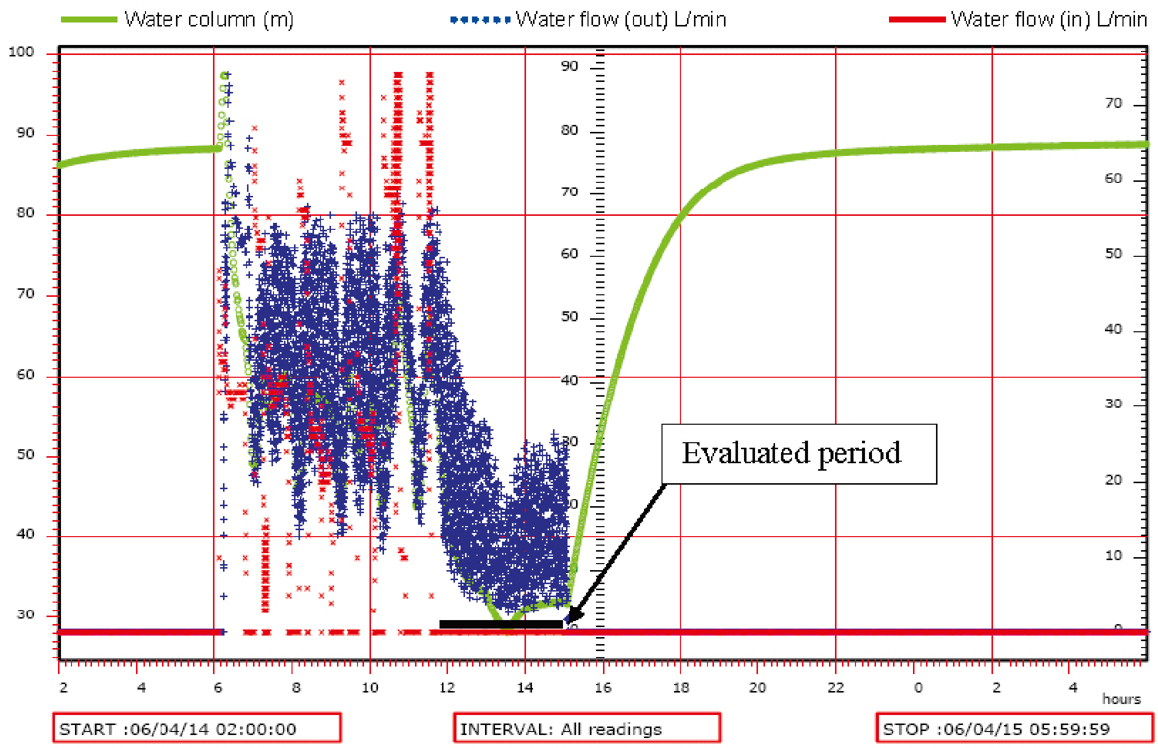


Figure 5-10. Airlift pumping in KLX18A 11.83–346.54 m. The green line represents the height of the water column in the borehole. The water flow out is shown as the blue dotted line and the inflow rate as the red line. Times are in Swedish Normal Time. The period for test evaluation is shown with a black bar.

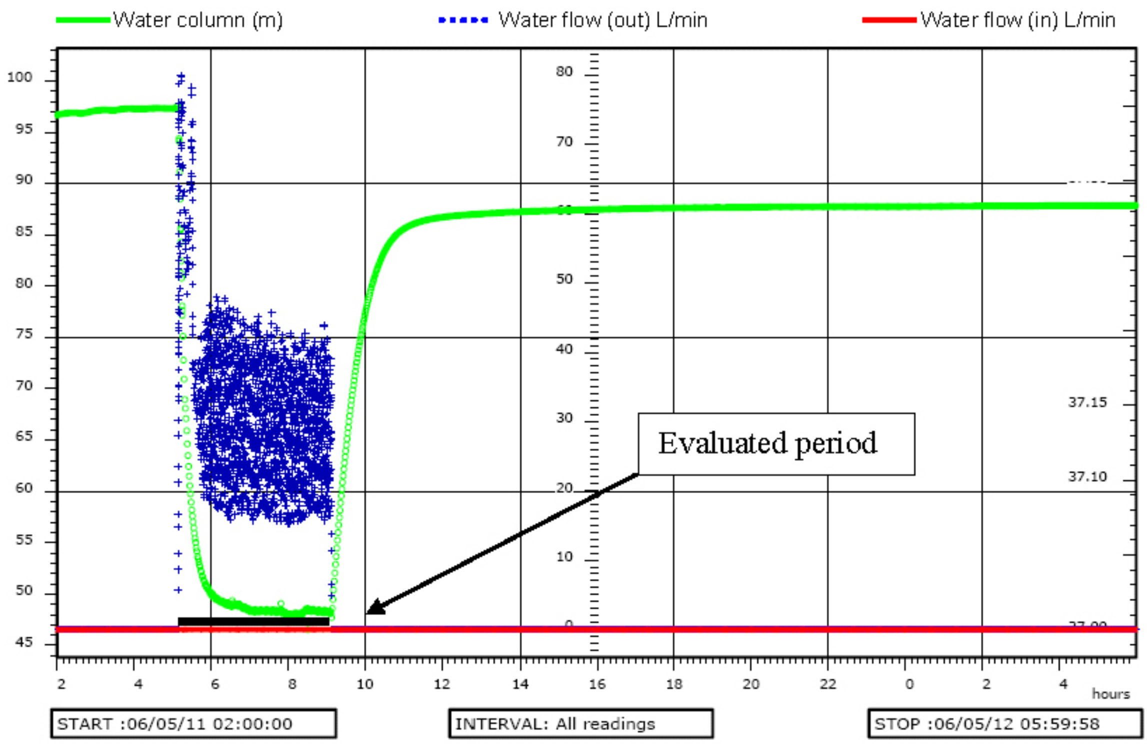


Figure 5-11. Airlift pumping in KLX18A 11.83–611.28 m. The green line represents the height of the water column in the borehole. The water flow out is shown as the blue dotted line and the inflow rate as the red line. The inflow rate was 0 L/min during the whole test period. Times are in Swedish Normal Time. The period for test evaluation is shown with a black bar.

Hydraulic responses in near-by boreholes from percussion of the telescopic section in KLX18A

No hydraulic responses from percussion drilling in KLX18A could be seen in the observation boreholes KLX03, HLX14, HLX25 or HLX30.

A plot showing the water table in observation borehole KLX03 (sections 1 to 10) during percussion drilling of the telescopic section in KLX18A is given in Figure 5-12. The recovery and abrupt drawdown in section 1 (light green curve) is related to sampling for water chemistry. Installation of pressure gauges for long-term monitoring of water pressure in a cored borehole, KLX03, is made with a series of sections divided by packers along the length of the borehole.

Hydraulic responses in near-by boreholes from air-lift pumping during drilling in KLX18A

No hydraulic response from air-lift pumping or other drilling activities could be seen in boreholes KLX03 (sections 1 through 10), HLX14, 25 or HLX30. A graphic example from KLX03 and HLX30 is given Figure 5-13.

Hydraulic responses from the final three day pumping with wireline equipment in KLX18A 060505–060508

Borehole KLX18A was forecast to penetrate a possible horizontal deformation zone "M1" at ca 500 m drilled length. Extra attention was therefore taken already at the preliminary mapping stage to identify possible candidates for the modelled structure "M1", see also Section 5.6. The most

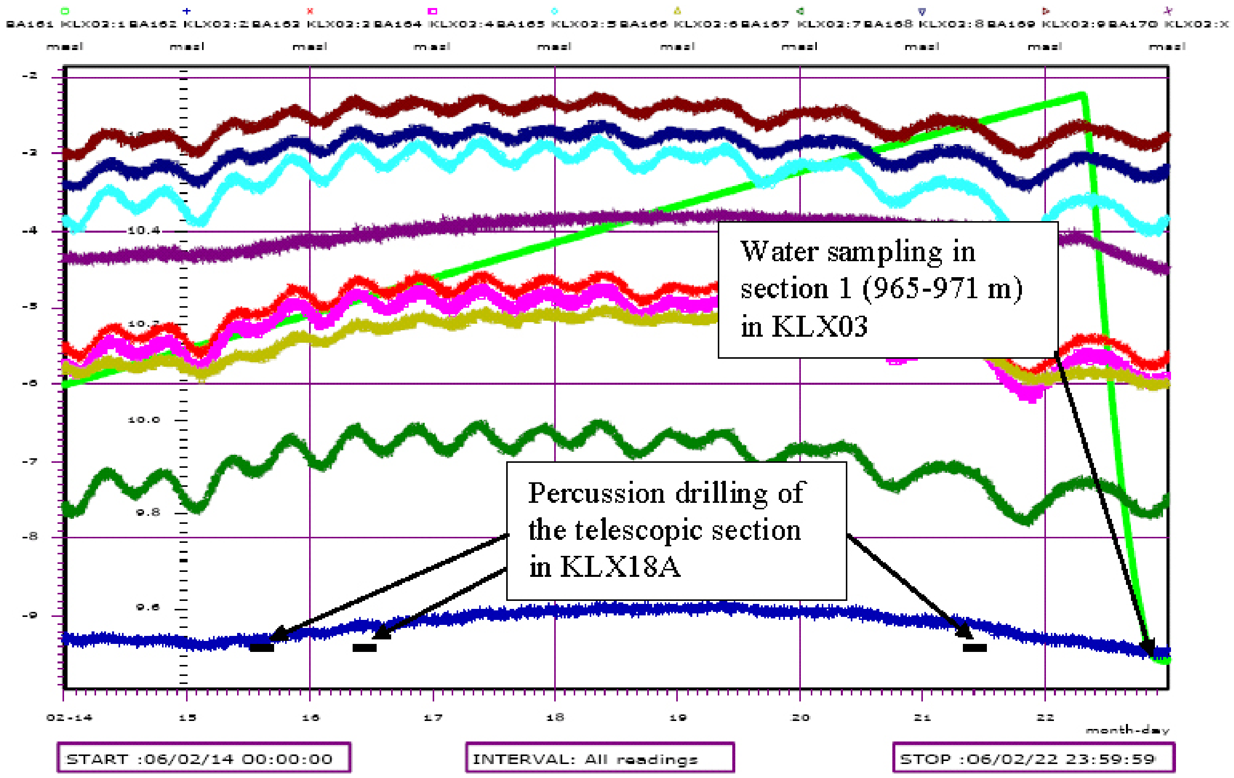


Figure 5-12. *Water table in observation borehole KLX03 (sections 1 to 10) during percussion drilling of the telescopic section in KLX18A. No response from percussion drilling in KLX18A could be seen in the observation borehole KLX03. The recovery and abrupt drawdown in section 1 (light green curve) is related to sampling for water chemistry.*

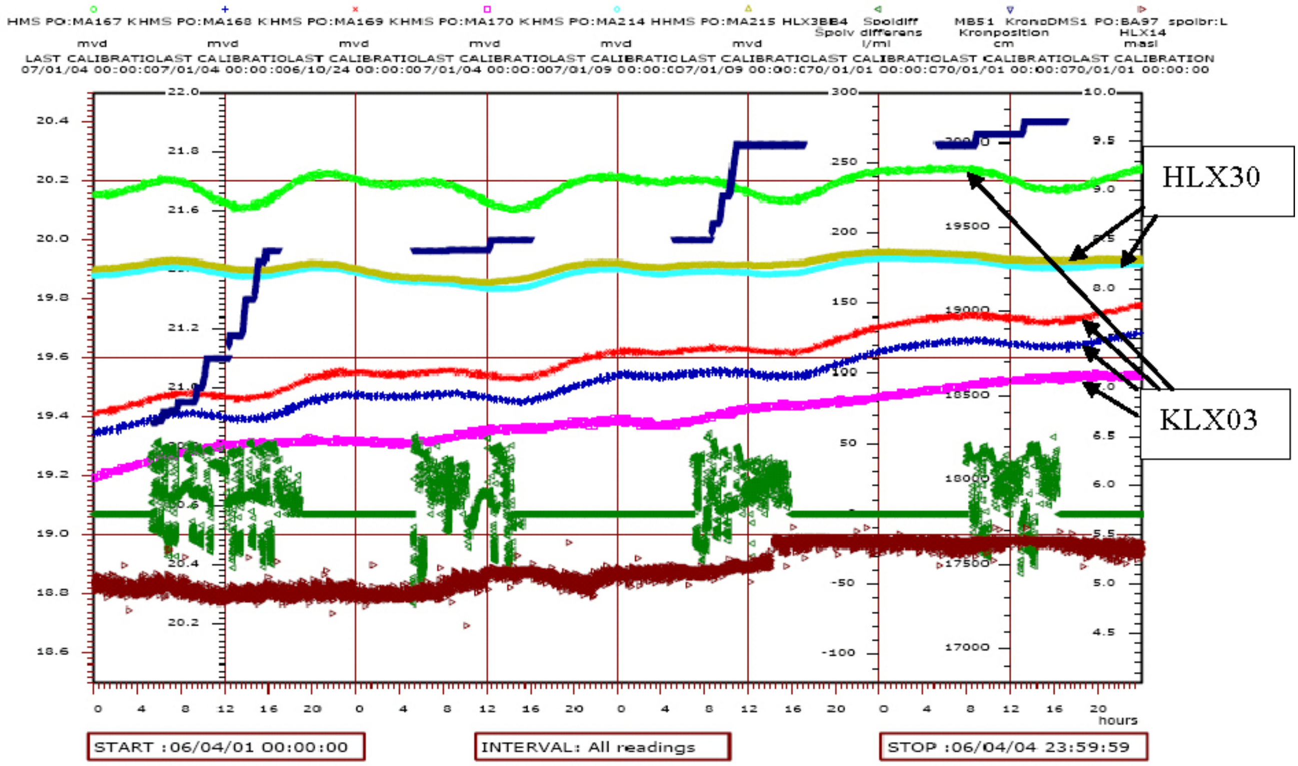


Figure 5-13. *Groundwater level in borehole KLX03 (sections 7–10) and HLX30 (sections 1–2) together with the drilling parameters; net flushing water flow rate (dark green), drill bit position (dark blue) and water level in the flushing water well, HLX14 (brown) during the drilling in borehole KLX18A. Detail 20060401–20060404.*

likely candidate was an interval with increased fracture frequency between 480 and 490 m drilled length. The final wireline pumping test from 312.00 to 611.28 m was prolonged to three full days of pumping in order to record any possible hydraulic responses in near-by boreholes.

Figure 5-14 shows the water table in observation borehole KLX03 (sections 1 through 6) together with the water table in the flushing water well, HLX28, and the position of the drill bit. No clear response from the pumping test between 060505 and 060508 can be seen in KLX03. The sudden decrease in water level in section 1 in KLX03 (green circle symbol) at the end of the drilling period is caused by known technical factors. In cored boreholes the long-term monitoring installation includes a pressure logger that is situated inside a standing pipe connected to the measured section at depth in the borehole. In order to manually plumb the water table in the standing pipes some small packers have to be deflated. This creates rapid pressure changes, and an example of this can be seen in KLX03, section 1 on May 3-4.

Hydraulic responses in near-by boreholes from nitrogen gas flushing in KLX18A

Nitrogen gas flushing covering the entire length of the borehole was done four times on 060514, twice on 060518 and once on 060524. No hydraulic response could be seen in observation boreholes KLX03 (sections one to ten) HLX14, 25 and HLX30. A plot of the water table during 060513 and 060526 in KLX03 is given in Figure 5-15.

The location of the mentioned boreholes is given in Figure 5-16.

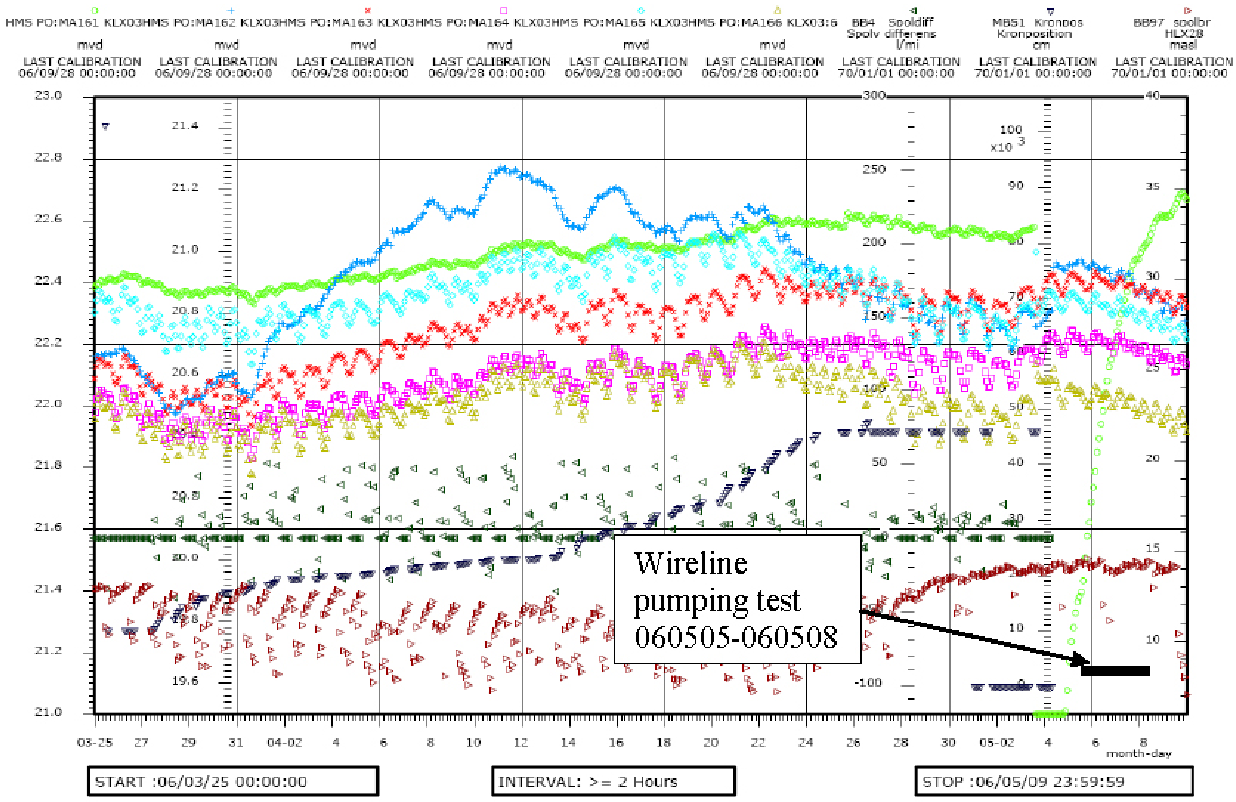


Figure 5-14. *The figure shows the water table in observation borehole KLX03 (sections 1 through 6) together with the water table in the flushing water well, HLX28, and the position of the drill bit. No clear response from the pumping test between 060505 and 060508 can be seen in KLX03. The sudden decrease in water level in section 1 in KLX03 (green circle symbol) at the end of the drilling period is caused by known technical factors.*

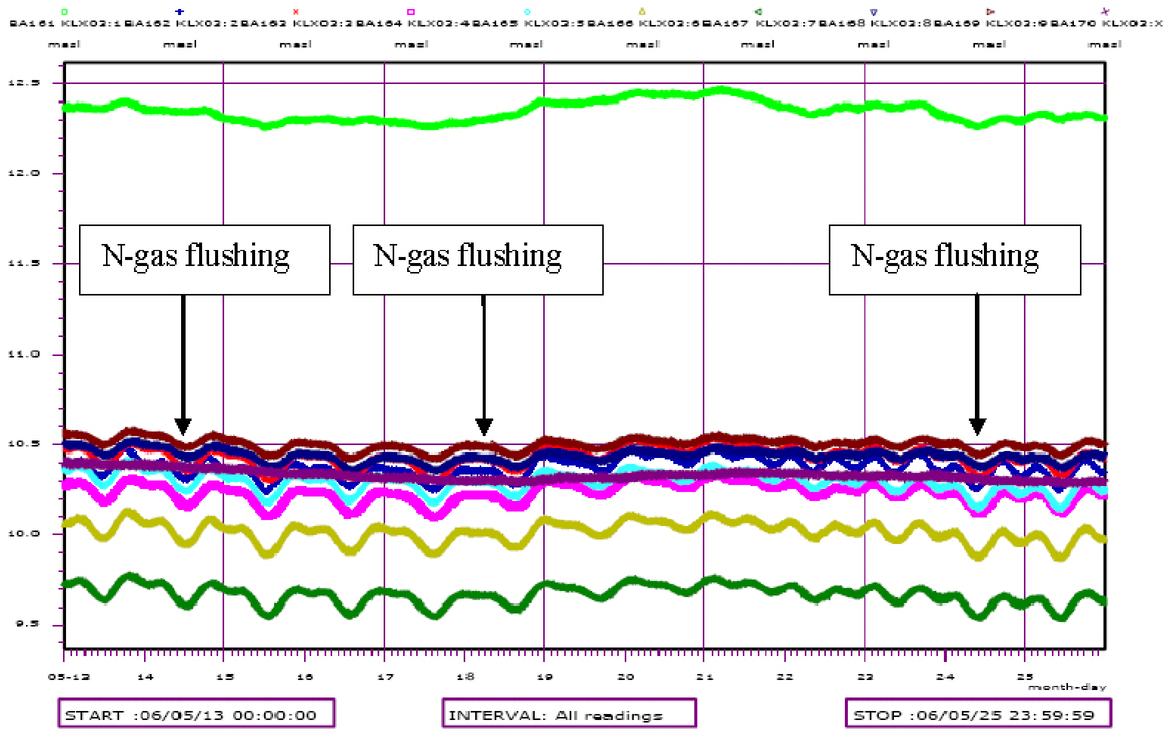


Figure 5-15. *Water levels in KLX03 (sections one through ten) during nitrogen gas flushing in KLX18A. No hydraulic response could be seen in any of the sections in observation borehole KLX03. The time scale of the plot is SNT (GMT +1).*

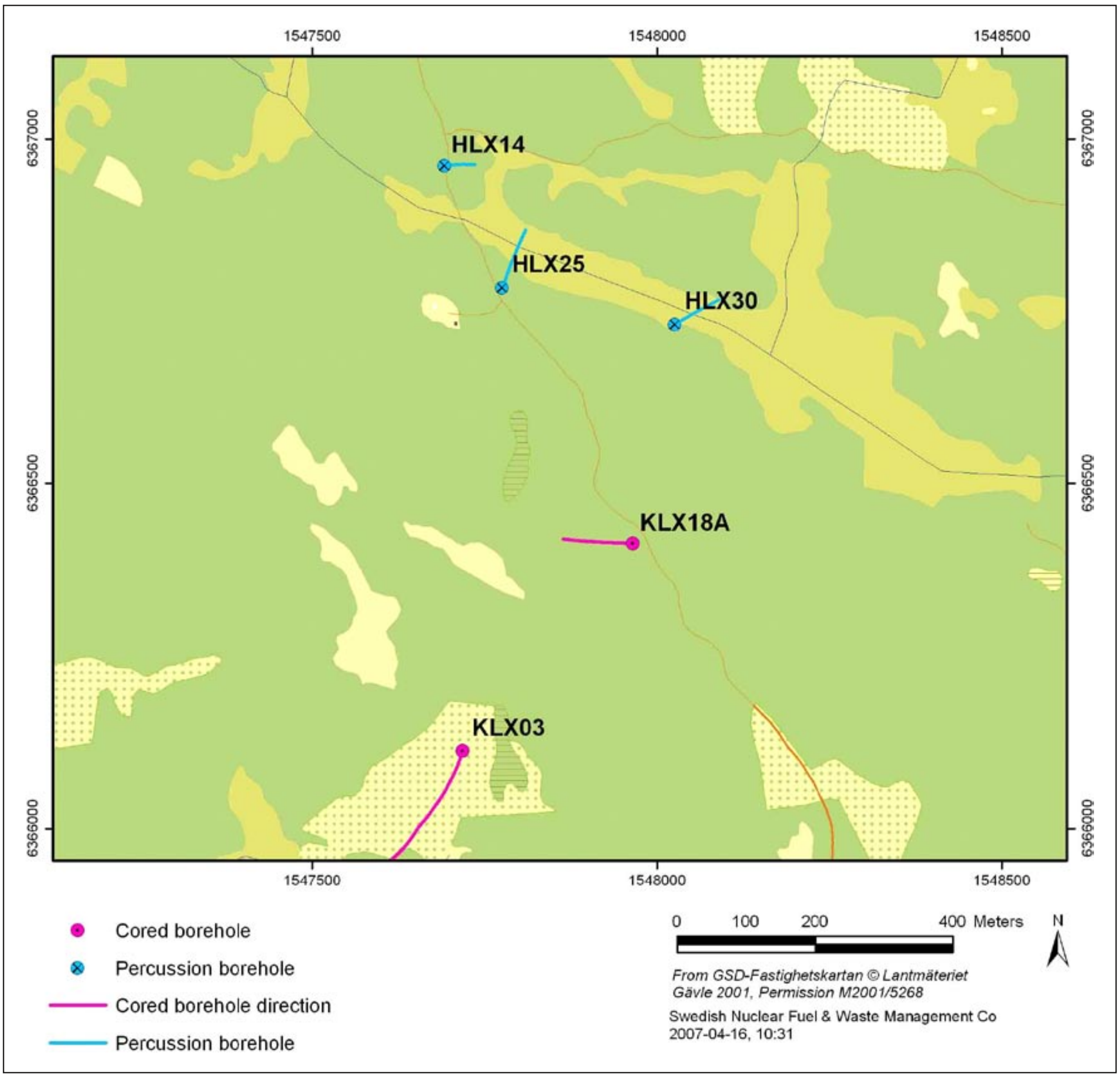


Figure 5-16. *Map showing the location of cored boreholes KLX18A and KLX03 and the percussion boreholes HLX14, HLX25 and HLX30.*

5.5 Drilling monitoring results

This section presents the results from drill monitoring i.e. continuous data series of water parameters or technical drilling parameters. The two main drilling steps, the telescope section 0–99.93 metres and the core drilling section 99.93–611.28 metres are described in Sections 5.2 and 5.3 respectively.

5.5.1 Drill monitoring system – DMS

The DMS database contains substantial amounts of drilling monitoring data. A selection of results primarily from the monitoring of the flushing water parameters are presented in Figures 5-17 through 5-19 below.

Selected parameters from the drill rig (MWD parameters) are presented in Appendix 1. The MWD parameters require some explanation:

- Drillability ratio – this parameter is defined as penetration rate divided by feed force.
- Flushing water ratio – this is defined as flushing water flow divided by flushing water pressure.

- Water pressure (of the water entering the drill stem).
- Flushing water flow (flow of ingoing water).
- Penetration rate (rate of drill bit penetration as measured on the surface on the drill stem).
- Hydraulic indication – this parameter is defined as penetration rate divided by flushing water flow.

In order to maintain reasonable size data files, a reduction in the number of points incorporated in the pictures has been done in Figures 5-17 through 5-19. Since DMS data are related to time (i.e. not strictly to borehole length) periods where drilling is not performed are also registered.

Figure 5-17 depicts the drill bit position (green) over time and the water level (red) in the telescope part of the drill hole. The water level, given as pressure of the overlying water column reflects the air-lift pumping activity in the hole.

Figure 5-18 shows the flushing water flow (green) entering the hole and the return water flow (red). The flushing water flows (green) show three distinct levels of flow:

- A flow of ca 30 litres/minute corresponding to pumped flow during drilling.
- A flow of 65–70 litres/minute corresponding to the flow while pumping down the core barrel.
- No flow (zero litres/minute) when no drilling is performed.

Figure 5-19 shows the conductivity of the ingoing flushing water, conductivity of the return water and the oxygen content of the flushing water. The oxygen content of the flushing water is typically low (< 4 mg/L) with only scattered slightly elevated readings.

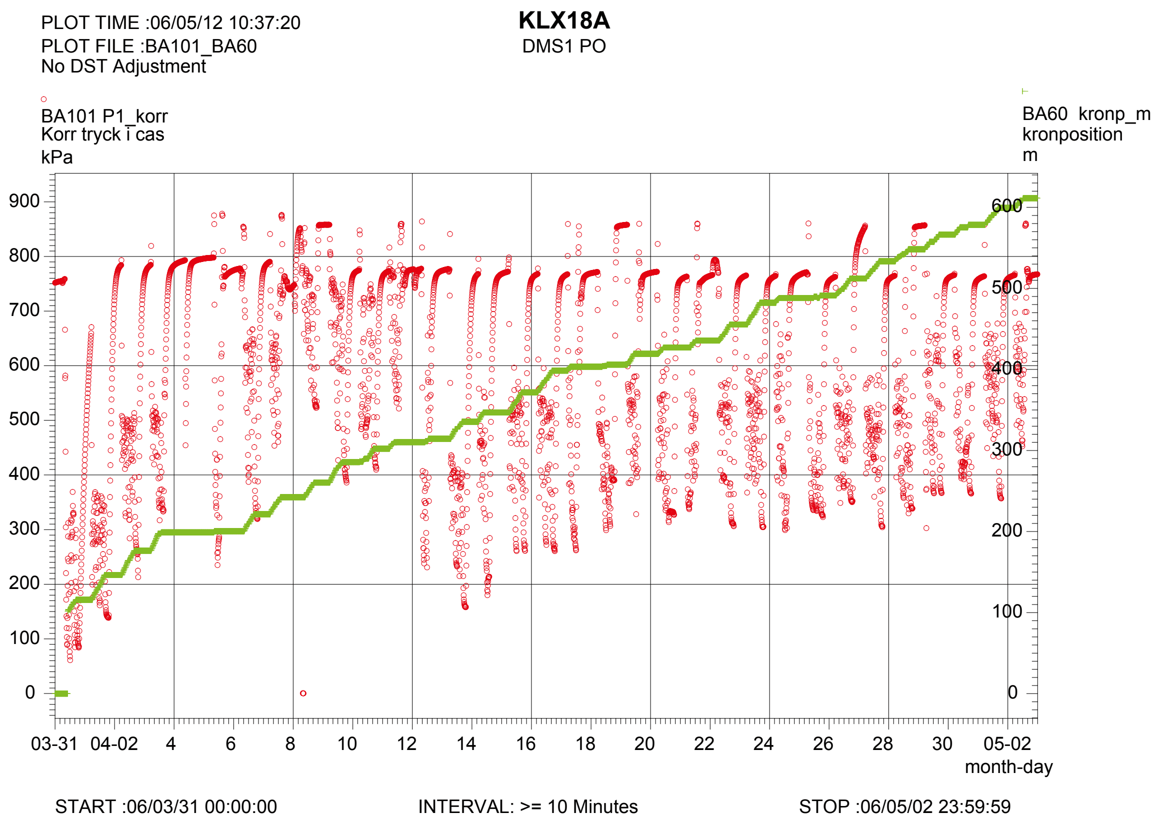


Figure 5-17. *Drill bit position (green) and water level from air-lift pumping (red). The water level is expressed as the pressure in kPa of the water column overlying the pressure gauge i.e. the ambient air-pressure has been subtracted. The pressure gauge is emplaced at 90 metres borehole length.*

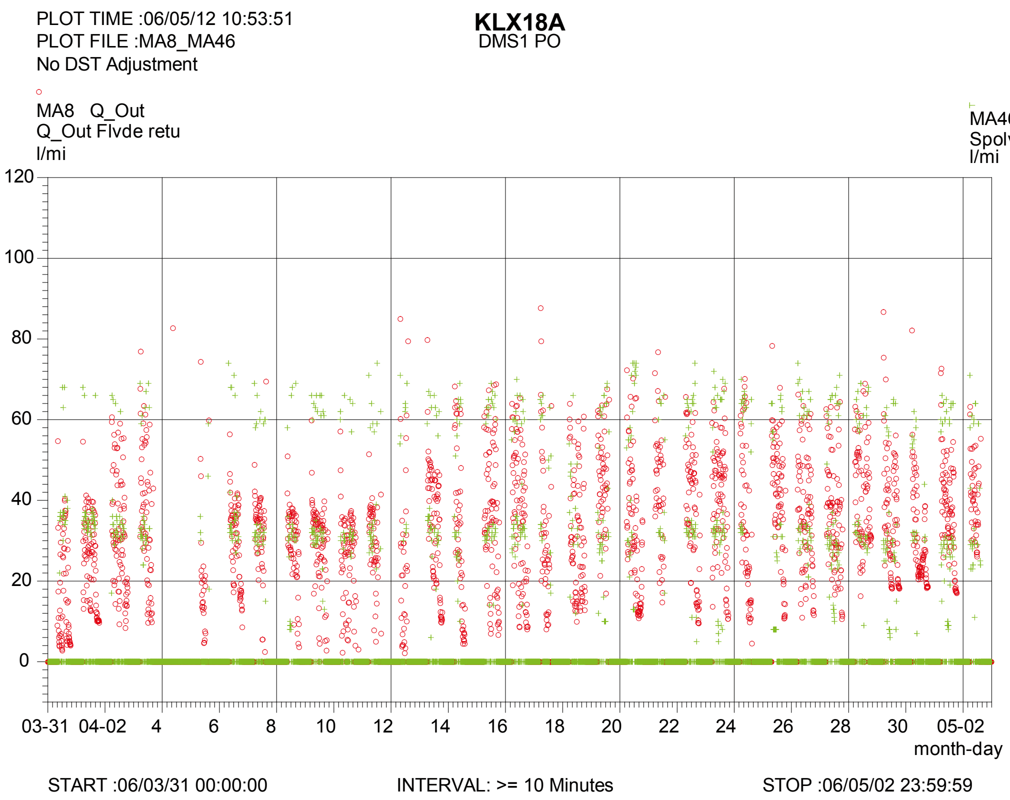


Figure 5-18. Flushing water flow (green) and return water flow (red) in litres per minute.

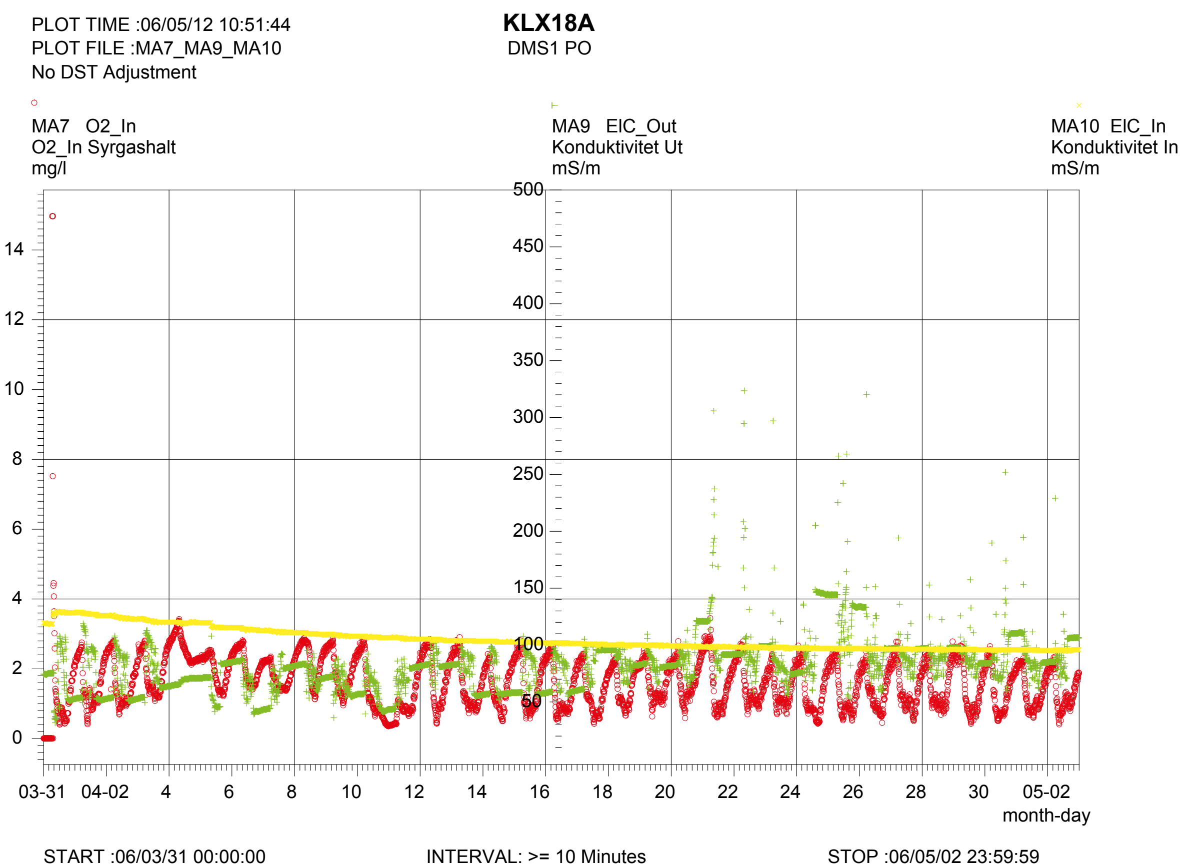


Figure 5-19. Conductivity of flushing water (yellow) and return water (green). The oxygen content in mg/L of the flushing water (red) is also shown. The oxygen content of the flushing water is typically low (< 4 mg/L) with only scattered slightly elevated readings.

5.5.2 Measurements of flushing water and drill cuttings

A calculation of accumulated amounts of water flowing in and out of the borehole based on water flow measurements from the DMS system (continuous readings) is given in Figure 5-20.

The amount of flushing water consumed during drilling was 400 m^3, giving an average consumption of ca 0.8 m^3 per metre core drilled. The amount of effluent return water from drilling in KLX18A was 710 m^3, giving an average of ca 1.4 m^3 per metre core drilled.

Drill cutting balance

The weight of cuttings in the settling containers amounted to 3,081 kg. The content of suspended material in the return water was not analysed in borehole KLX18A, however previous sampling has shown the content to be 400 mg/L /6/. The amount of material in suspension carried with the return water would amount to 280 kg. The theoretical amount that should be produced from drilling with 76 mm triple tubing (with core barrel N3/50) over a length of 500 metres is 3,375 kg assuming a density of 2.7 kg/dm^3. This means that close to 100% of the material liberated by drilling is accountable as removed from the borehole or the formation.

The recovered drill cuttings were collected in steel containers. After completion of drilling, the containers were removed from the site and emptied at an approved site.

Uranine tracer balance

The amount of introduced and recovered uranine is presented in Table 5-17. The results show that all (> 100% according to balance calculation!) of the introduced uranine was retrieved during drilling of KLX18A.

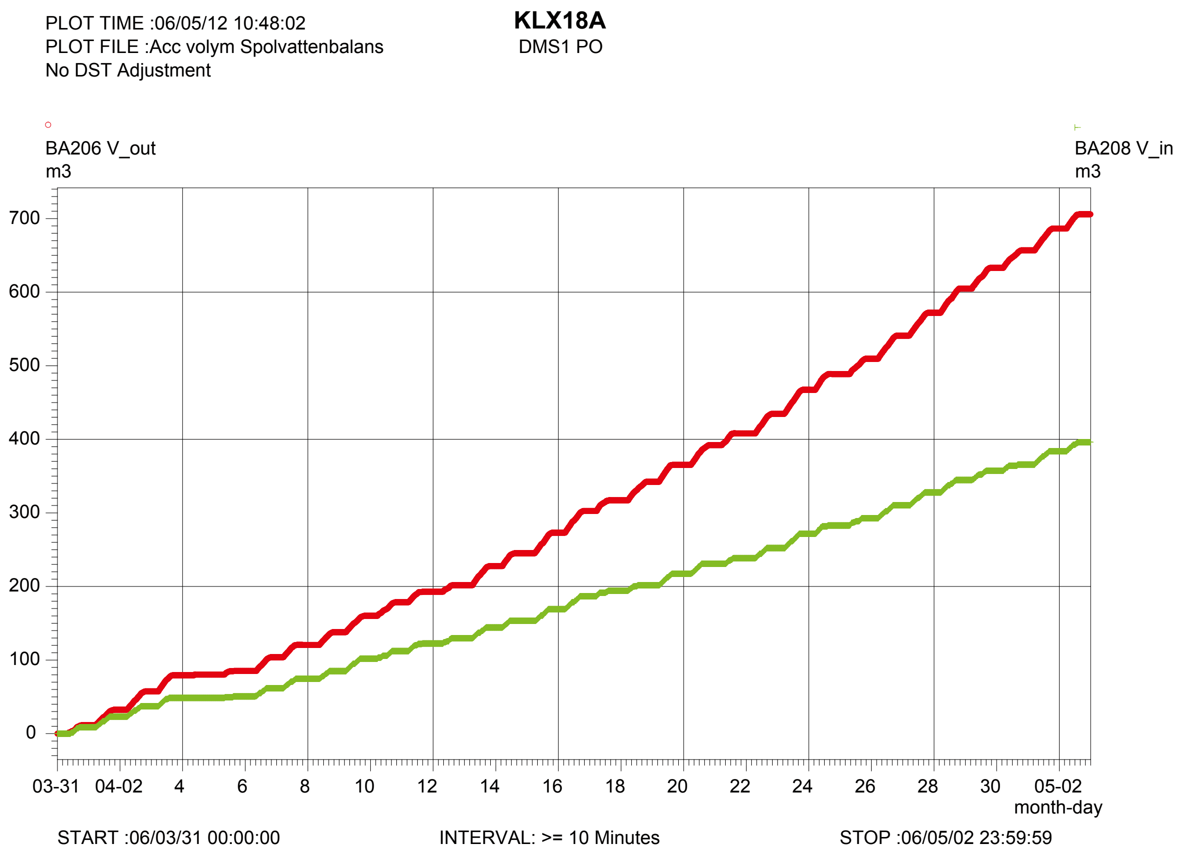


Figure 5-20. *The flushing water balance in KLX18A as recorded by the DMS system. The accumulated volume of the ingoing flushing water is shown in green and the outgoing return water is shown in red.*

Table 5-17. Balance calculation of uranine tracer in KLX18A.

Average uranine content IN (mg/L)	0.199
Flushing water volume IN (m^3)	400
Amount uranine introduced (g)	80
Average uranine content OUT (mg/L)	0.128
Return water volume OUT (m^3)	710
Amount uranine recovered (g)	91

5.6 Geology

A preliminary geological mapping of the core is done as drilling progresses as part of the drilling activity. This mapping phase includes a first pass mapping of major geological features as well as RQD-logging and photodocumentation of the core.

A more detailed mapping with the Boremap method is made after measurements have been made in the borehole that can provide orientation of geological features. Boremap mapping and the related measurements are not part of the drilling activity. The results from the Boremap logging are included in this report as it represents a more complete geological record than the preliminary geological mapping.

The geological results based on the Boremap logging are shown in Appendix 1. It should be stressed that the geological description given in this report is a brief summary only. A more complete account is given in /7/.

Borehole KLX18A was forecast to penetrate a possible horizontal deformation zone "M1" at ca 500 m drilled length. Extra attention was therefore given already at the preliminary mapping stage to identify possible candidates for the modelled structure "M1". The most likely candidate was an interval with increased fracture frequency between 480 and 490 m drilled length, see also Sections 5.4.1 and 5.4.4.

Lithologically the core is dominated by Ävrö granite with minor portions of diorite/gabbro or fine-grained diorite-gabbro.

Red staining with weak to medium intensity occurs sporadically to ca 490 m. Below 490 m length the presence of red staining is very rare. Sections with red staining are indicated as "oxidized" in Appendix 1.

The average fracture frequency over the entire core drilled section expressed as open fractures is 2.15 (fractures/metre). NB The fracture frequency given in Appendix 1 shows the total fracture frequency (i.e. open fractures, sealed fractures, sealed network and fractures in crushed sections).

5.7 Data handling

Data collected by the drilling contractor and the SKB drill coordinators were reported in daily logs and other protocols and delivered to the Activity Leader. The information was entered to SICADA (SKB database) by database operators.

5.8 Environmental control

The SKB routine for environmental control (SDP-301, SKB internal document) was followed throughout the activity. A checklist was filled in and signed by the Activity Leader and filed in the SKB archive.

All waste generated during the establishment, drilling and completion phases have been removed and disposed of properly. Water effluent from drilling was allowed to infiltrate to the ground in accordance with an agreement with the environmental authorities. The location of the water emission area and the environmental monitoring wells SSM000250 and SSM000251 is shown in Figure 5-21. Precautionary guideline values for effluent return water emission to the ground were prescribed by the Regional Authorities for the following parameters:

- Salinity, 2,000 mg/l (monitored as electrical conductivity, with the limit 300 mS/m).
- Uranine content, 0.3 mg/l.
- Suspended material, 600 mg/l.

Monitoring of effluent water

The electrical conductivity, as measured by the DMS system, of the return water from the core drilling of KLX18A peaked at 300 mS/m on three occasions in mid-April 2006, see Figure 5-18. Samples of the return water that were analysed for electrical conductivity, however never exceeded 150 mS/m, see Figure 5-9.

The uranine content was well below 0.3 mg/L, see Figure 5-9.

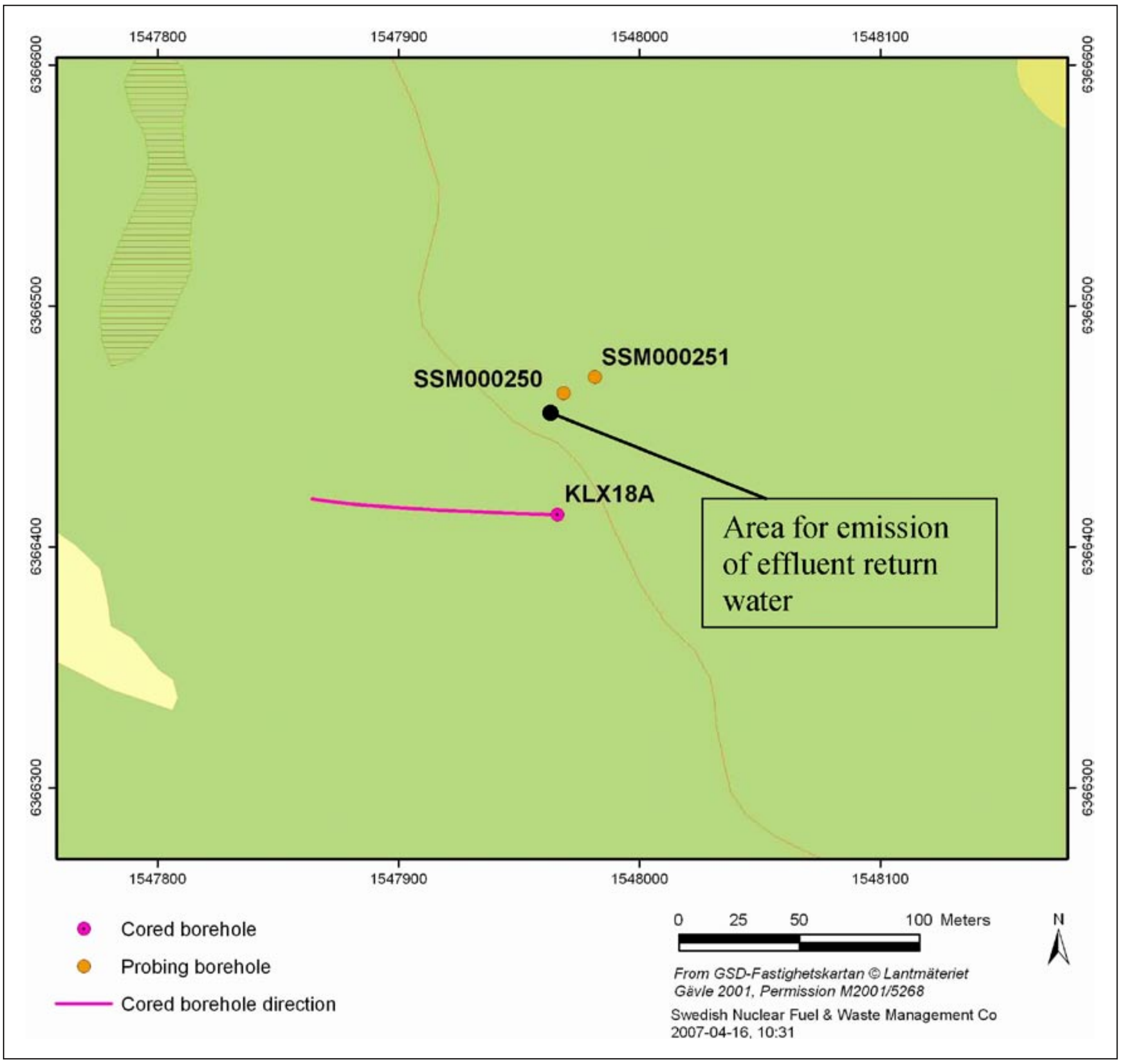


Figure 5-21. *Location of environmental monitoring wells SSM000250 and SSM000251 in relation to the core drill site for KLX18A.*

The concentration of suspended material was not analysed in the boreholes, however previous sampling has shown that the concentration was well below 600 mg/L /6/.

To sum up the monitored parameters in the emitted water complied with the prescribed guideline values.

Drilling of environmental monitoring wells

Drilling of environmental monitoring wells SSM000250 and SSM000251 was done between January 27 and 30, 2006. The technical data for the environmental wells are given in Appendix 6. The coordinates for the wells are given in Table 5-18. The location of the environmental monitoring wells SSM000250 and SSM000251 is shown in Figure 5-20.

Reference sampling

A reference sample of the surface soil, before drill start and establishment of the drill site, was taken for possible future use, see Table 5-19.

A reference water sample of ground water in environmental monitoring well SSM000250 was taken according to Table 5-20.

Monitoring of soil ground water levels

A pressure logger (transducer) for measuring the ground water table was installed in SSM000250 during the core drilling of KLX18A. The water levels are given graphically in Figures 5-22 and 5-23.

Monitoring of electrical conductivity and pH in ground water samples

Water samples were collected with a one to two week interval for monitoring of the electrical conductivity and pH in the ground water in the environmental monitoring wells SSM000250 and SSM000251. The results show steady and low values for pH and electrical conductivity, see Figures 5-24 and 5-25. No significant influence can be seen on the shallow ground water in the environmental monitoring wells from the drilling activity in KLX18A.

Table 5-18. Coordinates for environmental monitoring wells SSM000250 and SSM000251.

Well	Northing	Easting	Elevation (m.a.s.l.) of top of stand pipe
SSM000250	6366463.80	1547968.78	16.84
SSM000251	6366470.47	1547981.74	16.37

Table 5-19. Reference soil sample.

Sample id number	Date
SKB PO 9013	2006-04-03

Table 5-20. Reference water samples.

Monitoring well	Sample id number	Date
SSM000250	10799	2006-0 2-08

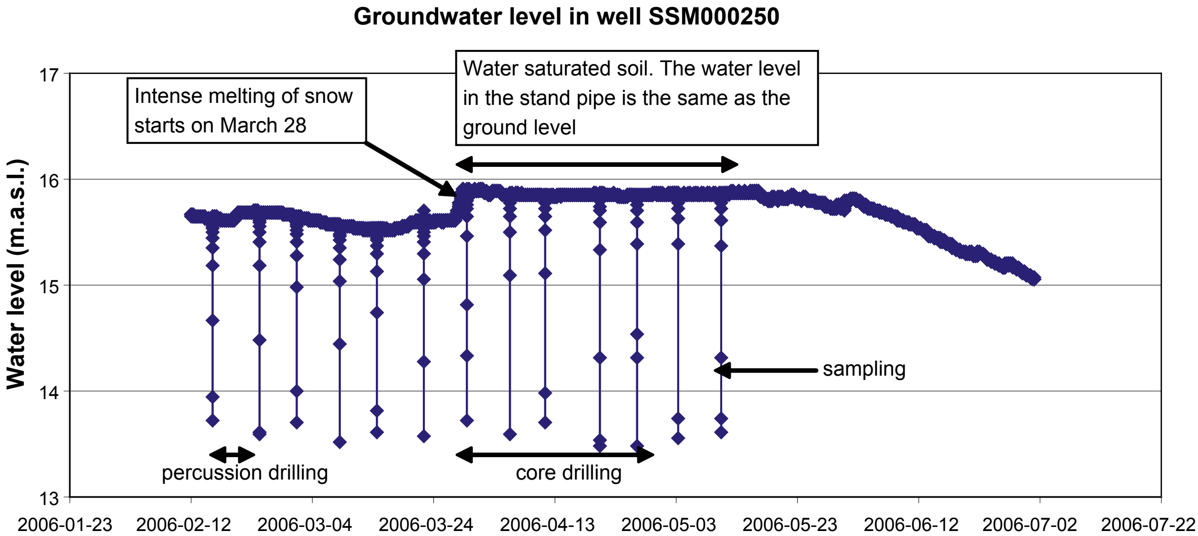


Figure 5-22. *The ground water level in well SSM000250. The dips in water levels are related to water sampling. The percussion drilling of the telescopic section did not influence the water level in the monitoring well SSM000250. The water level in the monitoring well during the time that core drilling was performed is strongly affected by melting of snow. It is here interpreted that the soil profile is saturated with water from March 28 and until the middle of May.*

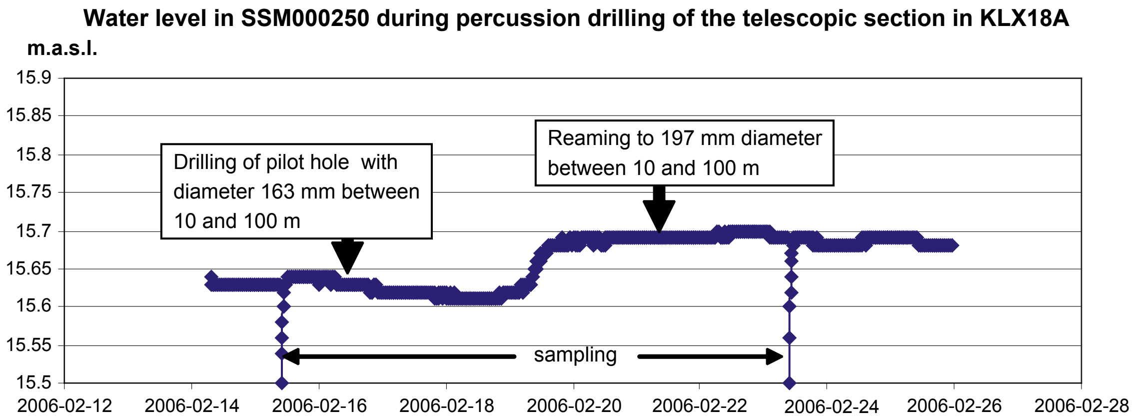


Figure 5-23. *The ground water level in well SSM000250 during percussion drilling of the telescopic section in KLX18A. No hydraulic response from percussion drilling can be seen in well SSM000250. The dips in water levels are related to water sampling.*

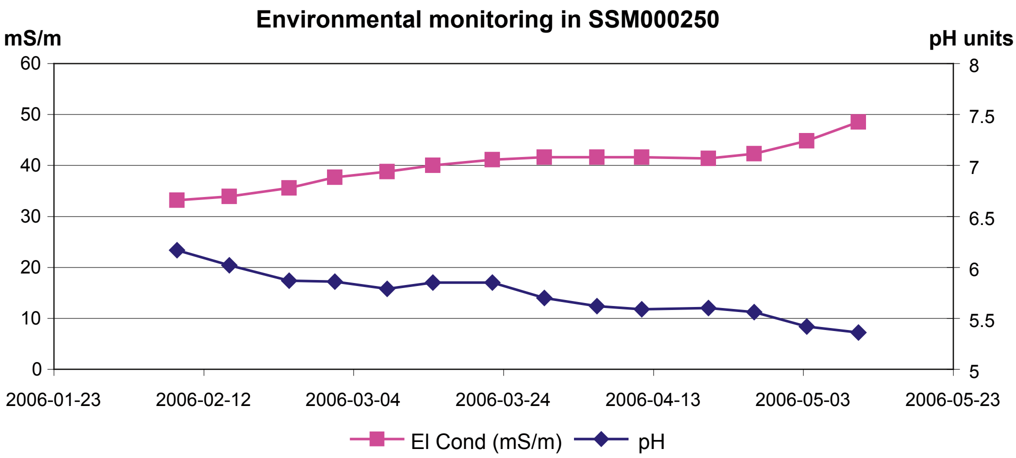


Figure 5-24. *Electrical conductivity and pH in ground water samples from SSM000250.*

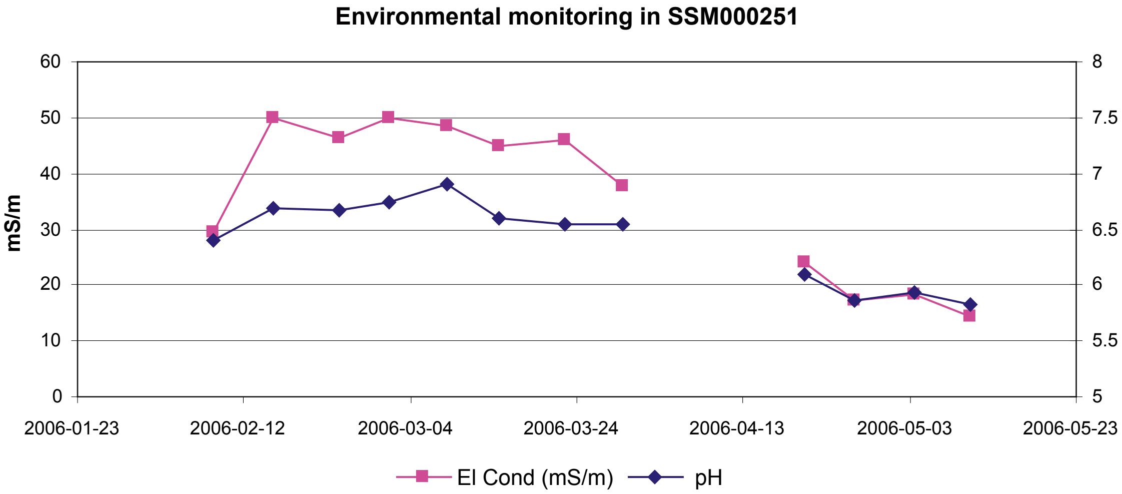


Figure 5-25. *Electrical conductivity and pH in ground water samples from SSM000251.*

5.8.1 Consumption of oil and chemicals

No significant amounts of oils or lubricants were consumed during the drilling.

The concrete consumption was 420 litres in total. The concrete was based on white silica, low alkali cement.

5.9 Nonconformities

The tightness of the concrete gap injection of the casing in the upper part of the telescopic section was not tested due to a slight modification of drilling procedure. Previous core drilling and related testing /6/, however, show that the gap injections fulfil the requirements stated in the method description (SKB MD 620.003 v1.0, internal document) for core drilling.

6 References

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

/2/ **SKB, 2005.** Platsundersökning Oskarshamn. Program för fortsatta undersökningar av berggrund, mark, vatten och miljö inom delområde Laxemar. SKB R-05-37, Svensk Kärnbränslehantering AB

/3/ **Moye D G, 1967.** Diamond drilling for foundation exploration, Civil Eng. Trans. Inst. Eng, Australia.

/4/ **Stenberg L, Håkanson N, 2007.** Revision of borehole deviation measurements in Oskarshamn. SKB P-07-55, in prep, Svensk Kärnbränslehantering AB.

/5/ **Ask H, Morosini M, Samuelsson, Ekström L, Håkanson N, 2005.** Drilling of cored borehole KLX03. SKB P-05-167, Svensk Kärnbränslehantering AB.

/6/ **Ask H, Morosini M, Samuelsson, Ekström L, Håkanson N, 2004.** Core drilling of KSH03. SKB P-04-233, Svensk Kärnbränslehantering AB.

/7/ **Mattsson K-J, Eklund S, 2006.** Boremap mapping of core drilled borehole KLX18A. SKB P-06-238, in prep, Svensk Kärnbränslehantering AB.

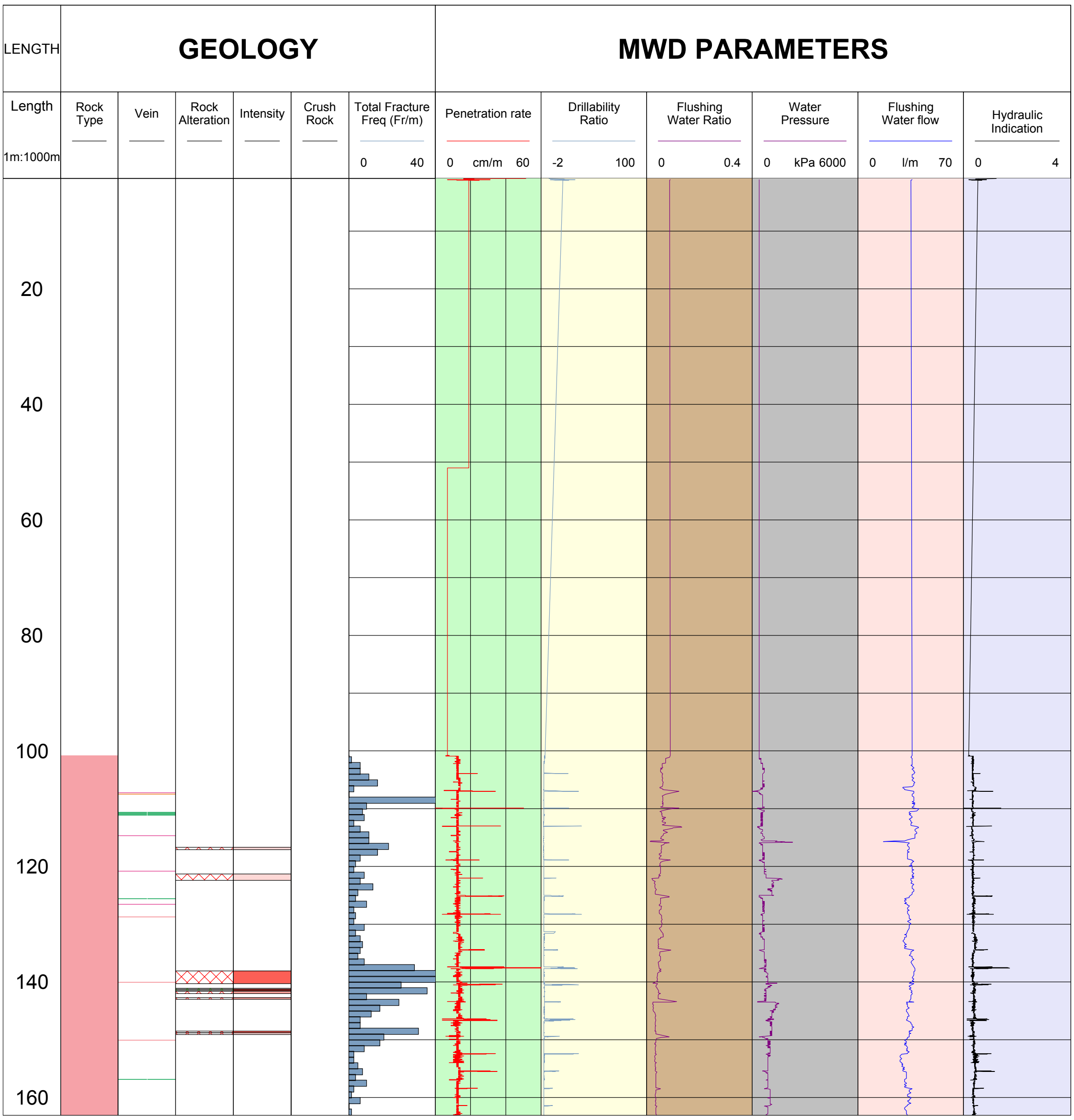
Geology and MWD parameters KLX18A

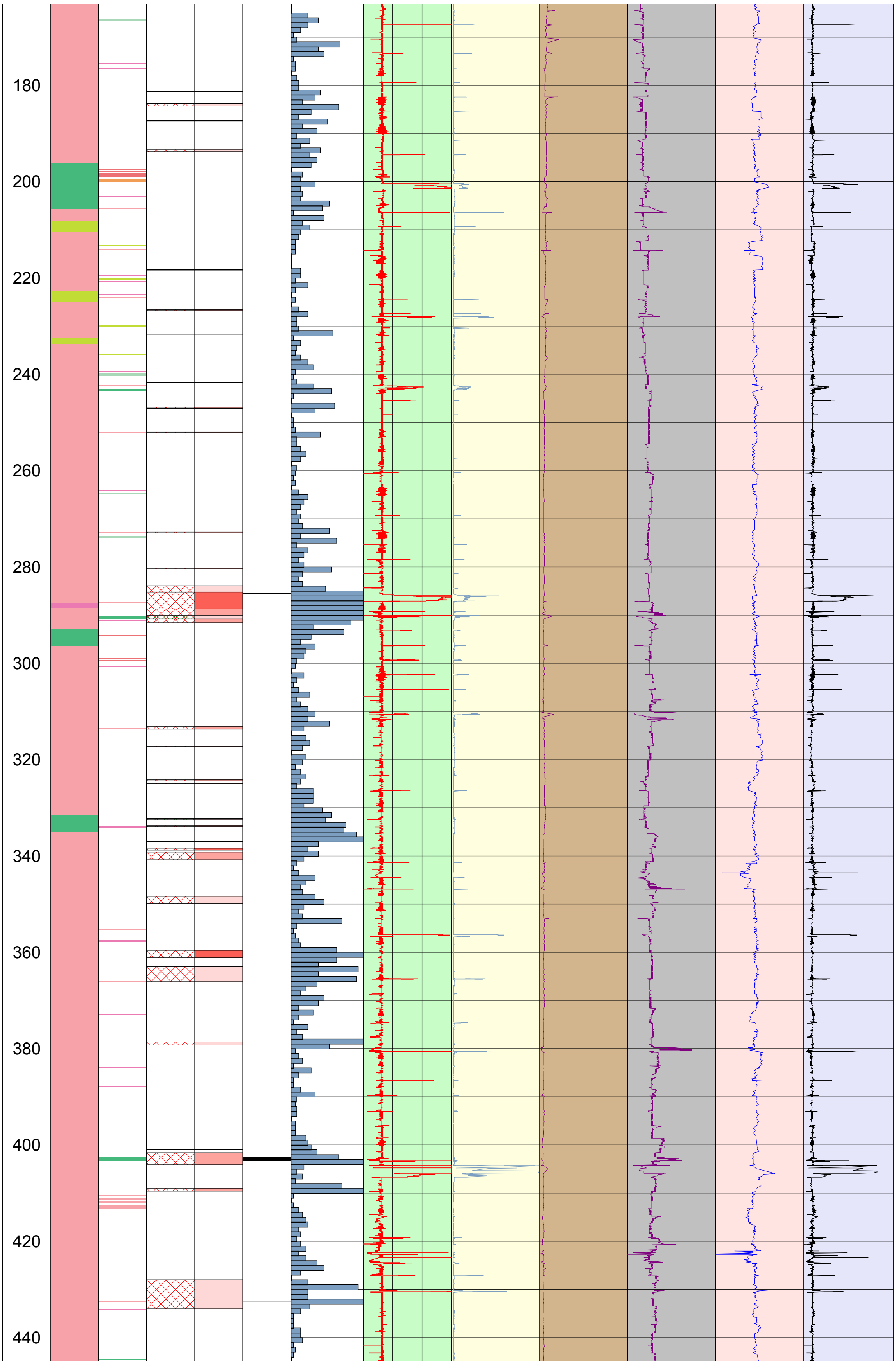
Site	LAXEMAR	**Coordinate System**	RT90-RHB70
Borehole	KLX18A	**Northing [m]**	6366413.39
Diameter [mm]	76	**Easting [m]**	1547966.35
Length [m]	611.280	**Elevation [m.a.s.l.]**	21.01
Bearing [°]	271.40	**Drilling Start Date**	2006-02-15 07:00:00
Inclination [°]	-82.10	**Drilling Stop Date**	2006-05-02 12:22:00
Date of mapping	2006-05-22 08:46:00	**Plot Date**	2007-06-03 23:15:13

ROCKTYPE LAXEMAR
- Fine-grained granite
- Ävrö granite
- Diorite / Gabbro
- Fine-grained diorite-gabbro

ROCK ALTERATION
- Oxidized
- Chloritisized
- Epidotisized
- Silicification
- Saussuritization

INTENSITY
- Faint
- Weak
- Medium
- Strong




180
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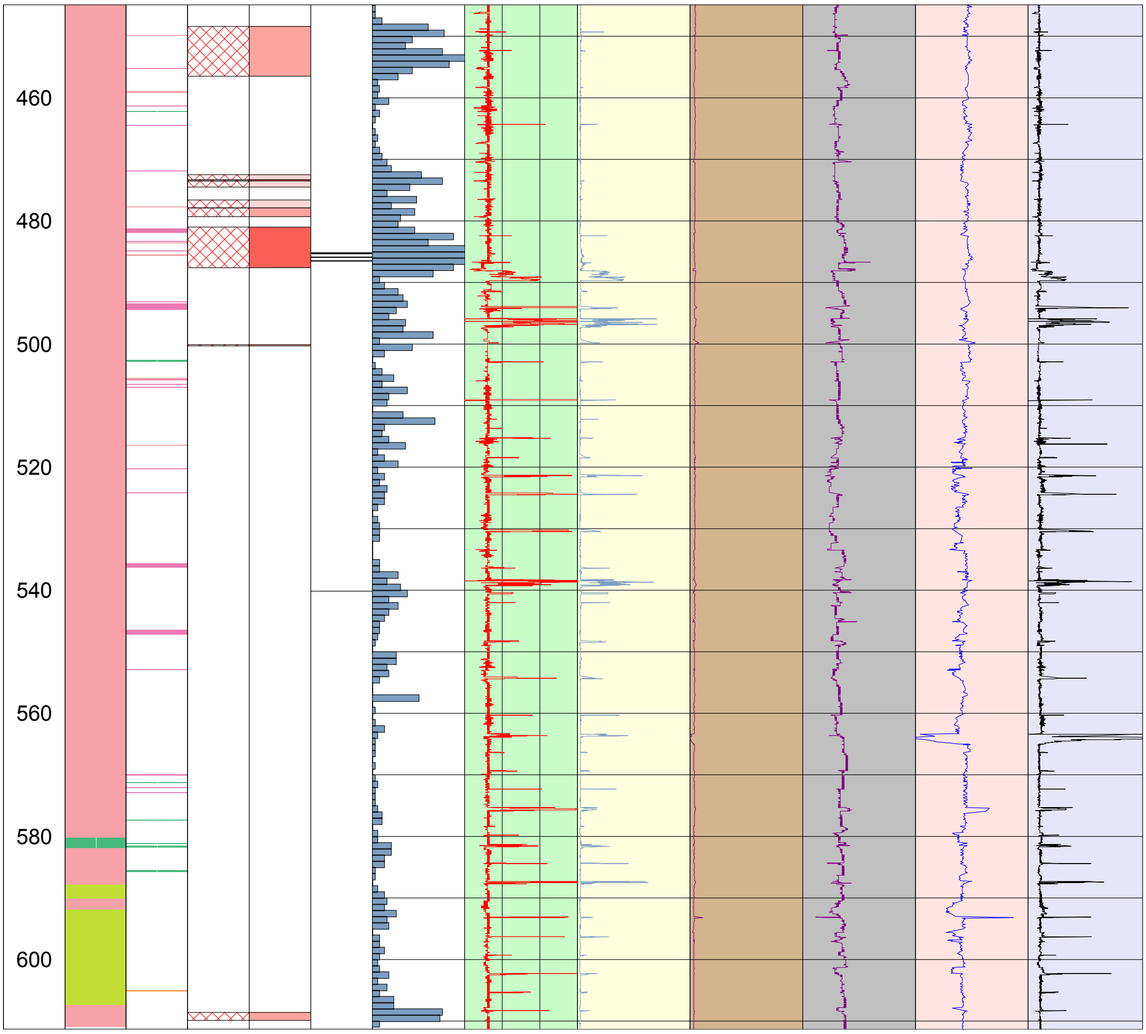

460
480
500
520
540
560
580
600

Appendix 2

Chemical results

Borehole	KLX18A	KLX18A	KLX18A	KLX18A
Date of measurement	2006-04-22	2006-04-22	2006-05-05	2006-05-08
Upper section limit (m)	102.00	312.00	471.00	312.00
Lower section limit (m)	242.35	435.65	611.33	611.33
Sample_no	10966	10994	11043	11044
Groundwater Chemistry Class	3	3	3	3
pH	8.23	7.47	7.47	8.07
Conductivity mS/m	70.5	458.0	378.0	426.0
Drill water %	16.70	2.95	17.60	1.31
Density g/ml	0.9974	0.9989	0.9986	0.9988
Charge balance %	–1.50	–0.90	1.07	–0.18
Na mg/l	134.0	675.0	573.0	655.0
K mg/l	3.28	5.35	7.50	5.10
Ca mg/l	12.5	209.0	184.0	201.0
Mg mg/l	3.6	18.7	16.0	15.1
HCO3 mg/l Alkalinity	236	114	101	129
Cl mg/l	60.7	1,360.0	1,080.0	1,260.0
SO4 mg/l	55.6	83.1	116.0	101.0
SO4_S mg/l Total Sulphur	19.50	30.00	42.10	36.20
Br mg/l	0.200	6.720	5.240	6.190
F mg/l	4.82	2.91	3.01	2.88
Si mg/l	9.40	8.72	21.40	8.29
Fe mg/l Total Iron	8.4500	5.9800	14.6000	4.4700
Mn mg/l	0.1590	0.3270	0.6270	0.5170
Li mg/l	0.014	0.102	0.098	0.104
Sr mg/l	0.341	4.120	3.450	3.960
PMC % Modern Carbon	x	xx	xx	x
C-13 dev PDB	–16.82	xx	xx	–17.01
AGE_BP Groundwater age	x	xx	xx	x
AGE_BP_CORR	x	xx	xx	x
D dev SMOW	–78.2	xx	xx	–98.9
Tr TU	–0.80	xx	xx	–0.80
O-18 dev SMOW	–11.00	xx	xx	–13.50
B-10 B-10/B-11	0.2387	xx	xx	0.2380
S-34 dev SMOW	15.0	xx	xx	8.4
Cl-37 dev SMOC	0.24	xx	xx	0.12
Sr-87 Sr-87/Sr86	0.715408	xx	xx	0.715530

x = result are not available at time of writing. The results will be reported elsewhere.
xx = not analysed

Appendix 3

Chemistry – analytical method and quality

SKB Chemistry class 3.

Analysis	Sample bottle	Preparation	SKB label	Laboratory
pH, conduktivity, alkalinity	250 ml		green	Äspö/field
Anions (F^-, Br^-, Cl^-, SO_4^{2-})	250 ml		green	Äspö/field
Uranine	100 ml brown glass		green	Äspö/field
Main components (except Fe, Mn)	Analytica's 100 ml acid washed	1 ml HNO_3 suprapur, filtering membrane filter	red	Analytica
Archive samples	2 ea 250 ml	Filtering Pallfilter	green	
Option				
Deuterium, O-18	100 ml square		green	IFE
Tritium	500 ml dried	Flooded at least once	green	Waterloo
Sr-87	100 ml square		green	IFE
Cl-37	500 ml		green	Waterloo
B-10	*Same as for main components*	1 ml HNO_3 suprapur, filtering membrane filter	red	Analytica
C-13, PMC	2 st 100 ml brown glass		green	Waterloo
S-34	1,000 ml		green	IFE

Quality of the analyses

The charge balance errors (see Appendix 2) give an indication of the quality and uncertainty of the analyses of the major components. The relative charge balance errors are calculated for the set of data from borehole KLX18A. The errors do not exceed ± 5% in any of the samples.

The following routines for quality control and data management are generally applied for hydrogeochemical analysis data, independent of sampling method or sampling object.

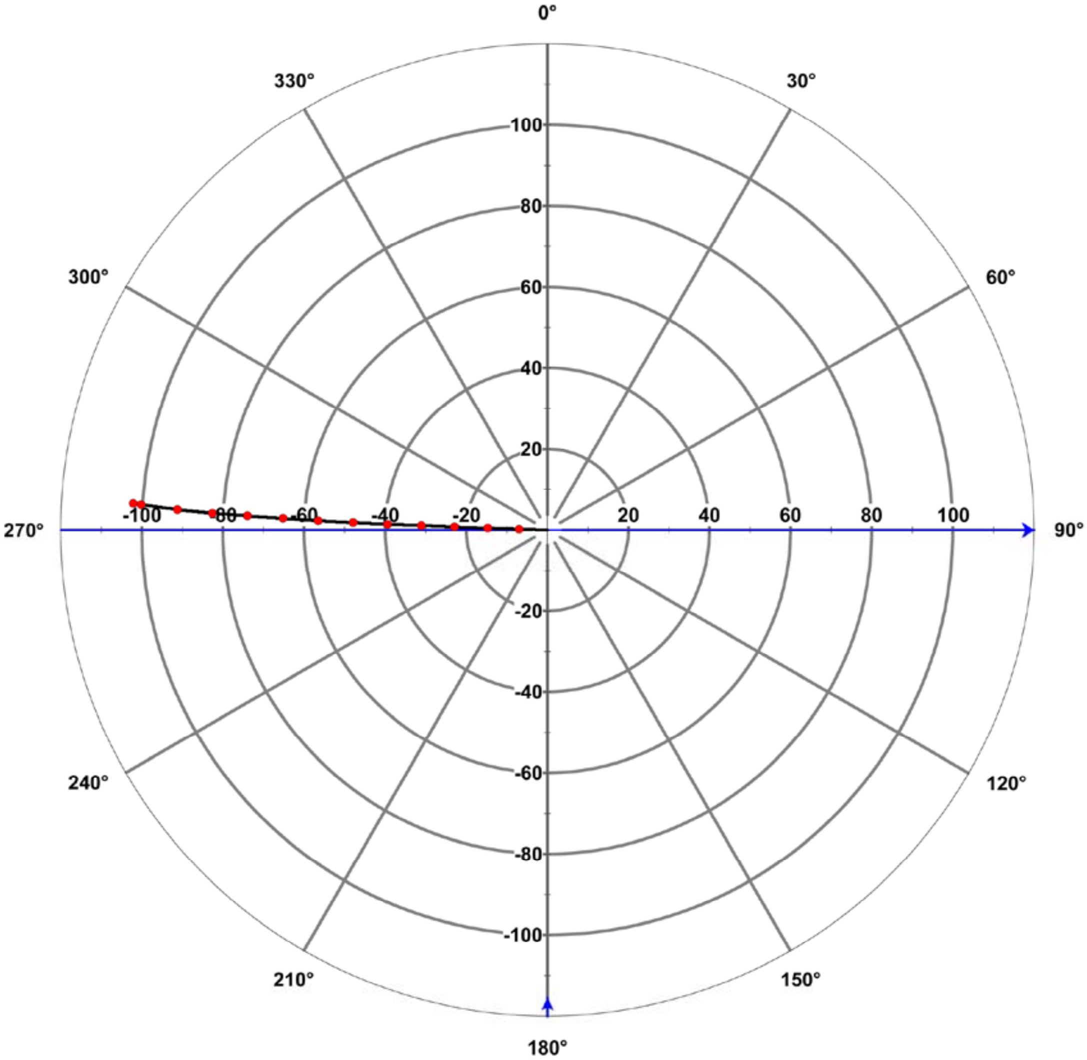
- Several components are determined by more than one method and/or laboratory. Control analyses by an independent laboratory are normally performed as a standard procedure on every five or ten collected samples. No control analyses were performed on the water samples from KLX18A.
- All analytical results were stored in the SICADA database. The chemistry part of the database contains two types of tables, raw data tables and primary data tables (final data tables).
- Data on basic water analyses are inserted into raw data tables for further evaluation. The evaluation results in a final reduced data set for each sample. These data sets are compiled in a primary data table named "water composition". The evaluation is based on:
  - Comparison of the results from different laboratories and/or methods. The analyses are repeated if a large disparity is noted (generally more than 10%).
  - Calculation of charge balance errors. Relative errors within ± 5% are considered acceptable. For surface waters errors of ± 10%.
  - $\text{Rel. Error (\%)} = 100 \times \frac{(\sum \text{cations(equivalents)} - \sum \text{anions(equivalents)})}{(\sum \text{cations(equivalents)} + \sum \text{anions(equivalents)})}$
  - General expert judgement of plausibility based on earlier results and experiences.

All results from "biochemical" components and special analyses of trace metals and isotopes are inserted directly into primary data tables. In those cases where the analyses are repeated or performed by more than one laboratory, a "best choice" notation will indicate those results which are considered most reliable.

Appendix 4

Deviation measurement

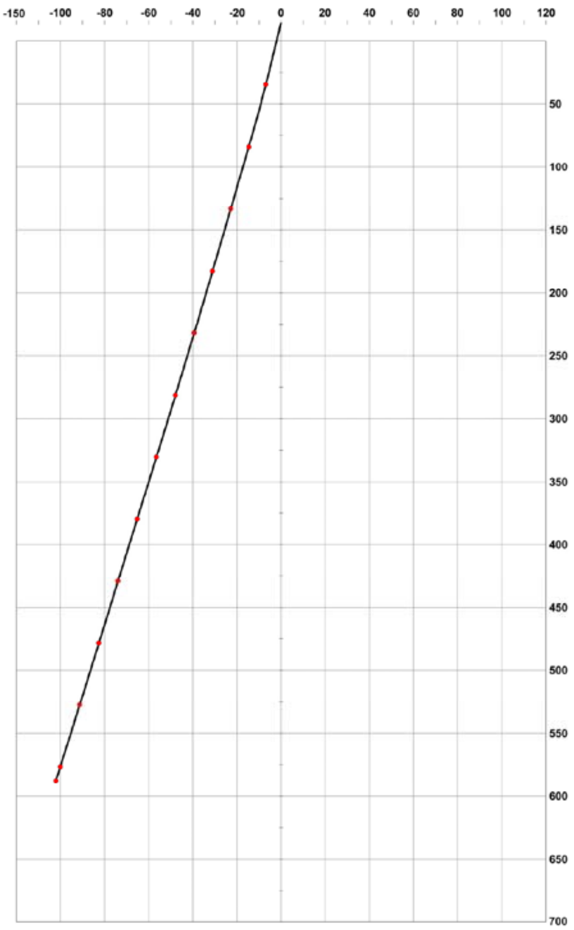
SKB	Site Borehole View from above	LAXEMAR KLX18A



Site	LAXEMAR
Borehole	KLX18A
Vertical Section	

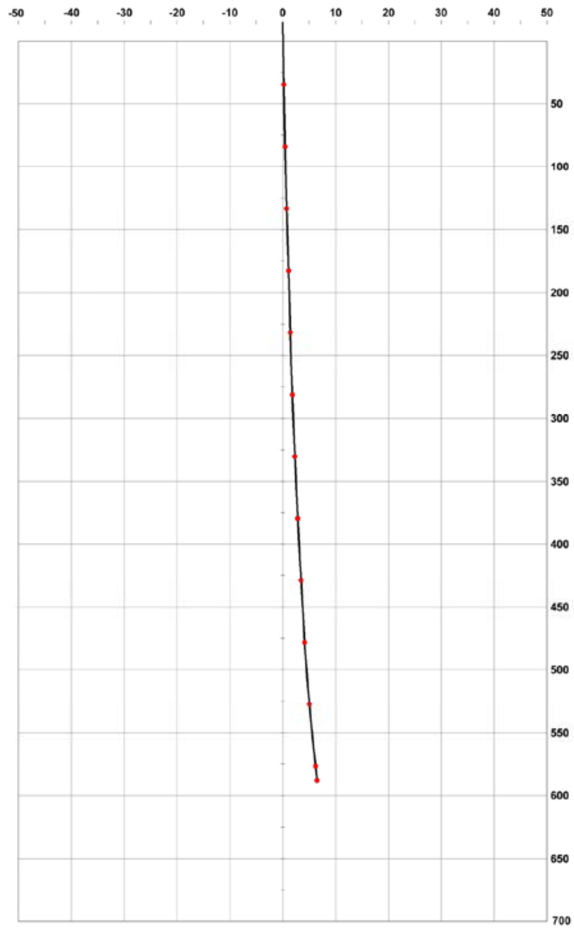
Easting

W 1547966.35 E



Northing

S 6366413.39 N



Appendix 5

Wireline pumping tests in KLX18A

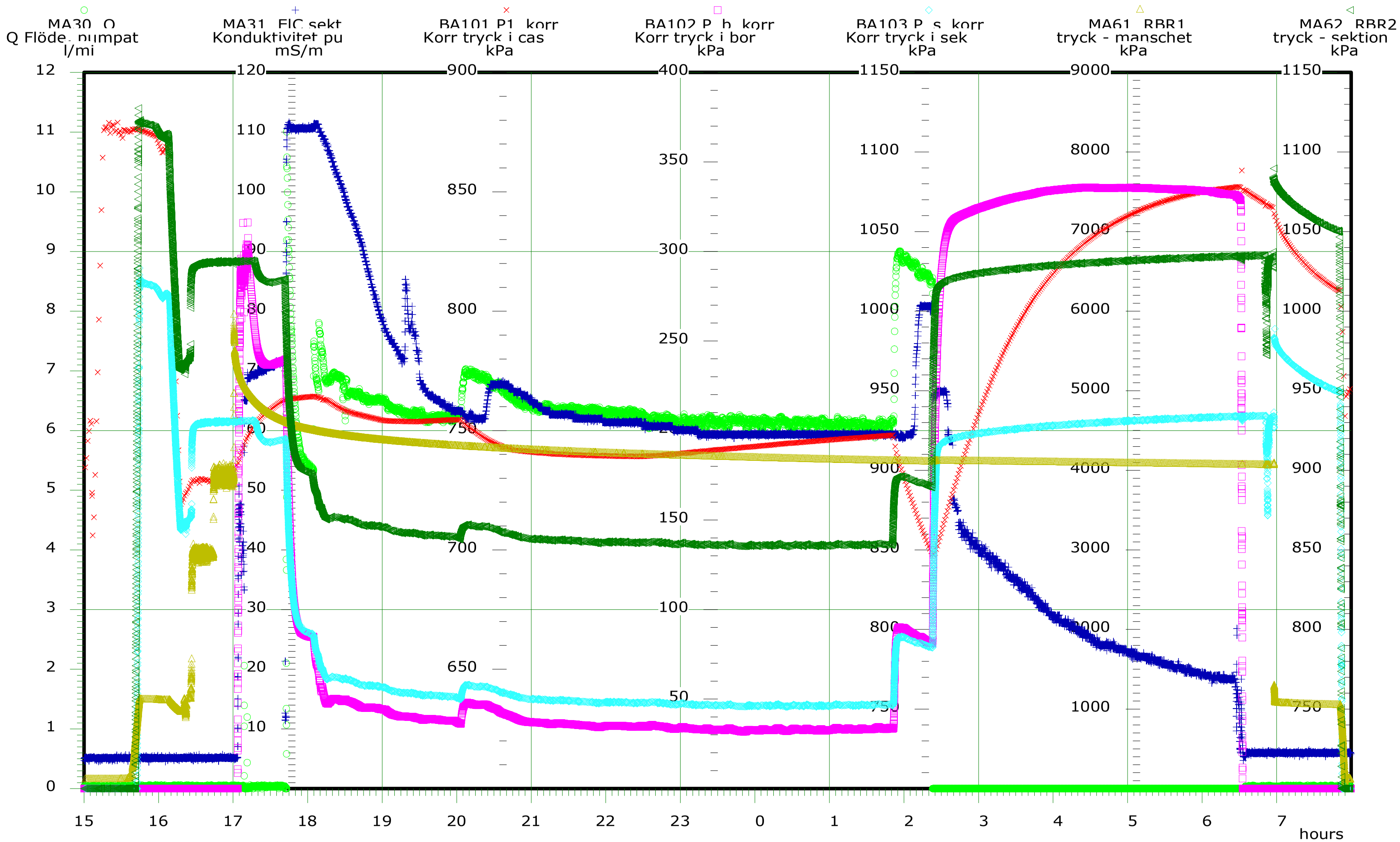
Description of the parameters in the enclosed plots.

Channel	Parameter	Unit	Description
MA30	Water flow	Litre/minute	Flow of water pumped up from the borehole during the test.
MA31	Electrical conductivity	mS/m	Electrical conductivity in the pumped out water.
BA101	Pressure	kPa	Pressure of the water column in the telescopic section subtracted with the ambient air pressure.
BA102	Pressure	kPa	Pressure of the water column in the test section i.e. at depth in the borehole, subtracted with the ambient air pressure.
BA103	Pressure – section	kPa	Pressure of the water column in the test section i.e. at depth in the borehole, subtracted with the ambient air pressure.
MA61	Pressure – packer	kPa	Inflation pressure in packer.
MA62	Pressure – section	kPa	Pressure of the water column in the test section i.e. at depth in the borehole. Not corrected for ambient air pressure.

PLOT TIME :06/04/11 10:46:08
PLOT FILE :P_Pumptest
Adjusted for DST

DMS1 PO

Pumping test wireline probe
KLX18A, 102.00-242.35 m



START :06/04/07 15:00:00

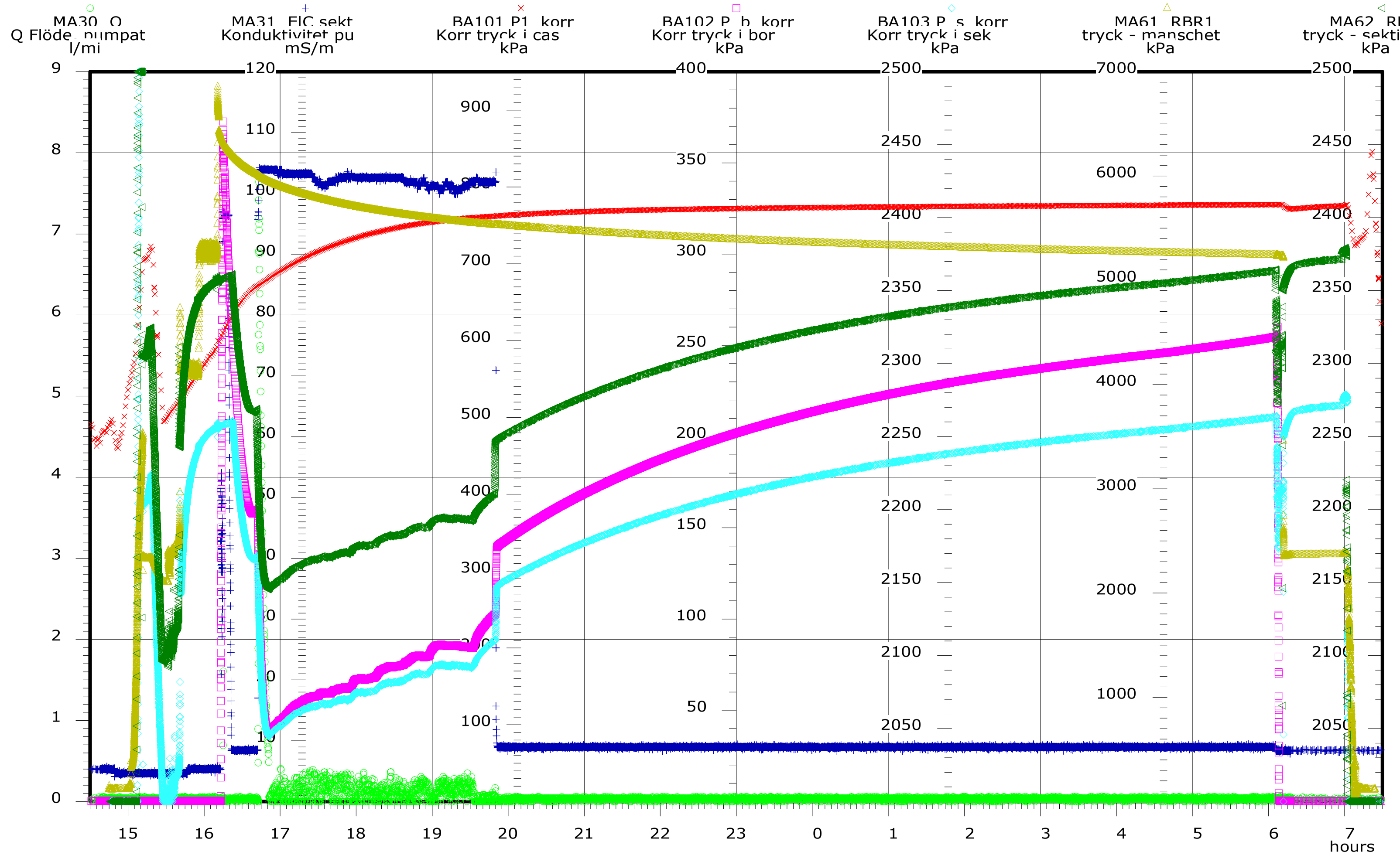
INTERVAL: All readings

STOP :06/04/08 07:59:59

PLOT TIME :06/04/21 13:22:07
PLOT FILE :P_Pumptest
Adjusted for DST

DMS1 PO

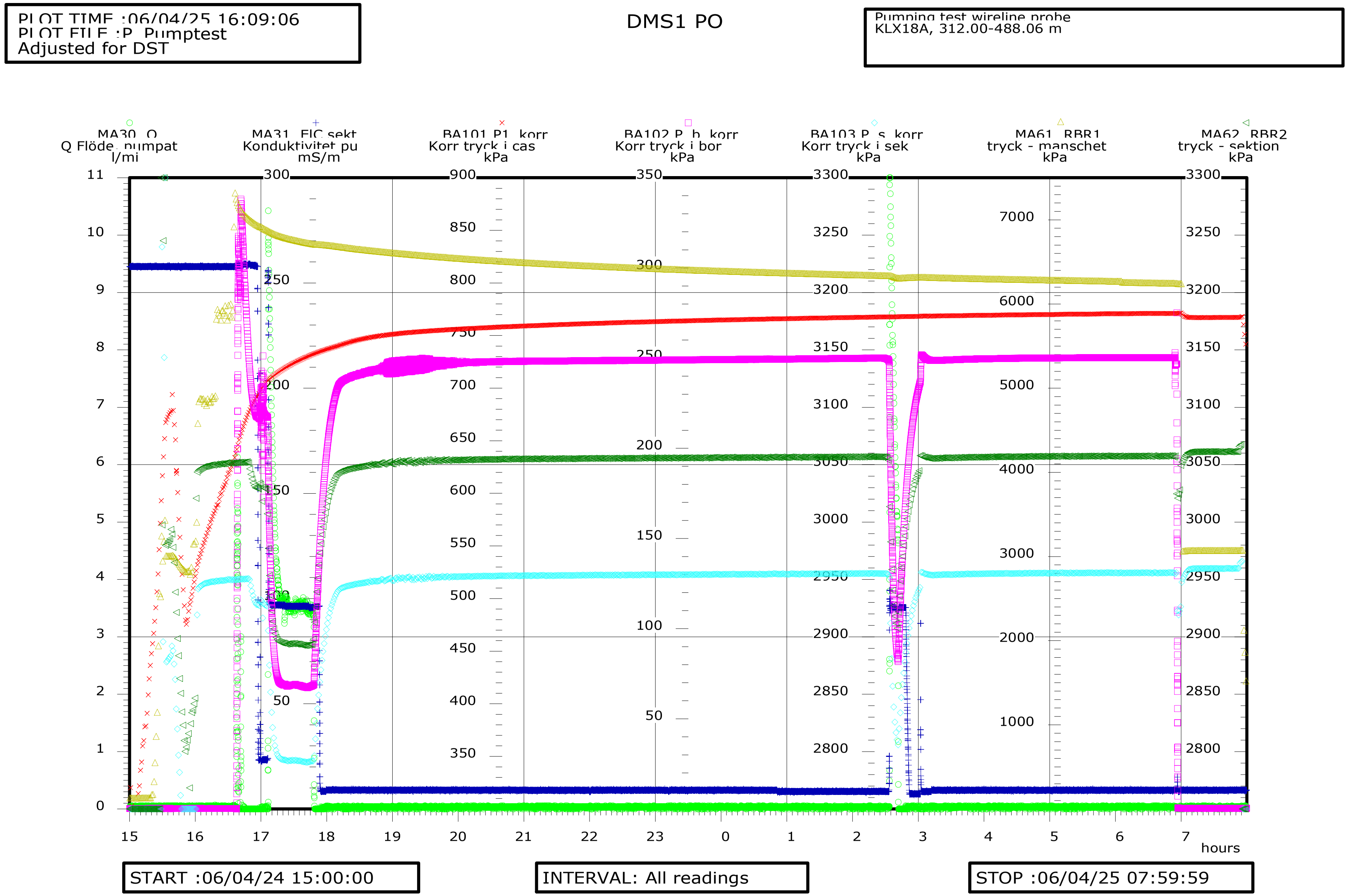
Pumping test wireline probe
KLX18A, 239.94-313.73 m



START :06/04/12 14:30:00

INTERVAL: All readings

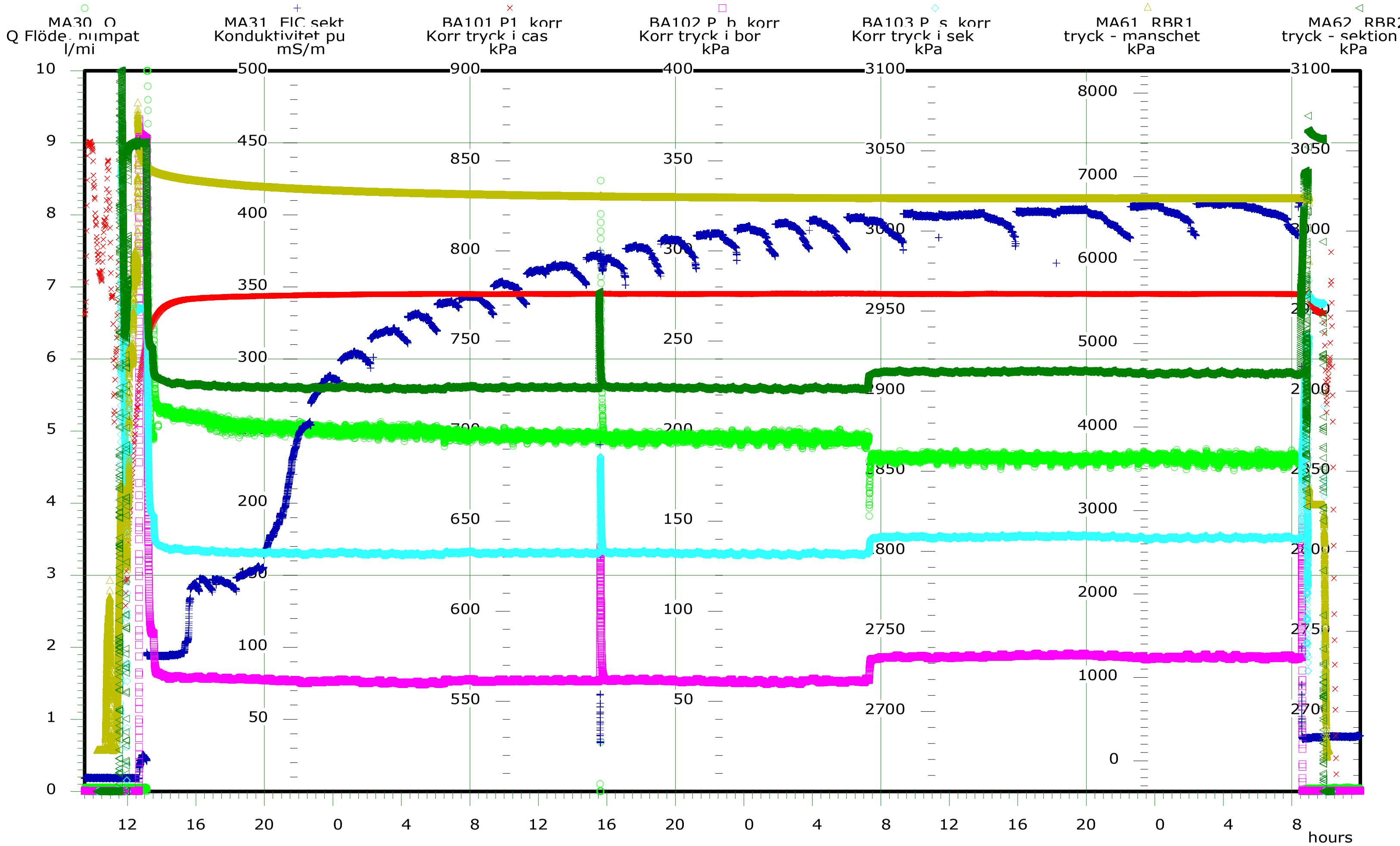
STOP :06/04/13 07:29:59


PLOT TIME :06/04/25 16:09:06
PLOT FILE :P_Pumptest
Adjusted for DST
DMS1 PO
Pumping test wireline probe
KLX18A, 312.00-488.06 m
MA30 Q
Q Flöde, pumpat
l/mi
MA31 EIC sekt
Konduktivitet pu
mS/m
BA101 P1 korr
Korr tryck i cas
kPa
BA102 P h korr
Korr tryck i bor
kPa
BA103 P s korr
Korr tryck i sek
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
hours
START :06/04/24 15:00:00
INTERVAL: All readings
STOP :06/04/25 07:59:59

PLOT TIME :07/04/23 09:14:53
PLOT FILE :P_Pumptest
Adjusted for DST

DMS1 PO

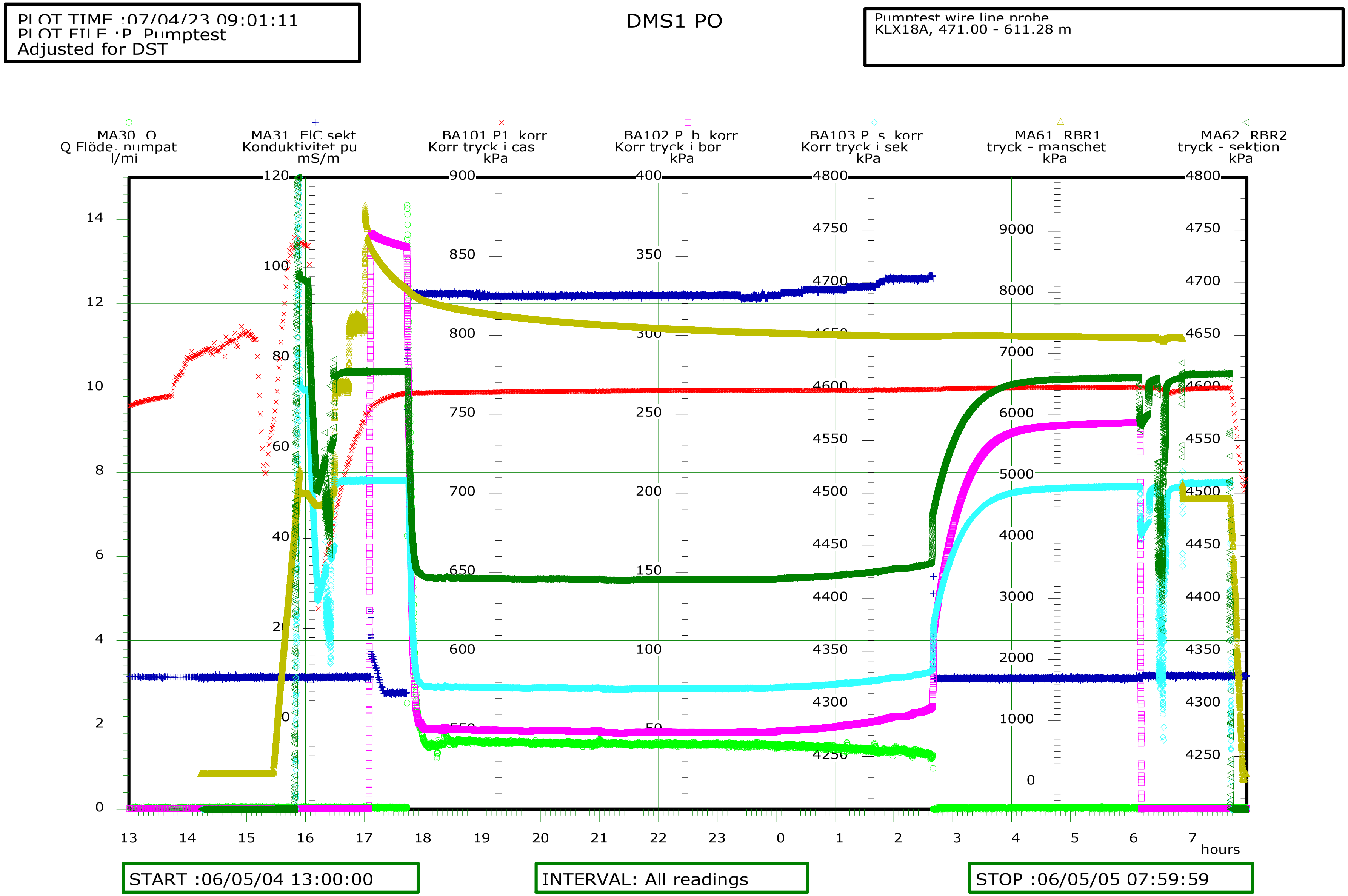
Pumptest wire line probe
KLX18A, 312.00 - 611.28 m

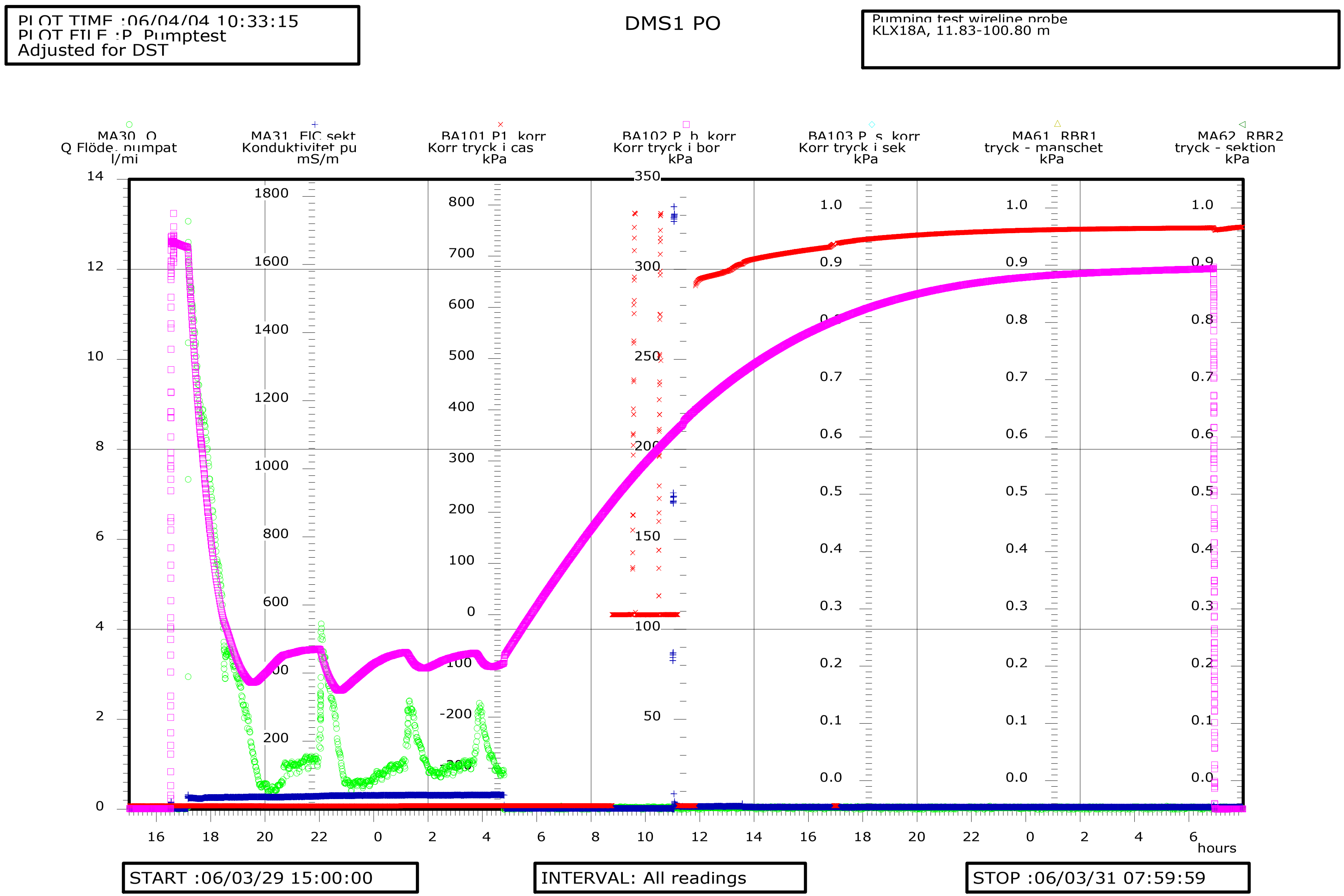


START :06/05/05 09:30:00

INTERVAL: All readings

STOP :06/05/08 11:59:59


PLOT TIME :07/04/23 09:01:11
PLOT FILE :P_Pumptest
Adjusted for DST
DMS1 PO
Pumptest wire line probe
KLX18A, 471.00 - 611.28 m
MA30_Q
Q Flöde, pumpat
l/mi
MA31_FIC sekt
Konduktivitet pu
mS/m
BA101 P1_korr
Korr tryck i cas
kPa
BA102 P_h_korr
Korr tryck i bor
kPa
BA103 P_s_korr
Korr tryck i sek
kPa
MA61_RBR1
tryck - manschet
kPa
MA62_RBR2
tryck - sektion
kPa
hours
START :06/05/04 13:00:00
INTERVAL: All readings
STOP :06/05/05 07:59:59



PLOT TIME :06/04/04 10:33:15
PLOT FILE :P_Pumptest
Adjusted for DST
DMS1 PO
Pumping test wireline probe
KLX18A, 11.83-100.80 m
MA30 Q
Q Flöde, pumpat
l/mi
MA31 EC sekt
Konduktivitet pu
mS/m
BA101 P1 korr
Korr tryck i cas
kPa
BA102 P_b korr
Korr tryck i bor
kPa
BA103 P_s korr
Korr tryck i sek
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
hours
START :06/03/29 15:00:00
INTERVAL: All readings
STOP :06/03/31 07:59:59

Appendix 6

Technical data from enviromental monitoring wells SSM000250 and SSM000251

LAXEMAR BOREHOLE SSM000250

Company rep.
Torbjörn Johansson

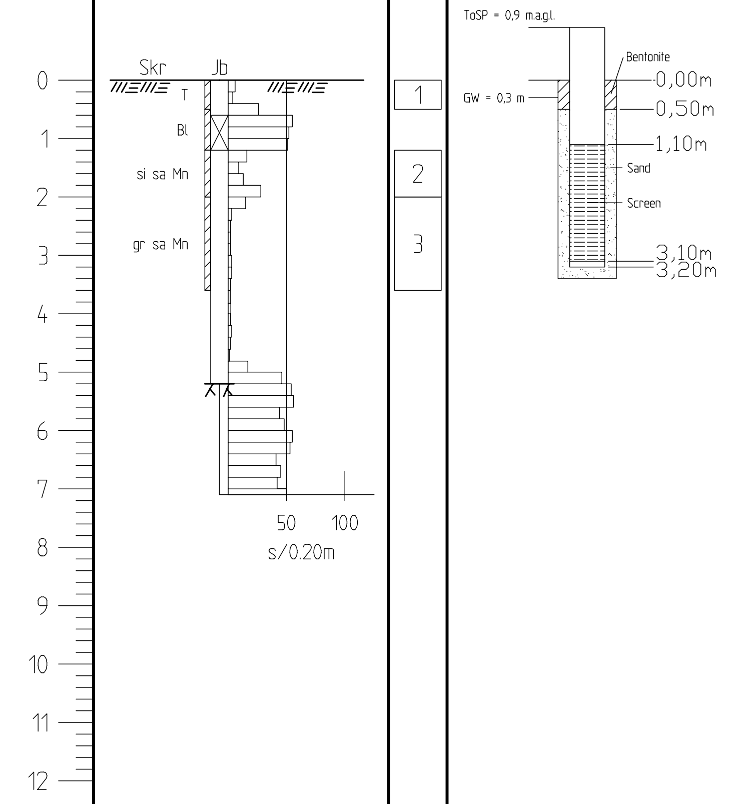
Client: Svensk Kärnbränslehantering AB

Northing :6366463,803
Easting :1547968,780

Coordinate system : RT90-RHB70

Top of stand pipe : 0,9 m.a.g.l.
Total pipe length : 4,10 m
Groundwater level : 0,3 m.b.g.l.
Date of completion : 2006-01-27

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information



Drilling method : NOEK
Borehole diameter : 120 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,50 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 2,70 m

DRILLING EQUIPMENT
Drilling rig : GM 65 GTT
Drill hammer : Furukawa HB2G
Drill rod : Geostång Φ44
Drill bit : Stift Φ54

GEOLOGICAL LOG
0-0,5m Peat
0,5-1,2m boulders
1,2-2,0m silty sandy till
2,0-5,2m gravelly sandy till
5,2m rock surface

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

Nomenclature see SGF homepage:
www.sgf.net

LAXEMAR BOREHOLE SSM000251

Company rep.
Torbjörn Johansson

Client: Svensk Kärnbränslehantering AB

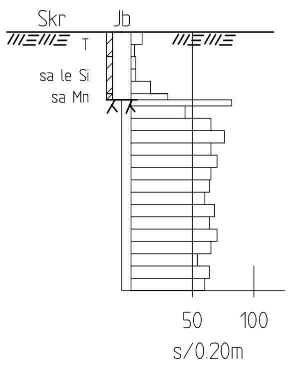
Northing :6366470,473
Easting :1547981,740

Coordinate system : RT90-RHB70

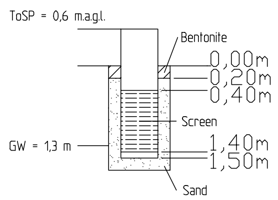
Top of stand pipe : 0,6 m.a.g.l.
Total pipe length : 2,10 m
Groundwater level : 1,30 m.b.g.l.
Date of completion : 2006-01-30

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information

Depth (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12



Samples: 1, 2, 3



Drilling method : NOEK
Borehole diameter : 120 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,20 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 1,30 m

DRILLING EQUIPMENT
Drilling rig : GM 65 GTT
Drill hammer : Furukawa HB2G
Drill rod : Geostång Φ44
Drill bit : Stift Φ54

GEOLOGICAL LOG
0-0,4m Peat
0,4-1,0m sandy clayey silt
1,0-1,1m sandy fill
1,1m rock surface

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

Nomenclature see SGF homepage:
www.sgf.net