P-06-306

Oskarshamn site investigation

Drilling of cored borehole KLX11A

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May 2007

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Abstract

Borehole KLX11A is located in the western part of the Laxemar subarea. Drilling was made between November 2005 and March 2006 as a part of the site investigation for a possible repository for spent nuclear fuel in Oskarshamn municipality, Sweden.

KLX11A was core drilled to a length of 992.29 metres with N-size (76 mm) equipment. The uppermost section, to the length of 100.06 metres, was constructed as a telescopic section with an inner nominal diameter of 200 mm.

No water inflow could be measured in the telescopic section during percussion drilling.

Nine pumping tests were performed in KLX11A with wireline equipment, typically with one hundred metre intervals. The resulting transmissivities (T_M) varied between 8.2×10^{-8} and 2.8×10^{-5} m^2/s. The most transmissive section was between 101 and 209 metres.

Continuous monitoring of drilling parameters and flushing water parameters with the drilling monitoring system was conducted throughout the core drilling phase in KLX11A.

Four water samples for chemical analysis were collected during the core drilling of KLX11A.

An air-lift pumping test in the telescopic section performed when borehole KLX11A was core drilled to its full length gave a transmissivity (T_M) of 6.8×10^{-5} m^2/s.

Lithologically the core is entirely dominated by Quart monzodiorite. Minor sections of fine-grained diorite-gabbro and pegmatite occur.

Red staining with medium intensity is primarily noted in two intervals; 250–260 m and 490–510 m. These two intervals also have an elevated fracture frequency. An increased fracture frequency is furthermore noted in two intervals; 580–590 m and 850–860 m.

Red staining with faint to weak intensity is present sporadically to ca 590 m. Alteration is very scarce below 590 m. 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 1.2 (fractures/metre). NB The fracture frequency given in Appendix 1 shows the total fracture frequency (i.e. open fractures, sealed fractures and fractures in crushed sections).

Sammanfattning

Borrhål KLX11A ligger den västra delen av delområde Laxemar. Borrningen utfördes mellan november 2005 och mars 2006 som ett led i platsundersökningen för ett möjligt djupförvar för använt kärnbränsle i Oskarshamns kommun.

KLX11A kärnborrades med borrstorlek N (76 mm) till 992,29 meters borrad längd. Den övre delen av hålet, från markytan till 100,06 meter, utfördes som en teleskopdel med ca 200 mm inre diameter.

Inget vatteninflöde kunde mätas i teleskopdelen vid hammarborrningen.

Nio pumptester med wireline-baserad mätutrustning utfördes över ca hundra meters intervaller. Uppmätta transmissiviteter (T_M) varierade mellan $8{,}2\times10^{-8}$ och $2{,}8\times10^{-5}$ m^2/s. Den mest transmissiva sektionen var mellan 101 och 209 meter.

Kontinuerliga mätningar av borrningsparametrar och spolvattenparametrar via DMS (**d**rilling **m**onitoring **s**ystem) gjordes under hela kärnborrningsfasen i KLX11A.

Fyra vattenprover för kemisk analysering togs i samband med borrning i KLX11A.

Ett pumptest med mammutpumpning i teleskopdelen som gjordes när kärnborrningen i KLX11A utförts till full längd gav en transmissivitet (T_M) på $6{,}8\times10^{-5}$ m^2/s.

Litologiskt domineras kärnan fullständigt av kvartsmonzodiorit. Mindre inslag av finkornig diorit-gabbro och pegmatit förekommer.

Rödfärgning med måttlig intensitet har företrädelsevis noterats i två intervall; 250–260 m och 490–510 m. Dessa båda intervall har även en förhöjd sprickfrekvens. En förhöjd sprickfrekvens har vidare noterats i två intervall; 580–590 m och 850–860 m.

Rödfärgning med obetydlig till svag intensitet återfinns sporadiskt ner till ca 590 m. Omvandling är mycket sällsynt under 590 m. Sektioner med rödfärgning anges som ”oxiderade” i Appendix 1.

Den genomsnittliga sprickfrekvensen över hela borrkärnan uttryckt som öppna sprickor är 1,2 (sprickor/meter). OBS Den sprickfrekvens som anges i Appendix 1 avser den totala mängden sprickor (dvs öppna sprickor, läkta sprickor och sprickor som ingår i sektioner med krossat berg).

Contents

1 Introduction

SKB, the Swedish Nuclear Fuel & 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 KLX11A is located in the western part of the Laxemar subarea of the investigation area in Oskarshamn.

Drilling and investigations in boreholes are fundamental activities in order to facilitate characterisation of rock and groundwater properties at depth. KLX11A was the thirteenth deep cored borehole within the Oskarshamn site investigation. The location of the core drilled borehole and the water source, HLX28 in the Laxemar subarea is shown in Figure 1-1.

The drilling of KLX11A and all related on-site operations were performed according to a specific activity plan (AP PS 400-05-065), which in turn refers to a number of method descriptions, see Table 1-1.

The activity plans and method descriptions are SKB internal documents.

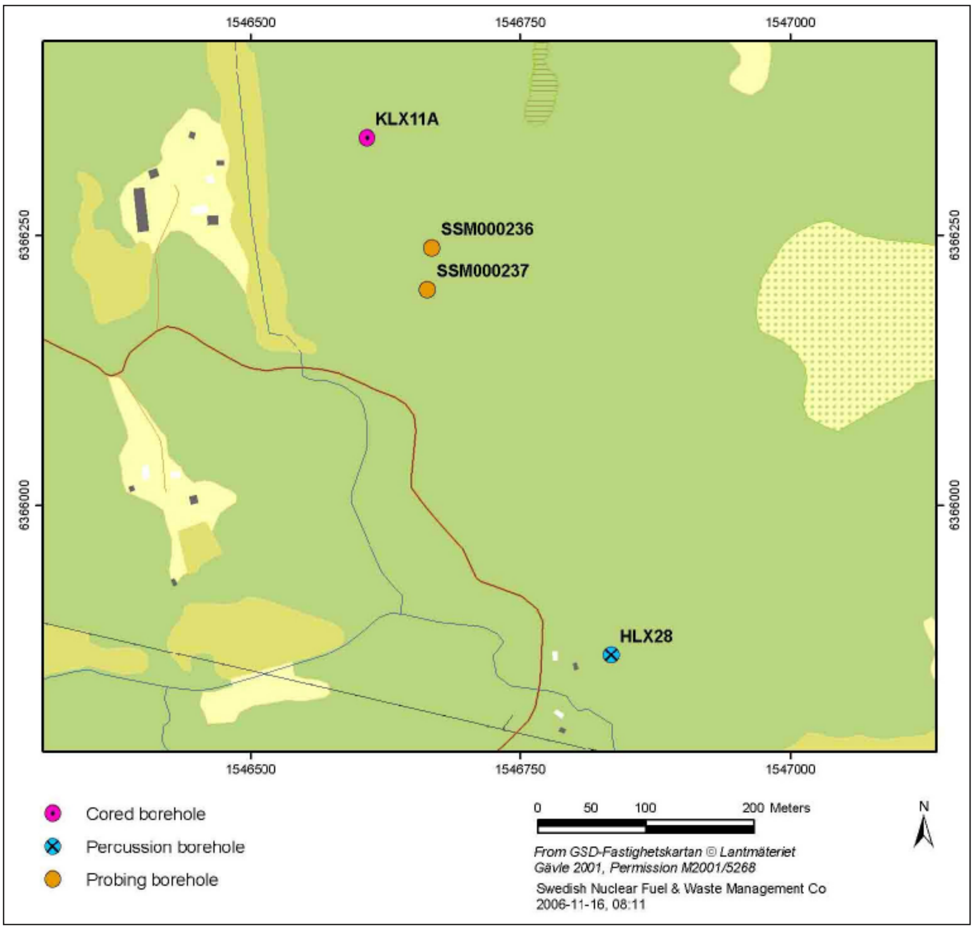


Figure 1-1. *Location of the cored borehole KLX11A and the water source, percussion borehole HLX28 in the western part of subarea Laxemar shown together with the two environmental monitoring wells SSM000236 and SSM000237.*

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

Activity plan	Number	Version
Kärnborrning KLX11A	AP PS 400-05-065	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 genomförande av hydrauliska enhålstrester	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 pumptest, tryckmätning och vattenprovtagning 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 krökningsmätnign 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

* Version 2 was approved on 2006-11-09.

** The method description was formally approved on 2005-11-17.

2 Objective and scope

This report will describe the methods employed and the results achieved during the drilling of borehole KLX11A. 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 KLX11A is given in SKB id no 1044815, dated 2005-10-03.

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 in accordance with the Environmental Code was sent to the Regional Authorities 2005-09-14, SKB id no 1044207. Information of the final coordinates and details regarding the return water handling was submitted to the Regional Authorities on 2005-10-04, SKB id no 1044759.

3 Overview of the drilling method

Drilling of deep cored boreholes requires the establishing of a drill site of ca 30×30 metres. Figure 3-1 shows the site during geological reconnaissance. Figure 3-2 shows the KLX11A drill site fully established with drilling equipment.

Figure 3-1. *Geologists reconnoitring the future drill site for KLX11A.*

Figure 3-2. *The drill site at KLX11A.*

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 metres 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 metres and 1,000 metres, see Figure 3-3. 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 3-4.

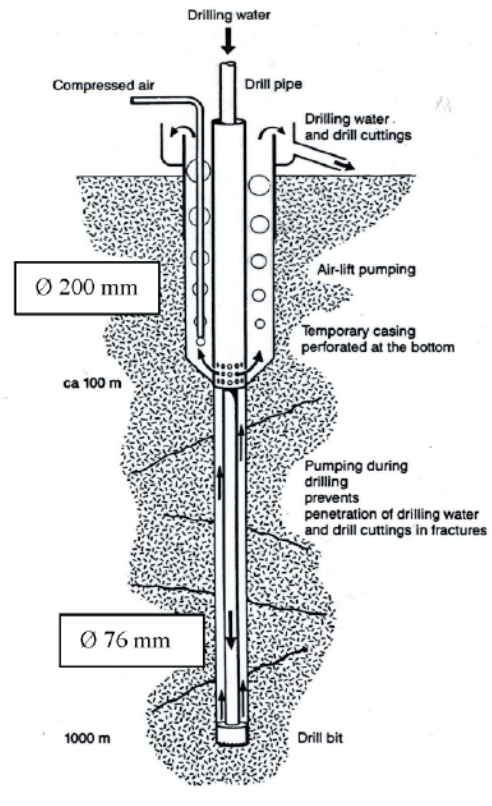


Figure 3-3. A sketch of the telescopic drilling method with air-lift pumping for retrieval of drilling water and cuttings.

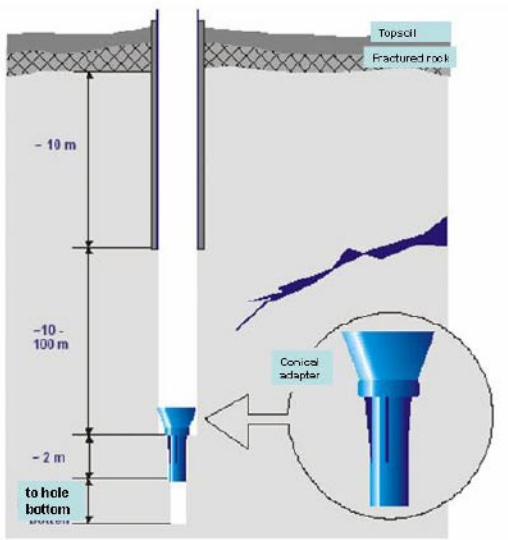


Figure 3-4. *Installation of the conical guide.*

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 3-5.

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 3-6.

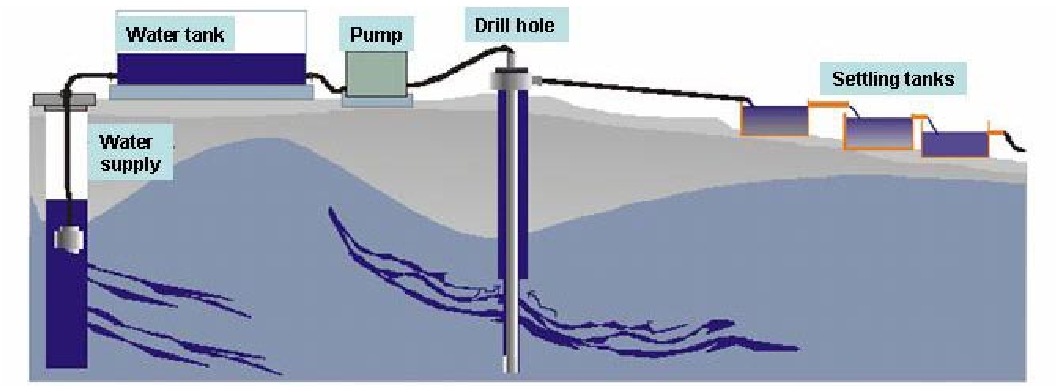


Figure 3-5. *The flushing water system from source to discharge point.*

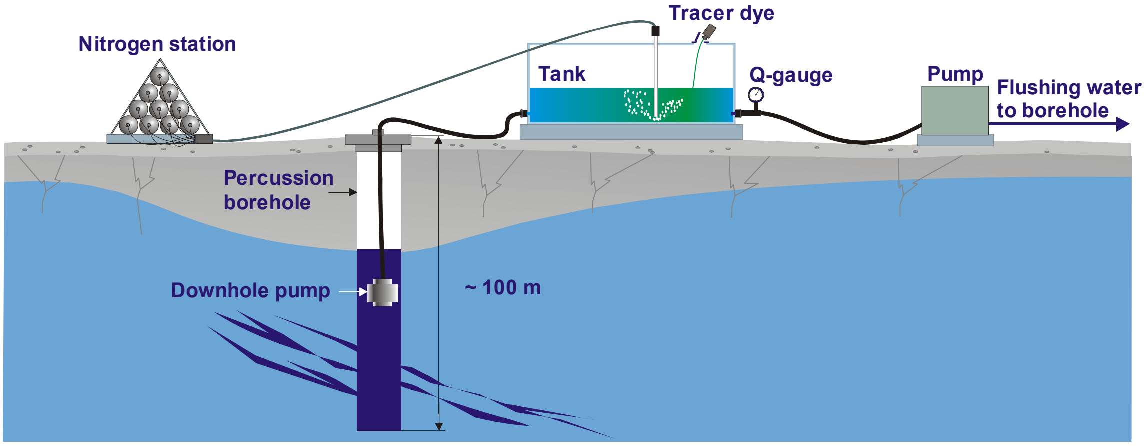


Figure 3-6. *Preparation of flushing water. Uranine is added to the water as a tracer dye. Nitrogen is bubbled through the water to remove dissolved oxygen.*

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 as drilling progresses. 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 KLX11A 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 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 discontinued on 2005-10-06 following an internal decision, SKB id 1044856, SKB 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, 700 and 1,000 metres 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).

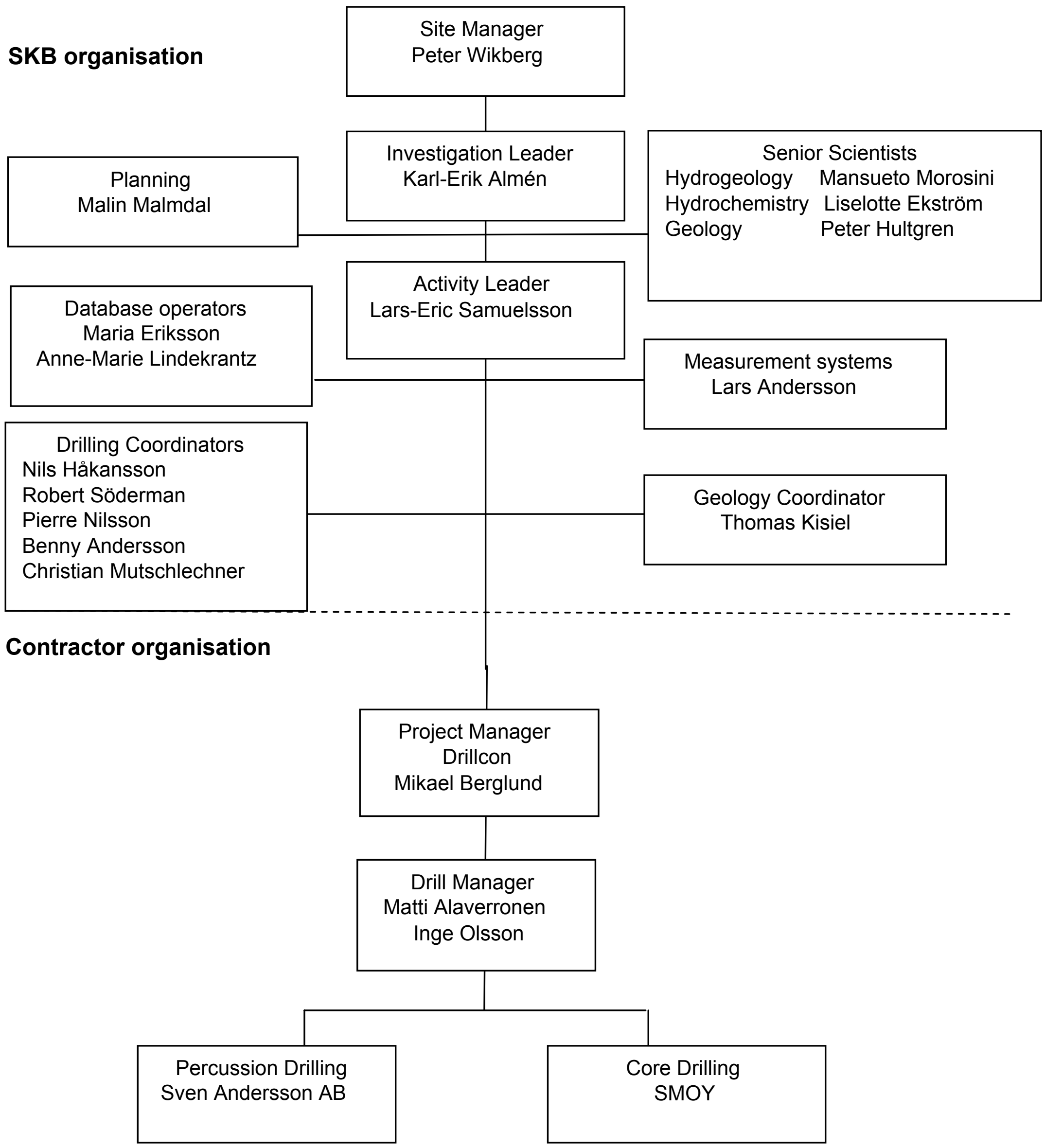
4 Contractors and equipment

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 KLX11A 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 311×15 mm (non stainless). The casing dimensions are presented here as outer diameter x thickness.

4.3 Core drilling equipment

Core drilling in KLX11A 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.

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.

Directional drilling, i.e. intentional guiding or changing of the drilling direction, was not made in KLX11A.

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 4-1.

A tightness test of the drill string is done before the pumping tests are made.

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.

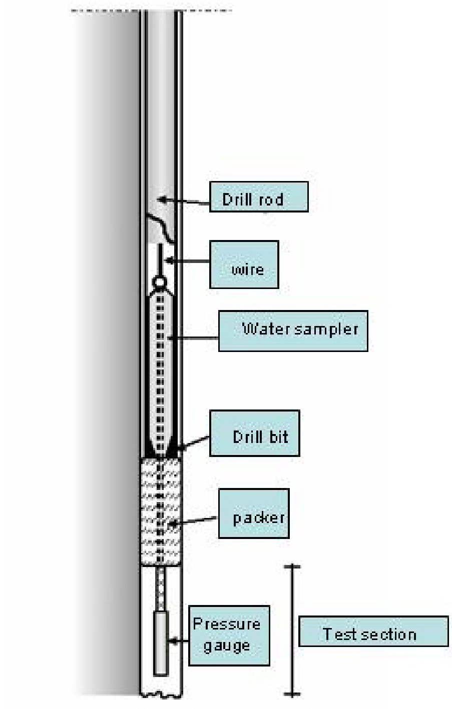


Figure 4-1. The wireline probe and its emplacement in the hole.

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 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

In accordance with the activity plan no measurements of absolute pressure were done in KLX11A.

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.

Figure 4-2. *The CR23 logging unit for parameters "barometric pressure" and "electrical conductivity".*

4.3.3 Deviation measurements

Two types of deviation measurements were made:

- Measurements to keep track on the borehole direction and dip in order to make decisions on whether directional drilling was needed or not were made at 100 metre intervals 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, were 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.

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.

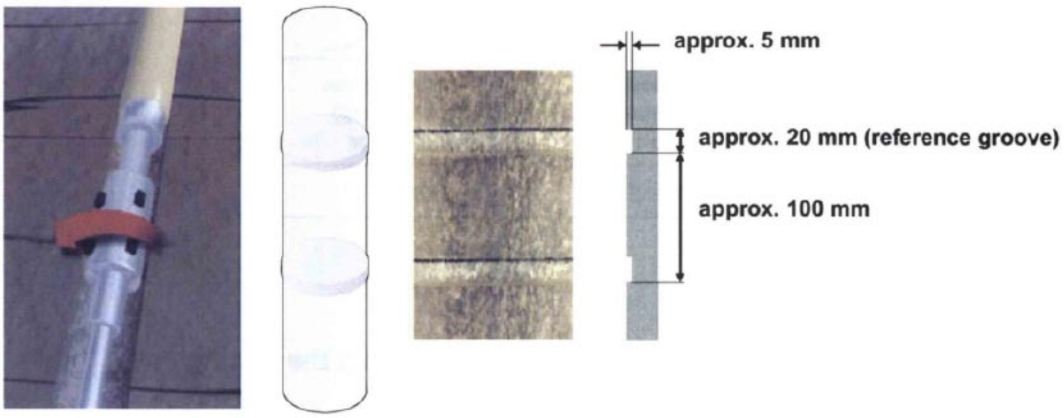


Figure 4-3. *The equipment for reaming of reference slots. To the left, the reaming tool with openings for the cutters is shown. The resulting reference slots are illustrated in the three pictures to the right.*

5 Execution and results

5.1 Summary of KLX11A drilling

A technical summary of the drilling of KLX11A 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.

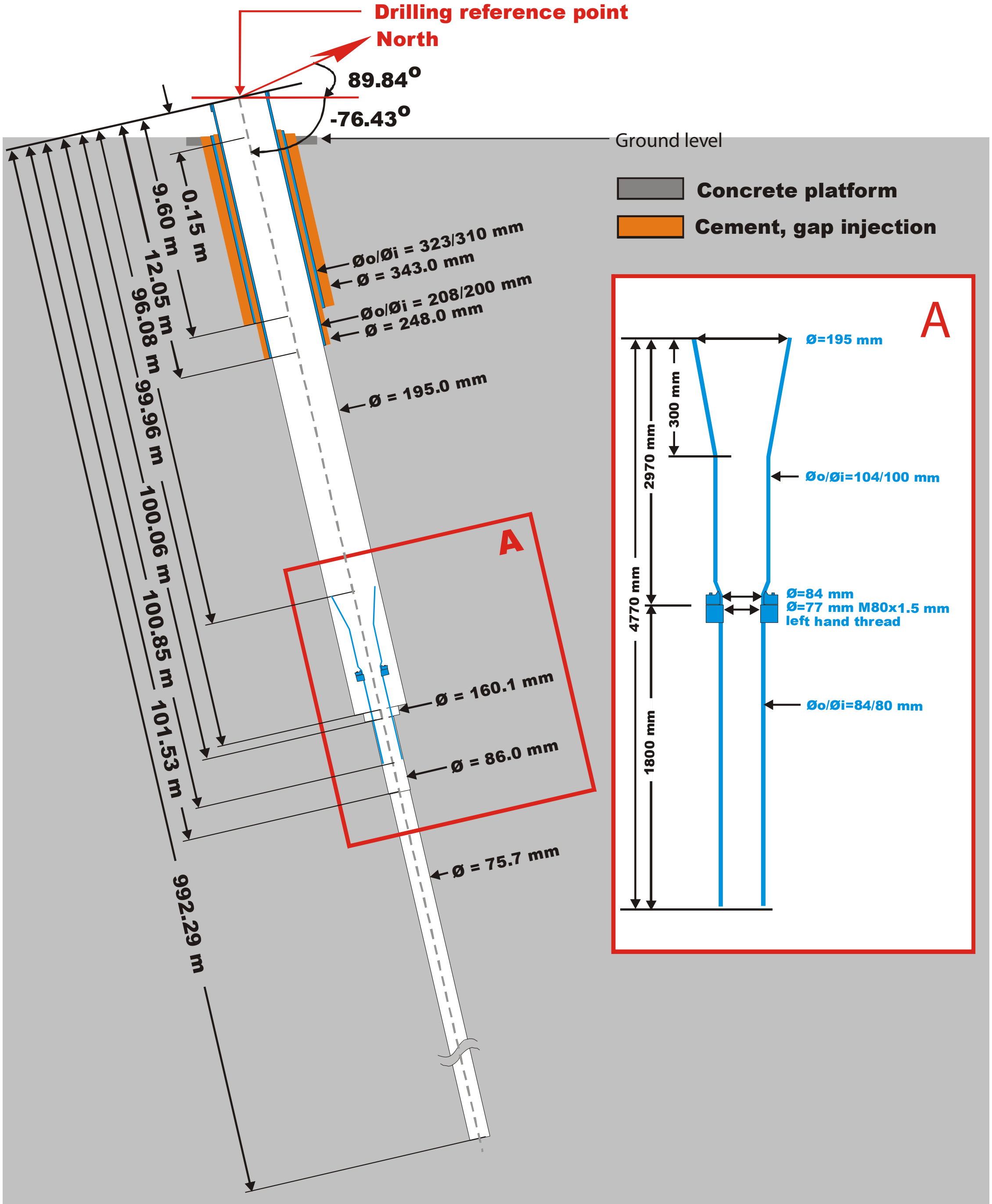
Further descriptions of the percussion drilling of the telescopic section 0–100.60 metres and the measurements performed during this phase are given in section 5.2. The core drilling between 100.06–992.29 metres is further described in section 5.3. Results from hydrogeological and hydrogeochemical measurements 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. KLX11A Technical summary.

General	Technical
Name of hole: KLX11A	*Percussion drill rig* Comacchio MC1500
Location: Laxemar, Oskarshamn Municipality, Sweden	*Percussion hole length* 99.96 m (diam 195.0 mm) 100.60 m (diam 160.1 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* 100.06–992.29 m
Subcontractor core drilling Suomen Malmi OY (SMOY)	*Average core length retrieved in one run* 2.69 m
	Number of runs 331
Drill start date- percussion drilling November 1, 2005	*Diamond bits used* 13
Drill start date- core drilling November 24, 2005	*Average bit life* 69 metres
Completion date March 2, 2006	*Position KLX11A (RT90 RH70) at top of casing:* N 6366339.72 E 1546608.49 Z 27.14 (m.a.s.l.)
	Azimuth (0–360)/ Dip (0–90) 89.84 / –76.43
	Position KLX11A (RT90 RH70) at 992.29 m length: N 6366333.09 E 1546930.16 Z –910.99 (m.a.s.l.)
	Azimuth (0–360)/ Dip (0–90) 95.6 / –68.2

Technical data

Borehole KLX11A



Drilling reference point

Northing: 6366339.72 (m), RT90 2,5 gon V 0:-15

Easting: 1546608.49 (m), RT90 2,5 gon V 0:-15

Elevation: 27.14 (m), RHB 70

Drilling period

Drilling start date: 2005-11-24

Drilling stop date: 2006-03-02

Ver 2007-03-08

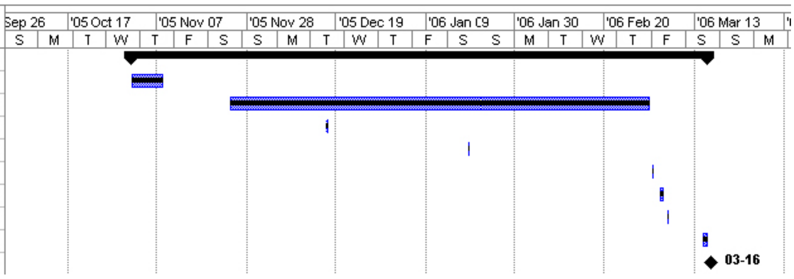
Figure 5-1. *Technical data for KLX11A. Minor modifications in the emplacement of the steel conical guide were made in June 2007, see also section 5.3.5.*

Table 5-2. Summary of core drilling progress and borehole measurements in KLX11A.

bh metres	Drilled length, pumping tests and water sampling	Airlift pumping with evaluation of drawdown and/or recovery	Deviation measurement	Miscellaneous
100	051126 Open hole pumping test 0–100.53 m. 13L/min at 16 m drawdown.		051107 Flexit 96 m Azimuth 85.8 Dip –73.0	
200	051205 Pumping test 101.59–209.02 m . 7.3 L/min at 10 m drawdown. Water sample.			
				051208. Fractured rock 265.75–266.15 m. Possibly loose rock in borehole wall.
300	051212 Pumping test 207.95–320.03 m. 9.0 L/min at 10 m drawdown. Water sample.			051210. Fractured rock 306.40–307.80 m.
400	051217 Pumping test 318.95–420.45 m. Water flow 0.2 L/min at 16 m drawdown. No water sample.	051216 Airlift pumping 12.05–420.29 m. No drillstem in borehole.		
500	060104 Pumping test 419.30–493.90 m. Water flow 0.4 L/min at 18 m drawdown. No water sample.		051221 Easy-shot at 490 m Azimuth 84.0 Dip –71.2.	
600	060114 Pumping test 492.85–604.90. Water flow 9.8 L/min at 15 m drawdown. Water sample.			
		060118 Airlift pumping 12.05–657.78 m. No drillstem in borehole.	060119 Easy-shot at 650 m Azimuth 85.2 Dip –70.9.	
700	060121 Pumping test 603.75–697.93 m. 0.2 L/min at 21 m drawdown. No water sample.			
			060125 Easy-shot at 750 m Azimuth 90.7 Dip –69.7.	
800	060130 Pumping test 695.37–802.67 m. 0.4 L/min at 19 m drawdown. No water sample.			
900	060208 Pumping test 802.00–907.90 m. 0.3 L/min at 20 m drawdown. No water sample.			
1000	060309 Pumping test 905.50–992.29 m. 0.2 L/min at 18 m drawdown. No water sample.	060306 Airlift pumping 12.05–992.29 m. No drillstem in borehole.	060316 Flexit at 981 m Azimuth 92.4 Dip –68.2.	060302 The borehole wall was mechanically rinsed with a rotating brush and with the drill bit from 992.01 m to 992.29 m. 060302 KLX11A completed at length 992.29 m.

Table 5-3. Chronological summary of main drilling events in KLX11A.

ID	Aktivitet	Start
1	**First activity starts**	**Tue 05-11-01**
2	Percussion drilling	Tue 05-11-01
3	Core drilling	Thu 05-11-24
4	Recovery test	Fri 05-12-16
5	Recovery test	Wed 06-01-18
6	Recovery test	Thu 06-03-02
7	Length calibration marks	Sun 06-03-05
8	Recovery test	Mon 06-03-06
9	Maxibor measurement	Wed 06-03-15
10	Last activity ends	Thu 06-03-16



5.2 Drilling, measurements and results in the telescopic section 0–100.06 m

Drilling, reaming and casing grouting (gap injection) were made from November 1 to 8, 2005.

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 (0–100.06 metres) of KLX11A 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 9.60 metres length with NO-X 280 mm equipment. This gave a hole diameter of 343 mm and left a casing (321/310 mm diameter) to a length of 9.60 m.
- Inner supportive casing for guidance for the drill string was mounted.
- A pilot percussion hole was drilled to a depth of 100.06 metres. The starting diameter of the drill bit was 160.7 mm and the diameter at full length was 160.1 mm.
- Reaming to diameter 248.0 mm was done from 9.20 to 12.05 m
- Stainless casing of 208×4 mm was installed from 0 to 12.05 m.
- Gap injection with low alkali cement based concrete (420 litres) was made for both sets of casing.
- After the concrete had hardened, the hole was reamed from 12.05 to 99.96 m. The reaming diameter at 12.05 m was 195.7 mm and the diameter at full length was 195.0 mm. The borehole was rinsed and flushed to remove concrete and water. No test of the tightness of the concrete seal (gap injection) was made, see section 5.9.
- Deviation measurement was made with Flexit to 96 metres length.

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.

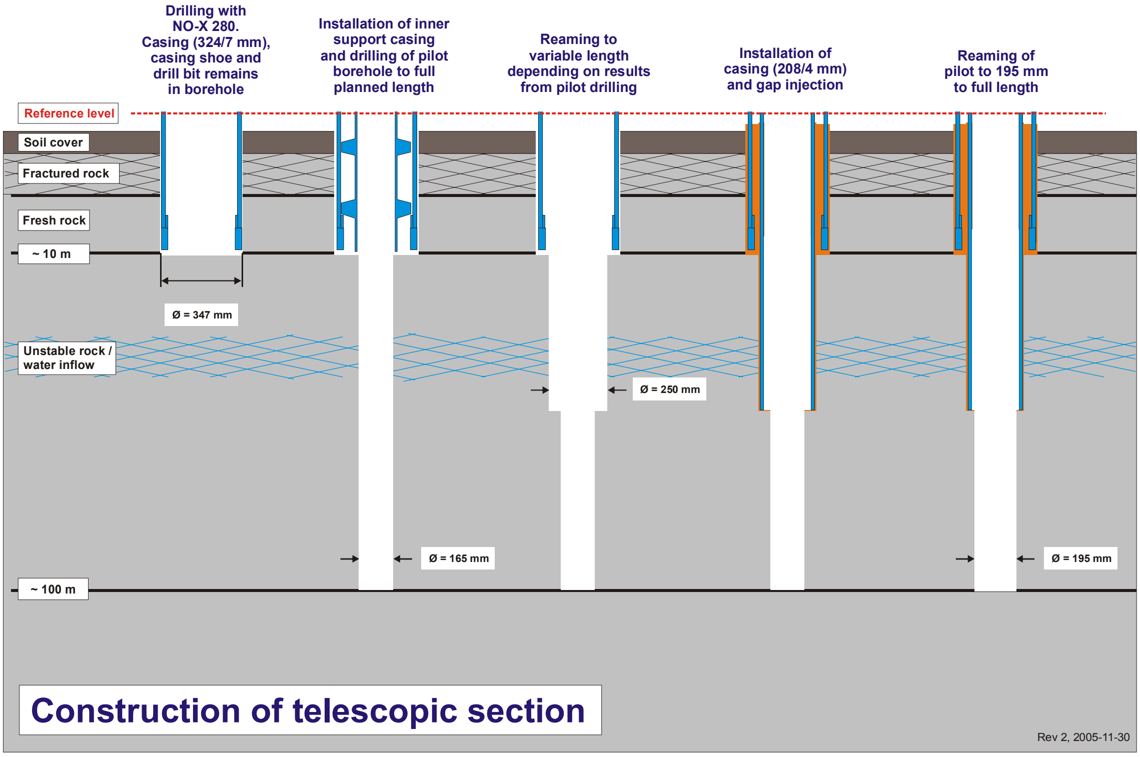


Figure 5-2. *Construction of the telescopic section. The grouting cement is introduced between the casing and the rock wall. The drill bit acts as a barrier so that cement does not enter the pilot hole.*

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 0.7 m i.e. drilling was performed through the concrete pad, gravel fill and then directly in bedrock. No natural soil was encountered. The distance from top-of-casing to the concrete pad is 15 cm, see also Figure 5-1.

Hydrogeological observations during percussion drilling

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

5.2.4 Hydrogeological and hydrochemical measurements and results in the telescopic section 12.05–100.53 m.

In section 12.05–100.53 m a pumping test was conducted, for results see Table 5-4. Pumping, with a flow of approximately 13 L/min, for nearly nine hours, caused 16 m drawdown.

The test was made on November 26–27 after reaming of the telescopic section and after T-86 mm core drilling to 100.53 m. The pumping curve is shown in Figure 5-4. The pumping test was evaluated with steady-state assumption in accordance with /2/.

Hydraulic responses

Pressure loggers were installed in the surrounding boreholes HLX28, HLX32 and HLX36 in order to see if any hydraulic response could be noted from the activities in KLX11A. The location of the boreholes is given in Figure 5-16. No hydraulic responses from air-lifting during the percussion drilling or the pumping in KLX11A could be seen in any of the observation boreholes.

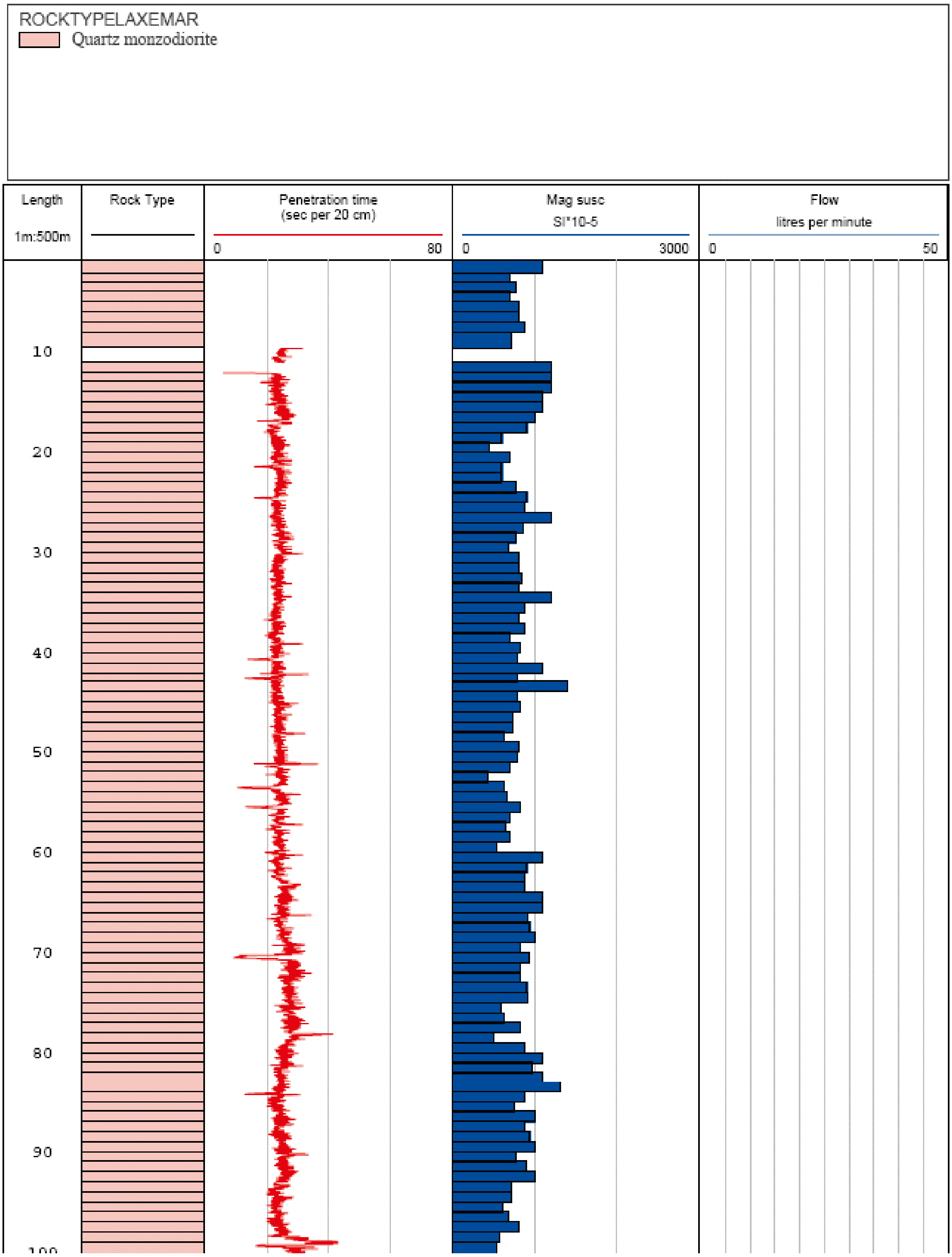


***Figure 5-3.** Preliminary geological results based on logging of drill cuttings and penetration rate from percussion drilling of KLX11A. A sample of the drill cuttings is missing between 9.6 and 11 metres ie in conjunction with the end of the casing. The drill penetration rate was not logged between 11.04–12.04 metres.*

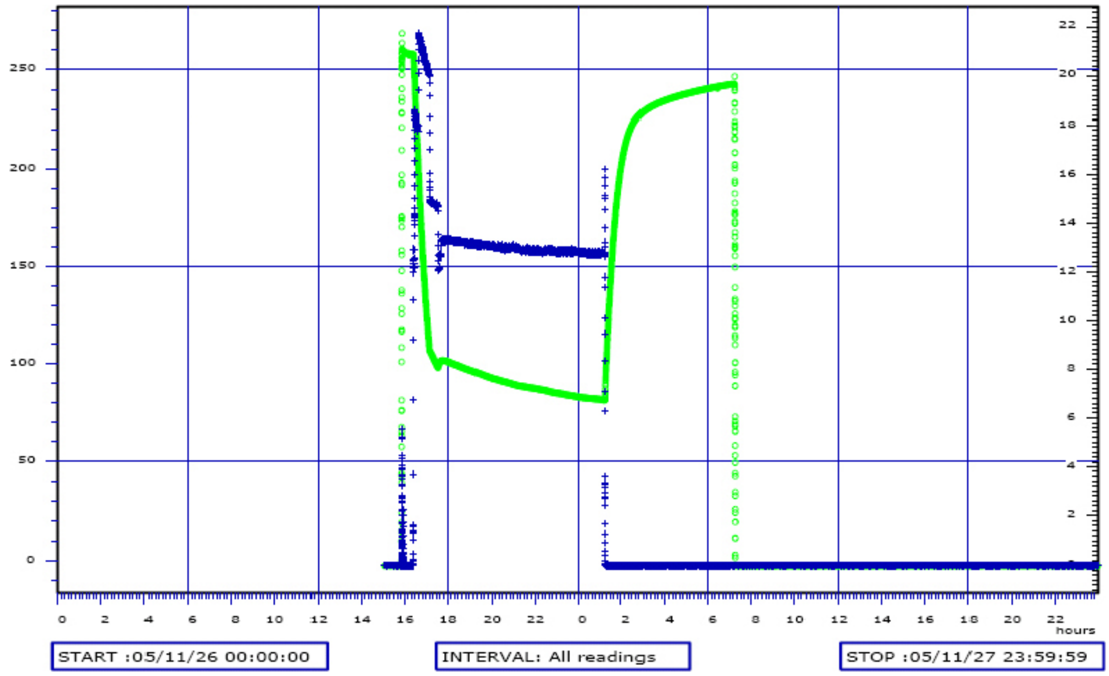


Figure 5-4. *Pumping and interference test November 26–27, 2005 in the telescopic section of KLX11A. The drawdown (green) is given in pressure unit (kPa) uncorrected for ambient air pressure. The flow rate (blue) is given in litres per minute on the right hand scale.*

Table 5-4. Pumping test 12.05–100.53 m in KLX11A.

Tested section [m]	Flow rate [L/min]	Drawdown [m]	Q/s [m²/s]	T_M [m²/s]
12.05–100.53	12.8	18	$1.2 \cdot 10^{-5}$	$1.3 \cdot 10^{-5}$

Hydrochemistry

One water sample was collected in the telescopic section in KLX11A. Sampling and analysis of sample 10652 were performed according to SKB class 3, see Table 5-5.

Selected results are reported in Table 5-6 and a complete account is given in Appendix 2.

Water from sample 10652 is archived in a freezer at the Äspö laboratory.

Table 5-5. Sample dates and length during percussion drilling in KLX11A.

SKB number	Date	Test section, length (m)	SKB chemistry class
10652	2005-11-26	12.05–100.53	3*

* Due to its long reporting time, the parameter "pmC" (percent modern carbon), is not reported in Appendix 2. The result will be reported to SICADA as soon as it is delivered

Table 5-6. Selected analytical results from sample 10652.

SKB number	pH	Conductivity (mS/m)	Chloride (mg/l)
10652	7.94	33.9	10.2

5.3 Core drilling KLX11A 100.06–992.29 m

Core drilling in KLX11A was conducted between November 24 and March 2, 2006.

The main work in KLX11A 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 bore 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 November 18, 2005 and consisted of installation of air-lift pumping equipment and supportive casing for alignment of the core drill rods, see Figure 5-5.

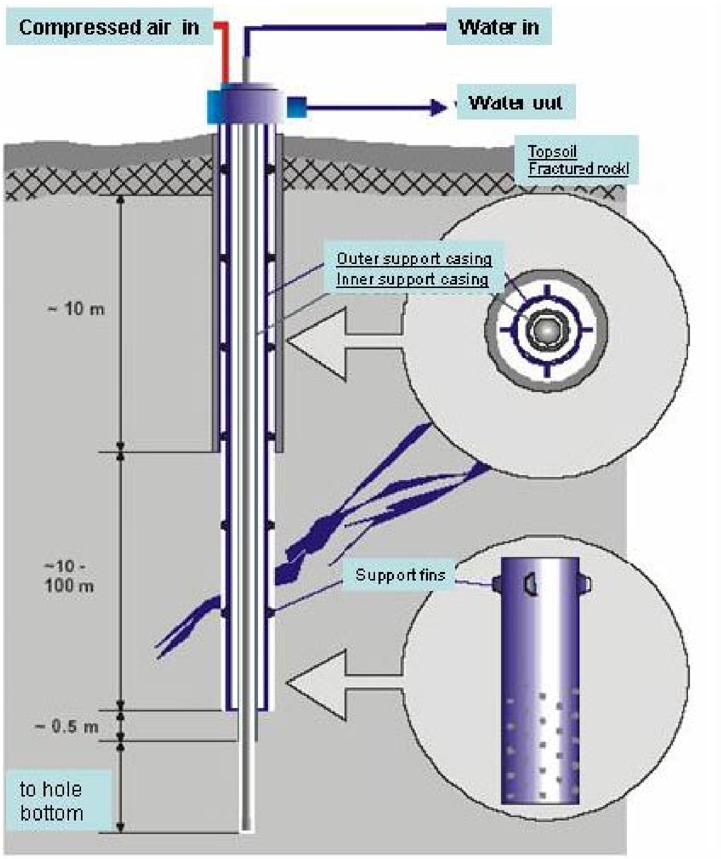


***Figure 5-5.** In the telescopic part of the drill hole a temporary installation is made with casing tubes for support and alignment and equipment for air-lift pumping. In the uppermost part the return water discharge header is mounted. The water discharge is led to the settling containers.*

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 on November 24 between 99.96 and 100.53 m with T-86 equipment. An inner supportive casing with diameter 84/77 mm was installed to 100.53 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.

5.3.2 Flushing and return water handling

The flushing water source was percussion borehole HLX28. The location 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 uranine tracer. 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 KLX11A is shown in Figure 5-6. A further account on flushing and return water handling is given section 5.5.

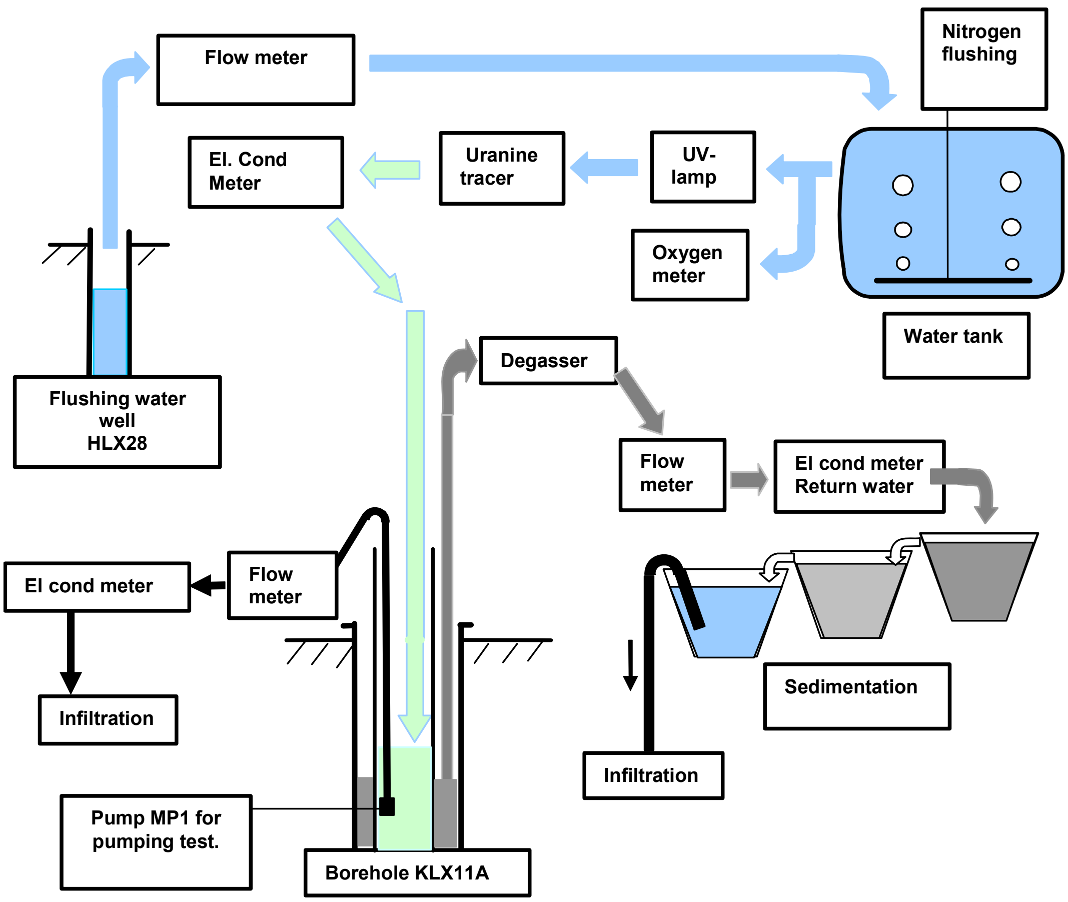


Figure 5-6. The flushing and return water handling and the emplacement of related monitoring equipment in KLX11A.

The targeted content for uranine in the flushing water was 0.20 mg/L and the actual average uranine content was 0.232 mg/L, see also Figure 5-10 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 and deviation measurements KLX11A

Core drilling with N-size (76 mm) triple-tube, wireline equipment was conducted from 100.53 m to the final length of 992.29 m in KLX11A.

The core diameters and intervals for drilling dimensions are given in Table 5-7.

Measurements of borehole deviation are made for two purposes:

- Monitoring of drilling progress, typically every hundred metres of drilled length.
- Measurements at full drilled length for final calculation of borehole deviation.

The core drilling progress was routinely followed by deviation measurements with the Easy-Shot method, normally with 100 metre intervals. The results from these measurements are not stored in the Sicada database but are given in a summary fashion in Table 5-2.

Four individual deviation measurements were done for the final evaluation of the borehole deviation. The Maxibor instrument was run up and down the borehole between 0 and 990 metres. The Flexit tool was run both up and down the borehole between 0 and 981 metres. In KLX11A the final deviation file is calculated based on measurements given in Table 5-8 together with the surveyed bearing and inclination of the top-of-casing. Further comment on how the calculations are made is given in /3/.

Table 5-7. Core diameters, borehole diameters and drilling dimensions during core drilling.

Core diameter (mm)	Borehole diameter (mm)	Interval (m)	Drilling dimension	Comment
72.0	86	99.96–101.53*	T-86	
50.2	76	101.53*–996.96	N	

* Reamed from 100.53 to 101.53 m after core drilling to full drilled length, see also section 5.3.4."Borehole completion".

Table 5-8. Measurements used for borehole deviation calculation in KLX11A.

Deviation measurement method	Used for calculation of bearing/ inclination	Interval from (m)	Interval to (m)	Sicada database activity ID
Flexit	Bearing	117	981	13120652
Flexit	Bearing	117	981	13140780
Flexit	Inclination	3	981	13120652
Flexit	Inclination	3	981	13140780
Maxibor	Bearing	117	981	13134828
Maxibor	Bearing	117	981	13140779

Horizontal and vertical plots of the results of the calculated deviation covering the entire length of borehole KLX11A are given in Appendix 4.

Core losses were noted in the Boremap mapping (see section 5.6) at the intervals given in Table 5-9.

A total of thirteen drill bits were used for KLX11A, see Figure 5-7.

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. The drilling progress over time is shown in section 5.5, see Figure 5-18.

5.3.4 Borehole wall risk assessment and completion

Borehole wall risk assessment

A borehole wall assessment was prepared on March 16, 2006, SKB id no 1051906, SKB internal document. The overall assessment was that the borehole wall was stable and the risk for rock fall-out was low.

Based on the results from dummy probing and evaluation of the drill core a decision was taken to rinse certain problematic section mechanically, see Table 5-10. The flush and brush tool is shown in Figure 5-8.

Table 5-9. Core losses noted in KLX11A.

From (m)	To (m)	Length (m)	comment
419.01	419.05	0.04	Missing core piece
419.95	420.08	0.13	Missing core piece
504.76	504.82	0.06	Mechanical
510.71	510.86	0.15	Missing core piece

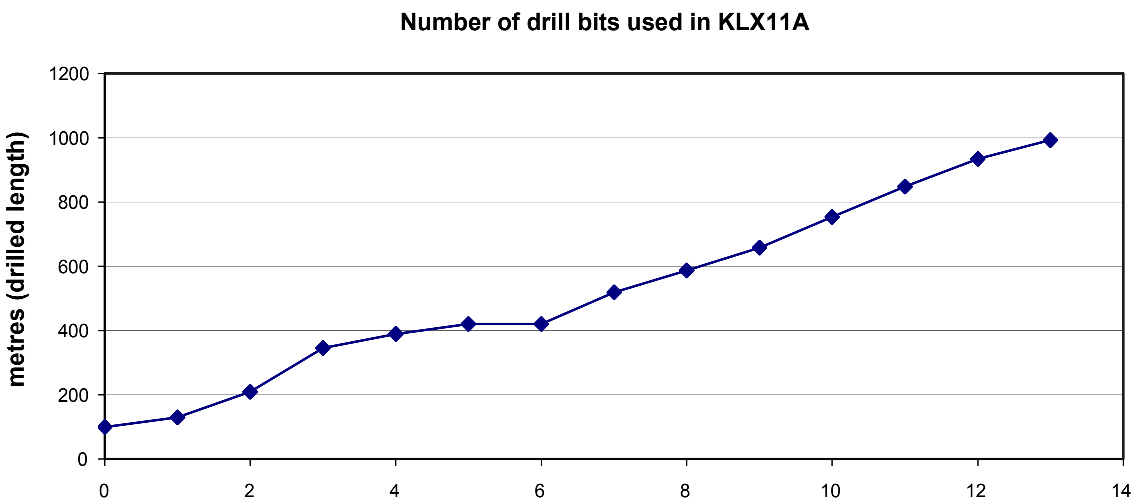


Figure 5-7. *Use of drill bits during core drilling in KLX11A.*

Table 5-10. Borehole section that were mechanically rinsed by water flushing and rotating steel brush.

From (bh length m)	To (bh length m)
118.5	119.5
142	143
168.5	170
248	249
250	252
262	268
306	308
345	347
417	419
447.5	449
481	482
497	498
502	511
525	526
532.5	534.5
579.5	581
582	583.5
853	855

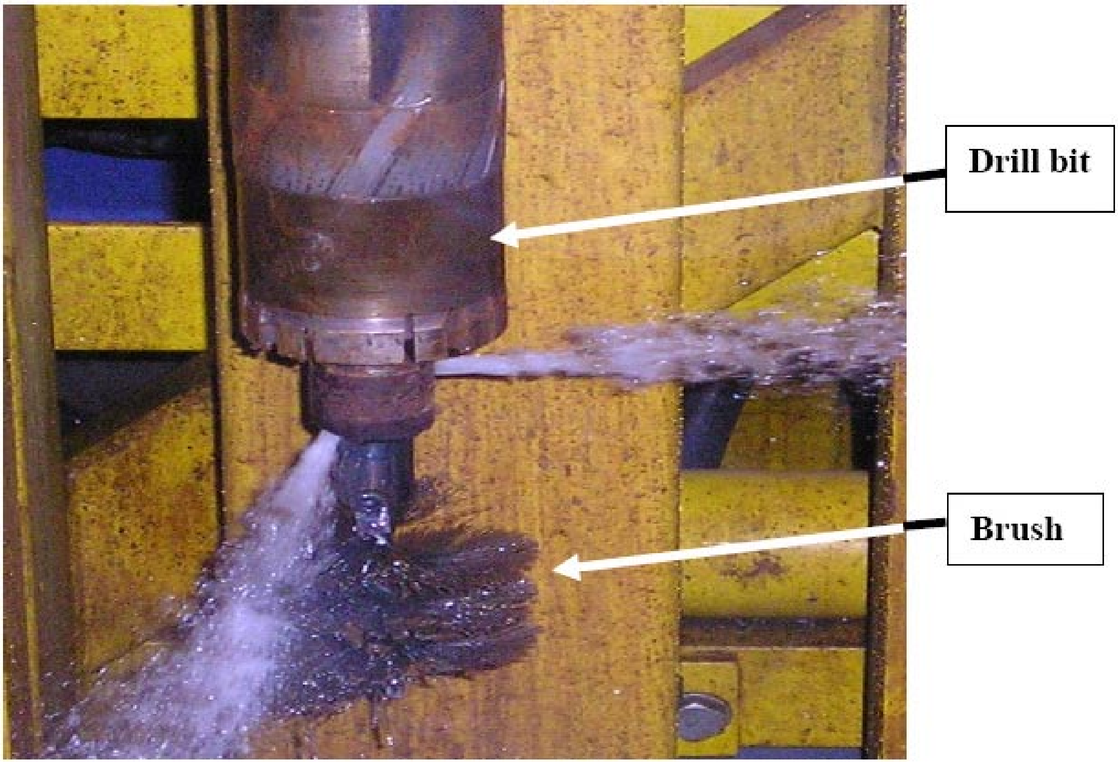


Figure 5-8. *The water flushing and rotating steel brush tool. The tool is lowered into the drill stem and can be seen in place just below the drill bit. During operation the drill string is moved up and down to remove loose rock fragments from the borehole wall.*

Borehole completion

Reaming of depth reference slots was done at the drilled lengths shown in Table 5-11. 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.

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

The borehole was reamed from 100.53 to 101.53 with T-86 equipment. A steel conical guide was installed in KLX11A between 96.08 m and 100.85 m. The conical guide tapers from an outer diameter of 195 mm to an inner diameter of 77 mm, see Figure 5-1.

The length of the holes was rinsed by flushing with nitrogen gas on November 13, 2005, see Table 5-12.

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.

5.3.5 Rescue operation, June 2007, and change of position of the steel conical guide

A hydrogeological measurement tool (the SWIW equipment) got stuck in the borehole on 2007-05-14.

A rescue operation was performed between 2007-05-14 and 2007-06-06 which resulted in the successful removal of the measurement tool. The position of the steel conical guide was changed and the new emplacement is shown in Figure 5-9.

Table 5-11. Depth reference slots (m) in KLX11A.

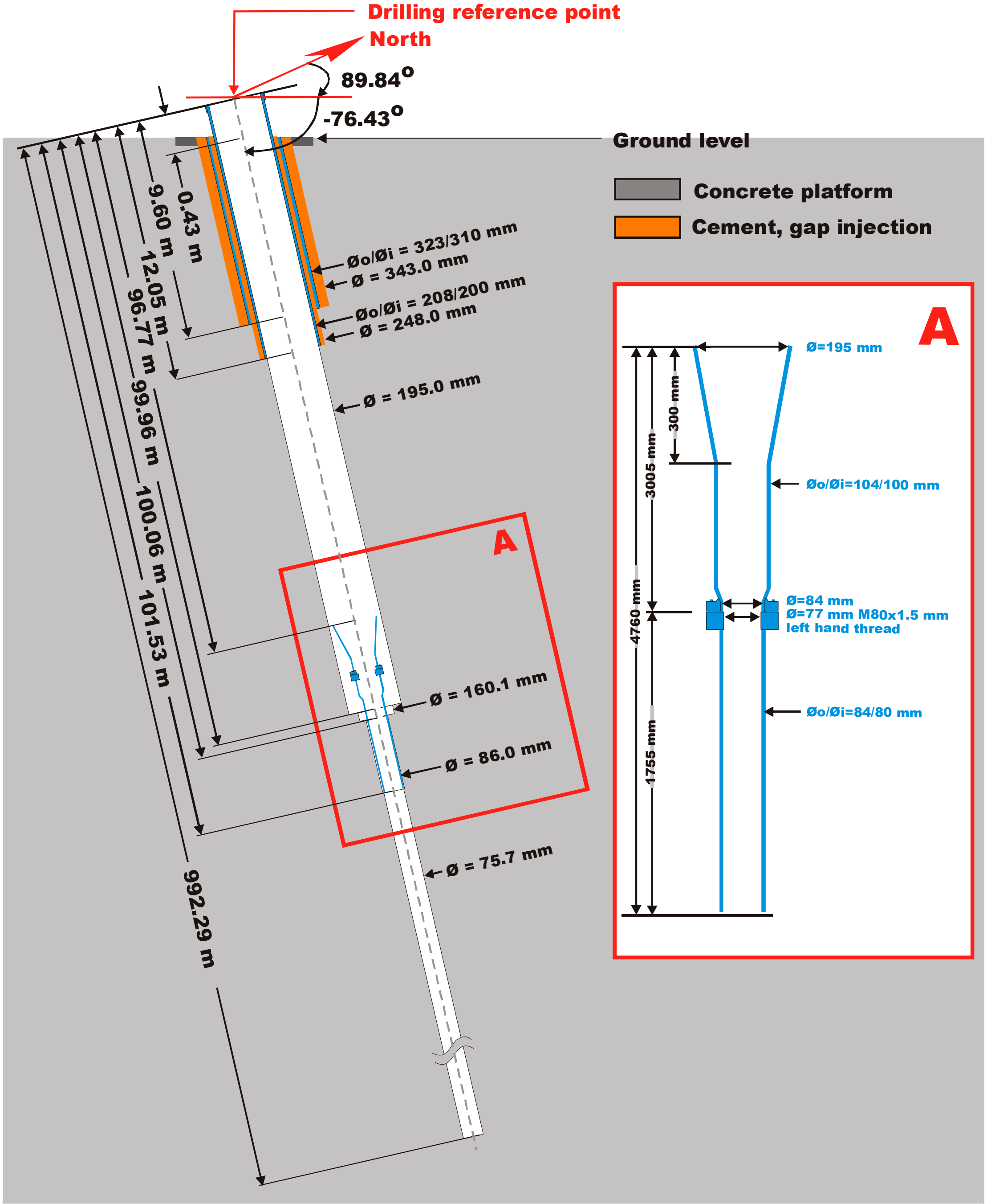
110.00	600.00
150.00	650.00
200.00	700.00
250.00	750.00
300.00	800.00
350.00	850.00
400.00	900.00
450.00	944.00
500.00	974.00
550.00	

Table 5-12. Dates for nitrogen gas flushing in KLX11A.

Date	Time
060321	15.51
060322	07.07
060322	8.47
060322	14.10
060322	15.34
060322	16.31

Technical data

Borehole KLX11A



Drilling reference point

Northing: 6366339.72 (m), RT90 2,5 gon V 0:-15
Easting: 1546608.49 (m), RT90 2,5 gon V 0:-15
Elevation: 27.14 (m), RHB 70

Drilling period

Drilling start date: 2005-11-24
Drilling stop date: 2006-03-02

Ver 2007-06-07

Figure 5-9. *Technical data for KLX11A after the change of position of the steel conical guide in June 2007.*

5.4 Hydrogeological and hydrochemical measurements and results 100.06–992.29 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 consisted of:

- Nine pumping tests conducted at various intervals, see section 5.4.1.
- Four water samples taken, see section 5.4.2.

Analytical results from sampling of flushing and return water are given in section 5.4.2.

Three 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 KLX11A are commented in section 5.4.4.

5.4.1 Hydrogeological results from wireline measurements

Results from the wireline tests in KLX11A are presented in Table 5-13 and Figure 5-10.

The pumping tests were evaluated with steady-state assumption in accordance with /2/. 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 twelve tests were performed in KLX11A, and nine achieved sufficiently stable conditions for calculating pseudo steady-state transmissivity and hydraulic conductivity. In some tests (603.75–697.93 m, 695.37–802.67 m, 802.00–907.90 m, 905.50–992.29 m), the measured flow was very low (<0.2 L/min). Despite the low flow, pseudo steady-state was reached.

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

Table 5-13. Pumping tests with wireline probe in KLX11A.

Tested section [m]	Q/s [m²/s]	TM [m²/s]	Comments
101.59–209.02	$2.4\cdot10^{-5}$	$2.8\cdot10^{-5}$	Pressure in casing is affected of previous disturbances in the borehole, not affected by pumping in tested section.
207.95–320.03	$8.9\cdot10^{-6}$	$1.2\cdot10^{-5}$	Pressure in casing affected of previous disturbances in the borehole, not affected by pumping in tested section.
318.95–420.45	$8.4\cdot10^{-8}$	$1.1\cdot10^{-7}$	Pressure in casing in transient recovery phase, unaffected by pumping test.
			Low, but stable flow. Good data, pseudo steady state.
419.30–493.90	$2.7\cdot10^{-7}$	$3.4\cdot10^{-7}$	Uncertain T-value since evaluation was done with variable flow i.e. the pseudo-steady state assumption was not fulfilled.
			Pressure in casing in transient recovery phase, unaffected by pumping test.
492.85–604.90	$1.6\cdot10^{-5}$	$2.1\cdot10^{-5}$	Pseudo steady state, good data.
603.75–697.93	$9.5\cdot10^{-8}$	$1.2\cdot10^{-7}$	Low flow but good data, pseudo steady state.
695.37–802.67	$1.4\cdot10^{-7}$	$1.8\cdot10^{-7}$	Low flow but good data, pseudo steady state.
802.00–907.90	$6.2\cdot10^{-8}$	$8.2\cdot10^{-8}$	Low flow but good data, pseudo steady state.
905.50–992.29	$8.8\cdot10^{-8}$	$1.1\cdot10^{-7}$	Low flow but good data, pseudo steady state.

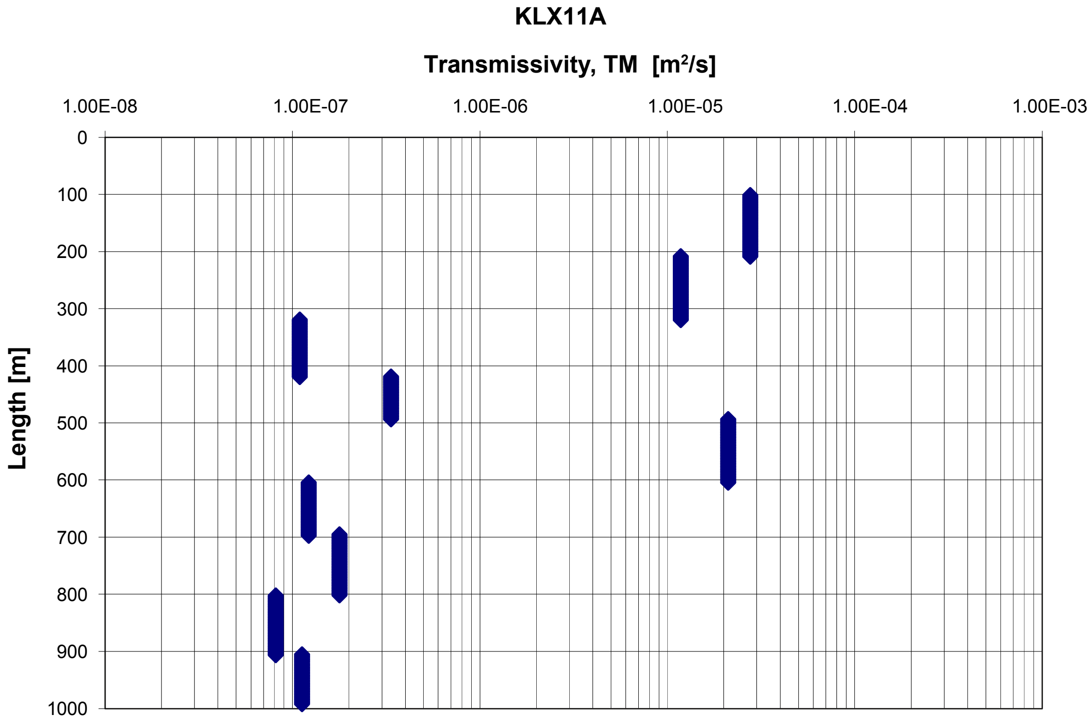


Figure 5-10. *Transmissivity from wireline pumping tests in KLX11A versus borehole length.*

The start and stop times for the interval used for evaluation of the pumping tests are given in Table 5-14.

After packer inflation the pressure stabilization phase often displays different types of transient effects, both of increasing and decreasing pressure. The reason for these transients is not known, though they might be attributable to previous disturbances in the borehole caused by the drilling operations, such as variations in pressure, salinity, and temperature.

5.4.2 Hydrochemistry

Four water samples were collected in connection with core drilling in KLX11A. Times and length intervals (test section) for the samples are given in Table 5-15.

Table 5-14. Evaluated test periods.

Tested section	Start (YYYY-MM-DD HH:MM)	Stop (YYYY-MM-DD HH:MM)
101.59–209.02	2005-12-05 17:03	2005-12-06 02:27
207.95–320.03	2005-12-11 16:16	2005-12-12 02:27
318.95–420.45	2005-12-17 16:11	2005-12-17 19:01
419.30–493.90	2006-01-04 15:41	2006-01-04 16:07
492.85–604.90	2006-01-14 16:23	2006-01-15 02:35
603.75–697.93	2006-01-21 15:24	2006-01-22 01:05
695.37–802.67	2006-01-29 16:05	2006-01-29 18:55
802.00–907.90	2006-02-08 16:35	2006-02-08 19:31
905.50–992.29	2006-03-09 16:41	2006-03-09 19:41

Table 5-15. Sample dates and lengths during core drilling in KLX11A.

Sample number	Date	Test section, length (m)	SKB chemistry class
10662	2005-12-06	101.59–209.02	3*
10669	2005-12-12	207.95–320.03	3 (not analysed for isotopes)
10764	2006-01-15	492.85–604.90	3*
10850	2006-02-24	905.50–992.01	3 (not analysed for isotopes)

* Due to its long reporting time, the parameter "pmC" (percent modern carbon), is not reported in Appendix 2. The result will be reported to SICADA as soon as it is delivered.

Sampling and analysis were performed according to the SKB classes specified in Table 5-15. The samples were collected at the drill site and were thereafter prepared and conserved at the Äspö laboratory as soon as possible. The samples were stored in a refrigerator until the drilling of the borehole was completed. At that time it was decided which samples should be sent to external laboratories for analyses.

All four samples were intended for analysis according to SKB chemistry class 3. Based on the analysis of drill water content a selection of the samples suited for further analysis was made. 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.

Samples 10669 and 10850 were not analysed for isotopes due to high drill water content. Sufficient amounts of water from these samples are stored, frozen or refrigerated, at the Äspö laboratory for possible future isotope analysis.

Sample 10764 was collected from possible repository depth and it was therefore decided to analyse this sample for isotopes despite its relatively high drill water content.

Archive samples (which are stored frozen at the Äspö laboratory) have been collected for all class 3 samples in Table 5-15.

Selected analytical results from KLX11A and the water source, HLX28, are given in Table 5-16. A complete record of analytical results is given in Appendix 2.

The percussion drilled borehole HLX28 was used as water source during the drilling of KLX11A.

One water sample (10231) was taken from HLX28 prior to the drilling of KLX11A. This sample was not analysed for Total Organic Carbon (TOC). Therefore, another sample, 10605, was collected from HLX28 in connection with the drilling of KLX11A.

Table 5-16. Analytical results from water chemistry sampling.

Borehole	Sample no	Date	From (m)	To (m)	Drill water %	TOC (mg/L)	pH	Conductivity (mS/m)	Cl (mg/L)
KLX11A	10662	2005-12-06	101.59	209.02	3.45		8.58	42.1	11.3
KLX11A	10669	2005-12-12	207.95	320.03	32.3		8.79	89.4	124
KLX11A	10764	2006-01-15	492.85	604.90	32.9		8.48	295	820
KLX11A	10850	2006-02-24	905.50	992.01	39.2		8.54	51.4	30.7
HLX28	10231	2005-04-12	6.03	154.20			8.17	57.1	23.0
HLX28	10605	2005-11-09	6.03	154.20		5.7	8.07	103	29.4

The concentration of total organic carbon (TOC) in sample 10605 was 5.7 mg/L. This value was considered acceptable for the water in borehole HLX28 to be used as flushing water for the core drilling in KLX11A without further filtration measures to lower the organic carbon content.

Sample 10605 was not analysed for isotopes. Sufficient amounts of water from this sample are stored, frozen or refrigerated, at the Äspö laboratory for possible future isotope analysis.

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

Sampling for determination of microorganism content

Sixteen samples were taken in order to determine the microorganism content within the flushing water system. They were collected on two occasions (December 21, 2005 and January 11, 2006) in connection with the cleaning of the system. The samples were taken from three different locations within the flushing water system. The results are reported separately /4/.

Sampling for uranine tracer content and electrical conductivity

From KLX11A, a total of 129 samples for uranine content and electrical conductivity in flushing and returning water were taken along the borehole.

The results are shown graphically in Figure 5-11. All the samples were analysed for uranine content and electrical conductivity at the Äspö laboratory.

The calculated average uranine content for the whole borehole is 0.232 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 available at the time of sampling.

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

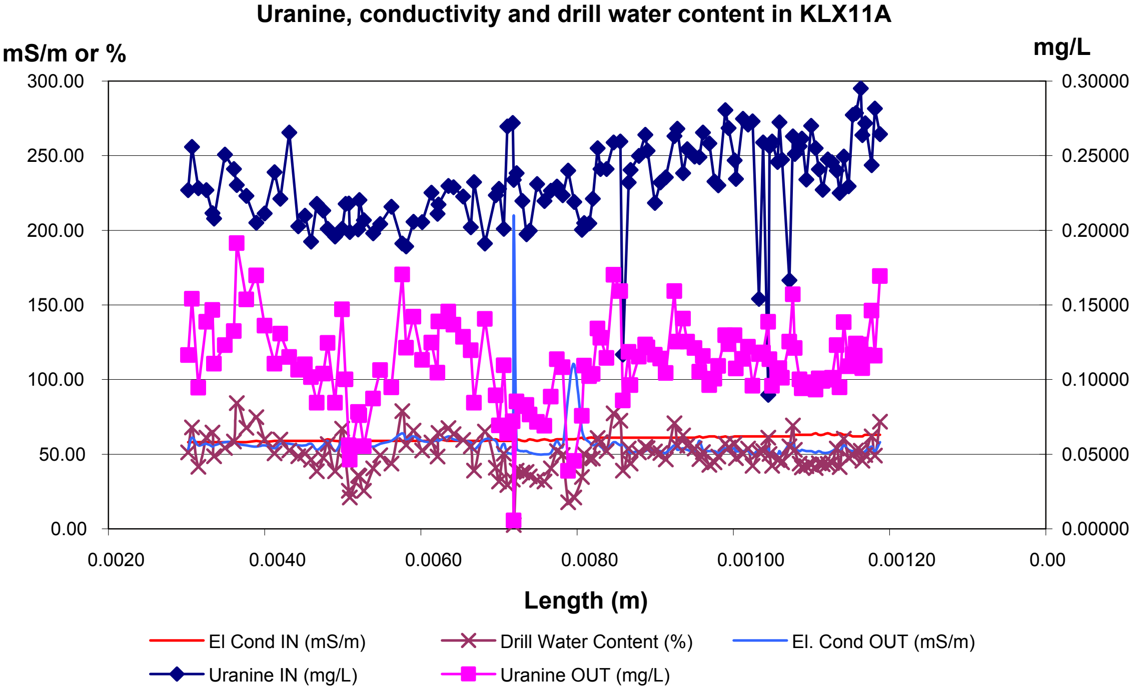


__Figure 5-11.__ The uranine concentration, electrical conductivity of flushing water (IN) and return water (OUT) and drill water percentage in KLX11A during drilling.

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

Two air-lift pumping tests were 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 /2/, as well as the specific capacity, *Q/s*. The results are shown in Table 5-17, and stored in the SICADA database as "recovery tests" (code HY050). The length of 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 5-12, 5-13, and 5-14. It should be emphasized that Figures 5-12 and 5-13 show a full day of drilling.

Table 5-17. Results from air-lift pumping in KLX11A.

Tested section [m]	Flow rate [L/min]	Drawdown [m]	Q/s [m²/s]	TM [m²/s]	Comments
12.05–420.29	41.3	50.5	1.4·10–5	2.1·10–5	Initial pressure is higher than static water level. If static water level is used, but with the same flow, TM = 2.8·10^{-05} m²/s. Q derives from accumulated volumes of water in and out. Q = ΣV/dt 16:00–17:20
12.05–657.78	55.0	26.5	3.5·10–5	5.5·10–5	Q derives from accumulated volumes of water in and out, between 15:00–17:40.
12.05–992.01	49.0	20	4.1·10–5	6.8·10–5	Q derives from accumulated volumes of water in and out. Q = ΣV/dt between 14:59–16:43.

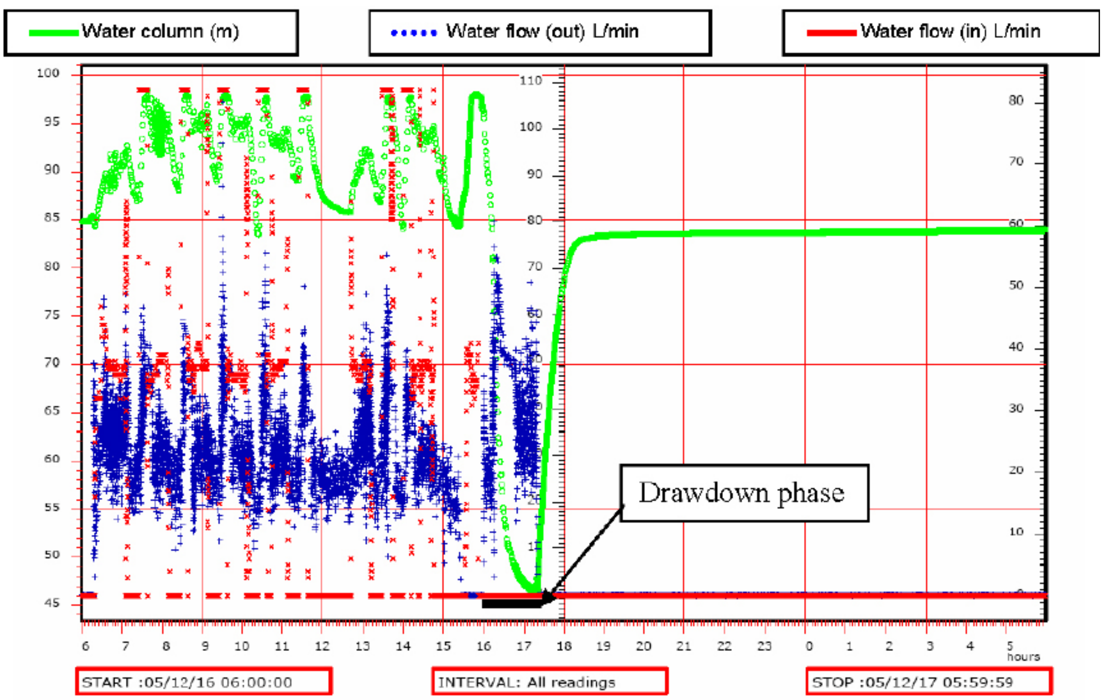


***Figure 5-12.** Air-lift pumping in KLX11A 12.05–420.29 m. The green line represents the height of the water column in the borehole, the out flow (ie pumped flow from air-lift pumping in the telescopic section) is shown as the blue dotted line and the inflow rate as the red line. The drawdown phase which includes the period for test evaluation is shown with a black bar.*

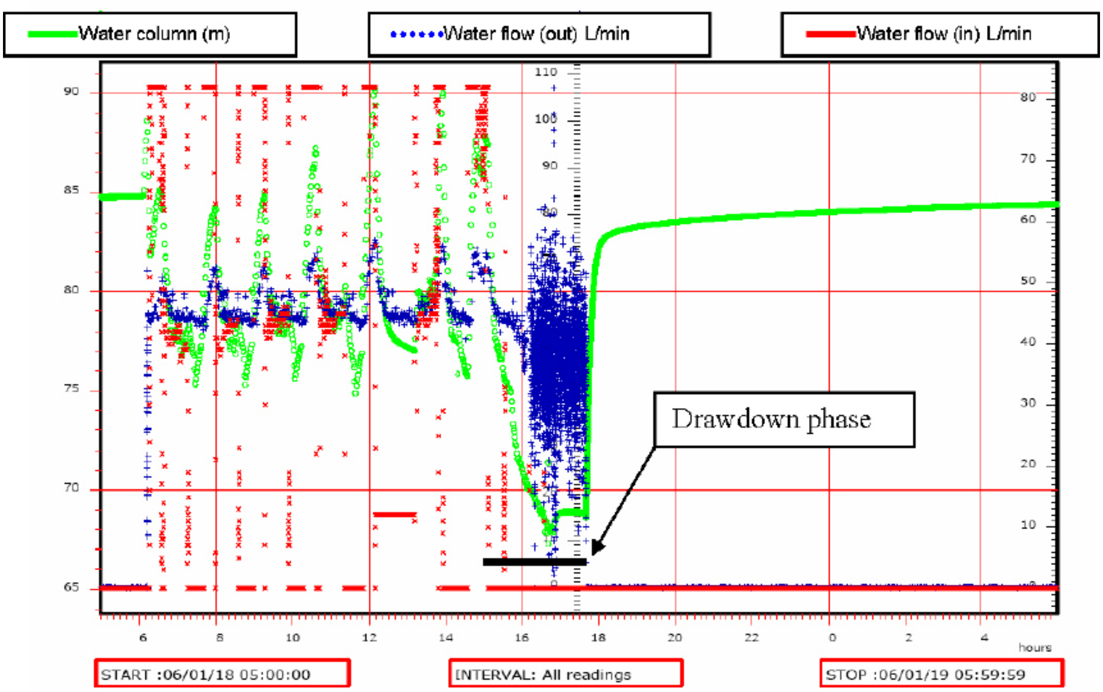


Figure 5-13. *Air-lift pumping in KLX11A 12.05–657.78 m. The green line represents the height of the water column in the borehole, the out flow (ie pumped flow from air-lift pumping in the telescopic section) is shown as the blue dotted line and the inflow rate as the red line. The drawdown phase which includes the period for test evaluation is shown with a black bar.*

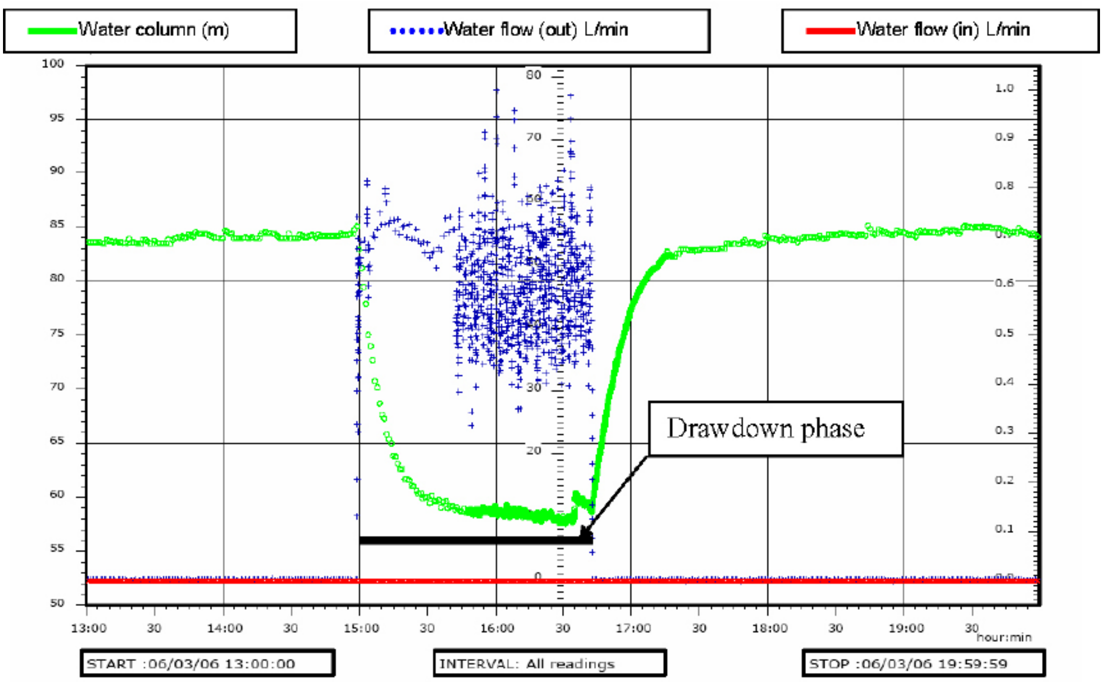


Figure 5-14. *Air-lift pumping in KLX11A 12.05–992.01 m. The green line represents the height of the water column in the borehole, the out flow (ie pumped flow from air-lift pumping in the telescopic section) is shown as the blue dotted line. The drawdown phase which includes the period for test evaluation is shown with a black bar.*

The air-lift pumping in the telescopic section starts in the morning and continues throughout most part of the day. Drilling is indicated by water being pumped into the borehole (flow in). Towards the end of the day drilling is stopped and the drill stem is removed from the borehole. The “flow in” is reduced to zero when drilling stops. Air-lift pumping in the telescopic section however continues for a period of 30 minutes to two hours after the core drilling has stopped. This constitutes the drawdown phase.

The times for the drawdown phases are given in Table 5-17 and shown graphically in Figures 5-12 through 5-14. Within a 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 activities in a borehole can be created by the drawdown from air-lift pumping, from flushing the borehole with nitrogen gas i.e. lifting by nitrogen gas and from other drilling related activities.

Hydraulic responses in near-by boreholes from air-lift pumping in KLX11A

No hydraulic response could be seen in observation boreholes HLX28, HLX32 and HLX36 from percussion drilling and related air-lift pumping of the telescopic section of KLX11A. No water table data is available from HLX37 during the period of percussion drilling in KLX11A, November 1 to 8, 2005. The location of the mentioned boreholes is given in Figure 5-17.

Hydraulic responses in near-by boreholes from nitrogen gas flushing in KLX11A

Nitrogen gas flushing covering the entire length of the borehole, was done six times during March 21 and 22, 2006, see Table 5-19.

No response from nitrogen gas flushing in KLX11A could be seen in KLX03, see Figure 5-15.

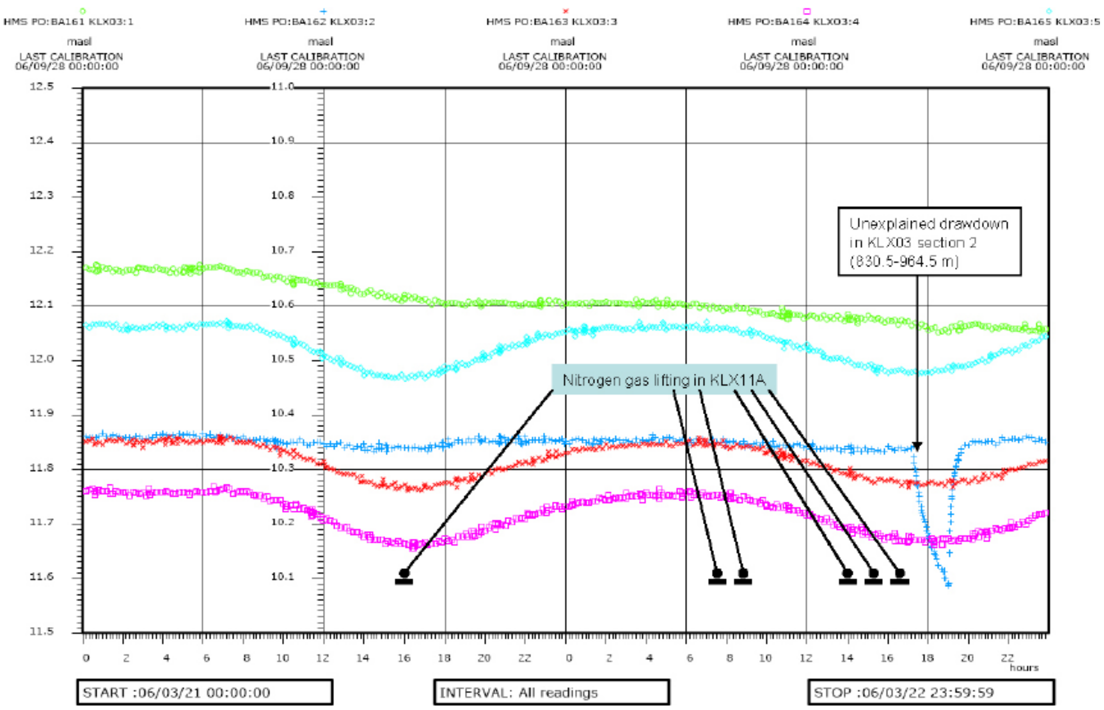


Figure 5-15. *Water tables from sections 1 through 5 in KLX03 during nitrogen gas flushing (gas lifting) in KLX11A. No hydraulic responses could be seen in any of the sections in KLX03.*

Percussion boreholes HLX28, HLX32, HLX36 and HLX37 were checked for possible hydraulic responses from nitrogen gas flushing in KLX11A, see Table 5-19.

No clear hydraulic responses could be seen in the percussion boreholes HLX28, HLX32 or HLX36 during the nitrogen gas flushing events on March 21 and 22. The water table in HLX28 was dominated by pumping i.e. recurring drawdowns and recoveries.

Very small scale drawdowns in HLX37 that coincide with the times for nitrogen gas lifting in KLX11A can be seen in Figure 5-16. The water table variations are of very small magnitude and any interpretation of hydraulic responses should be done with caution.

Table 5-19. Hydraulic responses from nitrogen gas flushing in KLX11A.

Borehole (section*)	Nitrogen flushing in KLX11A 060321 15:51	Nitrogen flushing in KLX11A 060322 07:07–16:31
HLX28	No	No
HLX32	No	No
HLX36	No	No
HLX37	No?	No?
KLX03 (1 through 10)	No	No

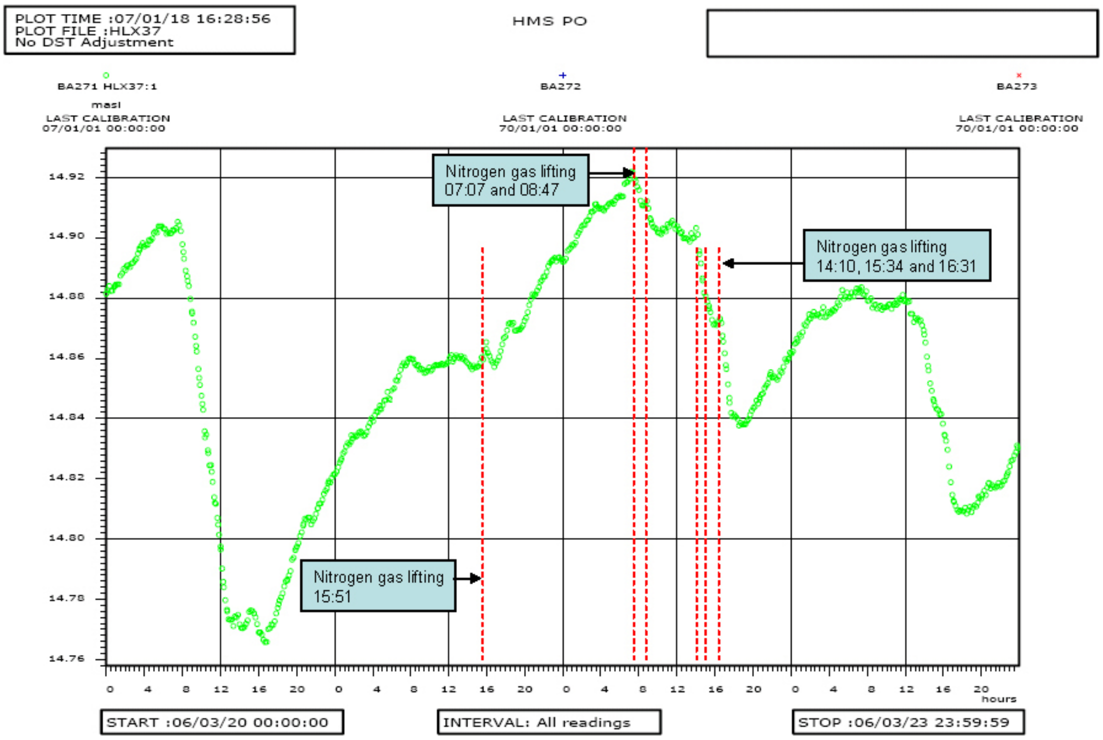


***Figure 5-16.** Groundwater levels in HLX37 during nitrogen gas flushing in KLX11A. No clear hydraulic response can be seen from nitrogen flushing, however small scale drawdowns of a few centimetres coinciding with the times for nitrogen flushing can be seen. It is nevertheless uncertain that the drawdowns are caused by the nitrogen flushing.*

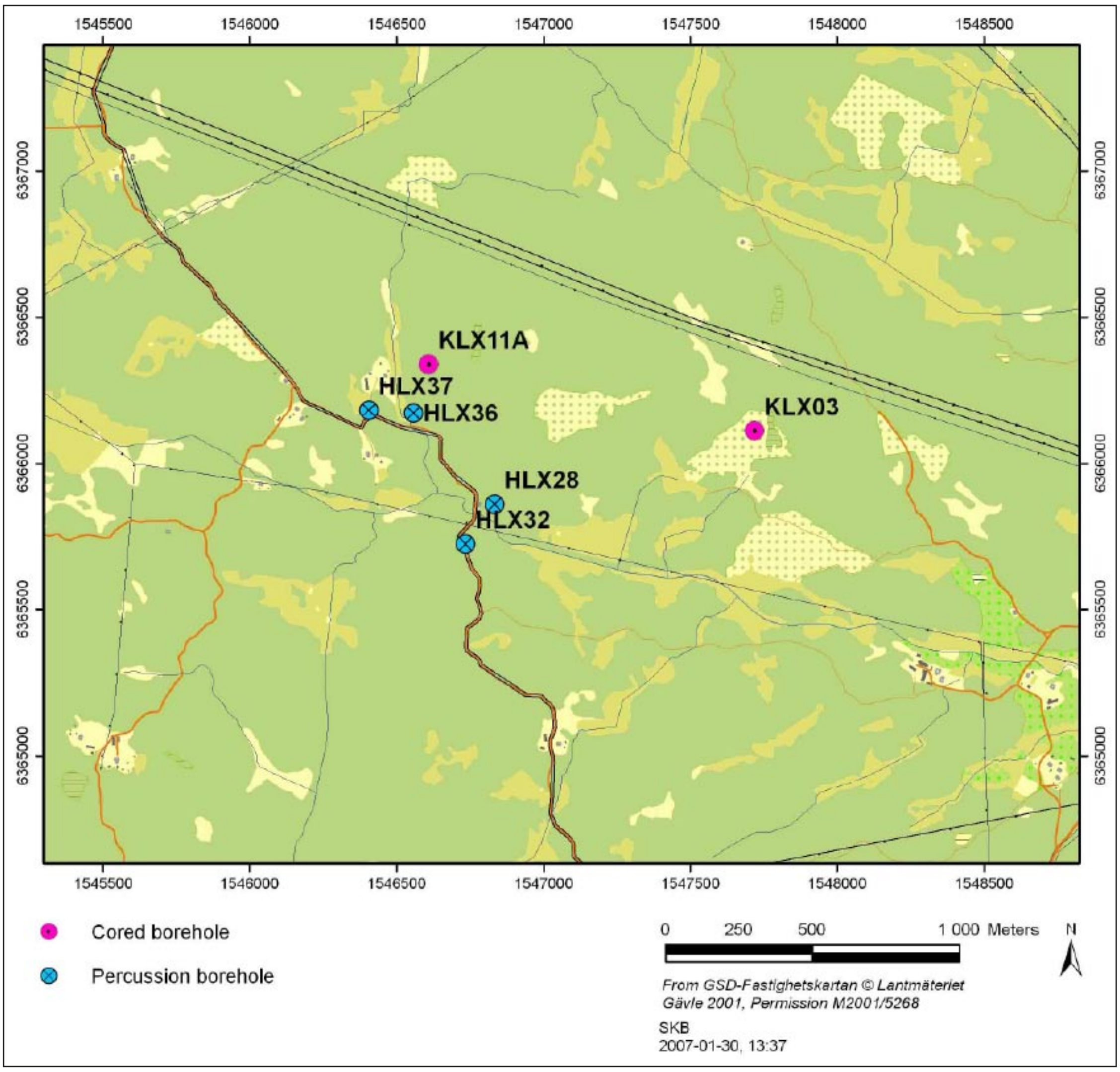


Figure 5-17. *Map showing the location of cored boreholes KLX11A and KLX03 and the percussion boreholes HLX28, 32, 36 and 37.*

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 0–100.06 metres and the core drilling section 100.06–992.29 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 5-18 through 5-20 below.

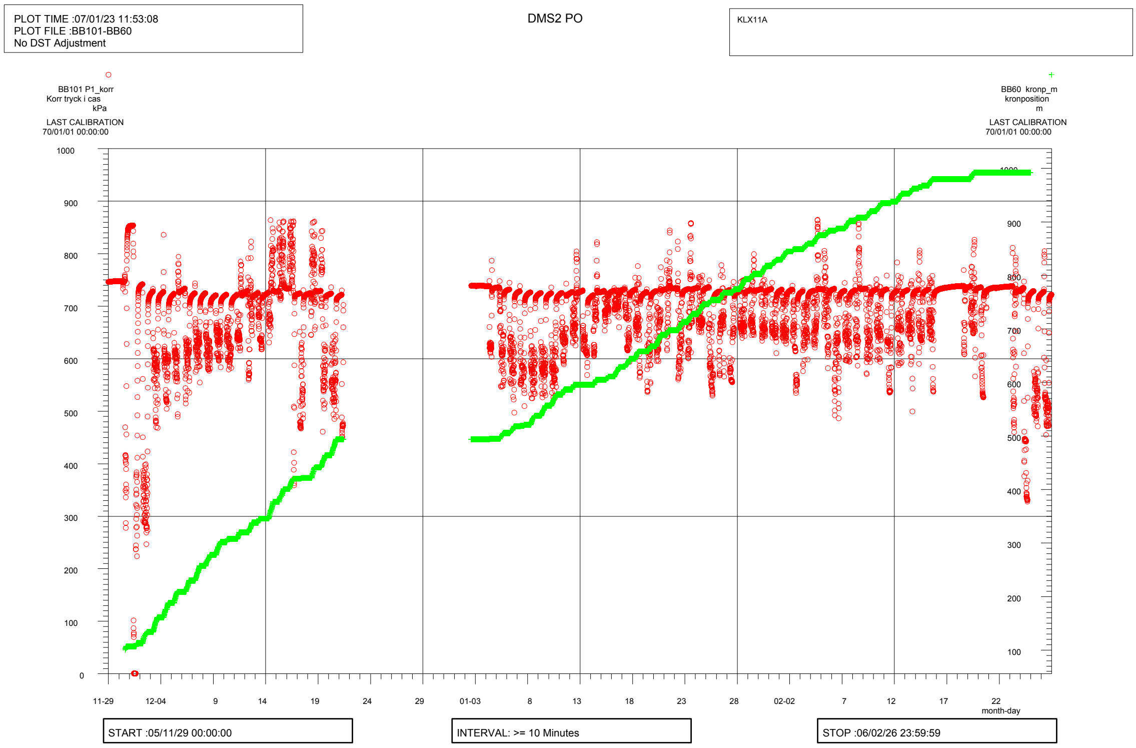


Figure 5-18. *Drill bit position (green) and water level from air-lift pumping (red). The water level is expressed as the pressure in kPa of the water column overlying the pressure gauge ie the ambient air-pressure has been subtracted. The pressure gauge is emplaced at 90 metres borehole length. The drill bit position is given in metres.*

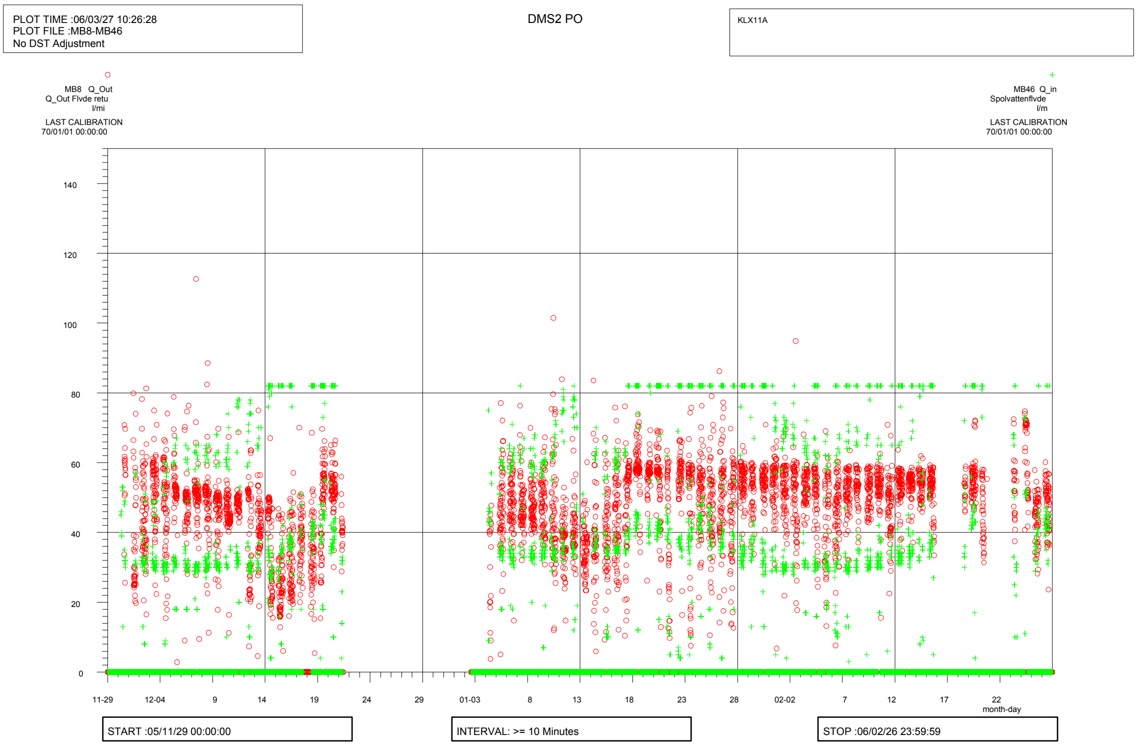


Figure 5-19. *Flushing water flow (green) and return water flow (red) in litres per minute.*

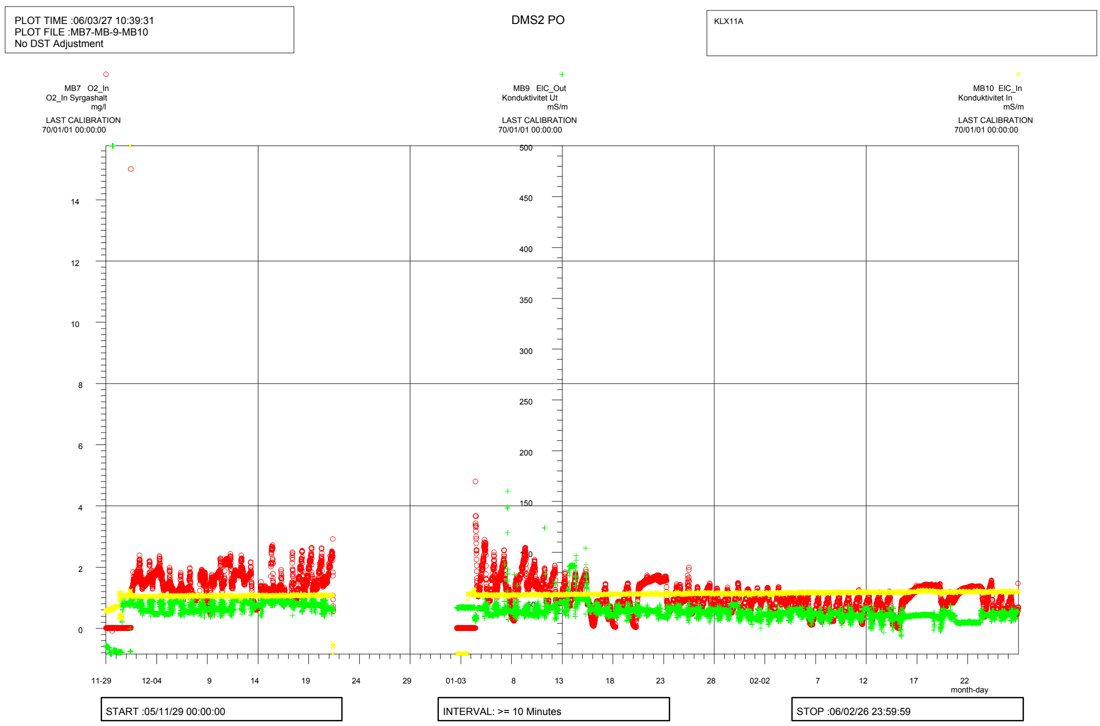


Figure 5-20. *Conductivity of flushing water (yellow) and return water (green). The oxygen content in mg/l of the flushing water (red) is also shown. The oxygen content of the flushing water was low and stable throughout the drilling period.*

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 5-18 through 5-20. Since DMS data are related to time (i.e. not strictly to borehole length) periods were drilling is not performed are also registered.

Figure 5-18 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 5-19 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 30–40 litres/minute corresponding to pumped flow during drilling.
- A flow of ca 80 litres/minute corresponding to the flow while pumping down the core barrel.
- No flow (zero litres/minute) when no drilling is performed.

Figure 5-20 shows the conductivity of the ingoing flushing water, conductivity of the return water and the oxygen content of the flushing water. The oxygen content was low throughout the drilling period.

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 5-21.

The amount of flushing water consumed during drilling was 1,040 m^3, giving an average consumption of ca 1.15 m^3 per metre drilled. The amount of effluent return water from drilling in KLX11A was 1,980 m^3, giving an average of ca 2.2 m^3 per metre drilled.

Drill cutting balance

The weight of cuttings in the settling containers amounted to 1,500 kg. The content of suspended material in the return water was not analysed in borehole KLX11A, however previous sampling has shown the content to be 400 mg/L /5/. The amount of material in suspension carried with the return water would amount to 790 kg. The theoretical amount that should be produced from drilling with 76 mm triple tubing over a length of 900 metres is 6,075 kg assuming a density of 2.7 kg/dm^3. This means that about 38% 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 5-20. The results show that 91% of the introduced uranine was retrieved during drilling of KLX11A.

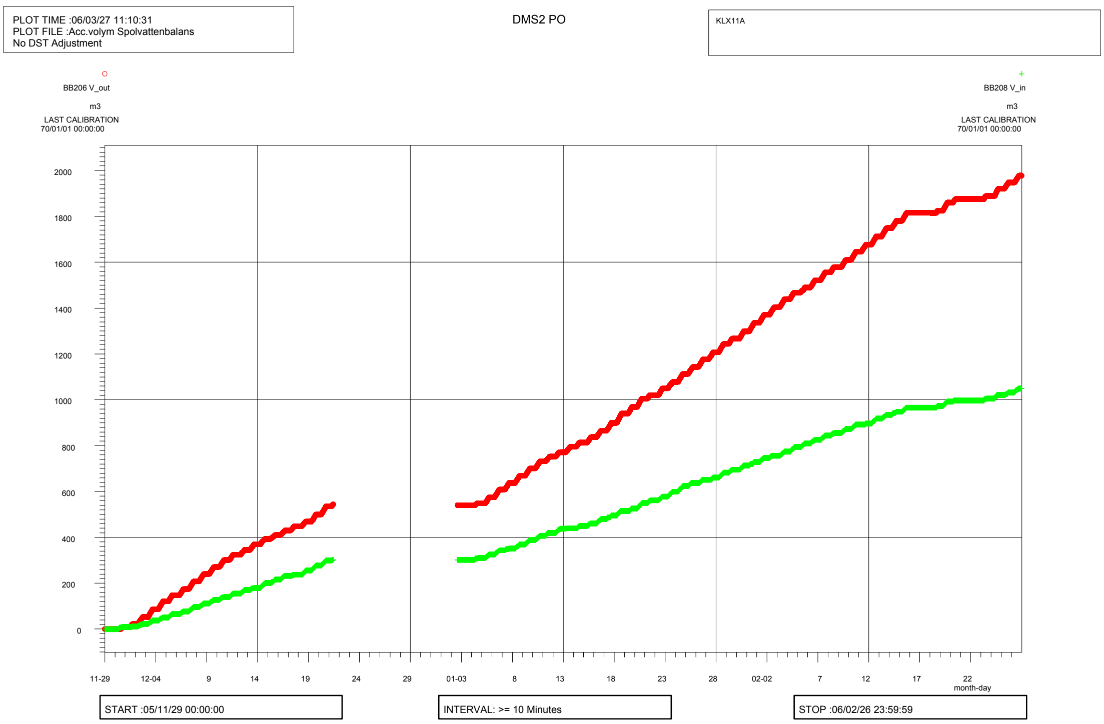


Figure 5-21. *Flushing water balance from KLX11A as recorded by the DMS system. The accumulated volume of the ingoing flushing water is shown in green and the outgoing return water is shown in red.*

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 /6/.

Lithologically the core is entirely dominated by Quart monzodiorite (97% of the core expressed as Boremap "Rock type"). Minor sections of fine-grained diorite-gabbro and pegmatite occur.

Red staining with medium intensity is primarily noted in two intervals; 250–260 m and 490–510 m. These two intervals also have an elevated fracture frequency. An increased fracture frequency is furthermore noted in two intervals; 580–590 m and 850–860 m.

Red staining with faint to weak intensity is present sporadically to ca 590 m. Alteration is very scarce below 590 m. 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 1.2 (fractures/metre). NB The fracture frequency given in Appendix 1 shows the total fracture frequency (i.e. open fractures, sealed fractures 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.

Table 5-20. Balance calculation of uranine tracer in KLX11A.

Average uranine content IN (mg/L)	0.232
Flushing water volume IN (m^3)	1,040
Amount uranine introduced (g)	241
Average uranine content OUT (mg/L)	0.111
Return water volume OUT (m^3)	1,980
Amount uranine recovered (g)	220

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 is shown in Figure 5-22. 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 effluent water, i.e. discharge to the ground, from the core drilling of KLX11A never exceeded the guideline value for electrical conductivity at 300 mS/m. Typically the conductivity of the emitted water was well below 100 mS/m, see Figures 5-11 and 5-20.

The uranine content was well below 0.3 mg/l, see Figure 5-11.

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 /5/.

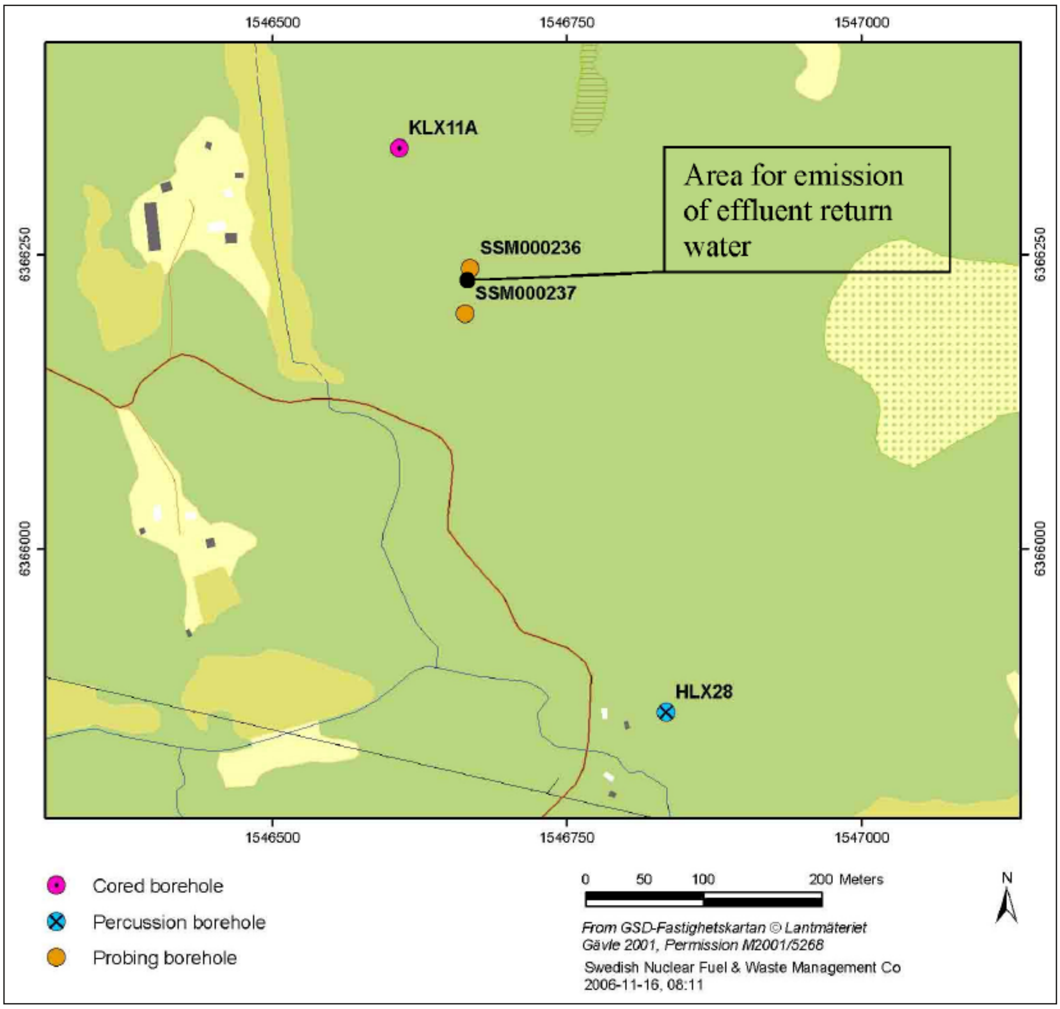


Figure 5-22. *Location of environmental monitoring wells SSM000236 and SSM000237 in relation to the core drill site for KLX11A and the flushing water well HLX28.*

To sum up the monitored parameters in the emitted water never exceeded the prescribed guideline values.

Drilling of environmental monitoring wells

Drilling of environmental monitoring wells SSM000236 and SSM000237 was done between October 31 and November 2, 2005. The technical data for the environmental wells are given in Appendix 6. The location of the environmental monitoring wells SSM000236 and SSM000237 is shown in Figure 5-22.

Reference sampling

A reference sample of surface soil from the drill site of KLX11A was taken on October 10, 2005. The SKB sample number is 9009.

Water samples for reference of the ground water in environmental monitoring well SSM000237 were taken according to Table 5-21.

Monitoring of soil ground water levels

A pressure logger (transducer) for measuring the ground water table was installed in SSM000237 during the core drilling of KLX11A. The water levels are given graphically in Figure 5-23.

Table 5-21. Reference water samples.

Monitoring well	Sample id number	Date
SSM000237	10607	2005-11-10

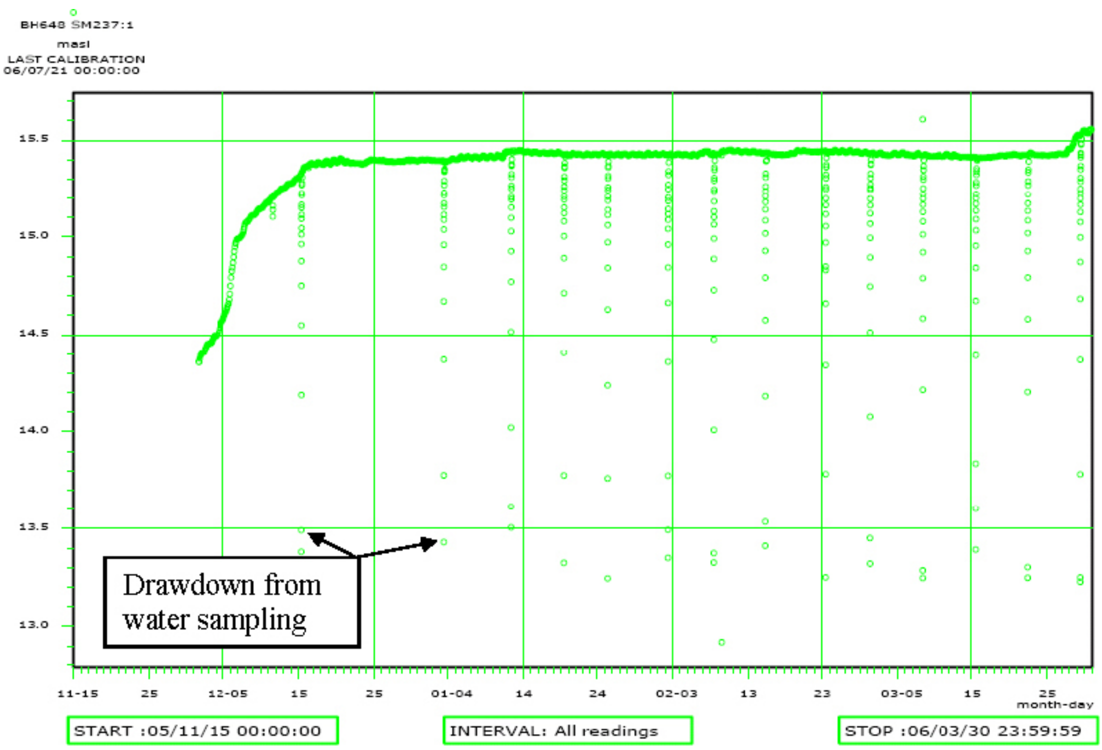


Figure 5-23. Ground water level in well SSM000237. The momentary drawdown curves with a more or less weekly interval are caused by water sampling in the monitoring well.

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 well SSM000237. The results show very steady values for pH and electrical conductivity, see Figure 5-24.

5.8.1 Consumption of oil and chemicals

No significant amounts of oils or lubricants were consumed during the drilling. The amount of hammer oil (Hydra 46) during the percussion drilling was 12 litres.

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 drillings and related testing show that the gap injections fulfil the requirements stated in the method description (SKB MD 620.003 v1.0, internal document) for core drilling.

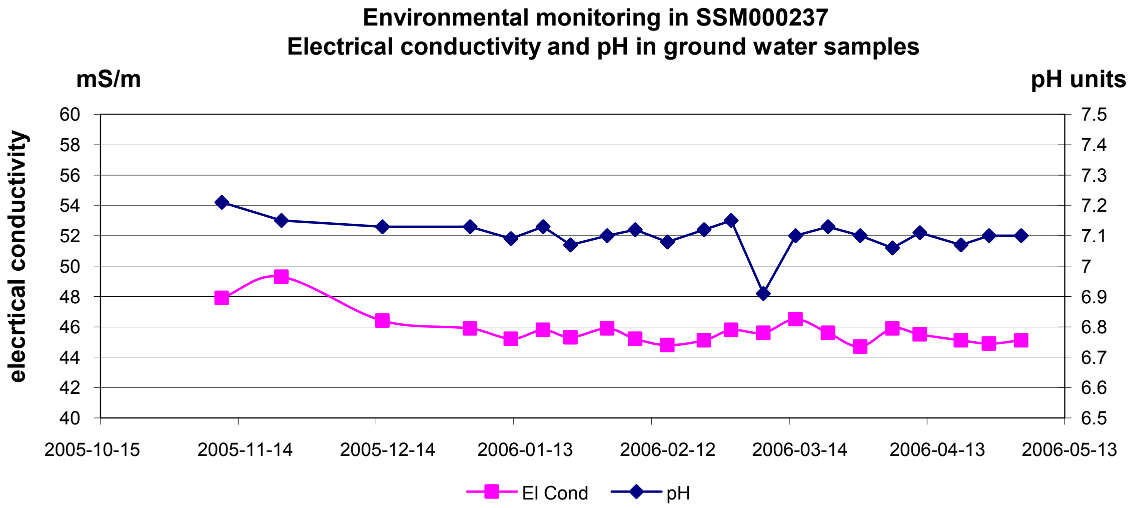


Figure 5-24. *Electrical conductivity and pH in ground water samples from SSM000220.*

6 References

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

/2/ **Moye D G, 1967.** Diamond drilling for foundation exploration, Civil Eng. Trans. Inst. Eng, Australia.

/3/ **Håkanson and Stenberg, 2007.** Compilation of borehole deviation measurements in Oskarshamn. SKB P-07-54, Svensk Kärnbränslehantering AB.

/4/ **Pedersen, 2006.** Control of microorganism content in flushing water used for drilling of KLX11A. SKB P-06-18, Svensk Kärnbränslehantering AB.

/5/ **Ask, Morosini, Samuelsson, Ekström, Håkanson, 2004.** Core drilling of KSH03. SKB P-04-233, Svensk Kärnbränslehantering AB.

/6/ **Raséus, Mattsson, Eklund, Ehrenborg, 2006.** Boremap mapping of core drilled borehole KLX11A. SKB P-06-237, Svensk Kärnbränslehantering AB.

Appendix 1

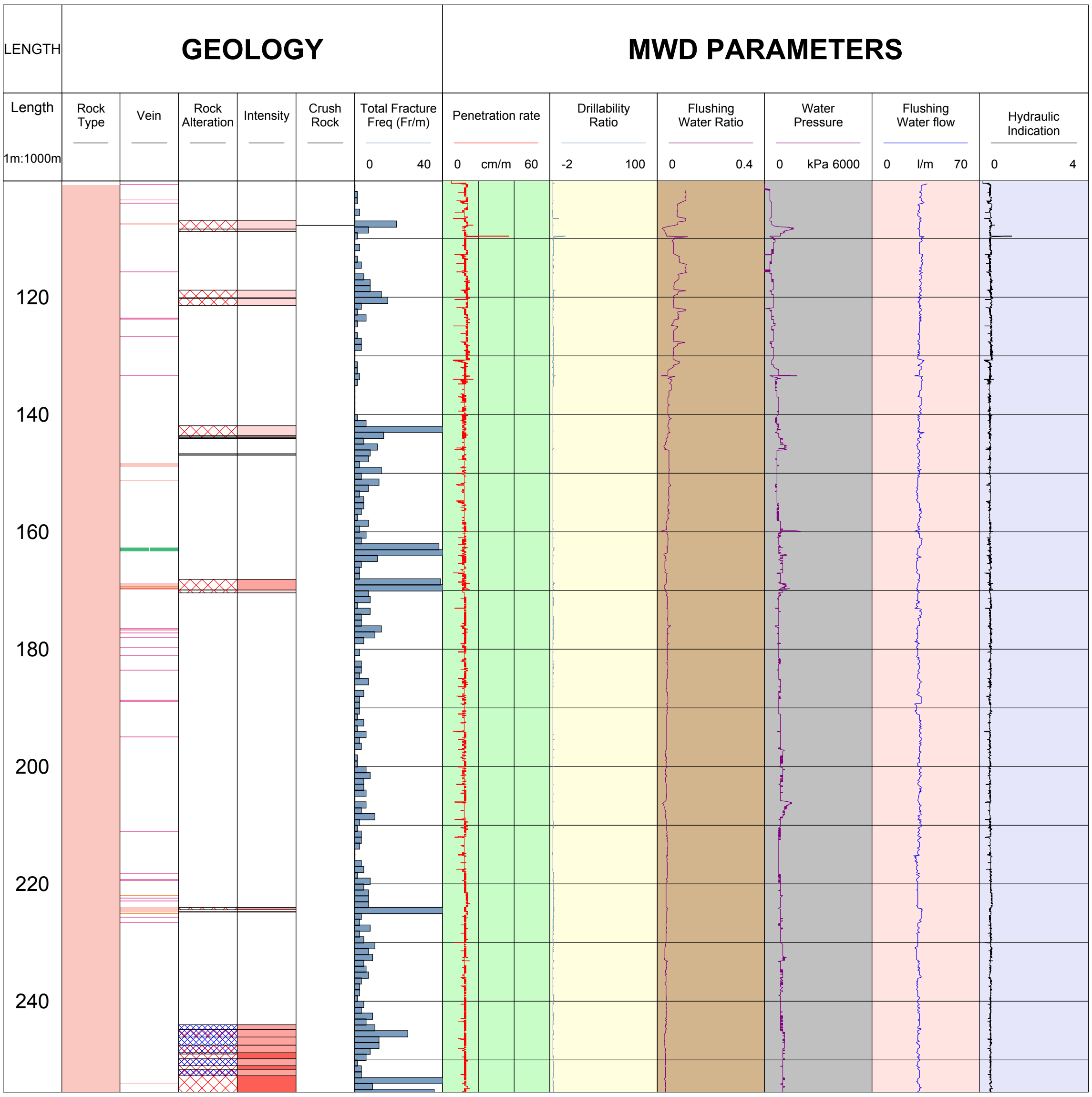
Geology and MWD parameters KLX11A

Title	**GEOLOGY & MWD PARAMETERS KLX11A**		**Appendix 1**
Site	LAXEMAR	**Coordinate System**	RT90-RHB70
Borehole	KLX11A	**Northing [m]**	6366339.72
Diameter [mm]	76	**Easting [m]**	1546608.49
Length [m]	992.290	**Elevation [m.a.s.l.]**	27.14
Bearing [°]	89.84	**Drilling Start Date**	2005-11-01 07:00:00
Inclination [°]	-76.42	**Drilling Stop Date**	2006-03-02 11:00:00
Date of mapping	2006-05-04 10:49:00	**Plot Date**	2007-01-16 22:15:47

ROCKTYPE LAXEMAR
- Fine-grained granite
- Pegmatite
- Quartz monzodiorite
- Fine-grained diorite-gabbro

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

INTENSITY
- Faint
- Weak
- Medium
- Strong



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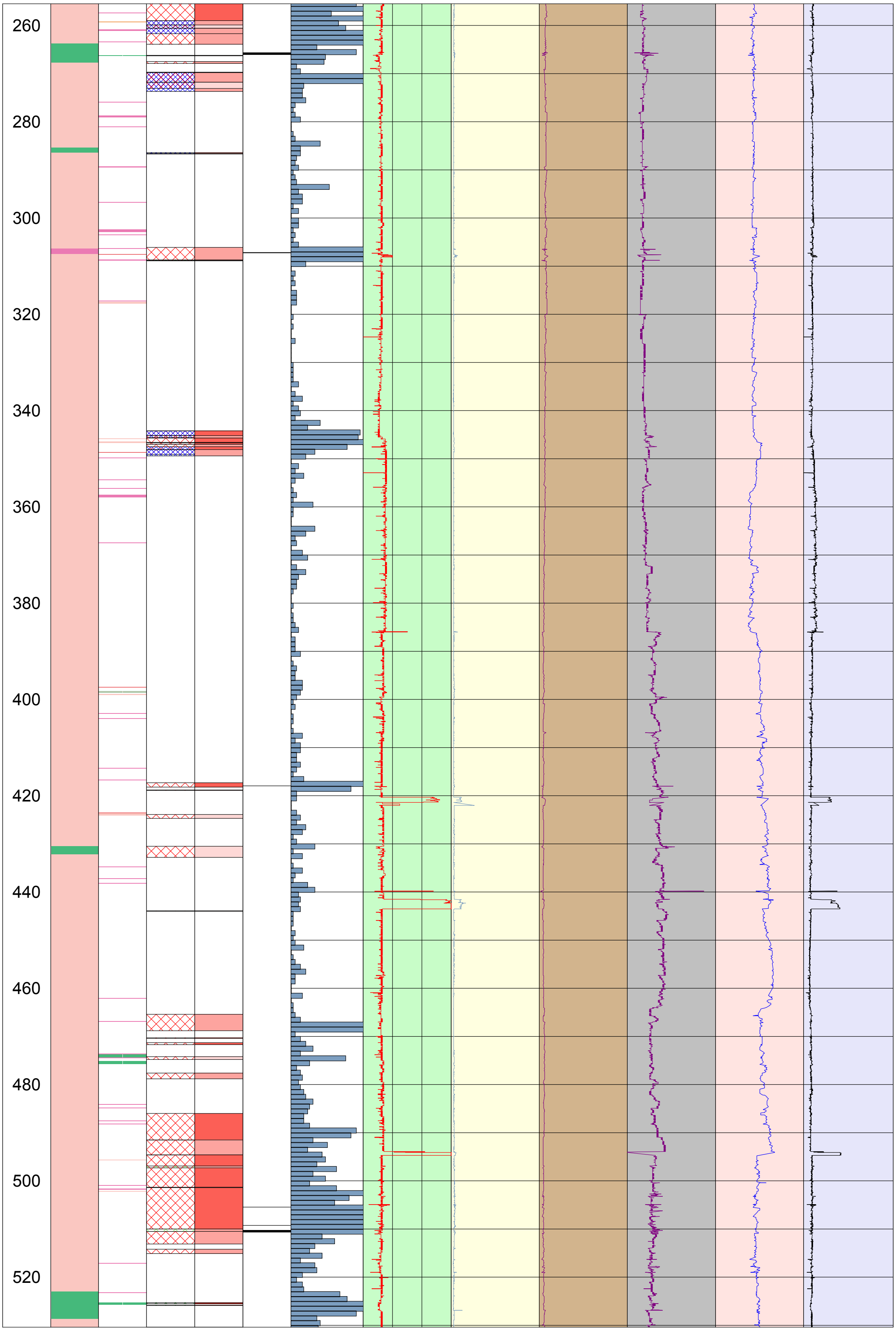

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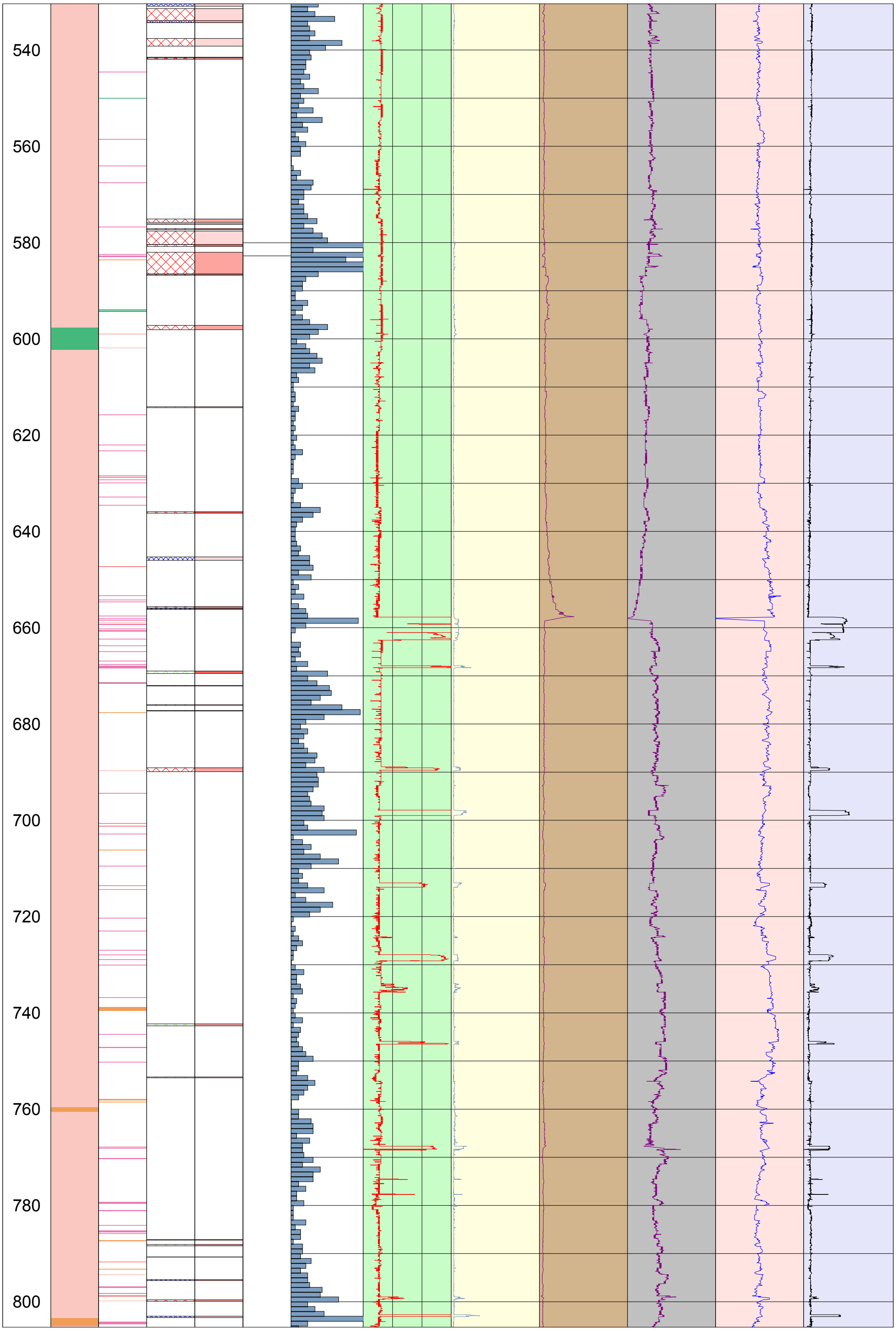

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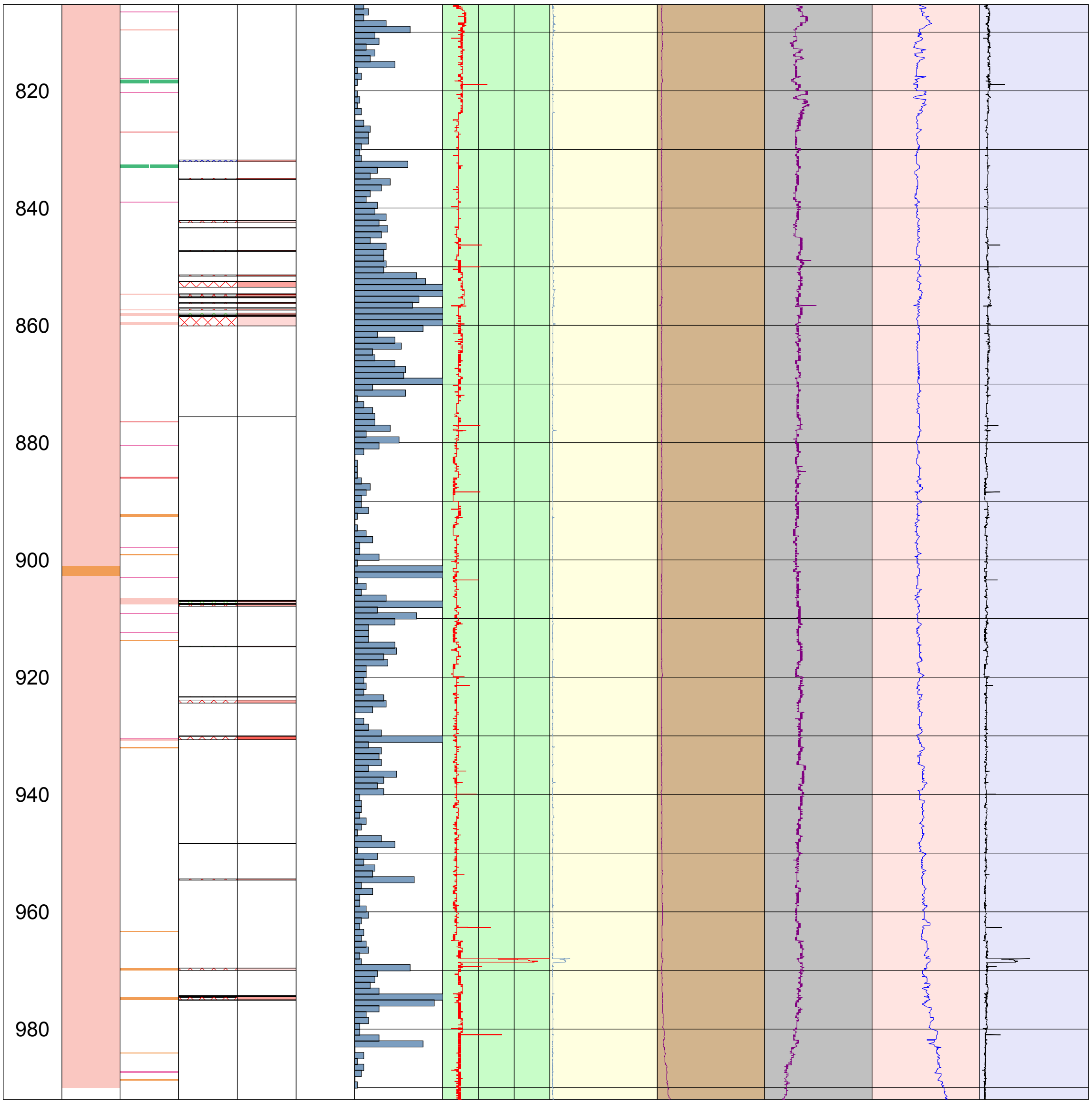

820
840
860
880
900
920
940
960
980

Appendix 2

Chemical results

Borehole	KLX11A	KLX11A	KLX11A	KLX11A	KLX11A	HLX28	HLX28
Date of measurement	2005-11-26	2005-12-06	2005-12-12	2006-01-15	2006-02-24	2005-04-12	2005-11-09
Upper section limit (m)	12.05	101.59	207.95	492.85	905.50	6.03	6.03
Lower section limit (m)	100.53	209.02	320.03	604.90	992.01	154.20	154.20
Sample_no	10652	10662	10669	10764	10850	10231	10605
Groundwater Chemistry Class	3	3	3	3	3	3	5
pH	7.94	8.58	8.79	8.48	8.54	8.17	8.07
Conductivity mS/m	33.9	42.1	89.4	295	51.4	57.1	103
Drill water %		3.45	32.3	32.9	39.2		
Density g/ml	0.9966		0.9965	0.9975	0.9965	0.9964	0.9963
Charge balance %	2.59	1.58	3.22	0.04	0.77	–1.92	0.92
Na mg/l	30.7	93.1	170	539	86.6	110	119
K mg/l	4.26	2.40	5.36	5.63	4.45	2.97	3.10
Ca mg/l	33.4	6.50	14.9	63.8	25.1	11.2	12.0
Mg mg/l	5.5	1.6	4.8	4.6	5.1	3.6	3.6
HCO3 mg/l Alkalinity	150	222	189	89.5	238	265	258
Cl mg/l	10.2	11.3	124	820	30.7	23.0	29.4
SO4 mg/l	27.0	8.91	55.1	101	24.0	35.8	37.8
SO4_S mg/l Total Sulphur	9.30	3.36	19.8	36.7	8.94	12.0	12.5
Br mg/l	<0.2	<0.2	0.52	4.21	<0.2	<0.2	<0.2
F mg/l	1.49	5.01	5.75	4.22	3.07	3.85	3.98
Si mg/l	6.28	6.56	25.3	13.9	12.3	6.97	6.81
Fe mg/l Total Iron	2.9100	2.2900	16.700	10.900	15.000	0.0794	0.0795
Mn mg/l	0.3830	0.0544	0.2420	0.1640	0.3140	0.0585	0.0617
Li mg/l	0.010	0.010	0.025	0.056	0.015	0.011	0.008
Sr mg/l	0.196	0.083	0.208	0.992	0.229	0.140	0.140
TOC mg/l							5.7
PMC % Modern Carbon						46.91	
C-13 dev PDB	–15.86	–17.03		–16.47		–16.15	
AGE_BP Groundwater age						6,027	
AGE_BP_CORR						35	
D dev SMOW	–70.3	–77.9		–102		–76.5	
Tr TU	9.9	–0.8		–0.8		1.0	
O-18 dev SMOW	–9.20	–11.0		–13.9		–10.9	
B-10 B-10/B-11	0.2566	0.2505		0.2438		0.2367	
S-34 dev SMOW	5.70	29.9		17.4		30.0	
Cl-37 dev SMOC	0.10	0.21		0.65		0.08	
Sr-87 Sr-87/Sr86	0.719938	0.716118		0.715585		0.715593	

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 the boreholes KLX11A and HLX28. The errors do not exceed ± 5% in any of the samples.

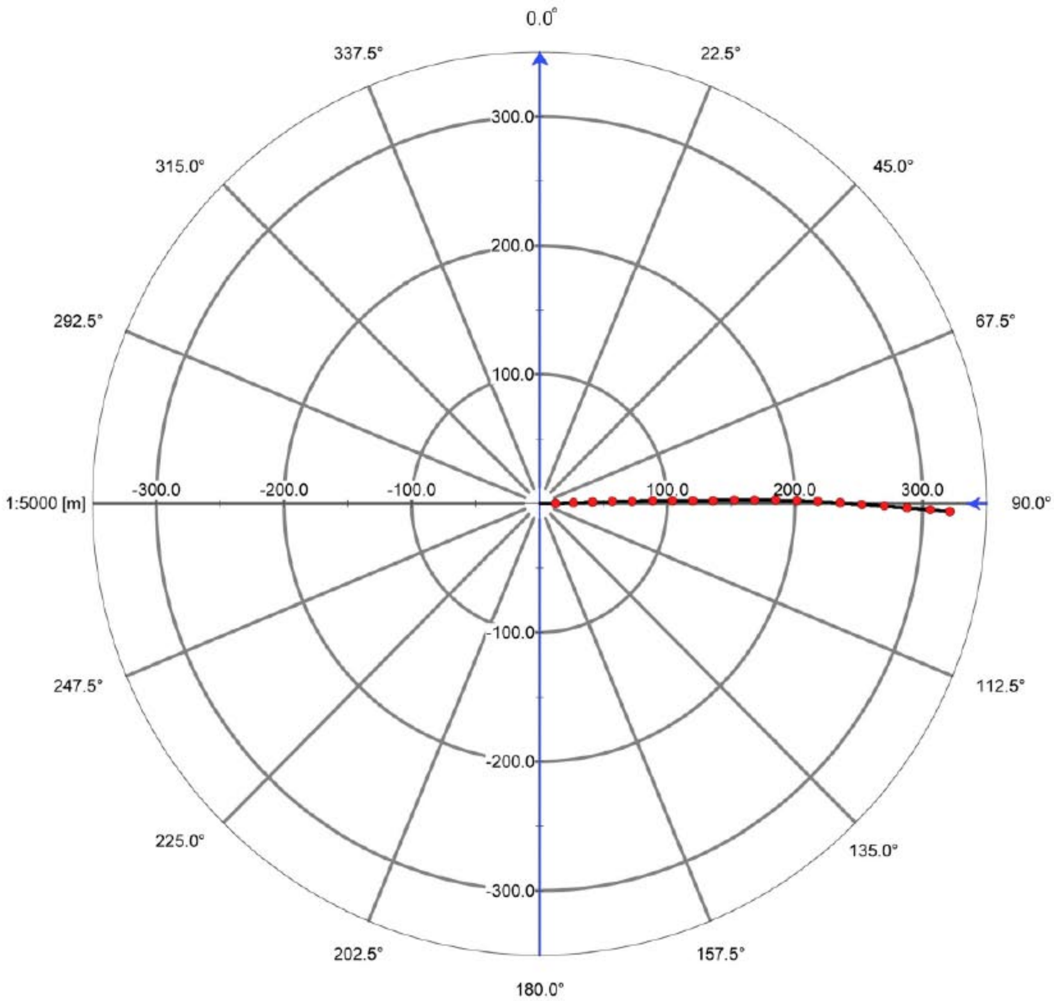
The following routines for quality control and data management are generally applied for hydrogeochemical analysis data, independent of sampling method or sampling object.

- 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 KLX11A and HLX28.
- 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.

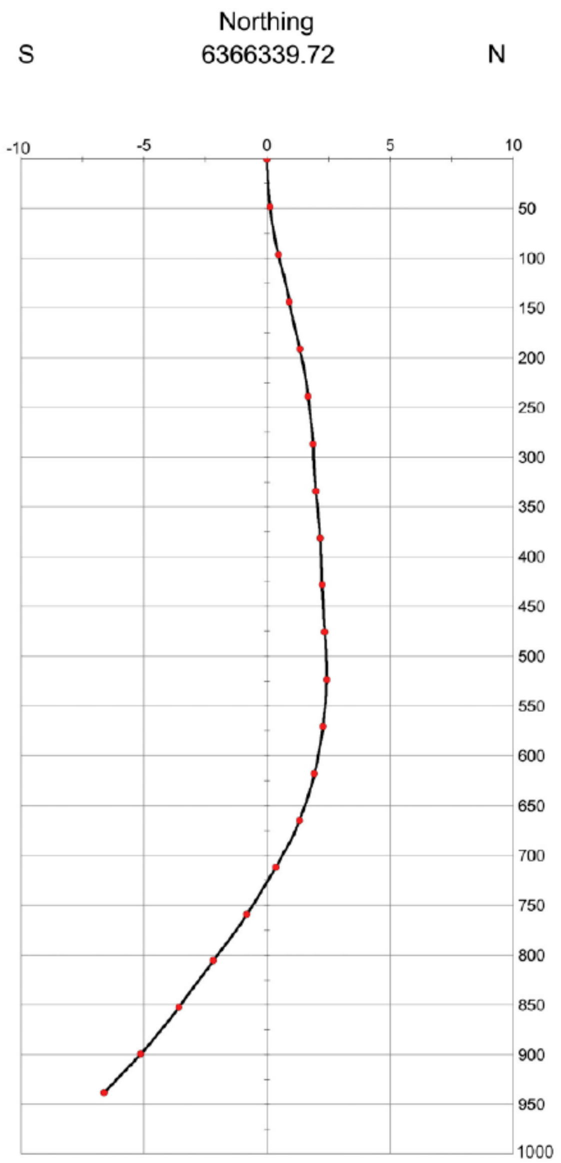
Deviation measurements

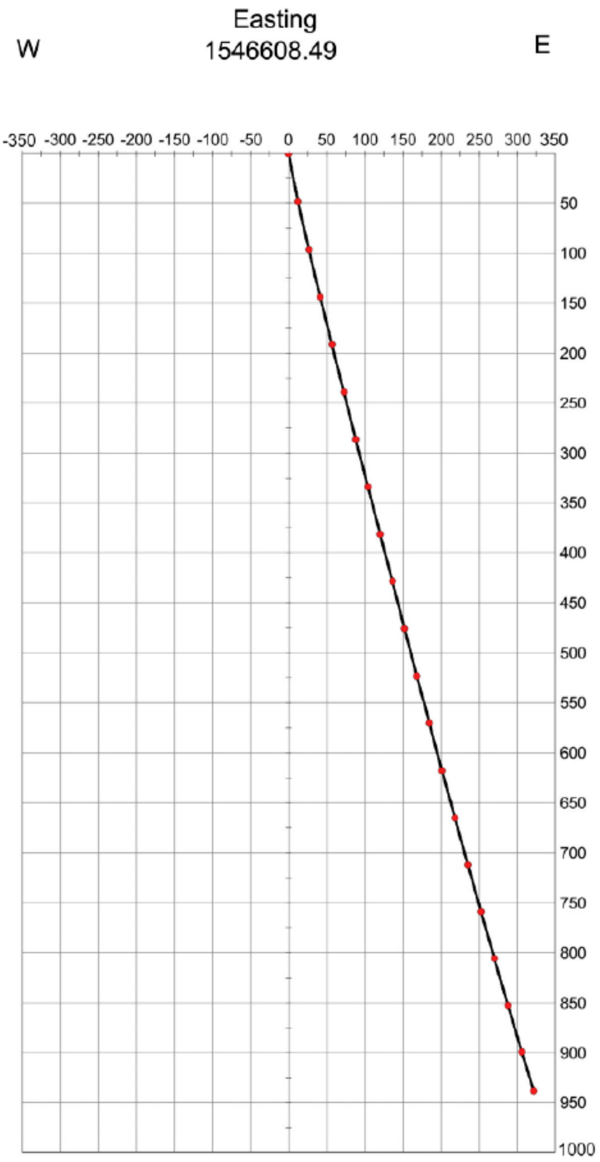
Deviation measurement			Appendix: 4
	Site	Laxemar	
	Borehole	KLX11A	
	View from above		
	Northing	6366339.72	
	Easting	1546608.49	



Deviation measurement | Appendix: 4

Site LAXEMAR
Borehole KLX11A
Vertical Section
The vertical scale is meters below reference level (top-of-casing)



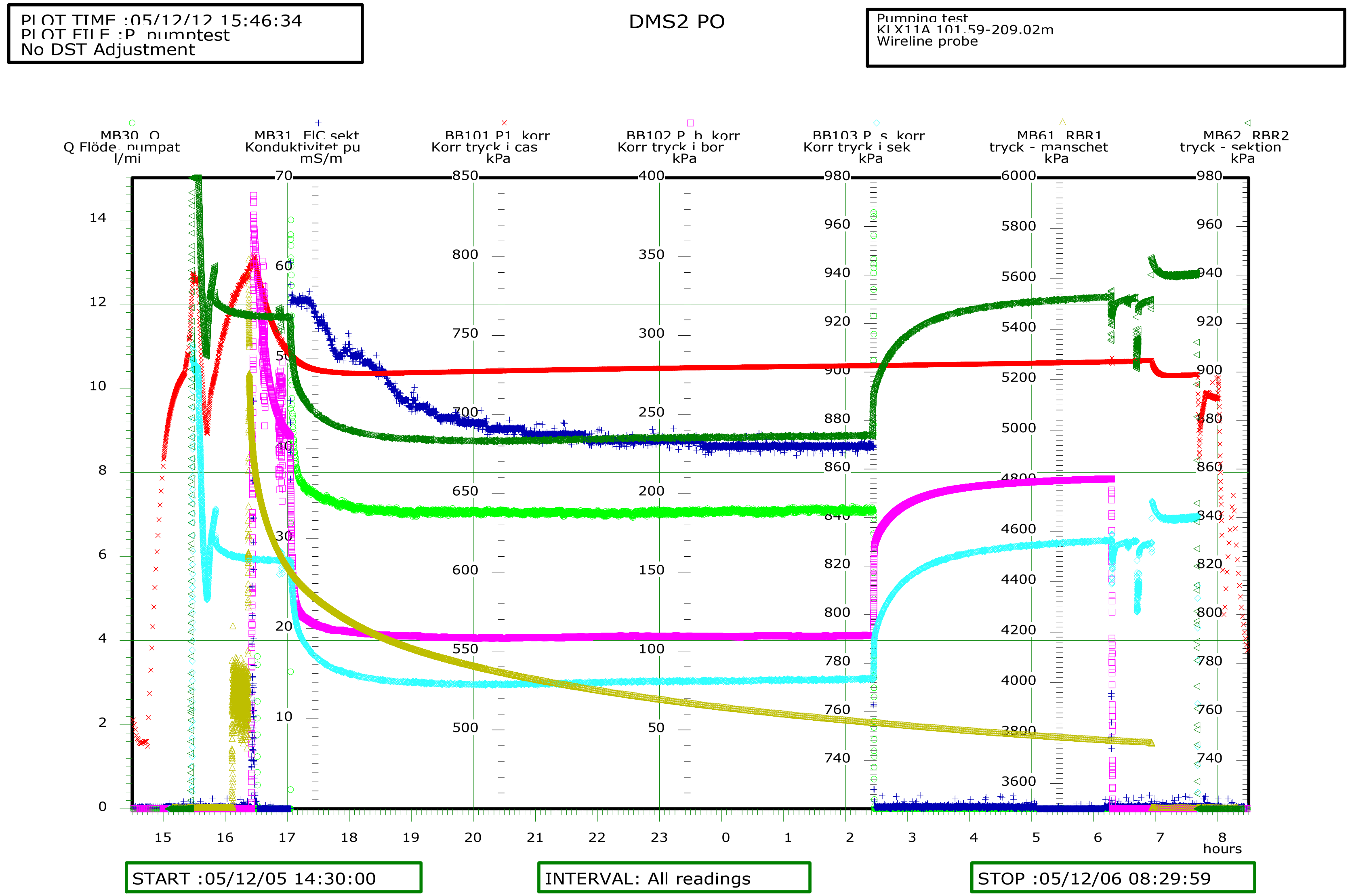


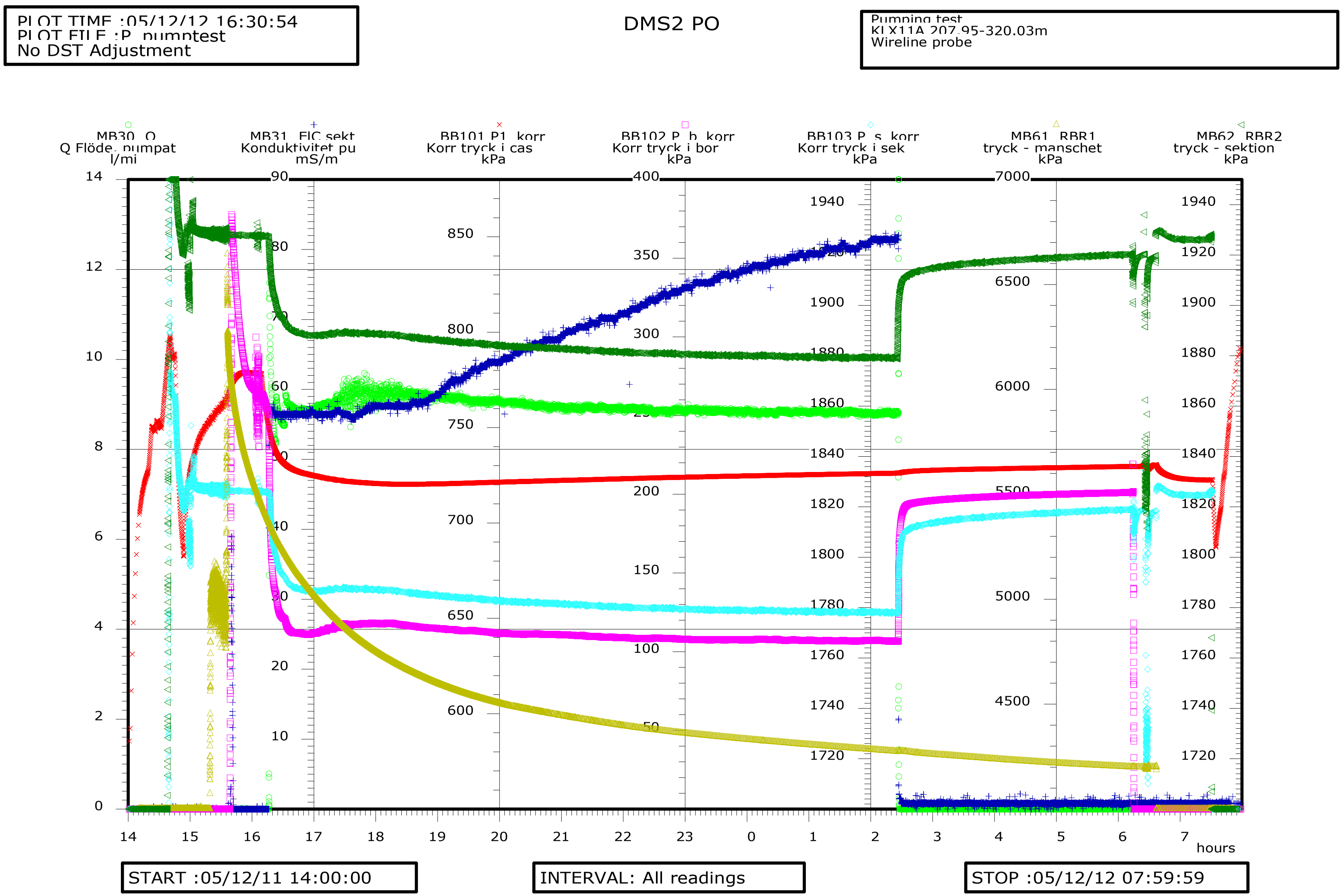
Appendix 5

Wireline pumping tests in KLX11A

Description of the parameters in the enclosed plots.

Channel	Parameter	Unit	Description
MB30	Water flow	Litre/minute	Flow of water pumped up from the borehole during the test.
MB31	Electrical conductivity	mS/m	Electrical conductivity in the pumped out water.
BB101	Pressure	kPa	Pressure of the water column in the telescopic section subtracted with the ambient air pressure.
BB102	Pressure	kPa	Pressure of the water column in the test section i.e. at depth in the borehole, subtracted with the ambient air pressure.
BB103	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.
MB61	Pressure – packer	kPa	Inflation pressure in packer.
MB62	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.

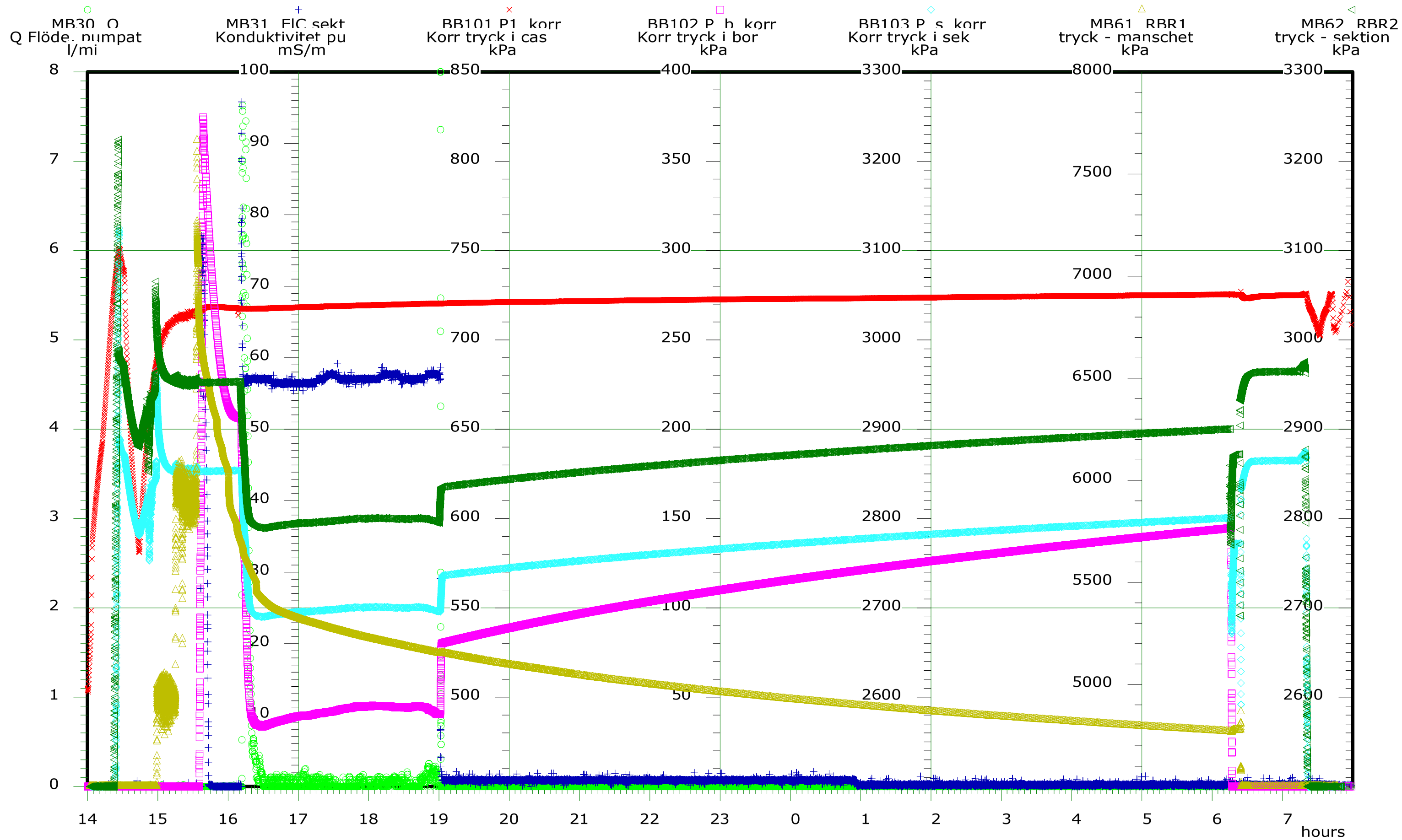

PLOT TIME :05/12/12 15:46:34
PLOT FILE :P_pumptest
No DST Adjustment
DMS2 PO
Pumping test
KLX11A 101.59-209.02m
Wireline probe
MB30_Q
Q Flöde, pumpat
l/mi
MB31_EIC sekt
Konduktivitet pu
mS/m
BB101_P1_korr
Korr tryck i cas
kPa
BB102_P_b_korr
Korr tryck i bor
kPa
BB103_P_s_korr
Korr tryck i sek
kPa
MB61_RBR1
tryck - manschet
kPa
MB62_RBR2
tryck - sektion
kPa
hours
START :05/12/05 14:30:00
INTERVAL: All readings
STOP :05/12/06 08:29:59


PLOT TIME :05/12/12 16:30:54
PLOT FILE :P_pumptest
No DST Adjustment
DMS2 PO
Pumping test
KLX11A 207.95-320.03m
Wireline probe
MB30 Q
Q Flöde, pumpat
l/mi
MB31 EIC sekt
Konduktivitet pu
mS/m
BB101 P1 korr
Korr tryck i cas
kPa
BB102 P b korr
Korr tryck i bor
kPa
BB103 P s korr
Korr tryck i sek
kPa
MB61 RBR1
tryck - manschet
kPa
MB62 RBR2
tryck - sektion
kPa
hours
START :05/12/11 14:00:00
INTERVAL: All readings
STOP :05/12/12 07:59:59

PLOT TIME :05/12/19 10:41:44
PLOT FILE :P_pumptest
No DST Adjustment

DMS2 PO

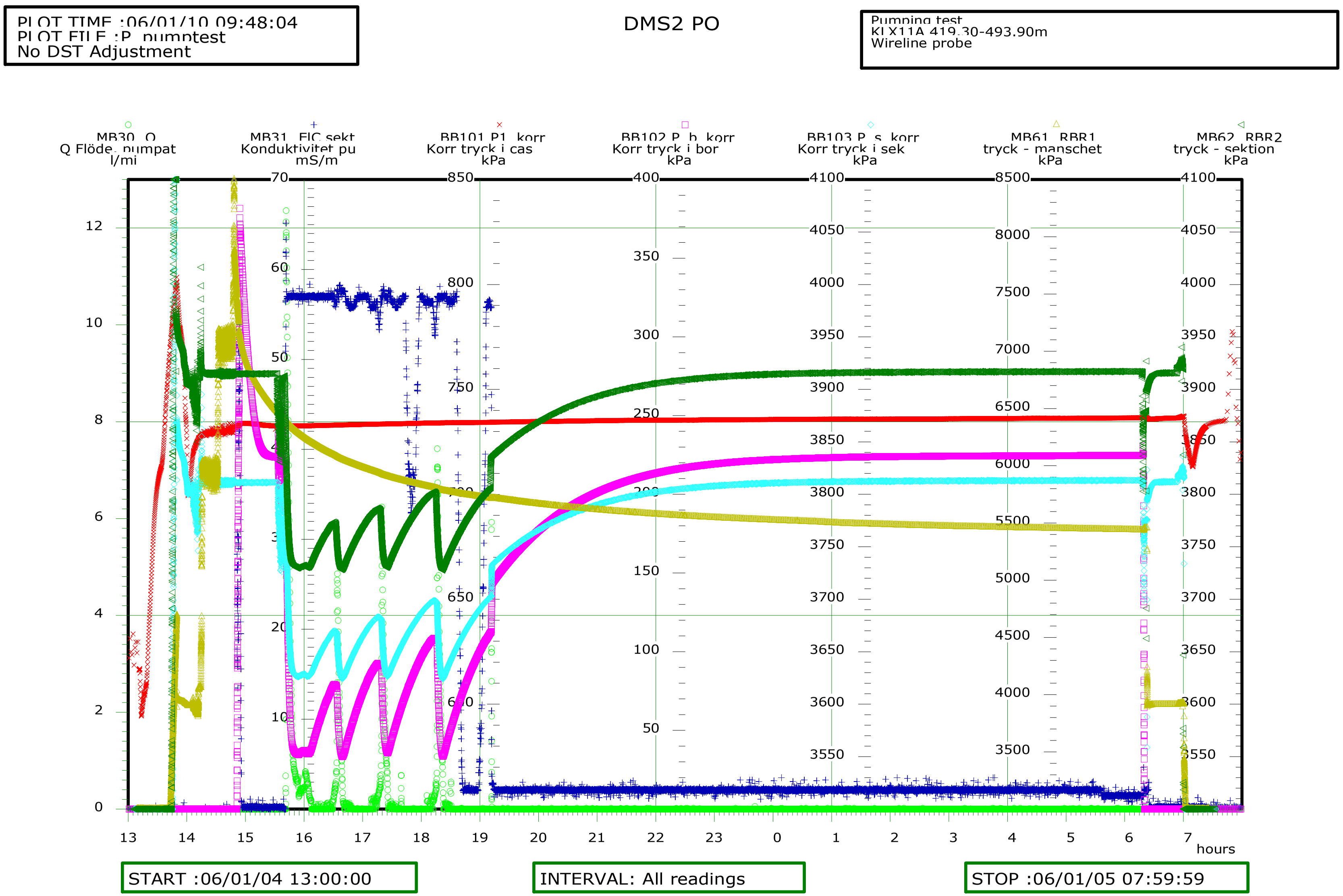
Pumping test
KLX11A 318.95-420.45m
Wireline probe



START :05/12/17 14:00:00

INTERVAL: All readings

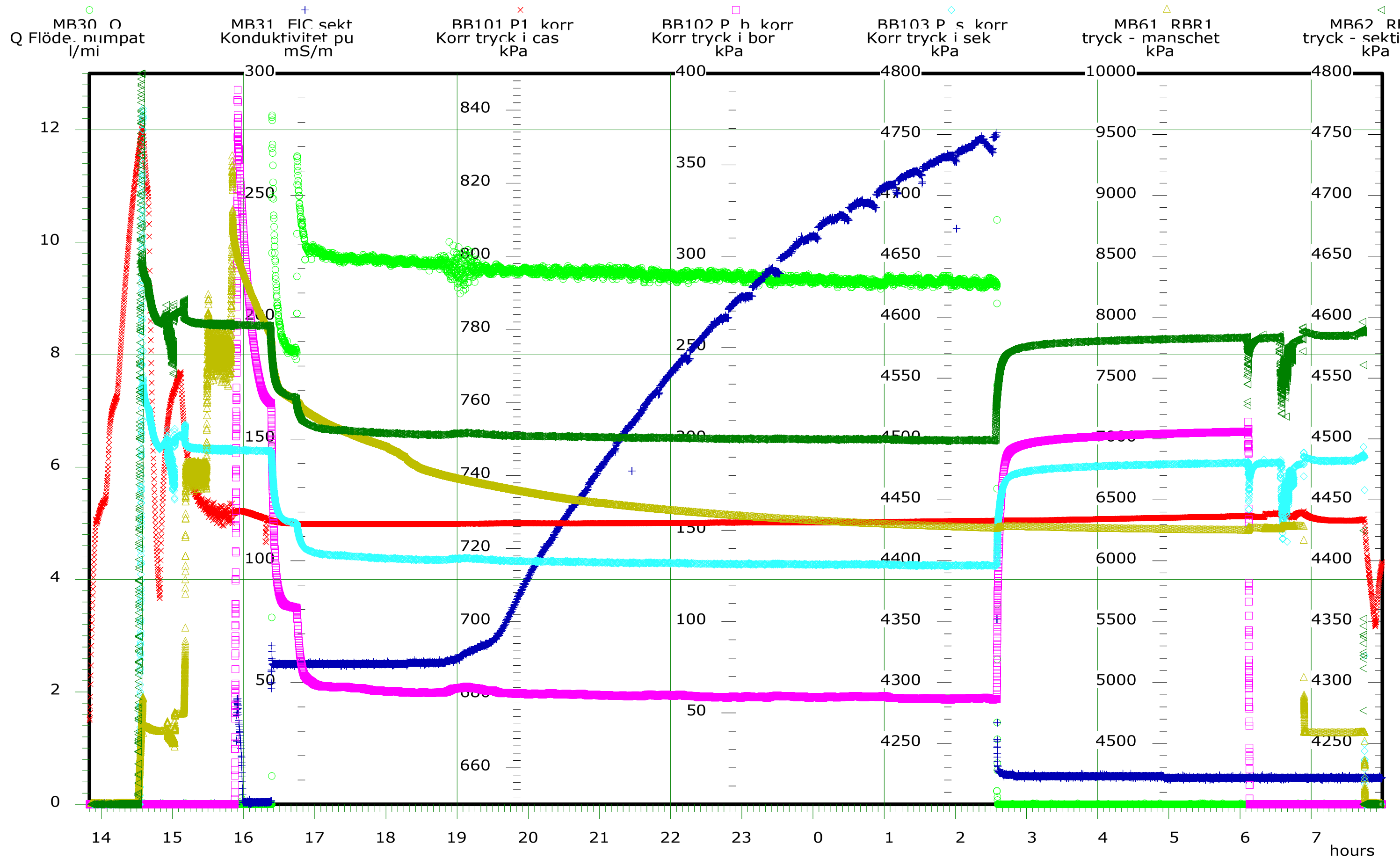
STOP :05/12/18 07:59:59


PLOT TIME :06/01/10 09:48:04
PLOT FILE :P_pumptest
No DST Adjustment
DMS2 PO
Pumping test
KLX11A 419.30-493.90m
Wireline probe
MB30 Q
Q Flöde, pumpat
l/mi
MB31 EIC sekt
Konduktivitet pu
mS/m
BB101 P1 korr
Korr tryck i cas
kPa
BB102 P_h korr
Korr tryck i bor
kPa
BB103 P_s korr
Korr tryck i sek
kPa
MB61 RBR1
tryck - manschet
kPa
MB62 RBR2
tryck - sektion
kPa
hours
START :06/01/04 13:00:00
INTERVAL: All readings
STOP :06/01/05 07:59:59

PLOT TIME :06/01/17 10:27:54
PLOT FILE :P_pumptest
No DST Adjustment

DMS2 PO

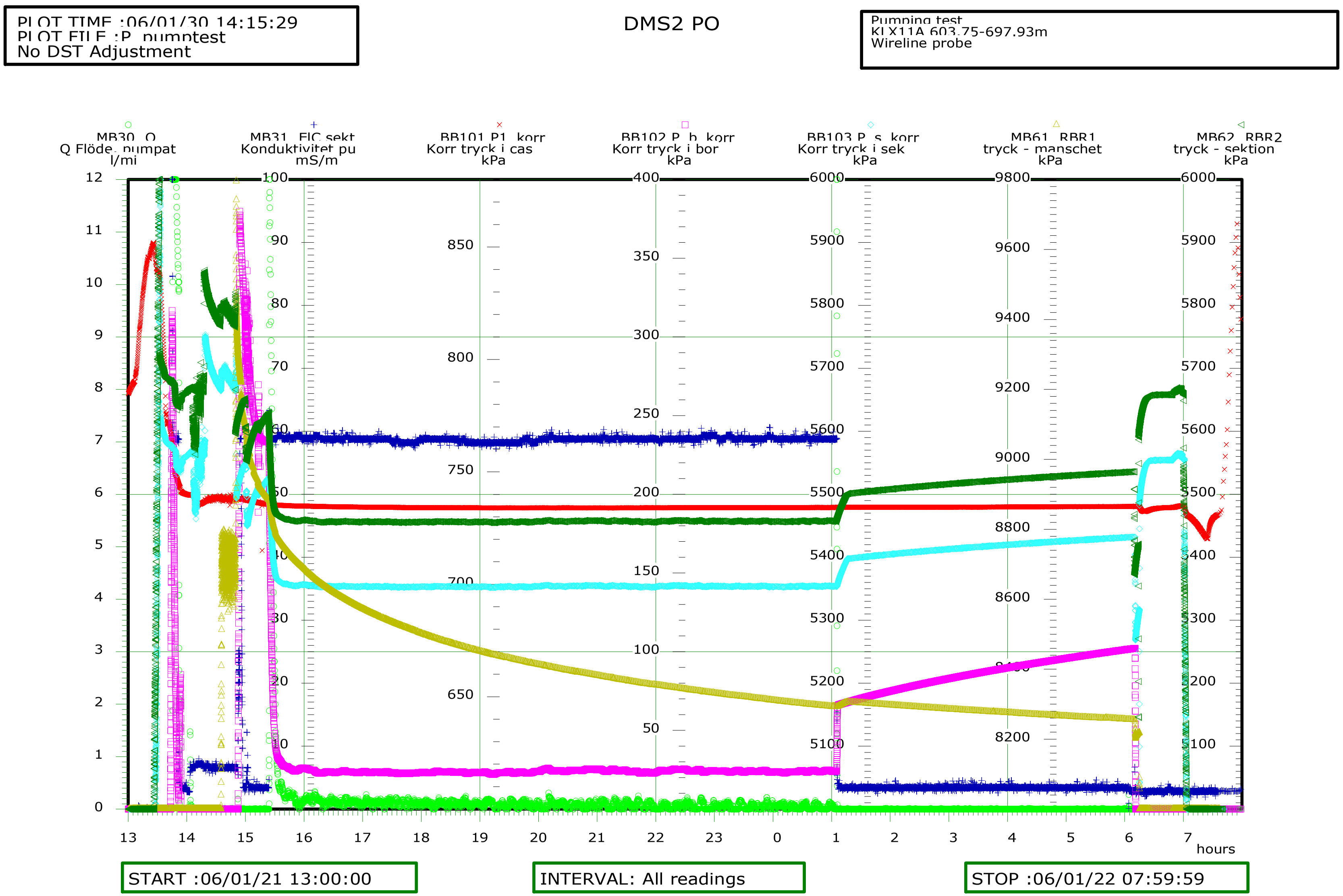
Pumping test
KLX11A 492.85-604.90m
Wireline probe

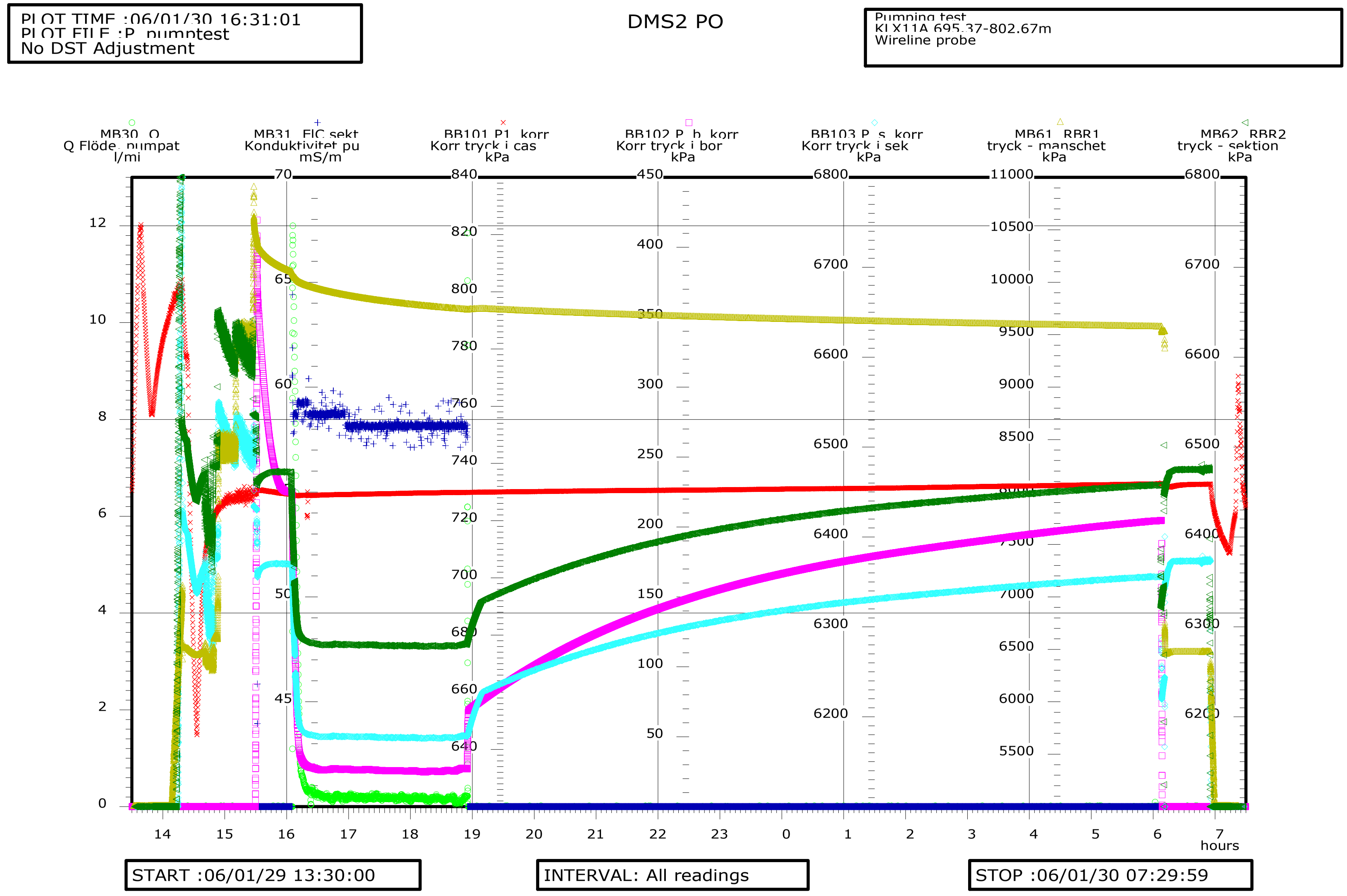


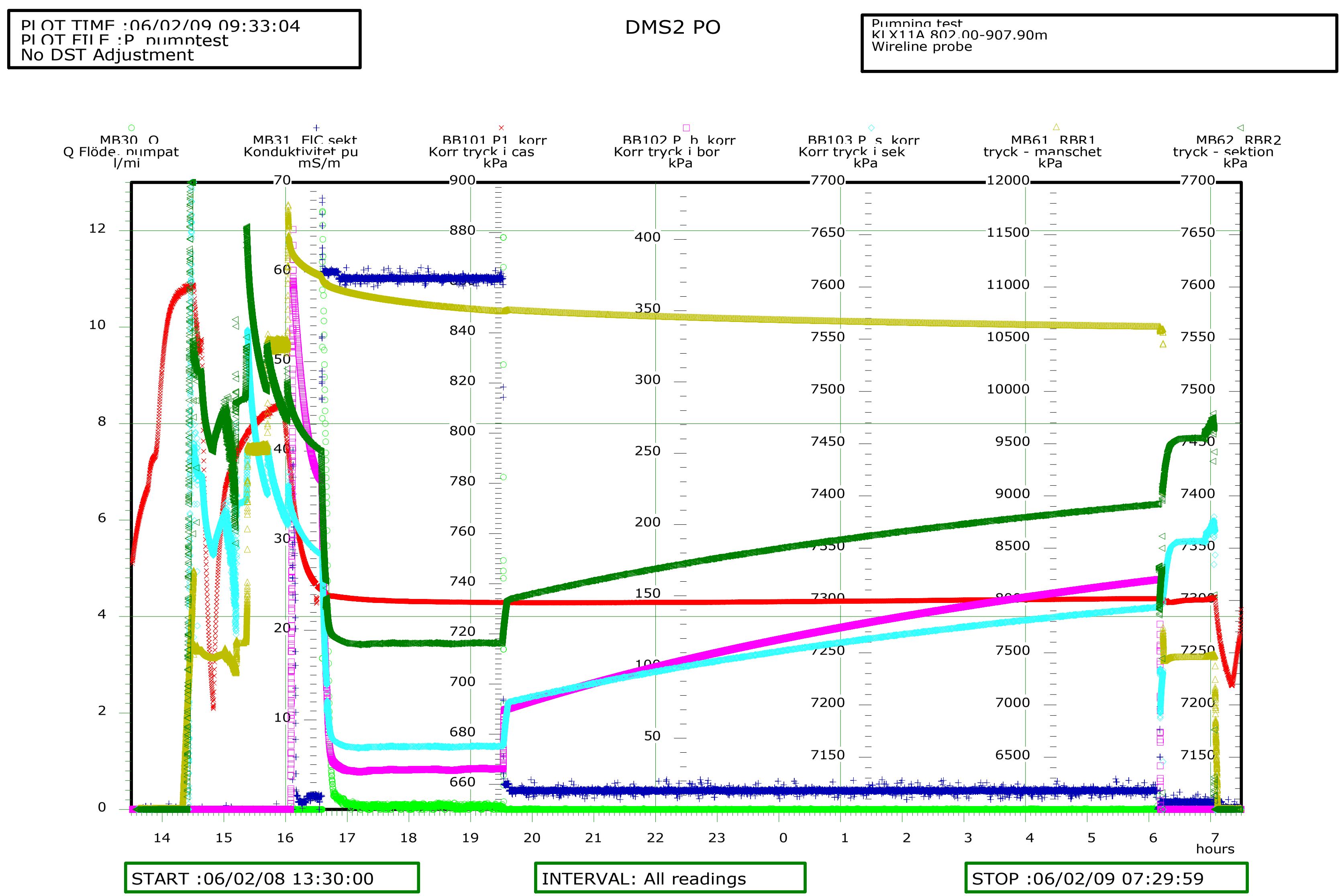
START :06/01/14 13:50:00

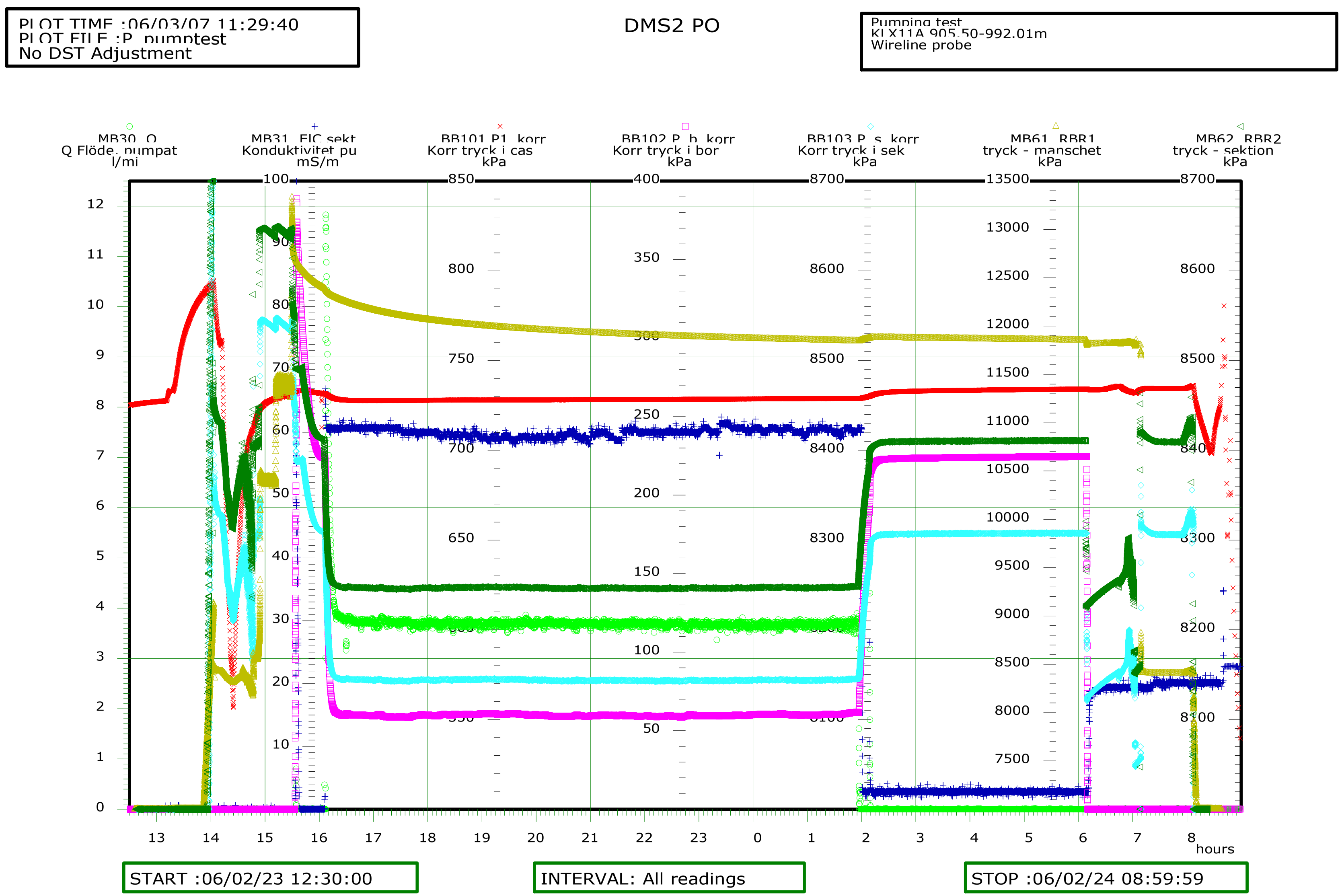
INTERVAL: All readings

STOP :06/01/15 07:59:59


PI OT TIMF :06/01/30 14:15:29
PI OT FII F :P pumptest
No DST Adjustment
DMS2 PO
Pumping test
KI X11A 603.75-697.93m
Wireline probe
MB30 Q
Q Flöde, pumpat
l/mi
MB31 EIC sekt
Konduktivitet pu
mS/m
BB101 P1 korr
Korr tryck i cas
kPa
BB102 P h korr
Korr tryck i bor
kPa
BB103 P s korr
Korr tryck i sek
kPa
MB61 RBR1
tryck - manschet
kPa
MB62 RBR2
tryck - sektion
kPa
hours
START :06/01/21 13:00:00
INTERVAL: All readings
STOP :06/01/22 07:59:59


PLOT TIME :06/01/30 16:31:01
PLOT FILE :P_pumptest
No DST Adjustment
DMS2 PO
Pumping test
KLX11A 695.37-802.67m
Wireline probe
MB30 Q
Q Flöde, pumpat
l/mi
MB31 EIC sekt
Konduktivitet pu
mS/m
BB101 P1 korr
Korr tryck i cas
kPa
BB102 P h korr
Korr tryck i bor
kPa
BB103 P s korr
Korr tryck i sek
kPa
MB61 RBR1
tryck - manschet
kPa
MB62 RBR2
tryck - sektion
kPa
hours
START :06/01/29 13:30:00
INTERVAL: All readings
STOP :06/01/30 07:29:59


PLOT TIME :06/02/09 09:33:04
PLOT FILE :P_pumptest
No DST Adjustment
DMS2 PO
Pumping test
KLX11A 802.00-907.90m
Wireline probe
MB30 Q
Q Flöde, pumpat
l/mi
MB31 EIC sekt
Konduktivitet pu
mS/m
BB101 P1 korr
Korr tryck i cas
kPa
BB102 P_b korr
Korr tryck i bor
kPa
BB103 P_s korr
Korr tryck i sek
kPa
MB61 RBR1
tryck - manschet
kPa
MB62 RBR2
tryck - sektion
kPa
hours
START :06/02/08 13:30:00
INTERVAL: All readings
STOP :06/02/09 07:29:59


PLOT TIME :06/03/07 11:29:40
PLOT FILE :P_pumptest
No DST Adjustment
DMS2 PO
Pumping test
KLX11A 905.50-992.01m
Wireline probe
MB30 Q
Q Flöde, pumpat
l/mi
MB31 EIC sekt
Konduktivitet pu
mS/m
BB101 P1 korr
Korr tryck i cas
kPa
BB102 P_b_korr
Korr tryck i bor
kPa
BB103 P_s_korr
Korr tryck i sek
kPa
MB61 RBR1
tryck - manschet
kPa
MB62 RBR2
tryck - sektion
kPa
hours
START :06/02/23 12:30:00
INTERVAL: All readings
STOP :06/02/24 08:59:59

Appendix 6

Technical data from environmental monitoring wells SSM000236 and SSM000237

WSP

LAXEMAR BOREHOLE SSM000236

Company rep.
Torbjörn Johansson

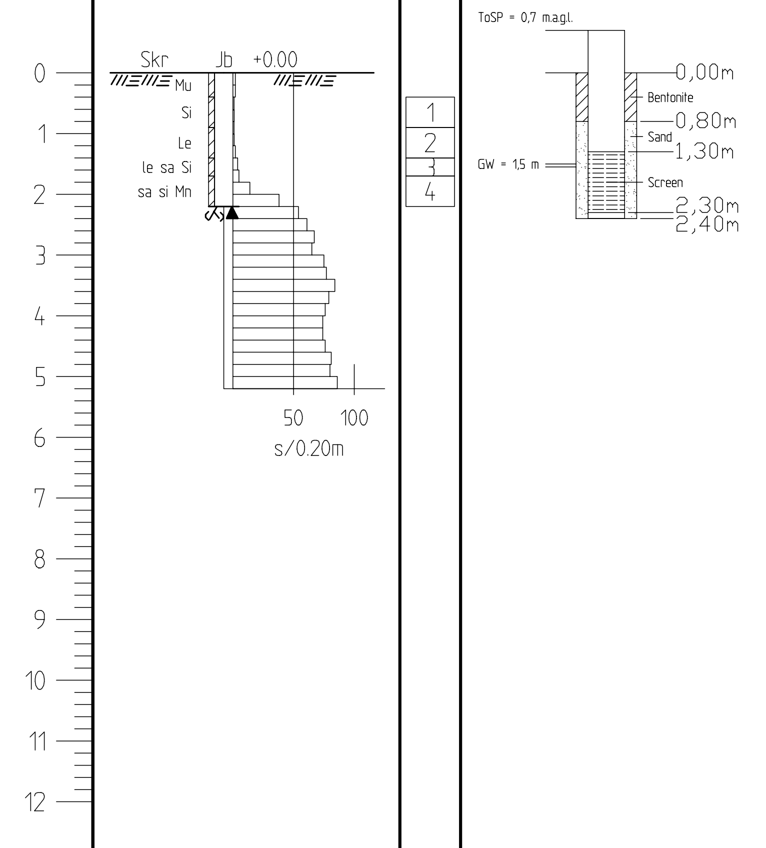
Client: Svensk Kärnbränslehantering AB

Northing :6366244
Easting :1546656

Coordinate system : RT90-RHB70

Top of stand pipe : 0,7 m.a.g.l.
Total pipe length : 3,10 m
Groundwater level : 1,5 m.b.g.l.
Date of completion : 2005-11-02

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 : 1,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,80 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 1,60 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 Topsoil
0,4-0,9m silt
0,9-1,4m clay
1,4-1,7m clayey sandy silt
1,7-2,2m sandy silty fill
2.2m rock surface

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

LAXEMAR BOREHOLE SSM000237

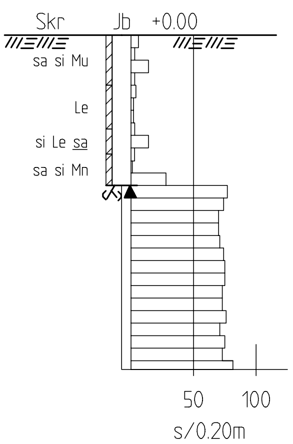
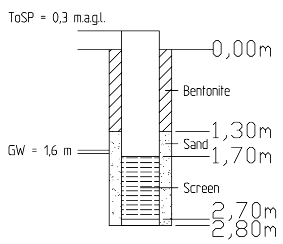
Company rep.
Torbjörn Johansson

Client: Svensk Kärnbränslehantering AB

Northing :6366203
Easting :1546651

Coordinate system : RT90-RHB70

Top of stand pipe : 0,3 m.a.g.l.
Total pipe length : 3,10 m
Groundwater level : 1,6 m.b.g.l.
Date of completion : 2005-10-31

Depth (m)	Description	Samples	Groundwater monitoring well description
0–12		1, 2, 3	

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 : 1,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 1,30 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 1,50 m

DRILLING EQUIPMENT
Drilling rig : GM 65 GTT
Drill hammer : Furukawa HB2G
Drill rod : Geostång Ø44
Drill bit : Stift Ø54

GEOLOGICAL LOG
0-0,8m Sandy silty topsoil
0,8-1,5m clay
1,5-1,9m silty clay with sand layers
1,9-2,4m sandy silty till
2,4m rock surface

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