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Oskarshamn site investigation

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Abstract

Borehole KLX13A is located in the Laxemar subarea. Drilling was made between March and August 2006 as a part of the site investigation for a possible repository for spent nuclear fuel in Oskarshamn municipality, Sweden. KLX13A was the seventeenth deep cored borehole within the site investigation in Oskarshamn.

KLX13A was core drilled to a length of 595.85 m with N-size (76 mm) equipment. The uppermost section, to the length of 99.86 m, was constructed as a telescopic borehole with an inner nominal diameter of 200 mm.

A water inflow of 11 L/minute could be measured over the entire length of the telescopic section after percussion drilling (diameter 160.4 mm).

Five successful pumping tests were performed with wireline equipment in KLX13A. The resulting transmissivities (T_M) varied between 6.6×10^{-5} and 2.6×10^{-6} m^2/s. The most transmissive section was between 396 and 487 m.

Continuous monitoring of drilling parameters and flushing water parameters with the drilling monitoring system was conducted throughout the core drilling phase in KLX13A.

Seven water samples for chemical analysis were collected during the core drilling of KLX13A.

The air-lift pumping test in the telescopic section performed when borehole KLX13A was core drilled to its full length gave a transmissivity (T_M) of 2.5×10^{-4} m^2/s.

Lithologically the core is dominated by Ävrö granite. Minor intercalations of diorite/gabbro, fine-grained diorite-gabbro and fine grained granite have been noted in the borehole.

Red staining with medium to strong intensity occurs frequently from ca 490 m and downwards. 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 4.24 (fractures/metre).

Sammanfattning

Borrhål KLX13A ligger inom delområde Laxemar. Borrningen utfördes mellan mars och augusti 2006 som ett led i platsundersökningen för ett möjligt djupförvar för använt kärnbränsle i Oskarshamns kommun. KLX13A var det sjuttonde djupa kärnborrhålet inom platsundersökningen i Oskarshamn.

KLX13A kärnborrades med borrstorlek N (76 mm) till 595,85 meters borrad längd. Den övre delen av hålet, från markytan till 99,86 meter, utfördes som en teleskopdel med ca 200 mm inre diameter.

Ett vatteninflöde på 11 minutliter kunde uppmätas över hela teleskopdelen vid hammarborrningen (diameter 160,4 mm).

Fem lyckade pumptester med wireline-baserad mätutrustning utfördes. De uppmätta transmissiviteterna (T_M) varierade mellan $6,6\times10^{-5}$ och $2,6\times10^{-6}$ m^2/s. Den mest transmissiva sektionen var mellan 396 och 487 meter.

Kontinuerliga mätningar av borrningsparametrar och spolvattenparametrar via DMS (drilling monitoring system) gjordes under hela kärnborrningsfasen i KLX13A.

Sju vattenprover för kemisk analysering togs i samband med borrning i KLX13A.

Mammutpumpningen i teleskopdelen som gjordes när kärnborrningen i KLX13A utförts till full längd gav en transmissivitet (T_M) på $2,5\times10^{-4}$ m^2/s.

Litologiskt domineras kärnan av Ävrögranit. Mindre inslag av diorit/gabbro, finkornig dioritgabbro och finkornig granit har noterats i borrhålet.

Rödfärgning med måttlig till stark intensitet är vanligt förekommande från ca 490 m och nedåt. Sektioner med rödfärgning är angivna som ”oxiderade” i Bilaga 1.

Den genomsnittliga sprickfrekvensen över hela borrkärnan uttryckt som öppna sprickor är 4,24 (sprickor/meter).

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 and 2/. The investigations are performed in two Swedish municipalities: Östhammar and Oskarshamn. Borehole KLX13A is located in the northwestern 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. KLX13A was the seventeenth 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.

The drilling of KLX13A and all related on-site operations were performed according to a specific Activity Plan (AP PS 400-06-010), 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 KLX13A	AP PS 400-06-010	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 enhålstrester	SKB MD 321.003	1.0
Metodbeskrivning för registrering och provtagning av spolvatten-parametrar samt borrkax under kärnborrning	SKB MD 640.001	1.0
Metodbeskrivning för vattenprovtagning, pumptest och tryckmätning i samband med wireline-borrning	SKB MD 321.002	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 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 ytvatten, ytnära grundvatten och mark vid borrning och pumpning i berg	SKB MD 300.003	2.0

* Two amendments to the Activity Plan exist.

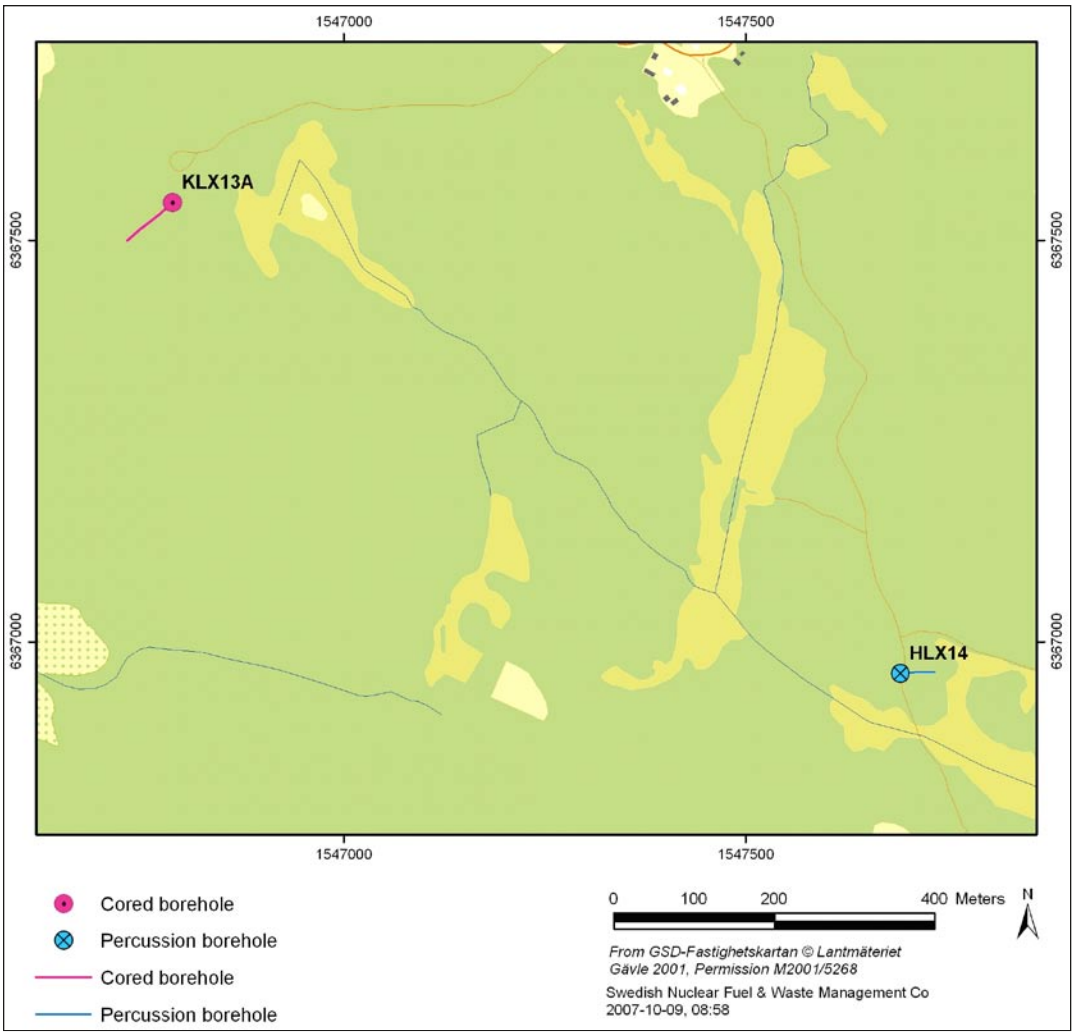


Figure 1-1. *Location of the cored borehole KLX13A and the water source, percussion borehole HLX14 in the Laxemar subarea.*

2 Objective and scope

This report will describe the methods employed and the results achieved during the drilling of borehole KLX13A. 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 verify and characterize possible rock volumes for a deep repository as well as to gain geological information and facilitate further investigation at depth in the northwest part of the Laxemar subarea. The decision to drill KLX13A is given in SKB id no 1049185, dated 2006-01-16.

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 2005-12-15, SKB id 1047829. Information of the final coordinates and details regarding the return water handling was sent to the Regional Authorities on 2006-01-17, SKB id 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.

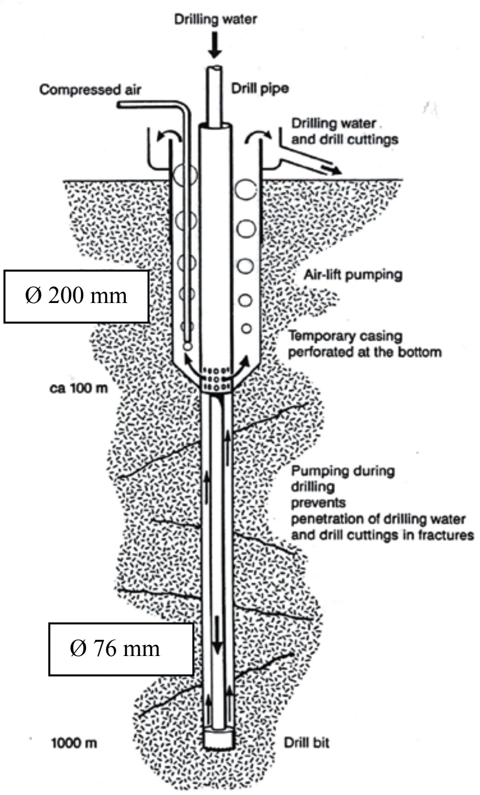


Figure 3-1. *A sketch of the telescopic drilling method with air-lift pumping for retrieval of drilling water and cuttings.*

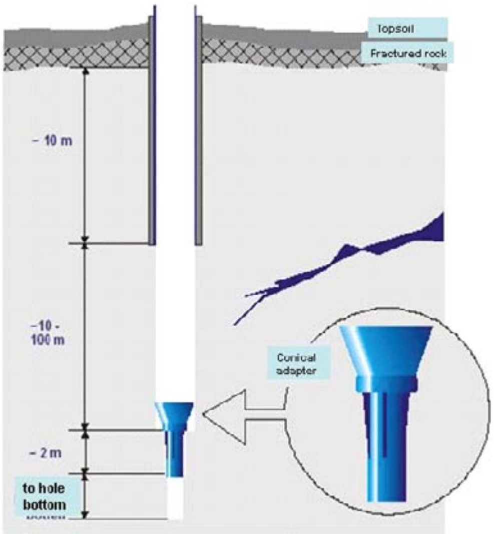


Figure 3-2. *Installation of the conical guide.*

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 pristine 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.

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 KLX13A consisted of:

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

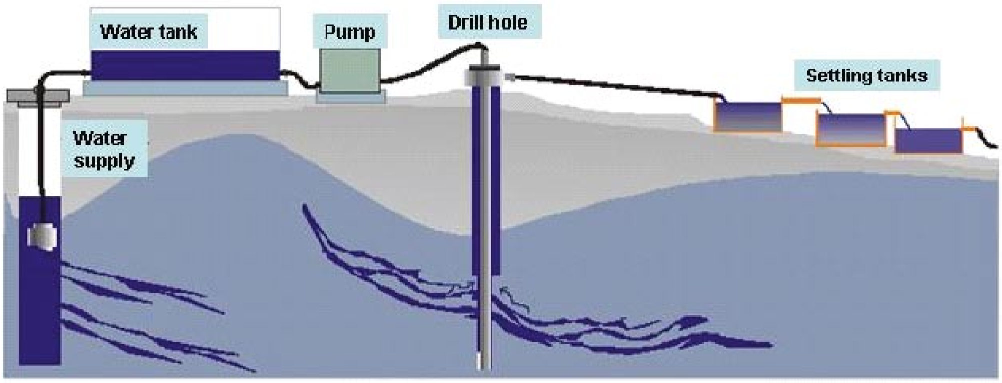


Figure 3-3. *The flushing water system from source to discharge point.*

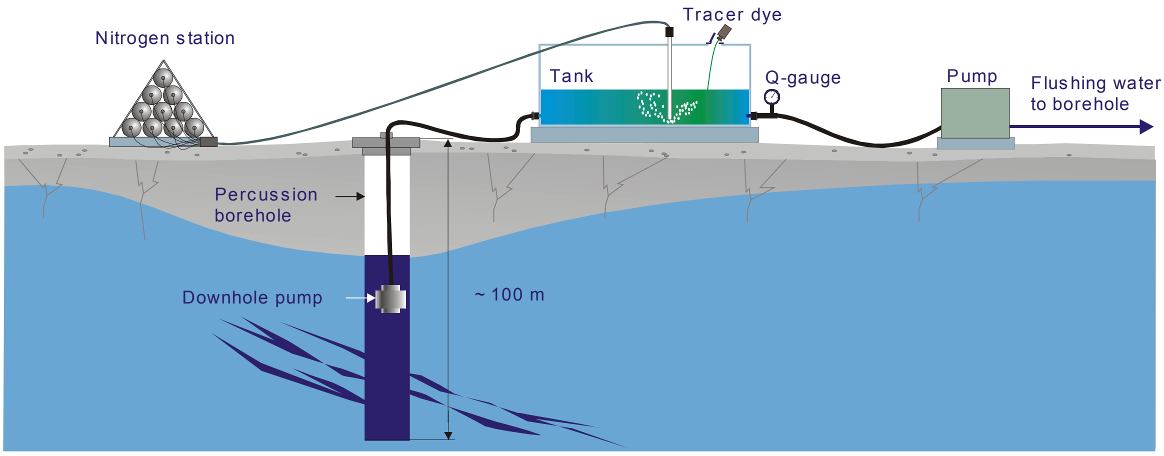


Figure 3-4. *Schematic drawing of the preparation of flushing water. Uranine is added to the water as a tracer dye and nitrogen is bubbled through the water to remove dissolved oxygen.*

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 KLX13A 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 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 and flushing water parameters in accordance with the Method Description for registration and sampling of flushing water parameters during drilling (SKB MD 640.001) and the Method Description for quality assurance of DMS-data (SKB MD 640.008). The Method Descriptions are SKB internal documents. The data is compiled into a database called drilling monitoring system (DMS).

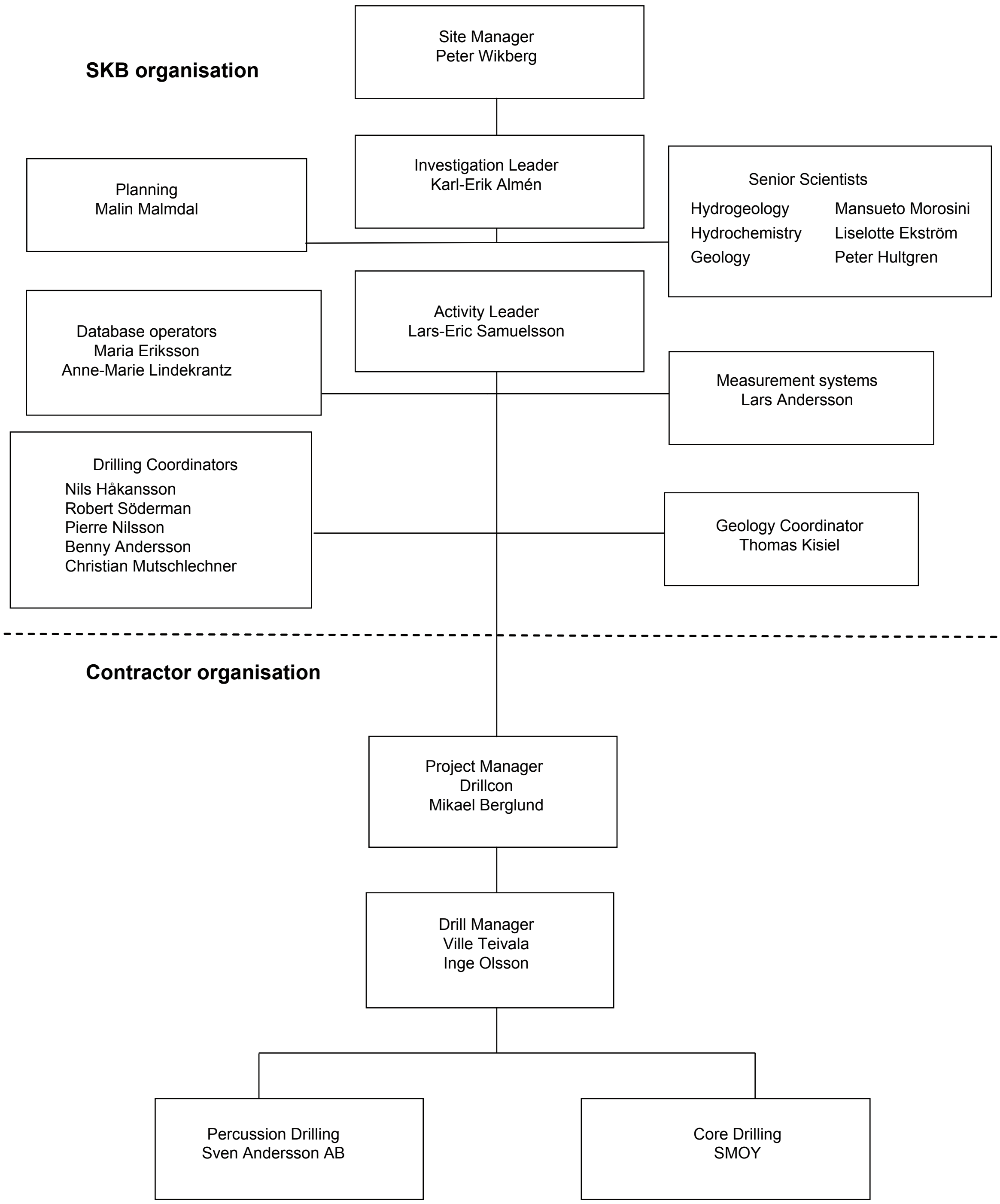
4 Contractors and equipment

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 KLX13A 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 KLX13A was made with a B20 APC Atlas Copco JKS Boyles 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 KLX13A.

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 4-1.

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

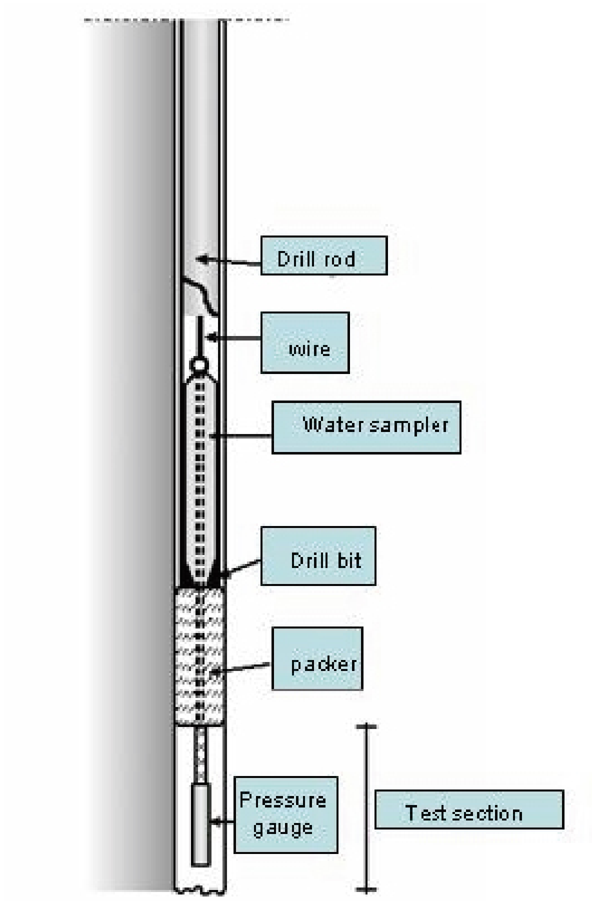


Figure 4-1. The wireline probe and its emplacement in the hole.

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

No measurements of absolute pressure were done in KLX13A.

4.3.2 Drilling monitoring system

During the core drilling phase continuous 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 disk to the DMS database.

4.3.3 Deviation measurements

Two types of deviation measurements were made:

- Measurements to keep track on the borehole orientation were made with the magnetometer/accelerometer method Reflex EZ-AQ/EMS (or Easy-Shot) and Flexit, see also Table 5-2 and section 5.3.3.
- 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.

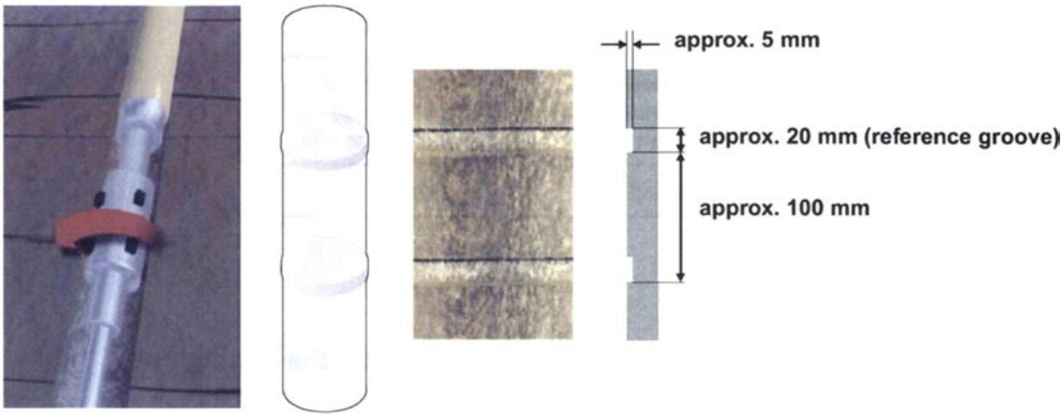


Figure 4-2. *The equipment for reaming of reference slots. To the left, the reaming tool with openings for the cutters is shown. The resulting reference slots are illustrated in the three pictures to the right.*

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 400-06-010.

5.1 Summary of KLX13A drilling

A technical summary of the drilling of KLX13A 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.

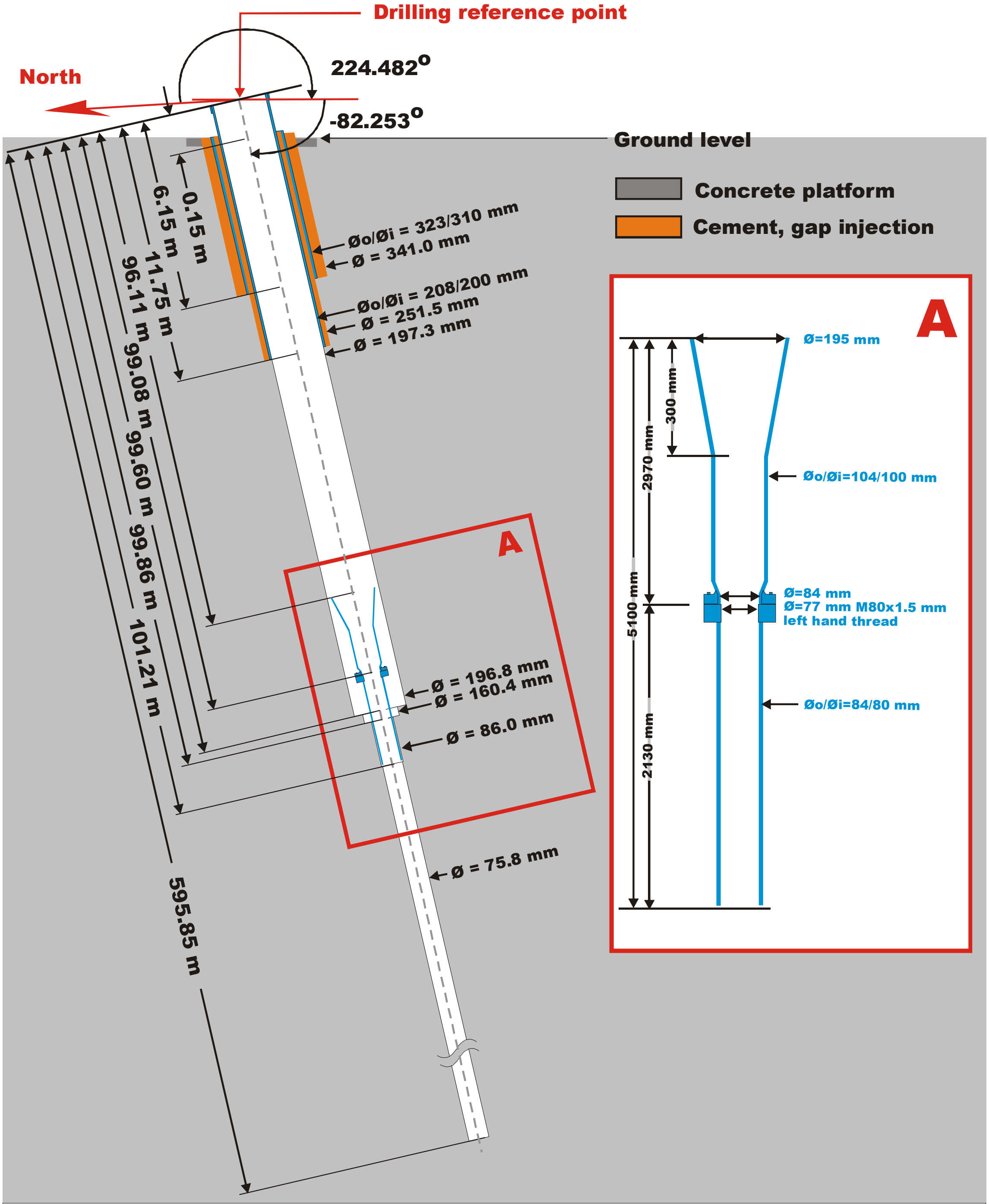
Further descriptions of the percussion drilling of the telescopic section 0–99.86 metres and the measurements performed during this phase are given in section 5.2. The core drilling between 99.86–595.85 metres is further described in section 5.3. Results from hydrogeological and hydrogeochemical measurements 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. KLX13A Technical summary.

General	Technical
Name of hole: KLX13A	*Percussion drill rig* Comacchio MC1500
Location: Laxemar, Oskarshamn Municipality, Sweden	*Percussion hole length* 99.60 m (diam 196.8 mm) 99.86 m (diam 160.4 mm)
Contractor for drilling	
Drillcon AB	*Core drill rig* B20 APC Atlas Copco
Subcontractor percussion drilling	*Core drill dimension* N-size (76 mm)
Sven Andersson AB	*Cored interval* 99.86–595.85 m
Percussion drill start date March 23, 2006	*Diamond bits used* 6 *Average bit life* 83 m
Completion date March 30, 2006	*Position KLX13A (RT90 RH70) at top of casing:* N 6367547.144 E 1546787.363 Z 24.15 (m.a.s.l.)
Subcontractor core drilling	*Azimuth (0–360) / Dip (0–90)*
Suomen Malmi OY (SMOY)	224.482 / –82.253
Core drill start date May 19, 2006	*Position KLX13A (RT90 RH70) at 595.85 m length:* N 6367500.00 E 1546730.23 Z –567.07 (m.a.s.l.)
Completion date August 16, 2006	*Azimuth (0–360) / Dip (0–90)* 229.01 / –83.22

Technical data

Borehole KLX13A



Drilling reference point

Northing: 6367547.144 (m), RT90 2,5 gon V 0:-15

Easting: 1546787.363 (m), RT90 2,5 gon V 0:-15

Elevation: 24.153 (m), RHB 70

Drilling period

Drilling start date: 2006-05-19

Drilling stop date: 2006-08-16

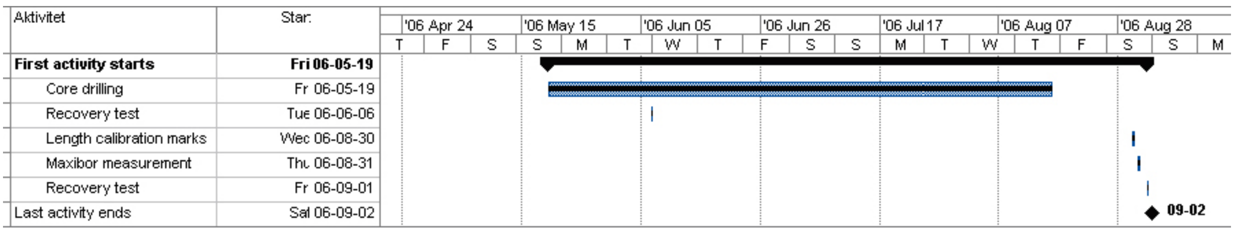
Ver 2007-04-12

Figure 5-1. *Technical data from KLX13A.*

Table 5-2. Summary of core drilling progress and borehole measurements in KLX13A.

bh metres	Drilled length, pumping tests and water sampling	Airlift pumping with evaluation of drawdown and/or recovery	Deviation measurement	Miscellaneous
			Borehole collar survey (drilled length 0 m) Azimuth 224.48 Dip –82.2	
100	060511 Pumping test 11.75–99.75 m. Water flow 19 L/min at 25.5 m drawdown.			
			060520 Flexit at 126 m Azimuth 232.6 Dip –82.8	
200	060523 Pumping test 102.55–194.25 m. Water flow 3 L/min at 19 m drawdown. Water sample taken			060523 Sample for microorganism content taken in the flushing water
300	060531 Pumping test 193.20–320.25 m. Water flow 5.8 L/min at 19 m drawdown. Water sample taken		060529 Flexit at 291 m Azimuth 234.7 Dip –83.0	
400	060605 Pumping test 320.00–397.39 m. 8.2 L/min at 8 m drawdown. Water sample taken	060606 Airlift pumping 11.75–397.39 m. No drillstem in borehole.	060606 Flexit at 395 m Azimuth 236.0 Dip –82.8	
			060611 Flexit at 445 m Azimuth 239.0 Dip –82.7	060609 A momentary loss of flushing water pressure was noted at 451.33 m. Two pumping tests (060609 and 060610), over short secions, were attempted but both failed due to the presence of drill cuttings in the borehole.
500	060614 Pumping test 395.70–487.30 m. 11 L/min at 12 m drawdown. Water sample taken			
			060809 Flexit at 537 m Azimuth 230.5 Dip –83.0	
600	060824 Pumping test 486.85–595.85 m. 2.2 L/min at 15 m drawdown. Water sample taken	060901 Airlift pumping 11.75–595.85 m. No drillstem in borehole.	060831 Maxibor att 591 m Azimuth 228.9 Dip –81.8	060822 KLX13A was discontinued at drilled length 595.85 m following a decision from meeting SUMP#8.

Table 5-3. Chronological summary of main core drilling events in KLX13A.



5.2 Drilling, measurements and results in the telescopic section 0–99.86 m

Drilling, reaming and grouting (gap injection) were made from February 22 to March 8, 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 (0–99.86 metres) of KLX13A 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 6.15 m length with NO-X 280 mm equipment. This gave a hole diameter of 340 mm and left a casing (323/310 mm diameter) to a length of 6.15 m.
- Inner supportive casing for guidance for the drill string was mounted.
- A pilot percussion hole was drilled to a depth of 99.86 m. The starting diameter was 161.0 mm and the diameter at full length was 160.4 mm. No deviation measurements were done after the pilot drilling.
- Reaming to diameter 251.5 mm was done from 6.15 to 11.75 m.
- Stainless casing of 208×4 mm was installed from 0 to 11.75 m.
- Casing grouting (gap injection) with low alkali cement based concrete (735 litres) was made for both sets of casing. The outer casing was cut along the ground surface.
- After the concrete had hardened the borehole was rinsed and flushed to remove loose concrete and water. The tightness of the concrete seal (casing grouting) was made by measuring the water table recovery.

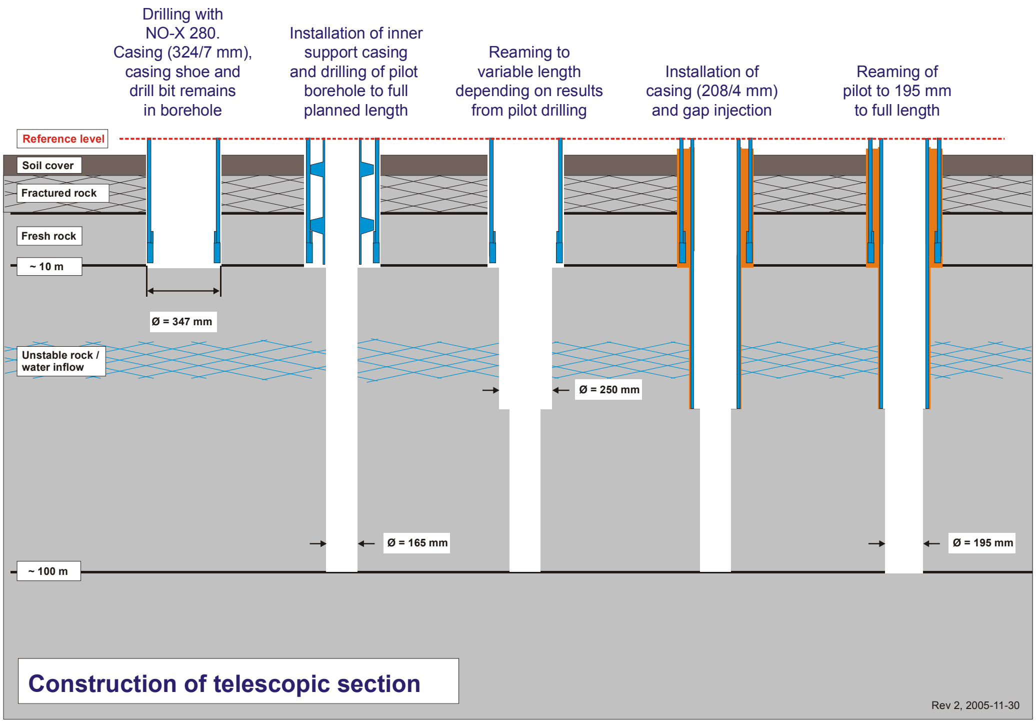


Figure 5-2. *Construction of the telescopic section. The cement for casing grouting is introduced between the casing and the rock wall. The drill bit acts as a barrier so that cement does not enter the pilot hole.*

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 (TOC) was 1.0 m. The depth of overburden (ground surface to rock) was 0.85 metres i.e. the drilling reference level (TOC) was located 15 cm above the concrete slab. No natural soils were encountered, the overburden consisted of concrete and gravel fill.

The percussion drilling was started in dry but fractured rock. Water was encountered first at ca 8 m. The flow was measured at 11.3 m to 6 L/min. This water flow was successfully sealed of by casing grouting. The results from the preliminary geological logging, measurements of magnetic susceptibility in the drill cuttings and water flow during drilling are given in Figure 5-3.

5.2.4 Hydrogeological measurements and results from the telescopic section 11.75–99.86 m

Measurements of water inflow during drilling were made as shown in Figure 5-3. The final inflow after pilot drilling (160 mm diameter) to full length was 11 L/min.

A single-hole pumping test was performed in open borehole in the percussion drilled part of KLX13A between 11.75 and 99.86 m. The test was made between May 11 and 13, i.e. after installation of the 208 mm casing and casing grouting. The result is shown in Table 5-4 below. The pumping phase was 24h and 12 min, and the recovery phase was 24h and 17 min.

5.3 Core drilling KLX13A 99.86–595.85 m

Core drilling in KLX13A was conducted between May 19 and August 16, 2006.

The main work in KLX13A after drilling the telescopic section consisted of the following steps:

- preparations for core drilling,
- flushing and return water handling,
- core 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.

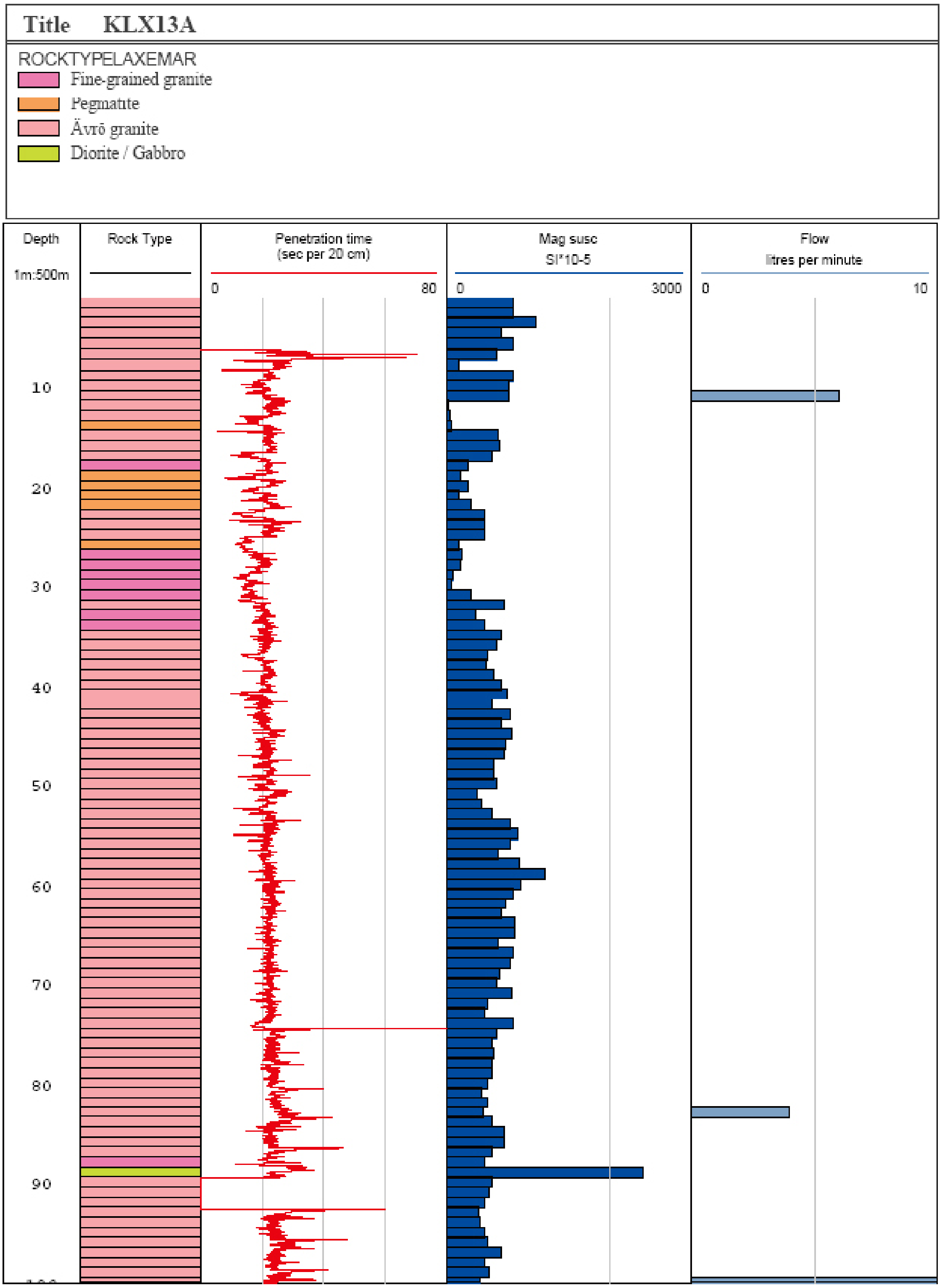


***Figure 5-3.** Preliminary geological results based on logging of drill cuttings and penetration rate from percussion drilling of KLX13A.*

Table 5-4. Results from single-hole pumping test in open borehole KLX13A, 11.75–99.74 m.

Tested section [m]	Q/s [m²/s]	T_M [m²/s]	Comments
11.75–99.86	1.2 10^{-5}	1.4 10^{-5}	Pumping test without wireline probe.

5.3.1 Preparations

The preparations for core drilling started on May 7, 2006 and consisted of mounting the drill rig, 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 99.86 and 100.36 m with T-86 equipment. An inner supportive casing with diameter 84/77 mm was installed to 100.36 m.

The supportive casings have a perforated section between 99.20 and 99.60 m 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 m.

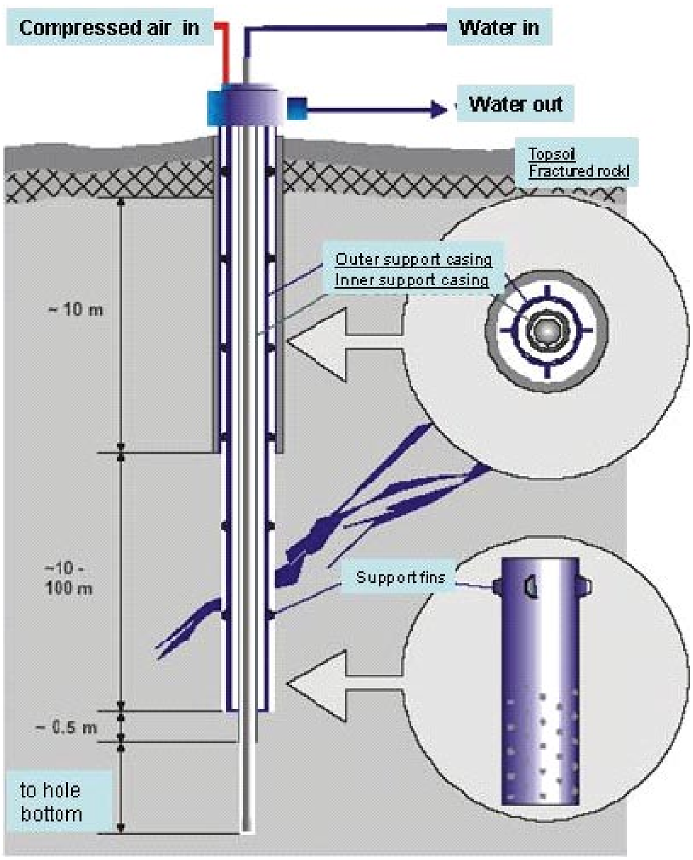


***Figure 5-4.** In the telescopic part of the drill hole a temporary installation is made with casing tubes for support and alignment and equipment for air-lift pumping. In the uppermost part the return water discharge header is mounted. The water discharge is led to the settling containers.*

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 stripping (removal) of oxygen with nitrogen gas 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 KLX13A 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 0.219 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 and deviation measurements KLX13A

Core drilling with T-86 equipment giving an 86 mm diameter hole was done from 99.86 to 101.21 m in KLX13A. The part from 100.36 to 101.21 m was first drilled with N-size and subsequently reamed to T-86 as part of the borehole completion, see section 5.3.4.

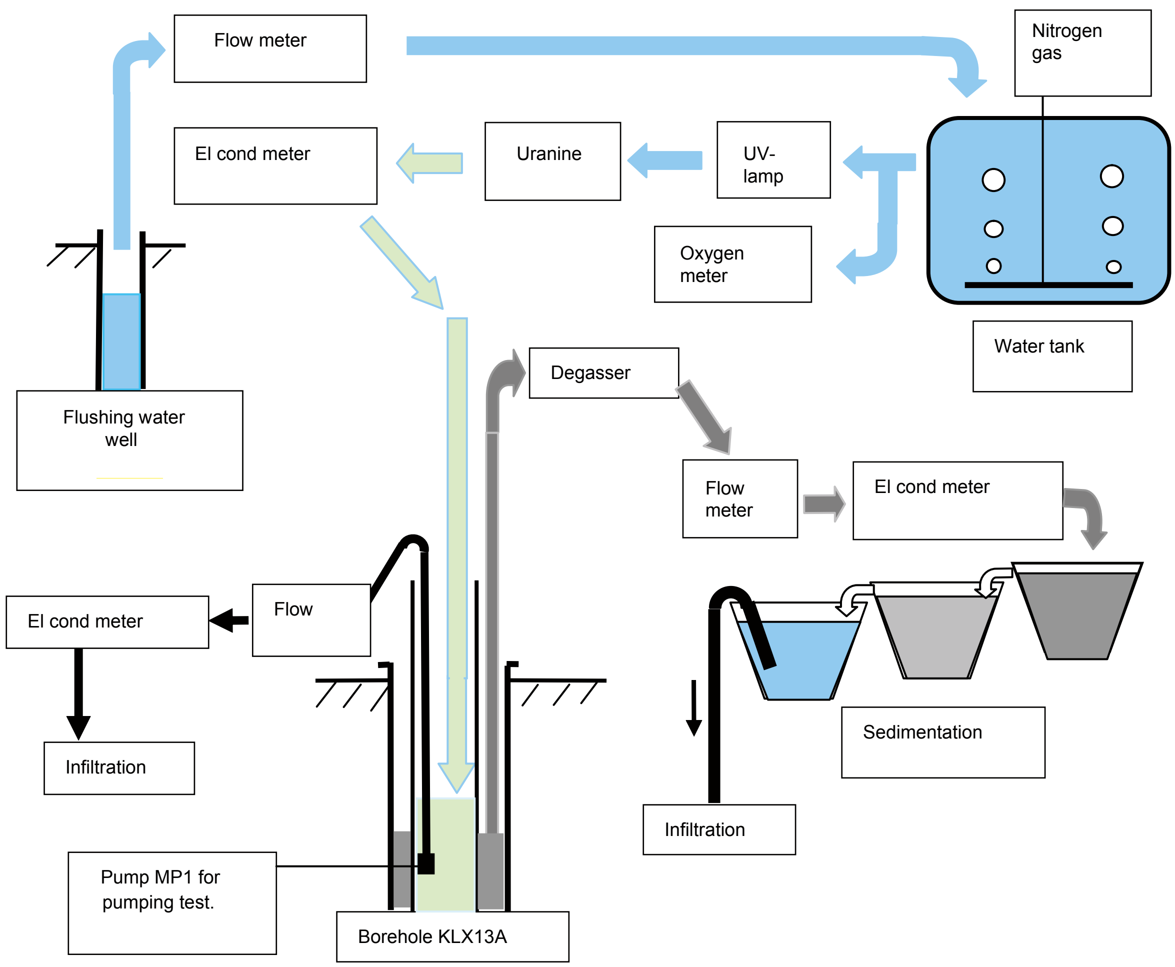


Figure 5-5. *The flushing and return water handling and the emplacement of related monitoring equipment in KLX13A.*

Core drilling with N-size (76 mm) triple-tube, wireline equipment was conducted from 101.21 m to the final length of 595.85 m in KLX13A.

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

Directional drilling, i.e. intentional change of direction or dip of the borehole was not made in KLX13A.

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 Flexit method five times along the borehole. The results from this measurement are not stored in the Sicada database but are given in a summary fashion in Table 5-2.

Measurements were done with the Flexit and Maxibor methods for the final evaluation of the borehole deviation in KLX13A. The Maxibor measurement was done as part of the drilling activity whereas the Flexit measurement was done as part of a separate geophysical logging activity. The Flexit tool was run both up and down the borehole from 0 to 594 m, however only data down to 591 m was used in the final calculation. In addition measurements with the Maxibor instrument were performed both up and down the hole between 0 and 591 m. The Flexit readings for bearing were only used in intervals where the magnetic disturbances from installations in the borehole (casings, steel conical guide etc) were deemed to be minimal.

The final deviation file in KLX13A is calculated based on the measurements given in Table 5-6 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/.

Table 5-5. Core diameters, borehole diameters and drilling dimensions during core drilling in KLX13A.

Core diameter (mm)	Borehole diameter (mm)	Interval (m drilled length)	Drilling dimension or directional drilling method	Comment
72.0	86	99.86–100.36	T-86	
50.2	86	100.36–101.21	N and T-86	Reamed to 86 mm diameter
50.2	76	101.21–595.85	N	

Table 5-6. Measurements used for borehole deviation calculation in KLX13A.

Deviation measurement method	Used for calculation of bearing/inclination	Interval From (m)	Interval To (m)	Measuring direction	Date	Sicada database activity ID
Maxibor	Bearing	3.00	591.00	in/down	2006-08-31	13120921
Maxibor	Bearing	3.00	591.00	out/up	2006-08-31	13142365
Flexit	Bearing	27.00	81.00	in/down	2006-09-19	13142373
Flexit	Bearing	117.00	591.00	in/down	2006-09-19	13142373
Flexit	Inclination	3.00	591.00	in/down	2006-09-19	13142373
Flexit	Bearing	27.00	81.00	out/up	2006-09-20	13142385
Flexit	Bearing	117.00	591.00	out/up	2006-09-20	13142385
Flexit	Inclination	3.00	591.00	out/up	2006-09-20	13142385

Horizontal and vertical plots of the results of the calculated deviation covering the entire length of borehole KLX13A are given in Appendix 4.

Core losses were noted during the Boremap mapping, see section 5.6, at the intervals given in Table 5-7. Core losses, of a similar magnitude as given in Table 5-7, were also noted during the preliminary logging of the core.

A total of six drill bits were used for KLX13A, see Figure 5-6.

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 September 18, 2006, SKB id no 1060430, SKB internal document.

Table 5-7. Core losses noted in KLX13A.

From (m)	To (m)	Core loss length (m)	Comment
473.068	473.150	0.082	Mechanical
487.050	487.241	0.191	Crushed Zone
494.846	495.305	0.459	Missing Core Piece
497.621	497.821	0.200	Missing Core Piece
503.301	504.998	1.697	Missing Core Piece
515.420	515.500	0.080	Missing Core Piece
520.543	520.932	0.389	Missing Core Piece
524.408	524.527	0.119	Soft Filling
541.452	541.576	0.124	Missing Core Piece
543.767	543.967	0.200	Missing Core Piece
592.712	592.740	0.028	Missing Core Piece

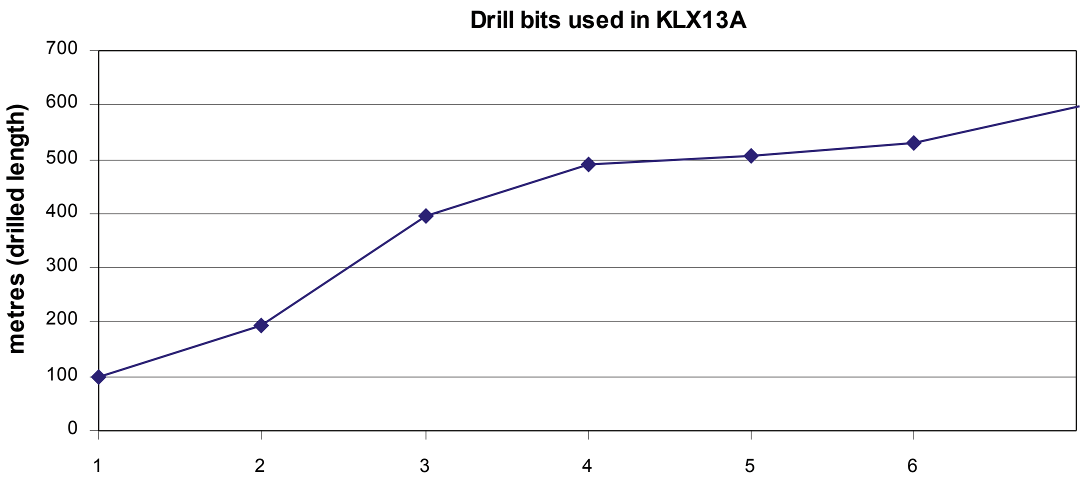


Figure 5-6. *Drill bit changes during core drilling in KLX13A.*

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

- BIPS logging was done for evaluation of structural geological and borehole wall stability properties from 380 to 545 m on August 10.
- Diamond drilling completed at 595.85 m on August 16.
- A decision was taken on August 17 not to stabilize the borehole ("Riskvärdering KLX13A, Beslut om stabilisering"), 2006-08-22, SKB id 1058699, internal document.
- Flushing and brushing with high water pressure on the borehole wall was done along intervals as given in Table 5-8. The selection of the intervals to rinse was based on study of the drill core and the available BIPS images. 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 595.85 m). 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 were made without stability problems.
- BIPS logging for final risk assessment was done along the full drilled length.

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

Borehole completion

Reaming of depth reference slots was done at the drilled lengths shown in Table 5-9. 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 5-8. Borehole sections that were mechanically rinsed by water flushing and rotating steel brush.

From (bh length m)	To (bh length m)
173	178
254	256
348	392
399	405
423	425
434	436
464	467
472	475
481	485
487	506
511	529
532	547
550	559
562	569
572	595.85

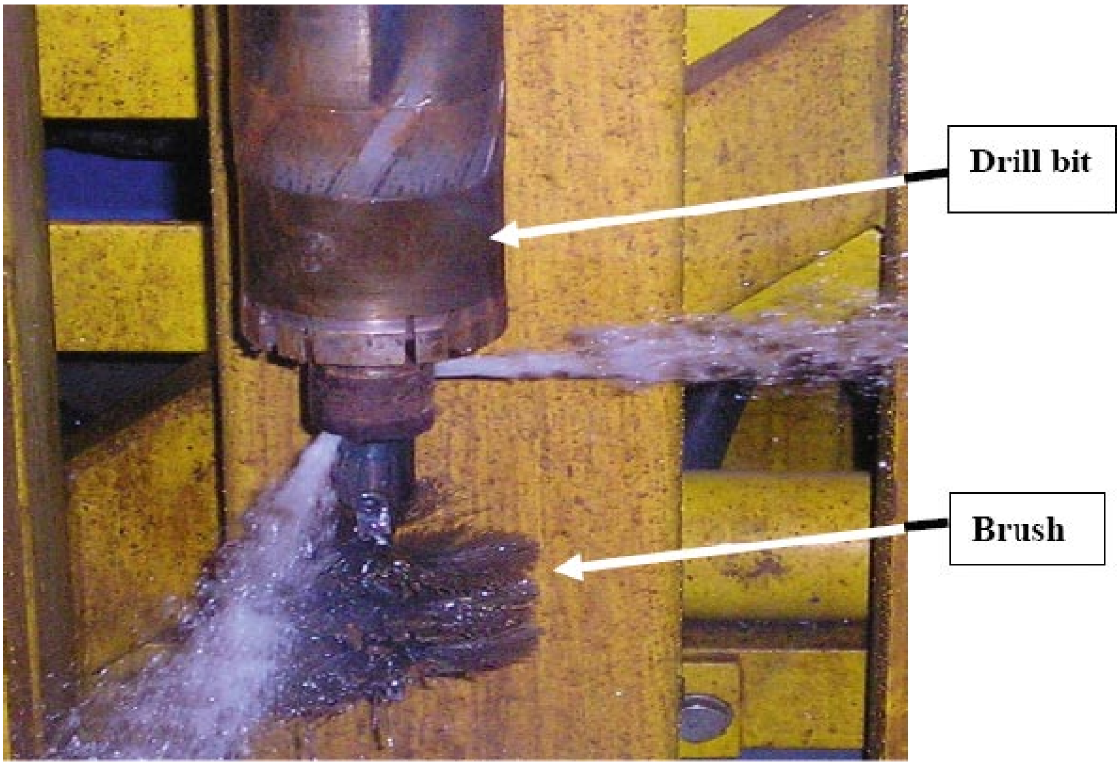


Figure 5-7. *The water flushing and rotating steel brush tool. The tool is lowered into the drill stem and can be seen in place just below the drill bit. During operating the drill string is moved up and down to remove loose rock fragments from the borehole wall.*

Table 5-9. Depth reference slots (m) in KLX13A.

110.00	400.00
150.00	450.00
200.00	500.00
250.00	550.00
300.00	581.00
350.00	

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

The borehole was reamed from 100.36 to 101.21 with T-86 equipment. A steel conical guide was installed in KLX13A between 96.11 m and 101.21 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 5-10.

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.

Table 5-10. Nitrogen gas flushing in KLX13A (time is given in local time including daylight saving time i.e. GMT+2).

Date	Time	Interval (m)	Volume removed (m^3)
060906	15.34–15.48	11.75–595.85	7
060906	16.33–16.50	11.75–595.85	5
060907	06.20–06.37	11.75–595.85	7
060907	07.13–07.33	11.75–595.85	7
060907	08.10–08.32	11.75–595.85	5

5.4 Hydrogeological and hydrochemical measurements and results 99.86–595.85 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 fully successful pumping tests were conducted at various intervals, see section 5.4.1.
- Seven 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 KLX13A are commented in section 5.4.4.

5.4.1 Hydrogeological results from wireline measurements

Results from the wireline tests in KLX13A are presented in Table 5-11 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 ten tests were performed in KLX13A, and five achieved sufficiently stable conditions for calculating pseudo steady-state transmissivity and hydraulic conductivity. The reason behind the failed tests is mainly leakage between the casing and the tested section caused by a malfunctioning check valve. In order to diminish the potential leakage, the check valve was sealed 2006-05-04.

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 5-12.

Table 5-11. Pumping tests with wireline probe in KLX13A.

Tested section [m]	Q/s [m²/s]	T_M [m²/s]	Comments
102.55–194.25	2.2×10^{-6}	2.6×10^{-6}	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.
193.20–320.25	7.4×10^{-6}	9.9×10^{-6}	Short test, but pseudo steady state.
			Pressure in casing during transient recovery phase is unaffected by pumping test.
320.00–397.39	6.3×10^{-5}	8.0×10^{-5}	Reduced flow by the end of the pumping phase. Evaluated test period 17:43–23:50, due to reduced flow.
395.70–487.3	5.1×10^{-5}	6.6×10^{-5}	Pressure in casing during transient recovery phase is unaffected by pumping test.
486.85–595.85	2.9×10^{-6}	3.8×10^{-6}	Pressure in casing during the test is unaffected by pumping.
			The flow rate decreases somewhat at the end of the flowing period. Correspondingly the section pressure increases.

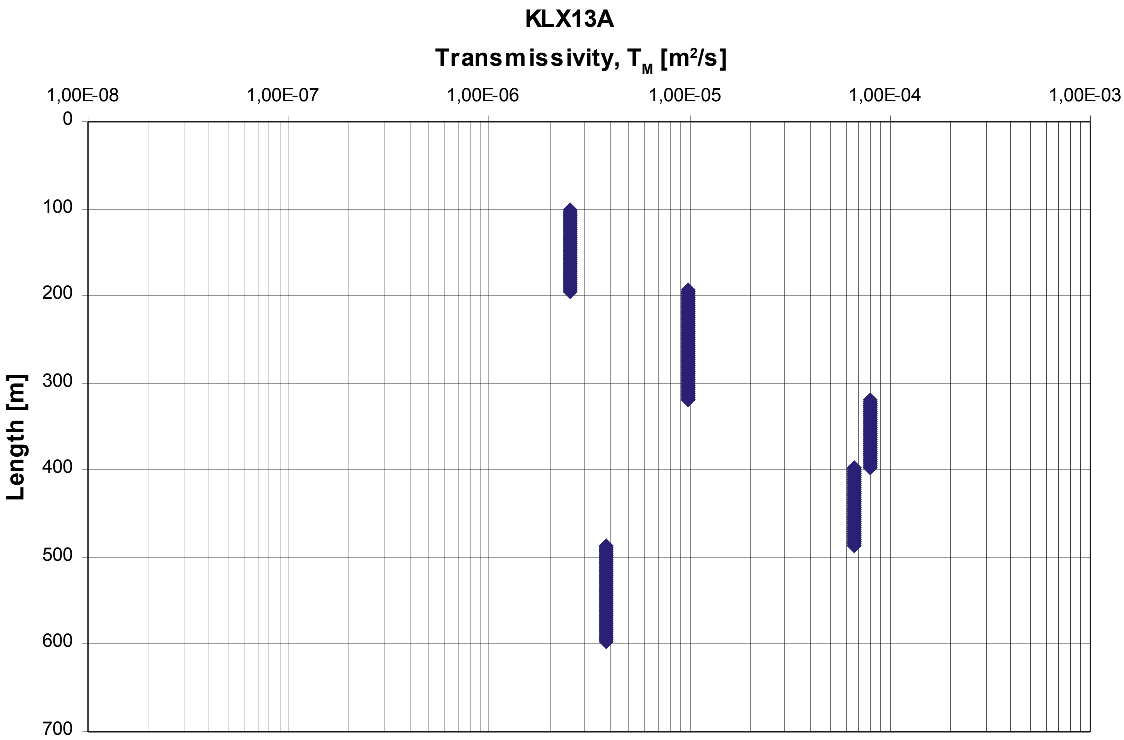


***Figure 5-8.** Transmissivity from wireline pumping tests in KLX13A versus borehole length.*

Table 5-12. Evaluated test periods.

Tested section	Start (YYYY-MM-DD HH:MM)	Stop (YYYY-MM-DD HH:MM)
102.55–194.25	2006-05-23 17:54	2006-05-24 03:12
193.20–320.25	2006-05-31 17:21	2006-06-01 02:36
320.00–397.39	2006-06-05 17:00	2006-06-06 02:18
395.70–487.30	2006-06-14 16:46	2006-06-15 03:21
486.85–595.85	2006-08-24 09:30	2006-08-24 15:20

5.4.2 Hydrochemistry

Seven water samples were collected in connection with core drilling in KLX13A. Times and lengths for the samples are given in Table 5-13.

Sampling and analysis were performed according to the SKB classes specified in Table 5-13. The samples were collected from 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.

The samples 11148 and 11149 were discarded due to probable leakage in the wireline probe during sampling. It was therefore decided not to analyse these samples for main components and isotopes. Since sample 11149 also had a relatively high amount of drilling water it was not analysed further. 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.

Sample 11089 was not analysed for isotopes since it was collected from a shallow section in the borehole.

Samples 11117, 11149 and 11170 were not analysed further since they had a relatively high amount of drilling water, see Table 5-14.

Collected bottles for isotope analysis from the samples 11089 and 11148 are stored in freezer at the Äspö laboratory. Water for tritium and carbon isotopes analysis is stored in a refrigerator. Water for analysis of main components from sample 11148 is also stored at the Äspö laboratory.

Archive samples have been collected for the samples 11089, 11116, 11148 and 11294. The samples are stored in a freezer at the Äspö laboratory.

Selected analytical results from KLX13A are given in Table 5-14. A complete record of analytical results is given in Appendix 2.

Table 5-13. Sample dates and length during core drilling in KLX13A.

Sample number	Borehole	Date	Test section, length (m)	SKB chemistry class
11089	KLX13A	2006-05-24	102.55–194.25	3 (isotope options not included)
11116	KLX13A	2006-06-01	193.20–320.25	3 (and all option isotopes)
11117	KLX13A	2006-06-06	320.00–397.39	1 (only drill water percentage)
11148	KLX13A	2006-06-10	442.85–451.33	3 (no main components or isotopes)
11149	KLX13A	2006-06-11	442.85–463.79	3 (only drill water percentage)
11170	KLX13A	2006-06-15	395.70–487.30	1 (only drill water percentage)
11294	KLX13A	2006-08-25	486.85–595.85	3 (and all option isotopes)

Table 5-14. Analytical results from water chemistry sampling.

Borehole	Sample no	Date	From m	To m	Drill water %	pH	Conductivity mS/m	Cl mg/l
KLX13A	11089	2006-05-24	102.55	194.25	11.10	8.16	59.8	56.0
KLX13A	11116	2006-06-01	193.20	320.25	1.69	7.88	51.5	57.2
KLX13A	11117	2006-06-06	320.00	397.39	43.50	–	–	–
KLX13A	11148	2006-06-10	442.85	451.33	12.10	8.11	221.0	607.0
KLX13A	11149	2006-06-11	442.85	463.79	34.90	–	–	–
KLX13A	11170	2006-06-15	395.70	487.30	39.20	–	–	–
KLX13A	11294	2006-08-25	486.85	595.85	16.90	7.32	360.0	1,070.0

The percussion drilled borehole HLX14 was used as water source during the drilling of KLX13A.

No water samples were collected from HLX14 in connection with the drilling of KLX13A. However, water samples have been collected from HLX14 in conjunction with drilling of borehole KLX03 and results from those analyses are reported in /5/.

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

Sampling for uranine tracer content and electrical conductivity

From KLX13A, 107 samples were taken along the borehole for analysis of uranine content and electrical conductivity in flushing and returning water.

The results are shown graphically in Figure 5-9. All the samples were analysed at the Äspö laboratory.

The calculated average uranine content for the whole borehole is 0.219 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.

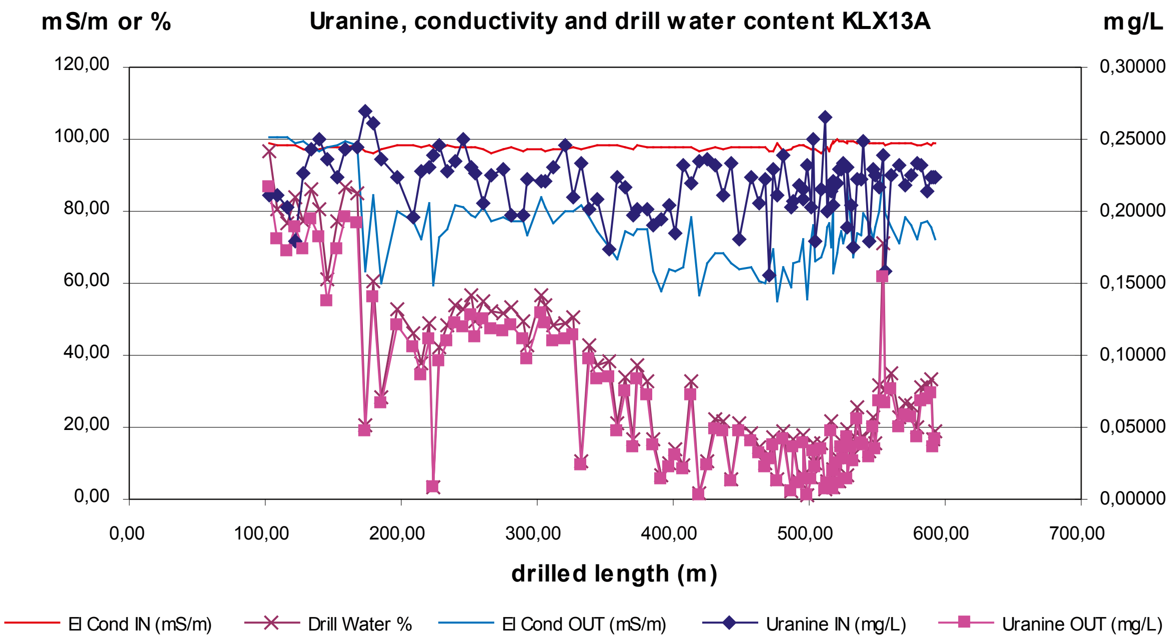


Figure 5-9. The uranine concentration and electrical conductivity of the flushing water (IN) and the return water (OUT) in KLX13A. The drill water content in the returning water is also shown.

Sampling of microbes

A total of 16 samples were taken in order to determine the micro organism content within the flushing water system. They were all collected after cleaning the flushing water system. Half of the samples were collected on June 15. The rest of the samples were collected on August 17. The samples were taken from four different locations within the flushing water system. The results are reported in /6/.

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

One airlift pumping test 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 /3/, as well as the specific capacity, *Q/s*. The results, shown in Table 5-15, are 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.

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. Hydraulic responses from drilling activities in KLX13A were monitored in a number of observation boreholes. The location of the observation boreholes is shown in Figure 5-17. No data from the water levels in boreholes KLX20A or HLX20 were available for the relevant timespan, these two boreholes are nevertheless included in Figure 5-17.

Hydraulic responses in near-by boreholes from percussion of the telescopic section in KLX13A

No hydraulic responses from percussion drilling in KLX13A could be seen in the observation boreholes HLX34, HLX35, HLX36, HLX37 or KLX06. Boreholes HLX39, HLX40 and HLX41 were not yet drilled at the time when the percussion drilling of the telescopic section in KLX13A took place. No data from the water levels in boreholes KLX20A or HLX20 were available.

A plot showing the water table in observation boreholes HLX34, HLX35 and KLX06 (sections 1 and 2) during percussion drilling of the telescopic section in KLX13A is given in Figure 5-12.

Table 5-15. Results from airlift pumping in KLX13A.

Tested section [m]	Flow rate [L/min]	Drawdown [m]	Q/s [m²/s]	T_M [m²/s]	Comments
11.75–397.39	52.5	11	8.0×10^{-5}	1.2×10^{-4}	
11.75–595.85	61.3	6.6	1.5×10^{-4}	2.5×10^{-4}	Q derives from accumulated volumes of water in and out. Q = ΣV/dt

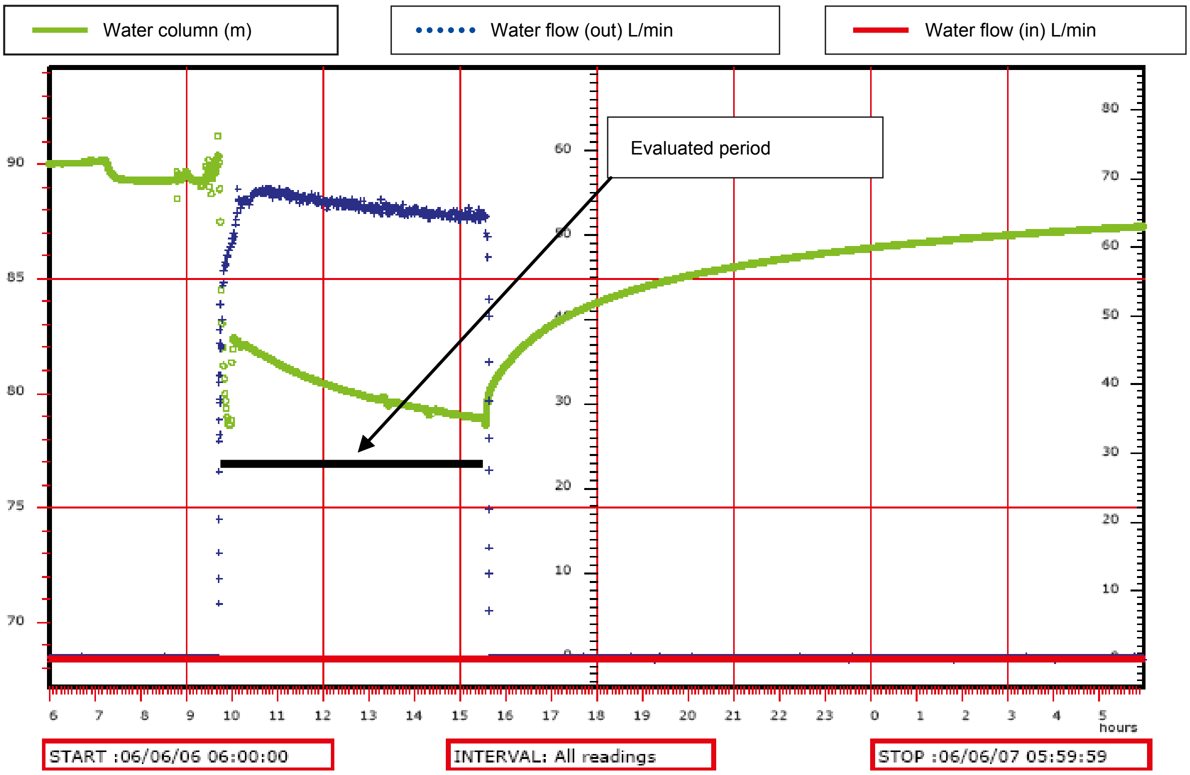


Figure 5-10. *Airlift pumping in KLX13A 11.75–397.39 m. The green line represents the height of the water column in the borehole, the out flow is shown as the blue dotted line and the inflow rate as the red line. The inflow rate was 0 L/min during the whole test period. The period for test evaluation is shown with a black bar.*

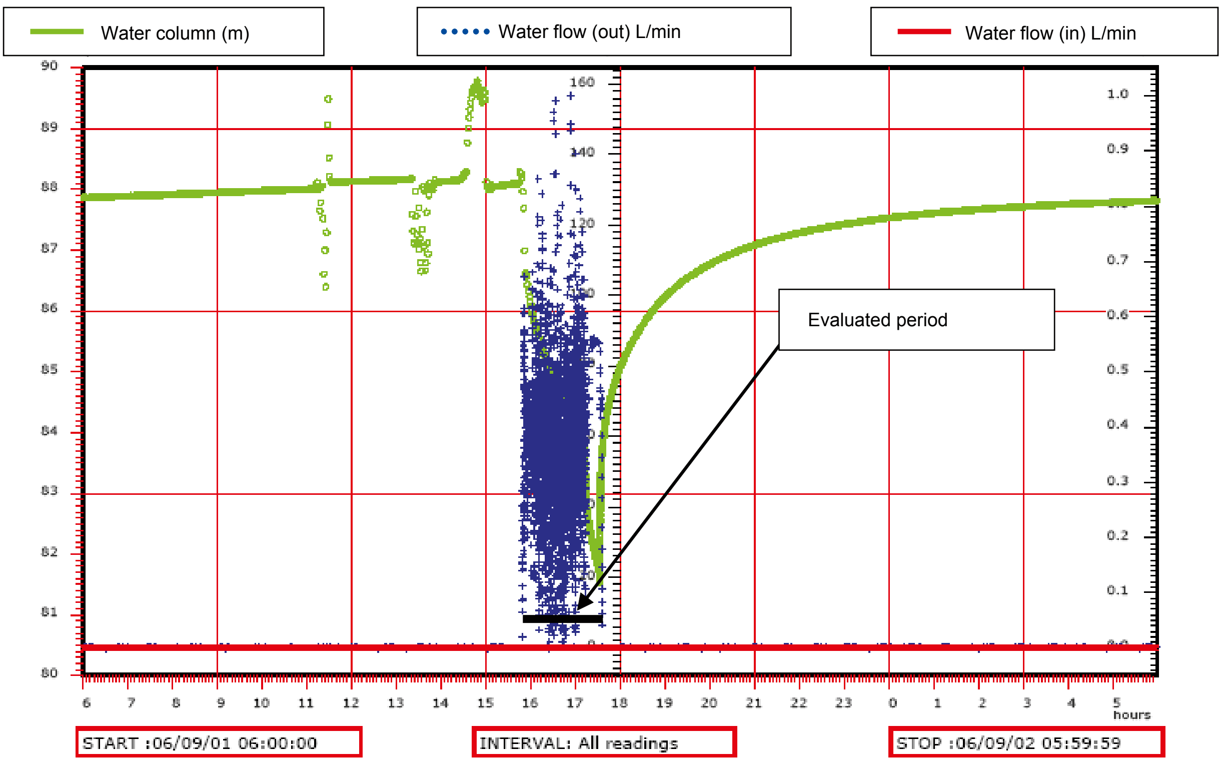


Figure 5-11. *Airlift pumping in KLX13A 11.75–595.85 m. The green line represents the height of the water column in the borehole, the out flow is shown as the blue dotted line and the inflow rate as the red line. The inflow rate was 0 L/min during the whole test period. The period for test evaluation is shown with a black bar.*

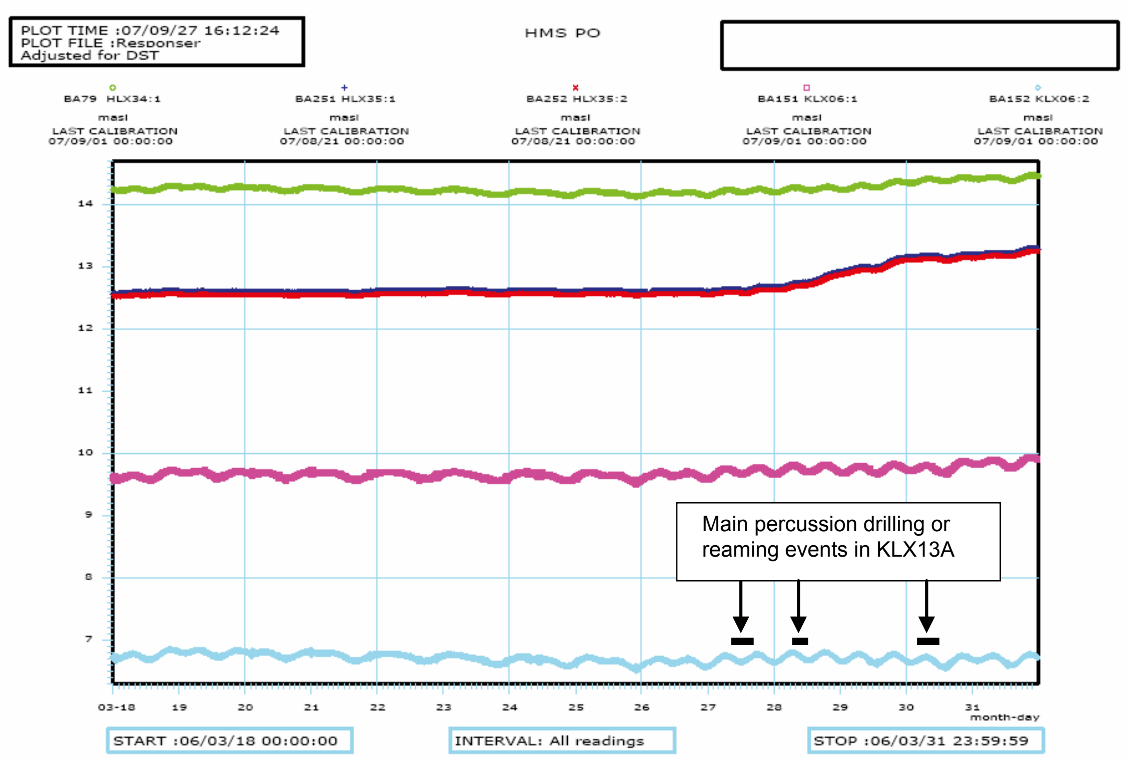


Figure 5-12. *Water table in observation boreholes HLX34, HLX35 (both sections) KLX06 (sections 1 and 2 i.e. the deepest sections) during percussion drilling of the telescopic section in KLX13A. No response from percussion drilling in KLX13A could be seen in the observation boreholes. Times are given in DST (GMT+2) after March 25.*

Hydraulic responses in near-by boreholes from air-lift pumping during core drilling in KLX13A

A weak response in HLX39, HLX40 and HLX41 could be seen from air-lift pumping in KLX13A. No correlation between the groundwater levels in observation boreholes HLX34, HLX35, HLX36, HLX37, KLX06 and drilling activities in KLX13A could be seen.

Graphical examples of the variations of the groundwater levels in observation boreholes HLX40 and HLX41, the flushing water well HLX14 and the water level in the telescopic section of KLX13A is shown together with the drill bit position during core drilling in KLX13A in Figures 5-13 and 5-14.

No data from the water levels in boreholes KLX20A or HLX20 were available.

Hydraulic responses in near-by boreholes from nitrogen gas flushing in KLX13A

Nitrogen gas flushing covering the entire length of the borehole was done twice on September 6 and three times on September 7. No hydraulic responses could be seen in observation boreholes KLX11A, KLX06, HLX34, HLX35, HLX36, HLX37, HLX39, HLX40 or HLX41. It should be stressed that no response was seen in HLX39, HLX40 or HLX41 from the nitrogen lifting i.e. from rapid hydraulic changes whereas these three percussion boreholes responded to the longer or slower shifts in water table from air-lift pumping during the core drilling phase in KLX13A.

A plot of the water table in KLX11A is given in Figure 5-15 and a plot of the water table in HLX34, HLX35, HLX36, HLX37, HLX39, HLX40 and HLX41 is given in Figure 5-16. No graphical results from observation borehole KLX06 are presented in this report. No data from the water levels in boreholes KLX20A or HLX20 were available.

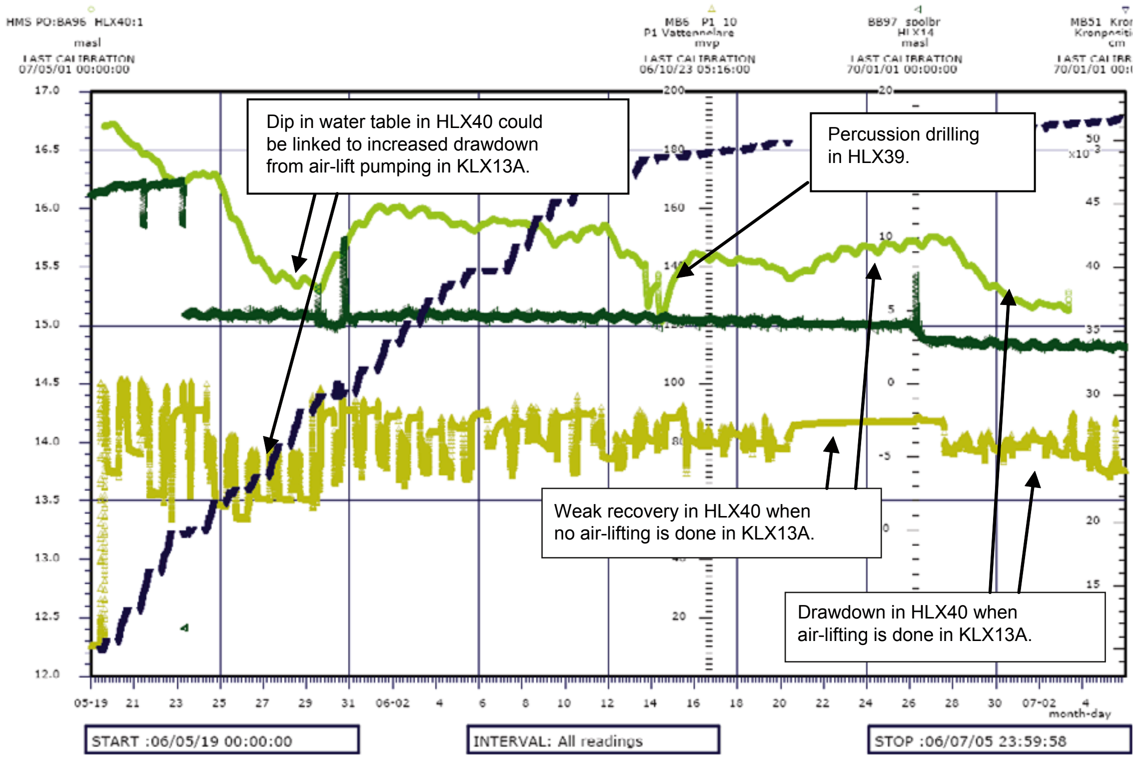


***Figure 5-13.** Groundwater levels in observation borehole HLX40, the flushing water well HLX14 and the water level in the telescopic section of KLX13A is shown together with the drill bit position during core drilling in KLX13A down to ca 515 m. A clear response from the percussion drilling of HLX39 can be seen in HLX40 (green). The reasonably clear correlation between the air-lift pumping in KLX13A (olive) and the water level in HLX40 (bright green) can also be seen.*

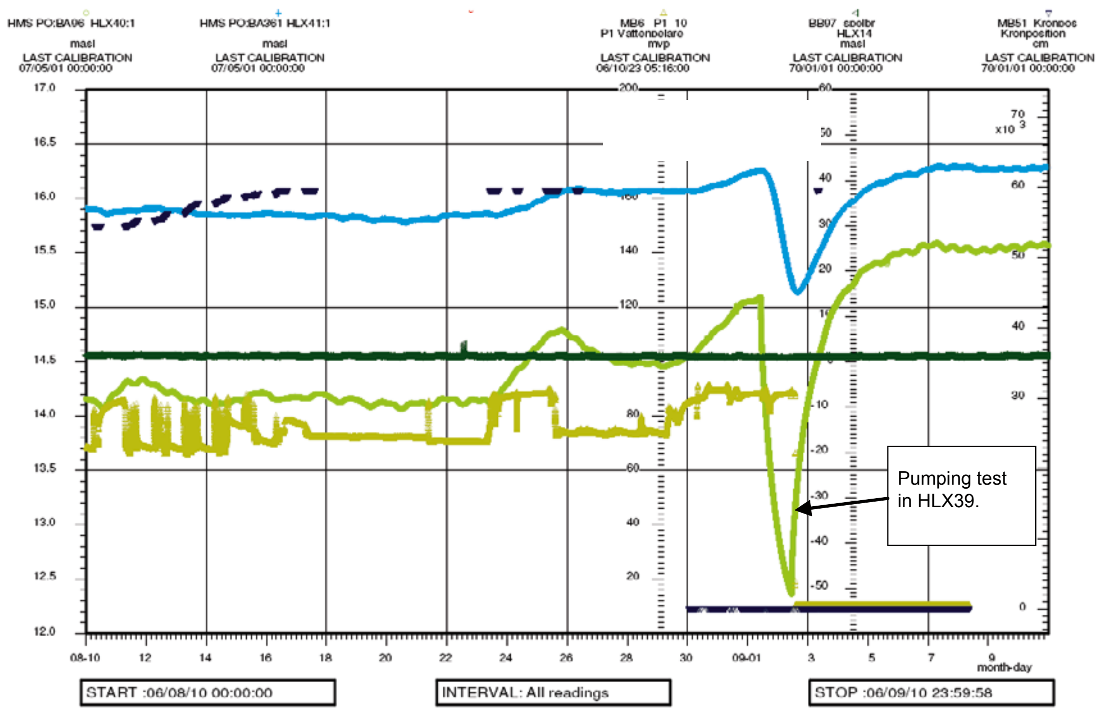


***Figure 5-14.** Groundwater levels in observation boreholes HLX40 and HLX41, the flushing water well HLX14 and the water level in the telescopic section of KLX13A is shown together with the drill bit position during core drilling in KLX13A from ca 530 to 585.95 m. A clear response from the pumping test in HLX39 can be seen in HLX40 (green) and HLX41 (blue).*

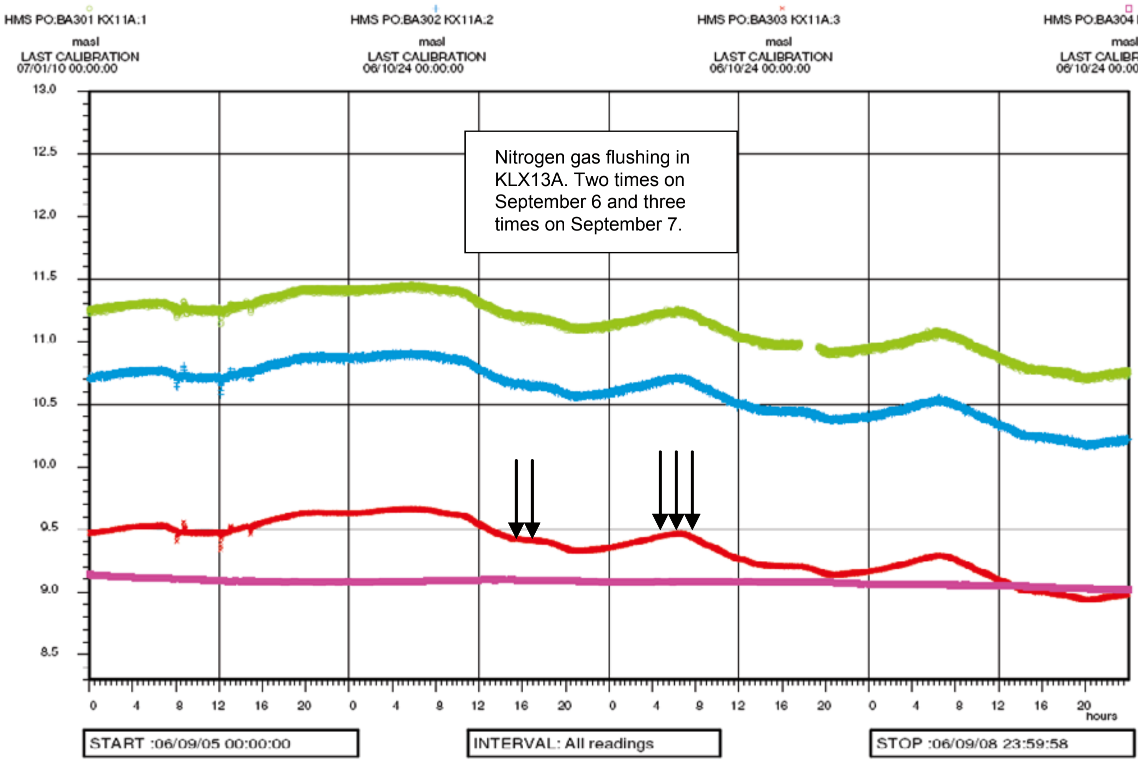


Figure 5-15. *Water levels in KLX11A during nitrogen gas flushing in KLX13A. No hydraulic response could be seen in the observation borehole KLX11A.*

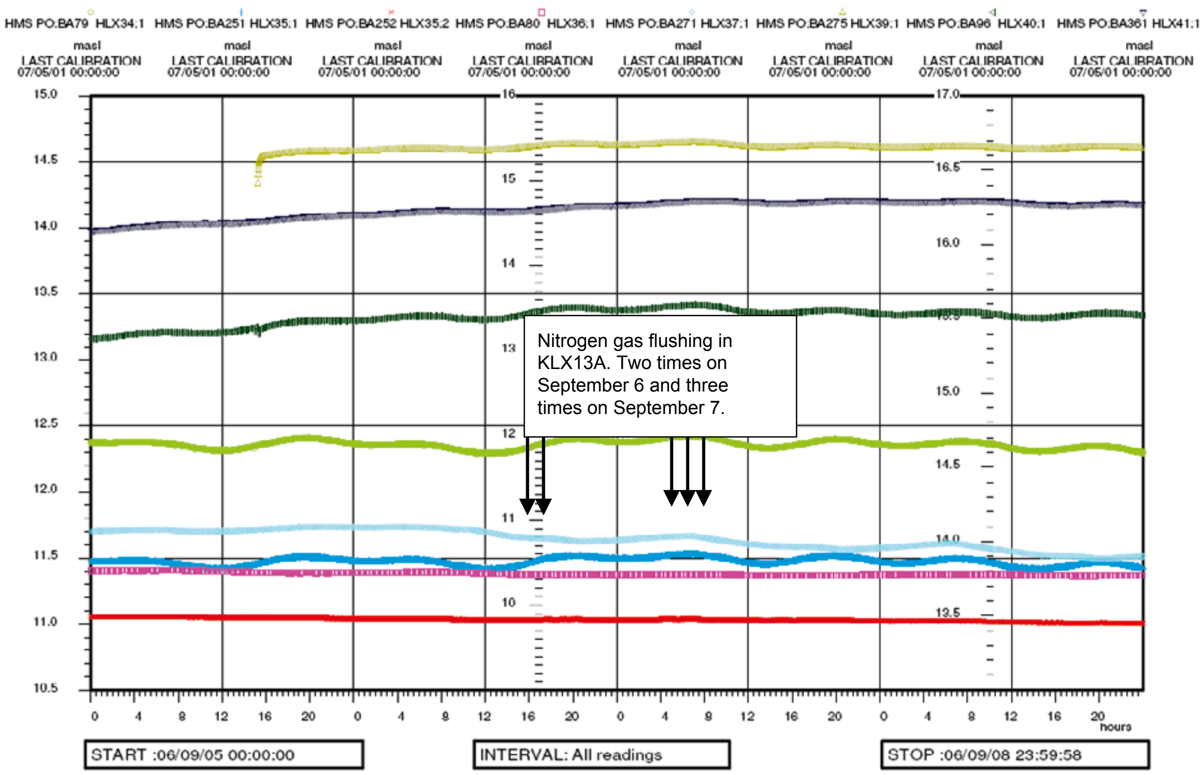


Figure 5-16. *Water levels in HLX34, HLX35, HLX36, HLX37, HLX39, HLX40 and HLX41 during nitrogen gas flushing in KLX13A. No hydraulic response could be seen in the observation boreholes.*

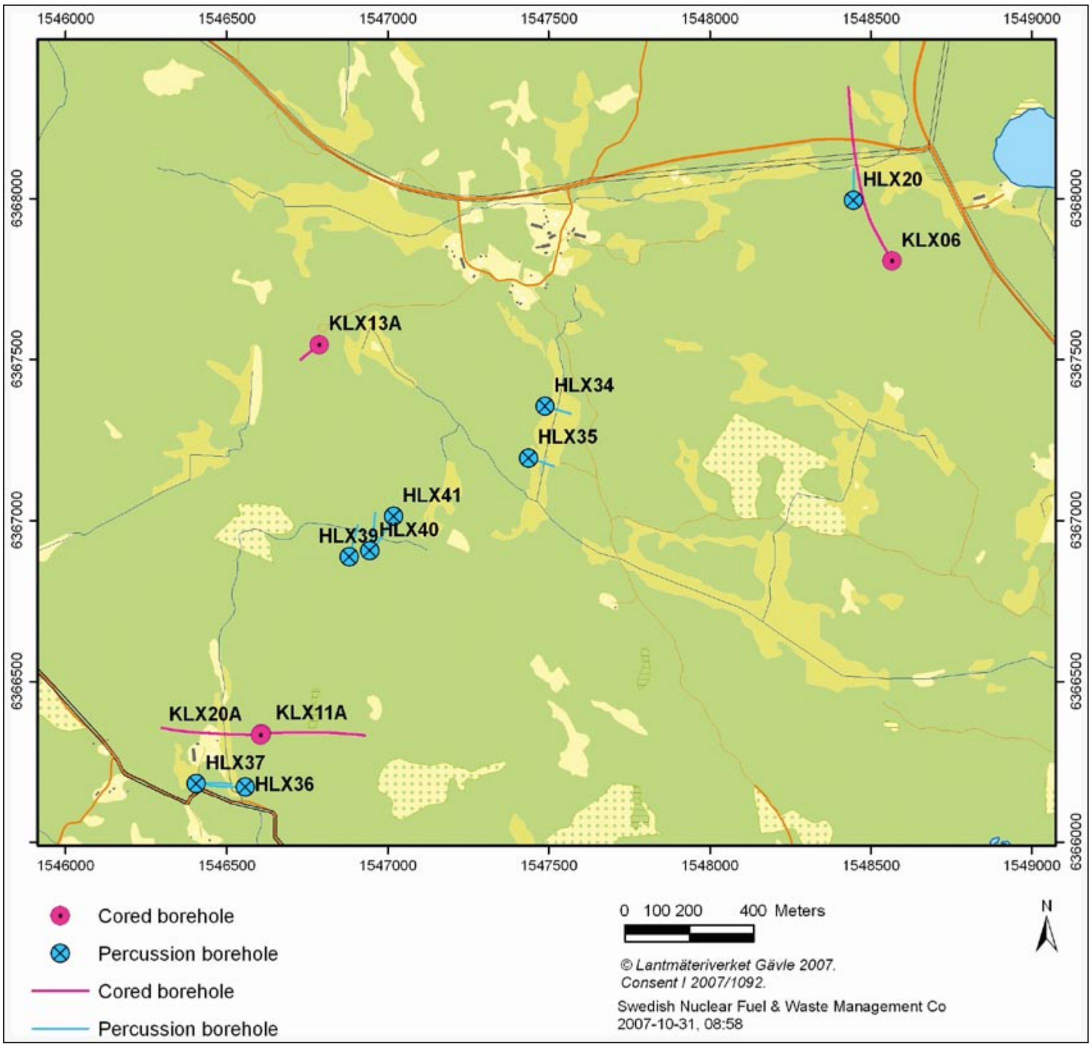


Figure 5-17. *Map showing the location of cored boreholes KLX13A, KLX06,KLX11A and KLX20A and the percussion boreholes HLX20, HLX34, HLX35, HLX36, HLX37, HLX39, HLX40 and HLX41.*

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 0–99.86 metres and the core drilling section 99.86–595.85 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.

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 5-16 through 5-18. Since DMS data are related to time (i.e. not strictly to borehole length) periods where drilling is not performed are also registered.

Figure 5-18 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 ca 40 litres/minute corresponding to pumped flow during drilling.
- A flow of 60–80 litres/minute corresponding to the flow while pumping down the core barrel.
- No flow (zero litres/minute) when no drilling is performed.

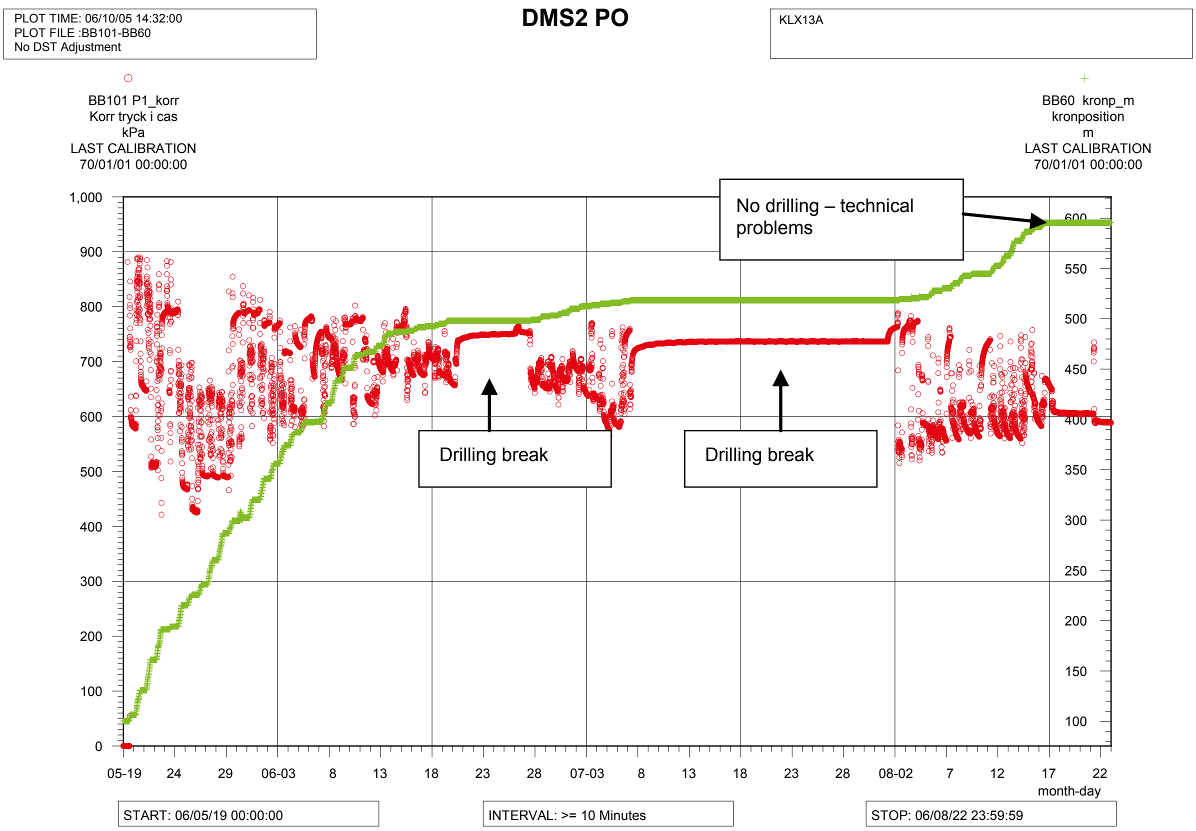


Figure 5-18. *Drill bit position (green) and water level from air-lift pumping (red). The water level is expressed as the pressure in kPa of the water column overlying the pressure gauge i.e. the ambient air-pressure has been subtracted. The pressure gauge is emplaced at 90 metres borehole length.*

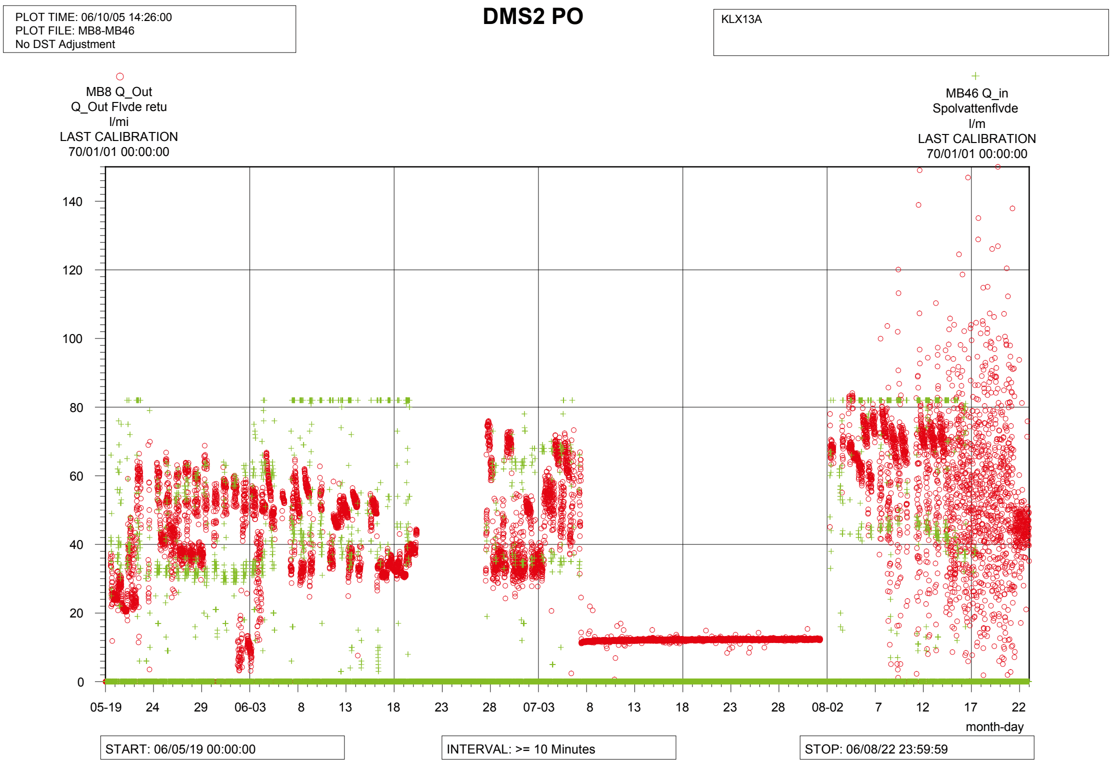


Figure 5-19. *Flushing water flow (green) and return water flow (red) in litres per minute.*

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 of the flushing water was typically low (< 5 mg/L) during periods when drilling was performed and flushing water entered the DMS system. However during periods when no flushing water was pumped into the borehole, the oxygen levels often become elevated. The periods when no flushing water is entering the borehole are clearly seen in Figure 5-19. It has also been noted that elevated oxygen levels are recorded when electrical power cuts occur. Some rather high oxygen readings were noted on June 27 and 28, i.e. just after drilling had commenced after the break between June 20 and 27. The oxygen meter was calibrated on June 28 and the readings returned to a lower, and more correct, level.

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 800 m^3, giving an average consumption of ca 1.6 m^3 per metre core drilled. The amount of effluent return water from drilling in KLX13A was measured by the DMS system to 4,000 m^3, giving an average of ca 8 m^3 per metre core drilled. It was proposed already at the time of drilling and monitoring of the return water flows that the measured flow rates were too high during the latter part of the core drilling phase.

The return water flow was 10 L/min during July when no drilling was done. The reason to pump water out of borehole KLX13A was to try and reduce the amount of uranine tracer i.e. reduce the flushing water content in the return water, to improve the quality of the water chemistry samples.

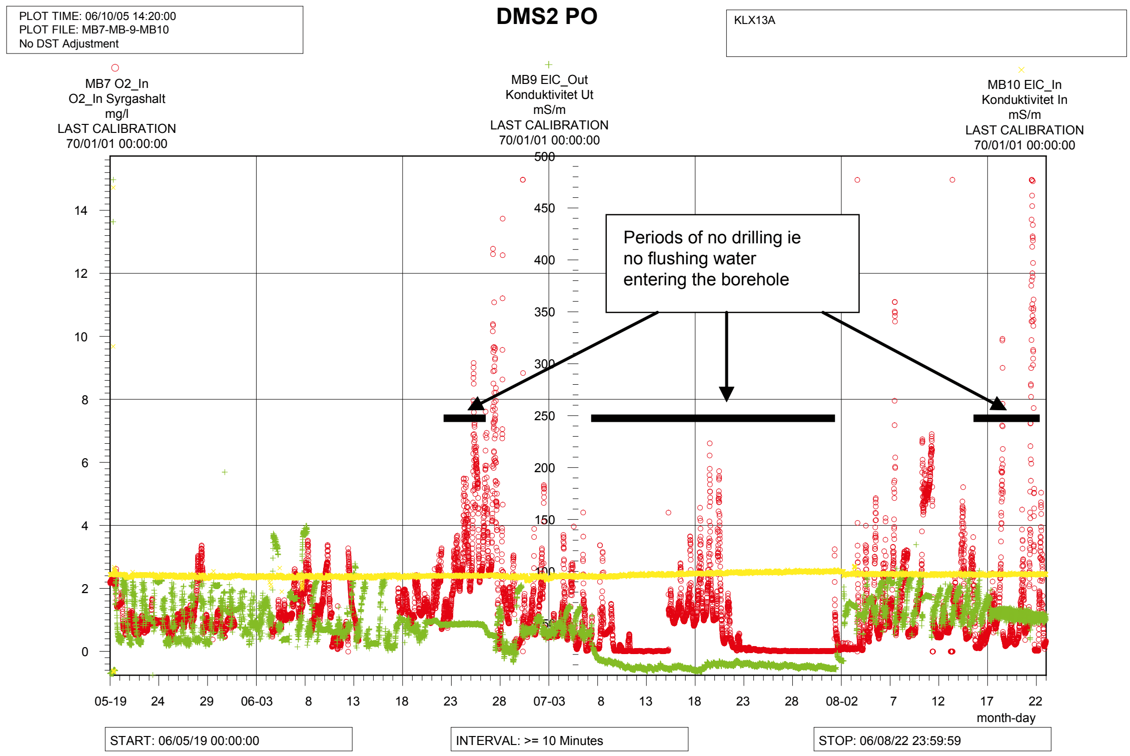


Figure 5-20. *Conductivity of flushing water (yellow) and return water (green). The oxygen content in mg/L of the flushing water (red) is also shown. The oxygen content of the flushing water was typically low (< 5 mg/L) during periods when drilling was performed and flushing water entered the DMS system. However during periods when no flushing water was pumped into the borehole, the oxygen levels often become elevated. It has also been noted that elevated oxygen levels are recorded when electrical power cuts occur.*

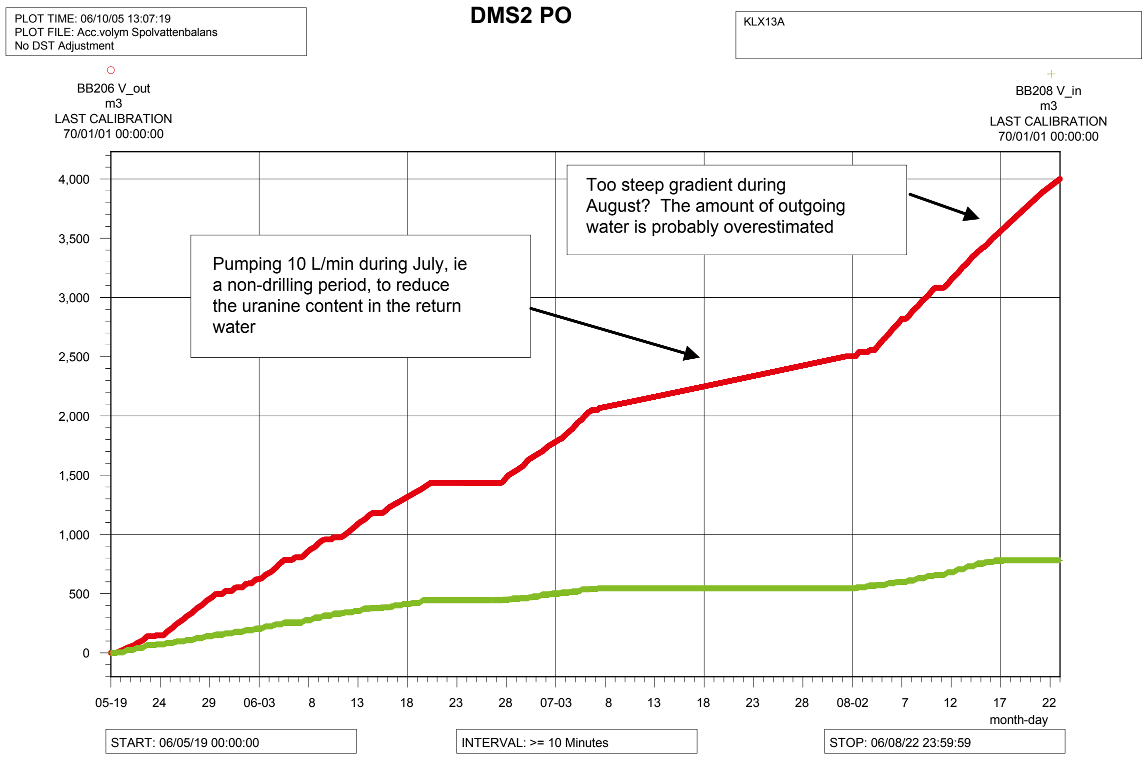


Figure 5-21. *The flushing water balance in KLX13A as recorded by the DMS system. The accumulated volume of the ingoing flushing water is shown in green and the outgoing return water is shown in red.*

The flows measured during August are also very high and are probably affected by air bubbles in the return water which can lead to an overestimate of the flow rates. The return water volume was calculated to 2,500 m^3 based on uranine balance calculation, see Table 5-15 and the related text for "Uranine tracer balance" below in this section.

The correct volume for the return water is somewhat speculative.

Drill cutting balance

The weight of cuttings in the settling containers amounted to 1,137 kg. The content of suspended material in the return water was not analysed in borehole KLX13A, 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 1,600 kg (based on 4,000 m^3 of return water). The theoretical amount that should be produced from drilling with 76 mm triple tubing (with core barrel N3/50) over a length of 496 m is 3,213 kg assuming a density of 2.7 kg/dm^3. This means that 85% of the material liberated by drilling is accountable as removed from the borehole or the formation. The calculations of the drill cuttings balance are of course heavily dependant on the amount of return water and it must be noted that this parameter is uncertain for borehole KLX13A.

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 5-16. The results show that almost the double amount of the introduced amount uranine was retrieved during drilling of KLX13A, if the amount of return water as measured by the DMS system is assumed to be correct. It should however not be possible to retrieve more uranine than was introduced and could be seen as a support for the argument that the amount of return water has been overestimated by the DMS system especially during the latter part of the core drilling phase in KLX13A. The calculated return water volume based on the assumption that the amount of recovered uranine should be same as introduced amount would be 2,500 m^3.

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

Table 5-16. Balance calculation of uranine tracer in KLX13A.

	Assuming that the DMS return water flow is correct	Assuming that the amount of uranine should be in perfect balance
Average uranine content IN (mg/L)	0.219	0.219
Flushing water volume IN (m^3)	800	800
Amount uranine introduced (g)	175	175
Average uranine content OUT (mg/L)	0.070	0.070
Return water volume OUT (m^3)	4,000	2,500
Amount uranine recovered (g)	280	175

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/.

Lithologically the core is dominated by Ävrö granite. Minor intercalations of diorite/gabbro, fine-grained diorite-gabbro and fine grained granite have been noted in the borehole.

Red staining with medium to strong intensity occurs frequently from ca 490 m and downwards. 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 4.24 (fractures/metre). Below ca 490 m, the fracture frequency is strongly elevated. 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 SSM000248 and SSM000249 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 electrical conductivity, as measured by the DMS system, of the return water from the core drilling of KLX13A was typically below 100 mS/m. Samples of the return water that were analysed for electrical conductivity were all below 80 mS/m, see Figure 5-9.

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

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 /8/.

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

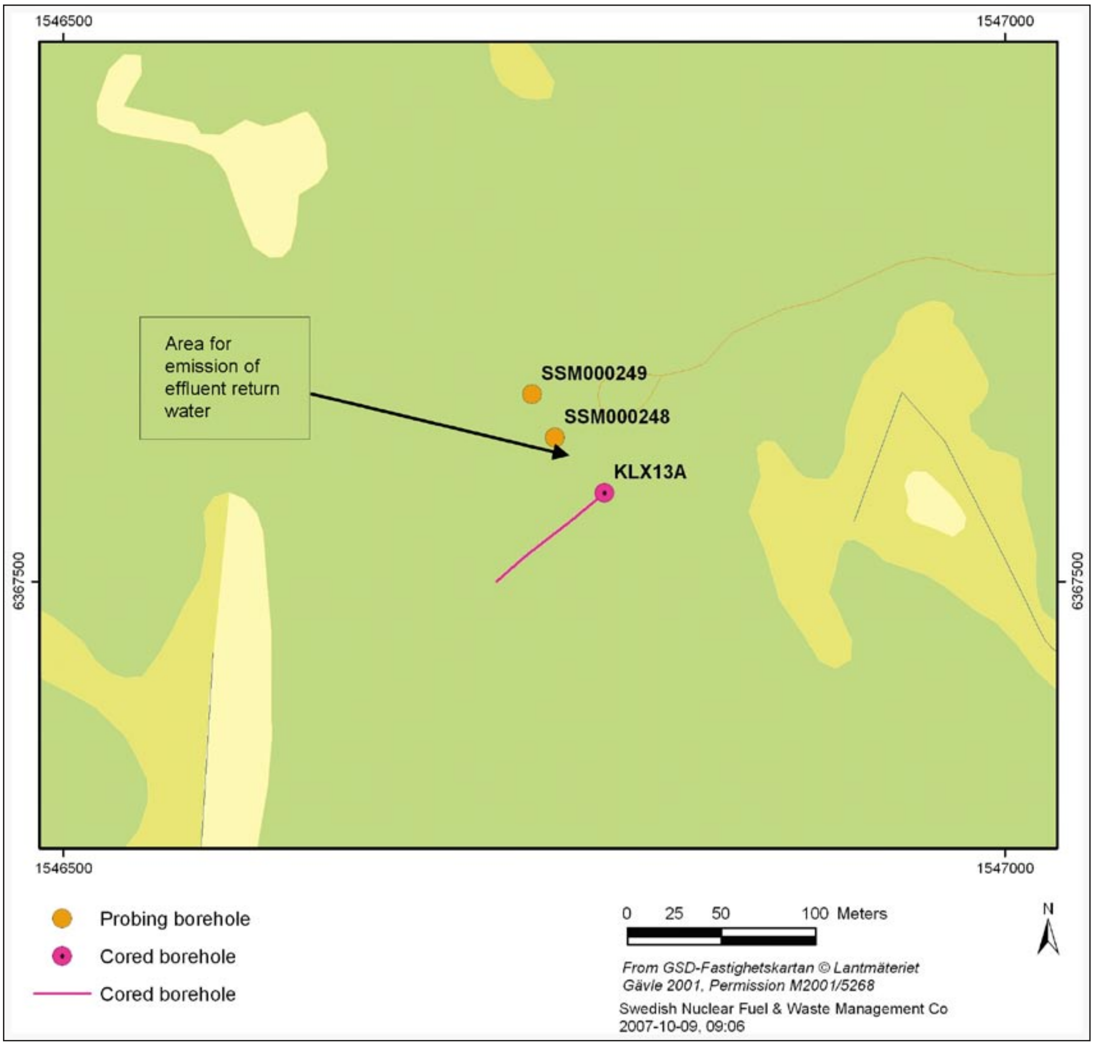


Figure 5-22. *The location of the site for return water emission and the environmental monitoring wells SSM000248 and SSM000249 in relation to the core drill site for KLX13A.*

Environmental monitoring wells and reference sampling

Two environmental monitoring wells, SSM000248 and SSM000249, were drilled as part of the core drilling activity for KLX13A. The technical specifications are given in Appendix 6.

Reference samples of the surface soil and ground water, before drill start and establishment of the drill site were taken as given in Table 5-17.

Monitoring of soil ground water levels

A pressure logger (transducer) for measuring the ground water table was installed in SSM000249 during the core drilling of KLX13A. The water levels are given graphically in Figure 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 SSM000248 and SSM000249. 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 KLX13A.

Table 5-17. Reference samples for environmental monitoring.

Date	Sample No	Comment
2006-04-18	SKB PO 9010	Undisturbed soil sample
2005-02-23	10843	Reference water sample in SSM000248
2006-02-15	10808	Reference water sample in SSM000249

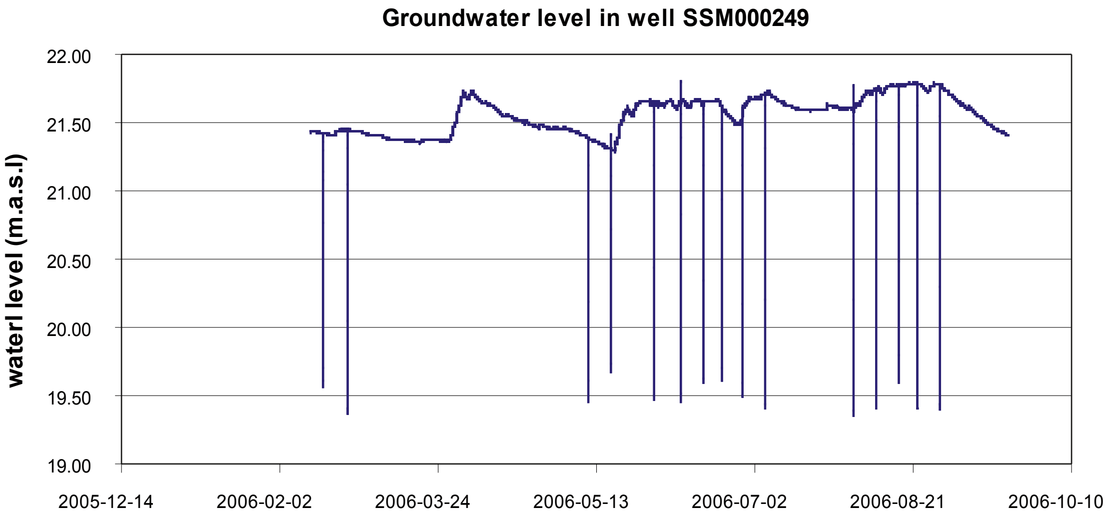


Figure 5-23. *The ground water level in well SSM000249. The dips in water levels are related to water sampling. The percussion drilling of the telescopic section did not influence the water level in the monitoring well SSM000249. The water level in the monitoring well is not affected by the core drilling activity in KLX13A.*

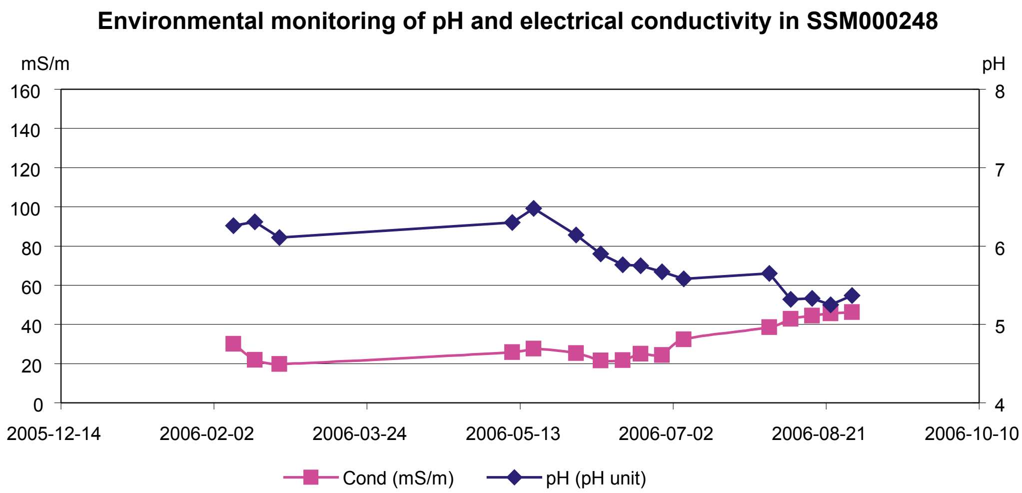


Figure 5-24. *Electrical conductivity and pH in ground water samples from SSM000248. The sampling events are shown with blue or purple symbols.*

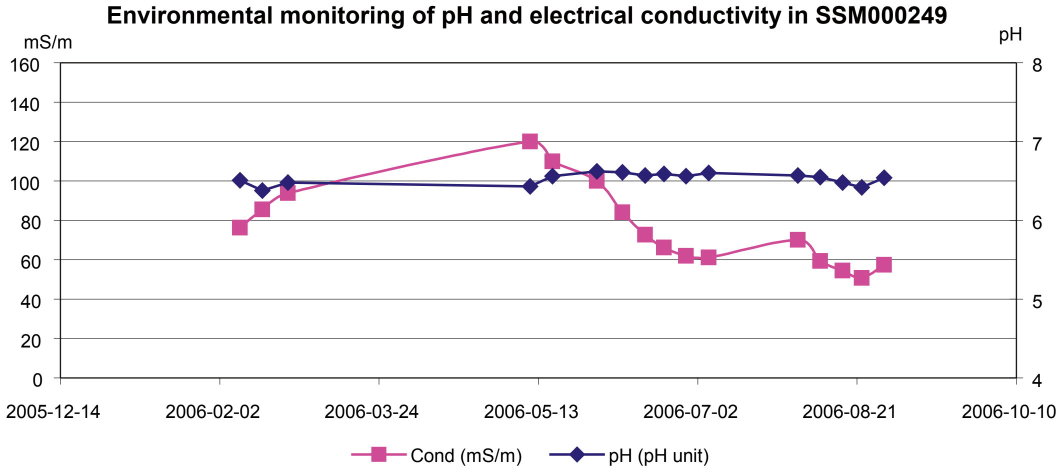


Figure 5-25. *Electrical conductivity and pH in ground water samples from SSM000249. The sampling events are shown with blue or purple symbols.*

5.8.1 Consumption of oil and chemicals

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

The concrete consumption was 735 litres in total. The concrete was based on white silica, low alkali cement.

5.9 Nonconformities

No formal nonconformities are noted for borehole KLX13A.

No deviation measurements were done after the pilot drilling.

The amount of return water from drilling is uncertain.

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 i 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, Svensk Kärnbränslehantering AB.

/5/ **Ask H, Morosini M, Samuelsson L-E, Ekström L, Håkanson N, 2007.** Drilling of cored borehole KLX03, SKB P-05-167, Svensk Kärnbränslehantering AB.

/6/ **Pedersen K, 2006.** Triple control of microorganism content in flushing water used for drilling of KLX13A. SKB P-06-200, Kärnbränslehantering AB

/7/ **Mattsson K-J**, **Rauséus G, Ehrenborg J, 2006.** Boremap mapping of telescopic drilled borehole KLX13A, SKB P-06-255, Svensk Kärnbränslehantering AB.

/8/ **Ask H, Morosini M, Samuelsson L-E, Ekström L, Håkanson N, 2004.** Core drilling of KSH03, SKB P-04-233, Svensk Kärnbränslehantering AB.

Geology and MWD parameters KLX13A

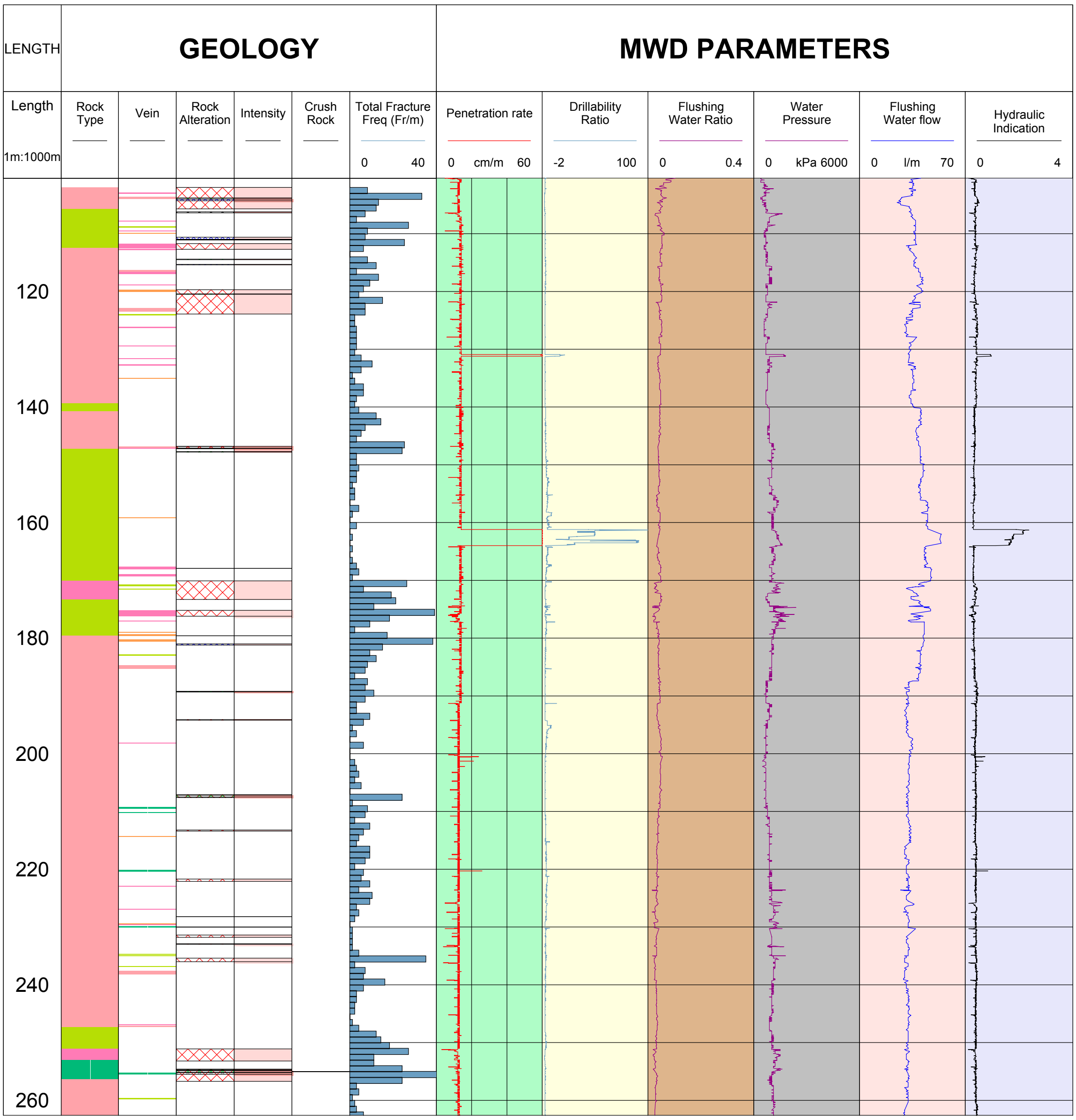
Title GEOLOGY & MWD PARAMETERS KLX13A **Appendix 1**

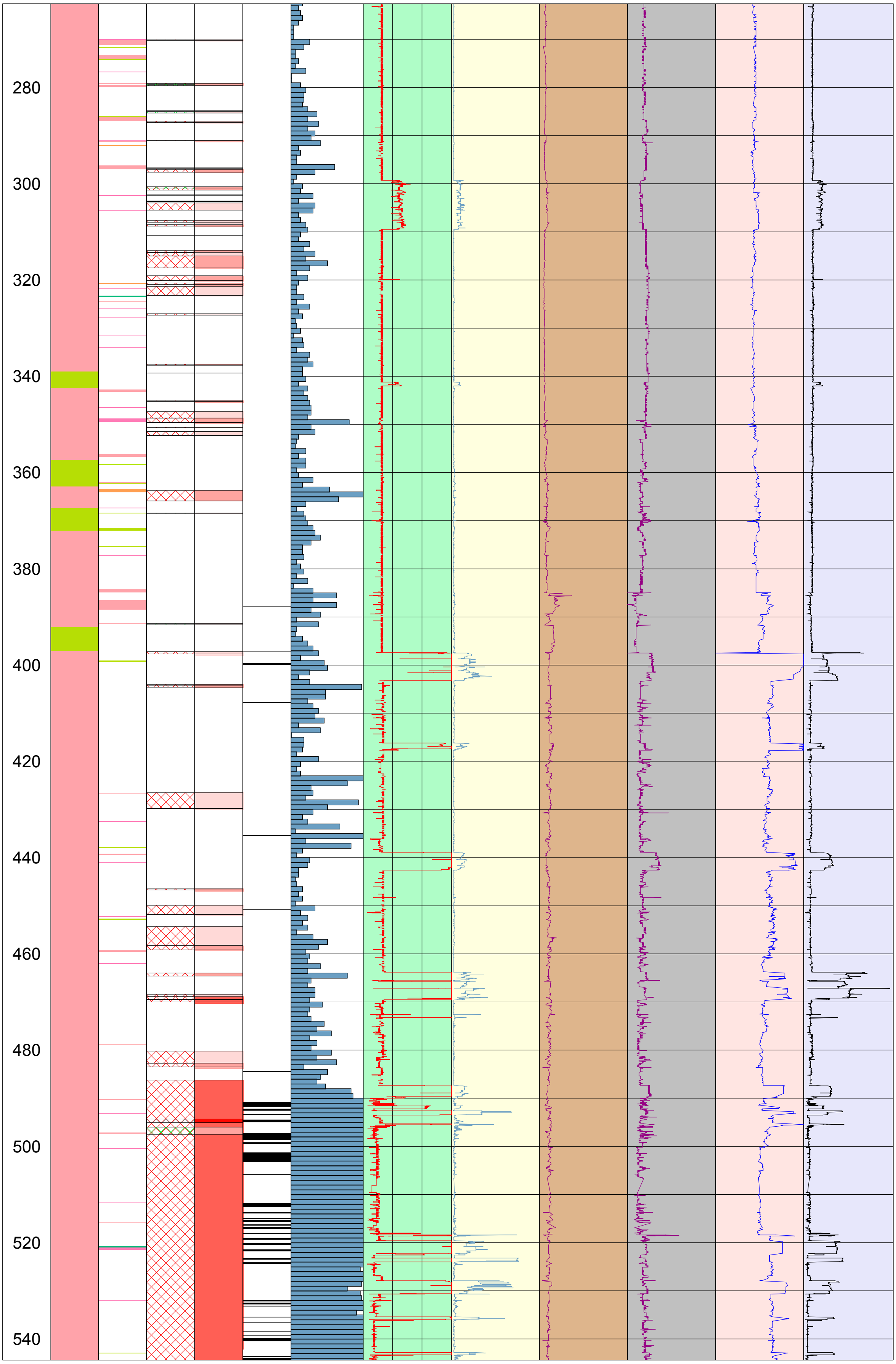
Site	LAXEMAR	**Coordinate System**	RT90-RHB70
Borehole	KLX13A	**Northing [m]**	6367547.14
Diameter [mm]	76	**Easting [m]**	1546787.36
Length [m]	595.850	**Elevation [m.a.s.l.]**	24.15
Bearing [°]	224.48	**Drilling Start Date**	2006-03-23 12:30:00
Inclination [°]	-82.23	**Drilling Stop Date**	2006-08-16 09:02:00
Date of mapping	2006-09-06 11:38:00	**Plot Date**	2007-09-24 22:04:52

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

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

INTENSITY
- Faint
- Weak
- Medium
- Strong

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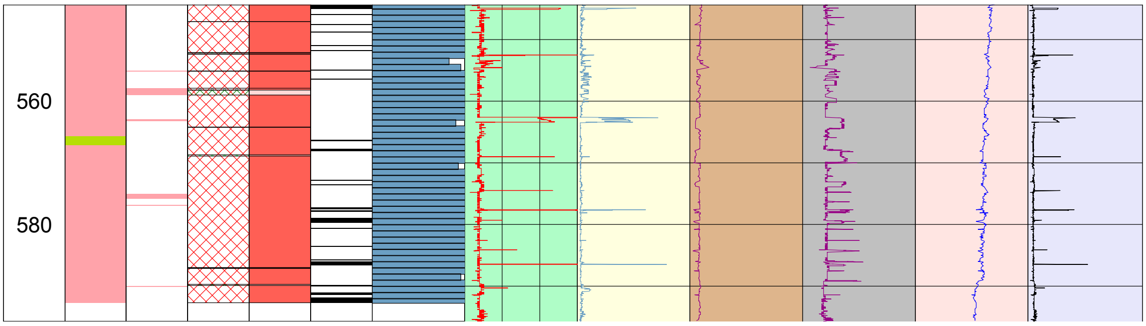

560
580

Appendix 2

Chemical results

Borehole	KLX13A	KLX13A	KLX13A	KLX13A	KLX13A	KLX13A	KLX13A
Date of measurement	2006-05-24	2006-06-01	2006-06-06	2006-06-10	2006-06-11	2006-06-15	2006-08-25
Upper section limit (m)	102.55	193.20	320.00	442.85	442.85	395.70	486.85
Lower section limit (m)	194.25	320.25	397.39	451.33	463.79	487.30	595.85
Sample_no	11089	11116	11117	11148	11149	11170	11294
Groundwater Chemistry Class	3	3	1	3	3	1	3
pH	8.16	7.88	x	8.11	x	x	7.32
Conductivity mS/m	59.8	51.5	x	221.0	x	x	360.0
Drill water %	11.10	1.69	43.50	12.10	34.90	39.20	16.90
Density g/ml	0.9973	0.9974	x	0.9978	x	x	0.9983
Charge balance %	–1.08	0.16	x	x	x	x	–0.31
Na mg/l	95.3	74.8	x	x	x	x	602.0
K mg/l	3.07	2.48	x	x	x	x	3.24
Ca mg/l	24.0	30.0	x	x	x	x	112.0
Mg mg/l	4.7	4.8	x	x	x	x	7.9
HCO3 mg/l Alkalinity	231	197	x	108	x	x	61
Cl mg/l	56.0	57.2	x	607.0	x	x	1,070.0
SO4 mg/l	10.70	8.68	x	30.50	x	x	61.80
SO4_S mg/l Total Sulphur	5.89	3.13	x	x	x	x	21.50
Br mg/l	< 0.2	0.280	x	2.950	x	x	6.950
F mg/l	4.14	3.29	x	3.48	x	x	3.10
Si mg/l	7.31	8.85	x	x	x	x	9.83
Fe mg/l Total Iron	12.300	14.700	x	x	x	x	9.1300
Mn mg/l	0.2910	0.3550	x	x	x	x	0.3180
Li mg/l	0.012	0.014	x	x	x	x	0.088
Sr mg/l	0.264	0.299	x	x	x	x	2.080
TOC mg/l	x	x	x	x	x	x	x
PMC % Modern Carbon	x	45.37	x	x	x	x	44.40
C-13 dev PDB	x	–17.51	x	x	x	x	–18.30
AGE_BP Groundwater age	x	6,293	x	x	x	x	6,470
AGE_BP_CORR	x	35	x	x	x	x	75
D dev SMOW	x	–84.0	x	x	x	x	–116.0
Tr TU	x	1.30	x	x	x	x	–0.80
O-18 dev SMOW	x	–11.70	x	x	x	x	–15.40
B-10 B-10/B-11	x	0.2388	x	x	x	x	0.2358
S-34 dev SMOW	x	34.6	x	x	x	x	19.3
Cl-37 dev SMOC	x	0.18	x	x	x	x	0.49
Sr-87 Sr-87/Sr86	x	0.716347	x	x	x	x	0.715239

x=not analysed

Appendix 3

Chemistry – analytical method

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	Filtered in connection with analyse	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/ Ångström
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 KLX13A. The errors do not exceed ± 5% in any of the samples.

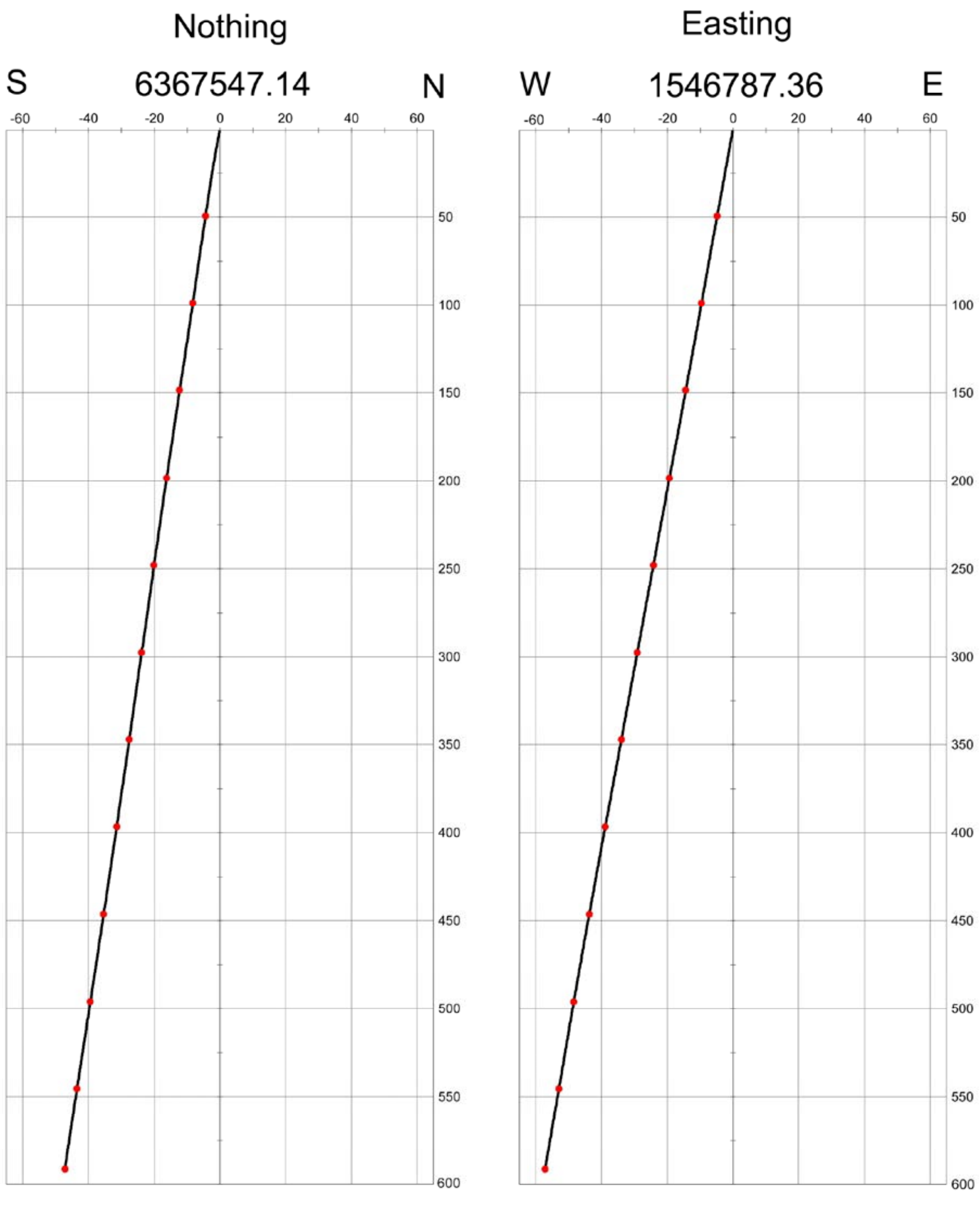
The following routines for quality control and data management are generally applied for hydrogeochemical analysis data, independent of sampling method or sampling object.

- 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 KLX13A.
- 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%.
  - 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.

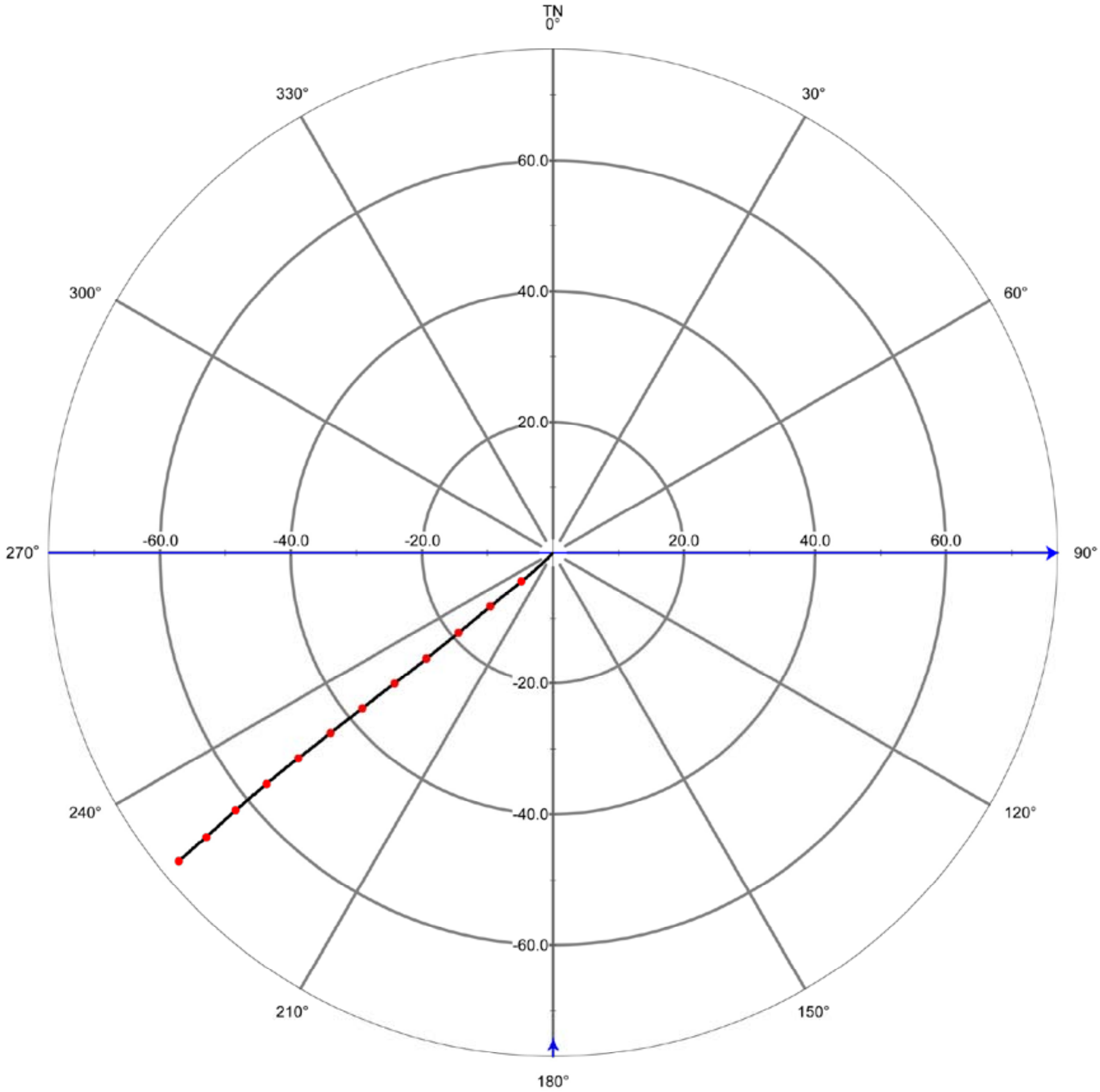
Deviation measurements

Deviation measurement	Appendix: 4
Site LAXEMAR Borehole KLX13A Vertical Section	



Deviation measurement	Appendix: 4

Site LAXEMAR
Borehole KLX13A
View from above



Appendix 5

Wireline pumping tests

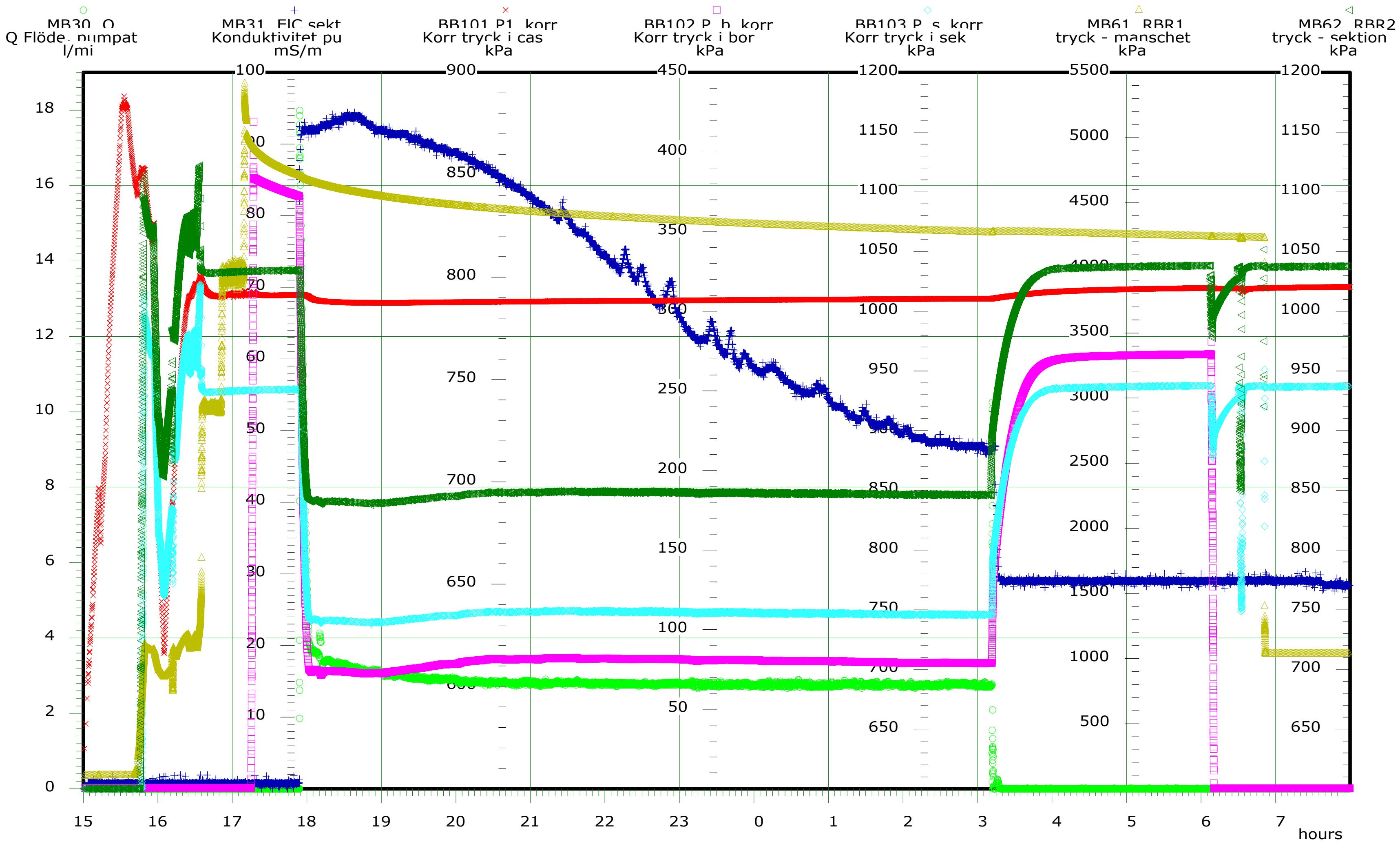
Description of the parameters in the enclosed plots

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 :06/06/07 16:09:52
PLOT FILE :P_pumptest
Adjusted for DST

DMS2 PO

Pumping test
KLX13A 102.55 - 194.25 m
Wireline probe



START :06/05/23 15:00:00

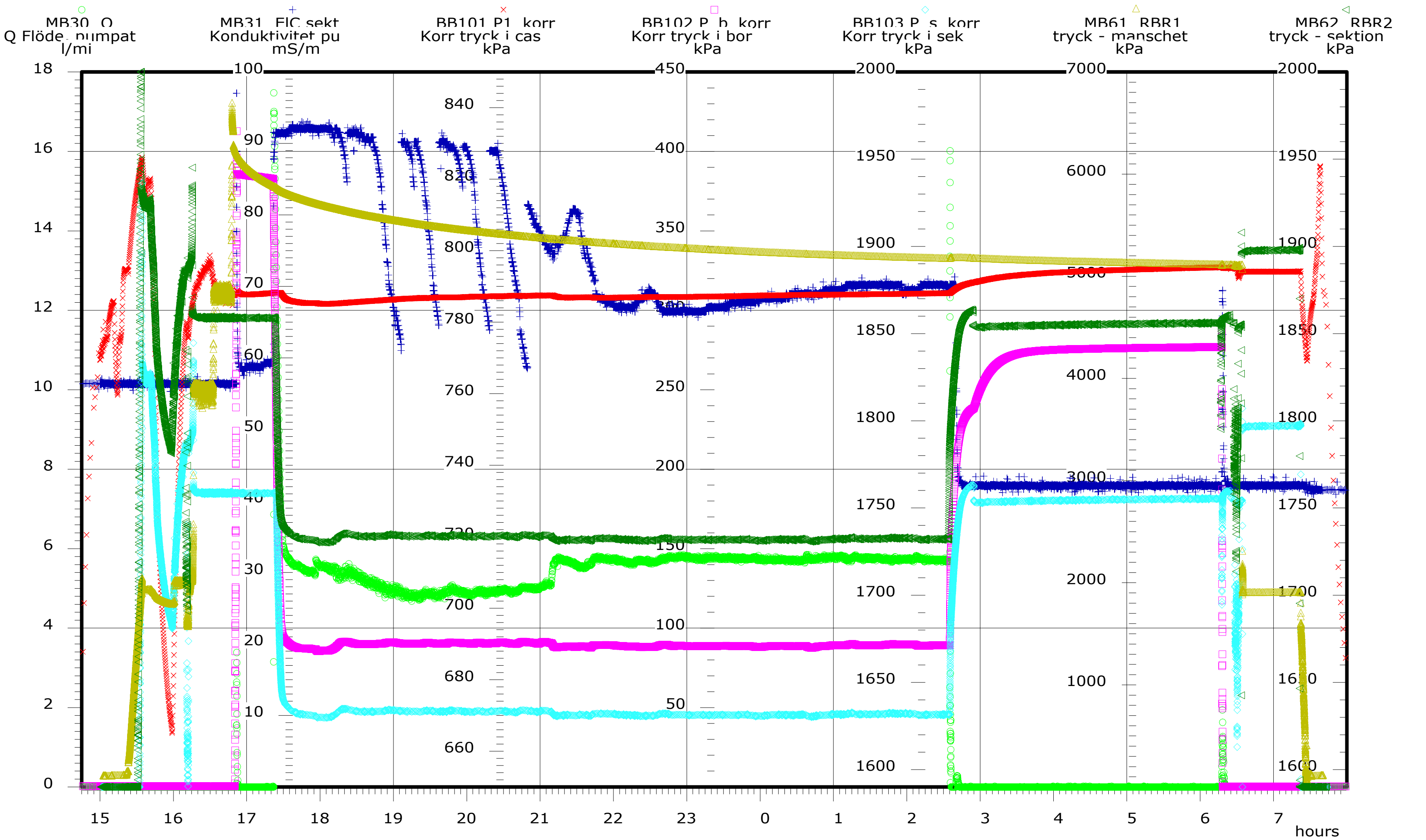
INTERVAL: All readings

STOP :06/05/24 07:59:59

PLOT TIME :06/06/07 16:38:24
PLOT FILE :P_pumptest
Adjusted for DST

DMS2 PO

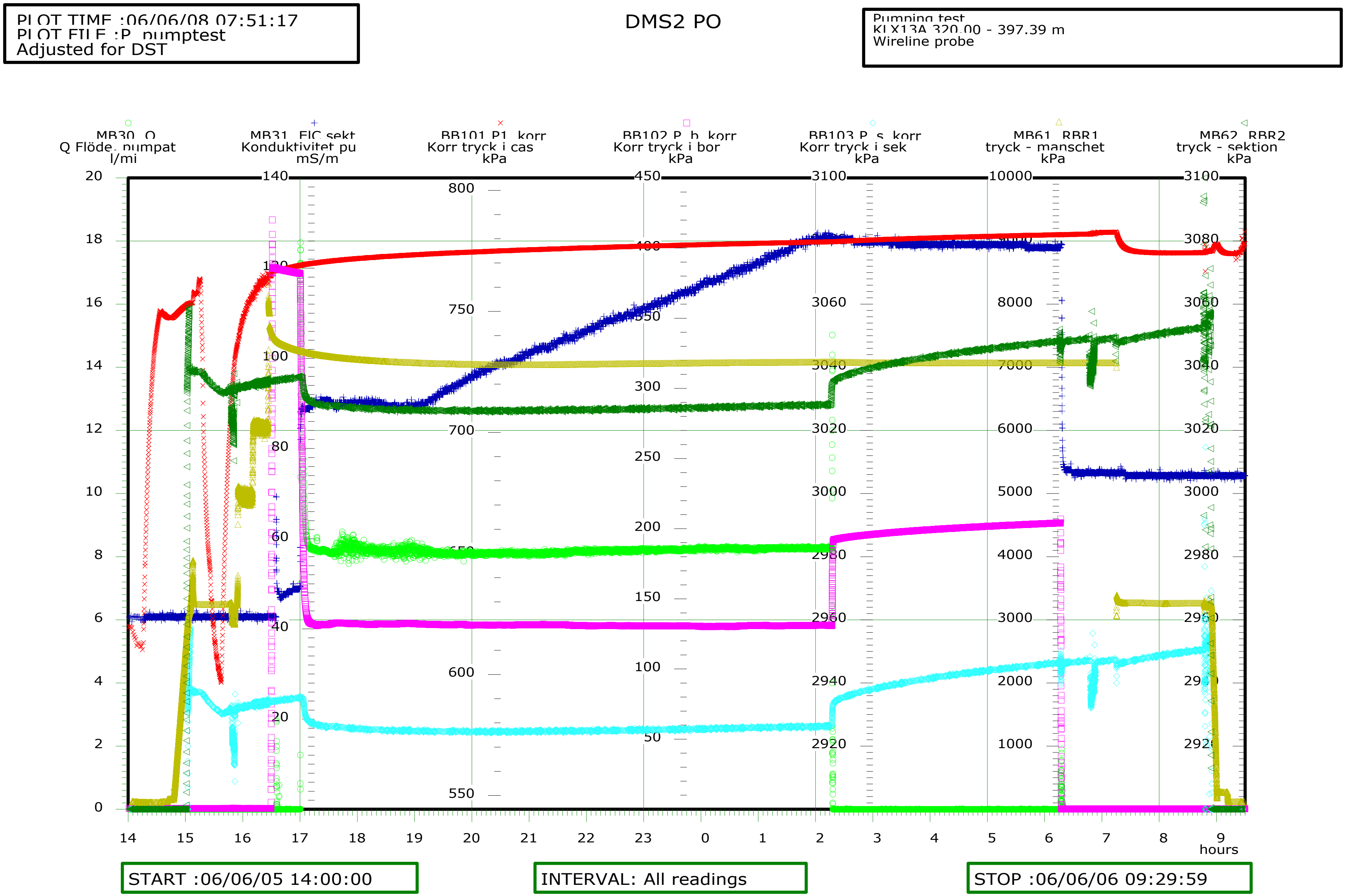
Pumping test
KLX13A 193.20 - 320.25 m
Wireline probe

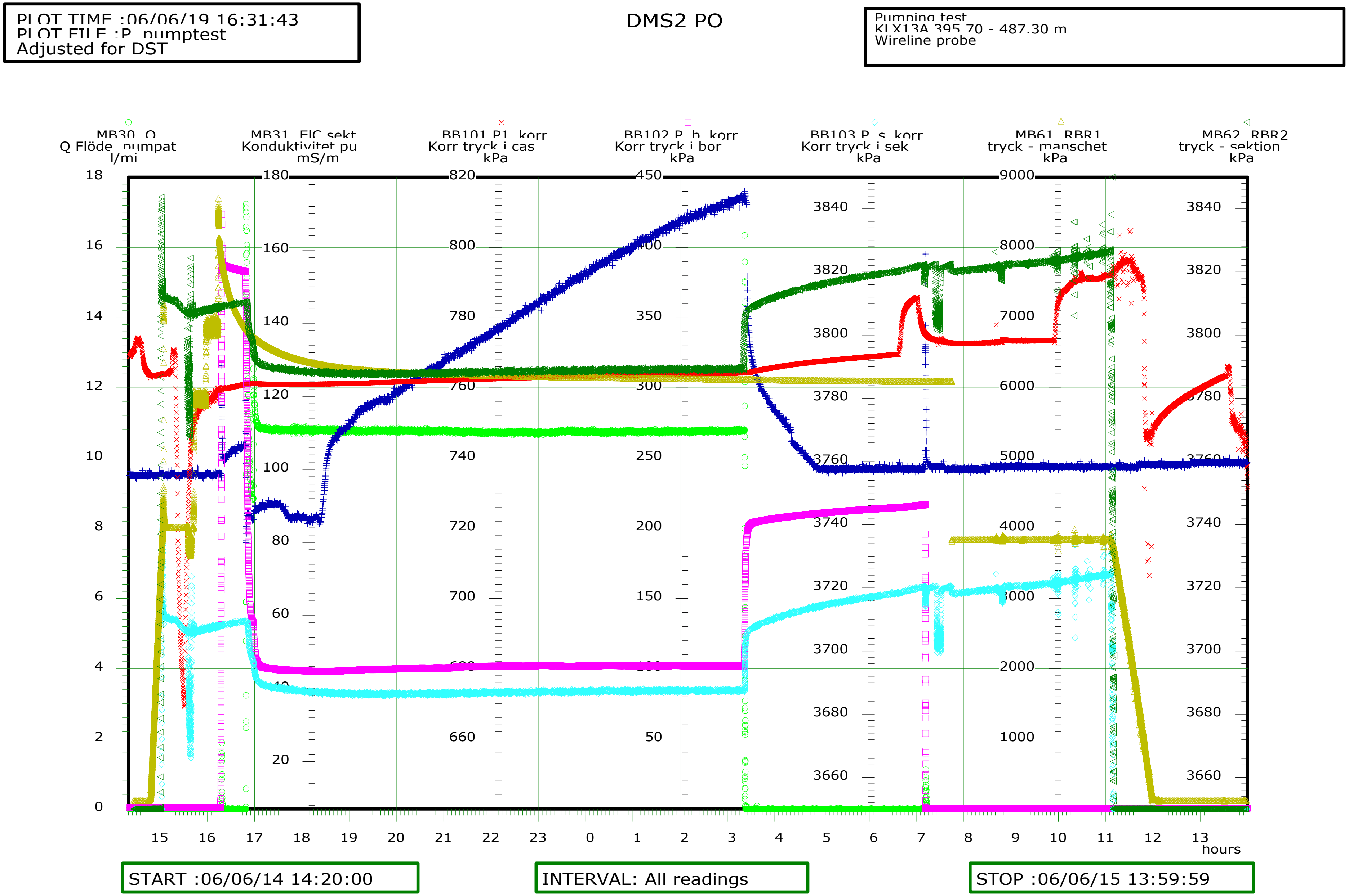


START :06/05/31 14:45:00

INTERVAL: All readings

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

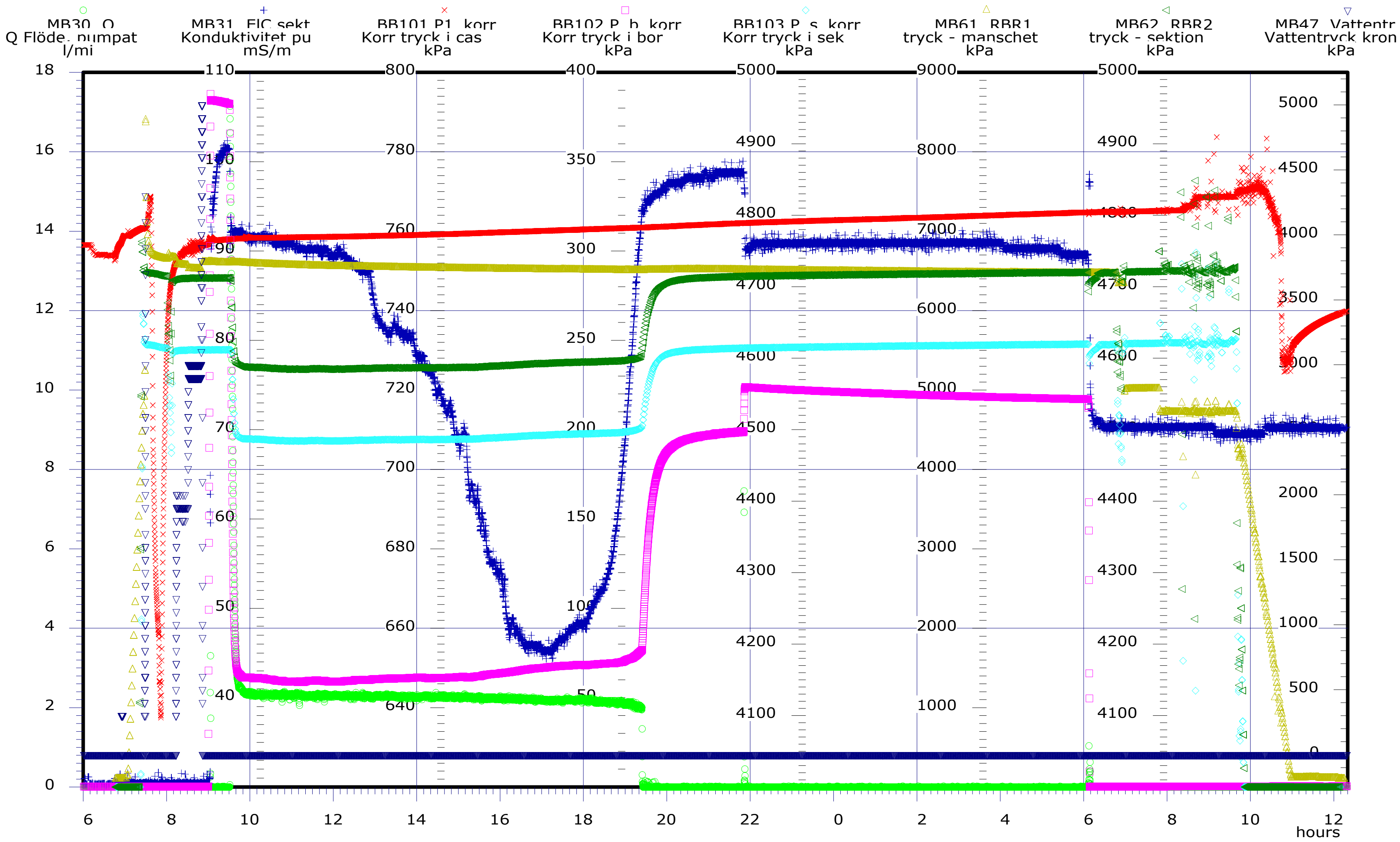

PLOT TIME :06/06/08 07:51:17
PLOT FILE :P_pumptest
Adjusted for DST
DMS2 PO
Pumping test
KLX13A 320.00 - 397.39 m
Wireline probe
MB30 Q
Q Flöde, pumpat
l/mi
MB31 EIC sekt
Konduktivitet pu
mS/m
BB101 P1 korr
Korr tryck i cas
kPa
BB102 P b korr
Korr tryck i bor
kPa
BB103 P s korr
Korr tryck i sek
kPa
MB61 RBR1
tryck - manschet
kPa
MB62 RBR2
tryck - sektion
kPa
hours
START :06/06/05 14:00:00
INTERVAL: All readings
STOP :06/06/06 09:29:59


PLOT TIME :06/06/19 16:31:43
PLOT FILE :P_pumptest
Adjusted for DST
DMS2 PO
Pumping test
KLX13A 395.70 - 487.30 m
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_RBP1
tryck - manschet
kPa
MB62_RBP2
tryck - sektion
kPa
hours
START :06/06/14 14:20:00
INTERVAL: All readings
STOP :06/06/15 13:59:59

PLOT TIME :06/08/30 15:05:49
PLOT FILE :P_pumptest
Adjusted for DST

DMS2 PO

Pumping test
KLX13A 486.85 - 595.85 m
Wireline probe



START :06/08/24 06:00:00

INTERVAL: All readings

STOP :06/08/25 12:19:59

Appendix 6

Technical data from environmental monitoring wells SSM000248 and SSM000249

LAXEMAR BOREHOLE SSM000248

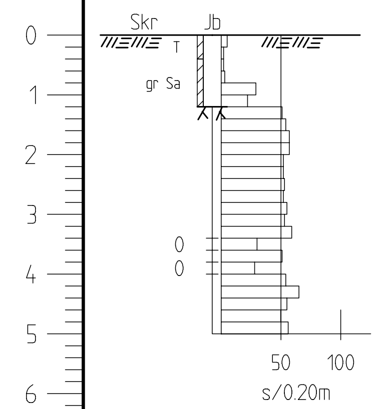
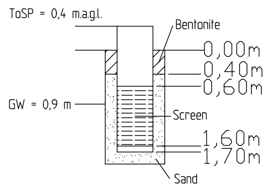
Company rep.
Torbjörn Johansson

Client: Svensk Kärnbränslehantering AB

Northing :6367576,481
Easting :1546760,980

Coordinate system : RT90-RHB70

Top of stand pipe : 0,4 m.a.g.l.
Total pipe length : 2,10 m
Groundwater level : 0,9 m.b.g.l.
Date of completion : 2006-01-25

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information
		1 2		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 : 0,40 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 Ø44 Drill bit : Stift Ø54 GEOLOGICAL LOG 0-0,4m peat 0,4-1,2m gravelly sand 1,2m 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 SSM000249

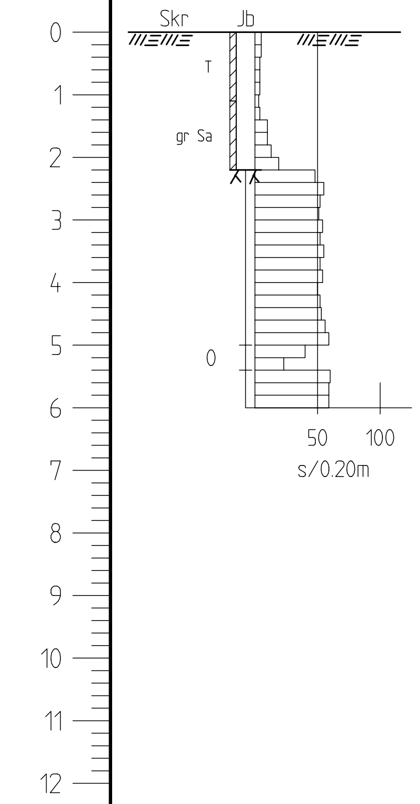
Company rep.
Torbjörn Johansson

Client: Svensk Kärnbränslehantering AB

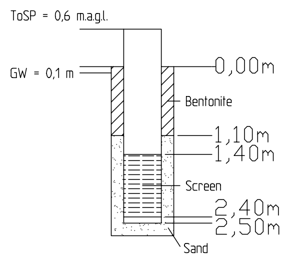
Northing	:6367599,380
Easting	:1546748,833
Coordinate system	: RT90-RHB70

Top of stand pipe	:0,6 m.a.g.l.
Total pipe length	:3,10 m
Groundwater level	:0,1 m.b.g.l.
Date of completion	:2006-01-26

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



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	: 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	: 1,10 m

SAND PACK

Grain size	: 0,4-0,8 mm
Total length	: 1,40 m

DRILLING EQUIPMENT

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

GEOLOGICAL LOG

0-1,1m	Peat
1,1-2,2m	gravelly sand
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

Nomenclature see SGF homepage:
www.sgf.net