P-07-202

Oskarshamn site investigation

Drilling of cored borehole KLX19A

Henrik Ask, H Ask Geokonsult AB

Mansueto Morosini, Lars-Erik Samuelsson
Svensk Kärnbränslehantering AB

Liselotte Tiberg, Studsvik Nuclear AB

December 2007

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 250, SE-101 24 Stockholm
Tel +46 8 459 84 00

ISSN 1651-4416
SKB P-07-202

Oskarshamn site investigation

Drilling of cored borehole KLX19A

Henrik Ask, H Ask Geokonsult AB

Mansueto Morosini, Lars-Erik Samuelsson
Svensk Kärnbränslehantering AB

Liselotte Tiberg, Studsvik Nuclear AB

December 2007

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

Abstract

Borehole KLX19A is located in the Laxemar subarea. Drilling was made between May and September 2006 as a part of the site investigation for a possible repository for spent nuclear fuel in Oskarshamn municipality, Sweden. KLX19A was the nineteenth deep cored borehole within the site investigation in Oskarshamn.

KLX19A was core drilled to a length of 800.07 metres with N-size (76 mm) equipment. The uppermost section, to the length of 99.33 metres, was constructed as a telescopic borehole with an inner nominal diameter of 200 mm.

A water inflow of 130 L/minute could be measured over the entire length of the telescopic section after percussion drilling of the pilot borehole (nominal diameter 165 mm).

Six successful pumping tests were performed with wireline equipment in KLX19A. The resulting transmissivities (T_M) varied between 1.5×10^{-4} and 1.2×10^{-6} m^2/s. The most transmissive section was between 102 and 197 metres.

Continuous monitoring of drilling parameters and flushing water parameters with the drilling monitoring system was conducted throughout the core drilling phase in KLX19A.

Six water samples for chemical analysis were collected during the core drilling of KLX19A.

The air-lift pumping test in the telescopic section performed when borehole KLX19A was core drilled to its full length gave a transmissivity (T_M) of 1.8×10^{-4} m^2/s.

Lithologically the core is dominated by Quartz monzodiorite. Dolerite is found between 480 and 550 m. Minor intercalations of pegmatite, fine-grained diorite-gabbro and fine-grained granite were noted in the borehole.

Rock alteration is rare and mostly weak. A section with significant red staining and chloritic alteration was logged from 430 to 480 m i.e. just above the dolerite. 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 1.72 (fractures/metre). The fracture frequency is very low throughout most of the Quartz monzodiorite rock.

Sammanfattning

Borrhål KLX19A ligger inom delområde Laxemar. Borrningen utfördes mellan maj och september 2006 som ett led i platsundersökningen för ett möjligt djupförvar för använt kärnbränsle i Oskarshamns kommun. KLX19A var det nittonde djupa kärnborrhålet inom platsundersökningen i Oskarshamn.

KLX19A kärnborrades med borrstorlek N (76 mm) till 800,07 meters borrad längd. Den övre delen av hålet, från markytan till 99,33 meter, utfördes som en teleskopdel med ca 200 mm inre diameter.

Ett vatteninflöde på 130 minutliter kunde uppmätas över hela teleskopdelen vid hammarborrningen av pilotdelen (nominell diameter 165 mm).

Sex lyckade pumptester med wireline-baserad mätutrustning utfördes. De uppmätta transmissiviteterna (T_M) varierade mellan $1{,}5\times10^{-4}$ och $1{,}2\times10^{-6}$ m^2/s. Den mest transmissiva sektionen var mellan 102 och 197 meter.

Kontinuerliga mätningar av borrningsparametrar och spolvattenparametrar via DMS (Drilling Monitoring System) gjordes under hela kärnborrningsfasen i KLX19A.

Sex vattenprover för kemisk analysering togs i samband med borrning i KLX19A.

Mammutpumpningen i teleskopdelen som gjordes när kärnborrningen i KLX19A utförts till full längd gav en transmissivitet (T_M) på $1{,}8\times10^{-4}$ m^2/s.

Litologiskt domineras kärnan av kvartsmonzodiorit. Diabas påträffades mellan 480 och 550 m. Mindre inslag av pegmatit, finkornig diorit-gabbro och finkornig granit har noterats i borrhålet.

Bergartsomvandling är sällsynt och oftast svag. Ett parti med betydande rödfärgning och kloritomvandling har uppmätts från 430 till 480 m, dvs precis ovanför diabasen. Sektioner med rödfärgning är angivna som ”oxiderade” i bilaga 1.

Den genomsnittliga sprickfrekvensen över hela borrkärnan uttryckt som öppna sprickor är 1,72 (sprickor/meter). Sprickfrekvensen är genomgående mycket låg i kvartsmonzodioriten.

Contents

1 Introduction

SKB, the Swedish Nuclear Fuel and Waste Management Company, performs site investigations in order to evaluate the feasibility of locating a deep repository for spent nuclear fuel /1, 2/. The investigations are performed in two Swedish municipalities: Östhammar and Oskarshamn. Borehole KLX19A is located in the southwestern 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. KLX19A was the nineteenth 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 KLX19A and all related on-site operations were performed according to a specific Activity Plan (AP PS 400-06-054), which in turn refers to a number of Method Descriptions, see Table 1-1.

The Activity Plans and Method Descriptions are SKB internal documents.

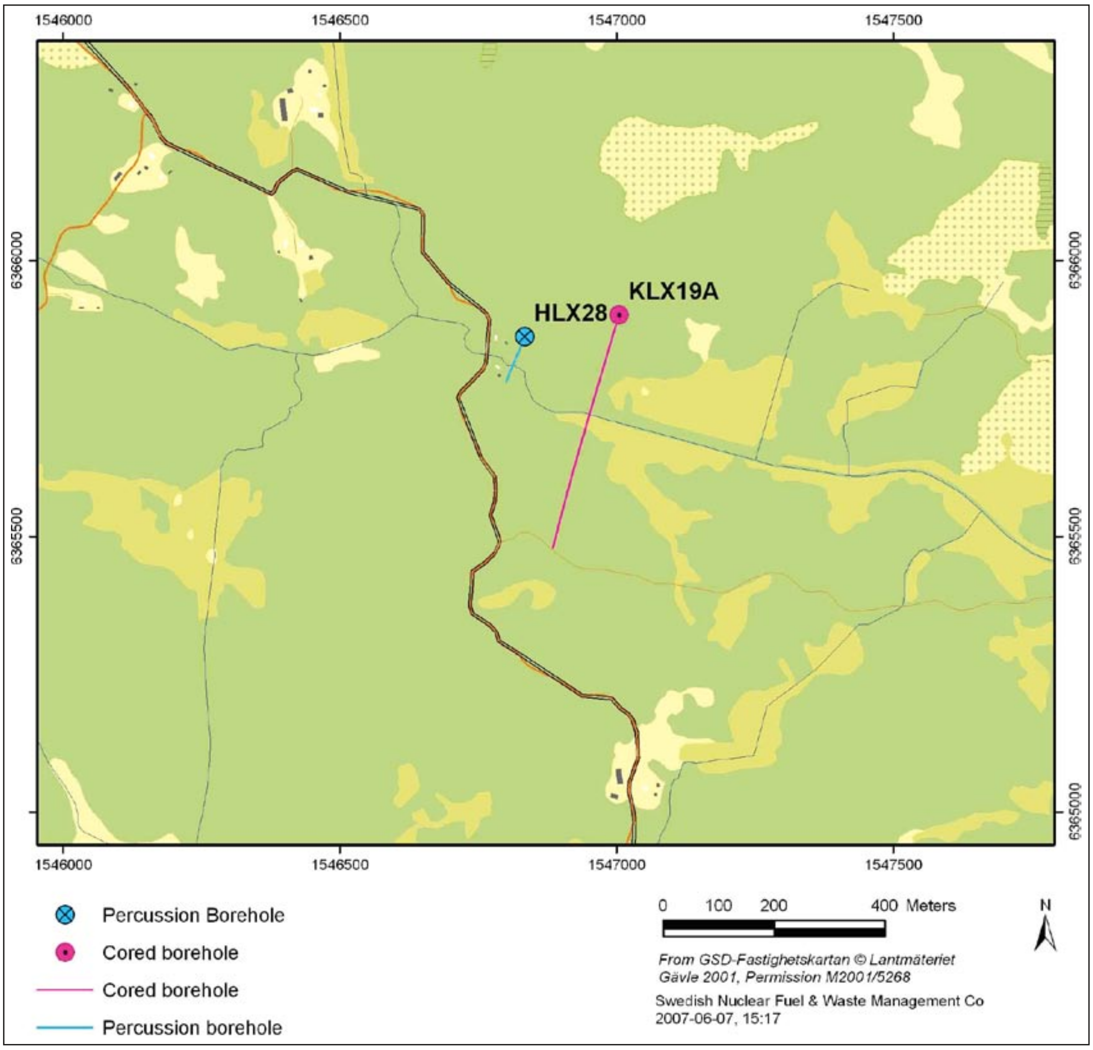


Figure 1-1. *Location of the cored borehole KLX19A and the water source, percussion borehole HLX28 in the Laxemar subarea.*

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

Activity Plan	Number	Version
Kärnborrning KLX19A	AP PS 400-06-054	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 spolvattenparametrar 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
Metodbeskrivning för jordborrning	SKB MD 630.003	1.0

2 Objective and scope

This report will describe the methods employed and the results achieved during the drilling of borehole KLX19A. 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 KLX19A is given in SKB ID no 1054828, dated 2006-05-16.

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 2006-02-17, SKB ID 1050723. Information of the final coordinates and details regarding the return water handling was sent to the Regional Authorities on 2006-04-27, SKB ID 1053754.

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 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 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.

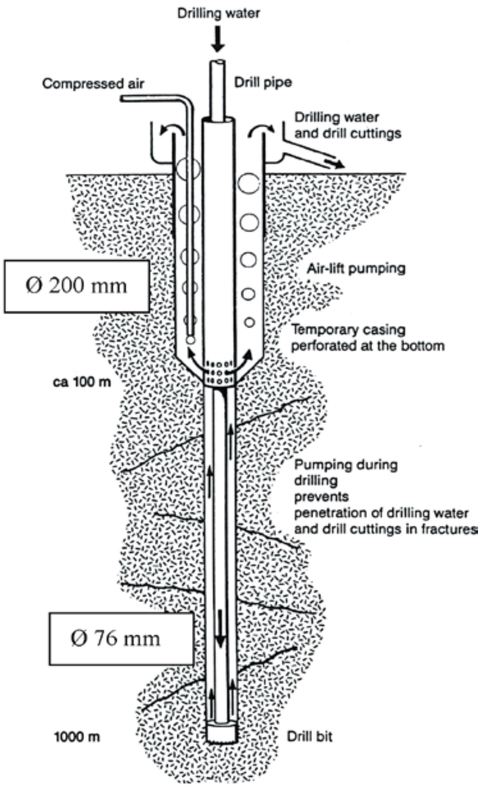


Figure 3-1. *A sketch of the telescopic drilling method with air-lift pumping for retrieval of drilling water and cuttings.*

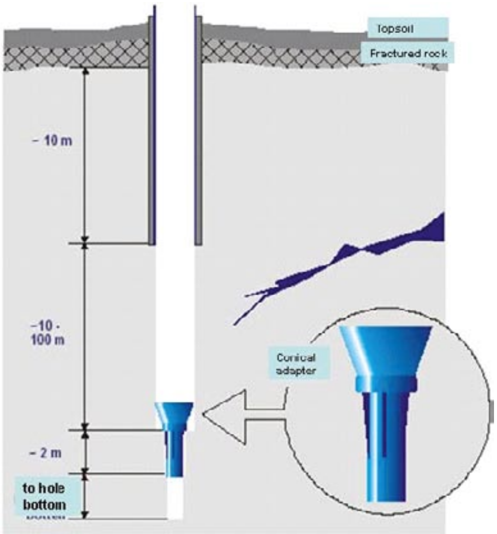


Figure 3-2. *Installation of the conical guide.*

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.

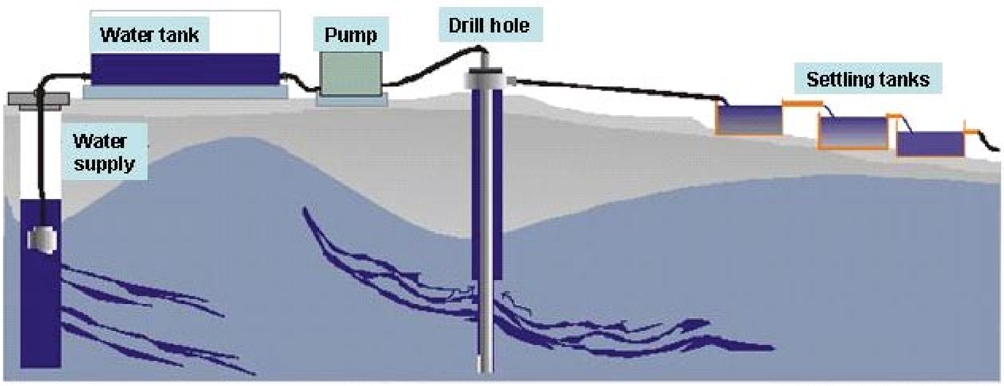


Figure 3-3. *The flushing water system from source to discharge point.*

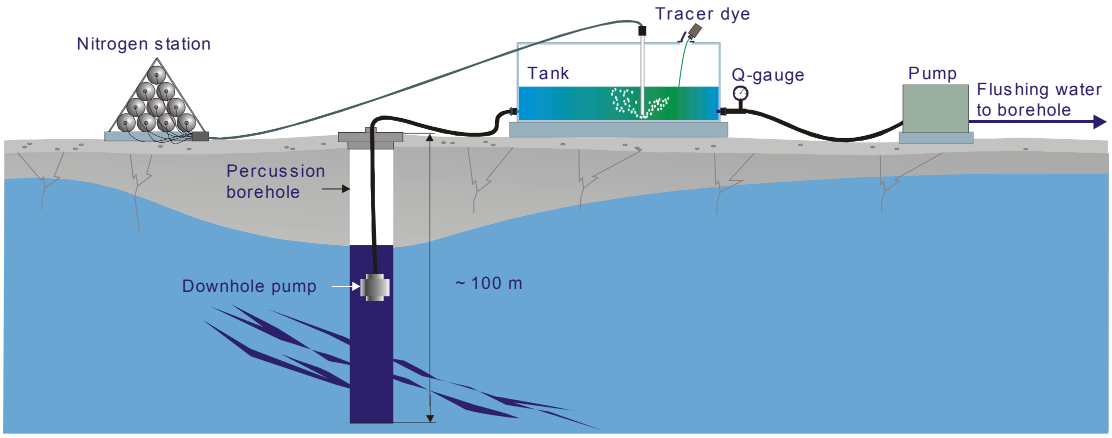


Figure 3-4. *Schematic drawing of the preparation of flushing water. Uranine is added to the water as a tracer dye and nitrogen is bubbled through the water to remove dissolved oxygen.*

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 KLX19A consisted of:

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

Wireline measurements and water sampling

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

NB Measurement of absolute pressure were not done in KLX19A 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).

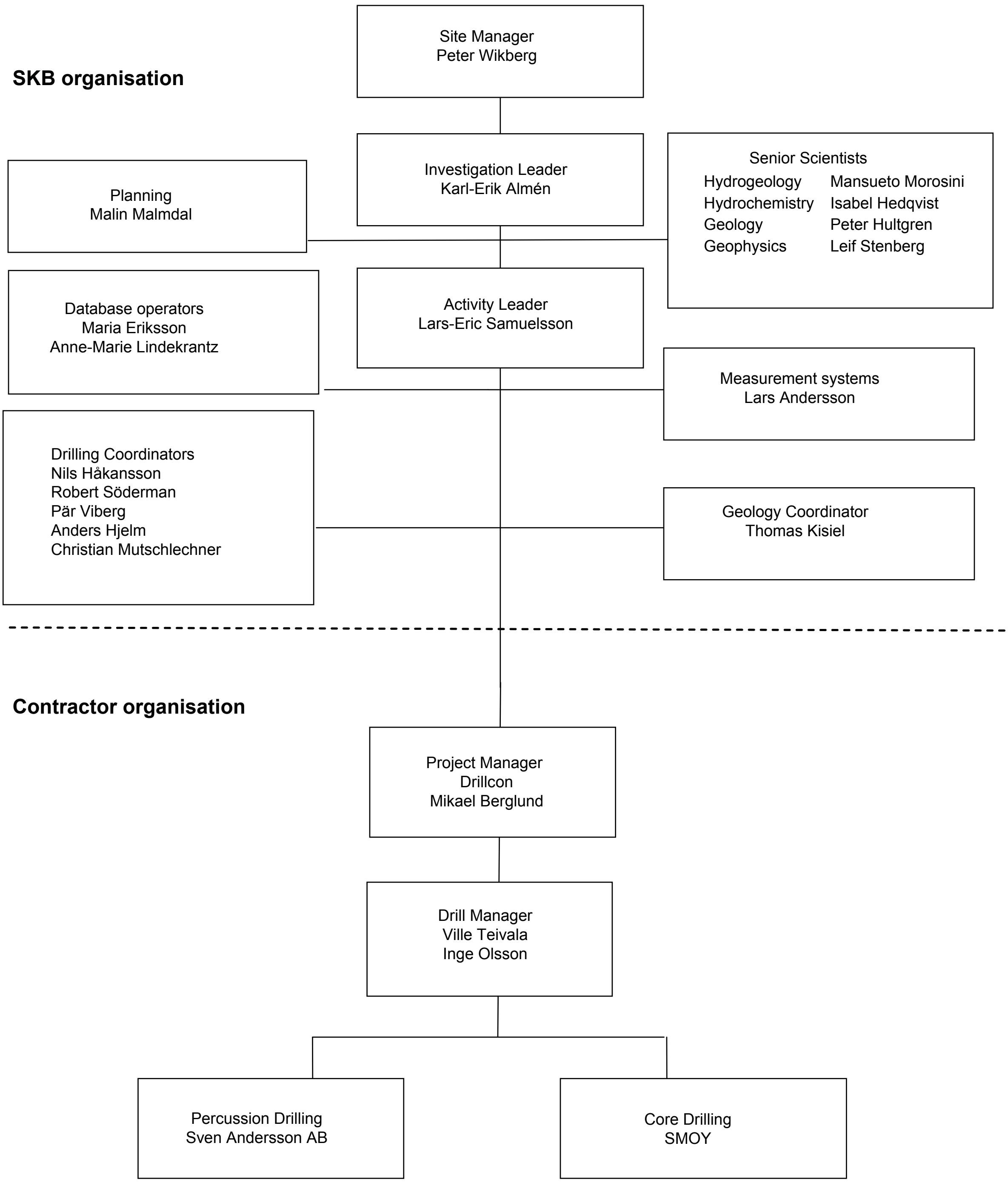
4 Contractors and equipment

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 KLX19A was a Enteco E14G 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 KLX19A 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 KLX19A.

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

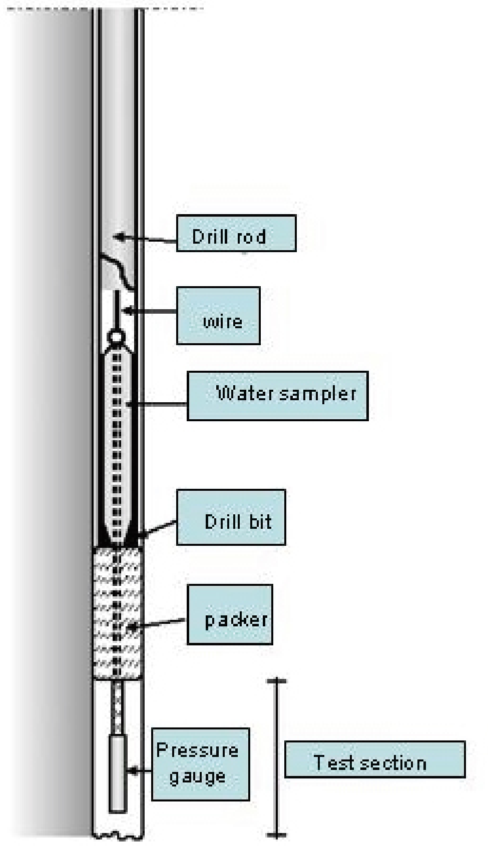


Figure 4-1. *The wireline probe and its emplacement in the hole.*

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

No measurements of absolute pressure were done in KLX19A.

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.

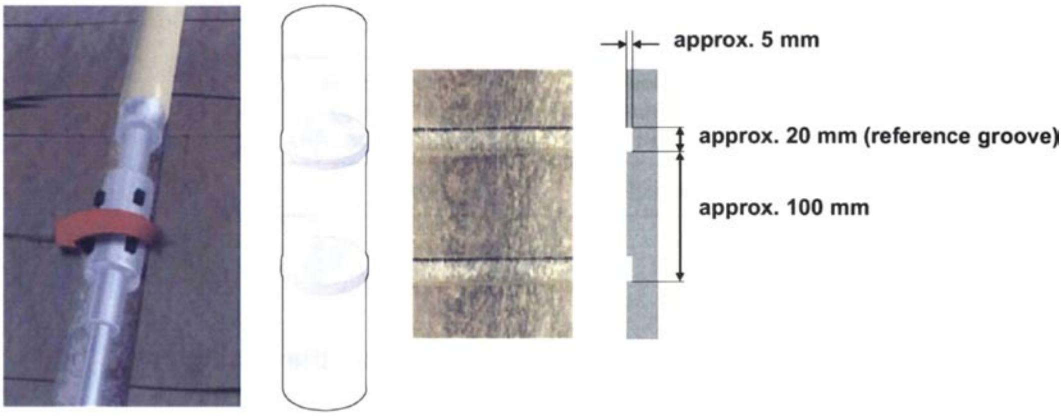


Figure 4-2. *The equipment for reaming of reference slots. To the left, the reaming tool with openings for the cutters is shown. The resulting reference slots are illustrated in the three pictures to the right.*

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 400-06-054.

5.1 Summary of KLX19A drilling

A technical summary of the drilling of KLX19A 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.

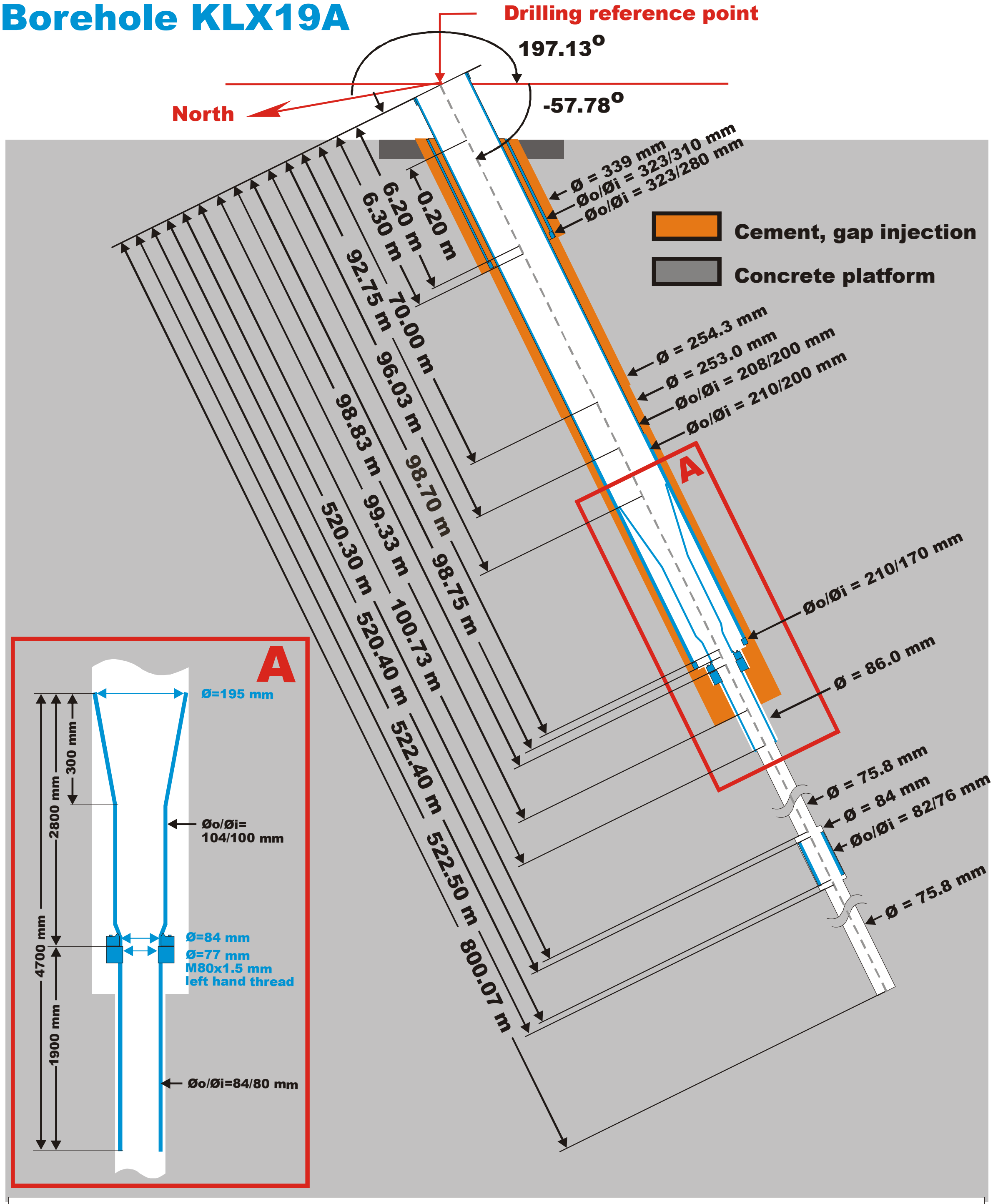
Further descriptions of the percussion drilling of the telescopic section 0–99.33 metres and the measurements performed during this phase are given in Section 5.2. The core drilling between 99.33–800.07 metres is further described in Section 5.3. Results from hydrogeological and hydrogeochemical measurements 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. KLX19A Technical summary.

General	Technical
Name of hole: KLX19A	Percussion drill rig Enteco E14G
Location: Laxemar, Oskarshamn Municipality, Sweden	Percussion hole length 99.33 m (diam 253.0 mm)
Contractor for drilling Drillcon AB	Core drill rig B20 APC Atlas Copco
Subcontractor percussion drilling Sven Andersson AB	Core drill dimension N-size (76 mm)
Percussion drill start date May 10, 2006	Cored interval 99.33–800.07 m
Completion date May 22, 2006	Diamond bits used 6
Subcontractor core drilling Suomen Malmi OY (SMOY)	Average bit life 117 metres
Core drill start date June 3, 2006	Position KLX19A (RT90 RH70) at top of casing: N 6365901.42 E 1547004.62 Z 16.87 (m.a.s.l.)
Completion date September 20, 2006	Azimuth (0–360)/ Dip (0–90) 197.13 / –57.78
	Position KLX19A (RT90 RH70) at 800.07 m length: N 6365480.03 E 1546885.34 Z –652.63 (m.a.s.l.)
	Azimuth (0–360)/ Dip (0–90) 193.63 / –56.03

Technical data

Borehole KLX19A



Drilling reference point

Northing: 6365901.42 (m), RT90 2,5 gon V 0:-15

Easting: 1547004.62 (m), RT90 2,5 gon V 0:-15

Elevation: 16.87 (m), RHB 70

Drilling period

Drilling start date: 2006-05-10

Drilling stop date: 2006-09-20

Ver 2007-04-24

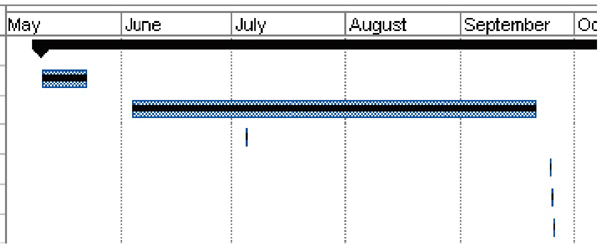
Figure 5-1. *Technical data from KLX19A.*

Table 5-2. Summary of core drilling progress and borehole measurements in KLX19A.

BH metres	Pumping tests and water sampling	Airlift pumping with evaluation of drawdown and/or recovery	Deviation measurement	Miscellaneous
			060522 Survey of borehole collar (TOC) Azimuth 197.13 Dip –57.78.	
100	060512 Pumping test 6.00–98.80 m. 109 L/min at 8 m drawdown.		060514 Flexit at 98 m (pilot percussion hole) Azimuth 197.5 Dip –58.	
200	060608 Pumping test 101.73–197.00 m. Water flow 10.1 L/min at 12 m drawdown. Water sample.		060609 Flexit at 190 m Azimuth 195.5 Dip –57.2.	
300			060614 Easy-shot at 297 m Azimuth 196.1 Dip –57.	
400	060619 Pumping test 194.60–371.00 m. Water flow 9 L/min at 12 m drawdown. Water sample.			
			060701 Easy-shot at 426 m Azimuth 196.1 Dip –56.8.	
500	060705 Pumping test 368.95–463.60 m. Water flow 8 L/min at 8 m drawdown. Water sample.	060704 Airlift pumping 98.75–460.23 m. No drillstem in borehole.		
				Rinsing action (air lifting, nitrogen gas lifting and water flushing) between 520 and 584 m drilled length.
600	060903 Pumping test 461.65–576.77 m. Water flow 4.5 L/min at 13 m drawdown. Water sample.			060902 BIPS measurement of section 520.20 to 526.20 m. 060905 Emplacement of PLEX tubing between 520.40 and 522.40 m.
700	060915 Pumping test 576.00–708.76 m. Water flow 0.4 L/min at 5 m drawdown. No water sample.			
800	060921 Pumping test 705.00–800.07 m. Water flow 1.2 L/min at 18 m drawdown. No water sample.	060924 Airlift pumping 98.75–800.07 m. No drillstem in borehole.	060925 Maxibor at 795 m Azimuth 194.1 Dip –54.6. 061010 Final Flexit at 792.	061006 Nitrogen gas flushing 0-800.07 m 1:st lifting 13:55–14:10 2:nd - " - 14:20–14:35 3:rd - " - 14:50–15:20

Table 5-3. Chronological summary of main core drilling events in KLX19A.

ID	Task Name	Start	Finish
1	**First activity starts**	**Wed 06-05-10**	**Sun 06-11-26**
2	Percussion drilling	Wed 06-05-10	Mon 06-05-22
3	Core drilling	Sat 06-06-03	Wed 06-09-20
4	Recovery test	Tue 06-07-04	Wed 06-07-05
5	Recovery test	Sun 06-09-24	Mon 06-09-25
6	Maxibor measurement	Mon 06-09-25	Mon 06-09-25
7	Maxibor measurement	Mon 06-09-25	Mon 06-09-25



5.2 Drilling, measurements and results in the telescopic section 0–99.33 m

Drilling, reaming and grouting (gap injection) were made from May 10 to May 22, 2006.

5.2.1 Preparations

A cement pad for emplacement of drill rig, fuel container and compressor was built. A suitable area was cleared and levelled for establishing of a drill site.

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

Figure 5-2. *Constructing the drill site for borehole KLX19A.*

5.2.2 Drilling and casing installation

The construction of the upper telescope section (0–99.33 metres) of KLX19A was made in steps as shown in Figure 5-3 and described below:

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

- Drilling was made to 6.3 metres length with NO-X 280 mm equipment. This gave a hole diameter of 339 mm and left a casing (323/310 mm diameter) to a length of 6.3 m.
- Inner supportive casing for guidance for the drill string was mounted.
- A pilot percussion hole was drilled to a depth of 99.33 m with 5" DTH-hammer (nominal diameter 165 mm). No record of the pilot bit diameter has been kept, see also Section 5.9, Nonconformities.
- Deviation measurements with the Flexit method was done in the pilot borehole to 98 m length. This measurement was part of a separate geophysical activity (Activity Plan AP PS 400-06-058, SKB internal document).
- Reaming to diameter 253 mm was done to full depth i.e. 99.33 m.
- Stainless casing of 208×4 mm was installed from 0 to 98.75 m.
- Casing grouting (gap injection) with low alkali cement based concrete (2,340 kg or 2,600 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.

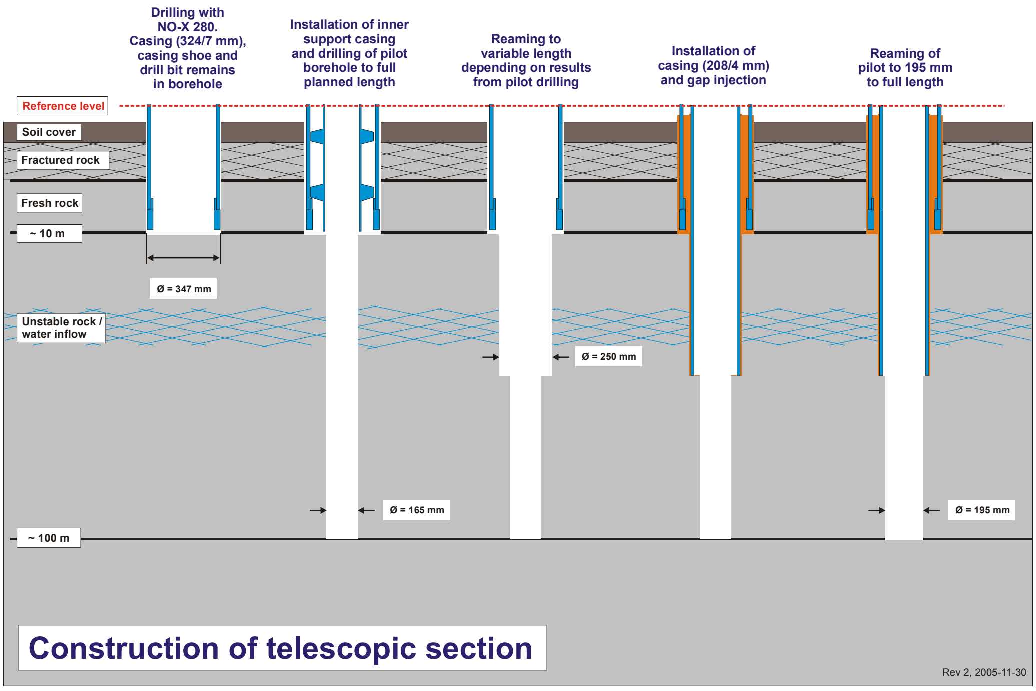


__Figure 5-3.__ Construction of the telescopic section. The cement for casing grouting is introduced between the casing and the rock wall. The drill bit acts as a barrier so that cement does not enter the pilot hole.

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 5-4.

The depth to bedrock from top of casing (TOC) was 0.4 m. The depth of overburden (ground surface to rock) was 0.2 metres i.e. the drilling reference level (TOC) was located 20 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 rock. Measurements of water inflow during drilling were made as shown in Figure 5-4. A water flow of 64 L/min was measured at 53.8 m. The final inflow after pilot drilling (165 mm nominal diameter) to full length was 130 L/min.

The results from the preliminary geological logging, measurements of magnetic susceptibility in the drill cuttings and water flow during drilling are given in Figure 5-4.

No water samples were collected in the telescopic section in KLX19A.

5.2.4 Hydrogeological measurements and results during percussion drilling

In the percussion drilled part of KLX19A, 6.00–99.30 m, one single-hole pumping test was performed in open borehole. The test was made with a flow rate of 110 L/min which generated a drawdown of 16 m. The result is shown in Table 5-4 and Figure 5-5 below. The pumping test was made in the pilot borehole (nominal diameter 165 mm) from May 12 to May 14, 2006. The test was evaluated according to Moye /3/. The pumping phase was 24h and 20 min, and the recovery phase was 22 h and 8 min.

5.3 Core drilling KLX19A 99.33–800.07 m

Core drilling in KLX19A was conducted between June 6 and August 20, 2006.

The main work in KLX19A 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.

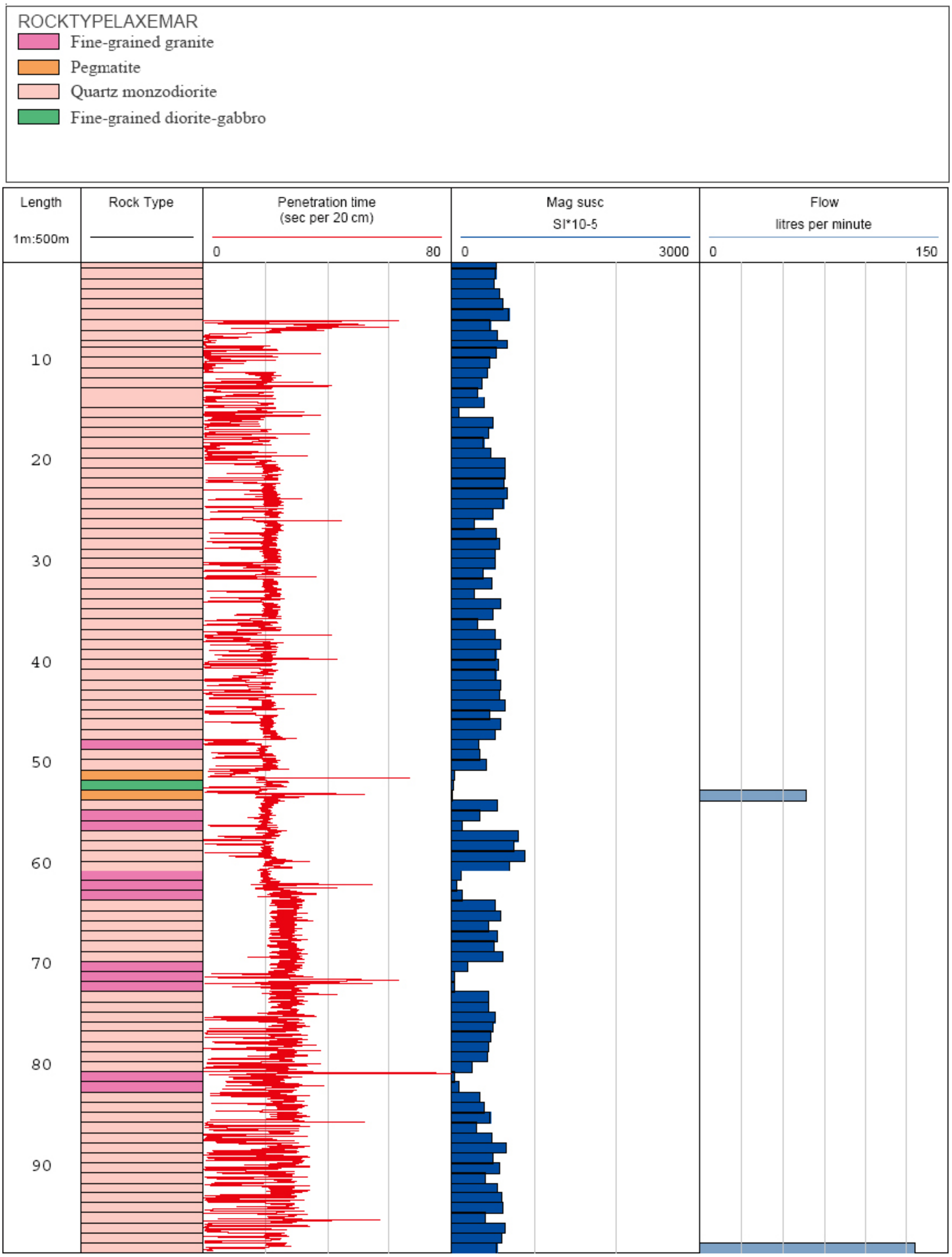


***Figure 5-4.** Preliminary geological results based on logging of drill cuttings and penetration rate from percussion drilling of KLX19A.*

Table 5-4. Results from single-hole pumping test in open borehole KLX19A, 6.00–99.30 m.

Tested section [m]	Q/s [m²/s]	T_M [m²/s]	Comments
6.00–99.30	$2.1 \cdot 10^{-4}$	$2.4 \cdot 10^{-4}$	Pumping test without wireline probe.

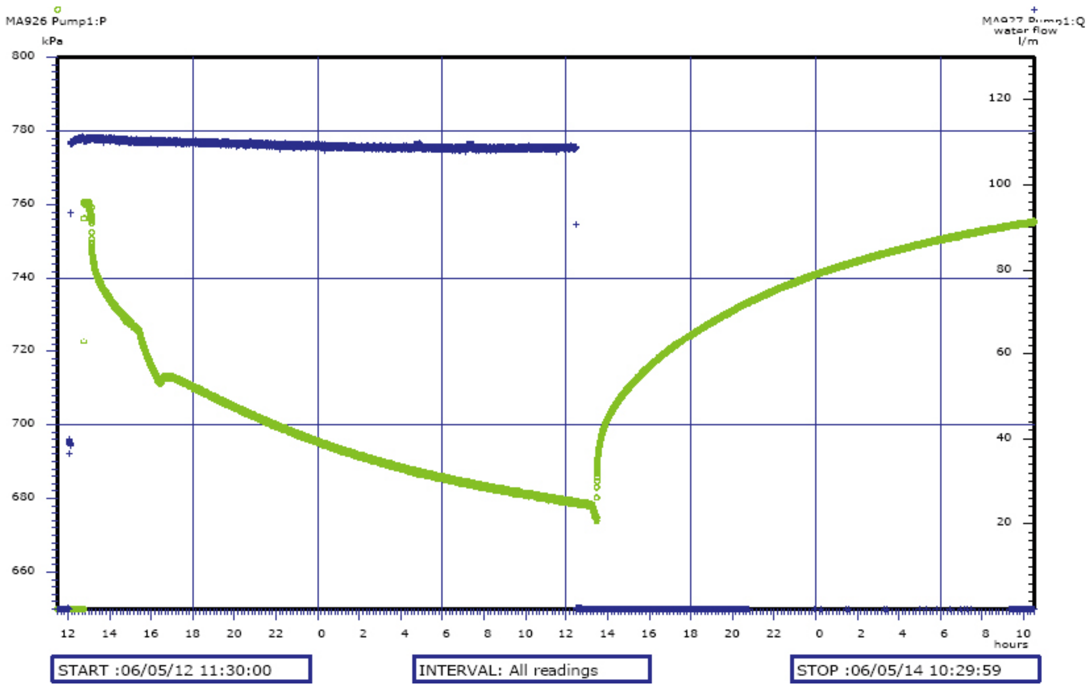


Figure 5-5. Pumping test in the telescopic section of KLX19A. The water table is shown with green and the pumping flow is shown with blue.

5.3.1 Preparations

The preparations for core drilling started on May 27, 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 5-6.

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 99.33 and 100.23 m with T-86 equipment. An inner supportive casing with diameter 84/77 mm was installed to 100.23 m.

The supportive casings have a perforated section below 90 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.

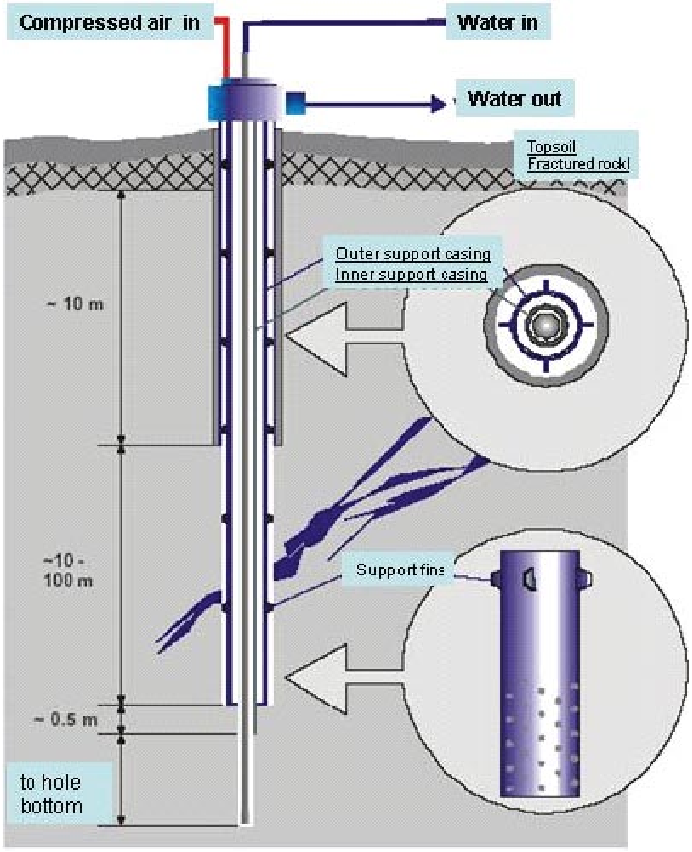


Figure 5-6. *In the telescopic part of the drill hole a temporary installation is made with casing tubes for support and alignment and equipment for air-lift pumping. In the uppermost part the return water discharge header is mounted. The water discharge is led to the settling containers.*

5.3.2 Flushing and return water handling

The flushing water source was percussion borehole HLX28, see also Sections 5.4.2 and 5.5. The location of the water source, borehole HLX28 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 KLX19A is shown in Figure 5-7.

The targeted content for uranine in the flushing water was 0.20 mg/L and the actual average uranine content was 0.169 mg/L, see also Figure 5-12 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 KLX19A

Core drilling with T-86 equipment giving an 86 mm diameter hole was done from 99.33 to 100.73 m in KLX19A. The part from 100.23 to 100.73 m was first drilled with N-size and subsequently reamed to T-86 as part of the borehole completion, see Section 5.3.4.

Core drilling with N-size (76 mm) triple-tube, wireline equipment was conducted from 100.23 m to the final length of 800.07 m in KLX19A.

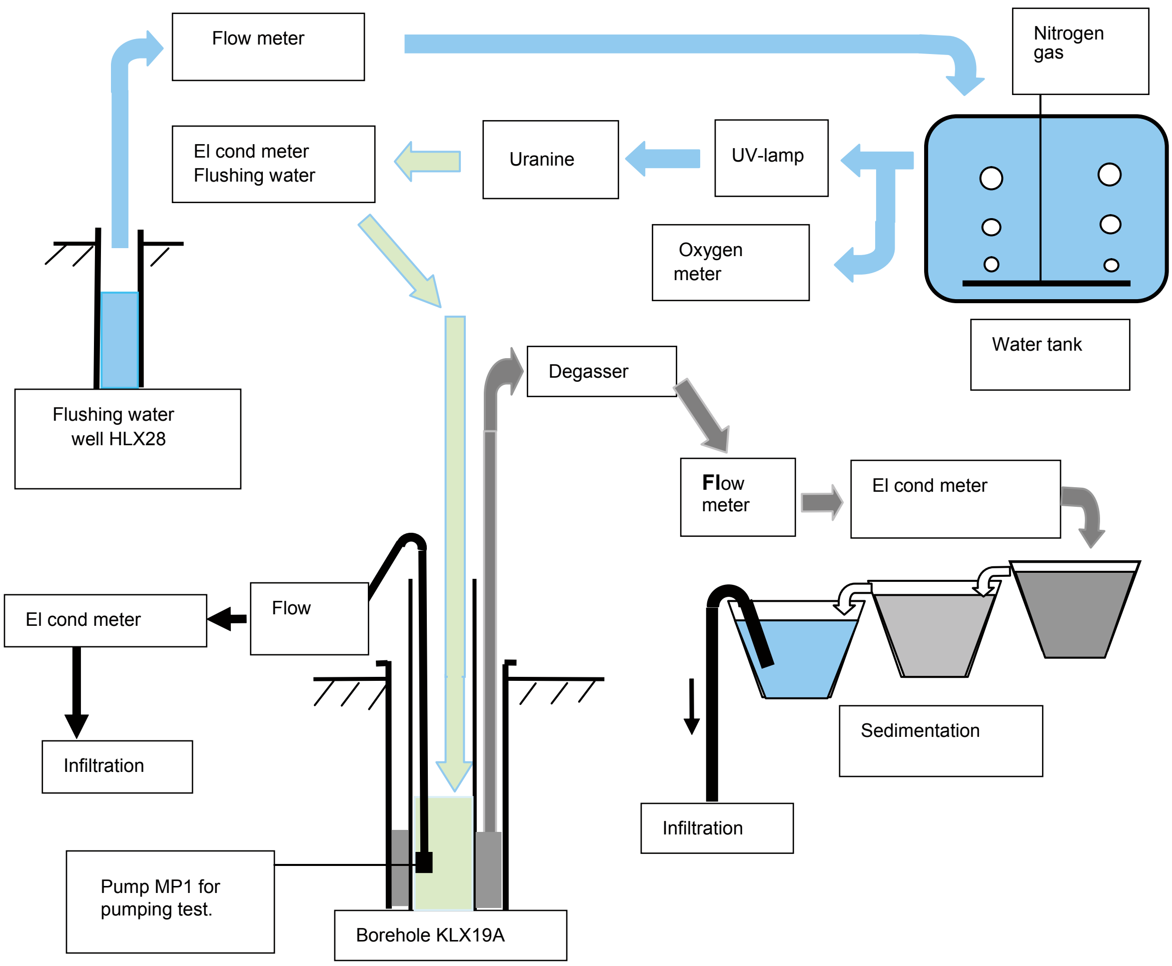


Figure 5-7. *The flushing and return water handling and the emplacement of related monitoring equipment in KLX19A.*

Drilling equipment (string and barrel) got stuck in the borehole on several occasions during drilling below 520 m. It was also noted that large amounts of drill cuttings accumulated in the bottom of the borehole. In the early days of September, at drilled lengths between 577 and 584 m, attempts to clear the borehole of cuttings and loose rocks were made with air-lifting and nitrogen gas lifting. The times for nitrogen lifting are given in Table 5-10. Digital images of the problematic section along the borehole wall were taken with the BIPS camera between 520.20 and 523.20 m on September 1 and 2. Emplacement of a stabilizing tube in the borehole wall with the PLEX method was done on September 5. An interval between 520.30 m and 522.50 m was reamed to a diameter of 82 mm and PLEX tubing was emplaced between 520.40 m and 522.40 m drilled length.

The PLEX method is schematically described in Figure 5-8 and consists of:

- Lowering of the PLEX tool to the section to be stabilised.
- Extruding the reaming cutters with water pressure and gently reaming the problematic section.
- Expanding the rubber packer with water pressure and thereby forcing the perforated roll of steel plate into contact with the borehole wall.
- When the water pressure is removed the PLEX tool can be retracted.

The borehole wall is stabilised but retains permeability for water flow and hence it is possible to do hydrogeological tests.

The core diameters and intervals for 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 KLX19A.

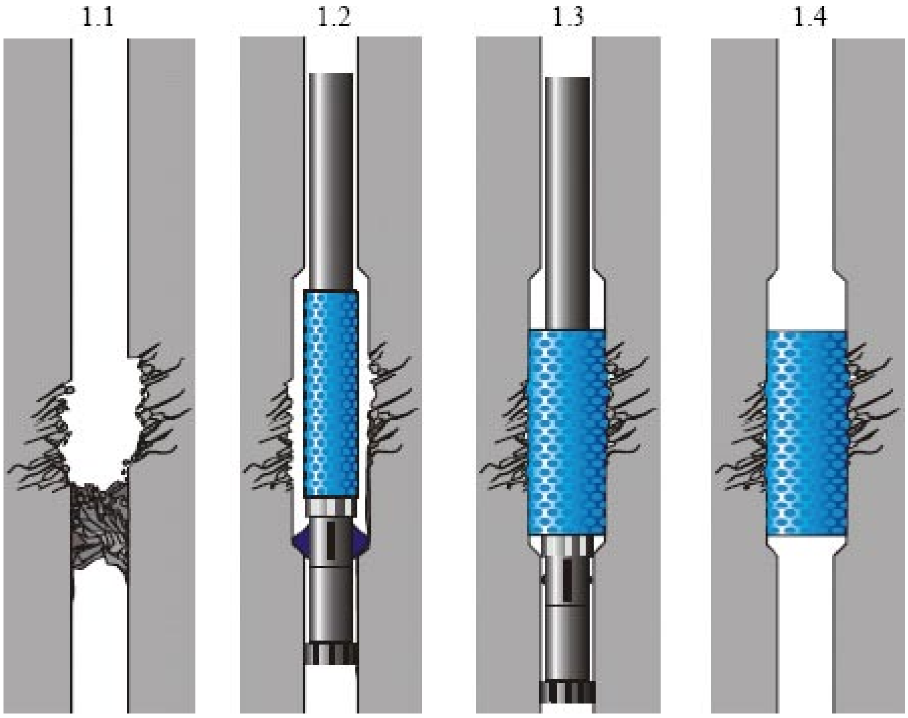


Figure 5-8. *Schematic description of the PLEX method.*

Table 5-5. Core diameters, borehole diameters and drilling dimensions during core drilling in KLX19A.

Core diameter (mm)	Borehole diameter (mm)	Interval (m drilled length)	Drilling dimension	Comment
72.0	86	99.33–100.23	T-86	
50.2	86	100.23–100.73	N and T-86	Reamed to 86 mm diameter
50.2	76	100.73–520.30	N	
50.2	82	520.30–522.50	N	PLEX-tube installed between 520.40 m and 522.40 m
50.2	76	522.50–800.07	N	

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 or EZ-shot method three times along the core drilled section of the borehole. The results from these measurements are not stored in the Sicada database but are given in a summary fashion in Table 5-2.

Measurements were done with the Flexit and Maxibor methods for the final evaluation of the borehole deviation in KLX19A. 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 (Activity Plan AP PS 400-06-117, SKB internal document). The Flexit tool was run both up and down the borehole from 0 to 792 m. In addition, measurements with the Maxibor instrument were performed both up and down the hole between 0 and 795 m, however only measurements down to 792 m were used for calculation of borehole deviation. 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 KLX19A 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/.

Horizontal and vertical plots of the results of the calculated deviation covering the entire length of borehole KLX19A 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.

A total of six drill bits were used for KLX19A, see Figure 5-9.

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.

Table 5-6. Measurements used for borehole deviation calculation in KLX19A.

Deviation measurement method	Used for calculation of bearing/ inclination	Interval from (m)	Interval to (m)	Measuring direction	Date	Sicada database activity ID
Maxibor	Bearing	117.00	792.00	down/in	2006-09-25	13131114
Maxibor	Bearing	117.00	792.00	up/out	2006-09-25	13141325
Flexit	Bearing	117.00	792.00	down/in	2006-10-10	13132082
Flexit	Inclination	3.00	792.00	down/in	2006-10-10	13132082
Flexit	Bearing	117.00	792.00	up/out	2006-10-10	13136111
Flexit	Inclination	3.00	792.00	up/out	2006-10-10	13136111

Table 5-7. Core losses noted in KLX19A.

From (m)	To (m)	Core loss length (m)	Comment
102.60	102.81	0.21	Missing Core Piece
105.11	105.44	0.32	Missing Core Piece
299.62	299.74	0.12	Missing Core Piece
301.31	301.53	0.22	Missing Core Piece
499.41	499.53	0.12	Missing Core Piece

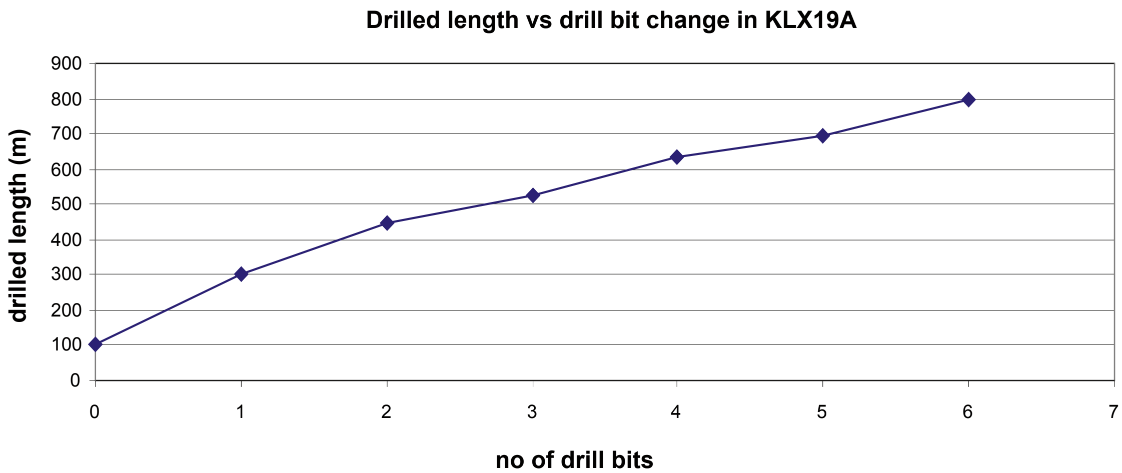


Figure 5-9. Drill bit changes during core drilling in KLX19A.

5.3.4 Borehole wall risk assessment, stabilisation and completion

Borehole wall risk assessment and stabilisation

A borehole wall assessment was prepared on October 19, 2006, SKB ID no 1062226, SKB internal document.

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

- Rinsing by air-lifting and flushing with water prior to logging with BIPS at 520 m.
- BIPS logging was done for evaluation of the borehole wall from 520 to 526 m on September 2.
- Nitrogen gas lifting for clearing the borehole of cuttings, September 4 and 5.
- Reaming the section 520.30 to 522.50 for emplacement of a PLEX tube between 520.40 and 522.40 m.
- Diamond drilling completed at 800.07 m on September 20.
- 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. The flush and brush tool is shown in Figure 5-10.
- The steel dummy was lowered without any problems along the entire length of the borehole (to 800 metres). The probe is designed so that it will run smoothly along the borehole if the curvature does not exceed 0.1°/metre.
- Downhole operations consisting of deviation measurements, milling of reference grooves and flushing of the borehole with nitrogen gas were made without stability problems.
- BIPS logging for final risk assessment was done to along the full drilled length.

The overall assessment was that the probability for rock fallout was low to medium in the borehole, but that extra care must be taken when logging in the section where the PLEX tube is located.

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.

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

The borehole was reamed from 100.23 to 100.73 with T-86 equipment. A steel conical guide was installed in KLX19A between 96.03 m and 100.73 m. The conical guide tapers from an inner diameter of 195 mm to 77 mm.

The length of the holes was rinsed by flushing (lifting) 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 5-8. Borehole sections that were mechanically rinsed by water flushing and rotating steel brush.

From (bh length m)	To (bh length m)
299	302
412	415
449	454
482	508
523	552

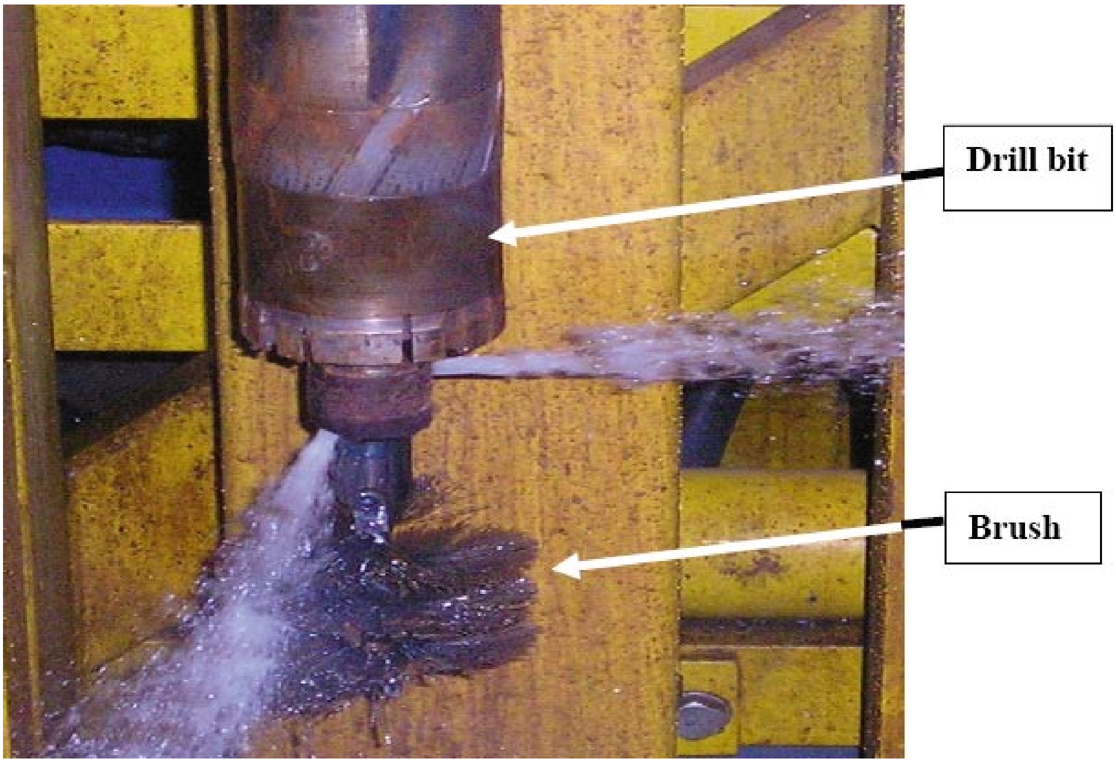


Figure 5-10. *The water flushing and rotating steel brush tool. The tool is lowered into the drill stem and can be seen in place just below the drill bit. During operating the drill string is moved up and down to remove loose rock fragments from the borehole wall.*

Table 5-9. Depth reference slots (m) in KLX19A.

110.00	507.00
150.00	547.00
200.00	597.00
250.00	647.00
303.00	697.00
350.00	748.00
403.00	778.00
447.00	

Table 5-10. Nitrogen gas lifting in KLX19A. (Time is given in local time including daylight saving time i.e. GMT+2).

Date	Time	Interval (m)	Volume removed (m^3)	Comment
060904	17.00–18.00	98.75–584.13	10	Two nitrogen gas liftings at ca 17.00 and 17.30 respectively. Each lifted about 5 cubic metres of water
060905	6.00–8.00	98.75–584.13	No data	The lifting was made at 06.22
061006	13.55–14.10	98.75–800.07	4	Final
061006	14.20–14.35	98.75–800.07	2	Final
061006	14.50–15.20	98.75–800.07	4	Final

5.4 Hydrogeological and hydrochemical measurements and results 99.33–800.07 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:

- Six fully successful pumping tests were conducted at various intervals, see Section 5.4.1.
- Six 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 KLX19A are commented in Section 5.4.4.

5.4.1 Hydrogeological results from wireline measurements

Results from the wireline tests in KLX19A are presented in Table 5-11 and Figure 5-11.

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 fourteen tests were performed in KLX19A, and six achieved sufficiently stable conditions for calculating pseudo steady-state transmissivity and hydraulic conductivity. The reasons behind the failed tests were mainly insufficient packer expansion, leakage of the pipe string or a malfunctioning check valve.

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.

5.4.2 Hydrochemistry

Six water samples were collected in connection with core drilling in KLX19A. 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 at the drill site as soon as possible after the sampling occasion and prepared and conserved at the Äspö laboratory. The samples were stored in refrigerator until the drilling of the borehole was completed.

The samples 11177, 11303, 11304 and 11306 were not analysed further due to high drilling water content. The drilling water content is calculated from the amount of uranine tracer in the return water. A high drilling water content implies that the amount of pristine formation water is low in the sample and therefore that the content of introduced uranine-spiked flushing water is high. The high drilling water content can in some instances (samples 11303 and 11304) be attributed to malfunctions in the wireline sampling equipment, as already mentioned in Section 5.4.1.

Sample 11217 was not analysed for isotopes since it had a relatively high amount of drilling water. Collected isotope bottles from sample 11217 are stored in a freezer (tritium and carbon isotopes in a refrigerator) at the Äspö laboratory.

Archive samples have been collected for the samples 11147 and 11217. The samples are stored in a freezer at the Äspö laboratory.

Selected analytical results from KLX19A are given in Table 5-14. A complete record of analytical results is given in Appendix 2.

Table 5-11 Pumping tests with wireline probe in KLX19A.

Tested section [m]	Q/s [m²/s]	T_M [m²/s]	Comments
101.73–197.00	$1.3·10^{-4}$	$1.5·10^{-4}$	Steady state is not reached completely. The section pressure increases c. 3 kPa during the flowing period (= 25% of dh_p). Pressure in casing is slightly affected by the pumping test.
194.6–371.00	$2.7·10^{-5}$	$3.7·10^{-5}$	The pressure- and flow rate curves vary a lot but pseudo steady-state conditions are considered to prevail. There is a pressure increase in casing parallel to the recovery after pump stop.
368.95–463.60	$1.4·10^{-5}$	$1.9·10^{-5}$	The flow rate decreases a little during the pumping, but the section pressure is almost at a constant level. The casing pressures goes down at pump start and up at pump stop indicating a leakage in the pipe string.
461.65–576.77	$4.5·10^{-6}$	$5.9·10^{-6}$	Smooth and declining pressure- and flow rate curves during the flowing period. No obvious impact on the casing pressure by pumping.
576.00–708.76	$1.1·10^{-6}$	$1.5·10^{-6}$	The pressure and flow rate look fairly well during the pumping phase. The section pressure does not recover to its initial level. At pump stop the pressure increase is very immediate.
705.00–800.07	$8.9·10^{-7}$	$1.2·10^{-6}$	An initial pumping period 16:20–16:56 was interrupted. The initial pressure, $h_{i,}$ was taken from 16:20 prior to the first pump start. The flow rate is unstable and declining, but the pressure curve is relatively even and on a constant level.

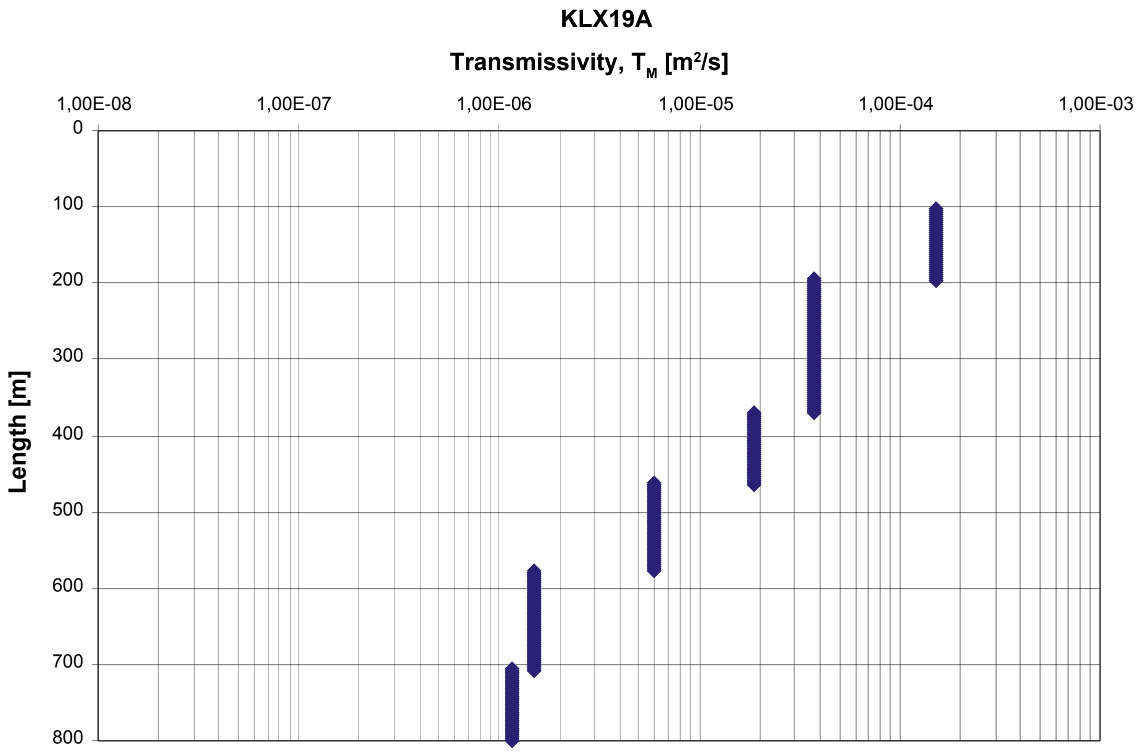


Figure 5-11. Transmissivity from wireline pumping tests in KLX19A versus borehole length.

Table 5-12. Evaluated test periods.

Tested section	Start (YYYY-MM-DD HH:MM)*		Stop (YYYY-MM-DD HH:MM)*	
101.73–197.00	2006-06-08	16:32	2006-06-09	02:41
194.6–371.00	2006-06-19	16:36	2006-06-20	03:03
368.95–463.60	2006-07-05	16:04	2006-07-06	02:38
461.65–576.77	2006-09-03	15:58	2006-09-04	02:30
576.00–708.76	2006-09-15	16:36	2006-09-16	20:20
705.00–800.07	2006-09-22	18:44	2006-09 22	22:06

* Times are given in daylight saving time (GMT+2).

Table 5-13. Sample dates and length during core drilling in KLX19A.

Sample number	Borehole	Date	Test section, length (m)	SKB chemistry class
11147	KLX19A	2006-06-09	101.73–197.00	3 (and all option isotopes)
11177	KLX19A	2006-06-20	194.60–371.00	1 (only drill water percentage)
11217	KLX19A	2006-07-06	368.95–463.60	3 (isotopes not included)
11303	KLX19A	2006-08-31	461.65–576.77	1 (only drill water percentage)
11304	KLX19A	2006-09-01	461.65–576.77	1 (only drill water percentage)
11306	KLX19A	2006-09-04	461.65–576.77	1 (only drill water percentage)

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
KLX19A	11147	2006-06-09	101.73	197.00	1.66	8.08	83.0	68.6
KLX19A	11177	2006-06-20	194.60	371.00	66.26	–	–	–
KLX19A	11217	2006-07-06	368.95	463.60	42.65	8.28	88.8	111.0
KLX19A	11303	2006-08-31	461.65	576.77	41.94	–	–	–
KLX19A	11304	2006-09-01	461.65	576.77	68.69	–	–	–
KLX19A	11306	2006-09-04	461.65	576.77	87.67	–	–	–

The percussion drilled borehole HLX28 was used as water source during the drilling of KLX19A. No water samples were collected from HLX28 in connection with the drilling of KLX19A. However, water samples have been collected from HLX28 at earlier occasions and results from those analyses are reported in the drilling reports for KLX11A /5/ and KLX20A /6/.

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 KLX19A, a total of 76 samples for uranine content and electrical conductivity in flushing and returning water were taken along the borehole.

The results are shown graphically in Figure 5-12. All the samples were analysed at the Äspö laboratory.

The calculated average uranine content for the whole borehole is 0.169 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.

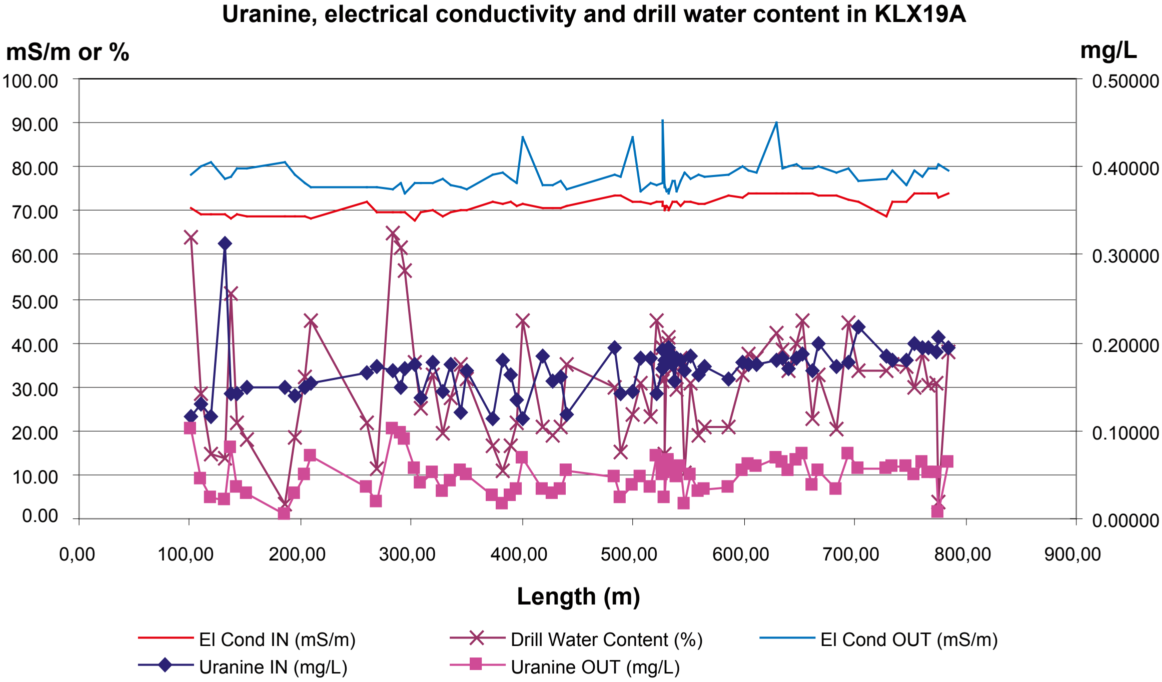


Figure 5-12. *The uranine concentration and electrical conductivity of the flushing water (IN) and the return water (OUT) in KLX19A. The drill water content in the returning water is also shown.*

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

Two air-lift pumping tests were conducted, one was done during drilling, and one was made 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 are shown in Table 5-15 and stored in the SICADA database as "recovery tests" (code HY050). The tested section is here defined as the section between the lower end of the grouted casing and the borehole bottom.

The plots from the drawdown and recovery tests are given in Figures 5-13 and 5-14.

Table 5-15. Results from airlift pumping in KLX19A.

Tested section [m]	Flow rate [L/min]	Drawdown [m]	Q/s [m²/s]	T_M [m²/s]	Comments
98.75–460.23	37.3	5.7	$1.1\cdot10^{-4}$	$1.6\cdot10^{-4}$	Q derives from accumulated volumes of water in and out Q = ΣV/dt.
98.75–800.07	58.5	8.6	$1.1\cdot10^{-4}$	$1.8\cdot10^{-4}$	Before the test there was a three hour period of water flushing, air lifting and borehole cleaning ending c. 4 hours prior to the air lift pumping test.

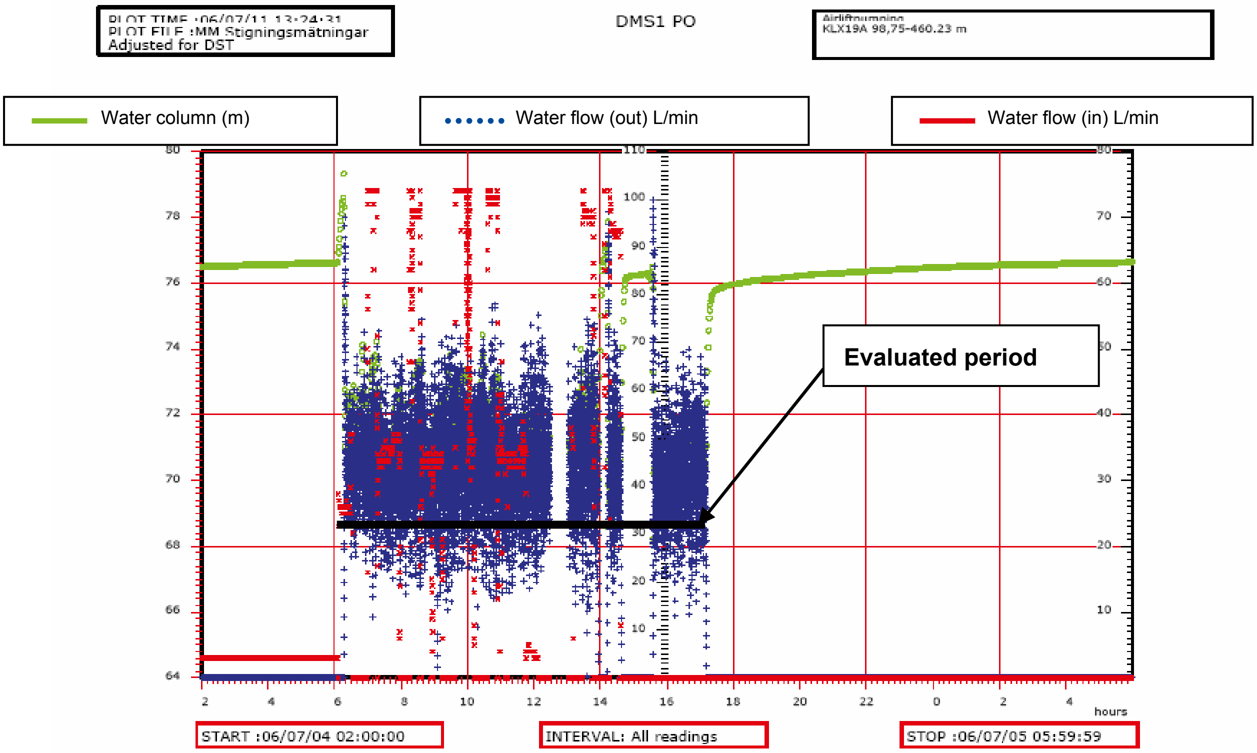


Figure 5-13. *Airlift pumping in KLX19A 98.75–460.23 m. The green line represents the height of the water column in the borehole; the out flow is shown as the blue dotted line and the inflow rate as the red line. Times are given in local time i.e. with daylight saving time (GMT+2). This test was conducted partly while drilling was done, which accounts for the inflow of water.*

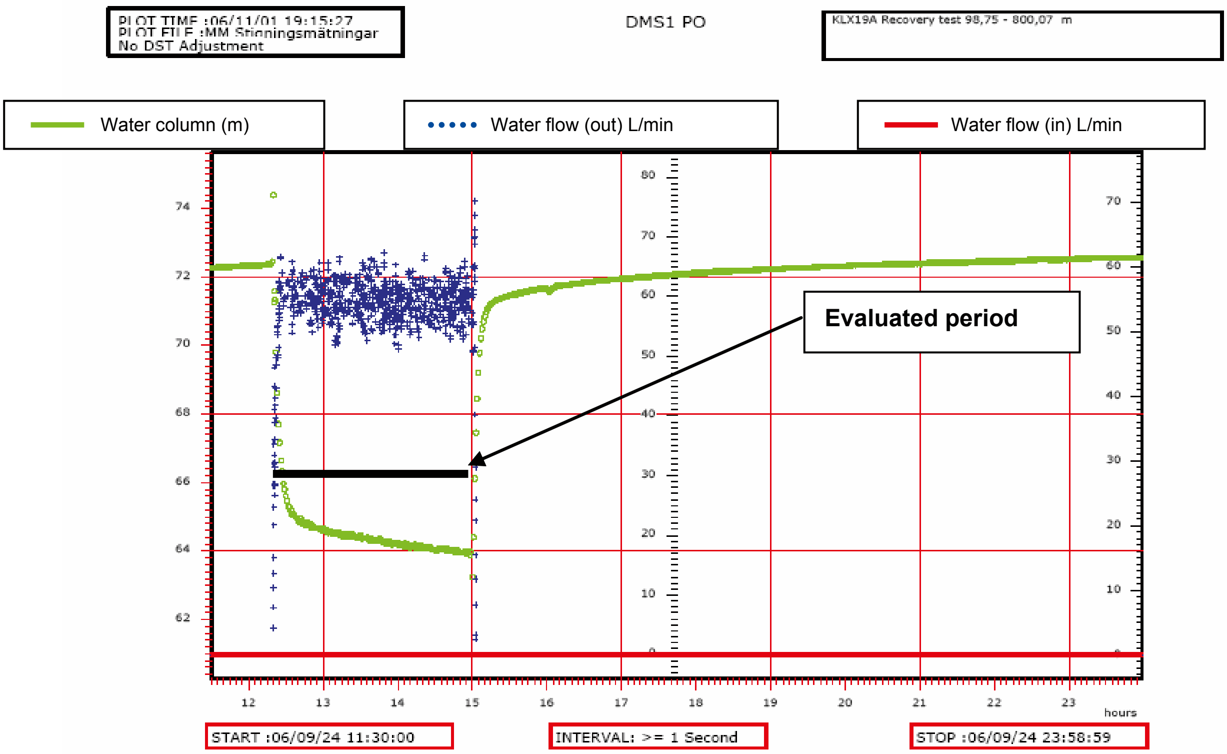


Figure 5-14. *Airlift pumping in KLX19A 98.75–800.75 m. The green line represents the height of the water column in the borehole; the out flow is shown as the blue dotted line and the inflow rate as the red line. The inflow rate was 0 L/min during the whole test period. This means that the test was done when no drilling or other drill related activities were made. The period for test evaluation is shown with a black bar. Times are given in Swedish Normal Time (GMT+1).*

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. All times in plots or text in Section 5.4.4 are given in Swedish Normal Time (GMT+1).

Summary conclusions are listed below. The locations of the boreholes are shown in Figure 5-22.

- No correlation between groundwater levels in the observation boreholes HLX27, HLX36 or KLX03 and the drilling activities in borehole KLX19A could be found.
- There is a clear hydraulic connection between the flushing water well (HLX28) and borehole KLX19A. HLX28 was used as a water supply well and therefore are any hydraulic responses from drilling activities in KLX19A obscured by pumping.
- Borehole HLX37 and borehole HLX32 are influenced by pumping in the flushing well HLX28 and also by air-lift pumping in borehole KLX19A.

No data was available for KLX20A during the drilling in KLX19A.

Hydraulic responses in near-by boreholes from percussion drilling of the telescopic section in KLX19A

No hydraulic responses from percussion drilling in KLX19A could be seen in the observation boreholes KLX03, HLX27, HLX36 or HLX37. A plot showing the water table in the water supply well HLX28 and observation boreholes HLX27 and HLX37 during percussion drilling of the telescopic section in KLX19A is given in Figure 5-15. No response from percussion drilling in KLX19A could be seen in the observation boreholes HLX27 or HLX37. The water table in HLX37 (purple) is however heavily affected by the pumping in HLX28 (red). Water was taken from HLX28 for drilling of boreholes for investigation of minor deformation zones (KLX22A and others).

A plot giving an overview of the water pressure levels in KLX03 (sections 1 to 5) is shown in Figure 5-16.

Hydraulic responses in near-by boreholes from air-lift pumping during core drilling in KLX19A

No response from drilling activities in KLX19A can be seen in KLX03 or HLX36, see Figures 5-16, 5-17 and 5-18.

A correlation can be seen between the air-lift pumping in KLX19A, the water level in the flushing water supply well HLX28 and the water table in HLX37, see Figure 5-16.

A clear response is also visible in Figure 5-18 between the pumping in the water supply well HLX28, air-lift pumping in KLX19A and the water table in HLX37.

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

Nitrogen gas flushing to a length of 584 m was done one time each on September 4 and 5. Lifting with nitrogen gas covering the entire length of the borehole was done three times on October 6. No hydraulic responses could be seen in observation boreholes KLX03, HLX27, HLX32, HLX36 or HLX37. A plot of the water tables in the percussion drilled (HLX) observation boreholes is given in Figure 5-19. Detailed plots of the water tables in HLX37 and HLX32 during the nitrogen gas flushing in KLX19A are given in Figures 5-20 and 5-21 respectively.

The location of the mentioned boreholes is given in Figure 5-22.

Additional comments on hydraulic responses are also given in Section 5.8 under "Monitoring of soil ground water levels".

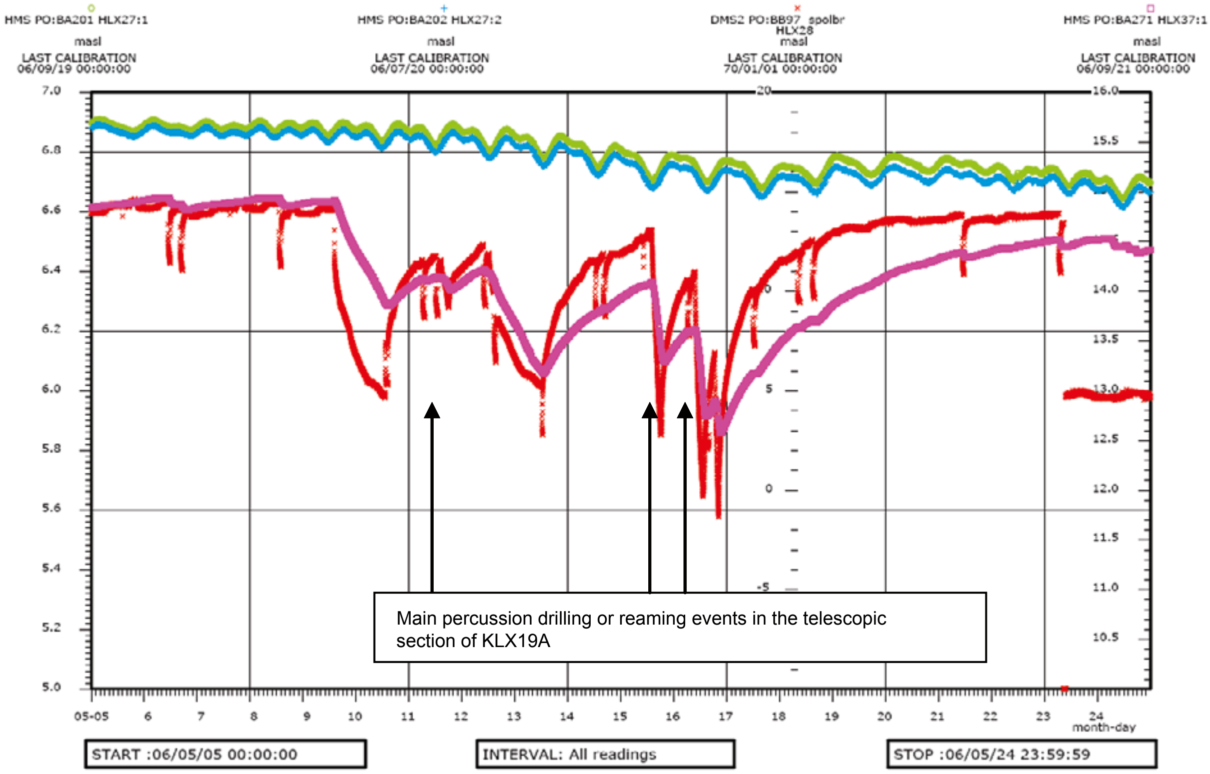


Figure 5-15. *Water table in the water supply well HLX28 and observation boreholes HLX27 and HLX37 during percussion drilling of the telescopic section in KLX19A. No response from percussion drilling in KLX19A could be seen in the observation boreholes HLX27 or HLX37. The water table in HLX37 (purple squares) is however heavily affected by the pumping in HLX28 (red crosses).*

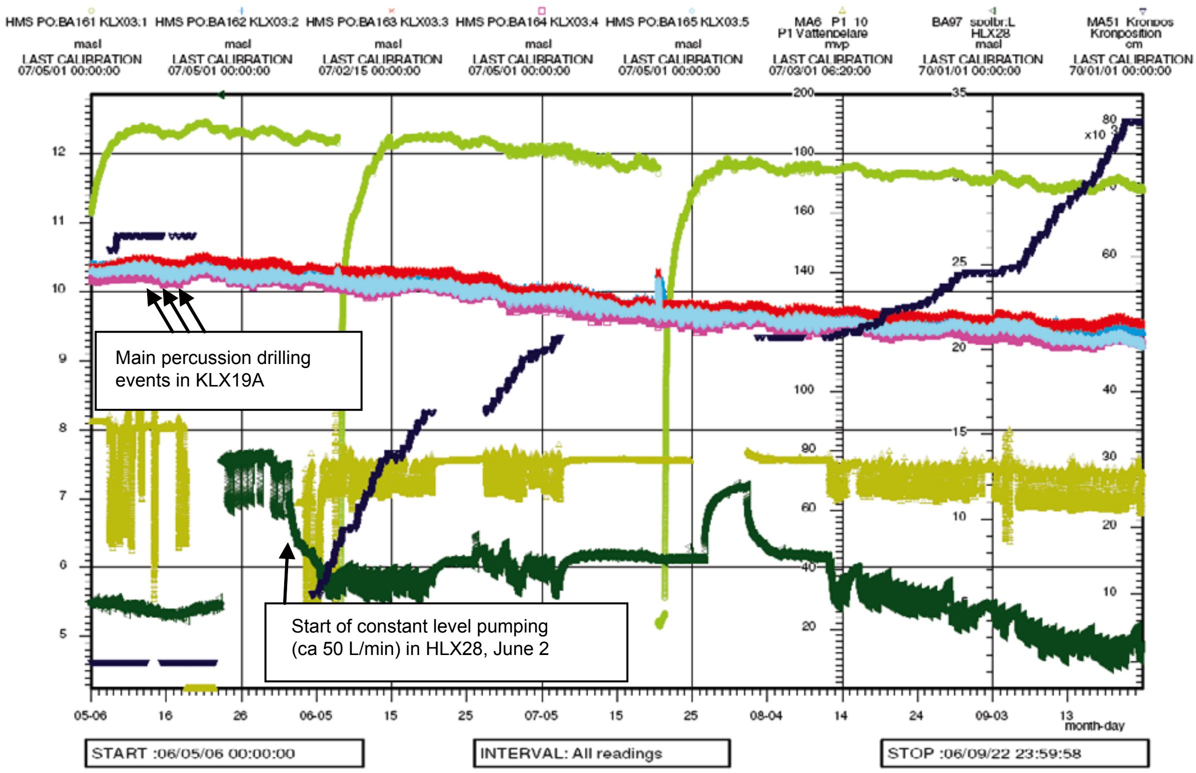


Figure 5-16. *Groundwater levels in sections 1–5 (the deeper sections) in observation borehole KLX03 together with water level in the flushing water well HLX28, the water level in the telescopic section of KLX19A and the drill bit position during the core drilling in KLX19A. A clear response is visible between the pumping in the water supply well HLX28 (dark green) and air-lift pumping in KLX19A (olive).*

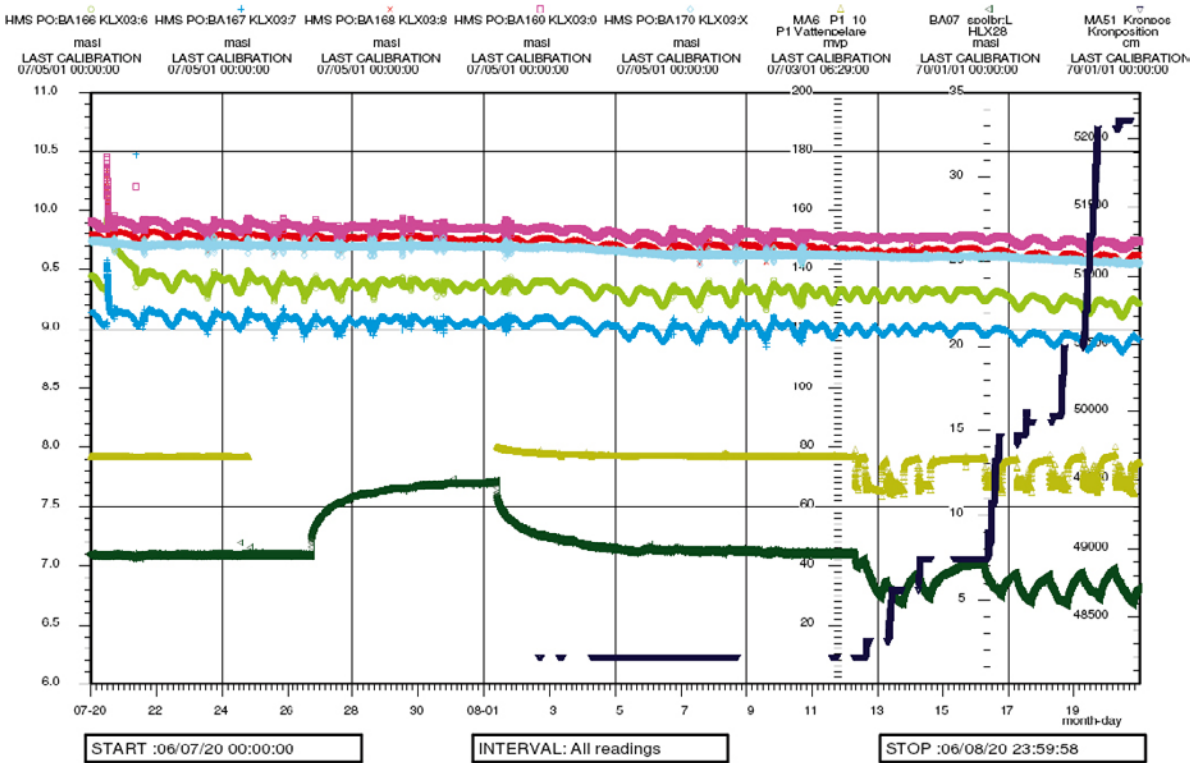


Figure 5-17. *Detail from core drilling in July–August. Groundwater levels in observation borehole KLX03 (sections 6–10), the flushing water well HLX28 and the water level in the telescopic section of KLX19A is shown together with the drill bit position during core drilling in KLX19A. No response from the drilling in KLX19A can be seen in KLX03. A clear correlation is visible between the pumping in the water supply well HLX28 (dark green and air-lift pumping in KLX19A (olive).*

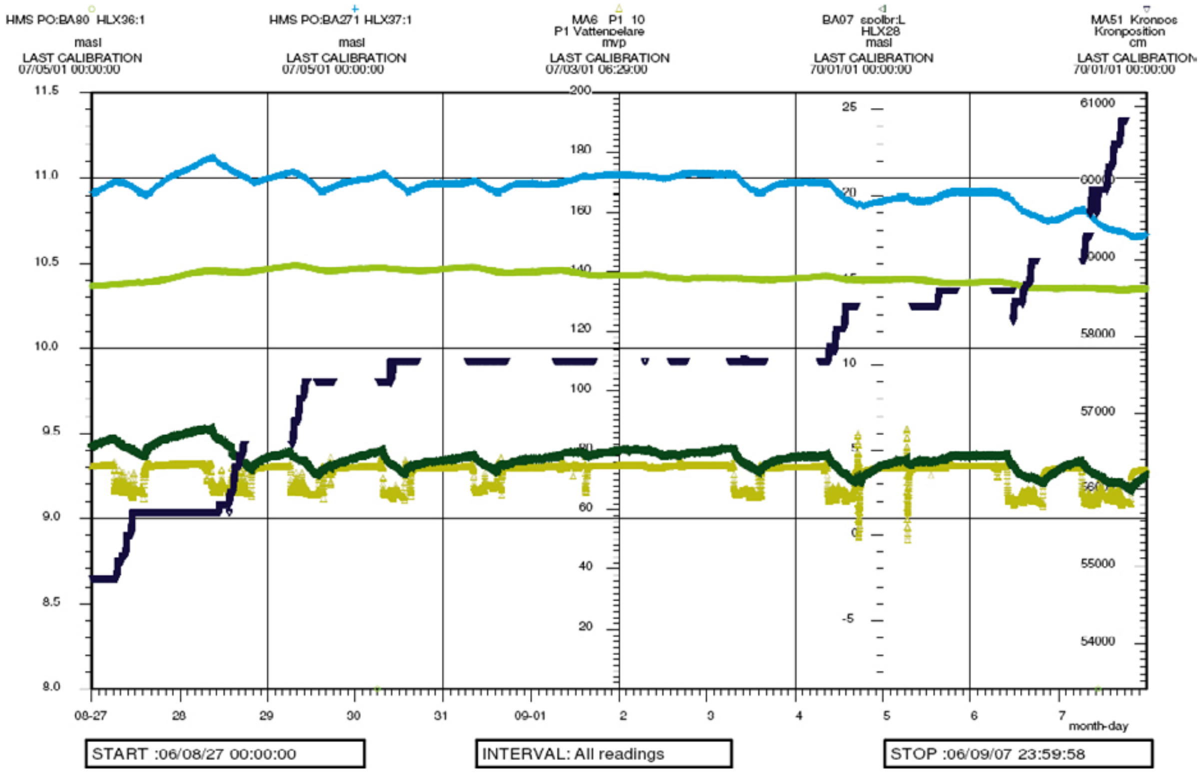


Figure 5-18. *Detail from core drilling in August–September. Groundwater level in boreholes HLX36 and HLX37 together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well) during the drilling in borehole KLX19A. No response from drilling in KLX19A can be seen in HLX36 (light green). A clear response is however visible between the pumping in the water supply well HLX28 (dark green), air-lift pumping in KLX19A (olive) and the water table in HLX37 (blue).*

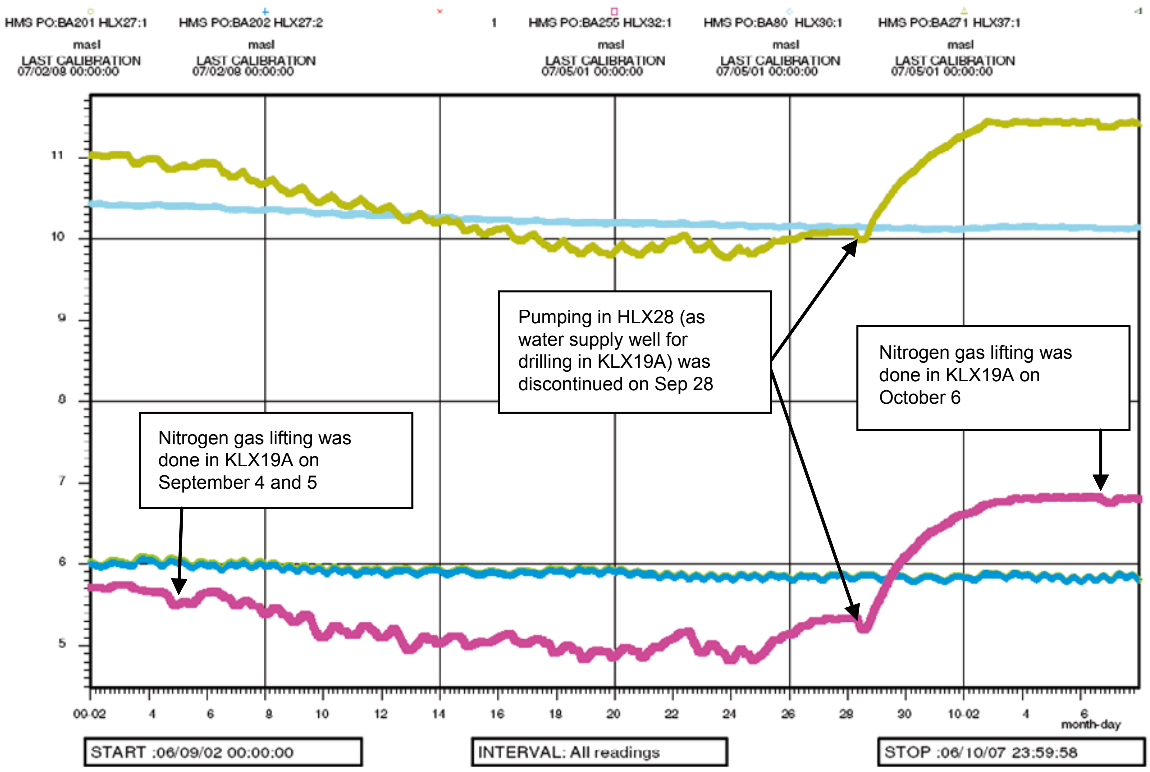


Figure 5-19. *Water levels in observation boreholes HLX27, HLX32, HLX36 and HLX37 during the final stages of the KLX19A drilling activity. No response from the nitrogen lifting in KLX19A could be seen in observation boreholes HLX27 and HLX36. Very subtle drawdown, occurring at a similar time as the nitrogen lifting, can be seen in HLX32 and to some extent also in HLX37. It is however demonstrated in Figures 5-20 and 5-21 that there is no response in HLX32 or HLX37 from the nitrogen lifting on October 6. A clear response corresponding to when the pumping in HLX28 was stopped can be seen in boreholes HLX32 and HLX37.*

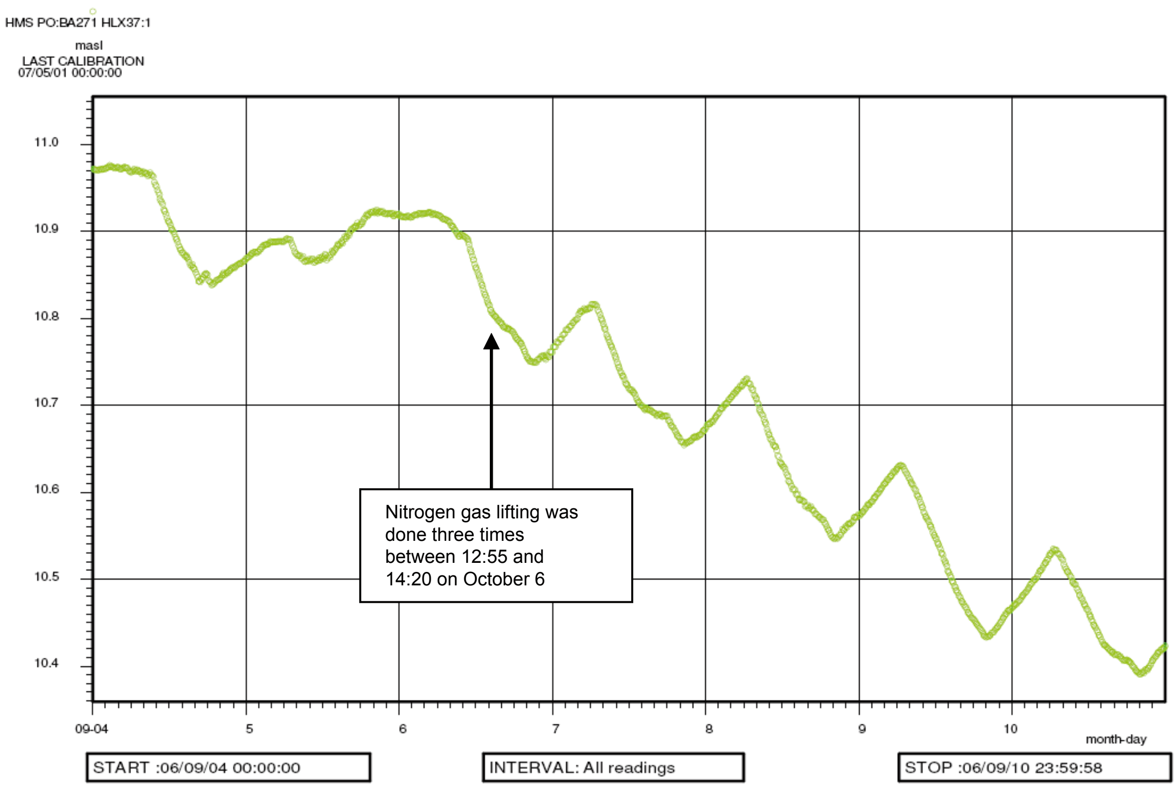


Figure 5-20. *Water level in observation borehole HLX37 during nitrogen gas lifting in KLX19A. No hydraulic response can be seen in HLX37.*

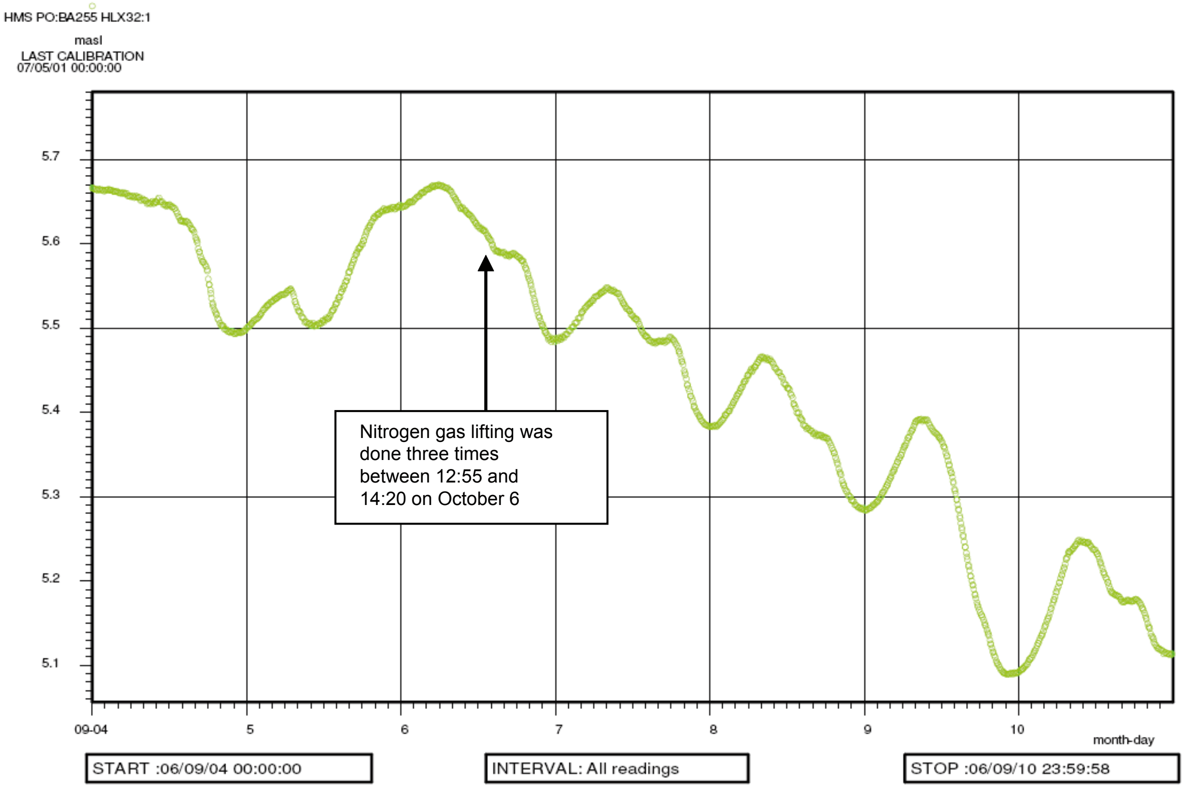


Figure 5-21. *Water level in observation borehole HLX32 during nitrogen gas lifting in KLX19A. No hydraulic response can be seen in HLX32.*

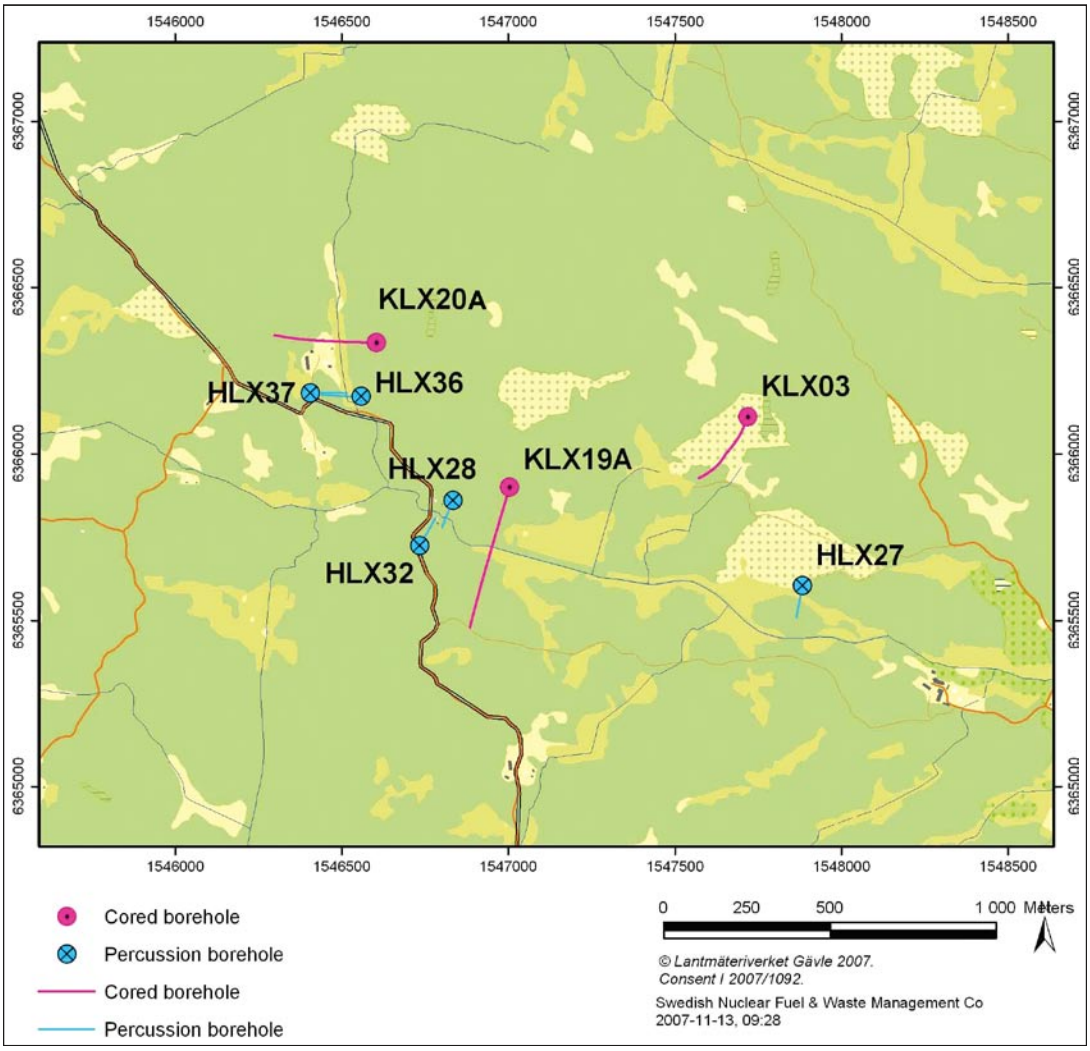


Figure 5-22. *Map showing the location of cored boreholes KLX03, KLX19A and KLX20A and the percussion boreholes HLX27, HLX28, HLX32, HLX36 and HLX37.*

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 0–99.33 metres and the core drilling section 99.33–800.07 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 5-23 through 5-25 below.

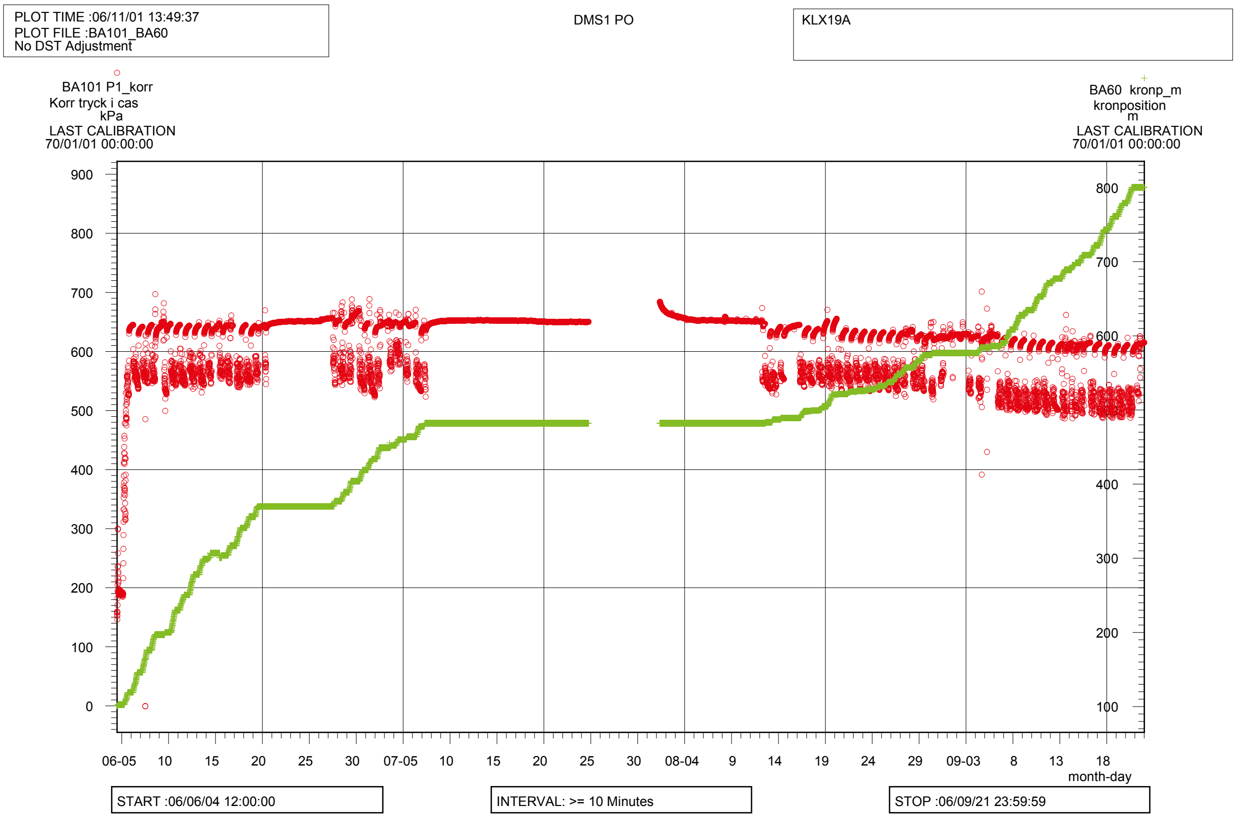


Figure 5-23. *Drill bit position (green) and water level from air-lift pumping (red). The water level is expressed as the pressure in kPa of the water column overlying the pressure gauge i.e. the ambient air-pressure has been subtracted. The pressure gauge is emplaced at 90 metres borehole length.*

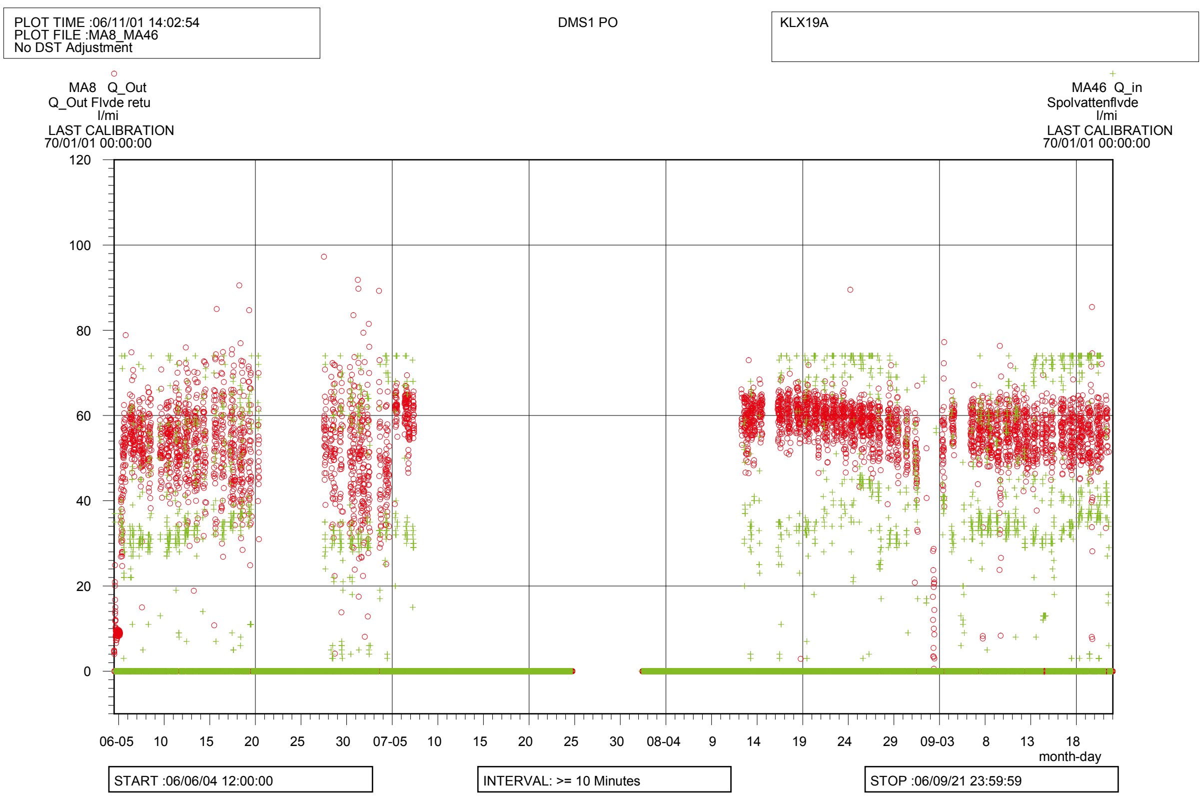


Figure 5-24. *Flushing water flow (green) and return water flow (red) in litres per minute.*

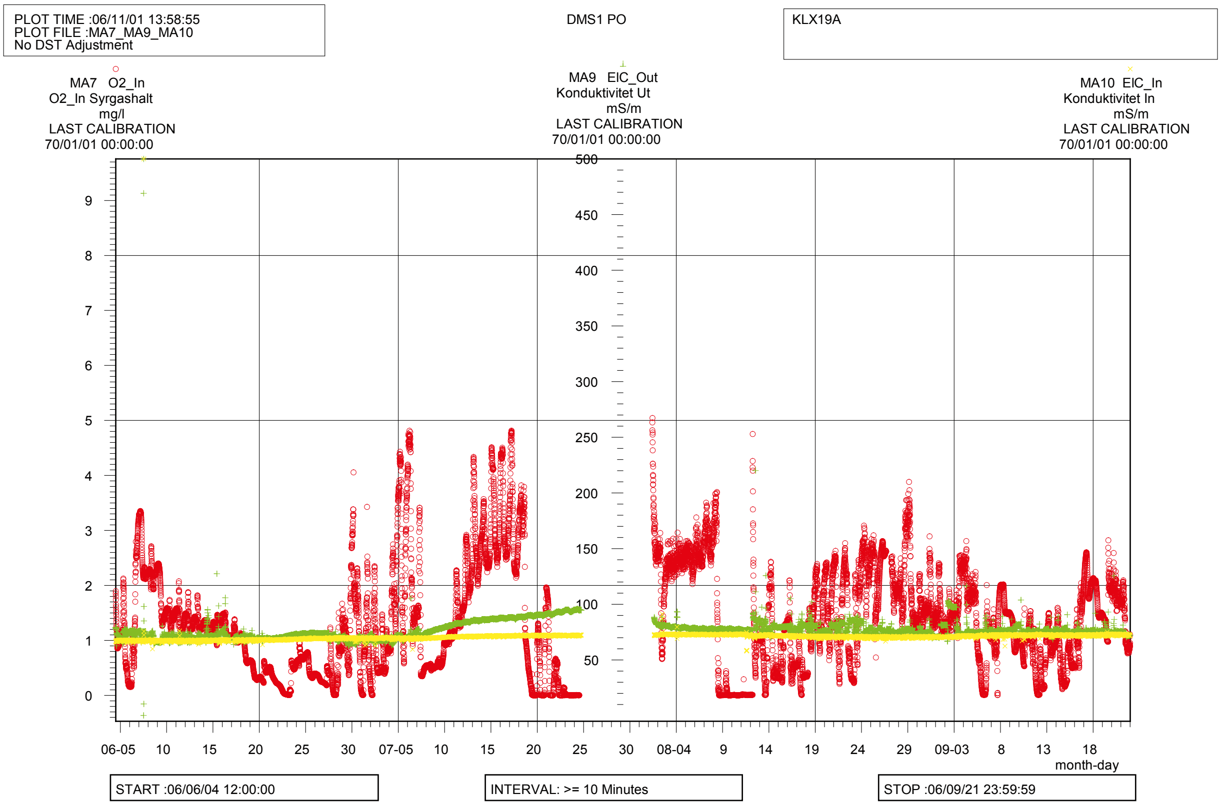


Figure 5-25. *Conductivity of flushing water (yellow) and return water (green). The oxygen content in mg/L of the flushing water (red) is also shown. The oxygen content of the flushing water is low (< 5 mg/L). The conductivity of the return water (green) is also low at below 100 mS/m.*

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 5-23 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 5-24 shows the flushing water flow (green) entering the hole and the return water flow (red). The flushing water flows (green) show three distinct levels of flow:

- A flow of ca 30–40 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 5-25 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 low (< 5 mg/L).

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 5-26.

The amount of flushing water consumed during drilling was 800 m^3, giving an average consumption of ca 1.1 m^3 per metre core drilled. The amount of effluent return water from drilling in KLX19A was measured by the DMS system to 2,300 m^3, giving an average of ca 3.3 m^3 per metre core drilled.

Drill cutting balance

The weight of cuttings in the settling containers amounted to 1,817 kg. The content of suspended material in the return water was not analysed in borehole KLX19A, however previous sampling has shown the content to be 400 mg/L /8/. The amount of material in suspension carried with the return water would amount to 920 kg (based on 2,300 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 700 metres is 4,725 kg assuming a density of 2.7 kg/dm^3. This means that 58% 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 5-16. The results show that almost 85% of the introduced amount uranine was retrieved during drilling of KLX19A.

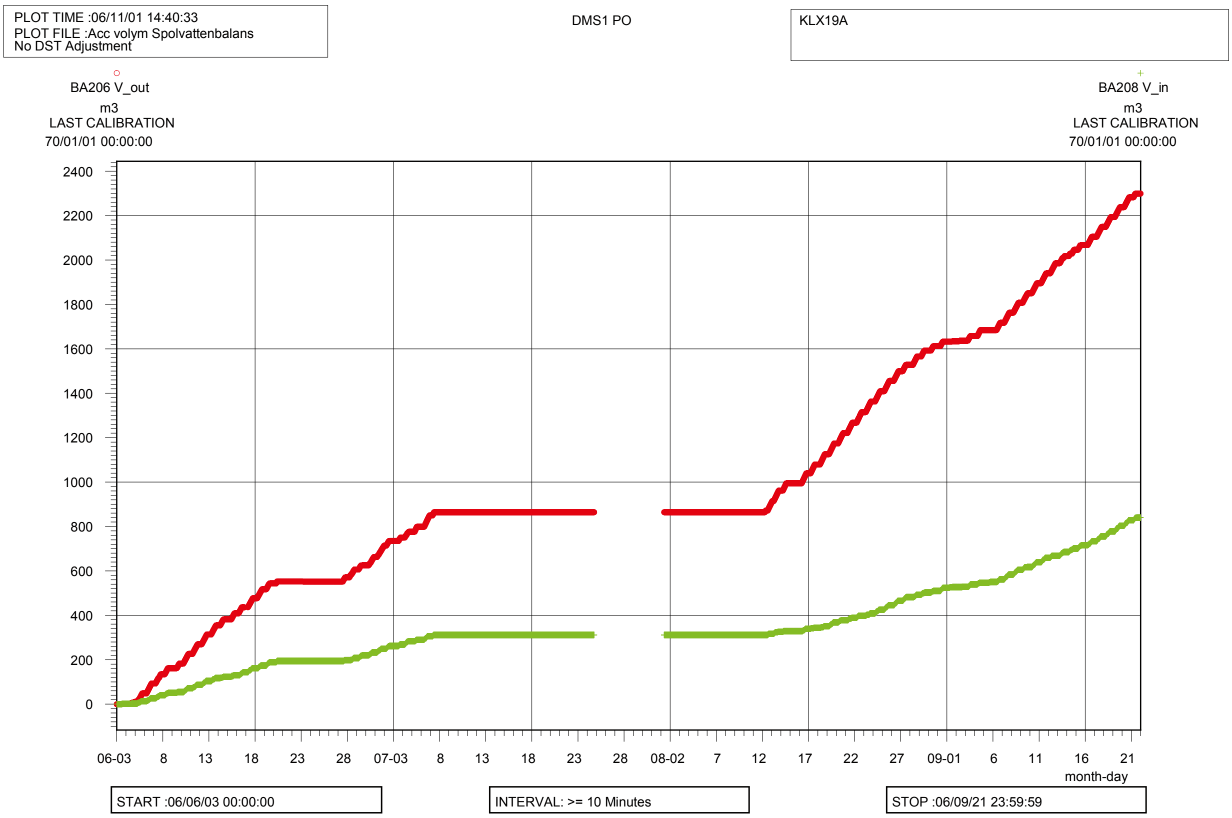


Figure 5-26. *The flushing water balance in KLX19A as recorded by the DMS system. The accumulated volume of the ingoing flushing water is shown in green and the outgoing return water is shown in red.*

Table 5-16. Balance calculation of uranine tracer in KLX19A.

Average uranine content IN (mg/L)	0.169
Flushing water volume IN (m^3)	800
Amount uranine introduced (g)	135
Average uranine content OUT (mg/L)	0.049
Return water volume OUT (m^3)	2,300
Amount uranine recovered (g)	113

5.6 Geology

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

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

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

Lithologically the core is dominated by Quartz monzodiorite. Dolerite is found between 480 and 550 m. Minor intercalations of pegmatite, fine-grained diorite-gabbro and fine-grained granite were noted in the borehole.

Rock alteration is rare and mostly weak. A section with significant red staining and chloritic alteration was logged from 430 to 480 m i.e. just above the dolerite. 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 1.72 (fractures/metre). The fracture frequency is very low throughout most of the Quartz monzodiorite rock. The altered section from 430 to 480 m also has an elevated amount of fractures. The fracture frequency is high in the dolerite. 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 SSM000254 and SSM000255 is shown in Figure 5-27. 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 KLX19A was typically below 100 mS/m. Samples of the return water that were analysed for electrical conductivity were also all below 100 mS/m, see Figure 5-12.

The uranine content was well below 0.3 mg/L, see Figure 5-12.

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.

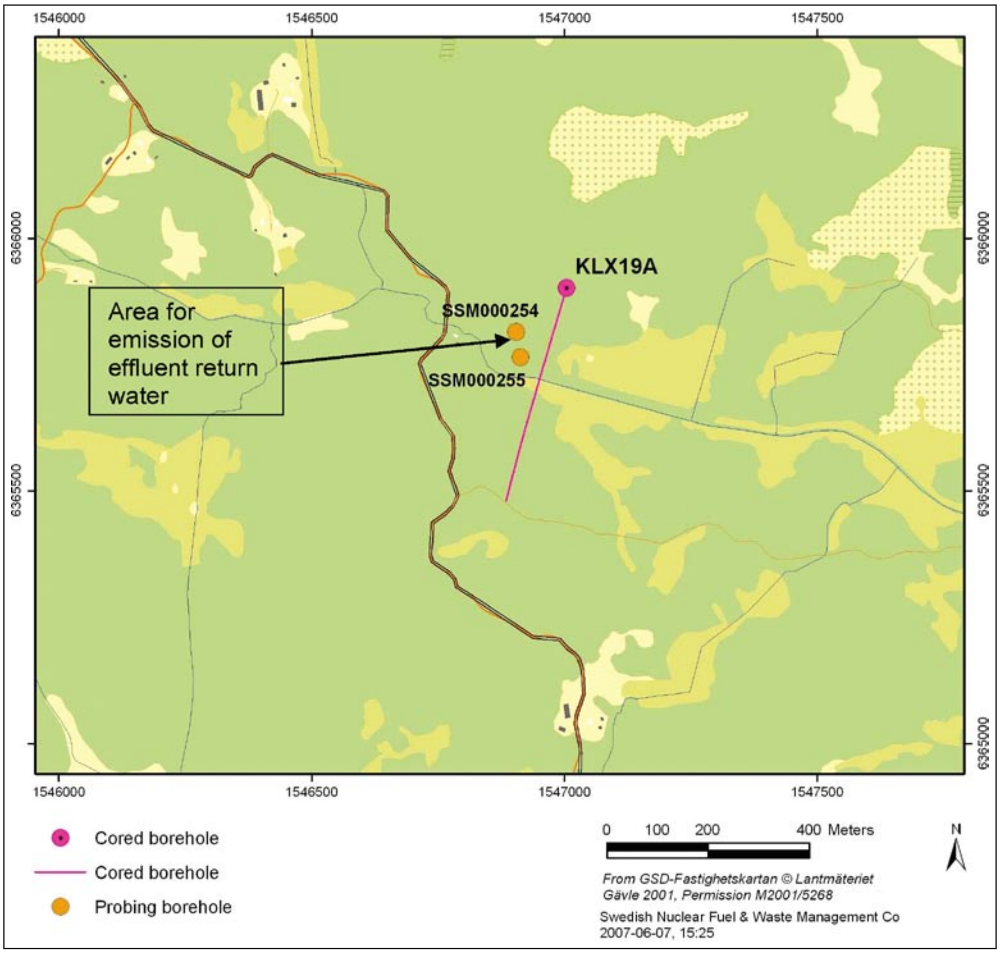


***Figure 5-27.** The location of the site for return water emission and the environmental monitoring wells SSM000254 and SSM000255 in relation to the core drill site for KLX19A.*

Environmental monitoring wells and reference sampling

Two environmental monitoring wells, SSM000254 and SSM000255, were drilled as part of the core drilling activity for KLX19A. The technical specifications including soil classifications are given in Appendix 6. It should be noted that the slotted filter section of the stand pipes are located in sandy till, i.e. permeable soil in both monitoring wells.

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 SSM000255 during the core drilling of KLX19A. The fluctuation of the water table from SSM000255 is given graphically in Figure 5-28. The water table is clearly affected by external activities, most likely nearby pumping and drilling.

Data presented in Figures 5-28 to 5-30 are interpreted so that infiltration of the return water from core drilling (the air-lift pumped water from the telescopic section) is the dominating factor for controlling the water table in SSM000255. When infiltration of return drilling water ceases i.e. air-lift pumping in KLX19A ceases, a drawdown occurs and the water table is lowered from the constant pumping in HLX28. The minor increases in the water table in SSM000255 during periods when there is no drilling (and hence no air-lift pumping) is mostly related to precipitation.

A plot of the water table in SSM000255 together with the water table in the telescopic section in KLX19A (controlled by air-lift pumping), the water table in HLX28 (controlled by pumping of flushing water to the core drilling of KLX19A) and diurnal precipitation is given in Figure 5-29.

A sketch illustrating the pumping and water use situation between the water source (HLX28), KLX19A and the monitoring well SSM000255 is shown in Figure 5-30.

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 SSM000254 and SSM000255, see Figures 5-31 and 5-32.

No significant influence can be seen on the shallow ground water in well SSM000254 from the drilling activity in KLX19A. The water chemistry in SSM000255 however seems to be affected by the infiltration of drilling return water from KLX19A as the electrical conductivity increases over periods when core drilling (and return water infiltration) is made.

Table 5-17. Reference samples for environmental monitoring.

Date	Sample No	Comment
2006-05-03	SKB PO 9012	Undisturbed soil sample
2006-05-18	11071	Reference water sample in SSM000254
2006-06-18	11070	Reference water sample in SSM000255

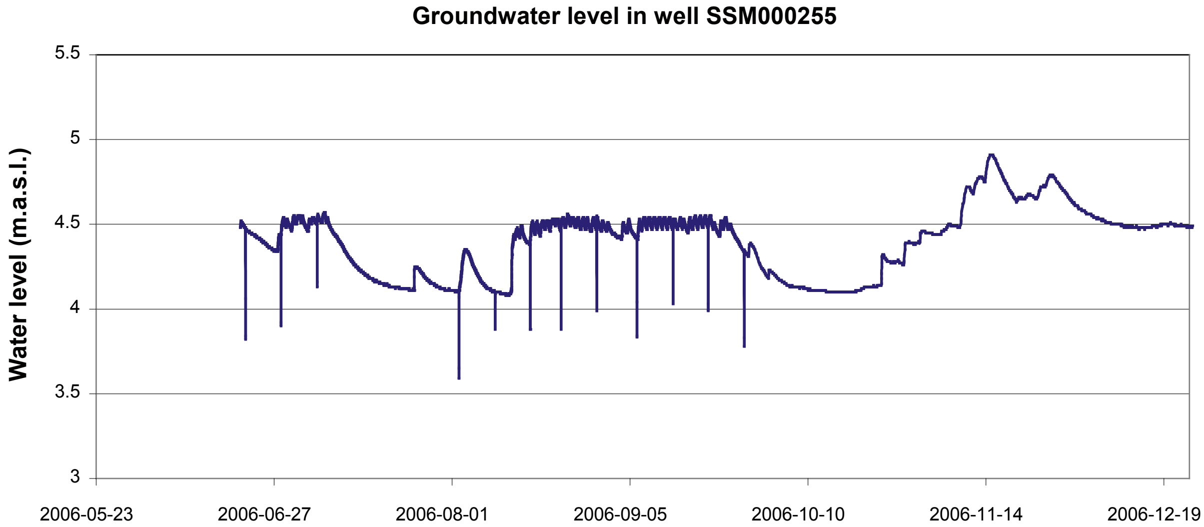


Figure 5-28. *The ground water level in well SSM000255. The momentary dips in water levels are related to water sampling. There is no water level data in the monitoring well SSM000255 from the time when percussion drilling of the telescopic section was made (May 10 to May 22). The water level in the monitoring well is strongly affected by surrounding activities.*

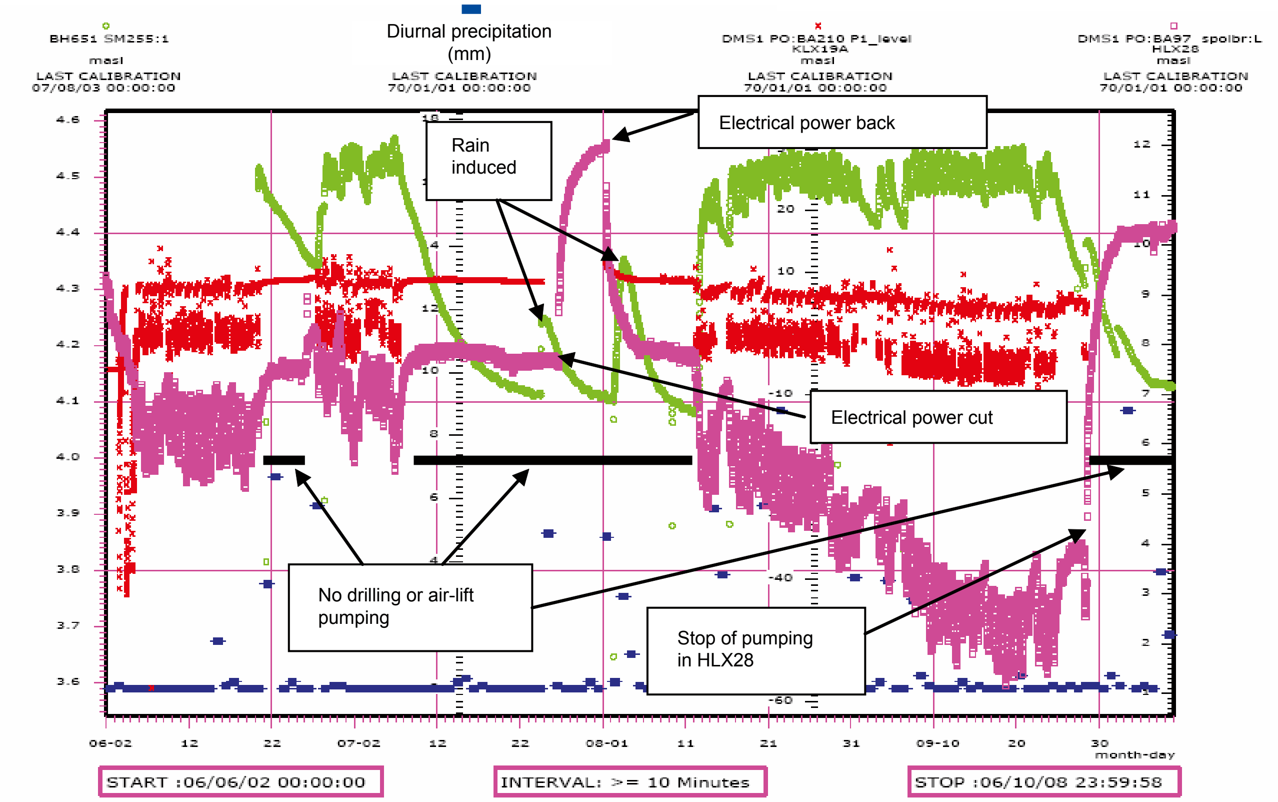
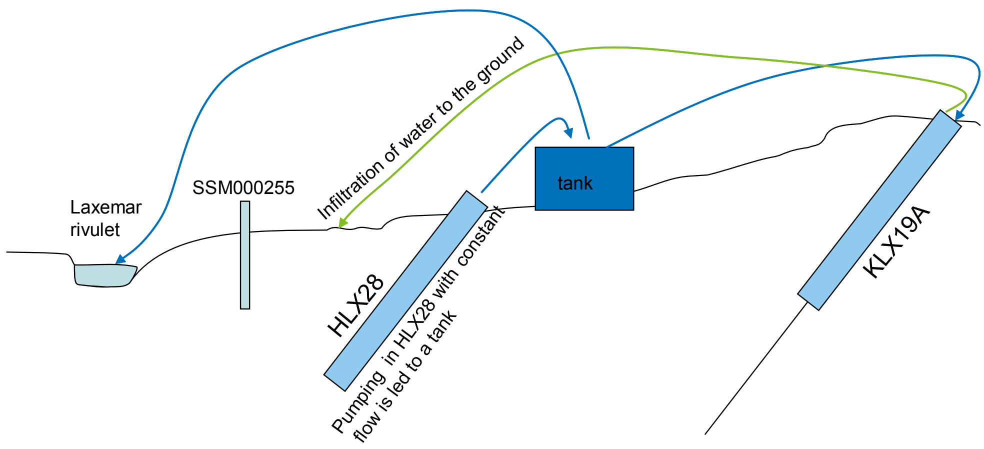


Figure 5-29. *Plot of the water table in SSM000255 together with the water table in the telescopic section in KLX19A (controlled by air-lift pumping), the water table in HLX28 (controlled by pumping of flushing water to the core drilling of KLX19A) and diurnal precipitation. A power cut from July 26 to August 1 causes a distinct recovery in the water table for HLX28 (red squares). Air-lift pumping in KLX19A (red crosses) is clearly related to or affected by pumping in HLX28 and the water table in SSM000255.*



Two scenarios:
1 Drilling – a constant flow is pumped up from HLX28 (ca 40–50 L/min). The amount needed for drilling (0-80 L/min) is led to the borehole. Air-lift pumping from the borehole retrieves the inserted volume plus some formation water from the bedrock. The water pumped from KLX19A is led to infiltration in the ground. The excess water from the constant pumping, ie overflow from the tank, is led directly to the Laxemar rivulet.

2 No drilling – all the water from the constant flow pumping in HLX28 is led directly to the Laxemar rivulet.

Figure 5-30. *Schematic vertical section of the pumping and water use situation between the flushing water source (HLX28), KLX19A and the monitoring well SSM000255.*

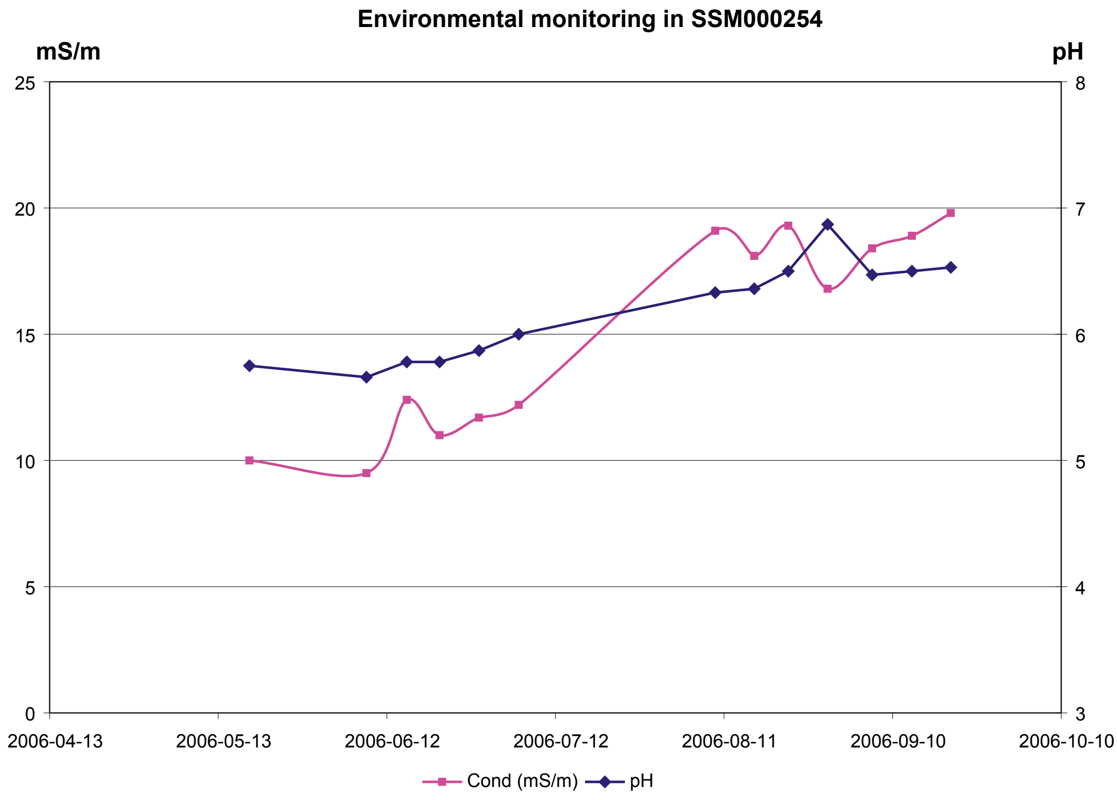


Figure 5-31. *Electrical conductivity and pH in ground water samples from SSM000254. The sampling events are shown with blue or purple symbols.*

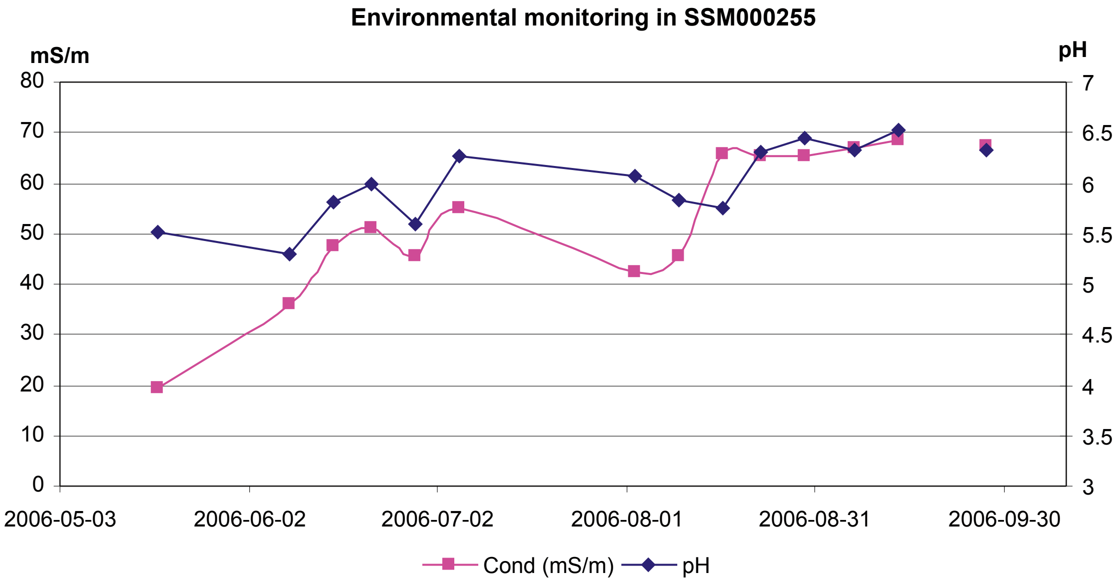


Figure 5-32. *Electrical conductivity and pH in ground water samples from SSM000255. The sampling events are shown with blue or purple symbols.*

5.8.1 Consumption of oil and chemicals

The consumption of hammer oil (Hydra 46) was 20 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 2,600 litres in total. The concrete was based on white silica, low alkali cement.

5.9 Nonconformities

No formal nonconformities are noted for borehole KLX19A.

No record of the pilot bit diameter during the percussion drilling of the telescopic section was kept. As the entire telescopic section was reamed and cased the missing diameter information is not significant for future investigations.

6 References

/1/ **SKB, 2001.** Platsundersökningar. Undersökningsmetoder och generellt genomförandeprogram 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 KLX11A, SKB P-06-306, Svensk Kärnbränslehantering AB.

/6/ **Ask H, Morosini M, Samuelsson L-E, Ekström L, Håkanson N, 2007.** Drilling of cored borehole KLX20A, SKB P-07-134, Svensk Kärnbränslehantering AB.

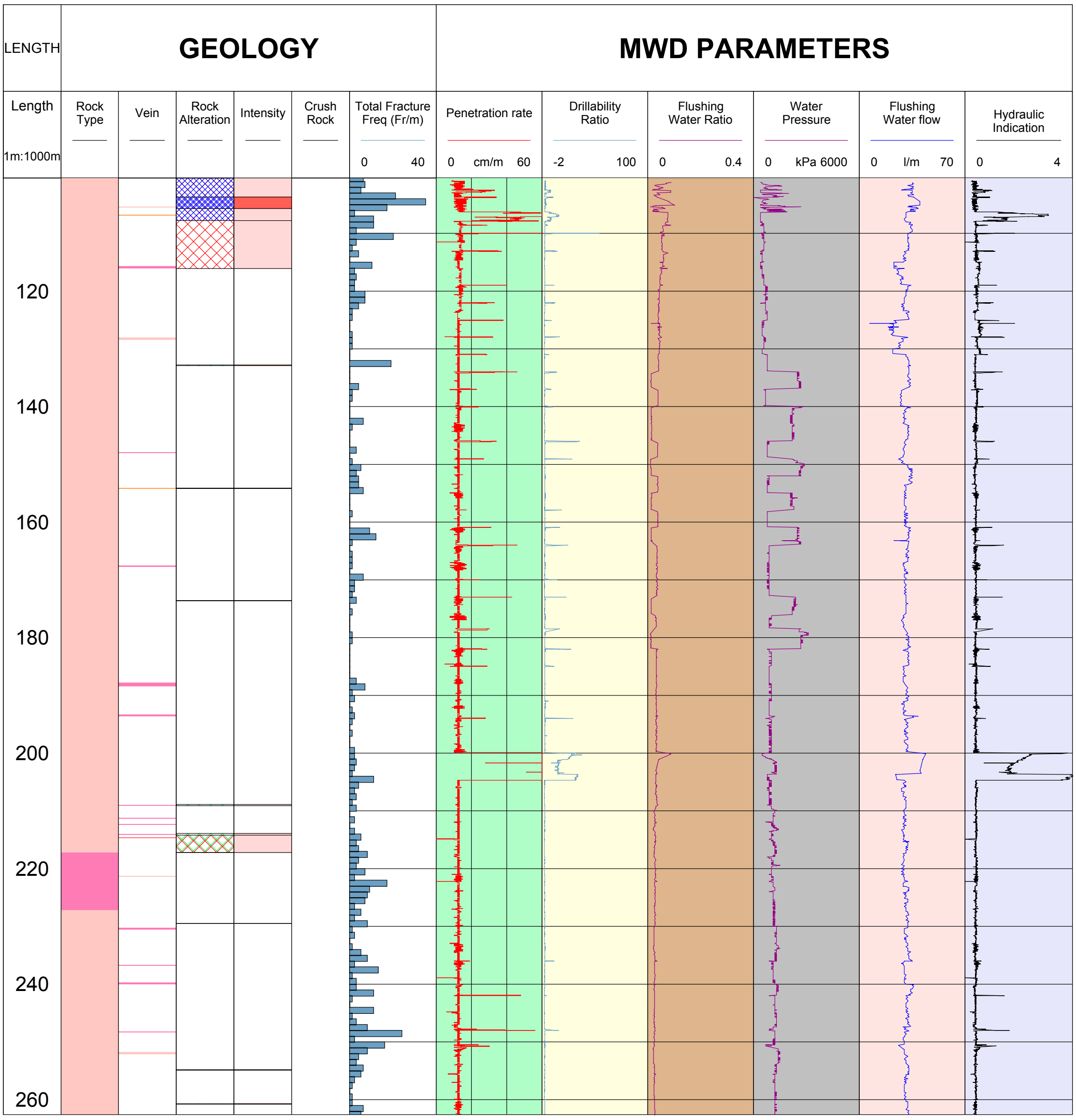
/7/ **Mattsson K-J**, **Dahlin P, Ehrenborg J, 2007.** Boremap mapping of telescopic drilled borehole KLX19A. SKB P-07-210, Svensk Kärnbränslehantering AB.

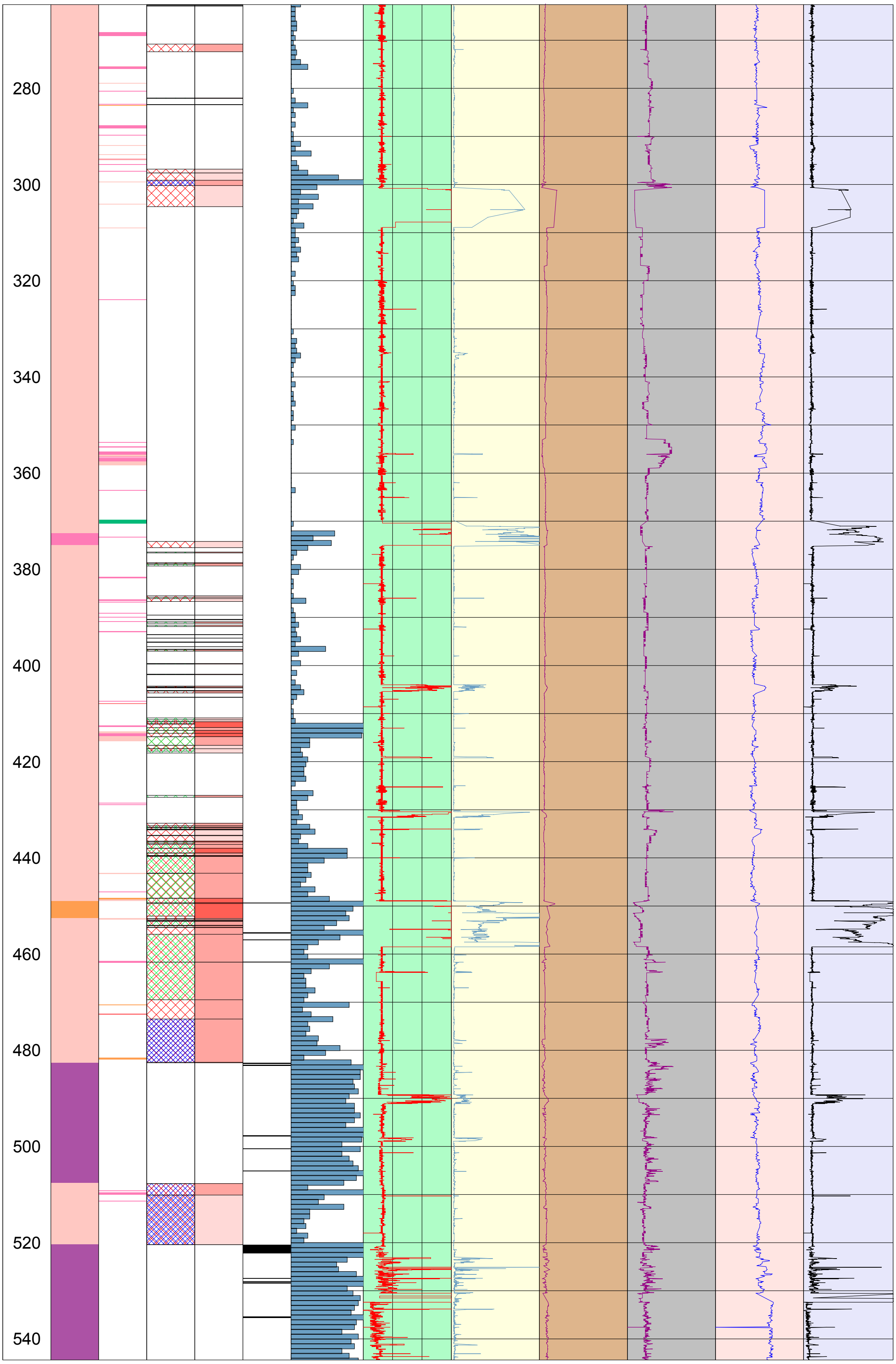
/8/ **Ask H, Morosini M, Samuelsson L-E, Ekström L, Håkanson N, 2004.** Core drilling of KSH03, SKB P-04-233, Svensk Kärnbränslehantering AB.

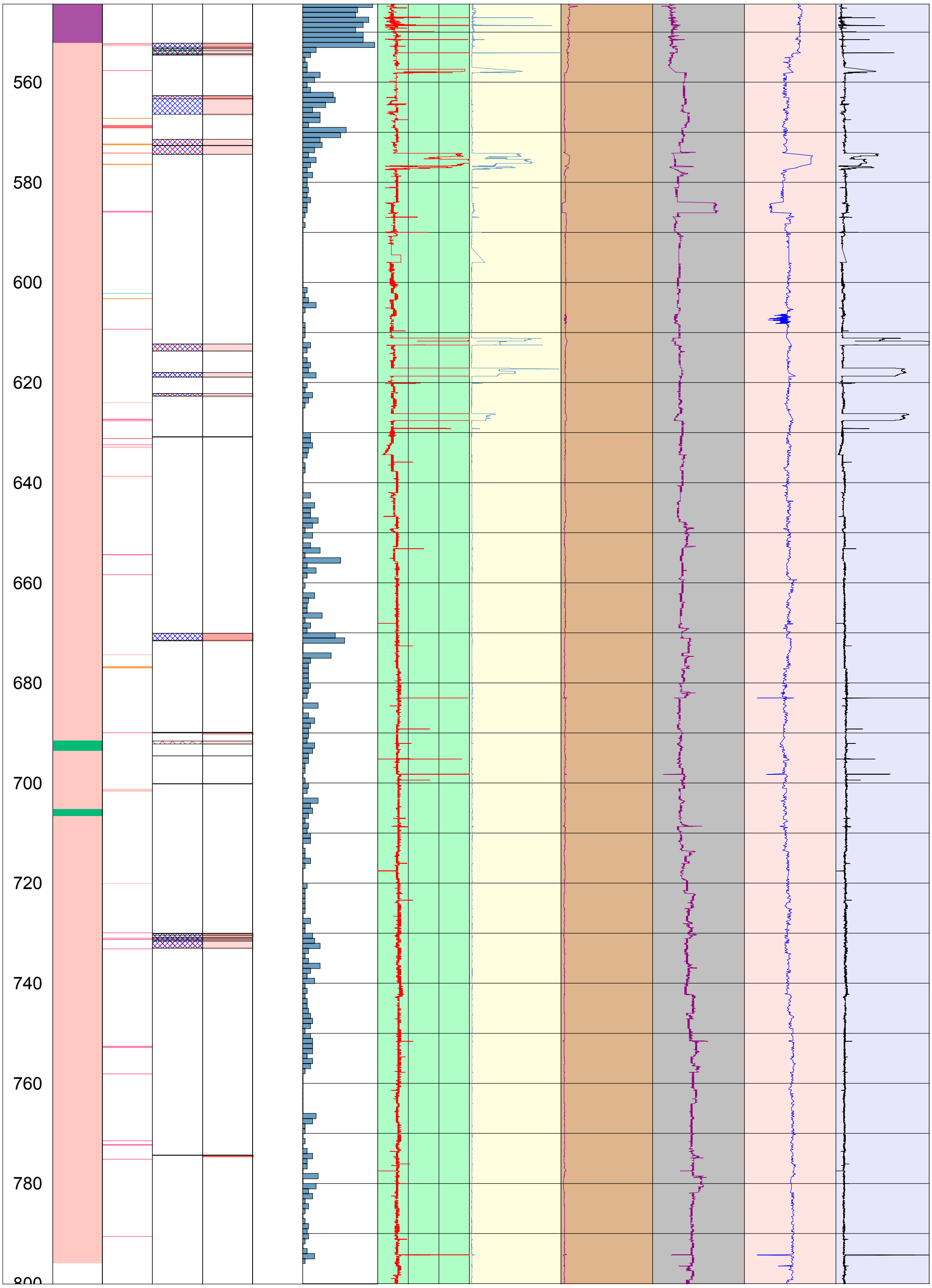
Geology and MWD parameters KLX19A

Title	GEOLOGY & MWD PARAMETERS KLX19A		Appendix 1
Site	LAXEMAR	Coordinate System	RT90-RHB70
Borehole	KLX19A	Northing [m]	6365901.42
Diameter [mm]	76	Easting [m]	1547004.62
Length [m]	800.070	Elevation [m.a.s.l.]	16.87
Bearing [°]	197.13	Drilling Start Date	2006-05-10 16:30:00
Inclination [°]	-57.54	Drilling Stop Date	2006-09-20 17:27:00
Date of mapping	2006-10-16 08:57:00	Plot Date	2007-06-03 23:15:13

ROCKTYPE LAXEMAR	ROCK ALTERATION	INTENSITY
Dolerite	Oxidized	Faint
Fine-grained granite	Chloritisized	Weak
Pegmatite	Epidotisized	Medium
Quartz monzodiorite	Silicification	Strong
Fine-grained diorite-gabbro	Argillization	
	Carbonatization	
	Saussuritization	




280
300
320
340
360
380
400
420
440
460
480
500
520
540


560
580
600
620
640
660
680
700
720
740
760
780
800

Appendix 2

Chemical results

Borehole	KLX19A	KLX19A	KLX19A	KLX19A	KLX19A	KLX19A
Date of measurement	2006-06-09	2006-06-20	2006-07-06	2006-08-31	2006-09-01	2006-09-04
Upper section limit (m)	101.73	194.60	368.95	461.65	461.65	461.65
Lower section limit (m)	197.00	371.00	463.60	576.77	576.77	576.77
Sample_no	11147	11177	11217	11303	11304	11306
Groundwater Chemistry Class	3	1	3	1	1	1
pH	8.08	x	8.28	x	x	x
Conductivity mS/m	83.0	x	88.8	x	x	x
Drill water %	1.66	66.26	42.65	41.94	68.69	87.67
Density g/ml	0.9974	x	0.9974	x	x	x
Charge balance %	–2.10	x	–2.83	x	x	x
Na mg/l	136.0	x	153.0	x	x	x
K mg/l	4.34	x	6.21	x	x	x
Ca mg/l	17.4	x	19.0	x	x	x
Mg mg/l	5.5	x	5.9	x	x	x
HCO3 mg/l Alkalinity	248	x	239	x	x	x
Cl mg/l	68.6	x	111.0	x	x	x
SO4 mg/l	70.50	x	69.10	x	x	x
SO4_S mg/l Total Sulphur	23.80	x	24.10	x	x	x
Br mg/l	0.260	x	0.360	x	x	x
F mg/l	3.61	x	3.59	x	x	x
Si mg/l	7.19	x	7.99	x	x	x
Fe mg/l Total Iron	4.5200	x	3.1400	x	x	x
Mn mg/l	0.2010	x	0.1690	x	x	x
Li mg/l	0.012	x	0.015	x	x	x
Sr mg/l	0.379	x	0.333	x	x	x
TOC mg/l	x	x	x	x	x	x
PMC % Modern Carbon	46.30	x	x	x	x	x
C-13 dev PDB	–16.10	x	x	x	x	x
AGE_BP Groundwater age	6130	x	x	x	x	x
AGE_BP_CORR	45	x	x	x	x	x
D dev SMOW	–82.2	x	x	x	x	x
Tr TU	1.80	x	x	x	x	x
O-18 dev SMOW	–11.30	x	x	x	x	x
B-10 B-10/B-11	0.2373	x	x	x	x	x
S-34 dev SMOW	26.7	x	x	x	x	x
Cl-37 dev SMOC	0.17	x	x	x	x	x
Sr-87 Sr-87/Sr86	0.715718	x	x	x	x	x

x = not analysed

Appendix 3

Chemistry – analytical method and quality

SKB Chemistry class 3

Analysis	Sample bottle	Preparation	SKB label	Laboratory
pH, conductivity, alkalinity	250 ml		green	Äspö/field
Anions (F^-, Br^-, Cl^-, SO_4^{2-})	250 ml	Filtered in connection with analyses	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 plastic		green	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 KLX19A. 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.

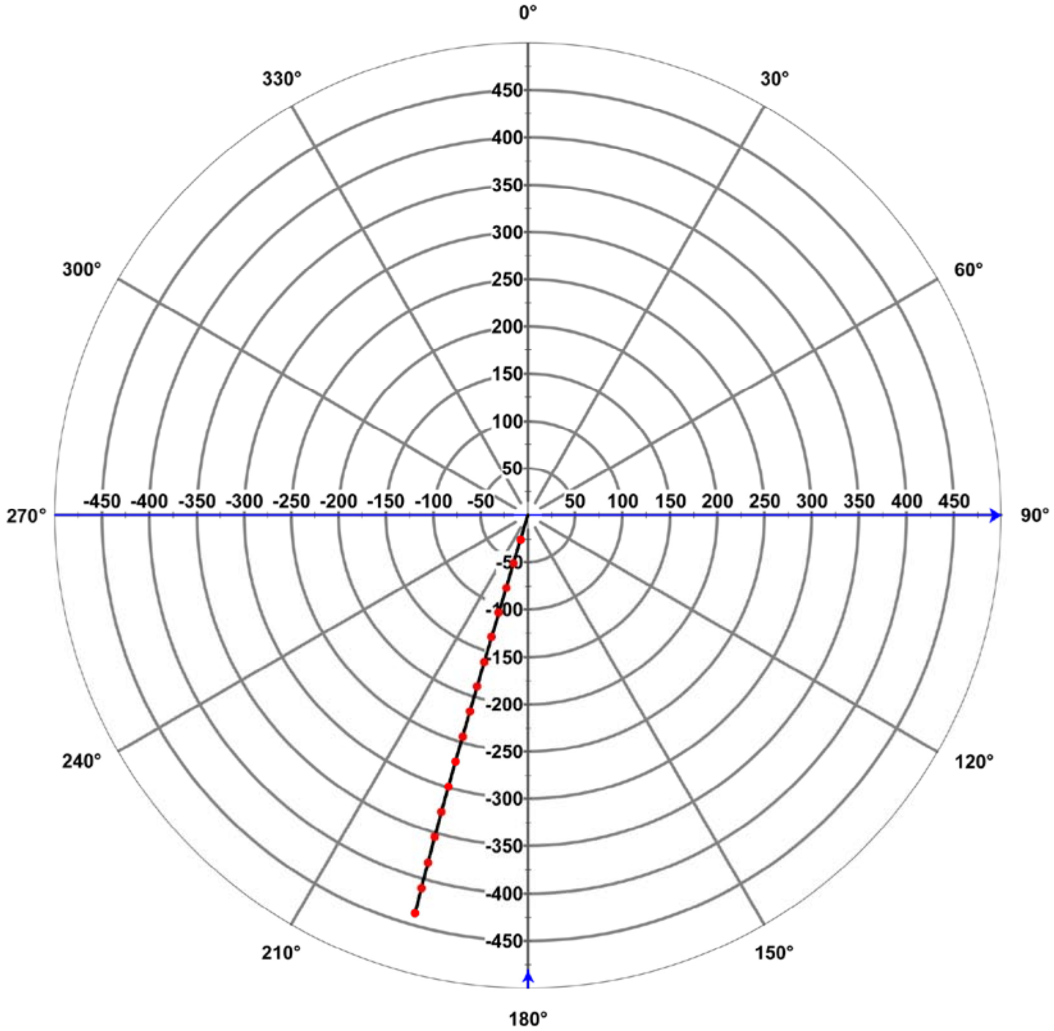
- Several components are determined by more than one method and/or laboratory. Control analyses by an independent laboratory are normally performed as a standard procedure on every five or ten collected samples. No control analyses were performed on the water samples from KLX19A.
- All analytical results were stored in the SICADA database. The chemistry part of the database contains two types of tables, raw data tables and primary data tables (final data tables).
- Data on basic water analyses are inserted into raw data tables for further evaluation. The evaluation results in a final reduced data set for each sample. These data sets are compiled in a primary data table named "water composition". The evaluation is based on:
- Comparison of the results from different laboratories and/or methods. The analyses are repeated if a large disparity is noted (generally more than 10%).
- Calculation of charge balance errors. Relative errors within ± 5% are considered acceptable. For surface waters errors of ± 10%.
- $\text{Rel. Error (\%)} = 100 \times \frac{(\sum \text{cations(equivalents)} - \sum \text{anions(equivalents)})}{(\sum \text{cations(equivalents)} + \sum \text{anions(equivalents)})}$
- General expert judgement of plausibility based on earlier results and experiences.

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

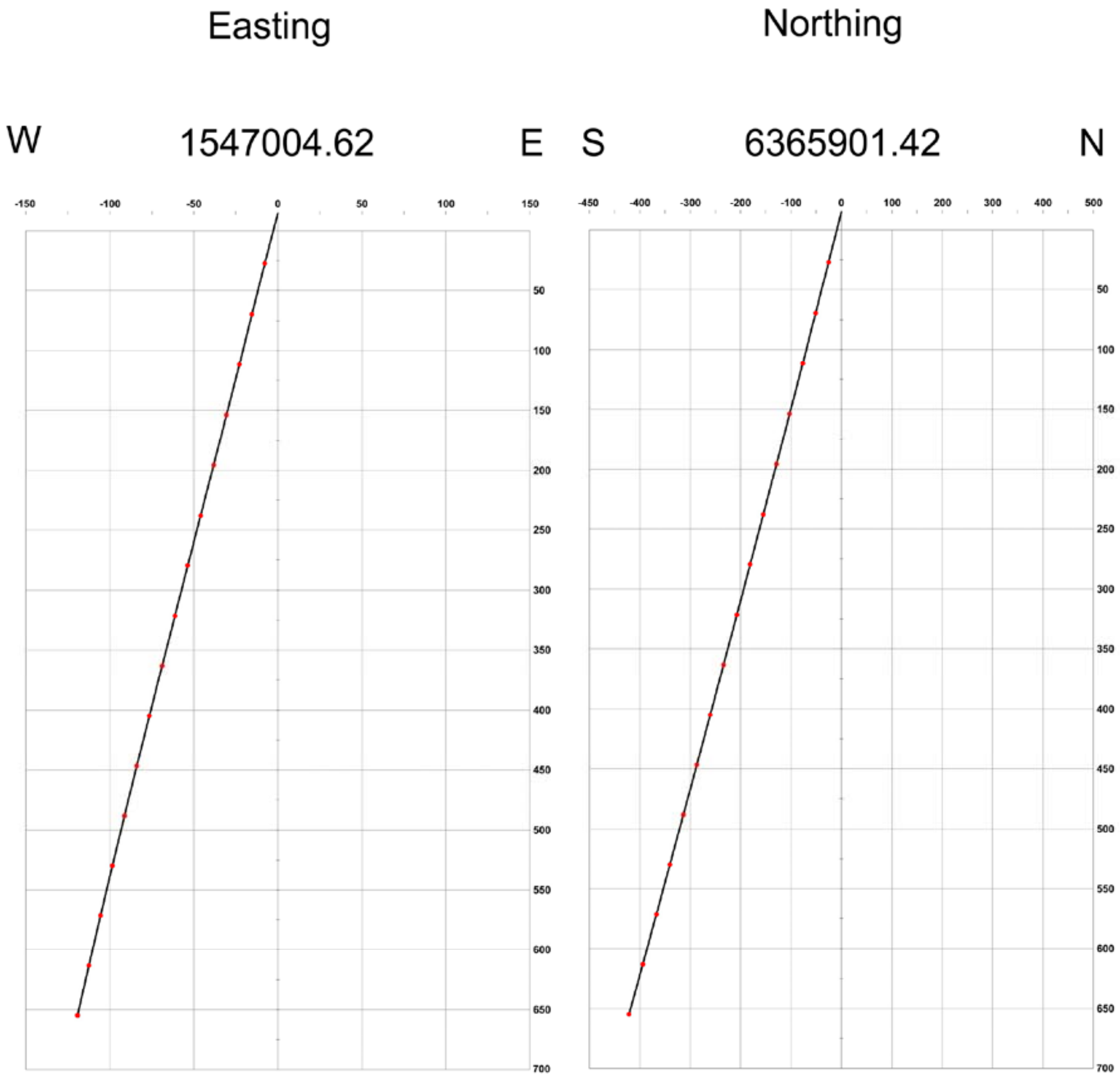
Appendix 4

Deviation measurements

Deviation measurement KLX19A		Appendix: 4
SKB	Site Borehole View from above	LAXEMAR KLX19A



Deviation measurement KLX19A		Appendix: 4
Site	LAXEMAR	
Borehole	KLX19A	
Vertical Section		



Wireline pumping tests in KLX19A

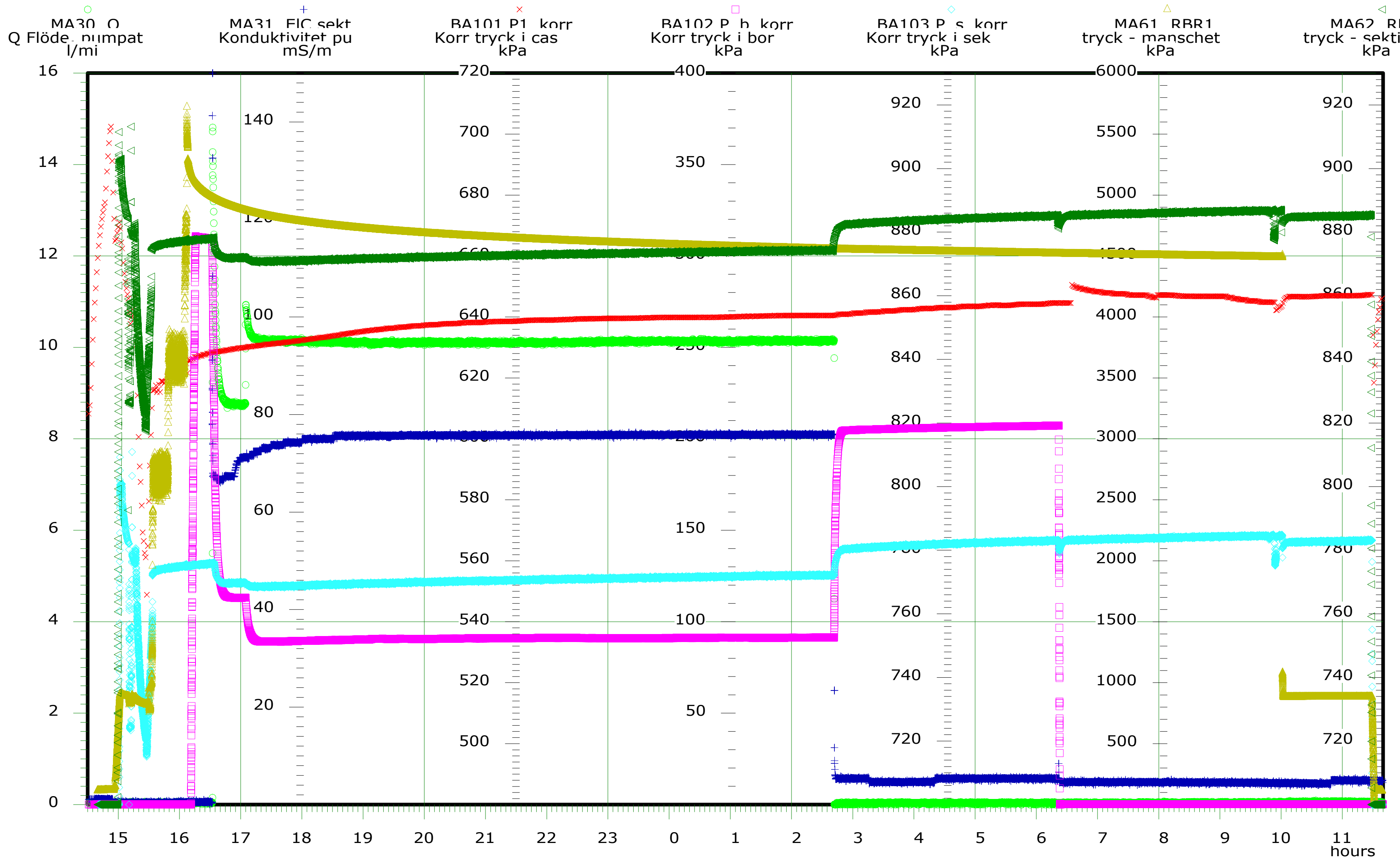
Description of the parameters in the enclosed plots

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

PLOT TIME :06/06/13 14:21:16
PLOT FILE :P_Pumptest
Adjusted for DST

DMS1 PO

Pumping test wireline probe
KLX19A, 101.73 - 197.00 m



START :06/06/08 14:30:00

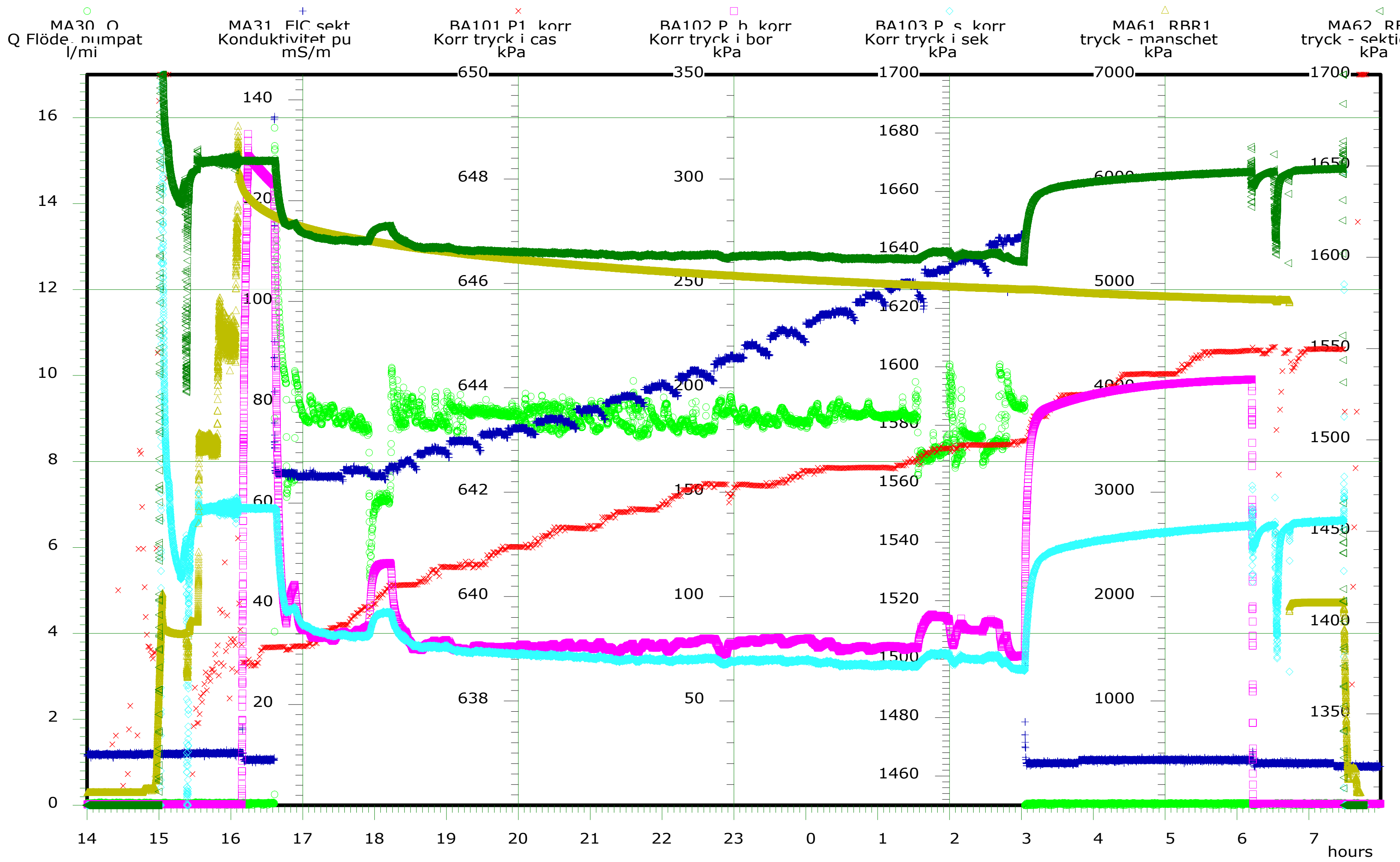
INTERVAL: All readings

STOP :06/06/09 11:39:59

PLOT TIME :06/06/20 08:35:15
PLOT FILE :P_Pumptest
Adjusted for DST

DMS1 PO

Pumping test wireline probe
KLX19A, 194.60 - 371.00 m



START :06/06/19 14:00:00

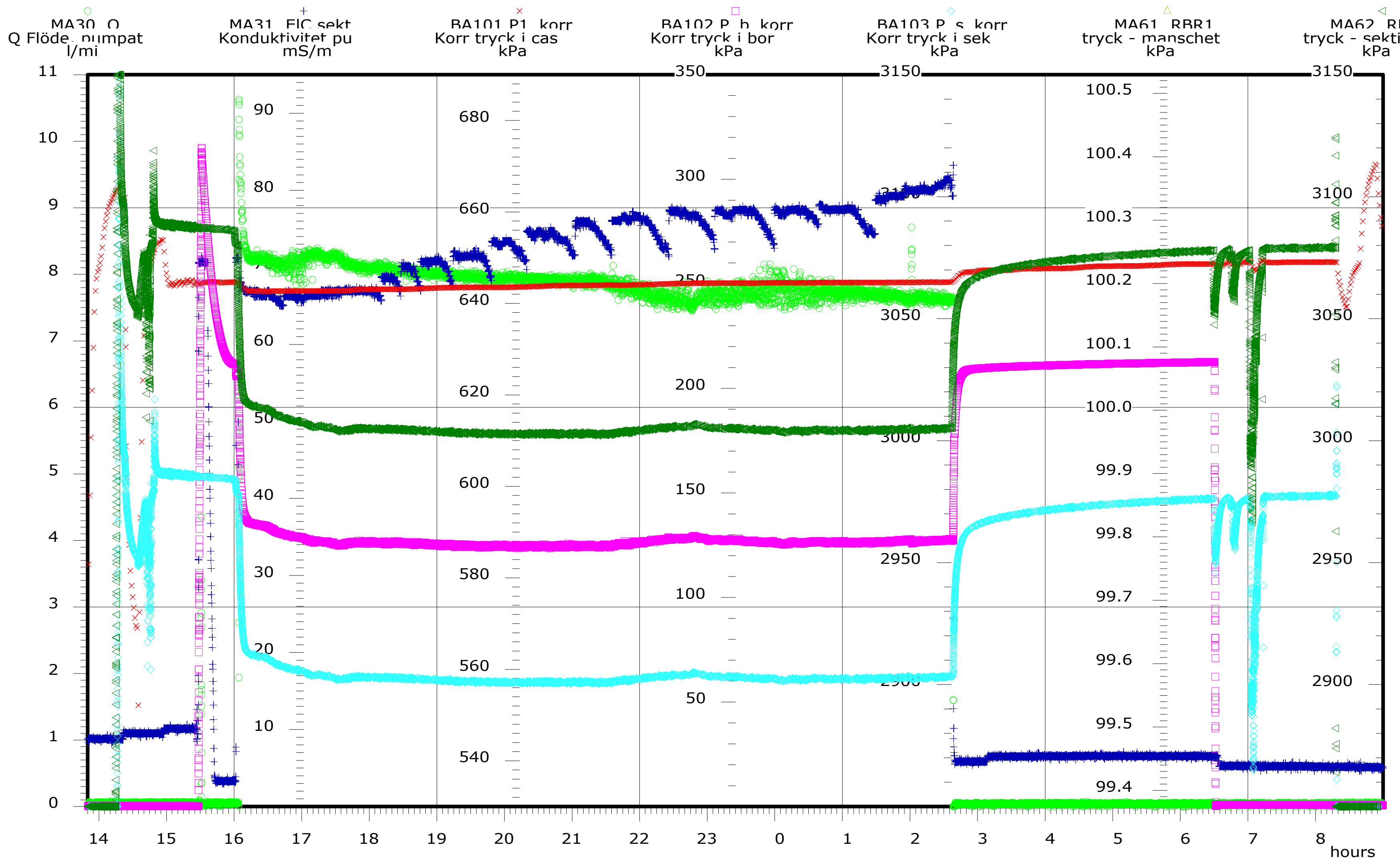
INTERVAL: All readings

STOP :06/06/20 07:59:59

PLOT TIME :06/07/06 10:28:11
PLOT FILE :P_Pumptest
Adjusted for DST

DMS1 PO

Pumping test wireline probe
KLX19A, 368.95 - 463.60 m



START :06/07/05 13:50:00

INTERVAL: All readings

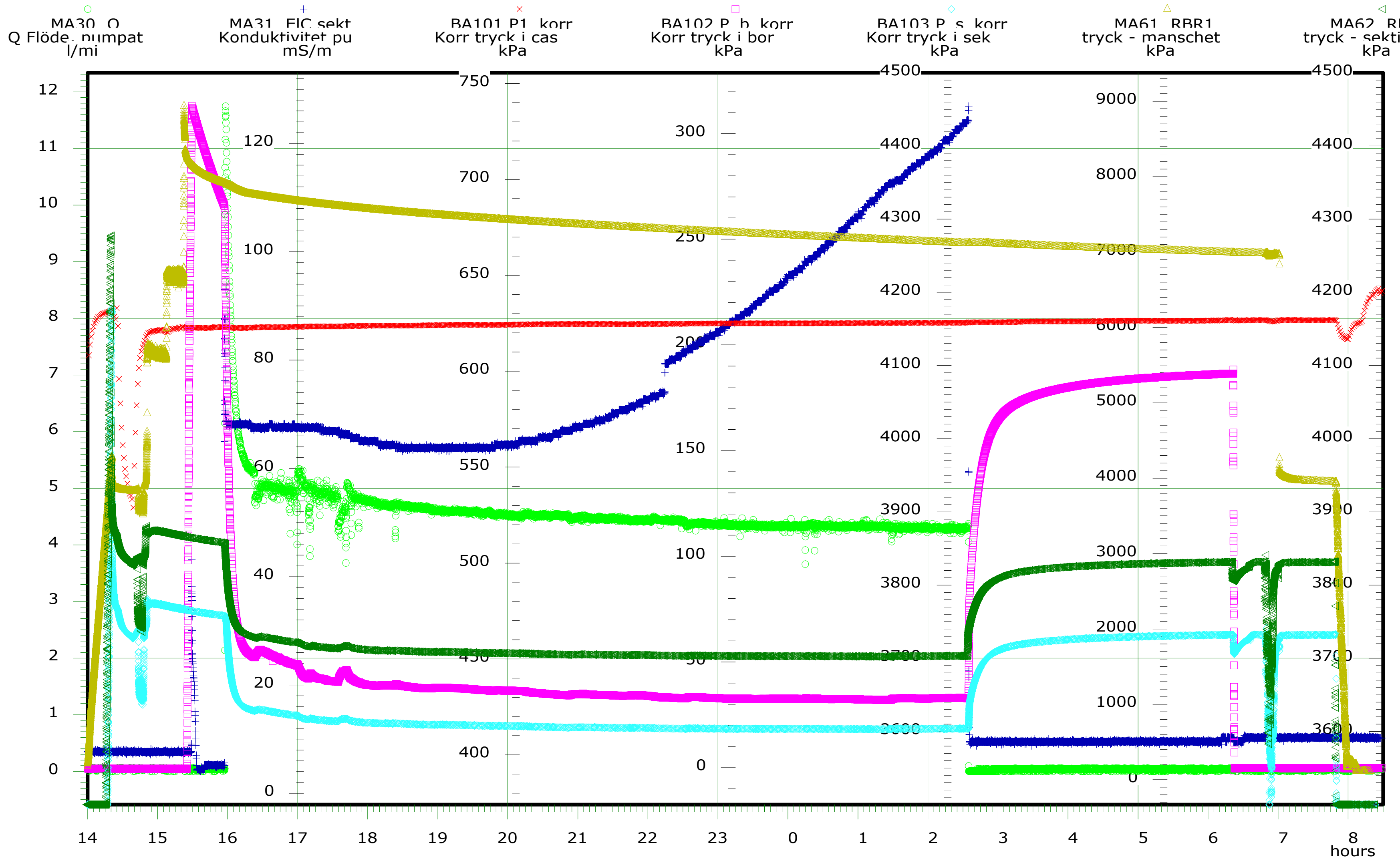
STOP :06/07/06 08:59:59

70

PLOT TIME :06/09/05 12:20:03
PLOT FILE :P_Pumptest
Adjusted for DST

DMS1 PO

Pumping test wireline probe
KLX19A, 461.65 - 576.77 m



START :06/09/03 14:00:00

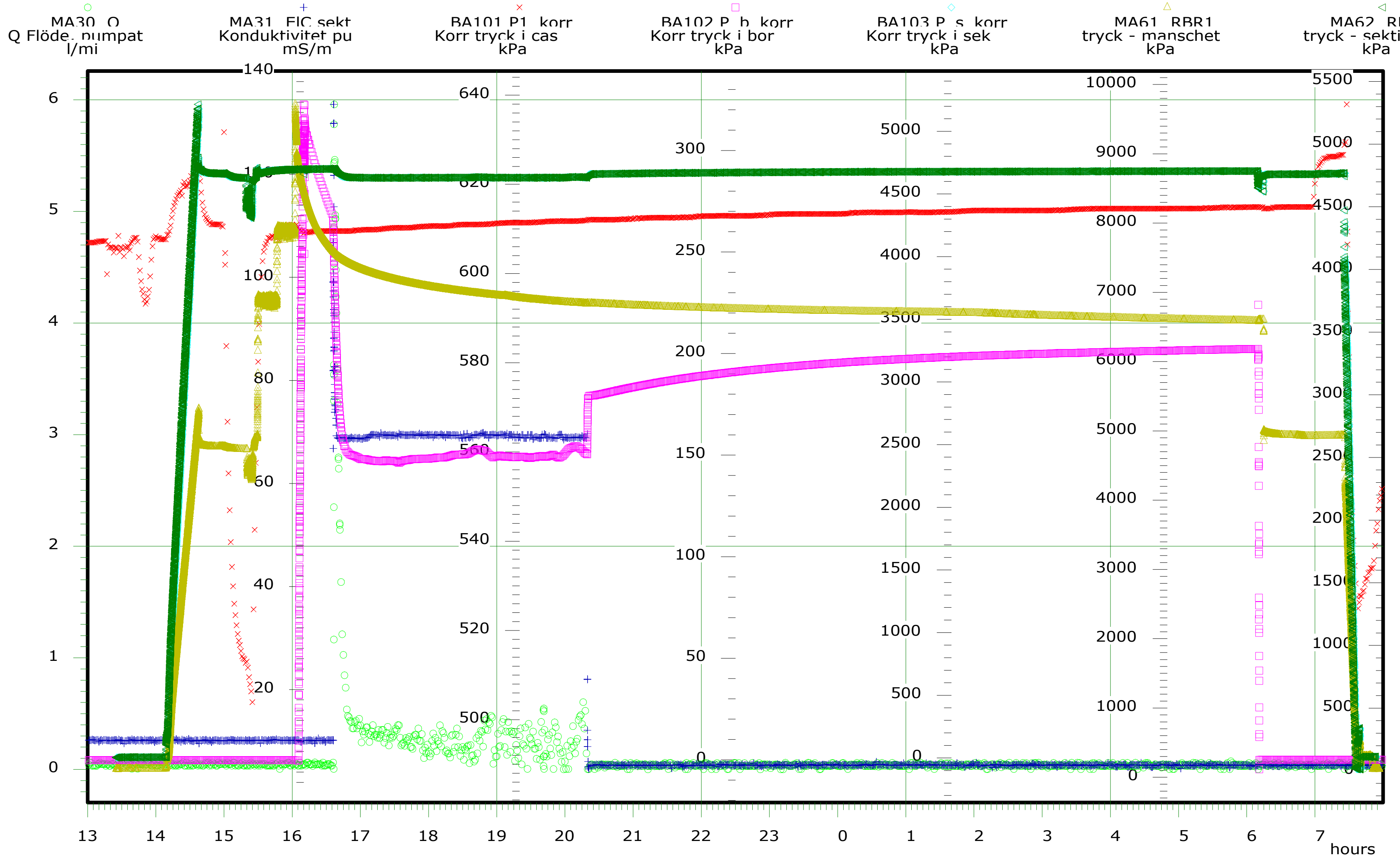
INTERVAL: All readings

STOP :06/09/04 08:29:59

PLOT TIME :06/11/07 17:16:50
PLOT FILE :P_Pumptest
Adjusted for DST

DMS1 PO

Pumping test wireline probe
KLX19A , 576.00 - 708.75 m



START :06/09/15 13:00:00

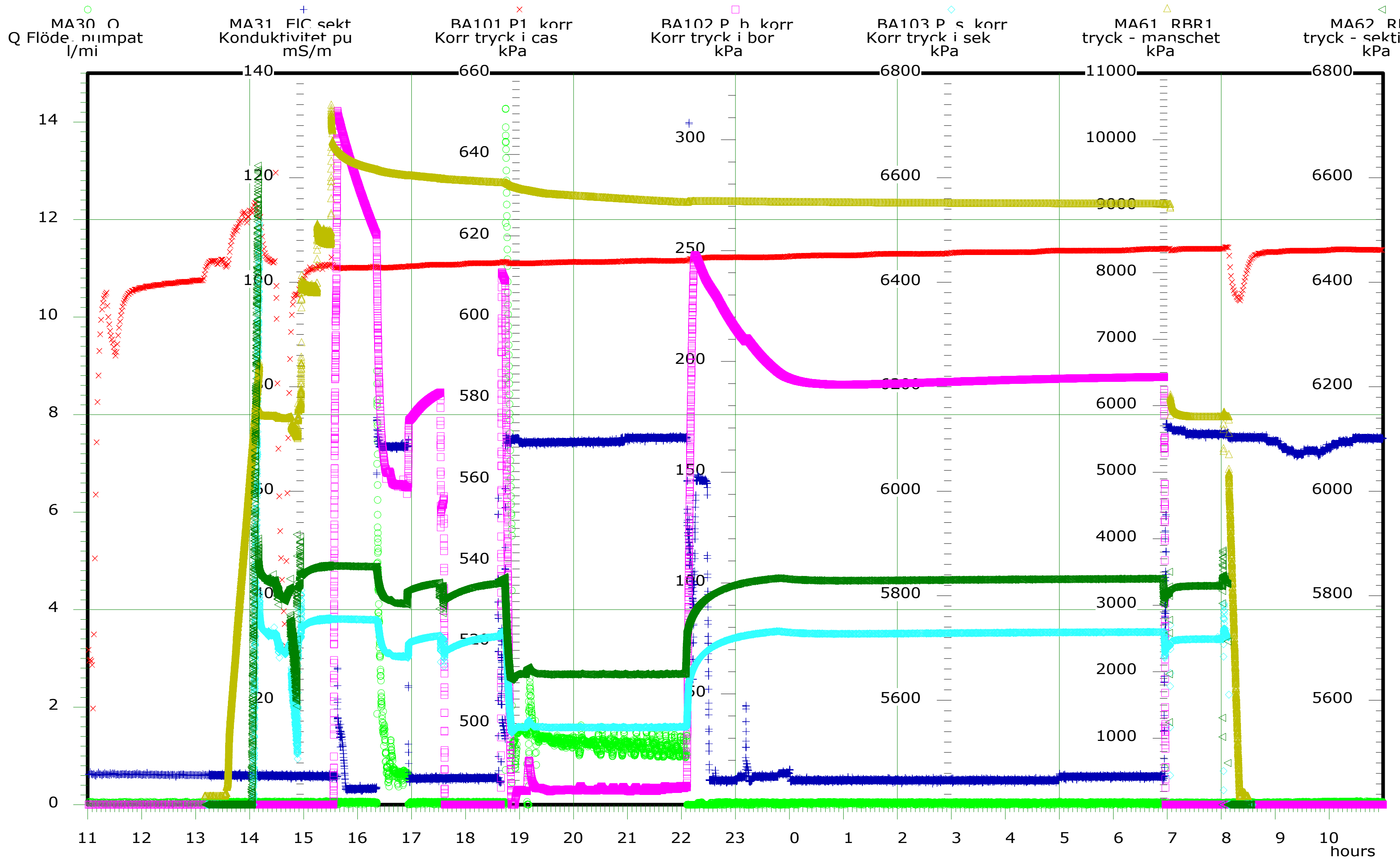
INTERVAL: All readings

STOP :06/09/16 07:59:59

PLOT TIME :06/09/27 07:48:06
PLOT FILE :P_Pumptest
Adjusted for DST

DMS1 PO

Pumping test wireline probe
KLX19A, 705.00 - 800.07 m



START :06/09/21 11:00:00

INTERVAL: All readings

STOP :06/09/22 10:59:59

Appendix 6

Technical data from environmental monitoring wells SSM000254 and SSM000255

LAXEMAR BOREHOLE SSM000254

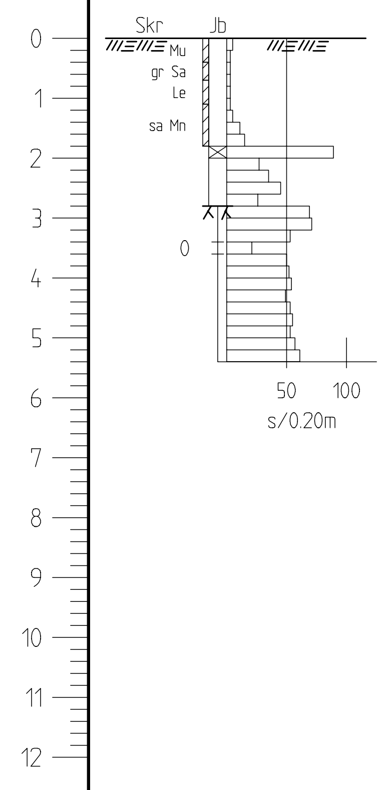
Company rep.
Torbjörn Johansson

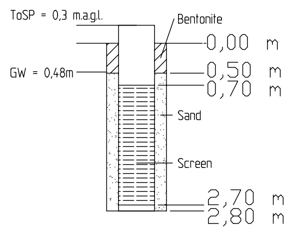
Client: Svensk Kärnbränslehantering AB

Northing	:6365814,784
Easting	:1546905,071
Coordinate system	: RT90-RHB70

Top of stand pipe	:0,3 m.a.g.l.
Total pipe length	:3,10 m
Groundwater level	:0,48 m.b.g.l.
Date of completion	:2006-05-15

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 : 1,0 m

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

ANNULUS SEAL
Material : Bentonite clay
Total length : 0.5 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 2,3 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
0,4-0,7m gravelly sand
0,7-1,1m clay
1,1-1,8m sandy till
1,8-2,0m boulders
2,0-2,8m gravelly sandy till
2,8m 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 SSM000255

Company rep.
Torbjörn Johansson

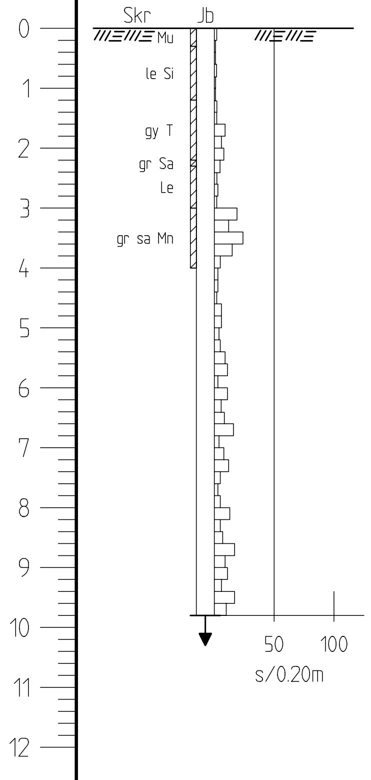
Client: Svensk Kärnbränslehantering AB

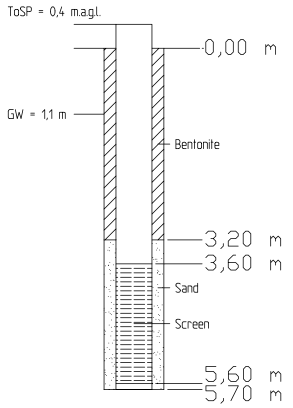
Northing :6365764,596
Easting :1546913,409

Coordinate system : RT90-RHB70

Top of stand pipe : 0,4 m.a.g.l.
Total pipe length : 6,10 m
Groundwater level : 1,1 m.b.g.l.
Date of completion : 2006-05-16

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 : 4,00 m

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

ANNULUS SEAL
Material : Bentonite clay
Total length : 3,2 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 2,5 m

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

GEOLOGICAL LOG
0-0,3m Topsoil
0,3-1,2m clayey silt
1,2-2,2m gyttja-bearing peat
2,2-2,3m gravelly sand
2,3-3,0m clay
3,0-9,8m gravelly sandy till

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