P-08-58

Oskarshamn site investigation

Drilling of cored borehole KLX15A

Henrik Ask, H Ask Geokonsult AB

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October 2008

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

Abstract

Borehole KLX15A is located in the Laxemar subarea. Drilling was made between December 2006 and February 2007 as a part of the site investigation for a possible repository for spent nuclear fuel in Oskarshamn municipality, Sweden. KLX15A was the twenty-second deep cored borehole within the site investigation in Oskarshamn.

KLX15A was core drilled to a length of 1,000.43 metres with N-size (76 mm) equipment. The uppermost section, to the length of 76.13 metres, was constructed as a telescopic borehole with an inner nominal diameter of 200 mm.

No water inflow could be measured over the entire length of the telescopic section during percussion drilling of the pilot borehole (nominal diameter 165 mm).

Nine successful tests were completed with wireline equipment in KLX15A from ten attempts at various intervals. The resulting transmissivities (T_M) varied between 8.2×10^{-5} and 3.7×10^{-8} m^2/s. The most transmissive section was between 77 and 176 metres.

Continuous monitoring of drilling parameters and flushing water parameters with the drilling monitoring system was conducted throughout the core drilling phase in KLX15A.

Three water samples for chemical analysis were collected during the core drilling of KLX15A.

The air-lift pumping test in the telescopic section performed when borehole KLX15A was core drilled to its full length gave a transmissivity (T_M) of 1.4×10^{-4} m^2/s.

Lithologically the core is dominated by Quartz monzodiorite (95%) with very minor intercalations of other rock types.

Rock alteration is mostly weak and thin. Scattered sections with some meters width of red staining have been noted throughout the length of the core.

The average fracture frequency over the core drilled section is 1.9 (fractures/metre) expressed as open fractures.

Sammanfattning

Borrhål KLX15A ligger inom delområde Laxemar. Borrningen utfördes mellan december 2006 och februari 2007 som ett led i platsundersökningen för ett möjligt djupförvar för använt kärnbränsle i Oskarshamns kommun. KLX15A var det tjugoandra djupa kärnborrhålet inom platsundersökningen i Oskarshamn.

KLX15A kärnborrades med borrstorlek N (76 mm) till 1 000,43 meters borrad längd. Den övre delen av hålet, från markytan till 76,13 meter, utfördes som en teleskopdel med ca 200 mm inre diameter.

Inget vatteninflöde kunde uppmätas över hela teleskopdelen vid hammarborrningen av pilotdelen (nominell diameter 165 mm).

Nio stycken lyckade pumptester slutfördes med wireline-baserad mätutrustning från tio försök på varierande nivåer. De uppmätta transmissiviteterna (T_M) varierade mellan $8,2 \times 10^{-5}$ och $3,7 \times 10^{-8}$ m^2/s. Den mest transmissiva sektionen var mellan 77 och 176 meter.

Kontinuerliga mätningar av borrningsparametrar och spolvattenparametrar via DMS (drilling monitoring system) gjordes under hela kärnborrningsfasen i KLX15A.

Tre vattenprover för kemisk analys togs i samband med borrning i KLX15A.

Mammutpumpningen i teleskopdelen som gjordes när kärnborrningen i KLX15A utförts till full längd gav en transmissivitet (T_M) på $1,4 \times 10^{-4}$ m^2/s.

Litologiskt domineras kärnan av kvartsmonzodiorit (95%) med mindre inslag av andra bergarter

Bergartsomvandling är oftast svag och tunn. Spridda sektioner av rödfärgning med någon meters bredd har noterats genom hela borrhålet

Den genomsnittliga sprickfrekvensen i det kärnborrade partiet är 1,9 (sprickor/meter) uttryckt som öppna sprickor.

Contents

1	**Introduction**	**7**
2	**Objective and scope**	**9**
3	**Overview of the drilling method**	**11**
3.1	The SKB telescope drilling method	11
	3.1.1 The flushing water system	12
3.2	Measurements and sampling during drilling	13
	3.2.1 Percussion drilling	13
	3.2.2 Core drilling	13
4	**Contractors and equipment**	**15**
4.1	Contractors	15
4.2	Percussion drilling equipment	16
4.3	Core drilling equipment	16
	4.3.1 Measurements with wireline probe	16
	4.3.2 Drilling monitoring system	18
	4.3.3 Deviation measurements	18
	4.3.4 Equipment for reaming reference slots	19
5	**Execution and results**	**21**
5.1	Summary of KLX15A drilling	21
5.2	Drilling, measurements and results in the telescopic section 0–76.13 m	24
	5.2.1 Preparations	24
	5.2.2 Drilling and casing installation	24
	5.2.3 Measurements and sampling during drilling of the telescopic section	24
	5.2.4 Hydrogeological measurements and results in the percussion drilled telescopic section 11.65–76.13 m	25
5.3	Core drilling KLX15A 76.13–1,000.43 m	27
	5.3.1 Preparations	27
	5.3.2 Flushing and return water handling	28
	5.3.3 Drilling and deviation measurements KLX15A	29
	5.3.4 Borehole wall risk assessment, stabilisation and completion	30
5.4	Hydrogeological and hydrochemical measurements and results 76.13–1,000.43 m.	33
	5.4.1 Hydrogeological results from wireline measurements	33
	5.4.2 Hydrochemistry	33
	5.4.3 Results from air-lift pumping with evaluation of drawdown and/or recovery	36
	5.4.4 Hydraulic responses in near-by boreholes.	38
5.5	Drilling monitoring results	42
	5.5.1 Drill monitoring system – DMS	42
	5.5.2 Measurements of flushing water and drill cuttings	44
5.6	Geology	46
5.7	Data handling	46
5.8	Environmental control	46
	5.8.1 Consumption of oil and chemicals	48
5.9	Nonconformities	48
6	**References**	**51**

Appendix 1	Geology and MWD parameters KLX15A	53
Appendix 2	Chemical results	57
Appendix 3	Chemistry – analytical method and quality	59
Appendix 4	Deviation measurements	61
Appendix 5	Wireline pumping tests in KLX15A	63
Appendix 6	Technical data from environmental monitoring wells SSM000215 and SSM000268	73

1 Introduction

SKB, the Swedish Nuclear Fuel & Waste Management Company, performs site investigations in order to evaluate the feasibility of locating a deep repository for spent nuclear fuel /1/ and /2/. The investigations are performed in two Swedish municipalities: Östhammar and Oskarshamn. Borehole KLX15A 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. KLX15A was the twenty-second deep cored borehole within the Oskarshamn site investigation. The location of the core drilled borehole and the water source, HLX14 in the Laxemar subarea is shown in Figure 1-1.

The drilling of KLX15A and all related on-site operations were performed according to a specific activity plan (AP PS 400-06-101), which in turn refers to a number of method descriptions, see Table 1-1.

The activity plans and method descriptions are SKB internal documents.

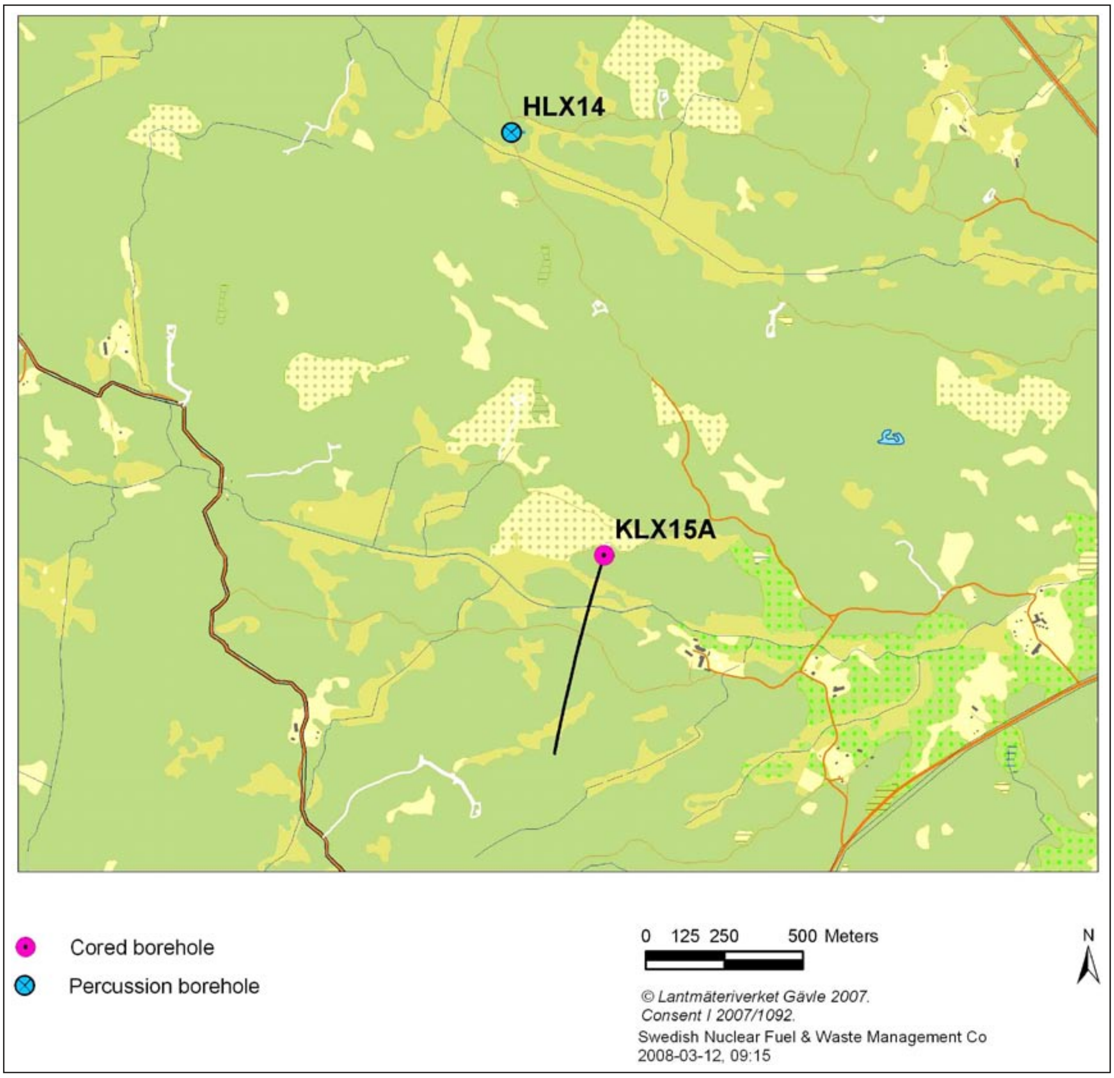


Figure 1-1. *Location of the cored borehole KLX15A and the water source, percussion borehole HLX14 in the Laxemar subarea.*

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

Activity plan	Number	Version
Kärnborrning KLX15A	AP PS 400-06-101	1.0*
Method descriptions	**Number**	**Version**
Metodbeskrivning för kärnborrning	SKB MD 620.003	2.0
Metodbeskrivning för hammarborrning	SKB MD 610.003	3.0
Metodbeskrivning för hydrauliska enhålspumptester	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 längdmarkering i kärnborrhål	SKB MD 620.009	2.0
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 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 grund-vatten och mark vid borrning och pumpning i berg	SKB MD 300.003	3.0
Metodbeskrivning för jordborrning	SKB MD 630.003	1.0

* Two amendments to the activity plan exists.

2 Objective and scope

This report will describe the methods employed and the results achieved during the drilling of borehole KLX15A. 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, according to the drilling decision for KLX15A, SKB id no 1064630, dated 2006-11-30, was to increase the knowledge of the geometry of the Quartz monzodiorite in the southern part of the Laxemar subarea and the modelled deformation zone NW042.

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 2006-10-25, SKB id 1062400. Information of the final coordinates and details regarding the return water handling was sent to the Regional Authorities on 2006-11-10, SKB id 1063398.

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 bore-hole wall and a conical guide of stainless steel is installed between the telescope part and the deeper core drilled part, see Figure 3-2.

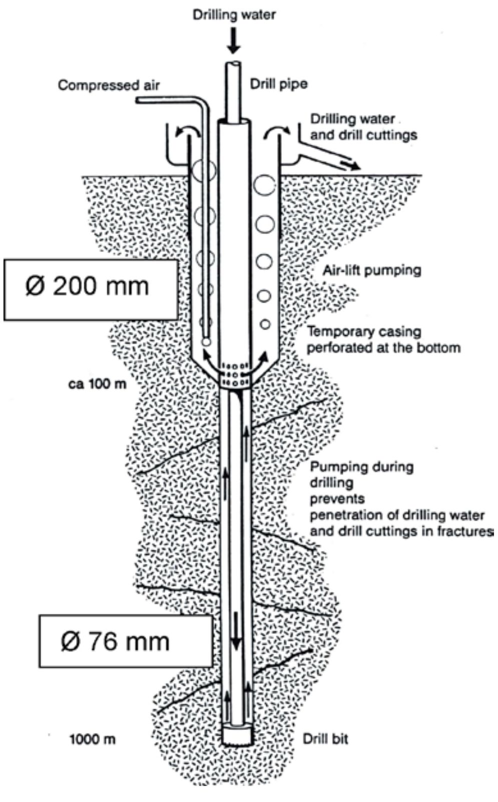


Figure 3-1. A sketch of the telescopic drilling method with air-lift pumping for retrieval of drilling water and cuttings.

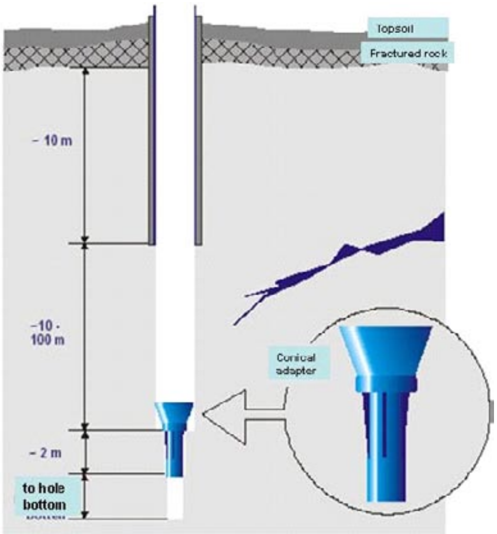


Figure 3-2. *Installation of the conical guide.*

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.

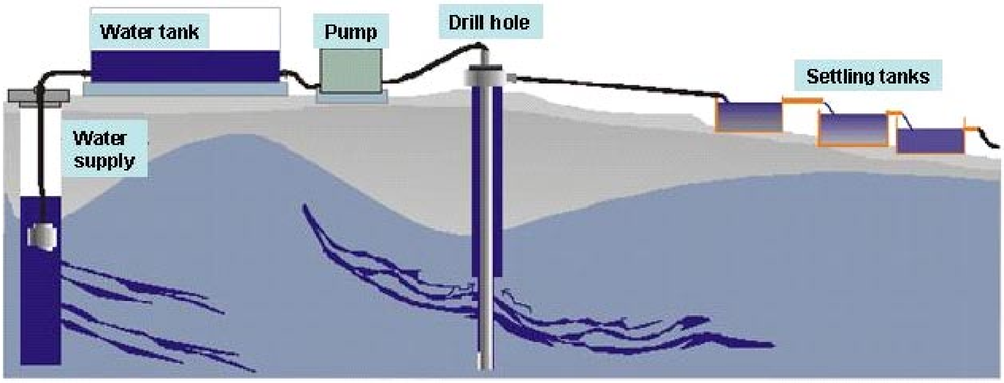


Figure 3-3. *The flushing water system from source to discharge point.*

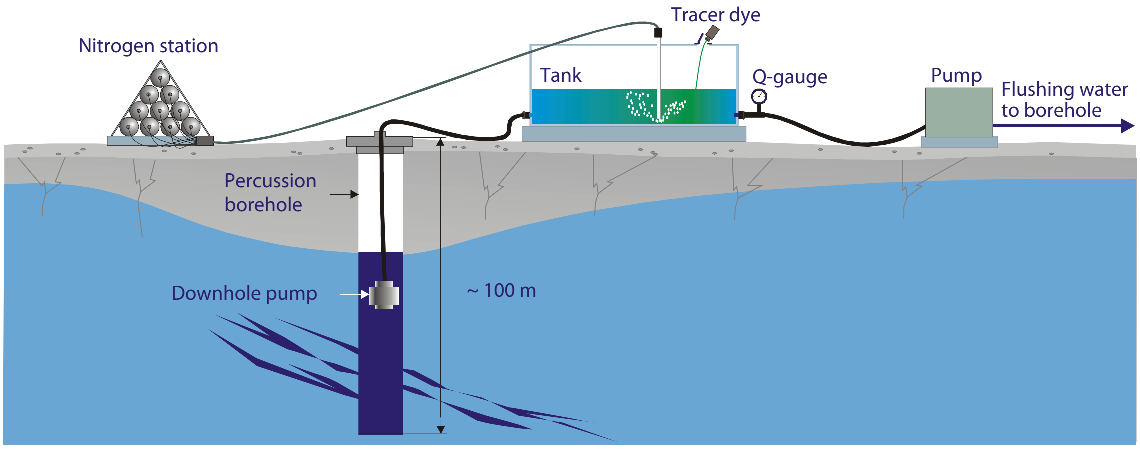


Figure 3-4. *Schematic drawing of the preparation of flushing water. Uranine is added to the water as a tracer dye and nitrogen is bubbled through the water to remove dissolved oxygen.*

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 KLX15A 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 KLX15A 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 m 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).

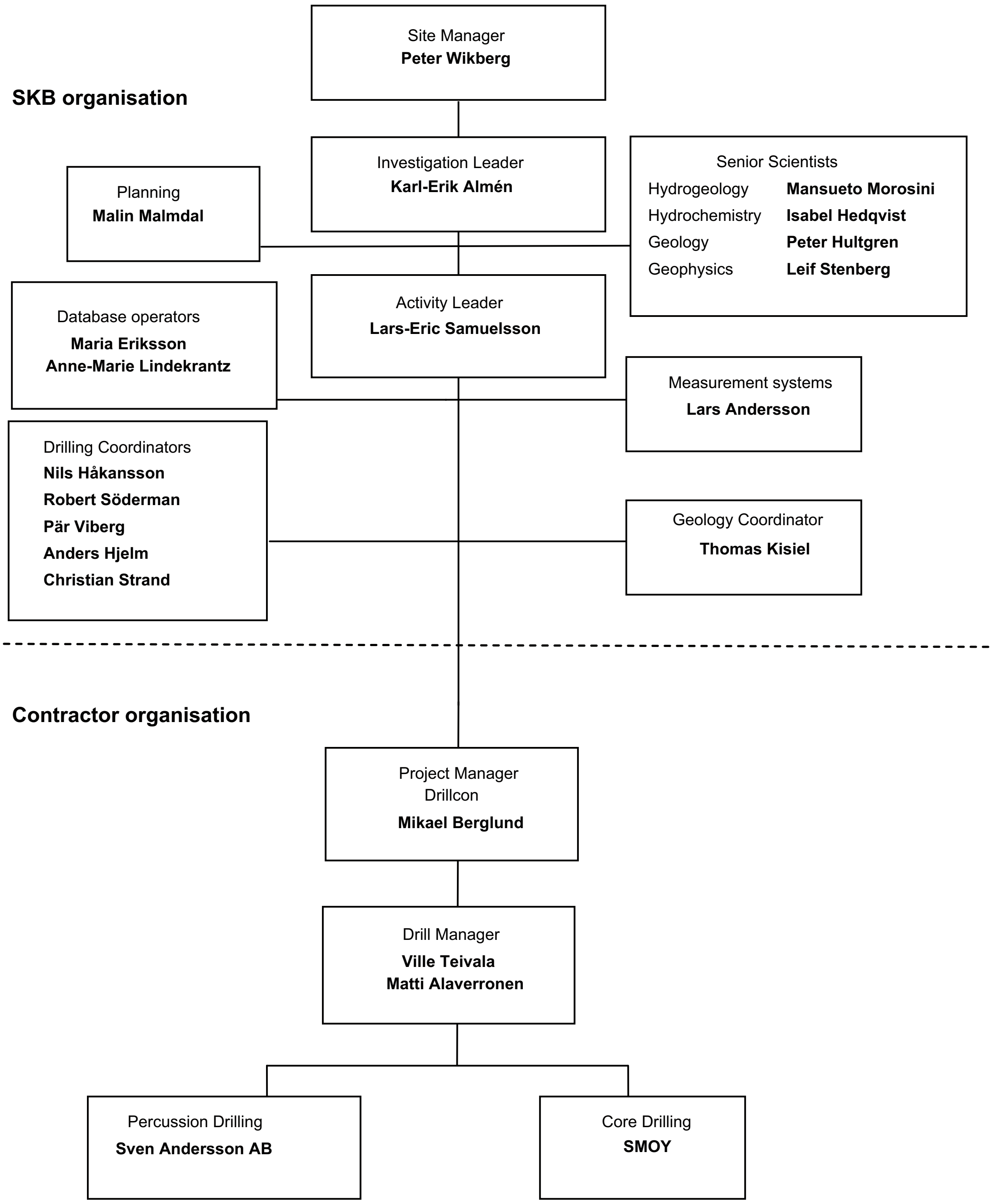
4 Contractors and equipment

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 KLX15A was a Puntel percussion drill rig with an Atlas Copco XRVS 455 Md air compressor, see Figure 4-1. 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 by thickness.

4.3 Core drilling equipment

Core drilling in KLX15A 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 KLX15A.

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.

Figure 4-1. *The Puntel percussion drill rig at the KLX15A site.*

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

The principal components are:

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

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

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

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

Pumping tests

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

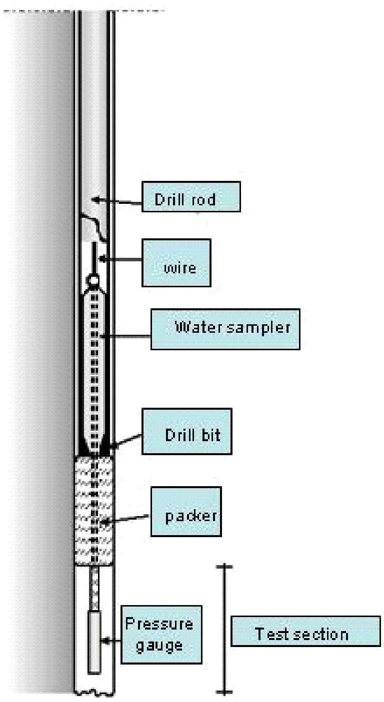


***Figure 4-2.** The wireline probe and its emplacement in the hole.*

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 KLX15A.

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.

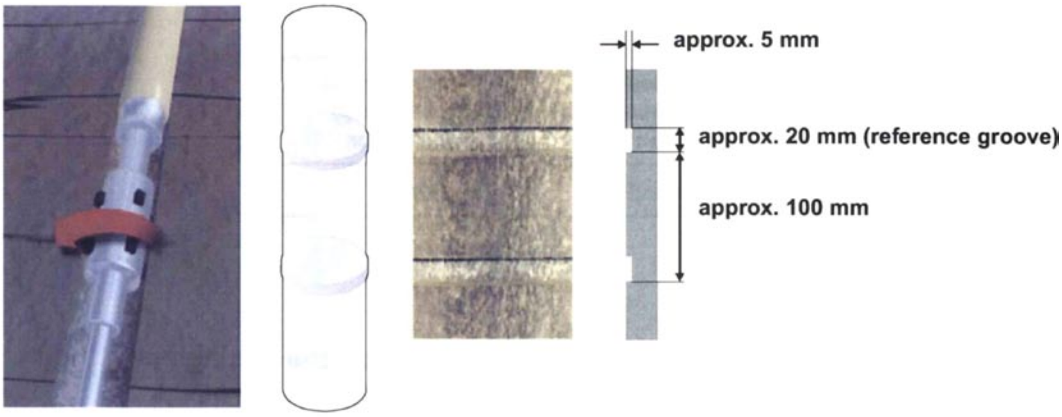


Figure 4-3. *The equipment for reaming of reference slots. To the left, the reaming tool with openings for the cutters is shown. The resulting reference slots are illustrated in the three pictures to the right.*

5 Execution and results

The original data and results are stored in the SICADA database. Only the datasets in the database will be used for further interpretation and modelling. The data is traceable in SICADA by the Activity Plan number, AP PS 400-06-101.

5.1 Summary of KLX15A drilling

A technical summary of the drilling of KLX15A 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 0–76.13 metres and the measurements performed during this phase are given in section 5.2. The core drilling between 76.13–1,000.43 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. KLX15A Technical summary.

General	Technical
Name of hole: KLX15A	*Percussion drill rig* Puntel
Location: Laxemar, Oskarshamn Municipality, Sweden	*Percussion hole length* 76.03 m (diam 197.5 mm) 76.13 m (diam 164.8 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)
	Cored interval 76.13–1,000.43 m
Percussion drill start date December 21, 2006	*Diamond bits used* 12
	Average bit life 77 metres
Completion date December 29, 2006	*Position KLX15A (RT90 RH70) at top of casing:* N 6365614.168 E 1547987.466 Z 14.590 (m.a.s.l.)
Subcontractor core drilling Suomen Malmi OY (SMOY)	*Azimuth (0–360)/ Dip (0–90)* 198.826/–54.425
Core drill start date January 17, 2007	*Position KLX15A (RT90 RH70) at 1,000.43 m length:* N 6364978.16 E 1547827.91 Z –733.99 (m.a.s.l.)
Completion date February 25, 2007	*Azimuth (0–360)/Dip (0–90)* 190.38/–46.81

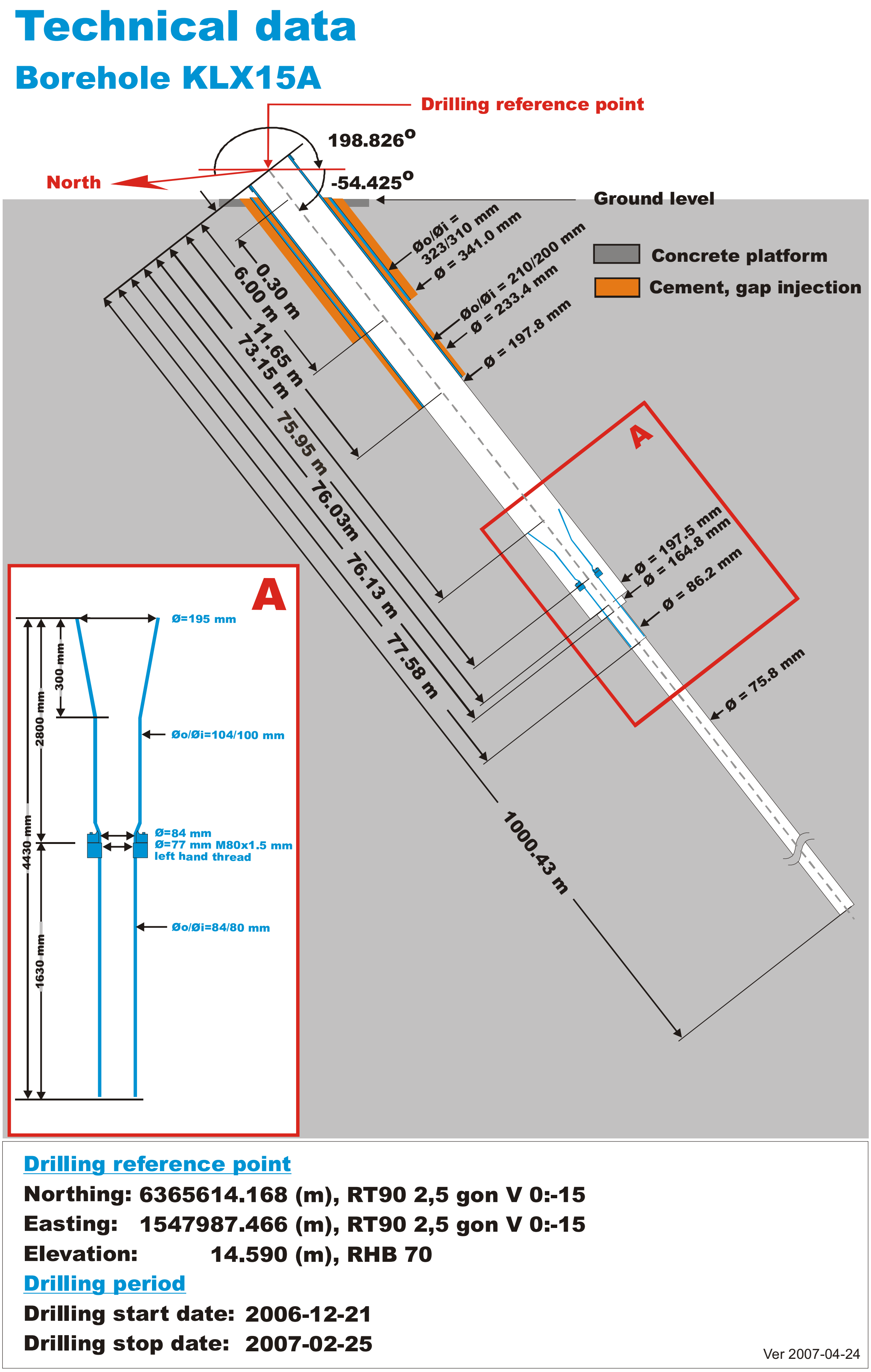


Figure 5-1. *Technical data from KLX15A.*

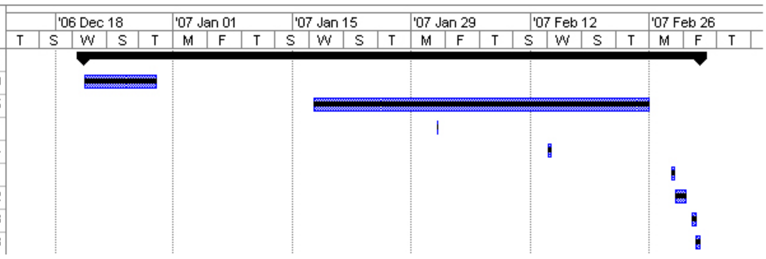
Table 5-2. Summary of core drilling progress and borehole measurements in KLX15A.

bh metres	Pumping tests and water sampling	Airlift pumping with evaluation of drawdown and/or recovery	Deviation measurement*	Miscellaneous
			070102 Collar survey Azimuth 198.8 Dip –54.4	
100	070113–070114 Pumping test without WL-probe in telescopic section 11.65–76.13 m 11.95–100.60. Flow 3 L/min at 17 m drawdown.			070122 Loss of water pressure during drilling at 130.9 m. Short pumping test performed.
	070122 Pumping test 120.13–130.90. Flow 9 L/min at 10 m drawdown. Water sample taken.		070123 EZ-shot 120 m Azimuth 193.9 Dip –50.8.	
200	070124 Pumping test 77.90–176.19 Flow 9.5 L/min at 9 m drawdown. Water sample taken.		070125 EZ-shot 184 m Azimuth 194.3 Dip –50.4.	
			070126 EZ-shot 235 m Azimuth 192.7 Dip –50.1.	
300			070127 EZ-shot 275 m Azimuth 192.2 Dip –50.0.	
400	070130 Pumping test 276.13–368.17 Flow 0.1 L/min at 23 m drawdown. No water sample taken.	070131 Airlift pumping 11.65–397.97 m. No drillstem in borehole.	070131 EZ-shot 397 m Azimuth 191.7 Dip –49.5.	
500			070203 EZ-shot 488 m Azimuth 190.5 Dip –48.9.	
600	070205 Pumping test 365.80–556.43 Flow was 2 L/min at 19 m drawdown. No water sample taken.		070206 EZ-shot 575 m Azimuth 190.3 Dip –48.5.	
	070209 Pumping test 551.70–651.88 Flow 1.6 L/min at 20 m drawdown. No water sample taken.		070208 EZ-shot 628 m Azimuth 191.6 Dip –48.2.	
700		070213 Airlift pumping 11.65–722.30 m. No drillstem in borehole.	070212 EZ-shot 704 m Azimuth 190.4 Dip –47.8.	
	070215 Pumping test 651.00–758.21. Flow 0.2 L/min at 19 m drawdown. No water sample taken.			
800			070216 EZ-shot 762 m Azimuth 190.8 Dip –47.3.	
900	070220 Pumping test 757.00–875.10 Flow 0.2 L/min at 18 m drawdown. No water sample taken.			
1,000	070226 Pumping test 873.1–1,000.43 Flow 0.4 L/min at 18 m drawdown. No water sample.	070228 Airlift pumping 11.65–1,000.43 m. Drillstem in borehole.		070225 Core drilling completed at 1,000.43 m

* NB The azimuth values for EZ-shot are not corrected for magnetic deviation

Table 5-3. Chronological summary of main core drilling events in KLX15A.

Aktivitet	Start	Finish
First activity starts	**Thu 06-12-21**	**Sat 07-03-03**
Percussion drilling	Thu 06-12-21	Fri 06-12-29
Core drilling	Wed 07-01-17	Sun 07-02-25
Recovery test	Wed 07-01-31	Thu 07-02-01
Recovery test	Tue 07-02-13	Wed 07-02-14
Recovery test	Wed 07-02-28	Thu 07-03-01
Length calibration marks by	Thu 07-03-01	Fri 07-03-02
Maxibor measurement	Sat 07-03-03	Sat 07-03-03
Maxibor measurement	Sat 07-03-03	Sat 07-03-03



5.2 Drilling, measurements and results in the telescopic section 0–76.13 m

Drilling, reaming and casing grouting (gap injection) were made from December 21 to 29, 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.

5.2.2 Drilling and casing installation

The construction of the upper telescope section (0–76.13 metres) of KLX15A was made in steps as shown in Figure 5-2 and described below:

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

- Drilling was made to 6.0 metres length with NO-X 280 mm equipment. This gave a hole diameter of 341 mm and left a casing (323/310 mm diameter) to a length of 6.0 m.
- Inner supportive casing for guidance for the drill string was mounted.
- A pilot percussion hole was drilled to a depth of 76.13 metres. The starting diameter was 165.0 mm and the final diameter was 164.8 mm at length 76.13 m.
- Reaming to diameter 233.4 mm was done to from 6.0 to 11.65 m.
- Stainless casing of 208×4 mm was installed from 0 to 11.65 m.
- Reaming was done from 11.65 m to 76.03 m. The initial diameter was 197.8 mm and the final diameter was 197.5 mm.
- Casing grouting (gap injection) with low alkali cement based concrete (684 kg or 760 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 emplacing a packer below the casing and filling the steel casing with water.

5.2.3 Measurements and sampling during drilling of the telescopic section

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

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

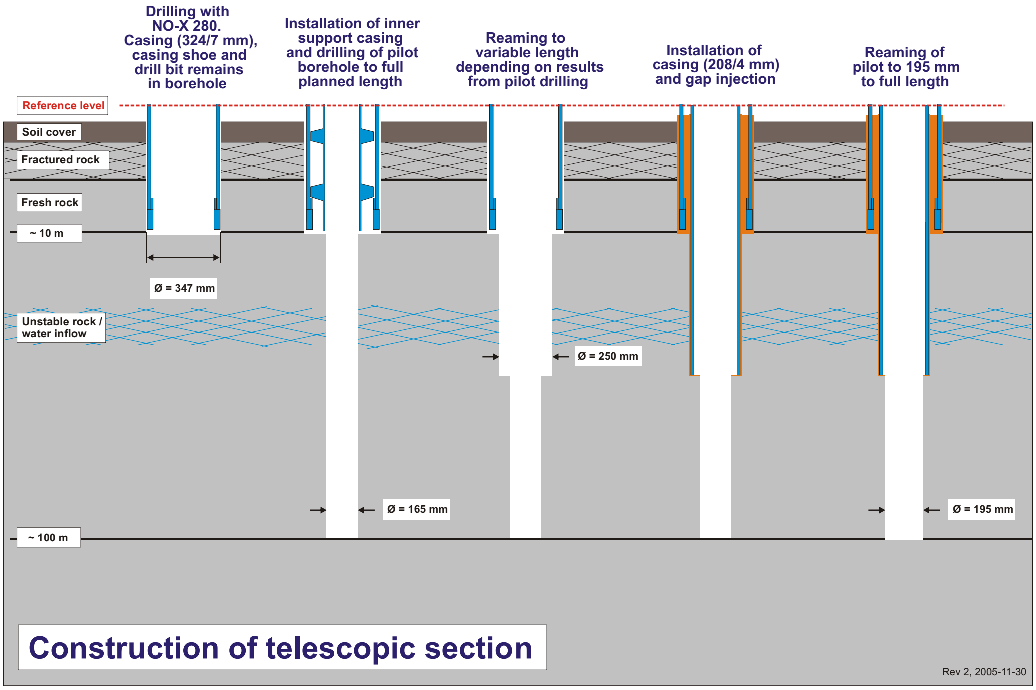


Figure 5-2. *Construction of the telescopic section. The cement for casing grouting is introduced between the casing and the rock wall. The drill bit acts as a barrier so that cement does not enter the pilot hole.*

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

The depth to bedrock from top of casing (TOC) was 6 m. The depth of overburden (ground surface to rock) was 5.7 metres i.e. the drilling reference level (TOC) was located 30 cm above the concrete slab.

The results from the preliminary geological logging, measurements of magnetic susceptibility in the drill cuttings and water flow during drilling are given in Figure 5-3.

No water samples were collected in the telescopic section in KLX15A as no inflow of water could be noted during the drilling of the telescopic section.

5.2.4 Hydrogeological measurements and results in the percussion drilled telescopic section 11.65–76.13 m

An open hole pumping test was performed in the percussion drilled part of KLX15A during January 13 to 14, 2007. The completed test comprised a pumping phase of 24h and 6 min, and a recovery phase of 24h and 8 min. The result is shown in Table 5-4.

No water samples were collected in the telescopic section in KLX15A.

Table 5-4. Results from single-hole pumping test in open borehole KLX15A, 11.65–76.13 m.

Tested section [m]	Q/s [m²/s]	T_M [m²/s]	Comments
11.65–76.13	$2.4 \cdot 10^{-6}$	$2.9 \cdot 10^{-6}$	Pumping test without wireline probe. The pump was without stop valve. This led to a rapid rise of water in the discharge hose after the pumping was stopped.

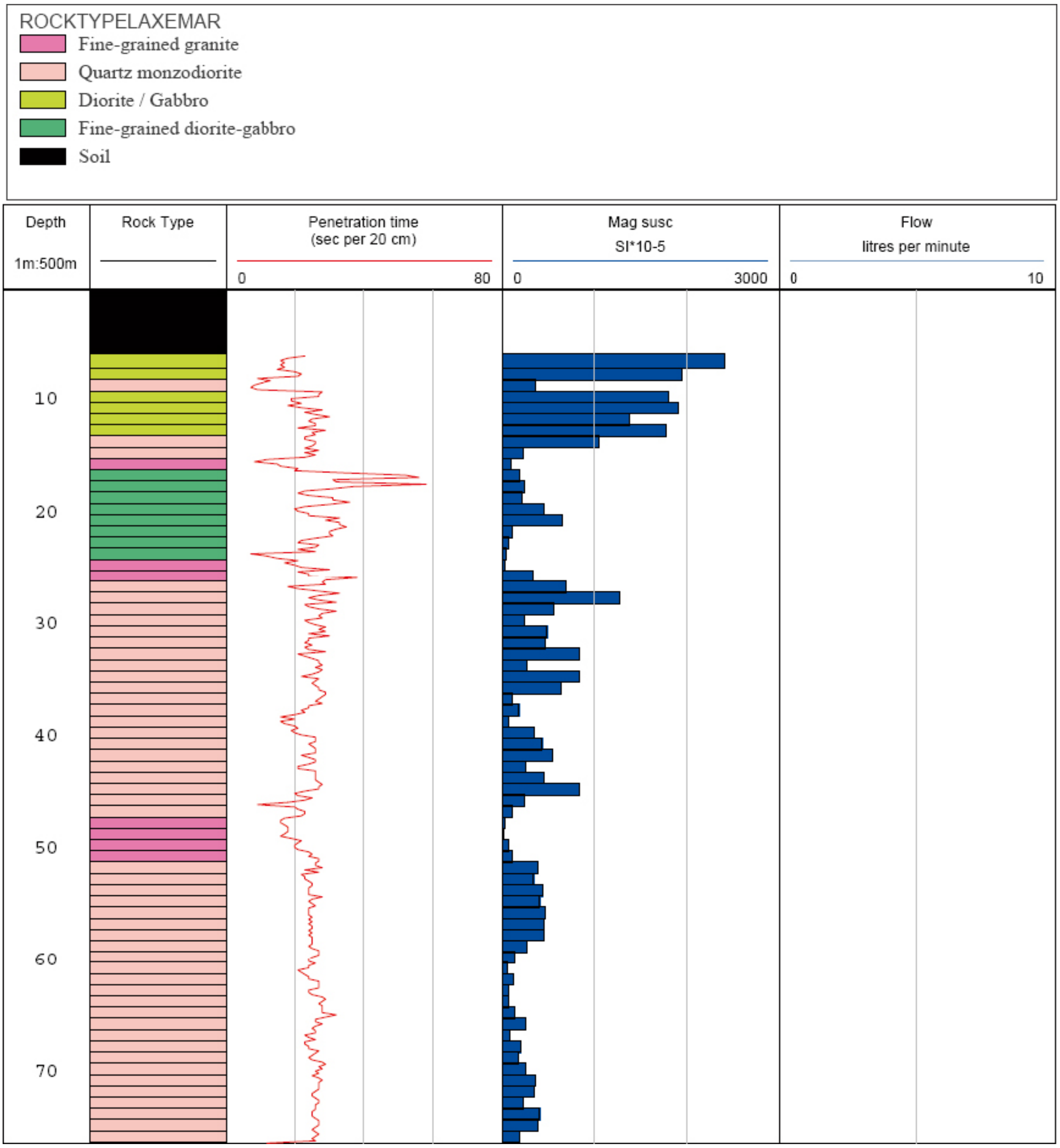


Figure 5-3. *Preliminary geological results based on logging of drill cuttings and penetration rate from percussion drilling of KLX15A. The transmissivity is also shown in Figure 5-8 together with results from other pumping tests in KLX15A.*

5.3 Core drilling KLX15A 76.13–1,000.43 m

Core drilling in KLX15A was conducted between January 17 and February 25, 2007.

The main work in KLX15A 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.

5.3.1 Preparations

The preparations for core drilling started on January 3, 2007 and consisted of mounting the drill rig, installation of air-lift pumping equipment and supportive casing for alignment of the core drill rods, see Figure 5-4.

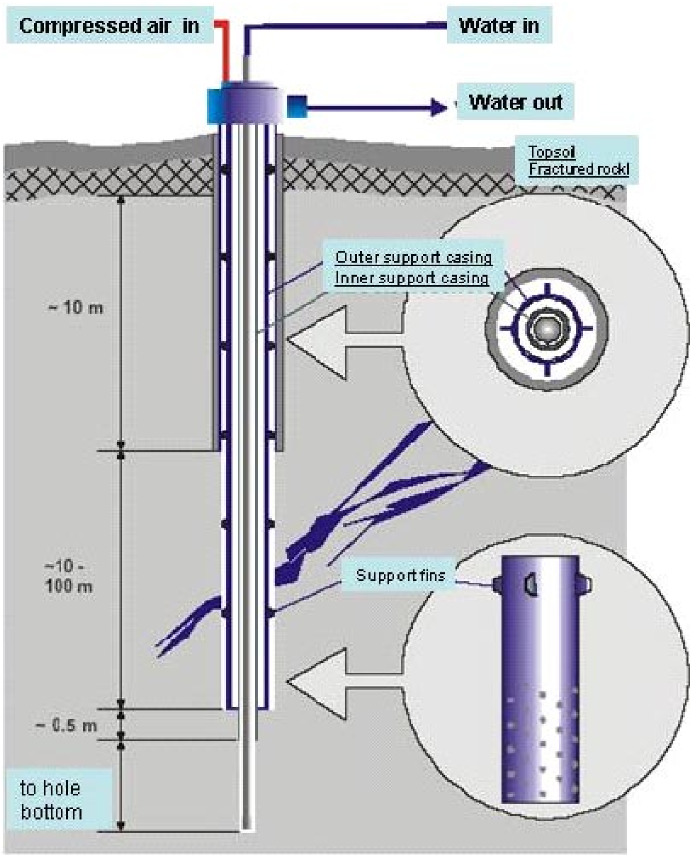


Figure 5-4. *In the telescopic part of the drill hole a temporary installation is made with casing tubes for support and alignment and equipment for air-lift pumping. In the uppermost part the return water discharge header is mounted. The water discharge is led to the settling containers.*

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 to 75 m.
- Equipment for air-lift pumping was installed and a discharge header was fitted to collect the return water.
- Drilling was made between 76.13 and 76.71 m with T-86 equipment. An inner supportive casing with diameter 84/77 mm was installed to the borehole bottom.

The supportive casings have a perforated section below 60 metres length so that water from the borehole can be lead to the air-lift pumping system outside the supportive casings. A pressure meter for monitoring of the water level was emplaced at a length of 70 metres.

5.3.2 Flushing and return water handling

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

Treatment of the flushing water before introduction into the boreholes consisted of stripping (removal) of oxygen with nitrogen gas and addition of the fluorescent tracer uranine. The water is also treated with ultraviolet light in order to reduce the microbial content. The flushing and return water handling and the emplacement of related monitoring equipment in KLX15A is shown in Figure 5-5.

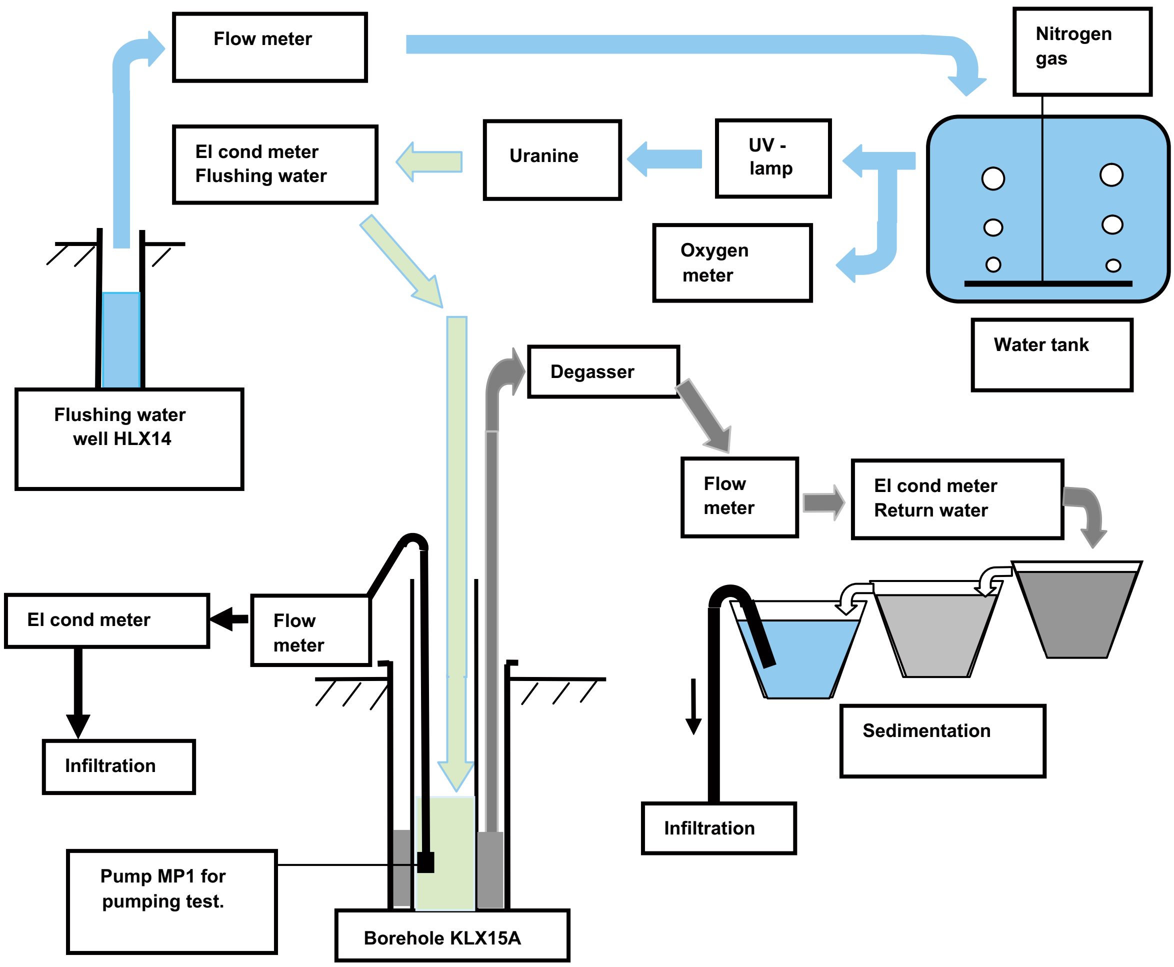


Figure 5-5. The flushing and return water handling and the emplacement of related monitoring equipment in KLX15A.

The targeted content for uranine in the flushing water was 0.20 mg/L and the actual average uranine content was 0.196 mg/L, see also Figure 5-9 and section 5.4.2.

The return water from drilling was led to a series of sedimentation containers in order to collect cuttings before infiltration to the ground. In KLX15A measures were taken to improve the efficiency of sediment capture in the containers. The return water was introduced through perforated hoses in order to reduce the velocity of the water and the pumps in the containers were emplaced so that erosion in the bottom of the containers would be minimized, see also section 5.8.

5.3.3 Drilling and deviation measurements KLX15A

Core drilling with T-86 equipment giving an 86 mm diameter hole was done from 76.13 to 76.71 m in KLX15A. The part from 76.71 to 77.58 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 76.71 m to the final length of 1,000.43 m in KLX15A.

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 KLX15A.

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 monitored by deviation measurements ten times with the EZ-shot method 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 Maxibor and Flexit methods for the final evaluation of the borehole deviation in KLX15A. The Maxibor measurement was done as part of the drilling activity. Measurements with the Maxibor instrument were performed both up and down the hole between 0 and 996 metres. The Flexit measurement was made as part of a separate geophysical activity (AP PS 400-07-037). Measurements with the Flexit method were done both up and down the borehole to a length of 978 m.

The final deviation file in KLX15A is calculated based on the measurements given in Table 5-6 together with the surveyed bearing and inclination of the top-of-casing. The calculations are made according to routines specified in the SICADA database and general expert judgement. Further comment on the method for calculation of final borehole deviation is given in /4/.

Table 5-5. Core diameters, borehole diameters and drilling dimensions during core drilling in KLX15A.

Core diameter (mm)	Borehole diameter (mm)	Interval (m drilled length)	Drilling dimension	Comment
72.0	86	76.13–76.71	T-86	
50.2	86	76.71–77.58	N and T-86	Reamed to 86 mm diameter
50.2	76	77.58-1,000.43	N	

Table 5-6. Measurements used for borehole deviation calculation in KLX15A.

Deviation measurement method	Used for calculation of bearing/inclination	Interval From (m)	Interval To (m)	Measuring direction	Date	Sicada database activity ID
Maxibor	BEARING	0	996	down/in	2007-03-03	13151041
Maxibor	INCLINATION	0	996	down/in	2007-03-03	13151041
Maxibor	BEARING	0	996	up/out	2007-03-03	13151042
Maxibor	INCLINATION	0	996	up/out	2007-03-03	13151042
Flexit	BEARING	0	978	down/in	2007-04-01	13155770
Flexit	INCLINATION	0	978	down/in	2007-04-01	13155770
Flexit	BEARING	0	978	up/out	2007-04-01	13155771
Flexit	INCLINATION	0	978	up/out	2007-04-01	13155771

Horizontal and vertical plots of the results of the calculated deviation covering the entire length of borehole KLX15A are given in Appendix 4. Information about which deviation measurement, or parts thereof, that are used for calculation of the borehole deviation are stored in the Sicada database under activity ID 13155937 (activity type code EG154).

Two sections with core losses were noted in KLX15A during the Boremap (geological) mapping: 216.54–216.59 and 996.08–996.58 m. The core losses were labelled as "missing core piece".

A total of twelve drill bits were used for KLX15A, see Figure 5-6.

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

5.3.4 Borehole wall risk assessment, stabilisation and completion

Borehole wall risk assessment and stabilisation

A borehole wall assessment was prepared on April 3, 2007, SKB id no 1070976, SKB internal document.

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

- Diamond drilling completed at 1,000.43 m on February 25.
- Flushing and brushing with high water pressure on the borehole wall was done along intervals as given in Table 5-7. The selection of the intervals to rinse was based on study of the drill core. The flush and brush tool is shown in Figure 5-7.
- Milling and indication of reference grooves was done between 100 and 980 m length. The detector for indicating groves was lowered with some problems around 264 m length.
- The steel dummy was lowered without any problems along the entire length of the borehole. The probe is designed so that it will run smoothly along the borehole if the curvature does not exceed 0.1 degree/metre.
- Downhole operations consisting of deviation measurements and flushing of the borehole with nitrogen gas were made without stability problems.
- BIPS logging for final risk assessment was done to the full drilled length.

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

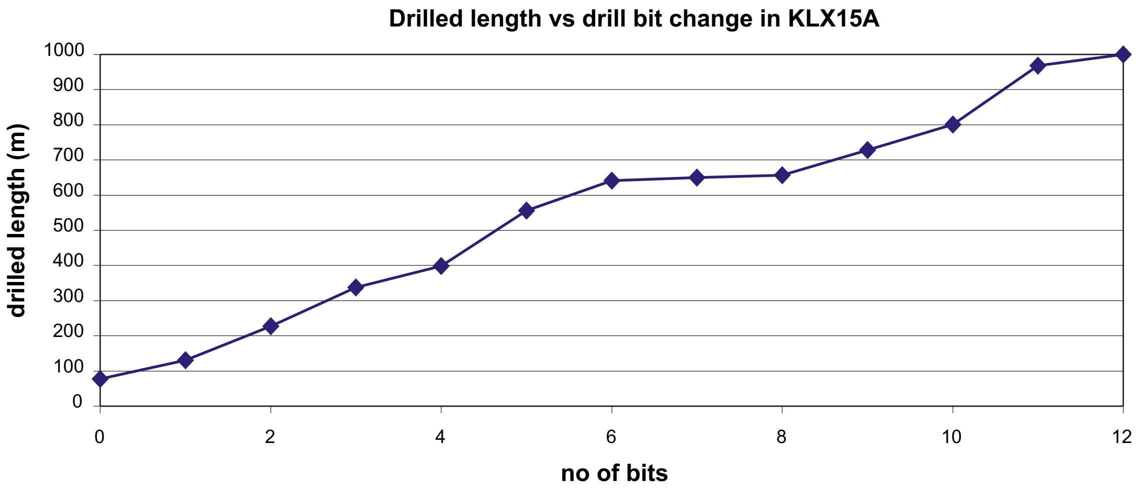


Figure 5-6. *Drill bit changes during core drilling in KLX15A.*

Table 5-7. Borehole sections that were mechanically rinsed by water flushing and rotating steel brush.

From (bh length m)	To (bh length m)
130	131
136	137
141	142
158.5	159.5
193	194
195.5	200
220.5	221.5
232.5	233.5
262.5	265.5
362.5	363.5
370	371
379.5	380.5
605.5	606.5
615	616
629	631.5
675	676
712.5	714.5
745	747
772	774.5
917.5	918.5
938.5	939.5
982.5	983.5
995	999

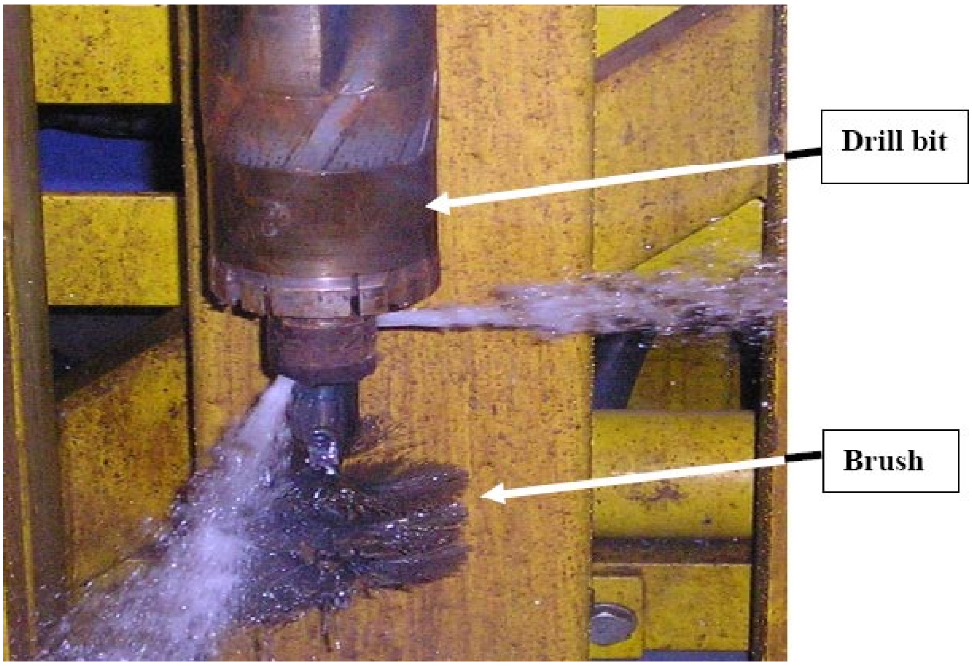


Figure 5-7. The water flushing and rotating steel brush tool. The tool is lowered into the drill stem and can be seen in place just below the drill bit. During operating the drill string is moved up and down to remove loose rock fragments from the borehole wall.

Borehole completion

Reaming of depth reference slots was done at the drilled lengths shown in Table 5-8. The depth reference slots are used for length 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 76.71 to 77.58 with T-86 equipment. A steel conical guide was installed in KLX15A between 73.15 m and 77.58 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 5-9.

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. Depth reference slots (m) in KLX15A.

100.00	600.00
150.00	650.00
200.00	700.00
250.00	750.00
300.00	800.00
350.00	850.00
400.00	900.00
450.00	950.00
500.00	980.00
550.00	

Table 5-9. Nitrogen gas lifting in KLX15A. (time is in Swedish Normal Time ie GMT+1).

Date	Time	Interval (m)	Volume removed (m^3)
070312	09:09–09:55	11.65–1,000.43	4
070312	10:47–11:26	11.65–1,000.43	2
070312	12:30–12:56	11.65–1,000.43	5
070312	14:18–14:51	11.65–1,000.43	3
070313	06:31–06:58	11.65–1,000.43	6
070313	08:14–08:42	11.65–1,000.43	4

5.4 Hydrogeological and hydrochemical measurements and results 76.13–1,000.43 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:

- Nine completely successful tests were conducted out of ten attempts at various intervals, see section 5.4.1.
- Three water samples were taken, see section 5.4.2.

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

Hydraulic responses in near-by boreholes from drilling in KLX15A are commented in section 5.4.4.

5.4.1 Hydrogeological results from wireline measurements

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

A total of ten tests were performed in KLX15A, and nine achieved sufficiently stable conditions for calculating pseudo steady-state transmissivity and hydraulic conductivity. Results from the nine successful wireline tests in KLX15A are presented in Table 5-10 and Figure 5-8. The plots from the nine successful pumping tests are given in Appendix 5.

The start and stop times (local time) for the intervals used for evaluation of the pumping tests are given in Table 5-11.

5.4.2 Hydrochemistry

Three water samples were collected in connection with core drilling in KLX15A. Times and lengths for the samples are given in Table 5-12.

Sampling and analysis were performed according to the SKB classes specified in Table 5-12. 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 drilling water content is a measure of the amount of uranine tracer in the return water. A low percentage of drilling water implies that the amount of pristine formation water is high in the sample i.e. low amount of the uranine-spiked flushing water.

Table 5-10. Pumping tests with wireline probe in KLX15A.

Tested section [m]	Q/s [m²/s]	T_M [m²/s]	Comments
120.13–130.90	$7.4 \cdot 10^{-5}$	$7.0 \cdot 10^{-5}$	The drawdown was 20 kPa in the test interval, but 102 kPa in the pipe-string. The flow rate was relatively stable but the pressure graph show a decreasing trend. The curves indicate a hydraulic connection with the casing and the derived parameters are therefore overestimated. Recovery = 68% of the drawdown.
77.9–176.19	$6.3 \cdot 10^{-5}$	$8.2 \cdot 10^{-5}$	Due to power failure two pumping breaks occurred before the evaluated flow phase and one short break happened during the pumping. The drawdown was 25 kPa in the test interval, but 95 kPa in the pipe-string. The electric conductivity was increasing. Recovery = 96% of the drawdown.
174.33–277.64	$1.9 \cdot 10^{-5}$	$2.5 \cdot 10^{-5}$	The pressure graph shows a decreasing trend. The drawdown was 74 kPa in the test interval, but 116 kPa in the pipe-string. The electric conductivity was increasing. Recovery = 86% of the drawdown.
276.13–368.17	$2.8 \cdot 10^{-8}$	$3.7 \cdot 10^{-8}$	The test is difficult to evaluate. The flow rate varied between 0 and 0.06 L/min. The section pressure was relatively stable, but decreasing before pump start. The recovery was slow (22% of the drawdown at the end of the test). In the pipe string the water level ended below the pressure sensor.
365.80–556.43	$2.1 \cdot 10^{-6}$	$2.9 \cdot 10^{-6}$	Three short pumping breaks during the later part of the flow period have a great impact on the flow- and pressure graphs. Recovery = 98% of the drawdown.
551.70–651.88	$7.6 \cdot 10^{-7}$	$9.9 \cdot 10^{-7}$	C. two hours of pseudo steady state conditions were followed by a period of unstable flow rate and pressure values, varying 0–6 L/min and 50–70 kPa respectively. Recovery = 98% of the drawdown.
651.00–758.21	$6.5 \cdot 10^{-8}$	$8.5 \cdot 10^{-8}$	After the instant pressure decrease at the beginning of the pumping period, the section pressure increased c. 20 kPa. Pi, and consequently the drawdown, was hard to define, probably it was overestimated. Recovery = 33% of the drawdown. If the evaluation was based on the recovery (instead of the drawdown), the transmissivity would be equal to $2.55 \cdot 10^{-7}$.
757.00–875.10	$9.2 \cdot 10^{-8}$	$1.2 \cdot 10^{-7}$	The flow rate varies between 0 and c. 1.3 L/min. The section pressure is not stable prior to the pump start, and is unstable during the pumping. The pressure was still rising when the recovery was interrupted. The recovery = 56% of the drawdown. If the evaluation was based on the recovery (instead of the drawdown), the transmissivity would be equal to $2.2 \cdot 10^{-7}$.
873.12–1,000.43	$2.2 \cdot 10^{-7}$	$2.9 \cdot 10^{-7}$	The flow rate curve is stable but somewhat declining. The section pressure is not stable prior to the pump start, but is stable during the pumping. The pressure was still rising when the recovery was interrupted. The recovery = 56% of the drawdown.

Table 5-11. Evaluated test periods.

Tested section	Start (YYYY-MM-DD HH:MM)	Stop (YYYY-MM-DD HH:MM)
120.13–130.90	2007-01-22 17:37	2007-01-22 21:09
77.9–176.19	2007-01-24 19:28	2007-01-24 22:06
174.33–277.64	2007-01-27 15:26	2007-01-27 17:45
276.13–368.17	2007-01-30 12:19	2007-01-30 15:09
365.80–556.43	2007-02-05 16:15	2007-02-05 17:21
551.70–651.88	2007-02-09 12:06	2007-02-09 15:30
651.00–758.21	2007-02-15 12:37	2007-02-15 14:42
757.00–875.10	2007-02-19 16:30	2007-02-19 19:27
873.12–1,000.43	2007-02-25 01:40	2007-02-25 04:42

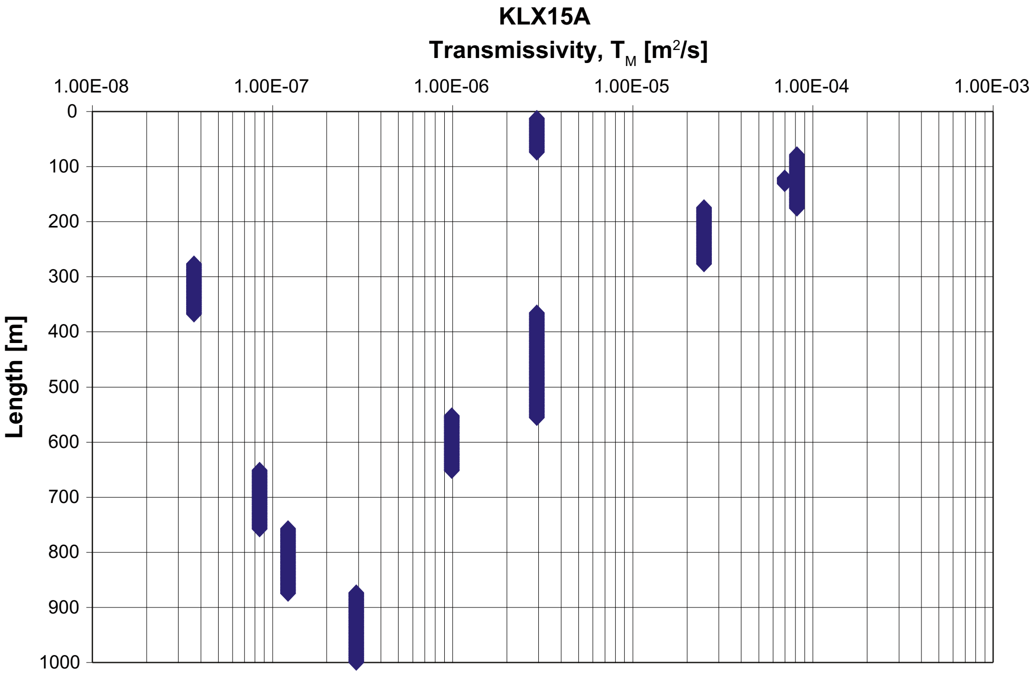


Figure 5-8. *Transmissivity from the nine successful wireline pumping tests in KLX15A versus borehole length. The transmissivity for the open-hole pumping test in the telescopic section 11.65–76.13 m is also shown.*

Table 5-12. Sample dates and length during core drilling in KLX15A.

Sample number	Date	Test section, length (m)	SKB chemistry class
11660	2007-01-23	120.13–130.90	1 (uranine)
11677	2007-01-25	77.90–176.19	3 (isotope options included)
11680	2007-01-27	174.33–277.64	1 (uranine)

Two archive samples have been collected for the samples 11677. The samples are stored in a freezer at the Äspö laboratory.

Selected analytical results from KLX15A are given in Table 5-13. A complete record of analytical results is given in Appendix 2.

The percussion drilled borehole HLX14 was used as water source during the drilling of KLX15A.

One water sample was collected from HLX14 in conjunction with drilling of KLX15A. The sample was taken as part of a separate activity (AP PS 400-06-110) and strictly not part of the drilling activity in KLX15A. The results are nevertheless presented in Appendix 2.

Four water samples have been collected from HLX14 at earlier occasions and results from those analyses are given in an earlier drilling report /5/.

Table 5-13. Analytical results from water chemistry sampling in KLX15A.

Sample no	Date	Section (m)	Drill water (%)	pH	Electrical conductivity (mS/m)	Cl (mg/L)
11660	2007-01-23	120.13–130.90	38.60	–	–	–
11677	2007-01-25	77.90–176.19	38.10	8.31	155.0	290.0
11680	2007-01-27	174.33–277.64	75.10	–	–	–

Monitoring of uranine tracer content

From KLX15A, a total of 133 samples for uranine content and electrical conductivity in flushing and returning water were taken along the borehole. The calculated average uranine content for the whole borehole is 0.196 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.

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

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

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

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

The steady state transmissivity, T_M, was calculated according to Moye /3/, as well as the specific capacity, Q/s. The results are shown in Table 5-14, and stored in the SICADA database as "recovery tests" (code HY050). The tested section is here defined as the section between the lower end of the grouted casing and the borehole bottom.

The plots from the drawdown and recovery tests are given in Figures 5-10, 5-11 and 5-12.

Table 5-14. Results from airlift pumping in KLX15A.

Tested section [m]	Flow rate [L/min]	Drawdown [m]	Q/s [m²/s]	T_M [m²/s]	Comments
11.65–397.97	47.5	7.79	$1.0\ 10^{-4}$	$1.5\ 10^{-4}$	The section pressure was still increasing when the flow period started.
11.65–728.30	40.0	8.29	$8.0\ 10^{-5}$	$1.3\ 10^{-4}$	No undisturbed conditions prior to the pump start. The recovery (p_f–p_p) was used as d_p.
11.65–1,000.43	40.0	8.19	$8.1\ 10^{-5}$	$1.4\ 10^{-4}$	The section pressure was still increasing when the flow period started.

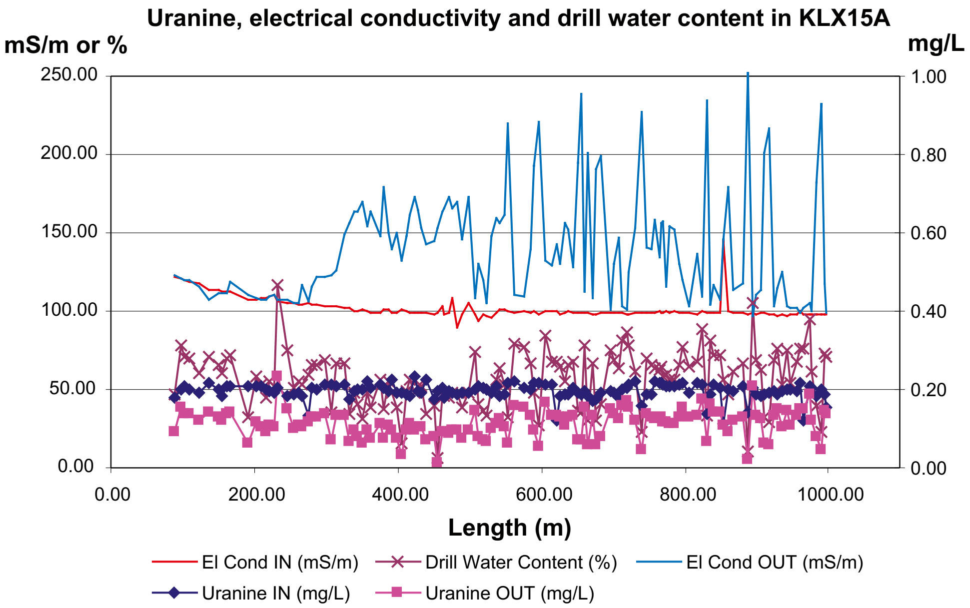


Figure 5-9. The uranine concentration and electrical conductivity of the flushing water (IN) and the return water (OUT) in KLX15A. The drill water content in the returning water is also shown.

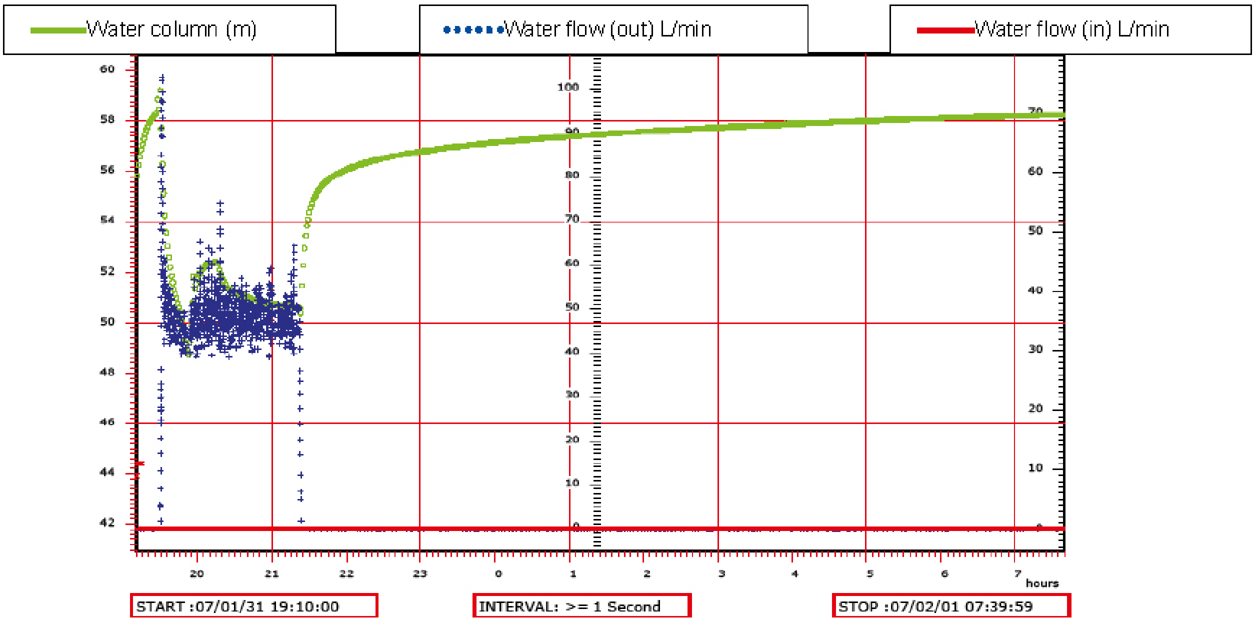


Figure 5-10. *Airlift pumping in KLX15A 11.65–397.97 m. The green line represents the height of the water column in the borehole, the flow out of the borehole is shown as the blue dotted line and the inflow rate as the red line. The inflow rate was 0 L/min during the whole test period. Times are given in Swedish Normal Time (GMT+1).*

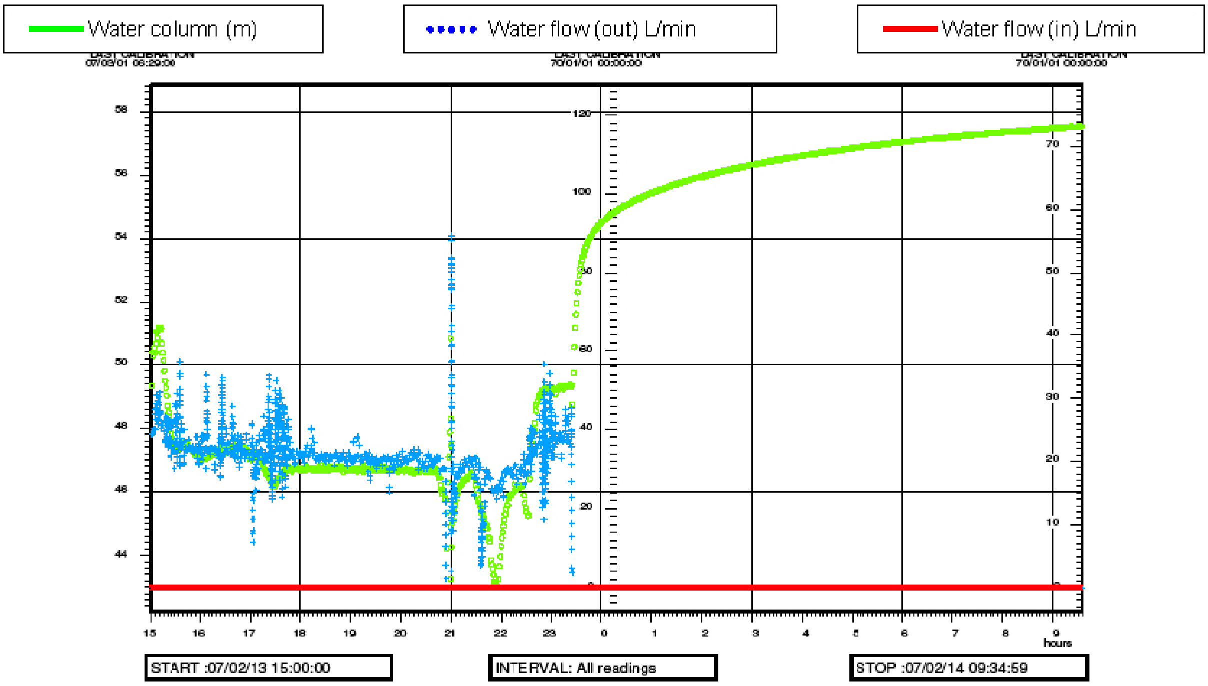


Figure 5-11. *Airlift pumping in KLX15A 11.65–728.30 m. The green line represents the height of the water column in the borehole, the out flow is shown as the blue dotted line and the inflow rate as the red line. The inflow rate was 0 L/min during the whole test period. Times are given in Swedish Normal Time (GMT+1).*

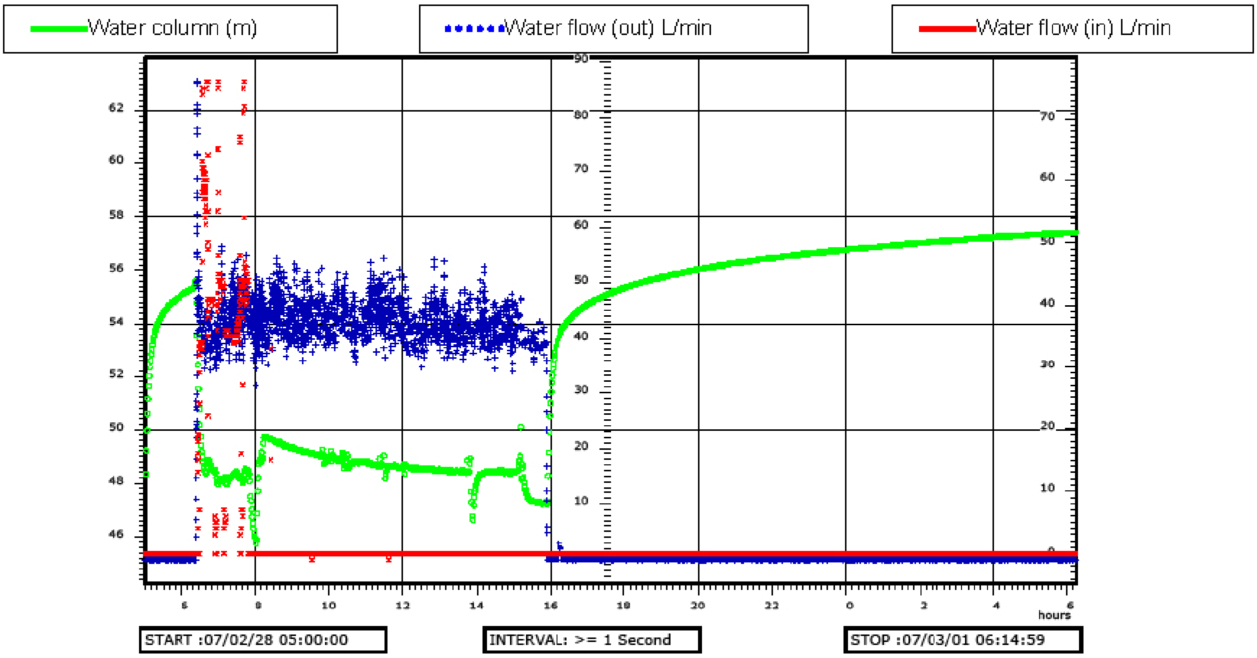


Figure 5-12. Airlift pumping in KLX15A 11.65–1,000.43 m. The green line represents the height of the water column in the borehole, the flow out of the borehole is shown as the blue dotted line and the inflow rate as the red line. Times are given in Swedish Normal Time (GMT+1).

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, from percussion drilling and from nitrogen gas lifting.

Summary conclusions of the hydraulic responses are listed below. The locations of the observation boreholes and KLX15A are shown in Figure 5-18.

- Clear hydraulic responses from drilling activities in KLX15A could be seen in HLX27, see Figure 5-13.
- No correlation between groundwater levels in the observation boreholes KLX03, KLX05, KLX12A, KLX16A, HLX15, HLX26 or HLX38 and the drilling activities in borehole KLX15A could be found. Graphical examples are shown in Figures 5-14 trough 5-17.

No data was available for KLX14A or KLX19A during the drilling in KLX15A.

The location of the observation boreholes and KLX15A is given in Figure 5-18.

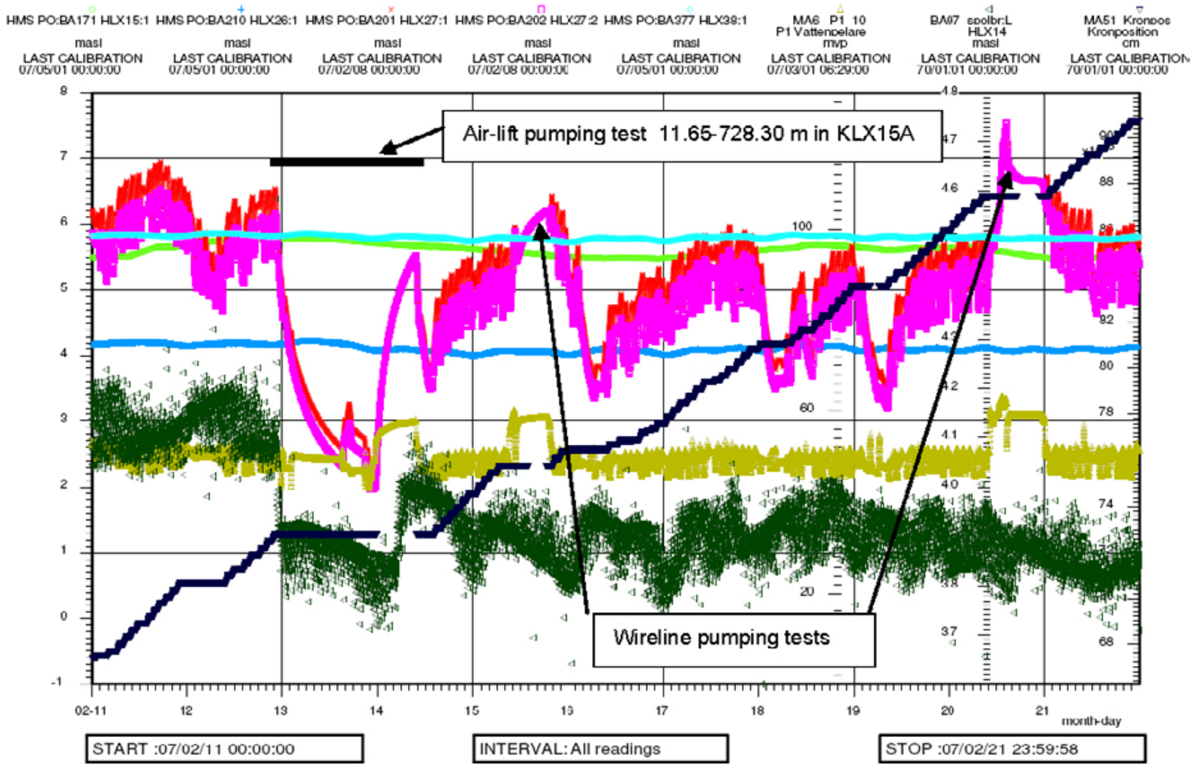


Figure 5-13. *Groundwater level in boreholes HLX15, HLX26, HLX27 and HLX38 together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well, HLX14) during drilling in borehole KLX15A in the period from February 11 to 21, 2007. The water level in HLX27 is clearly affected by drilling activities and hydraulic testing in KLX15A.*

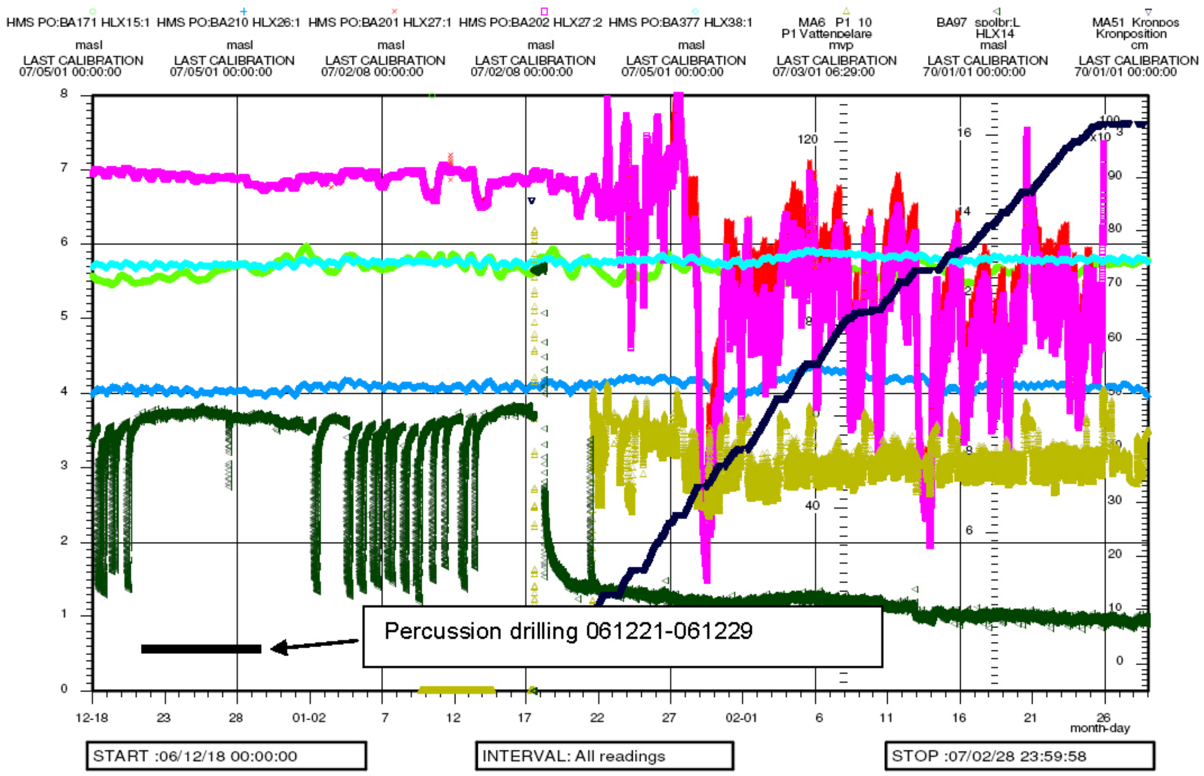


Figure 5-14. *Water levels in observation boreholes HLX15, HLX26, HLX27 and HLX38 together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well, HLX14) during the drilling in borehole KLX15A. No hydraulic responses can be seen in the observation hole HLX15, HLX26 or HLX38 from drilling activities in KLX15A.*

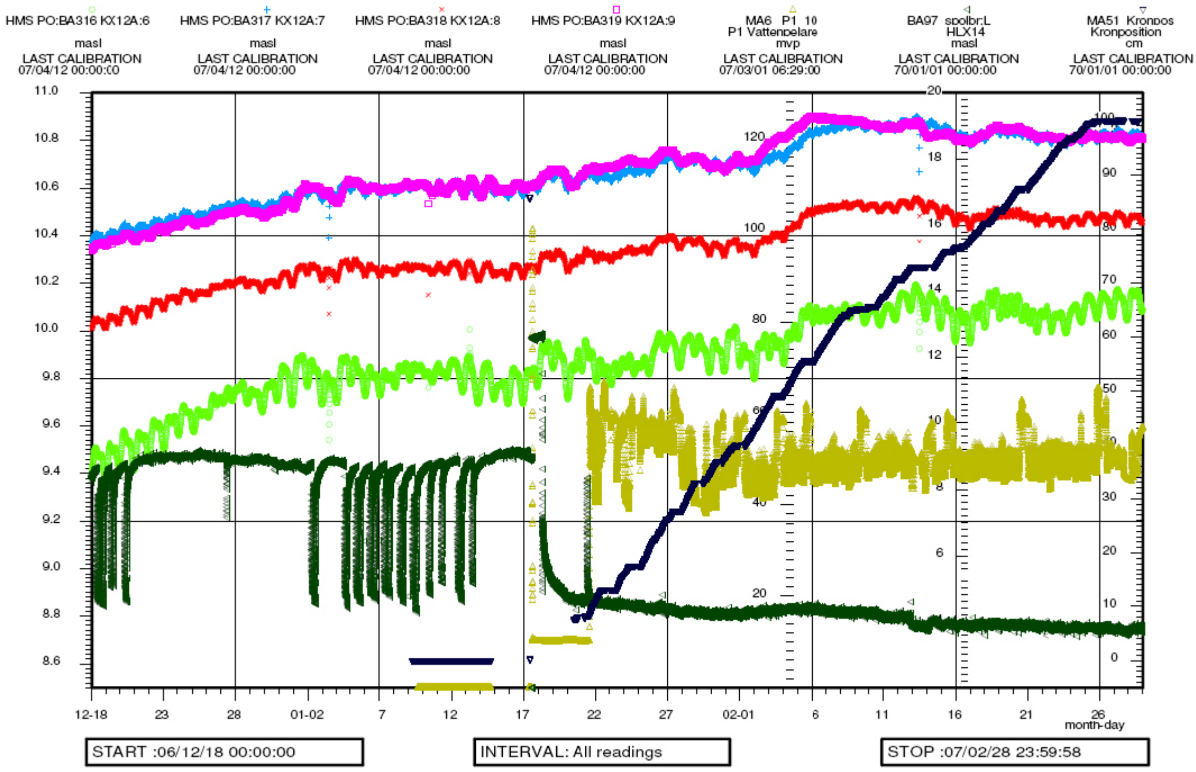


Figure 5-15. Groundwater level in the upper section (6-9) borehole KLX12A together with drilling parameters (pressure in the drilling borehole, position of drill bit and water level in the flushing water well, HLX14) during the drilling in borehole KLX15A. No hydraulic responses can be seen in borehole KLX12A from drilling activities in KLX15A.

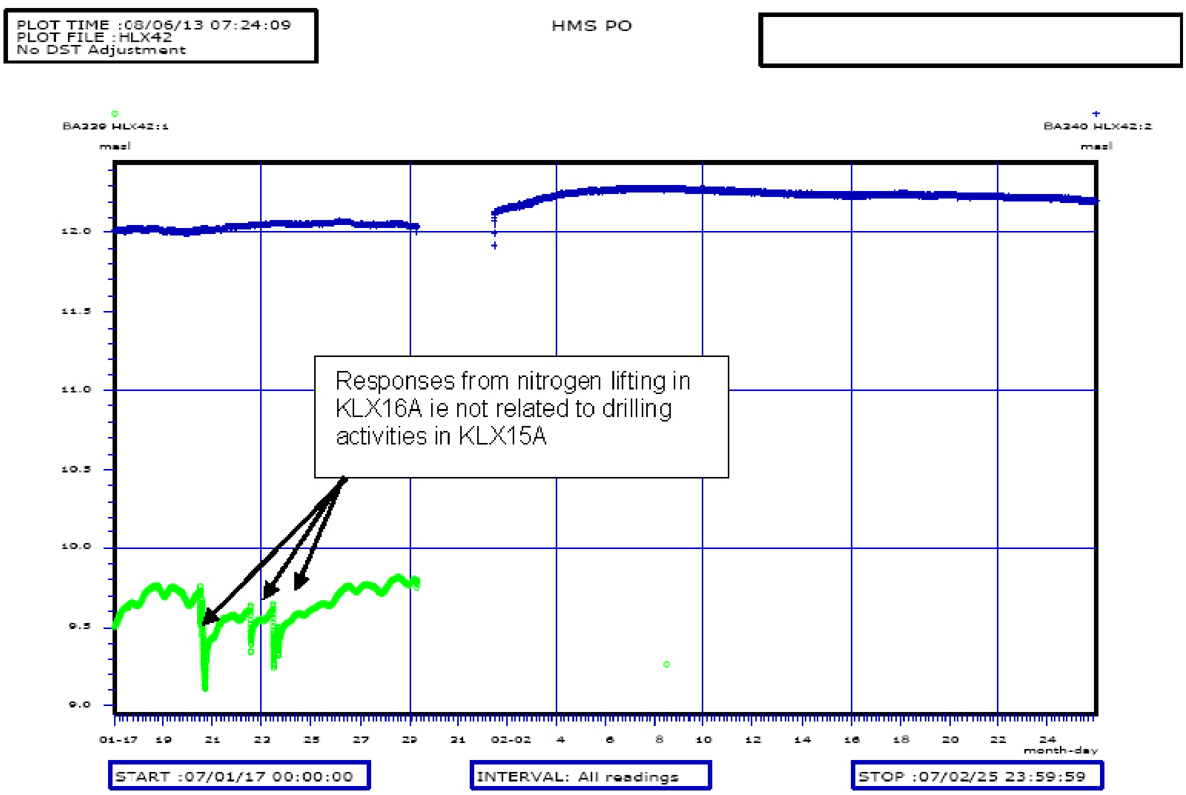


Figure 5-16. The water level in observation borehole HLX42 during the period of core drilling in KLX15A. Clear hydraulic responses can be seen in HLX42 that corresponds to nitrogen lifting in KLX16A. No visible responses from drilling activities in KLX15A can however be seen in HLX42.

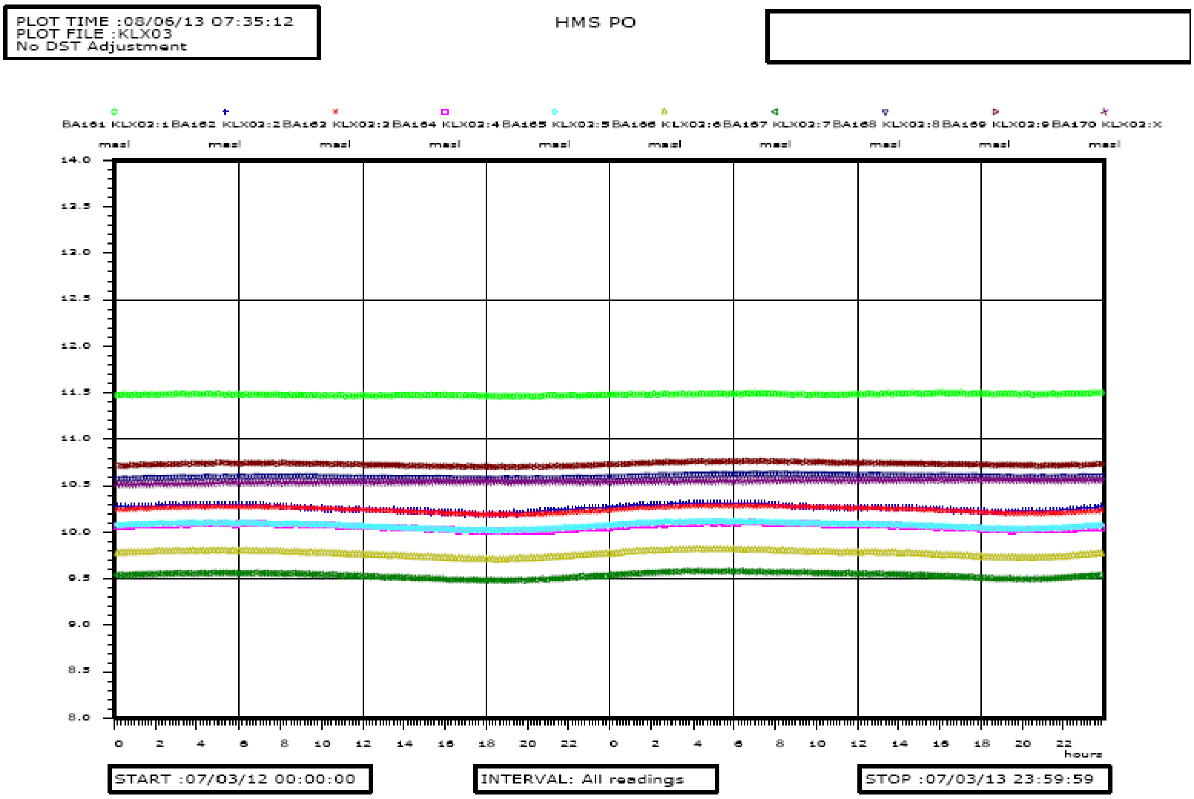


Figure 5-17. *The water table in KLX03 (all ten sections 1 through 10) during the period of nitrogen lifting in KLX15A. No hydraulic response in KLX03 can be seen from nitrogen lifting in KLX15A (March 12 and 13).*

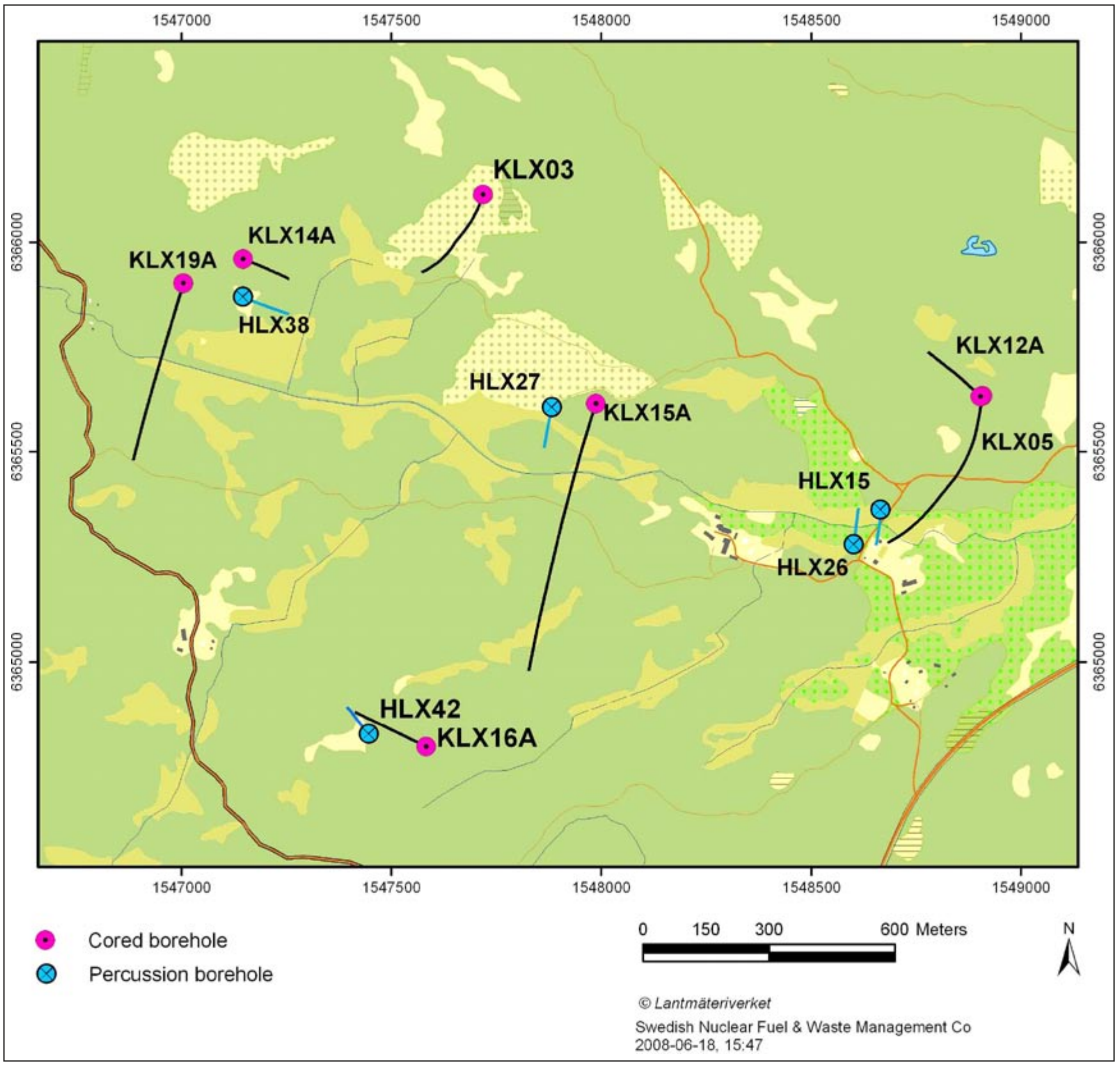


Figure 5-18. *Map showing the location of cored boreholes KLX03, KLX05, KLX12A, KLX14A, KLX15A, KLX16A and KLX19A and the percussion boreholes HLX15, HLX26, HLX27, HLX38 and HLX42.*

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.

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 5-19 through 5-21 below.

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

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

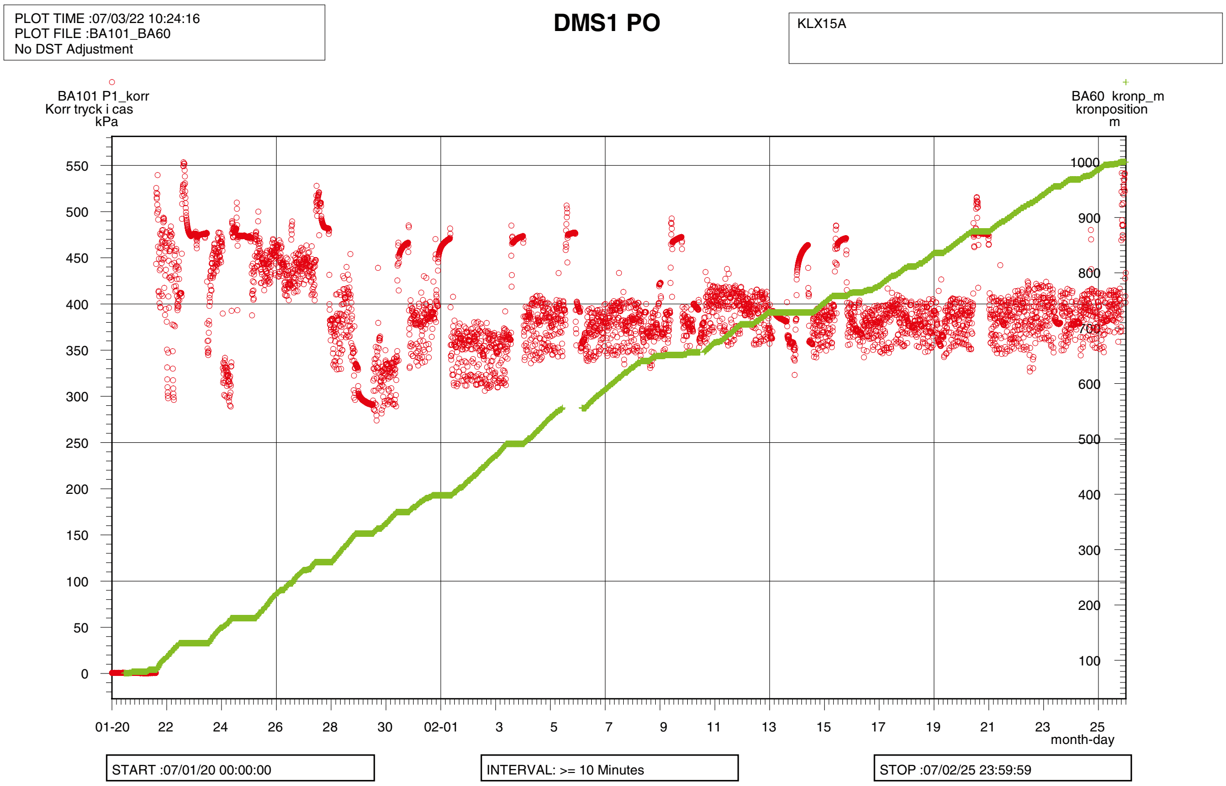


Figure 5-19. *Drill bit position (green) and water level from air-lift pumping (red). The water level is expressed as the pressure in kPa of the water column overlying the pressure gauge ie the ambient air-pressure has been subtracted. The pressure gauge is emplaced at 90 metres borehole length.*

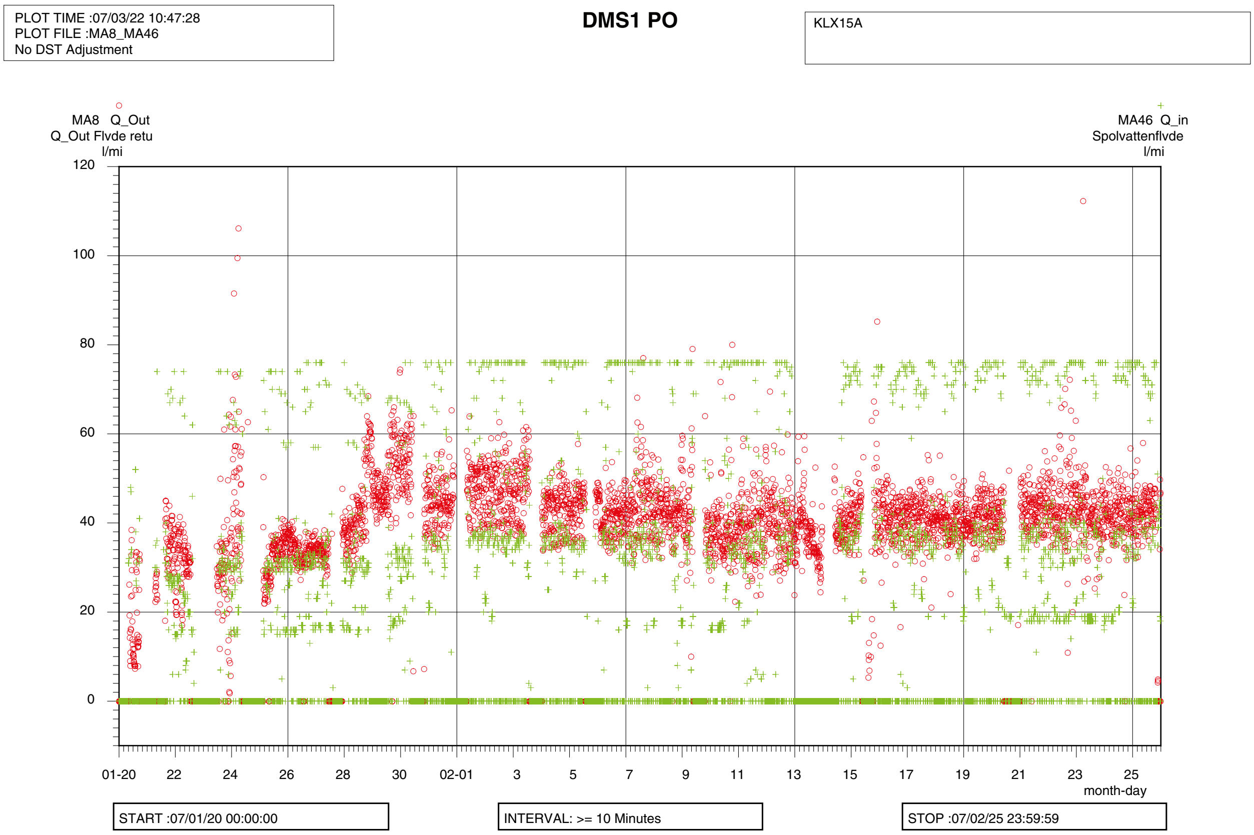


Figure 5-20. *Flushing water flow (green) and return water flow (red) in litres per minute.*

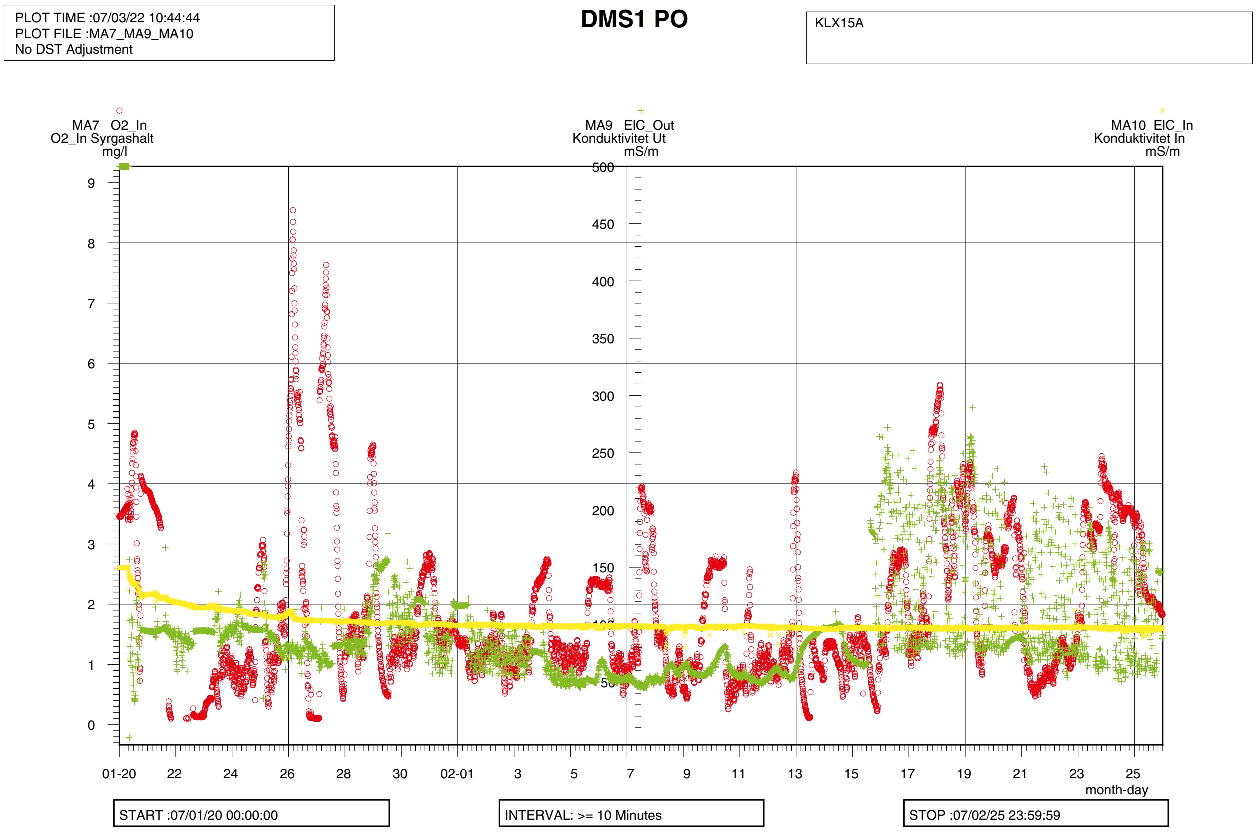


Figure 5-21. *Conductivity of flushing water (yellow) and return water (green). The oxygen content in mg/L of the flushing water (red) is also shown. The oxygen content of the flushing water is typically below 5 mg/L. The conductivity of the return water (green) is always under 300 mS/m.*

In order to maintain reasonable size data files, a reduction in the number of points incorporated in the pictures has been done in Figures 5-19 through 5-21. Since DMS data are related to time (i.e. not strictly to borehole length) periods where drilling is not performed are also registered.

Figure 5-19 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 5-20 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 5-21 shows the conductivity of the ingoing flushing water, conductivity of the return water and the oxygen content of the flushing water. The oxygen content of the flushing water is typically below 5 mg/L. The conductivity of the return water is always under 300 mS/m.

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 5-22.

The amount of flushing water consumed during drilling was 1,100 m^3, giving an average consumption of 1.2 m^3 per metre core drilled. The amount of effluent return water from drilling in KLX15A was measured by the DMS system to 1,780 m^3, giving an average of ca 1.9 m^3 per metre core drilled.

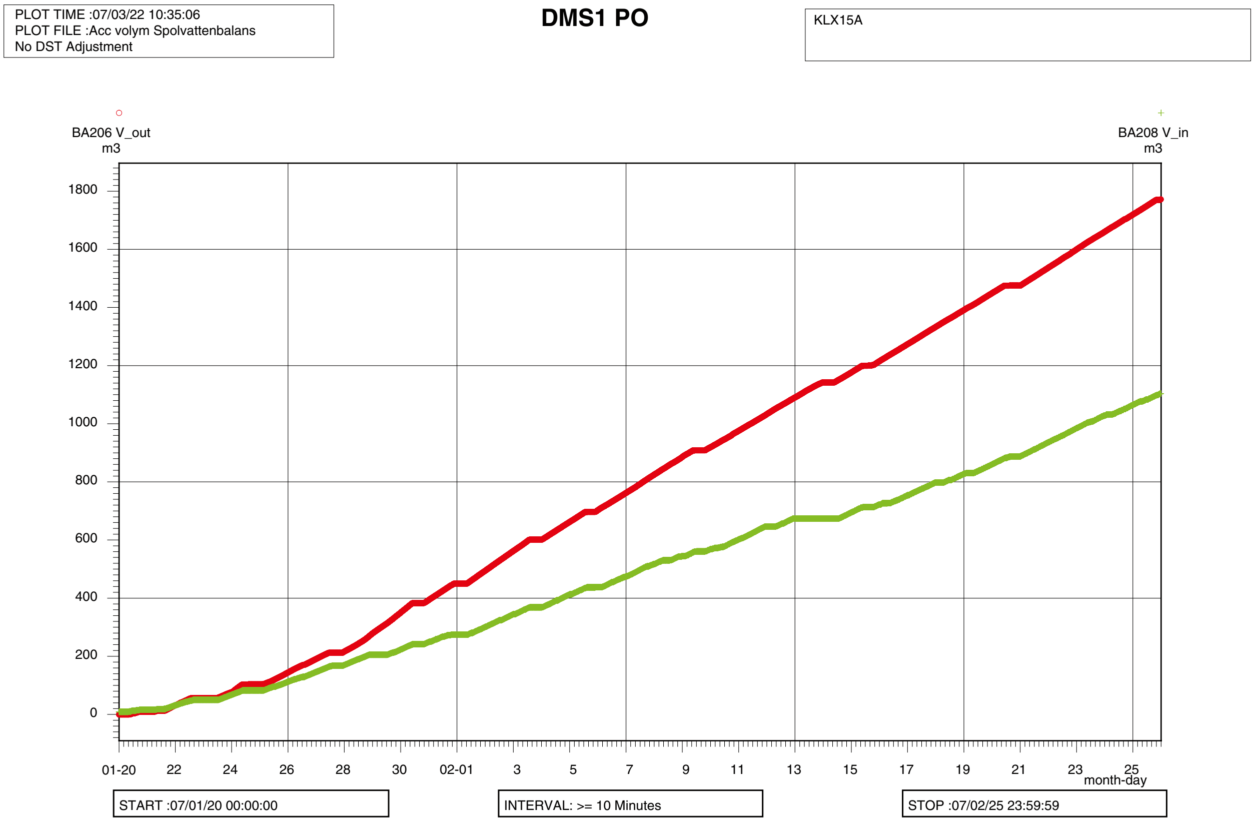


Figure 5-22. *The flushing water balance in KLX15A as recorded by the DMS system. The accumulated volume of the ingoing flushing water is shown in green and the outgoing return water is shown in red.*

Drill cutting balance

The weight of cuttings in the settling containers amounted to 3,080 kg. The content of suspended material in the return water is assumed to be 600 mg/L, see section 5.8 "Environmental control, monitoring of effluent water". The amount of material in suspension carried with the return water would amount to 1,070 kg (based on 1,780 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 924 metres is 6,240 kg assuming a density of 2.7 kg/dm^3. This means that 67% 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 5-15. The results show that most (> 90%) of the introduced amount uranine was retrieved during drilling of KLX15A.

Table 5-15. Balance calculation of uranine tracer in KLX15A.

Average uranine content IN (mg/L)	0.196
Flushing water volume IN (m^3)	1,100
Amount uranine introduced (g)	216
Average uranine content OUT (mg/L)	0.113
Return water volume OUT (m^3)	1,780
Amount uranine recovered (g)	201

5.6 Geology

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

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

The geological results based on the Boremap logging are shown in Appendix 1. It should be stressed that the geological description given in this report is a brief summary only. A more complete account is given in /6/.

Lithologically the core is dominated by Quartz monzodiorite (95%) with very minor intercalations of other rock types.

Rock alteration is mostly weak and thin. Scattered sections with some meters width of red staining or oxidisation, as labelled in Appendix 1, have been noted throughout the length of the core.

Two sections with core losses were noted in KLX15A during the Boremap mapping: 216.54–216.59 and 996.08–996.58 m. The core losses were labelled as "missing core piece", see also section 5.3.3.

The average fracture frequency over the core drilled section is 1.9 (fractures/metre) expressed as open fractures. 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 SSM000215 and SSM000268 is shown in Figure 5-23. 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 corresponding limiting value of 300 mS/m).
- Uranine content, 0.3 mg/l.
- Suspended material, 600 mg/l.

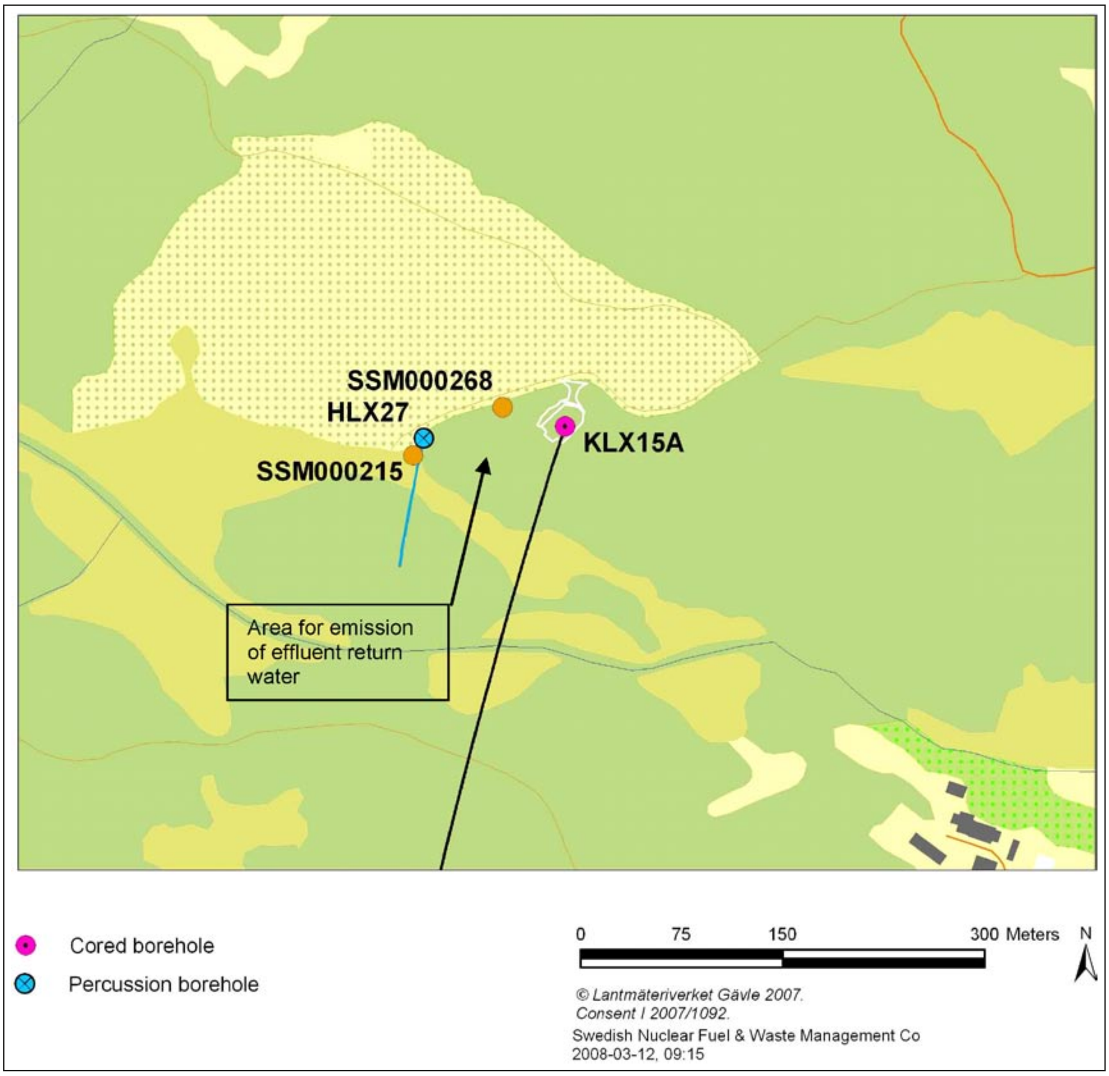


Figure 5-23. *The location of the site for return water emission and the environmental monitoring wells SSM000215 and SSM000268 in relation to the core drill site for KLX15A and percussion borehole HLX27.*

Monitoring of effluent water

The electrical conductivity, as measured by the DMS system, of the return water from the core drilling of KLX15A was below 300 mS/m throughout the core drilling phase, see Figure 5-21. Samples of the return water that were analysed for electrical conductivity were typically around 150 mS/m with peak values up to 250 mS/m, see Figure 5-9.

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

The concentration of suspended material in the return water from drilling has been analysed in previous drillings in boreholes KSH03 and KLX17A. The average amount of suspended material from the sampling campaign in KSH03 was 400 mg/L /7/ and in KLX17A it was 1,200 mg/L /8/. Changes in the handling of the return water were initiated in borehole KLX15A as a direct result of the sampling in KLX17A (SKB id 1091530, internal document). It is therefore reasonable to assume that the content of suspended material in the return water from KLX15A is considerably lower than 1,200 mg/L. A figure of 600 mg/L has therefore been used for mass-balance calculations of borehole cuttings, see section 5.5.2.

Environmental monitoring wells and reference sampling

Two environmental monitoring wells, SSM000215 and SSM000268, were used for the core drilling KLX15A. The technical specifications for the two environmental wells are given in Appendix 6.

Reference samples of the surface soil and ground water, before drill start and establishment of the drill site were taken as given in Table 5-16.

Monitoring of soil ground water levels

A pressure logger (transducer) for measuring the ground water table was installed in SSM000215 and SSM000268 during the core drilling of KLX15A. Plot from SSM000215 and SSM000268 are given graphically in Figures 5-24 and 5-25. The water table is not significantly affected by external activities, such as pumping or drilling.

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 SSM000215 and SSM000268, see Figures 5-26 and 5-27.

No influence can be seen on the shallow ground water in the monitoring wells SSM000215 or SSM000268 from the drilling activity in KLX15A.

5.8.1 Consumption of oil and chemicals

The consumption of hammer oil (Hydra 46) is typically around 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 360 litres (324 kg) in total. The concrete was based on white silica, low alkali cement.

5.9 Nonconformities

No formal nonconformities are noted for borehole KLX15A.

No deviation measurement was done in the percussion drilled section of the borehole.

Table 5-16. Reference samples for environmental monitoring.

Date	Sample No	Comment
2006-11-15	SKB PO 9016	Undisturbed soil sample
2006-11-30	11563	Reference water sample in SSM000215
2006-11-30	11564	Reference water sample in SSM000268

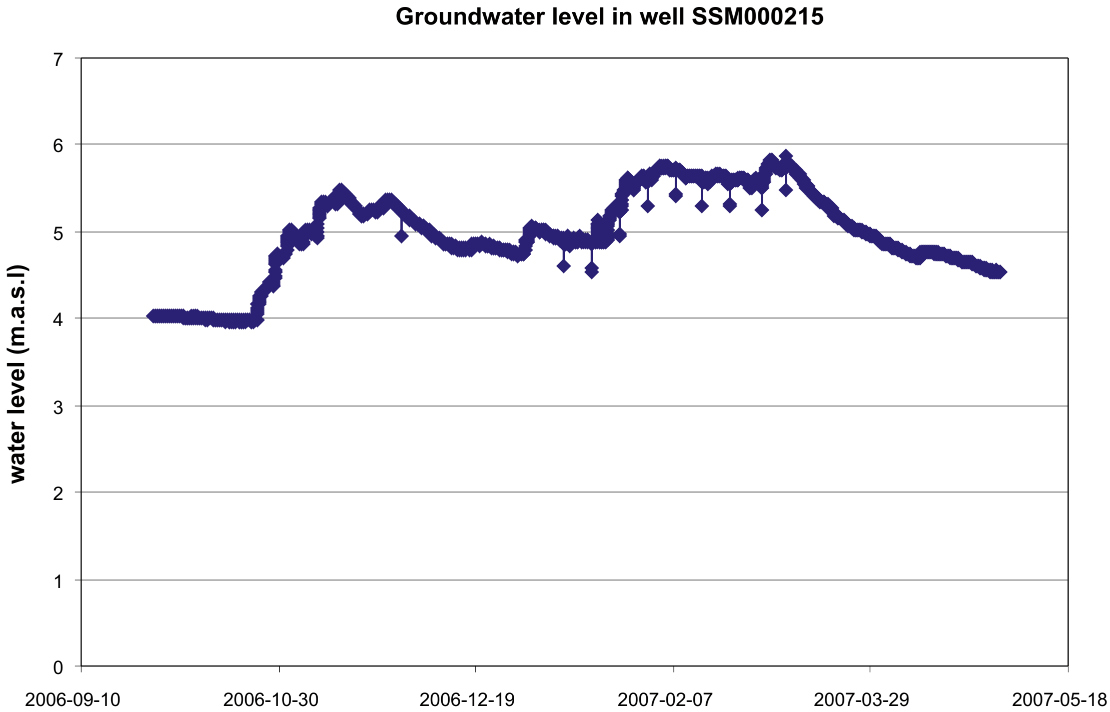


Figure 5-24. The ground water level in well SSM000215. The momentary dips in water levels are related to water sampling.

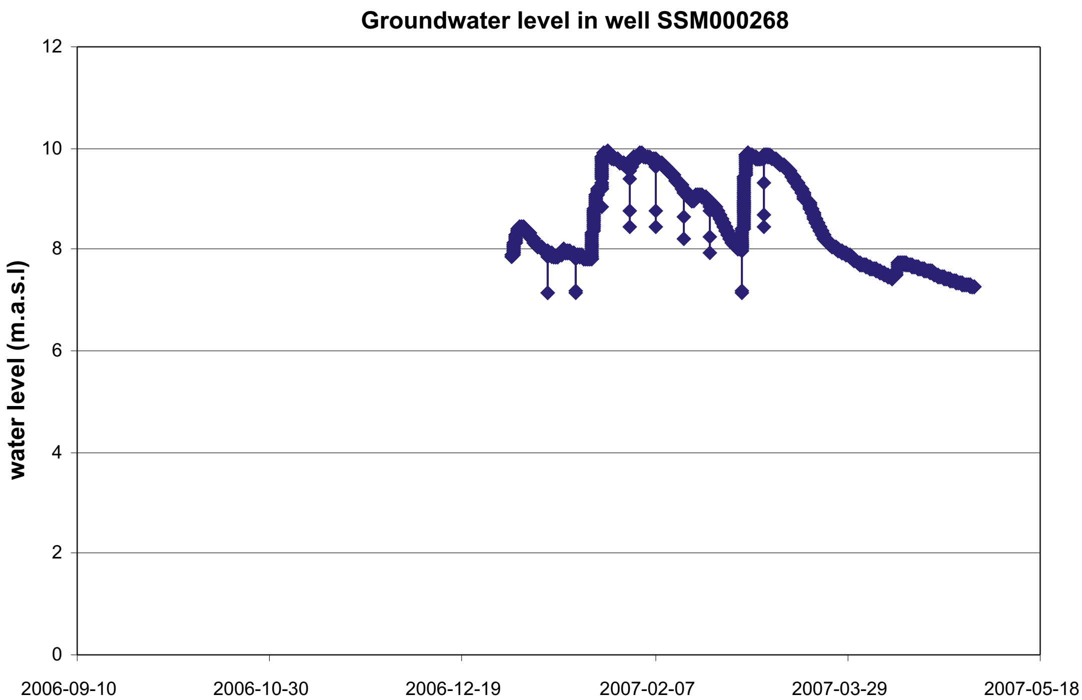


Figure 5-25. The ground water level in well SSM000268. The momentary dips in water levels are related to water sampling.

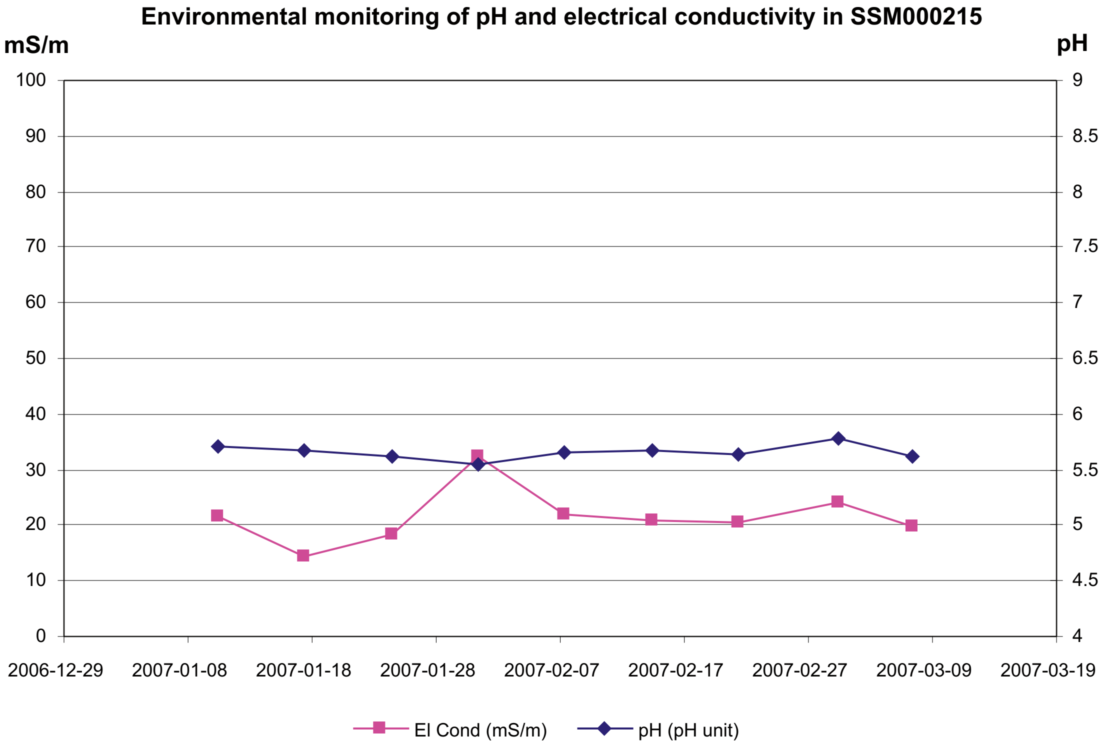


Figure 5-26. *Electrical conductivity and pH in ground water samples from SSM000215. The sampling events are shown with blue or purple symbols.*

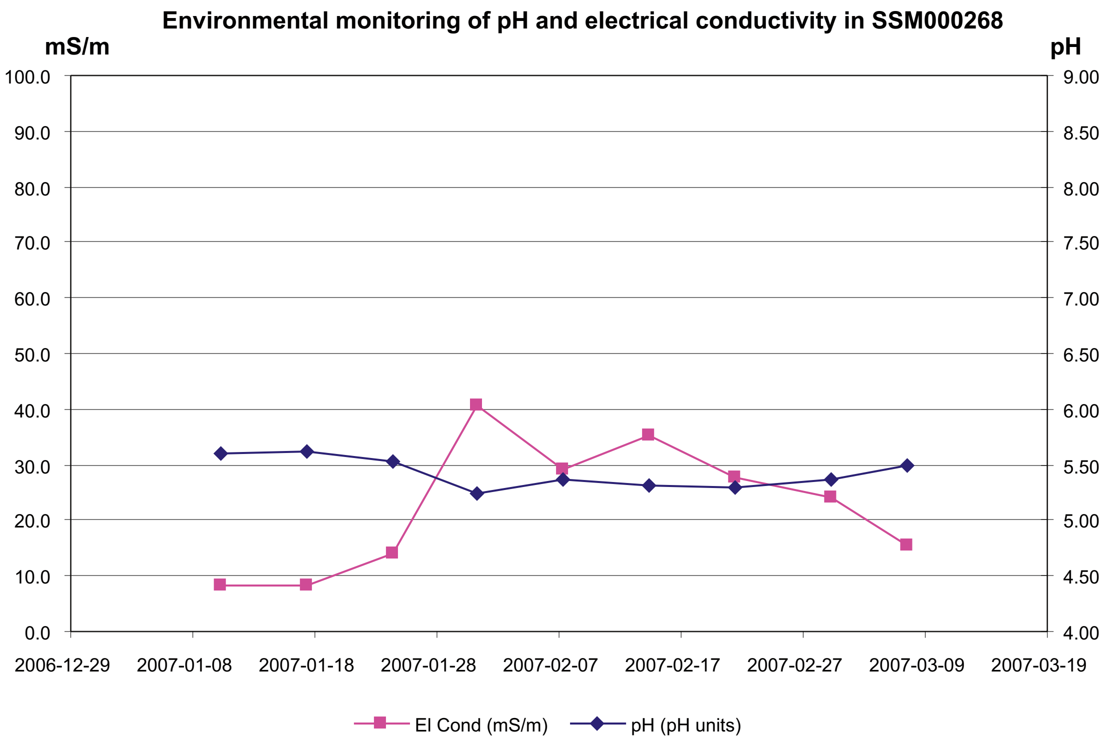


Figure 5-27. *Electrical conductivity and pH in ground water samples from SSM000268. The sampling events are shown with blue or purple symbols.*

6 References

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

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

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

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

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

/6/ **Mattsson K-J, Dahlin P, 2007.** Boremap mapping of telescopic drilled borehole KLX15A. SKB P-07-157, Svensk Kärnbränslehantering AB.

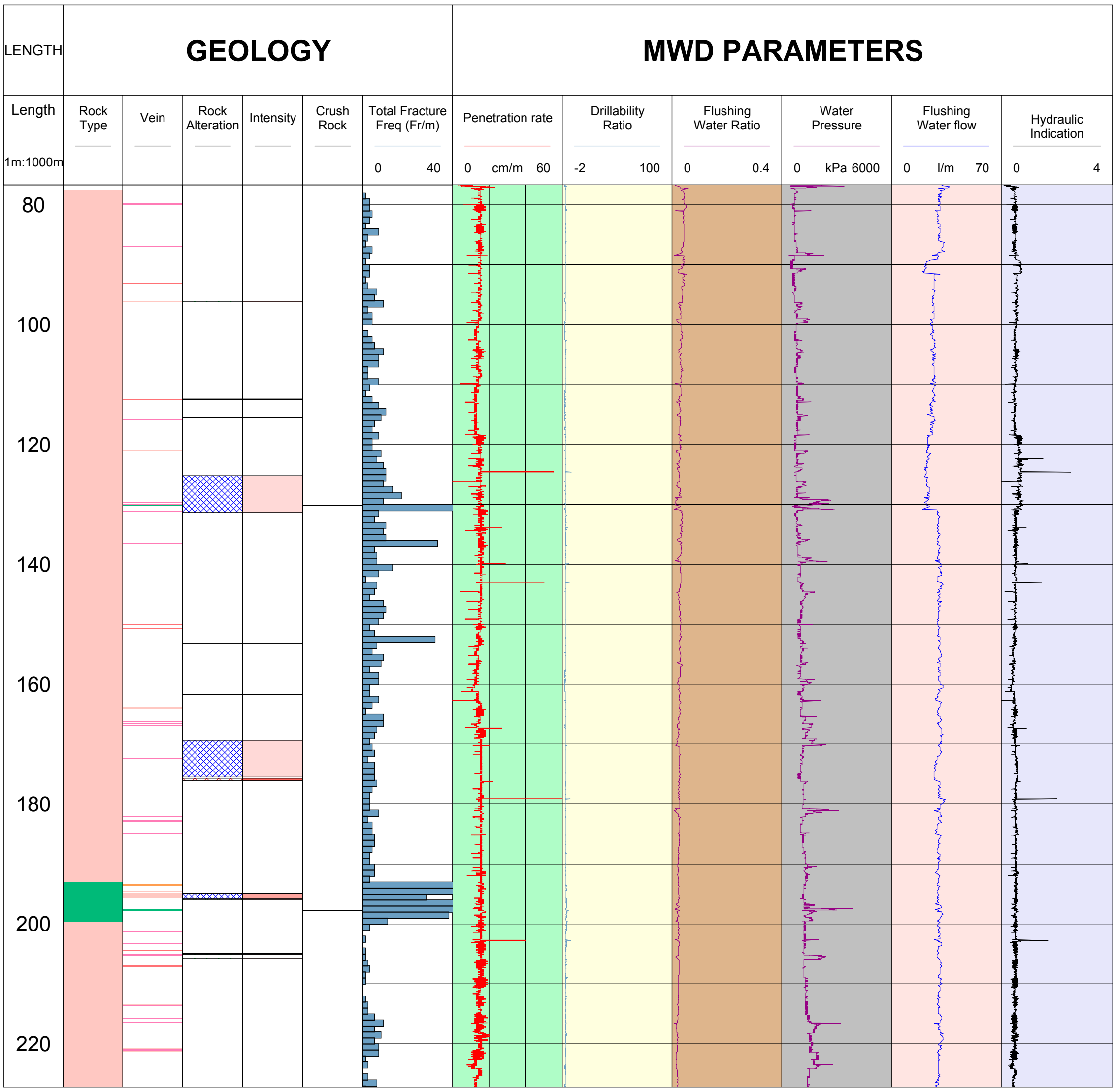
/7/ **Ask H, Morosini M, Samuelsson L-E, Ekström L and Håkanson N, 2004.** Drilling of cored borehole KSH03. SKB P-04-233, Svensk Kärnbränslehantering AB.

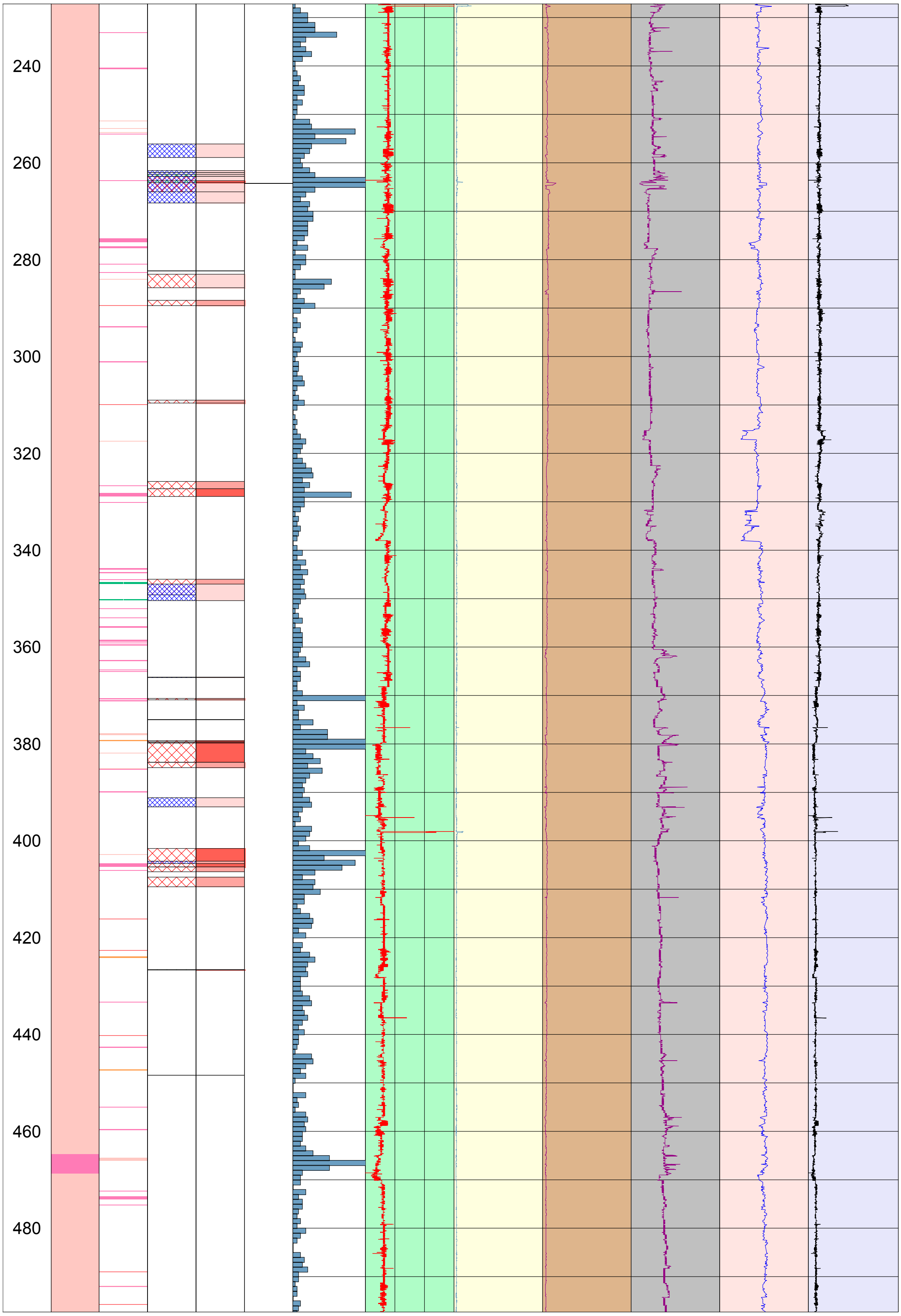
/8/ **Ask H, Morosini M, Tiberg L, 2007.** Core drilling of KLX17A. SKB P-07-221, Svensk Kärnbränslehantering AB.

Geology and MWD parameters KLX15A

Title	GEOLOGY & MWD PARAMETERS KLX15A		Appendix 1
Site	LAXEMAR	Coordinate System	RT90-RHB70
Borehole	KLX15A	Northing [m]	6365614.17
Diameter [mm]	76	Easting [m]	1547987.47
Length [m]	1000.430	Elevation [m.a.s.l.]	14.59
Bearing [°]	198.83	Drilling Start Date	2006-12-21 08:30:00
Inclination [°]	-54.41	Drilling Stop Date	2007-02-25 20:00:00
Date of mapping	2007-04-04 16:08:00	Plot Date	2008-02-05 22:03:18

ROCKTYPE LAXEMAR	ROCK ALTERATION	INTENSITY
Fine-grained granite	Oxidized	Faint
Pegmatite	Chloritisized	Weak
Granite	Epidotisized	Medium
Ävrö granite	Saussuritization	Strong
Quartz monzodiorite		
Fine-grained diorite-gabbro		





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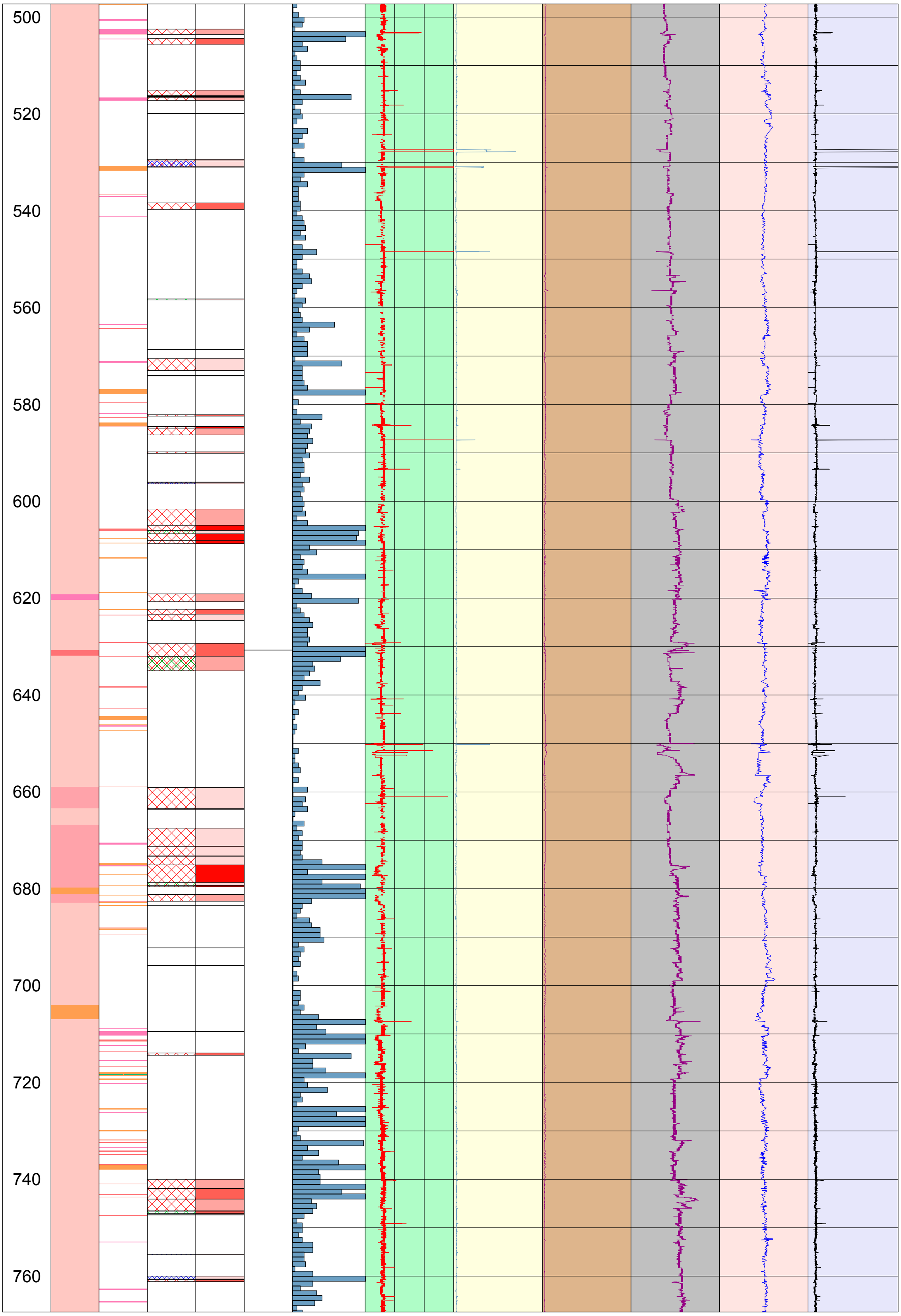
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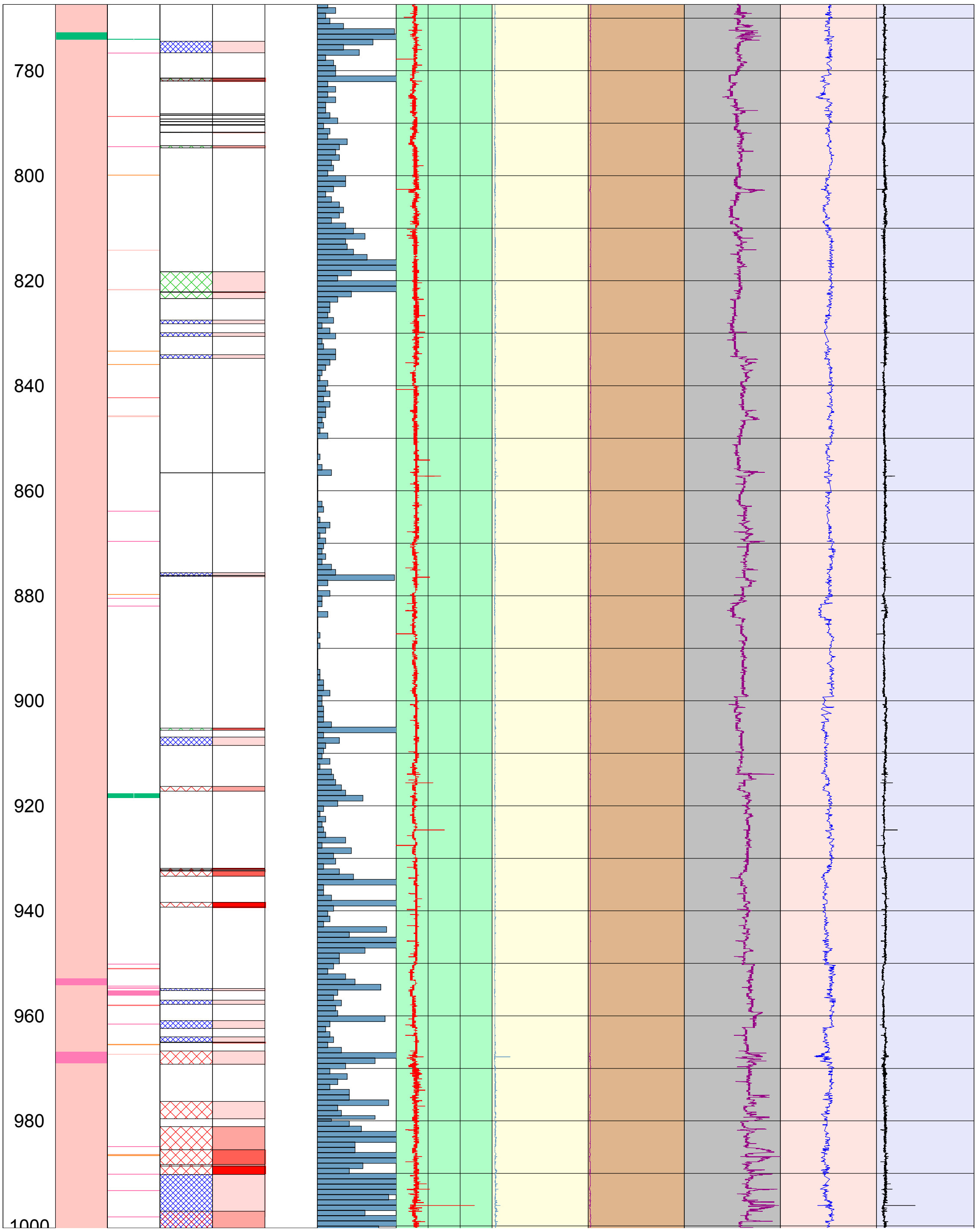
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Appendix 2

Chemical results

Borehole	HLX14	KLX15A	KLX15A	KLX15A
Date of measurement	2006-11-04	2007-01-23	2007-01-25	2007-01-27
Upper section limit (m)	11.9	120.13	77.9	174.33
Lower section limit (m)	115.9	130.9	176.19	277.64
Sample_no	11503	11660	11677	11680
Groundwater Chemistry Class	3	1	3	1
pH	7.97	x	8.31	x
Conductivity (mS/m)	156.0	x	155.0	x
Drill water (%)	0.05	38.60	38.10	75.10
Density (g/ml)	0.9985	x	0.9977	x
Charge balance (%)	–2.75	x	0.81	x
Na (mg/l)	248.0	x	267.0	x
K (mg/l)	5.35	x	9.22	x
Ca (mg/l)	44.1	x	40.7	x
Mg (mg/l)	12.9	x	13.1	x
HCO3 (mg/l Alkalinity)	223.00	x	248.00	x
Cl (mg/l)	357.0	x	290.0	x
SO4 (mg/l)	53.60	x	103.00	x
SO4_S (mg/l Total Sulphur)	18.00	x	36.80	x
Br (mg/l)	1.290	x	0.980	x
F (mg/l)	2.88	x	3.62	x
Si (mg/l)	7.34	x	21.00	x
Fe (mg/l Total Iron)	0.3620	x	14.8000	x
Mn (mg/l)	0.14700	x	0.30700	x
Li (mg/l)	0.024	x	0.033	x
Sr (mg/l)	0.844	x	0.588	x
PMC (% Modern Carbon)	49.70	x	48.90	x
$\delta^{13}C$ (dev PDB)	–17.20	x	–16.50	x
$\delta^{2}H$ (dev SMOW)	–84.4	x	–80.8	x
^{3}H (TU)	2.50	x	1.40	x
$\delta^{18}O$ (dev SMOW)	–11.20	x	–10.70	x
B-10 (B-10/B-11)	0.2369	x	0.2370	x
$\delta^{34}S$ (dev CDT)	26.9	x	23.3	x
$\delta^{37}Cl$ (dev SMOC)	x	x	–0.13	x
^{87}Sr ($^{87}Sr/^{86}Sr$)	x	x	0.716459	x

x = not analysed.

Appendix 3

Chemistry – analytical method and quality

SKB Chemistry class 3

Analysis	Sample bottle	Preparation	SKB label	Laboratory
pH, conduktivity, alkalinity	250 ml		green	Äspö/field
Anions (F^-, Br^-, Cl^-, SO_4^{2-})	250 ml	Filtered in connection with analyse	green	Äspö/field
Uranine	100 ml brown glass		green	Äspö/field
Main components (except Fe, Mn)	Analytica's 100 ml acid washed	1 ml HNO_3 suprapur, filtering membrane filter	red	Analytica
Archive samples	2 ea 250 ml	Filtering Pallfilter	green	
Option				
Deuterium, O-18	100 ml square		green	IFE
Tritium	500 ml dried	Flooded at least once	green	Waterloo
Sr-87	100 ml square		green	IFE
Cl-37	500 ml		green	Waterloo
B-10	*Same as for main components*	1 ml HNO_3 suprapur, filtering membrane filter	red	Analytica
C-13, PMC	2 st 100 ml 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 error is calculated for the set of data from borehole KLX15A, i.e. sample 11677. The error does not exceed ± 0.81%.

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

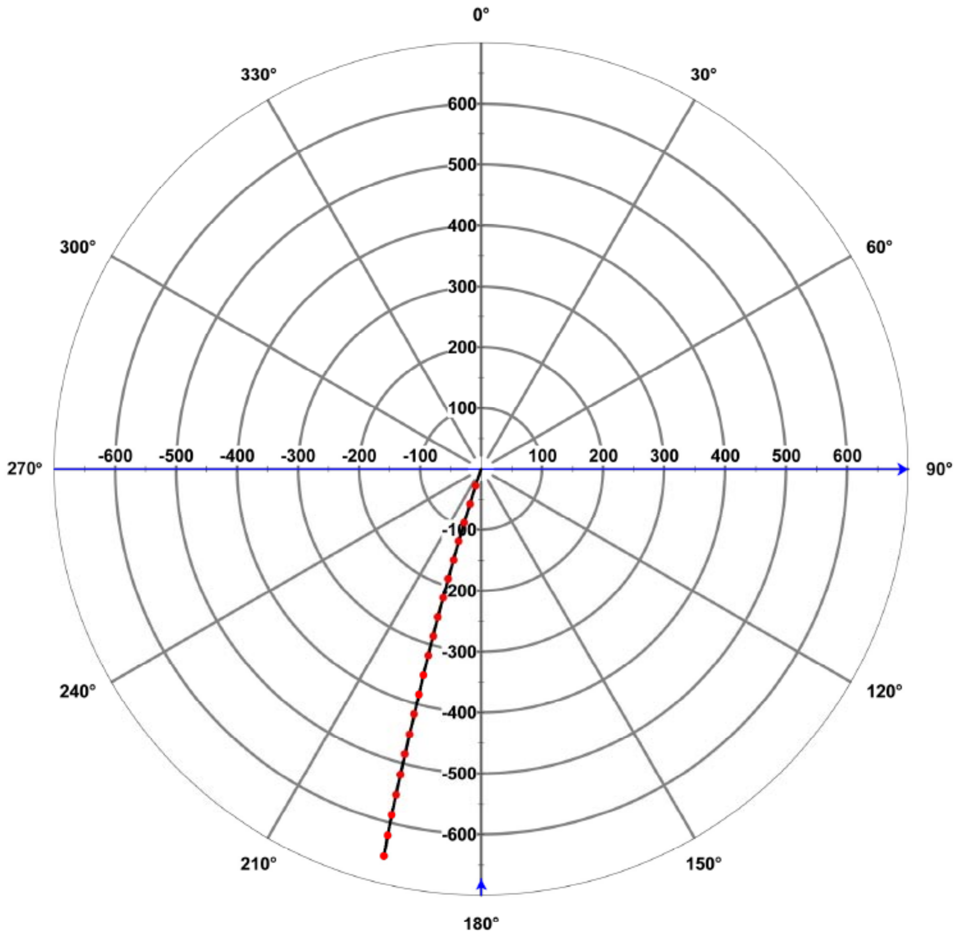
- Several components are determined by more than one method and/or laboratory. Control analyses by an independent laboratory are normally performed as a standard procedure on every five or ten collected samples. No control analyses were performed on the water samples from KLX15A.
- All analytical results were stored in the SICADA database. The chemistry part of the database contains two types of tables, raw data tables and primary data tables (final data tables).
- Data on basic water analyses are inserted into raw data tables for further evaluation. The evaluation results in a final reduced data set for each sample. These data sets are compiled in a primary data table named "water composition". The evaluation is based on:
  – Comparison of the results from different laboratories and/or methods. The analyses are repeated if a large disparity is noted (generally more than 10%).
  – Calculation of charge balance errors. Relative errors within ± 5% are considered acceptable. For surface waters errors of ± 10%.
  – Rel. Error (%) = $100 \times \dfrac{(\sum \text{cations(equivalents)} - \sum \text{anions(equivalents)})}{(\sum \text{cations(equivalents)} + \sum \text{anions(equivalents)})}$
  – 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

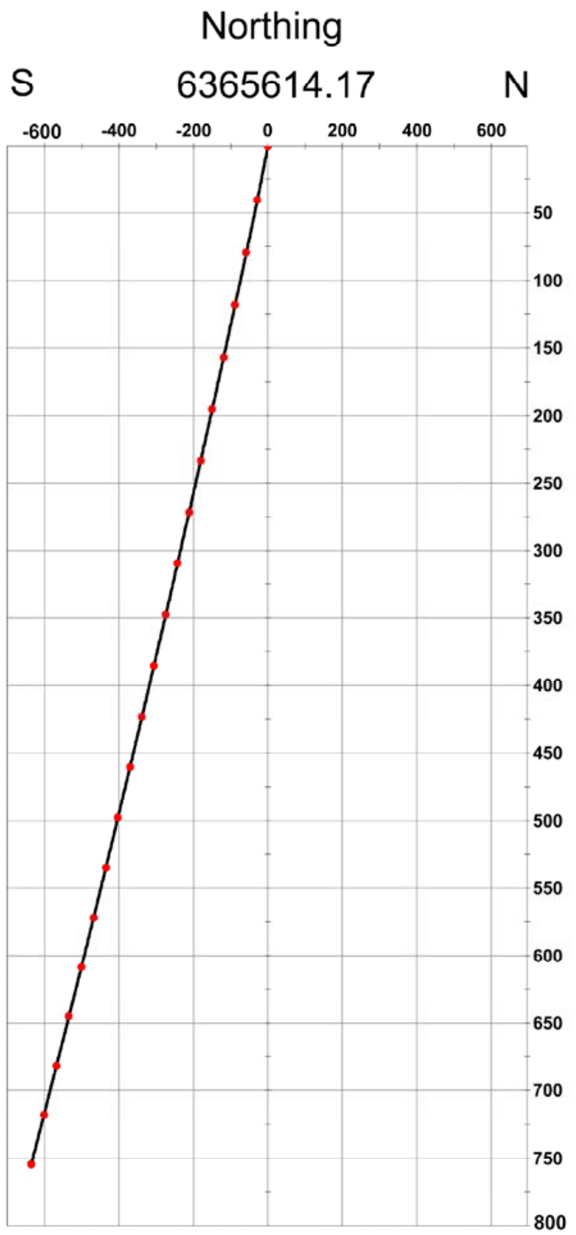
Deviation measurements

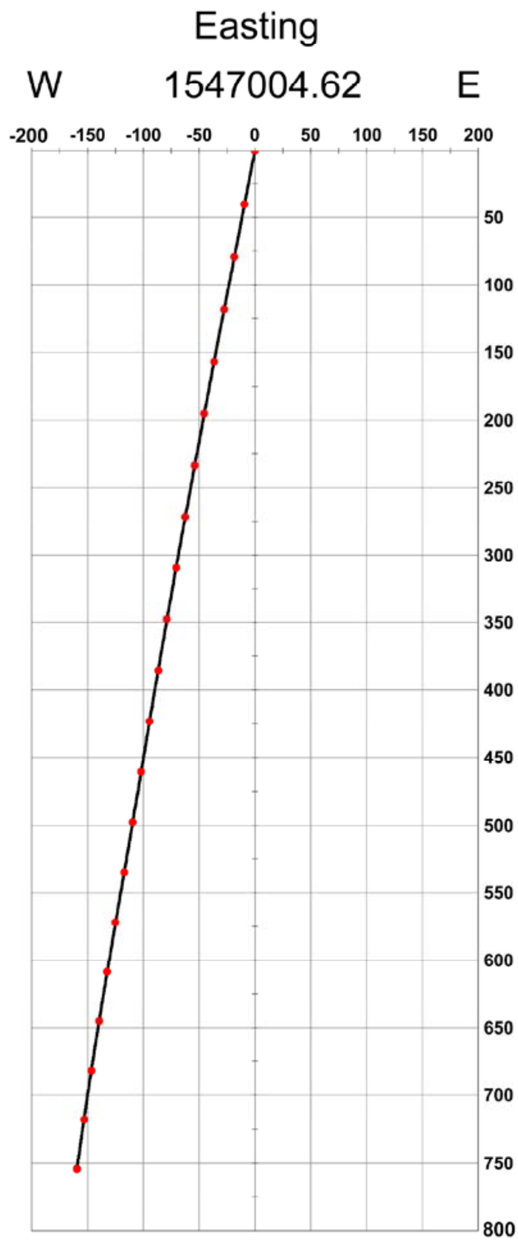
Deviation measurement	Appendix: 4
Site LAXEMAR Borehole KLX15A View from above	



Deviation measurement	Appendix: 4

Site LAXEMAR
Borehole KLX15A
Vertical Section





Wireline pumping tests in KLX15A

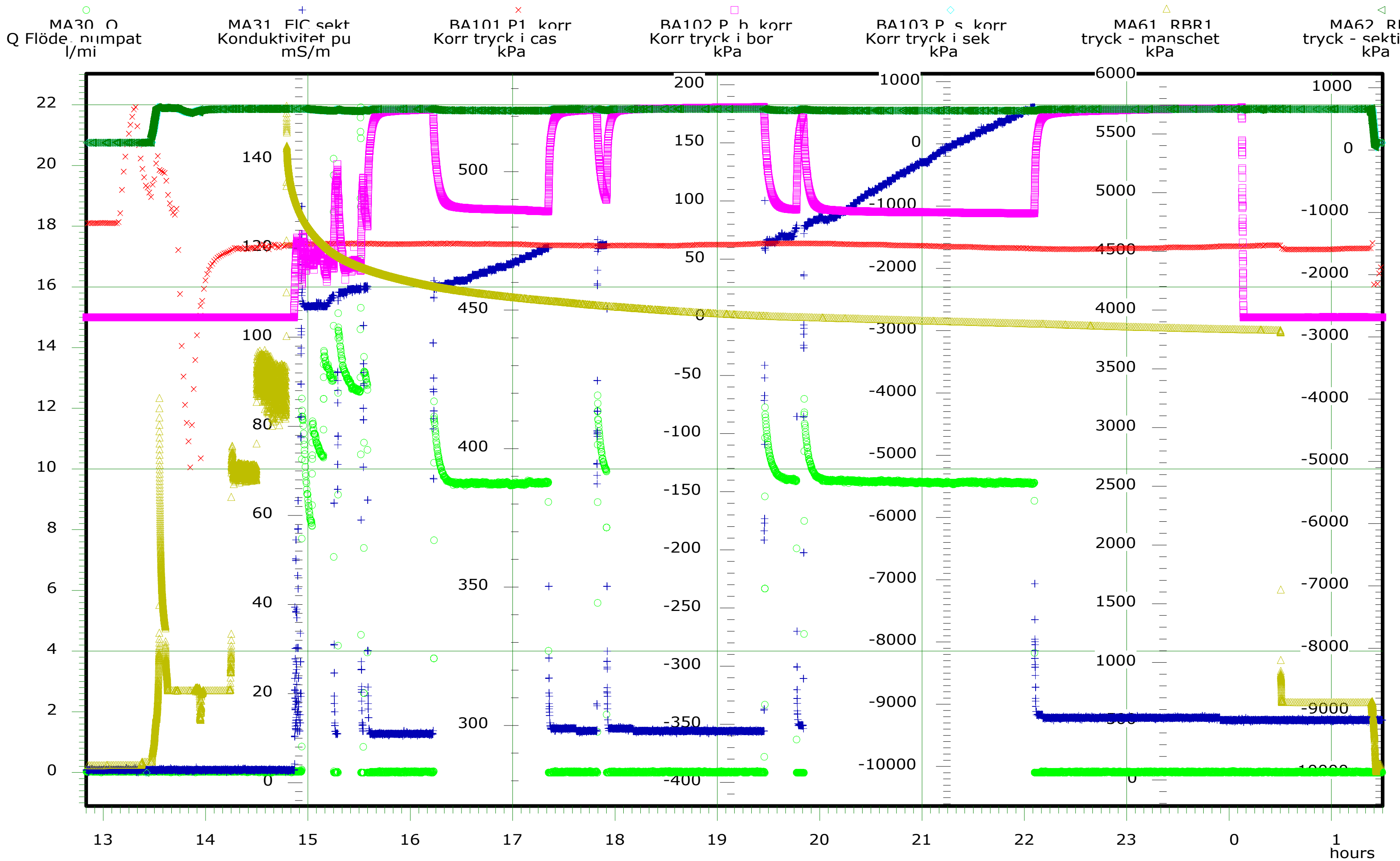
Description of the parameters in the enclosed plots

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 :07/01/25 18:26:21
PLOT FILE :P_Pumptest
No DST Adjustment

DMS1 PO

Pumptest wire line probe KLX15A
77.90 m - 176.19 m



START :07/01/24 12:50:00

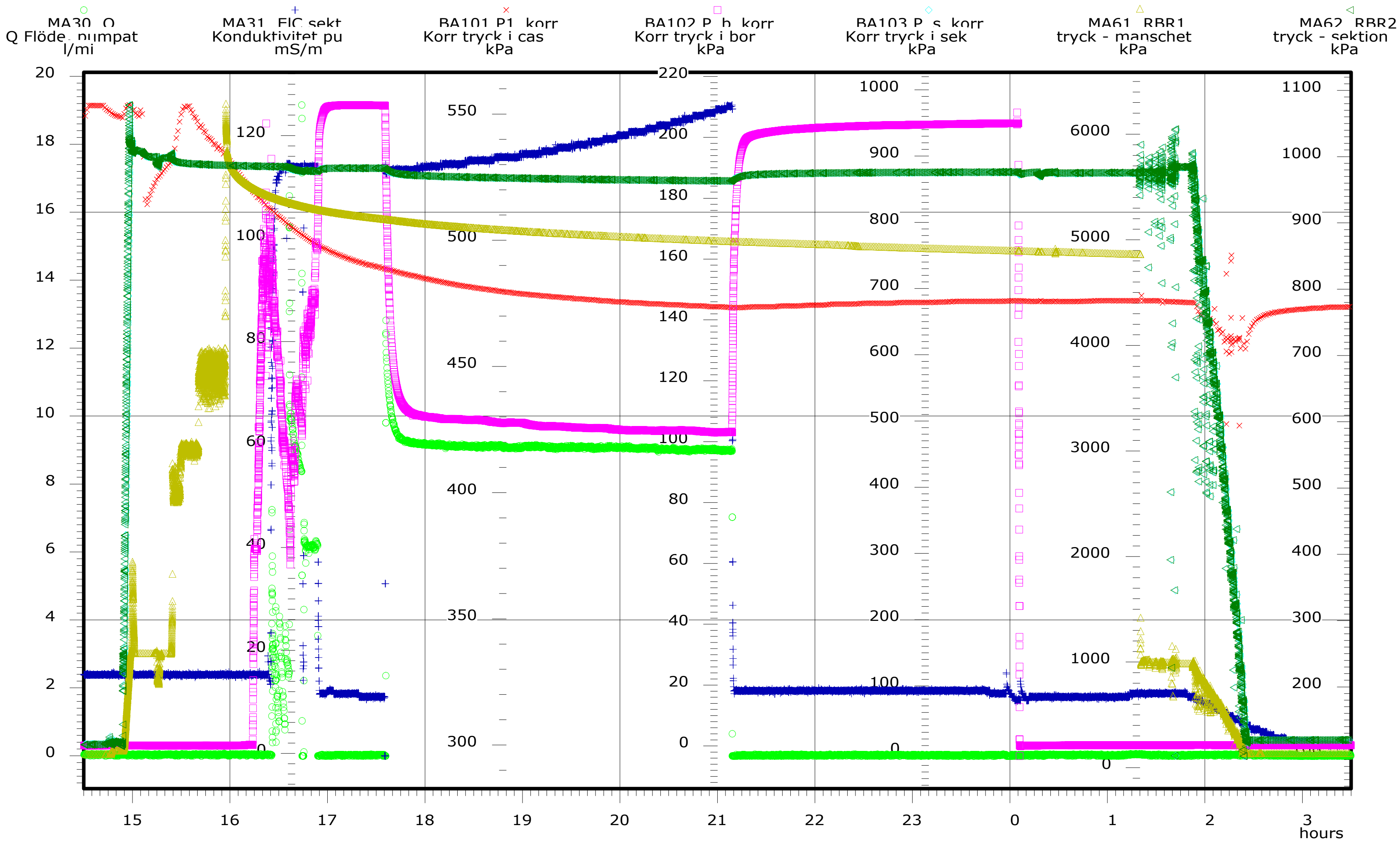
INTERVAL: All readings

STOP :07/01/25 01:29:59

PLOT TIME :07/01/23 14:33:31
PLOT FILE :P_Pumptest
No DST Adjustment

DMS1 PO

Pumptest wire line probe KLX15A
120.13 m - 130.90 m



START :07/01/22 14:30:00

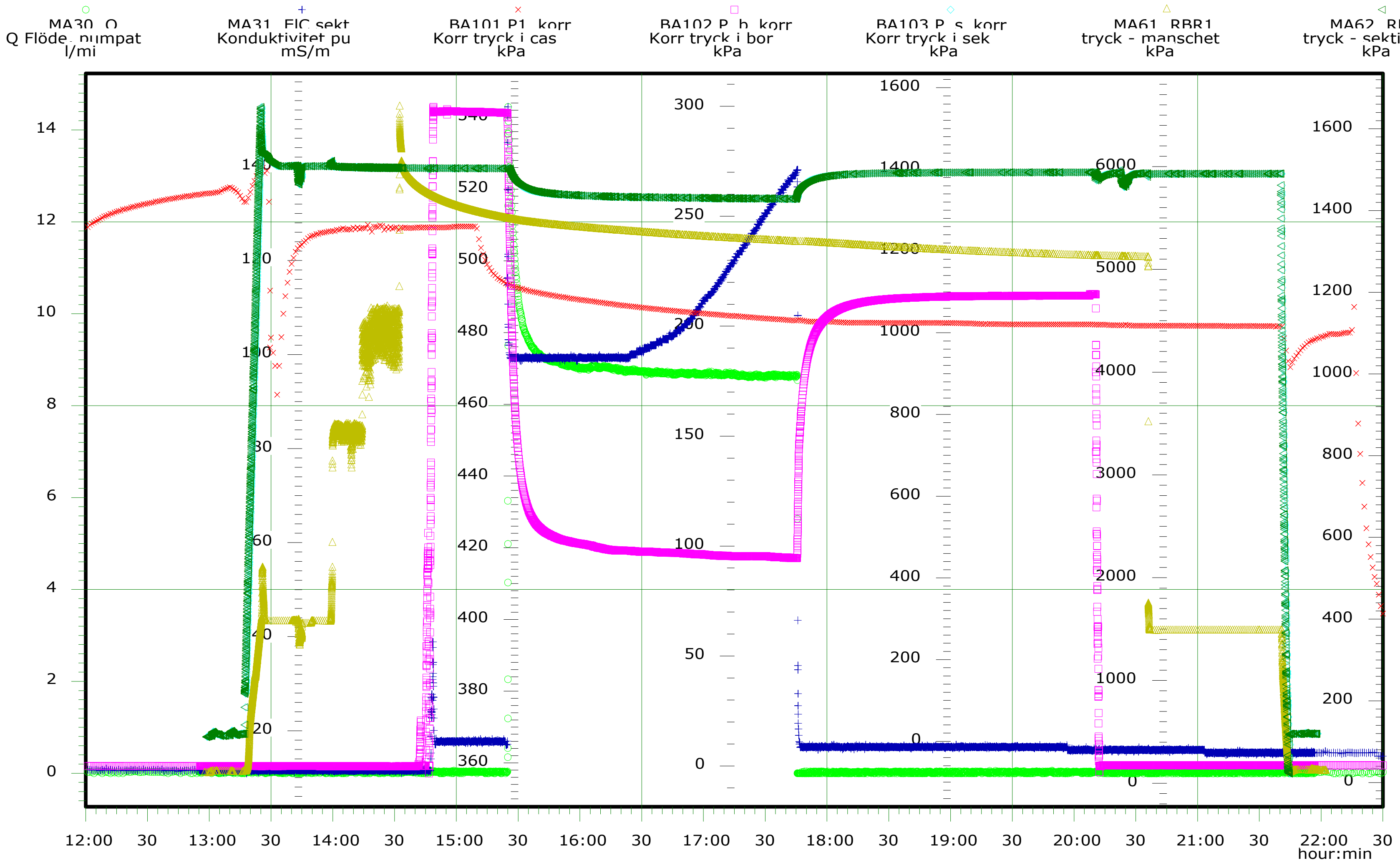
INTERVAL: All readings

STOP :07/01/23 03:29:59

PLOT TIME :07/01/29 11:09:43
PLOT FILE :P_Pumptest
No DST Adjustment

DMS1 PO

Pumptest wire line probe KLX15A
174.33 m - 277.94 m



START :07/01/27 12:00:00

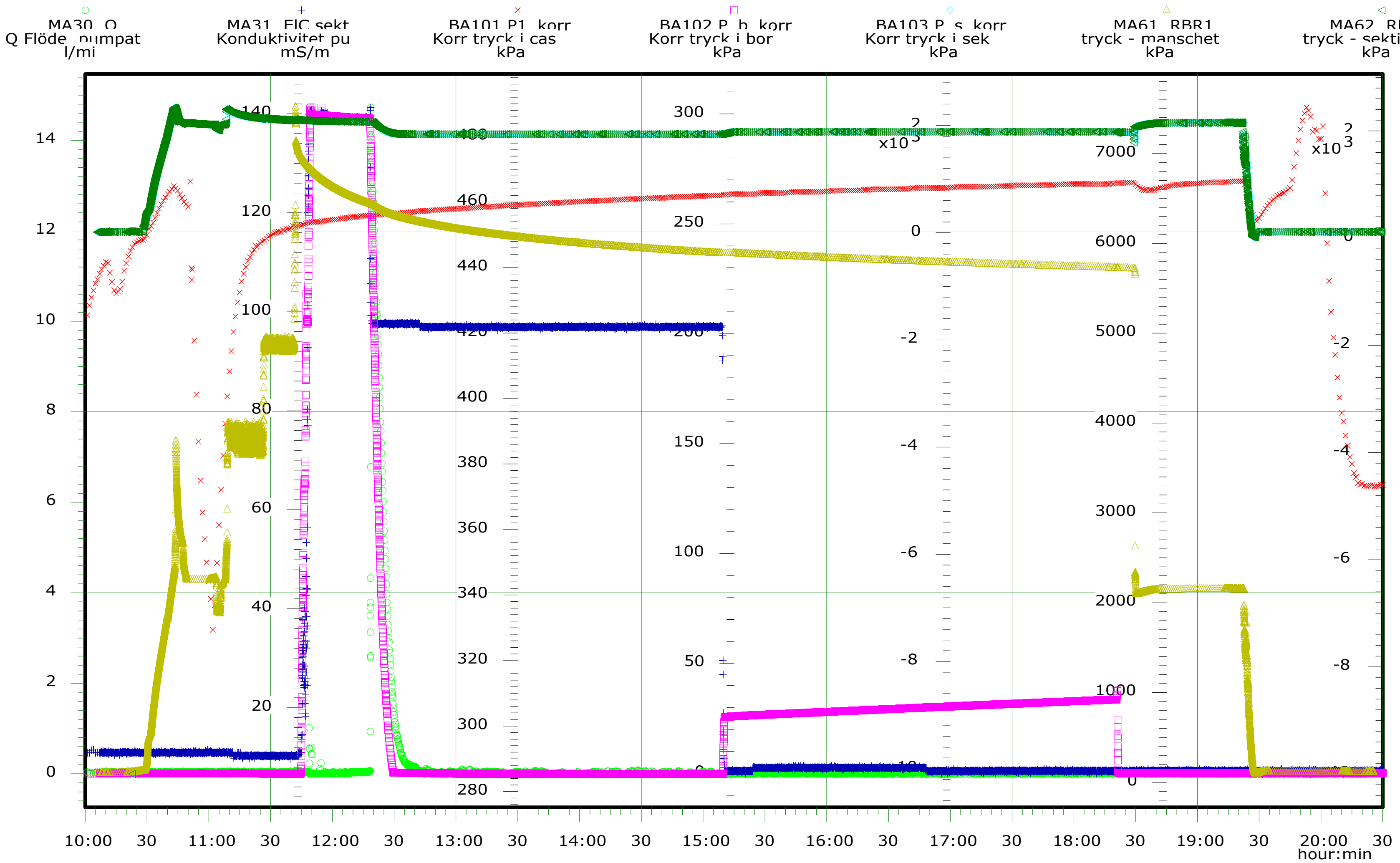
INTERVAL: All readings

STOP :07/01/27 22:30:00

PLOT TIME :07/01/31 15:15:58
PLOT FILE :P Pumptest
No DST Adjustment

DMS1 PO

Pumptest wire line probe KLX15A
276.13 m - 368.17 m



START :07/01/30 10:00:00

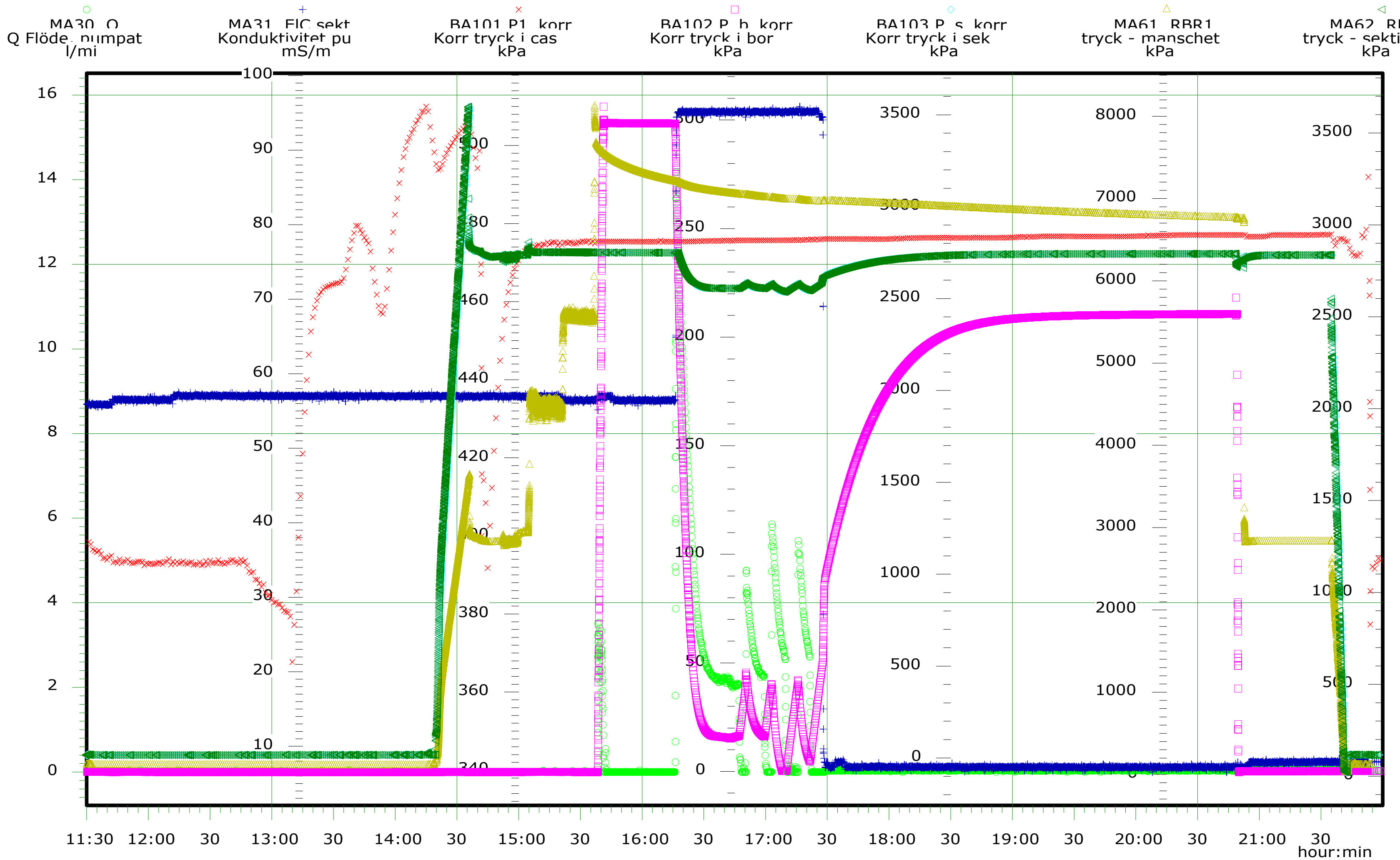
INTERVAL: All readings

STOP :07/01/30 20:30:00

PLOT TIME :07/02/08 20:41:29
PLOT FILE :P_Pumptest
No DST Adjustment

DMS1 PO

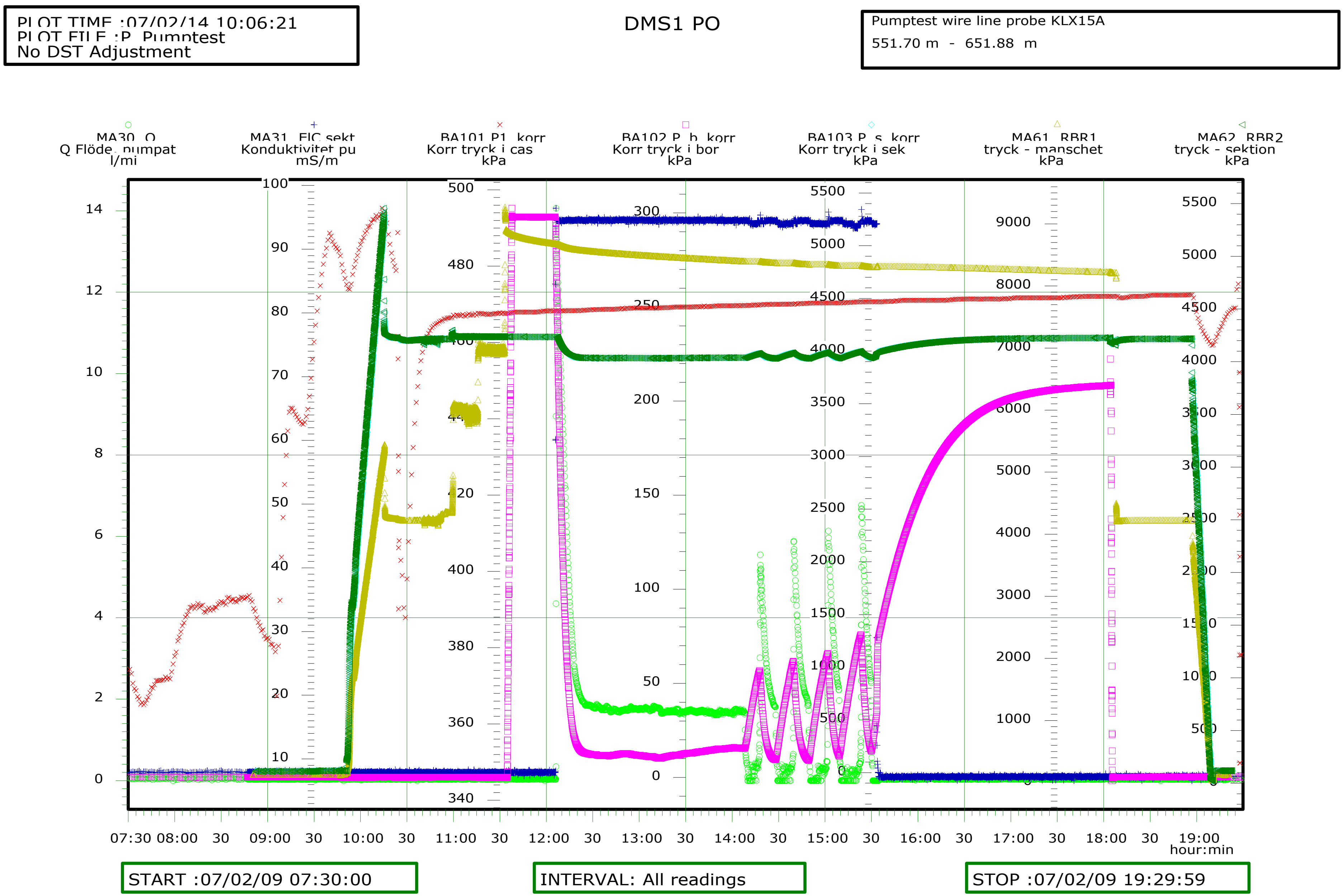
Pumptest wire line probe KLX15A
365.80 m - 556.43 m



START :07/02/05 11:30:00

INTERVAL: All readings

STOP :07/02/05 21:59:59

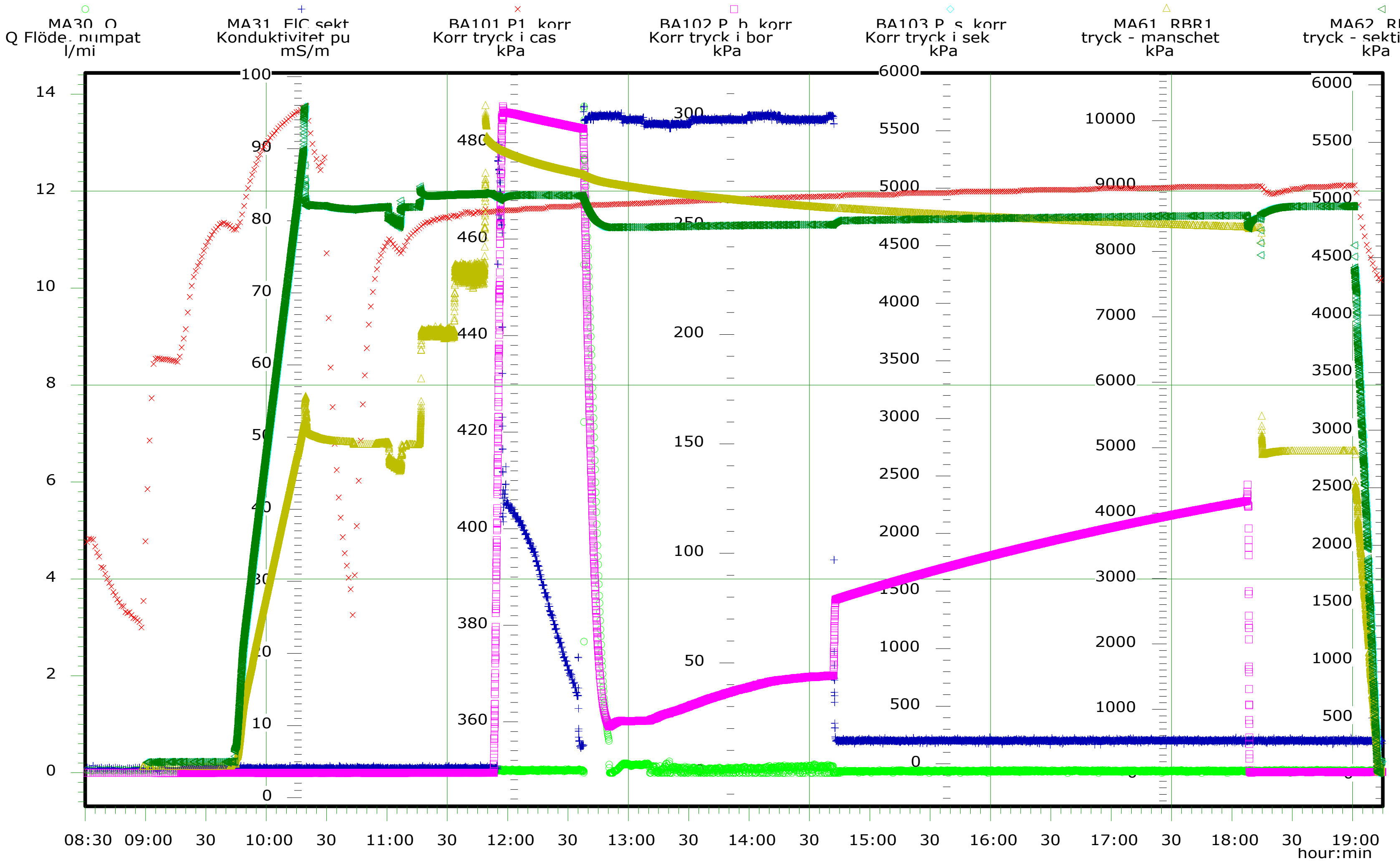


PLOT TIME :07/02/14 10:06:21
PLOT FILE :P_Pumptest
No DST Adjustment
DMS1 PO
Pumptest wire line probe KLX15A
551.70 m - 651.88 m
MA30 Q
Q Flöde- pumpat
l/mi
MA31 EIC sekt
Konduktivitet pu
mS/m
BA101 P1 korr
Korr tryck i cas
kPa
BA102 P b korr
Korr tryck i bor
kPa
BA103 P s korr
Korr tryck i sek
kPa
MA61 RBR1
tryck - manschet
kPa
MA62 RBR2
tryck - sektion
kPa
07:30 08:00 30 09:00 30 10:00 30 11:00 30 12:00 30 13:00 30 14:00 30 15:00 30 16:00 30 17:00 30 18:00 30 19:00
hour:min
START :07/02/09 07:30:00
INTERVAL: All readings
STOP :07/02/09 19:29:59

PLOT TIME :07/02/19 16:36:03
PLOT FILE :P_Pumptest
No DST Adjustment

DMS1 PO

Pumptest wire line probe KLX15A
651.00 m - 758.21 m



START :07/02/15 08:30:00

INTERVAL: All readings

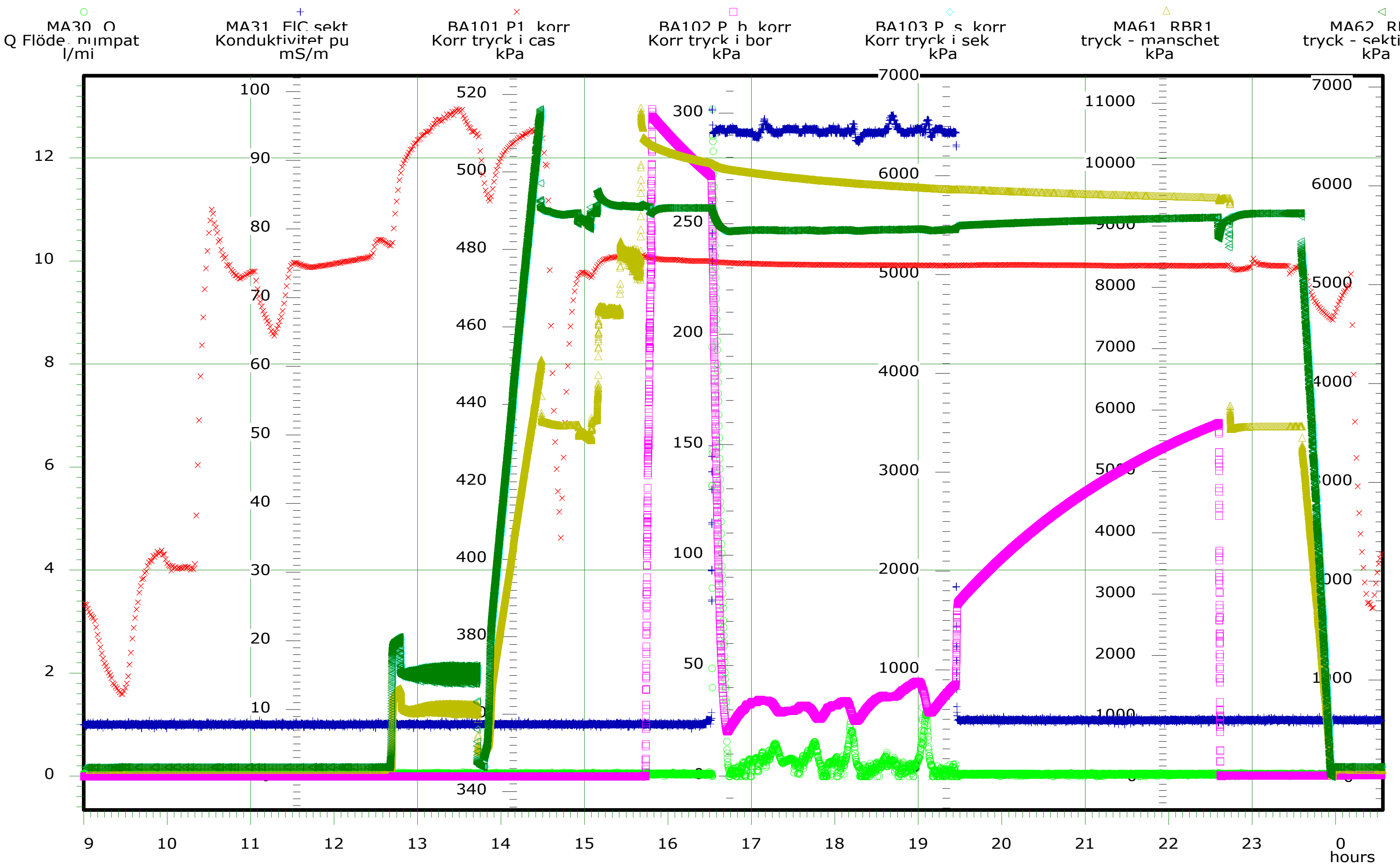
STOP :07/02/15 19:14:59

70

PLOT TIME :07/02/21 14:02:01
PLOT FILE :P Pumptest
No DST Adjustment

DMS1 PO

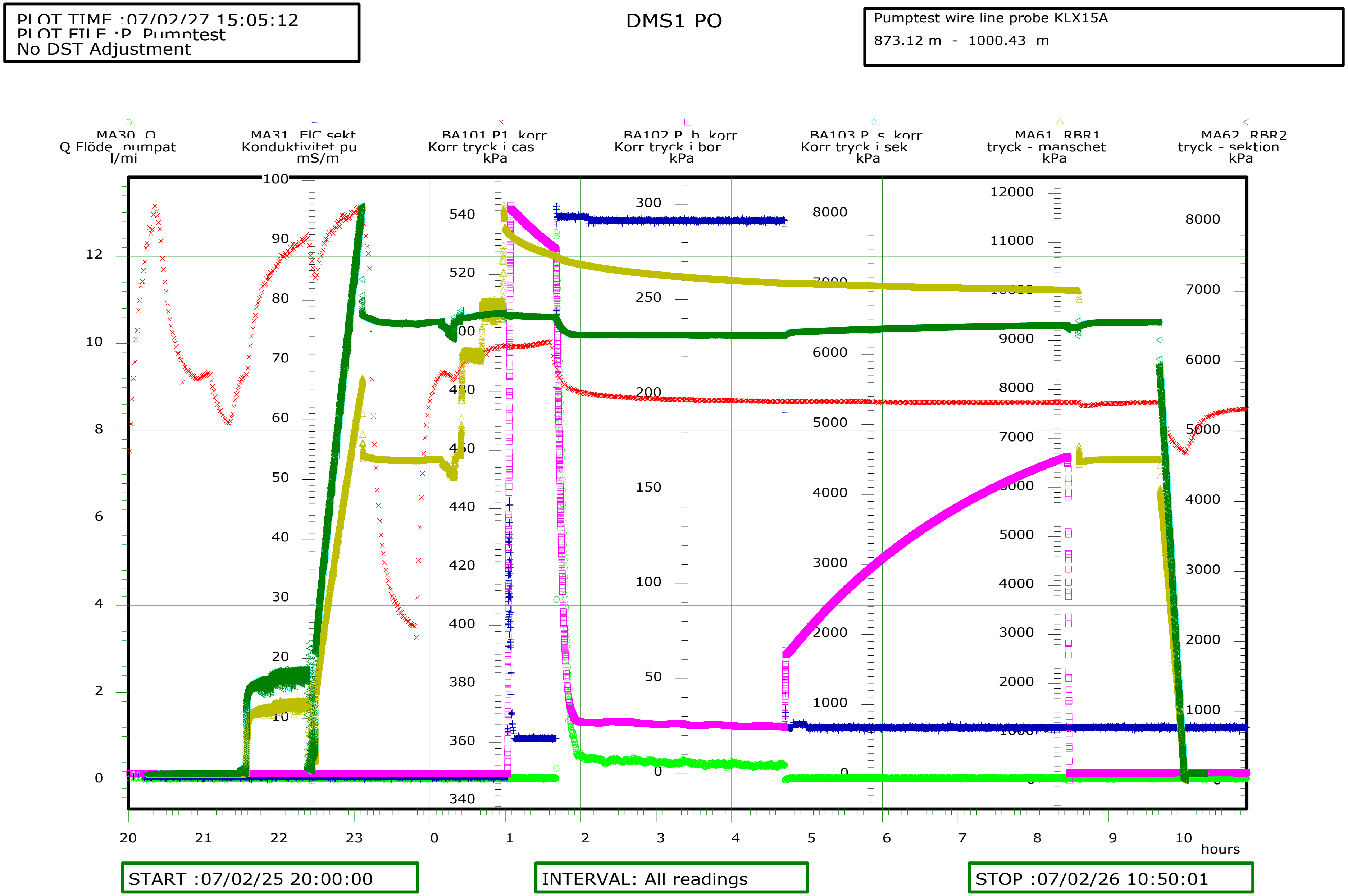
Pumptest wire line probe KLX15A
757.00 m - 875.10 m



START :07/02/20 09:00:00

INTERVAL: All readings

STOP :07/02/21 00:33:59



PLOT TIME :07/02/27 15:05:12
PLOT FILE :P_Pumptest
No DST Adjustment
DMS1 PO
Pumptest wire line probe KLX15A
873.12 m - 1000.43 m
MA30_Q
Q Flöde, pumpat
l/mi
MA31_EIC sekt
Konduktivitet pu
mS/m
BA101 P1_korr
Korr tryck i cas
kPa
BA102 P_b_korr
Korr tryck i bor
kPa
BA103 P_s_korr
Korr tryck i sek
kPa
MA61_RBR1
tryck - manschet
kPa
MA62_RBR2
tryck - sektion
kPa
hours
START :07/02/25 20:00:00
INTERVAL: All readings
STOP :07/02/26 10:50:01

Appendix 6

Technical data from environmental monitoring wells SSM000215 and SSM000268

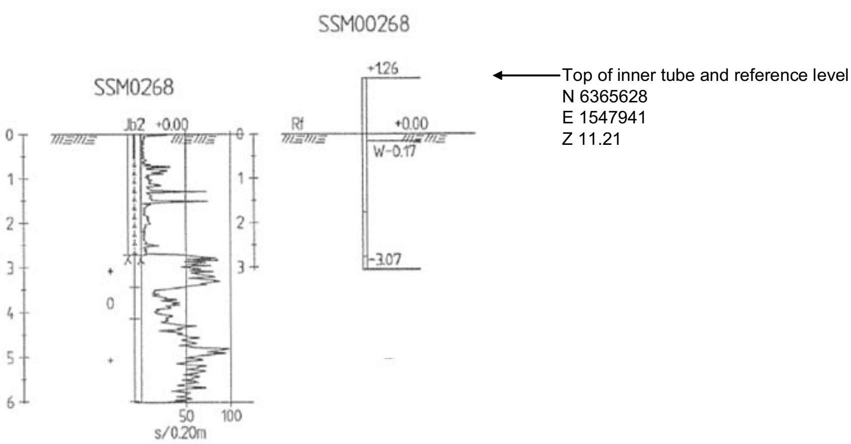
Geometric and technical data for environmental monitoring well SSM000268

Parameter	SSM000268	
Drilling date (probing and NO-X)	2006-11-15	
Borehole length	3.20 m (below reference)	
Soil depth	1.32–3.1 m (below reference)	
Reference point coordinates (system RT90/RHB70)	Northing: 6365628.31 m Easting: 1547941.42 m Elevation: 11.21 m.a.s.l.	
Ground water level (observation after drilling 2006-11-15	9.74 m.a.s.l. 1.43 m (below reference)	
Borehole diameter (interval) (diameter)	0–1.26 m 1.26–4.33m	N/A 125 mm
Inner tube (interval) (diameter)	0–4.33 m	$Ø_o$ = 63 mm $Ø_i$ = 50 mm
Probing depth (interval) (diameter)	1.26–7.26 m	Ø = 54 mm

Probing and drilling of environmental monitoring well SSM000268

Probing	
Drill rig:	HAFO 1500
Hammer:	Furukawa
Stem:	44 mm
Bit:	54 mm Star (four-cutter)
Flushing media :	Air

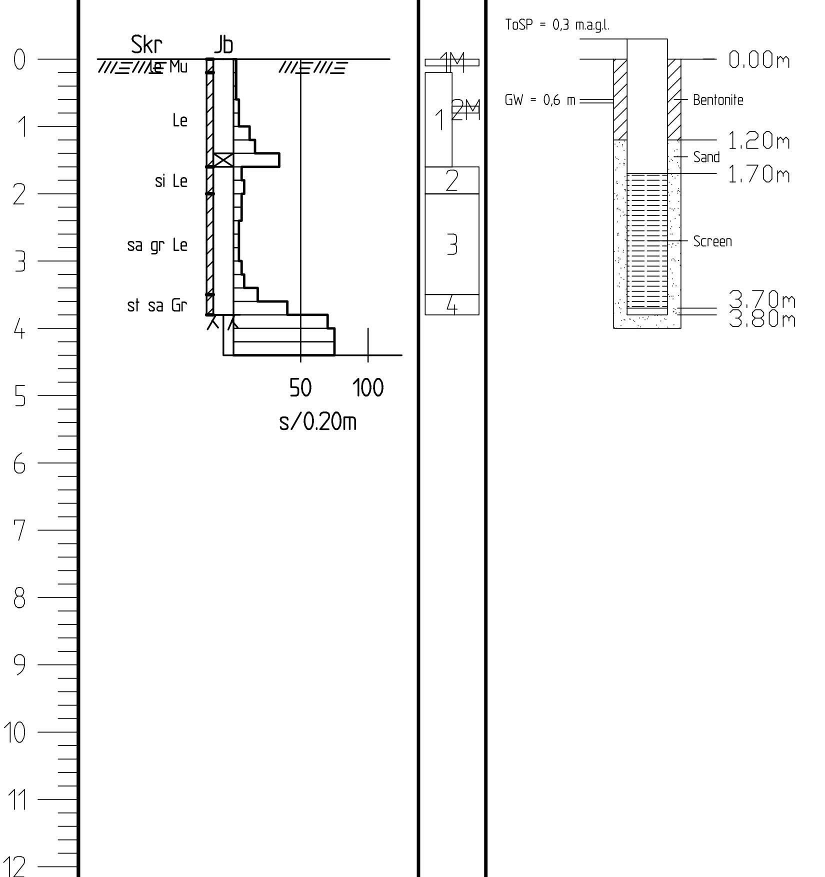
Drilling	
Drill rig:	HAFO 1500
Drill Dimension:	NO-X 90
Borehole diameter:	125 mm
Inner tube	63/50 mm



LAXEMAR BOREHOLE SSM000215

Company rep. Lennart Adestam and Torbjörn Johansson	Northing :6365593	Top of stand pipe : 0,3 m.a.g.l.
	Easting :1547861	Total pipe length : 4,10 m
		Groundwater level : 0,6 m.b.g.l.
	Coordinate system : RT90-RHB70	Date of completion : 2004-12-06
Client: Svensk Kärnbränslehantering AB		

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



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

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

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

ANNULUS SEAL
Material : Bentonite clay
Total length : 1,20 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 2,80 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång Φ44
Drill bit : Stift Φ54

GEOLOGICAL LOG
0-0,2m Clayey topsoil
0,2-1,6m clay
1,6-2,0m silty clay
2,0-3,5m sandy gravelly clay
3,5-3,8m cobble-bearing sandy gravel
3,8m rock surface

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