P-05-233

Oskarshamn site investigation

Drilling of cored borehole KLX05

Henrik Ask, H Ask Geokonsult AB

Mansueto Morosini, Lars-Erik Samuelsson
Svensk Kärnkraftsbränslehantering AB

Liselotte Ekström, Studsvik RadWaste AB

Nils Håkanson, HCC- Håkanson Coring Consultants

January 2006

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

ISSN 1651-4416
SKB P-05-233

Oskarshamn site investigation

Drilling of cored borehole KLX05

Henrik Ask, H Ask Geokonsult AB

Mansueto Morosini, Lars-Erik Samuelsson
Svensk Kärnbränslehantering AB

Liselotte Ekström, Studsvik RadWaste AB

Nils Håkanson, HCC- Håkanson Coring Consultants

January 2006

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

Abstract

Borehole KLX05 is located in the southern part of the Laxemar subarea. Drilling was made between August, 2004 and January, 2005 as a part of the site investigation for a possible repository for spent nuclear fuel in Oskarshamn municipality, Sweden.

The hole was core drilled to a depth of 1,000.16 m with N-size (76 mm) equipment. The uppermost section, to a depth of 75.10 m, was constructed as a telescopic section with an inner diameter of 195 mm.

A water inflow of over 100 litres per minute was estimated over the whole length of the telescopic section during percussion drilling.

Ten successful pumping tests were performed with wireline equipment. The resulting transmissivities (T_M) varied between 1.1×10^{-7} and 2.0×10^{-5} m^2/s. The most transmissive section was between 107 and 203 m.

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

Water sampling for chemical analysis was done during drilling, however only one sample was collected from the core drilling phase.

An airlift pumping test in the telescopic section performed when the cored hole was drilled to its full length gave a transmissivity (T_M) of 3.4×10^{-5} m^2/s.

The upper 460 m is lithologically heterogeneous with predomintly Ävrö granite, diorite/gabbro or granite together with minor sections of fine-grained dioritoide and fine grained diorite-gabbro. Below 460 m the core is dominated by quartz monzodiorite with minor sections of pegmatite and fine-grained granite.

Oxidation (red-staining) and saussuritization i.e. alteration of calcic plagioclase feldspar, occur sporadically throughout the length of the borehole.

The distribution of total fractures in the core is rather homogeneous with a frequency of 0–10 fractures/m. Slight increases in fracture frequency do however occur locally. Two narrow sections with crushed rock (fracture frequency > 40) have been noted at 510 and 655 m drilled length respectively.

Sammanfattning

Borrhål KLX05 ligger inom delområde Laxemar. Borrningen utfördes mellan augusti 2004 och januari 2005 som ett led i platsundersökningen för ett möjligt djupförvar för utbränt kärnbränsle i Oskarshamns kommun.

Hålet kärnborrades med dimension N (76 mm) utrustning till 1 000,16 m borrad längd. Den övre delen av hålet, från markytan till 75,10 m, utfördes som en teleskopdel med 195 mm inre diameter.

Ett vatteninflöde på över 100 liter per minut uppskattades över hela teleskopdelen vid hammarborrningen.

Tio lyckade pumptester med wireline-baserad mätutrustning utfördes. Uppmätta transmissiviteter (T_M) varierade mellan $1{,}1\times10^{-7}$ och $2{,}0\times10^{-5}$ m^2/s. Den mest transmissiva sektionen var mellan 107 och 203 m.

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

Vattenprovtagning för kemisk analysering genomfördes i samband med borrning, dock togs endast ett prov under kärnborrningsfasen.

En mammutpumpning i teleskopdelen som gjordes när kärnborrningen utförts till full längd gav en transmissivitet (T_M) på 3.4×10^{-5} m^2/s.

Ner till 460 m är kärnan litologiskt heterogen och domineras av Ävrö granit, diorite/gabbbro eller granit med mindre partier av finkornig dioritoid och finkornig diorit-gabbro. Under 460 m domineras kärnan av kvartsmonzodiorit med mindre inslag av pegmatit och finkornig granit.

Oxidation (rödfärgning) och saussuritisering dvs omvandling av kalciumrik plagioklasfältspat, förekommer sporadiskt genom hela borrhålet.

Fördelningen av sprickor (”total fractures”) är ganska jämn över hela borrkärnan med en frekvens på 0–10 sprickor/meter. Mindre förhöjningar av sprickfrekvensen förekommer dock lokalt. Två smala sektioner med krossat berg (sprickfrekvens > 40) har noterats vid 510 respektive 655 m borrad längd.

Contents

1 Introduction

SKB, the Swedish Nuclear Fuel & Waste Management Company, performs site investigations in order to evaluate the feasibility of locating a deep repository for spent nuclear fuel /1/. The investigations are performed in two Swedish municipalities: Östhammar and Oskarshamn. Borehole KLX05 is located in 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. KLX05 was the eighth deep cored borehole within the Oskarshamn site investigation. The location of the core drilled borehole, KLX05 and the water source, HLX10 in the Laxemar subarea is shown in Figure 1-1.

The drilling of KLX05 and all related on-site operations were performed according to a specific Activity Plan, which in turn refers to a number of method descriptions, see Table 1-1.

The activity plans and method descriptions are SKB internal documents.

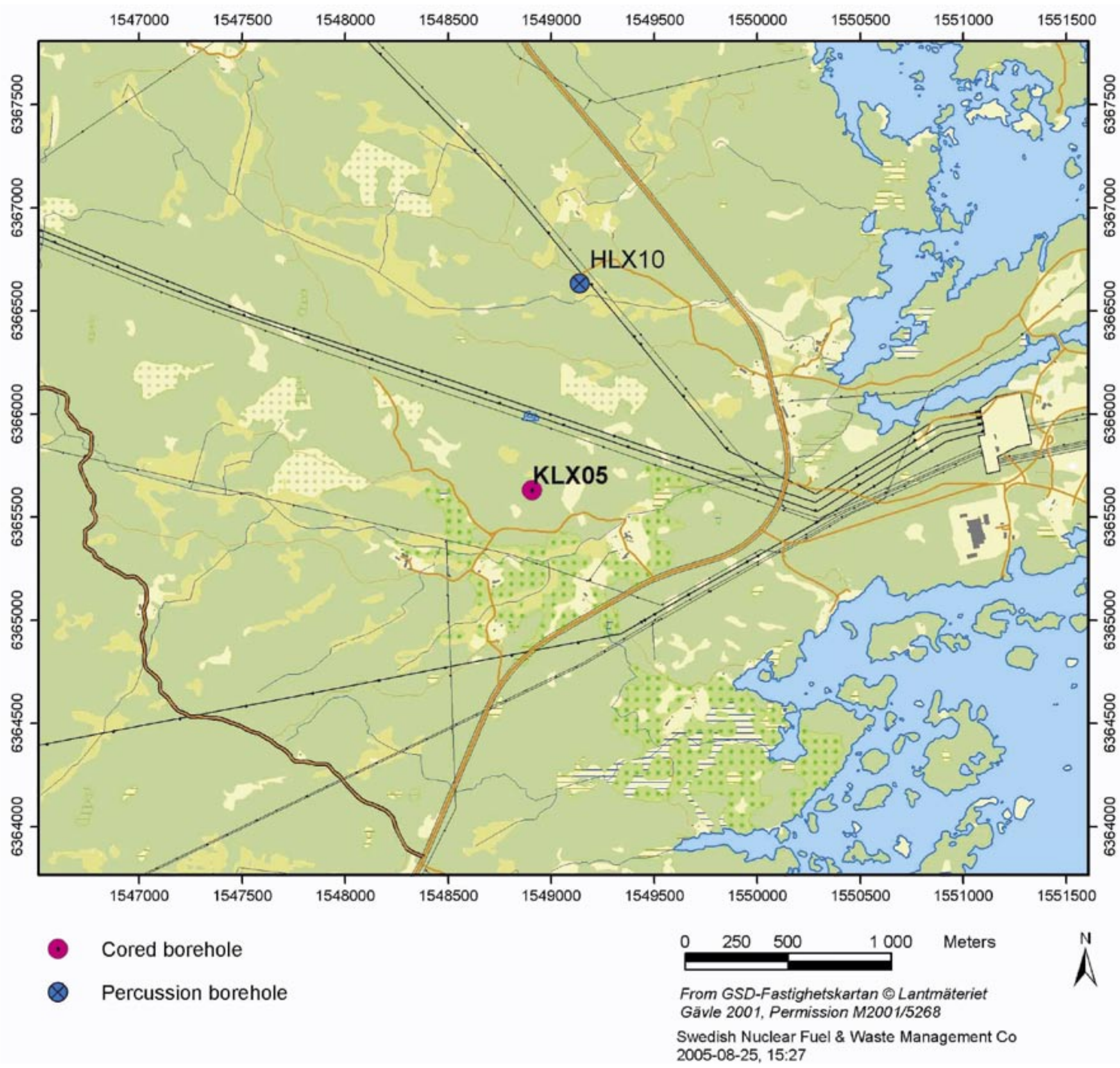


Figure 1-1. *Location of the cored borehole KLX05 in the Laxemar subarea and percussion borehole HLX10.*

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

Activity plan	Number	Version
Kärnborrning KLX05	AP PS 400-04-056	1.0*
Method descriptions	**Number**	**Version**
Metodbeskrivning för kärnborrning	SKB MD 620.003	1.0
Metodbeskrivning för hammarborrning	SKB MD 610.003	1.0
Metodbeskrivning för genomförande av hydrauliska enhålstrester	SKB MD 321.003	1.0
Metodbeskrivning för registrering och provtagning av spolvattenparametrar samt borrkax under kärnborrning	SKB MD 640.001	1.0
Metodbeskrivning för pumptest, tryckmätning och vattenprovtagning i samband med wireline-borrning	SKB MD321.002	1.0
Mätsystembeskrivning för längdmarkering (spårfräsning)	SKB MD620.009	1.0
Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning	SKB MD 600.004	1.0
Instruktion för användning av kemiska produkter och material vid borrning och undersökningar	SKB MD 600.006	1.0
Instruktion för borrplatsanläggning	SKB MD 600.005	1.0
Instruktion för spolvattenhantering	SKB MD 620.007	1.0
Instruktion för utsättning och inmätning av borrhål	SKB MD 600.002	1.0

*An amendment dated 2004-08-18 exists.

2 Objective and scope

This report will describe the methods employed and the results achieved during the drilling of KLX05. 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 reasons for drilling borehole KLX05 was to gain geological information at depth in the south-central part of the Laxemar subarea and to facilitate further investigation at depth in the borehole. The decision to drill KLX05 is given in SKB id no 1027698, dated 2004-08-25.

The hole was constructed as a "telescope hole", which means that the upper, normally, 100 m 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 issued to the regional authorities on 2004-05-13, SKB id no 1024636. Detailed information with borehole coordinates and specifications on return water handling was sent to the Regional Authorities, SKB id no 1027697.

3 Overview of the drilling method

3.1 The SKB telescope drilling method

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

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

After drilling 0–100 m, equipment for air lift pumping is installed in the borehole. The air lift pumping will create a pressure drawdown and help remove water and cuttings while core drilling between 100 m and 1,000 m, 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.

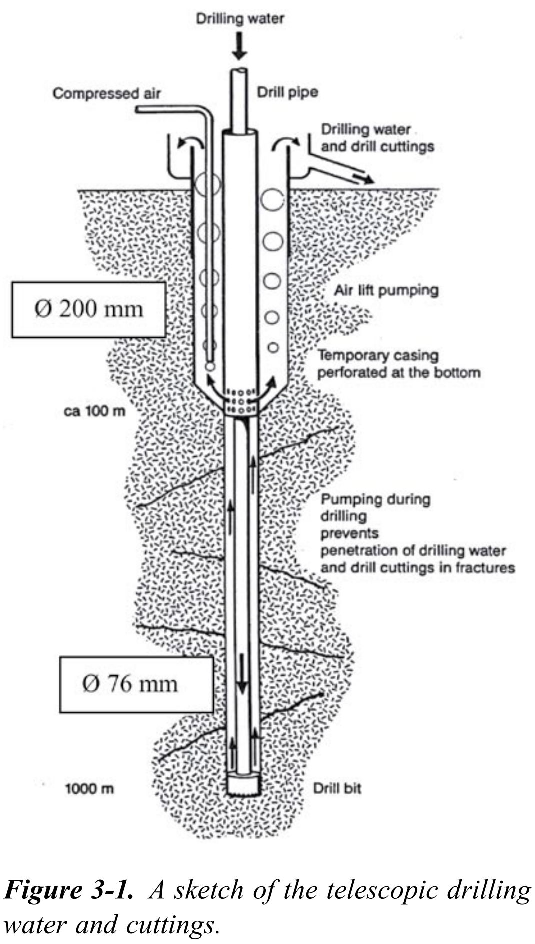


Figure 3-1. *A sketch of the telescopic drilling method with air lift pumping for retrieval of drilling water and cuttings.*

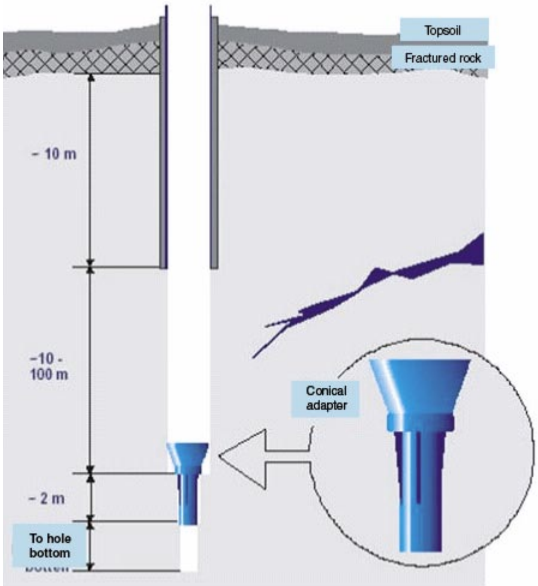


Figure 3-2. *Installation of the conical guide.*

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.

3.1.1 The flushing water system

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

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

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

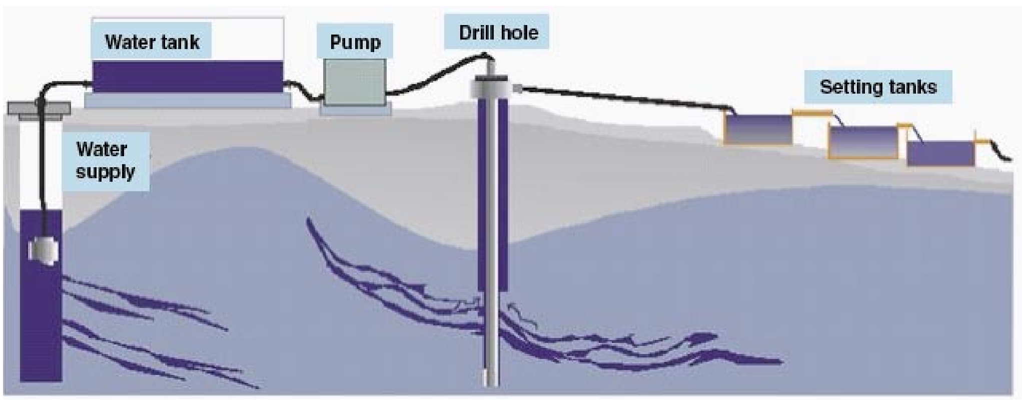


Figure 3-3. *The flushing water system from source to discharge point.*

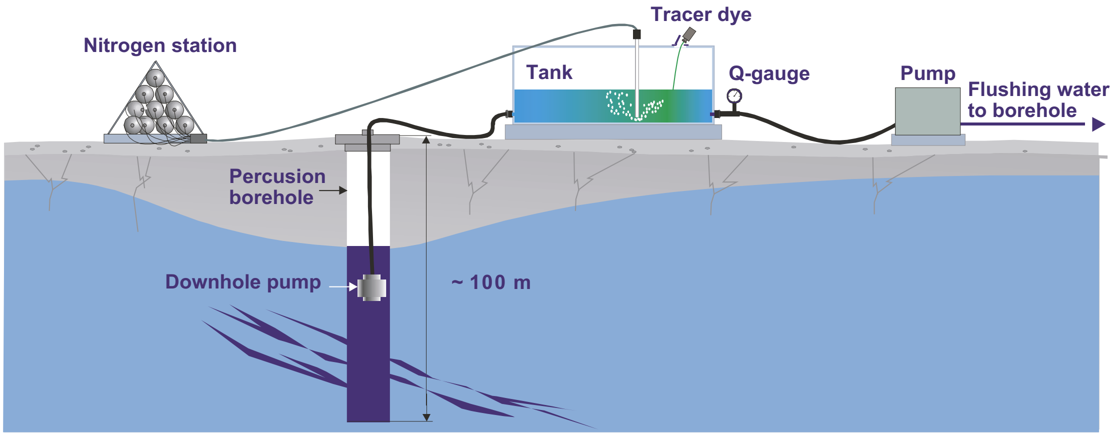


Figure 3-4. *Preparation of flushing water. Uranine is added to the water as a tracer dye. Nitrogen is bubbled through the water to remove dissolved oxygen.*

3.2 Measurements and sampling during drilling

3.2.1 Percussion drilling

Drill cuttings are collected manually during percussion drilling. The return water flow is measured and a sample is taken when noticeable changes in flow occur. The water colour is noted at the same time. The drill penetration rate is logged manually.

At the end of the percussion drilling phase, a recovery test is made by blowing compressed air to remove the water in the hole. The recovery of the water table is then measured manually.

3.2.2 Core drilling

The sampling and measurements during the core drilling phase of KLX05 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 wire-line based equipment. The measurements for hydrogeological purposes include pumping tests and measurements of absolute pressure and are normally performed for every 100 m of drilled length. Sampling of water for chemical analysis is done in conjunction with the hydrogeological measurement where feasible. The wireline tests are done in accordance with SKB Method Description MB 321.002, SKB internal document.

Air lift pumping with evaluation of drawdown and/or recovery

Air lift pumpings with evaluation of drawdown and/or recovery are done with 300 m intervals, nominally at 400, 700 and 1,000 m length. The actual levels are adapted to when changes of drill bit, or some other reason to raise the drill stem, occur. The test cycle can include both the drawdown phase and the recovery phase, however normally the recovery phase would be used for evaluation.

- 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 one hour 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 m intervals of drilled length for analysis of drilling water content (percentage of water with uranine tracer content) and electrical conductivity.

Drilling monitoring system (DMS)

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

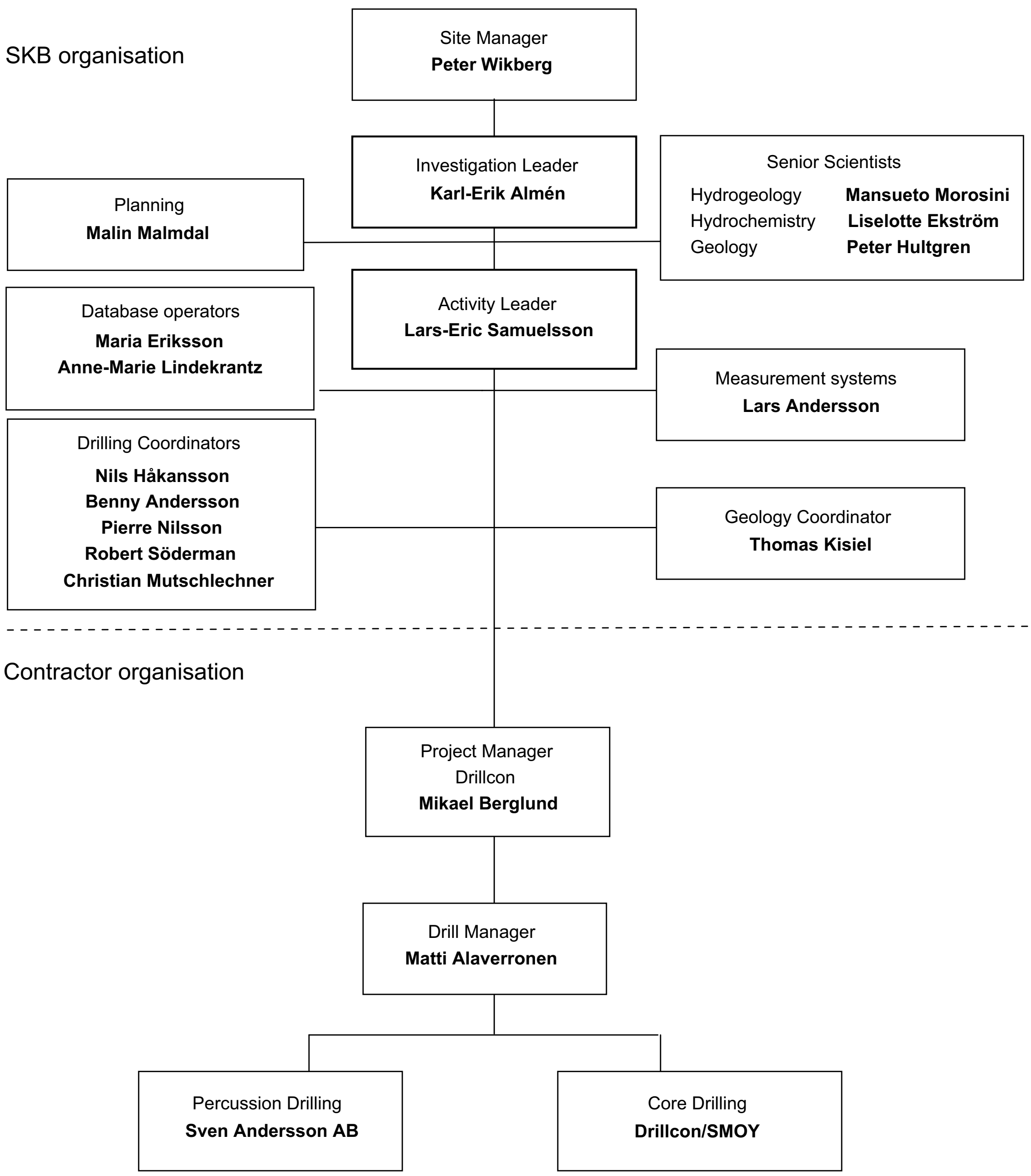
4 Contractors and equipment

4.1 Contractors

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

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

Table 4-1. Drill activity organisation.



4.2 Percussion drilling equipment

The equipment used was a Comacchio MC 15000 percussion drill rig with an Atlas Copco XRVS 455 Md air compressor. The down-the-hole hammer was a Secoroc 8" or 6" and the drill rods were Driqoneq 114 mm. The casing utilized was SS 2343 208x4 mm and 324x7 mm. The casing dimensions are presented as outer diameter and thickness.

4.3 Core drilling equipment

Core drilling in KLX05 was made with a B 20 P Atlas Copco fully hydraulic machine fitted with a modern and environmentally adapted diesel engine. The drilling was done with N-size, i.e. giving a borehole of 76 mm diameter. The core barrel was of the type Corac N3/50, a triple tube wireline equipment which gives a core diameter of 50.1 mm. The rods were of type NT.

Directional drilling was made with the Liwinstone tool for N-size (76 mm) boreholes. The tool consists of a set of rods that can create an angle between the bit and the drill stem and is entered into the borehole by the conventional method, i.e. not by wireline. The obtainable deviation varies between 0.1 to 0.3 degrees per drilled metre. The core barrel allows for up to 3 m of recovery. The recovered core has a diameter of 45 mm.

Figure 4-1. *The KLX05 drill site*

The working procedure for the directional tool is as follows:

- The Liwinstone tool is lowered into the borehole.
- The direction of the tool is adjusted by measurements with a Maxibor equipment.
- The directional rod surrounding the core barrel is fixed to the borehole wall by water pressure so that it doesn't rotate but can still be moved downwards in the borehole.
- The rotation of the drill stem, core barrel and drill bit is started and a feed force applied. The outer directional rod does not rotate during drilling.

4.3.1 Wireline measurements equipment

The wireline probe equipment 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 with a wireline probe as specified in method description SKB MD 321.002, SKB internal document.

The principal components are:

- an inflatable packer,
- a probe fitted with 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 and packer are 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.

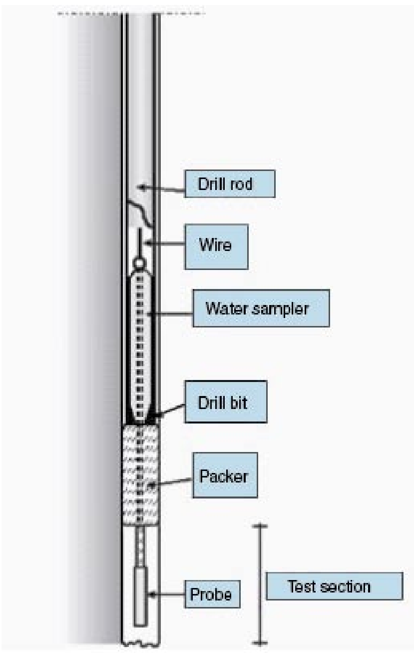


Figure 4-2. *The wireline probe and its emplacement in the hole.*

Before the pumping tests are made, measurements for absolute pressure and a leakage test of the drill string is 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 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 in the probe 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 in the probe. The pumped surface flow rate is recorded to a data logger on the ground surface. The 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 a maximum sample 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

The wireline probe is placed in position at the drill bit. The packer is inflated and the pressure build-up in the test section is recorded for a period of at least eight hours, typically this is done overnight. The measuring range for the pressure gauge is 0–20 MPa (± 0.05% FSD). The absolute pressure measurement is conducted if the flowrate during the pumping test exceeds 1 litre per minute.

4.3.2 Drilling monitoring system

During the core drilling phase continual monitoring was made of several measurement-while-drilling (MWD) parameters and flushing water parameters. The data is compiled into the DMS database.

The results presented in this report have been checked in accordance with a working routine for quality assurance of DMS.

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).
- Air pressure (kPa).

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

Figure 4-3. *The CR23 logging unit for parameters "air pressure" and "electrical conductivity".*

4.3.3 Equipment for deviation measurements

Deviation measurements were performed in the borehole using a Reflex MAXIBOR™ which is a non-magnetic, optical equipment and with two magnetometer/accelerometer instruments: FLEXIT SmartTool and DeviTool PeeWee.

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 mm, 76 mm and N-size (75.8 mm) drilling equipment. The reaming tool is operated hydraulically from the surface, so that when the water pressure is increased the cutters expand.

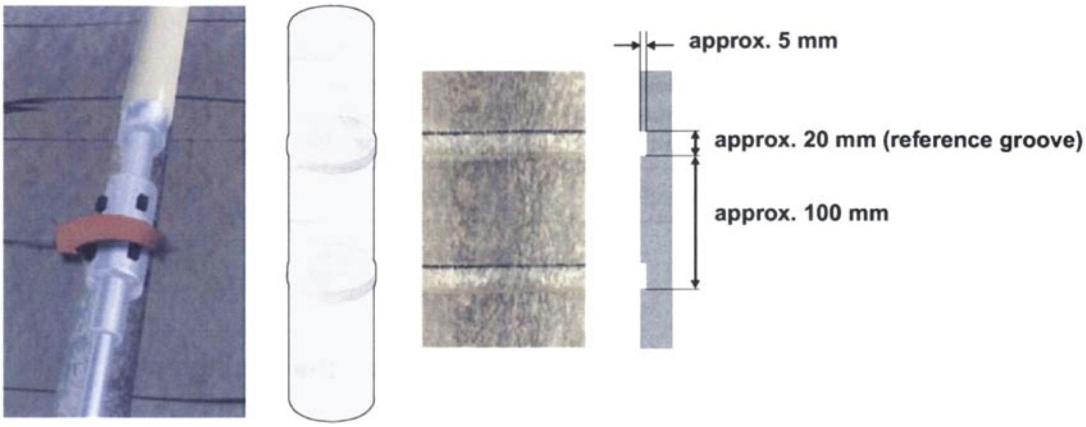


***Figure 4-4**. The equipment for reaming of reference slots. To the left, the reaming tool with openings for the cutters is shown. The resulting reference slots are illustrated in the three pictures to the right.*

5 Execution and results

5.1 Summary of KLX05 drilling

A technical summary of the drilling of KLX05 and the borehole design after completion is given in Table 5-1 and 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. Drilling progress over time is further reported in section 5.5 "Drilling monitoring results".

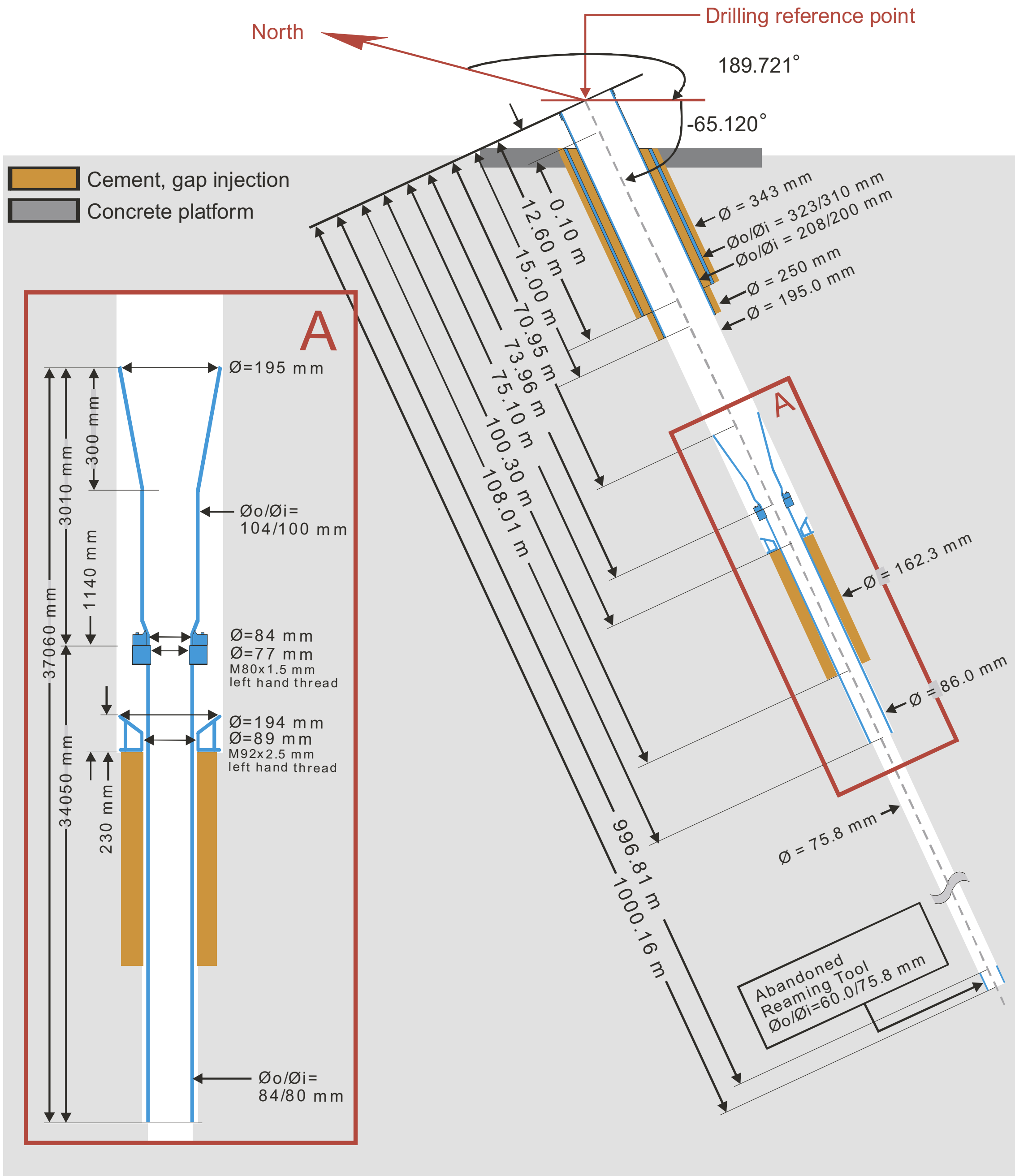
Further descriptions of the two main drilling steps, the telescope section 0–100.3 m and the core drilling section 75.10–1,000.16 m are given in sections 5.2 and 5.3 respectively.

Table 5-1. KLX05 Technical summary.

General	Technical
Name of hole: KLX05	**Percussion drill rig:** Comacchio MC 15000
Location: Laxemar, Oskarshamn Municipality, Sweden	**Percussion hole length:** 100.3 m
Contractor for drilling: Drillcon AB	**Core drill rig:** B 20 P Atlas Copco
Subcontractor percussion drilling: Sven Andersson AB	**Core drill dimension:** N-size (76 mm)
Subcontractor core drilling: Suomen Malmi OY (SMOY)	**Cored interval:** 75.1–1,000.16 m
Drill start date: August 11, 2004	**Average core length retrieved in one run:** 2.54 m
Completion date: January 22, 2005	**Number of runs:** 363
	Diamond bits used: 11
	Average bit life: 84 m
	Position KLX05 (RT90 RH70) at top of casing: N 6365633.34.59 E 1548909.41.93 Z 17.63 (m.a.s.l.)
	Azimuth (0–360)/ Dip (0–90): 189.7/ –65.1
	Position KLX05 (RT90 RH70) at 981 m length: N 6365272.01 E 1548696.64 Z –863.21 (m.a.s.l.)
	Azimuth (0–360)/ Dip (0–90) : 237.2/ –63.3

Technical data

Borehole KLX05



Drilling reference point

Northing:	6365633.34 (m),	RT90 2,5 gon V
Easting:	1548909.41 (m),	RT90 2,5 gon V
Elevation:	17.63 (m),	RHB 70

Drilling period

Drilling start date:	2004-08-11
Drilling stop date:	2005-01-22

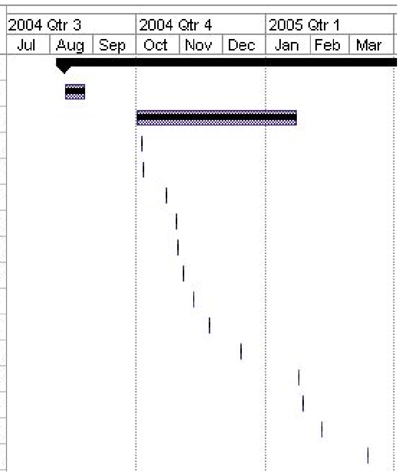
Figure 5-1. *Technical data from KLX05.*

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

Depth	Drilled length, pumping tests and water sampling	Measurements of absolute pressure	Airlift pumping with evaluation of drawdown and/or recovery	Deviation measurement	Miscellaneous
0 m	041007. Pumping test without wl-probe. 15-108.75 m. Flow 8.3 L/min with 5 m drawdown.				041008-9. cementing was done in two steps to fill up section between 97 and 100.4 where loose rock had been noted.
	041016. Pumping test 107.80 - 202.94 m. Flow 5 L/min with 10 m drawdown. Water sample collected with new sampling unit.	041017. Measurement of absolute pressure 107.80 - 206.50 m.		041006. Maxibor 0 - 102 m. 0.08 m left 1.02 m up.	Forecast of deviation at 1000 m drilled length after measurement at 294 m. Easting - 30 m (right) Northing + 63 m (down).
	041022. Pumping test 200.80 - 303.58 m. Flow 2.5 L/min with 13 m drawdown. Pump MP1 stopped after 2 h. No water sample taken. 041023. Pumping test 220.80 - 313.93 m. Flow 2.5 L/min with 13 m drawdown. No water sample taken as the pump MP1stopped after 3 h.	041024. Measurement of absolute pressure 200.80 - 334.97 m.		041022. Maxibor 90 - 294 m. 0.76 m left 3.24 up. Dip: -65.57 Azimuth: 194.00	Forecast of deviation at 1000 m drilled length after measurement at 412.96 m. Easting -120.52 m (right) Northing +68.25 m (down) Elevation -3.32 m
				041029. Maxibor 293 - 412.96 m -8.29 m right 1.53 m up. Dip -65.86 Azimuth 207.41	
	041031. Pumping test 311.90 - 424.95 m. Flow 0.3 L/min with 23 m drawdown.		041030. Air lift pumping 15 - 412.96 m. No drill stem in borehole.	041103. Maxibor 372 - 495 m. 20.59 m right 2,67 m down. Dip -66.71 Azimuth 214.55	Forecast of deviation at 1000 m drilled length after measurement at 495 m. Easting - 111.69 m (right) Northing +80.65 m (down). Decision taken to direct the borehole to the left
	041104. Pumping test 422.85 - 502.95 m. No noticable flow with 22 m drawdown.				
	041119. Pumping test 500.58 - 616.45 m. Modified WL-probe. < 0.1 L/min with 20 m drawdown.			041121. Maxibor 495 - 630 m. 44.39 m right 9.84 m down. Dip -65.99 Azimuth 215.24	041122. Decision taken to perform three directional drillings and renewed deviation measurement.
	041212. Pumping test 614.65 - 695.46 m. Modified WL-probe. 0.2 L/min with 20 m drawdown.		041213. Air lift pumping 15 - 695.46 m. No drill stem in borehole.	041213.Maxibor 630 - 693 m. 56.02 m right 12.75 m down. Dip -65.04 Azimuth 216.82	Forecast of deviation at 1000 m drilled length after measurement at 693 m. 124.44 m right 24.16 m down. Dip -63.18 Azimuth 224.93
	050104.Pumping test 692 - 794 m. New WL-probe (modified) 0.2 L/min with 25 m drawdown.				
	050115. Pumping test 791 - 905 m. New WL-probe. 0.2 L/min with 19 m drawdown.				
1,000 m	050123. Pumping test 902.55 - 1000.16 m. New WL-probe. 1.1 L/min with 17 m drawdown.	050124. Measurement of absolute pressure. 902.55 - 1000.16 m.		050123. Maxibor 0 - 990 m. 115.81 right 25.77 down Dip -65.58 Azimuth 232.46	

Table 5-3. Chronological summary of main drilling events KLX05.

ID	Aktivitet	Start	Finish
1	**First activity starts**	**Wed 04-08-11**	**Thu 05-07-07**
2	Percussion drilling	Wed 04-08-11	Wed 04-08-25
3	Core drilling	Fri 04-10-01	Sat 05-01-22
4	Recovery test	Mon 04-10-04	Tue 04-10-05
5	Recovery test	Mon 04-10-04	Tue 04-10-05
6	Maxibor measurement	Fri 04-10-22	Fri 04-10-22
7	Maxibor measurement	Fri 04-10-29	Fri 04-10-29
8	Recovery test	Fri 04-10-29	Sat 04-10-30
9	Maxibor measurement	Wed 04-11-03	Wed 04-11-03
10	Maxibor measurement	Wed 04-11-10	Wed 04-11-10
11	Maxibor measurement	Sun 04-11-21	Sun 04-11-21
12	Recovery test	Mon 04-12-13	Mon 04-12-13
13	Maxibor measurement	Sun 05-01-23	Sun 05-01-23
14	Recovery test	Wed 05-01-26	Thu 05-01-27
15	Length calibration marks	Tue 05-02-08	Wed 05-02-09
16	Maxibor measurement	Sun 05-03-13	Sun 05-03-13



5.2 Drilling, measurements and results in the telescopic section 0–100.3 m

Drilling, reaming and gap injection were made from August 11 to 25, 2004.

5.2.1 Preparations

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

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

5.2.2 Drilling and casing installation

The construction of the upper telescope section (0–100.3 m) of KLX05 was made in steps as described below:

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

- Drilling was made to 12.60 m length with NO-X 280 mm equipment. This gave a hole diameter of 347 mm and left a casing (324×7 mm diameter) to a depth of 12.60 m. Drilling started directly on the rock surface.
- A pilot percussion hole of 163.3 mm was drilled to a depth of 100.30 m. A large influx of water was encountered at 83 m together with an unstable borehole wall with rock fragments falling out.
- The hole was reamed to diameter 250 mm between 12.60 and 15.00 m and a stainless casing of 208x4 mm was installed from surface to 15.00 m.
- The entire pilot hole was grouted and supposedly back-filled with concrete from 100.30 to 9.10 m i.e. from the bottom of the borehole and up. A total 2,500 litres of low alkali cement based concrete was used. As shown in Figure 5-6, it was concluded during the initial stages of core drilling that the borehole was only filled by concrete to ca 97 m, leaving an unfilled pocket at the bottom of the hole.
- Gap injection around the casings was made with 480 litres of low alkali cement based concrete as described in Figure 5-2.

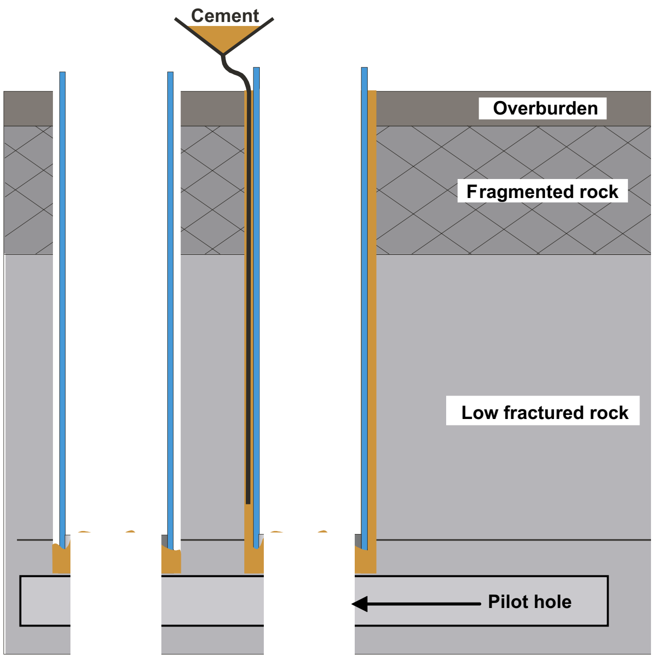


Figure 5-2. *Gap injection. A cement plug is emplaced at the bottom and allowed to harden. The gap filling cement is introduced between the casing and the rock wall.*

- After several days of hardening, the cement was removed in two steps. The hole was reamed first to 161 mm and subsequently to 195 mm to a drilled length of 75.10 m. The borehole was rinsed and flushed to remove concrete and water.

5.2.3 Measurements and sampling in the telescopic section

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

- The percussion drilling progress was monitored by the geology coordinator (or 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 manually and observations of changes in water flow and water colour were noted.

The preliminary geological results and penetration rate is presented in Figure 5-3.

Hydrogeology

The total water yield at full length was more than 100 L/min. The water inflow was observed at 83 m drilled length.

Hydrochemistry

Two water samples were collected from the telescopic section in KLX05. Sampling and analysis of the samples 7670 and 7671 were performed according to SKB classes 3 and 5, see Table 5-4. Selected analytical results are given in Table 5-5. A complete record of analytical results is given in Appendix 2.

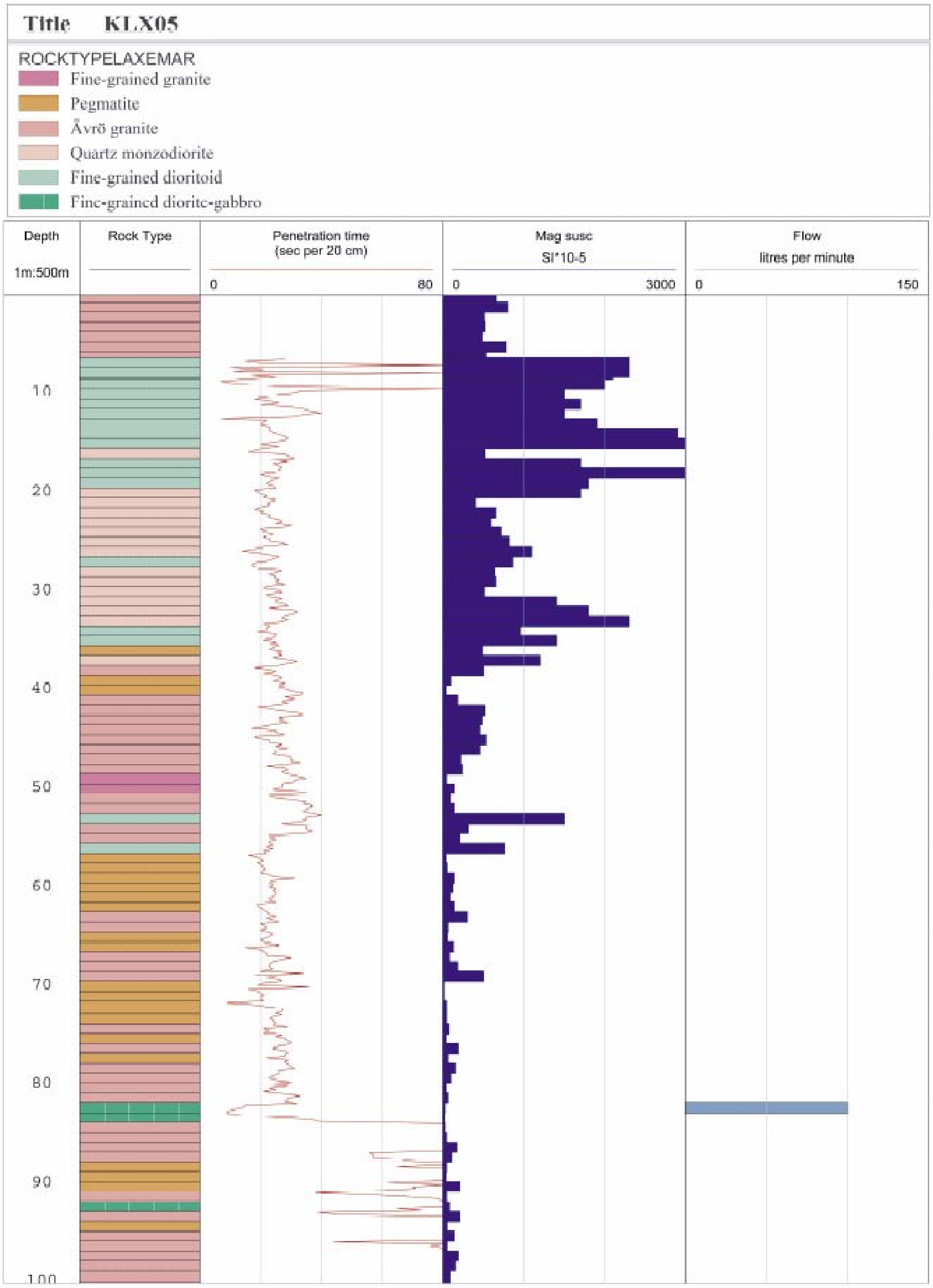


***Figure 5-3.** Preliminary geological results based on logging of drill cuttings and penetration rate from percussion drilling of KLX05.*

Table 5-4. Sample dates and length during percussion drilling in KLX05.

SKB number	Date	Test section, drilled length (m)	SKB chemistry class
7670	2004-08-16	15.00–100.00	3 (not analysed for main components or isotopes
7671	2004-08-16	15.00–100.00	5 (not analysed for main components or isotopes)

Table 5-5. Analytical results from water samples 7670 and 7671.

Borehole	Sample no	Date	From	To	pH	Conductivity	Cl
			m	m		mS/m	mg/l
KLX05	7670	2004-08-16	15.00	100.00	7.99	51.8	6.9
KLX05	7671	2004-08-16	15.00	100.00	7.88	53.3	10.0

Sample 7670 was collected for complete class 3 analysis including all options except carbon isotopes. Sample 7671 was collected for class 5 analysis i.e. including TOC.

Water bottles for the parameters that have not been analysed are saved and stored at the Äspö laboratory.

A further account on analytical methods, chemistry classes and quality is given in Appendix 3.

5.3 Core drilling 75.10–1,000.16 m

Core drilling in KLX05 was conducted by Drillcon/SMOY between October 1, 2004 and January 22, 2005.

The main work in KLX05 after drilling the telescopic section consisted of the following steps:

- preparations for core drilling,
- core drilling including directional drilling,
- deviation measurements,
- borehole completion.

Measurements and results from wireline tests and drill monitoring are given in sections 5.4 and 5.5.

5.3.1 Preparations

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

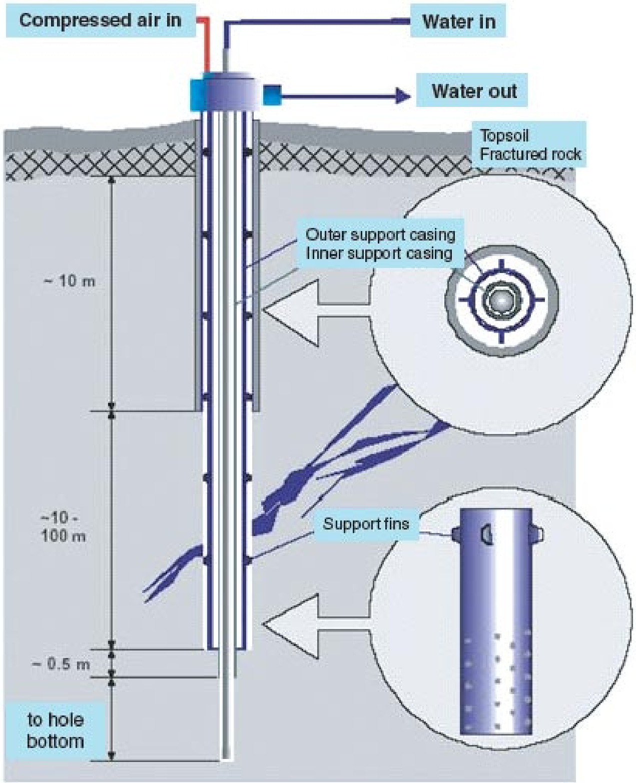


Figure 5-4. *In the telescopic part of the drill hole a temporary installation is made with casing tubes for support and alignment and equipment for air lift pumping. In the uppermost part the return water discharge header is mounted. The water discharge is led to the settling containers. NB The length of the telescopic section in KLX05 is however 75.1 m and not 100 m as stated in the figure.*

The installation of supportive casing was done in two 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 75.10 and 76.48 m with T-86 equipment. An inner supportive casing with diameter 84/77 mm was installed to 76.48 m.

The supportive casings have a perforated section between 74.50 and 74.70 m length so that water from the borehole can be lead to the air lift pumping system outside the supportive casings. A pressure meter for monitoring of the water level was emplaced at a length of 70 m.

The flushing water source was percussion borehole HLX10, see Figure 1-1. Treatment of the flushing water before introduction into borehole KLX05 consisted of removal of oxygen by nitrogen flushing and addition of the fluorescent tracer uranine. The water is also treated with ultraviolet light in order to reduce the microbial content. The flushing and return water handling and the emplacement of related monitoring equipment in KLX05 is shown in Figure 5-5.

The targeted content for uranine in the flushing water is 0.20 mg/L and the average uranine content was indeed 0.20 mg/L, see also Figure 5-16 and section 5.5.2.

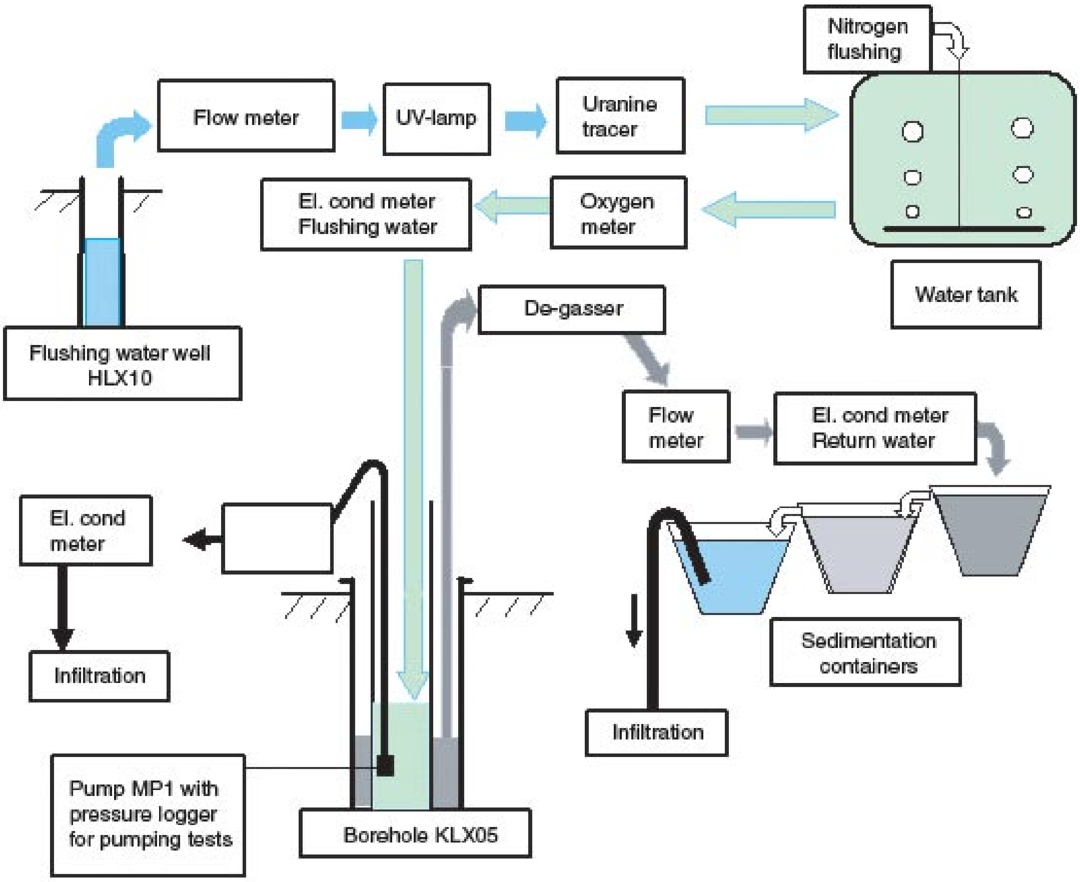


Figure 5-5. *The flushing and return water handling and the emplacement of related monitoring equipment in KLX05.*

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

5.3.2 Drilling

Core drilling with 76 mm triple-tube, wireline equipment was conducted from 76.48 m.

Core drilling was temporarily stopped at 108.75 m due to rock fragments falling into the borehole. Inspection with a down-hole camera showed that no concrete was present below 97 m i.e. in the lowermost part of the telescopic section. Grouting was done twice, in batches of 60 litres each, on October 8 and October 9, 2004. The situation in the borehole after the second grouting is shown in Figure 5-6.

The concrete was emplaced with equipment developed by Drillcon. A valve is fitted to the lower end of the N-size drill stem, see Figure 5-7. A sufficient amount of concrete is placed inside the drill stem, a piston is inserted above the concrete, see Figure 5-8. Water is pumped into the drill stem from the surface thereby pressurizing the piston on the inside of the N-size drill stem so that the concrete opens the bottom valve. The concrete enters the borehole through a 33 mm pipe. The bottom valve remains open so that suction will not act on the concrete when the drill stem is retracted.

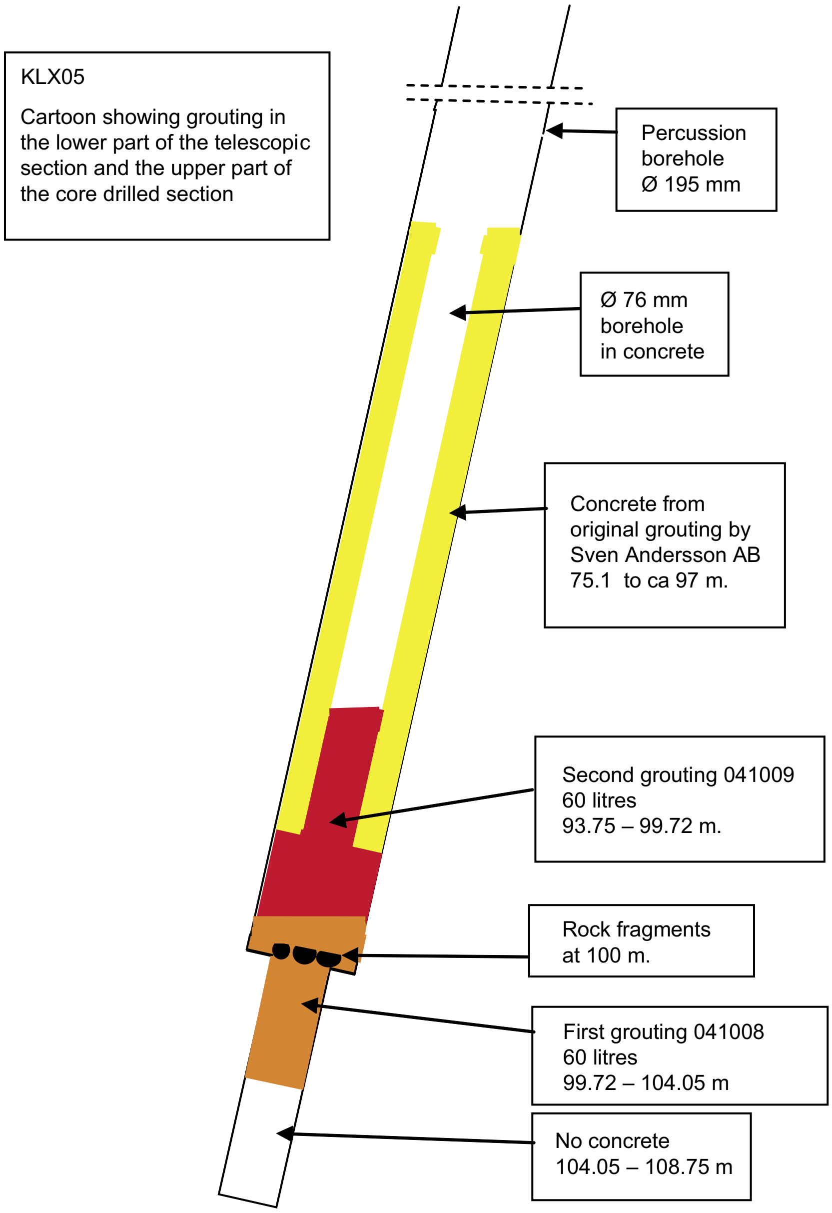


Figure 5-6. *Grouting in the lower part of the telescopic section and the upper part of the core drilled section.*

Figure 5-7. *The bottom valve and its emplacement in the N-size drill stem. The 33 mm aluminium pipe can be seen below the N-sized seat for the valve.*

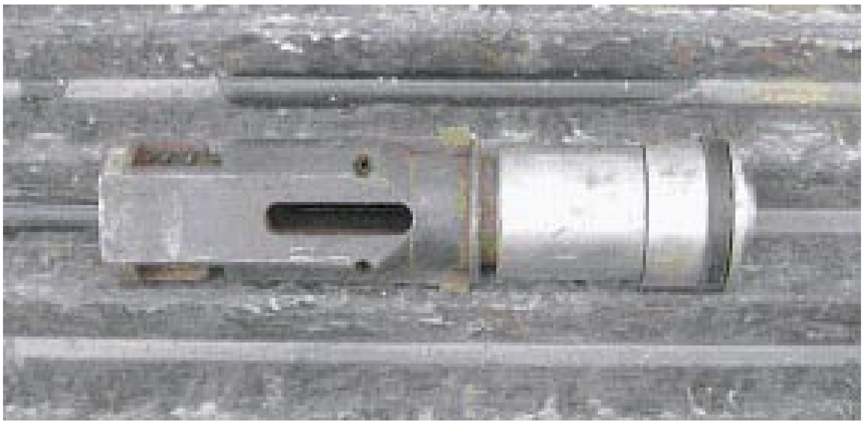


Figure 5-8. The piston for insertion into the N-size rods. The piston is forced downward by water pressure. This causes the concrete to exit the N-size rods through the bottom valve and enter the borehole.

Drilling with the Corac N3 core barrrel gives a core of 50.1 mm diameter. Directional drilling was, however, made in ten intervals between 502.95 and 667.18 m length. The core diameter in these sections is reduced to 45 mm. The core diameters and intervals for different drilling dimensions are given in Table 5-6.

A total of eleven drill bits were used for KLX05, see Figure 5-9.

The elasticity of the drill stem was not measured during the drilling of KLX05.

Further results from drill monitoring i.e. drill penetration rate and various measurements will be presented in chapter 5.5 "Drilling monitoring results" and in Appendix 1. The drilling progress over time is shown in section 5.5, see Figure 5-21.

Table 5-6. Core diameters, borehole diameters and intervals for different drilling dimensions during core drilling.

Core diameter (mm)	Borehole diameter	Interval (m)	Drilling dimension	Comment
72	86	75.10–76.48	T-86	
50.1	86	76.48–108.10	N and T-86	reamed
50.1	76	108.10–502.95	N	
45	76	502.95–505.00	Liwinstone N	directional
50.1	76	505.00–511.25	N	
45	76	511.25–511.55	Liwinstone N	directional
50.1	76	511.55–520.55	N	
45	76	520.55–521.34	Liwinstone N	directional
50.1	76	521.34–535.98	N	
45	76	535.98–538.59	Liwinstone N	directional
50.1	76	538.59–589.82	N	
45	76	589.82–592.62	Liwinstone N	directional
50.1	76	592.62–598.20	N	
45	76	598.20–600.94	Liwinstone N	directional
50.1	76	600.94–607.94	N	
45	76	607.94–610.60	Liwinstone N	directional
50.1	76	610.60–652.86	N	
45	76	652.86–655.59	Liwinstone N	directional
50.1	76	655.59–658.71	N	
45	76	658.71–661.59	Liwinstone N	directional
50.1	76	661.59–664.21	N	
45	76	664.21–667.18	Liwinstone N	directional
50.1	76	667.18–1,000.16	N	

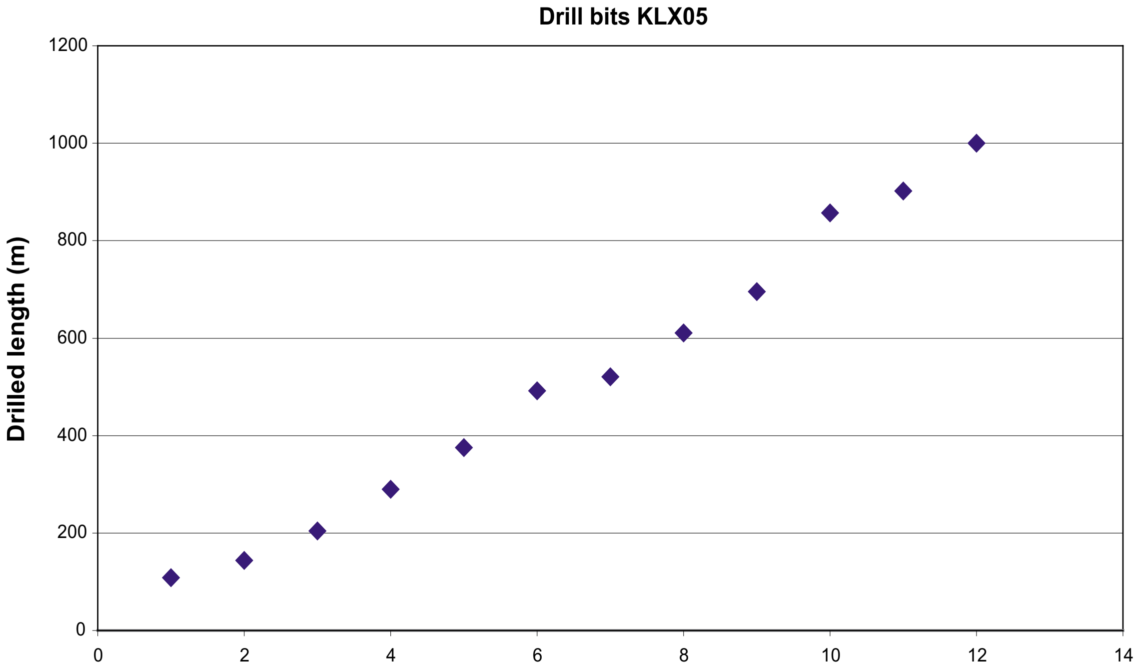


Figure 5-9. Changes of drill bit during core drilling in KLX05.

5.3.3 Deviation measurements

Plots of the results of the final run with the Maxibor method covering the entire length of borehole KLX05 is given in Appendix 4. The borehole was also measured with the following methods:

- DeviTool PeeWee, March 13, 2005, performed by Devico AS, Norway.
- FLEXIT SmartTool, May 20, 2005, performed by Raycon AB, Sweden.

All sets of data are stored in the SICADA database, however, in accordance with method description MD 620.003, the Maxibor data should be used as deviation data and measurements from other sources should be seen as checks only. The FLEXIT measurement was done after the drilling was completed but should however be seen as part of the drilling activity.

A comparison of the results obtained by the three different methods at two levels in the borehole is given in Figures 5-10 and 5-11.

5.3.4 Borehole completion

Borehole completion was initiated on January 23 with reaming of depth reference slots and running of a dummy probe.

The probing with a steel dummy showed that tight or angular sections existed in the borehole. This was especially evident where directional drilling had been done. The borehole was therefore reamed to obtain a smooth curvature that would allow later use of measurement tools. A sketch of the reaming tool is shown in Figure 5-12.

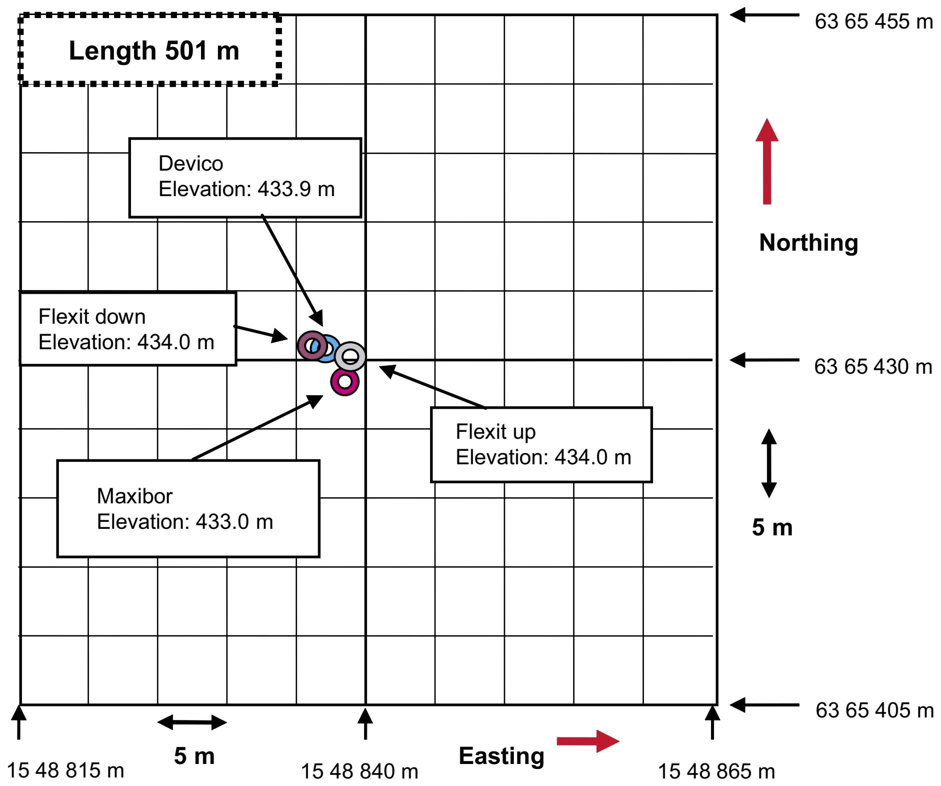


__Figure 5-10.__ A comparison of results from different methods for measuring borehole deviation at drilled length 501 m.

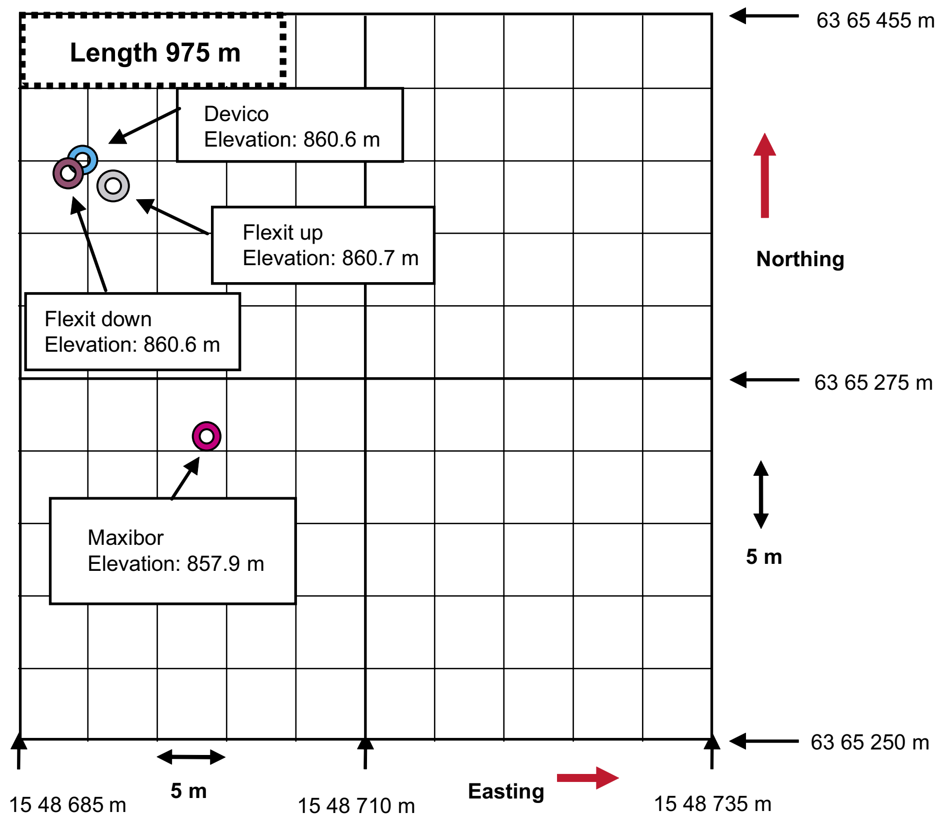


__Figure 5-11.__ A comparison of results from different methods for measuring borehole deviation at drilled length 975 m.

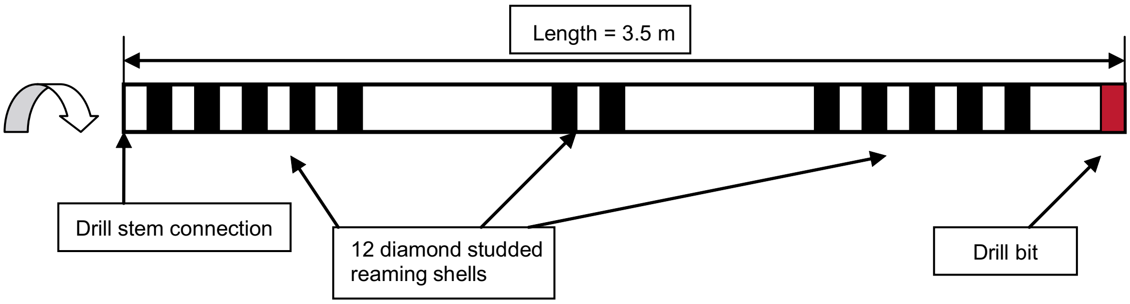


Figure 5-12. *Schematic drawing of the reaming tool.*

However, during reaming, the drill string snapped and a 520 m long set of drill string was dropped in the borehole on January 31. Attempts at retrieving the drill stem were made over a period of over one month, until March 5. A reaming tool had to be abandoned in the bottom of the borehole between 996.81 m and 1,000.16 m.

Reaming of the depth reference slots was finalized on March 9. The intervals are shown in Table 5-7. 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.

After core drilling was concluded, the air lift pumping equipment and the inner supportive casing in the telescopic section was removed.

The 76 mm borehole was reamed to 86 mm diameter from 76.48 to 108.01 m. A steel conical guide was installed between 70.95 m and 73.96 m depth together with a 84/80 mm casing between 73.96 and 108.01 m. The conical guide tapers from an inner diameter of 195 mm to 77 mm.

The length of the hole was rinsed by flushing with nitrogen gas on March 21 and 22. A total of 7 m^3 of water was flushed out of the hole. The flushing creates a powerful drawdown in the borehole and the near-by located percussion boreholes HLX26, HLX27 and HLX28 were checked for possible hydraulic responses, see section 5.4.3.

The borehole was secured by mounting a lockable steel cap 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 5-7. Depth reference slots (m).

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

5.4 Hydrogeological and hydrochemical measurements and results 75.1–1,000.16 m.

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

- One open hole pumping, see section 5.4.1.

Wireline measurements:

- Ten pumping tests at various intervals, all gave useful results, see section 5.4.1.
- Three tests for absolute pressure, see section 5.4.1.
- One water sample was successfully collected from the ten pumping tests, see section 5.4.2.

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

Four air lift pumping and recovery tests were made, see section 5.4.3.

5.4.1 Hydrogeological results

In section 15.00–108.75 m a single-hole pumping test was conducted, for results see Table 5-8 and Figure 5-13. Pumping, with a flow of 8.3 L/min, for approximately 2 hours and 40 minutes, caused a 4.9 m drawdown. The pumping was done on October 7 i.e. before the grouting shown with red and orange colour in Figure 5-6.

Wireline measurements

Results from the wireline tests in KLX05 are presented in Table 5-9 and Figure 5-14.

The pumping tests are evaluated with steady-state assumption in accordance with /2/. The flow rate, Q, in L/min, and the drawdown, s, in kPa, at the end of the drawdown phase were used for calculating the specific capacity, Q/s, and the transmissivity, T_M.

A total of ten pumping tests were performed and all of them achieved sufficiently stable conditions for calculating pseudo steady-state transmissivity. 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 5-10.

Table 5-8. Pumping test 15.00–108.75 m in KLX05.

Tested section [m]	Flow rate [L/min]	Drawdown [m]	Q/s [m²/s]	T_M [m²/s]	Comments
15.00–108.75	8.3	4.9	2.8×10^{-5}	3.7×10^{-5}	Values of pressure before pumping start and pumping stop are taken from the drill stem.

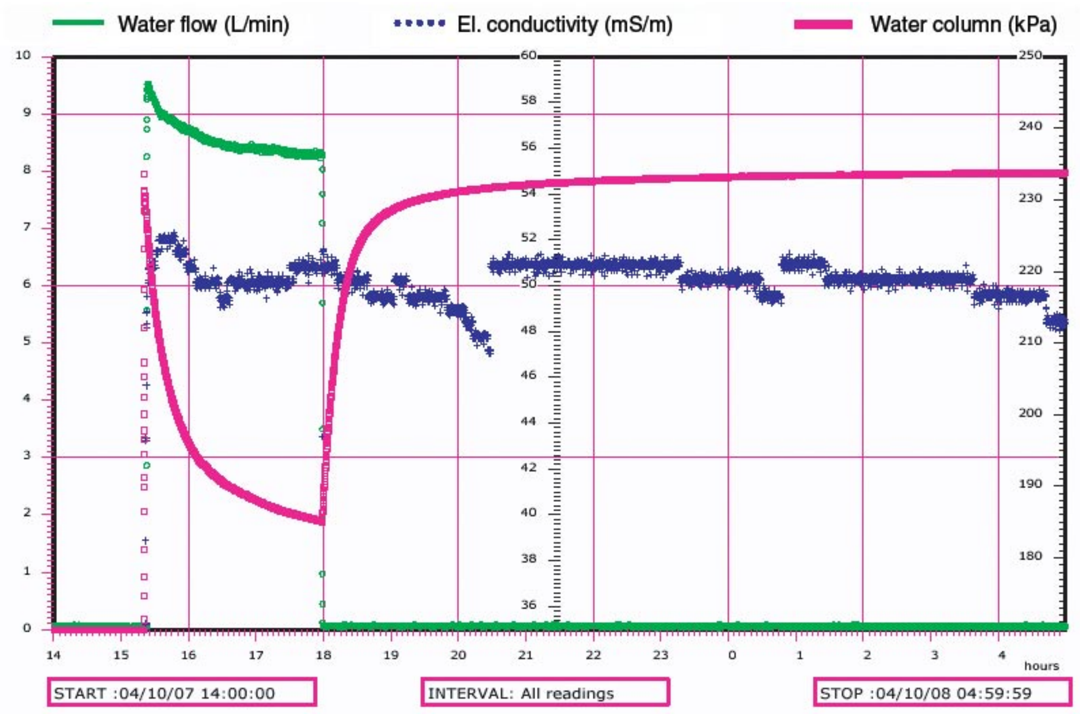


Figure 5-13. *Open hole pumping test 15–108.75 m.*

Table 5-9. Pumping test with wireline probe in KLX05.

Tested section [m]	Q/s [m²/s]	T_M [m²/s]	Comments
107.80–202.94	1.5×10^{-5}	2.0×10^{-5}	Test functionally OK, good data. Pressure in casing in transient recovery phase, unaffected of pumping test.
200.80–303.58	3.6×10^{-6}	4.7×10^{-6}	Good test, despite only 2 hours of pumping. Pressure in casing in transient recovery phase, unaffected by the pumping test.
200.80–313.93	3.4×10^{-6}	4.5×10^{-6}	Time for pumping stop somewhat unclear as the pump stopped by itself and not because of the timer. Values of flow and pressure from the plot at t=19:33. Pressure in casing in transient recovery phase, unaffected by the pumping test.
311.90–424.95	9.9×10^{-7}	1.3×10^{-6}	Test functionally OK.
422.85–502.95	1.8×10^{-7}	2.3×10^{-7}	Varying flow, values of flow and pressure from the plot at t=17:02.
500.58–616.45	1.5×10^{-7}	2.0×10^{-7}	Test functionally OK.
614.65–695.46	2.0×10^{-7}	2.5×10^{-7}	Test functionally OK, good data.
692.95–794.10	2.4×10^{-7}	3.13×10^{-7}	Test functionally OK, though short pumping.
791.73–905.05	8.44×10^{-8}	1.12×10^{-7}	Test functionally OK, good data.
902.55–1,000.16	8.17×10^{-7}	1.06×10^{-6}	Test functionally OK, good data.

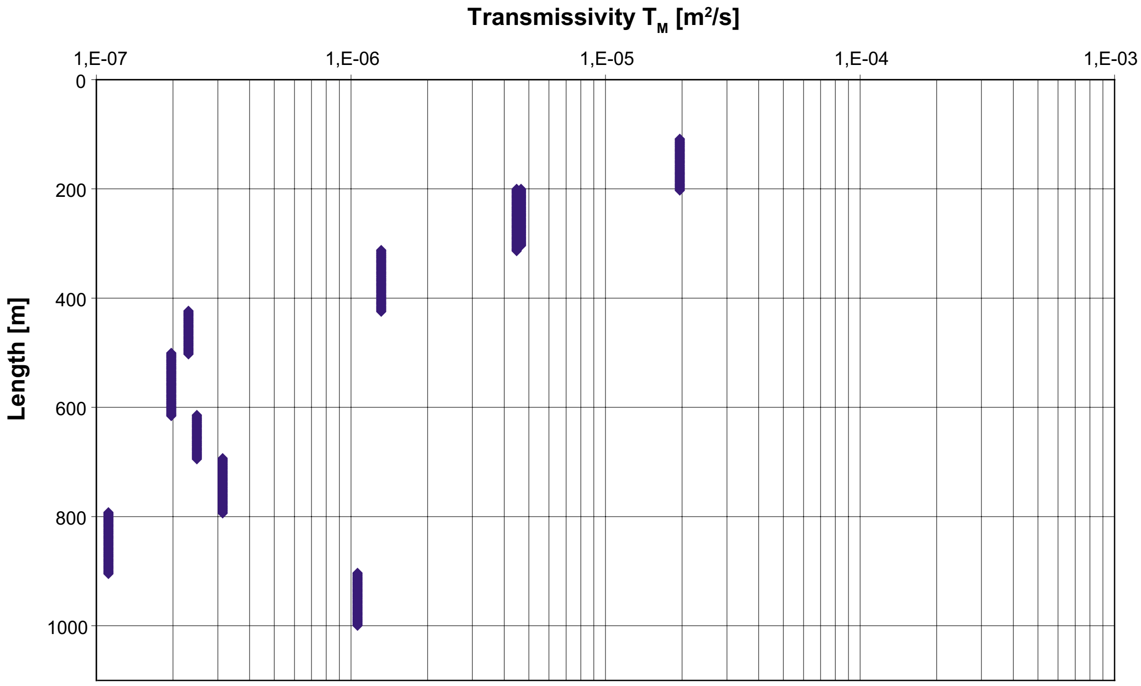


Figure 5-14. *Transmissivity from wireline pumping tests in KLX05 versus borehole length.*

Table 5-10. Start and stop times for the interval used for evaluation of the pumping tests.

Tested section	Start (YY-MM-DD HH:MM)	Stop (YY-MM-DD HH:MM)
107.80–202.94	2004-10-15 15:30	2004-10-16 02:40
200.80–303.58	2004-10-22 16:40	2004-10-22 18:58
200.80–313.93	2004-10-23 16:14	2004-10-23 19:33
311.90–424.95	2004-10-30 15:23	2004-10-30 18:27
422.85–502.95	2004-11-03 16:40	2004-11-03 17:02
500.58–616.45	2004-11-19 20:37	2004-11-19 21:05
614.65–695.46	2004-12-12 08:25	2004-12-12 11:23
692.95–794.10	2005-01-04 16:45	2005-01-04 17:22
791.73–905.05	2005-01-15 17:08	2005-01-16 20:14
902.55–1,000.16	2005-01-23 17:35	2005-01-23 20:13

Measurements of the absolute pressure were conducted in three sections, as specified in Table 5-11 and Figure 5-15. Graphic plots of the individual measurements are given in Appendix 6.

Table 5-11. Absolute pressure measurements in KLX05.

Tested section	Last pressure reading during build-up [kPa]	Duration of pressure build-up [hours]	Borehole length to pressure gauge [m]
107.80–206.50	980	13.0	108.90
200.80–334.97	1,800	12.8	201.90
902.55–1,000.16	8,235	15.3	903.65

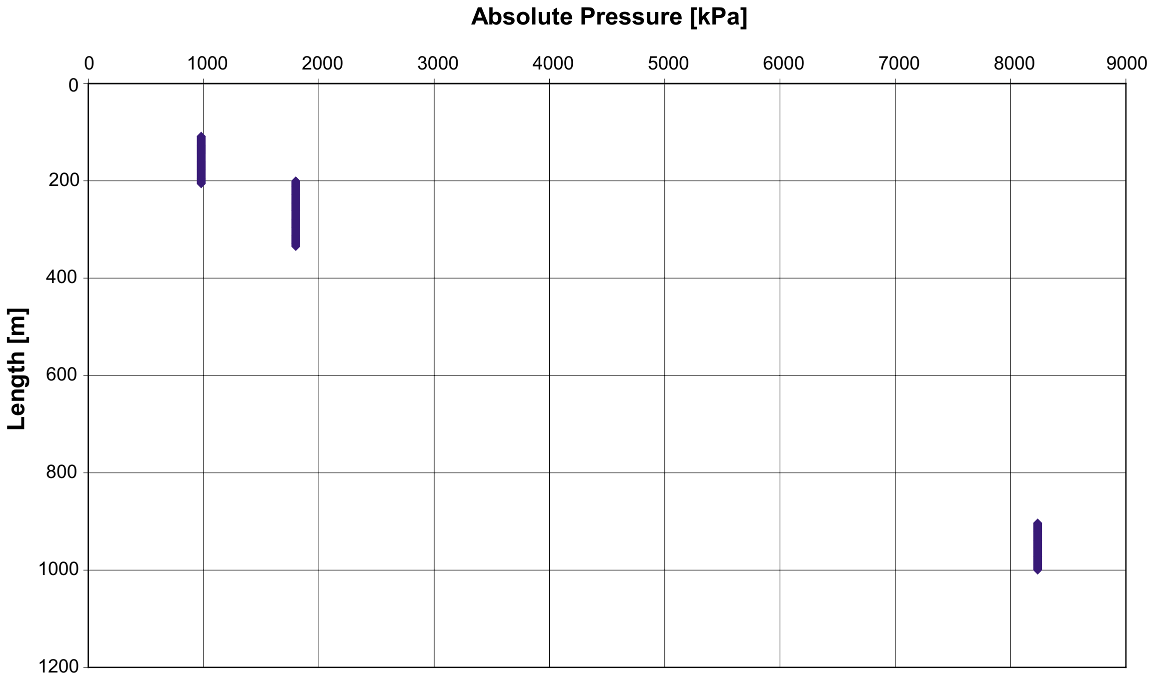


Figure 5-15. *Absolute pressure measurements from wireline tests in KLX05 versus borehole length.*

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

5.4.2 Hydrochemistry

One water sample was collected in connection with core drilling in KLX05. The time and length for the sample is given in Table 5-12.

Sampling and analysis were performed according to the SKB class 3.

Selected analytical results from KLX05 (sample 7861) and the water source, HLX10 (sample 10072), are given in Table 5-13. A complete record of analytical results is given in Appendix 2.

Table 5-12. Sample dates and length during core drilling in KLX05.

SKB number	Date	Test section, length (m)	SKB chemistry class
7861	2004-10-16	107.80–202.94	3 and all option isotopes

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

Borehole	Sample no	Date	From (m)	To (m)	Drill water (%)	TOC (mg/l)	pH	Conductivity (mS/m)	Cl (mg/l)
KLX05	7861	2004-10-16	107.80	202.94	16.20		8.07	63.2	45.7
HLX10	10072	2005-02-01	3.00	85.00		5.5	8.25	54.0	29.1

The percussion drilled borehole HLX10 was used as water source. One water sample, 10072, was taken from HLX10 in connection with the drilling of KLX05. The concentration of total organic carbon (TOC) in the sample was 5.5 mg/l. This value was considered acceptable for the groundwater to be used as flushing water for the core drilled part of KLX05 without further filtration measures to reduce the organic carbon content.

Samples have also been collected from HLX10 at earlier occasions and results from those analyses are reported in /6/.

A total of 131 samples for laboratory testing of uranine content and electrical conductivity in flushing and returning water were taken along the borehole. The results are shown in Figure 5-16.

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

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

Four airlift pumping tests were conducted during drilling, and one additional test was conducted after the borehole was drilled to full depth. The test in section 15.00–97.00 m was too short for evaluation.

The execution of the tests can vary in detail as drilling or other related activities such as cleaning and flushing of drill cuttings can occur prior to lifting the stem.

The steady state transmissivity, T_M, was calculated according to /2/, as well as the specific capacity,*Q/s*. The results are shown in Table 5-14, 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.

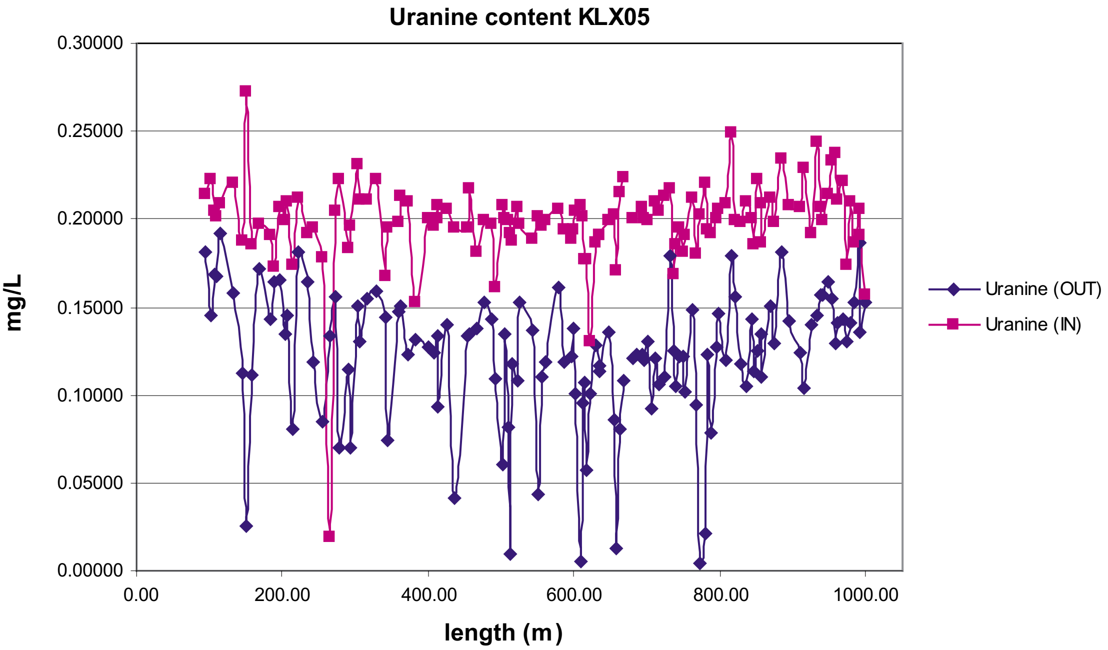


***Figure 5-16.** The uranine concentration of flushing water (IN) and return water (OUT) in KLX05 during drilling.*

Table 5-14. Results from airlift pumping in KLX05.

Tested section [m]	Flow rate [L/min]	Drawdown [m]	Q/s [m^2/s]	T_M [m^2/s]	Comments
15.00–97.00					Test too short for evaluation.
15.00–102.26	8.0	11.0	1.2×10^{-5}	1.6×10^{-5}	Test Q derives from accumulated volumes of water in and out.Q = ΣV/dt
15.00–412.96	37.0	31.0	2.0×10^{-5}	3.0×10^{-5}	Q derives from accumulated volumes of water in and out.Q = ΣV/dt
15.00–695.46	35.0	35.0	1.7×10^{-5}	2.7×10^{-5}	Q derives from accumulated volumes of water in and out.Q = ΣV/dt
15.00–1,000.16	17.5	14.2	2.1×10^{-5}	3.4×10^{-5}	Q derives from accumulated volumes of water in and out.Q = ΣV/dt

The plots from the drawdown and recovery tests are given in Figures 5-17 through 5-20.

Hydraulic response from nitrogen flushing

Rinsing of borehole KLX05 by flushing with nitrogen gas can create a powerful drawdown in the borehole, see section 5.3.4. The near-by located percussion boreholes along the lineament NW042 were checked for possible hydraulic responses. The locations of the boreholes and the lineament are given in Figure 5-21. No hydraulic response could however be seen in boreholes HLX26, HLX27 or in HLX28. No data was available from HLX15, HLX29 or HLX32.

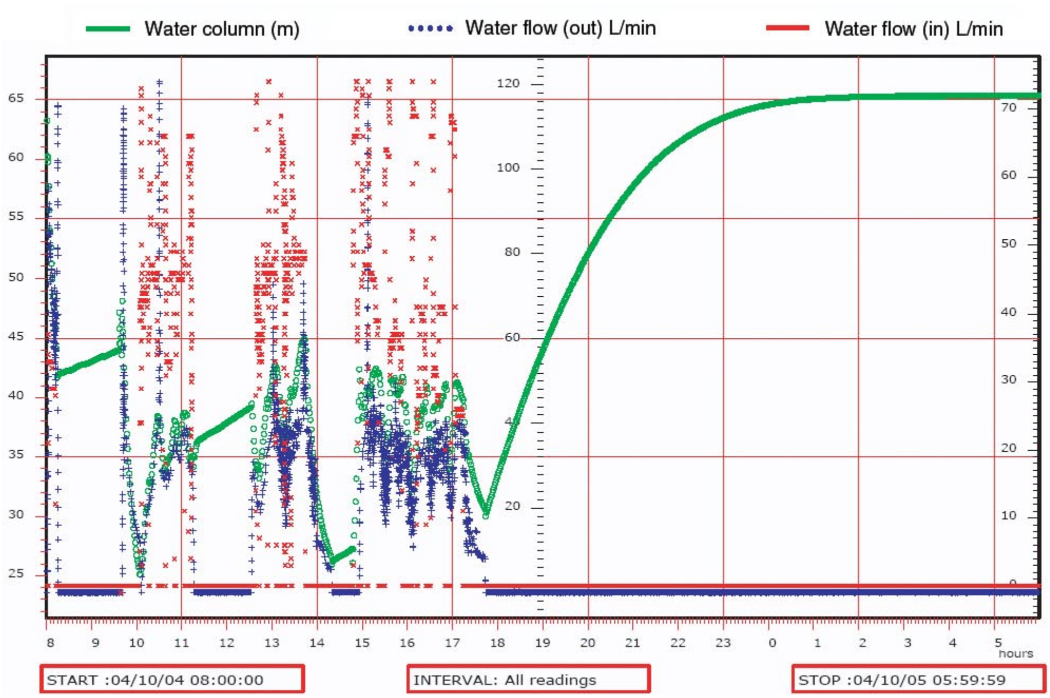


Figure 5-17. *Airlift pumping in KLX05 15.00–102.26 m. The green line represents the height of the water column in the telescopic section of the borehole, the pumped flow rate is shown with a blue dotted line and the inflow rate as the red line. The pressure transducer was positioned 70 m below top of casing and the flow rate was measured at the ground surface. Core drilling was made between the hours 9:41–13:45 and 14:47–17:14 which explains why there was an inflow of water in the borehole.*

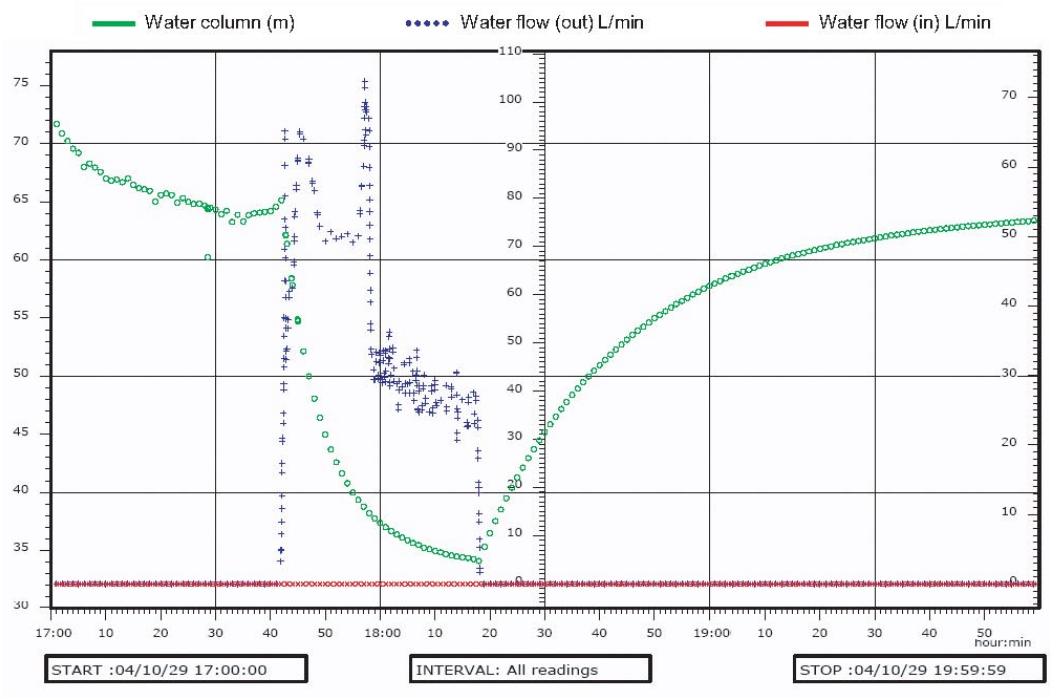


Figure 5-18. *Airlift pumping in KLX05 15.00–412.96 m. The green line represents the height of the water column in the telescopic section of the borehole, the pumped flow rate is shown with a blue dotted line and the inflow rate as the red line. The pressure transducer was positioned 70 m below top of casing and the flow rate was measured at the ground surface.*

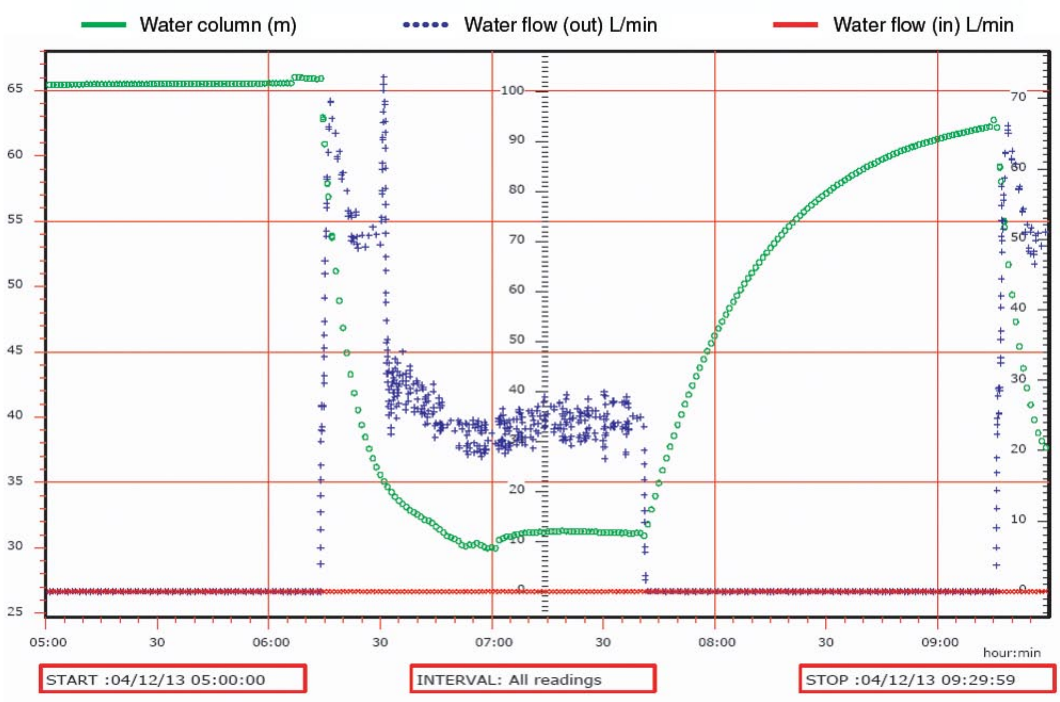


Figure 5-19. *Airlift pumping in KLX05 15.00–695.46 m. The green line represents the height of the water column in the telescopic section of the borehole, the pumped flow rate is shown as the blue dotted line. There was no inflowing water during the test, as shown by the red line. The pressure transducer was positioned 70 m below top of casing and the flow rate was measured at the ground surface.*

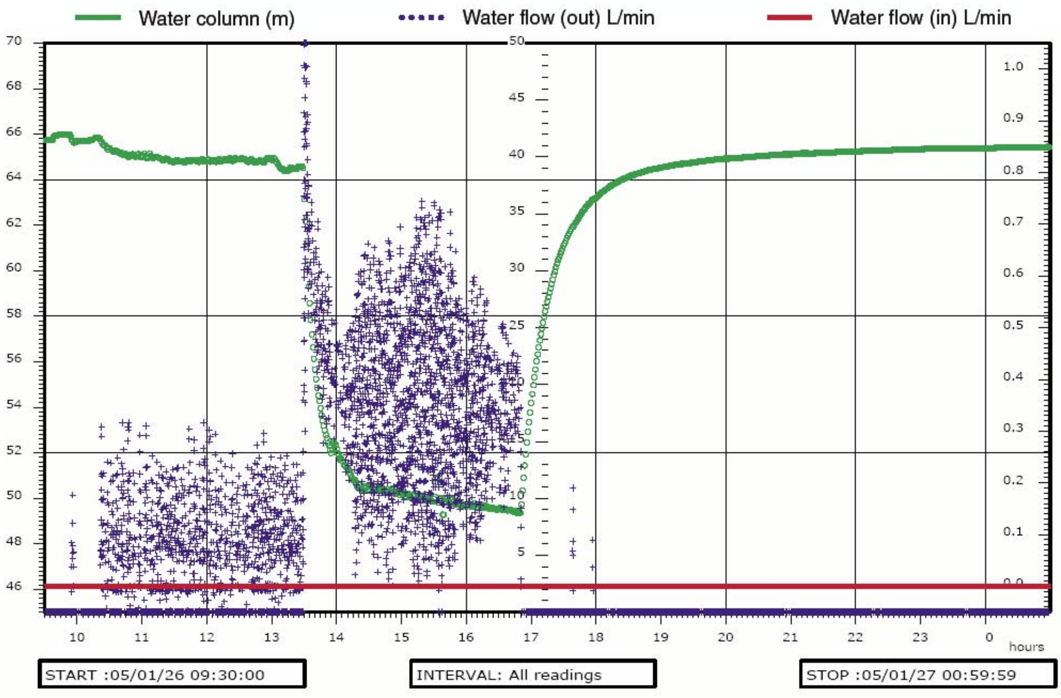


Figure 5-20. *Airlift pumping in KLX05 15.00–1,000.16 m. The green line represents the height of the water column in the telescopic section of the borehole, the pumped flow rate is shown as the blue dotted line. There was no inflowing water during the test, as shown by the red line. Air lift pumping with a flow of ca 5 L/min was done before the test commenced. At 13:30 the flow of water was increased to ca 20–25 L/min which corresponds to the significant drawdown i.e. drop in water column (green line). The pressure transducer was positioned 70 m below top of casing and the flow rate was measured at the ground surface.*

5.4.4 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 5-22 through 5-24 below.

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

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

In order to maintain reasonable size data files, a reduction in the number of points incorporated in the pictures has been done in Figures 5-22 through 5-24. Since DMS data are related to time (i.e. not strictly to borehole length) periods were drilling is not performed are also registered.

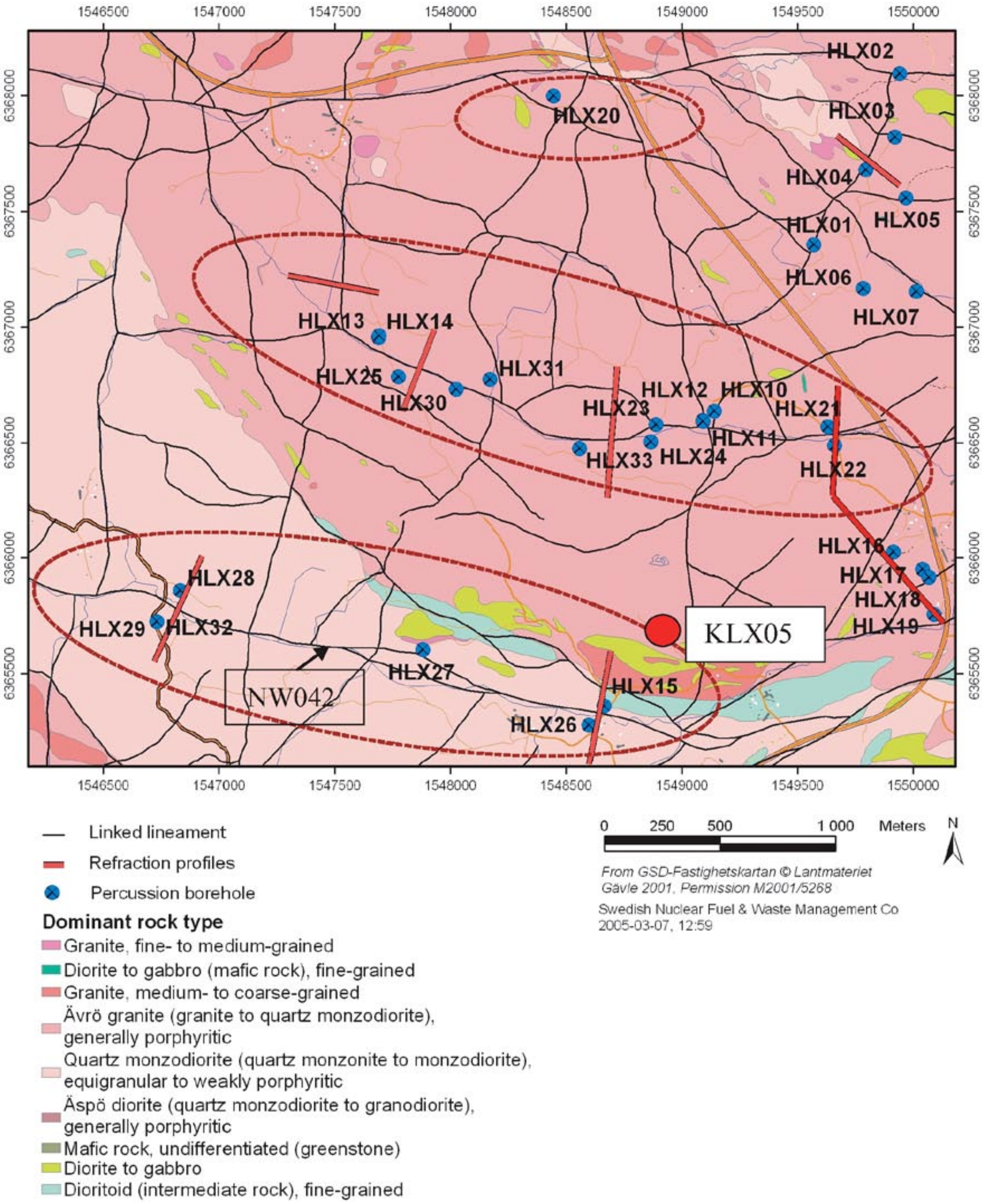


Figure 5-21. *Location of boreholes KLX05, HLX15, HLX26, HLX2, HLX28, HLX29 and HLX32 in the Laxemar subarea.. The map shows the bedrock geology, lineaments and surface geophysical profiles. The boreholes are located within the southernmost ellipse which circumscribes the east-west trending lineament NW042.*

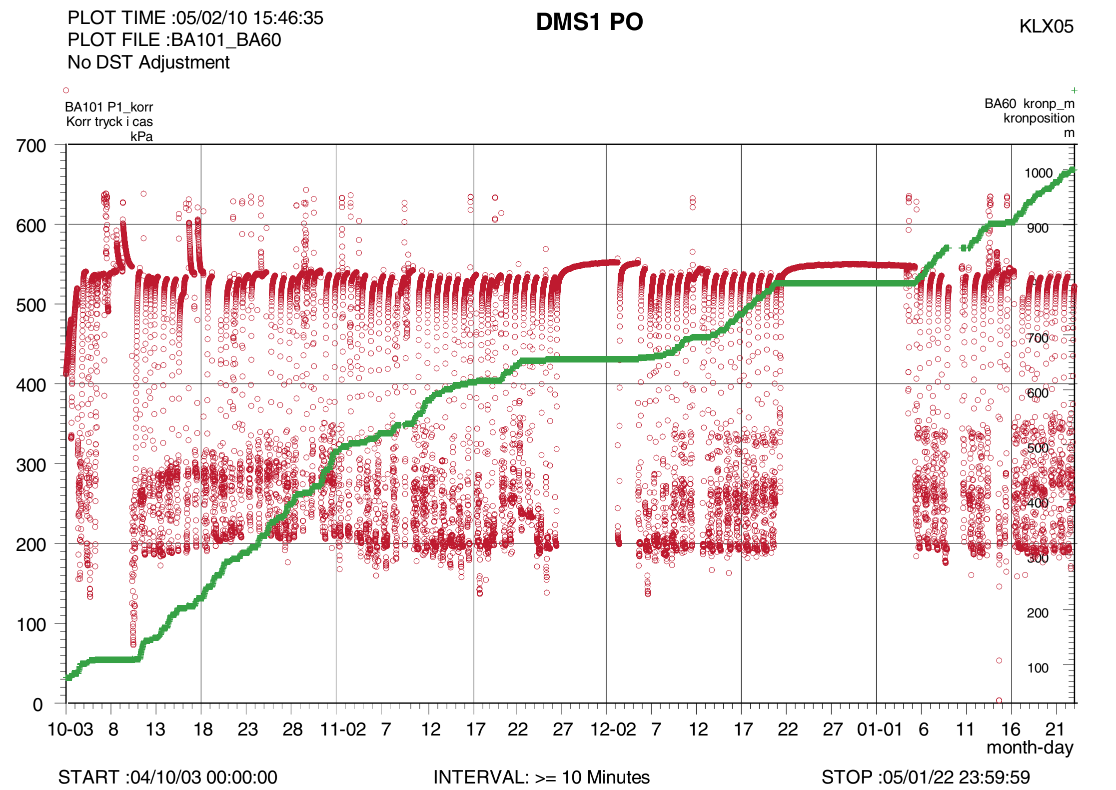


Figure 5-22. *Drill bit position (green) and water level from air lift pumping (red). The water level is expressed as the pressure in kPa of the water column overlying the pressure gauge i.e the ambient air-pressure has been subtracted. The pressure gauge is emplaced at 90 m borehole length. The drill bit position is given in cm × 10³.*

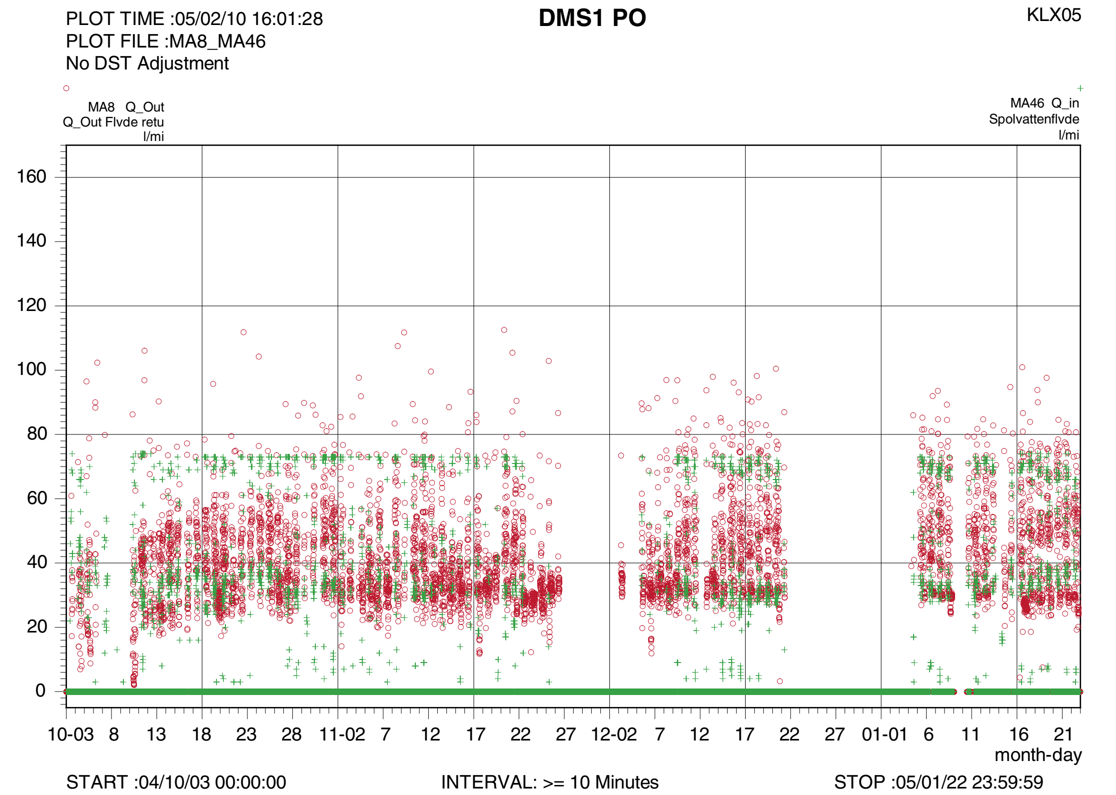


Figure 5-23. *Flushing water flow (green) and return water flow (red) in litres per minute.*

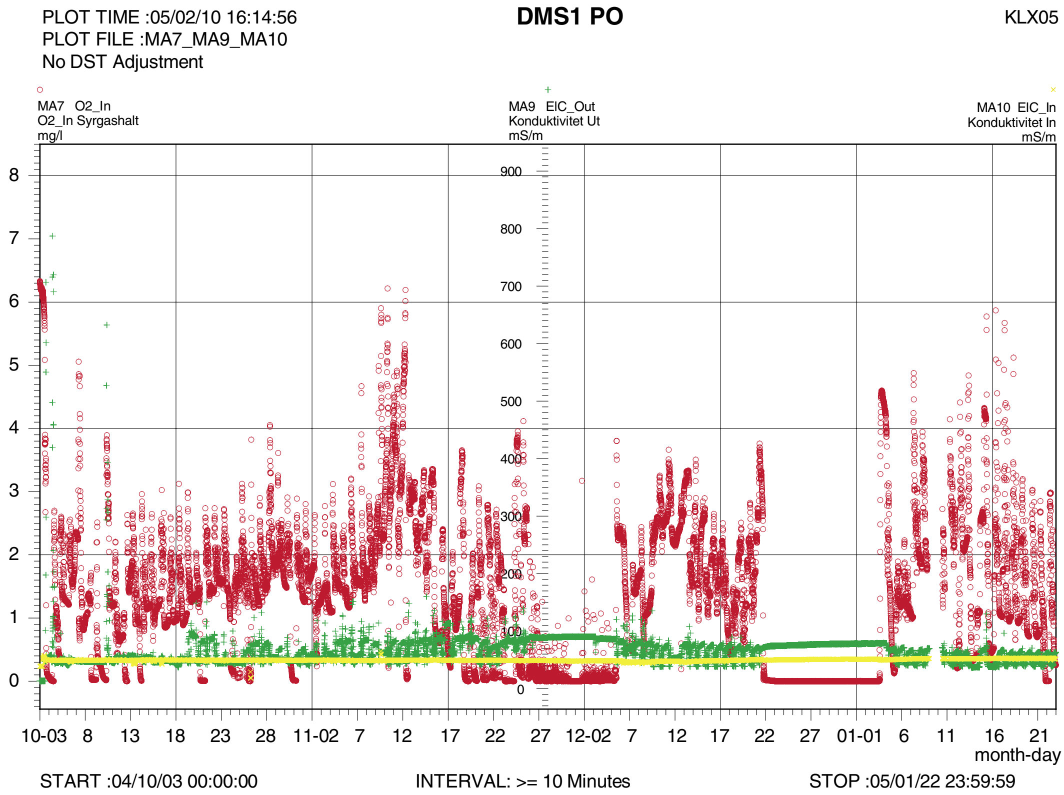


Figure 5-24. *Conductivity of flushing water (yellow) and return water (green). The oxygen content in mg/l of the flushing water (red) is also shown. The oxygen content of the flushing water is normally below 4 mg/l. The initially high conductivities in the return water are attributed to drilling through concrete.*

Figure 5-22 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 5-23 shows the flushing water flow (green) entering the hole and the return water flow (red).

Figure 5-24 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 4 mg/L. The initially high conductivities in the return water are attributed to drilling through concrete.

5.4.5 Measurements of flushing water and drill cuttings

A calculation of accumulated water flow based on water flow measurements from the DMS system (continuous readings) is given in Figure 5-25.

The amount of flushing water consumed during drilling was 1,800 m^3, giving an average consumption of ca 2.0 m^3 per metre drilled. The amount of effluent return water from drilling in KLX05 was 2,260 m^3, giving an average consumption of ca 2.5 m^3 per metre drilled.

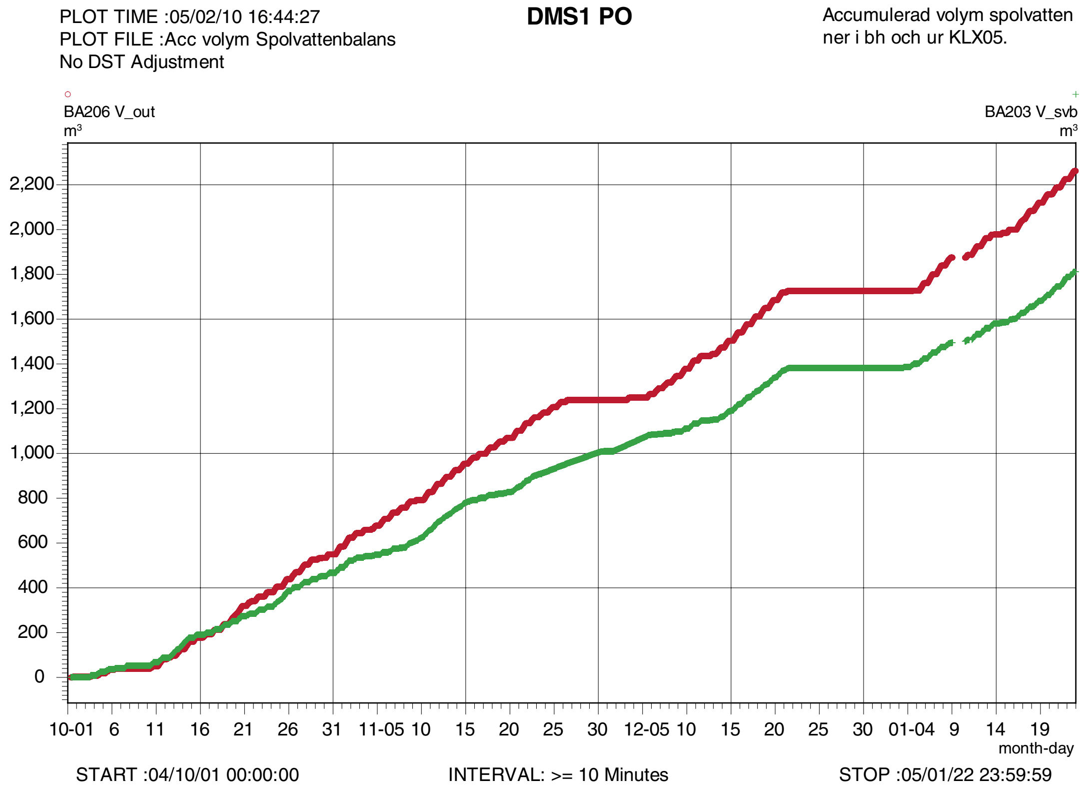


Figure 5-25. *Flushing water balance from KLX03 as recorded by the DMS system. The accumulated volume of the ingoing flushing water is shown in green and the outgoing return water is shown in red.*

Drill cutting balance

The weight of cuttings in the settling containers amounted to 3,300 kg. The content of suspended material in the return water was not analysed in borehole KLX05, however previous sampling has shown the content to be 400 mg/L /5/. The amount of material in suspension carried with the return water would amount to 900 kg. The theoretical amount that should be produced from drilling with 76 mm triple tubing over a length of 900 m is 6,000 kg assuming a density of 2.65 kg/dm³. This means that about 70% of the material liberated by drilling is removed from 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 75% of the introduced uranine was retrieved during drilling.

Table 5-15. Balance calculation of uranine tracer in KLX05.

Average uranine content IN (mg/L)	0.20
Volume IN (m³)	1,800
Amount uranine introduced (g)	360
Average uranine content OUT (mg/L)	0.12
Volume OUT (m³)	2,260
Amount uranine recovered (g)	270

5.5 Geology

The geological results based on the Boremap logging, /3/, are shown in Appendix 1.

The upper 460 m is lithologically heterogeneous with predomintly Ävrö granite, diorite/gabbro or granite together with minor sections of fine-grained dioritoide and fine grained diorite-gabbro. Below 460 m the core is dominated by quartz monzodiorite with minor sections of pegmatite and fine-grained granite.

Oxidation (red-staining) and saussuritization i.e. alteration of calcic plagioclase feldspar, occur sporadically throughout the length of the borehole.

The distribution of total fractures in the core is rather homogeneous with a frequency of 0–10 fractures/m. Slight increases in fracture frequency do however occur locally. Two narrow sections with crushed rock (fracture frequency > 40) have been noted at 510 and 655 m drilled length respectively.

5.6 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.

5.7 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 is shown in Figure 5-26. Precautionary guidelines 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.

Drilling of environmental monitoring wells

Two environmental monitoring wells SSM000212 and SSM000213 were drilled and the locations are shown in Figure 5-26.

Technical specifications on drilling of the environmental monitoring wells are given in /4/.

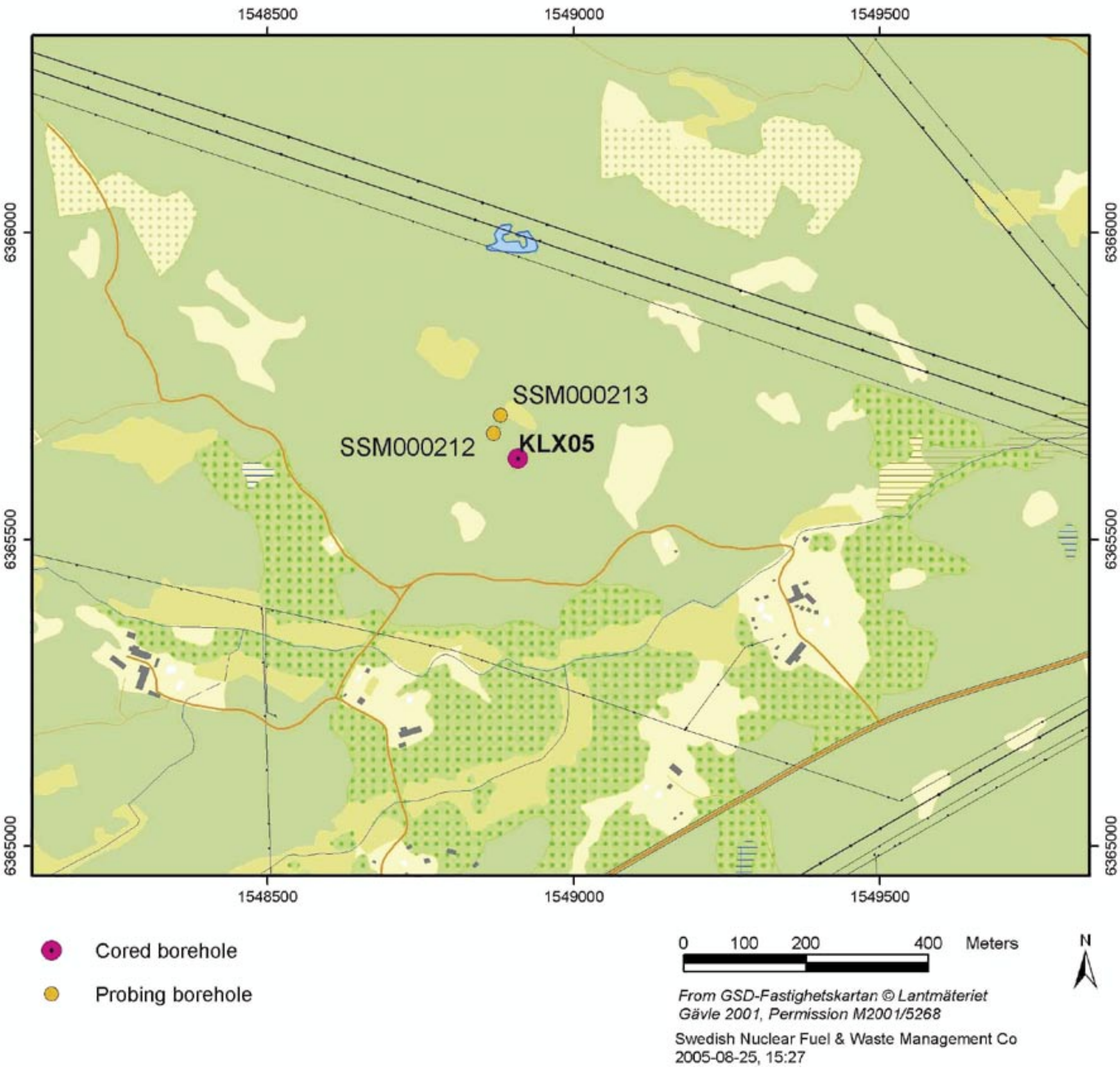


Figure 5-26. *Location of environmental monitoring wells SSM000212 and SSM000213 in relation to the core drill site for KLX05. The effluent return water was infiltrated to the ground some 50 m north of KLX05.*

Reference sampling

A reference sample of surface soil from the core drill site was taken on July 27, 2004. The sample ID is SKB PO 09006.

Reference samples of ground water from the environmental wells were not taken, see also section 5.8.

Monitoring of soil ground water levels

Pressure loggers (transducers) for measuring the ground water table were installed as shown in Table 5-16.

Table 5-16. Measurements in environmental monitoring wells.

Monitoring well	Measurement	Date
SSM000212	Transducer installation	040902–050407
SSM000213	Transducer installation	040902–

Monitoring of effluent water

The effluent water, i.e. discharge to the ground, from the core drilling of KLX05 did not exceed the guideline value of 300 mS/m during drilling in rock. Drilling through concrete on October 1, 3, 4 and 10 generated shorter periods of 2–4 hours with conductivity values up to 700–800 mS/m, as can be seen in the DMS data given in Figure 5-22. The initially high conductivity does therefore not indicate the presence of saline ground water. The conductivity in the effluent water returned to a stable value of typically below 100 mS/m while drilling in rock.

The uranine content was below 0.25 mg/l, see Figure 5-16.

The concentration of suspended material was not analysed in this borehole, however previous sampling has shown that the concentration was well below the prescribed guideline value /5/.

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

5.7.1 Consumption of oil and chemicals

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

The concrete consumption was 3,000 litres in total. The concrete was based on white silica, low alkali cement with a 2% addition of calcium chloride as an accelerator.

5.8 Nonconformities

No reference water samples were taken from the environmental wells, this has been reported as a formal nonconformity.

High conductivity values (700–800 mS/m) in the effluent return water were recorded by the DMS system during short periods of time in the initial stages of drilling. Releases of small quantities of water with a conductivity exceeding the guideline value of 300 mS/m cannot be excluded. The high initial conductivities have however been attributed to drilling through concrete and should not be taken as an indication of saline ground water. No action was taken as the conductivity dropped to a stable value of typically below 100 mS/m when drilling in rock was resumed. A formal nonconformity report has however been submitted.

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

6 References

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

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

/3/ **Ehrenborg and Dahlin, 2005.** Boremap mapping of core drilled borehole KLX05, SKB P-05-224, Svensk Kärnbränslehantering AB.

/4/ **Johansson and Adestam, 2004.** Installation of groundwater monitoring wells in the Laxemar area, SKB P-04-317, Svensk Kärnbränslehantering AB.

/5/ **Ask, Morosini, Samuelsson, Ekström and Håkanson, 2004.** Drilling of cored borehole KSH03, SKB P-04-233, Svensk Kärnbränslehantering AB.

/6/ **Ask, Morosini, Samuelsson and Ekström, 2004.** Drilling of cored borehole KSH02, SKB P-04-151, Svensk Kärnbränslehantering AB.

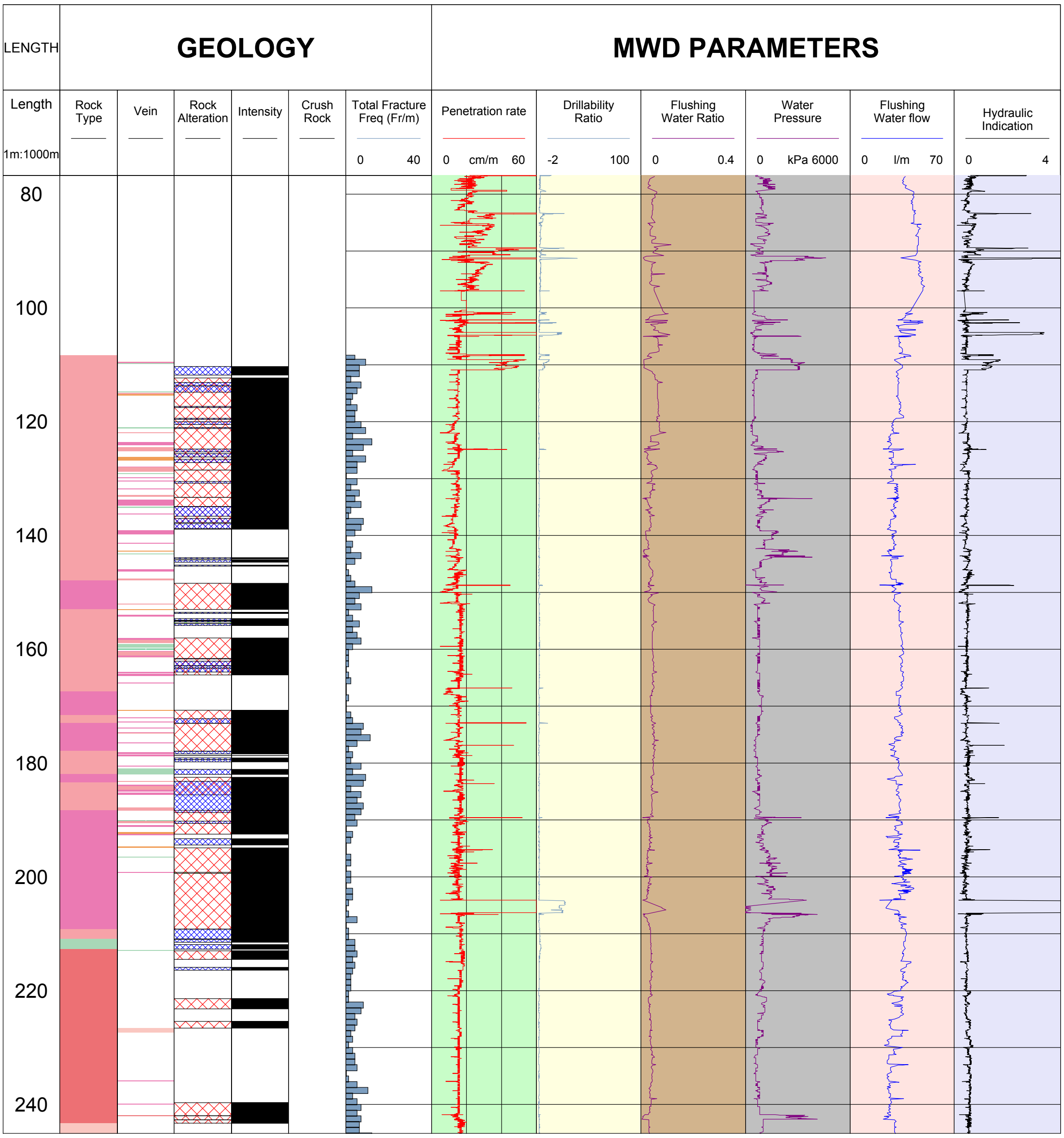
Geology and MWD Parameters KLX05

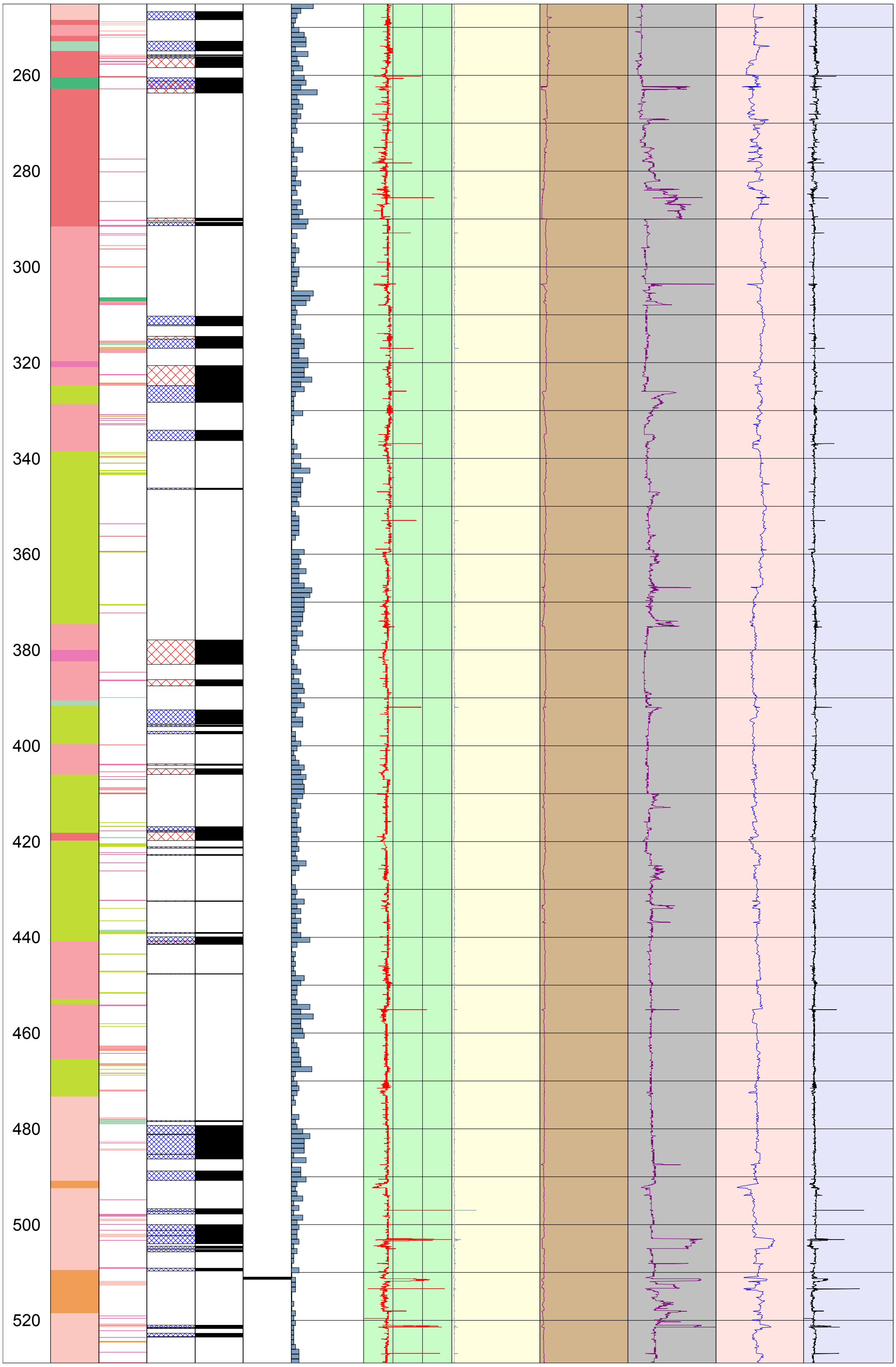
Site	LAXEMAR	**Coordinate System**	RT90-RHB70
Borehole	KLX05	**Northing [m]**	6365632.52
Diameter [mm]	76	**Easting [m]**	1548909.46
Length [m]	1000.160	**Elevation [m.a.s.l.]**	17.56
Bearing [°]	190.05	**Drilling Start Date**	2004-08-11 07:00:00
Inclination [°]	-65.15	**Drilling Stop Date**	2005-01-22 13:45:00
Date of mapping	2005-03-14 16:38:00	**Plot Date**	2005-08-23 23:28:38

ROCKTYPE LAXEMAR
- Fine-grained granite
- Pegmatite
- Granite
- Ävrö granite
- Quartz monzodiorite
- Diorite / Gabbro
- Fine-grained dioritoid
- Fine-grained diorite-gabbro

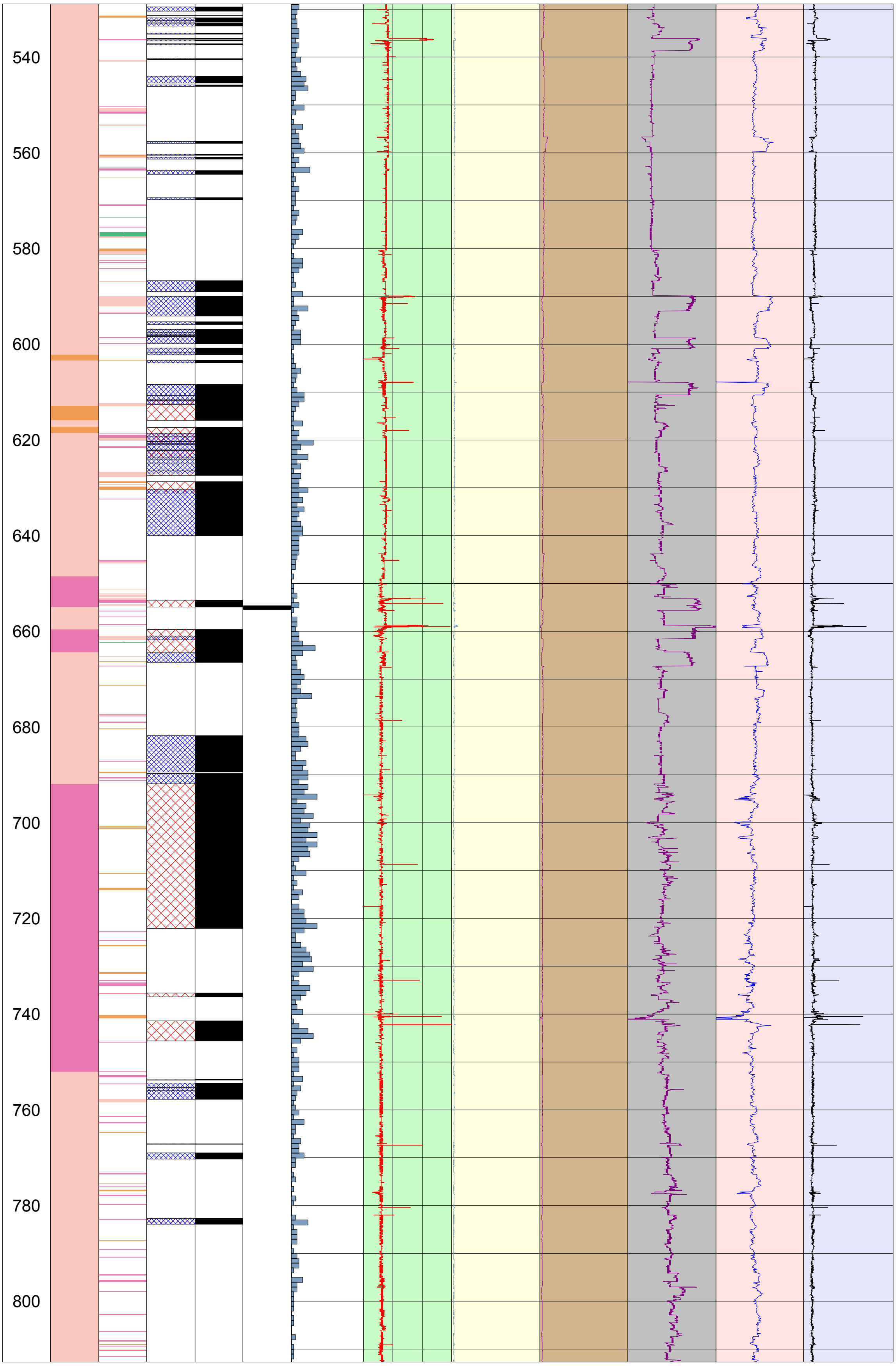
ROCK ALTERATION
- Oxidized
- Chloritisized
- Epidotisized
- Saussuritization

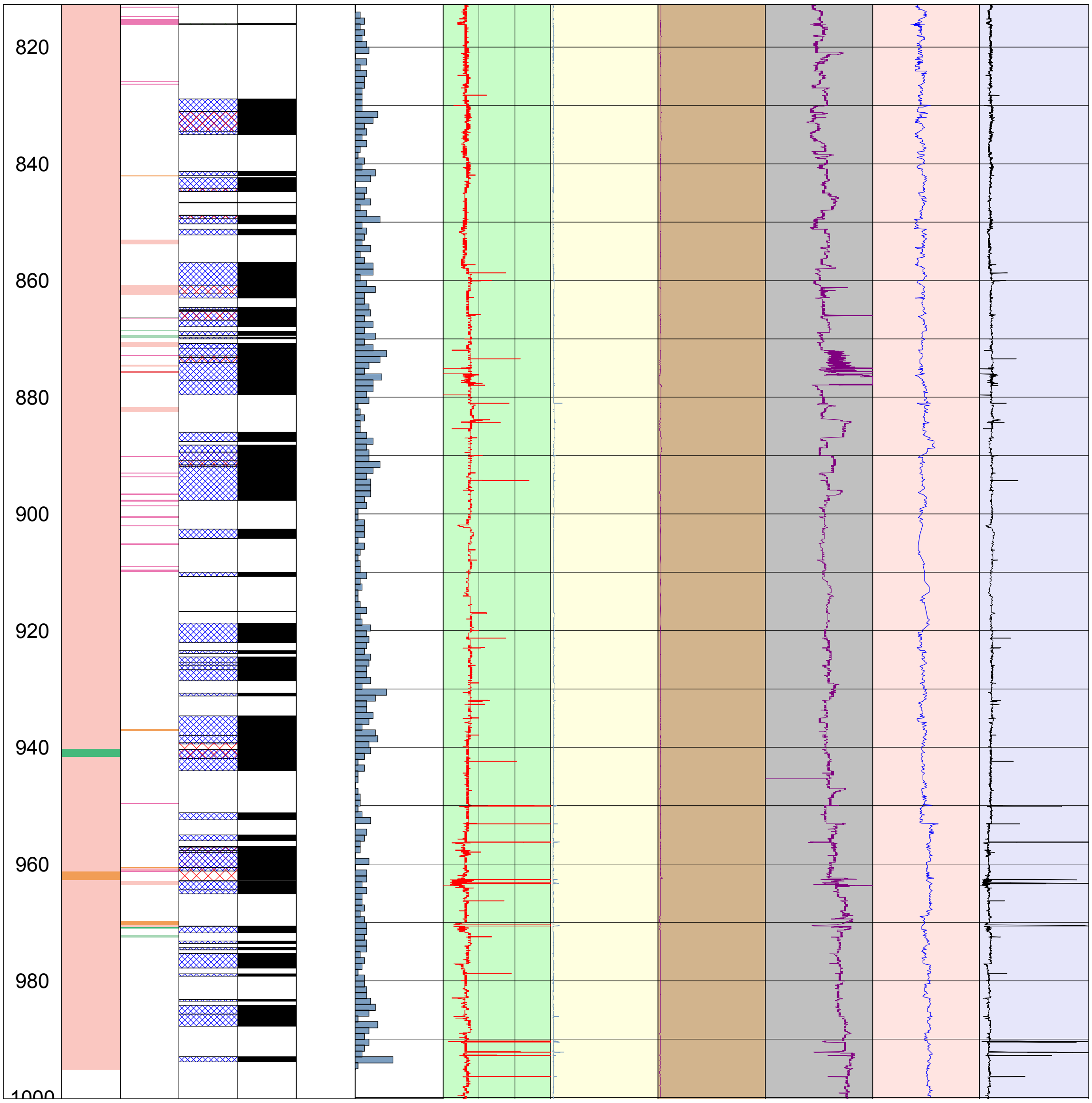
INTENSITY
- Faint
- Weak
- Medium
- Strong





260
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


820
840
860
880
900
920
940
960
980
1000

Appendix 2

Chemical results

Borehole	KLX05	KLX05	KLX05	HLX10
Date of measurement	8/16/04	8/16/04	10/16/04	2/1/05
Upper section limit (m)	15.00	15.00	107.8	3.00
Lower section limit (m)	100.00	100.00	202.94	85.00
Sample_no	7670	7671	7861	10072
Groundwater Chemistry Class	3	5	3	5
pH	7.99	7.88	8.07	8.25
Conductivity mS/m	51.8	53.3	63.2	54,0
TOC mg/l				5.5
Drill water %			16.2	
Densitet g/cm^3				0.9965
Charge balance %			–1.32	–0.44
Na mg/l			109	105
K mg/l			2.82	3.55
Ca mg/l			23.6	11.8
Mg mg/l			6.7	3.9
HCO3 mg/l Alkalinity	302	301	284	221
Cl mg/l	6.9	10.0	45.7	29.1
SO4 mg/l	21.7	22.6	32.3	46.3
SO4_S mg/l Total Sulphur			10.7	16.0
Br mg/l	<0.2	<0.2	<0.2	<0.2
F mg/l	1.93	2.1	2.33	3.46
Si mg/l			7.69	5.55
Fe mg/l Total Iron			1.17	0.101
Mn mg/l			0.151	0.0605
Li mg/l			0.019	0.01
Sr mg/l			0.366	0.111
PMC % Modern Carbon			62.56	51.72
C-13 dev PDB			–14.29	–16.43
AGE_BP Groundwater age			3,714	5,242
AGE_BP_CORR			35	35
D dev SMOW			–75.5	–75,0
Tr TU			1.9	5.2
O-18 dev SMOW			–10.6	–10.9
B-10 B-10/B-11			0.2368	0.2403
S-34 dev SMOW			17.6	16.9
Cl-37 dev SMOC			0.15	–0.05
Sr-87 Sr-87/Sr86			0.715285	0.715733

Appendix 3

Chemistry – analytical method

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		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*	Filtering membrane filter	red	Analytica
C-13, PMC	2 st 100 ml brown glass		green	Waterloo
S-34	1,000 ml		green	IFE

SKB Chemistry class 5.

Analysis	Sample bottle	Preparation	SKB label	Laboratory
pH, conductivity, alkalinity	250 ml		green	Äspö/field
Anions (F^-, Br^-, Cl^-, SO_4^{2-})	250 ml		green	Äspö/field
Uranine	100 ml brown glass		green	Äspö/field
Main components (except Fe, Mn)	Analytica's 100 ml acid washed	1 ml HNO_3 suprapur, filtering membrane filter	red	Analytica
Fe II + Fe tot	500 ml acid washed PEH	5 ml HCl suprapur, filtering membrane filter	red	Äspö/field
NH_4	25 ml in 2 st reagents dished 50 ml measurement vessel			Äspö/field
		Filtering Pallfilter		
HS^-	2 st Winkler	Conserved with 0,5 ml 1M ZnAc and 1M NaOH		Äspö/field
B-10				
As, In				
Environmental metals				
Lanthanides				
Trace elements	Analytica's 100 ml acid washed	1 ml HNO_3 suprapur, filtering membrane filter	red	Analytica
I^-	Analytica's 100 ml	Filtering membrane filter	green	Analytica
NO_2, NO_3, NO_2+NO_3 and PO_4	250 ml	Filtering Pallfilter	green	System ekologen
DOC	250 ml	Filtering Pallfilter	green	Paavo Ristola
TOC	250 ml		green	Paavo Ristola

Deuterium, O-18	100 ml square		green	IFE
Sr-87	100 ml square		green	IFE
Tritium	500 ml dried	Flooded at least once	green	Waterloo
Cl-37	500 ml		green	Waterloo
C-13, PMC	2 st 100 ml brown glass		green	Waterloo
S-34	1,000 ml		green	IFE
U-, Th-isotopes	1,000 ml HDPE		green	SUERC
Ra-, Rn-isotopes	1,000 ml HDPE		green	SUERC
Archive samples				
2 st 100 ml acid washed		1 ml HNO_3 suprapur, filtering membrane filter	red	
2 st 250 ml		Filtering Pallfilter	green	

Comment: TOC, C-13, PMC, S-34, Cl-37, Sr-87, B-10, As, In, environmental metals, lanthanides, trace elements, U-, Th-, Ra- and Rn-isotopes are options.

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 selected set of data from the boreholes KLX05 and HLX10. The errors do not exceed ± 5% in the samples 7861 and 10072 which is fully satisfactory.

The charge balance error is not calculated for the samples 7670 and 7671 collected in KLX05.

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. Control analyses were not performed in this case because of the small numbers of samples taken.
- 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%.

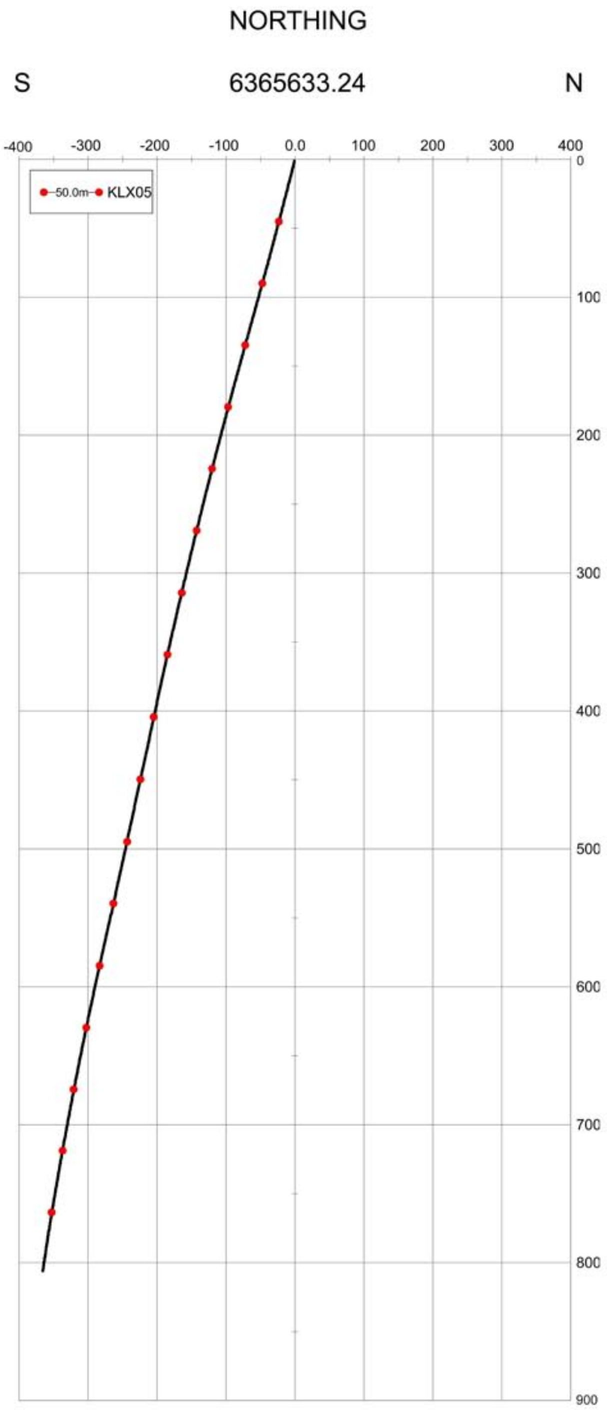
  $$\text{Rel. Error (\%)} = 100\times \frac{(\sum \text{cations(equivalents)} - \sum \text{anions(equivalents)})}{(\sum \text{cations(equivalents)} + \sum \text{anions(equivalents)})}$$

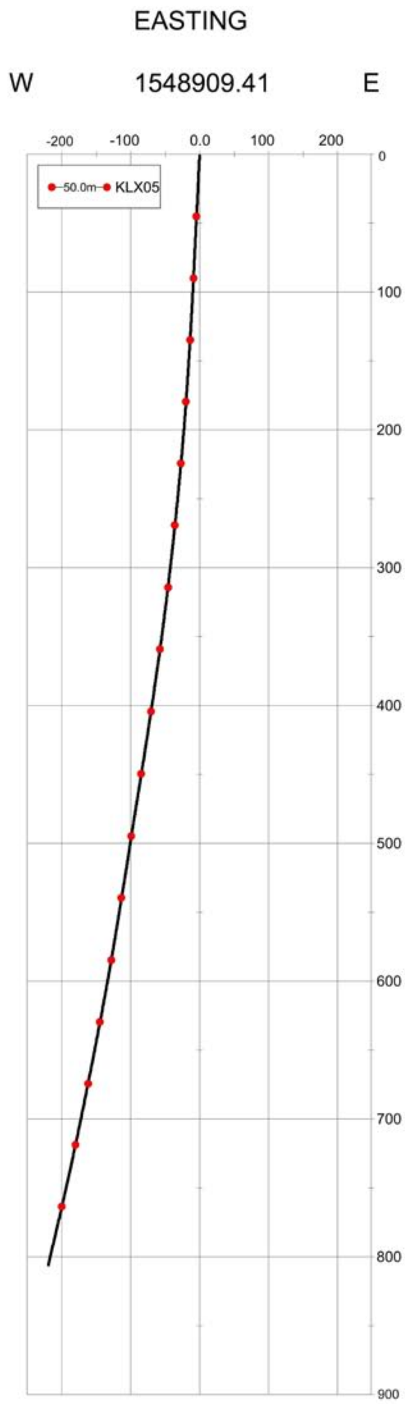
  General expert judgement of plausibility based on earlier results and experiences.

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.

Vertical section/Orthogonal projection

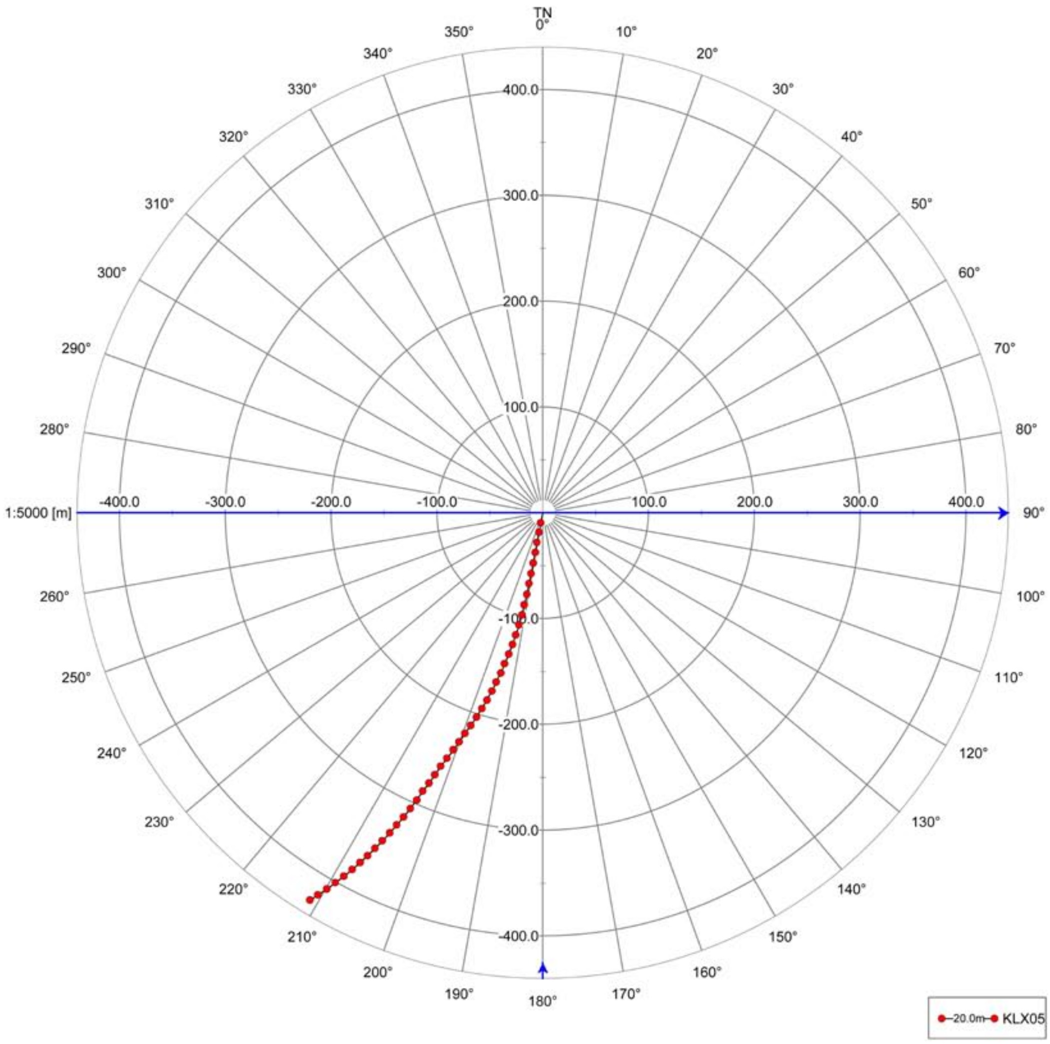
Borehole	KLX05
Site	Laxemar
Coordinate system	RT90-RHB70
Length	1000.160
Bearing	190.05
Inclination	-65.15
● Interval	50 m





Deviation measurement.

SKB	Site	LAXEMAR
	Borehole	KLX05
	View from above	



Appendix 5

Wireline pumping tests

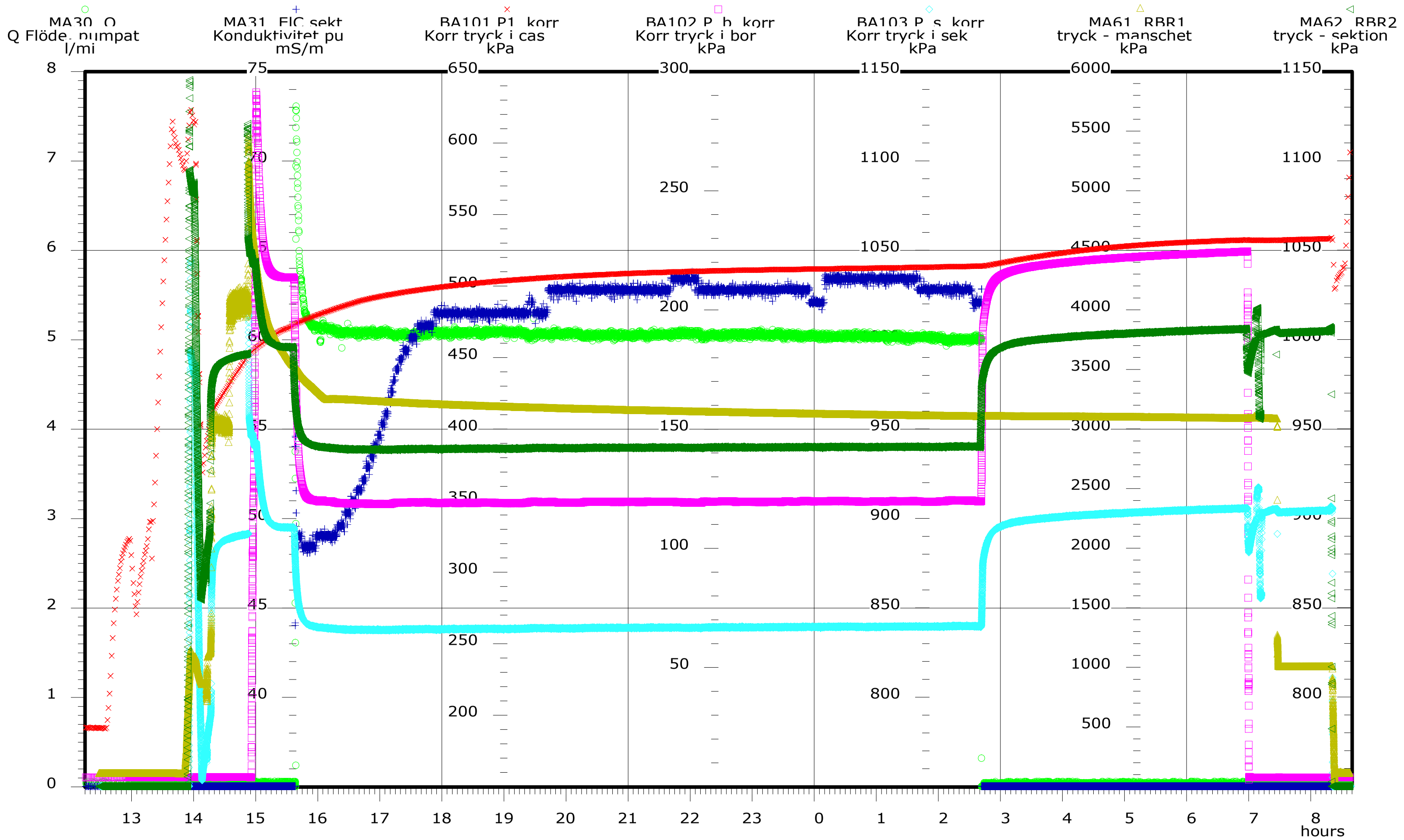
Description of the parameters in the enclosed plots.

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

PLOT TIME :04/10/19 13:47:08
PLOT FILE :P_Pumptest
Adjusted for DST

DMS1 PO

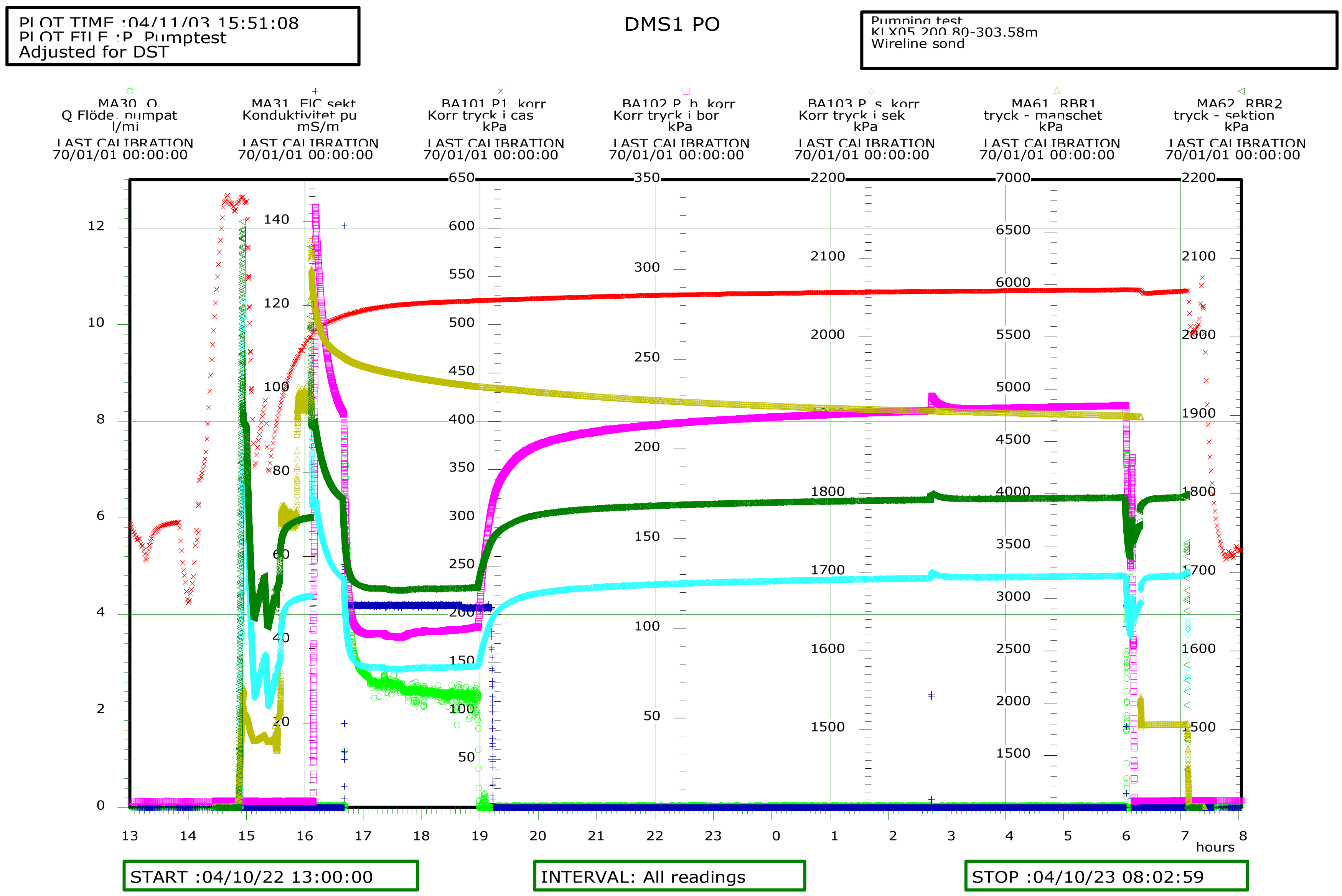
Pumping test
KLX05 107.80-202.94m
Wireline sond

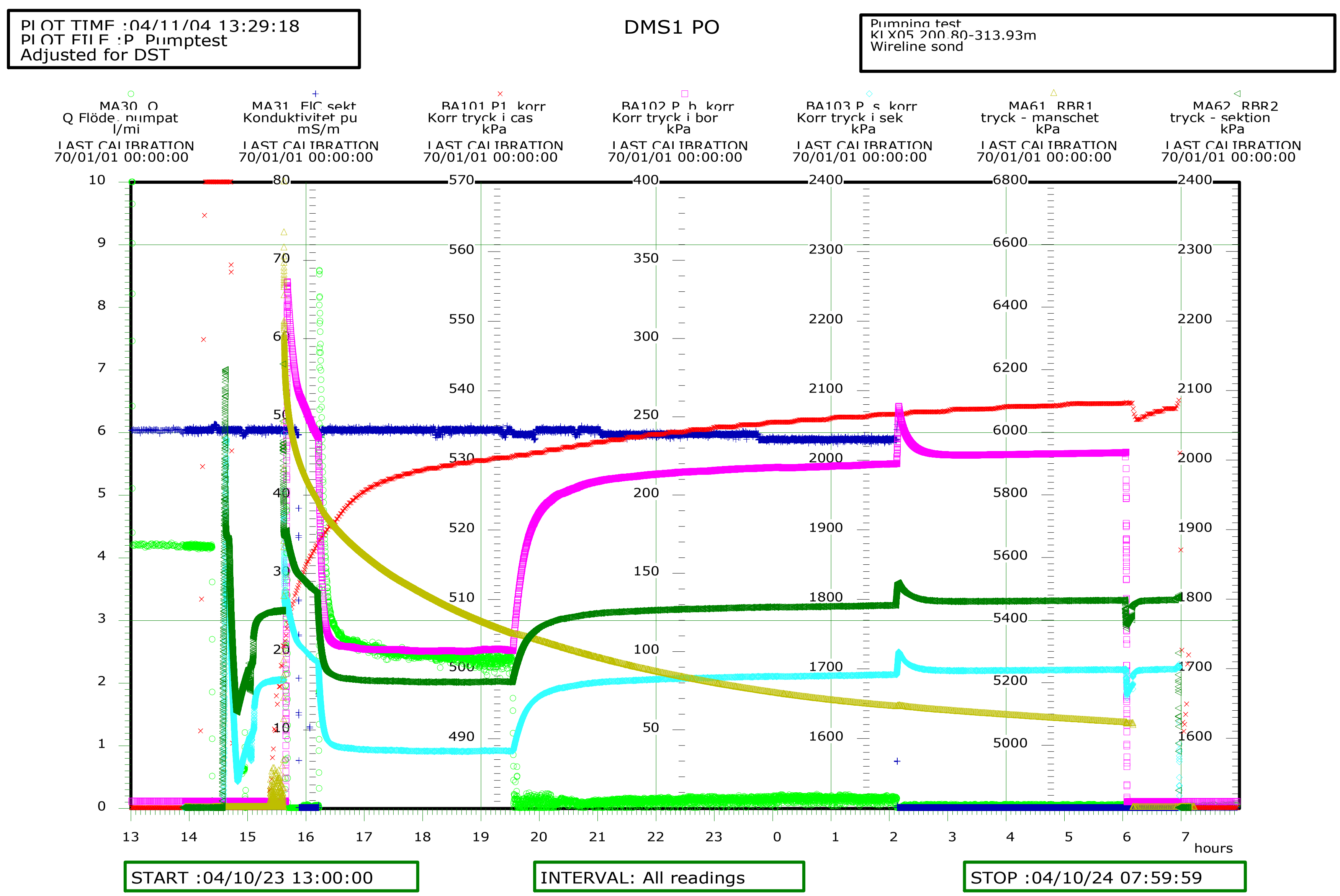


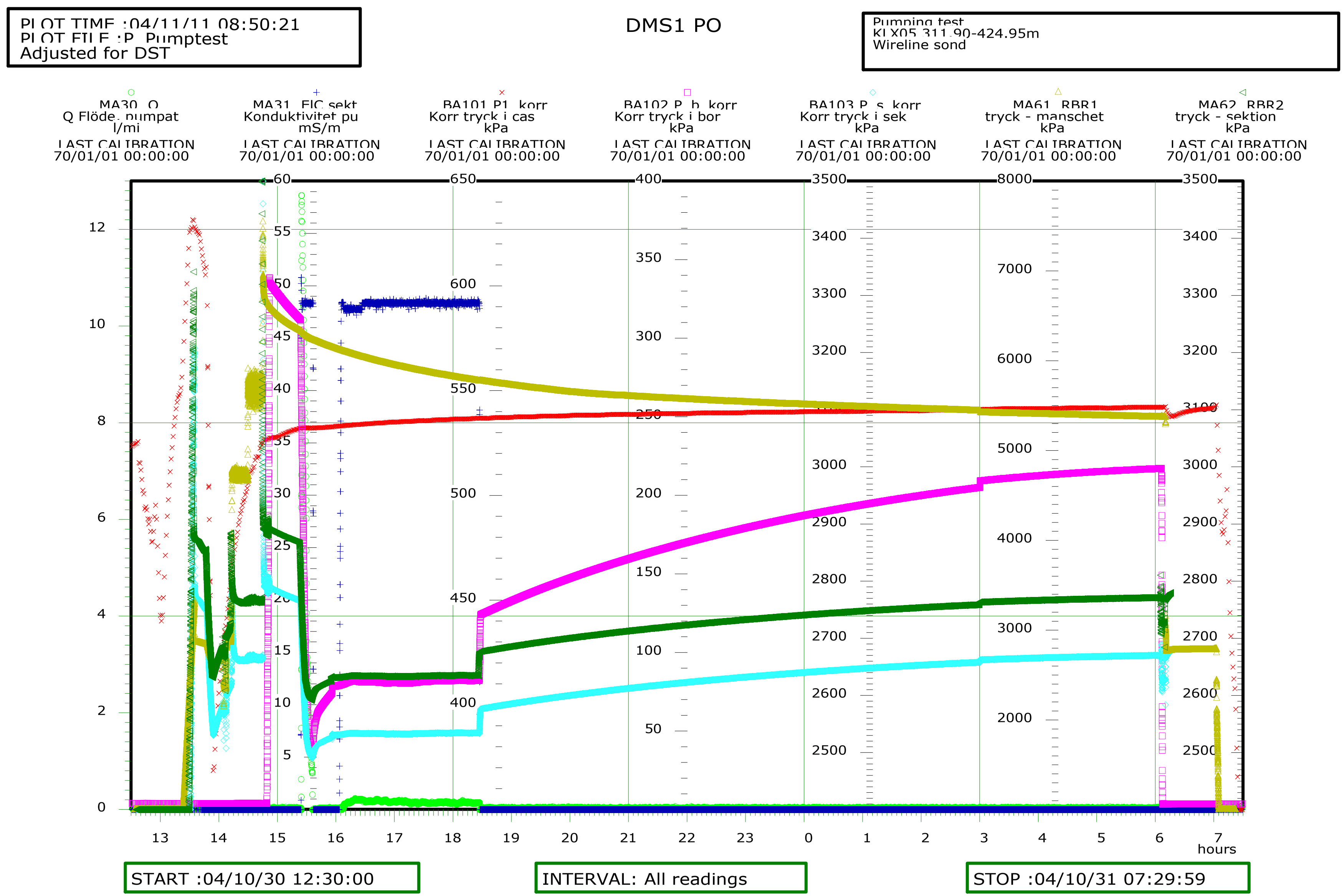
START :04/10/15 12:15:00

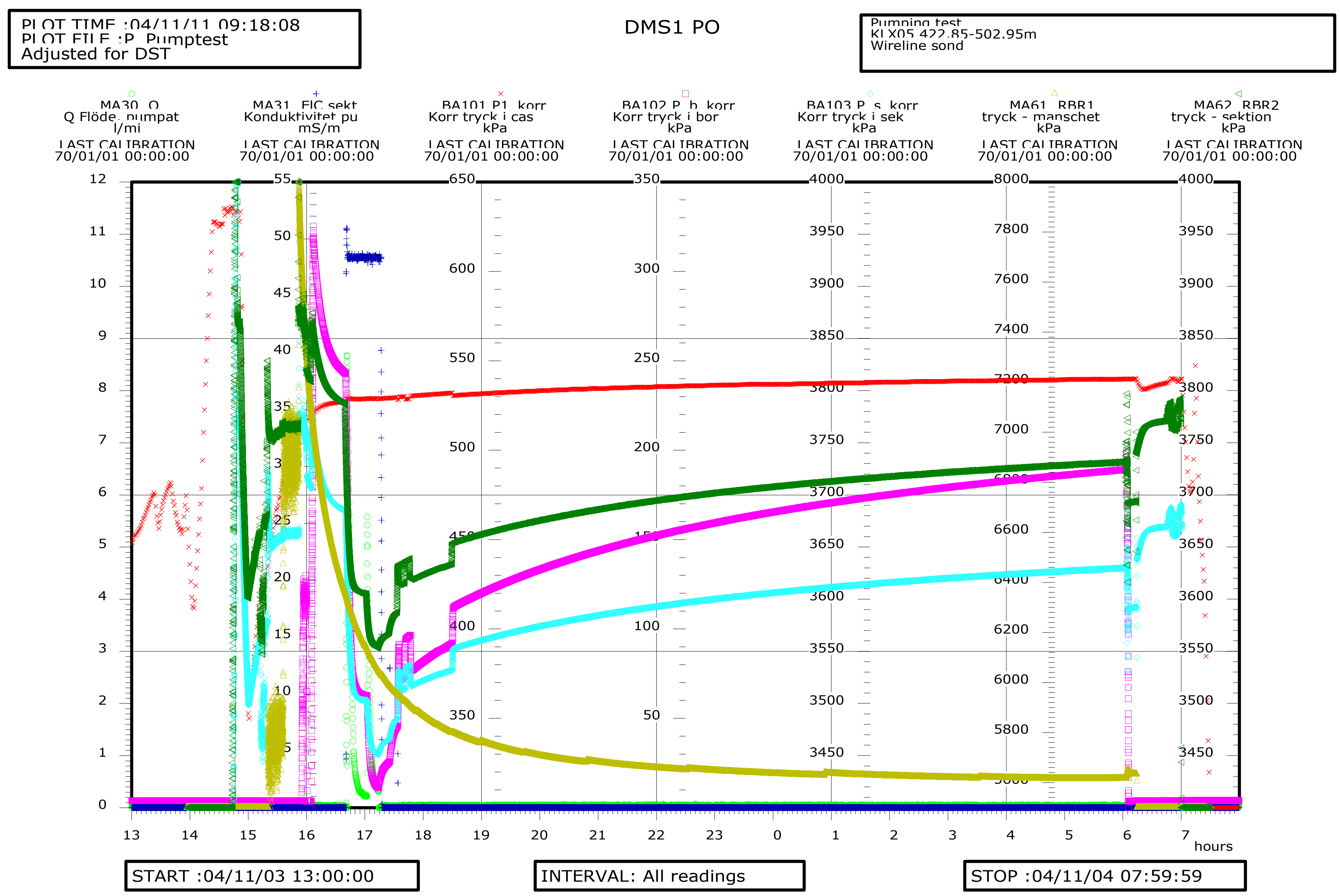
INTERVAL: All readings

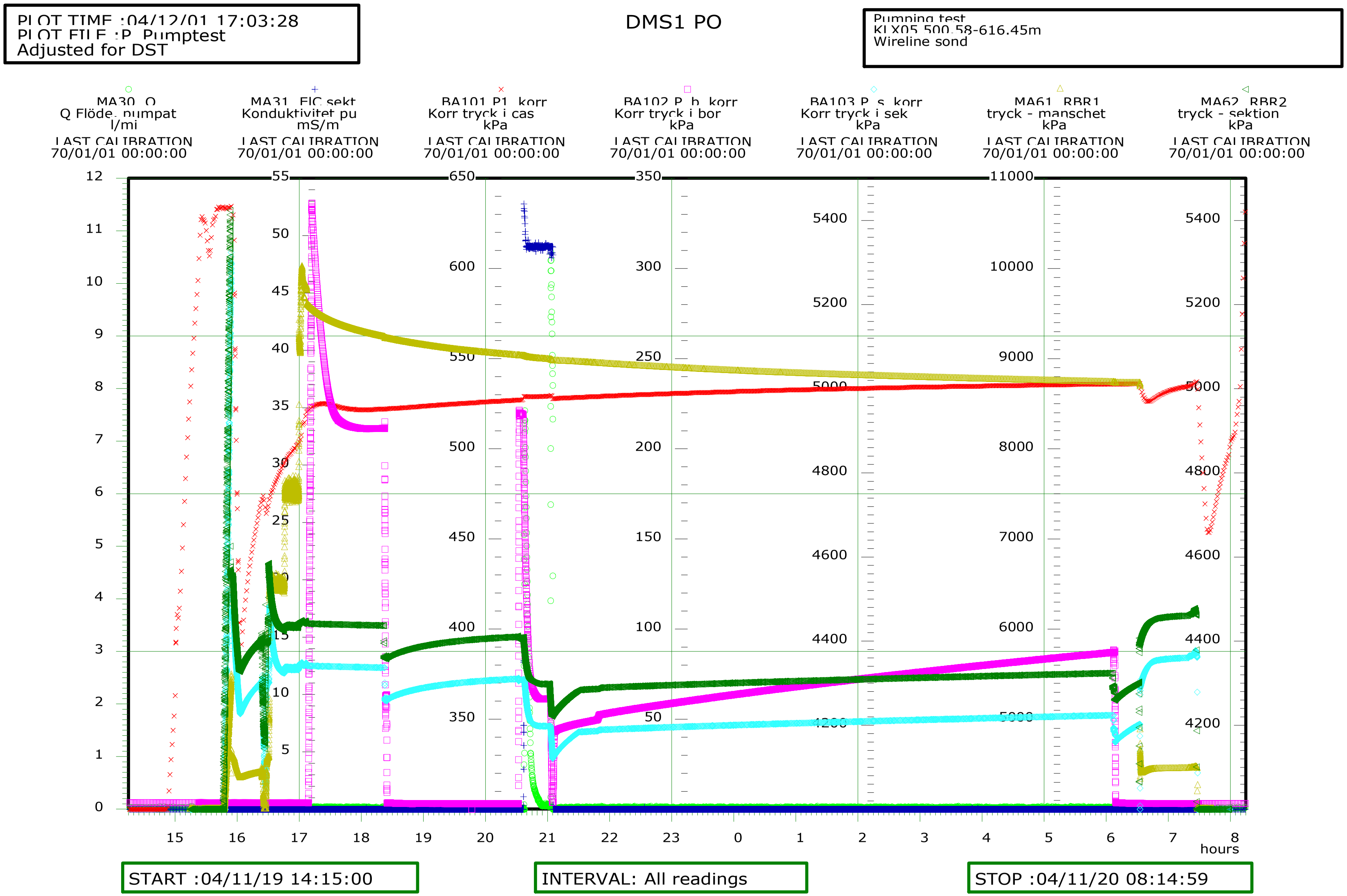
STOP :04/10/16 08:39:59

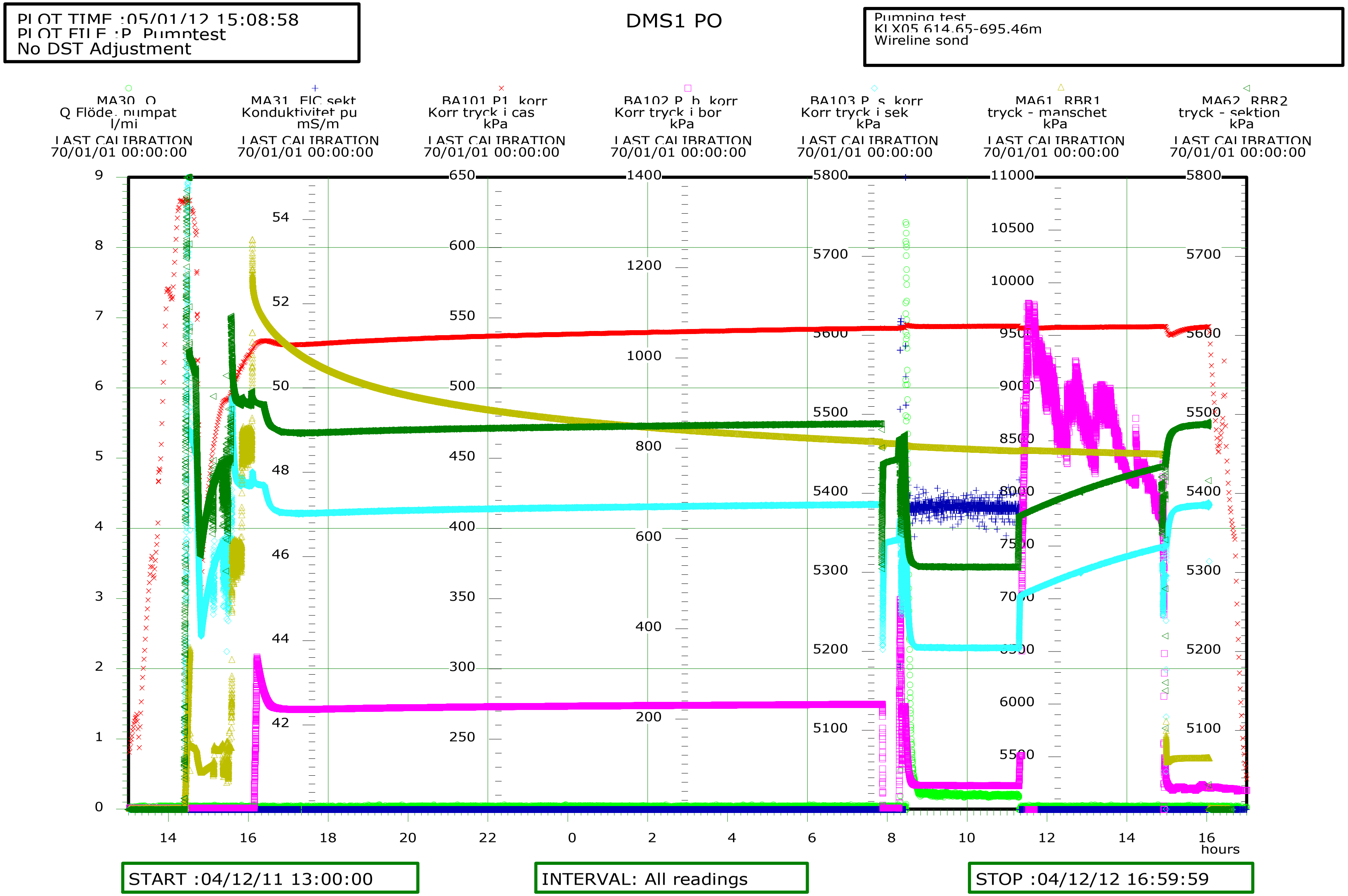

PLOT TIME :04/11/03 15:51:08
PLOT FILE :P_Pumptest
Adjusted for DST
DMS1 PO
Pumping test
KLX05 200.80-303.58m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MA31 EC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BA101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA102 P_b korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA103 P_s korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA62 RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :04/10/22 13:00:00
INTERVAL: All readings
STOP :04/10/23 08:02:59


PLOT TIME :04/11/04 13:29:18
PLOT FILE :P_Pumptest
Adjusted for DST
DMS1 PO
Pumping test
KLX05 200.80-313.93m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MA31 EC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BA101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA102 P_b korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA103 P_s korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA62 RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :04/10/23 13:00:00
INTERVAL: All readings
STOP :04/10/24 07:59:59

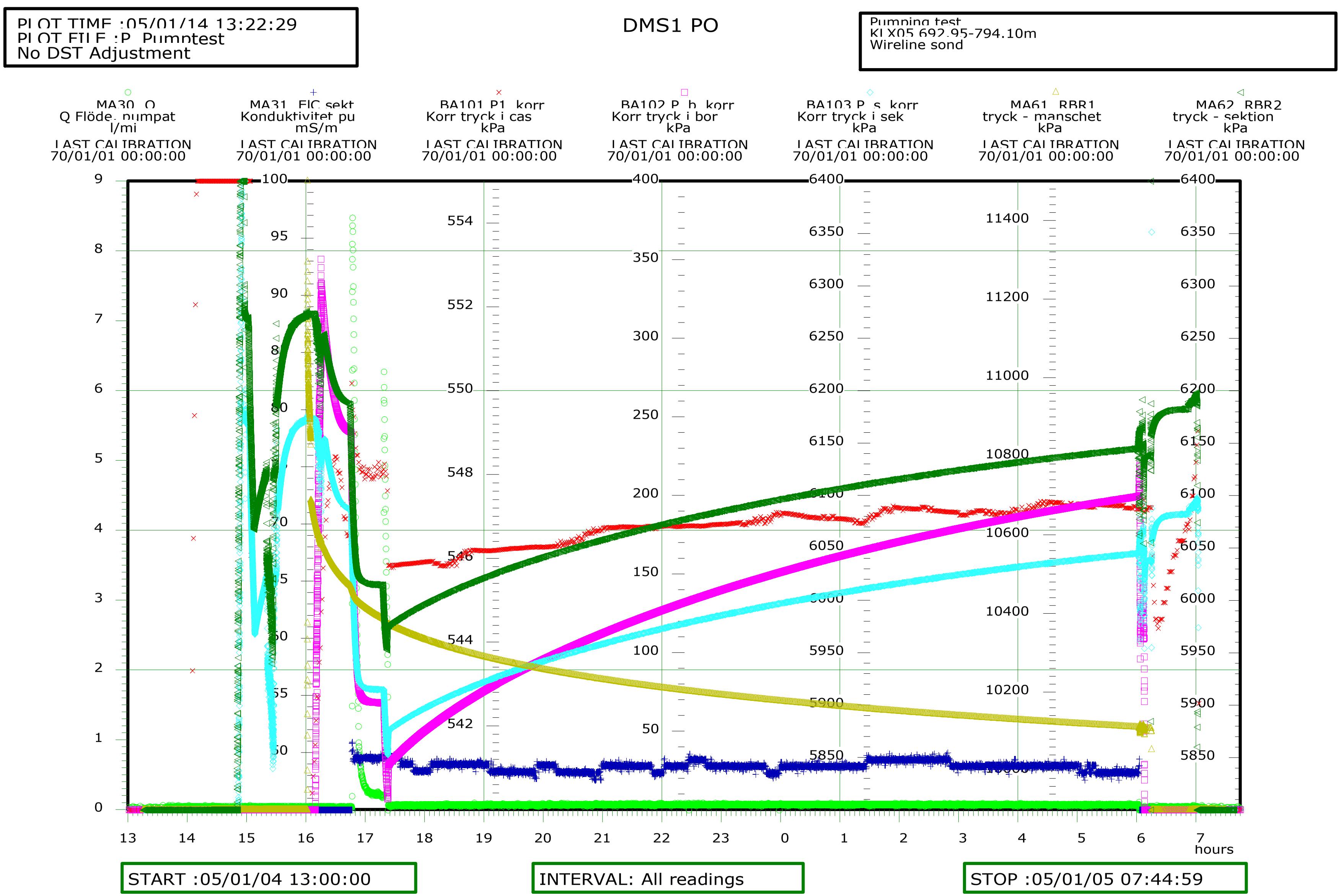

PLOT TIME :04/11/11 08:50:21
PLOT FILE :P_Pumptest
Adjusted for DST
DMS1 PO
Pumping test
KLX05 311.90-424.95m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MA31 EC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BA101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA102 P_b_korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA103 P_s_korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA62 RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :04/10/30 12:30:00
INTERVAL: All readings
STOP :04/10/31 07:29:59

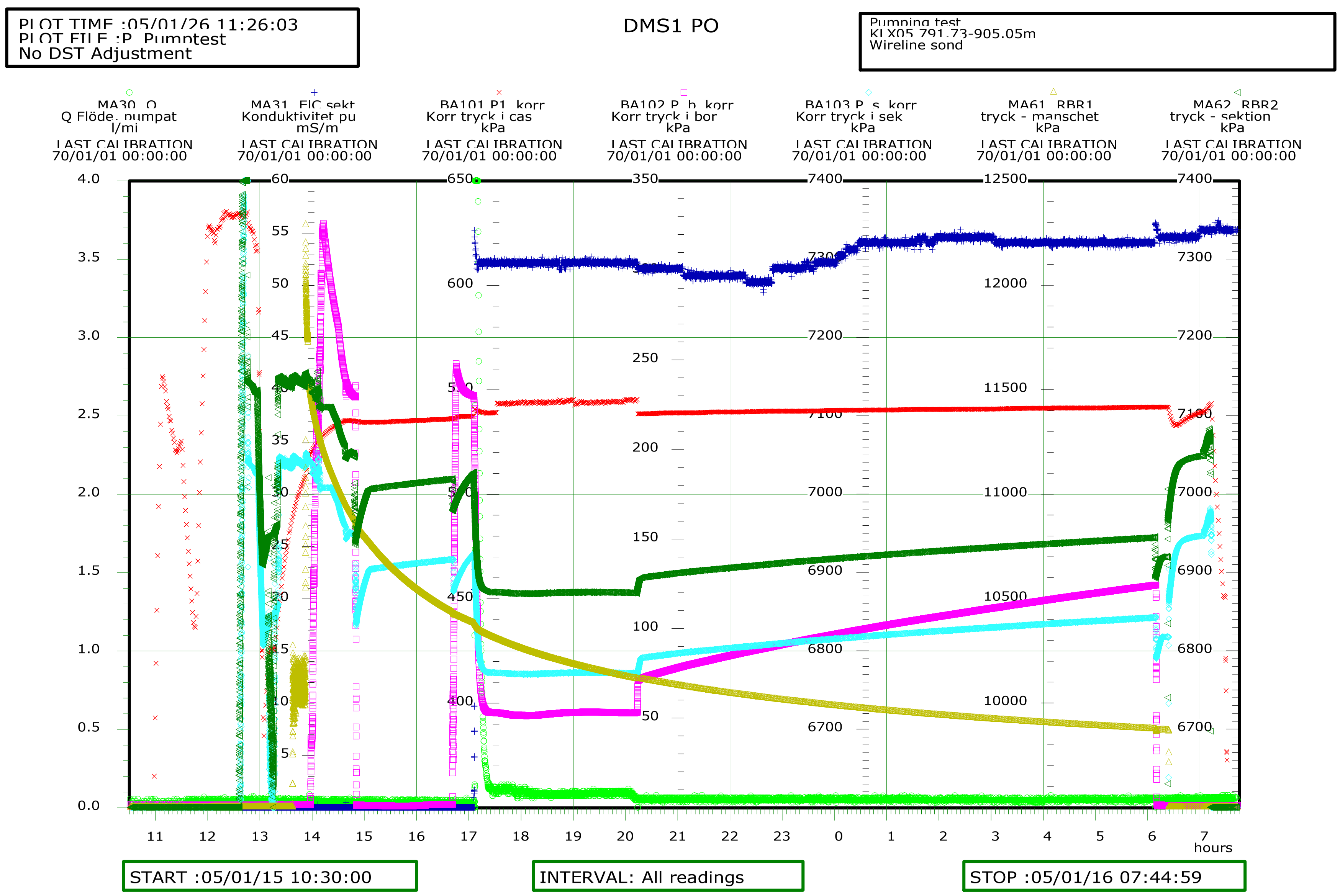

PLOT TIME :04/11/11 09:18:08
PLOT FILE :P_Pumptest
Adjusted for DST
DMS1 PO
Pumping test
KLX05 422.85-502.95m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MA31 EC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BA101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA102 P_b korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA103 P_s korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA62 RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :04/11/03 13:00:00
INTERVAL: All readings
STOP :04/11/04 07:59:59


PLOT TIME :04/12/01 17:03:28
PLOT FILE :P_Pumptest
Adjusted for DST
DMS1 PO
Pumping test
KLX05 500.58-616.45m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MA31 EC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BA101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA102 P_b korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA103 P_s korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA62 RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :04/11/19 14:15:00
INTERVAL: All readings
STOP :04/11/20 08:14:59

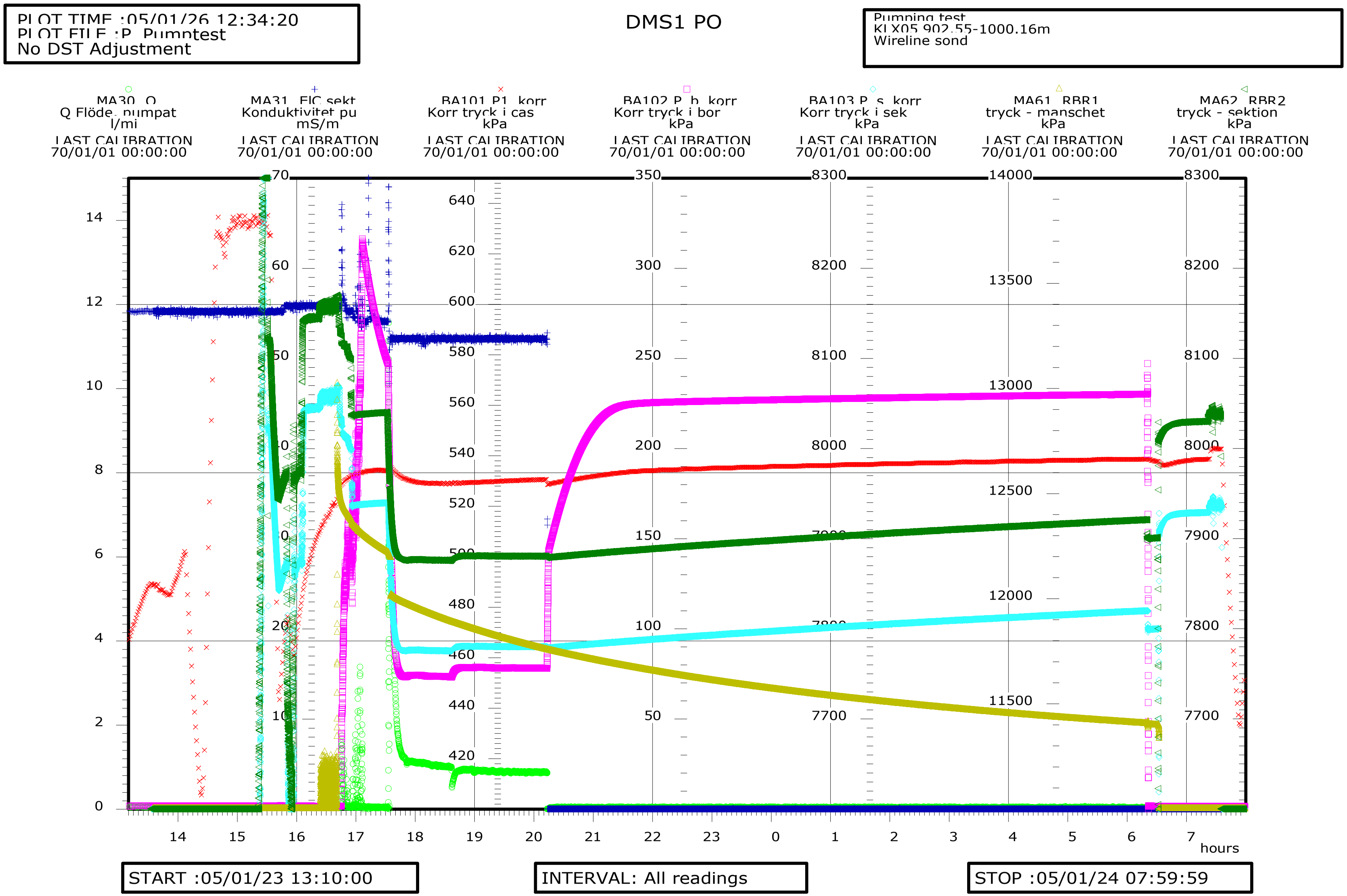


PLOT TIME :05/01/12 15:08:58
PLOT FILE :P_Pumptest
No DST Adjustment
DMS1 PO
Pumping test
KLX05 614.65-695.46m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MA31 EC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BA101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA102 P_b korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA103 P_s korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA62 RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :04/12/11 13:00:00
INTERVAL: All readings
STOP :04/12/12 16:59:59


PLOT TIME :05/01/14 13:22:29
PLOT FILE :P_Pumptest
No DST Adjustment
DMS1 PO
Pumping test
KLX05 692.95-794.10m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MA31 EC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BA101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA102 P_b korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA103 P_s korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA62 RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :05/01/04 13:00:00
INTERVAL: All readings
STOP :05/01/05 07:44:59



PLOT TIME :05/01/26 11:26:03
PLOT FILE :P_Pumptest
No DST Adjustment
DMS1 PO
Pumping test
KLX05 791.73-905.05m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MA31 EC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BA101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA102 P_b korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA103 P_s korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA62 RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :05/01/15 10:30:00
INTERVAL: All readings
STOP :05/01/16 07:44:59


PLOT TIME :05/01/26 12:34:20
PLOT FILE :P_Pumptest
No DST Adjustment
DMS1 PO
Pumping test
KLX05 902.55-1000.16m
Wireline sond
MA30 Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MA31 EC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BA101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA102 P_h korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BA103 P_s korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA62 RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :05/01/23 13:10:00
INTERVAL: All readings
STOP :05/01/24 07:59:59

Appendix 6

Absolute pressure measurement

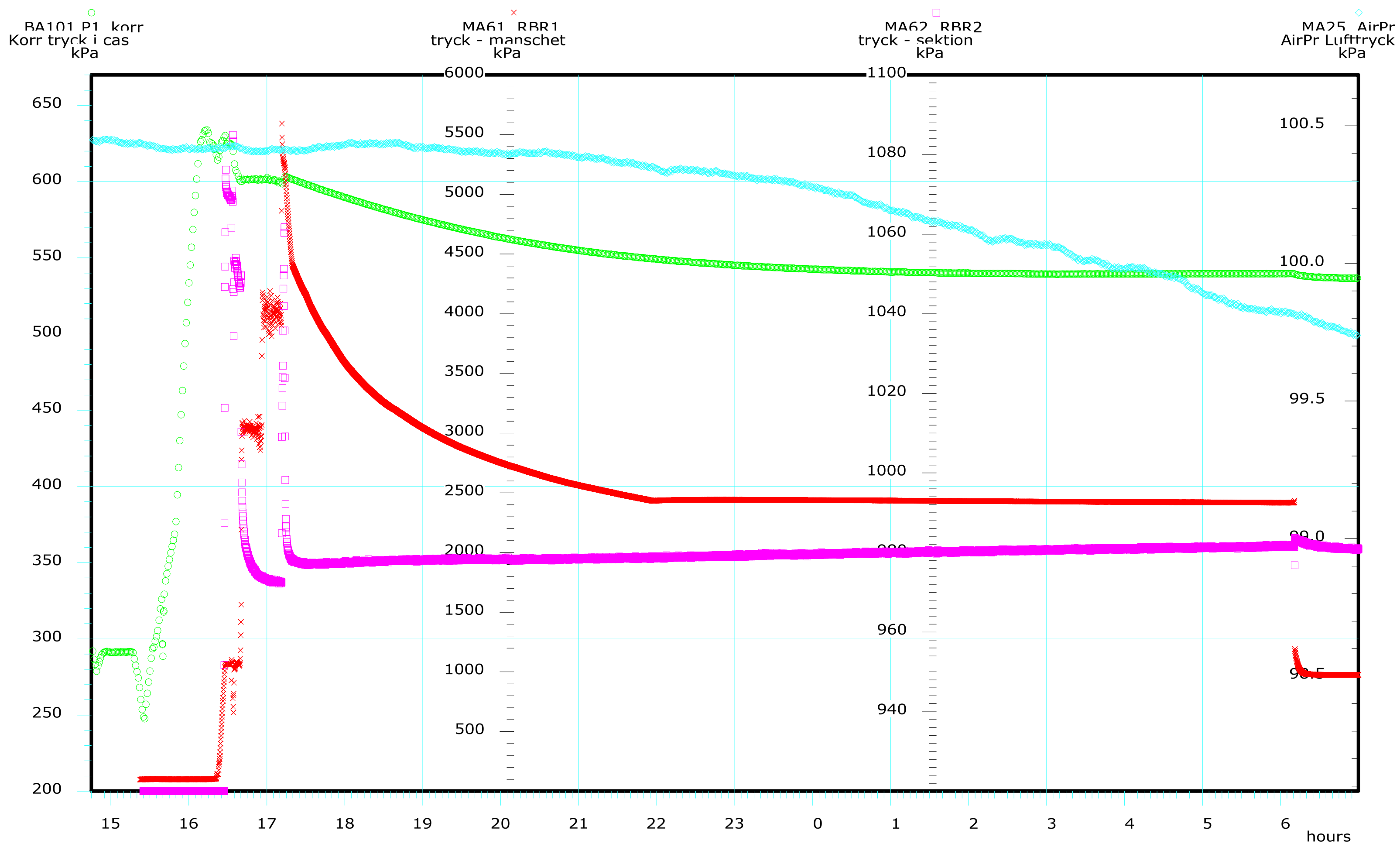
Description of the parameters in the enclosed plots.

Channel	Parameter	Unit	Description
BA101	Pressure	kPa	Pressure of the water column in the telescopic section subtracted with the ambient air pressure.
MA61	Pressure – packer	kPa	Inflation pressure in packer.
MA62	Pressure – section	kPa	Pressure of the water column in the test section i.e. at depth in the borehole. Not corrected for ambient air pressure.
MA25	Air pressure	kPa	

PLOT TIME :04/10/19 13:09:25
PLOT FILE :P_tryck_i _sektion
Adjusted for DST

DMS1 PO

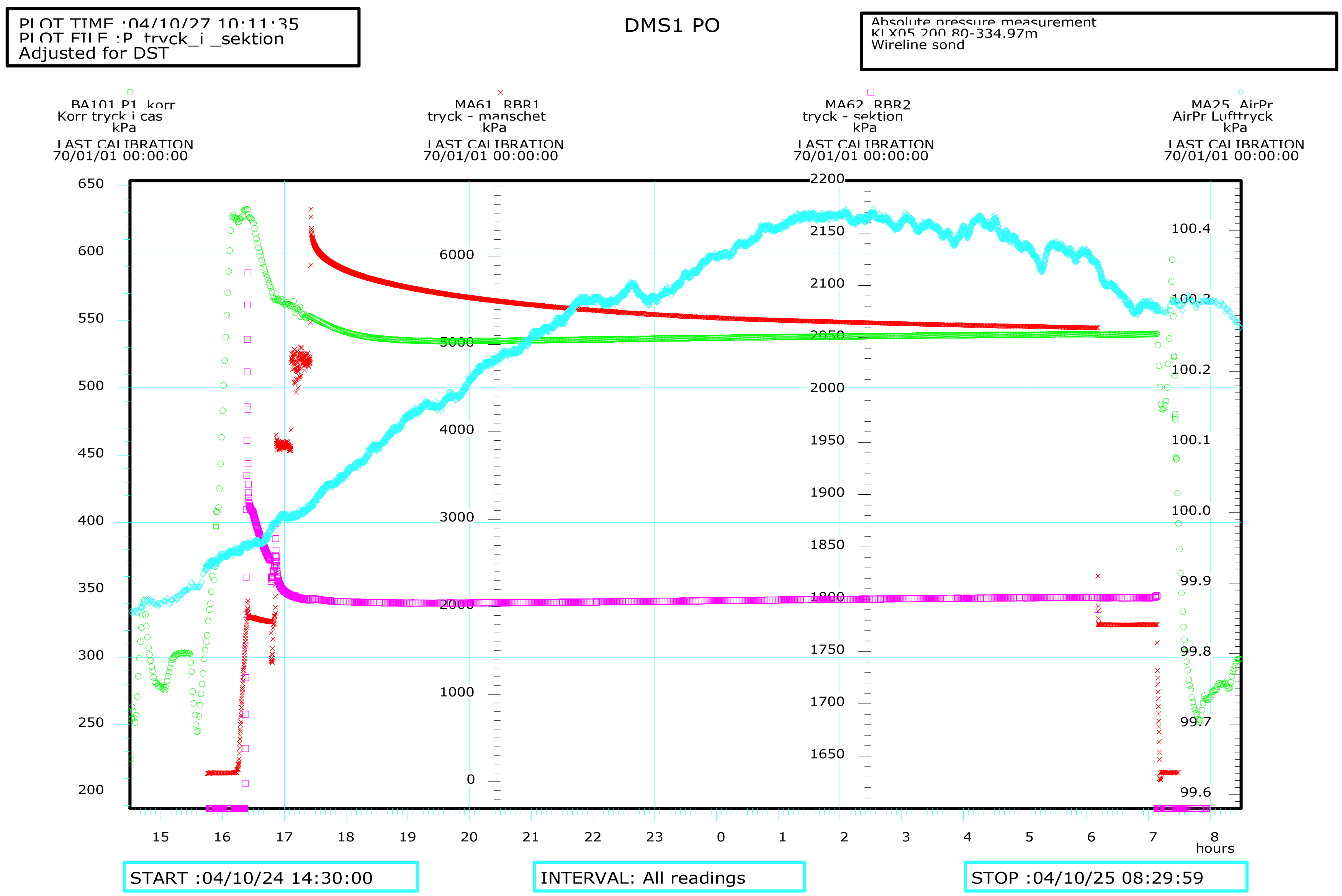
Absolute pressure measurement
KLX05 107.80-206.50m
Wireline sond

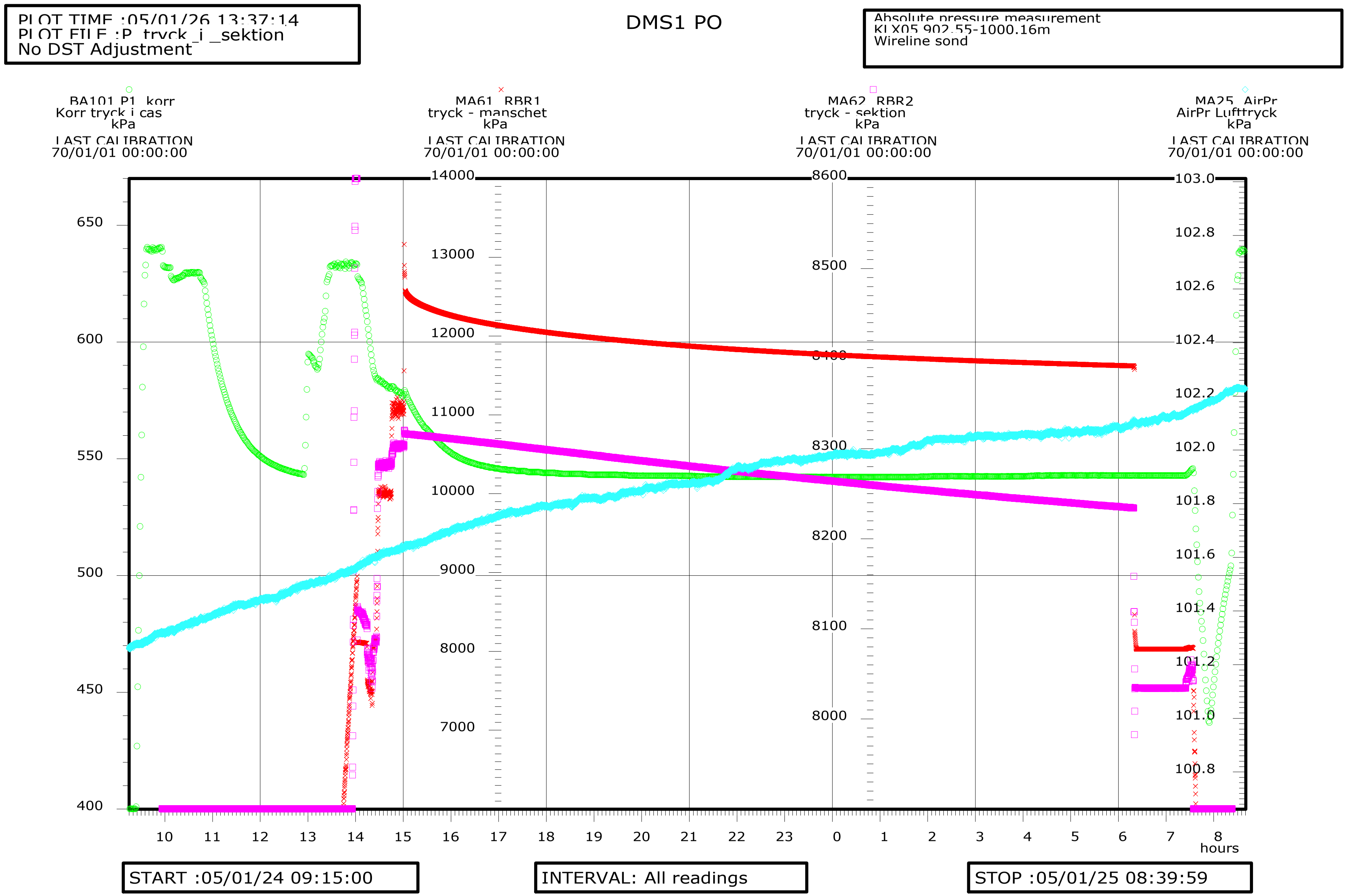


START :04/10/16 14:45:00

INTERVAL: All readings

STOP :04/10/17 06:59:59


PLOT TIME :04/10/27 10:11:35
PLOT FILE :P_tryck_i _sektion
Adjusted for DST
DMS1 PO
Absolute pressure measurement
KLX05 200.80-334.97m
Wireline sond
BA101_P1_korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA61_RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA62_RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA25_AirPr
AirPr Lufttryck
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :04/10/24 14:30:00
INTERVAL: All readings
STOP :04/10/25 08:29:59


PLOT TIME :05/01/26 13:37:14
PLOT FILE :P_tryck_i _sektion
No DST Adjustment
DMS1 PO
Absolute pressure measurement
KLX05 902.55-1000.16m
Wireline sond
BA101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA62 RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
MA25 AirPr
AirPr Lufttryck
kPa
LAST CALIBRATION
70/01/01 00:00:00
650
600
550
500
450
400
14000
13000
12000
11000
10000
9000
8000
7000
8600
8500
8400
8300
8200
8100
8000
103.0
102.8
102.6
102.4
102.2
102.0
101.8
101.6
101.4
101.2
101.0
100.8
10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8
hours
START :05/01/24 09:15:00
INTERVAL: All readings
STOP :05/01/25 08:39:59