P-05-234

# Oskarshamn site investigation

# Drilling of cored borehole KLX06

Henrik Ask, H Ask Geokonsult AB

Mansueto Morosini, SKB

Lars-Erik Samuelsson, SKB

Liselotte Ekström, Studsvik RadWaste AB

Nils Håkanson, HCC- Håkanson Coring Consultants

November 2005

**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-05-234

# Oskarshamn site investigation

# Drilling of cored borehole KLX06

Henrik Ask, H Ask Geokonsult AB

Mansueto Morosini, SKB

Lars-Erik Samuelsson, SKB

Liselotte Ekström, Studsvik RadWaste AB

Nils Håkanson, HCC- Håkanson Coring Consultants

November 2005

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

# Abstract

Borehole KLX06 is located in the Laxemar subarea. Drilling was made between August and November 2004 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 994.94 m with N-size (76 mm) equipment. The uppermost section, to a depth of 100.3 m, was constructed as a telescopic section with an inner nominal diameter of 200 mm.

A water inflow of 9–10 litres per minute was estimated over the whole length of the telescopic section during percussion drilling.

Pumping tests were performed with wireline equipment, typically with one hundred m intervals. The resulting transmissivities ($T_M$) varied between $9.7\times10^{-8}$ and $4.5\times10^{-4}$ $m^2/s$. The most transmissive section was between 103 and 202 m.

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

Eight water samples for chemical analysis were collected during drilling. Seven of these were collected during pumping tests ie down the hole. One sample was collected on the surface in conjunction with nitrogen flushing in a borehole section. Three samples had too high drill water content to warrant any further analysis.

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 $9.8\times10^{-5}$ $m^2/s$.

Lithologically the core is dominated by Ävrö granite. Intercalations of fine-grained diorite-gabbro and fine grained granite are not uncommon between 320 and 600 m. A rather heterogeneous section consisting of granite, fine-grained granite, Ävrö granite and fine grained diorite-gabbro occurs from 840 m to the bottom of the borehole.

Modest oxidation occurs sporadically along the length of the core, but between 200 m and 410 m the intensity of the oxidation is somewhat elevated. Saussuritization ie alteration of calcic plagioclase feldspar, with faint to weak intensity is noted between 340 m and 380 m and between 670 m and 740 m.

The distribution of total fractures in the core is typically in the range of 5–10 fractures/metre with minor sections containing slightly elevated fracture frequencies. One noteable exception exists between 150 m and 350 m where the fracture frequency is in the range of 10–20. Several crushed sections (fracture frequency > 40) have also been logged in this interval.

# Sammanfattning

Borrhål KLX06 ligger inom delområde Laxemar. Borrningen utfördes mellan augusti och november 2004 som ett led i platsundersökningen för ett möjligt djupförvar för använt kärnbränsle i Oskarshamns kommun.

Hålet kärnborrades med dimension N (76 mm) utrustning till 994,94 m borrad längd. Den övre delen av hålet, från markytan till 100.3 m, utfördes som en teleskopdel med ca 200 mm inre diameter.

Ett vatteninflöde på 9–10 liter per minut uppskattades över hela teleskopdelen vid hammarborrningen.

Pumptester med wireline-baserad mätutrustning utfördes normalt var hundrade meter. Uppmätta transmissiviteter ($T_M$) varierade mellan $9{,}7\times10^{-8}$ och $4{,}5\times10^{-4}$ $m^2/s$. Den mest transmissiva sektionen var mellan 103 och 202 m.

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

Åtta vattenprover för kemisk analysering togs i samband med borrning. Sju av dessa inhämtades vid pumptester dvs nere i borrhålet. Ett prov togs i samband med kvävgasblåsning i en borrhålssektion. Tre prover hade ett för högt spolvatteninnehåll för att medge ytterligare analysering.

En mammutpumpning i teleskopdelen som gjordes när kärnborrningen utförts till full längd gav en transmissivitet ($T_M$) på $9{,}8\times10^{-5}$ $m^2/s$.

Litologiskt domineras kärnan av Ävrögranit. Inslag av finkornig diorit-gabbbro och finkornig granit är inte ovanligt mellan 320 och 600 m. En ganska heterogen sektion bestående av granit, finkornig granit, Ävrögranit och finkornig diorit-gabbbro uppträder från 840 m till hålets botten.

Måttlig oxidation återfinns ställvis längs hela kärnan, men mellan 200 m och 410 m är intensiteten på oxidationen något förhöjd. Saussuritisering dvs omvandling av kalciumrik plagioklasfältspat, med obetydlig till svag intensitet, har noterats mellan 340 m och 380 m samt mellan 670 m och 740 m.

Fördelningen av totala sprickor i kärnan är oftast kring 5–10 sprickor/meter med mindre partier med något förhöjda sprickfrekvenser. Ett väsentligt undantag finns mellan 150 m och 350 m där sprickfrekvensen är i intervallet 10 till 20. Flera sektioner med krossat berg (sprickfrekvens > 40) har även karterats inom detta parti.

# 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 KLX06 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. KLX06 was the seventh deep cored borehole within the Oskarshamn site investigation. The location of the core drilled borehole, KLX06 and the water sources, HLX10 and HLX20 in the Laxemar subarea is shown in Figure 1-1.

The drilling of KLX06 and all related on-site operations were performed according to a specific activity plan (AP PS 400-04-055), which in turn refers to a number of method descriptions, see Table 1-1. The environmental monitoring wells were emplaced as part of a separate activity (AP PS 400-04-019).

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

| Activity plan | Number | Version |
|---|---|---|
| Kärnborrning KLX06 | AP PS 400-04-055 | 1.0 |
| Karaktärisering av jordlager med geotekniska metoder- jordborrning, jordprovtagning och installationer av grundvattenrör, Laxemar 2004 | AP PS 400-04-019 | 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 |

The activity plans and method descriptions are SKB internal documents.

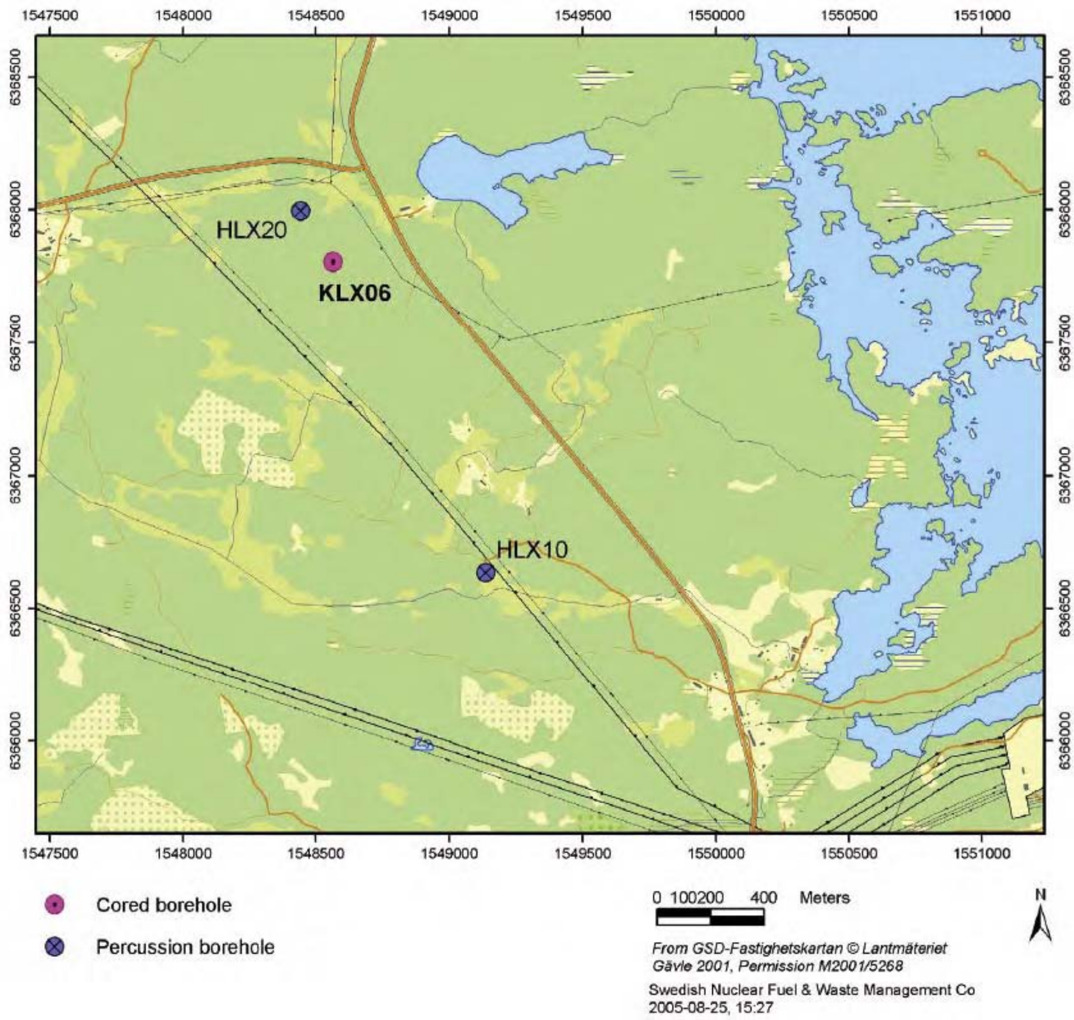



***Figure 1-1.*** *Location of the cored borehole KLX06 the Laxemar subarea and percussion boreholes HLX10 and HLX20.*

# 2 Objective and scope

This report will describe the methods employed and the results achieved during the drilling of KLX06 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 KLX06 was to gain geological information at depth in the northern part of the Laxemar subarea especially the deformation zone EW002 (“the Mederhult zone”) and to facilitate further investigation at depth in the borehole. The decision to drill KLX06 is given in SKB id no 1026833, dated 2004-06-29.

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 1025990.

# 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.

After the core drilling is completed to full length, depth reference slots are reamed in the borehole wall and a conical guide of stainless steel is installed between the telescope part and the deeper core drilled part, see Figure 3-2.

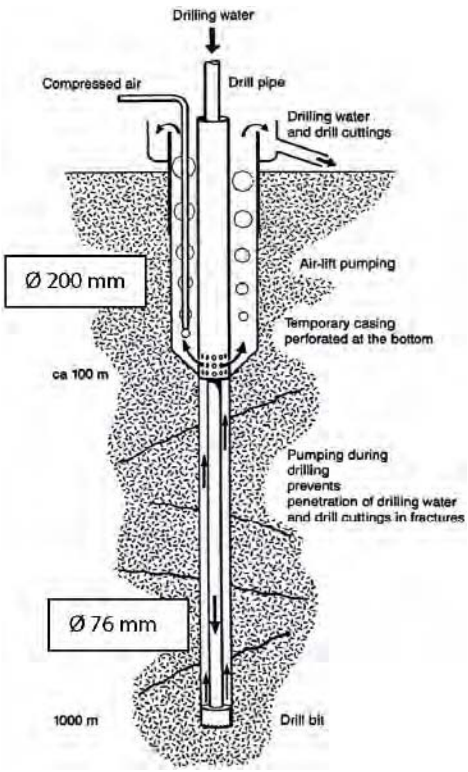



***Figure 3-1.** A sketch of the telescopic drilling method with air-lift pumping for retrieval of drilling water and cuttings.*

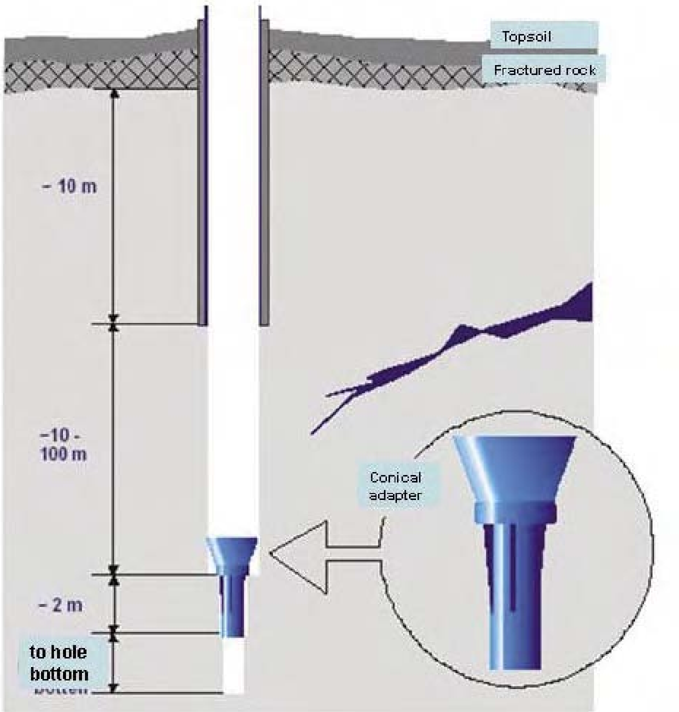



***Figure 3-2.*** *Installation of the conical guide.*

### 3.1.1 The flushing water system

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

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

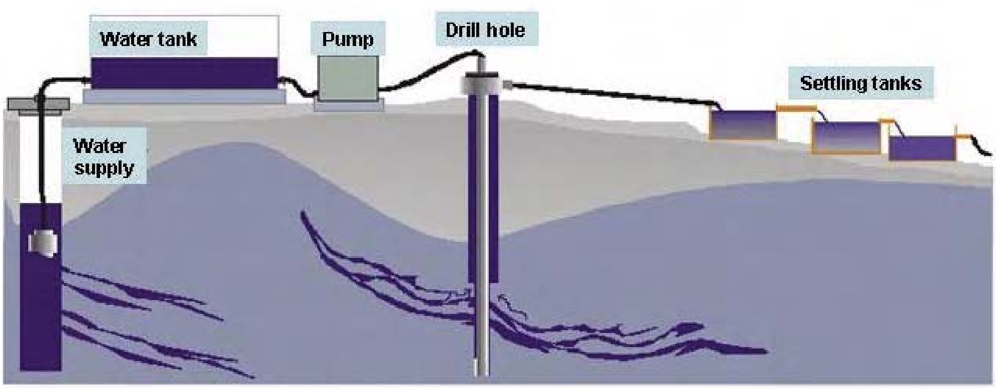



***Figure 3-3.*** *The flushing water system from source to discharge point.*

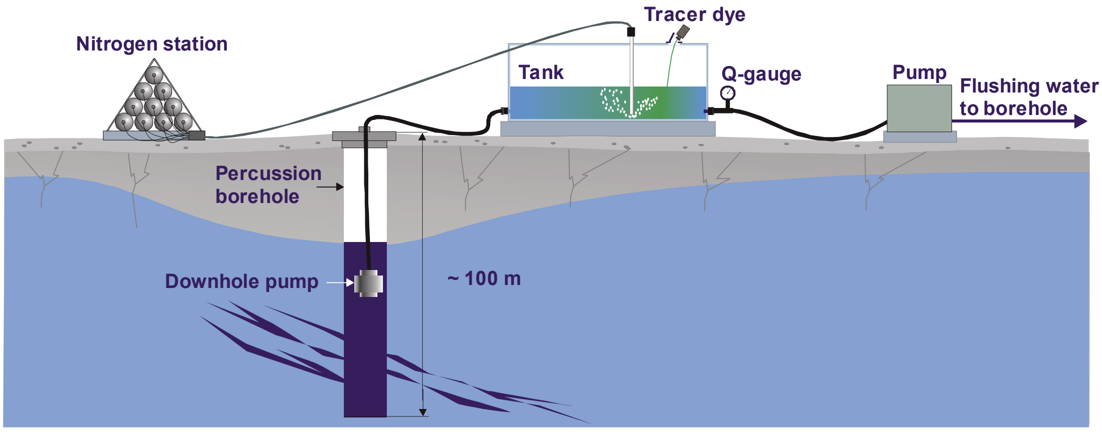



***Figure 3-4.*** *Preparation of flushing water. Uranine is added to the water as a tracer dye. Nitrogen is bubbled through the water to remove dissolved oxygen.*

## 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 KLX06 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 pumping with evaluation of drawdown and/or recovery is 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, ie 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).

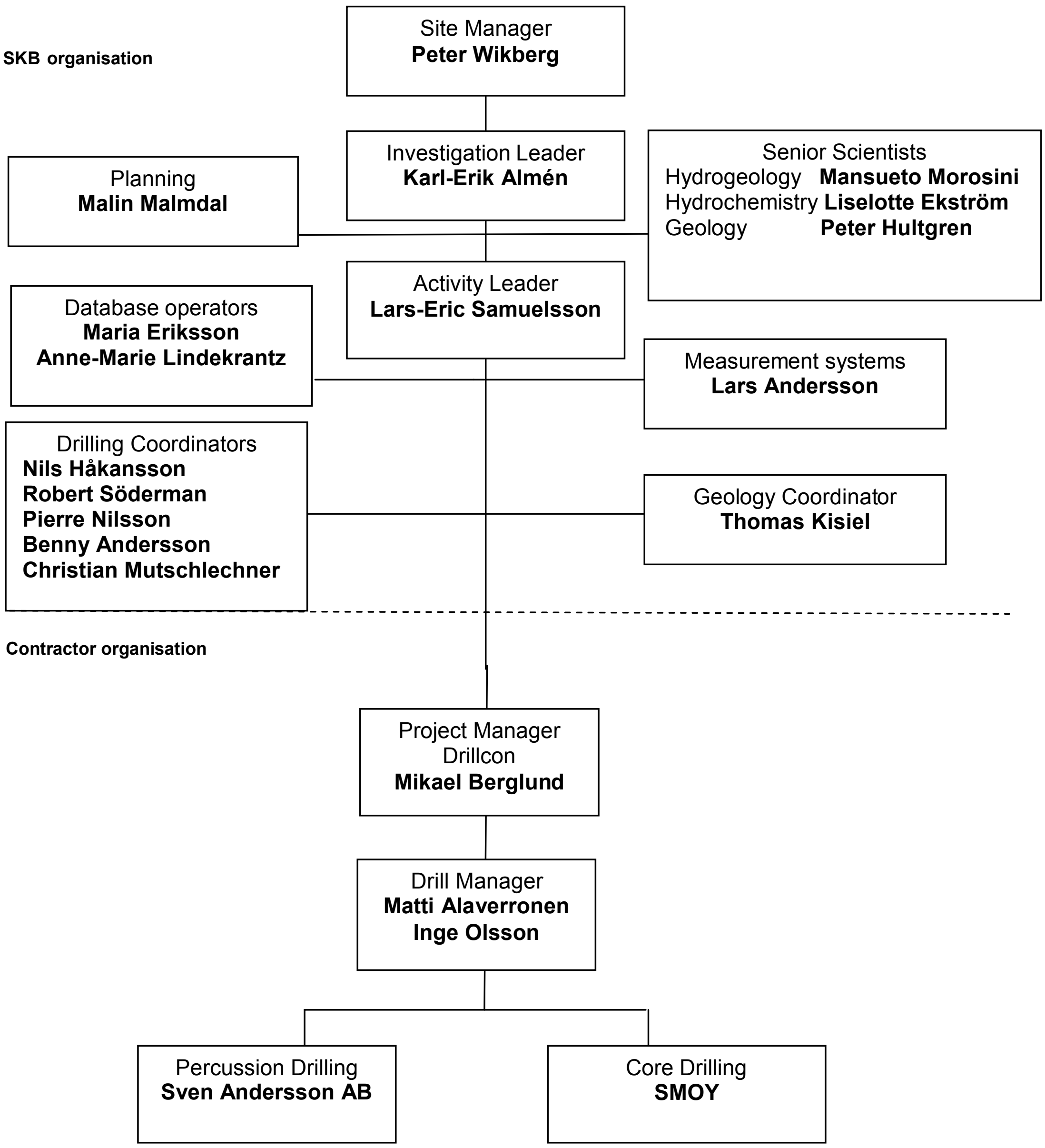
# 4 Contractors and equipment

## 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 MC15000 percussion drill rig with an Atlas Copco XRVS 455 Md air compressor. Overburden drilling was made with NO-X 280 mm equipment. The down-the-hole hammer was a Secoroc 165 mm for the pilot borehole and the drill rods were Driqoneq 114 mm. Reamings were done with Secoroc DTH-hammers for 200 or 250 mm diameter. The casings utilized were 208×4 mm (SS 2343, stainless) and 324×7 mm (non stainless). The casing dimensions are presented here as outer diameter x thickness.

## 4.3 Core drilling equipment

Core drilling in KLX06 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, ie 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, ie 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 KLX06 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 (20 bar).
- 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 Measurements with wireline probe

The wireline probe has been developed by SKB. With this equipment water sampling, pump tests and measurements of absolute pressure in a borehole section can be made without having to lift the drill stem.

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

The principal components are:

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

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

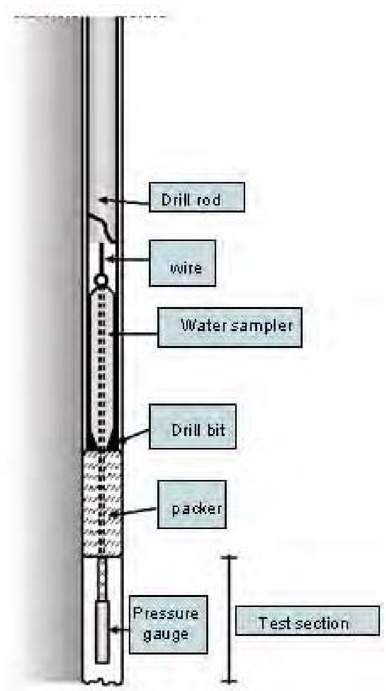



***Figure 4-2.*** *The wireline probe and its emplacement in the hole.*

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 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.

#### *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*

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 data that have been in use since October 2003.

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™** (non-magnetic) optical equipment. Check-up deviation measurements were made with a Reflex EZ-AQ/EMS equipment, a multifunctional surveying instrument with single and multishot capabilities, for comparison.

### 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 when the water pressure is increased the cutters expand.

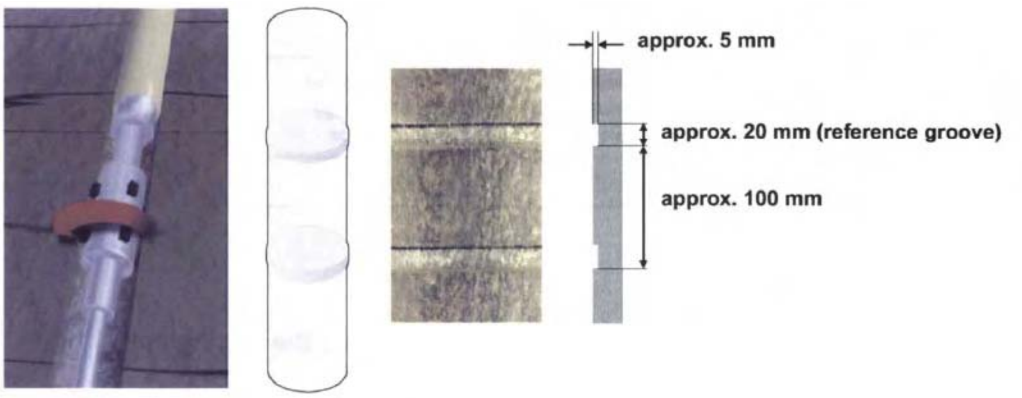



***Figure 4-4.*** *The equipment for reaming of reference slots. To the left, the reaming tool with openings for the cutters is shown. The resulting reference slots are illustrated in the three pictures to the right.*

# 5 Execution and results

## 5.1 Summary of KLX06 drilling

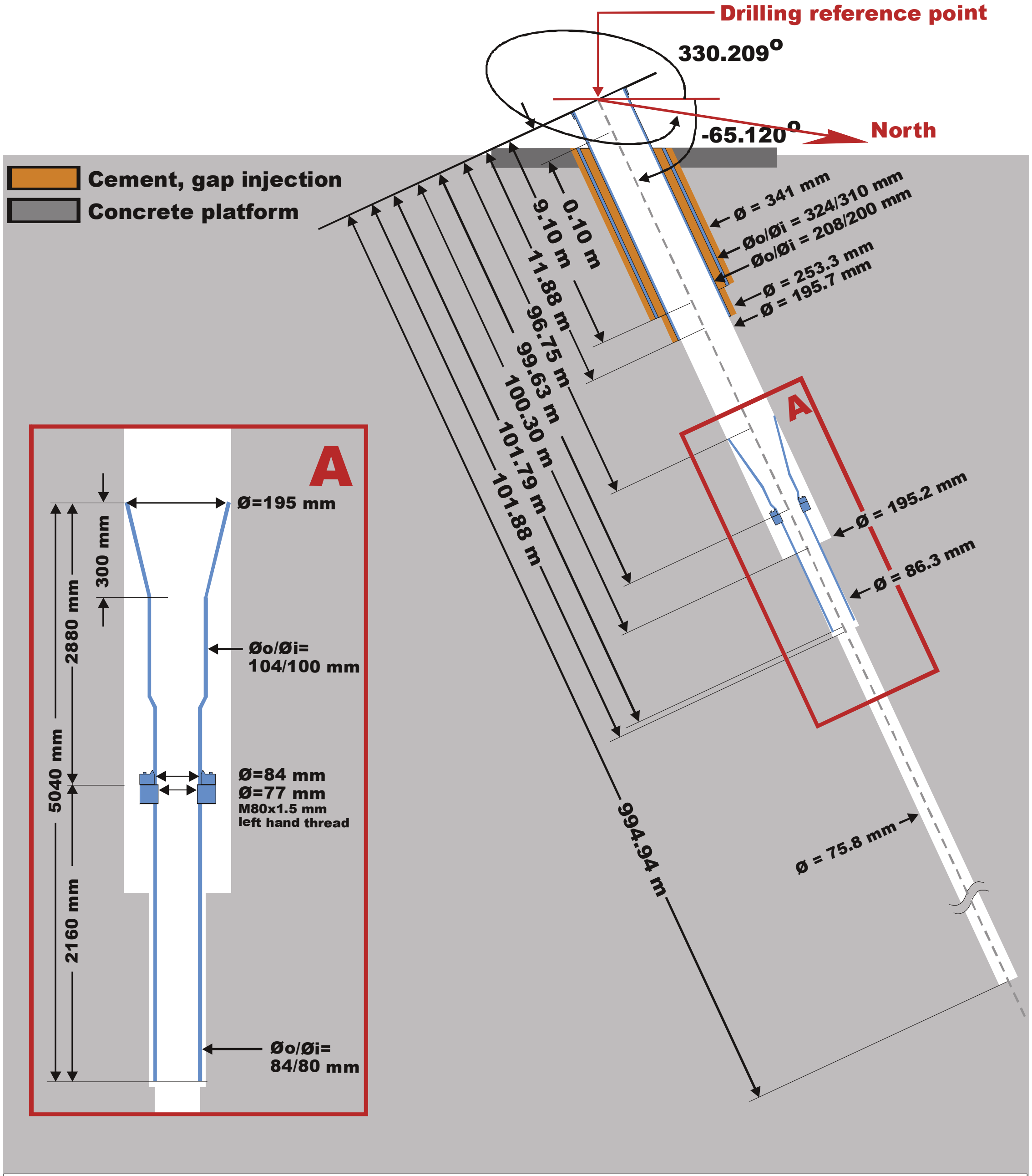
A technical summary of the drilling of KLX06 and the borehole design after completion is given in Table 5-1 and Figure 5-1. A summary of drilling progress and borehole measurements is given in Table 5-2 and chronological summary is presented in Table 5-3. Further descriptions of the two main drilling steps, the telescope section 0–100.3 m and the core drilling section 100.3–994.94 m are given in Sections 5.2 and 5.3 respectively. 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. KLX06 Technical summary.**

| General | Technical |
|---|---|
| Name of hole: KLX06 | Percussion drill rig Comacchio MC1500 |
| 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 | Core drill dimension N-size (76 mm) |
| Sven Andersson AB | Cored interval 100.3–994.94 m |
| Subcontractor core drilling | Average core length retrieved in one run 2.64 m |
| Suomen Malmi OY (SMOY) | Number of runs 339 |
| Drill start date August 03, 2004 | Diamond bits used 14 |
| Completion date November 25, 2004 | Average bit life 64 m |
| | Position KLX06 (RT90 RH70) at top of casing:<br>N 6367806.64 E 1548566.88 Z 17.68 (m a s l)<br>Azimuth (0–360)/Dip (0–90)<br>330.2/–65.1 |
| | Position KLX06 (RT90 RH70) at 993 m length:<br>N 6368332.26 E 1548426.04 Z –790.81 (m a s l)<br>Azimuth (0–360)/Dip (0–90)<br>357.0/–40.4 |

# Technical data

## Borehole KLX06




**Drilling reference point**

**Northing:** 6367806.64 (m), RT90 2,5 gon V

**Easting:** 1548566.88 (m), RT90 2,5 gon V

**Elevation:** 17.68 (m), RHB 70

**Drilling period**

**Drilling start date:** 2004-08-03

**Drilling stop date:** 2004-11-25

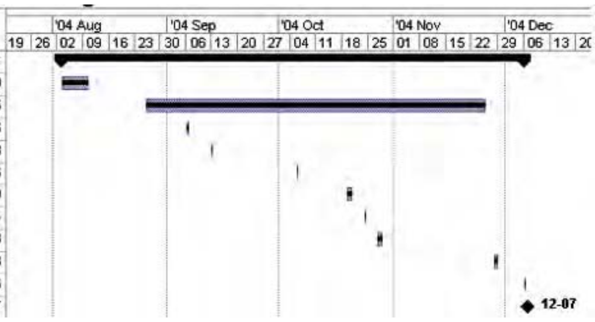
***Figure 5-1.*** *Technical data from KLX06.*

**Table 5-2. Summary of drilling progress and borehole measurements in KLX06.**

| 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 | 040905. Pumping test 103.00 - 202.26 m.<br>6.8 L/min with 13 m drawdown. Water sample taken with new samling unit. | 040906.<br>Measurement of absolute pressure 103.00 - 214.26 m | 040923. Airlift pumping<br>0 - 415.49 m<br>No drillstem in borehole | 040903. Maxibor 0 - 183 m<br>2.72 m right<br>2.85 m up<br>Dip -63.91 Azim 331.68 | Directional drilling was done intermittently between 166.94 -202.26 m. |
| | 040910. Pumping test 260.50 - 268.70 m.<br>7.5 L/min wiht 13 m drawdown. Water sample with new unit | 040911<br>Measurement of absolute pressure 260.50 - 289.50 m. | 041005. 0 - 562.18 m.<br>Airlift pumping with drillstem in borehole.<br>Interference test with HLX20. | 040913. Maxibor 0 - 300 m<br>5.42 right<br>7.53 up<br>Dip -61.45<br>Azimuth 334.88 | Sections with crushed rock occur after 199 m. |
| | 040912. Pumping test 200.50 - 310.20 m.7.8 L/min with 13 m drawdown. Sample with | 040914<br>Measurement of absolute pressure 200.50 - 317.84 m. | 041019. 0 - 721.94 m.<br>Airlift pumping without drillstem in borehole.<br>HLX20 closed at 15:00 | 040921.Maxibor 0 - 390 m<br>12.05 right<br>14.17 up<br>Dip -59.85<br>Azimuth 340.39 | 040910. Distinct reduction in flushing water pressure while drilling 265-268 m. |
| | 040919. Pumping test 331.02-364.23 m. 8.5 L/min with 11 m drawdown. Sample with new unit | 040924.<br>Measurement of absolute pressure 307.50 - 415.49 m. | 041127. Airlift pumping 0 -995 m. No drillstem in borehole.<br>HLX20 closed for interference test. | 040930. Maxibor 0-507 m 28 m right<br>25 m up<br>Dip -56.68<br>Azimuth 348.82 | 040929 Pieces of fallen rock, size 0-4 cm were found in the bottom of the borehole. |
| | 040923. Pumping test 307.50 - 415.49 m.<br>8.5 L /min with 20 m drawdown. Water sample with new unit | 041030.<br>Measurement of absolute pressure 715.14 - 790.94 m. | | 041024. Maxibor 0 - 735 m.<br>76 m right<br>64 m up<br>Dip -49.64<br>Azimuth 349.32 | |
| | 040929. Pumping test 412.50 - 517.94 m<br>0 - 0.2 L/min with 22 m drawdown.<br>No water sample. | | | 041127. Maxibor 0-995 m.<br>223.45 m right<br>87.50 m up<br>Dip -41.95<br>Azimuth 12.54<br><br>041206 Maxibor calculation by connecting partial measurements.<br>151.73 m right<br>135.76 m up<br>Dip -40.37<br>Azimuth 357.03<br><br>EZ-shot measurement at 995 m gave:<br>Dip -37.1<br>Azimuth 352.4 ( + 2 for magnetic deviation) | |
| | 041009. Pumping test 514.60 - 613.94 m.<br>7.4 L/min with 16 m drawdown.<br>Water sample with new unit. | | | | |
| | 041019. Pumping test 611.50 - 715.94 m.<br>0.8 L/min with 21 m drawdown.<br>No water sample. | | | | |
| | 041029. Pumping test 715.14 - 784.94 m. 2 L/min with 29 m drawdown. HLX20 closed 10:04 28/10 to 09:14 29/10. Water sample with new sampling unit | | | | |
| | 041111. Pumping test 782.50 - 898.94 m. 0.95 L/min with 20 m drawdown.<br>No water sample. | | | | |
| 1000 m | 041126. Pumping test 895-995 m. 0.1 L/min with 20 m drawdown. No water sample HLX20 closed for interference testing | | | | |

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

| ID | Aktivitet | Start | Finish |
|---|---|---|---|
| 1 | **First activity starts** | **Tue 04-08-03** | **Mon 04-12-06** |
| 2 | Percussion drilling | Tue 04-08-03 | Tue 04-08-10 |
| 3 | Core drilling | Wed 04-08-25 | Thu 04-11-25 |
| 4 | Maxibor measurement | Mon 04-09-06 | Mon 04-09-06 |
| 5 | Maxibor measurement | Mon 04-09-13 | Mon 04-09-13 |
| 6 | Recovery test | Tue 04-10-05 | Wed 04-10-06 |
| 7 | Recovery test | Tue 04-10-19 | Wed 04-10-20 |
| 8 | Maxibor measurement | Sun 04-10-24 | Sun 04-10-24 |
| 9 | Recovery test | Wed 04-10-27 | Thu 04-10-28 |
| 10 | Length calibration marks | Sun 04-11-28 | Sun 04-11-28 |
| 11 | Maxibor measurement | Mon 04-12-06 | Mon 04-12-06 |
| 12 | Last activity ends | Tue 04-12-07 | Tue 04-12-07 |




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

Drilling, reaming and gap injection were made from August 3 to 10, 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 KLX06 was made in steps as described below:

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

- Drilling was made to 9.10 m length with NO-X 280 mm equipment. This gave a hole diameter of 341 mm and left a casing (324×7 mm diameter) to a depth of 9.1 m. The soil depth was 1.0 m.
- Inner supportive casing for guidance for the drill string was mounted.
- A pilot percussion hole was drilled to a depth of 100.30 m. The initial diameter of the bit was 162.7 mm and the diameter at full length was 162.4 mm.
- The hole was reamed to diameter 253.3 mm between 9.10 and 11.88 m.
- Stainless casing of 208×4 mm was installed from 0 to 11.88 m and gap injection with low alkali cement based concrete (428 litres) was made as described in Figure 5-2.
- After the concrete had hardened, the hole was reamed from 11.88 to 100.3 m. The initial diameter of the hole was 195.7 mm and the diameter at full length was 195.2 mm. The borehole was rinsed and flushed to remove concrete and water. The outer 324 mm casing was cut along the ground surface.

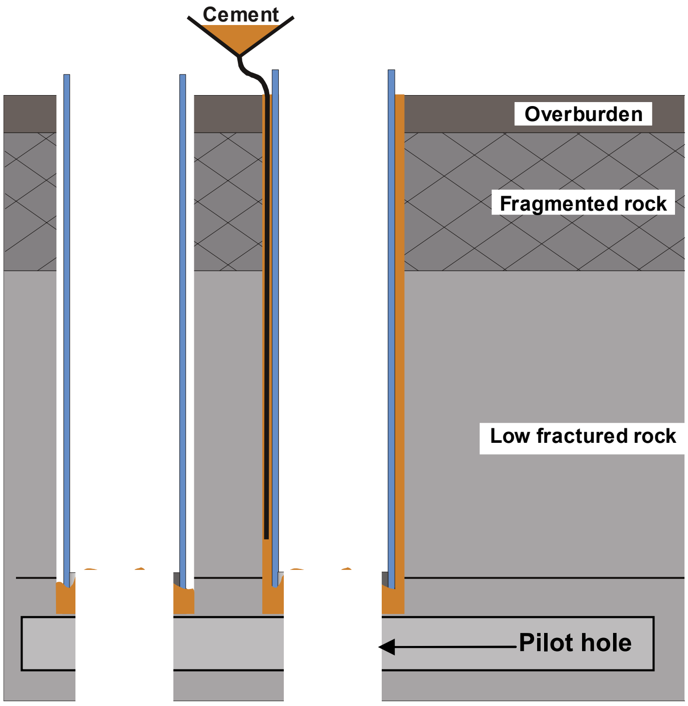



***Figure 5-2.*** *Gap injection technique 1. The gap filling cement is introduced between the casing and the rock wall. The drill bit acts as a barrier so that cement does not enter the pilot hole.*

### 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 were noted.

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

#### *Hydrogeology*

The total water yield at full length (100 m) was 9–10 L/min. The observations of water yield during percussion drilling of the pilot hole are summarized in Table 5-4.

**Table 5-4. Water yield during percussion drilling.**

| From (m) | To (m) | Observed water flow (L/min) |
|---|---|---|
| 11.88 | 100.3 | 9–10 |

#### *Hydrochemistry*

No water samples were collected from the telescopic section in KLX06.

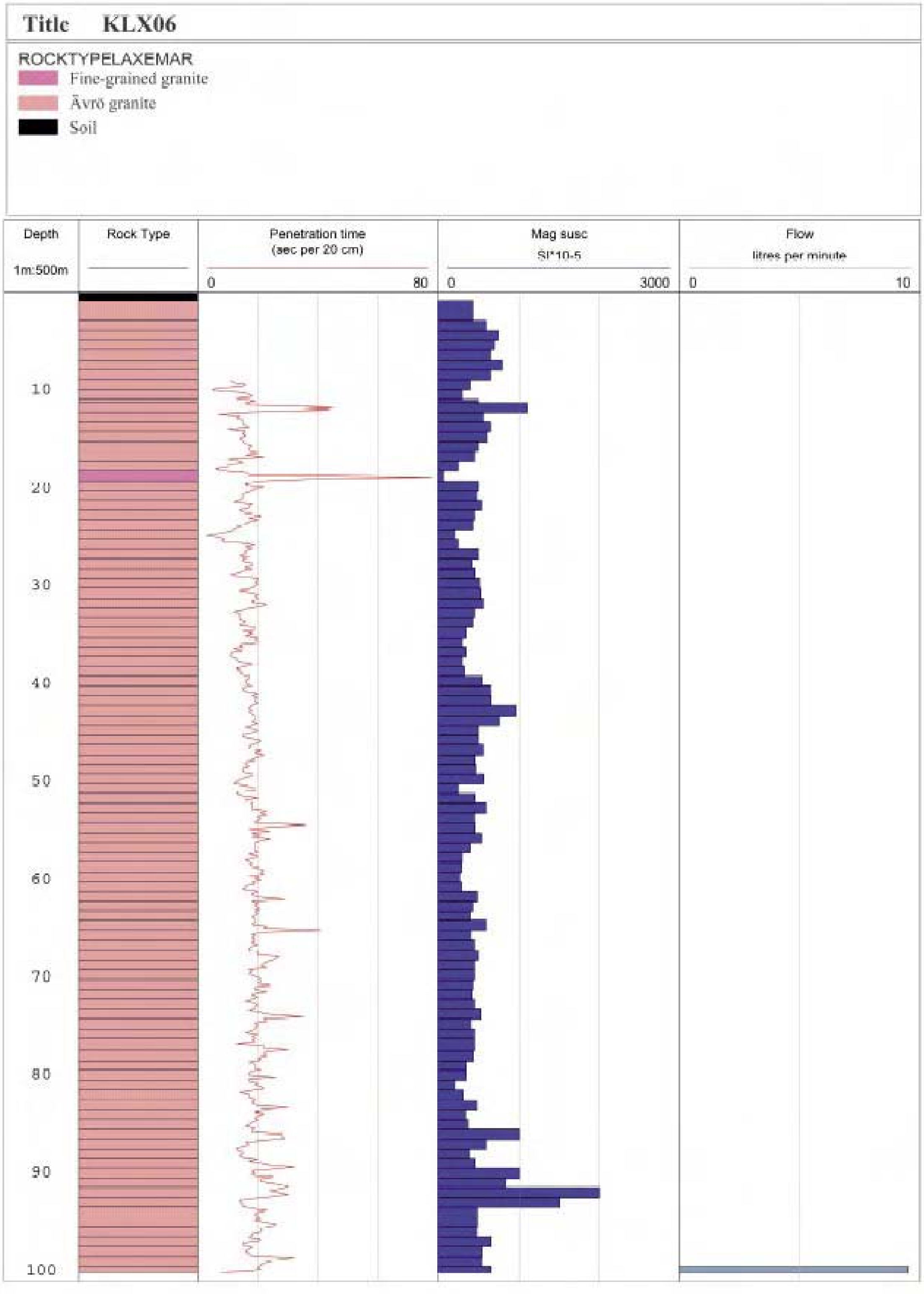



***Figure 5-3.*** *Preliminary geological results based on logging of drill cuttings and penetration rate from percussion drilling of KLX06.*

## 5.3 Core drilling 100.3–994.94 m

Core drilling in KLX06 was conducted between August 28, 2004 and November 25, 2004.

The main work in KLX06 after drilling the telescopic section consisted of the following steps:

- preparations for core drilling,
- flushing and return water handling,
- 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 core drilling started on August 17, 2004 and consisted of installation of air-lift pumping equipment and supportive casing for alignment of the core drill rods, see Figure 5-4.

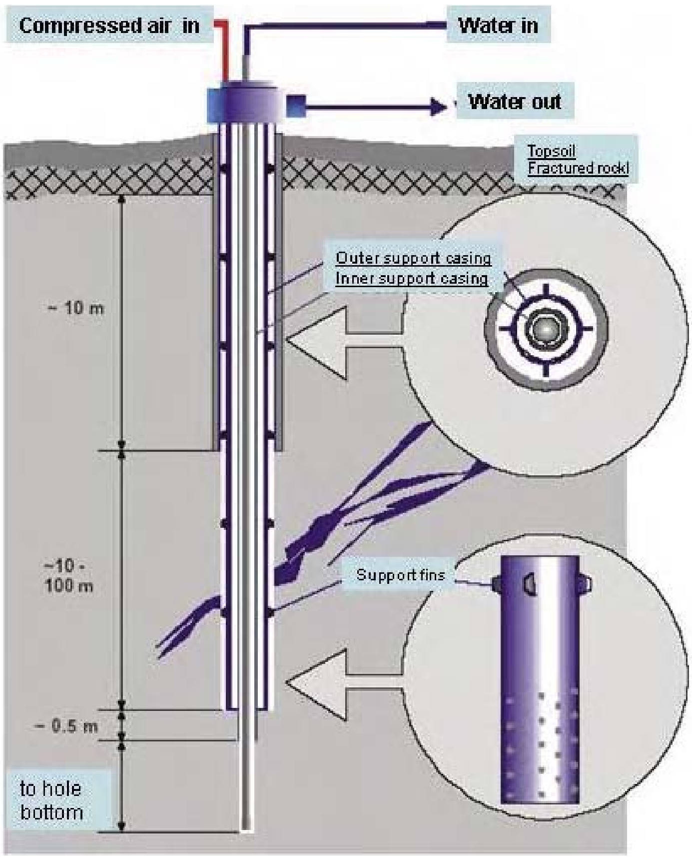



***Figure 5-4.*** *In the telescopic part of the drill hole a temporary installation is made with casing tubes for support and alignment and equipment for air-lift pumping. In the uppermost part the return water discharge header is mounted. The water discharge is led to the settling containers.*

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 100.29 and 101.69 m with T-86 equipment. An inner supportive casing with diameter 84/77 mm was installed to 101.69 m.

The supportive casings have a perforated section between 99.20 and 99.60 m length so that water from the borehole can be lead to the air-lift pumping system outside the supportive casings. A pressure meter for monitoring of the water level was emplaced at a length of 90 m.

### 5.3.2 Flushing and return water handling

The flushing water sources were percussion boreholes HLX10 and HLX20, see Figure 1-1. Between August 27, 2004 and October 6, 2004 HLX10 was utilized whereas after October 6, HLX20 was used.

Treatment of the flushing water before introduction into borehole KLX06 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 KLX06 is shown in Figure 5-5.

The targeted content for uranine in the flushing water is 0.20 mg/L and the actual average uranine content was 0.23 mg/L, see also Figure 5-9 and Section 5.5.2.

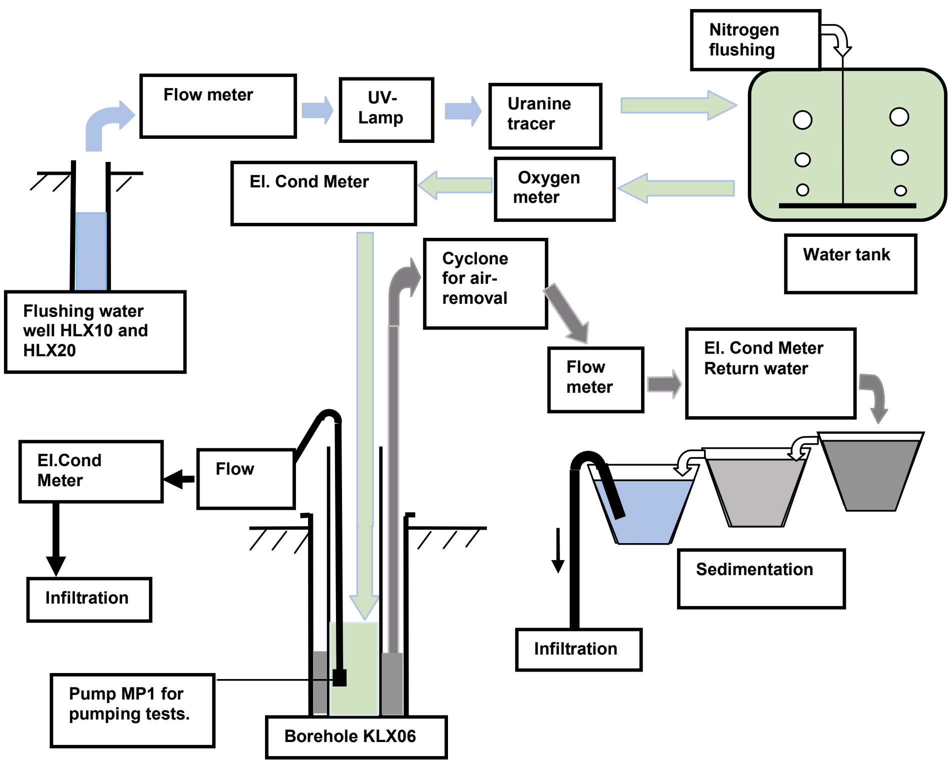



*Figure 5-5. The flushing and return water handling and the emplacement of related monitoring equipment in KLX06.*

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.

### 5.3.3 Drilling

Core drilling with N-size (76 mm) triple-tube, wireline equipment was conducted from 101.69 m to the final length of 994.94 m which gave a core of 50.1 mm diameter over most of the cored section. Directional drilling was made in four intervals between 166.94 and 202.26 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 5-5.

A total of fourteen drill bits were used for KLX06, see Figure 5-6.

**Table 5-5. 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 | 100.29–101.69 | T-86 | |
| 50.2 | 86 | 101.69–101.88 | N and T-86 | Reamed |
| 50.2 | 76 | 101.88–166.94 | N | |
| 45 | 76 | 166.94–170.70 | Liwinstone N | Directional |
| 50.2 | 76 | 170.70–173.64 | N | |
| 45 | 76 | 173.64–177.75 | Liwinstone N | Directional |
| 50.2 | 76 | 177.75–193.63 | N | |
| 45 | 76 | 193.63–196.57 | Liwinstone N | Directional |
| 50.2 | 76 | 196.57–199.58 | N | |
| 45 | 76 | 199.58–202.26 | Liwinstone N | Directional |
| 50.2 | 76 | 202.26–994.94 | N | |

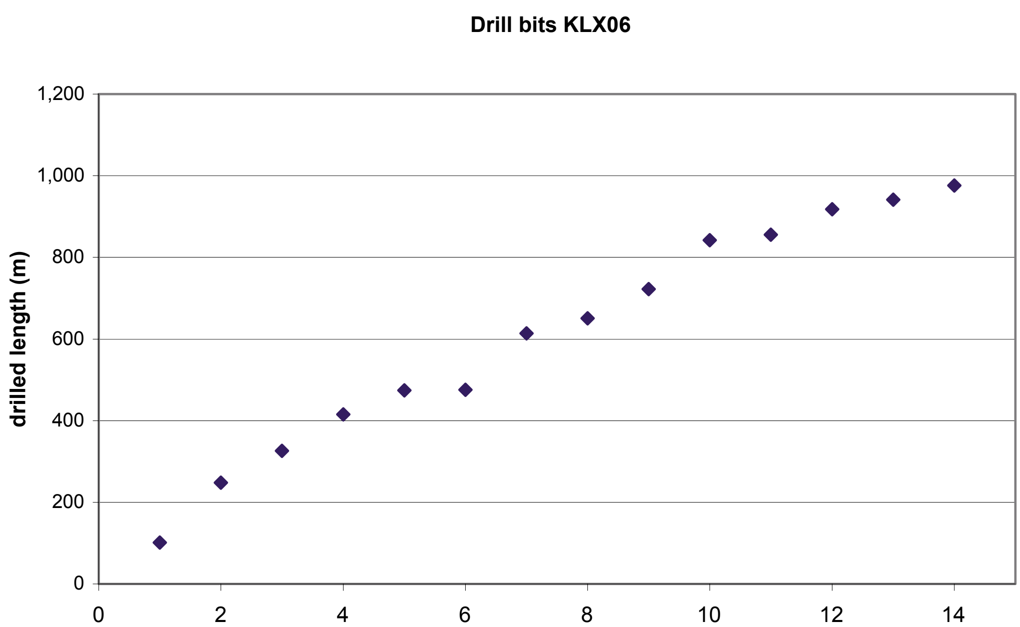



***Figure 5-6*** *Changes of drill bit during core drilling in KLX06.*

Further results from drill monitoring ie 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 5-13.

### 5.3.4 Deviation measurements

Horizontal and vertical plots of the results of the final run with the Maxibor method covering the entire length of borehole KLX06 is given in Appendix 4. Borehole KLX06 was also measured with a Reflex EZ-AQ/EMS (EZ-tool) after borehole completion. In accordance with method description MD 620.003, the Maxibor data are used as deviation data and stored in the Sicada database. The results from the EZ-tool should be seen as a check-up measurement only.

A comparison of the results from the different methods is given in Table 5-6.

**Table 5-6. Comparison of the results from Maxibor and EZ-tool deviation measurements.**

| Drilled length (m) | Maxibor results | | EZ-tool results (average of two measurements) | | Differense | |
|---|---|---|---|---|---|---|
| | Azimuth | Dip | Azimuth | Dip | Azimuth | Dip |
| 190 m | 331.9 | –63.7 | 331.5 | –64 | 0.4 | 0.3 |
| 390 m | 340.8 | –59.9 | 339.6 | –60 | 1.2 | 0.1 |
| 590 m | 349.2 | –54.4 | 349.5 | –53.2 | 0.3 | 1.2 |
| 800 m | 352.3 | 47.4 | 351.2 | –47 | 1.1 | 0.4 |
| 990 m | 357 | –40.4 | 352.4 | –37.1 | 4.6 | 3.3 |

### 5.3.5 Borehole completion

Reaming of depth reference slots was done at intervals as shown in Table 5-7. The depth reference slots are used for depth calibration of down-hole equipment for subsequent investigations in the hole.

**Table 5-7. Depth reference slots (m).**

| | |
|---|---|
| 103.00 | 600.00 |
| 151.00 | 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 | |

The presence of the depth reference slots have been confirmed by caliper log measurements.

The air lift pumping equipment and the inner supportive casing in the telescopic section was removed. The section from 101.69 m to 101.88 m was reamed from 76 to 86 mm diameter.

A steel conical guide was installed between 96.75 m and 99.63 m depth together with a 86/80 mm casing between 99.63 and 101.79 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 and a dummy probe was run through the length of the hole to ensure that the hole was unobstructed.

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.

## 5.4 Hydrogeological and hydrochemical measurements and results 100.3–994.42 m.

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

Wireline probe measurements:

- Eleven pumping tests were made and all gave useful results, see Section 5.4.1.
- Five tests for absolute pressure, see Section 5.4.1.
- Eight water samples were successfully collected from nine 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.

Three air lift pumping and recovery tests were made, see Section 5.4.3.

### 5.4.1 Hydrogeological results from wireline measurements

Results from the wireline tests in KLX06 are presented in Table 5-8 and Figure 5-7. The times for start and stop together with section lengths for pumping tests are given in Table 5-9.

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

A total of eleven 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.

**Table 5-8. Pumping test with wireline probe in KLX06.**

| Tested section | Q/s ($m^2/s$) | $T_M$ ($m^2/s$) | Comments |
|---|---|---|---|
| 103.00–202.26 | $3.5\times10^{-4}$ | $4.5\times10^{-4}$ | Test functionally OK; good data, pseudo steady state. Pressure in casing in transient recovery phase, unaffected by the pumping test. |
| 260.50–268.7 | $6.1\times10^{-5}$ | $5.5\times10^{-5}$ | Test functionally OK; good data, pseudo steady state. Pressure in casing in transient recovery phase, unaffected by the pumping test. |
| 200.50–310.2 | $1.0\times10^{-4}$ | $1.3\times10^{-4}$ | Test functionally OK; good data, pseudo steady state. Pressure in casing in transient recovery phase, unaffected by the pumping test. |
| 331.02–364.23 | $7.4\times10^{-5}$ | $8.3\times10^{-5}$ | Test functionally OK; good data, pseudo steady state. Pressure in casing in transient recovery phase, unaffected by the pumping test. Transient evaluation performed:<br>$T_{Sf} = 2.1\times10^{-4}$ $m^2/s$ (drawdown)<br>$T_{Ss} = 2.0\times10^{-4}$ $m^2/s$ (recovery) |
| 307.50–415.49 | $6.2\times10^{-5}$ | $8.2\times10^{-5}$ | Test functionally OK; good data, pseudo steady state. Pressure in casing in transient recovery phase, unaffected by the pumping test.<br>Transient evaluation performed:<br>$T_{Sf} = 1.2\times10^{-4}$ $m^2/s$ (drawdown)<br>$T_{Ss} = 1.4\times10^{-4}$ $m^2/s$ (recovery) |
| 412.50–517.94 | $1.5\times10^{-7}$ | $1.94\times10^{-7}$ | Very short pumping period. Pressure in casing in transient recovery phase, unaffected by the pumping test. No water sample. |
| 514.60–613.94 | $8.4\times10^{-6}$ | $1.1\times10^{-5}$ | Test functionally OK; good data, pseudo steady state. Pressure in casing in transient recovery phase, unaffected by the pumping test. |
| 611.50–715.94 | $1.1\times10^{-6}$ | $1.5\times10^{-6}$ | Pressure in casing in transient recovery phase, unaffected by the pumping test. No water sample. |
| 715.14–784.94 | $< 1.5\times10^{-6}$ | $< 1.9\times10^{-6}$ | Highly variable intermittent flow during the pumping period since too high pumping rate was set causing the water level to drop to pump intake whereby the pump automatically switches of. After the level recovered somewhat the pump automatically starts. Only upper bound for T-value can be calculated. |
| 782.50–898.94 | $4.1\times10^{-7}$ | $5.4\times10^{-7}$ | Test functionally OK; good data, pseudo steady state. Pressure in casing in transient recovery phase, unaffected by the pumping test. No water sample. |
| 896.50–994.94 | $7.4\times10^{-8}$ | $9.7\times10^{-8}$ | Short pumping period with very low flow, due to tight section. No water sample. |

**Table 5-9. Pumping test start and stop times in KLX06.**

| From (m) | To (m) | Start | Stop |
|---|---|---|---|
| 103.00 | 202.26 | 2004-09-04 18:29 | 2004-09-05 00:33 |
| 260.50 | 268.7 | 2004-09-10 14:32 | 2004-09-11 06:00 |
| 200.50 | 310.2 | 2004-09-12 17:30 | 2004-09-13 05:30 |
| 331.02 | 364.23 | 2004-09-18 16:46 | 2004-09-19 06:30 |
| 307.50 | 415.49 | 2004-09-22 16:06 | 2004-09-23 05:58 |
| 412.50 | 517.94 | 2004-09-29 18:05 | 2004-09-29 18:27 |
| 514.60 | 613.94 | 2004-10-08 15:15 | 2004-10-09 02:38 |
| 611.50 | 715.94 | 2004-10-18 16:53 | 2004-10-18 20:12 |
| 715.14 | 784.94 | 2004-10-28 14:15 | 2004-10-29 03:00 |
| 782.50 | 898.94 | 2004-11-10 17:14 | 2004-11-10 20:39 |
| 896.50 | 994.94 | 2004-11-26 10:39 | 2004-11-26 11:39 |

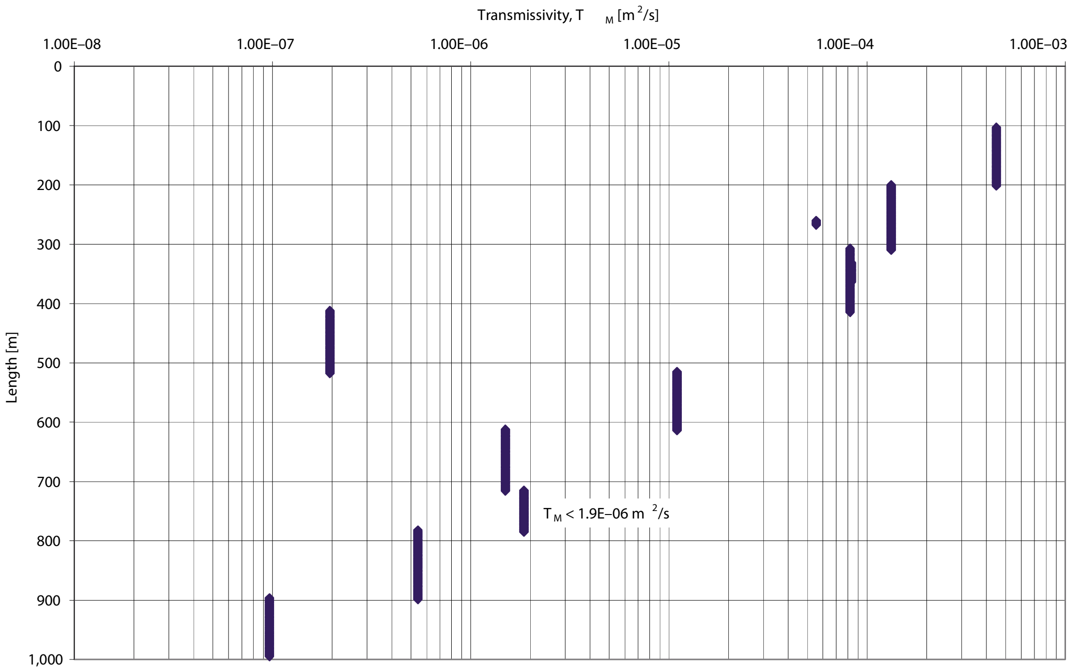



*Figure 5-7. Transmissivity from wireline pumping tests in KLX06 versus borehole length.*

Measurements of the absolute pressure were conducted in five sections, as specified in Table 5-10 and Figure 5-8.

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.

**Table 5-10. Absolute pressure measurements in KLX06.**

| Tested section | Last pressure reading during build-up (kPa) | Duration of pressure build-up (hours) | Borehole length to pressure gauge (m) |
|---|---|---|---|
| 103.00–214.26 | 957 | 14.0 | 104.10 |
| 200.50–317.84 | 1,829.5 | 13.2 | 201.60 |
| 260.50–289.50 | 2,357 | 12.9 | 261.60 |
| 307.50–415.49 | 2,770 | 13.1 | 309.60 |
| 715.14–790.94 | 6,060 | 13.3 | 716.24 |

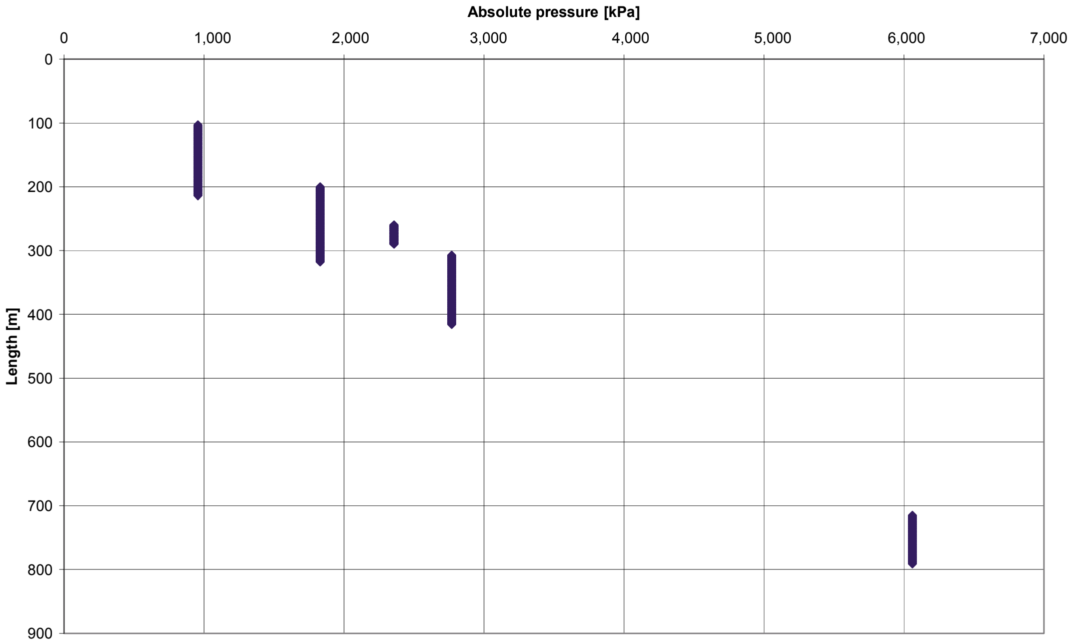



*Figure 5-8. Absolute pressure measurements from wireline tests in KLX06 versus borehole length.*

### 5.4.2 Hydrochemistry

In total, eight water samples were collected in connection with core drilling in KLX06. Seven of these samples were collected during pumping tests, whereas one sample (7757) was collected at the surface during nitrogen gas flushing of the borehole section.

Selected analytical results from KLX06 and the water source, HLX20, are given in Table 5-12. A complete record of analytical results is given in Appendix 2.

The times and lengths for the samples together with specification of SKB chemistry class is given in Table 5-11.

All eight samples were intended for analysis according to SKB chemistry class 3, however samples 7760, 7798 and 7859 were only analysed for drill water content. Samples 7757 and 7775 had a relatively high drill water percentage and were therefore not analysed for main components or isotopes. Sample 7900 was collected from the deepest sampled section in the borehole and therefore analysed for main components despite the high drill water content. Since samples 7757, 7775 and 7900 were collected as complete class 3 samples with all options included the remaining water bottles from the sampling are saved and stored at the Äspö laboratory.

The drilling water content is a reflection of how successful the sampling is. A low percentage of drilling water implies that the amount of pristine formation water is high in the sample.

The percussion drilled boreholes HLX10 and HLX20 were used as water sources. HLX10 was used from the start of the drilling until October 6, 2004. After that date, HLX20 was used as water source until the end of the drilling period, see also Section 5.3.2.

**Table 5-11. Sample dates and length during core drilling in KLX06.**

| SKB number | Date | Test section, length (m) | SKB chemistry class |
|---|---|---|---|
| 7722 | 2004-09-05 | 103.00–202.26 | 3 and all option isotopes |
| 7757 | 2004-09-10 | 265.50–268.50 | 3 (not analysed for main components or isotopes) |
| 7759 | 2004-09-11 | 260.50–268.70 | 3 and all option isotopes |
| 7760 | 2004-09-13 | 200.50–310.20 | 1 (only analysed for drill water percentage) |
| 7775 | 2004-09-19 | 331.02–364.23 | 3 (not analysed for main components or isotopes) |
| 7798 | 2004-09-23 | 307.50–415.49 | 1 (only analysed for drill water percentage) |
| 7859 | 2004-10-09 | 514.60–613.94 | 1 (only analysed for drill water percentage) |
| 7900 | 2004-10-29 | 715.14–784.94 | 3 (not analysed for isotopes) |

**Table 5-12. Analytical results from water chemistry sampling.**

| Borehole | Sample no | Date | From (m) | To (m) | Drill water % | pH | Conductivity mS/m | Cl mg/l |
|---|---|---|---|---|---|---|---|---|
| KLX06 | 7722 | 2004-09-05 | 103.00 | 202.26 | 17.40 | 8.39 | 46.7 | 25.4 |
| KLX06 | 7757 | 2004-09-10 | 265.50 | 268.50 | 19.30 | 8.82 | 48.4 | 22.4 |
| KLX06 | 7759 | 2004-09-11 | 260.50 | 268.70 | 4.03 | 8.60 | 48.5 | 15.7 |
| KLX06 | 7760 | 2004-09-13 | 200.50 | 310.20 | 47.50 | – | – | – |
| KLX06 | 7775 | 2004-09-19 | 331.02 | 364.23 | 35.60 | 9.05 | 76.1 | 73.2 |
| KLX06 | 7798 | 2004-09-23 | 307.50 | 415.49 | 66.50 | – | – | – |
| KLX06 | 7859 | 2004-10-09 | 514.60 | 613.94 | 74.70 | – | – | – |
| KLX06 | 7900 | 2004-10-29 | 715.14 | 784.94 | 48.70 | 7.59 | 506.0 | 1,330.0 |
| HLX20 | 7560 | 2004-06-24 | 9.03 | 202.20 | 2.4 | 8.42 | 54.4 | 29.4 |
| HLX20 | 7561 | 2004-06-24 | 9.03 | 202.20 | – | 8.43 | 52.8 | 29.5 |

Sample 7561 is a control sample of sample 7560, i.e. it is not sent for analyses (except for some time critical parameters such as pH and alkalinity) but the sample is saved and stored at the Äspö laboratory.

No samples taken from HLX10 in connection with the drilling of KLX06 but samples have been collected from HLX10 at earlier occasions and have been reported previously /4/.

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

There were two water samples taken from HLX20 in connection with the drilling of KLX06. (The reason they are SKB chemistry class 5 is that TOC only exists as a parameter in that specific class). The only analyses performed are the ones recorded in Appendix 2.

### *Organic content and microorganisms*

The concentration of total organic carbon (TOC) in sample 7560 was 2.4 mg/l. This value was considered acceptable for the groundwater to be used as flushing water for the core drilled part of KLX06 without further filtration measures to lower the organic carbon content.

### *Monitoring of uranine tracer content*

A total of 142 samples for laboratory testing of uranine content in flushing and returning water were taken along the borehole. The analytical results are shown in Figure 5-9. A calculation of the uranine balance is given in Section 5.5.2, Table 5-14.

## 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 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 inflow of water in the tests is normally due to on-going drilling. From the drawdown phase the steady state transmissivity, $T_M$, was calculated according to Moye /2/, as well as the specific capacity, $Q / s$. The results are shown in Table 5-13.

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

**Table 5-13. Results from airlift pumping in KLX06.**

| Tested section | Flow rate (L/min) | Drawdown (m) | Q/s ($m^2/s$) | $T_M$ ($m^2/s$) | Comments |
|---|---|---|---|---|---|
| 11.88–562.18 | 94 | 5.3 | $3.0 \times 10^{-4}$ | $4.7\times10^{-4}$ | |
| 11.88–721.94 | 60 | 6.3 | $1.6\times10^{-4}$ | $2.6\times10^{-4}$ | |
| 11.88–994.94 | 15.9 | 4.5 | $5.9\times10^{-5}$ | $9.8\times10^{-5}$ | Extremely variable flow. Flow rate is estimated from accumulated volumes of water pumped over the pumping period: $Q = \frac{\sum_{i=1}^{n} V_i}{dt}$ |

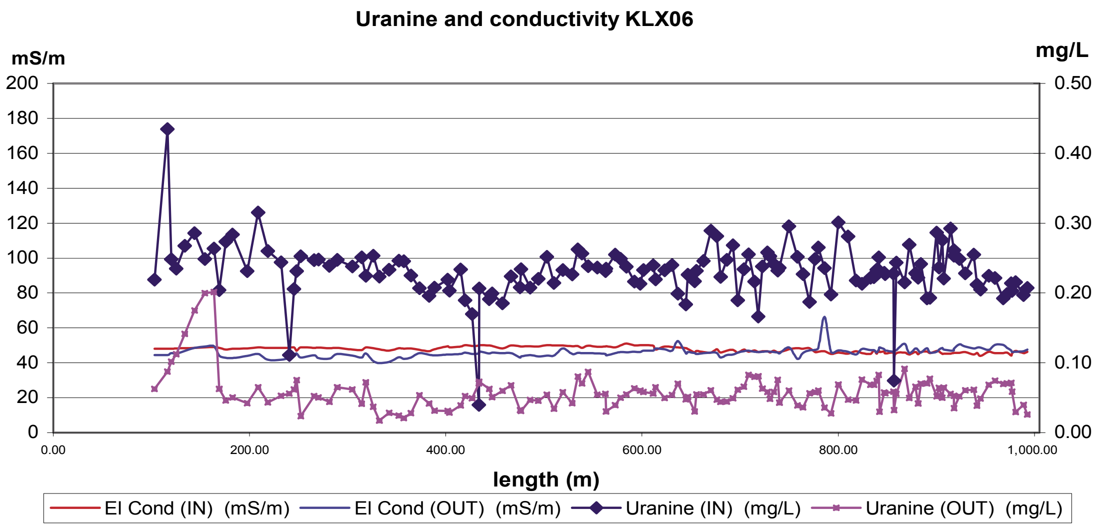



***Figure 5-9.** The uranine concentration and electrical conductivity of flushing water (IN) and returning water (OUT) in KLX06 during drilling.*

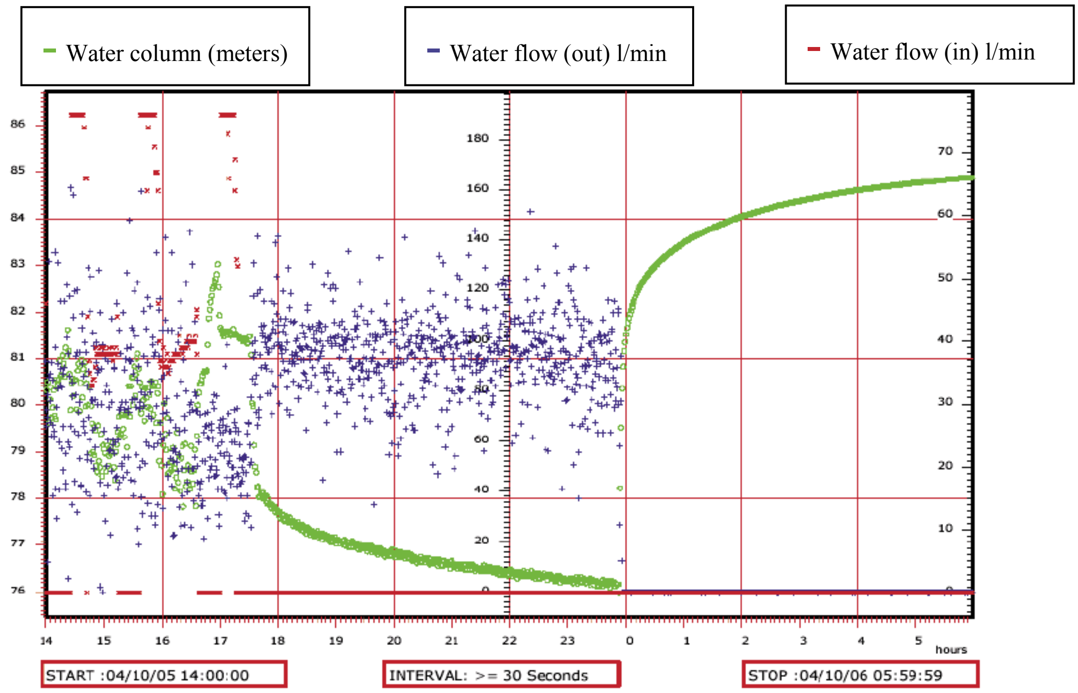



***Figure 5-10.** Air lift pumping test in KLX06 11–562 m showing the pumped flowrate (blue), water inflow from drilling(red) and the height of the water column (green) in the telescopic part of the borehole. The pressure transducer was positioned 90 m below top of casing and the flow rate was measured at the ground surface.*

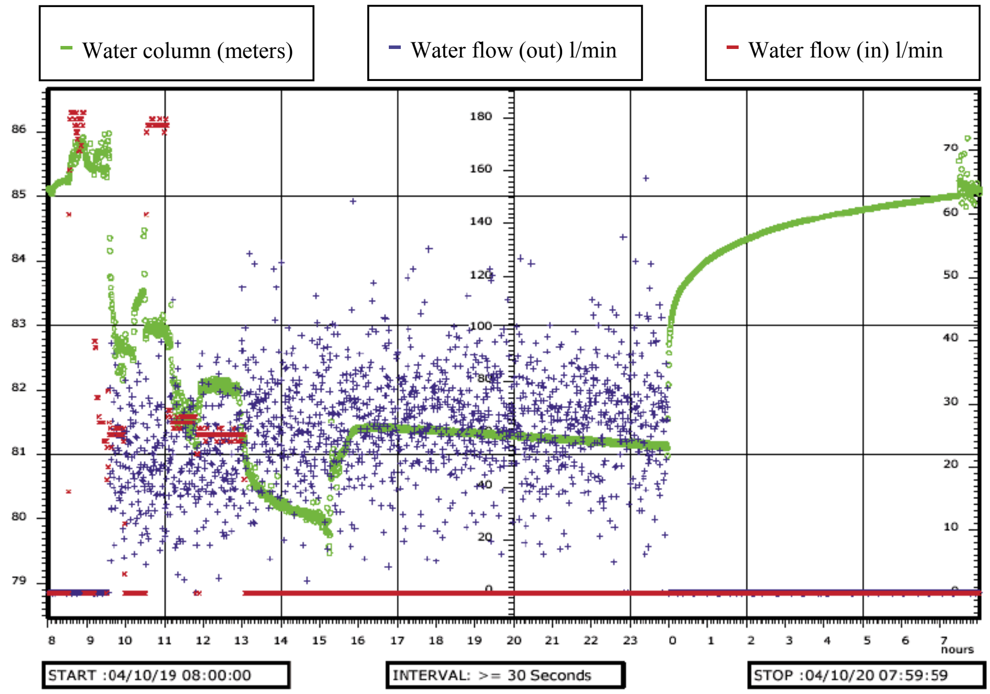



***Figure 5-11.** Air lift pumping in KLX06 11–721 m showing the inflow rate(red), the net outflow rate (blue) and the height of the water column (green) in the telescopic part of the borehole. The pressure transducer was positioned 90 m below top of casing and the flow rate was measured at the ground surface.*

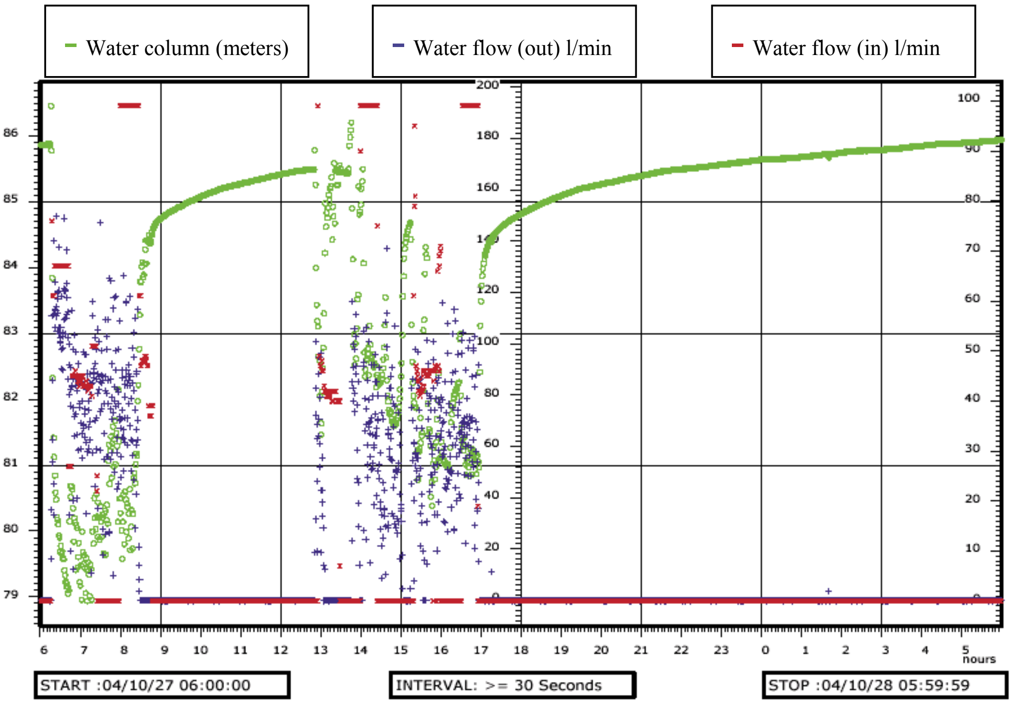



*Figure 5-12. Air lift pumping in KLX06 11–904 m showing the outflow rate (blue), water inflow from drilling (red) and the height of the water column (green) in the telescopic part of the borehole. The pressure transducer was positioned 90 m below top of casing and the flow rate was measured at the ground surface.*

### Hydraulic responses in HLX20

The nearby percussion borehole, HLX20, responded clearly to air-lift pumping in KLX06. The water level in HLX20 fell by 1.5–2 m during periods of drilling in KLX06 ie when air-lift pumping was conducted, see Figure 5-13.

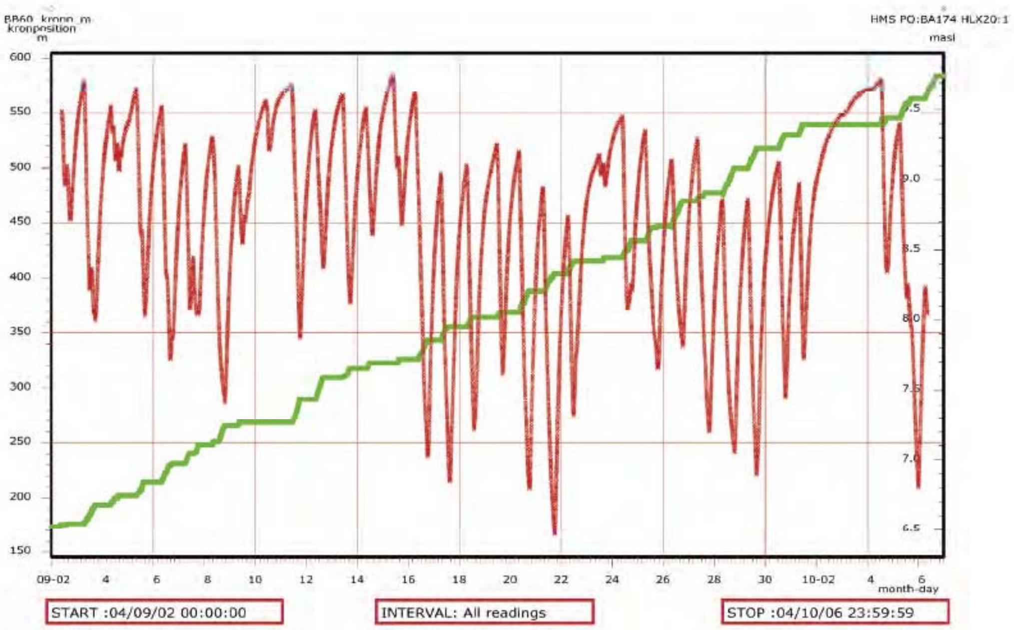



*Figure 5-13. The water level in HLX20 (red) and the drill bit position in KLX06 (green). Distinct reductions in the water level in HLX20 (red) can be seen during periods of drilling in KLX06 ie when air-lift pumping was conducted.*

## 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 100.3–994.94 m are given in Sections 5.2 and 5.3 respectively.

### 5.5.1 Drill monitoring system DMS

The DMS database contains substantial amounts of drilling monitoring data. A selection of results primarily from the monitoring of the flushing water parameters are presented in Figures 5-14 through 5-16 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.

A brief study of the water pressure indicates that the expected trend of gradually increasing water pressure with drilled length was not fulfilled in KLX06. Instead the water pressures were variable and sometimes very high until drilling reached 250 m. After this point the water pressure was low and reasonably stable.

In order to maintain reasonable size data files, a reduction in the number of points incorporated in the pictures has been done in Figures 5-14 through 5-16. Since DMS data are related to time (ie not strictly to borehole length) periods were drilling is not performed are also registered.

Figure 5-14 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 5-15 shows the flushing water flow (green) entering the hole and the return water flow (red).

Figure 5-16 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 low, typically below 4 mg/L.

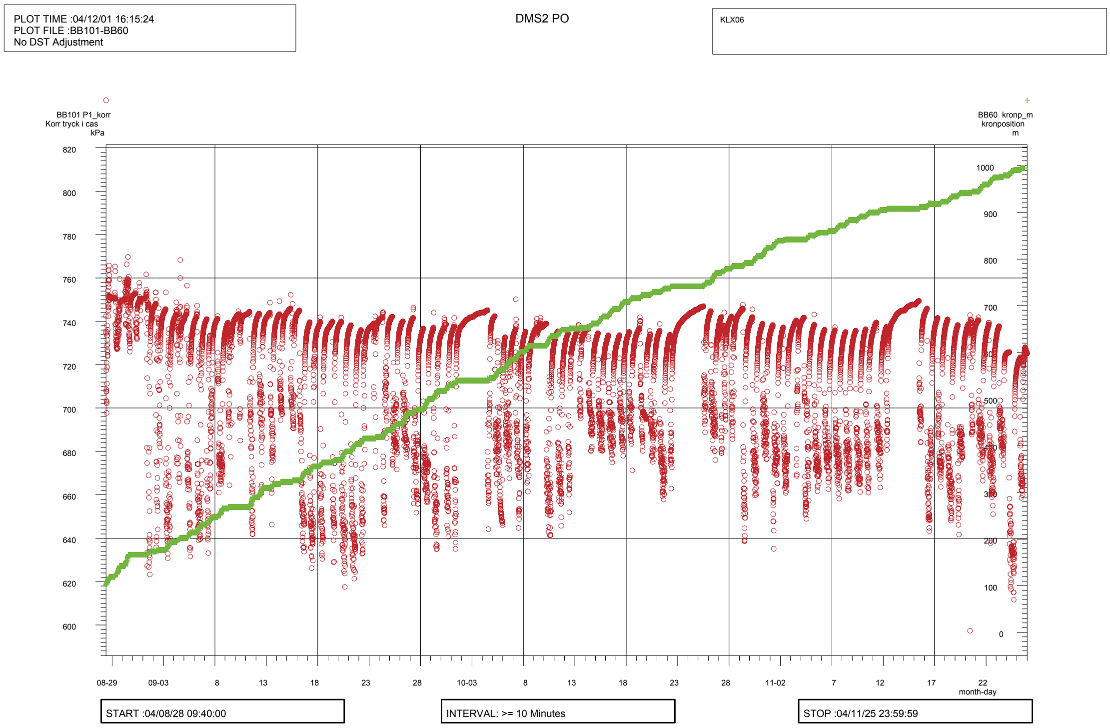



*__Figure 5-14.__ Drill bit position (green) and water level from air-lift pumping (red). The water level is expressed as the pressure in kPa of the water column overlying the pressure gauge ie the ambient air-pressure has been subtracted. The pressure gauge is emplaced at 90 m borehole length. The drill bit position is given in cm x 10$^{3}$.*

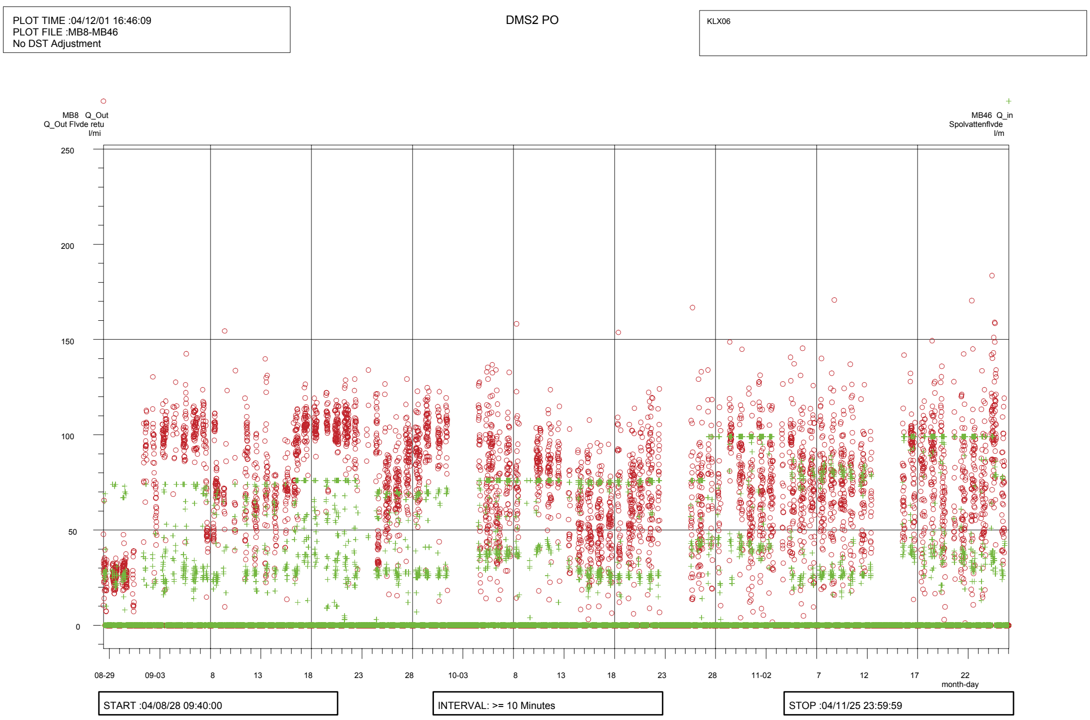



*__Figure 5-15.__ Flushing water flow (green) and return water flow (red) in litres per minute.*

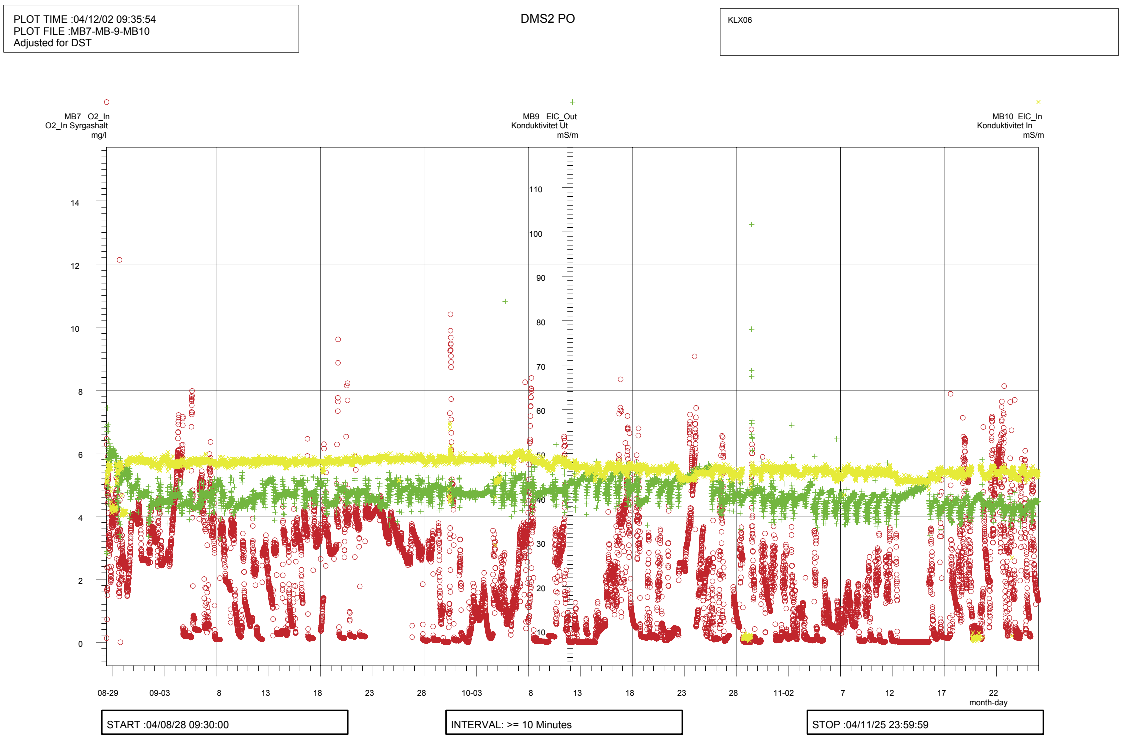



***Figure 5-16.*** *Conductivity of flushing water (yellow) and return water (green). The oxygen content in mg/l of the flushing water (red) is also shown. The oxygen content of the flushing water is normally below 4 mg/l. The change of flushing water source from HLX10 to HLX20 on October 6 is reflected by the slightly more variable conductivity after this date.*

## 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 5-17.

The amount of flushing water consumed during drilling was 1,800 $m^3$, giving an average consumption of ca 2 $m^3$ per metre drilled. The amount of effluent return water from drilling in KLX06 was 3,300 $m^3$, giving an average of ca 3.7 $m^3$ per metre drilled.

### *Drill cutting balance*

The weight of cuttings in the settling containers amounted to 1,050 kg. The content of suspended material in the return water was not analysed in borehole KLX06, 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 1,320 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/$dm^3$. This means that about 40% 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.

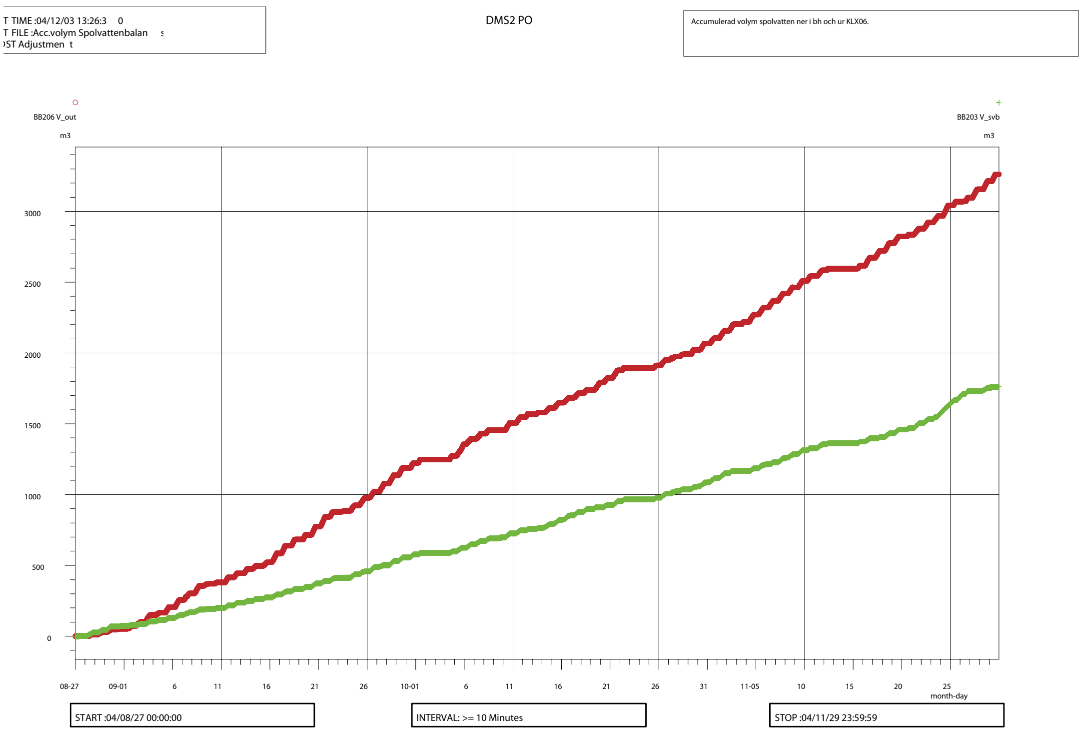



***Figure 5-17.*** *Flushing water balance from KLX06 as recorded by the DMS system. The accumulated volume of the ingoing flushing water is shown in green and the outgoing return water is shown in red.*

### *Uranine tracer balance*

The amount of introduced and recovered uranine is presented in Table 5-14. The results show that 46% of the introduced uranine was retrieved during drilling.

**Table 5-14. Balance calculation of uranine tracer in KLX06.**

| | |
|---|---|
| Average uranine content IN (mg/L) | 0.23 |
| Flushing water volume IN ($m^3$) | 1,800 |
| Amount uranine introduced (g) | 416 |
| Average uranine content OUT (mg/L) | 0.06 |
| Return water volume OUT ($m^3$) | 3,300 |
| Amount uranine recovered (g) | 192 |

## 5.6 Geology

A preliminary geological mapping of the core is done as drilling progresses as part of the drilling activity. 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 but the results from the Boremap logging is nevertheless 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, /3/, are shown in Appendix 1.

Lithologically the core is dominated by Ävrö granite. Intercalations of fine-grained diorite-gabbro and fine grained granite are not uncommon between 320 and 600 m. A rather heterogeneous section consisting of granite, fine-grained granite, Ävrö granite and fine grained diorite-gabbro occurs from 840 m to the bottom of the borehole.

Modest oxidation occurs sporadically along the length of the core, but between 200 m and 410 m the intensity of the oxidation is somewhat elevated. Saussuritization ie alteration of calcic plagioclase feldspar, with faint to weak intensity is noted between 340 m and 380 m and between 670 m and 740 m.

The distribution of total fractures in the core is typically in the range of 5–10 fractures/metre with minor sections containing slightly elevated fracture frequencies. One noteable exception exists, however. Between 150 m and 350 m the fracture frequency is in the range of 10–20, coupled with several crushed sections (fracture frequency > 40).

## 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 is shown in Figure 5-18. 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.

### *Monitoring of effluent water*

The effluent water, ie discharge to the ground, from the core drilling of KLX06 never exceeded the guideline value of 300 mS/m. Typical conductivity values were in the range of 40–50 mS/m, see Figures 5-9 and 5-16.

The uranine content was below 0.25 mg/l, see Figure 5-9.

The concentration of suspended material was not analysed in this borehole, however previous sampling has shown that the concentration was well below 600 mg/L /5/.

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

### *Drilling of environmental monitoring wells*

Three environmental monitoring wells SSM000209, SSM000210 and SSM000211 were drilled. Wells SSM000210 and SSM000211 were emplaced to monitor the water effluence or other possible impact from KLX06. SSM000209 is located by the percussion borehole HLX20 which served as a source of water for most of the core drilling of KLX06. No water emission to the ground took place at HLX20. The locations of the wells are given in Figure 5-18.

A description of the drilling of the environmental monitoring wells is given in /6/.

### *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 09005. Reference samples of ground water from the environmental wells were not taken.

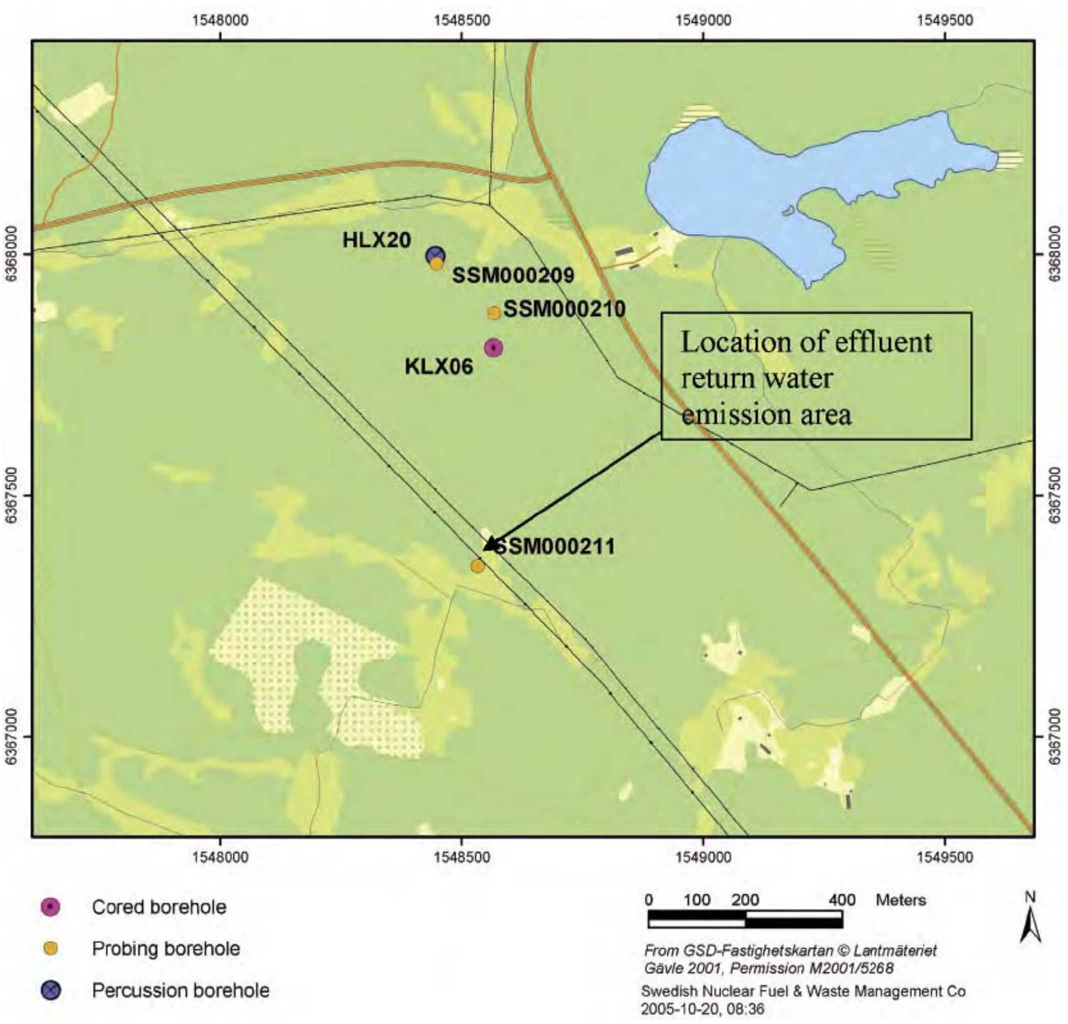



***Figure 5-18.*** *Location of environmental monitoring wells SSM000209, SSM000210 and SSM000211 in relation to the core drill site for KLX06 and percussion borehole HLX20. The effluent return water was infiltrated to the ground some 400 m south of KLX06.*

### *Monitoring of soil ground water levels*

Pressure loggers (transducers) for measuring the ground water table were installed as shown in Table 5-15.

**Table 5-15. Measurements in environmental monitoring wells.**

| Monitoring well | Measurement | Date |
|---|---|---|
| SSM000209 | Transducer installation | 040827–041209 |
| SSM000210 | Transducer installation | 040827–041209 |
| SSM000211 | Transducer installation | 040827–041209 |

### 5.8.1 Consumption of oil and chemicals

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

The concrete consumption was 428 litres in total. The concrete was based on white silica, low alkali cement.

## 5.9 Nonconformities

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

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/ **SKB, 2005.** Boremap mapping of core drilled boreholes KLX06, SKB P-05-185 (in prep), Svensk Kärnbränslehantering AB.

/4/ **Ask, Morosini, Samuelsson, Ekström, 2004.** Drilling of cored borehole KSH02, SKB P-04-151, Svensk Kärnbränslehantering AB.

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

/6/ **Johansson, Adestam, 2004.** Installation of groundwater monitoring wells in the Laxemar area, SKB P-04-317, Svensk Kärnbränslehantering AB.

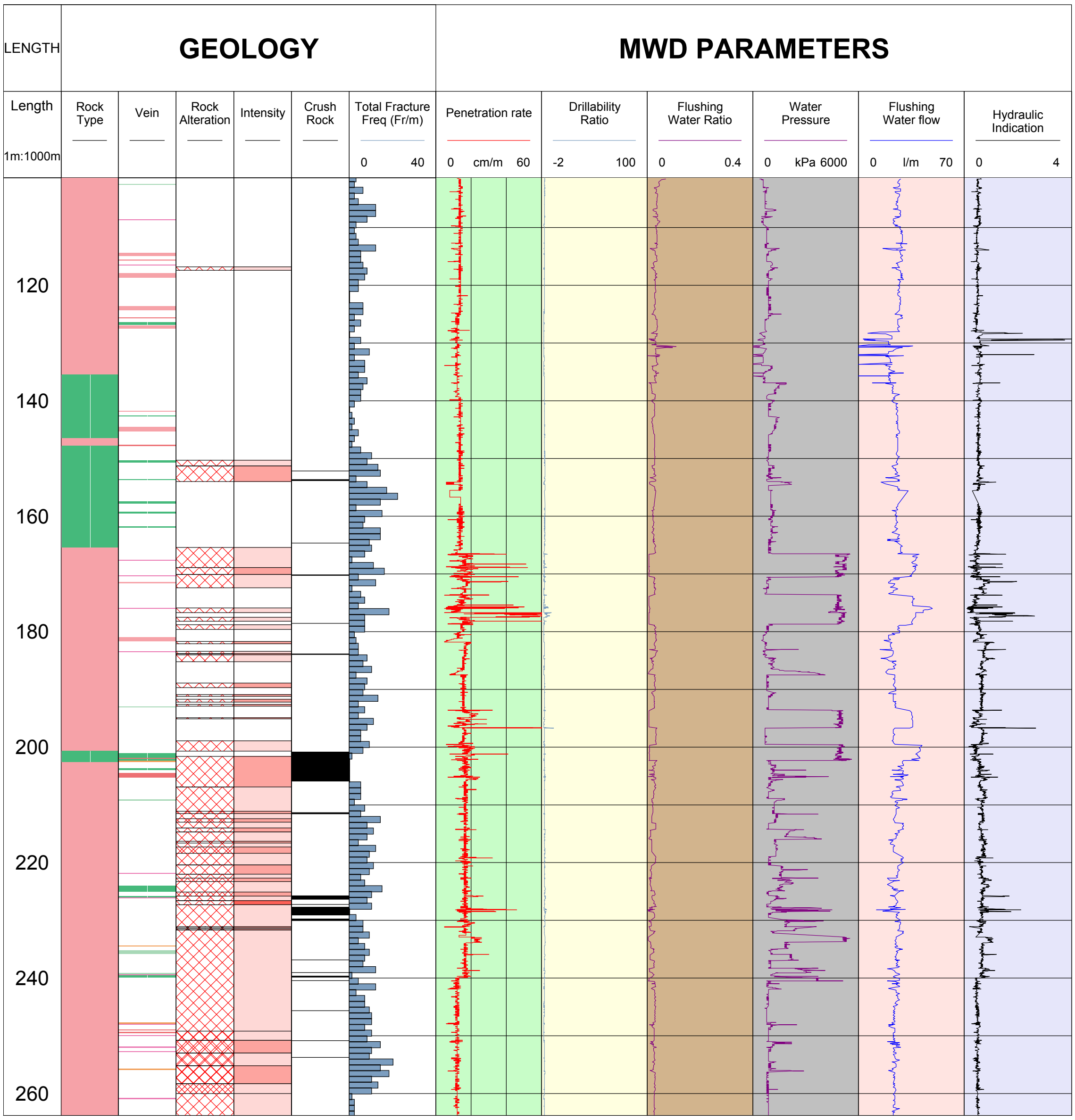
# Geology and MWD parameters KLX06

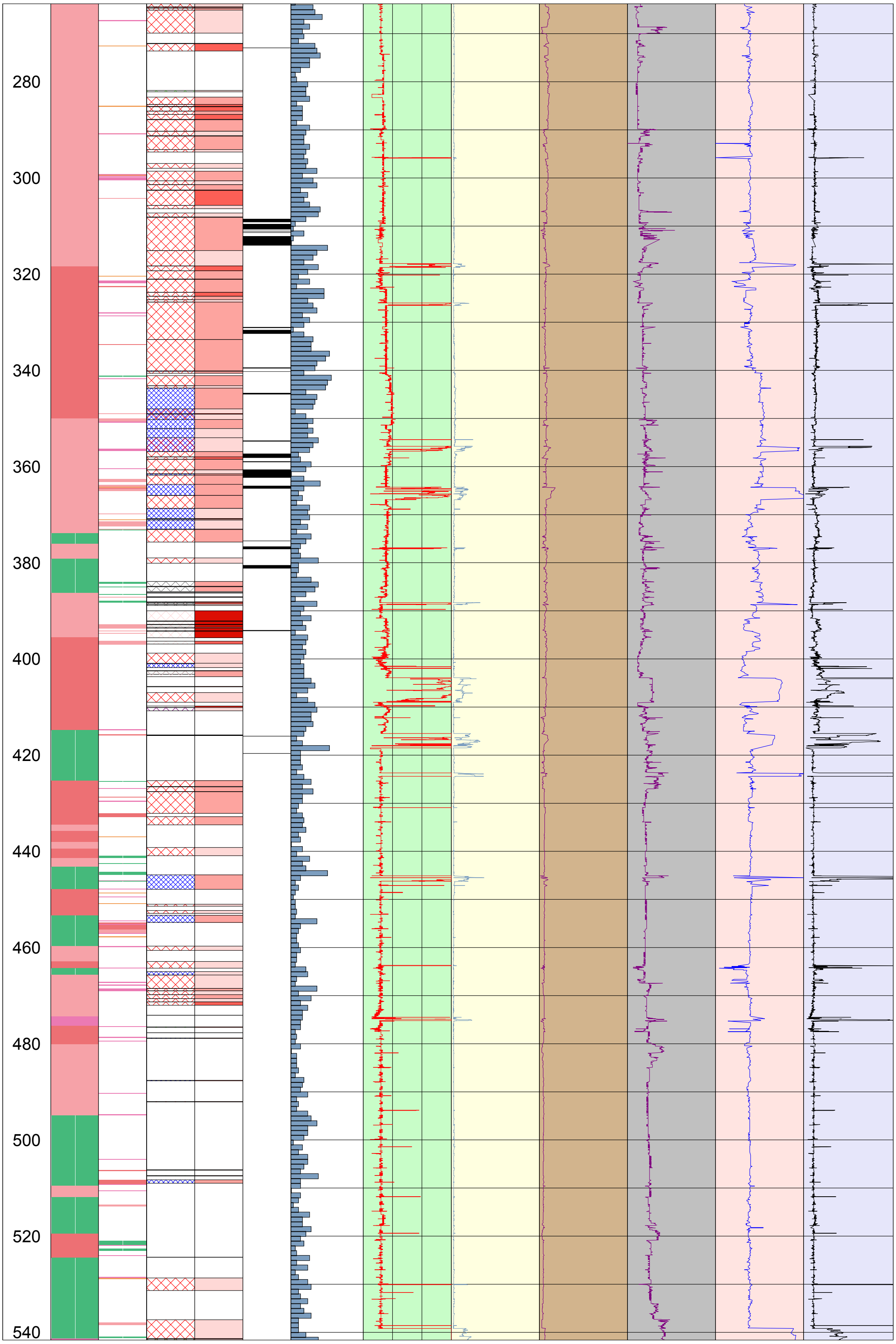
| Title | GEOLOGY & MWD PARAMETERS KLX06 | | Appendix 1 |
|---|---|---|---|
| **Site** | LAXEMAR | **Coordinate System** | RT90-RHB70 |
| **Borehole** | KLX06 | **Northing [m]** | 6367805.82 |
| **Diameter [mm]** | 76 | **Easting [m]** | 1548566.93 |
| **Length [m]** | 994.940 | **Elevation [m.a.s.l.]** | 17.61 |
| **Bearing [°]** | 328.81 | **Drilling Start Date** | 2004-08-03 10:30:00 |
| **Inclination [°]** | -65.22 | **Drilling Stop Date** | 2004-11-25 11:30:00 |
| **Date of mapping** | 2005-01-11 11:53:00 | **Plot Date** | 2005-08-23 23:28:38 |

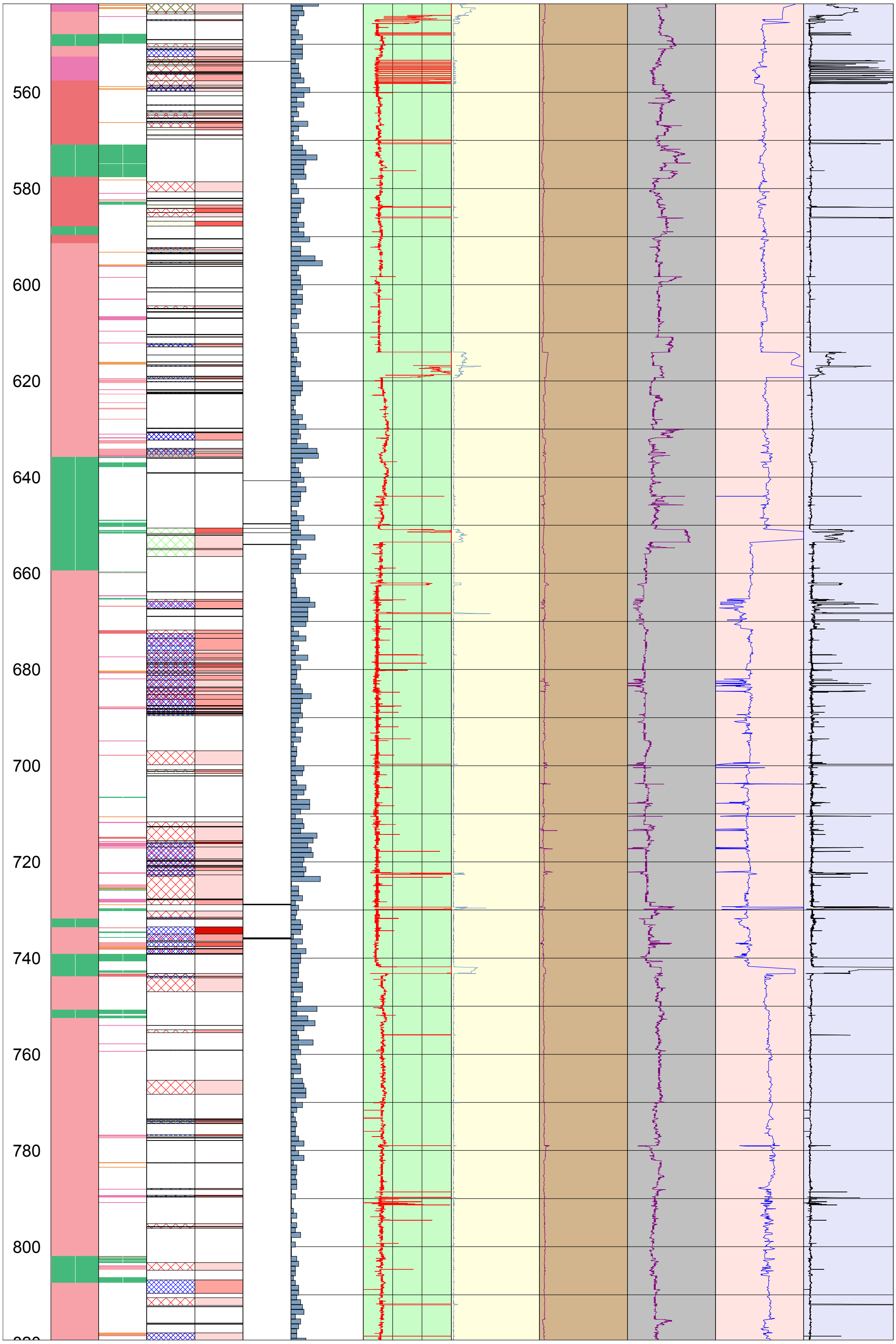
ROCKTYPE LAXEMAR
- Fine-grained granite
- Granite
- Ävrö granite
- Fine-grained diorite-gabbro

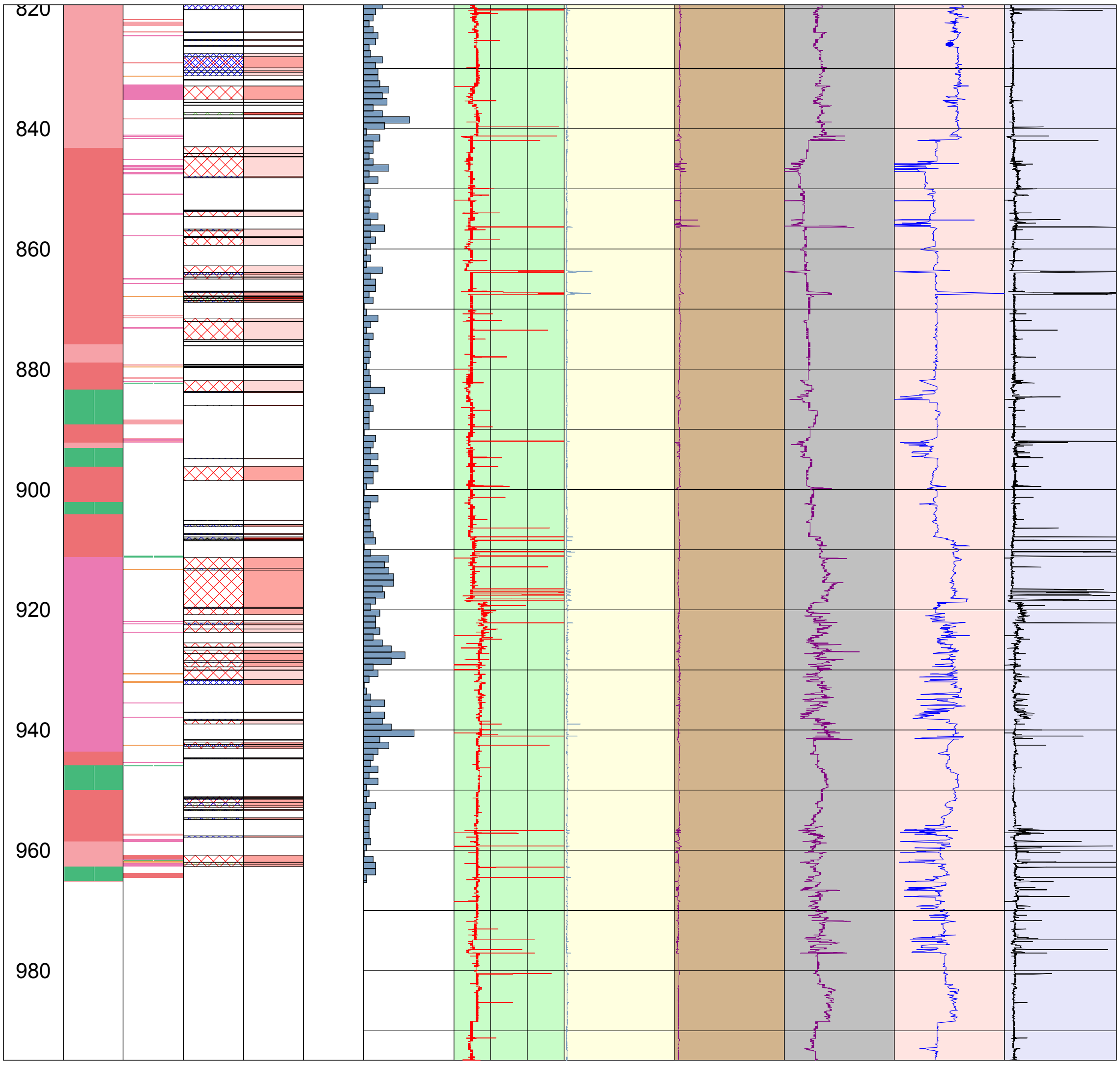
ROCK ALTERATION
- Oxidized
- Epidotisized
- Sericitisized
- Quartz dissolution
- Silicification
- Argillization
- Saussuritization

INTENSITY
- Faint
- Weak
- Medium
- Strong




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

# Appendix 2

## Chemical results

| Borehole | KLX06 | KLX06 | KLX06 | KLX06 | KLX06 | KLX06 | KLX06 | KLX06 | HLX20 | HLX20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Date of measurement | 9/5/2004 | 9/10/2004 | 9/11/2004 | 9/13/2004 | 9/19/2004 | 9/23/2004 | 10/9/2004 | 10/29/2004 | 6/24/2004 | 6/24/2004 |
| Upper section limit (m) | 103.0 | 265.5 | 260.5 | 200.5 | 331.02 | 307.5 | 514.6 | 715.14 | 9.03 | 9.03 |
| Lower section limit (m) | 202.26 | 268.5 | 268.7 | 310.2 | 364.23 | 415.49 | 613.94 | 784.94 | 202.2 | 202.2 |
| Sample_no | 7722 | 7757 | 7759 | 7760 | 7775 | 7798 | 7859 | 7900 | 7560 | 7561 |
| Groundwater Chemistry Class | 3 | 3 | 3 | 1 | 3 | 1 | 1 | 3 | 5 | 5 |
| pH | 8.39 | 8.82 | 8.6 | | 9.05 | | | 7.59 | 8.42 | 8.43 |
| Conductivity mS/m | 46.7 | 48.4 | 48.5 | | 76.1 | | | 506.0 | 54.4 | 52.8 |
| TOC mg/l | | | | | | | | | 2.4 | |
| Drill water % | 17.4 | 19.3 | 4.03 | 47.5 | 35.6 | 66.5 | 74.7 | 48.7 | | |
| Densitet g/cm³ | 0.9964 | 0.9964 | 0.9964 | | 0.9967 | | | 0.9988 | 0.9965 | 0.9966 |
| Na mg/l | 92.7 | | 99.5 | | | | | 778.0 | 107.0 | |
| K mg/l | 4.54 | | 0.88 | | | | | 12.8 | 1.34 | |
| Ca mg/l | 12.8 | | 6.0 | | | | | 369.0 | 7.5 | |
| Mg mg/l | 5.3 | | 1.2 | | | | | 23.4 | 2.1 | |
| HCO3 mg/l Alkalinity | 216.0 | 221.0 | 222.0 | | 220.0 | | | 89.1 | 205.0 | 204.0 |
| Cl mg/l | 25.4 | 22.4 | 15.7 | | 73.2 | | | 1,330.0 | 29.4 | 29.5 |
| SO4 mg/l | 24.3 | 26.1 | 23.4 | | 67.8 | | | 771.0 | 47.8 | 48.0 |
| SO4_S mg/l Total Sulphur | 8.11 | | 7.69 | | | | | 262.0 | 16.0 | |
| Br mg/l | 0.109 | < 0.2 | 0.033 | | 0.47 | | | 13.1 | < 0.2 | < 0.2 |
| F mg/l | 4.74 | 5.99 | 7.24 | | 6.27 | | | 2.65 | 4.95 | 4.96 |
| Si mg/l | 21.6 | | 6.7 | | | | | 37.6 | 6.39 | |
| Fe mg/l Total Iron | 8.98 | | 2.04 | | | | | | 0.0753 | |

| Borehole | KLX06 | KLX06 | KLX06 | KLX06 | KLX06 | KLX06 | KLX06 | KLX06 | HLX20 | HLX20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Mn mg/l | 0.323 | | 0.0544 | | | | | 0.824 | 0.0239 | |
| Li mg/l | 0.025 | | 0.014 | | | | | 0.158 | 0.016 | |
| Sr mg/l | 0.212 | | 0.167 | | | | | 6.74 | 0.137 | |
| PMC % Modern Carbon | 48.15 | | 47.29 | | | | | | 41.68 | |
| C-13 dev PDB | –16.23 | | –16.31 | | | | | | –17.01 | |
| AGE_BP Groundwater age | 5,817 | | 5,963 | | | | | | 6,978 | |
| AGE_BP_CORR | 35 | | 40 | | | | | | 30 | |
| D dev SMOW | –78.0 | | –77.3 | | | | | | –80.3 | |
| Tr TU | 2.8 | | 1.5 | | | | | | –0.8 | |
| O-18 dev SMOW | –11.3 | | –11.2 | | | | | | –11.3 | |
| B-10 B-10/B-11 | 0.2352 | | 0.2331 | | | | | | 0.2391 | |
| S-34 dev SMOW | 24.4 | | 26.3 | | | | | | 25.4 | |
| Cl-37 dev SMOC | 0.12 | | 0.25 | | | | | | 0.28 | |
| Sr-87 Sr-87/Sr86 | 0.717168 | | 0.715589 | | | | | | 0.715122 | |

# Appendix 3

## Chemistry – analytical method and quality

### SKB Chemistry Class 1.

| Analysis | Sample bottle | Preparation | SKB label | Laboratory |
|---|---|---|---|---|
| pH, conductivity | 250 ml | | Green | Äspö/field |
| Uranine | 100 ml brown glass | | Green | Äspö/field |

### 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 |
| $HS^-$ | 2 st Winkler | Filtering Pallfilter | | Äspö/field |
| | | Conserved with 0.5 ml 1M ZnAc and 1M NaOH | | |

| Analysis | Sample bottle | Preparation | SKB label | Laboratory |
|---|---|---|---|---|
| B-10<br>As, In<br>Environmental metals<br>Lanthanides<br>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 | Systemekologen |
| 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 give an indication of the quality and uncertainty of the analyses of the major components. The relative charge balance error is calculated for the selected set of data from the borehole KLX06. The errors do not exceed ± 5% in the samples (7722, 7759 and 7900) which is fully satisfactory.

The charge balance error in sample 7560 from the borehole HLX20 is –1.94% which also is fully satisfactory.

The charge balance error is not calculated for the samples 7760, 7757 and 7775 and 7798 collected in KLX06 due to the high drilling water percentage.

Figures A3-1 and A3-2 illustrate the consistency of the analyses. The figures are based on the data presented in Appendix 2. Electric conductivity values are plotted versus chloride concentrations in Figure A3-1.

The bromide and chloride concentrations are plotted in Figure A3-2. A plot of bromide versus chloride serves as a rough quality control of the bromide analyses.

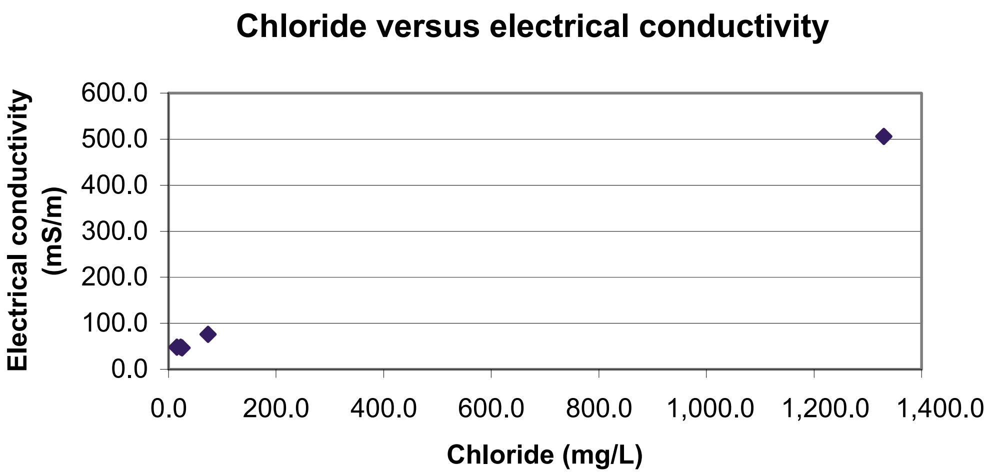



***Figure A3-1.*** *Plot of electrical conductivity versus chloride concentration.*

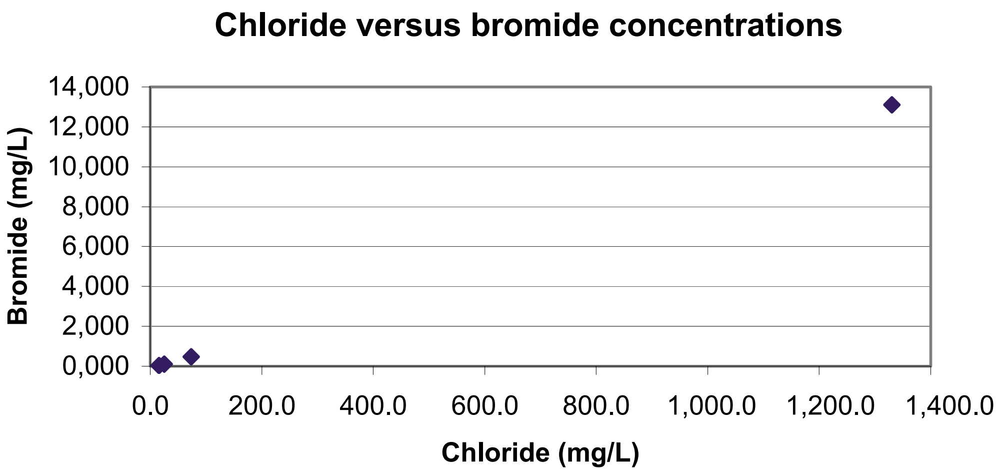



***Figure A3-2.*** *Plot of bromide concentrations versus chloride concentrations.*

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 of Br were sent to Analytica for the samples 7722, 7759 and 7775.
- All analytical results were stored in the SICADA database. The chemistry part of the database contains two types of tables, raw data tables and primary data tables (final data tables).

- Data on basic water analyses are inserted into raw data tables for further evaluation. The evaluation results in a final reduced data set for each sample. These data sets are compiled in a primary data table named “water composition”. The evaluation is based on:
  - Comparison of the results from different laboratories and/or methods. The analyses are repeated if a large disparity is noted (generally more than 10%).
  - Calculation of charge balance errors. Relative errors within ± 5% are considered acceptable. For surface waters errors of ± 10%.
  - Rel. Error (%) = $100 \times \frac{(\sum \text{cations(equivalents)} - \sum \text{anions(equivalents)})}{(\sum \text{cations(equivalents)} + \sum \text{anions(equivalents)})}$
  - General expert judgement of plausibility based on earlier results and experiences.

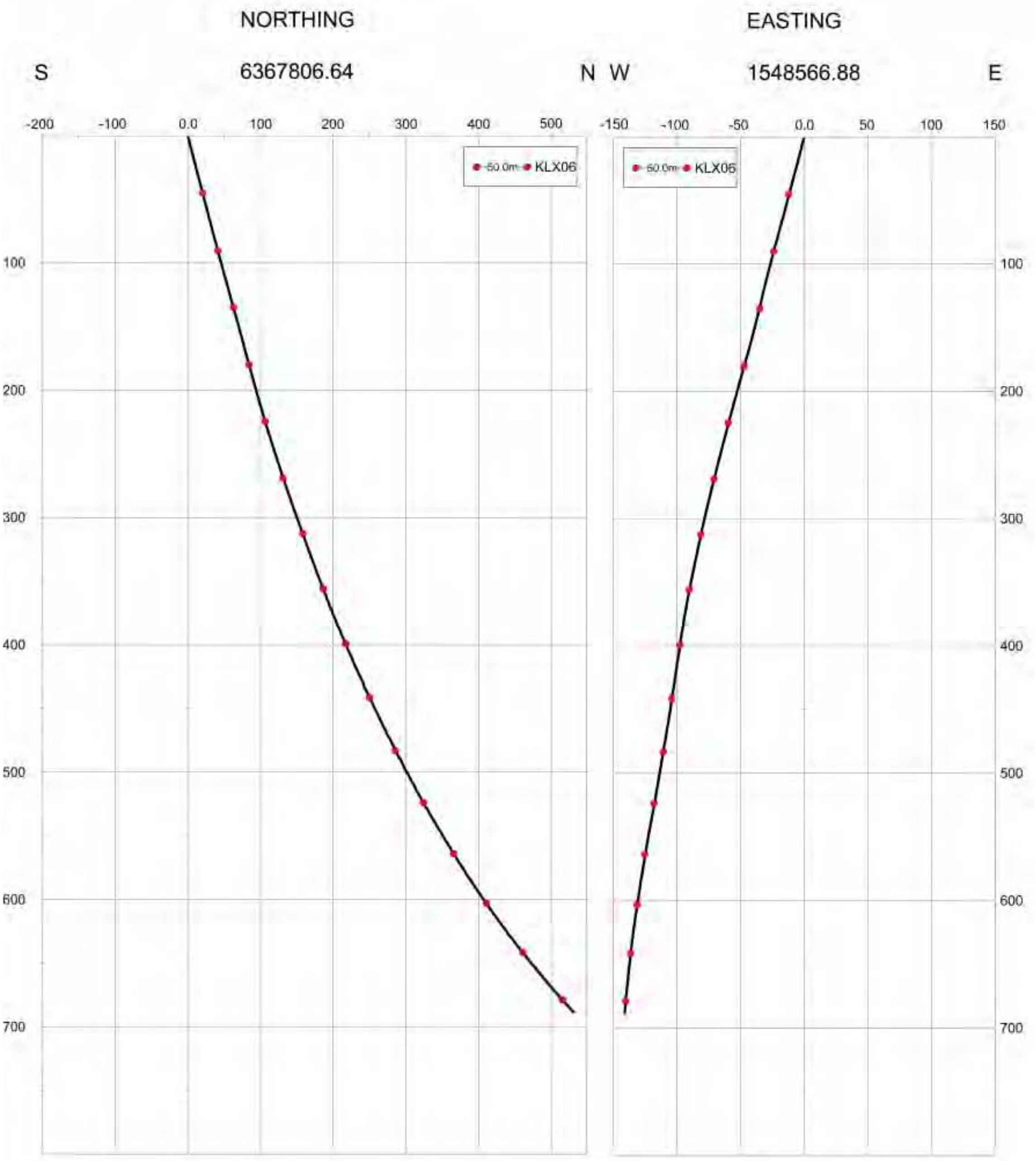
All results from “biochemical” components and special analyses of trace metals and isotopes are inserted directly into primary data tables. In those cases where the analyses are repeated or performed by more than one laboratory, a “best choice” notation will indicate those results which are considered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

# Appendix 4

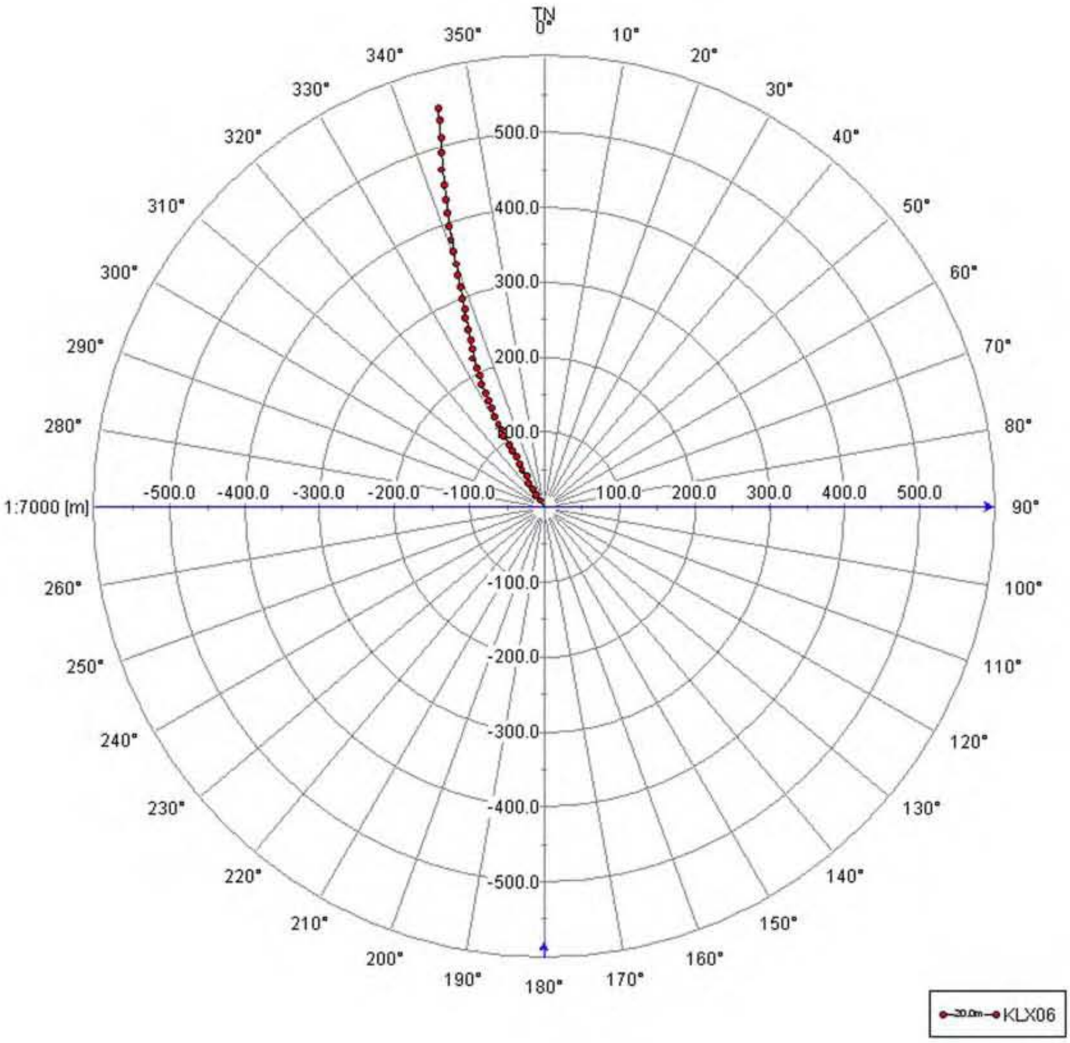
## Deviation measurements

Vertical section / Orthogonal projection — Appendix 4

| | |
|---|---|
| Borehole | KLX06 |
| Site | Laxemar |
| Coordinate system | RT90-RHB70 |
| Length | 994.940 m |
| Bearing | 328.81 |
| Inclination | -65.22 |
| Interval | 50 m |



| Deviation measurement | | Appendix: 4 |
|---|---|---|
| Site | LAXEMAR | |
| Borehole | KLX06 | |
| View from above | | |



# Appendix 5

## Wireline pumping tests

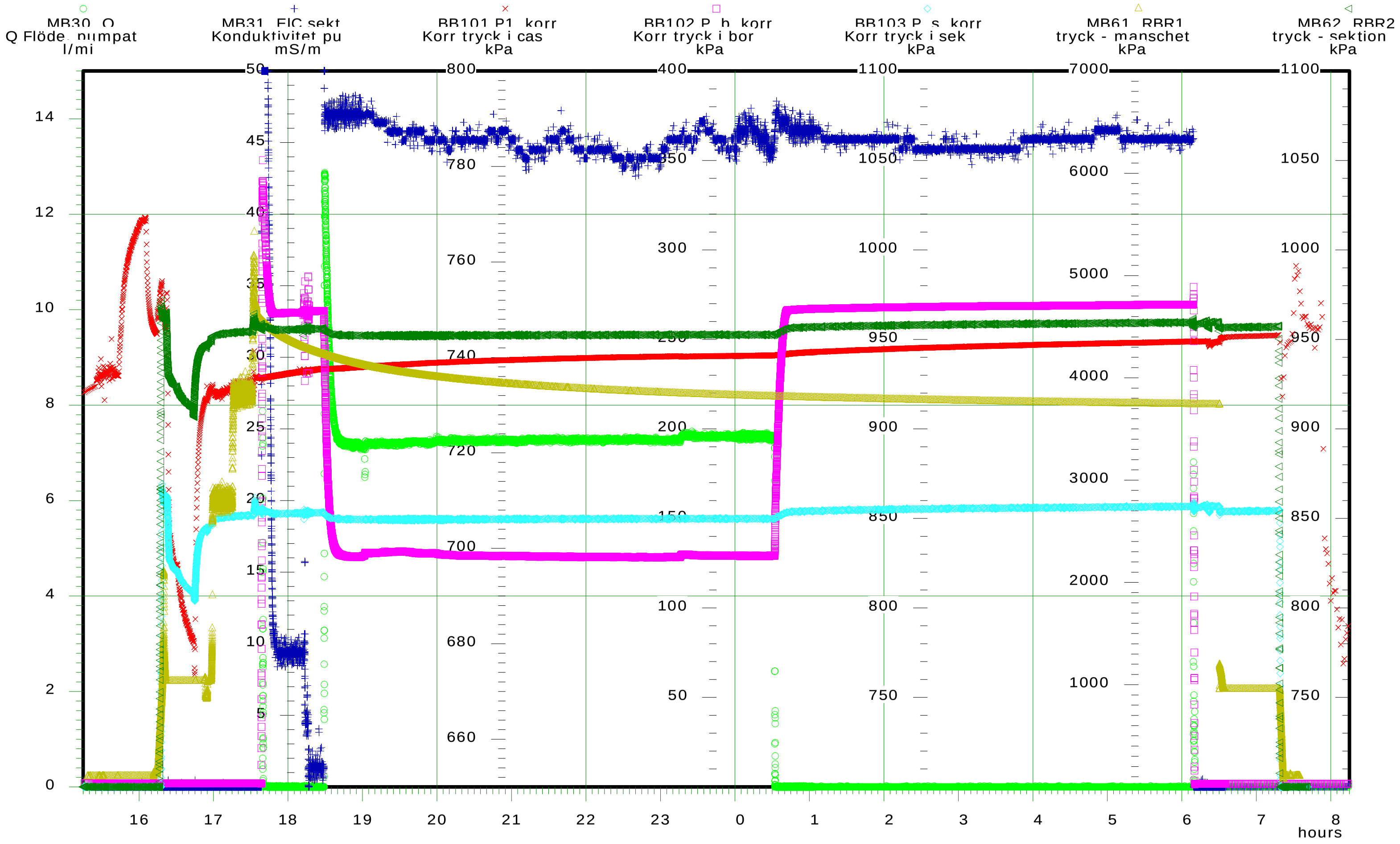
### Description of the parameters in the enclosed plots.

| Channel | Parameter | Unit | Description |
|---|---|---|---|
| MB30 | Water flow | Litre/minute | Flow of water pumped up from the borehole during the test. |
| MB31 | Electrical conductivity | mS/m | Electrical conductivity in the pumped out water. |
| BB101 | Pressure | kPa | Pressure of the water column in the telescopic section subtracted with the ambient air pressure. |
| BB102 | Pressure | kPa | Pressure of the water column in the test section ie at depth in the borehole, subtracted with the ambient air pressure. |
| BB103 | Pressure – section | kPa | Pressure of the water column in the test section ie at depth in the borehole, subtracted with the ambient air pressure. |
| MB61 | Pressure – packer | kPa | Inflation pressure in packer. |
| MM62 | 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 :04/09/30 08:08:15
PLOT FILE :P_pumptest
Adjusted for DST

DMS2 PO

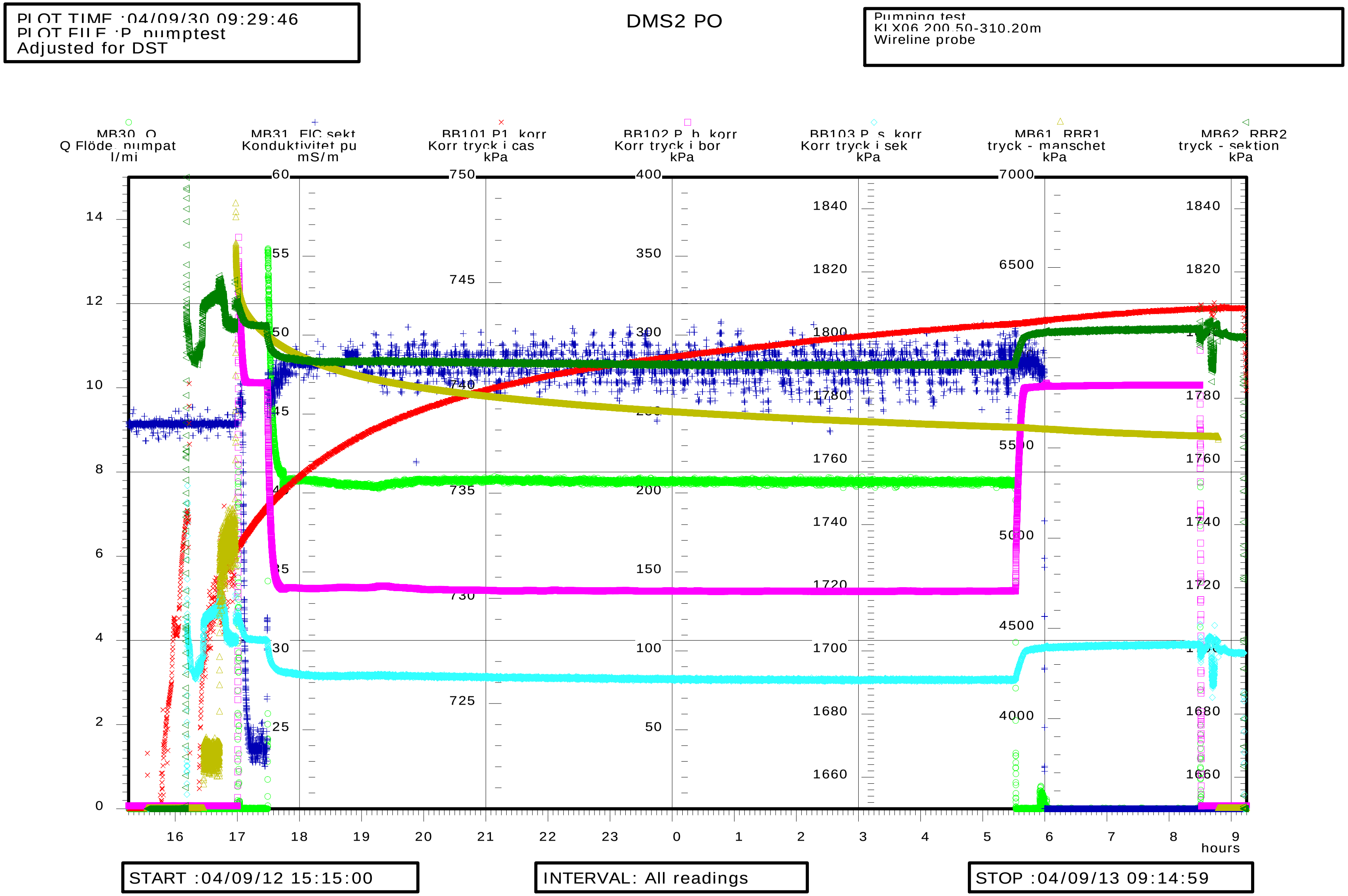
Pumping test
KLX06 103.00-202.26m
Wireline probe



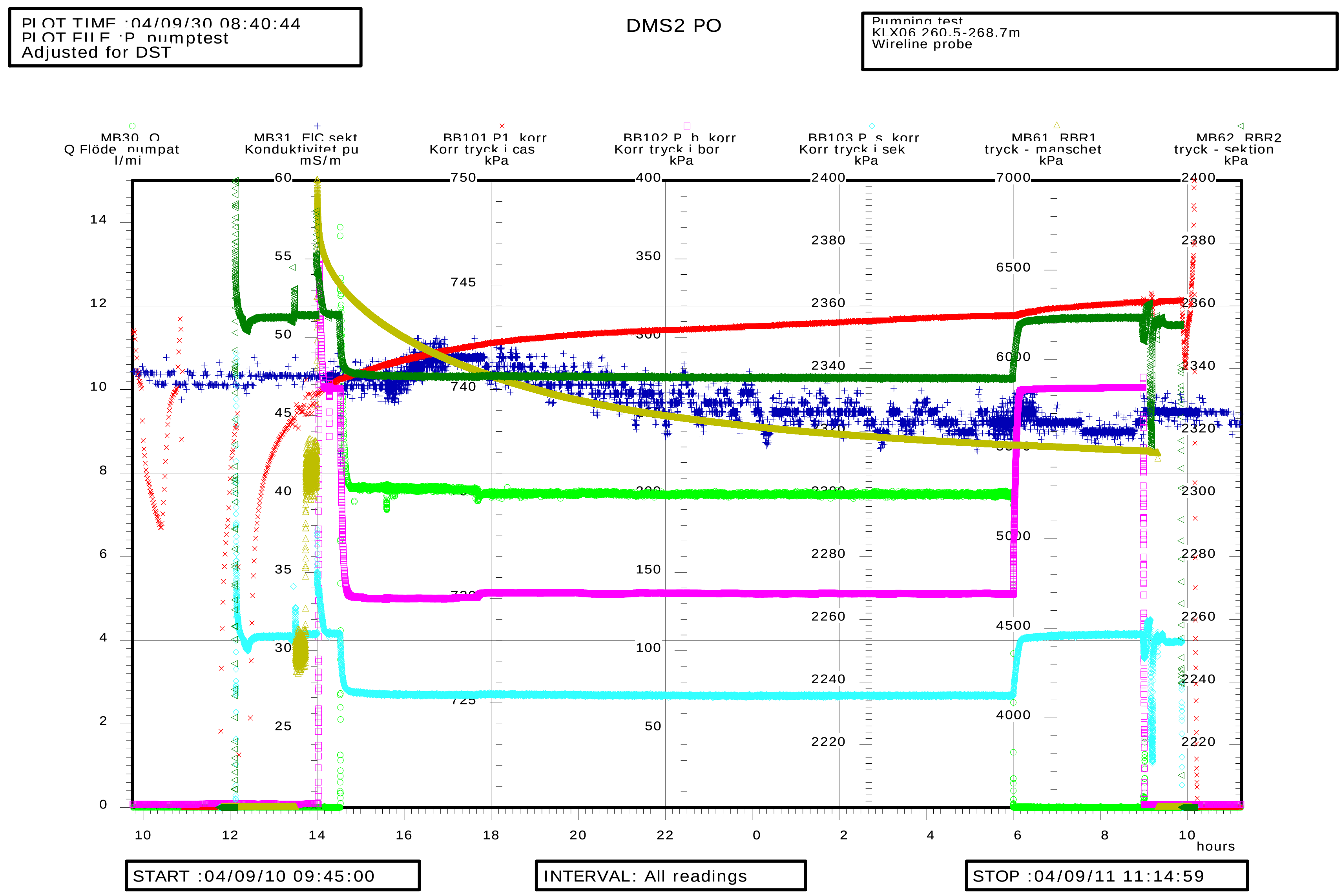

START :04/09/04 15:15:00

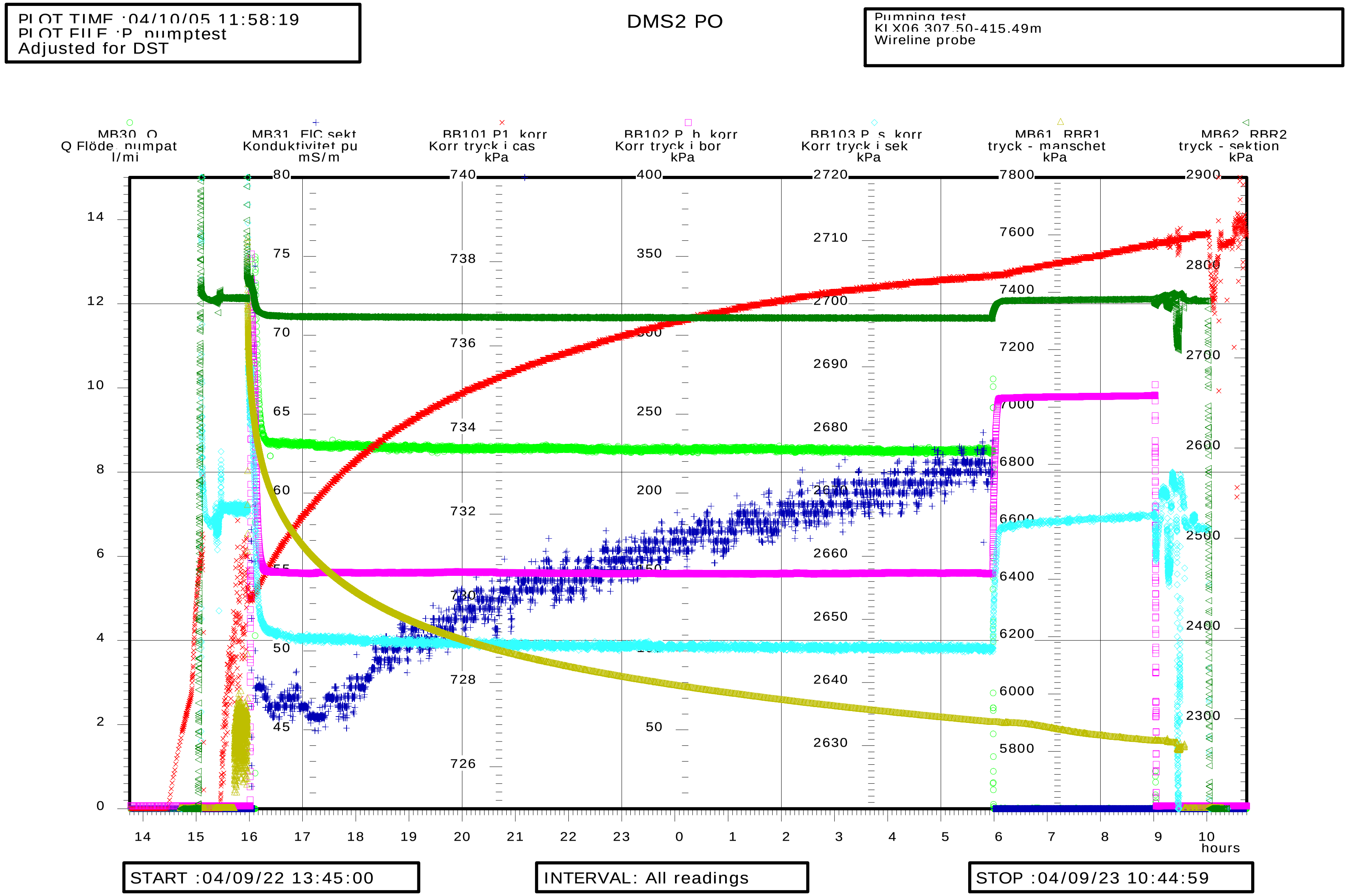
INTERVAL: All readings

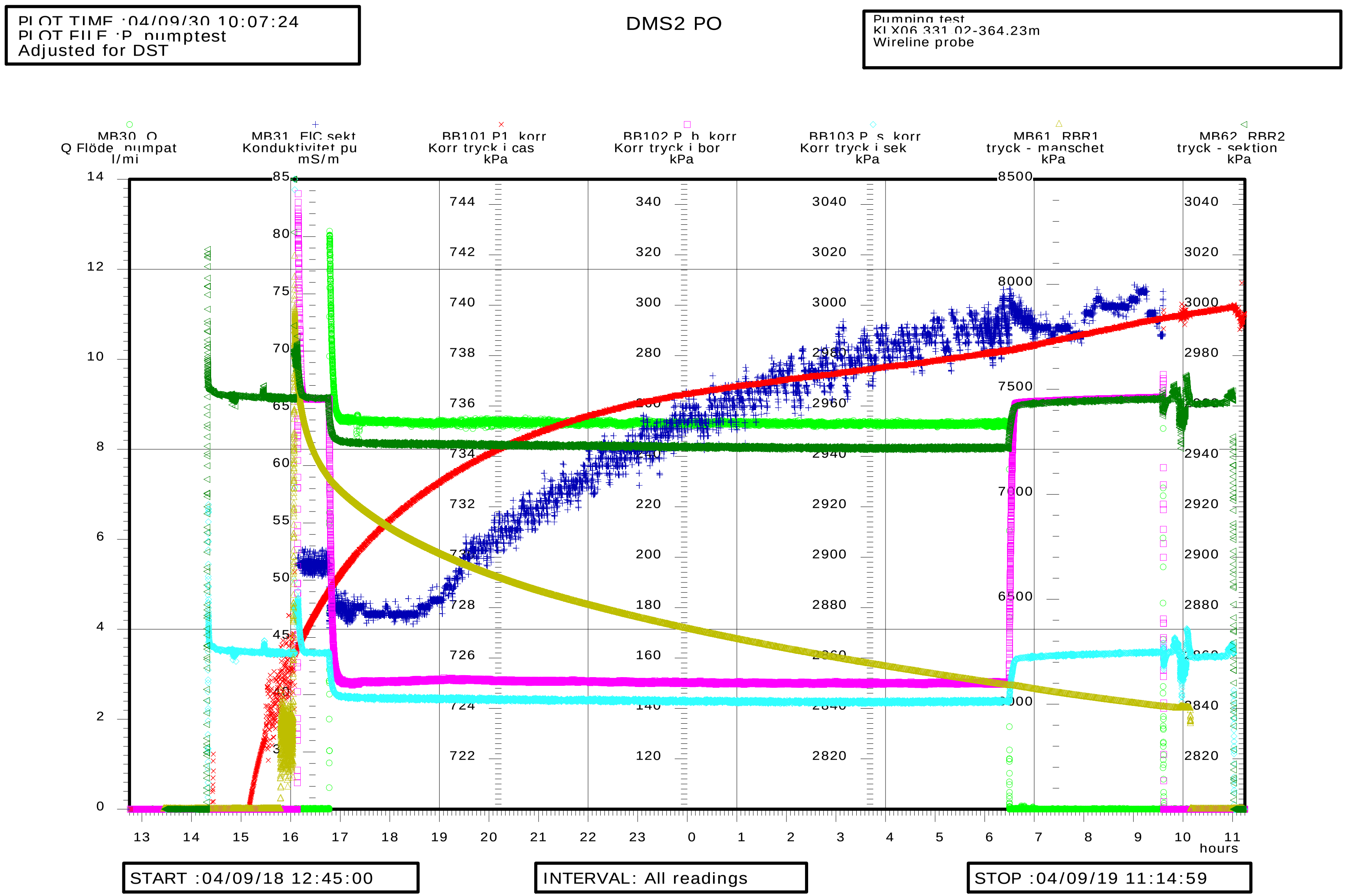
STOP :04/09/05 08:14:59

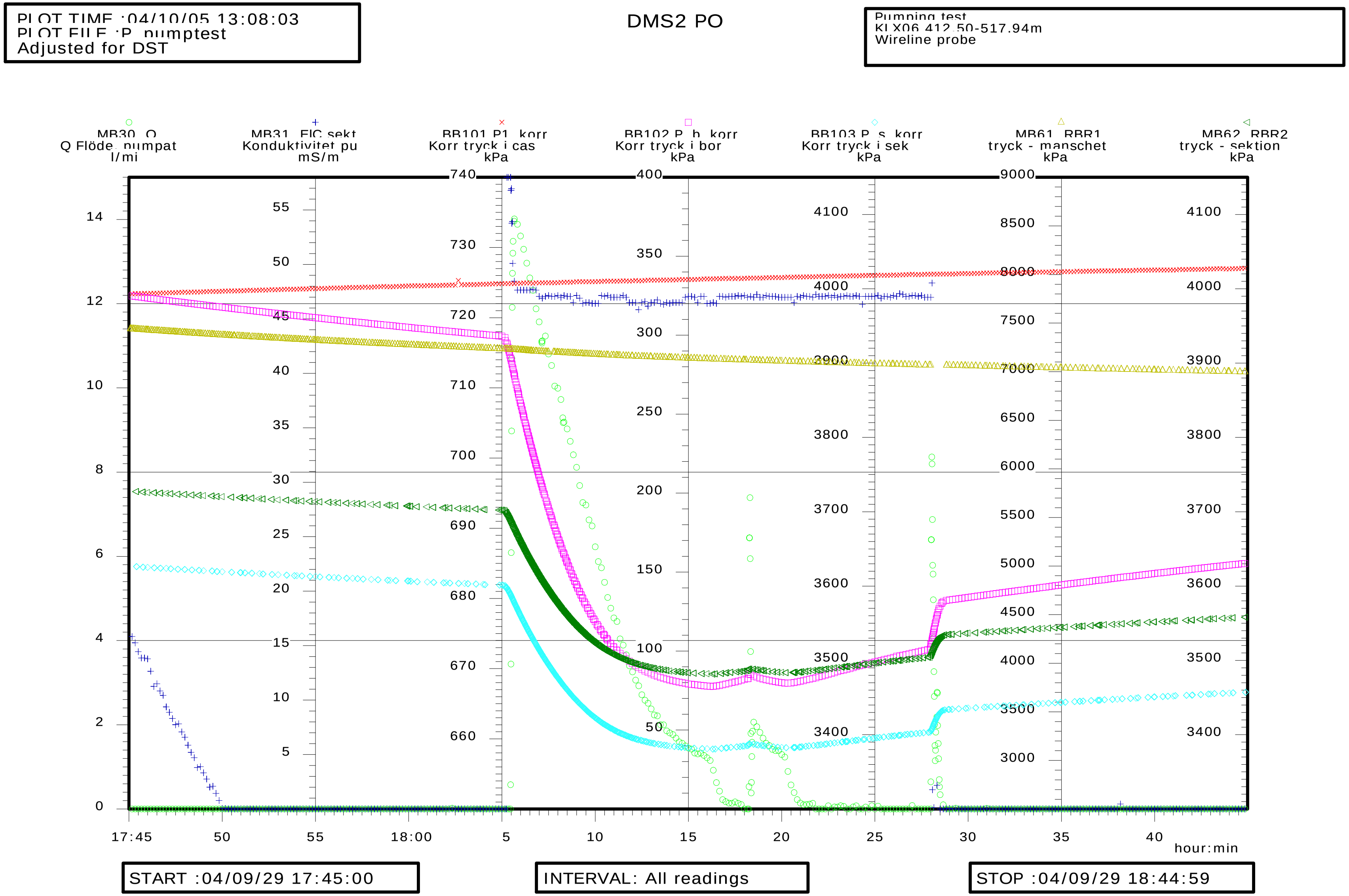


PLOT TIME :04/09/30 09:29:46
PLOT FILE :P_pumptest
Adjusted for DST
DMS2 PO
Pumping test
KLX06 200.50-310.20m
Wireline probe
MB30 Q
Q Flöde pumpat
l/mi
MB31 EC sekt
Konduktivitet pu
mS/m
BB101 P1 korr
Korr tryck i cas
kPa
BB102 P b korr
Korr tryck i bor
kPa
BB103 P s korr
Korr tryck i sek
kPa
MB61 RBR1
tryck - manschet
kPa
MB62 RBR2
tryck - sektion
kPa
hours
START :04/09/12 15:15:00
INTERVAL: All readings
STOP :04/09/13 09:14:59


PLOT TIME :04/09/30 08:40:44
PLOT FILE :P_pumptest
Adjusted for DST
DMS2 PO
Pumping test
KLX06 260.5-268.7m
Wireline probe
MB30 Q
Q Flöde pumpat
l/mi
MB31 EC sekt
Konduktivitet pu
mS/m
BB101 P1 korr
Korr tryck i cas
kPa
BB102 P_b korr
Korr tryck i bor
kPa
BB103 P_s korr
Korr tryck i sek
kPa
MB61 RBR1
tryck - manschet
kPa
MB62 RBR2
tryck - sektion
kPa
hours
START :04/09/10 09:45:00
INTERVAL: All readings
STOP :04/09/11 11:14:59


PLOT TIME :04/10/05 11:58:19
PLOT FILE :P_pumptest
Adjusted for DST
DMS2 PO
Pumping test
KLX06 307.50-415.49m
Wireline probe
MB30 Q
Q Flöde, pumpat
l/mi
MB31 EIC sekt
Konduktivitet pu
mS/m
BB101 P1 korr
Korr tryck i cas
kPa
BB102 P h korr
Korr tryck i bor
kPa
BB103 P s korr
Korr tryck i sek
kPa
MB61 RBR1
tryck - manschet
kPa
MB62 RBR2
tryck - sektion
kPa
hours
START :04/09/22 13:45:00
INTERVAL: All readings
STOP :04/09/23 10:44:59

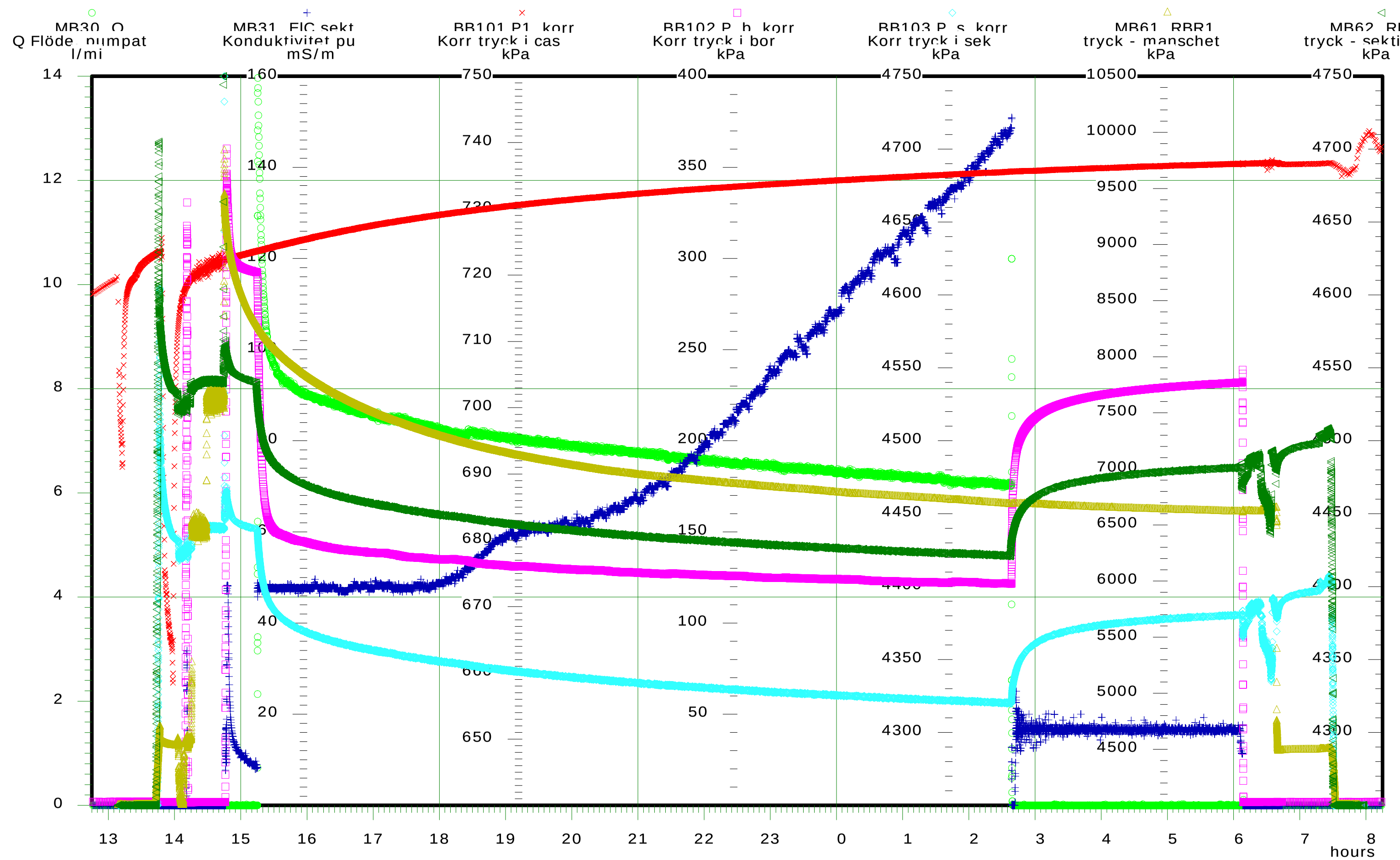

PLOT TIME :04/09/30 10:07:24
PLOT FILE :P_pumptest
Adjusted for DST
DMS2 PO
Pumping test
KLX06 331.02-364.23m
Wireline probe
MB30 Q
Q Flöde pumpat
l/mi
MB31 EIC sekt
Konduktivitet pu
mS/m
BB101 P1 korr
Korr tryck i cas
kPa
BB102 P_b korr
Korr tryck i bor
kPa
BB103 P_s korr
Korr tryck i sek
kPa
MB61 RBR1
tryck - manschet
kPa
MB62 RBR2
tryck - sektion
kPa
hours
START :04/09/18 12:45:00
INTERVAL: All readings
STOP :04/09/19 11:14:59


PLOT TIME :04/10/05 13:08:03
PLOT FILE :P_pumptest
Adjusted for DST
DMS2 PO
Pumping test
KLX06 412.50-517.94m
Wireline probe
MB30 Q
Q Flöde pumpat
l/mi
MB31 EIC sekt
Konduktivitet pu
mS/m
BB101 P1 korr
Korr tryck i cas
kPa
BB102 P_h_korr
Korr tryck i bor
kPa
BB103 P_s_korr
Korr tryck i sek
kPa
MB61 RBR1
tryck - manschet
kPa
MB62 RBR2
tryck - sektion
kPa
hour:min
START :04/09/29 17:45:00
INTERVAL: All readings
STOP :04/09/29 18:44:59

PLOT TIME :04/10/19 10:51:47
PLOT FILE :P_pumptest
Adjusted for DST

# DMS2 PO

Pumping test
KLX06 514.60-613.94m
Wireline probe




START :04/10/08 12:45:00

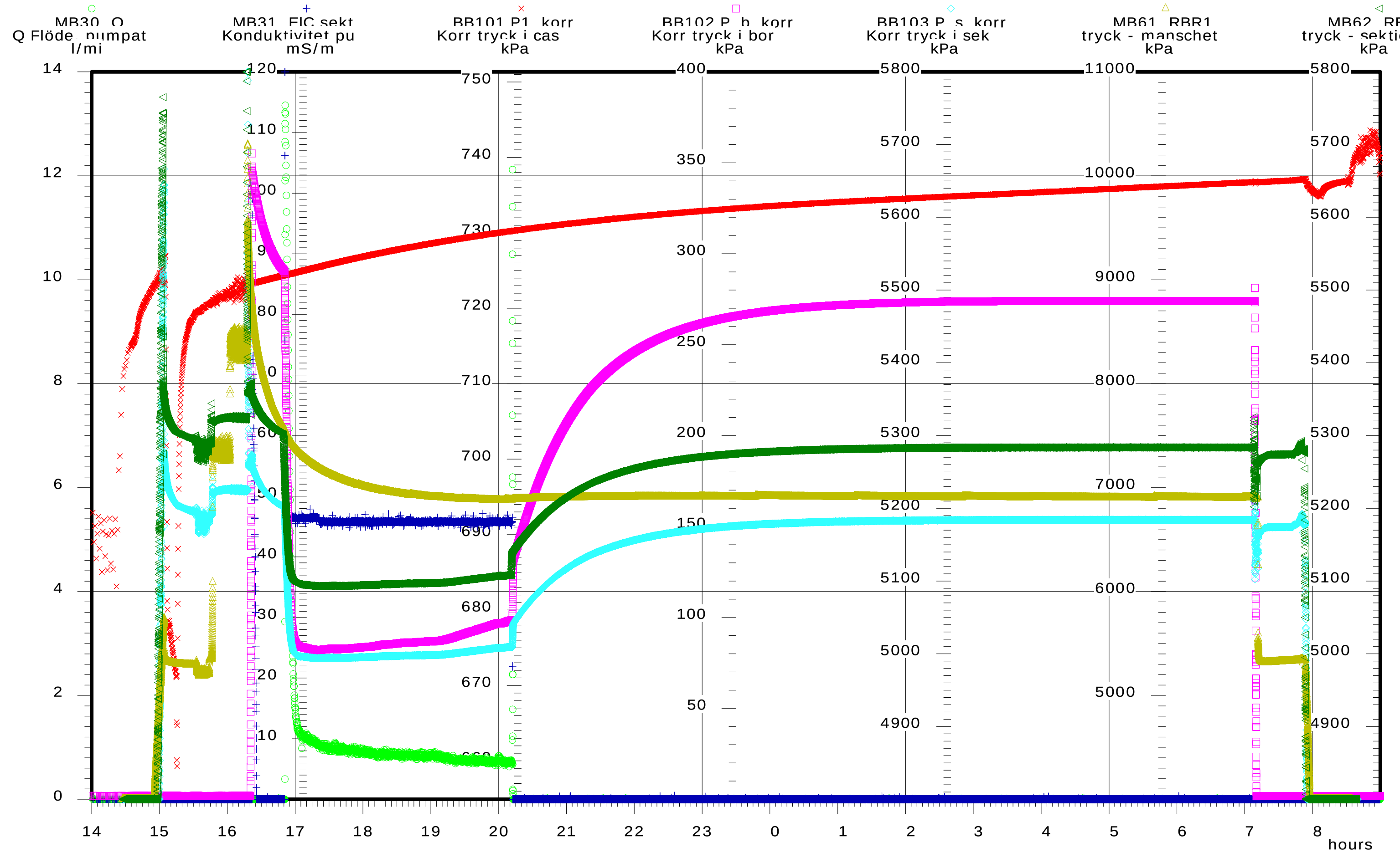
INTERVAL: All readings

STOP :04/10/09 08:14:59

PLOT TIME :04/10/19 12:23:27
PLOT FILE :P_pumptest
Adjusted for DST

DMS2 PO

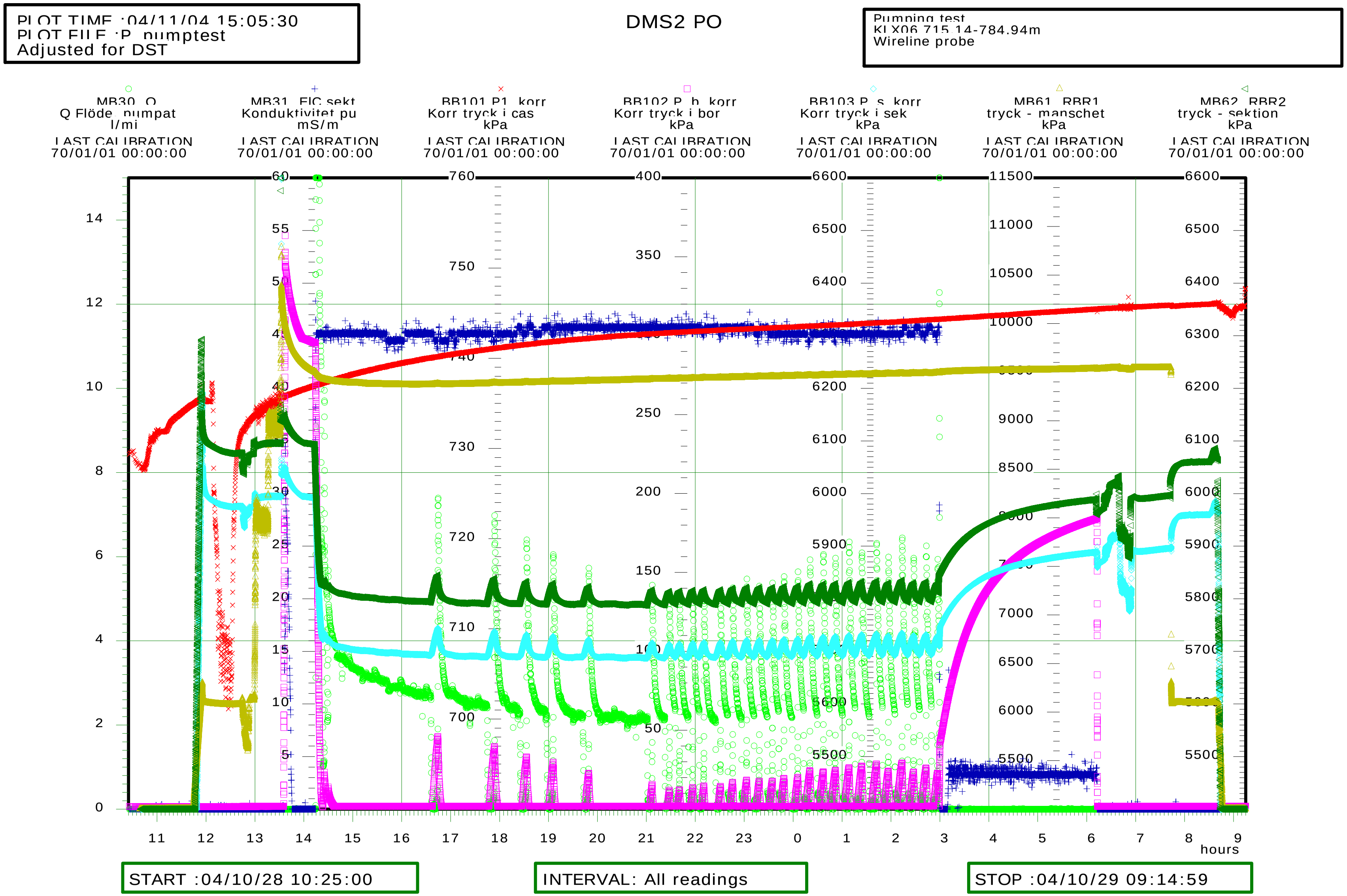
Pumping test
KLX06 611.50-715.94m
Wireline probe

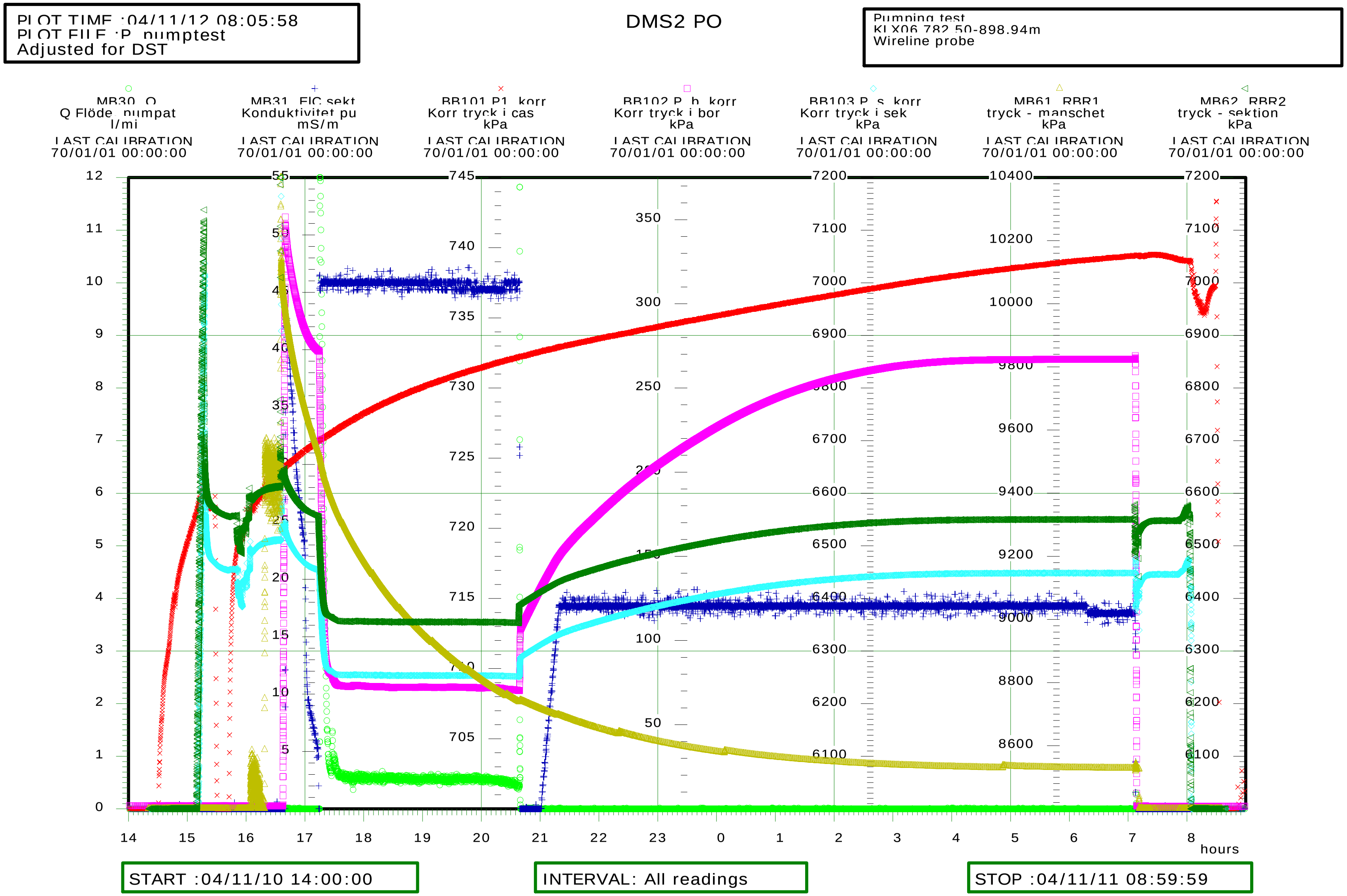


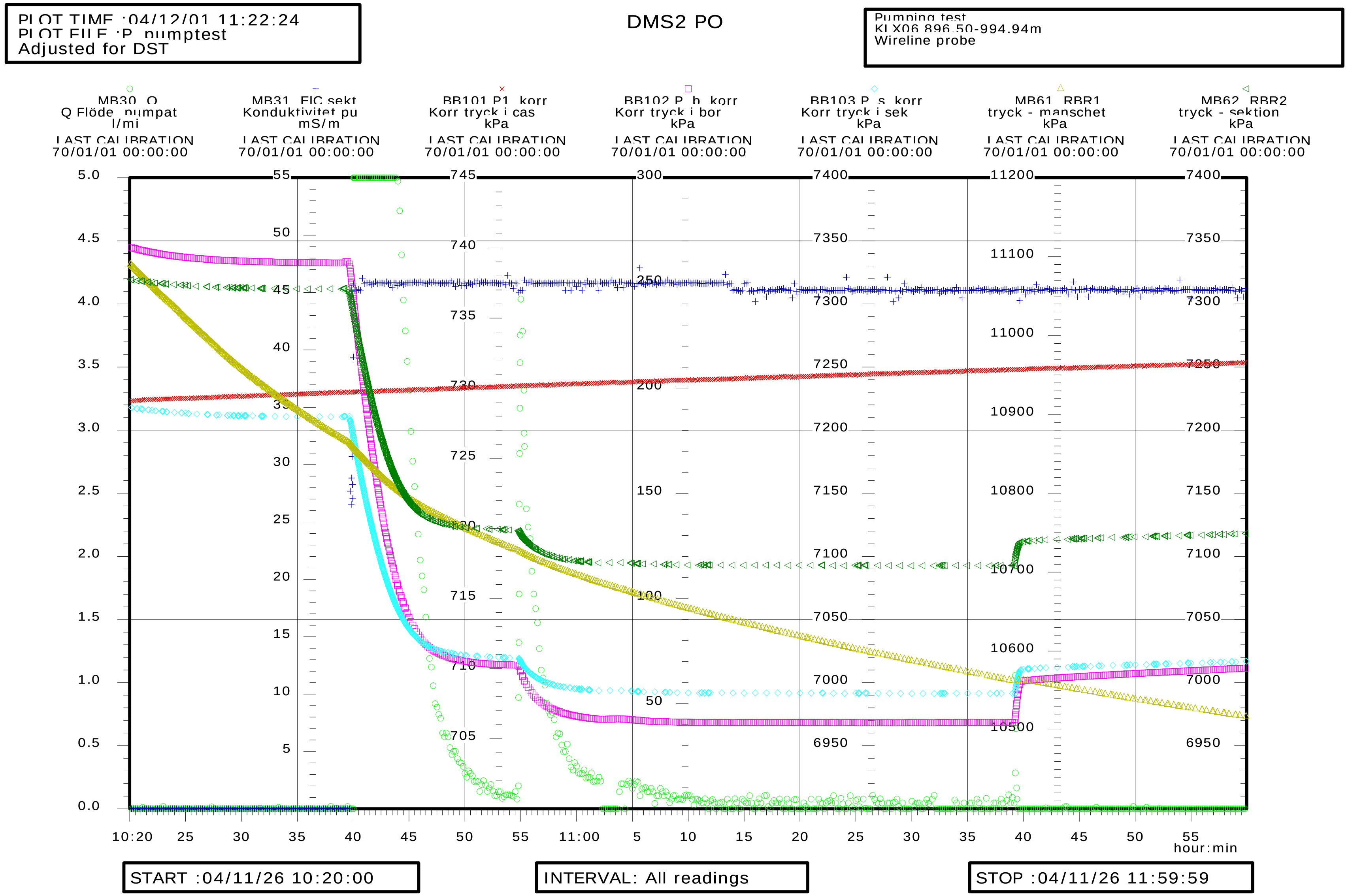

START :04/10/18 14:00:00

INTERVAL: All readings

STOP :04/10/19 08:59:59


PLOT TIME :04/11/04 15:05:30
PLOT FILE :P_pumptest
Adjusted for DST
DMS2 PO
Pumping test
KLX06 715.14-784.94m
Wireline probe
MB30_Q
Q Flöde pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MB31_EC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BB101 P1_korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB102 P_h_korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB103 P_s_korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB61_RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB62_RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :04/10/28 10:25:00
INTERVAL: All readings
STOP :04/10/29 09:14:59


PLOT TIME :04/11/12 08:05:58
PLOT FILE :P_pumptest
Adjusted for DST
DMS2 PO
Pumping test
KLX06 782.50-898.94m
Wireline probe
MB30_Q
Q Flöde pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MB31_EIC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BB101 P1_korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB102 P_b_korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BB103 P_s_korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB61_RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB62_RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :04/11/10 14:00:00
INTERVAL: All readings
STOP :04/11/11 08:59:59



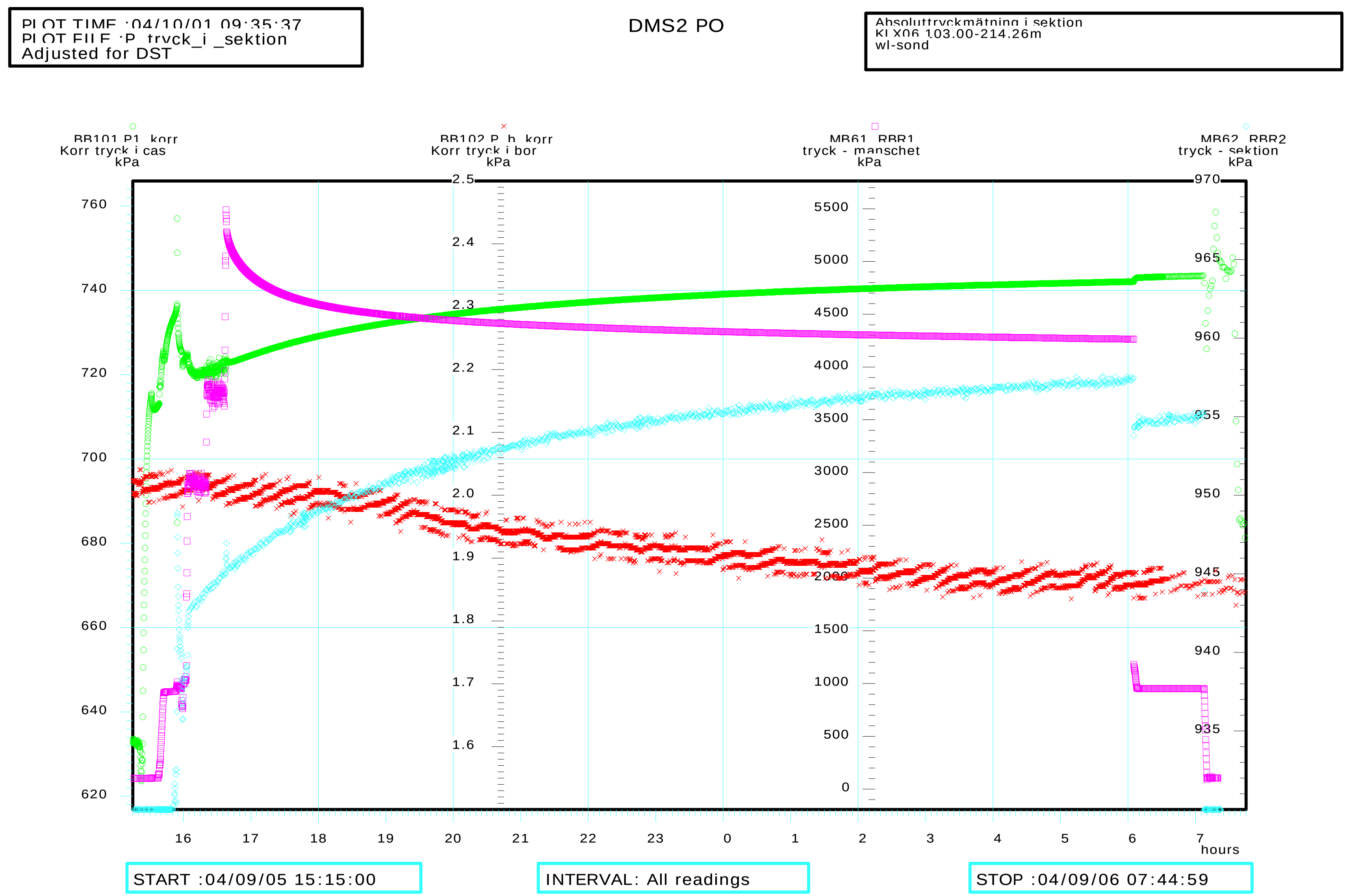
PLOT TIME :04/12/01 11:22:24
PLOT FILE :P_pumptest
Adjusted for DST
DMS2 PO
Pumping test
KLX06 896.50-994.94m
Wireline probe
MR30_Q
Q Flöde, pumpat
l/mi
LAST CALIBRATION
70/01/01 00:00:00
MR31_EIC sekt
Konduktivitet pu
mS/m
LAST CALIBRATION
70/01/01 00:00:00
BR101 P1_korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
BR102 P_b_korr
Korr tryck i bor
kPa
LAST CALIBRATION
70/01/01 00:00:00
BR103 P_s_korr
Korr tryck i sek
kPa
LAST CALIBRATION
70/01/01 00:00:00
MR61_RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MR62_RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
55 50 45 40 35 30 25 20 15 10 5
745 740 735 730 725 720 715 710 705
300 250 200 150 100 50
7400 7350 7300 7250 7200 7150 7100 7050 7000 6950
11200 11100 11000 10900 10800 10700 10600 10500
7400 7350 7300 7250 7200 7150 7100 7050 7000 6950
10:20 25 30 35 40 45 50 55 11:00 5 10 15 20 25 30 35 40 45 50 55
hour:min
START :04/11/26 10:20:00
INTERVAL: All readings
STOP :04/11/26 11:59:59

# Appendix 6

## Time series of absolute pressure measurements

### Description of the parameters in the enclosed plots.

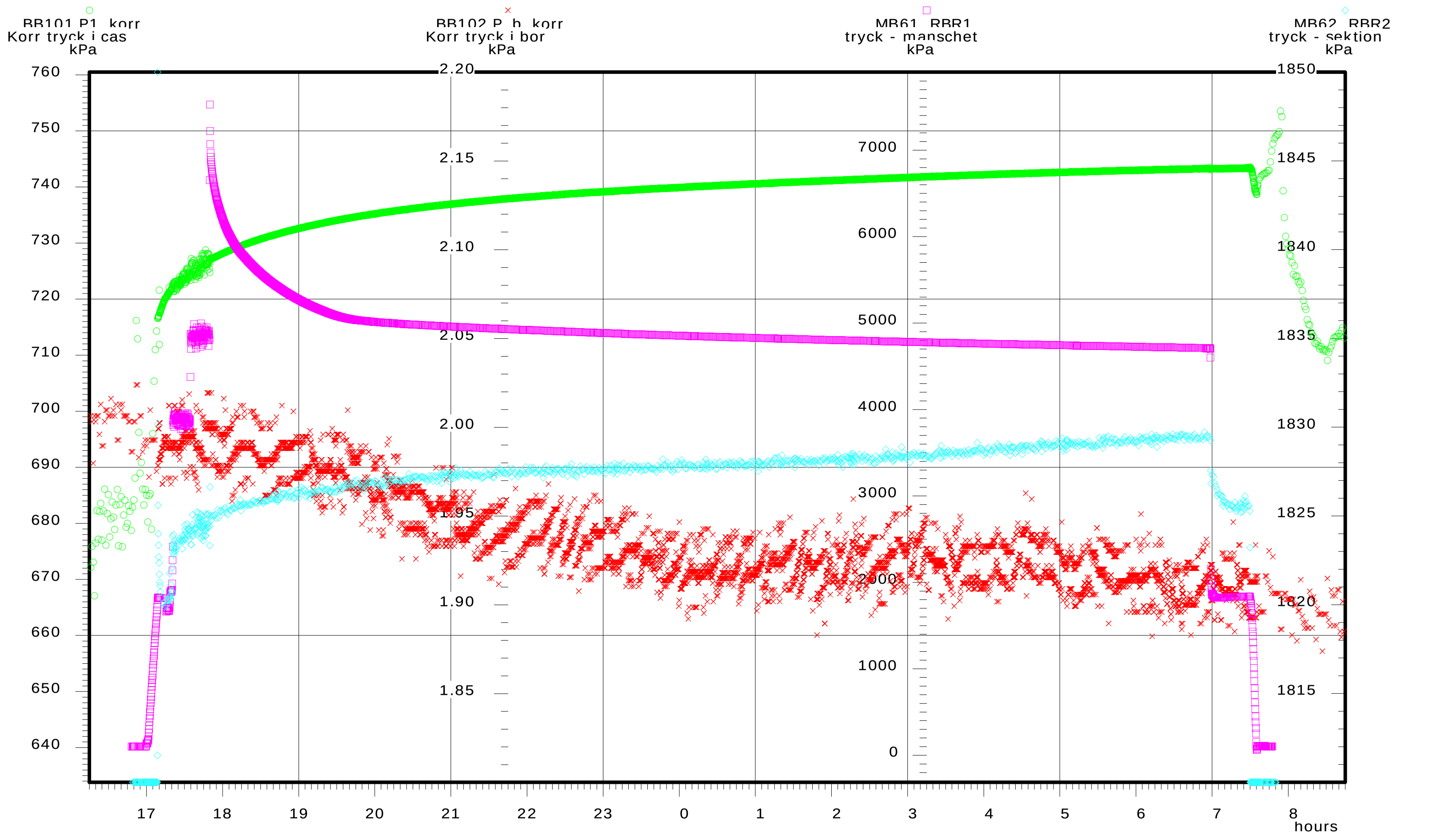
| Channel | Parameter | Unit | Description |
|---|---|---|---|
| BB101 | Pressure | kPa | Pressure of the water column in the telescopic section subtracted with the ambient air pressure. |
| MB61 | Pressure – packer | kPa | Inflation pressure in packer. |
| MB62 | Pressure – section | kPa | Pressure of the water column in the test section ie at depth in the borehole. Not corrected for ambient air pressure. |
| MB25 | Air pressure | kPa | |


PLOT TIME :04/10/01 09:35:37
PLOT FILE :P_tryck_i _sektion
Adjusted for DST
DMS2 PO
Absoluttryckmätning i sektion
KLX06 103.00-214.26m
wl-sond
BB101 P1 korr
Korr tryck i cas
kPa
BB102 P_b korr
Korr tryck i bor
kPa
MB61 RBR1
tryck - manschet
kPa
MB62 RBR2
tryck - sektion
kPa
760
740
720
700
680
660
640
620
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
970
965
960
955
950
945
940
935
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
hours
START :04/09/05 15:15:00
INTERVAL: All readings
STOP :04/09/06 07:44:59

PLOT TIME :04/10/01 09:57:27
PLOT FILE :P_tryck_i _sektion
Adjusted for DST

DMS2 PO

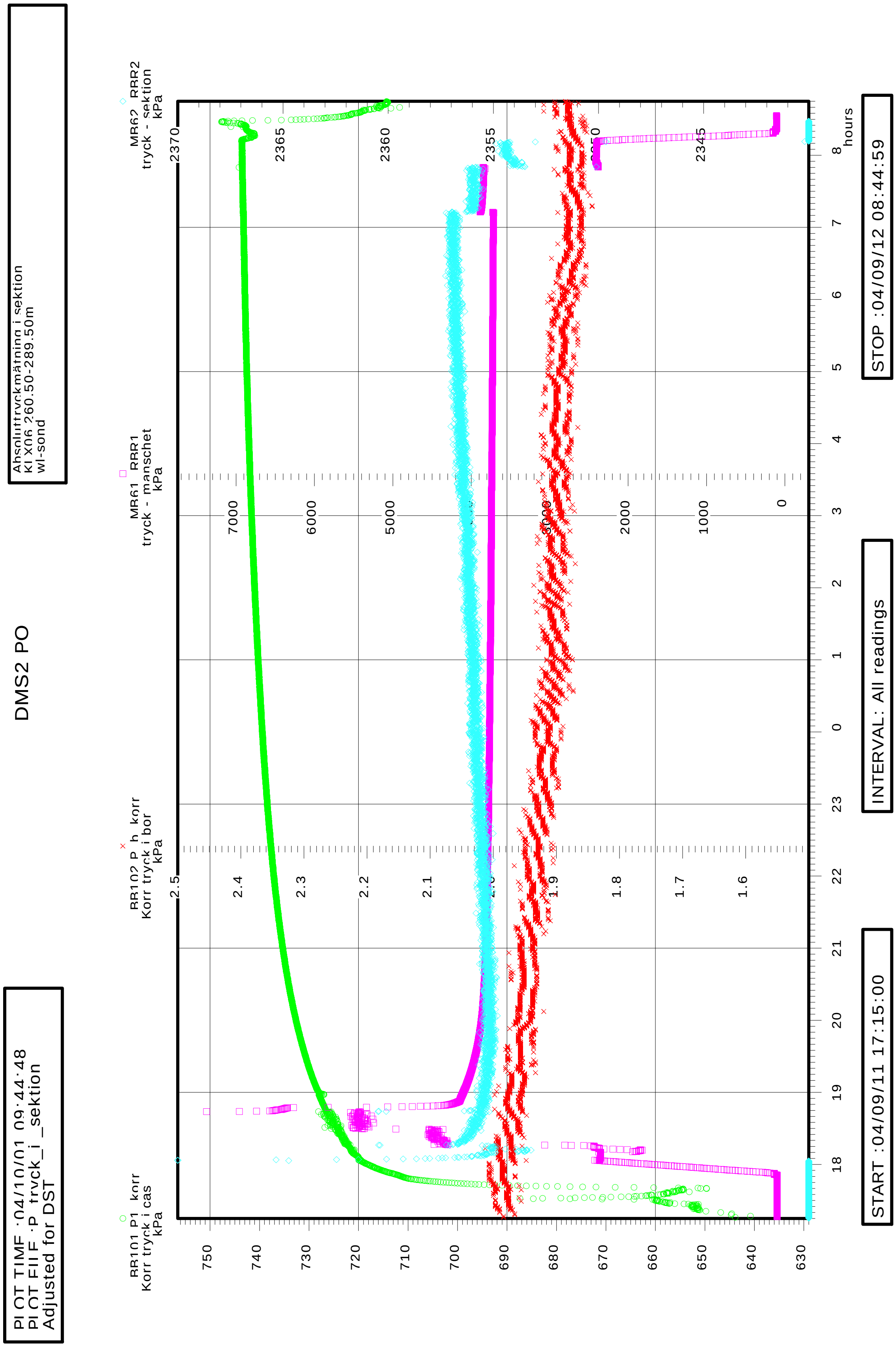
Absoluttryckmätning i sektion
KLX06 200.50-317.84m
wl-sond




START :04/09/13 16:15:00

INTERVAL: All readings

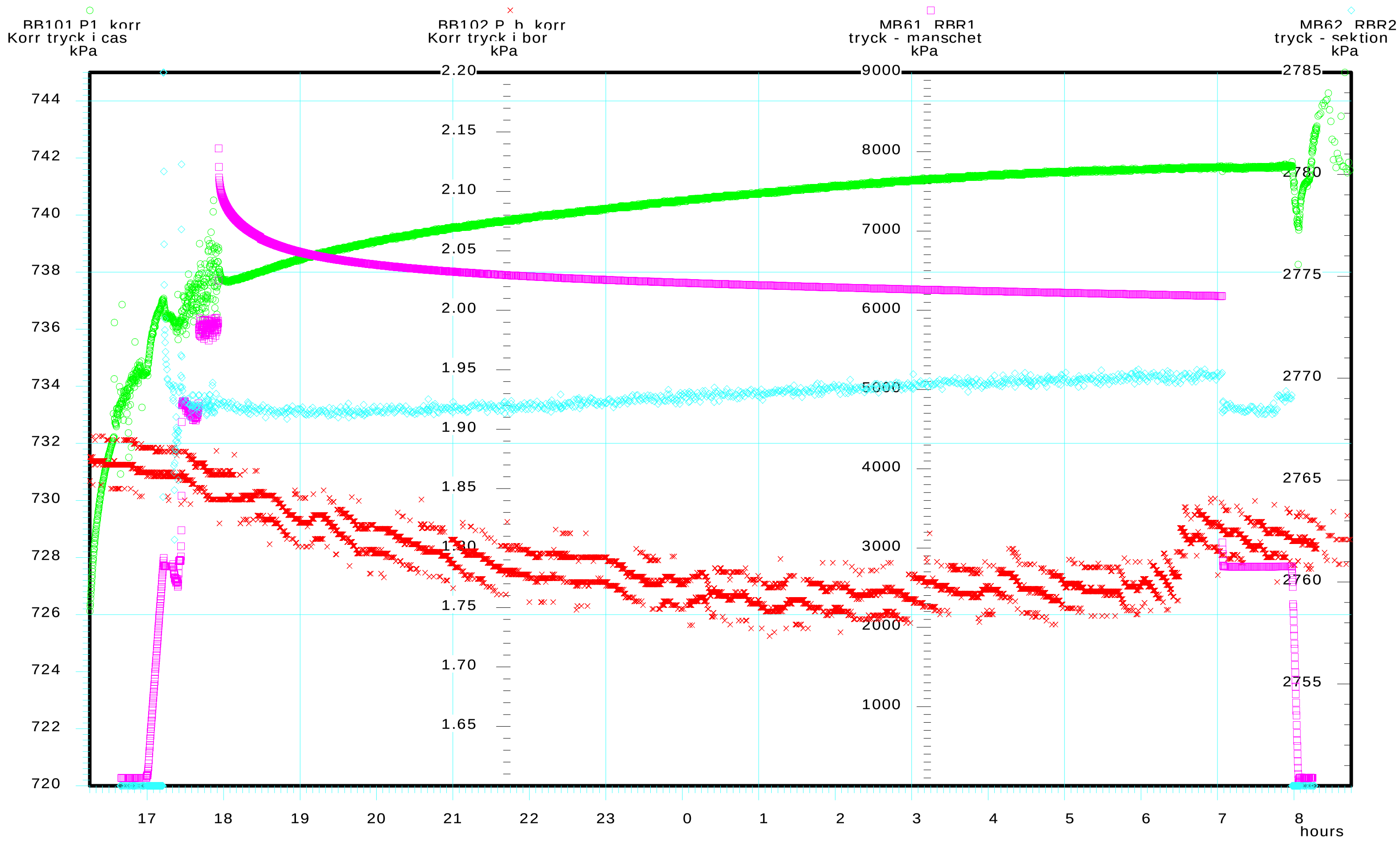
STOP :04/09/14 08:44:59


PLOT TIME :04/10/01 09:44:48
PLOT FILE :P_tryck_i _sektion
Adjusted for DST
DMS2 PO
Absoluttryckmätning i sektion
KLX06 260.50-289.50m
wl-sond
BR101 P1_korr
Korr tryck i cas
kPa
BR102 P_h_korr
Korr tryck i bor
kPa
MR61 RRR1
tryck - manschet
kPa
MR62 RRR2
tryck - sektion
kPa
750 740 730 720 710 700 690 680 670 660 650 640 630
2.5 2.4 2.3 2.2 2.1 2.0 1.9 1.8 1.7 1.6
7000 6000 5000 3000 2000 1000 0
2370 2365 2360 2355 2350 2345
18 19 20 21 22 23 0 1 2 3 4 5 6 7 8
hours
START :04/09/11 17:15:00
INTERVAL: All readings
STOP :04/09/12 08:44:59

PLOT TIME :04/10/05 12:19:19
PLOT FILE :P_tryck_i _sektion
Adjusted for DST

DMS2 PO

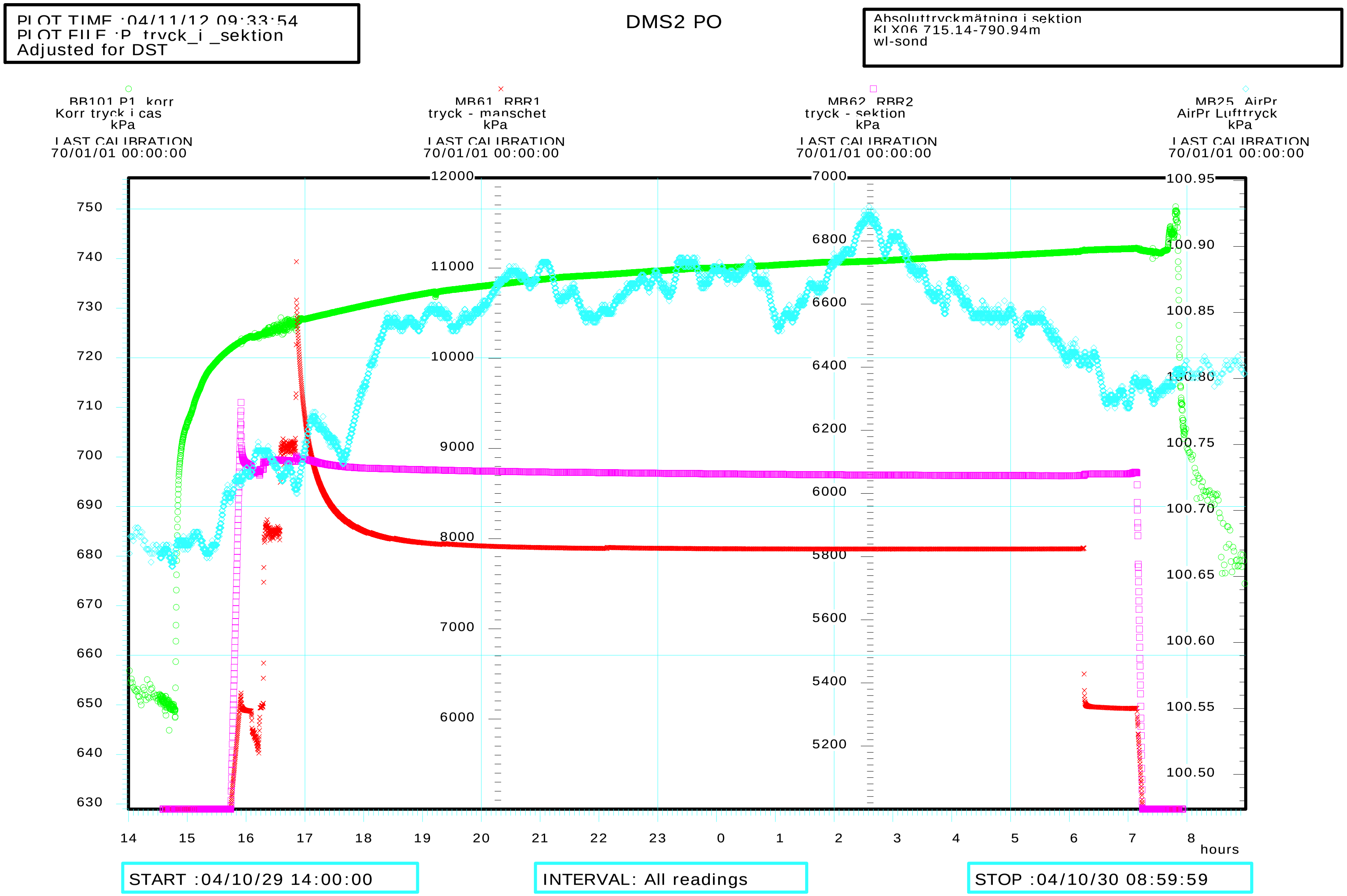
Absoluttryckmätning i sektion
KLX06 307.50-415.49m
wl-sond




START :04/09/23 16:15:00

INTERVAL: All readings

STOP :04/09/24 08:44:59



PLOT TIME :04/11/12 09:33:54
PLOT FILE :P_tryck_i _sektion
Adjusted for DST
DMS2 PO
Absoluttryckmätning i sektion
KLX06 715.14-790.94m
wl-sond
BB101 P1 korr
Korr tryck i cas
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB61 RBR1
tryck - manschet
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB62 RBR2
tryck - sektion
kPa
LAST CALIBRATION
70/01/01 00:00:00
MB25 AirPr
AirPr Lufttryck
kPa
LAST CALIBRATION
70/01/01 00:00:00
hours
START :04/10/29 14:00:00
INTERVAL: All readings
STOP :04/10/30 08:59:59