P-05-190

Oskarshamn site investigation

Percussion drilling of boreholes HLX16, HLX17, HLX18 and HLX19

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July 2005

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Keywords: Percussion drilling, Lineament investigation, Hydraulic responses.

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

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Abstract

Drilling of percussion holes is required as a supplement to the drilling of deep cored holes. In general, the percussion holes serve two principal purposes: water supply for core drilling and as investigation boreholes to shallow depth.

Boreholes HLX16, HLX17, HLX18 and HLX19 were drilled as part of a tentative study for placing a tunnel between the Simpevarp subarea and the southeastern part of the Laxemar subarea within the site investigation in Oskarshamn.

The encountered geology in the boreholes corresponds well with expectations based on surface geological mapping.

The water yields varied from nil to over 160 litres per minute.

No definite indication of a deformation zone could be established from the drilling results in boreholes HLX16, HLX17 or HLX19.

A significant water bearing structure was encountered in HLX18.

A clear hydraulic response in borehole HLX17 could be seen during drilling and pumping in HLX18.

Sammanfattning

Hammarborrhål borras i allmänhet för två olika ändamål: dels för vattenförsörjning vid kärnborrrning och dels för att möjliggöra undersökningar i ytligare berggrund.

Borrhålen HLX16, HLX17, HLX18 och HLX19 utfördes som en del i en förundersökning för en eventuell tunnelpassage mellan delområdena Simpevarp och Laxemar inom platsundersökningen i Oskarshamn.

Den geologi som påträffades i borrhålen överrensstämmer väl med det som kunde förväntas från den geologiska karteringen på ytan.

Vatteninflödet i borrhålen varierade mellan noll och 160 minutliter.

Ingen tydlig indikation på någon deformationszon kunde erhållas från borrningsresultaten i hålen HLX16, HLX17 eller HLX19.

En ordentligt vattenförande struktur påträffades i HLX18.

En tydlig hydraulisk respons i HLX17 kunde ses under borrning av HLX18.

Contents

1 Introduction

SKB performs site investigations in order to evaluate the feasibility of locating a deep repository for high level radioactive waste /1/ in two Swedish municipalities: Östhammar and Oskarshamn /2/.

A number of linear features, lineaments, covering the site investigation area were identified by airborne geophysical methods or by remote sensing, primarily of topography /3/.

Follow-up ground geophysics, as outlined in Figure 1-1, was done over selected lineaments /4/.

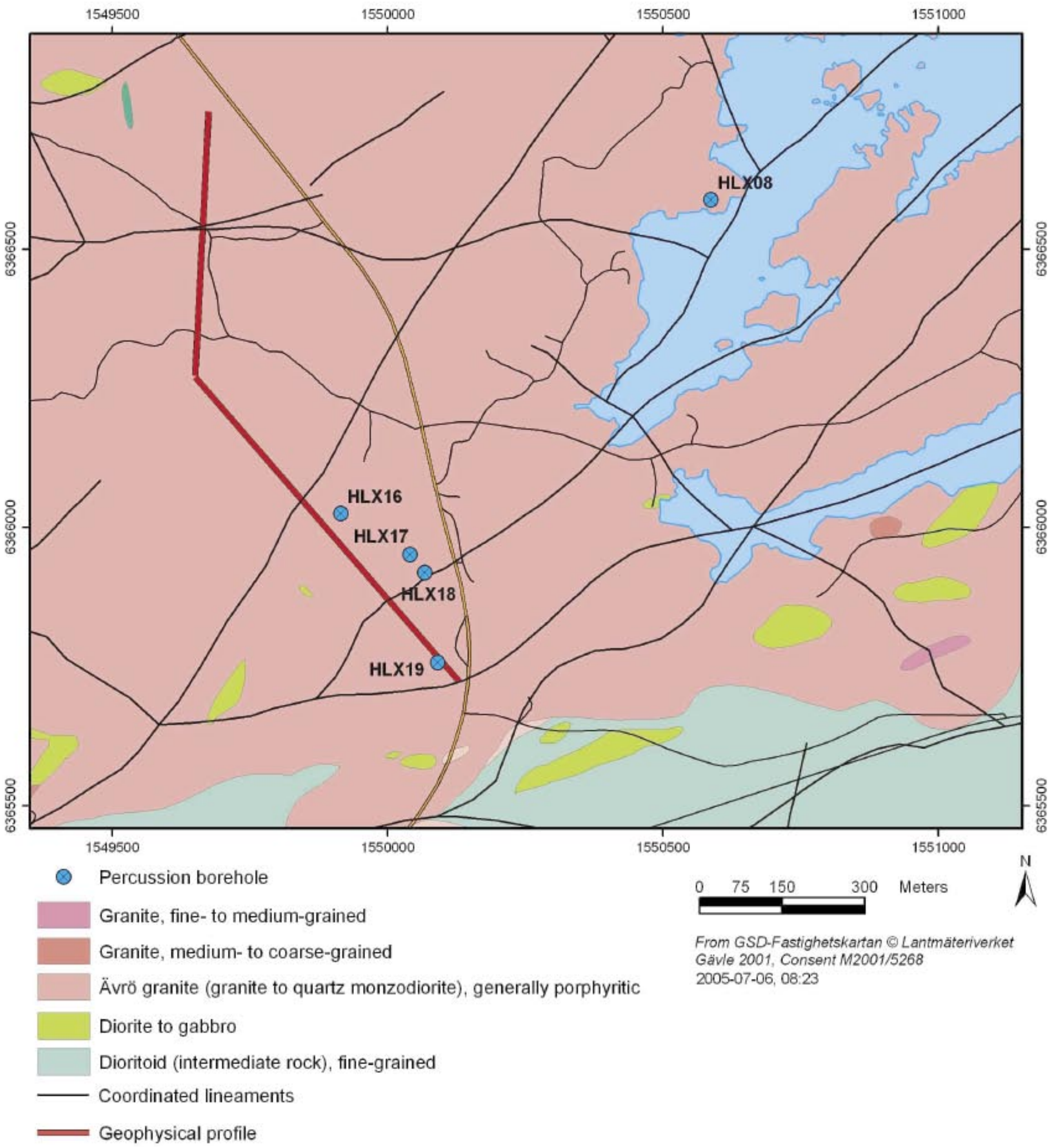


Figure 1-1. *Location of boreholes HLX16, HLX17, HLX18 and HLX19 in the Laxemar subarea. The map shows the bedrock geology, lineaments and the seismic refraction profile. Borehole HLX08 is also shown as this hole was monitored during drilling in order to register possible hydraulic responses.*

Percussion drilling to depths of 150–200 m was done to investigate the interpreted lineaments and related geophysical anomalies.

This report will describe the drilling of four percussion holes, HLX16, HLX17, HLX18 and HLX19, and the measurements performed during the drilling phase.

The holes were drilled in the southeastern part of the Laxemar subarea, see Figure 1-1. The original purpose was to provide data for a tentative study for placing a tunnel between the Simpevarp and Laxemar subareas.

The decision to perform the drilling is given in SKB id 1025745, internal document.

The regional authorities were informed by letter on 2004-06-17, SKB id 1026276, internal document.

The drilling and all related on-site operations were performed according to a specific Activity Plan (AP PS 400-04-052). Reference is given in the activity plan to procedures in the SKB Method Description for Percussion Drilling (SKB MD 610.003, Version 1.0) and relevant method instructions for handling of chemicals, surveying and evaluation of cuttings, see Table 1-1. Method descriptions and activity plans are SKB internal documents.

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

Activity plan	Number	Version
Hammarborrning av HLX16–HLX19 för undersökning av tunnelpassage (CLAB-Laxemar)	AP PS 400-04-052	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för hammarborrning	SKB MD 610.003	1.0
Metodbeskrivning för undersökning av borrkax	SKB MD 142.001	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.

All data were stored in the SICADA database for Oskarshamn.

2 Objective and scope

This report will describe the drilling of the four percussion holes, HLX16, HLX17, HLX18 and HLX19 and the measurements performed during drilling i.e. logging of preliminary geology, pumping test and measurements of hydraulic responses.

The objectives for the boreholes, prior to drilling, are summarised in Table 2-1.

Table 2-1. Borehole objectives before drilling.

Borehole	Drilling objective
HLX16	Drilled towards a low velocity zone indicated by surface geophysics (refraction seismics). The borehole would intercept a possible subvertical deformation zone at 100–150 m length.
HLX17	Drilled towards a low velocity zone indicated by surface geophysics (refraction seismics). The borehole would intercept a possible subvertical deformation zone at 100–150 m length.
HLX18	The borehole would intercept a possible subvertical deformation zone that could be connected to surface lineament (magnetic) at 100–150 m drilled length.
HLX19	The borehole would intercept a possible subvertical deformation zone that could be connected to surface lineament (topographic) at 100–150 m drilled length.

3 Equipment

In this chapter the drilling equipment and the equipment used for measurements and sampling are briefly described.

Drilling and completion were made by contractor Sven Andersson, Uppsala AB.

3.1 Drilling equipment

Drilling of the boreholes HLX16, HLX17, HLX18 and HLX19 was made with a Puntel drilling rig supplied with accessories.

For the raising of water and drill cuttings from the borehole, a 27 bar diesel air-compressor, type Atlas-Copco XRVS 455 Md was used. The DTH drillhammer was of type Secoroc 5", lowered into the borehole by a Driconeq 114 mm pipe string.

3.2 Equipment for measurements and sampling

Flow measurements during drilling were performed using a graded vessel and a stop watch. Measurement of the drilling penetration time was done manually with readings for every 20 cm.

Samples of soil and drill cuttings were collected in sampling pots.

The pumping test was done with a submersible pump, Grundfoss MS 402 SP2A-23.

4 Execution

The work was performed in accordance with SKB MD 610.003, Version 1.0 (Method Description for Percussion Drilling, SKB internal document) and consisted of:

- preparations,
- drilling through overburden,
- gap injection techniques and equipment,
- percussion drilling in hard rock,
- sampling and measurements,
- borehole completion,
- pumping tests and hydraulic responses,
- data handling,
- environmental control.

4.1 Preparations

The preparation stage included the Contractor's functional control of his equipment. The machinery and chemicals used have to comply with SKB MD 600.006, Version 1.0 (Method Instruction for Chemical Products and Materials, SKB internal document).

The equipment was cleaned in accordance with SKB MD 600.004, Version 1.0 (Method Instruction for Cleaning Borehole Equipment and certain Ground-based Equipment, SKB internal document).

4.2 Drilling through overburden

Excentric percussion drilling with 200 mm diameter ("ODEX 160") was made through the unconsolidated soil and fractured near-surface bedrock to a depth of between 9 and 15 m.

4.3 Gap injection techniques and equipment

In order to prevent surface water and shallow groundwater to infiltrate into deeper parts of the borehole, the gap between the borehole wall and the casing was grouted with cement, see Figure 4-1.

A packer was installed at the bottom of the cased section. The concrete was introduced through the packer and allowed to flow up between the casing and the bedrock wall. A reference sample of the cement paste was kept cool and dark on the surface to ensure that drilling was not resumed until the mixture had hardened.

The concrete seal was tested by blowing compressed air in the hole and measuring the amount of in-flowing water. As no water could be measured in the hole, the tightness of the gap injection was considered to be sufficient.

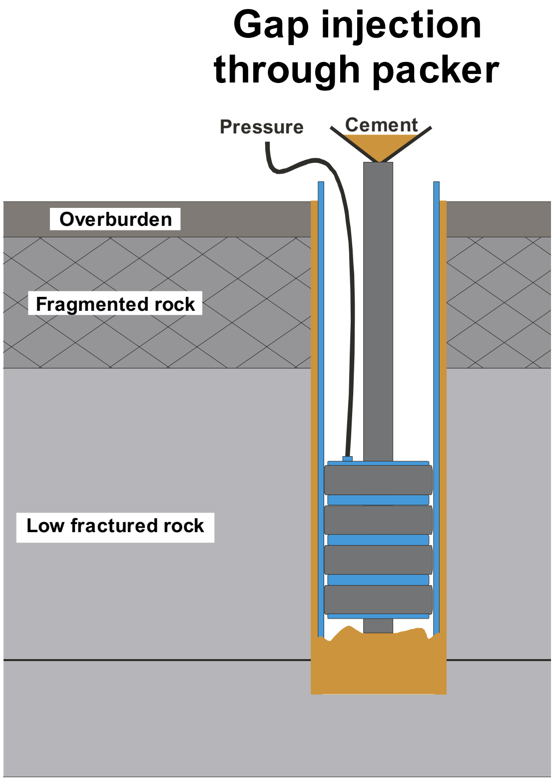


Figure 4-1. *Gap injection technique.*

4.4 Percussion drilling in hard rock

After allowing the cement to harden, drilling could continue and was performed to the full borehole length with conventional percussion drilling with a nominal diameter of 140 mm.

4.5 Sampling and measurements

Sampling and measurements done by the drillsite geologist and the drilling crew during drilling included:

- Samples of rock chip drill cuttings were taken along the hole. One sample was taken per metre drilled. The samples were stored for subsequent logging of preliminary geology (lithology, dominant mineralogy, grain-size, roundness and, if possible, structural or textural information) and measurement of magnetic susceptibility with hand held equipment. Small cups of return water were collected during drilling, one for every metre, for estimation of water colour and intensity which in turn gives an indication of clay content and level of oxidation.
- Penetration time (expressed as seconds per 20 cm) was recorded manually.
- The water yield from the hole was estimated when noticeable changes in water flow occurred and after the drilling phase was completed. The method employed was to blow compressed air through the drill stem and to measure the amount of return water during steady state conditions.

Figure 4-2. *Drilling rig at the site for HLX17. The preliminary geological mapping can be seen in the foreground.*

When the drilling was completed the hole was rinsed from drill cuttings by blowing air with the compressor at maximum capacity for 30 minutes.

Deviation measurements were not made in conjunction with drilling of the holes.

4.6 Borehole completion

The boreholes were secured by mounting of lockable steel caps on the casing.

All equipment was removed, the sites cleaned and joint inspections were made by representatives from SKB and the Contractor to ensure that the sites had been restored to a satisfactory level.

4.7 Pumping test and hydraulic responses

Pumping test

Pumping tests as specified in the activity plan was only made in HLX18. Pumping tests were not made in boreholes HLX16, HLX17 and HLX19 due to very low water yields.

The pumped flow was measured manually. Initially the flow was measured frequently, when stable flow conditions were achieved, the measurements were conducted with longer intervals.

The water level was measured with a mini-Troll logger.

Hydraulic responses

Measurements of hydraulic responses during drilling and pumping tests were conducted by emplacing pressure loggers in nearby holes. The logger settings can be varied for the following parameters:

- Scan time.
- Log time.
- Event.

The scan time is the interval for the pressure readings. With an event function of say 0.1 kPa, the logger saves any data that has changed more than 0.1 kPa since the previous scanning. The log time is the interval between data savings regardless of pressure changes. Manual measurements of the groundwater level were conducted to check the logger data.

4.8 Data handling

Data collected by the drillers and drill site personnel 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.

4.9 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 water amounted to small quantities.

Recovered drill cuttings were collected in a steel container. After completion of drilling, the container was removed from the site and emptied at an approved site.

5 Results

Technical data from drilling are presented in Section 5.1.

Hydrogeological results from drilling, pumping tests and measurements of hydraulic responses are given in Section 5.2.

The results from the preliminary geological mapping are commented in Section 5.3.

Hydrogeochemical results are presented in Section 5.4.

5.1 Borehole design

A summary of data from the borehole are presented in Tables 5-1 and 5-2.

Table 5-1. Geometric and technical data for boreholes HLX16 and HLX17.

Parameter	HLX16		HLX17	
Drilling period	From 2004-06-22 to 2004-06-24		From 2004-06-28 to 2004-07-01	
Borehole inclination (starting point) (0 to –90)	–58.10°		–59.49°	
Borehole azimuth (0–360)	139.90°		310.94°	
Borehole length	200.20 m		202.20 m	
Soil depth	2.1 m		1.2 m	
Drill bit diameter	0.138 m		0.139 m	
Starting point coordinates (system RT90/RHB70)	Northing: 6,366,025.43 m Easting: 1,549,914.88 m Elevation: 3.652 m a s l		Northing: 6,365,951.51 m Easting: 1,550,040.75 m Elevation: 3.350 m a s l	
Water yield (interval)	0 l/min		0.6 l/min (9.03–120.9 m)	
Borehole diameter (interval) (diameter mm)	0–12.12 m 12.12–202.2 m	190 mm 138 mm	0–9.12 m 9.12–202.2 m	190 mm 139 mm
Casing diameter (interval) (diameter mm)	0–11.94 m 11.94–12.03 m	$Ø_o$ = 168 $Ø_i$ = 160 $Ø_o$ = 168 $Ø_i$ = 147	0–8.94 m 8.94–9.03 m	$Ø_o$ = 168 $Ø_i$ = 160 $Ø_o$ = 168 $Ø_i$ = 147

Table 5-2. Geometric and technical data for boreholes HLX18 and HLX19.

Parameter	HLX18	HLX19
Drilling period	From 2004-07-01 to 2004-07-06	From 2004-08-10 to 2004-08-12
Borehole inclination (starting point) (0 to –90)	–57.60°	–57.90°
Borehole azimuth (0–360)	135.91°	130.04°
Borehole length	181.20 m	202.20 m
Soil depth	1.1 m	2.65 m
Drill bit diameter	0.139 m	0.137 m
Starting point coordinates (system RT90/RHB70)	Northing: 6,365,919.12 m Easting: 1,550,067.64 m Elevation: 4.036 m a s l	Northing: 6,365,757.88 m Easting: 1,550,090.87 m Elevation: 5.951 m a s l
Water yield (interval)	161 l/min (15.03–181.2 m)	5 l/min (12.03–202.2 m)

Parameter	HLX18		HLX19	
Borehole diameter (interval) (diameter mm)	0–15.12 m 15.12–181.2 m	190 mm 139 mm	0–12.12 m 12.12–202.2 m	190 mm 137 mm
Casing diameter (interval) (diameter mm)	0–14.94 m 14.94–15.03 m	$Ø_o$ = 168 $Ø_i$ = 160 $Ø_o$ = 168 $Ø_i$ = 147	0–11.94 m 11.94–12.03 m	$Ø_o$ = 168 $Ø_i$ = 160 $Ø_o$ = 168 $Ø_i$ = 147

Technical drawings of the boreholes are given in Appendix 1.

5.2 Hydrogeological results

5.2.1 Results from drilling

The water yields obtained from blowing of compressed air during drilling are given in Table 5-3 and are also shown in Appendix 2. Yields below ca 1–2 litres per minute should be regarded as very approximative estimates only. The uncertainty of the measuring method also increases with flows over ca 100 litres per minute.

The amount of effluent water that was released to the ground from the drilling activities is estimated in Table 5-4. The release of water was made within 30 m from the collar location.

Table 5-3. Observed water yields from drilling.

Borehole	From (m)	To (m)	Measured water yield (L/min)	Specific Capacity, Q/s (m^2/s)	Date	Time for final rinsing by air blow (local time)
HLX16	12.03	202.2	0	1.63×10^{-8} *	040624	19:45
HLX17	9.03	151.2	0.6	9.55×10^{-8}	040701	15:40
HLX18	15.03	54.9	1.5	5.26×10^{-7}	040705	
HLX18	15.03	57.9	20	6.65×10^{-6}	040705	
HLX18	15.03	66.9	21		040705	
HLX18	15.03	111.9	37		040705	
HLX18	15.03	111.9	70		040706	
HLX18	15.03	151.2	130	1.62×10^{-5}	040706	
HLX18	15.03	175.2	130		040706	
HLX18	15.03	181.2	161	1.72×10^{-5}	040706	14:00
HLX19	12.03	120.9	2	3.18×10^{-7}	040811	
HLX19	12.03	202.2	5	4.76×10^{-7}	040812	18:00

* No water yield could be established during drilling. The calculation is therefore based on two measurements of water table recovery. The first reading was taken on 040630, however the water table could not be established as the depth exceeded 100 meters (the length of the available cable). The second reading on 040707 showed a water table at 63.30 m. Based on the the assumption that the borehole was completely dry after final rinsing during drilling, the maximum specific capacity of HLX16 was calculated to 1.63×10^{-8} m^2/s.

Table 5-4. Amount of released water from drilling.

Borehole (interval m)	Estimated amount of water released (m^3)
HLX16	0
HLX17	< 1
HLX18	100
HLX19	< 3

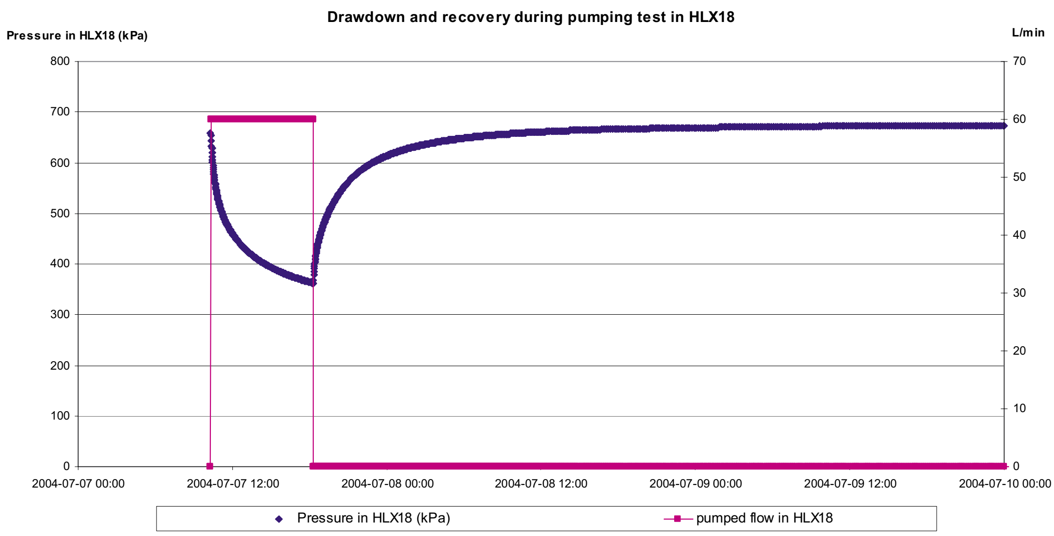
5.2.2 Pumping test and hydraulic responses

A pumping test was performed in HLX18. The pumping period was eight hours and the recovery was monitored for four days further. The flow during the pumping test was constant at 60 L/min. During the whole test a miniTroll logger registered the pressure.

Pump start:	2004-07-07	11:20
Pump stop:	2004-07-07	19:17
Flow:	60	L/min

MiniTroll logger setting:	Log time:	1 h
	Scan time:	1 min
	Event:	0.1 kPa

The drawdown and recovery phase of the pumping test are shown in Figure 5-1 together with the hydraulic response in HLX17 related to the pumping test in HLX18.



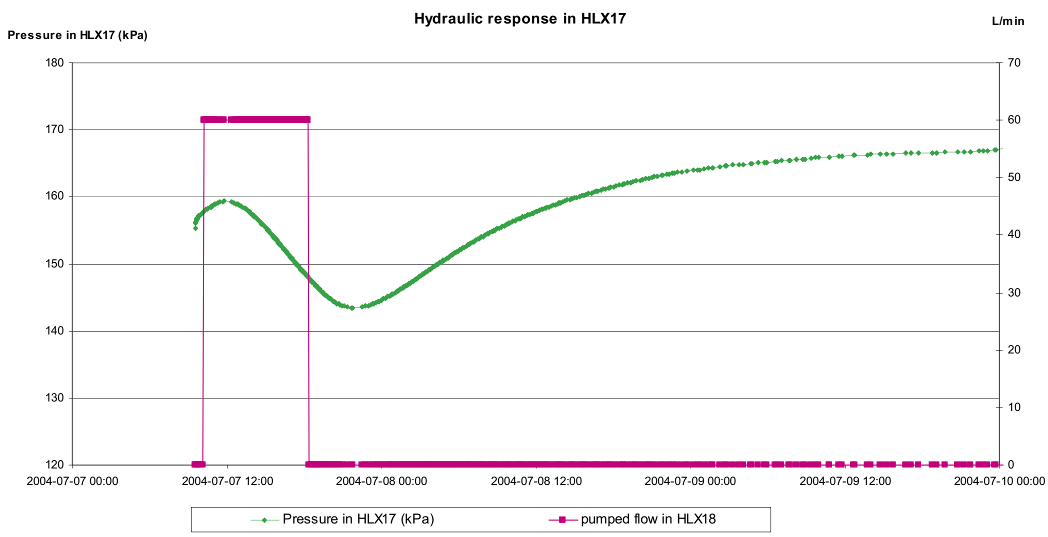


Figure 5-1. *The drawdown and recovery in in HLX18 in connection with the pumping test is given in the upper graph. The hydraulic response in HLX17 related to the pumping test in HLX18 is shown in the lower graph.*

Evaluation of the pumping data in borehole HLX18, in accordance with /5 and 6/, gave results as shown in Table 5-9. Further background on evaluation of the transmissivity of the pumping test is given in Appendix 3.

The hydraulic responses, i.e. variations in water level that can be related to drilling or pumping in other boreholes, in HLX17 that was noted during the drilling of HLX18 is shown in Figure 5-2. The hydraulic response in HLX17 during the pumping test in HLX18 are shown in Figure 5-1.

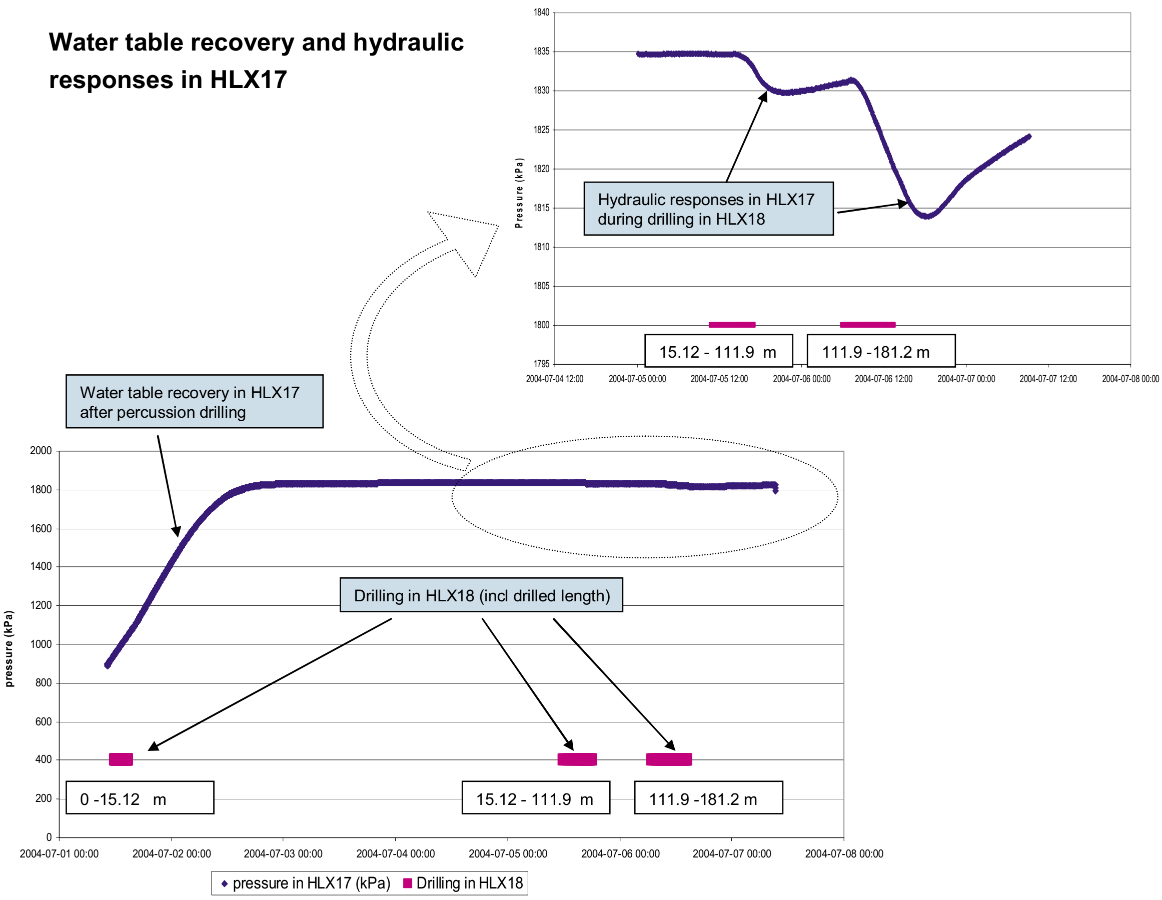


Figure 5-2. *The water table in HLX17 during drilling of HLX18. Initially the water table can be seen to recover after percussion drilling. A distinct hydraulic response from drilling in HLX18 can be seen between 040705–040706. This is particularly visible in the detail graph in the upper right corner.*

Table 5-9. Results from pumping test in HLX18.

Specific Capacity, Q/s (m²/s)	3.31×10^{-5}
Transmissivity – Moye, T_M (m²/s)	4.26×10^{-5}
Hydraulic Conductivity–Moye, K_M (m/s)	2.57×10^{-7}
Transmissivity, T_T (m²/s)	1.3×10^{-5}

Measurements of hydraulic responses were made in borehole HLX08 throughout the drilling of boreholes HLX16–19. The location of HLX08 is shown in Figure 1-1.

The slightly anomalous trend occuring between 040710 and 040714 is probably due to a combination of precipitation and variations in air-pressure rather than a hydraulic response from drilling in HLX18, see Figure 5-3. A record of the precipitation, air-pressure and sea water level in the vicinity of HLX08 together with the water table in HLX08 is given in Appendix 4.

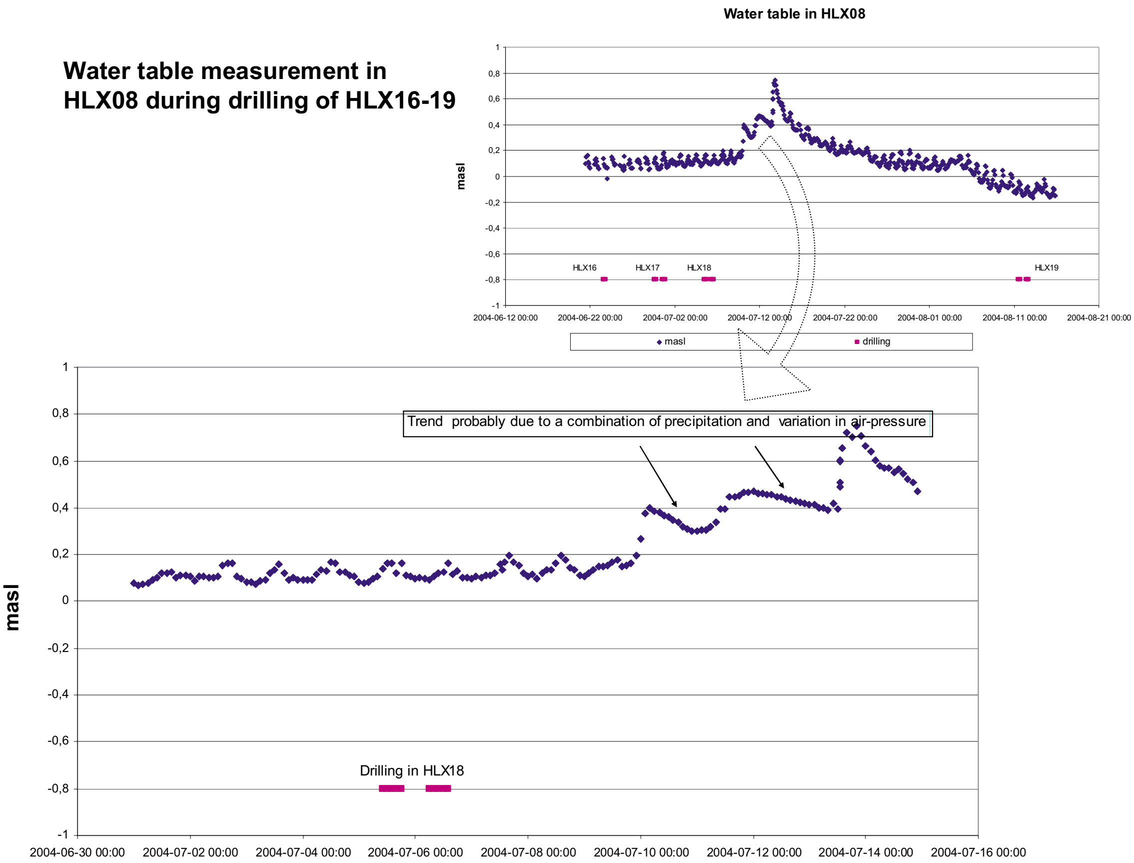


Figure 5-3. *Water table measurement in borehole HLX08 during the drilling of HLX16–19. The slightly anomalous trend occuring between 040710 and 040714 is probably due to a combination of precipitation and variations in air-pressure rather than a hydraulic response from drilling in HLX18.*

5.3 Geological results

Lithologically boreholes HLX16, HLX17 and HLX18 were dominated by Ävrö granite with minor intercalations of subordinate rock types (pegmatite, fine-grained diorite-gabbro and diorite-gabbro). HLX19 consists of Ävrö granite with subordinate rock types to 120 m. Below 120 m length diorite-gabbbro was encountered.

Logging results of preliminary geology together with magnetic susceptibility, penetration time and measured water flow are presented in Figure 6-1 and Appendix 2.

5.4 Hydrogeochemical results

Two water samples were taken during the drilling of HLX18. The samples were assayed for electrical conductivity only. The results are given in Table 5-10.

Table 5-10. Electrical conductivity in the water at HLX18.

Borehole	Sample id	Date	Length interval (m)	Electrical conductivity (mS/m)
HLX18	7566	2004-07-05	15.1–66.9	127
HLX18	7567	2004-07-06	15.1–181.2	821

5.5 Consumption of oil and chemicals

Small amounts of hammer oil and compressor oil enter the holes during drilling but are continuously retrieved by air flushing during drilling. After the drilling is completed, only minor remainders of the products are left in the borehole.

The consumption of cement paste (low alkali cement) and oils is given in Table 5-6.

Table 5-6. Consumption of cement paste and oils.

Borehole	Cement paste used (kg)	Hammer oil – Preem Hydra 46 (L)	Compressor oil – Schuman 46 (L)
HLX16	71	Ca 15	None noted
HLX17	71	Ca 15	None noted
HLX18	106	Ca 15	None noted
HLX19	71	15	None noted

5.6 Nonconformities

No formal nonconformities have been registered for the activity.

Minor changes compared to the activity plan were done as results from drilling emerged. The geophysically indicated low-velocity zone could not be seen during drilling in borehole HLX16. As a consequence the drilling direction and starting point of borehole HLX17 were adjusted in order to increase the possibility of locating the low-velocity anomaly.

6 Interpretation

No definite indication of a deformation zone that could be connected with the seismic low-velocity zone could be seen from the drilling results in boreholes HLX16 or HLX17.

A water bearing structure was encountered in HLX18 and a possible interpretation of a deformation zone linking to the surface lineament is given in Figure 6-1. The overall low magnetic susceptibility in the upper 100 m of the borehole would imply a northern dip of a deformation zone. The positions for water inflow indicate a steeply dipping or even vertical structure.

No clear indication of any deformation zone could be established from the drilling results in boreholes HLX19.

The drilling results are summarized in a vertical profile in Figure 6-1.

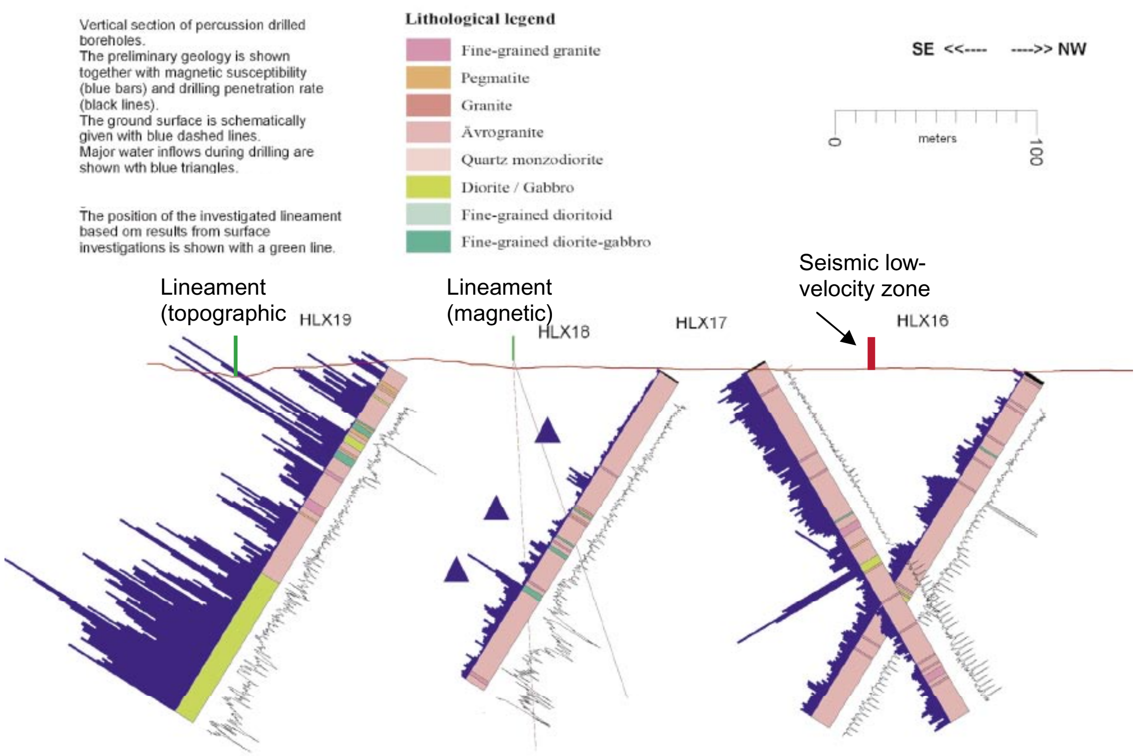


Figure 6-1. *Boreholes HLX16, 17, 18 and 19 are shown with preliminary geological results, magnetic susceptibility (blue bars) and drilling penetration time (black line). Positions for water inflow are indicated by blue triangles. The position of surface lineaments are given with green bars and the position of the refraction seismic low-velocity zone is given with a red bar. The surface topography is presented with a solid red line.*

7 References

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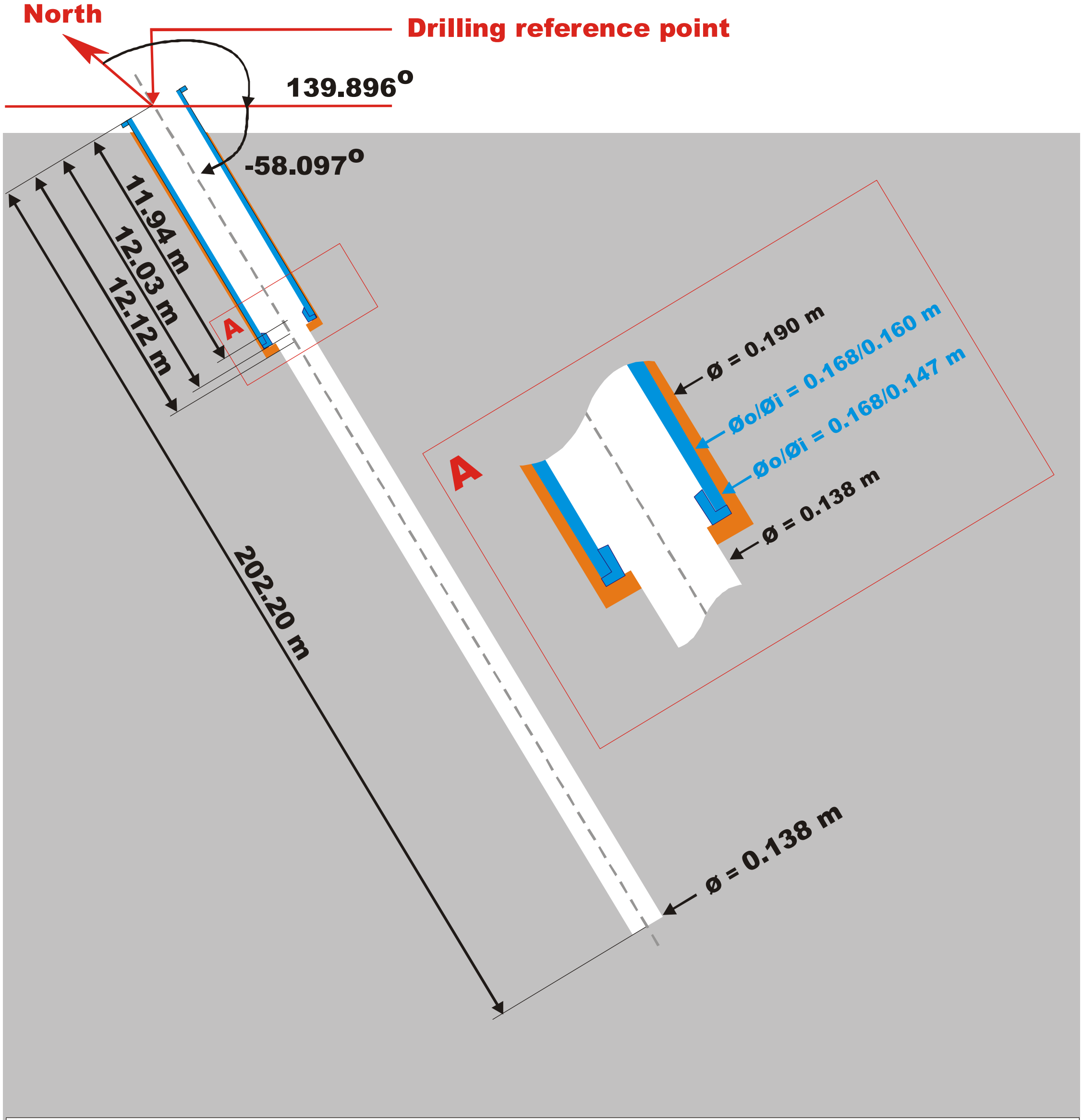
/6/ **Cooper H H, Jacob C E, 1946.** A generalized graphical method for evaluating formation constants and summarizing well field history, Am. Geophys. Union Trans, vol. 27, pp 526–534.

Technical data boreholes HLX16, HLX17, HLX18 and HLX19

Technical data

Borehole HLX16



Drilling reference point

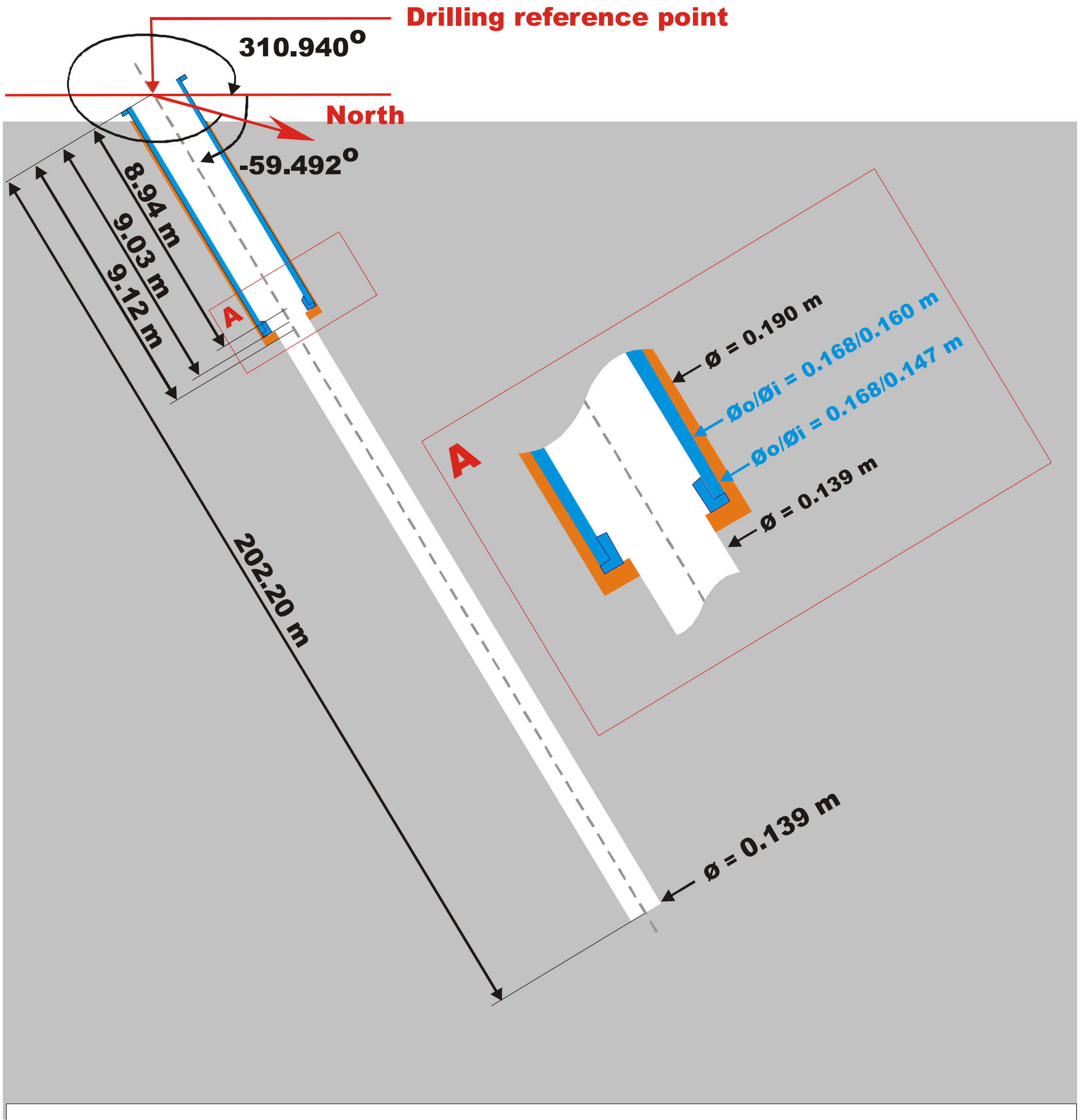
Northing:	**6366025.426 (m), RT90 2,5 gon V**
Easting:	**1549914.882 (m), RT90 2,5 gon V**
Elevation:	**3.652 (m), RHB 70**

Drilling period

Drilling start date: 2004-06-22
Drilling stop date: 2004-06-24

Technical data

Borehole HLX17



Drilling reference point

Northing: 6365951.514 (m), RT90 2,5 gon V

Easting: 1550040.753 (m), RT90 2,5 gon V

Elevation: 3.350 (m), RHB 70

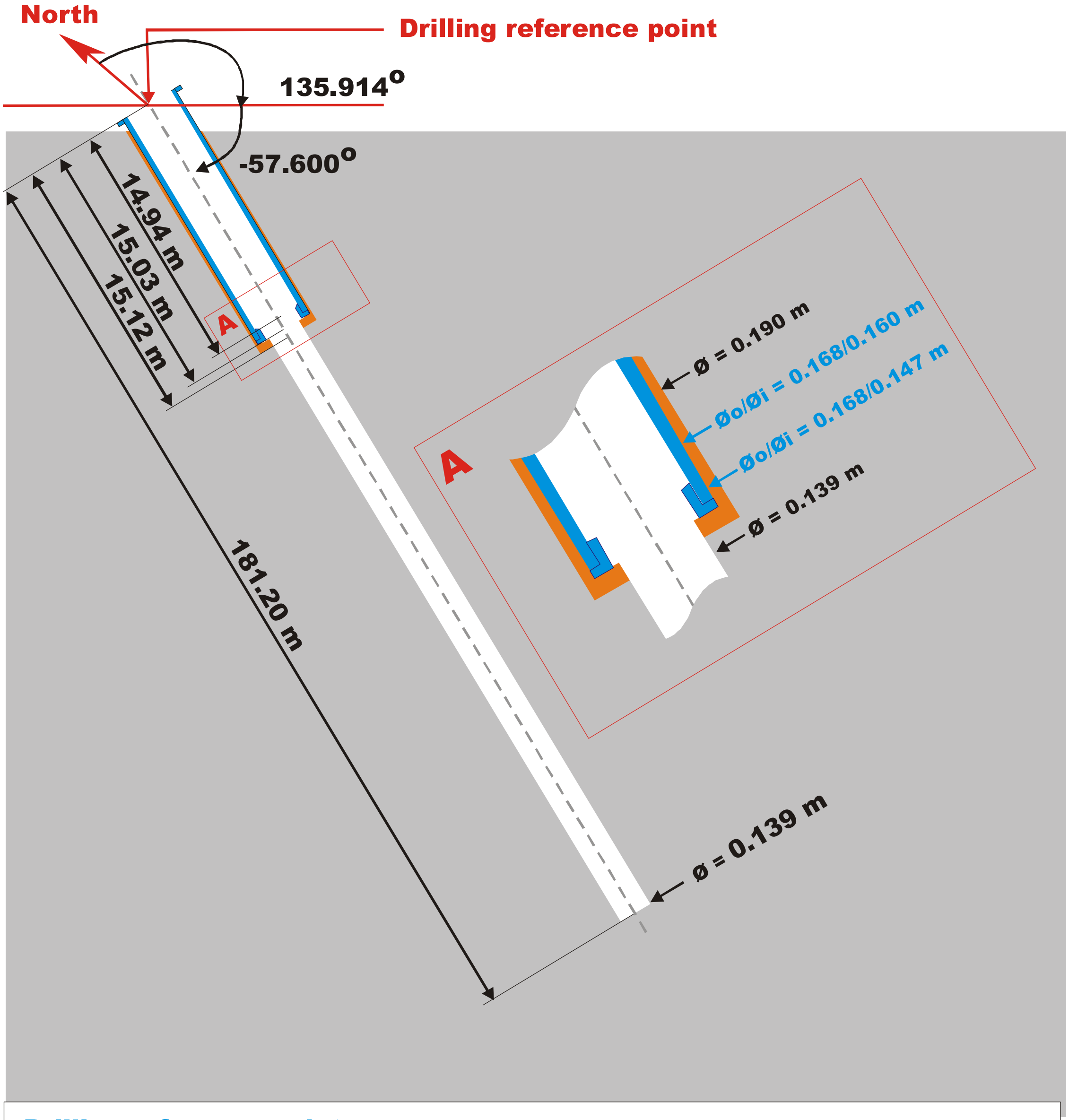
Drilling period

Drilling start date: 2004-06-28

Drilling stop date: 2004-07-01

Technical data

Borehole HLX18



Drilling reference point

Northing:	**6365919.121 (m), RT90 2,5 gon V**
Easting:	**1550067.642 (m), RT90 2,5 gon V**
Elevation:	**4.036 (m), RHB 70**

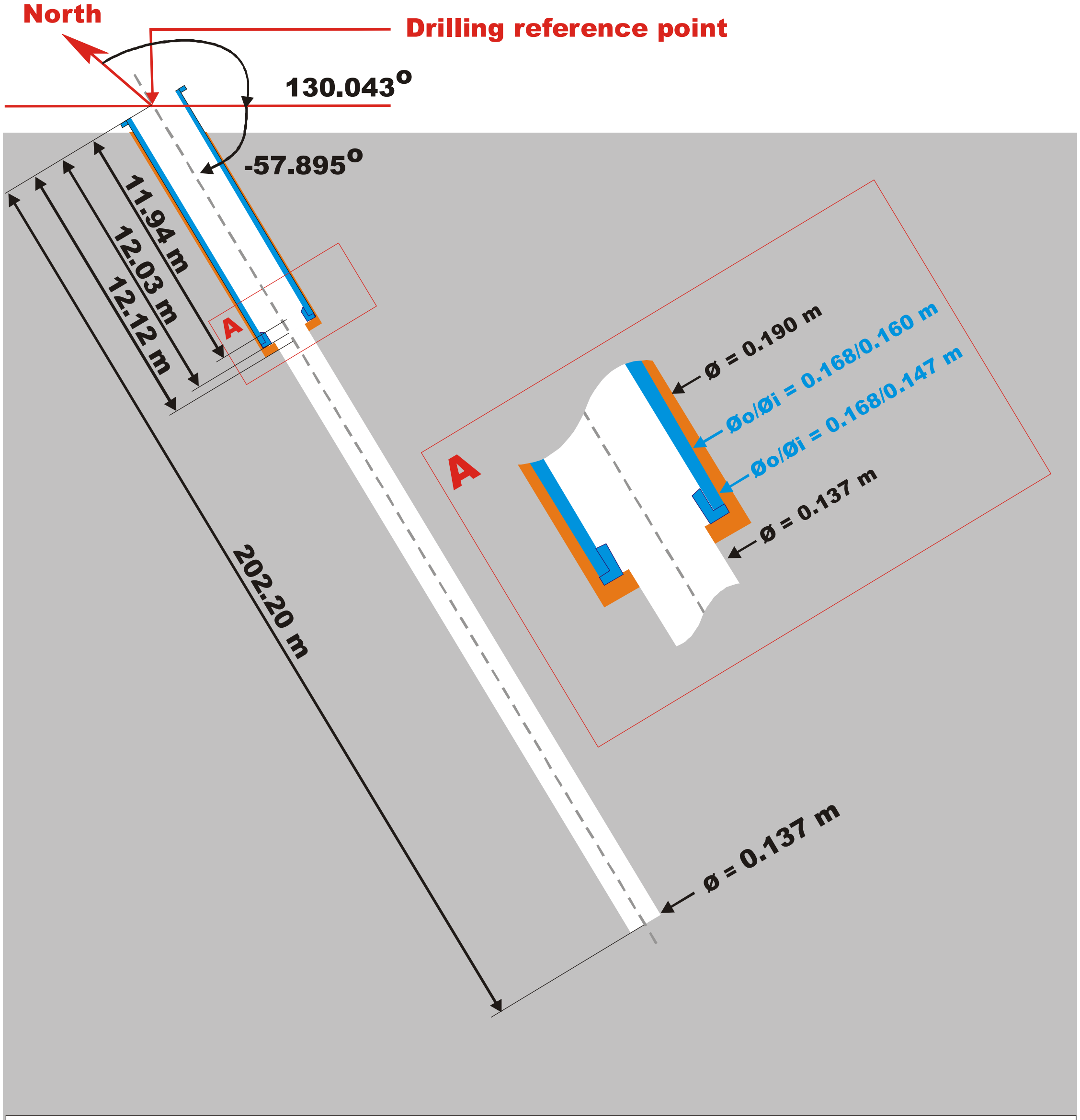
Drilling period

Drilling start date: 2004-07-01

Drilling stop date: 2004-07-06

Technical data

Borehole HLX19



Drilling reference point

Northing: 6365757.879 (m), RT90 2,5 gon V

Easting: 1550090.867 (m), RT90 2,5 gon V

Elevation: 5.951 (m), RHB 70

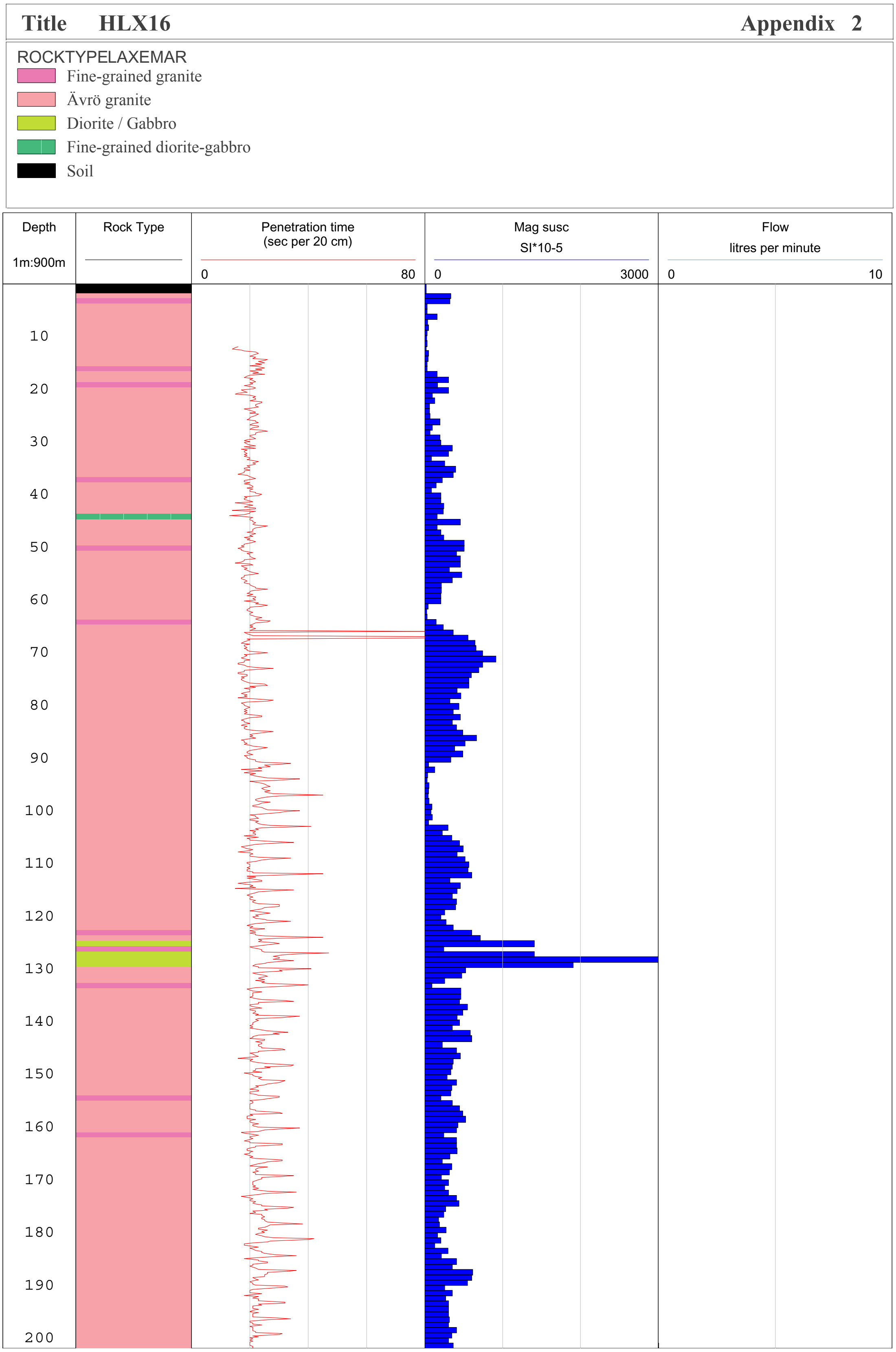
Drilling period

Drilling start date: 2004-08-10

Drilling stop date: 2004-08-12

Appendix 2

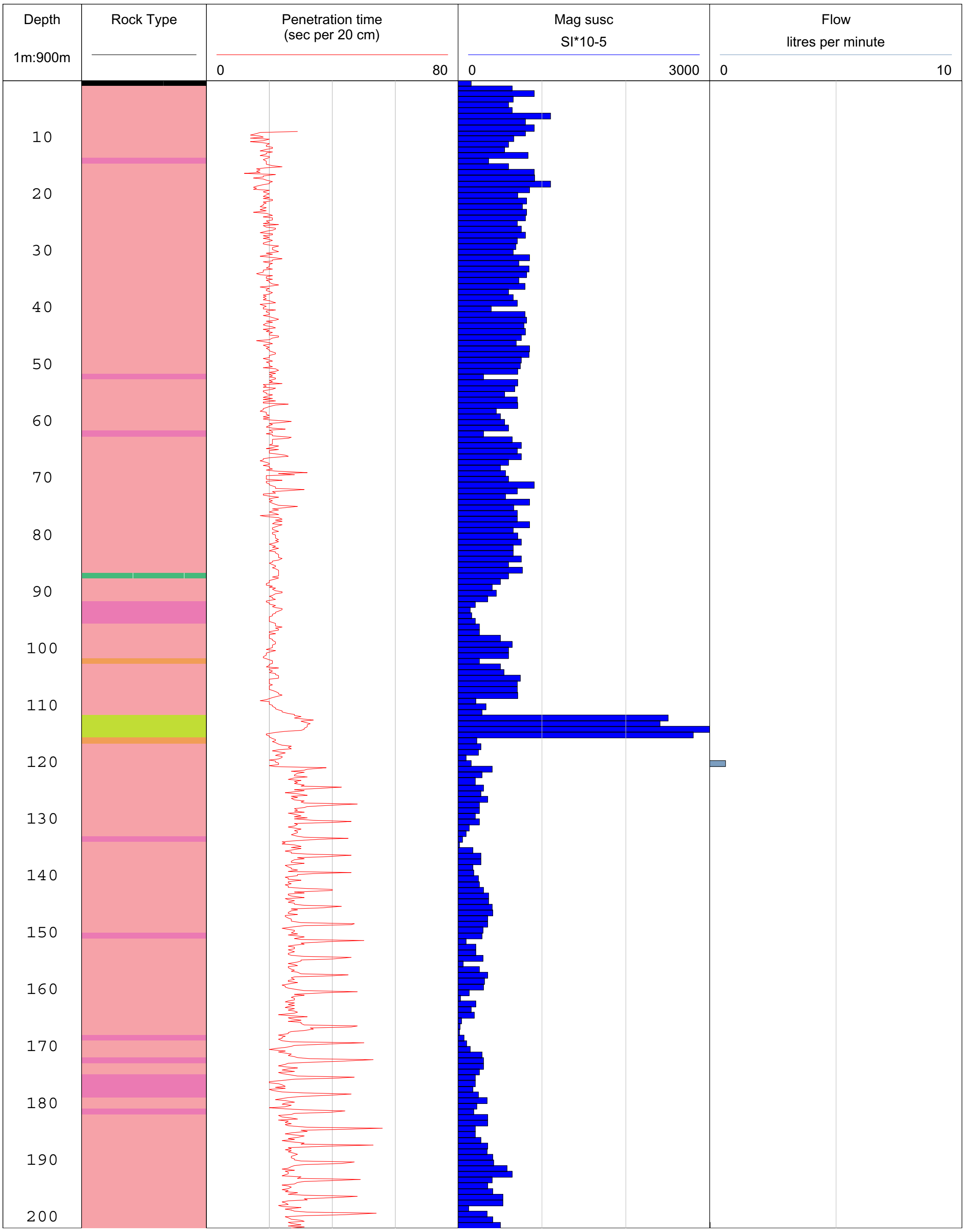
WellCad plots for boreholes HLX16, HLX17, HLX18 and HLX19. Preliminary geological mapping, drilling penetration time and magnetic susceptibility.



Title HLX17 **Appendix 2**

ROCKTYPELAXEMAR

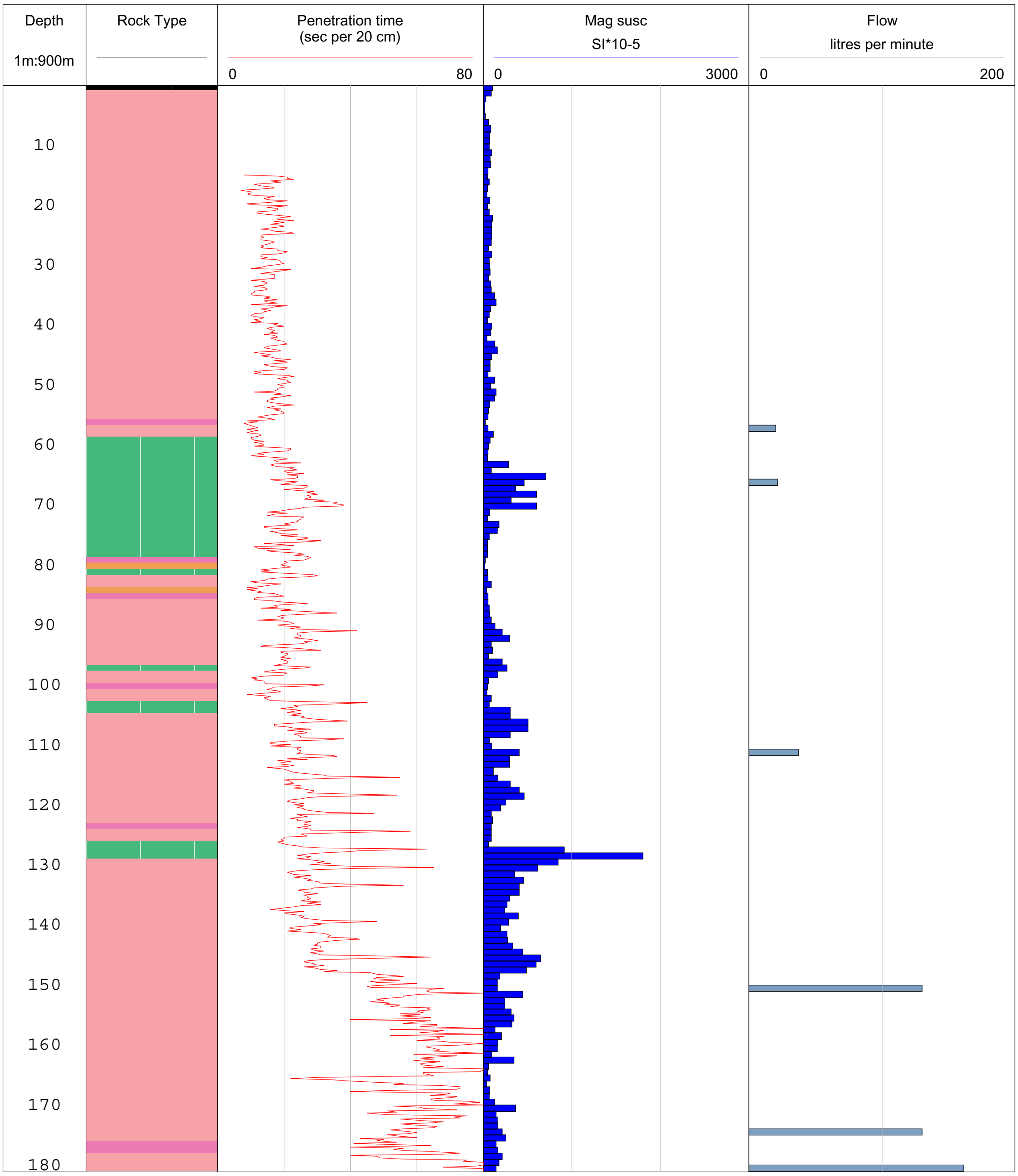
- Fine-grained granite
- Pegmatite
- Ävrö granite
- Diorite / Gabbro
- Fine-grained diorite-gabbro
- Soil



Title HLX18 **Appendix 2**

ROCKTYPELAXEMAR

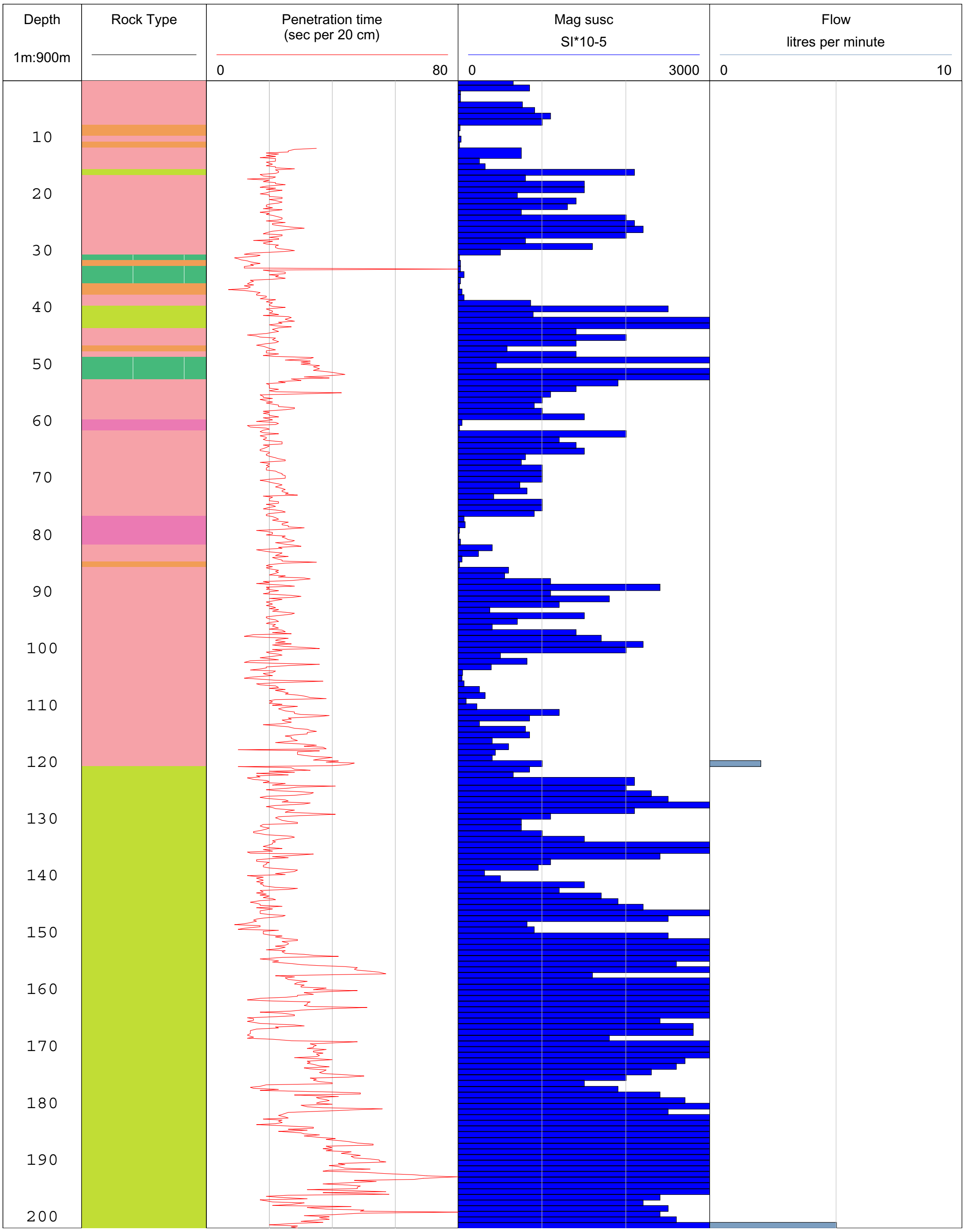
- Fine-grained granite
- Pegmatite
- Ävrö granite
- Fine-grained diorite-gabbro
- Soil



Title HLX19 **Appendix 2**

ROCKTYPELAXEMAR

- Fine-grained granite
- Pegmatite
- Ävrö granite
- Diorite / Gabbro
- Fine-grained diorite-gabbro



Appendix 3

Lognormal plot from pumping test in HLX18

The supposition for using Cooper-Jacob's method in the evaluation of the transmissivity was tested by plotting the drawdown versus logarithmic time as shown in Figure A3-1.

With a flow of 60 L/min during the pumping test, the drawdown of one logarithmic cycle (ie between 10 and 100 minutes) is 14 m. According to Cooper-Jacob's method /6/ the transmissivity can be calculated as:

$T = (Q/\Delta s)\cdot(\ln 10/4\pi) = 0.183\cdot(Q/\Delta s)$

Thus, the transmissivity in HLX18 was found to be $T = 1.3\times10^{-5}$ m^2/sec.

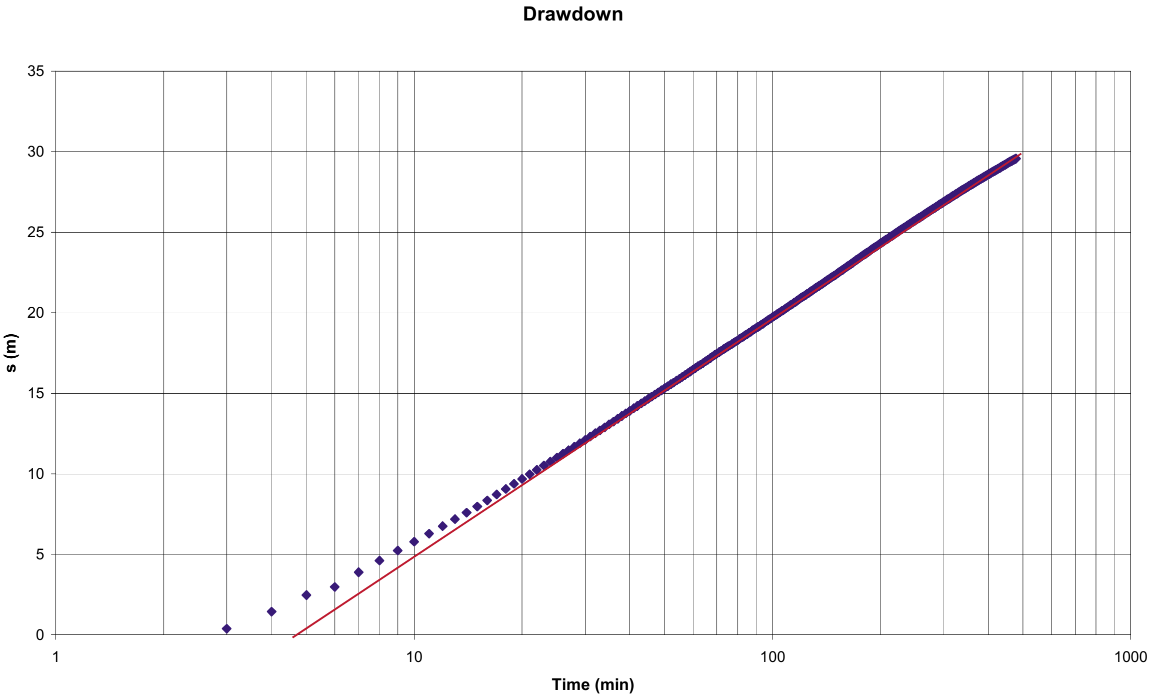


Figure A3-1. *Drawdown in HLX18. The pumped flow, Q, was 60 litres per minute or 1.0×10^{-3} m^3/s. The drawdown, Δs, over one logarithmic cycle (between 10 and 100 minutes) was 14 m.*

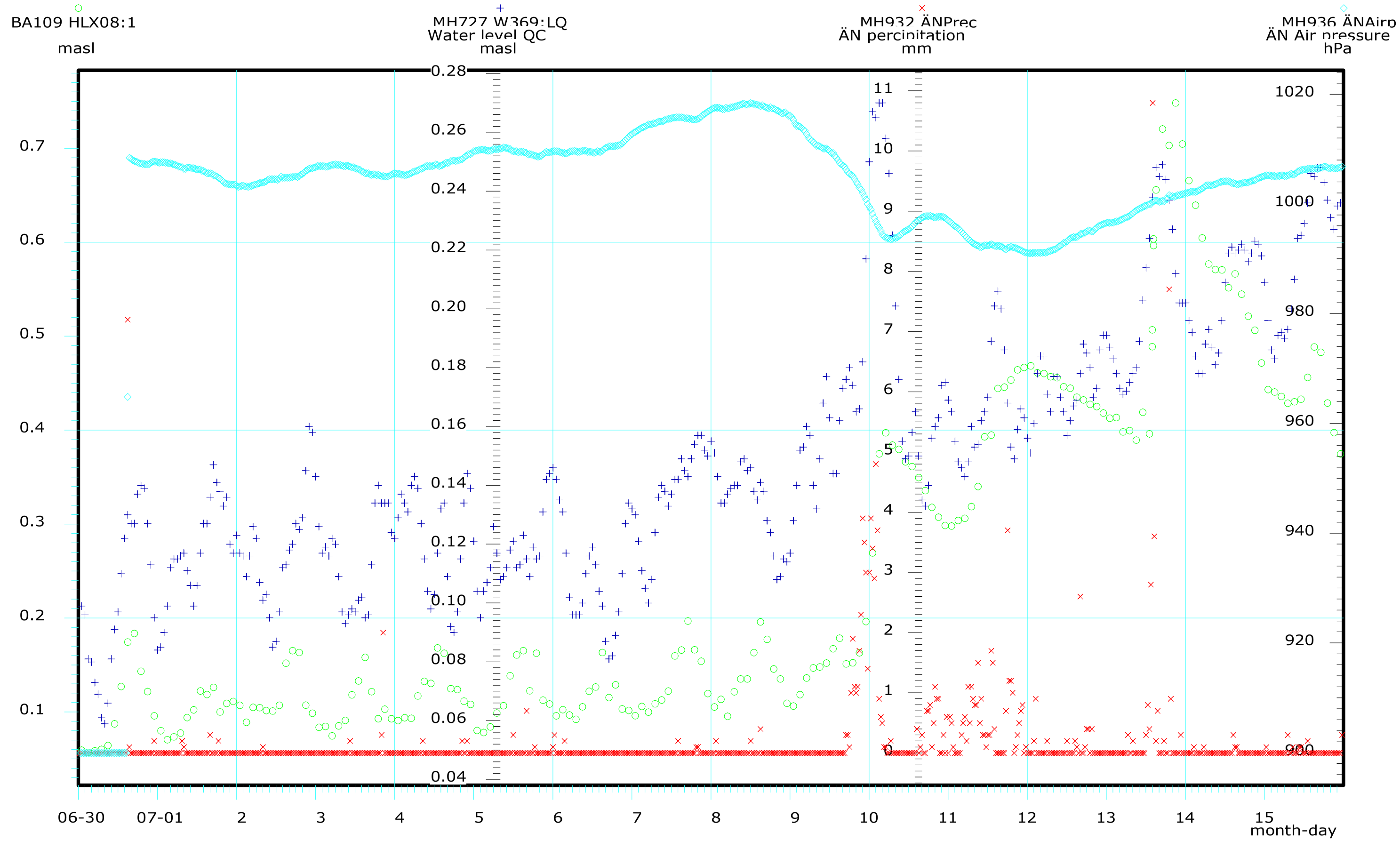
Appendix 4

Sea level, precipitation and ambient air pressure in the vicinity of HLX08

PLOT TIME :05/07/05 13:05:18
PLOT FILE :Drilling HLX18
Adjusted for DST

HMS PO

HLX08, sea level, precipitation and air pressure during drilling of HLX18.



START :04/06/30 00:00:00

INTERVAL: All readings

STOP :04/07/15 23:59:59