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Oskarshamn site investigation

Percussion drilling of boreholes HLX21, HLX22, HLX23, HLX24, HLX25, HLX30, HLX31 and HLX33 for investigation of lineament EW007

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March 2005

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Keywords: Percussion drilling, Lineament investigation, Hydraulic responses.

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, typically 150 to 200 metres.

Boreholes HLX21, HLX22, HLX23, HLX24, HLX25, HLX30, HLX31 and HLX33 were drilled for investigation of lineament EW007 in the central part of the Laxemar subarea. The eight boreholes were dispersed over a distance of two kilometres along the east-west trending lineament.

Indications of a deformation zone could be seen in all boreholes as high water yields, reduced magnetic susceptibility and variable penetration rates.

Any geometrical interpretation of a deformation zone should however be done with great caution as the scale (thickness) of the zone could be more or less equal to the reach of the percussion boreholes. It seems most likely, however, that the dip of EW007 is to the north.

The encountered lithologies in the boreholes correspond well with the results from the surface geological mapping.

The water yields were generally high and varied from 120 to more than 600 litres per minute.

Hydraulic responses in surrounding boreholes during drilling or pumping tests could be established in several cases.

The hydraulic responses during drilling give the impression that the geological structure underlying the lineament EW007 may be divided in an eastern and a western segment. The responses were very distinct between boreholes in the western part of the lineament. The responses between boreholes in the eastern part are distinct only in short distances.

Sammanfattning

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

Borrhålen HLX21, HLX22, HLX23, HLX24, HLX25, HLX30, HLX31 och HLX33, utfördes för undersökning av lineament EW007 i den centrala delen av Laxemarsområdet. De åtta borrhålen spreds över två kilometer längs det öst-västliga lineamentet.

Indikationer på en deformationszon kunde ses i samtliga borrhål som hög vattenföring, reducerad magnetisk susceptibilitet och varierande borrsjunkhastighet.

Varje tolkning av geometri på deformationszonen skall göras med stor försiktighet eftersom bredden på zonen kan vara i samma storleksordning som räckvidden för hammarborrhålen. Det är dock troligt att EW007 har en nordlig stupning.

De litologier som påträffas i borrhålen överrensstämmer väl med resultaten från den geologiska karteringen på markytan.

Vattenflödena var generellt sett höga och varierade från 120 till över 600 minutliter.

Hydrauliska responser i omgivande borrhål under borrning och provpumpning kunde ses i flera fall.

De hydrauliska responserna vid borrning ger vid hand att den geologiska struktur som ligger under lineament EW007 kan delas upp i en östlig och en västlig gren. Responserna är tydliga mellan borrhål i den västra delen av lineamentet. Responserna mellan borrhål i den östra delen är tydliga endast på korta avstånd.

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 were identified by air-borne 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/.

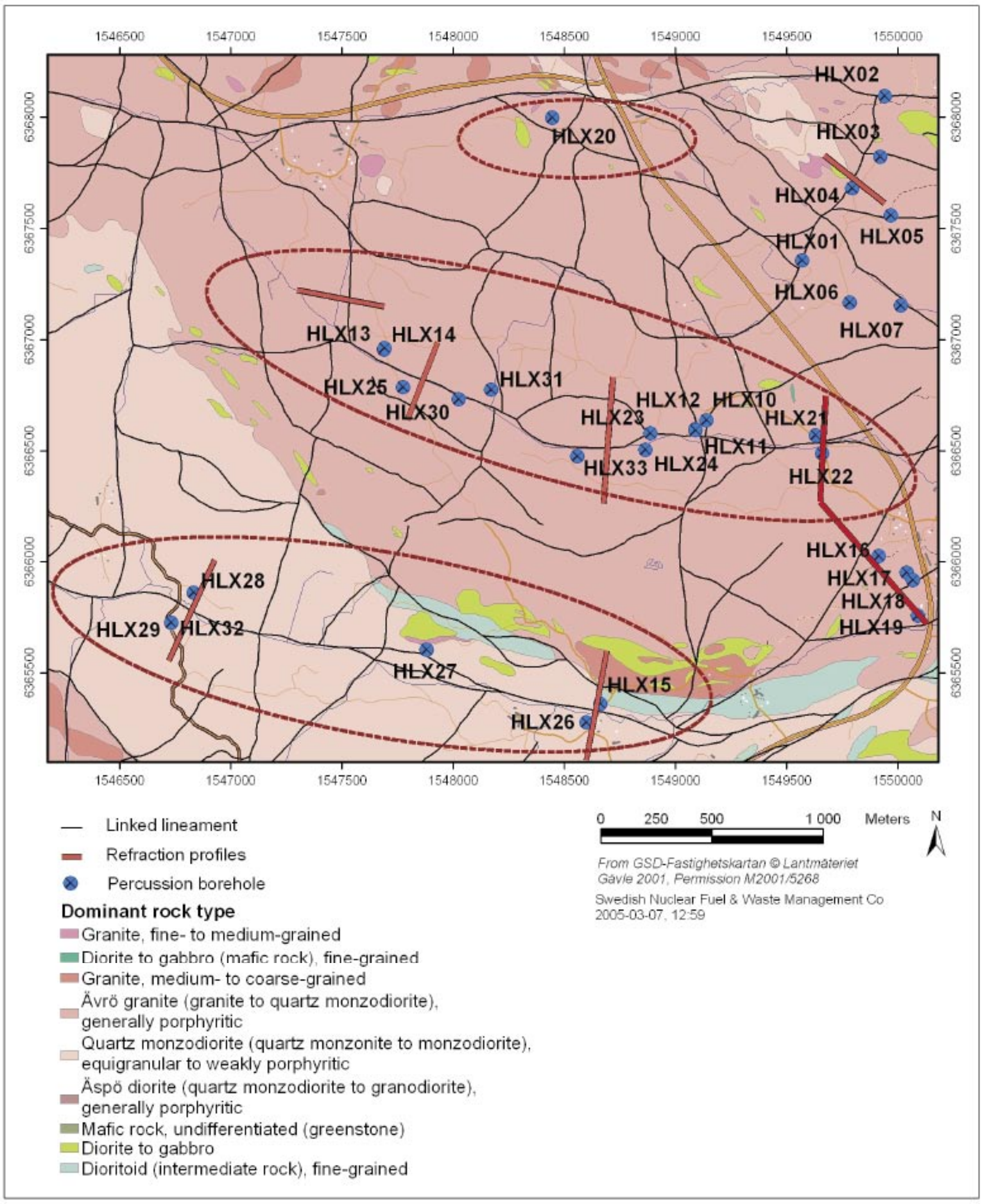


Figure 1-1. *Location of boreholes HLX21, HLX22, HLX23, HLX24, HLX25, HLX30, HLX31 and HLX33 in the Laxemar subarea. The map shows the bedrock geology, main lineaments and surface geophysical profiles. The boreholes are located within the central ellipse which circumscribes the east-west trending lineament EW007.*

Percussion drilling to a depth of 150–200 metres was done to investigate the interpreted major lineaments and selected geophysical anomalies.

This report will describe the drilling of the eight percussion holes, HLX21, 22, 23, 24, 25, 30, 31 and 33 and the measurements performed during the drilling phase. The holes were drilled on lineament EW007 in the Laxemar subarea of the Oskarshamn site investigation, see Figure 1-1.

The decision to drill boreholes HLX21–25 is given in SKB id 1027822, internal document. The decision to drill boreholes HLX30, 31 and 33 is given in AP PS 400-04-112, internal document.

The regional authorities were informed by letters on 2004-09-10, SKB id 1028807 (HLX21–25), 2004-10-28, SKB id 1030977 (HLX30 and 31) and 2004-11-26, SKB id 1032245 (HLX33), internal documents.

The drilling and all related on-site operations were performed according to two specific activity plans (AP PS 400-04-072 and AP PS 400-04-112). 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.

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 HLX21–HLX29	AP PS 400-04-072	1.0
Hammarborrning av HLX30 och HLX31	AP PS 400-04-112	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

An amendment concerning the drilling of HLX33 is included in AP PS 400-04-112.

All data were stored in the SICADA database for Oskarshamn.

2 Objective and scope

This report will describe the drilling of eight percussion boreholes, HLX21, 22, 23, 24, 25, 30, 31 and 33, and the measurements performed during drilling ie logging of preliminary geology, pumping tests and measurements of hydraulic responses.

The initial scope was to drill boreholes HLX21–25 on lineament EW007. Boreholes HLX30 and 31 were added on to give further structural information of the lineament. Borehole HLX33 was drilled to give structural information and a more even distribution of boreholes along strike of the lineament for forthcoming hydraulic tests.

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

Table 2-1. Borehole objectives before drilling.

Borehole	Drilling objective
HLX21	The borehole would intercept a possible subvertical deformation zone at 100 metres drilled length. Drilled along a ground geophysical profile.
HLX22	The borehole would intercept a possible subvertical deformation zone at 100–120 metres drilled length. Drilled along a ground geophysical profile.
HLX23	The borehole would intercept a possible subvertical deformation zone at 100 metres drilled length. The drilling is done 150 metres east of a ground geophysical profile.
HLX24	The borehole would intercept a possible subvertical deformation zone at 150 metres drilled length. The drilling is done 150 metres east of a ground geophysical profile.
HLX25	The borehole would intercept a possible subvertical deformation zone at 100 metres drilled length. Drilled along a ground geophysical profile.
HLX30	The borehole would intercept a possible subvertical deformation zone at 100 metres drilled length.
HLX31	The borehole would intercept a possible subvertical deformation zone at 100–150 metres drilled length.
HLX33	The borehole would intercept a possible subvertical deformation zone at 100 metres drilled length.

3 Equipment

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

3.1 Drilling equipment

Drilling of boreholes HLX21, 22, 23, 24 and 25, performed by Sven Andersson AB, was made with a Puntel percussion drilling machine supplied with accessories.

The drilling machine was equipped with separate engines for transportation and power supplies. 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.

The drilling of boreholes HLX30, 31 and 33 were performed by Håkans Vatten och Energibrunnar AB with a Gemsa drill rig supplied with accessories. The drilling machine was a Gemrok 55S and the compressor was an Ingersoll Rand 1070. The drillhammer was a 140 mm (5") Secoroc 54 with a working pressure of 25 bar. The drill stem was Driconeq 114 mm diameter on the lowermost 15 metres and otherwise 89 mm diameter.

Figure 3-1. *Drill site HLX22 and the Puntel drill rig.*

3.2 Equipment for measurements and sampling during drilling

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 centimetres or automatically with MWD equipment, see also section 4.5.

Samples of soil and drill cuttings were collected in sampling pots. Magnetic susceptibility in the samples was measured with a hand-held meter, JH-8 from Geoinstruments, Finland.

The pumping tests were done with a submersible pump, Grundfoss MS 402 SP2A-23. Hydraulic responses were normally measured with Mini-Troll pressure loggers.

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 6 and 9 metres.

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 low-alkali 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.

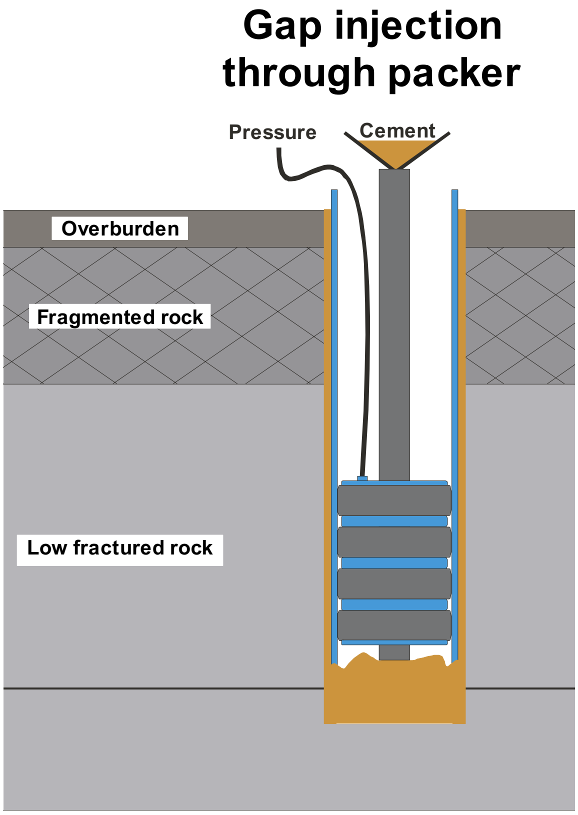


Figure 4-1. *Gap injection technique.*

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

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 included the following items:

- 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 centimetres) was manually recorded in HLX21, 22, 25, 30, 31 and 33. In HLX21, 22, 23 and 24 the penetration rate was logged automatically.
- 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. The method employed gives an indication of the actual yield. The lower detection limit is estimated at 1–2 litres/minute. At higher flow rates (over 100 litres/minute) the uncertainty of the method increases.

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

Borehole deviation measurements were not made in conjunction with drilling.

Figure 4-2. *Return water from drilling (HLX30) is led to a settling container. The cyclone for collecting the cuttings can be seen fastened on top of the container. Equipment for the preliminary geological logging can be seen in the foreground.*

4.6 Borehole completion

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. Lockable steel caps on the casing will be installed in June 2005.

4.7 Pumping tests and hydraulic responses

Short pumping tests were made in boreholes HLX22, HLX24, and HLX25. Pumping tests were not made in HLX21 and HLX23 as these are located in the same profiles as HLX22 and HLX24 respectively. No pumping tests were made in HLX30, 31 or 33 because a larger separate pumping test (AP PS 400-04-105, SKB internal document) was planned to start shortly after drilling of these boreholes.

The water levels in the pumping well and in selected neighbouring boreholes (hydraulic responses) were monitored with MiniTroll pressure loggers. The logger settings were:

Scan time: 1s

Log time: 10s

Event: 0.1 kPa

The scan time is the interval for the pressure readings. With an event function of 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.

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

The pumping phase lasted for approximately 24 hours.

Manual measurements of the groundwater level were conducted to check the logger data.

Water samples were collected in conjunction with pumping tests in two cases.

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.

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

Boreholes HLX21, HLX22, HLX23, HLX24, HLX25, HLX30, HLX31 and HLX33 were drilled for investigation of lineament EW007 in the southern part of the Laxemar subarea. The eight boreholes were dispersed over a distance of 2 kilometres along the east-west trending lineament. A chronological summary of drilling, pumping tests and water table measurements in surrounding boreholes (hydraulic responses) is given in Figure 5-1.

The encountered lithologies in the boreholes correspond well with the expectations based on surface geological mapping.

The water yields were generally high and varied between 120 and to more than 600 litres per minute.

Hydraulic responses in surrounding boreholes during drilling or pumping, could be established in several cases.

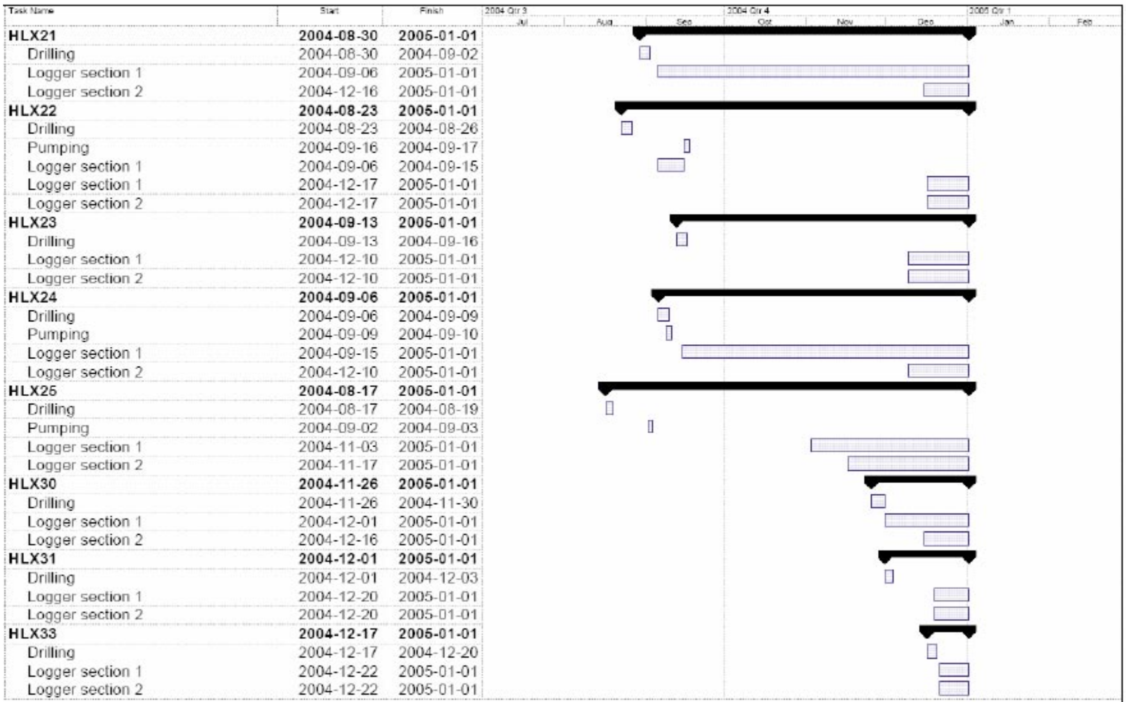


Figure 5-1. *Chronological summary of drilling, pumping tests and water table measurements in percussion boreholes included in this report. The time span is limited to January 1, 2005 for reporting purposes only, it does not mean that monitoring in the boreholes was discontinued after this date.*

5.1 Borehole design

A summary of data from the borehole are presented in Tables 5-1, 5-2 and 5-3. Technical data of the boreholes are illustrated in Appendix 1.

Table 5-1. Geometric and technical data for borehole HLX21, HLX22 and HLX23.

Parameter	HLX21	HLX22	HLX23
Drilling period	From 2004-08-30 to 2004-09-02	From 2004-08-23 to 2004-08-26	From 2004-09-13 to 2004-09-16
Borehole inclination (starting point) (0 to –90)	–56.99°	–59.44°	–58.18°
Borehole azimuth (0–360)	185.5°	13.5°	182.9°
Borehole length	150.30 m	163.20 m	160.20 m
Soil depth	3.0 m	7.4 m	3.8 m
Drill bit diameter	0.138 m	0.138 m	0.139 m
Starting point coordinates (system RT90/RHB70)	Northing: 6366567.93 m Easting: 1549632.36 m Elevation: 10.312 m a s l	Northing: 6366487.83 m Easting: 1549661.52 m Elevation: 10.057 m a s l	Northing: 6366578.01 m Easting: 1548888.67 m Elevation: 14.690 m a s l
Water yield (interval)	> 225 L/min (0–150.3 m)	> 125 L/min (0–163.2 m)	> 118 L/min (0–160.2 m)
Borehole diameter (interval) (diameter mm)	0–9.10 m 190 mm 9.10–150.3 m 138 mm	0–9.10 m 190 mm 9.10–163.2 m 138 mm	0–6.10 m 190 mm 6.10–160.2 m 139 mm
Casing diameter (interval) (diameter mm)	0–8.94 m Ø$_o$ = 168 8.94–9.03 m Ø$_i$ = 160 Ø$_o$ = 168 Ø$_i$ = 147	0–8.94 m Ø$_o$ = 168 8.94–9.03 m Ø$_i$ = 160 Ø$_o$ = 168 Ø$_i$ = 147	0–5.94 m Ø$_o$ = 168 5.94–6.03 m Ø$_i$ = 160 Ø$_o$ = 168 Ø$_i$ = 147

Table 5-2. Geometric and technical data for borehole HLX24, HLX25 and HLX30.

Parameter	HLX24	HLX25	HLX30
Drilling period	From 2004-09-06 to 2004-09-09	From 2004-08-17 to 2004-08-19	From 2004-11-26 to 2004-11-30
Borehole inclination (starting point) (0 to –90)	–59.44°	–58.59°	–60.76°
Borehole azimuth (0–360)	358.7°	17.9°	55.8°
Borehole length	175.20 m	202.50 m	163.40 m
Soil depth	4.8 m	0 m	4.0m
Drill bit diameter	0.139 m	0.135 m	0.139 m
Starting point coordinates (system RT90/RHB70)	Northing: 6366503.72 m Easting: 1548865.89 m Elevation: 12.769 m a s l	Northing: 6366783.97 m Easting: 1547776.32 m Elevation: 20.656 m a s l	Northing: 6366730.73 m Easting: 1548026.73 m Elevation: 12.184 m a s l
Water yield (interval)	175 L/min (0–175.2 m)	112 L/min (0–202.5 m)	> 200 L/min (0–163.4 m)
Borehole diameter (interval) (diameter mm)	0–9.10 m 190 mm 9.10–175.2 m 139 mm	0–6.12 m 190 mm 6.12–202.5 m 135 mm	0–9.10 m 191 mm 9.10–163.40 m 139 mm
Casing diameter (interval) (diameter mm)	0–8.94 m Ø$_o$ = 168 8.94–9.03 m Ø$_i$ = 160 Ø$_o$ = 168 Ø$_i$ = 147	0–5.94 m Ø$_o$ = 168 5.94–6.03 m Ø$_i$ = 160 Ø$_o$ = 168 Ø$_i$ = 147	0–8.94 m Ø$_o$ = 168 8.94–9.03 m Ø$_i$ = 160 Ø$_o$ = 168 Ø$_i$ = 143

Table 5-3. Geometric and technical data for borehole HLX31 and HLX33.

Parameter	HLX31		HLX33	
Drilling period	From 2004-12-01 to 2004-12-03		From 2004-12-17 to 2004-12-20	
Borehole inclination (starting point) (0 to –90)	–58.76°		–58.76°	
Borehole azimuth (0–360)	231.8°		21.8°	
Borehole length	133.20 m		202.10 m	
Soil depth	1.7 m		2.6 m	
Drill bit diameter	0.139 m		0.139 m	
Starting point coordinates (system RT90/RHB70)	Northing: 6366774.51 m Easting: 1548172.27 m Elevation: 12.162 m a s l		Northing: 6366471.74 m Easting: 1548562.71 m Elevation: 12.201 m a s l	
Water yield (interval)	> 600 L/min (0–133.2 m)		168 L/min (0–202.1 m)	
Borehole diameter (interval) (diameter mm)	0–9.10 m 9.10–133.2 m	190 mm 139 mm	0–9.10 m 6.12–202.1 m	190 mm 139 mm
Casing diameter (interval) (diameter mm)	0–8.94 m 8.94–9.03 m	$Ø_o$ = 168 $Ø_i$ = 160 $Ø_o$ = 168 $Ø_i$ = 143	0–8.94 m 8.94–9.03 m	$Ø_o$ = 168 $Ø_i$ = 160 $Ø_o$ = 168 $Ø_i$ = 143

5.2 Hydrogeological results

The water yields obtained from blowing of compressed air during drilling are given in Table 5-4.

Table 5-4. Water yields from drilling.

Borehole	From (m)	To (m)	Water yield (L/min)	Date	Time for final rinsing by air blow (local time)
HLX21	9.03	66.9	11.5	040831	
HLX21	9.03	87.9	172	040831	
HLX21	9.03	121.2	175	040831	
HLX21	9.03	121.2	225	040901	
HLX21	9.03	150.3	> 225	040901	17:30
HLX22	9.03	57.9	5	040824	
HLX22	9.03	120.9	85	040824	
HLX22	9.03	120.9	> 190	040825	
HLX22	9.03	163.2	> 125	040825	17:50
HLX23	6.03	21.9	2	040914	
HLX23	6.03	48.9	26	040914	
HLX23	6.03	51.9	29	040914	
HLX23	6.03	66.9	71	040914	
HLX23	6.03	121.2	95	040914	
HLX23	6.03	121.2	145	040915	
HLX23	6.03	160.2	> 118	040915	17:40

Borehole	From (m)	To (m)	Water yield (L/min)	Date	Time for final rinsing by air blow (local time)
HLX24	9.03	9.9	40	040907	
HLX24	9.03	120.9	95	040907	
HLX24	9.03	120.9	120	040908	
HLX24	9.03	175.2	175	040908	19:00
HLX25	6.03	51.9	23	040818	
HLX25	6.03	120.9	26	040818	
HLX25	6.03	120.9	59	040819	
HLX25	6.03	202.5	112	040819	16:30
HLX30	9.03	61.4	6.8	041129	
HLX30	9.03	88.4	60	041129	
HLX30	9.03	130.4	> 144	041129	
HLX30	9.03	139.4	> 160	041129	
HLX30	9.03	163.4	> 2–300	041130	12:40
HLX31	9.03	9.1	8.5	041202	
HLX31	9.03	118.1	88	041202	
HLX31	9.03	127.1	> 160	041202	
HLX31	9.03	133.2	> 600	041202	15:50
HLX33	9.03	6.0	17	041220	
HLX33	9.03	22.1	6.8	041220	
HLX33	9.03	181.1	168	041220	
HLX33	9.03	202.1	168	041220	19:40

NB In the geoscientific summary given in Appendix 2 only the lowest of two measurements from the same length in the borehole is presented. Measurements at the same length in a hole typically occur because one measurement is done at the end of the working day and another is done the following morning. The latter measurement normally gives a significantly higher value due to recovery and storage.

The level at which the water yield was measured does not always correspond to the observed level of inflow.

The observed levels of water inflow during drilling are summarised in Table 5-5 and shown graphically in Figures 6-1 and 6-2.

The amount of effluent water to the ground from the drilling activities is estimated in Table 5-6.

The release of water was made within 30 metres from the collar location.

Table 5-5. Observed levels of water inflow during drilling.

Borehole	Noticeable inflow of water during drillling (meters drilled length)
HLX21	65.3, 86 m
HLX22	54.5, 99.5, 117.8 m
HLX23	21.5, 47.5, 65.2 m
HLX24	5–9, 145 m
HLX25	46–50, 176–180 m
HLX30	61.4, 87.9–88.4, 128, 135–138 m
HLX31	2.5–3, 117, 126 m
HLX33	4, 19.4, 177 m

Table 5-6. Amount of released water from drilling.

Borehole	Amount of water released (m^3)
HLX21	175
HLX22	78
HLX23	108
HLX24	115
HLX25	64
HLX30	132
HLX31	98
HLX33	28

Pumping tests

Pumping tests were performed in boreholes HLX22, 24 and 25. The results are shown in Table 5-7 and graphically in Figures 5-2, 5-3 and 5-4. The transmissivities have been calculated according to /5/.

Pumping was done twice in HLX22 as can be seen in Figure 5-5, however only the test shown in Figure 5-2 was part of this drilling activity and included in this report.

Table 5-7. Hydrogeological results from pump tests in HLX22, 24 and 25.

Borehole	Specific capacity Q/s (m^2/s)	Transmissivity T_M (m^2/s)
HLX22	2.40×10^{-4}	3.30×10^{-4}
HLX24	5.27×10^{-4}	7.29×10^{-4}
HLX25	1.56×10^{-4}	2.20×10^{-4}

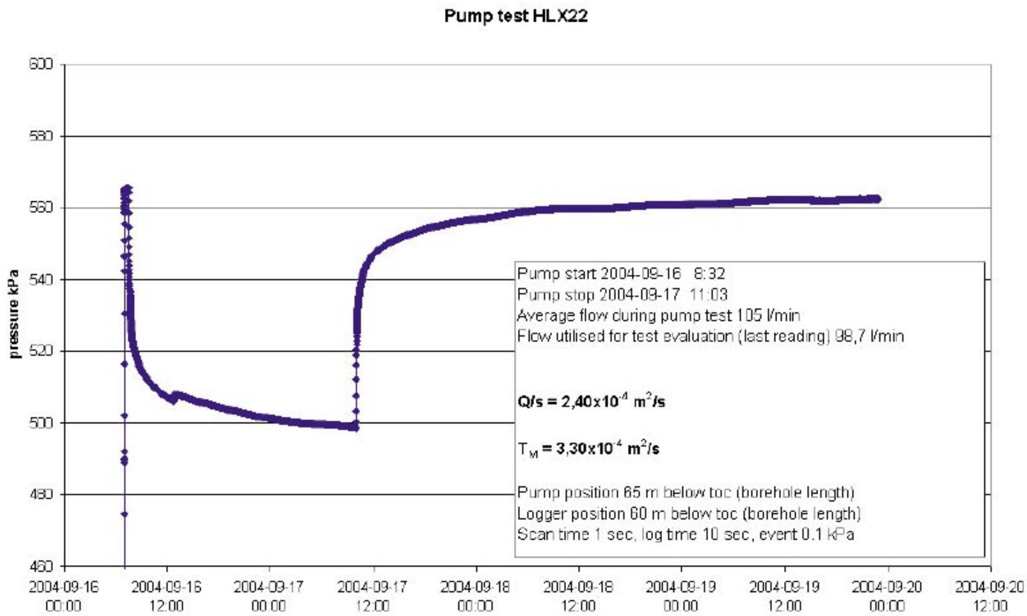


Figure 5-2. *Drawdown and recovery in HLX22. The pressure has not been corrected for ambient air-pressure. The lowering of the logging unit into the borehole can be seen as the initial, more or less vertical, increase in pressure which is followed by the drawdown phase.*

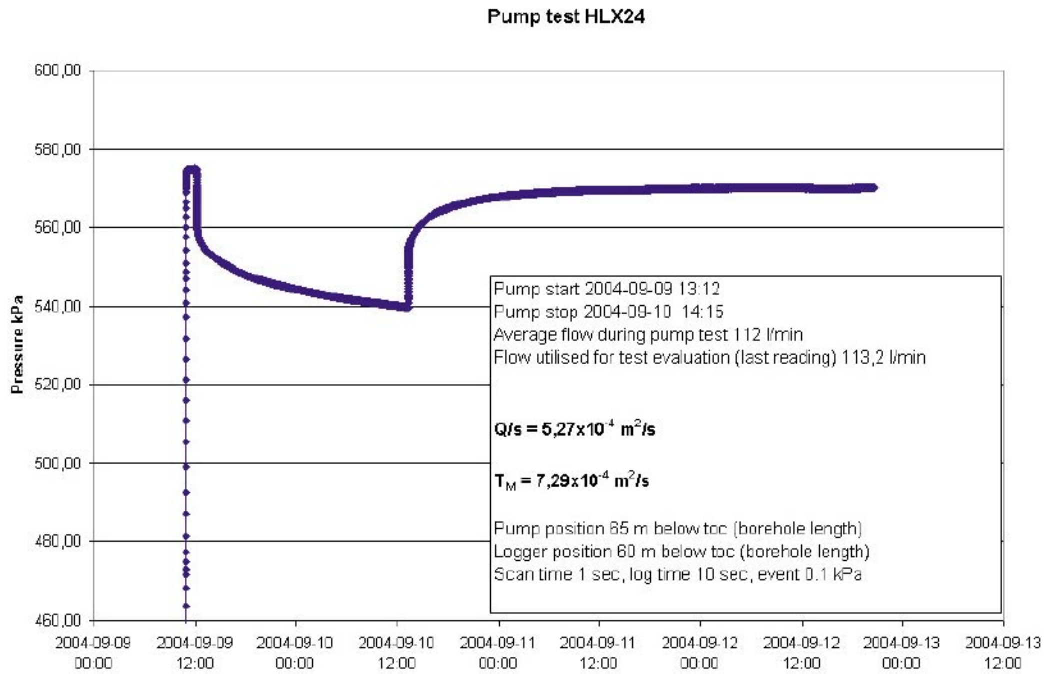


Figure 5-3. *Drawdown and recovery in HLX24. The pressure has not been corrected for ambient air-pressure. The lowering of the logging unit into the borehole can be seen as the initial, more or less vertical, increase in pressure which is followed by the drawdown phase.*

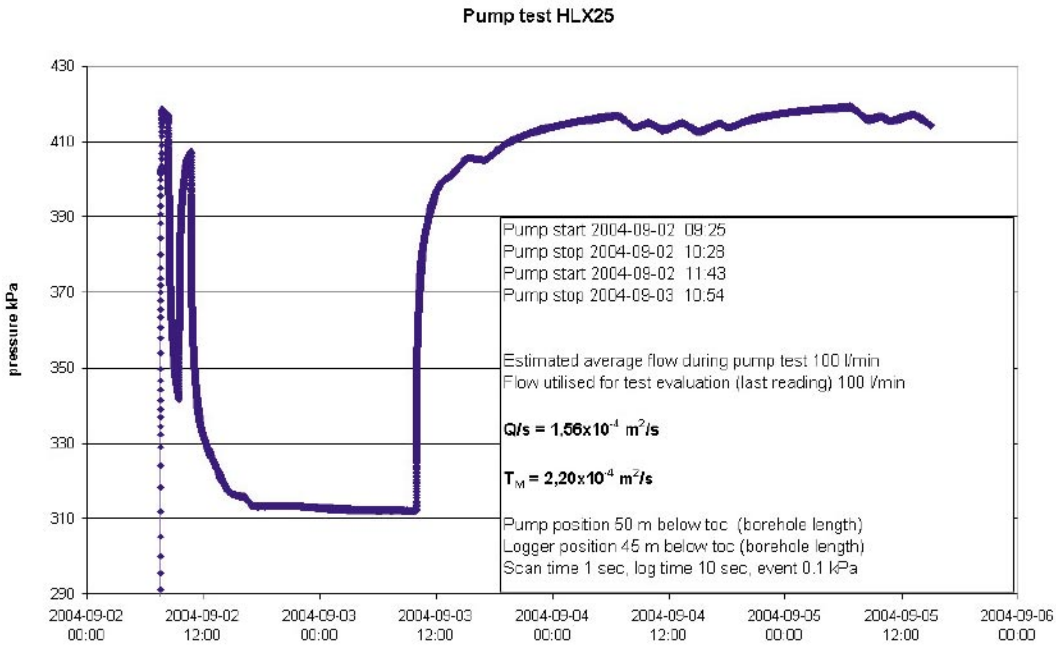


Figure 5-4. *Drawdown and recovery in HLX25. The pressure has not been corrected for ambient air-pressure. The lowering of the logging unit into the borehole can be seen as the initial, more or less vertical, increase in pressure which is followed by the drawdown phase.*

Hydraulic responses

Selected results from the monitoring of hydraulic responses in surrounding boreholes during drilling and pumping tests are presented in Figures 5-5 and 5-6. Some boreholes that are not strictly a part of this report are mentioned in Figure 5-5, the location are however given in Figure 5-7.

Hydraulic responses in surrounding boreholes during drilling or pumping tests could be established in several cases.

A summary of observations made in the percussion boreholes included in the report is given in Table 5-8. A response could be seen in HLX21 while pumping in HLX22 and was also noted in HLX24 while drilling in HLX23. Responses were seen in HLX23 and HLX24 during the drilling of HLX33 although only in the lower section of HLX23. During drilling of HLX30 a response was recorded in HLX25; during drilling of HLX30 responses were seen in HLX25 and HLX30.

Table 5-8. Summary of hydraulic response observations.

Event in borehole	Hydraulic response: HLX21	HLX22	HLX23	HLX24	HLX25	HLX30	HLX31	HLX33
HLX21 drilling	—	nm	nd	nd	nm	nd	nd	nd
HLX22 drilling	nd	—	nd	nd	nm	nd	nd	nd
HLX22 pumping	r	r	nm	nr	nm	nd	nd	nd
HLX23 drilling	nr	nr	—	r	nm	nd	nd	nd
HLX24 drilling	nr	nr	nd	—	nm	nd	nd	nd
HLX24 pumping	nr	nr	nd	r	nm	nd	nd	nd
HLX25 drilling	nd	nd	nd	nd	—	nd	nd	nd
HLX25 pumping	nm	nm	nd	nd	r	nd	nd	nd
HLX30 drilling	ne	nm	nm	nr	r	—	nd	nd
HLX31 drilling	ne	nm	nm	nr	r	r	—	nd
HLX33 drilling	ne	ne	r	r	nr	nr	nr	—

Legend

nd	not drilled
nm	not monitored
nr	no response
r	response
—	drilling
ne	not evaluated

The hydraulic responses during drilling in HLX30, 31 and 33 give the impression that the geological structure underlying the lineament EW007 may be divided in an eastern and a western segment. The responses were very distinct between boreholes in the western part of the lineament. The responses between boreholes in the eastern part are distinct only in short distances.

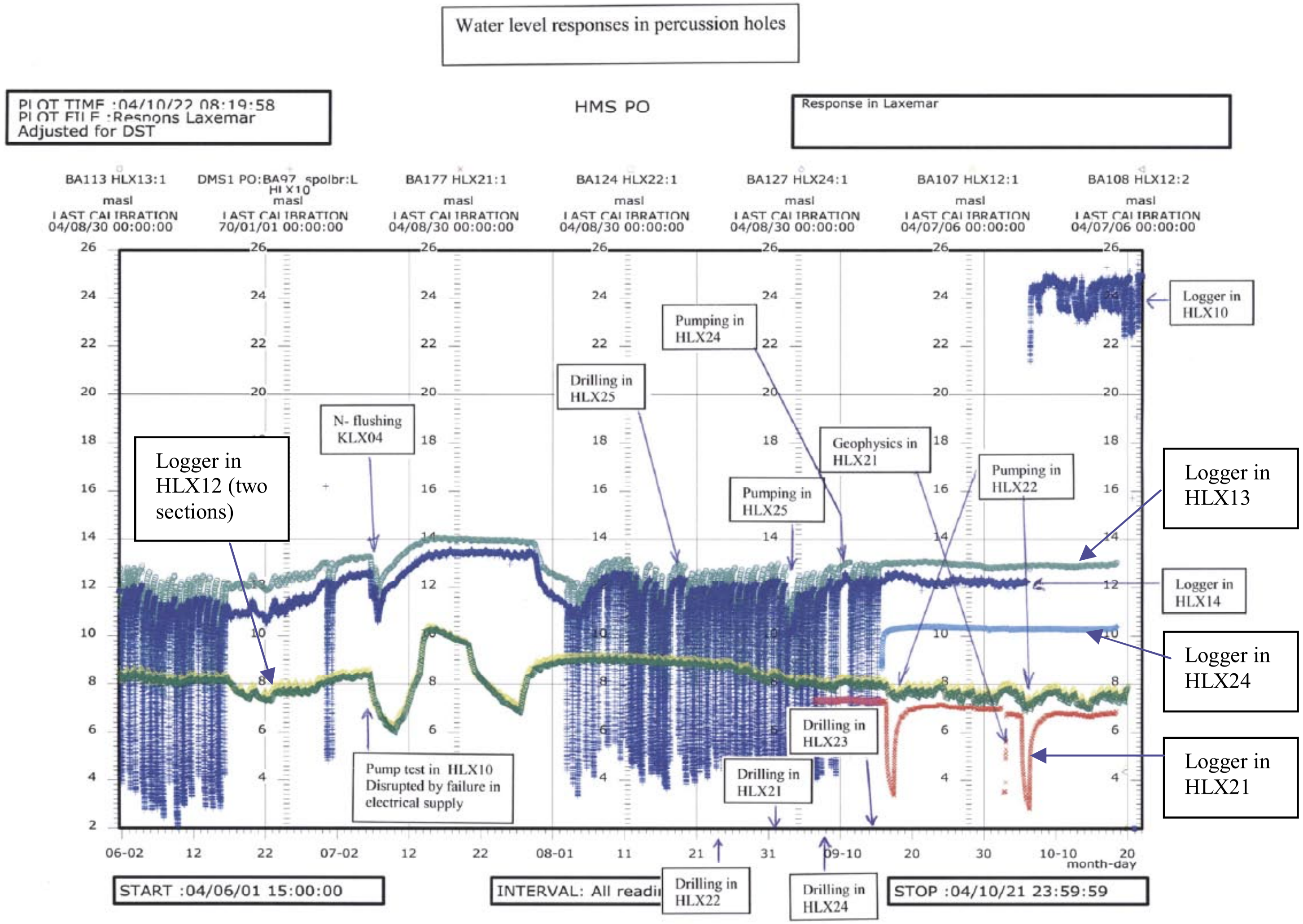


Figure 5-5. *Selected hydraulic responses in boreholes during drilling and pumping of boreholes HLX21–25. Clear responses between boreholes in the same profile ie HLX21–22 and HLX23–24 can be seen, however no response could be seen in HLX21 during drilling of HLX23 or HLX24. A clear response could be seen in HLX13 and HLX14 during drilling in HLX25. The locations of the boreholes not previously addressed in this report are shown in Figure 5-7. Pumping was made twice in HLX22 however only the one performed on September 16–17 was a part of this drilling activity.*

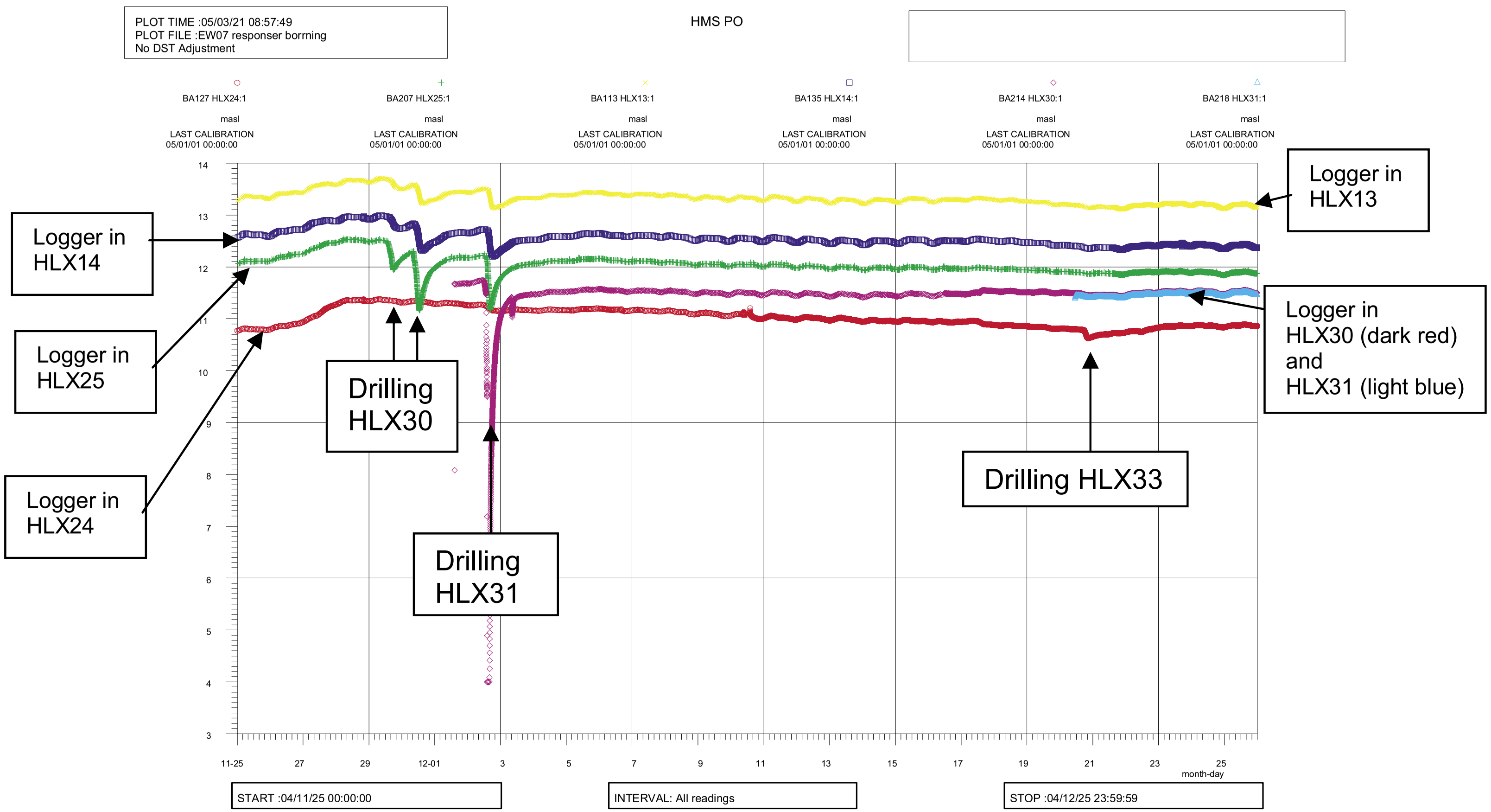


Figure 5-6. *Selected hydraulic responses during the drilling of HLX30, 31 and 33. Responses in the boreholes located to the west (HLX13-yellow, 14-blue and 25-green) can be seen during drilling of HLX30 and HLX31. A very distinct response can be seen in HLX30 (dark red) during drilling of HLX31. A weak response could be seen in HLX24 (bright red) during drilling of HLX33 whereas no response could be seen in HLX31.*

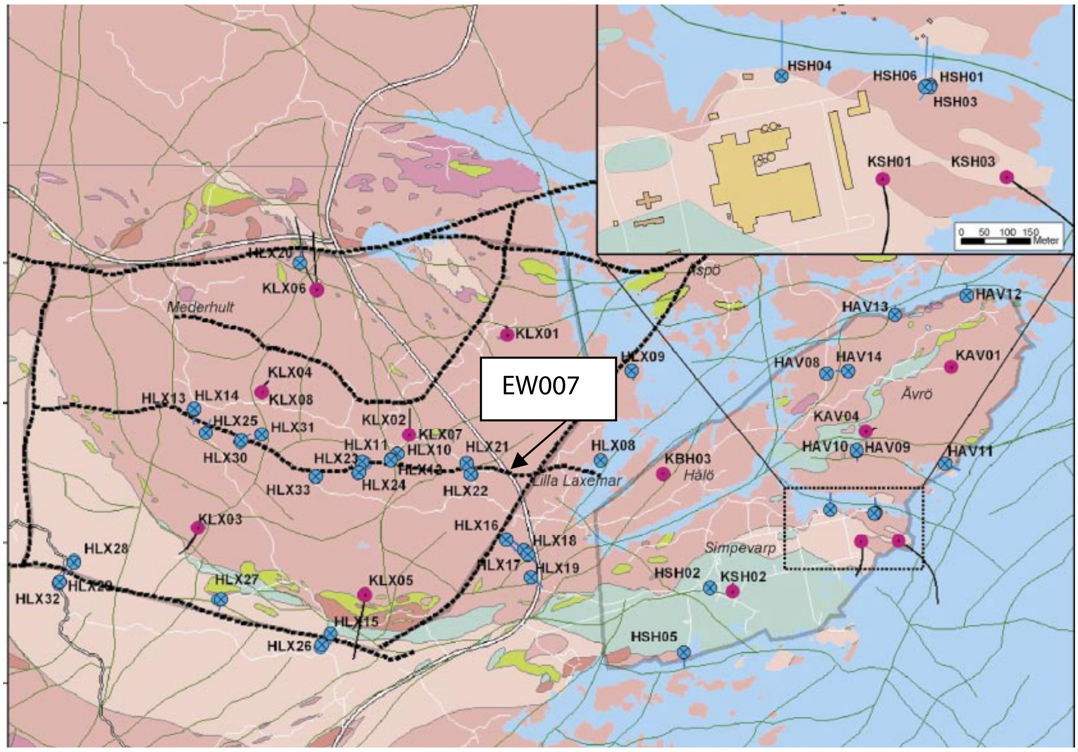


Figure 5-7. The Oskarshamn site investigation area with borehole locations and the position of the E-W trending lineament EW007.

A summary of the lengths in the boreholes to installed packers and the times for measurements with pressure loggers are given in Table 5-9.

Table 5-9. Length in hole to packer and times for measurements with pressure loggers.

Borehole	Date (from)	Date (to)	Length in hole to packer (m)	Comment
HLX21	040906	041103	open hole	1 section
HLX21	041103	041215	10–11	1 section
HLX21	041216	–	80–81	2 sections
HLX22	040906	040915	open hole	1 section
HLX22	041217	–	85–86	2 sections
HLX23	041210	–	60–61	2 sections
HLX24	040915	041104	open hole	1 section
HLX24	041104	041210	10–11	1 section
HLX24	041210	–	40–41	2 sections
HLX25	041103	041117	15–16	1 section
HLX25	041117	–	60–61	2 sections
HLX30	041201	041216	10–11	1 section
HLX30	041216	–	100–101	2 sections
HLX31	041220	–	100–101	2 sections
HLX33	041222	–	30–31	2 sections

5.3 Geological results

Lithologically the holes were dominated by Ävrö granite with minor intercalations of subordinate rock types. Minor sections of up 20 metres of "Diorite/Gabbro" occur in HLX25. The lithologies encountered during drilling correspond well to the results from surface geological mapping.

Distinguishing between "Ävrö granite" and "Granite" is difficult with drill cuttings. It is possible that parts in boreholes HLX21–25, that have been mapped as "Granite" could be oxidized varieties of "Ävrö granite".

Geological results accumulated during drilling are presented in Appendix 2.

5.4 Hydrogeochemical results

Water samples were taken during the pumping tests in HLX22 and HLX24.

Selected results are given in Table 5-10 and a full account is given in Appendix 3.

Table 5-10. Selected analytical results from water sampling in HLX22 and HLX24.

Start date	2004-09-17	2004-09-10
Borehole	HLX22	HLX24
Sample No	7762	7758
Na (mg/l)	107	41.7
HCO_3 (mg/l)	221	121.00
Cl (mg/l)	23	15.1
SO_4 (mg/l)	53.09	29.58
F (mg/l)	4.75	2.67
Fe (mg/l)	0.0633	5.55
pH (pH unit)	8.24	6.66
Electrical Conductivity (mS/m)	54.1	54.1

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 low alkali cement paste and oils are given in Table 5-11.

Table 5-11. Consumption of cement paste and oils.

Borehole	Cement paste used (low-alkali White Cement) litres/ kg	Hammer oil (Preem Hydra 46) litres	Compressor oil (Schuman 46) litres
HLX21	40/35.5	15	None noted
HLX22	40/35.5	15	None noted
HLX23	40/35.5	10	None noted
HLX24	40/35.5	15	None noted
HLX25	40/35.5	10	None noted
HLX30	40/35	10	None noted
HLX31	40/35	1.5	None noted
HLX33	40/35	1.5	None noted

5.6 Nonconformities

Pumping tests were made in three holes only; HLX22, 24 and 25.

Pumping tests in HLX21 and 23 were not performed since it was considered not necessary based on the strong hydraulic responses during pumping in HLX22 and 24 respectively.

No test pumping, as specified in the activity plan, was made in HLX30. The reason for this was that placing a logger in HLX30 during drilling of HLX31 was prioritised.

A further reason for reducing the amount of pumping tests in the percussion boreholes along EW007 was that a separate large scale pumping test was planned during December 2004 and January 2005, which would give further hydraulic information from the same area.

6 Interpretation

The results from drilling are summarised in Figures 6-1 and 6-2. All profiles are in north-south direction unless otherwise stated. Two profiles for boreholes HLX30 and HLX31 are presented, one in direction N50E and one in N-S.

Significant water bearing structures were encountered in all eight boreholes. Geological and technical indicators of deformation zones (oxidation, reduced magnetic susceptibility and highly variable penetration rate) could also be seen in all boreholes. Significant increases in drilling penetration time can be seen in some holes beneath levels of high water inflow.

Any geometrical interpretation of a deformation zone should however be done with great caution as the scale (thickness) of the zone could be more or less equal to the reach of the percussion boreholes. It seems most likely, however, that the dip of EW007 is to the north

The geometry of the structure seems to vary somewhat along strike. In the eastern part, in boreholes HLX21–24, the thickness of the deformation zone is on the same scale as the boreholes ie drilling starts and ends in more or less altered and fractured rocks. However a deformation zone with a steep northerly dip can be interpreted based on positions for major water inflow in the boreholes.

The information from HLX33, as a single borehole in a profile, is less conclusive. The major water inflow occurs at ca 180 m which supports a steep northern dip of the water bearing structure.

Further to the west in boreholes HLX30–31 the dip of the zone would be more or less vertical when connecting the surface lineament with the positions of main water inflows. In borehole HLX25 there are two distinct levels of water inflow, one that would give a steep northern dip and one that would give an apparent dip of 30 degrees to the south.

The measurements of hydraulic responses give an impression that the structure underlying the lineament EW007 could be divided in an eastern and a western segment. Responses from drilling or pumping tests in surrounding boreholes are very distinct in and between boreholes HLX13, 14, 25, 30, and 31 ie the western part of the investigated area. The responses between boreholes in the eastern part (HLX21, 22, 23, 24 and 33) are distinct only in short distances.

NB Different blue coloured triangles (light and darker blue) have been used in some cases in Figures 6-1 and 6-2 in order to distinguish between levels of water inflow from different boreholes in the same profile. The colour difference does not have any geoscientific meaning.

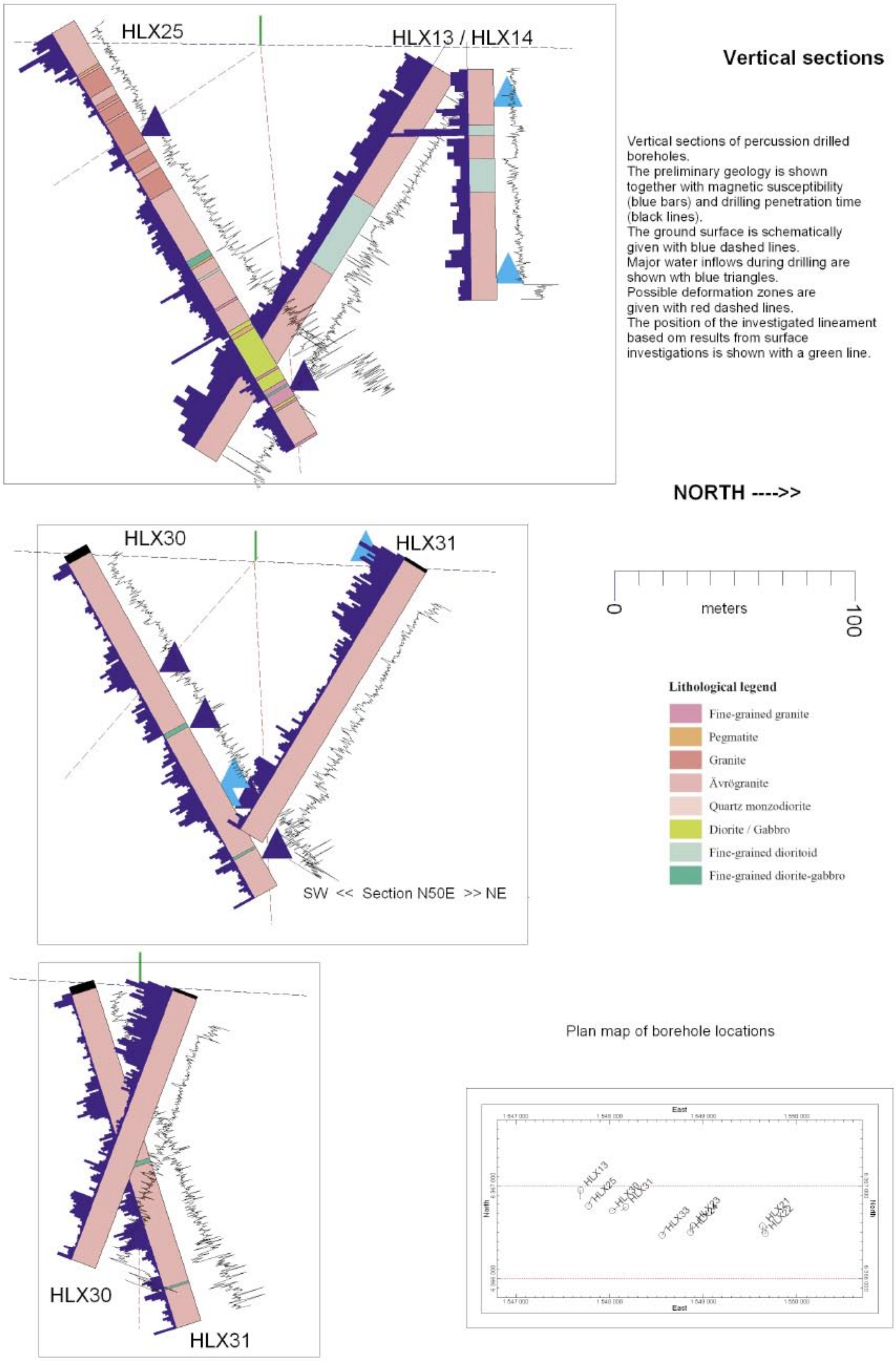


Figure 6-1. *Boreholes HLX13, 14, 25, 30 and 31 in the western part of the investigated lineament are shown with preliminary geological results, magnetic susceptibility (blue bars) and drilling penetration time (black line). Positions for water inflow are indicated by blue triangles. Soil is shown with black colour in the borehole.*

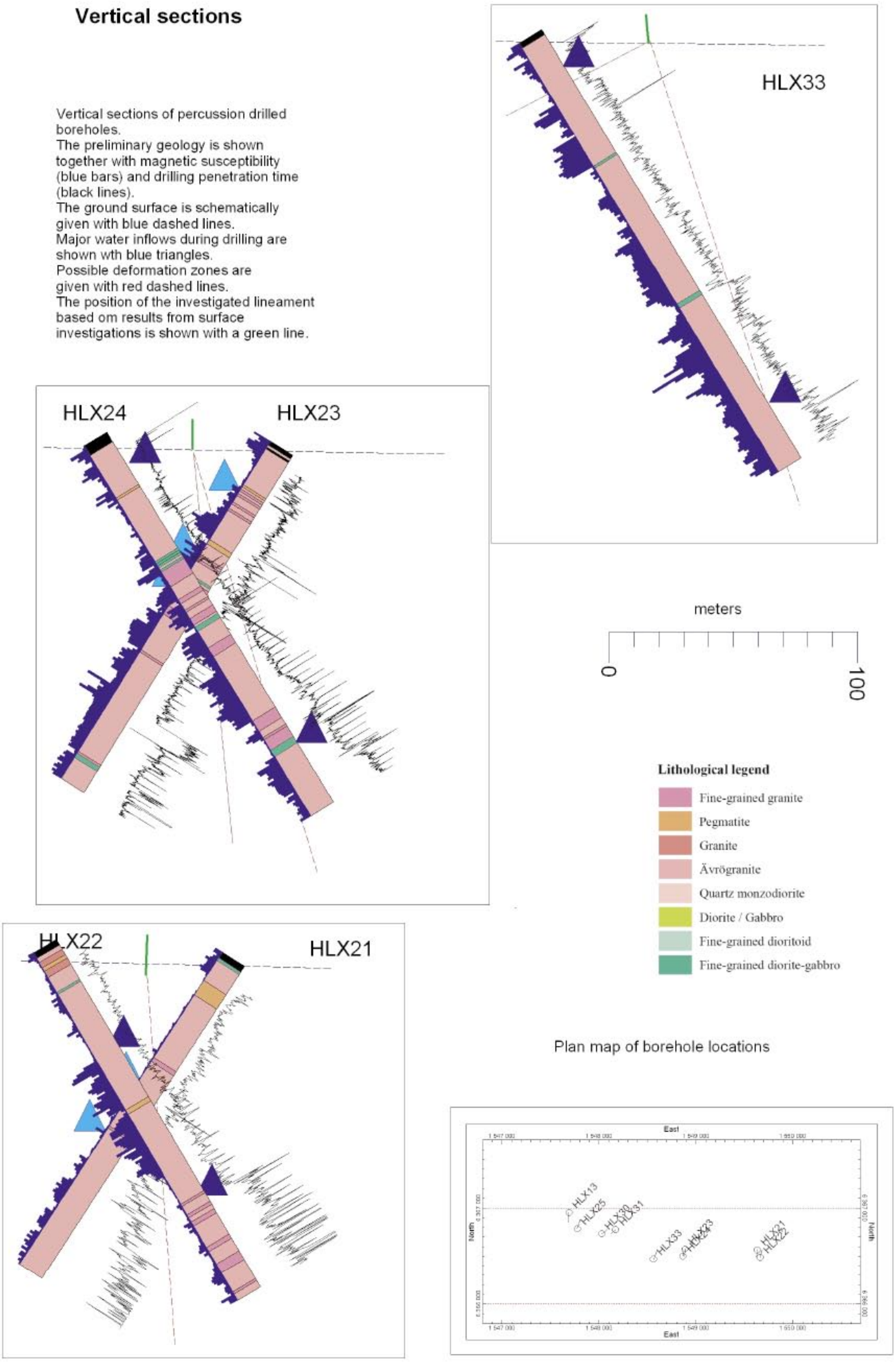


Figure 6-2. *Boreholes HLX21, 22, 23, 24 and 33 in the eastern section of the investigated lineament are shown with preliminary geological results, magnetic susceptibility (blue bars) and drilling penetration time (black line). Positions for water inflow are indicated by blue triangles. Soil is shown with black colour in the borehole.*

7 References

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

/2/ **SKB, 2001.** Geovetenskapligt program för platsundersökning vid Simpevarp. SKB R-01-44, Svensk Kärnbränslehantering AB.

/3/ **SKB, 2004.** Oskarshamn site investigation. Joint interpretation of lineaments. SKB P-04-49, Svensk Kärnbränslehantering AB.

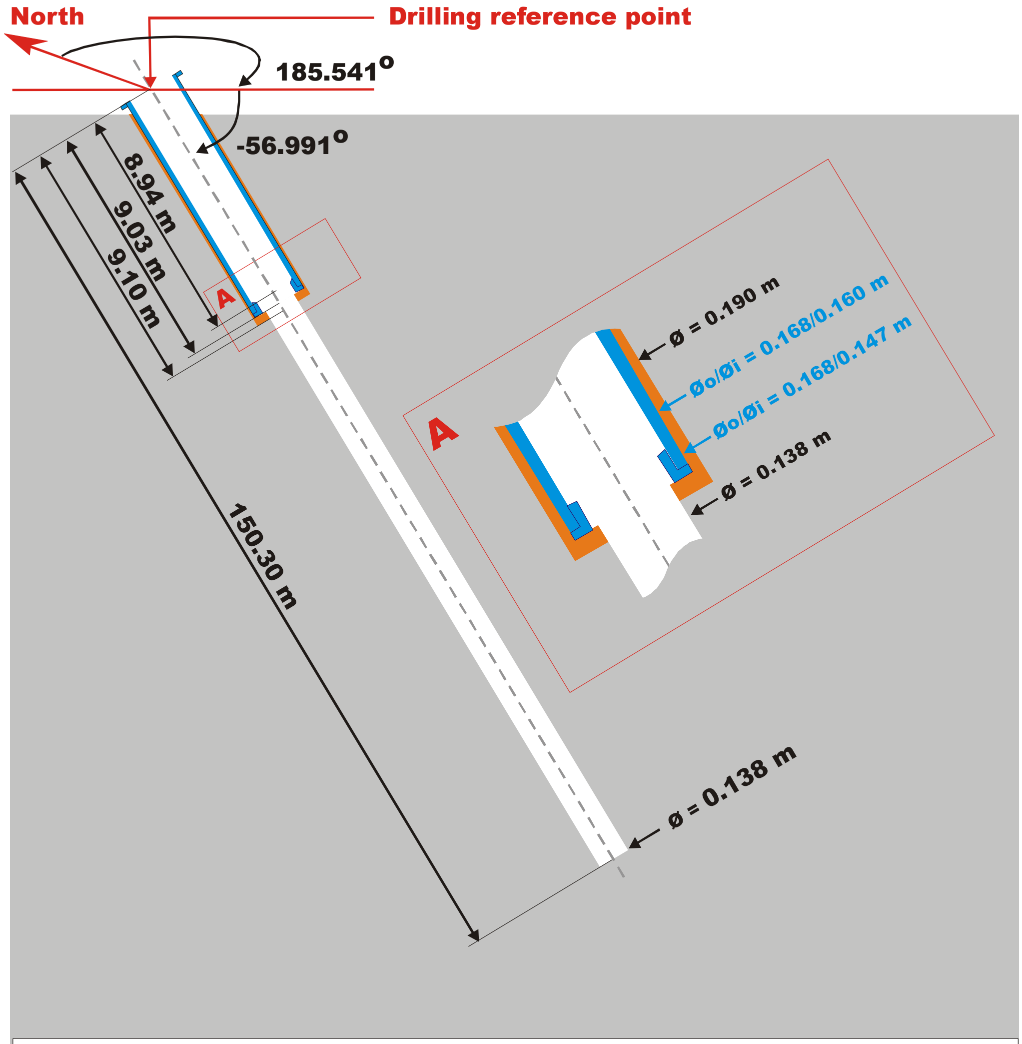
/4/ **SKB, 2004.** Oskarshamn site investigation. Refraction seismic measurements in Laxemar. SKB P-04-134, Svensk Kärnbränslehantering AB.

/5/ **Moye D G, 1967.** Diamond drilling for foundation exploration. Civil Eng Trans, Inst Eng, Australia.

Technical data boreholes HLX21, 22, 23, 24, 25, 30, 31 and 33

Technical data

Borehole HLX21



Drilling reference point

Northing: 6366567.931 (m), RT90 2,5 gon V 0:-15

Easting: 1549632.363 (m), RT90 2,5 gon V 0:-15

Elevation: 10.312 (m), RHB 70

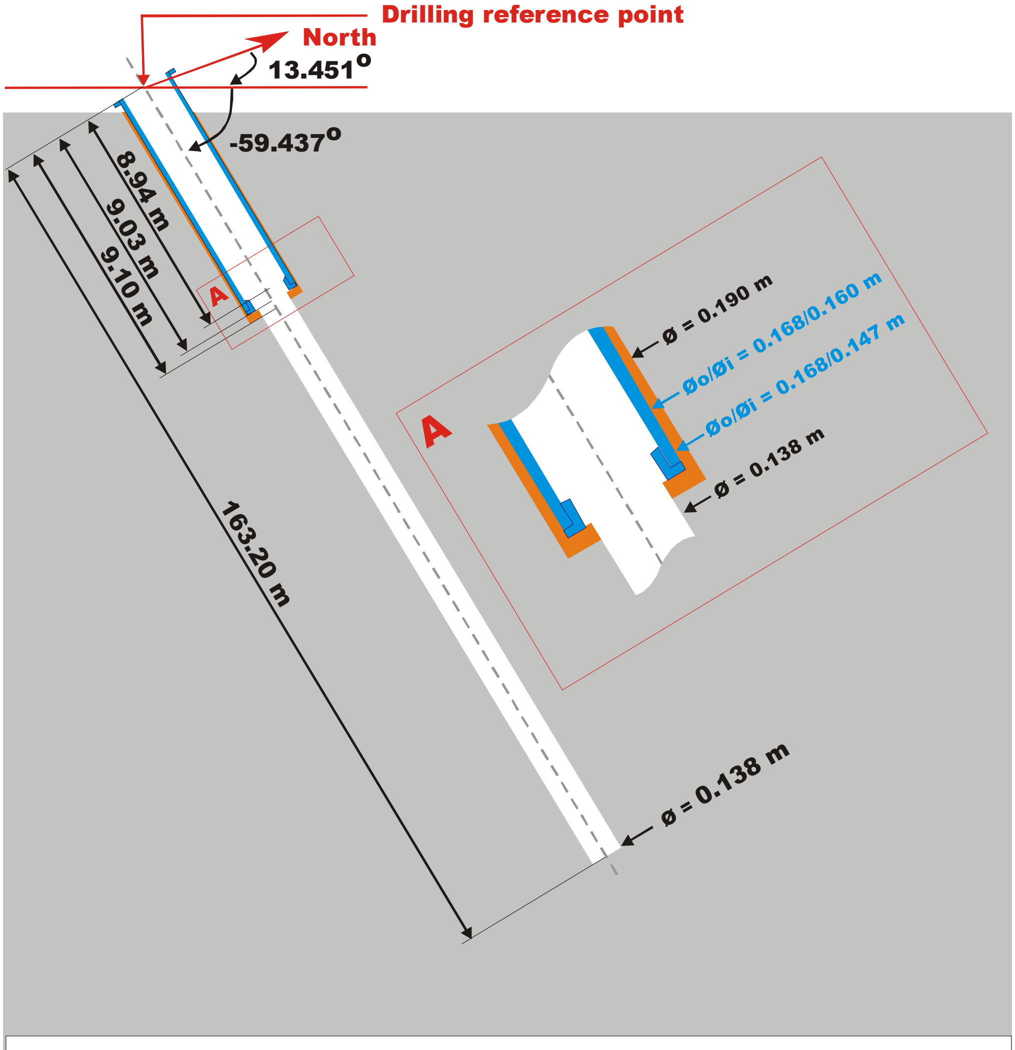
Drilling period

Drilling start date: 2004-08-30

Drilling stop date: 2004-09-02

Technical data

Borehole HLX22



Drilling reference point

Northing: 6366487.834 (m), RT90 2,5 gon V 0:-15

Easting: 1549661.524 (m), RT90 2,5 gon V 0:-15

Elevation: 10.057 (m), RHB 70

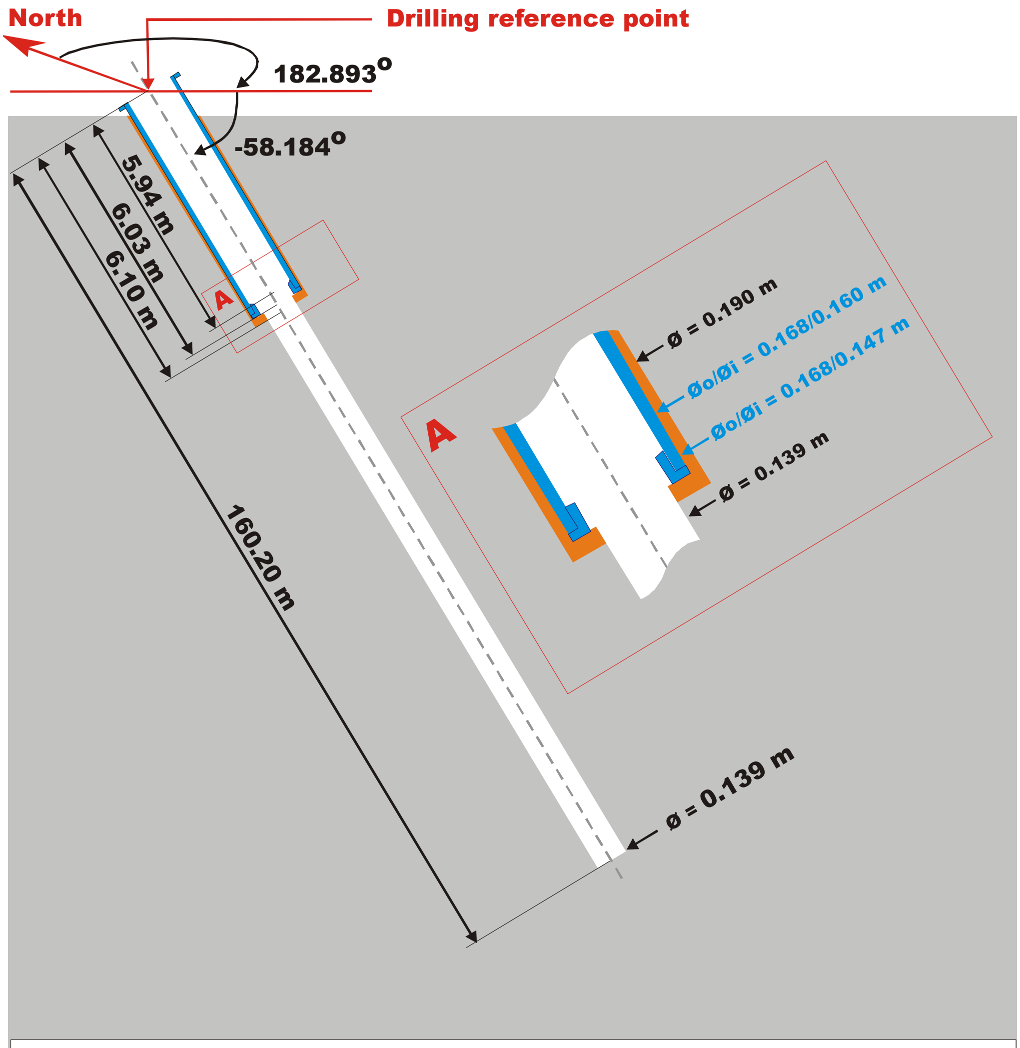
Drilling period

Drilling start date: 2004-08-23

Drilling stop date: 2004-08-26

Technical data

Borehole HLX23



Drilling reference point

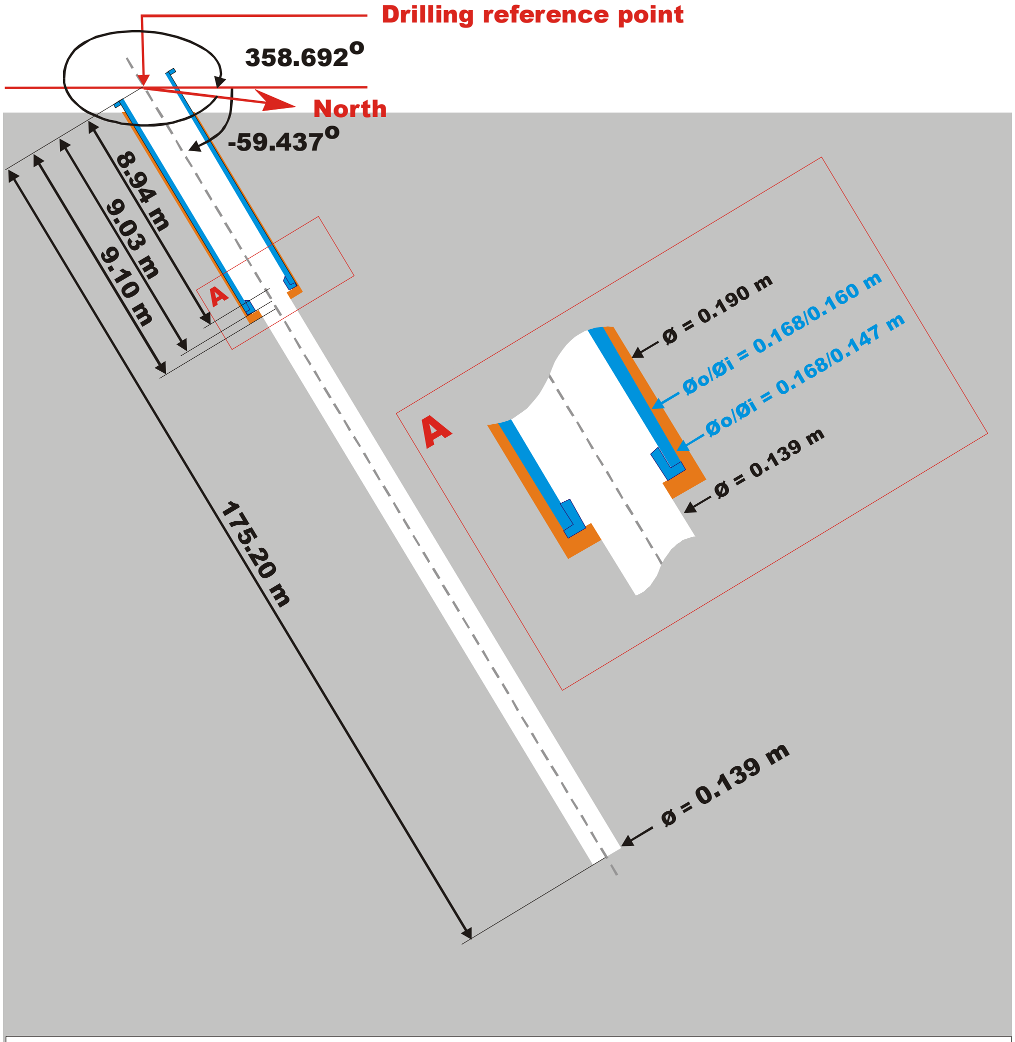
Northing:	**6366578.005 (m), RT90 2,5 gon V 0:-15**
Easting:	**1548888.673 (m), RT90 2,5 gon V 0:-15**
Elevation:	**14.690 (m), RHB 70**

Drilling period

Drilling start date: 2004-09-13
Drilling stop date: 2004-09-16

Technical data

Borehole HLX24



Drilling reference point

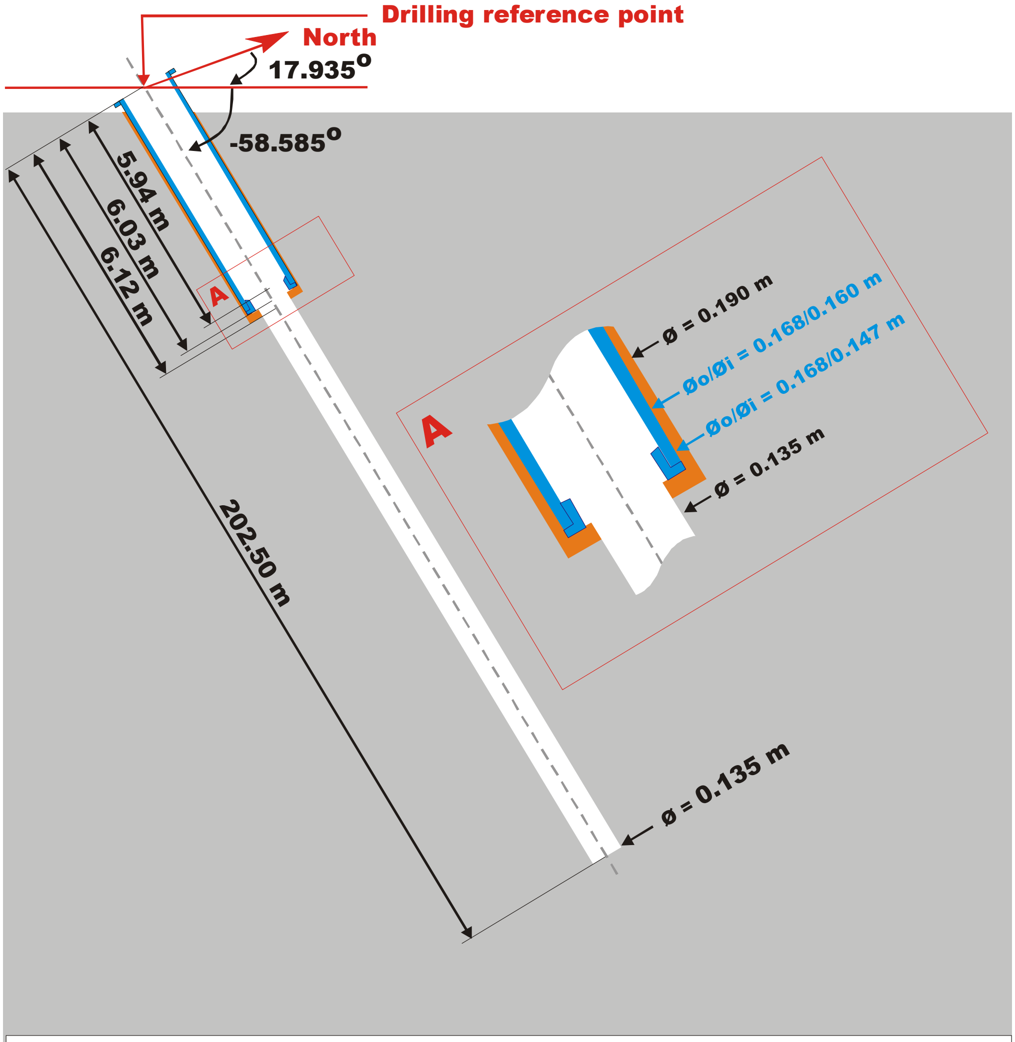
Northing:	**6366503.722 (m), RT90 2,5 gon V 0:-15**
Easting:	**1548865.890 (m), RT90 2,5 gon V 0:-15**
Elevation:	**12.769 (m), RHB 70**

Drilling period

Drilling start date: 2004-09-06
Drilling stop date: 2004-09-09

Technical data

Borehole HLX25



Drilling reference point

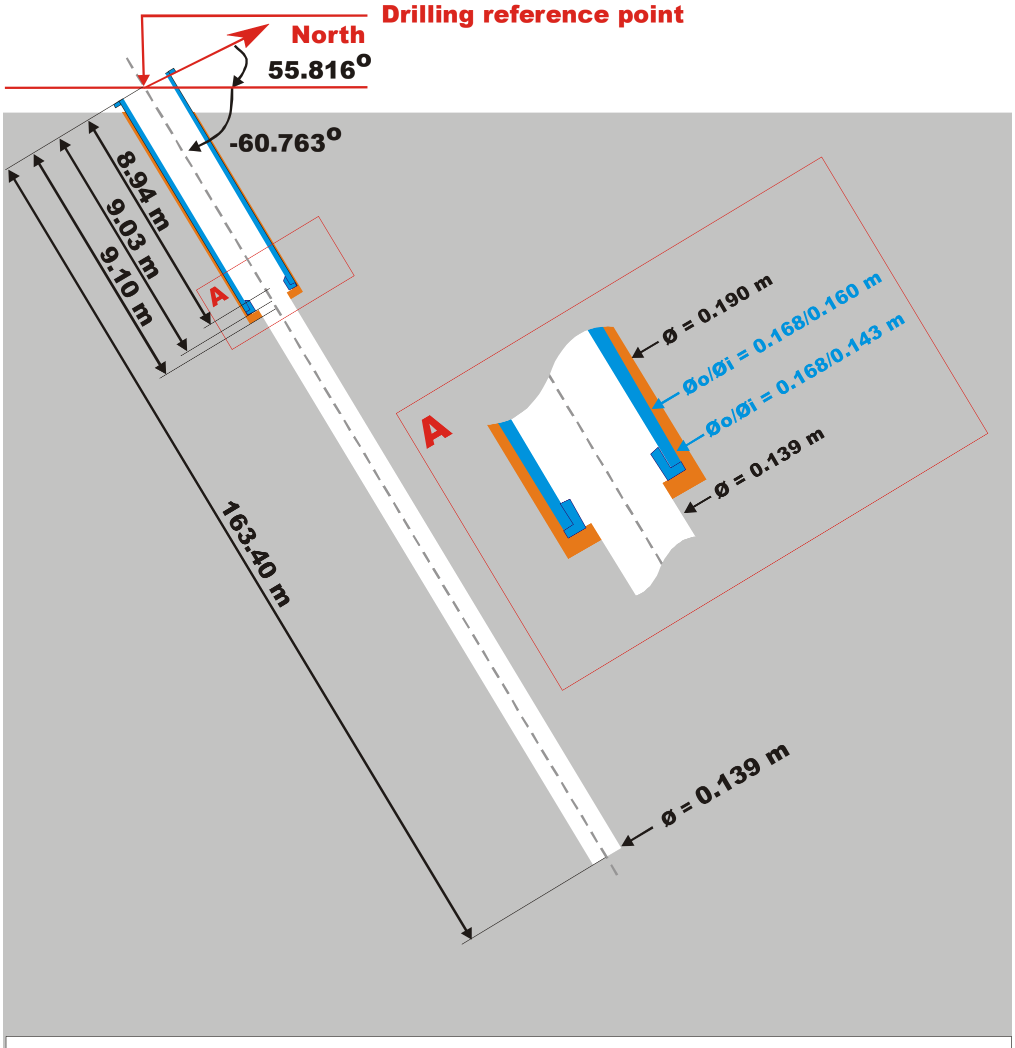
Northing:	**6366783.974 (m), RT90 2,5 gon V 0:-15**
Easting:	**1547776.324 (m), RT90 2,5 gon V 0:-15**
Elevation:	**20.656 (m), RHB 70**

Drilling period

Drilling start date: 2004-08-17
Drilling stop date: 2004-08-19

Technical data

Borehole HLX30



Drilling reference point

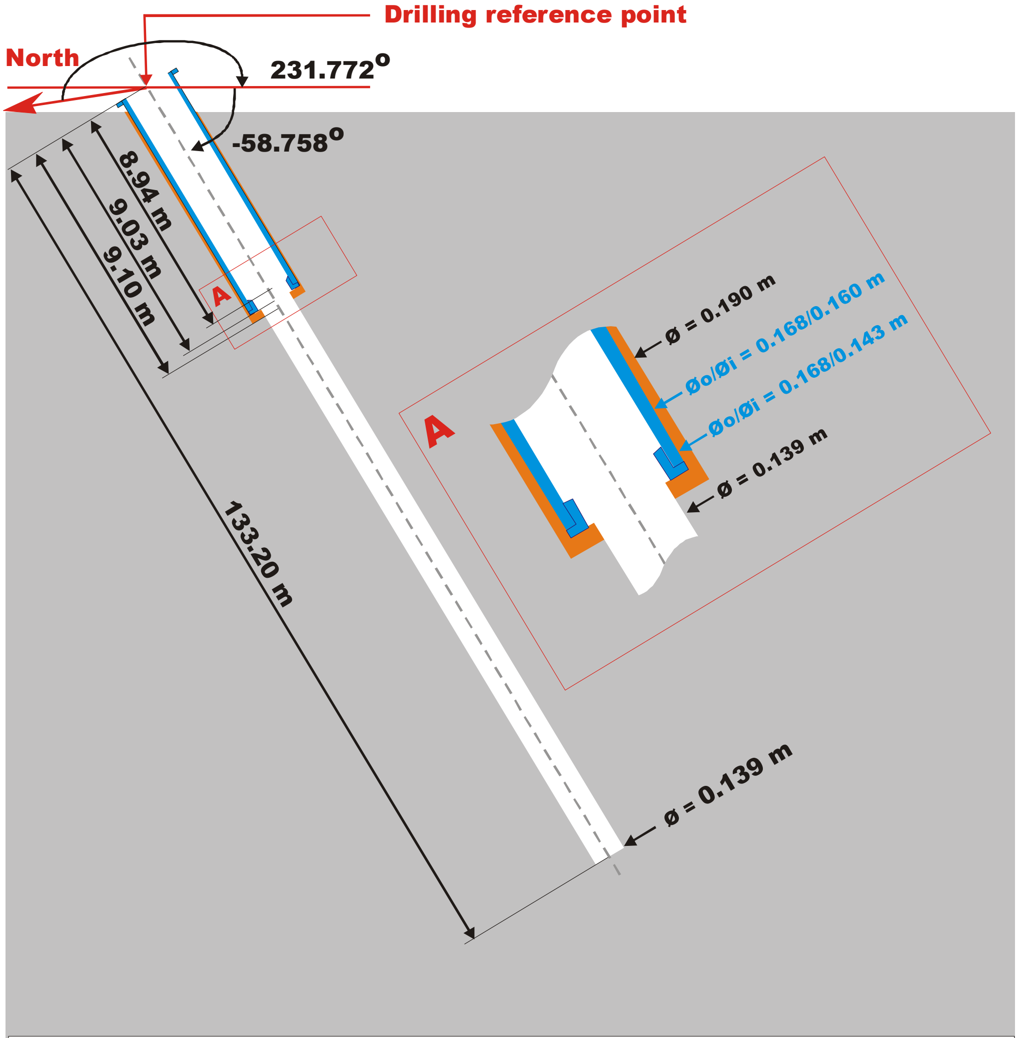
Northing:	**6366730.734 (m), RT90 2,5 gon V 0:-15**
Easting:	**1548026.729 (m), RT90 2,5 gon V 0:-15**
Elevation:	**12.184 (m), RHB 70**

Drilling period

Drilling start date:	**2004-11-26**
Drilling stop date:	**2004-11-30**

Technical data

Borehole HLX31



Drilling reference point

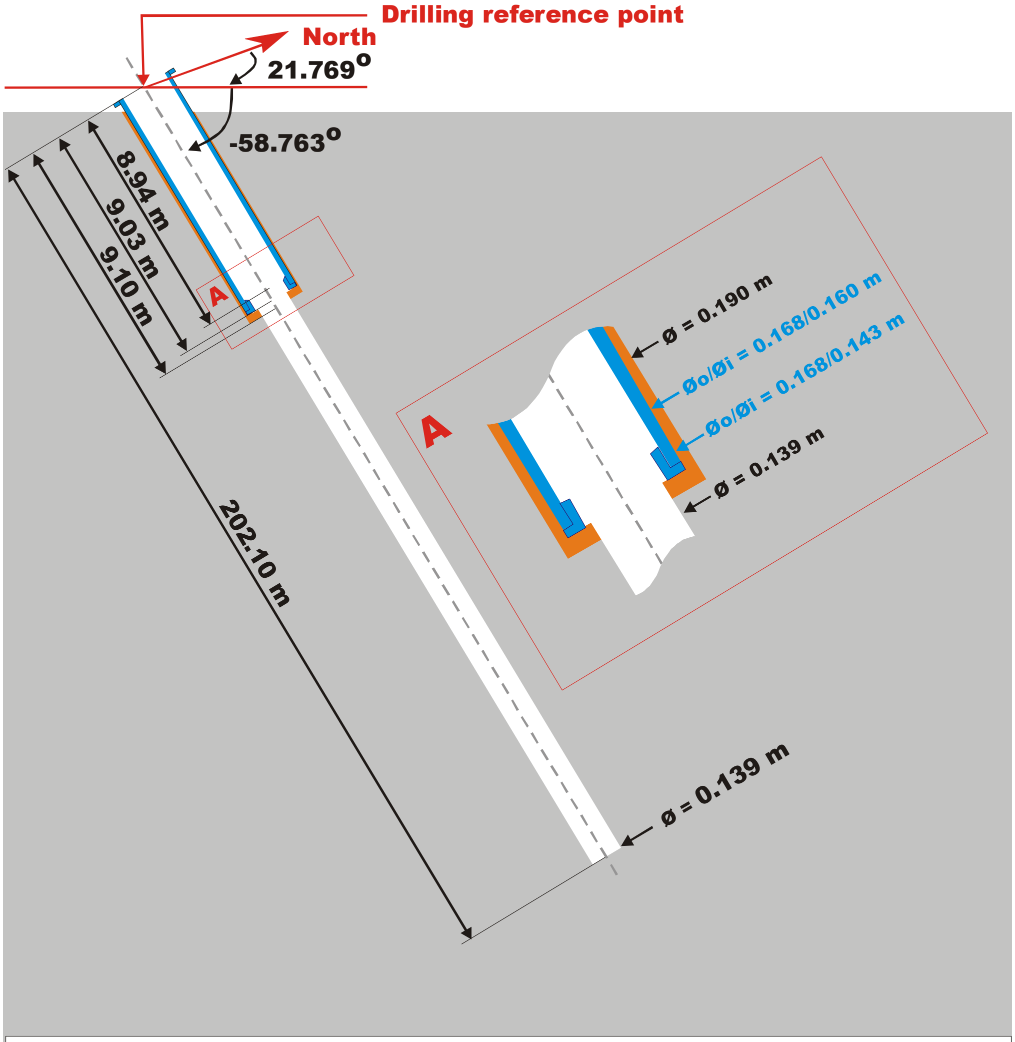
Northing:	**6366774.513 (m), RT90 2,5 gon V 0:-15**
Easting:	**1548172.268 (m), RT90 2,5 gon V 0:-15**
Elevation:	**12.162 (m), RHB 70**

Drilling period

Drilling start date:	**2004-12-01**
Drilling stop date:	**2004-12-03**

Technical data

Borehole HLX33



Drilling reference point

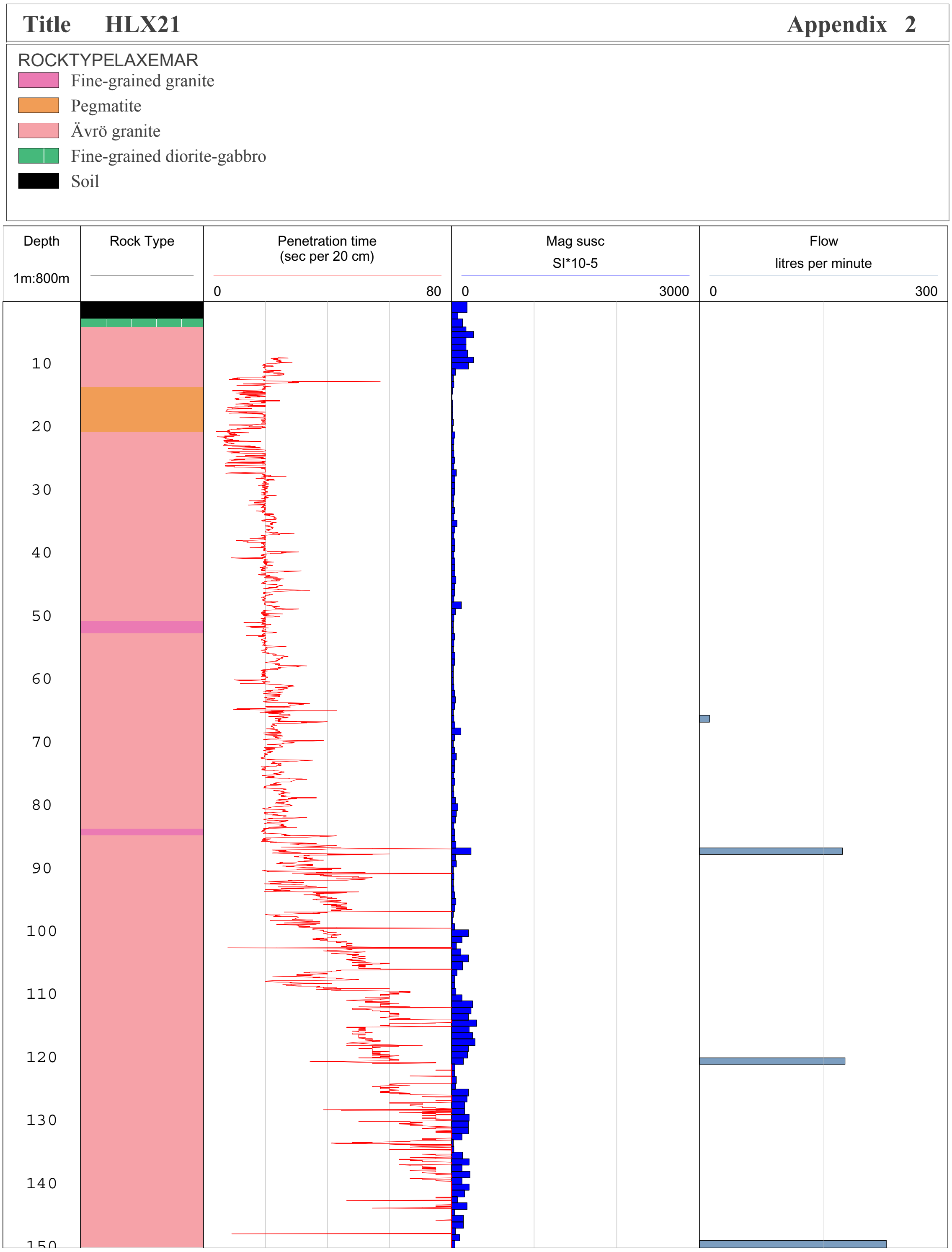
Northing:	**6366471.744 (m), RT90 2,5 gon V 0:-15**
Easting:	**1548562.705 (m), RT90 2,5 gon V 0:-15**
Elevation:	**12.201 (m), RHB 70**

Drilling period

Drilling start date:	**2004-12-17**
Drilling stop date:	**2004-12-20**

Appendix 2

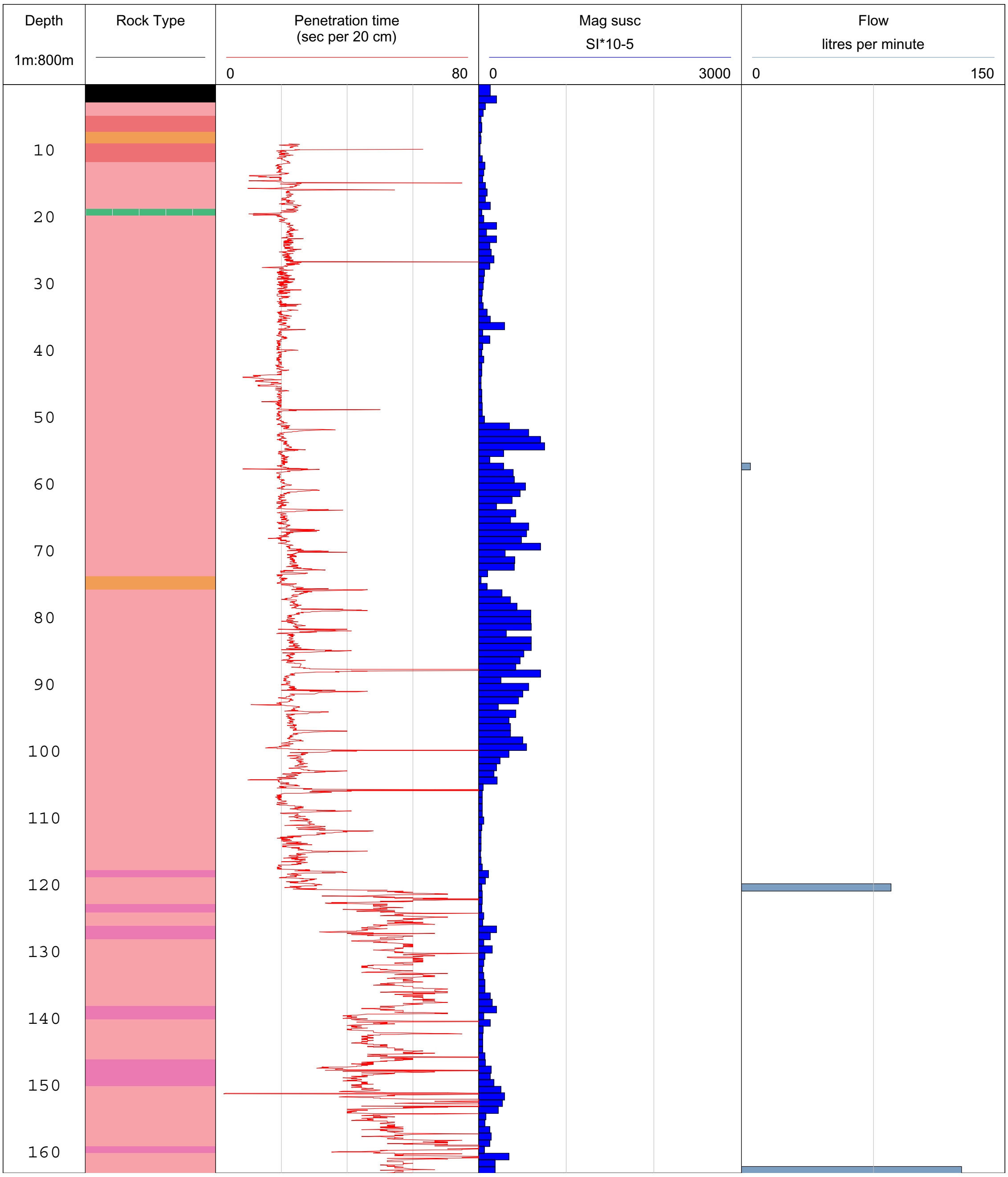
Geoscientific summary for boreholes HLX21, 22, 23, 24, 25, 30, 31 and 33



Title HLX22 **Appendix 2**

ROCKTYPELAXEMAR

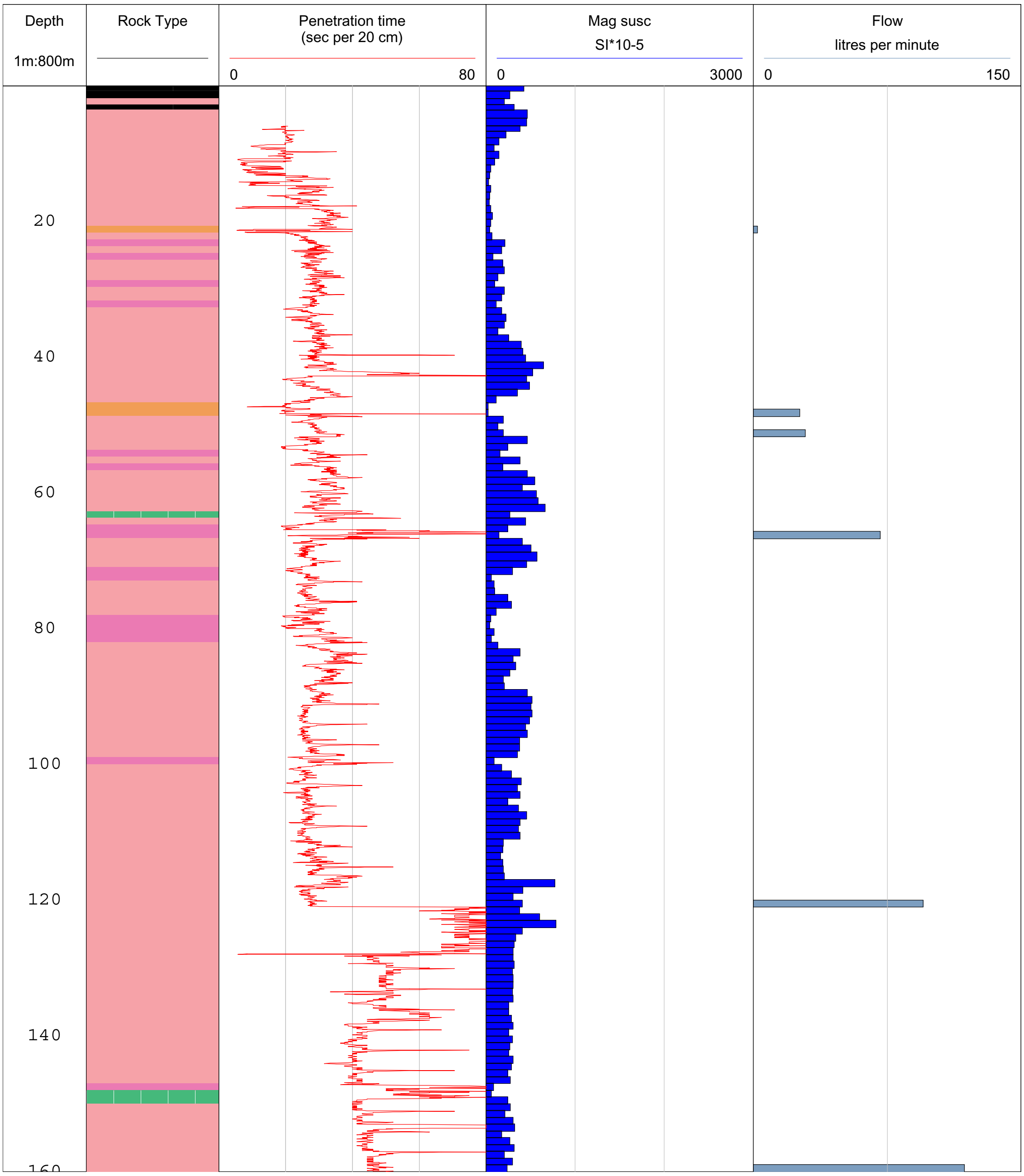
- Fine-grained granite
- Pegmatite
- Granite
- Ävrö granite
- Fine-grained diorite-gabbro
- Soil



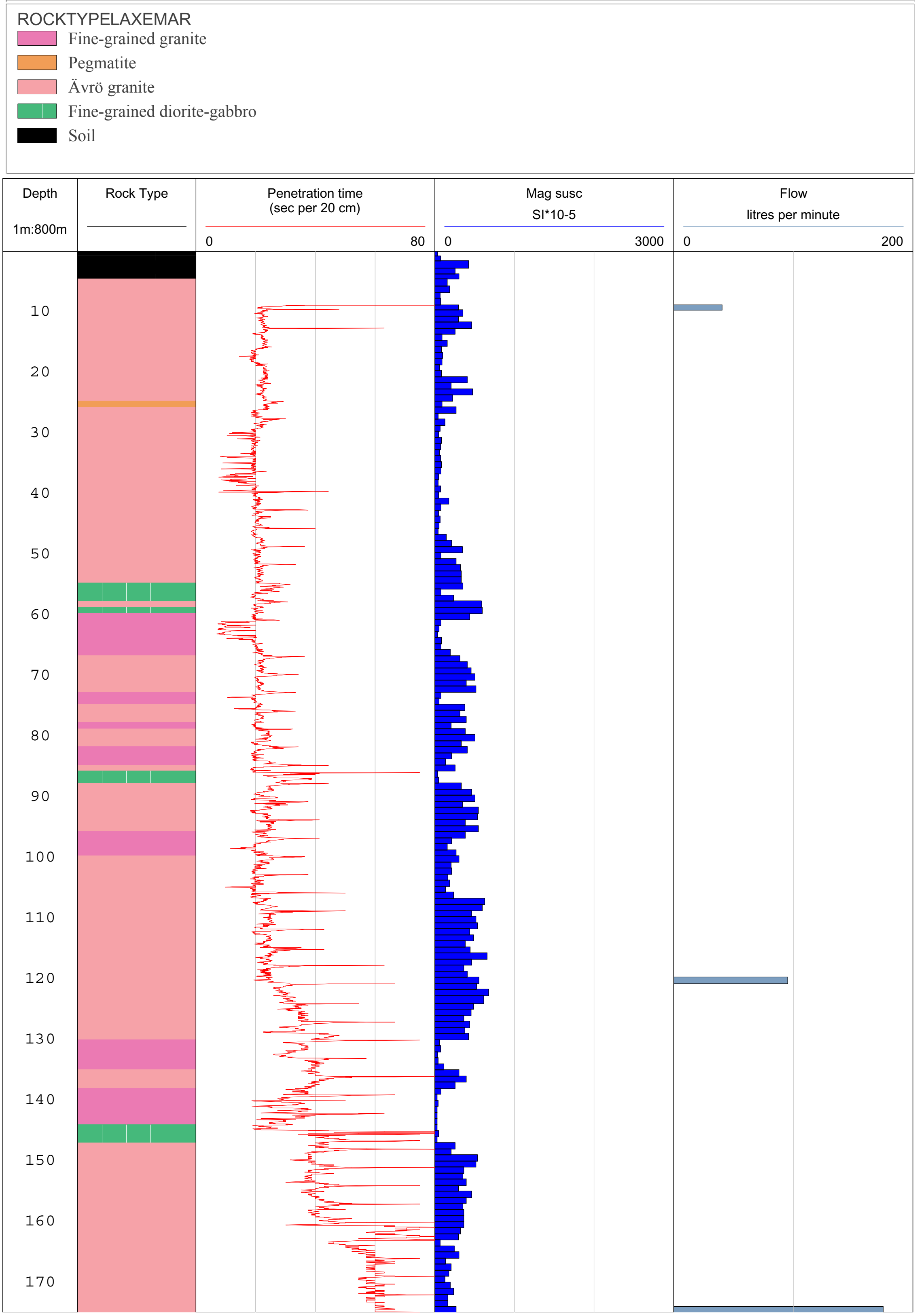
Title HLX23 **Appendix 2**

ROCKTYPELAXEMAR

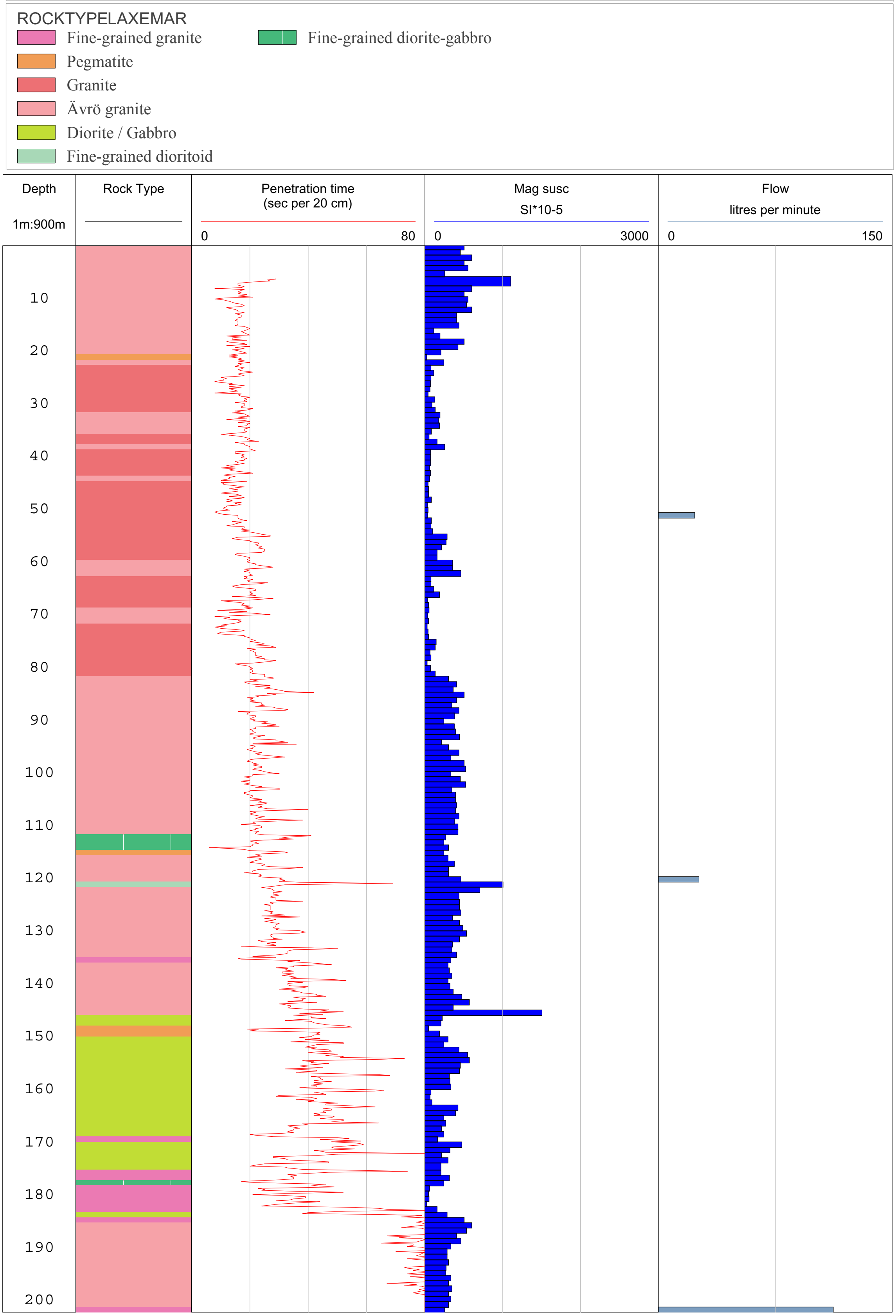
- Fine-grained granite
- Pegmatite
- Ävrö granite
- Fine-grained diorite-gabbro
- Soil



Title HLX24 **Appendix 2**

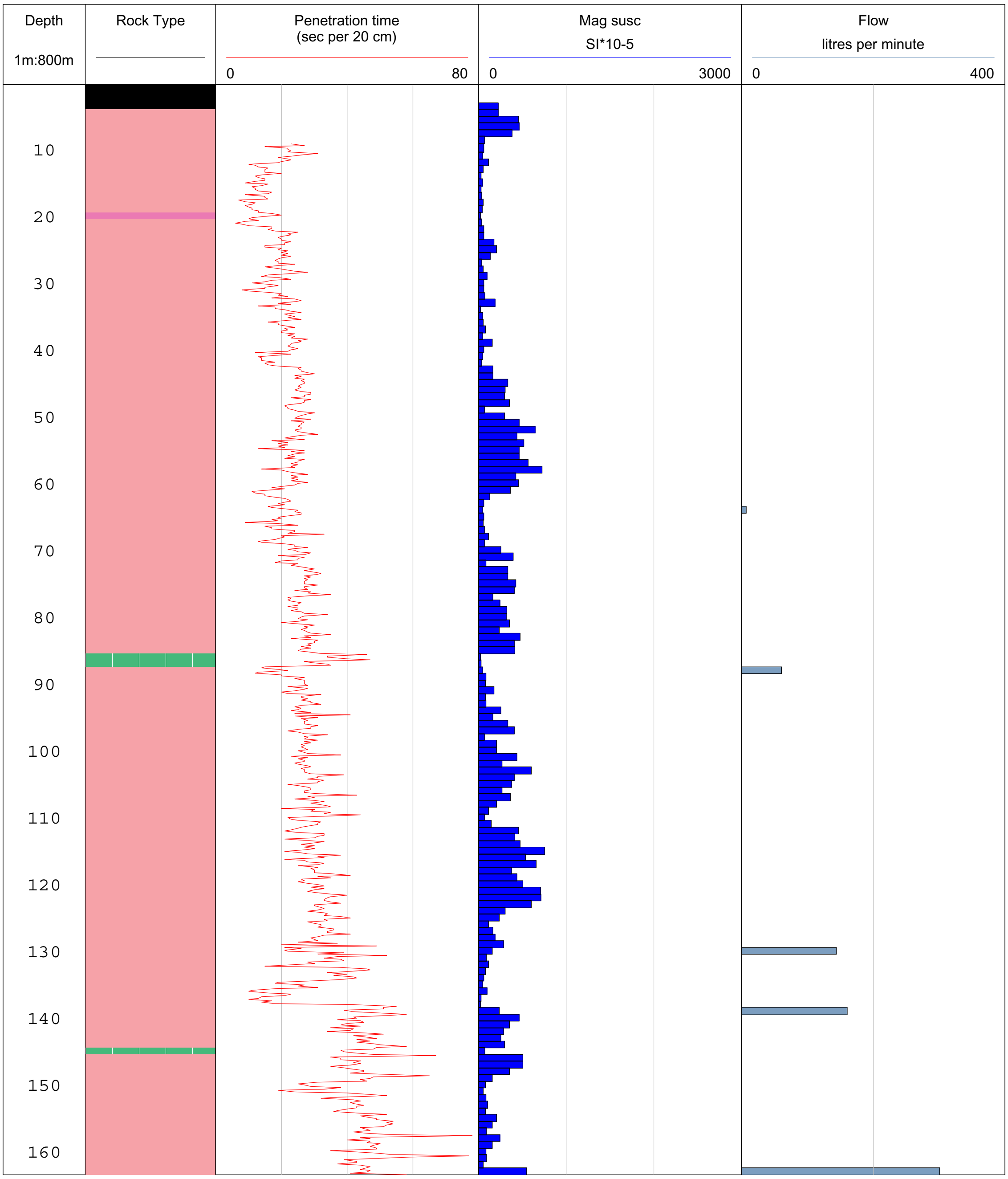


Title HLX25 Appendix 2



Title HLX30 **Appendix 2**

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

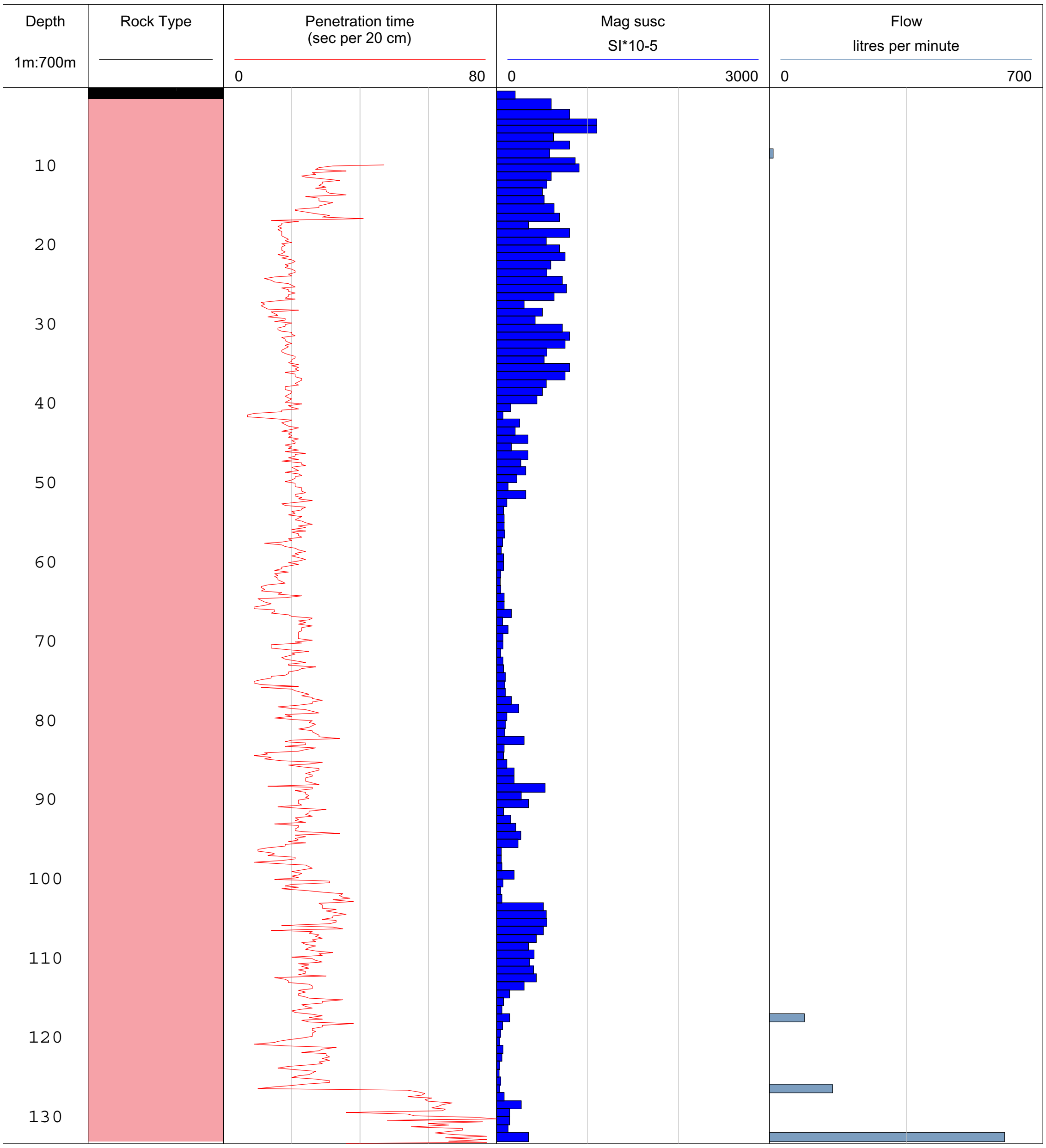


Title HLX31 **Appendix 2**

ROCKTYPELAXEMAR

Ävrö granite

Soil



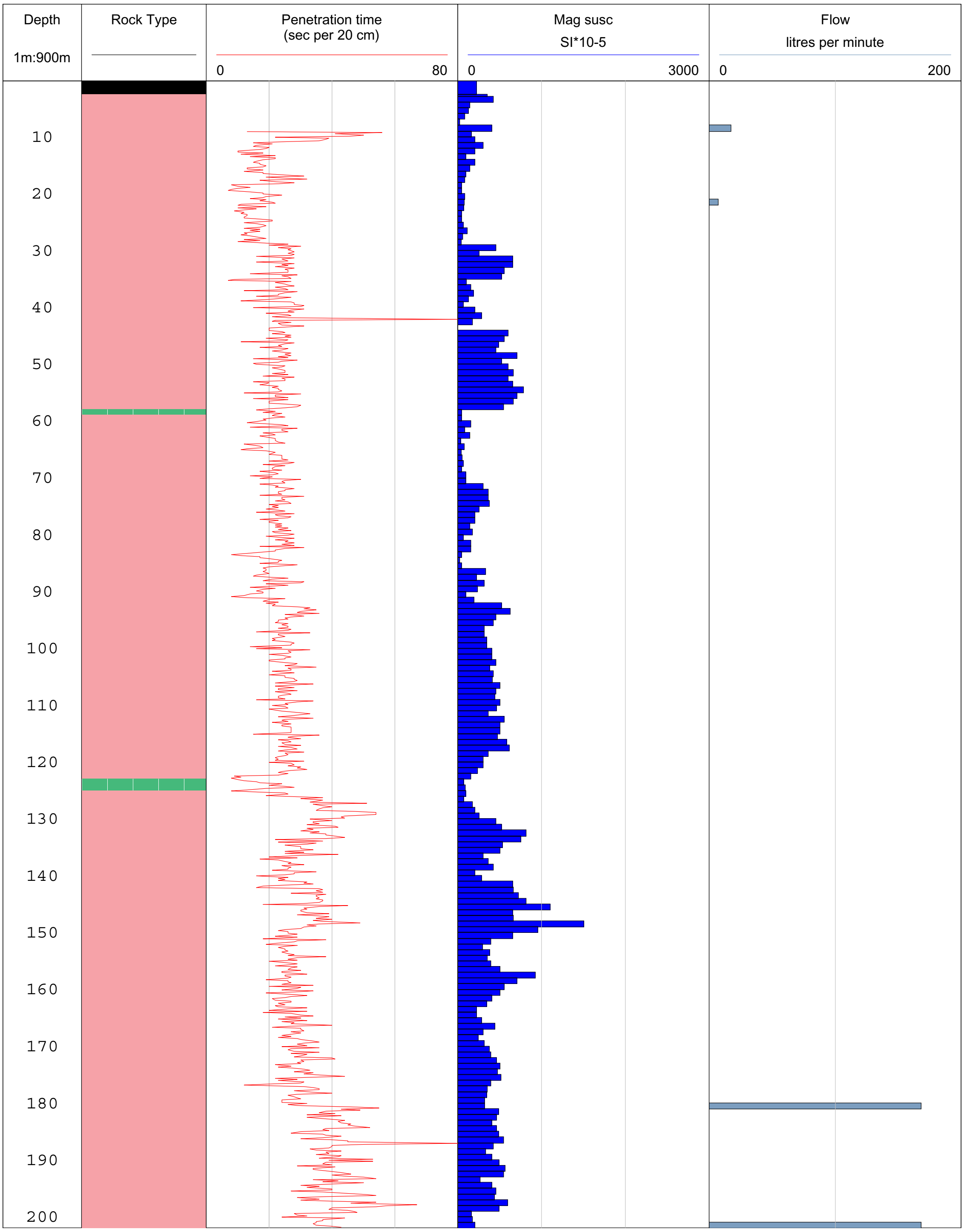
Title HLX33 **Appendix 2**

ROCKTYPELAXEMAR

Ävrö granite

Fine-grained diorite-gabbro

Soil



Appendix 3

Water chemistry data from HLX22 and HLX24

Start Date	2004-09-17	2004-09-10
Borehole	HLX22	HLX24
Sample No	7762	7758
Na (mg/l)	107	41.7
K (mg/l)	2.71	2.8
Ca mg/l	9.6	20.7
Mg (mg/l)	2.4	4.3
HCO3 (mg/l)	221	121.00
Cl (mg/l)	23	15.1
SO4 (mg/l)	53.09	29.58
SO4 S (mg/l)	17.1	9.83
Br (mg/l)	0.000	0.000
F (mg/l)	4.75	2.67
Si (mg/l)	6.09	14.6
Fe (mg/l)	0.0633	5.55
Mn (mg/l)	0.036	0.262
Li (mg/l)	0.013	0.011
Sr (mg/l)	0.221	0.101
pH (pH unit)	8.24	6.66
Electrical Conductivity (mS/m)	54.1	54.1