Groundwater Study and Emergency Implementation Plan

Aruküla Municipality Water Supply

Final Draft Report

Hedeselskabet
Environmental and
Energy Division
Tel. +45 46 30 03 10

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Project Manager:	Jesper Bruhn Nielsen, M.Sc.,Geology		
Project Team:	Thomas Larsen, Ph.D. Enviromental Engenieering Kim Weiss Tønder, M.Sc.,Hydrogeology Claus Westergaard, Enviromental Engenieer Mati Salu, M.Sc.,Geology Vahur Keerberg, M.Sc.,Hydrogeology	Key Words:	Oil contamination, riskassessment, implementation plan, water supply

HEDESELSKABET

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0 SUMMARY

With support from the Danish Enviromental Protection Agency (DEPA) an emergency groundwater study to estimate the risk of oil contamination to the existing deep water supply wells, and to confirm an alternative groundwater source for the town Aruküla has been acomplished

The background for the study is an oil spill that took place in 1993 and caused contamination of around 50 shallow water supply wells. Investigations carried out in 1994 and 1995 concluded that there was a risk of oil contamination reaching the deep water supply wells.

A deep well, PK-6, located on the former military base has been proposed as an emergency water source. The scope of this study has been to confirm a safe yield from well PK-6 and to assess the risk of oil contamination of the deep water supply wells and to prepare a costed emergency implementation plan.

Field work including test pumping and collection of water samples from selected deep wells in Aruküla has been carried out in March 1997.

The regional geology and hydrogeology in the area has been described. On the basis of the exsisting data from investigation reports an environmental assessment and a risk assessment has been prepared.

From the present groundwater study it is concluded:

- that the water quality in the well PK-6 meet Estonian standards.

-that the test pumping confirms a yield of 12 m^3/h from well PK-6.

-that there is a risk for contamination of the exsisting deep wells.

It is recommended to establish an emergency water supply from well PK-6, located on the former military base. In addition it is recommended to alter the current monitoring programme and implement methods capable of measuring contaminants at a lower detection limit. Remediation measures should be implemented to control the spread of the oil plume and to systematically reduce the free oil phase in the hot spot area. Finally it is recommended to assess the physical conditions of the lining and screens on the remaining deep water supply wells.

A costed implementation plan for commissioning well PK-6 as an emergency water source is described.

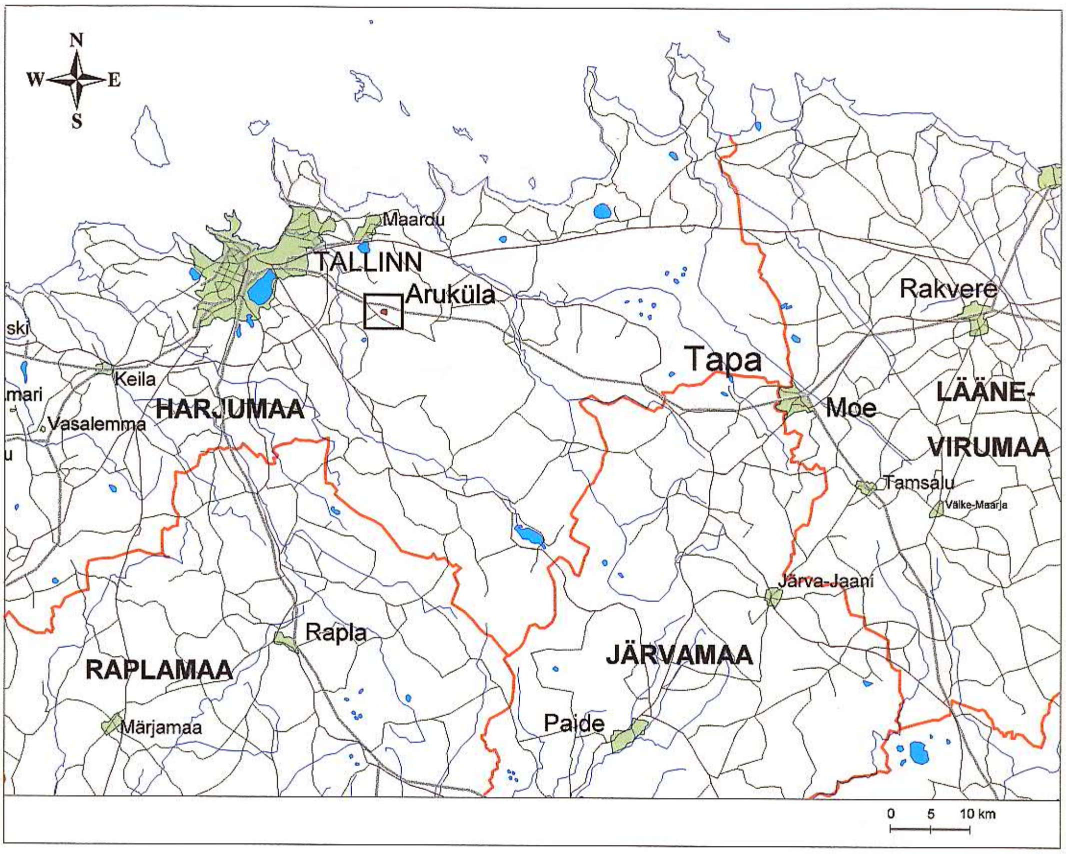

N
W
E
S
Maardu
TALLINN
Aruküla
Rakvere
Tapa
Keila
HARJUMAA
Vasalemma
Moe
LÄÄNE-
VIRUMAA
Tamsalu
Väike-Maarja
Järva-Jaani
Rapla
RAPLAMAA
JÄRVAMAA
Märjamaa
Paide
0 5 10 km

Figure 1.1

1 INTRODUCTION

The project titled "Groundwater Study and Emergency Implementation Plan, Aruküla Municipality Water Supply" is part of the Danish Environmental Protection Agency's (DEPA) grant-aided environmental programmes, which include assistance to small urban Municipalities in Estonia.

A programme of environmental co-operation between the Estonian Ministry of Environment (EME) and DEPA was agreed upon in July 1996, involving increased support to cover several small towns including Tapa and Aruküla.

This report comprises the results of a groundwater study and an emergency implementation plan for Aruküla Municipality Water Supply.

1.1 Background

Aruküla Town is located 25 km to the east of Tallinn in Estonia and has a population of around 1,600 people. For location see Figure 1.1.

An oil spill that took place in October 1993 caused contamination of around 50 shallow (15-20 m of depth) water supply wells in the town. The contamination was not detected until the residents observed a strong odor and a yellowish-brown color in the water. As a result of the contamination 210 families are supplied with water delivered by road-tankers.

Investigations carried out in 1994 and 1995 /1/ show that the oil contamination has spread in the upper aquifer and has affected an area of about 22 ha. The oil spill was estimated to 6-8 tons of Russian heating oil. The oil contained toxic components including trimethylbenzene, toluen, xylene and styrene. In the report /1/ it is concluded, that intense exploitation of the deep aquifer from the wells of the municipality water supply could cause a risk for affecting the water quality in these wells. If the oil plume reaches the deep water supply wells it will cause a serious problem for the town. A 40 years old well (PK-6) located on the nearby military base has been proposed as an emergency source for water supply. The well has not been in use for the last 5 years and needs to be examined.

On the basis of this, DEPA has supported an Emergency Groundwater Study to estimate the risk of the oil contamination and to examine the proposed water supply well at the military base. DEPA has asked Hedeselskabet, Environmental and Energy Division (HEED) to manage this project. The present report which comprises the results of this project is prepared by HEED with assistance from the Estonian company MAVES A/S. All analyses have been worked out by the Estonian Environmental Research Center (EERC) with the exception of analyses for chlorinated solvents, which have been analyzed by Hedeselskabet's Laboratory (HL).

1.2 Purpose of the Project

The purpose of the project is to:

Assess the risk of contamination to the deep wells in Aruküla

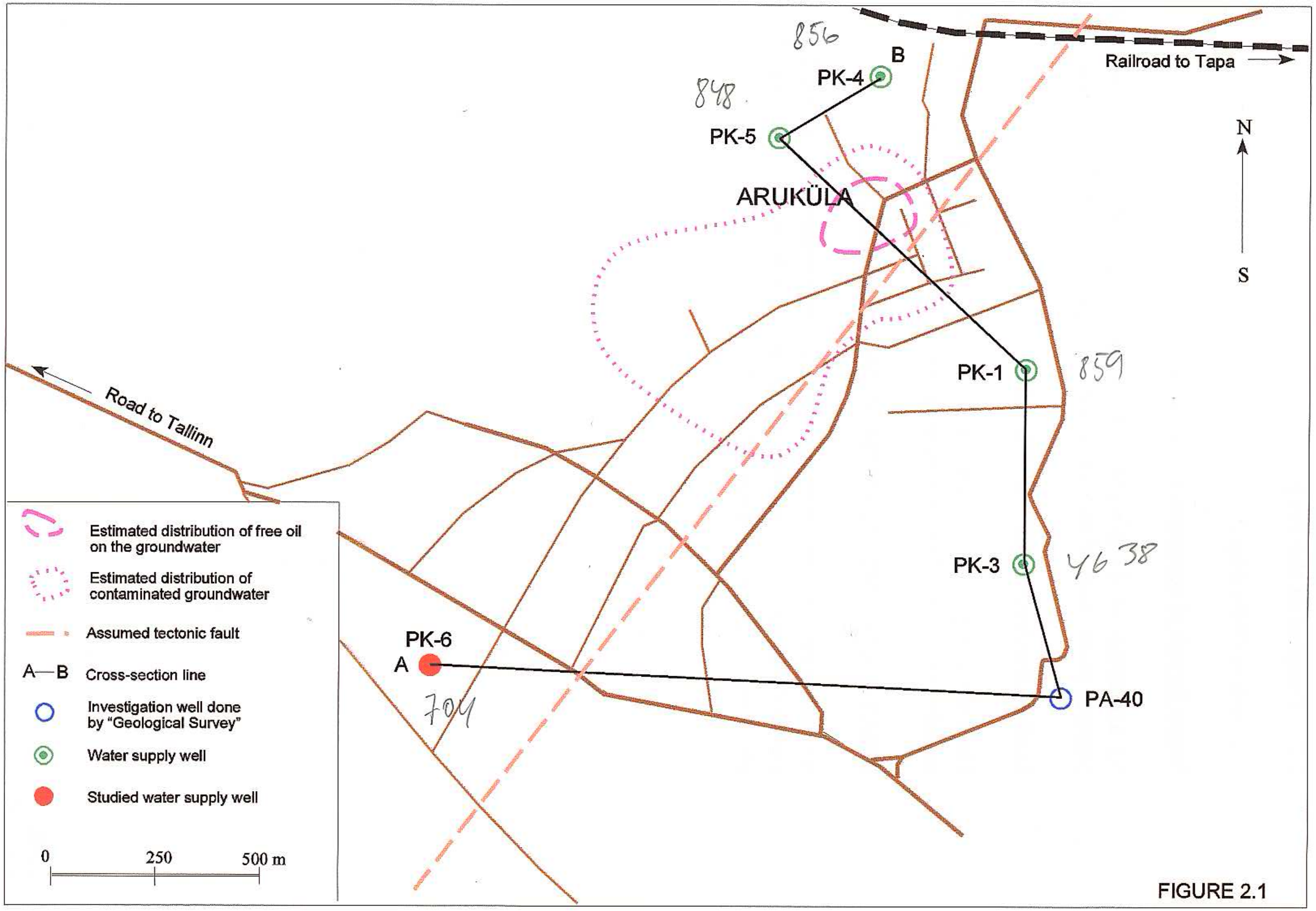
An assessment of the potential risk of contamination to the deep wells is to be prepared on the basis of the results from the report made by the AS Asker.

Examine the existing deep well PK-6 at the military base

The yield and the water quality of the well PK-6 is to be confirmed by making a drawdown test. The physical condition of the well will be examined.

Prepare an Emergency Implementation Plan of the Well Field

An emergency implementation plan for commissioning well PK-6 is to be prepared.The emergency implementation plan forms the basis for final design and preparation of plans and specifications of the well field.



Railroad to Tapa
N
S
B
PK-4
PK-5
ARUKÜLA
PK-1
PK-3
PA-40
Road to Tallinn
PK-6
A
Estimated distribution of free oil on the groundwater
Estimated distribution of contaminated groundwater
Assumed tectonic fault
A—B Cross-section line
Investigation well done by "Geological Survey"
Water supply well
Studied water supply well
0
250
500 m

FIGURE 2.1

2 GENERAL GEOLOGY AND HYDROGEOLGY

2.1 Topography and Surface Geology

Aruküla is located on a relatively flat limestone plateau. The absolute elevations of the ground range from 41-46 m above sea level (a.s.). The Quaternary sediments consist of a 1-2 m thick layer of clayey till and meltwater deposits.

Well PK-6 is located on a military base in the southern part of Aruküla. In this area Quaternary sediments are almost absent and only a thin soil horizon is found. The location of well PK-6 is shown in Figure 2.1.

2.2 Geological Setting

Below the Quaternary sediments, there is a sequence of limestone and glauconitic sandstone from Middle and Lower Ordovician with a total thickness of about 63 meters.

Below the limestone and glauconitic sandstone, glauconitic clay and shale (Dictyonema shale) from Lower Ordovician are found with a total thickness of up to 6 meters.

Underlying the Dictyonema shale, Cambrian-Ordovician sandstone with a thickness of up to 34 meters is found, followed by Cambrian clay ("blue clay") with a thickness of about 58 meters.

Underlying the Cambrian clay, Vendian sandstone with a thickness of up to 80 meters is found.

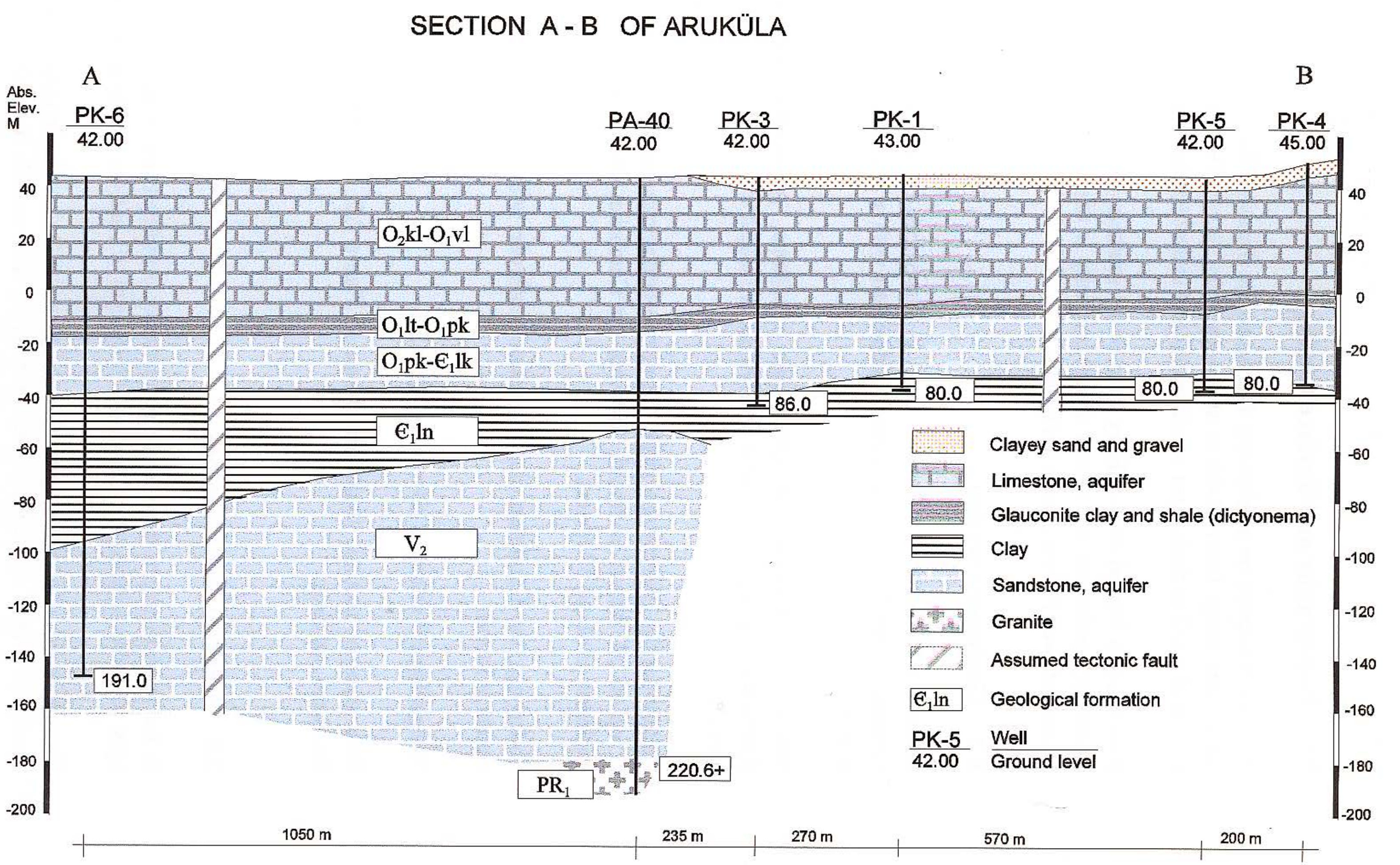
The geological setting is shown in Figure 2.2.

Two assumed tectonic faults are shown in Figure 2.2. The depths of the tectonic faults are not clear.

2.3 General Hydrogeology

In the reion there are three major groundwater complexes related to strata of various ages: the Ordovician (I), the Cambrian-Ordovician (II), and the Cambrian-Vendian (III).

The upper groundwater complex (I) belongs to the Ordovician limestone sequence and consists of several aquifers separated by relatively impermeable layers found at depths of 13-14 m and 23-29 m. The lateral and vertical hydraulic conductivity in the limestone is approx.1-10 m/d and 0.001-1 m/d respectively /2/. In the vicinity of a tectonic fault zones, such as those found at Aruküla, the vertical hydraulic conductivity can be 10 to 30 times higher.



SECTION A - B OF ARUKÜLA
A
B
Abs. Elev. M
PK-6
42.00
PA-40
42.00
PK-3
42.00
PK-1
43.00
PK-5
42.00
PK-4
45.00
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
O2kl-O1vl
O1lt-O1pk
O1pk-Є1lk
Є1ln
V2
PR1
191.0
220.6+
86.0
80.0
80.0
80.0
Clayey sand and gravel
Limestone, aquifer
Glauconite clay and shale (dictyonema)
Clay
Sandstone, aquifer
Granite
Assumed tectonic fault
Geological formation
Well
Ground level
1050 m
235 m
270 m
570 m
200 m

FIGURE 2.2

The water table in the upmost phreatic limestone aquifer is reported to be located 0.5 to 8.9 m below ground level (b.g.) with a fluctuation of 0.8-2.0 m /1/. The groundwater flow in this aquifer is directed towards northeast and southwest due to the groundwater divide located in the central part of the town.

The middle groundwater complex (II) belongs to the sandstone sequences of Ordovician and Cambrian age. The hydraulic conductivity in the sandstone is around 10-50 times lower than in the upper complex (I). The pressure head in the artesian aquifer is reported to be as high as 5-12 m b.g. /2/.

The lower groundwater complex (III) belongs to the Cambrian-Vendian sandstone. This water complex is separated from the Ordovician-Cambrian complex (II) by an aquitard namely the up to 58 m thick Cambrian "blue clay". The pressure head in the artesian aquifer is reported to be 41 m b.g. /2/. The present study concludes that the pressure head is aprox. 58 m b.g. at well PK-6.

The water in the Cambrian-Vendian complex (III) underlying the "blue clay" is estimated to be around 10,000 years of age /3/. This age indicates that the leakage through the "blue clay" is very limited, and that this sandstone aquifer is well-protected.

3 WATER SUPPLY

3.1 Existing Water Supply Facilities

Aruküla Town's water supply system is operated by a non governmental organisation called "Aruküla Veefond". There are two deep-wells, PK-3 and PK-5, currently connected to the town's central water supply system. One private well (PK-4) and one old pumping station left from the Russian period (PK-1) supply water to local areas of the town. Due to the contamination of the shallow private wells, 210 families are now supplied with water from road-tankers.

All existing deep water supply wells produce water from the Cambrian-Ordovician aquifer complex (C-O (II)). However, the well PK-6, which is proposed as an emergency water source, produce water from the Cambrian-Vendian complex (C-V (III)). The productions from the wells in 1995 and 1996 are shown in Table 3.1.

Table 3.1 Deep water supply wells

Owner	Well No.	Aquifer	Production[2] 1995 m^3	Production[2] 1996 m^3
Raasiku Municipality	PK-1	C-O (II)	15,000	23,800
Aruküla Veefond	PK-3	C-O (II)	7,521	8,914
AS Saile	PK-4	C-O (II)	no information	no information
Aruküla Veefond	PK-5	C-O (II)	1,270	652
Aruküla Veefond[1]	PK-6	C-V (III)	not in operation	not in operation
AS Lignar	"Lignar"	C-O (II)	64,000	74,000

[1] Former military well
[2] data from the Municipality

From Table 3.1 it appears that the quantity of water pumped from the deep wells in 1996 is approximately 107,300 m^3/year, corresponding to approximately 290 m^3/day. There is no information on the actual average daily production rate of the the town pipeline network. Well PK-1 has been out of operation in 1997 and well PK-5 is currently not used.

According to the Municipality, an expected production of 12 m^3/h from well PK-6, will be adequate for the future demand for water on a short-term and emergency basis. The future water demand is estimated to be approx. 25 m^3/h corresponding to 200.000 m^3/ year. The Municipality has the permission to use the water from well PK-6. The only questions concern the change of ownership and the payment of the water.

4 TECHNICAL ANALYSES

4.1 Aquifer Testing

A test pumping was performed in well PK-6 in Aruküla during the period 8 to 10 March, 1997. The test only involved PK-6, as no surrounding wells were usable for observation purposes. Thus, a test in well PK-6 is not usable for description of long-range prognoses. From this pump test it is only possible to estimate the transmissivity value of the screened part of the aquifer immediately around the pump well. The purpose of this test pumping was to verify a minimum yield from well PK-6 of 12 m^3/h.

In the following the results of the test pumping are described.

Description of Well PK 6

Well PK-6 is approximately 191 meters deep. The well is screened from approx. 161 to 191 m b.g. in the Cambrian-Vendian (C-V) aquifer complex (III), see enclosure 1. In 1955 the water table was reported to be approx. 51 m b.g. In connection with the preporatory works for this study the water table was measured to be approx. 10 m b.g. This indicates a leak along the casing. Based on this, a TV-inspection, gamma logging and caliper logging were performed. The caliper curve showed, that the casing was corroded from approximately 35 to 82 meters below ground level, see enclosure 1, logging curves. Therefore, it was decided to install a new casing to a depth of 90 m b.g. In addition, it was decided to leave the original pump in the bottom of the well, and to clean up until approximately 185 m b.g. Consequently, the total length of screen is now 24 meters. Having repaired the casing, the water table stabilized at approx. 58 m b.g.

To determine the characteristics of the well, a stepwise test pumping and a full-yield test pumping over a 24 hours period with following recovery test was performed.

Stepwise Test Pumping

A stepwise test pumping was performed to determine the characteristics of the well. However, these data proved to be unreliable and were not usable for a detailed assessment.

Test Pumping

The test pumping was performed with 24 hours pumping followed by 16 hours recovery. The pumping yield was kept constant at 12 m^3/h throughout the pumping period.

The result of this test pumping sequence is shown in enclosure 2. It appears, that the barometric pressure is almost constant during the test pumping period. Potential influences can therefore be disregarded

The draw-down and recovery curves are shown in enclosure 2.

The Draw-Down Curve

The first part of the draw-down curve from pump start to approx. two minutes is due to well storing. From two minutes to approx. 400 minutes of pumping a gradual decrease of the draw-downwas observed. After approx. 400 minutes of pumping the water table in the well was slightly increasing. This development continued until pump stop. The last development could be a result of various hydrogeologic conditions, such as:

a) Leakage from an upper or underlying aquifer with a higher pressure level.

b) Positive hydrological boundary causing an increase of the inflow of water to the aquifer.

c) A development in which the inflow to the well is improved during pumping. This effect will not be observed in the recovery data.

Whether it is due to one of the above conditions can only be determined with simultaneus observations from monitoring wells situated in the same aquifer.

Recovery Curve

It appears from the recovery data that the recovery is influenced by the back-flow of groundwater from the pipe from 0 to 1.5 minutes. Hereafter the curve follows a traditional recovery.

Determination of Transmissivity

The test pumping data are interpreted on the basis of a semilogarithmic plot, in which the draw-down and recovery curves are plotted on a lineary scale whereas time is plotted on a logarithmic scale.

Based on this plot, the transmissivity can be determined according to the following equation that is valid for artesian aquifers:

$$T = \frac{2.3Q}{4\pi\Delta s}$$

in which Q is the discharge (m^3/min.), and Δs is the change in draw-down occuring over 1 log cycle.

Based on this, it is assumed that the transmissivity value should be determined for the interval between 2 and 400 minuts of pumping as regards the draw-down data.

Using this interval the transmissivity value can be determined to of 0.12 m^2/min (= $2*10^{-3}$ m^2/s).

As regards the recovery data, a corresponding value can be found.

Thus, the test pumping in well PK-6 has verified, that the well is able to reach the expected minimum yield of 12 m^3/h with a draw-down of approximately 9 meters. However, it should be noticed that the transmissivity has been determined from a short-time test pumping (24 hours of pumping followed by 16 hours of recovery). Long-range prognoses will have to include monitoring wells, and pumping periods of 2-3 months.

In connection with the test pumping some unclarified questions have turned up. One unclarified question is the slightly increase of the water table during the last 16 hours of the pumping period. A possible explanation could be a leak from the new installed casing.

4.2 Chemical Analyses

Water samples from selected wells of Aruküla water supply were analyzed for content of oil components and chlorinated solvents by means of gaschromatographic analyses. The results of analyses are shown in Table 4.2. Detailed information on the sampling conditions are shown in Enclosure 3.

Table 4.2 Water samples from Aruküla water supply (March 1997)

Well	Aquifer	BTEX[1]	Jet fuel	Chlorinated solvents
	μg/l			
PK-3 4638	C-O (II)	<0.1	<10	0.05[2]
PK-5 848	C-O (II)	<0.1	<10	0.06[2]
PK-6 704	C-O (II)	<0.1	<10	0.05[2]

[1] Benzene, Toluene, Ethyl-benzene and Xylene

[2] Chloroform

It appears from Table 4.2 that samples from Aruküla water supply and well PK-6 do not contain oil components and jet fuel. Three samples were analyzed for chlorinated solvents, and all three samples contain chloroform in very low concentrations. The content of chlorinated solvents in the water samples is caused by contamination from chlorinated drinking water used in the laboratory in Tallinn.

4.3 Groundwater Chemistry

To assess the waterquality, watersamples were collected from the Aruküla water supply wells PK-3 and PK-5 and the proposed new water supply well PK-6. PK-3 and PK-5 are located in the Cambrian-Ordovician aquifer (C-O (II)) and PK-6 in the lower Cambrian-Vendian aquifer (C-V (III)). PK-6 was sampled twice during a test pumping. The ion composition of the samples is shown in Figure 4.3 and 4.4.

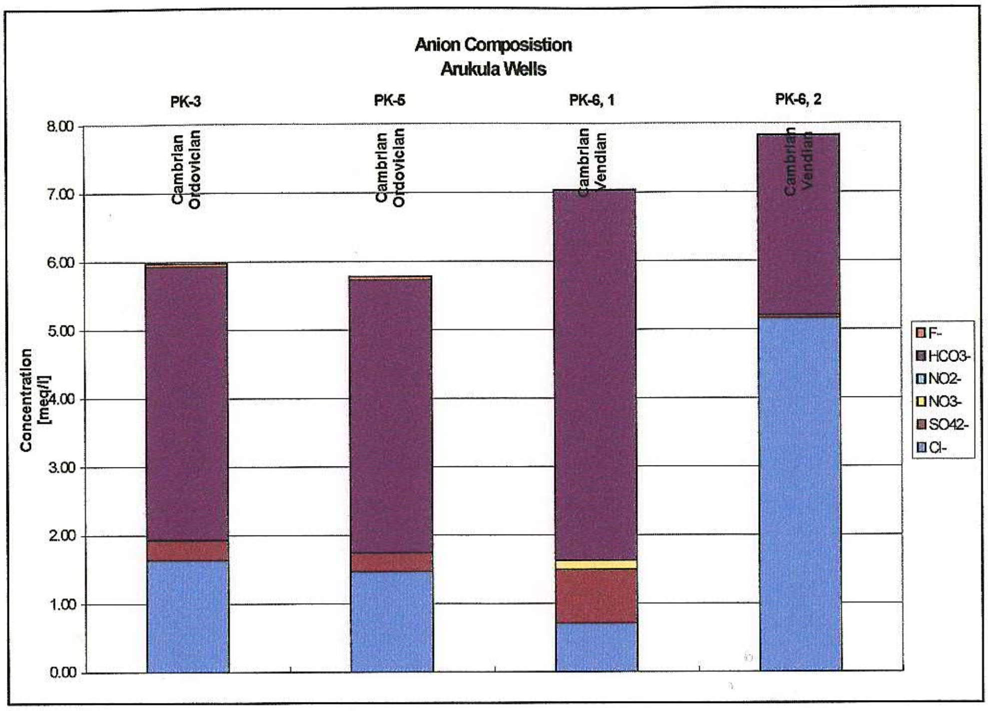


Figure 4.3. Anion composition of wells in Aruküla

The data from the test pumping of PK-6 indicate a leak along the casing in the beginning of the test (Sample PK-6, 1). This is clearly demonstrated by the high nitrate and high bicarbonate and calcium content of the sample, corresponding to the composition known from wells located in the upper part of the Ordovician aquifer (O (I)). After prolonged pumping, the water composition changes to a composition found elsewhere in the regional Cambrian-Vendian aquifer (C-V(III)). The dominating species are chloride and sodium originating from ion exchange in the "blue clay" separating the C-O (II) and the C-V (III) aquifer. In the C-O (II) aquifer the dominating anion is bicarbonate, although the chloride content is fairly high, as compared to the normal content of the uppermost aquifer O (I) not sampled here.

With respect to the general water quality of the wells the results are ranked according to the Estonian drinking water standards in Table 4.3.

Table 4.3. Quality of water ranked by Excellent, Good, Satisfying, Not Acceptable

Well	Quality according to Estonian drinking water standards	Most Critical Parameter
PK-3	Satisfying (Good)	Iron (Ammonia)
PK-5	Satisfying (Good)	Iron (Ammonia)
PK-6	Satisfying	Iron, COD

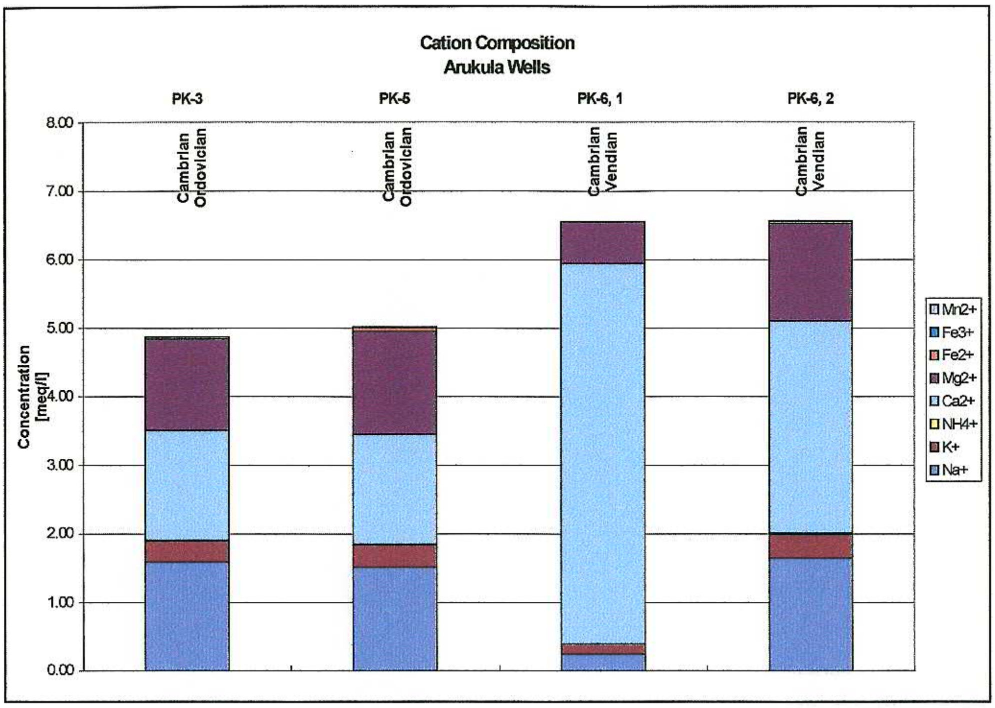


Figure 4.4. Cation composition of wells in Aruküla

Water treatment like aeration and filtration will raise the quality of PK-3 and PK-5 into the category "good". PK-6 will probably have the same raise in quality although the organic content is fairly high. It is not possible to judge on the basis of the short term test pumping if this is caused by an artifact or is a real value from the aquifer.

5 ENVIRONMENTAL ASSESSMENT

The oil contamination was first detected in shallow private wells in Aruküla in November 1993. The oil plume has spread very rapidly in the fractured limestone, and by the end of that year an area of around 22 ha was affected and about 50 shallow wells were contaminated. The oil product found in the wells showed a different composition than regular fuel oil. The oil contained toxic components including benzene, toluen, xylene, naphthalene and styrene. The most toxic component, benzene, was found in concentrations up to 267 mg/l.

The presumed source of the groundwater contamination in Aruküla was heating oil tanks belonging to TAPP Ltd., a wood processing facility. However, the source of the contamination has not been fully confirmed.

The oil plume has spread primarily to the southwest along a tectonic faultzone that facilitates movement towards the groundwater discharge area, in this case the Leiva River. It is presumed that this faultzone may also carry dissolved oil products to the northeast, in the direction of the Jõelähtme River. However, there is little information on the distribution of the oil plume in that direction. The estimated distribution of the oil plume, based on data from 1995, is shown in Figure 2.1. In 1996 oil contamination was found in a monitoring well close to the well PK-1/6/.

The thickness of free phase oil has been measured in several monitoring wells established during the investigation in 1994. In January 1994 the thickness of free phase oil was found to be from 30 to 252 cm in the central part of the oil plume/1/.The free phase oil has been remediated by pumping groundwater from shallow water supply wells and monitoring wells in the source area. Over a period of five weeks in 1994, a total of 97 m^3 of contaminated water containing from 1,000 to 2,900 l of oil have been remediated /4/. The total oil spill was estimated to 6-8 tons.

According to the monitoring programme carried out from 1994 to 1995 by AS Asker, the oil plume did not expand during this period /1/. The monitoring programme included 63 Ordovician wells and 13 Cambrian-Ordovician artesian wells. It was concluded, that it was not possible to predict the contamination risk of the Cambrian-Ordovician water supply wells/1/. In 1996 the oil plume had expanded further to the southest towards well PK-1 /6/. So far, contaminants have not been detected in the Cambrian-Ordovician wells. However, most of the water samples were analyzed for total oil products and only to a lesser extent for single components. Therefore, it cannot be excluded that oil components are already present in more wells in very low concentrations, although in the present study the samples analyzed did not contain oil components.

6 RISKASSESSMENT

The environmental assessment concludes that the oil plume has spread in the upmost Ordovician aquifer and has contaminated 50 private wells in an area of 22 ha. The contamination has not yet been detected in the deeper aquifers.

In the Ordovician limestone two aquitards, acting as relatively impermeable layers, are present at depths of 13-14 m and 23-29 m b.g. The protection from these aquitards against downward leakage of contaminated groundwater is limited in the presence of tectonic fracture zones. In these fracture zones the water exchange between the aquifers could be substantial. In Aruküla at least one fracture zone is assumed running through the town, affecting the spread of the oil plume. If the catchment areas of the C-O (II) water supply wells coincide with the fracture zone there is a risk for affecting the water quality in these wells. It is not possible to verify the risk on the basis of the available data. However, with the present knowledge of the spread of the contamination PK-1 and PK-5 is the most endangered wells.

There is also a possibility of leakage around the wells, especially if the casings have been corroded. An increased abstraction from the existing C-O (II) water supply wells will, other things being equal, increase the risk of contamination.

The C-V (III) complex is assessed to be well-protected due to the overlying 20-60 meters of Cambrian clay ("blue clay"). Investigations of the age of the groundwater in this complex show an age of approx. 10,000 years /3/. This age of the groundwater supports the assumption of the Cambrian-Vendian groundwater being well-protected against contamination, and that leakage from overlying aquifers is disregardable. However, there is a risk for contamination around the Cambrian-Vendian wells with corroded casing. This is the fact in well PK-6.

7 RECOMMENDATIONS

Based on the conclusions from the groundwater study the following recommendations are given regarding establishment of an emergency water supply for Aruküla:

- An emergency water supply from well PK-6 is recommended including a fully equipped pump station and a transmission line connected to the existing supply network. Prior to this, a detailed design plan have to be worked out, including economy, time schedule and tender material.

- An additional test of well PK-6 should be carried out in order to verify the tightness of the renovated casing before extending the well.

- The current monitoring programme should be altered and include sampling and analysis at regular intervals (at least once a year) from all C-O (II) water supply wells. The monitoring programme requires a capability of analyzing oil components at a sufficiently low detection limit, maximum 0,1 µg/l for each component.

- An examination of the remaining C-O (II) water supply wells should be carried out in order to assess the state of the well installations. Especially the physical condition of lining and screens will have to be examined.

- Remediation measures should be implemented to control the spread of the oil plume and to systematically reduce the free oil phase in the hot spot area.

8 EMERGENCY IMPLEMENTATION PLAN

8.1 General Remarks

In order to secure a safe source of drinkingwater for Aruküla it is proposed to move a part of the water withdrawal from the wells in the town area to a new well field outside Aruküla.

On a short-term basis it is proposed to rehabilitate the old deepwell PK-6 at the former military base south-west of Aruküla and build a new waterworks on the site. A new transmission main is necessary to connect the well field with the existing pipe network in Aruküla.

8.2 Water Demand

The present water consumption in Aruküla is approx. 107,000 m^3/year. This corresponds to a mean hourly water demand of 12.2 m^3/h. The future water demand in Aruküla is estimated to be approx. 25 m^3/h corresponding to approx. 200,000 m^3/year.

The existing well PK-3 and pumping station located in the residential zone in the central part of Aruküla is well maintained. The capacity is 10 m^3/h /5/.

Preliminary investigations of the well PK-6 at the former military territory has shown that the well has a safe yield of approx. 12 m^3/h.

By connecting PK-6 to the existing water supply system, the water demand is met not only in the present situation, but also in the near future.

8.3 New Waterworks at the former Military Base

A new waterworks including reservoir, water treatment facility, and pumps as well as a transmission main must be constructed before well PK-6 can be connected to the existing water supply system.

It is proposed that the waterworks is designed for a capacity of 12 m^3/h.

Well PK-6 must be equipped with a submersible pump with a capacity of approx. 12 m^3/h, e.g. Grundfos SP16.

The waterworks must have a reservoir capacity of 150 m^3 providing for fluctuations in the daily demand and as a reserve for fire fighting purposes. The filter capacity must be 12 m^3/h, and the pumps pumping to the transmission main must have a capacity of approx. 16 m^3/h.

The submersible pump feeding the reservoir is to be operated in accordance with the water level in the reservoir. Two step-regulated centrifugal pumps each with a capacity of 8 m^3/h pump water from the reservoir through a filter to the transmission main.

Water pressure is controlled by two membrane hydrophores (volumen 300 liters) and the step-regulated centrifugal pumps. The water pressure in the transmission main is measured by a pressure transmitter, allowing the pumps to work stepwise depending on the actual water demand.

In order to connect the waterworks at PK-6 to the existing pipe network a transmission main at a size of 90 mm is necessary.

8.4 Estimated Construction Costs

Estimated construction costs for rehabilitation of the well PK-6 and establishment of a new waterworks including transmission main to the nearest public road is:

Rehabilitation of well PK-6:	EKK	75,000
Detail design work:	EKK	175,000
Building and construction of waterworks:	EEK	1,200,000
Construction of transmission main (250m)	EEK	350,000
Unforeseen expenses:	EEK	250,000
Total cost	EKK	2,050,000

9 REFERENCES

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/3/ Estonian geological Survey, 1997, Pers. Comm. Report in preparation.

/4/ Maves AS, 1997, Summary on Groundwater Contamination at Aruküla.

/5/ Hofman Andersen & Partners, 1997, Project Preparation Mission Report for Small Municipality Water Supplies and Wastewater Project., Towns of Keila, Tapa and Aruküla, Estonia. Draft Report.

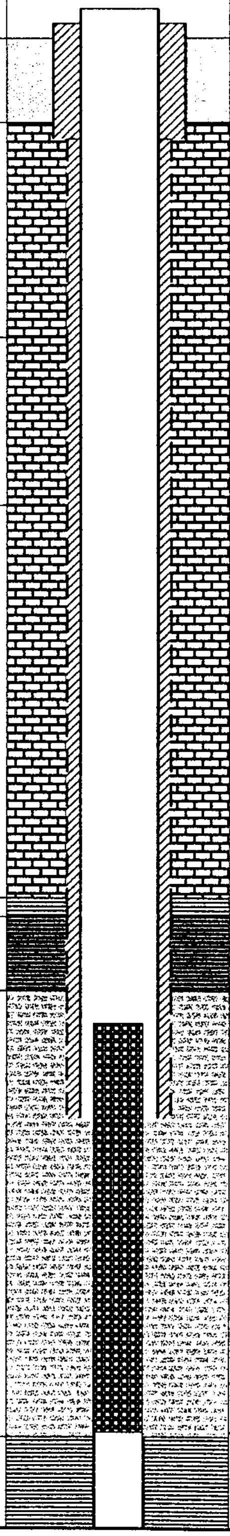
/6/ AS MINARON, 1997, Groundwater Monitoring in Village Aruküla, 1996 to 1997.

10 ABBREVIATIONS

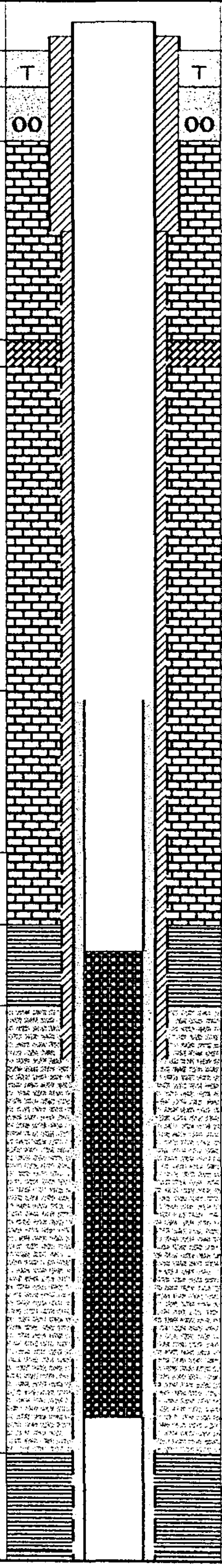
DEPA	Danish Enviromental Protection Agency
EME	Estonian Ministry of Enviroment
HEED	Hedeselskabet Enviromental and Energy Division
EERC	Estonian Enviromental Research Center
HL	Hedeselskabet's Laboratory
O (I)	Ordovician Groundwater Complex
C-O(II)	Cambrian-Ordivician Groundwater Complex
C-V(III)	Cabrian-Vendian Groundwater Complex

Enclosure 1

Well Construction and Well Logging

Construction of drill well 859 PK-1				ARUKÜLA	59°22' north latitude 25°05' east longitude		
Geol. index	Bottom depth, m	Layer thick-ness m	Description of soils	Abs. Elevation 43.00 m	Interval length m	Casing tube Ø mm	Water level m 4.4.72
	0.00				0.20 0.40		
Q_{III}^{gl}	4.50	4.50	Sand with gravel and limestone shingles		5.40	10" and 6"	
O_2jh-O_2id	16.00	11.50	Limestone and clayley limestone				10.00
O_2kk	25.00	9.00	Bituminous limestone				
O_2tl-O_1vl	46.00	21.00	Limestone and dolomite limestone		47.30	6"	
O_1lt	47.00	1.00	Glauconite clay				
O_1pk	51.00	4.00	Dictyonema shale				
O_1pk-$Єm_1pr$	75.00	24.00	Sandstone Aquifer		5.10 16.9	6" and 4" 4" filter	
$Єm_1ln$	80.00	5.00	Clay		5.30	4"	

4638

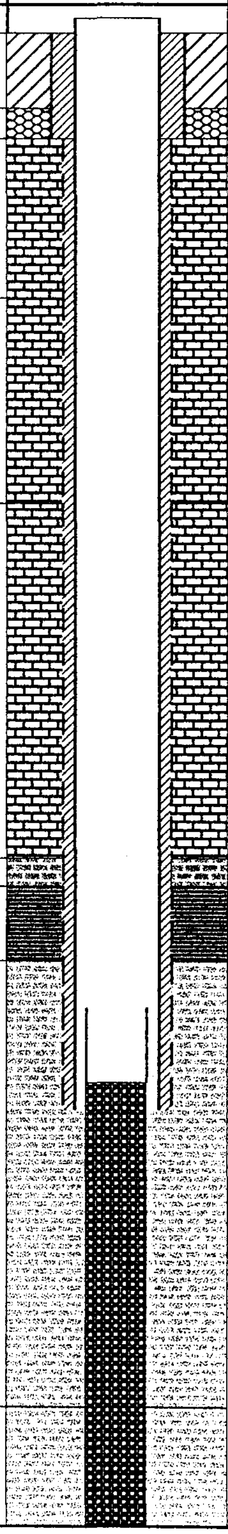
Construction of drill well PK-3				ARUKÜLA	59°21' north latitude 25°05' east longitude		
Geol. index	Bottom depth, m	Layer thick-ness m	Description of soils	Abs. Elevation 42.00 m	Interval length m	Casing tube Ø mm	Water level m 12.12.90
	0.00				0.20 0.20		
Q_{IV}	2.00	2.00	Fill		10.00	377 and 273	
Q_{III}^{fgl}	5.00	3.00	Claley gravel with pebbles				
O_2kl-O_2jh	16.00	11.00	Limestone and marly limestone				11.00
O_2id	17.50	1.50	Marl				
O_2kk-O_2uh	35.50	18.00	Limestone and marly limestone		30.00	273	
O_2ls-O_2as	44.50	9.00	Limestone and dolomite limestone		10.00	273 and 168	
O_1kn-O_1vl	48.50	4.00	Marly and glauc. limestone				
O_1lt-O_1pk	53.00	4.50	Glauconite clay and dictyonema shale		6.00	273 and 147 f.	
O_1pk-$Є_1pr$	79.00	26.00	Aleurolite sandstone Aquifer		21.00	147 filter	
$Є_1ln$	86.00	7.00	Clay and aleurolite		9.00	168	

856

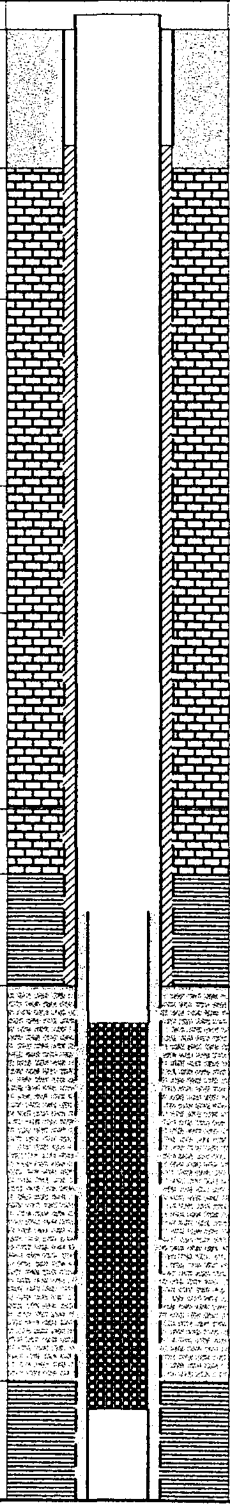
Construction of drill well PK-4	ARUKÜLA	59°22' north latitude 25°04' east longitude

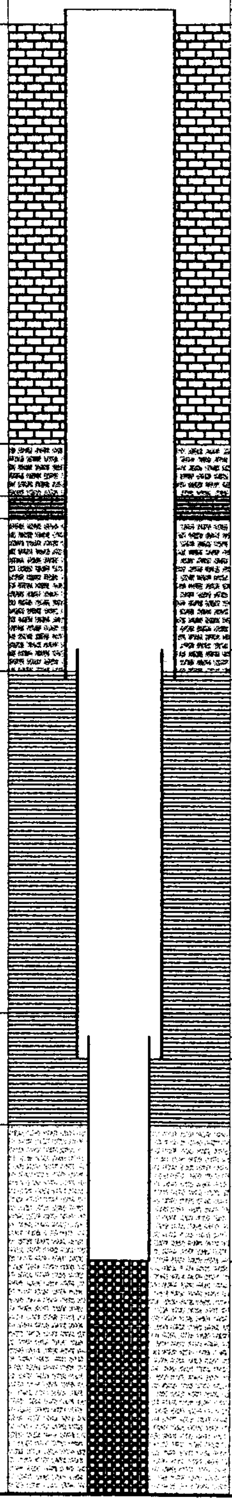
Abs. Elevation 45.00 m

Geol. index	Bottom depth, m	Layer thick-ness m	Description of soils
	0.00		
Q_{III}^{gl}	4.00	4.00	Sandy loam with limestone pebbles
Q_{III}^{gl}	5.50	1.50	Limestone pebbles
O_2jh-O_2id	14.00	8.50	Limestone and marly limestone
O_2kk	25.00	11.00	Marly limestone and bituminous limestone
O_2tl-O_1vl	44.00	19.00	Limestone and dolomite limestone
O_1lt	45.50	1.50	Glauconite sandstone
O_1pk	49.50	4.00	Dictyonema shale
O_1pk-$Є_1pr$	73.50	24.00	Sandstone Aquifer
$Є_1pr$	80.00	6.50	Sandstone with intermediate clay layers, aquifer

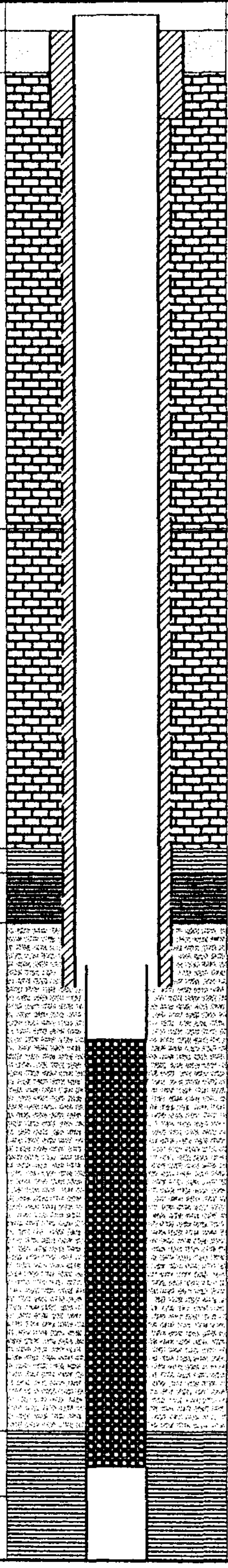


Interval length m	Casing tube Ø mm	Water level m 5.5.70
0.50		
5.50	10" and 6"	5.20
46.500	6"	
4.00	6"and 4"	
1.50		
22.50	4" filter	

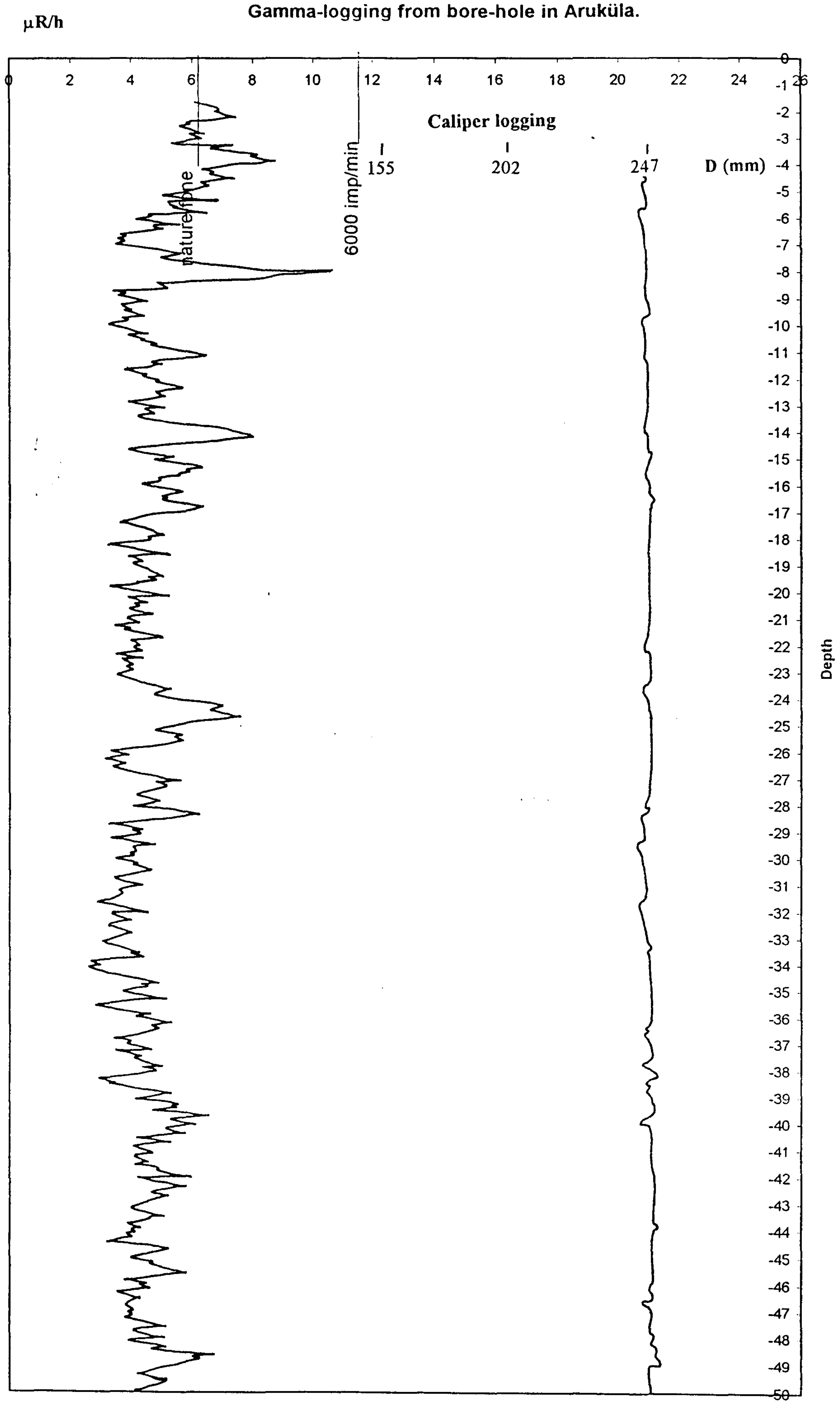
Construction of drill well PK-5 878				ARUKÜLA	59°22' north latitude 25°04' east longitude		
Geol. index	Bottom depth, m	Layer thick-ness m	Description of soils	Abs. Elevation 42.00 m	Interval length m	Casing tube Ø mm	Water level m 5.3.91
	0.00				0.50		
Q_{III}^{gl}	6.20	6.20	Clayey sand and grawel		5.00	377 ja 273	
O_2jh- O_2id	13.20	7.00	Limestone and marly limestone				12.00
O_2kk	23.20	10.00	Limestone and bituminous limestone				
O_2uh	30.00	6.80	Limestone and marly limestone		41.00	273	
O_2ls- O_2as	40.50	10.50	Limestone and dolomite limestone				
O_1kn- O_1vl	44.00	3.50	Marly and glauc. limestone				
O_1lt- O_1pk	50.00	6.00	Glaukonite clay and dictyonema shale		4.00	273 ja 146	
O_1pk- $Є_1$pk	73.50	23.50	Aleurolite sandstone Aquifer		2.00 10.40 12.60	146 168 filter 146 filter	
$Є_1$lk	80.00	6.50	Aleurolite and clay		5.00	146	

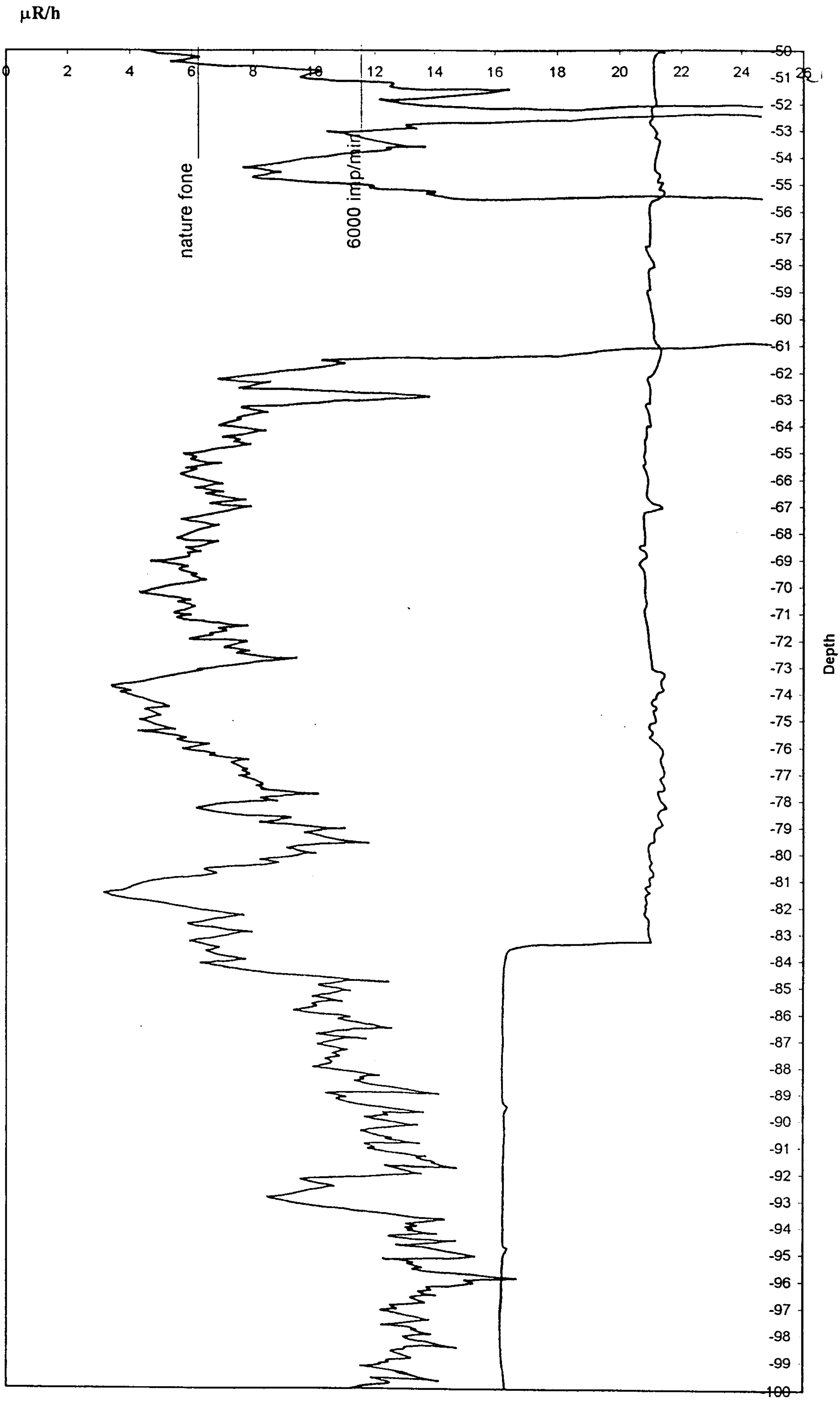
Construction of drill well PK-6 704				ARUKÜLA	59°22' north latitude 25°04' east longitude		
Geol. index	Bottom depth, m	Layer thick-ness m	Description of soils	Abs. Elevation 42.00 m	Interval length m	Casing tube Ø mm	Water level m 1955
	0.00				0.80		
O_{12}kn-O_2on	56.00	56.00	Compact limestone		81.90	273	41.00
O_1lt-vl	63.00	7.00	Glauconite sandstone				
O_1pk-	64.50	1.50	Argillite				
$Є_1$pk-O_1ts	83.00	18.50	Fine - grained sandstone		1.30	273, 219	
$Є_1$ln	128.00	45.00	Clay with intermediate sandstone layers		45.80	219	
$Є_1$ln	141.00	13.00	Clay		0.90	219, 168	
V_2vr	191.00	50.00	Quartz sandstone Aquifer		29.30	168	
					31.80	168 filter	

Construction of drill well PK-Lignar (PK-2)				ARUKÜLA	59°21' north latitude 25°05' east longitude		
Geol. index	Bottom depth, m	Layer thick-ness m	Description of soils	Abs. Elevation 42.00 m	Interval length m	Casing tube Ø mm	Water level m 9.12.77
	0.00				0.25		
Q_{III}^{gl}	2.50	2.50	Clayey gravel, sand		5.30	12" and 8"	6.30
O_2kl-O_2kk	30.00	27.50	Limestone and marly limestone		53.70	8"	
O_2tl-O_1vl	52.00	22.00	Limestone and dolomite limestone				
O_1lt	53.50	1.50	Glauconite clay				
O_1pk	56.50	3.00	Dictyonema shale				
O_1pk-$Єm_1pr$	87.00	30.50	Fine - grained sandstone Aquifer		1.00 3.15 26.00	8", 6" 6" 6" filter	
$Єm_1pr$-$Єm_1ln$	91.00	4.00	Clay with intermediate sandstone layers				
$Єm_1ln$	95.00	4.00	Blueclay		5.85	6"	



Gamma-logging from bore-hole in Aruküla.





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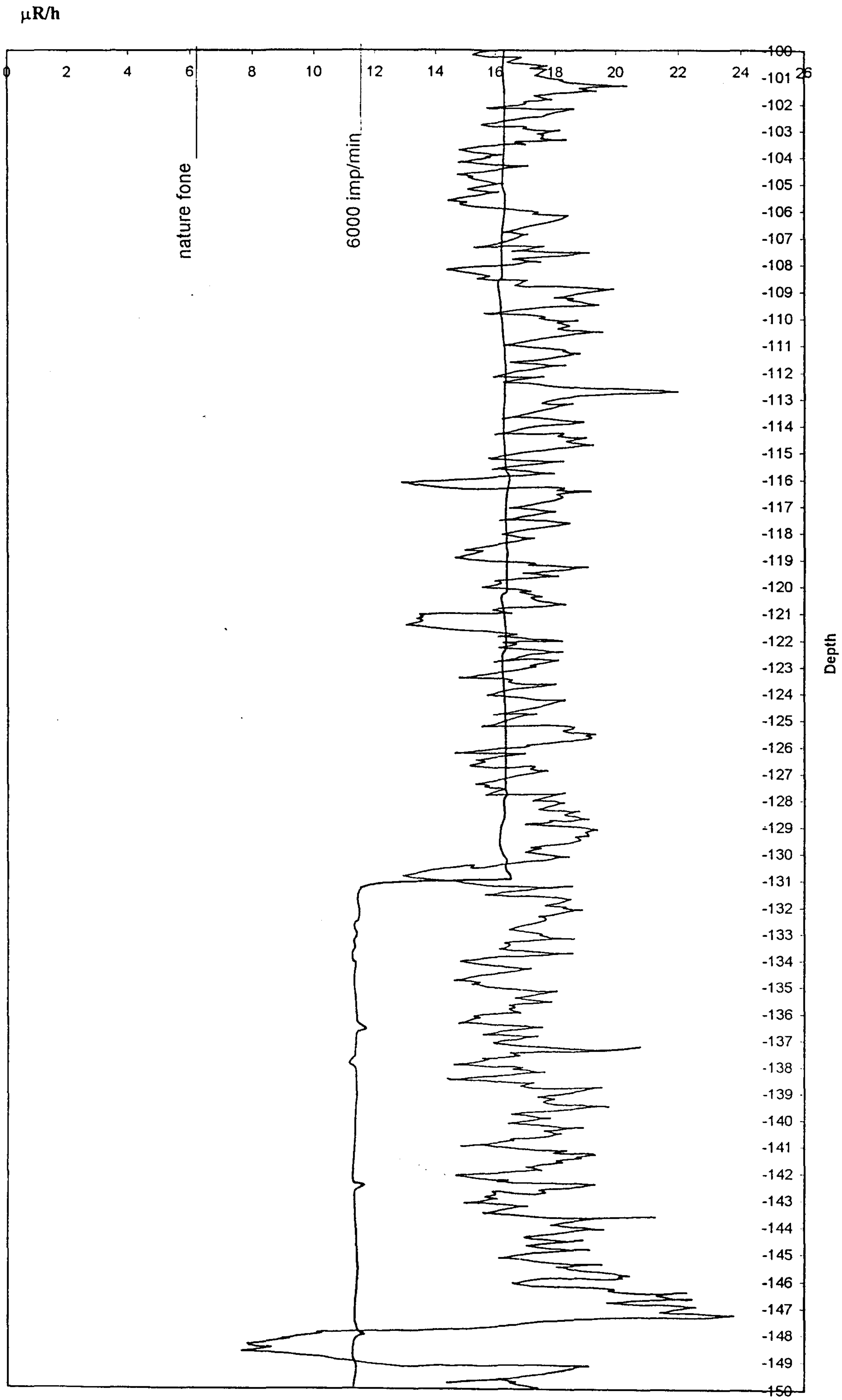
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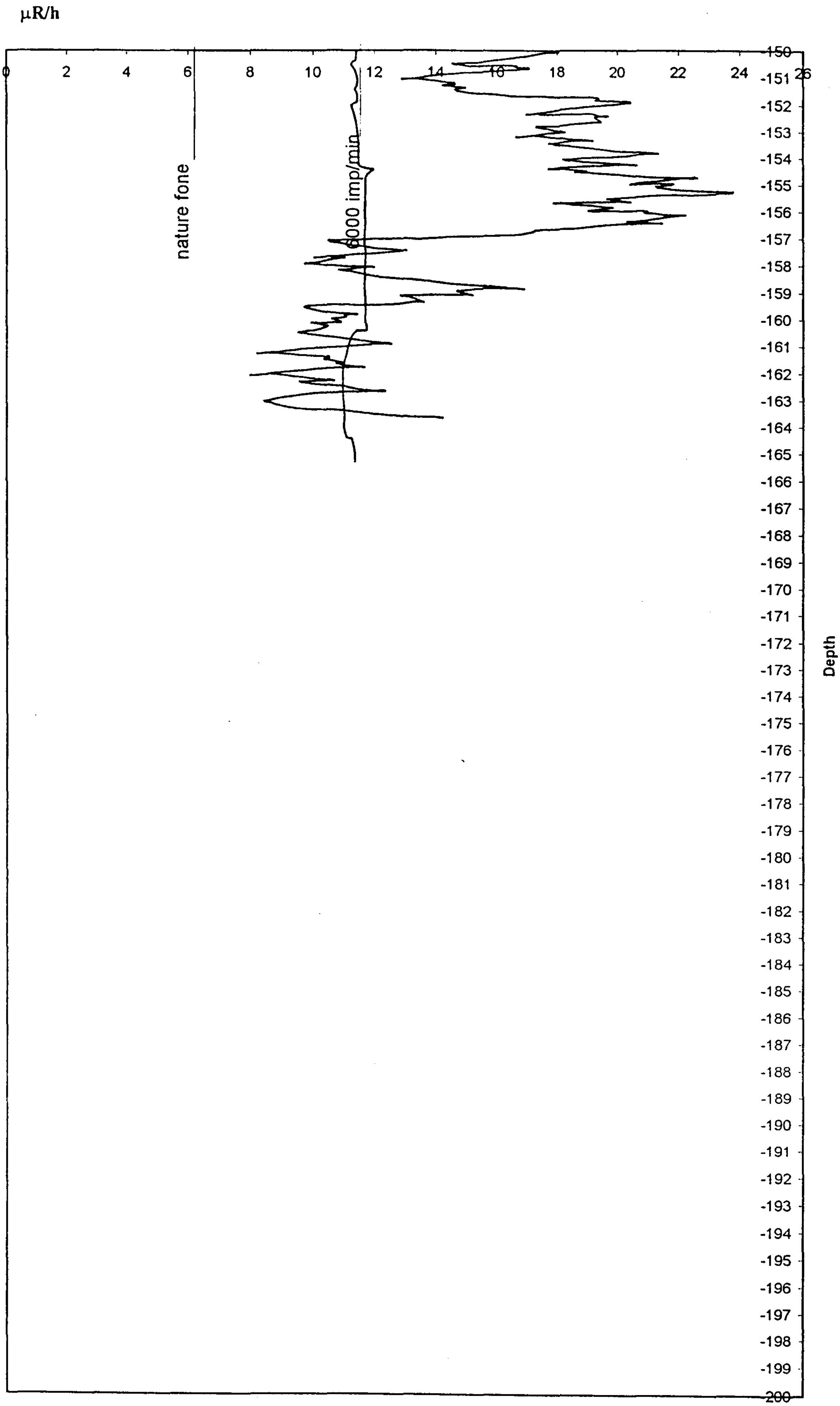
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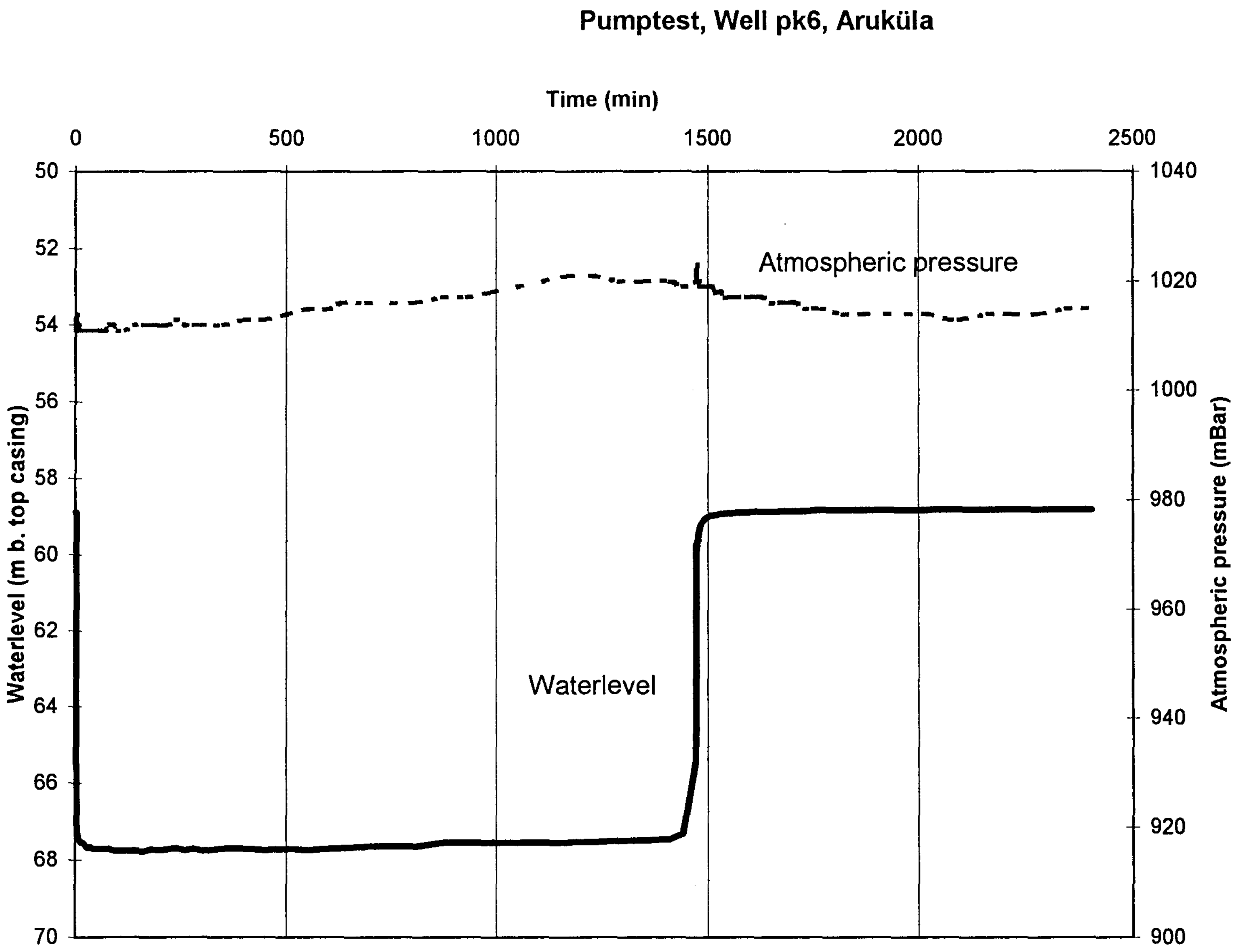
Enclosure 2

Test Pumping


Pumptest, Well pk6, Aruküla
Time (min)
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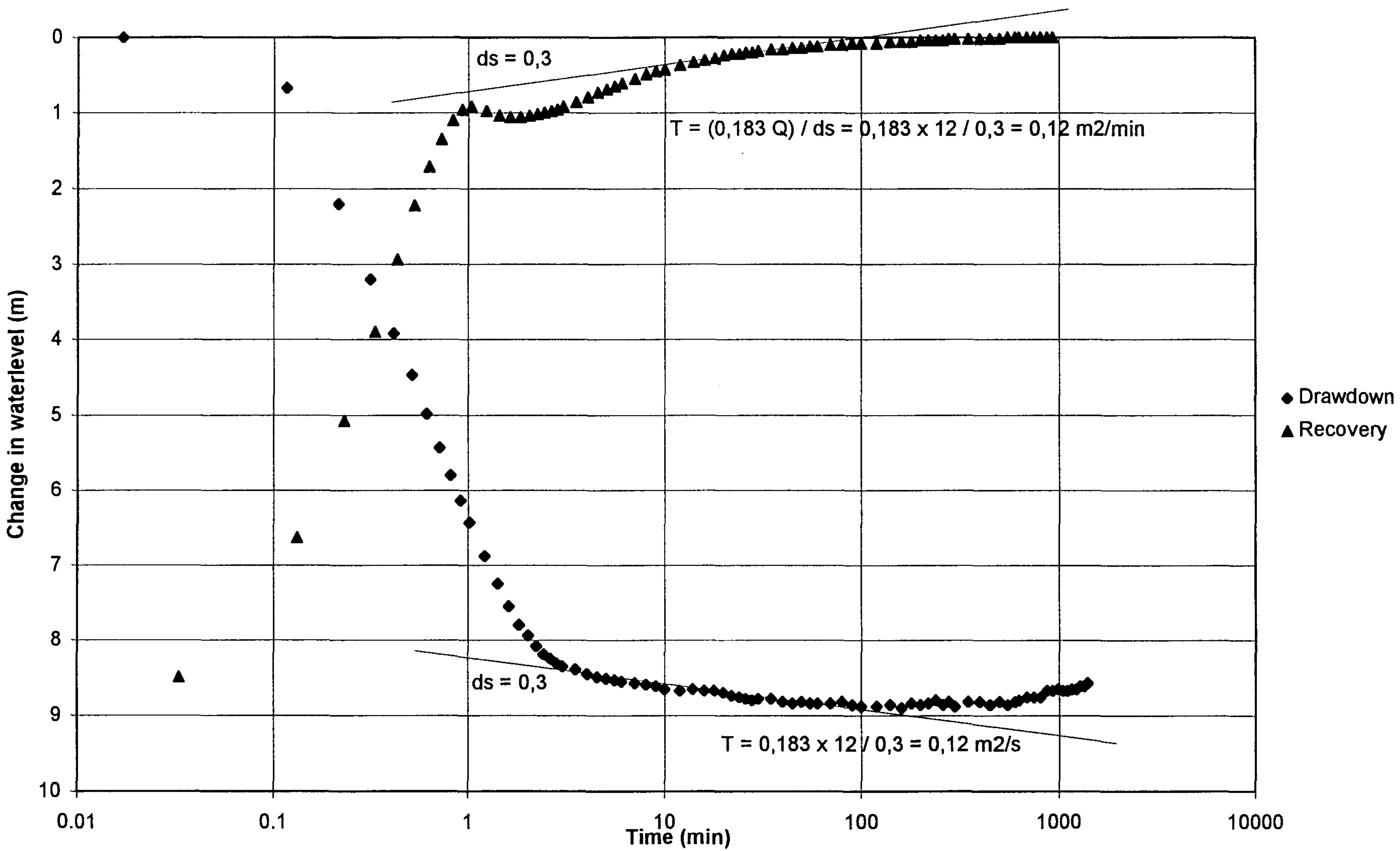
500
1000
1500
2000
2500
50
52
54
56
58
60
62
64
66
68
70
Waterlevel (m b. top casing)
1040
1020
1000
980
960
940
920
900
Atmospheric pressure (mBar)
Atmospheric pressure
Waterlevel

Drawdown and recovery test, Well pk6, Aruküla



Enclosure 3

Chemical Analyses

Chemical analyses from Aruküla watersupply wells

A: Jet fuel, BTEX and Naphthalene

Drill well	Depth, m	Water level absolute elevation, m	Date	Pumping time, h	Benzene	Toluene	Ethyl-benzene	Xylene	fuel	PAH(Naphthalene)	Date of sampling and analysing	Notes
					µg/l							
1638 PK-3	86	~31	12.12.90.	-	<0.1	<0.1	<0.1	<0.1	<10	<0.1	09.03.97. 10.03.97.	Russian pump: ЕЦВ6 -10 -80
848 PK-5	30	~30	05.03.91.	-	<0.1	<0.1	<0.1	<0.1	<10	<0.1	09.03.97. 10.03.97.	Russian pump: ЕЦВ6 -6.3 -85
704 PK-6	181	- 16.64	14.03.97	24	<0.1	<0.1	<0.1	<0.1	<10	<0.1	09.03.97. 10.03.97.	Russian pump: ЕЦВ6 -10 -110
Concentration Limits in Water, µg/l	Reference Value				0.2	0.5	0.5	0.5	20*	0.2	Regulation of EV Covernment no. 179. 11.04.1995.	*) Oil products total
	Remediation Investigation Value				5	50	60	60	600*	10		*) Oil products total

Chemical analyses from Arukũla watersupply wells

D: Standard analyses for groundwater quality

Drill well, Drill hole	Date of sampling and analysing	Total solids g/l	Na^+	K^+	NH_4^+	Ca^{2+}	Mg^{2+}	Fe^{2+}	Fe^{3+}	Cl^-	SO_4^{2-}	NO_3^-	NO_2^-	CO_2 free	HCO_3^-	F^-	P	Mn	Total hardness	Carbonate hardness	Non-carbonate hardness	pH	COD	Bacteriolocical test: Aerobic viable at 37°C	Bacteriolocical test: Coliform bacteria	Bacteriolocical test: Thermotolerant coliform bacteria
			mg/l																mg-ekv/l				mgO/l	nests/100 cm^3		
PK-3 4038	09.03.97. 10.03.97.	0.314	62	7.0	0.25	32.0	16.0	0.68	0.063	58.0	14.0	0.13	<0.001	0	244	0.80	<0.002	0.03	2.9	4.0	-	8.0	<1.0	n.a.	0	0
PK-5 848	09.03.97. 10.03.97.	0.300	59	7.5	0.25	32.0	18.0	1.6	0.23	52.0	13.0	<0.02	0.003	0	244	0.77	<0.002	0.03	3.1	4.0	-	8.15	<1.0	n.a.	0	0
PK-6 704	08.03.97. 10.03.97.	0.390	9.5	3.5	<0.01	111.0	17.3	n.a.	n.a.	25.0	38.0	2.92	0.102	0.1	330	0.09	0.012	0.07	6.2	5.4	0.8	7.5	3.0	n.a.	n.a.	n.a.
PK-6	09.03.97. 10.03.97.	0.486	64	8.0	0.36	62.0	17.0	0.79	0.12	183	2.5	0.13	0.007	0	159	0.35	0.018	0.07	4.5	2.6	1.9	7.95	2.2	n.a.	0	0
Drinking water quality classes	Excellent	1	-	-	0	-	-	0.1		100	100	1.0	0	-	-		-	0.05	5	-	-	6.5-8.5	1.0	-	0	0
	Good	1	-	-	0.5	-	-	0.3		250	250	10.0	0.01	-	-		-	0.1	7	-	-	6.0-9.0	2.0			
	Satisfying	1.5	-	-	1.0	-	-	1.0		350	500	45.0	0.1	-	-		-	0.2	10	-	-	6.0-9.0	4.0			

n.a. - the sample is not analysed

Drinking water quality classes are from FVS 663:1995 (Drinking Water)

HEDESELSKABET

Laboratoriedivisionen

Klostermarken 12
Postboks 110
8800 Viborg

Telefon 86 67 61 11
Telefax 86 67 13 17

Hedeselskabet
Miljø- & Energidivisionen
Ringstedvej 20
4000 Roskilde

Registernr.:	433828
Kundenr.:	70910
Ordrenr.:	416653
Modt. dato.:	1997.03.12
Sidenr.:	1 af 2

ANALYSERAPPORT

Rekvirent.....: MAVES Ltd.
Marja 4D, EE0006 Tallinn, Estonia,

Prøvested.....:

Prøvetype.....: Grundvand

Prøveudtagning:

Prøvetager....: Marti Saln

Analyseperiode: 1997.03.12 - 1997.04.01

Udførte analyser	H-133 Resultat	H-67 Resultat	PK-115 Resultat	PK-3 Resultat	Enheder	Metoder
Polychlorerede biphenyler			<0.01		mg/l	GC/FID
Klorerede opløsningsmidler						GC/ECD
Kloroform	0.04	0.04	0.07	0.05	µg/l	GC/ECD
Tetraklormethan	<0.01	<0.01	0.03	<0.01	µg/l	GC/ECD
Triklorethylen	<0.01	0.01	0.01	0.01	µg/l	GC/ECD
Tetraklorethylen	0.01	<0.01	<0.01	<0.01	µg/l	GC/ECD
Triklorethan	<0.01	<0.01	<0.01	<0.01	µg/l	GC/ECD

KOPI

Tegnforklaring:

< : mindre end. i.p. : ikke påvist.
> : større end. i.m. : ikke målelig.

den 02. April 1997

Birgit Pedersen

Usikkerhed på analyserne kan oplyses ved henvendelse til laboratoriet.
Analyserapporten må kun gengives i uddrag, hvis rapporten er offentlig tilgængelig, eller laboratoriet har godkendt ...

HEDESELSKABET
Laboratoriedivisionen

Klostermarken 12
Postboks 110
8800 Viborg

Telefon 86 67 61 11
Telefax 86 67 13 17

Hedeselskabet
Miljø- & Energidivisionen
Ringstedvej 20
4000 Roskilde

Registernr.:	433828
Kundenr.:	70910
Ordrenr.:	416653
Modt. dato.:	1997.03.12
Sidenr.:	2 af 2

ANALYSERAPPORT

KOPI

Rekvirent.....: MAVES Ltd.
Marja 4D, EE0006 Tallinn, Estonia,

Prøvested.....:

Prøvetype.....: Grundvand

Prøveudtagning:

Prøvetager....: Marti Saln

Analyseperiode: 1997.03.12 - 1997.04.01

Udførte analyser	PK-5 Resultat	PK-6 Resultat	Enheder	Metoder
Polychlorerede biphenyler	<0.01	<0.01	mg/l	GC/FID
Klorerede opløsningsmidler				GC/ECD
Kloroform	0.06	0.05	µg/l	GC/ECD
Tetraklormethan	<0.01	<0.01	µg/l	GC/ECD
Triklorethylen	0.01	0.01	µg/l	GC/ECD
Tetraklorethylen	<0.01	<0.01	µg/l	GC/ECD
Triklorethan	<0.01	<0.01	µg/l	GC/ECD

Pentan-ekstrakterne er analyseret på gaschromatograf med ECD-detektor.

Resultaterne er beregnet i ug/l vandprøve, udfra oplyst ekstraktion med 10 ml pentan til 1000 ml vandprøve.

Kopi af rapporten er sendt til:
- Hedeselskabet, Miljø- & Energidivisionen, Ringstedvej 20, 4000 Roskilde

Tegnforklaring:

< : mindre end. i.p. : ikke påvist.
> : større end. i.m. : ikke målelig.

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