IRISH-DUTCH PEATLAND STUDY

GEOHYDROLOGY AND ECOLOGY

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HYDROLOGY OF CLARA AND RAHEENMORE BOGS

EVAPOTRANSPIRATION, STORAGE COEFFICIENTS, LATERAL FLOW IN THE ACROTELM, CATCHMENT DEFINITION, TEST OF THE PIEZOMETER METHOD FOR HYDRAULIC CONDUCTIVITY

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Sketch of Clara Bog by Catherine O' Brien, Clara, County Offaly.

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PREFACE

This research was done as a part of our study land- and watermanagement (cultuurtechniek), at the agricultural university in Wageningen (The Netherlands). It is an 860 s.b.u. (study hours) graduate subject (agro-)hydrology.

Though we were already happy with our opportunity to go to the raised bogs in Ireland, our experiences transcended all our expectations. It was not only an interesting research, but there were also the very very nice and hospitable people from Clara, especially the ones visiting this particular pub.

It was good to do the research as a part of a project. This way we met a lot of nice fellow-students with whom we enjoyed our stay very much (understatement). On the other hand we learned much by working in a project and it made the involvement in the work very large. Together with being abroad in Ireland these were the ideal circumstances to do a research.

We would like to thank the supervisors for their information and cooperation in the project. We especially would like to thank Sake Van Der Schaaf for his accompany and the supply of equipment. Also special thanks to Margaret Keegan, who supported us both in working and relaxing. At last we would like to thank Jim Moore for the interesting excursion to several raised bogs in the area, and sociable drinking and sleeping!

CONTENTS

SUMMARY

Mainly because of turf cutting, raised bogs have become rare in the north-western part of Europe. From an ecological point of view they are important. Therefore the Irish government has acquired raised bogs as reserves. Sound hydrological management for them is needed because their systems are disturbed by drainage and cutting at the edges. An Irish-Dutch project is set up to find solutions concerning the hydrological management. The project is a cooperation between the Irish Wildlife Service and the Dutch National Forest Service (S.B.B.). The Agricultural University of Wageningen is mainly involved in the hydrology of Raheenmore bog.

The main topics of this report are studies on factors of the waterbalance, i.e. the evapotranspiration, storage coefficient and the lateral flow in the acrotelm. Also an attempt is made to make a calculation of the waterbalance. Further on a piezometer test and modifications on the boundary survey of the catchment area have been carried out.

It was the intension to make a calculation of the waterbalance in this research. Thanks to data that were not available at the time the report was written this was not possible. Only the method is described in this report.

The evapotranspiration is measured with lysimeters. A lysimeter is a weighable container filled with a column of soil and vegetation. There are four types of vegetation studied, all with both well and poor developed acrotelms. Every vegetation and acrotelmtype is measured in duplicate so there are 16 lysimeters in total. The actual evapotranspiration is being measured. As the lysimeters are isolated from their surroundings water has to be added or subtracted. The evapotranspiration is calculated by the difference in weight, the measured rainfall and the known quantities of added or subtracted water. For a good comparison the LAI (Leaf Area Index) and SCI (Sphagnum Cover Index) of the lysimeters are measured.

This research has only been running for 6 weeks yet. There are too few measurements to draw good conclusions. The values that are measured will be compared with calculations with the Penman formula using meteorological data of the three weather stations Mullingar, Birr and Derrygreenagh. The data were not available at the time this report was written, so this will be done by other students.

With the lysimeters also the storage coefficient of the upper layer is measured. It is calculated by the difference in volume of water and the change of waterlevel in the lysimeter. The storage coefficient is measured in two ways, with water adding data and with weighing data. Because of the abrupt adding or subtracting the storage coefficients calculated with adding data are smaller than those calculated with weighing data, the difference is approximately 0.1. The storage coefficients of the

different lysimeters vary between 0.2 and 0.5. Mostly the coefficients in lysimeters with poor developed acrotelms are smaller than those with well developed acrotelms. In the Sphagnum lysimeters there is no difference. All the conclusions are conditional because they are based on a few measurements, later on other students will give more results.

The main topic of this research is the study of the lateral flow through the acrotelm. The acrotelm is the top layer of a raised bog with living Sphagna and their water supply. Its hydrological characteristics are its high permeabilities/ transmissivities, fluctuating groundwaterlevel and change in height, caused by shrinkage and swelling of the bog.

The acrotelm research has been split in two parts. In the first part the transmissivity/conductivity is measured along two transects and in the second part a mapping of colour and humification of the whole acrotelm on the bog has been done. The humification is correlated to the transmissivity/ conductivity, in order to try to extrapolate the transmissivities on the whole bog.

The transmissivity/conductivity is very complex because of the heterogeneous structure of the acrotelm, the non stationary flow caused by a change in watertable during the season and the downward decreasing permeability. During the season there is also a change of conductivity because of swelling and shrinkage of the acrotelm. The mutual differences between the transmissivities/conductivities are very big. Therefore three methods are used: the Augerhole, Pit Bailing and Guinness method. The latter one is specially developed for measurements of high transmissivities in the acrotelm. All methods are based on the same principle: by measuring the velocity of water flow into a borehole the permeability/transmissivity of the surrounding medium is derived.

Because of the hummock-hollow complex, the differences in transmissivities at short distance can be very large. The hollows are more permeable than the hummocks and form a network. As these are the parts that are most important for the discharge, for the measurements the hollows are chosen.

It seems that there is a correlation between the humification degree and the transmissivity/hydraulic conductivity. An acrotelm with a humification degree between 2 and 4 has a high permeability (25 to 1000 m/d), while an acrotelm with a humification degree of 6 or 7 can be considered to be impermeable (0.1 to 7 m/d). Yet, it is not clear in what way an acrotelm with humification degree 5 should be interpretated. For that more measurements have to be added.

The large variation in the values of the transmissivities/ hydraulic conductivities can be associated with the large heterogeneity of the acrotelm structure at short distance, depending on the hummock and hollow complex.

The decreasing permeability with depth has not sufficiently been tested yet. For that more measurements are required.

The pattern of the acrotelm thickness that is obtained from the mapping is very heterogeneous. To the edges the acrotelm thickness decreases and near the edges it is (almost) absent. In the hollow network on the central part of the bog, the acrotelm is continuously present. At flat parts it is thick. On the slopes the acrotelm is thin or absent. This is not only the case at the edges, but also in the central part of the bog. It seems as if the acrotelm is built up like a staircase. Sometimes the stairs are separated by more humified parts. The stairs seem to form basins. With a low water level these basins are isolated and the discharge decreases strongly.

There is a second permeable layer between 0.5 and 1.0 meter below the surface with a humification degree of 4 and 5.

In the project the piezometer method has been used in different ways for measuring permeabilities in the catotelm. the results were being questioned. A piezometer test has been set up to sort out this problem. It deals with 3 subjects:
- filter geometry,
- sealing of the tube, and
- 3 different methods; falling-, rising- and constant head.

The test is carried out in duplicate and has been done on 2 plots.

When equal piezometers and tests are mutually compared the values differ a lot. They differ from 1 to 20 times. This means that the test field is not homogeneous. The remaining results have to be interpretated carefully. Another test has to be done, if possible in a homogeneous area.

With all methods, the values measured in piezometers with furrel are much higher than those with cork. The furrel probably drives a hole around the piezometer, through which the water can flow away (or in) very fast. This means that the present piezometers used in the project, all with furrels, are not suitable to measure permeabilities.

With these tests no influences of filter length and perforation rate have been determined.

When the three methods are compared there is a big difference in magnitude in determined hydraulic conductivities. At the first plot the rising head tests give bigger values than the falling head tests. In the second plot the opposite happens. This difference between test 1 and 2 can be caused by the difference in time between placing of the tubes and measuring. At the second plot the hydraulic conductivities measured with the constant head show no distinctive difference with the rising head method. The hydraulic conductivities measured with the falling head are much higher. May be the high water pressure at the start of the falling head test causes a hole around the piezometer, through which the water flows away easily.

For the estimation of the catchment area the boundary survey has been modified. Drains are taken into account as well, piezometers are placed there. More piezometers and more measurements have to be done to give accurate results.

CHAPTER 1

INTRODUCTION

Intact raised bogs in the north-western part of Europe are very rare. In the past centuries serious damage has been done to the ecosystems by turf cutting and other anthropogenic influences. The few survivors are important from an ecological point of view, mainly because of their particular vegetation and their remarkable nutrient supply : the ombrotrophy, i.e. the sole manner of feeding by precipitation (Streefkerk en Casparie, 1989).

In the Midlands of Ireland raised bogs still occur. In the last few years the Irish government acquired various bogs as reserves and it hopes to purchase several more of such areas in the years to come. Sound hydrological management for them is needed because their hydrological systems are easily disturbed by drainage and cutting on the edges.

The raised bogs in the central part of Ireland can be compared with the original Dutch systems. Therefore the knowledge gathered in The Netherlands in the course of restoration and hydrological management of remnants of raised bogs is relevant to the Irish ones. On the other hand the knowledge and experience in Ireland with regard to intact bogs is of great importance to the restoration projects in The Netherlands.

General analysis of the problems

The hydrological problems in and around bogs can be divided in two categories, namely:

a. drainage problems:
   - superficial drainage by ditches cut in the surface of the bog,
   - drainage of marginal zones as a result of peat cutting,
   - marginal drainage by deep ditches, and
   - effects of arterial drainage.

b. conservation problems.
   In the safeguarding of bogs, problems arise in identifying and analyzing the hydrological conditions for conservation. These problems are, for example, the lack of specific hydrological knowledge regarding the bog system in general and the lack of specific knowledge regarding the effects of hydrological interventions.

Wageningen research

The research of the Wageningen students mainly takes place on

Raheenmore Bog. The location of the bog in Ireland is shown in figure 1.1.. It is situated in County Offaly near Tyrrellspass.

Raheenmore bog is a particular example of a raised bog. It rises above the surrounding area and is positioned in a basin. On the edges some cutting has been done and on the eastern side an old drainage system is present. This system has already been filled up by Sphagnum growth, but watertransport is still taking place there. Around the bog a deep drain has been dug.

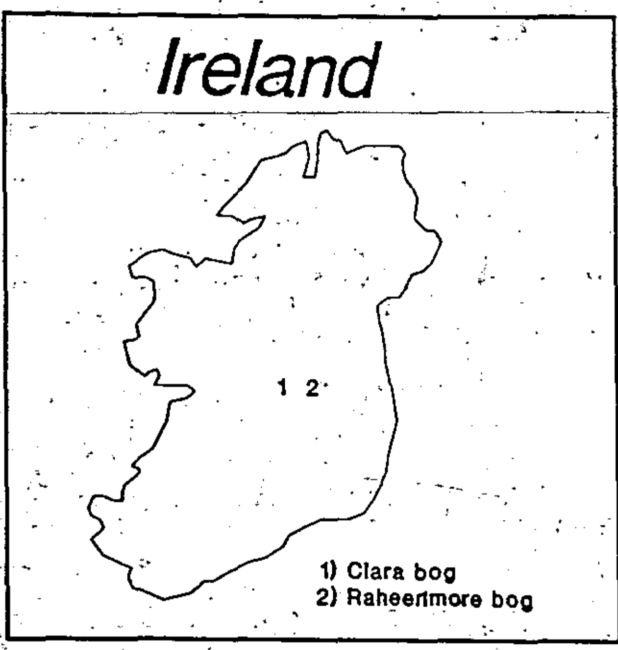

Figure 1.1 Location of Clara and Raheenmore bog in Ireland (from H.A. Lensen, 1991)

The second bog involved in the Wageningen research is Clara bog (for location see figure 1.1). It is not a representative example of a raised bog because it is not situated in a typical basin and the "new road" runs through the bog. This has a big influence on the hydrology of the bog and makes the hydrological system of the bog very complex. Therefore it is decided to work Raheenmore out first.

Clara bog is very special. It has soak systems and it is the largest raised bog remaining in Western-Europe. Two third of the bog is nature reserve. The other part is still private property where turf cutting takes place. On the eastern half of the bog a lot of drains were dug just before the bog became nature reserve.

The three main topics of the Wageningen hydrology work in 1991 on Raheenmore are:
-the waterbalance,
-the influence of cutting on bog edges on the hydrologic system of the bog, and
-the modelling of the hydrological system.

This research

This research deals for a great deal with studies for the waterbalance. It was the intention to make a calculation of the waterbalance. However, thanks to the often promised but never valised delivery of the necessary discharge data by T. Joyce of the O.P.W. this is not possible in this report. In chapter 2 only the method is described.

Further on this research has dealt with three factors of the waterbalance which are still unknown: the evapotranspiration, the storage coefficient and the lateral flow through the acrotelm. This work will be continued by other students. In chapter 3 the evapotranspiration will be discussed and in chapter 4 the storage coefficient. In chapter 5 the main subject of this research, the acrotelm, will be discussed.

In previous research work in this project different piezometer methods and materials have been used to measure permeabilities of the catotelm. The different results were being questioned. A piezometertest, discussed in chapter 6, is set up to sort out this problem.

The discharge of the drains on Raheenmore is continuously measured by a recorder. This is done to calculate the surface runoff and lateral seepage loss of the waterbalance. To use the measured discharges in the waterbalance the catchment area has got to be known. For the determination of this area a boundary survey has been carried out. The survey was not working sufficiently, the influences of drains were not taken into account. Some modifications are made. This subject is discussed in chapter 7.

Some work has been done on density research. This research is set up to study the influence of cutting on the edges and of the 'new road' on the bog. The road and the cutting cause subsidence which influences the hydrology of the bog. The development of density with depth on a certain point of the bog is a parameter that might give information about this. By taking a saturated sample with a certain volume the density of that sample can be determined. It is determined by the quantity of water that the sample contains. This subject will not be discussed in this report. For that, too few measurements have been done. The next Wageningen students, B. Sytsma and A. Veldhuizen, will continue this research and will describe it entirely in their report.

The monitoring and levelling work both on Clara and Raheenmore bog has been continued. The monitoring consists of:

- -measuring waterlevels in tubes on Clara and Raheenmore,
- -measuring waterlevels of open water and near recorders,
- -measuring rainfall,
- -checking of the rainfall- and waterlevelrecorders and changing the charts, and
- -processing measured data.

This work took thirty percent of time of the Wageningen students. The monitoring of the hydraulic heads in tubes is carried out ones a fortnight. The checking of the discharge and groundwaterrecorders and the raingauges is weekly. Because of the movement of the bog, the recorders and tubes have to be levelled every 3 months. For the levelling Benchmarks have been placed. They are levelled by the O.P.W. All levels are regarded to BOD.

The monitoring and levelling will not be discussed in this report. The measurements add no new information to this research at this moment. They are already discussed in the previous reports of Lensen (1991) and Huisman (1990).

CHAPTER 2

WATERBALANCE

2.1 INTRODUCTION

The water-balance is the equation of amounts of water involved in inflow, outflow, withdraw and change in storage over a certain period in a certain area (C.H.O, 1986). With a waterbalance knowledge is gathered of the pedological and hydrological characteristics of an area. By calculating water-balances, different kinds of raised bogs can be compared, i.e. damaged bogs can be compared with living ones.

The waterbalance of a raised bog over a certain period of time can be written as follows (Streefkerk and Casparie, 1989):

$$P - E - R - L - D = \Delta S \qquad (1)$$

P	= precipitation	(mm)
E	= evapotranspiration	(mm)
R	= surface runoff	(mm)
L	= lateral seepage loss	(mm)
D	= downward vertical seepage	(mm)
ΔS	= change in storage	(mm)

Raised bogs lie higher than their surroundings, so there is no surface, lateral or upward inflow. The only source of inflow from water is precipitation.

A few factors could be added to this equation (Ingram, 1983). At first, in a bog there can also be pipeflow. This is flow in pipes and fissures which are not directly open to the atmosphere. Secondly, open channel flow can be added in case drains have been dug in the bog.

Calculations of the waterbalance have not been made. There were no discharge data available yet and researches for other factors are still running or being improved. In the next part only a description of the methods and materials is given.

2.2 METHODS AND MATERIALS

The waterbalance is made for a catchment area on Raheenmore. In the catchment area several measurements take place to estimate the different factors of the waterbalance.

The surface runoff and the lateral flow are both intercepted by drains. The whole drain system (see appendix 19) on Raheenmore has two outlets. There is one drain where leakage takes place, it was supposed to be part of the catchment area. The boundary in the drains, where the division between the two outlets is, still has to be investigated (see also chapter 7). The drains of the catchment area all go to one outlet where the discharge is measured by a V-Notch and a waterlevel recorder. The drains are all very old and fullgrown with Sphagnum. It is very hard to distinguish lateral flow and surface runoff from channel flow because the first two go over in the latter. In spite of the blocks in the drains there is a discharge of water from the bog through the drains.

The precipitation is measured by 3 raingauges. Two handgauges of 5" are read every week and one 7" syphon is continually registrating. The 5" raingauges are taken as absolute. The syphon values are corrected by the average of the two handgauges. For the waterbalance the average value of the two 5" handgauges is used.

To measure the evapotranspiration and the storage coefficient (the latter is needed to calculated the change of storage) a research with lysimeters is set up (see chapters 3 and 4). The measurements on the lysimeters have been going since April. This means that the period is too short to draw conclusions for the evapotranspiration and storage coefficient. In a later stage the results will be used for the waterbalance.

The evapotranspiration can also be calculated by the Penman formula with meteo data. These data are available of the weather stations of Mullingar and Birr . These are the two nearest big weather stations for meteodata of the Penman formula. Near to Raheenmore (about 10 km) there is a small weather station called Derrygreenagh. It is owned by Bord Na Mona. The data of this station can also be used for the calculation of the evapotranspiration. B. Sijtsma and A. Veldhuizen will involve these data in their research. The results with the Penman formula can be compared with the values of evapotranspiration that are measured with the lysimeters.

A mobile weather station will be placed on Clara as well. When it is installed the data can be used and compared with the data of the other stations and the results of the lysimeters.

The vertical seepage is estimated. It is highly dependent on the unknown vertical resistance of the underlying layer. This layer exists of lagustrine clay . The vertical seepage is estimated to be 40 mm a year (oral communication J. Streefkerk, 1991).

The change in storage is derived from the waterlevel and storage coefficient measurements. They are measured with the monitoring of respectively the tubes and the lysimeters (the storage coefficient will be discussed in chapter 4).

CHAPTER 3

EVAPOTRANSPIRATION

3.1 INTRODUCTION

The (actual) evapotranspiration is the total evaporation flux of an overgrown surface. It includes the evaporation of intercepted water, the soil evaporation and the transpiration. The transpiration is the evaporation flux through leaf pores and the cuticula of a dry leaf surface of the plants (C.H.O., 1986).

The evapotranspiration has to be taken into consideration, as it is an important factor of the waterbalance. Data from studies of raised bogs in Ireland show evapotranspiration values with an order of magnitude of 450 to 550 mm per year (Burke, 1975).

The determination of the evapotranspiration is normally done by elimination of water supply and water discharge factors of the waterbalance or by formulas based on weather measurements. In this study a direct method is being used. The evapotranspiration is determined with weighable lysimeters. The results will be compared with the evapotranspiration calculated with meteorological data with the Penman formula. As said in chapter 2 a mobile weather station will be installed. The data from the weather stations Mullingar, Birr and Derrygreenagh can also be used.

3.2 MATERIALS AND METHODS

A lysimeter is a weighable container with a column of soil with vegetation. The lysimeters used on Raheenmore are 0,50 meter high and have a diameter of 0,40 meter. The bottom is completely sealed. The baskets are placed in holes in the bog in which they fit exactly (figure 3.1).

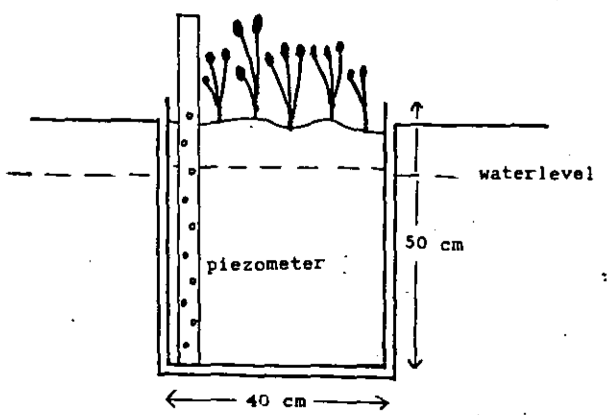

figure 3.1 Formation of a lysimeter in the field.

In this way a system is created where the circumstances are as much as possible the same as in the surrounding environment. Only the lateral and vertical flow of water through the soil is not possible.

The lysimeters are weighed with the help of a tripod, a pulleyblock with six sheaves, a weighscale and a three armed bars with hooks, which can be put in the eyes of the lysimeters. If, for a certain period, the difference in weight and the rainfall are measured, the evapotranspiration can be calculated.

Because the actual evapotranspiration is being determined, the waterlevel has to change equally with that of the sites where the lysimeters are filled. As the lysimeters are isolated from their surroundings, water has to be added or subtracted. This means that next to the rainfall and difference in weight also the added weight or volume of water has to be taken into account to calculate the evapotranspiration.

The evapotranspiration over one period is calculated with the following formula:

$$E = P + (V_a - \Delta W) / A \qquad (2)$$

E	= evapotranspiration	(mm)
P	= precipitation	(mm)
V_a	= volume of added water	(l)
A	= surface area of lysimeter	(m^2)
ΔW	= volume change of stored water, determined by difference in weight	(l)

The values for one period are transmitted in average daily values. With these values it is easier to make a mutual comparison in time.

Sixteen lysimeters have been filled with four different kind of vegetation, so there are four lysimeters of each kind of vegetation. These vegetation are the most dominating types on the bog. The vegetation are:
- Calluna vulgaris (Heather) and some Erica (also Heather) with Sphagnum (Peat Moss),
- Eriophorum vaginatum (Cotton Grass) with Sphagnum,
- Narthecium ossifragum (Bog Asphodel) with Sphagnum, and
- Sphagnum.

Of each kind of vegetation there are two with poor and two with well developed acrotelms (see chapter 5). A scheme of the formation is given in figure 3.2. In the appendix 2 (fixed data lysimeters) the position of the locations where the lysimeters have been filled is given. The location is expressed in coordinates of the grid system of Raheenmore bog. On the bog the grid is marked with pegs. A map with the grid is given in appendix 1.

The lysimeters have been moved to one spot to facilitate the monitoring. Their location is K20 880 (see grid appendix 1). Here new holes have been dug, in which the lysimeters fit as well as possible. This is important because too big holes will give extra heating of the sides of the lysimeters, which might result in an increase in evapotranspiration.

vegetation / acrotelm	Calluna vulgaris	Narthecium ossifragum	Eriophorum vaginatum	Sphagnum spec.
poor	1 , 2	3 , 5	4 , 6	7 , 8
well	15 , 16	13 , 14	11 , 12	9 , 10

figure 3.2 Test scheme lysimeter research.

Once per month the Leaf Area Indexes (L.A.I.) of Calluna vulgaris, Narthecium ossifragum, and Eriophorum valinatum are determined. The L.A.I. is the ratio of the leaf area and the surface area. For E. vaginatum and N. ossifragum this is done as follows:
- dividing of the surface area into 4 parts,
- counting of the leaves in 1 part, and
- measuring the surface area of several leaves.

Then the total leaf area is:

$$\text{leaf area} = 4 \times n \times a \qquad (3)$$

n = amount of leaves in 1 part
a = average surface area of one leaf

C. vulgaris has a huge number of small leaves which are hard to measure. Therefore a constant leaf area of separate leaves in time is considered and the amount of increase of leaves on 5 standard tops is counted. Further on, the amount of tops in a quarter of the surface area are counted. Then the total leaf area is:

$$\text{leaf area} = 4 \times n_t \times n \times a_c \qquad (4)$$

n_t = number of tops in one quarter of the lysimeter
n = average number of leaves on a standard top
a_c = constant surface area of a standard leaf

For Sphagnum it is very hard to estimate leaf areas. Therefore only an estimation of the covering degree of the living Sphagna is made: the Sphagnum Cover Index (S.C.I.).

Further on, also the L.A.I. of the dead material is estimated. This is an important factor for the interception of the precipitation. In the period this research is done, April and May, the L.A.I. of dead material is considered to be constant with time, so it is only measured once. The index is formed by the twigs or stems of the plants, the dead leaves and the dead material laying on the surface. The surface areas of the twigs or stems and leaves are derived in a similar way as discussed for N. ossifragum and E. vaginatum. The LAI of the dead material on the ground is derived by estimating the cover degree, multiplied by a factor. This factor is dependent on the shape and composition of the material. The material forms flat slices and is for the greater part not laying on the surface. Therefore the factor is estimated to be 2.

With the help of mapping of vegetation plots and aerial photographs the vegetation types and distribution of them on the bog will be investigated. With this and the results of the lysimeter research and the calculations with the Penman formula the evapotranspiration of the catchment area of the whole bog can hopefully be determined.

The lysimeters are also being used to determine the storage coefficient and the degree of swelling/shrinking of the upper part of the bog. The storage coefficient will be dealt with in chapter 4 of this report. The change in surface level of the lysimeters will be analyzed by successive students. There was only one measurement done yet so it is not possible to have any discussion on this subject.

3.3 RESULTS AND CONCLUSIONS

The data used for the calculations are in appendix 2. The evapotranspiration results from 15 April to 23 May are given in table 3.1. In table 3.2 the L.A.I. and S.C.I. are given.

The results are discussed briefly. There are not enough results yet to make statistically correct comparisons. Further on there were no weather reports of the months April and May available at the time the analysis was made. Therefore the Penman values could not be calculated and be compared with the lysimeter values. This should be done by the new students as soon as the weather reports are available.

All evapotranspiration values are rather high. This is probably caused by a combination of good weather and a high waterlevel (around 5 cm below surface), which caused a high soil evaporation.

In May the Sphagnum and Calluna vulgaris lysimeters have the highest evapotranspiration values. As there is almost no rainfall in May, the evaporation of intercepted water and the soil evaporation decrease and the transpiration relatively increases. This means that Sphagnum and Calluna vulgaris probably have the highest transpiration.

There is no distinctive difference between the evapotranspiration values of the poor and well developed acrotelms. This is possible as the waterlevels in both kind of lysimeters have been high.

No correlations can be found between the evapotranspiration values and the L.A.I. and S.C.I. yet. More measurements have to be done.

Table 3.1 Average evapotranspiration from lysimeters (mm/day)

Vegetation: Calluna vulgaris

Lysimeter	1		2		15		16	
Acrotelm	-		-		+		+	
period	EVA	WL	EVA	WL	EVA	WL	EVA	WL
15-Apr-91		7.9		5.7		3		6.2
19-Apr-91	2.3	11.1	2.7	7.9	2.3	4.6	3.5	9
26-Apr-91	2.4	3.8	2.1	4.5	1.8	-0.2	2.0	4.3
03-May-91	2.5	3.2	1.5	4	2.5	1.7	2.5	4.5
10-May-91	2.6	8.2	2.4	5.1	1.7	2.7	2.3	7.6
17-May-91	3.6	12.3	2.2	7.8	1.7	5.2	2.2	9.3
23-may-91	3.3	13.2	2.6	9.3	1.7	5	2.5	8.9

Vegetation: Narthecium ossifragum

Lysimeter	3		5		13		14	
Acrotelm	-		-		+		+	
period	EVA	WL	EVA	WL	EVA	WL	EVA	WL
15-Apr-91		7.1		4.8		4.6		5.2
19-Apr-91	2.7	10.5	2.3	9	2.3	6.7	3.1	7.7
26-Apr-91	1.8	3.3	1.9	1.5	1.6	2	2.0	3.9
03-May-91	2.2	5.5	2.7	5.7	2.4	3.6	3.1	3.7
10-May-91	2.0	7	1.5	8.5	1.8	5.3	2.2	6.5
17-May-91	1.8	8.7	1.3	7.6	1.9	6.1	2.1	6.5
23-may-91	2.2	10	1.4	7.1	2.2	6.3	1.8	6

Vegetation: Eriophorum augustifolium

Lysimeter	4		6		11		12	
Acrotelm	-		-		+		+	
period	EVA	WL	EVA	WL	EVA	WL	EVA	WL
15-Apr-91		4.9		5.7		8.1		7.5
19-Apr-91	2.7	9.3	2.3	8.8	3.1	11.3	3.9	10.4
26-Apr-91	2.0	2.1	1.6	2.1	2.1	6.5	2.2	6.6
03-May-91	2.7	3.1	2.4	3.9	2.3	5.7	2.7	6.2
10-May-91	2.2	7.5	1.8	6.5	2.3	8.5	2.5	9.2
17-May-91	1.9	9.1	1.6	10.1	2.2	9.6	2.5	10.7
23-may-91	2.1	10.7	1.8	10.3	2.6	9.8	2.3	11.2

Vegetation: Sphagnum spec.

Lysimeter	7		8		9		10	
Acrotelm	-		-		+		+	
period	EVA	WL	EVA	WL	EVA	WL	EVA	WL
15-Apr-91		6.7		9.1		6.6		9
19-Apr-91	3.5	10.5	3.9	13.5	3.1	9.7	2.9	2
26-Apr-91	2.1	5.6	2.6	9.7	1.8	3.5	2.0	6.3
03-May-91	2.4	4.7	2.8	8.8	4.1	5.9	2.8	4.7
10-May-91	2.5	8	3.1	10	2.2	6.3	2.3	6.7
17-May-91	2.7	10.7	3.2	12	2.4	7.9	2.4	7.7
23-may-91	3.0	12	3.6	14.8	3.0	8.1	3.1	8.2

EVA is evapotranspiration
WL is waterlevel measured to average surfacelevel

Table 3.2 Leaf area and Sphagnum cover indexes (L.A.I and S.C.I.) of vegetation in lysimeters.

Vegetation	date	Calluna vulgaris			
Lysimeter		1	2	15	16
Acrotelm		-	-	+	+
L.A.I. (dead)	16-4-91	3.18	3.72	0.33	0.52
L.A.I. (alive)	16-4-91	2.30	2.02	2.40	3.16
S.C.I.	16-4-91	0.15	0.75	0.35	0.30

Vegetation		Narthecium ossifragum			
Lysimeter		3	5	13	14
Acrotelm		-	-	+	+
L.A.I. (dead)	16-4-91	1.50	1.50	1.50	1.80
L.A.I. (alive)	16-4-91	0.05	0.06	0.00	0.00
	05-6-91	1.22	1.57	0.76	1.02
S.C.I.	16-4-91	0.02	0.40	0.15	0.30
	05-6-91	0.01	0.00	0.01	0.25

Vegetation		Eriophorum augustifolium			
Lysimeter		4	6	11	12
Acrotelm		-	-	+	+
L.A.I. (dead)	16-4-91	1.05	1.07	2.84	0.82
L.A.I. (alive)	16-4-91	0.24	0.24	1.13	0.26
	11-6-91	0.73	0.61	1.48	0.96
S.C.I.	16-4-91	0.20	0.50	0.10	0.60
	11-6-91	0.15	0.50	0.25	0.80

Vegetation		Sphagnum spec.			
Lysimeter		7	8	9	10
Acrotelm		-	-	+	+
L.A.I. (dead)	16-4-91	0.10	0.05	0.05	0.05
S.C.I.	16-4-91	0.95	1.00	1.00	1.00
	11-6-91	0.99	1.00	1.00	0.90

CHAPTER 4

STORAGE COEFFICIENT

4.1 INTRODUCTION

The storage coefficient is the ratio of change in specific storage and the associated change of the hydraulic head or phreatic level. The specific storage is the storage above a certain reference level per unit of a horizontal surface. The storage is the volume of water in a certain part of the ground (C.H.O., 1986).

The storage coefficient is an important factor for the waterbalance. In combination with phreatic levels the change in storage of the bog in a certain period can be calculated. The storage coefficient is also important for the calculation of the transmissivity (see chapter 5).

4.2 METHODS AND MATERIALS

The storage coefficient can be measured with the lysimeters. There are two different ways. At first it can be calculated from changes in waterlevels with corresponding changes in weights. Secondly it can be calculated when water is added or removed from the lysimeters. This gives the following formulas:

$$\mu = [(W_1 - W_2) / A] / (h_1 - h_2) \qquad (5)$$

or

$$\mu = [(V_1 - V_2) / A] / (h_1 - h_2) \qquad (6)$$

μ	= storage coefficient	(-)
W_1, W_2	= volume of water determined by the weight at time 1, time 2	(l)
V_1, V_2	= volume at time 1, time 2	(l)
A	= surface area lysimeter	(m^2)
h_1, h_2	= phreatic level at time 1, time 2	(mm)

Only data with a difference in phreatic level of at least 3.0 cm are used. The amount of available and usable data is small, and only includes (part of) the upper layer of 0 to 10 cm. So it is not possible yet to distinguish layers with different storage coefficients and to include the deeper layers. However, the calculations can give a good first impression.

Like the evapotranspiration, the storage coefficient is also investigated for different kinds of vegetation with well or poorly developed acrotelms. The set up has already been described in chapter 3.

4.3 RESULTS AND CONCLUSIONS

The data used for the calculations are in appendix 2. The calculation spreadsheet of the weighing data is in appendix 3, the calculation spreadsheet of adding data in appendix 4. The results of the calculations are given in table 4.1.

Table 4.1 Storage coefficients of upperlayers in lysimeters

Vegetation	Calluna vulgaris			
Lysimeter	1	2	15	16
Acrotelm	-	-	+	+
layer (cm -surface)	3-11	3-7	0-5	5-10
storage coef. (weight)	0.27	0.57	0.50	0.42
storage coef. (adding)	0.20	0.50	0.41	0.30
Vegetation	**Narthecium ossifragum**			
Lysimeter	3	5	13	14
Acrotelm	-	-	+	+
layer (cm -surface)	4-10	1-9	3-7	5-10
storage coef. (weight)	0.25	0.20	0.44	0.49
storage coef. (adding)	0.20	0.16	0.38	0.32
Vegetation	**Eriophorum augustifolium**			
Lysimeter	4	6	11	12
Acrotelm	-	-	+	+
layer (cm -surface)	3-12	3-10	8-13	8-13
storage coef. (weight)	0.24	0.31	0.42	0.46
storage coef. (adding)	0.19	0.26	0.32	0.33
Vegetation	**Sphagnum spec.**			
Lysimeter	7	8	9	10
Acrotelm	-	-	+	+
layer (cm -surface)	5-11	8-15	2-9	2-9
storage coef. (weight)	0.41	0.42	0.31	-
storage coef. (adding)	0.31	0.25	0.27	0.21

It is remarkable that the storage coefficient calculated by difference in weight at every lysimeter is higher than with adding water. The explanation is that if the water is added there is an amount of air enclosed in the small pores. Then there is a higher watertable measured as it would be in equilibrium situation. The enclosure is possible because of the abrupt addition. When water is removed there is still an amount of water enclosed in the small pores. Then a lower watertable is measured as in equilibrium situation.

This means that the storage coefficients calculated with weighing data are the most suitable in the waterbalance study. With the transmissivity tests in the acrotelm research water is removed abruptly from the acrotelm as well. Therefore the coefficients calculated with the water adding data are the most suitable for the transmissivity research.

The storage coefficient used for the calculation of the transmissivity is assumed to be 0.5. This seems to be rather high. An improvement has not been made yet because the results are based on only a few measurements and the influence on the value of the transmissivity is not very big.

The values of Calluna vulgaris are very variable. In the lysimeters with Nartecium ossifragum and Eriophorum vaginatum there is a distinctive difference between the values of well and poor developed acrotelms. In the lysimeters with Sphagnum this is not the case. This is probably because of the structure of the Sphagnum upper layer. They are the same, the storage coefficient is only measured in this upper layer.

CHAPTER 5

THE ACROTELM

5.1 INTRODUCTION

Description of the acrotelm

According to Ingram (1983), raised bogs function in two different zones from a hydrological point of view, i.e. the acrotelm and the catotelm. It can be stated that in a living raised bog the upper part of the peat deposit can be considered as a component of the acrotelm. In a raised bog of this kind this will usually consist of fresh to poorly humified peat for the greater part, but this is not necessarily so (Streefkerk and Casparie, 1989).

The acrotelm is defined as the system of living Sphagna, including their water supply. This is in practice the top layer of the living raised bog with a thickness of 0.10 to 0.30 m. The hydrological characteristics of this layer are its relatively high permeability and its periodically fluctuating groundwaterlevel which is mainly regulated by the amount of precipitation and evapotranspiration. Furthermore a change in height of the bog surface occurs during the year, caused by the capacity of the substratum to swell and shrink, depending on the weather conditions (Streefkerk and Casparie, 1989).

In the waterbalance and the modelling of the bogs the water transport in the acrotelm is considered to be of great importance. The transmissivity of the acrotelm can be very high because of horizontal water flow through big pores. This is in contrast with the catotelm where the transmissivity is very low.

Because of three main properties the acrotelm is hydrologically very complex:
- the variability of the structure of the acrotelm,
- the non stationary flow caused by a changing watertable,
- the downward decreasing permeability.

The structure of the acrotelm changes a lot on short and long distance. Because the acrotelm consists of hummocks and hollows there is a big difference in transmissivity at short distance. This is caused by different vegetation types. These have all there own structure which causes a very heterogenic pattern in the hydrological system.

At long distance the difference is also big, on the edge of the bog there is a poorly developed acrotelm with a low transmissivity and in the middle there is a well developed acrotelm with a high transmissivity.

The other aspect that makes the transmissivity very complex is the change of it during the year in relation to the watertable. Besides this change the hydraulic conductivity (k) in the layer is not homogeneous, this makes the system even more complex. The conductivity in the layer changes also during the year because of shrinking or swelling of the aquifer.

Objectives of the acrotelm research

It is considered that the outflow through the acrotelm can be derived from the surface slope and transmissivity (v.d. Schaaf, 1990). In this research work has been done to obtain a better insight in the transmissivity of the acrotelm.

As mentioned before the acrotelm has different hydrological characteristics. In this research the acrotelm is defined as the surfacepart of the bog, having high permeabilities and low humification degrees, compared to the catotelm. For groundwatermodelling this is a usable definition for the determination of the transmissivity of the acrotelm. The first purpose of this research is to test if there is an acrotelm in this sense on Raheenmore. This will be tested by comparing hydraulic conductivities of completely highly humificated surface aquifers with those of low humificated surface aquifers.

The second purpose is to determine different zones (with respect to humification and permeability) within the acrotelm.

The third purpose is the investigation of the relation between transmissivity and waterlevel (or relative thickness of the aquifer).

The fourth purpose is the investigation of the spatial variability of the thickness of the acrotelm on Raheenmore bog.

5.2 METHODS AND MATERIALS

The work is carried out in 2 parts:
- transmissivity/permeability tests on certain transects and with different waterlevels, and
- mapping of the colour and the humification degree of the first meter below the surface of the bog.

The plots where the transmissivity/permeability tests are done are also mapped. This combination will give answers to the questions concerning the relation between acrotelm structure and transmissivity. With the total mapping these results can be extrapolated to the whole bog.

In paragraph 5.2.1 the methods and materials of the transmissivity/ hydraulic conductivity tests are discussed. The mapping research is described in paragraph 5.2.2. The results will be discussed as a unit in paragraph 5.3.

5.2.1 TRANSMISSIVITY/HYDRAULIC CONDUCTIVITY

The transmissivity/hydraulic conductivity on Raheenmore bog is measured along two transects. For these transects the grid is used (appendix 1). This grid was placed by the O.P.W. (Office of Public Works). The grid has intervals of 100 m. On the bog it is marked with pegs. The holes are situated along the pegs of line L and 600. This means there is a North-South and East-West transect.

The holes are square. The size of a hole is approximately 0.2 x 0.2 meter. They are dug with a spade. Plastic tubes are put in to measure the watertables (figure 5.1)

At every peg one hole is dug. One should be aware of the fact that the variation in transmissivity at small distances is very large and not measured. Because of lack of time it was not possible to measure this. The holes are all situated in the lower parts of the bog (the hollows). That is the most important part where flow takes place.

When water is flowing through the acrotelm the transmissivity can be measured. When the thickness of the acrotelm is known, the permeability can be calculated. When the waterlevel is below the acrotelm, or when there is no acrotelm, there is only catotelm flow or surface flow. In the catotelm the permeability is measured. The surface flow is not measured.

The differences in transmissivities/permeabilities are so big that for measuring all of them 3 methods were needed:

- -Guinness method, for high acrotelm transmissivities/ permeabilities,
- -Pit Bailing method, for lower acrotelm transmissivities/ permeabilities and for high catotelm permeabilities,
- -Augerhole method, for low catotelm permeabilities.

These three methods are all based on Darcy's law. The principles of all three methods are the same. By measuring the velocity of water flow into a borehole with a certain waterlevel the permeability or transmissivity from the surrounding media is derived. The methods differ in marginal conditions and in approach of the measurements. They are described in the following part.

<u>The Guinness method</u>

For the measurements of high transmissivities in the acrotelm no method was available. Therefore S. Van Der Schaaf developed a new method. It is based on a radial flow towards a well. The well consists of an approximately square hole, dug with a spade, that fully penetrates the acrotelm. The waterlevel in the hole recovers very quickly. The sizes of the hole are measured to calculate the effective radius.

The effective radius is calculated with the formula (Van Der Schaaf, 1990):

$$r_{eff} = 0.6\ a \qquad (7)$$

r_{eff} = effective radius (m)
a = length of a side of the square borehole (m)

By taking out a constant discharge and measuring the drawdown the transmissivity can be derived (figure 5.1). In the beginning water was taken out with a 1 pint beer glass (hence the name of this method). By taking out a constant volume at constant intervals an approximately constant waterlevel was achieved. Later, a plungepump was used. The constant waterlevel installs in a very short time (1 to 2 minutes).

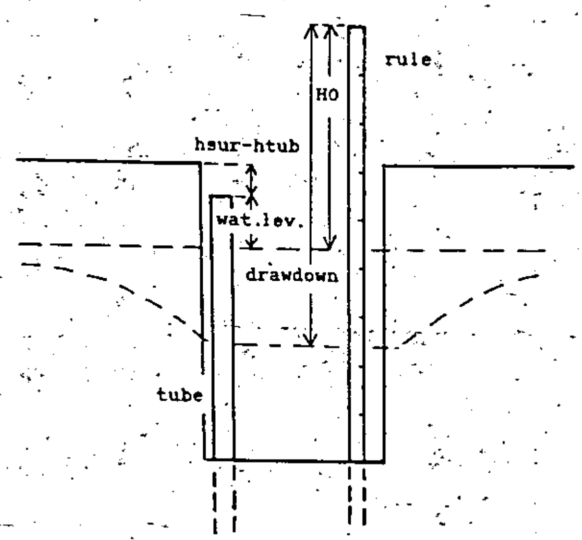

Figure 5.1 The set up of the acrotelm holes for the transmissivity/permeability tests.

Two different discharges were used. This is achieved with different lengths and diameters of the tubes through which the water is pumped away. The discharges were tested and measured. It is assumed that the discharge during the measurements are the same as the corresponding tested ones.

The transmissivity can be calculated with the formula:

$$T = Q \times \ln(n) / (2\pi \times s_w) \qquad (8)$$

T = transmissivity (m^2/s)
Q = discharge (m^3/s)
n = ratio between the radius of the well and the radius of the drawdowncone (-)
s_w = drawdown in well (m)

The ratio between the radius of the well and radius of the drawdowncone can be calculated with the formula (Van Der Schaaf, 1990):

$$t = \{1 + \{\mu\,[n^2 - 2 \times \ln(n) - 1]\} / 2\ln(n)\} \times \pi \times r_w^2 \times s_w / Q \qquad (9)$$

t = time needed to reach equilibrium (s)
μ = storagecoefficient (-)

The value of n cannot be calculated directly from the equation. It can however be read from the table in appendix 5. In the table the values of n are given for the term $[n^2 - 2\ln(n) - 1] / \ln(n)$. This term is equal to $(t \times Q / \pi \times r_w^2 \times s_w - 1) \times 2/\mu$. A high accuracy of n is not needed because the transmissivity depends on the logarithm of n.

For this method the following conditions have to be satisfied:
- the aquifer has to be penetrated totally,
- the extent of the acrotelm is much larger then the distance to which the phreatic level is noticeably effected by the drawdown in the well,
- the aquifer is homogeneous,
- the phreatic waterlevel is approximately horizontal before the test,
- the discharge rate has to be constant,
- the flow is horizontal,
- the thickness of the acrotelm is constant, and
- the drawdown must not exceed over 10% (preferably 5%) of the thickness of the acrotelm. It is therefore not allowed to be more than 3 cm.

Calibration of the Guinness method

The method has been calibrated. Therefore at some distance of the big hole, a small hole was added (see fig 5.2). The calibration has been done in two different ways. The first method was with plates (plate method). With the plates three sides of the big hole were blocked and the flow path from the small hole to the big one was screened. With this, while pumping, a horizontal flow was created. The hydraulic conductivity can simply be determined with Darcy's law and the continuity equation.

The second method is without plates. The only difference from the ordinary test is that a small hole, made with a finger, is added (finger method). For the calculation of the transmissivity formula 8 is used, with the value of n derived from the calibration (ratio between the radius of the well and the distance of the hole to the middle of the well). This method is derived from a pump test.

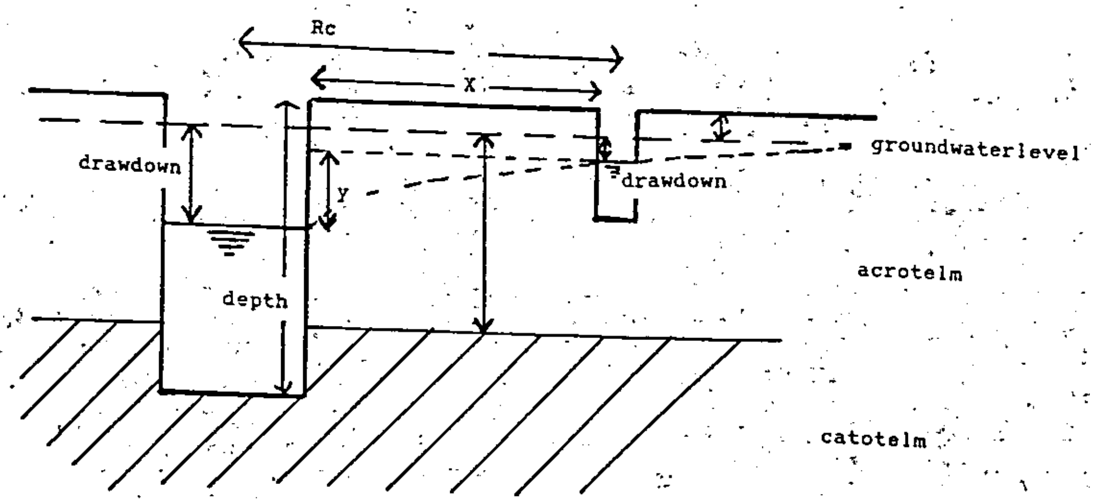

Figure 5.2 Calibration of the Guinness method

The Pit Bailing method

In case the drawdown exceeds over 2.5 cm, the Guinness method is not suitable anymore (drawdown exceeds 10% of the thickness of the acrotelm). Then, there is a switch to the Pit Bailing method.

This method was developed by Healy and Laak (1973) as a basis for the design of drain fields for septic tanks. The method has been refined by Bouwer and Rice (1983). The article of the latter two has been used.

With this method the same hole as with the Guinness method is used. When, after digging, the waterlevel in the hole has come to equilibrium, the waterlevel is lowered rapidly over a small distance (about 3 cm). The subsequent rate of rise of the water level is measured for calculation of k.

The method of calculating the hydraulic conductivity depends on wether the waterlevel is in or below the acrotelm. When it is in the acrotelm the Thiem equation is used. When it is below the acrotelm, the piezometer method equation is used.

The Thiem equation describes horizontal, steady state flow to a completely penetrating well. Laak and Healy assumed that the radius of influence of the pit was 4 times its own radius. The conductivity is calculated with the formula (see also figure 5.3, with the difference that the hole penetrates the whole aquifer):

$$k = A \times (dh/dt) \times \{1 / [2.27 (H^2 - h^2)]\} \qquad (10)$$

k = hydraulic conductivity	(m/s)
A = water surface area	(m^2)
dh/dt = velocity water rise	(m/s)
H = equilibrium height of watertable above the impermeable layer	(m)
h = height of rising water table above the impermeable layer	(m)

The main requirement for this equation is that the hole penetrates the aquifer completely. It is assumed that the catotelm has a very low hydraulic conductivity in comparison with the acrotelm, the catotelm is considered to be impermeable. In paragraph 5.3 the correctness of the assumption will be discussed.

The transmissivity is calculated by multiplying the thickness of the acrotelm by the calculated conductivity. The measured value is an average of the whole layer.

When the waterlevel is below the bottom of the acrotelm, there is only catotelm flow. Then, the Thiem equation cannot be used. It does not account for the upward flow through the bottom of the pit. In this case the piezometer method equation can be used (Bouwer and Rice, 1983). It can be used because the geometry of the flow system in the aquifer after the waterlevel in the pit has been lowered to measure its rate of rise is similar to that of the piezometer method. The formula is (for explanation see also figure 5.4):

$$k = \{\pi \times r / [(A_p/r) \times t]\} \times \ln (y_0/y_t) \qquad (11)$$

k = hydraulic conductivity	(m/s)
r = average radius of the hole	(m)
y_0 = distance y of the waterlevel below the equilibrium level after the waterlevel is lowered, at time 0	(m)
y_t = distance y at time t	(m)
t = time for the waterlevel to rise from y_0 to y_t	(s)
A_p = geometry factor	(m)

The geometry factor A_p can be obtained from the graph in appendix 7. Therefore the following factors need to be known (see also figure 5.3):

- the equilibrium waterdepth in the pit Lc,
- the average radius r, and
- the depth D of the impermeable layer below the bottom of the pit.

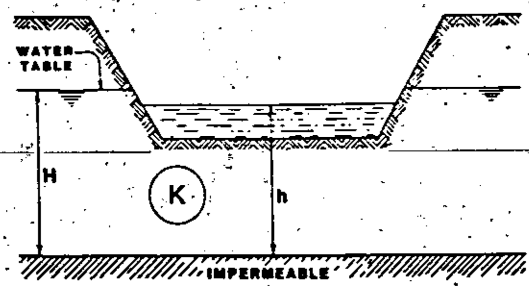

Figure 5.3 Geometry and symbols for the Pit Bailing method

The Augerhole method

The augerhole method is only used on the border from the bog. Here the inflow of water was so low that the rate of rise with the Pit Bailing method could not be measured. There was no acrotelm or the waterlevel was below the acrotelm and did not take part in the watersupply. This means that the conductivity from the catotelm is measured.

This method is very well described by Van Beers (1976) and in various other literature. Therefore this method will not be discussed in much detail.

In a borehole the groundwaterlevel is abruptly lowered to a certain point. By measuring the recovering velocity of the waterlevel the hydraulic conductivity of the surrounding ground can be calculated. The following formula is used to calculate the hydraulic conductivity (for explanation of the terms see also figure 5.4):

$$k = -C \times \Delta h/\Delta t \qquad (12)$$

k	= hydraulic conductivity	(m/d)
C	= geometry factor	(-)
$\Delta h/\Delta t$	= water rise velocity	(cm/s)

The geometry factor is a function of:

- the average hydraulic head,
- depth and radius of the borehole, and
- the distance of the bottom of the borehole to the sealing layer.

The value of C is calculated with a nomogram (appendix 8). The measuring of the rise of the watertable must be done before 25% of the bailed water has returned.

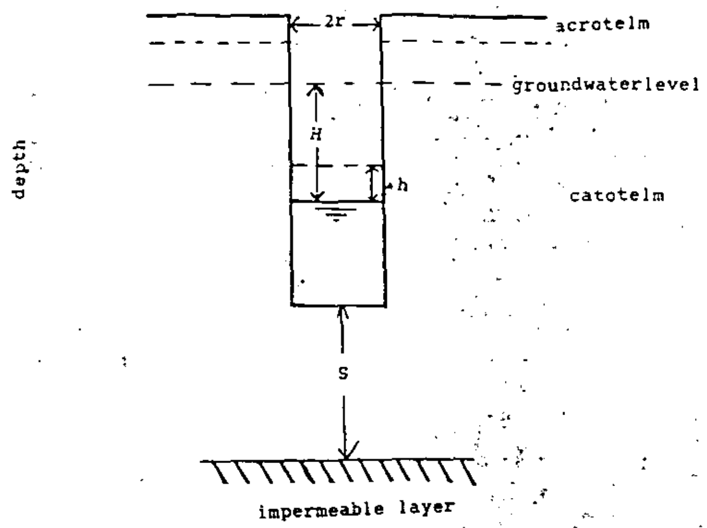

figure 5.4 The augerhole method.

5.2.2 ACROTELM MAPPING

At first instance a drilling to a depth of 1 meter below surface is carried out, using a special peat-auger. With this instrument relatively undisturbed peat samples can be taken. The drill has a sampling body consisting of half a cylinder with a length of 50 cm and a diameter of 4.5 cm. The drill turned out not to be suitable to sample poorly or unhumified peat near the surface of the bog. The drill compresses this peat and the peat is too fibrous to stay in the sampling body. The method was modified by using a spade for the upperpart.

The samples are investigated on humification degree and colour. The humification degree is determined with the "Von Post and Granlund scale" (appendix 11). The colours are determined with "Munsell's standard soil colour charts".

The drillings and diggings were carried out near all the pegs of the gridsystem (see appendix 1). This means that the plots have intervals of 100 meter. At first instance near each peg a plot was chosen randomly. With the results of these tests hardly any pattern could be drawn. This will be described in paragraph 5.3. The explanation was found in literature and by own experience.

The surface of a raised bog is characterised by a hummock and hollow complex. Hummocks and hollows respectively lie slightly higher and lower than the average bog surface. Sphagna occur more often in the hollows than on the hummocks. (Streefkerk and Casparie, 1989). The hollows consist of unhumified to poorly humified Sphagna, the hummocks are higher humificated. The hollows form a net-shaped discharge system. They are decisive for the acrotelm transmissivity. In figures 5.5 and 5.6 this is illustrated.

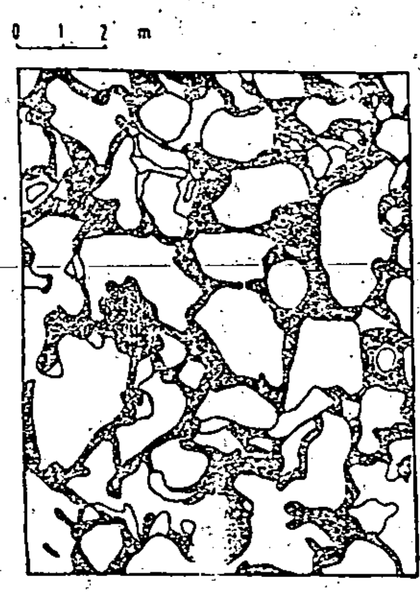

Figure 5.5 Vegetation pattern of the central part of Carbury Bog, Ireland. White areas portray hummocks; black areas represent for the most hollows and also some areas of open water (Schouten, 1984).

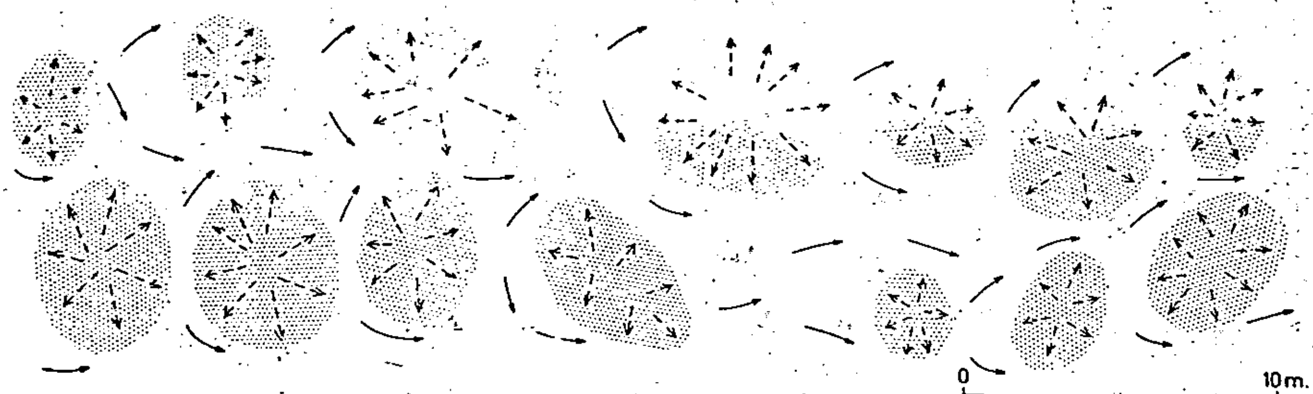

Figure 5.6 Water discharge from hummocks and via hollows of a raised bog (Streefkerk and Casparie, 1989).

With this new information a second mapping was done. It is assumed that this system also exists in the central parts of Raheenmore bog. Aerial photographs and vegetation mapping that will be done by Lara Kelly may give a definite answer. The method is modified as follows: if a digging/drilling isn't done in a Sphagnum vegetation, a digging at a plot with this vegetation in a hollow is added.

In order to correlate the mapping results with the transmissivity measurements the transmissivity holes are investigated. As it is not allowed to disturb the holes the drillings for the mapping of the deeper layers are done near the holes (at a distance of about 1 meter).

5.3 RESULTS AND CONCLUSIONS

The data of the first mapping are summarized in appendix 12. The data of the supplementary mapping are in appendix 13.

Acrotelm variation on short distance

At first some results of the first mapping research, where plots were randomly chosen, are compared to those where plots were chosen in hollows with Sphagnum (table 5.1).

Table 5.1 Differences in humification degree of corresponding layers of diggings near one peg, the mutual distances are approximately 1 meter.

coordinate	layer (cm)	vegetation	humification (Von Post)	humification Sphagnum hollow (Von Post)
J 300	0-10	Narthecium	5	3
K 000	0-10	Calluna	5	4
K 100	0-10	Narthecium	5/6	3
K 200	5-25	Calluna	6	3
K 300	0-20	Narthecium	6	3/4
K 400	0-15	Calluna	6	3
K 500	5-15	Sphagnum	6	4
K 900	0-30	Sphagnum	5/6	3
L 400	0-20	Sphagnum	5/6	4
L 500	5-20	Sphagnum	7	4

Only the most extreme diggings are selected. The results show that the humification of upperlayers can vary very much on a small distance. The humification in hollows with Sphagnum can be 1 to 3 degrees lower than at other locations, even on locations were Sphagnum grows as well. An explanation for this is the existence of many different kinds of Sphagna, connected with their own particular environments.

Relation between permeability and humification: determination of the acrotelm

In table 5.2 the results of the mapping and transmissivity/ hydraulic conductivity tests are summarised. The hydraulic conductivities are plotted against the humification in figure 5.7.

table 5.2 Permeabilities, transmissivities and humifications of the surface layer(s) on the transects on Raheenmore bog

date	coordinate	humification (Von Post)	method	conduct. (m/day)	thickn. perm.lay. (m)	transmis. (m2/day)
16-4-91	L-200	7	A	0.16	-	-
	L-100	4	P	104	0.06	6.2
	L 000	5	P	52	0.07	3.6
	L 100	4	P	60	0.07	4.2
	L 200	2	G	79	0.38	30
	L 300	3	G	237	0.38	90
	L 400	5	P	106	0.13	14
	L 500	4	G	380	0.15	57
	L 600	3	G	388	0.15	58
	L 700	3	P	123	0.03	6.2
	L 800	3.5	G	204	0.45	92
	L 900	3	G	2989	0.38	1187
	L1000	4	G	383	0.12	46
	L1100	3	G	896	0.13	116
	L1200	3	G	412	0.15	62
	L1300	4	G	533	0.12	64
	L1400	7	A	0.35	-	-
	I 600	6.6	A	0.11	-	-
	J 600	4	P	115	0.04	4.6
	K 600	4	G	329	0.08	26
	M 600	3.9	G	785	0.13	102
	N 600	3	G	222	0.15	33
	O 600	4	G	206	0.23	47
	P 600	3	G	101	0.32	32
	Q 600	4	G	788	0.08	63
	R 600	6.8	A	0.32	-	-
05-6-91	L-100	6	P	3.4	-	-
	L 000	7	P	1.2	-	-
	L 100	6	P	4.8	-	-
	L 200	2	P	24	0.28	6.8
	L 300	3	G	245	0.31	77
	L 400	6	A	1.2	-	-
	L 500	4	P	57	0.09	5.1
	L 600	3	P	56	0.09	5.1
	L 700	7	P	1.4	-	-
	L 800	4	P	27	0.25	6.8
	L 900	3	P	51	0.23	12
	L1100	5	P	4.5	-	-
	K 600	7	P	7	-	-
	M 600	3	G	1108	0.04	49.9
	N 600	3	P	63	0.06	3.8
	O 600	4	G	280	0.12	34
	P 600	3	G	199	0.20	40
	Q 600	6	A	0.34	-	-

At 05-6-91 holes L-200, L1000, L1200, L1300, L1400, I600 and J600 were dry or too muddy to measure.

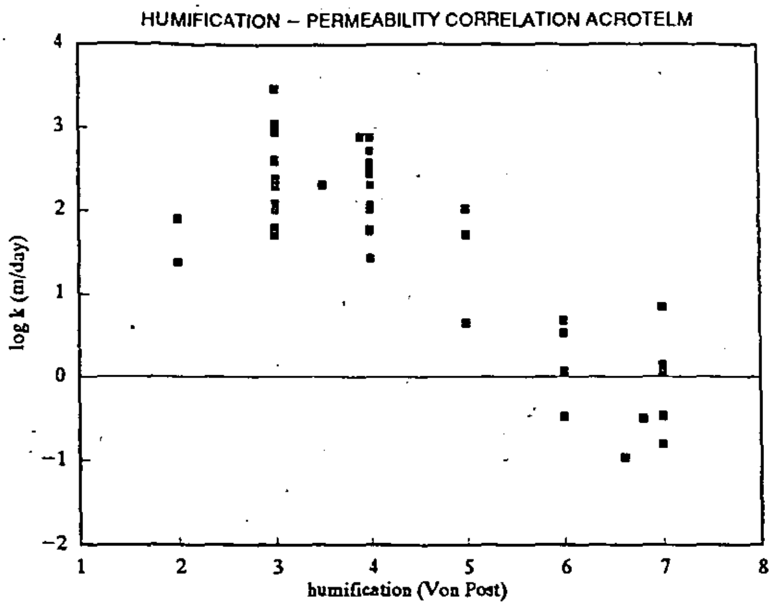

fig 5.7 Humification and permeability correlation graph

With the calculations it was assumed that the catotelm, being highly humificated, was impermeable compared with the acrotelm. The results show that this assumption was right.

The graph shows that there is a correlation between the humification degree and the hydraulic conductivity. There are two ranges of points, one from H2 to H4 and one of H6 and H7, having a different order of magnitude in hydraulic conductivity. From this it can be derived that, compared to layers having humification degrees from 2 to 4, layers with humification degrees 6 and 7 can be considered impermeable. Secondly, the mutual differences in hydraulic conductivities in the two groups are small. Therefore it is allowed to take a mean humification degree, when both layers are in the same group.

It is not clear in what way the layers with a humification degree 5 should be interpreted. At first only 3 measurements in these layers have been done. Secondly these measurements were done with high waterlevels (2 and 3 cm below surface). When there is a decreasing hydraulic conductivity with depth, these tests will overestimate the mean hydraulic conductivity of a surface layer with humification degree 5.

In total the results prove the existence of an acrotelm and a catotelm, with respect to hydraulic conductivity and humification. The acrotelm is the unhumified to poorly humified upperlayer (H1 to H4) with hydraulic conductivities from 25 to over 1000 m/day. The upperpart of the catotelm is highly humified (H6 and H7) with hydraulic conductivities varying between 0.1 and 7 m/day.

The variation is rather large. The variation can be associated with the large variations of the acrotelm quality in short distance, depending on the hummock-hollow complex. For instance, there are relatively low transmissivity values in a hole with a well developed acrotelm in a small hollow. Then, the flow to the hole is relatively small compared to a well developed acrotelm.

Checking of the permeability/transmissivity tests

The transmissivities measured with the Guinness method vary between 25 and 115 m^2/day. With the Pit Bailing method the values with the Thiem equation are between 8 and 15 m^2/day. Though there is a gap between these intervals, there is no reason to assume that the methods do not connect properly. The connection can be investigated by calculating the borderline cases with two methods.

The conductivities measured with the Augerhole method vary between 0.1 and 1 m/day. The conductivities measured with the Pit Bailing method in the catotelm vary between 1 and 7 m/day. This means that there is a good connection between these methods.

Calibration of the Guinness method

The calculations and results are summarized in appendix 6. The values derived with the Guinness method are given as well. The plate method gives much higher transmissivity values as the values calculated with the formula. A possible explanation for this is leakage between the plates. The finger method values are much more in agreement. Two of the three values agree sufficiently.

The calibration of the method is based on too few measurements. More measurements with the finger method have to be done by the other students.

Decreasing permeability with depth

Further on there is the question of the non-linear relation of transmissivity with the change of waterlevel, because of increasing hydraulic conductivity in the acrotelm with depth and because of shrinkage. Therefore the transmissivities are plotted against the relative thickness of the acrotelm saturated with water: D aquifer / D acrotelm (fig 5.8). The used data (locations, dates, waterlevels, acrotelm thickness) are given in table 5.3

Table 5.3 Acrotelm transmissivity in relation to waterlevel and thickness of the aquifer.

			16-4-1991			05-6-1991		
coordinate	humification (V Post)	thickn. acrot. (cm)	wat lev.-surf (cm)	thickn. welled layer (cm)	trans-miss. (m/d)	wat. lev-surf (cm)	thickn. welled layer (cm)	trans-miss. (m/d)
L-100	4	10	4	6	6.2	-	-	-
L 100	4	15	8	7	4.2	-	-	-
L 200	2	40	2	38	30	12	29	6.8
L 300	3	40	2	38	90	9	32	77
L 500	4	20	0	20	57	11	9	5.1
L 600	3	15	0	15	58	6	9	5.1
L 700	3	10	7	3	6.2	-	-	-
L 800	3/4	45	0	45	92	20	25	5.5
L 900	3	40	2	38	1187	18	22	12
L1000	4	15	3	12	46	-	-	-
L1100	3	15	2	13	116	-	-	-
L1200	3	20	5	15	62	-	-	-
L1300	4	15	3	12	64	-	-	-
K 600	4	10	2	8	26	-	-	-
M 600	3	15	2	13	102	11	4	50
N 600	3	15	0	15	33	9	6	3.8
O 600	4	25	2	23	47	13	12	34
P 600	3	35	3	32	32	15	20	40
Q 600	4	10	2	8	63	-	-	-

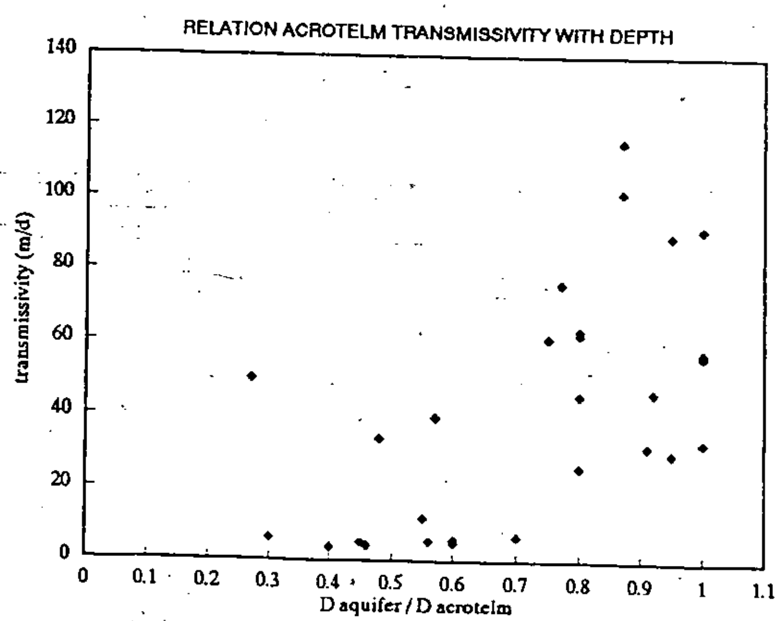

Figure 5.8 Relation transmissivity and relative thickness of the aquifer in the acrotelm

It is very hard to distinguish a relation in the graph in fig 5.8. Perhaps this will be possible when more measurements in the same holes with different waterlevels are done.

Mapping of the whole bog

The complete drillings are worked out in cross sections along the grid lines. They are given in appendix 14. As a result of the previous research on the transects it is known that the acrotelm is formed by surface layers with almost unhumified to poorly humified peat (H2-H4). The moderately humified surface layers (H5) are not taken into account, as it is not clear if they belong to the acrotelm or the catotelm. The catotelm is below the acrotelm and consists of highly humified peat (H6 and H7), and also a layer with moderately humificated peat.

The cross sections show that the acrotelm is well developed in the central part of the bog (in the hollow network). The pattern is very heterogeneous. This can be caused by a large variation in the depths of the hollows. In the direction of the bog edge the acrotelm quality decreases. Near the edges the acrotelm is (almost) absent.

Again, the acrotelm is continuously present in the hollow network at the central parts of the bog. At flat parts of the bog the acrotelm is thick. On the slopes the acrotelm is thin or absent. This is not only the case at the edges, but also in the central part of the bog. It seems as if the acrotelm is built up like a staircase. Sometimes the stairs are separated by more humified parts. The stairs seem to form basins. With a low water level these basins are isolated and the discharge decreases strongly.

At places where the acrotelm is thin the abundance of the hollows usually decreases. At some stage they will not form a network anymore. This can be the case on the edges of the basins. Then the higher humified upperparts of the bog will be the decisive medium for the waterflow. There will be a high resistance for the waterflow. The groudwaterflow will change here in overland flow in times of big discharge.

It is recommended to investigate the basin working nearer, by an investigation of the absence or presence of the hollow network on the edges of the basins. This can be done by comparing the acrotelm mapping with the vegetation mapping and with supplementary fieldwork. If the network is absent supplementary augerings have to be done at plots where until now only augerings are carried out in Sphagnum.

The presence or absence of basins can also be derived in another way. In future the transmissivities will be measured at low waterlevels. By comparing the calculated discharge with the measured discharge in the v-notch, it can be derived if there is a basin working.

There is a second permeable layer between 0.5 and 1.0 meter below the surface. If the layer is continuous it might transmit a considerable amount of water. The humification degree is 4 and 5. The transmissivity cannot be derived from the previous tests, as the layer is probably more compact than a acrotelm layer with the same degree of humification. The transmissivity can be measured with tests in deep holes, at places without waterflow through the acrotelm. This is possible on the edges of the bog and/or during dry periods when the watertable is low.

CHAPTER 6

PIEZOMETERTEST

6.1 INTRODUCTION

In order to calculate the flow of water in the peat the hydraulic conductivity must be known. The basic relationship describing soil water flow is Darcy's law:

$$v = - k \cdot i \qquad (13)$$

v = flow velocity (m/d)
k = hydraulic conductivity (m/d)
i = dh/dx = hydraulic gradient (-)

In this project two methods have been used to measure the hydraulic conductivity:
- the rising head piezometer method (Van Gerwen, 1990, Huisman, 1991 and Flynn, 1990), and
- the constant head piezometer method (Flynn, 1990 and Henderson, 1991).

The results of the previous rising head tests give lower values as reported in literature (Van Der Schaaf, 1990). It is not unlikely that the tests give too low values. A piezometer test is set up to sort out this problem.

The test deals with the following subjects:
- filter geometry: perforation rate and filter length,
- sealing of the tube, and
- falling, rising and constant head method.

The piezometers used in the project are all made by hand. Because of this there is no standard perforation rate and filter length, every tube is slightly different. According to the descriptions of the used methods the perforation has no influence on the derived conductivity as long as the inflow of water is not limited. The filter length has influence on the derived conductivity as it is calculated in the geometry factor.

The influence of the shape of the sealing of the piezometers is also tested. According to J. Mulqueen (Teagasc/UCG) the sealing of the tubes as used in the project has an influence on the permeability measurements. All piezometers in the project are sealed with rubber furrels. They have a slightly larger diameter then the tubes. Therefore they make a bigger hole around the piezometer (see fig 6.2).

Besides rising head, falling and constant head methods are examined. According to Flynn (1990) falling and rising head methods are not suitable as the peat is disturbed excessively. The constant head test is an approximative method of acquiring undisturbed hydraulic conductivities.

6.2 METHODS AND MATERIALS

The coordinates of the locations of the tests are: K 900 for test 1 and K 1250 for test 2. (See appendix 1). The testscheme with the numbers of the tubes is given in figure 6.1.

furrel			cork		
perforation (%) \ filter length (cm)	10	20	perforation (%) \ filter length (cm)	10	20
10	2,6	1,5	10	10,14	9,13
20	3,7	4,8	20	12,16	11,15

test 1: falling, rising and constant head with furrel sealing
test 2: falling, rising and constant head with furrel and cork sealing

figure 6.1 Scheme piezometer test

The test has been carried out at two different plots. The piezometers at the first plot were placed by H. Lenses in December 1990, with a mutual distance of 0.5 meter. The total length of the piezometers is 3 meter, 35 cm of that sticks above surface level, so the cavities are at ± 2.65 meter below surfacelevel. The diameter of the tubes is 2.5 cm.

The first plot existed of two piezometers of each kind of filter geometry. Their numbers are 1 to 8 (see fig 6.1). The test consists piezometers having filters with perforation percentages of 10 and 20%, and filter lengths of 10 and 20 cm. All piezometers were sealed with a furrel.

When the piezometers of the first test were taken out the geotextile of all piezometers appeared to have the same length (25 cm). This might have had an influence on the measurements concerning the shapefactor.

Besides piezometers sealed with furrel, there were also piezometers sealed with cork at the second plot. The cork fits completely in the tube (see figure 6.2). The geotextile had the same length as the filter. This test was also carried out in duplicate. This makes a total of 16 piezometers. (see fig 6.1). Their mutual distances were 1 meter. The measurements took place 14 days after the piezometers were installed.

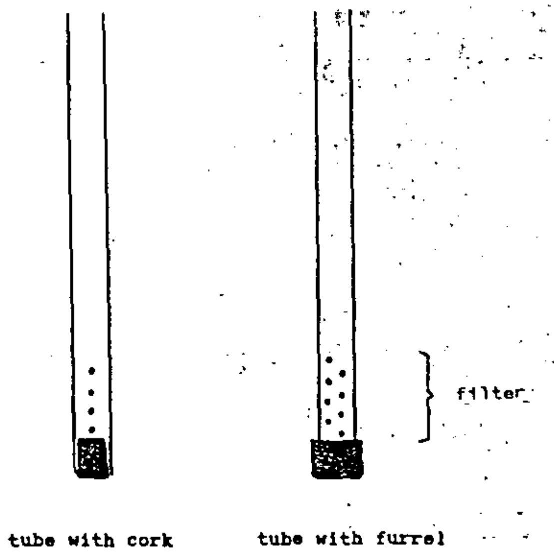

figure 6.2 Tubes sealed with a furrel and with a cork.

<u>Rising and falling head test</u>

The rising head piezometer method was developed by Luthin and Kirkham (1949). It consists of measuring the rate of flow into a piezometer, after removing a certain amount of water from the tube. In Van Gerwen (1990) a more comprehensive description is given. R.M. Flynn used the approach of Hvorslev (1951) for the rising head.

The formulas for the calculation of the conductivity of the rising and falling head are the same. They are supposed to be each others contrary. The principles of both of them are the same. The only difference is that water is added with the falling head and that water is drawn out with the rising head. The calculated conductivity of both methods in one tube should be the same.

The formula used for calculations is developed by Luthin and Kirkham. For explanation of the terms see also fig 6.3.

$$k = \pi \times R^2 \times \ln(Y1/Y2) \; / \; (A \times (t2 - t1)) \qquad (14)$$

k = hydraulic conductivity	(m/s)
t1, t2 = time at time 1, 2	(s)
Y1, Y2 = hydraulic head at time 1, 2	(m)
R = radius of the tube	(m)
A = geometrical constant	(m)

The geometric constant is dependent on dimensions of the filter part. It can be obtained from the graph in appendix 15.

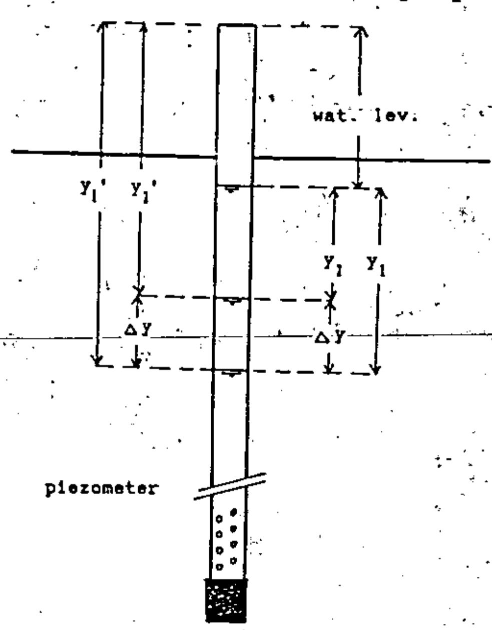

fig 6.3 Symbols of rising and falling head piezometer test

Constant head test

The constant head method was developed by Rycroft (1973) It consists of measuring the inflow of water in a piezometer by using a small imposed constant head. A more comprehensive description is given by Flynn (1990) and Henderson (1991).

The constant head is achieved with a mariotte vessel (see fig 6.4), in which the outflow can be measured. The conductivity can simply be derived with the formula:

$$k = Q\ infin / (S \times Y0) \tag{16}$$

Q infin = steady flow rate (m^3/s)
k = hydraulic conductivity (m/s)
Y0 = constant imposed head (m)
S = shapefactor (m)

The shapefactor is calculated with the next formula (Flynn 1990) :

$$S = 2 \times \pi \times L / \ln\{L / d + [1 + (l / d)^2]^{1/2}\} \tag{17}$$

L = length of the tube with cavities (m)
d = diameter (m)

The imposed head can be calculated with the following formula (for explanation of the symbols see also fig 6.4):

$$YO = (h_0 + a) - (l_{tv} + b) \qquad (15)$$

YO = imposed head (m)
h_0 = equilibrium height of watertable (below top of piezometer) (m)
a = distance between top of piezometer and waterlevel instrument (m)
l_{tv} = length of tube in vessel (m)
b = distance between top of tube in vessel and waterlevel instrument (m)

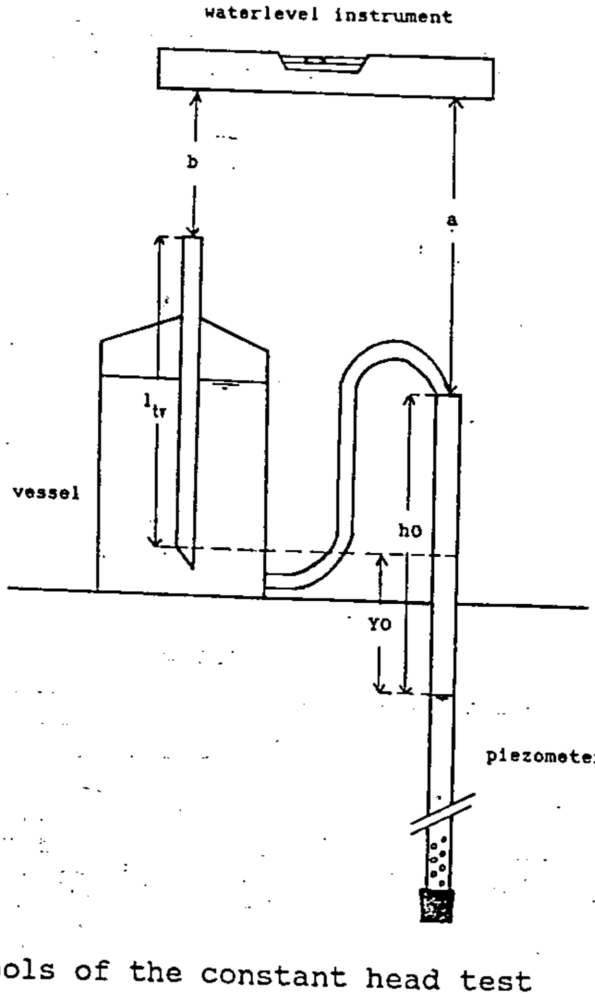

fig 6.4 Symbols of the constant head test

The rising and falling head tests at the first plot were carried out slightly different from the tests at the second plot. With the first rising and falling head tests the waterlevel was measured in one serie of about 2 hours. The drawdown was 0.2 to 0.4 meter. The calculations have been done as described above.

After a meeting with S. van der Schaaf it was agreed that the measurements in one tube would be repeated several times after each other. By repeating the tests several times the changes of the waterlevels become steady. Then the situation around the piezometer is stationary. Therefore the last measured velocities are used for calculating the conductivity.

With this method the water level should be measured in the part where the imposed head was bigger than 0.20 meter (Klute, 1986). Therefore the measurements in test 2 are done in a shorter time and with bigger imposed head than in test 1. The calculations of this plot have been done as described in appendix 18.

From the first plot the measurements of the steepest part of the graph were used. This was the part where the imposed head was bigger than 20 cm. In comparison with the measurements of the second plot the velocity that is measured is higher and therefore the conductivity is relatively higher as well. The measurements could not be repeated because the tubes were already moved.

6.3 RESULTS AND CONCLUSIONS

The calculations and the graphs of the measurements of the first plot are in appendix 16, the calculations and graphs of the second plot are in appendix 17. The calculated conductivities are in table 6.1.

When equal piezometers and tests are mutually compared the values differ a lot. They differ from 1 to 20 times. Probably the test field is not homogeneous. This means that the results must be interpretated carefully. Another test, if possible in a more homogeneous area, has to be added.

The values of the different conductivities measured with the same method are not distinctive. Considering the graphs in appendix 16 and 17 there is a little changing difference between the rise or fall of the waterlevel in the piezometers. The conductivity especially depends on the transect that is chosen for calculations and the geometry factor. Most graphs are about the same. They only differ in starting height. At the first plot this might be caused by the geotextile, but at the second plot the same thing occurs with both falling and rising head. With the constant head there are also a lot of piezometers with the same rate of inflow. This means that with these tests no influence of filter length and perforation rate can be determined yet.

When the three methods are compared there is a big difference in magnitude in determined hydraulic conductivities. At the first plot the rising head tests give bigger values than the falling head tests. In the second plot the opposite happens. This difference between test 1 and 2 can be caused by the difference in time between placing of the tubes and measuring. At the second plot the hydraulic conductivities measured with the constant head show no distinctive difference with the rising head method. The hydraulic conductivities measured with the falling head are much higher. May be the high water pressure at the start of the falling head test causes a hole around the piezometer, through which the water flows away easily.

Table 6.1 Hydraulic conductivities obtained from piezometer tests

test 1

tubenr.	perforation (%)	lenght cavity (cm)	conductivity (m/day) rising	falling	constant
2	10	10	0.23	0.09	0.16
6	10	10	0.56	0.39	-
1	10	20	0.42	0.12	0.08
5	10	20	0.87	0.43	0.03
4	20	10	0.55	0.16	0.12
8	20	10	0.55	0.45	0.20
3	20	20	0.35	0.15	0.07
7	20	20	0.63	0.35	0.07

test 2

tubenr.	perforation (%)	lenght cavity (cm)	conductivity (m/day) rising	falling	constant
2	10	10	0.80	x	10.13
6	10	10	0.88	x	1.70
1	10	20	0.07	x	0.13
5	10	20	0.39	x	0.58
4	20	10	0.44	x	1.59
8	20	10	0.13	x	0.09
3	20	20	0.06	x	0.21
7	20	20	0.01	0.44	-
10	10	10	0.032	0.59	-
14	10	10	0.117	0.63	0.06
9	10	20	0.024	0.61	0.18
13	10	20	0.070	0.81	0.01
12	20	10	0.130	0.52	0.31
16	20	10	0.140	0.53	0.18
11	20	20	0.055	0.55	0.03
15	20	20	0.231	0.98	0.04

x = flow rate too high to be measured
- = no value due to failure vessel

With all methods, the values measured in piezometers with furrel are much higher than those with cork. The furrel probably drives a hole around the piezometer, through which the water can flow away (or in) very fast. This means that the present piezometers used in the project, all with furrels, are not suitable to measure permeabilities.

The constant head is difficult because a lot of water is needed, the equipment sometimes doesn't operate and failures in the measurements are hard to see. The falling and rising tests are simple and their equipment is very limited. Because of the high flow rate the falling head test was hard to execute.

CHAPTER 7

BOUNDARY SURVEY

7.1 INTRODUCTION

A catchment boundary is the border of a catchment area, an area where all water discharge is going through one watercourse. The catchment boundary of groundwater is not necessary the same as the boundary of the surfacewater.

At Raheenmore the discharge that takes place in the drains is supposed to be measured. Therefore a special drain has been dug which connects a lot of drains. The discharge is measured by a V-notch and a waterlevel recorder. They are installed at the end of the drain.

For catchment calculations it is necessary to have an estimation of the size of the catchmentarea. For this purpose a boundary survey was set up. Four sets of 3 phreatic tubes are placed on Raheenmore (locations see appendix 19). This was based on the topography of the bog. By measuring the waterlevel in the tubes every 2 weeks the catchment boundary was hoped to be estimated.

After a field inspection of the waterflow in the drains it appeared that the catchment boundary is not properly assessed. Two sets of piezometers have a drain in between them. The waterlevels of those piezometers will be influenced by the drains. Even though the drains are fullgrown with vegetation there is still a flow in the drains. This will have an influence on the waterlevel in the ground next to the drain and the water in the drains was flowing to another side as the boundary indicated. As a result of the influence of the drains not the catchment boundary is measured, but the waterlevels of different areas.

It also appeared that the main drain (drain nr 1 appendix 18) on the North-side in the area is not included in the catchment, there is a lot of water flowing through that drain and it is not exactly known where it flows to. Partly it will go as overlandflow into the drain that leads to the V-notch but there is also a part that runs off without being measured.The drain is blocked and at the end water is visible leaking. The boundary survey sets 3 and 4 are both outside this area and therefore overestimate the catchmentarea.

7.2 METHODS AND MATERIALS

The fieldinspection was done on 22-3-1991, after a period with a lot of rainfall. Then it was decided to place a few extra

piezometers on the crucial points. In total 9 phreatic piezometers were installed. They had 3 meter of tube under the filter, because of the instable place where they were installed (old drain).
The waterlevel in the piezometers has been measured twice and they are levelled on 25-4-1991.

7.3 RESULTS

The results of the measurements are in table 7.1 The locations of the piezometers are shown in appendix 19

The measurements from the two data of the piezometers 1, 2, 3, 5, 6 and 7 are giving different flow directions. Conclusions based on these two measurements concerning the catchment boundary cannot be drawn. It is recommended to measure these tubes with the normal monitoring and place another 3 or 4 tubes in addition.

The water that is not measured in drain 1 should be led in catchment area or a new boundary-line has to be drawn. It is hard to find out what is happening in this drain. A good block and a little drain to the recorder would solve the problem.

table 7.1 levelling and monitoring data extra piezometers

tube	top tube level (m BOD)	waterlevel 13-4-91	waterlevel 3-5-1991
1	104.928	104.55	104.52
2	104.952	104.56	104.53
3	104.919	104.56	104.53
4	104.832	104.45	104.40
5	104.835	104.40	104.33
6	104.816	104.33	104.29
7	104.823	104.31	104.39
8	103.697	103.28	103.27
9	103.701	103.27	103.23

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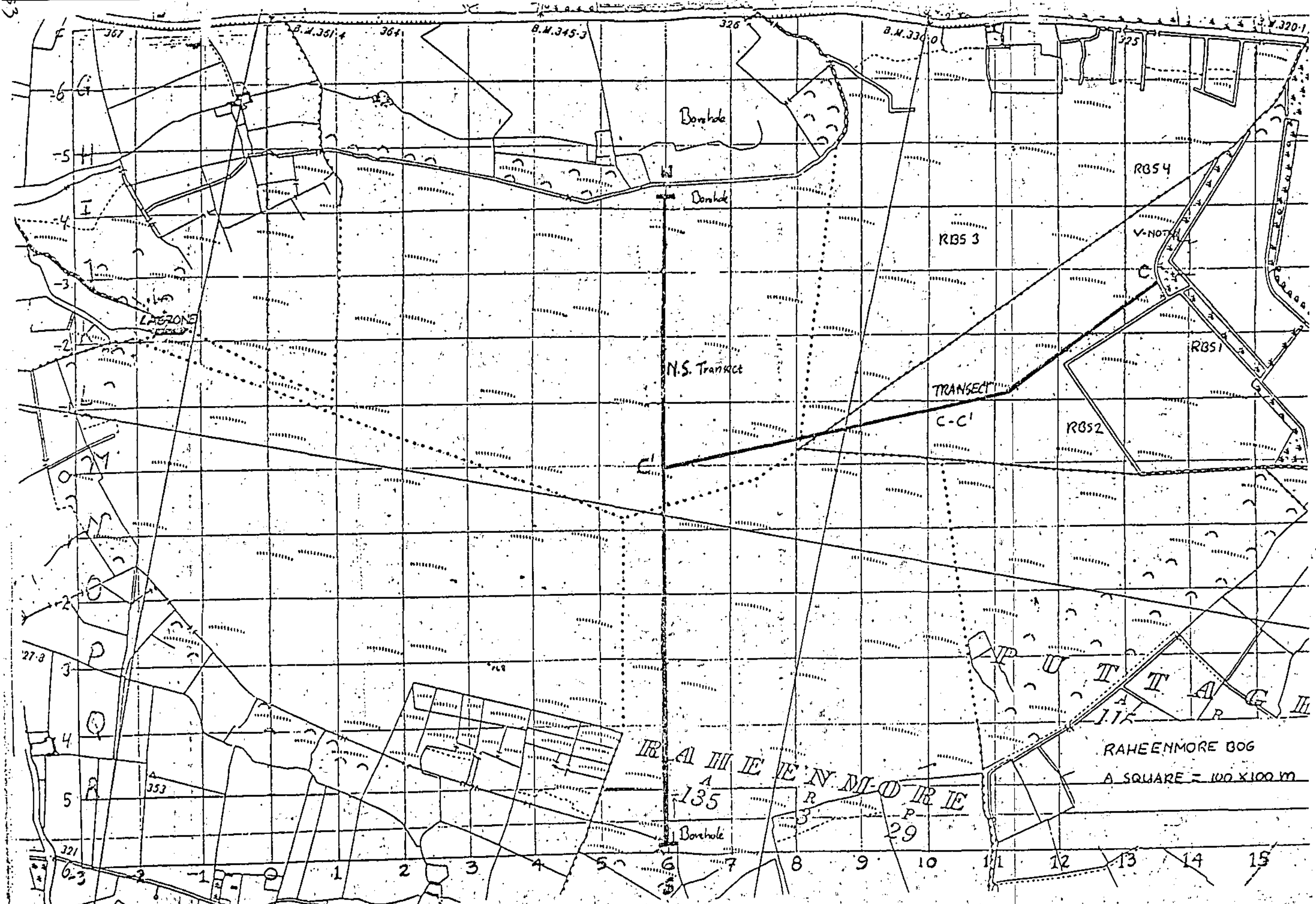
APPENDICES

1 Grid Raheenmore
2 Data lysimeters Raheenmore
3 Calculations storage coefficients of upperlayers in lysimeters with weighing data
4 Calculations storage coefficients of upperlayers in lysimeters with water adding data
5 Table for determination n-value in the formula of the Guinness method
6 Data and calculations of the calibration of the Guinness method
7 Graph for the determination of the geometry factor A_p in the Pit Bailing test (piezometer method approach)
8 Graph for the determination of the geometry factor C in the Augerhole test
9 Data and calculations of the acrotelm transmissivity/ permeabillity tests at 16-4-1991
10 Data and calculations of the acrotelm transmissivity/ permeabillity tests at 5-6-1991
11 The Von Post and Granlund humification scale
12 Data of the first acrotelm mapping
13 Data of the supplementary acrotelm mapping in Sphagnum holes
14 Cross sections of the acrotelm
15 Nomograms for the determination of the geometric constant in the falling and rising head test
16 Data, calculations and graphs of piezometer test 1
17 Data, calculations and graphs of piezometer test 2
18 Standard paper for Rising head piezometertest and nomogram for determing A'
19 Map of drains and additional piezometers on Raheenmore

APPENDIX 1 THE GRID ON RAHEENMORE



APPENDIX 2 DATA LYSIMETERS RAHEENMORE

FIXED DATA

NR	INSTAL-DATE	VEGETATION	VEG. (ENGLISH)	ACRO-TELM	TUBE-LENGHT (CM)
01	12-2-91	Calluna vulgaris (+ Erica)	Heather	bad	66.8
02	12-2-91	Calluna vulgaris (+Erica)	Heather	bad	88.0
03	12-2-91	Narthecium ossifragum	Bog Asphodel	bad	67.7
04	12-2-91	Eriophorum augustifolium	Common Cotton-Grass	bad	67.1
05	12-2-91	Narthecium ossifragum	Bog Asphodel	bad	67.8
06	12-2-91	Eriophorum augustifolium	Common Cotton-Grass	bad	68.7
07	12-2-91	Sphagnum spec.	Peat Moss	bad	67.4
08	12-2-91	Sphagnum spec.	Peat Moss	bad	68.5
09	19-2-91	Sphagnum spec.	Peat Moss	good	68.8
10	19-2-91	Sphagnum spec.	Peat Moss	good	69.4
11	19-2-91	Eriophorum augustifolium	Common Cotton-Grass	good	68.6
12	19-2-91	Eriophorum augustifolium	Common Cotton-Grass	good	69.2
13	19-2-91	Narthecium ossifragum	Bog Asphodel	good	67.8
14	19-2-91	Narthecium ossifragum	Bog Asphodel	good	69.5
15	19-2-91	Calluna vulgaris (+Erica)	Heather	good	68.5
16	19-2-91	Calluna vulgaris (+Erica)	Heather	good	70.5

- LOCATIONS: lysimeters with bad acrotelm: K70 1160
  lysimeters with good acrotelm: K20 880
  all lysimeters are removed to K20 880

- LYSIMETER HEIGHT: 50 cm
  LYSIMETER DIAMETER: 40 cm

WEIGHING DATA

W = Weight (kg)

DATE	W1	W2	W3	W4	W5	W6
07-Apr-91	65.5	62.5	63.2	64.4	66.9	64.0
15-Apr-91	65.4	63.0	63.1	64.2	67.0	64.0
19-Apr-91	64.3	61.7	61.8	62.9	65.9	62.9
26-Apr-91	66.1	63.8	63.7	64.8	67.4	65.4
03-May-91	66.3	64.2	63.5	64.6	66.7	64.7
10-May-91	64.9	63.0	62.7	63.1	65.8	63.5
17-May-91	62.9	61.2	62.4	62.6	65.8	62.3
23-may-91	62.5	60.3	61.8	62.1	65.8	62.0

	W7	W8	W9	W10	W11	W12
07-Apr-91	64.4	64.4	65.1	63.6	63.3	63.9
15-Apr-91	65.0	63.8	65.0	63.0	62.9	64.7
19-Apr-91	63.3	61.9	63.5	61.6	61.4	62.8
26-Apr-91	65.4	63.6	65.9	63.8	63.5	64.8
03-May-91	66.1	64.2	65.1	64.4	64.2	65.1
10-May-91	64.3	62.9	64.6	63.8	62.6	63.3
17-May-91	63.1	62.3	64.2	63.9	61.8	62.3
23-may-91	63.1	62.2	65.0	64.6	61.9	63.1

	W13	W14	W15	W16
07-Apr-91	62.2	63.1	59.4	63.3
15-Apr-91	62.8	63.4	61.9	65.0
19-Apr-91	61.7	61.9	60.8	63.3
26-Apr-91	64.2	64.1	63.2	65.5
03-May-91	63.6	64.1	62.5	65.5
10-May-91	62.4	62.6	61.4	63.9
17-May-91	61.9	62.4	60.1	63.1
23-may-91	62.6	63.1	59.9	62.8

REMARKS

07-Apr-91 lysimeters overflooding?

15-Apr-91 lysimeter 5 missed the bungs, water in/out flow

WATERLEVEL DATA

WL = Waterlevel in cm from top of tube.
B, the first A, and N stand for resp. before, after and no.
W and the second A stand for resp. weighing and adding water.

DATE	ORDER	WL1	WL2	WL3	WL4	WL5	WL6
07-Apr-91		23.7	24.1	26.4	23.2	24.2	26.6
15-Apr-91	BW-NA	25.9	24.7	27.6	24.9	23.8	26.7
19-Apr-91	BW-BA	29.1	26.9	31.0	29.3	28.0	29.8
19-Apr-91	AW-AA	20.9	23.7	25.4	23.7	21.2	23.7
26-Apr-91	BW-BA	21.8	23.5	23.8	22.1	20.5	23.1
03-May-91	AW-AA	21.2	23.0	26.0	23.1	24.7	24.9
10-May-91	BW-NA	26.2	24.1	27.5	27.5	27.5	27.5
15-May-91	NW-BA	29.7	25.9	30.9	31.8	29.2	30.2
15-May-91	NW-AA	27.3	26.1	26.4	26.2	24.5	30.4
17-May-91	BW-BA	30.3	26.8	29.2	29.1	26.6	31.1
21-May-91	NW-BA	31.0	29.2	32.0	34.0	28.6	33.0
23-May-91	BW-BA	31.2	28.3	30.5	30.7	26.1	31.3
23-May-91	AW-AA	31.2	28.3	30.5	30.7	26.1	31.3

DATE	ORDER	WL7	WL8	WL9	WL10	WL11	WL12
07-Apr-91		25.1	26.0	25.6	27.7	26.5	27.5
15-Apr-91	BW-NA	24.2	26.6	26.6	30.0	27.1	26.5
19-Apr-91	BW-BA	28.0	31.0	29.7	23.0	30.3	29.4
19-Apr-91	AW-AA	23.2	25.8	23.9	27.2	26.0	25.3
26-Apr-91	BW-BA	23.1	27.2	23.5	27.3	25.5	25.6
03-May-91	AW-AA	22.2	26.3	25.9	25.7	24.7	25.2
10-May-91	BW-NA	25.5	27.5	26.3	27.7	27.5	28.2
15-May-91	NW-BA	28.8	32.9	30.1	32.0	29.8	30.7
15-May-91	NW-AA	26.0	26.2	25.6	25.0	26.8	27.8
17-May-91	BW-BA	28.2	29.5	27.9	28.7	28.6	29.7
21-May-91	NW-BA	30.3	32.1	28.5	29.9	29.7	31.3
23-May-91	BW-BA	29.5	32.3	28.1	29.2	28.8	30.2
23-May-91	AW-AA	27.0	28.5	25.0	25.1	27.4	27.7

DATE	ORDER	WL13	WL14	WL15	WL16
07-Apr-91		27.7	28.5	29.5	31.4
15-Apr-91	BW-NA	26.6	27.7	26.5	27.7
19-Apr-91	BW-BA	28.7	30.2	28.1	30.5
19-Apr-91	AW-AA	24.5	25.5	24.2	25.2
26-Apr-91	BW-BA	24.0	26.4	23.3	25.8
03-May-91	AW-AA	25.6	26.2	25.2	26.0
10-May-91	BW-NA	27.3	29.0	26.2	29.1
15-May-91	NW-BA	29.4	31.2	28.0	31.7
15-May-91	NW-AA	26.7	27.4	28.2	29.0
17-May-91	BW-BA	28.1	29.0	28.7	30.8
21-May-91	NW-BA	29.0	29.2	29.4	31.5
23-May-91	BW-BA	28.3	28.5	28.5	30.4
23-May-91	AW-AA	26.4	27.2	28.5	30.4

WATER ADDING DATA

V = volume of added water (l)

DATE	ADD	V1	V2	V3	V4	V5	V6
13-Apr-91	-	-2.30	-3.23	-3.55	-3.04	88.88	-3.21
19-Apr-91	aft	2.00	2.00	1.50	1.68	1.26	2.00
26-Apr-91	aft	-0.70	-0.44	0.00	-0.44	-0.96	-0.69
03-May-91	bef	0.00	-0.94	-1.32	-0.46	-0.46	-1.00
08-May-91	-	0.50	0.50	0.50	0.00	0.00	0.00
15-May-91	-	1.00	0.00	1.07	1.00	1.00	0.00
17-May-91	aft	1.00	0.00	0.00	0.00	0.00	0.00
21-May-91	-	1.00	1.00	1.00	1.00	1.00	1.00
23-May-91	bef	0.00	0.00	0.00	0.00	0.00	0.00

DATE	ADD	V7	V8	V9	V10	V11	V12
13-Apr-91	-	-2.27	-3.00	-1.30	-3.10	-3.44	-3.14
19-Apr-91	aft	2.00	2.00	2.00	2.00	2.00	2.00
26-Apr-91	aft	-0.26	0.00	-0.31	0.00	-0.38	-0.40
03-May-91	bef	0.00	0.00	0.00	0.00	0.00	0.00
08-May-91	-	0.00	1.00	1.00	1.00	0.00	0.00
15-May-91	-	1.00	2.00	1.50	2.00	1.00	1.00
17-May-91	aft	0.45	0.55	1.00	1.00	0.50	0.50
21-May-91	-	1.00	1.00	1.00	1.00	1.00	1.00
23-May-91	bef	0.70	1.00	1.00	1.00	0.50	1.00

DATE	ADD	V13	V14	V15	V16
13-Apr-91	-	-1.75	-2.61	-0.86	-1.52
19-Apr-91	aft	2.00	2.00	2.00	2.00
26-Apr-91	aft	-0.79	-0.37	-0.80	-0.47
03-May-91	bef	-0.83	0.00	-0.84	-0.42
08-May-91	-	0.00	0.00	0.00	0.00
15-May-91	-	1.00	1.50	0.00	1.00
17-May-91	aft	0.50	0.50	0.00	0.50
21-May-91	-	1.00	1.00	1.00	1.00
23-May-91	bef	0.81	0.58	0.00	0.00

ADD explains if the water is added to the lysimeter before or after weighing.

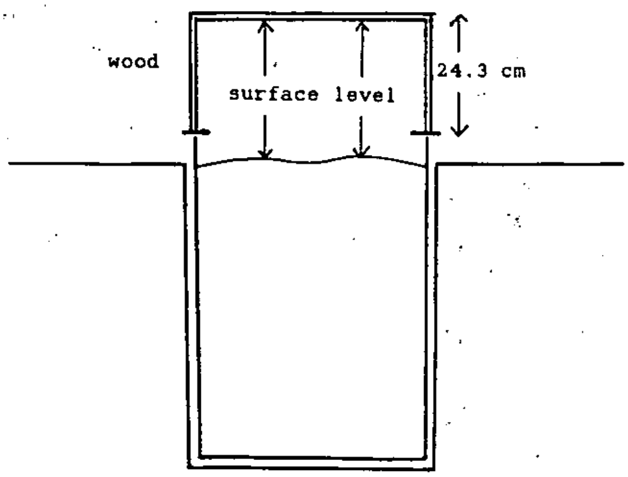
RAINFALLL DATA

DATE	RAINFALL (MM)
12-Apr-91	66.1
19-Apr-91	0.3
26-Apr-91	15.5
03-May-91	24.7
10-May-91	3.3
17-May-91	1.3

SURFACE LEVEL DATA

Levels meausered from wood. Height wood above edge of lysimeter = 24.3 cm. Measured at 17-May-91

Lysimeter	level (cm)
1	25.3
2	26.7
3	27.5
4	26.6
5	25.6
6	26
7	24.6
8	23.6
9	26.3
10	27.5
11	22.9
12	22.6
13	27.9
14	26.5
15	29.8
16	24.9



APPENDIX 3 CALCULATIONS OF STORAGE COEFFICIENTS WITH WEIGHING DATA (1)

lysimeter	date	1	2	3	4	5	6	7	8
Surface l(wood)		25.3	26.7	27.5	26.6	25.6	26.0	24.6	23.6
Surface l(edge lys)		1.0	2.4	3.2	2.3	1.3	1.7	0.3	-0.7
tube leng		16.8	18.0	17.7	17.1	17.8	18.7	17.4	18.5
layer upper border	26-4	4.0	3.1	2.9	2.7	1.4	2.7	5.4	9.4
	03-4	3.4	2.6	5.1	3.7		4.5	4.5	
	26-4	4.0	3.1	2.9	2.7	1.4	2.7	5.4	
	03-5	3.4	2.6	5.1	3.7		4.5	4.5	8.5
	26-4	4.0	3.1	2.9	2.7	1.4	2.7	5.4	9.4
	03-5	3.4	2.6	5.1	3.7		4.5	4.5	8.5
layer under border	17-5	12.5	6.4	8.3	9.7	7.5	10.7	10.5	11.7
	23-5	13.4	7.9	9.6	11.3		10.9	9.3	
	23-5	13.4	7.9	9.6	11.3	7.0	10.9	9.3	
	17-5	12.5	6.4	8.3	9.7		10.7	10.5	11.7
	19-4	11.3	6.5	10.1	9.9	8.9	9.4	10.3	13.2
	19-4	11.3	6.5	10.1	9.9		9.4	10.3	13.2
Storage coefficient	26-4/1	0.30	0.63	0.19	0.25	0.21	0.31	0.36	0.45
	03-4/2	0.30	0.59	0.30	0.26		0.34	0.50	
	26-4/2	0.31	0.58	0.23	0.25	0.23	0.33	0.47	
	03-5/1	0.30	0.63	0.27	0.27		0.31	0.40	0.47
	26-4/1	0.20	0.49	0.21	0.21	0.16	0.30	0.34	0.36
	03-5/1	0.20	0.51	0.27	0.22		0.29	0.39	0.39
average storage coef		0.27	0.57	0.25	0.24	0.20	0.31	0.41	0.42

APPENDIX 4

CALCULATIONS OF STORAGE COEFFICIENTS WITH WATER ADDING DATA (1)

date: 19-4-1991

lysimeter	1	2	3	4	5	6
Volume added (l)	2.00	2.00	1.50	1.68	1.26	2.00
Waterlevel before (cm)	29.1	26.9	31.0	29.3	28.0	29.8
Waterlevel after (cm)	20.9	23.7	25.4	23.7	21.2	23.7
Surface level (wood)	25.3	26.7	27.5	26.6	25.6	26.0
Surface lev.(edge lysi)	1.0	2.4	3.2	2.3	1.3	1.7
tube lenght	16.8	18.0	17.7	17.1	17.8	18.7
layer (under border)	11.3	6.5	10.1	9.9	8.9	9.4
layer (upper border)	3.1	3.3	4.5	4.3	2.1	3.3
Storage coefficient	0.20	0.50	0.21	0.24	0.15	0.26

lysimeter	7	8	9	11	12	13
Volume added (l)	2.00	2.00	2.00	2.00	2.00	2.00
Waterlevel before (cm)	28.0	31.0	29.7	30.3	29.4	28.7
Waterlevel after (cm)	23.2	25.8	23.9	26.0	25.3	24.5
Surface level (wood)	24.6	23.6	26.3	22.9	22.6	27.9
Surface lev.(edge lysi)	0.3	-0.7	2.0	-1.4	-1.7	3.6
tube lenght	17.4	18.5	18.8	18.6	19.2	17.8
layer (under border)	10.3	13.2	8.9	13.1	11.9	7.3
layer (upper border)	5.5	8.0	3.1	8.8	7.8	3.1
Storage coefficient	0.33	0.31	0.28	0.37	0.39	0.38

lysimeter	14	15	16
Volume added (l)	2.00	2.00	2.00
Waterlevel before (cm)	30.2	28.1	30.5
Waterlevel after (cm)	25.5	24.2	25.2
Surface level (wood)	26.5	29.8	24.9
Surface lev.(edge lysi)	2.2	5.5	0.6
tube lenght	19.5	18.5	20.5
layer (under border)	8.5	4.1	9.4
layer (upper border)	3.8	0.2	4.1
Storage coefficient	0.34	0.41	0.30

DETERMINATION OF STORAGE COEFFICIENT WITH WEIGHING DATA (2)

lysimeter	date	9	10	11	12	13	14	15	16
Surface l(wood)		26.3	27.5	22.9	22.6	27.9	26.5	29.8	24.9
Surface l(edge lys)		2.0	3.2	-1.4	-1.7	3.6	2.2	5.5	0.6
tube leng		18.5	19.4	18.6	19.2	17.8	19.5	18.5	20.5
layer	26-4	3.0		8.3	8.1	2.6	4.7	-0.7	4.7
upper border	03-4			7.5	7.7	4.2	4.5	1.2	4.9
	26-4			8.3	8.1	2.6	4.7	-0.7	4.7
	03-5			7.5	7.7	4.2	4.5	1.2	4.9
	26-4	3.0						-0.7	4.7
	03-5							1.2	4.9
layer	17-5	7.4		11.4	12.2	6.7	7.3	4.7	9.7
under border	23-5			11.4	12.2	6.7	7.3	4.5	9.3
	23-5			13.1	11.9	7.3	8.5	4.5	9.3
	17-5			13.1	11.9	7.3	8.5	4.7	9.7
	19-4	9.2						4.1	9.4
	19-4							4.1	9.4
Storage	26-4/1		0.44	0.49	0.45	0.52	0.46	0.38	
coefficient	03-4/2		0.49	0.50			0.63	0.49	
	26-4/2		0.35	0.42	0.43	0.46	0.51	0.47	
	03-5/1		0.40	0.44			0.55	0.40	
	26-4/1						0.40	0.37	
	03-5/1						0.47	0.39	
average storage coef		0.31		0.42	0.46	0.44	0.49	0.50	0.42

CALCULATIONS STORAGE COEFFICIENTS WITH WATER ADDING DATA (2)

15-5-91

Lysimeter	3	4	5	7	8	9
Volume added (l)	1.07	1.00	1.00	1.00	2.00	1.50
Waterlevel before (cm)	30.9	31.8	29.2	28.8	32.9	30.1
Waterlevel after (cm)	26.4	26.2	24.5	26.0	26.2	25.6
Surface level (cm)	27.5	26.6	25.6	24.6	23.6	26.3
Surface level	3.2	2.3	1.3	0.3	-0.7	2.0
tube lenght	17.7	17.1	17.8	17.4	18.5	18.8
layer (cm -surface)	10.0	12.4	10.1	11.1	15.1	9.3
layer	5.5	6.8	5.4	8.3	8.4	4.8
Storage coefficient	0.19	0.14	0.17	0.29	0.24	0.27

Lysimeter	10	11	12	14	16
Volume added (l)	2.00	1.00	1.00	1.50	1.00
Waterlevel before (cm)	32.0	29.8	30.7	31.2	31.7
Waterlevel after (cm)	25.0	26.8	27.8	27.4	29.0
Surface level (cm)	27.5	22.9	22.6	26.5	24.9
Surface level	3.2	-1.4	-1.7	2.2	0.6
tube lenght	19.4	18.6	19.2	19.5	20.5
layer (cm -surface)	9.4	12.6	13.2	9.5	10.6
layer	2.4	9.6	10.3	5.7	7.9
Storage coefficient	0.23	0.27	0.28	0.32	0.30

23-5-91

Lysimeter	8	9	10
Volume added (l)	1.00	1.00	1.00
Waterlevel before (cm)	32.3	28.1	29.2
Waterlevel after (cm)	28.5	25.0	25.1
Surface level (cm)	23.6	26.3	27.5
Surface level	-0.7	2.0	3.2
tube lenght	18.5	18.8	19.4
layer (cm -surface)	14.5	7.3	6.6
layer	10.7	4.2	2.5
Storage coefficient	0.21	0.26	0.20

Lysimeter	1	2	3	4	5	6
average storage coeff.	0.21	0.24	0.20	0.19	0.16	0.26

Lysimeter	7	8	9	10	11	12
average storage coeff.	0.31	0.25	0.27	0.21	0.32	0.33

Lysimeter	13	14	15	16
average storage coeff.	0.38	0.33	0.41	0.30

APPENDIX 5 TABLE FOR THE DETERMINATION OF N IN THE GUINNESS METHOD FORMULA

first column: n
second column: ((n^2) - 2ln(n) -1) / ln(n)

1.1	0.203332	5.1	13.35071
1.2	0.413319	5.2	13.79466
1.3	0.629931	5.3	14.24386
1.4	0.853133	5.4	14.6983
1.5	1.082879	5.5	15.15796
1.6	1.319123	5.6	15.62282
1.7	1.561816	5.7	16.09285
1.8	1.810906	5.8	16.56805
1.9	2.066346	5.9	17.0484
2	2.328085	6	17.53387
2.1	2.596075	6.1	18.02446
2.2	2.87027	6.2	18.52014
2.3	3.150622	6.3	19.02089
2.4	3.437087	6.4	19.52672
2.5	3.729623	6.5	20.03759
2.6	4.028185	6.6	20.55349
2.7	4.332735	6.7	21.07441
2.8	4.643231	6.8	21.60033
2.9	4.959637	6.9	22.13124
3	5.281914	7	22.66712
3.1	5.610026	7.1	23.20796
3.2	5.94394	7.2	23.75376
3.3	6.28362	7.3	24.30448
3.4	6.629034	7.4	24.86012
3.5	6.980151	7.5	25.42067
3.6	7.336938	7.6	25.98612
3.7	7.699367	7.7	26.55645
3.8	8.067408	7.8	27.13164
3.9	8.441032	7.9	27.7117
4	8.820213	8	28.2966
4.1	9.204923	8.2	29.48088
4.2	9.595136	8.4	30.68441
4.3	9.990827	8.6	31.90709
4.4	10.39197	8.8	33.14884
4.5	10.79854	9	34.40957
4.6	11.21052	9.2	35.6892
4.7	11.62788	9.4	36.98765
4.8	12.0506	9.6	38.30484
4.9	12.47866	9.8	39.6407
5	12.91204	10	40.99515

APPENDIX 6 DATA AND CALCULATIONS OF THE CALLIBRATION OF THE GUINNESS METHOD

callibration with plates

gat	1	2
x-coord	j95	j95
y-coord	870	870
length (cm)	18	17
width (cm)	16	17
depth (cm)	40	40
thickn acrotelm (cm)	38	40
wat.level (cm)	-2	-2
tubes	1+1+12	1+1+12
Q (m3/s)	2E-05	2E-05
HO (cm)	67.2	58.6
drawd. big hole (cm)	63.4	50.7
drawd small hole(cm)	2.0	3.2
distance x (cm)	32	33
distance y (cm)	1.8	4.7
welled width w(w)	16	17
welled height h(w)	32.2	30.1
gradient i (-)	0.056	0.142
well.surf. A(w) (m2)	0.0515	0.0512
velocity v (m/s)	0.0005	0.0005
permeability k (m/d)	742	295
transm. T (m/d)	282	118

calculation with formul

	1	2
x-coord	j95	j95
y-coord	870	870
length	18	17
width	16	17
depth	38	38
r eff.(m)	0.10	0.10
wat.level	-2	-2
tubes	1+1+12	1+1+12
Q (m3/s)	2E-05	2E-05
HO	80.0	57.5
Drawdown	79.0	55.9
time (s)	60	120
s(w)cons.	0.010	0.016
n(form.)	14.3	18.8
n	5.3	6.3
T (m/dag)	57.0	39.3

callibration with fingermethod

bergfact.	0.5		
pie	3.1416		
gat	2	3	4
x-coord	j95	j95	j95
y-coord	870	870	870
length (cm)	17	20	23
width (cm)	17	20	23
depth (cm)	38	38	38
r eff.(m)	0.10	0.12	0.14
wat.level (cm)	-2	-2	-2
tubes	1+1+12	1+1+12	1+1+12
Q (m3/s)	2E-05	2E-05	2E-05
time (s)	120	60	160
HO (cm)	57.5	55.6	57.5
Drawd. big hole (cm)	55.9	55.1	55.9
drawd small hole(cm)	1.1	0.2	0.8
distance x (cm)	25	30	34
distance y (cm)	0.5	0.3	0.8
n	3.3	3.3	3.3
T finger (m/dag)	82.4	137.3	51.5

calculation with formula

s(w)cons.	0.016	0.005	0.016
n(form.)	18.8	22.4	12.6
n	6.3	6.9	4.9
T formula (m/s)	39.3	132.1	34.0

APPENDIX 7 GRAPH FOR THE DETERMINATION OF THE GEOMETRY FACTOR Ap IN THE PIT BAILING METHOD

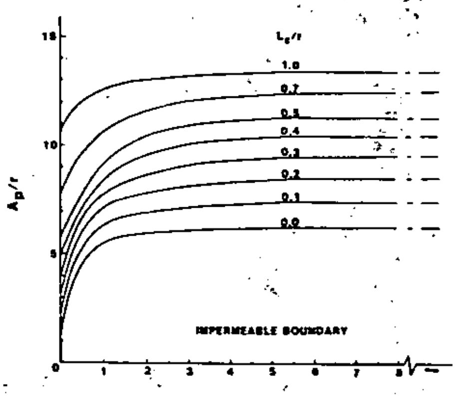
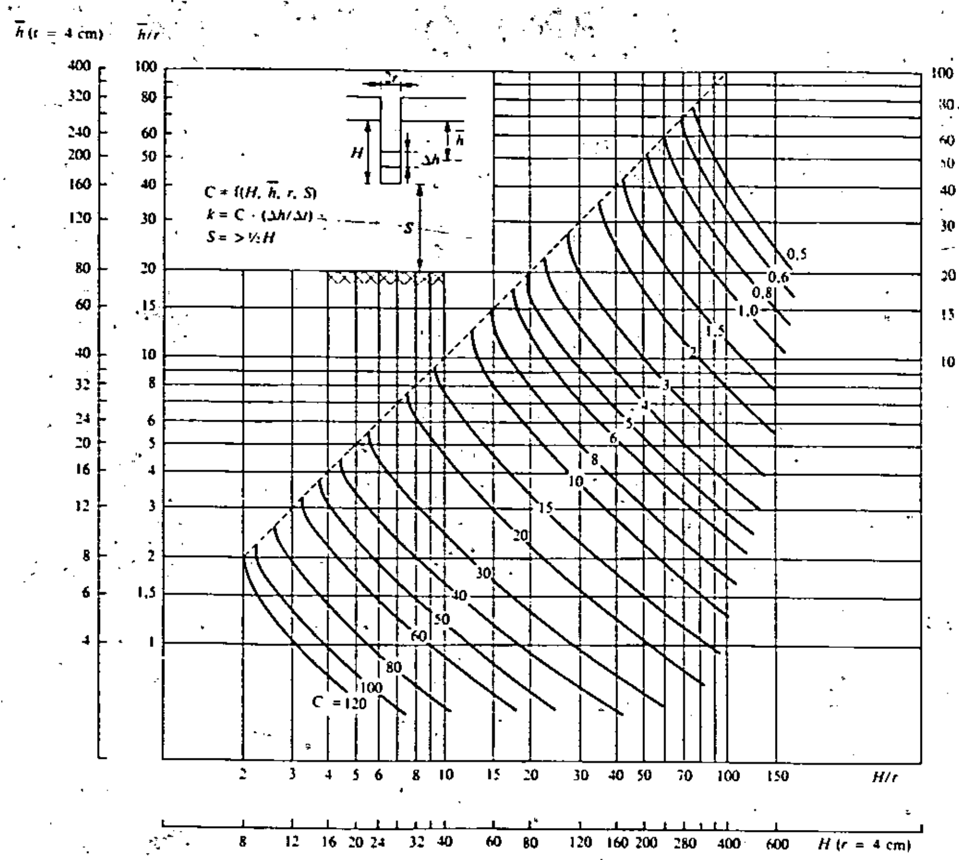


Fig. 4—Curves of A_p/r vs. D/r for different values of L_e/r (on the curves) for pit bailing method in soil underlain by impermeable material.

APPENDIX 8 NOMOGRAM FOR THE DETERMINATION OF THE GEOMETRY FACTOR C IN THE AUGERHOLE METOD FORMULA



APPENDIX 9 DATA AND CALCULATIONS OF THE ACROTELM TRANSMISSIVITY/ PERMEABILITY TESTS AT 16-4-1991

GUINNESS METHOD

bergfact. 0.5

x-coord	1	1	1	1	1	1	1	1
y-coord	200	300	500	600	800	900	1000	1100
vegetation	moss	moss	moss		moss			moss
length (cm)	19	20	17	18	18	16	17	17
width (cm)	15	18	16	16	17	16	14	17
depth (cm)	38	40	31	31	37	28	30	33
r eff.(m)	0.10	0.11	0.10	0.10	0.11	0.10	0.09	0.10
wat.lev(cm)	-2	-2	-2	-2	-2	-2	-2	-2
hsur-htub	0	0	-2	-2	-2	0	1	0
tubes	1+1+12	1+1+12	1+1+12	1+1+12	1+1+12	1	1+1+12	1+1+12
Q (l/s)	0.025	0.025	0.025	0.025	0.025	0.118	0.025	0.025
HO (cm)	47.7	49.3	57	54.6	55.1	37.2	56	70.3
Hc (cm)	46.1	48.7	56.2	53.4	54.5	36.8	54.8	69.7
time (s)	70	40	30	120	35	30	55	60
s(w) (m)	0.016	0.006	0.008	0.012	0.006	0.004	0.012	0.006
n (formula)	9.3	12.2	8.1	26.4	12.8	117.9	12.8	26.4
n	4.1	4.9	3.8	7.7	5.0	18.8	5.0	7.7
T (m/day)	30	90	57	58	92	1187	46	116

x-coord	1	1	q	p	o	n	m	k
y-coord	1200	1300	600	600	600	600	600	600
vegetation	moss	moss		moss	moss	moss	moss	moss
length (cm)	16	17	20	20	19	20	22	20
width (cm)	16	16	17	19	18	19	20	15
depth (cm)	30	34	30	40	32	40	39	38
r eff.(m)	0.10	0.10	0.11	0.12	0.11	0.12	0.13	0.11
wat.lev(cm)	-2	-2	-2	-2	-2	-2	-2	-2
hsur-htub	3	1	0	1	0	-2		0
tubes	1+1+12	1+1+12	1+1+12	1+1+12	1+1+12	1+1+12	1+1+12	1+1+12
Q (l/s)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
HO (cm)	55.5	51.8	36.5	32.3	38	50.1	52.5	49
Hc (cm)	54.4	50.8	35.5	31	37	48.6	51.9	47.2
time (s)	90	75	90	60	50	90	65	80
s(w) (m)	0.011	0.01	0.01	0.013	0.01	0.015	0.006	0.018
n (formula)	24.1	20.2	19.1	6.7	8.9	9.9	17.6	8.8
n	7.3	6.5	6.3	3.4	4.0	4.3	6.0	4.0
T (m/day)	62	64	63	32	47	33	102	26

PIT BAILING METHOD, THIEM EQUATION

x-coord	l	l	l
y-coord	0	-100	100
vegetat	B/M	M	M
length (cm)	17	16	20
width (cm)	16	15	18
depth (cm)	39	41	37
hsur-htub	1	2	6
wat.lev(cm)	-2	-2	-2
D perm.(cm)	10	10	15
HO (cm)	67.8	56	39.7
Drawdown(cm)	64.8	53.2	36.9

	time	level	K (m/d)	time	level	K (m/d)	time	level	K (m/d)
	0	64.8		0	53.2		0	36.9	
	16	65	41.3	11	53.8	231.1	13	37.1	71.1
	25	65.2	77.6	18	54	130.5	27	37.4	109.1
	32	65.4	106.2	25	54.2	142.2	43	37.6	68.5
	37	65.5	76.9	32	54.4	156.8	52	37.8	132.4
	46	65.7	92.1	43	54.6	111.9	60	37.9	78.0
	60	65.9	64.3	55	54.8	117.5	70	38	65.5
	67	66	67.3	67	54.9	63.5	80	38.1	69.1
	75	66.1	61.9	75	55	103.8	93	38.2	56.2
	85	66.2	52.2	90	55.1	61.0	106	38.3	59.8
	95	66.3	55.2	112	55.2	46.3	130	38.4	34.6
	107	66.4	48.9						
	117	66.5	62.7						
	130	66.6	51.8						
	165	66.8	45.5						
	185	66.9	43.9						
k (m/d)	t=75-185		51.5	t=11-112		103.7	t=52-130		60.5

x-coord	l	l	j
y-coord	400	700	600
vegetat		B/M	M
length (cm)	17	16	19
width (cm)	16	16	16
depth (cm)	32	35	31
hsur-htub	0	5	-1
wat.lev(cm)	-2	-2	-2
D perm.(cm)	15	12	10
HO (cm)	53	48.5	48
Drawdown(cm)	49.9	46	45.4

	time	level	K (m/d)	time	level	K (m/d)	time	level	K (m/d)
	0	49.9		0	45.9		0	45.4	
	5	50.3	131.7	6	46.1	178.1	5	45.3	-56.0
	9	50.5	88.1	11	46.3	227.1	11	45.7	213.6
	13	50.8	148.3	15	46.5	304.5	16	45.9	138.6
	18	51	86.3	22	46.7	188.6	20	46	90.4
	22	51.2	118.8	29	46.9	207.1	28	46.2	99.2
	25	51.4	176.8	35	47	127.4	35	46.4	126.0
	29	51.5	70.4	41	47.1	134.9	42	46.6	142.3
	36	51.7	92.1	48	47.2	123.1	52	46.8	114.8
	42	51.9	126.0	54	47.3	153.8	62	47	136.1
	50	52.1	114.6	61	47.4	142.2	71	47.1	83.5
	61	52.3	106.3	68	47.5	154.7	78	47.2	120.1
	67	52.4	113.2	80	47.6	99.1	85	47.3	136.5
	75	52.5	101.5	92	47.7	110.3	97	47.4	92.4
							112	47.5	88.2
k (m/d)	t=13-75		106.0	t=41-92		123.0	t=11-112		114.0

AUGERHOLE METHOD

x-coord	1			r			i		
y-coord	-200			600			600		
length	16			17			19		
width	16			16			18		
watdepth	19			25			24		
wat.level	-2			-2			-2		
hsur-htub	6								
W'	31.8			29.2			2		
Drawdown	46.2			48.8			15.8		
C (graf)	160			160			160		
	time	level	k (m/d)	time	level	k (m/d)	time	level	k (m/d)
	0	46.2		0	48.8		0	15.8	
	2.5	45	1.28	2.5	48	0.85	2.5	15.7	0.11
	5	45.5	-0.53	5	47.6	0.43	5	15.6	0.11
	7.5	45.3	0.21	7.5	47.3	0.32	7.5	15.5	0.11
	10	45.2	0.11	10	47	0.32	10	15.4	0.11
	12.5	45	0.21	12.5	46.7	0.32	12.5	15.3	0.11
	15	44.9	0.11	15	46.4	0.32	15	15.2	0.11
k (m/d)	t=5-15		0.16	t=5-15		0.32	t=0-15		0.11

x-coord	1		
y-coord	1400		
length	18		
width	17		
watdepth	23		
wat.level	-2		
hsur-htub			
W'	2		
Drawdown	18.9		
C (graf)	160		
	time	level	k (m/d)
	0	18.9	
	2.5	18	0.96
	5	17.5	0.53
	7.5	17.2	0.32
	10	16.8	0.43
	12.5	16.5	0.32
	15	16.2	0.32
k (m/d)	t=5-15		0.35

APPENDIX 10. DATA AND CALCULATIONS OF THE ACROTELM TRANSMISSIVITY/PERMEABILITY TESTS AT 5-6-1991

GUINNESS METHOD

bergfact. 0.5

x-coord	l	p	o	m
y-coord	300	600	600	600
vegetation	moss	moss	moss	moss
length (cm)	20	20	19	22
width (cm)	18	19	18	20
depth (cm)	40	40	32	39
r eff.(m)	0.11	0.12	0.11	0.13
wat.lev(cm)	-9	-14	-13	-11
hsur-htub	0	1	0	0
tubes	1+1+12	1+1+12	1+1+12	1+1+12
Q (l/s)	0.025	0.025	0.025	0.025
H0 (cm)	57.0	49.5	78.0	87.0
Hc (cm)	56.1	47.7	75.9	85.5
time (s)	112	255	278	285
s(w) (m)	0.009	0.018	0.021	0.015
n(form.)	26.3	28.8	30.0	33.9
n	7.7	8.1	8.3	8.9
T (m/day)	77	40	34	50

PIT BAILING METOD WITH THE THIEM EQUATION

x-coord	1			1			1		
y-coord	900			800			600		
vegetat	moss			moss			moss		
length (cm)	16			18			18		
width (cm)	16			17			16		
depth (cm)	28			37			31		
hsur-htub	0			-2			-2		
wat.lev(cm)	-17.5			-22.4			-8.3		
D perm.(cm)	40			45			20		
HO (cm)	20.7			33.3			51.5		
Drawdown(cm)	18.4			29			46.8		
	time	level	K (m/d	time	level	K (m/d	time	level	K (m/d
	3.5	18.4		3	29		0	46.8	
	10.5	19	113.5	8	29.3	38.7	6	47	35.5
	16	19.3	87.1	9	29.5	135.0	11	47.2	44.1
	18.5	19.5	148.3	15	30	64.1	14	47.5	117.1
	30	19.8	64.0	21	30.2	27.2	18	47.7	61.1
	37	19.9	39.4	26	30.4	34.7	21	47.9	85.3
	40	20	104.7	30	30.6	46.4	26	48	26.2
	51	20.1	33.3	35	30.7	19.2	29	48.2	91.9
	84	20.2	13.3	38	30.8	33.3	34	48.4	58.2
				40	30.9	51.8	38	48.6	77.1
				47	31	15.4	47	48.8	36.5
				55	31.1	14.1	51.5	49	78.3
				57	31.2	58.9	57	49.2	69.0
				64	31.3	17.6	64	49.4	58.9
				70	31.4	21.6	68	49.5	53.9
				78	31.5	17.1	78	49.7	47.6
				88	31.6	14.4	82	49.8	62.7
				103	31.7	10.2	91	49.9	29.5
K gem (m/d)	t=18.5-t=84		50.9	t=15-103		27.3	t=29-91		56.3

x-coord	1			1			n		
y-coord	500			200			600		
vegetat	moss			moss			moss		
length (cm)	17			19			20		
width (cm)	16			15			19		
depth (cm)	31			38			40		
hsur-htub	-2			0			-2		
wat.lev(cm)	-13			-11.5			-11.2		
D perm.(cm)	20			40			15		
HO (cm)	32.4			53.5			89.5		
Drawdown(cm)	28.6			49.5			85.4		
	time	level	K (m/d	time	level	K (m/d	time	level	K (m/d
	0	28.6		1	49.5		1	85.4	
	9	28.8	47.2	7	49.8	29.5	9	85.7	123.3
	15	29	73.9	11	50	31.1	12	85.8	111.1
	20	29.2	92.9	15	50.2	32.9	20	86	85.9
	26	29.4	81.5	19	50.4	34.9	30	86.3	108.7
	34	29.6	64.6	23	50.6	37.1	40	86.5	75.5
	41	29.8	78.5	27	50.8	39.7	58	86.8	67.6
	49	30	73.4	34	51	24.4	70	87	71.4
	62	30.2	48.7	43	51.2	20.6	87	87.2	53.6
	77	30.4	45.8	50	51.4	28.9	102	87.4	65.1
	88	30.5	32.7	59	51.6	24.7	122	87.6	52.9
	95	30.6	53.9	69	51.8	24.8	142	87.8	57.9
				83	52	20.0	165	88	55.9
K gem (m/d)	t=26-95		56.8	t=27-83		23.9	t=30-165		62.5

PIT BAILING METHOD WITH PIEZOMETER METHOD EQUATION (1)

x-coord	1			1			1			1		
y-coord	1100			700			400			100		
vegetat	moss			moss			moss			moss		
length (cm)	17			16			17			20		
width (cm)	17			16			16			18		
depth (cm)	33			35			32			37		
hsur-htub	0			5			0			6		
wat.lev(cm)	-18			-14			-11			-8		
D perm (cm)	15			10			15			15		
HO (cm)	38.0			39.1			57.3			58.0		
Drawdown	34.6			34.9			51.0			54.5		
r eff (cm)	10.2			9.6			9.9			11.4		
Lc/r	1.5			2.2			2.1			2.5		
Ap/r	14.5			16.0			15.5			16.0		
Ap	148			154			153			182		
	time	level	K	time	level	K	time	level	K	time	level	K
	0	34.6		0	34.9		0	51.0		4	54.5	
	37	34.9	4.8	34	35.0	1.2	11	51.2	5.1	15	54.7	7.6
	49	35.0	4.9	62	35.1	1.3	26	51.3	3.3	24	54.8	7.2
	67	35.1	4.5	85	35.2	1.4	32	51.4	3.6	34	54.9	6.9
	81	35.2	4.6	110	35.3	1.5	37	51.5	3.9	42	55.0	7.1
	101	35.3	4.4	146	35.4	1.4	51	51.6	3.4	49	55.1	7.4
	116	35.4	4.4	181	35.5	1.4	64	51.7	3.2	60	55.2	7.2
	132	35.5	4.4				79	51.8	3.0	68	55.3	7.4
	147	35.6	4.5				95	51.9	2.8	87	55.4	6.6
	171	35.7	4.4				104	52.0	2.9	128	55.5	5.1
	186	35.8	4.5							151	55.6	4.8
	202	35.9	4.6							168	55.7	4.8
										187	55.8	4.8
										206	55.9	4.8
										232	56.0	4.7
K (m/d)	t=0-202		4.5	t=0-181		1.4	t=11-104		3.2	t=128-232		4.8

PIT BAILING METHOD WITH PIEZOMETER METHOD EQUATION (2)

x-coord	l	l	k
y-coord	0	-100	600
vegetat	b asp/moss	moss	moss
length (cm)	17	16	20
width (cm)	16	15	15
depth (cm)	39	41	38
hsur-htub	1	2	0
wat.lev(cm)	-12	-9	-9
D perm (cm)	10	10	0
H0 (cm)	38.2	37.5	90.0
Drawdown	33.7	32.0	86.2
r eff (cm)	9.9	9.3	10.5
Lc/r	2.7	3.5	2.8
Ap/r	16.0	17.0	16.0
Ap	158	158	168

time	level	K	time	level	K	time	level	K
0	33.7		0	32.0		2	86.2	
42	33.9	1.8	24	32.4	4.7	17	86.5	8.6
90	34.0	1.3	34	32.5	4.2	29	86.6	6.8
104	34.1	1.5	41	32.6	4.2	37	86.7	6.8
160	34.2	1.2	51	32.7	4.0	42	86.8	7.3
204	34.3	1.2	59	32.8	4.0	54	86.9	6.7
251	34.4	1.1	72	32.9	3.7	61	87.0	6.9
288	34.5	1.1	80	33.0	3.7	68	87.1	7.1
			91	33.1	3.6	80	87.2	6.8
			101	33.2	0.0	91	87.3	6.7
			114	33.3	3.5	98	87.4	6.9
			127	33.4	3.4	108	87.5	6.9
			138	33.5	3.4	117	87.6	7.0
			149	33.6	3.4	126	87.7	7.1
			164	33.7	3.3	134	87.8	7.3
			181	33.9	3.5	145	87.9	7.3
			203	34.0	3.3	156	88.0	7.3
			212	34.1	3.4			
			232	34.2	3.3			
			246	34.3	3.3			
			260	34.4	3.3			

K gem (m/d) t=42-288 1.2 t=101-260 3.4 t=17-156 7.0

AUGERHOLE METHOD

x-coord	1			r				q	
y-coord	400			600				600	
length	17			17				20	
width	16			16				17	
depth	32			?				28	
wat.level	-11			26				26	
hsur-htub	0			29.2				0	
W'	-			-					
H0	57.3			16.2				30.8	
drawdown	51			9.8				19	
C (graf)	160			160				160	
	time	level	k(m/d)	time	level	k(m/d)	time	level	k(m/d)
	0	51		0	9.8		0	19	
	11	51.2	2.91	3.2	10	0.17	1.2	19.3	0.67
	26	51.3	1.07	7.3	10.1	0.07	2.3	19.5	0.48
	32	51.4	2.67	11.4	10.2	0.07	4.7	19.8	0.33
	37	51.5	3.20				5.8	20	0.48
	51	51.6	1.14				7.1	20.2	0.41
	64	51.7	1.23				8.3	20.3	0.22
	79	51.8	1.07				9.2	20.4	0.30
	95	51.9	1.00				10.8	20.5	0.17
	104	52	1.78						
k (m/d)	t=37-104		1.24	t=0-11.4		0.10	t=1-11		0.34

APPENDIX 11 THE VON POST AND GRANLUND HUMIFICATION SCALE

H 1 Completely unhumified plant remains, from which by hand only almost colourless water can be squeezed.

H 2 Almost unhumified plant remains; the squeeze water is light brown and almost clear.

H 3 Very poorly humified plant remains; the squeeze water is cloudy and brown.

H 4 Poorly humified plant remains; peaty substance does not escape from between the fingers by squeezing.

H 5 Moderately humified plant remains; the structure is however still clearly visible; the squeeze water is dark brown and very cloudy, while some peat escapes between the fingers.

H 6 Fairly highly humified plant remains; the structure (texture) is unclear. About a third part of the peat escapes through the fingers. The part remaining in the hand has a more clear plant structure than the part that was squeezed out.

H 7 Highly humified plant remains; about half of the material escapes when squeezed. The water which may escape is dark brown in colour.

H 8 Very highly humified plant remains; two-thirths escapes through the fingers. The remainder consists mainly of resistant bits of roots, wood etc.

H 9 Almost completely humified plant remains; almost all the peat escapes through the fingers. Structure is almost absent.

H10 Totally humified plant remains; amorphous peat; all the peat escapes the fingers without any water being squeezed out.

APPENDIX 12 DATA OF THE FIRST ACROTELM MAPPING

COORD	V	LAY1	H	COL1	LAY2	H	COL2	LAY3	H	COL3	LAY4	H	COL4
H1000	M	10-30	7	7.5-2/3	30-50	5	7.5-4/6	50-70	6	5-2/4	70-100	5	5-3/6
H1100	B	5-30	6	5-2/4	30-40	5	5-4/8	40-50	4	7.5-2/3	50-100	5	5-3/4
H1200	M	5-20	6	5-2/2	20-30	5	7.5-3/4	30-50	4	7.5-4/6	50-100	4	7.5-3/6
H1300	M	10-30	6	5-2/3	30-50	5	7.5-5/8	50-100	4				
H1400	M	0-5	3	7.5-5/8	5-20	7	5-3/2	20-30	6	7.5-5/8	30-50	6	5-3/2
I0000	H	0-15	6	5-3/3	15-40	7	2.5-2/2	40-50	5	5-2/3	50-100	4	2.5-3/3
I0100		0-10	7	5-2/4	10-20	7	10-3/3	20-30	4	2.5-3/4	30-55	6	2.5-2/4
I0200		20-50	5	5-3/2	50-70	4	5-4/8	70-100	3	7.5-5/8			
I0300	M	5-35	6	5-2/2	35-50	4	5-4/8	50-75	4	5-4/8	75-100	5	5-3/4
I0400	M	5-50	6	5-3/3	50-55	3	7.5-5/8	55-80	5	5-3/3	80-100	4	5-5/8
I0500	M	0-10	4	10-6/6	10-40	5	7.5-6/8	40-50	5	5-3/2	50-80	5	5-3/3
I0600	C	0-30	6	5-2/2	30-50	4	7.5-4/6	50-65	5	7.5-5/6	65-100	4	7.5-5/8
I0700		0-50	6	5-2/4	50-90	6	5-2/2	90-100	5	5-3/3			
I0800	H	0-25	6	5-2/4	25-50	4	5-3/3	50-70	5	5-4/8	70-100	5	5-3/6
I0900		no dri											
I1000	M	5-30	6	2.5-2/4	30-100	5	5-3/3						
I1100	M	10-30	7	5-2/4	30-55	6	5-4/6	55-85	5	5-2/3	85-100	5	5-4/6
I1200	M	5-15	6	5-3/3	15-25	6	2.5-2/3	25-100	4	5-3/4			
I1300	M	5-25	6	5-2/3	25-75	4	5-4/6	75-85	5	5-4/6	85-100	4	2.5-3/4
J0000	B	0-20	6	5-2/2	20-35	5	5-4/6	35-50	4	7.5-5/6	50-75	4	5-3/6
J0100	B	5-25	6	2.5-3/2	25-50	5	5-3/4	50-100	5	5-3/4			
J0200	M	0-10	3	10-6/6	10-65	5	5-3/6	65-85	4	5-4/8	85-100	5	5-3/3
J0300		0-10	5	5-4/6	10-50	6	5-3/4	50-100	5	5-4/8			
J0400	B	10-30	6	5-3/3	30-70	7	7.5-4/6	70-100	7	5-3/6			
J0500	B	0-10	3	10-6/4	10-40	6	5-2/3	40-50	4	5-5/8	50-75	4	2.5-3/3
J0600	M	10-20	6	5-3/2	20-40	5	5-3/3	40-55	4	5-3/6	55-80	6	2.5-3/4
J0700	M	0-10	4	7.5-4/4	10-20	6	5-3/3	20-50	5	5-4/6	50-75	5	5-3/6
J0800	M	15-20	6	5-2/4	20-40	6	5-3/4	40-50	5	5-3/3	50-100	6	5-2/4
J0900	M	0-15	3	10-6/6	15-30	5	7.5-4/6	30-50	5	7.5-3/4	50-100	5	5-3/6
J1000	B	5-15	6	5-2/3	15-100	5	5-3/4						
J1100	M	10-20	6	2.5-2/4	20-80	5	5-3/6	80-100	6	2.5-3/4			
J1200	C	0-10	5	2.5-2/3	10-75	6	2.5-2/3	75-100	6	2.5-2/4			
J1300	H	5-10	6	5-2/2	10-40	5	5-3/4	40-75	4	5-3/6	75-85	5	5-3/6
K0000	H	0-10	5	2.5-2/2	10-40	6	5-2/4	40-100	5	5-3/3			
K0100	B	5-25	6	5-2/3	25-45	5	2.5-2/4	45-60	5	5-3/6	60-100	6	5-3/6
K0200	H	5-25	6	2.5-2/4	25-40	5	5-3/4	40-60	5	5-2/4	60-100	5	5-2/4
K0300		0-20	6	5-2/4	20-45	5	2.5-3/3	45-55	6	5-4/6	55-70	6	2.5-2/4
K0400	H	0-50	6	2.5-3/3	50-100	5	2.5-3/3						
K0500	M	0-5	3	10-6/6	5-15	6	2.5-2/4	15-25	4	5-3/6	25-40	6	5-2/4
K0600	B	10-20	7	5-3/4	20-40	6	5-2/4	40-50	5	5-3/6	50-100	5	2.5-2/4
K0700	B	5-35	6	5-2/3	35-80	5	5-3/6	80-100	5	5-2/4			
K0800	M	0-10	2	10-6/8	10-20	6	5-3/3	20-40	4	5-4/8	40-50	5	5-3/4
K0900	M	15-25	6	5-2/4	25-45	5	5-2/4	45-100	5	5-3/4			
K1000	C	5-15	6	5-2/3	15-100	5	5-2/4						
K1100	B	10-20	6	5-1.7/1	20-40	6	5-2/3	40-55	5	5-3/3	55-80	6	5-2/3
K1200	H	15-40	6	5-2/3	40-100	5	2.5-3/4						
K1300	M	5-20	6	5-2/2	20-30	5	5-2/3	30-100	5	2.5-2/4			
K1400	M	0-10	5	10-5/6	10-30	6	7.5-2/3	30-100	5				
L-100	M	0-10	4	7.5-4/6	30-80	5	5-3/6	80-100	6	5-3/6			
L-200	M	5-30	7	7.5-2/2	30-90	5	5-3/4	90-100	6	5-3/4			
L0000	M	0-10	5	10-2/3	10-25	6	5-3/3	25-35	6	5-3/4	35-50	6	5-2/4
L0100	M	0-15	4	10-4/6	15-50	6	7.5-4/3	50-75	5	5-3/5	75-90	6	5-3/4
L0200	M	0-20	4	10-4/6	20-40	4	10-4/6	40-50	6	2.5-2/3	50-80	5	5-3/6
L0300	M	0-15	3	10-5/8	15-40	3	10-5/8	40-45	7	7.5-3/4	45-80	5	2.5-3/4
L0400	M	0-15	5	7.5-4/6	15-50	6	5-3/6	50-100	5	2.5-2/4			
L0500	M	20-30	6	7.5-3/4	30-50	6	5-3/3	50-80	5	2.5-3/6	80-100	6	2.5-3/3
L0600	M	0-15	3	10-5/6	15-30	6	2.5-3/3	30-45	5	2.5-2/4	45-55	6	2.5-2/4
L0700	B	0-10	3	10-4/8	10-30	6	2.5-3/3	30-45	6	2.5-2/4	45-50	4	5-3/6
L0800	M	0-20	3	10-5/6	20-45	4	10-4/4	45-100	5	5-3/6			
L0900	M	0-40	3	10-4/6	40-50	6	5-2/3	50-90	5	5-2/3	90-100	4	5-4/6
L1000		0-15	4	7.5-4/3	15-30	6	2.5-2/4	30-50	6	5-3/6	50-60	5	7.5-5/6
L1100		0-15	3	10-5/6	15-35	6	5-3/4	35-60	5	5-6/8	60-75	5	2.5-2/4
L1300		0-15	4	2.5-2/2	15-30	6	2.5-3/4	30-100	5				
L1400		20-35	6	5-3/3	35-80	5	5-3/6	80-100	6	5-2/4			
L1200		20-35	6	5-3/3	35-80	5	5-3/6	80-100	6	2.5-3/4			

```
          LAY5  H COL5    LAY6  H COL6    LAY7  H COL7    LAY8  H COL8
H1000
H1100
H1200
H1300
H1400     50-1004 5-4/6
I0000
I0100     55-80 4 7.5-6/8 80-1003 5-4/8
I0200
I0300
I0400
I0500     80-1006 5-3/4
I0600
I0700
I0800
I0900
I1000
I1100
I1200
I1300
J0000     75-1005 2.5-3/3
J0100
J0200
J0300
J0400
J0500     75-1005 5-2/3
J0600     80-1004 5-3/6
J0700     75-1006 5-3/6
J0800
J0900
J1000
J1100
J1200
J1300     85-1005 5-3/6
K0000
K0100
K0200
K0300     70-1005 5-4/8
K0400
K0500     40-50 5 5-3/3   50-1005 5-3/3
K0600
K0700
K0800     50-1005 5-4/8
K0900
K1000
K1100     80-1005 5-3/3
K1200
K1300
K1400
L-100
L-200
L0000     50-1005 2.5-3/4
L0100     90-1007 5-3/4
L0200     80-1006 2.5-2/4
L0300     80-1007 2.5-3/4
L0400
L0500
L0600     55-75 4 2.5-2/4 75-90 6 7.5-4/6 90-1006 2.5-2/4
L0700     50-60 6 2.5-3/4 60-70 5 2.5-3/4 70-80 4 2.5-3/4 80-1007 2.5-3/4
L0800
L0900
L1000     60-75 5 2.5-3/4 75-85 4 2.5-3/6 85-1006 2.5-3/3
L1100     75-80 6 2.5-2/4 80-85 5 2.5-2/4 85-1006 2.5-2/4
L1300
L1400
L1200
```

	LAY9	H	COL9	LAY10	H	COL10	LAY_X1	H	COL_X1	LAY_X2	H	COL_X2
H1000							0-10	5				
H1100							0-5	4	10-4/4			
H1200							0-5	3	10-6/6			
H1300							0-10	5	5-2/3			
H1400												
I0000												
I0100												
I0200							0-20	7	5-3/2			
I0300							0-5	4	10-6/4			
I0400							0-5	3	5-4/6			
I0500												
I0600												
I0700												
I0800												
I0900												
I1000							0-5	5				
I1100							0-10	4				
I1200							0-5	5	10-6/6			
I1300							0-5	5	5-2/3			
J0000												
J0100							0-5	5	2.5-3/2			
J0200												
J0300												
J0400							0-10	4	10-5/8			
J0500												
J0600							0-5	4	10-6/4	5-10	5	7.5-3/2
J0700												
J0800							0-5	3	7.5-5/6	5-15	5	7.5-2/3
J0900												
J1000							0-5	3	10-5/4			
J1100							0-10	5	7.5-3/3			
J1200												
J1300							0-5	5	5-2/2			
K0000												
K0100							0-5	5	5-2/3			
K0200							0-5	3	10-4/6			
K0300												
K0400												
K0500												
K0600							0-10	4	5-3/4			
K0700							0-5	5	5-2/3			
K0800												
K0900							0-15	5	7.5-3/4			
K1000							0-5	3	10-5/4			
K1100							0-10	3	10-6/6			
K1200							0-15	5	5-2/3			
K1300							0-5	4	7.5-4/6			
K1400												
L-100							10-30	6	7.5-3/3			
L-200							0-5	4	7.5-4/4			
L0000												
L0100												
L0200												
L0300												
L0400												
L0500							0-5	5	7.5-3/4	5-20	7	7.5-3/2
L0600												
L0700												
L0800												
L0900												
L1000												
L1100												
L1300												
L1400							0-5	4	10-7/8	5-20	7	2.5-3/2
L1200							0-5	2	10-7/8	5-20	3	10-6/8

COORD	V	LAY1	H	COL1	LAY2	H	COL2	LAY3	H	COL3	LAY4	H	COL4
M-100	M	0-10	3	7.5-5/8	10-30	6	5-3/4	30-50	5	5-2/4	50-80	4	5-4/8
M0000	M	0-15	3	7.5-5/8	15-20	6	5-2/3	20-30	6	5-4/4	30-45	4	5-4/8
M0100	H	0-10	5	7.5-2/3	10-50	6	5-3/4	50-55	6	5-3/4	55-65	7	5-3/4
M0200	M	0-10	3	10-6/6	10-30	4	10-5/6	30-50	6	5-2/4	50-100	6	5-2/4
M0300	M	0-10	3	7.5-6/8	10-30	4	10-5/6	30-50	5	5-3/4	50-65	5	5-3/4
M0400	M	10-50	6	5-3/6	50-55	5	5-3/6	55-75	6	7.5-4/4	75-90	5	5-3/6
M0500	M	0-5	5	10-6/6	15-30	6	5-3/3	30-50	5	5-3/6	50-100	5	5-3/6
M0600	M	0-5	4	10-3/2	5-15	3	10-6/6	25-35	5	5-3/4	35-50	6	5-3/3
M0700	M	0-10	3	10-6/8	10-25	4	7.5-4/4	25-35	6	5-2/4	35-50	4	7.5-5/8
M0800		0-10	3	7.5-5/8	20-35	5	5-4/6	35-50	5	7.5-4/4	50-100	6	5-3/6
M0900	H	0-15	3	10-7/6	15-50	6	7.5-4/4	50-60	7	7.5-4/4	60-100	5	5-3/6
M1000	M	0-20	3	7.5-5/8	30-45	5	7.5-3/4	45-50	4	5-4/8	50-65	4	5-4/8
M1100	H	10-25	6	5-3/3	25-50	5	5-2/4	50-60	4	5-4/8	60-70	5	5-3/6
M1200		0-15	6	7.5-3/3	15-20	6	7.5-2/2	20-35	6	5-3/2	35-50	5	5-3/2
M1300		0-5	6	5-2/3	5-15	6	5-3/3	15-30	6	5-2/4	30-50	5	5-3/4
M1400		0-5	4	10-5/6	5-15	5	7.5-2/3				15-30	6	2.5-2/3
M1500		0-20	6	5-2/4	20-35	6	2.5-2/2	35-45	4	5-3/3	45-50	6	5-2/3
N-100	M	10-15	7	7.5-2/3	15-25	6	5-3/4	25-35	5	5-4/8	35-50	6	5-3/3
N0000	M	5-20	7	5-3/2	20-50	6	2.5-2/4	50-100	6	2.5-2/4			
N0100	M	5-15	4	7.5-5/8	15-30	6	5-2/3	30-35	5	5-3/6	35-50	6	2.5-2/4
N0200		0-20	3	7.5-6/8	20-40	6	5-3/3	40-50	5	7.5-3/4	50-100	5	5-3/6
N0300	M	10-20	6	5-2/4	20-40	6	5-3/4	40-50	5	7.5-4/4	50-60	5	7.5-4/4
N0400		0-10	6	5-2/2	10-20	4	5-4/8	20-50	6	5-4/6	50-85	4	2.5-4/8
N0500	M	0-20	3	7.5-5/8	20-50	6	5-3/4	50-70	6	5-3/4	70-100	5	5-3/6
N0600	M	0-15	3	10-6/6	15-30	6	5-3/3	30-45	6	5-4/2	45-50	7	5-3/6
N0700		0-10	5	7.5-2/3	10-20	6	7.5-3/4	20-50	6	5-3/3	50-65	6	2.5-3/3
N0800		0-10	4	7.5-4/6	10-50	4	5-3/6	50-100	6	5-3/6			
N0900		0-10	3	5-3/6	10-20	5	5-2/3	20-35	7	7.5-4/4	35-50	6	5-2/4
N1000		0-20	6	7.5-2/3	20-40	4	5-4/6	40-50	6	5-3/3	50-65	5	2.5-3/3
N1100		0-10	2	10-5/8	10-25	7	7.5-2/2	25-50	6	5-2/4	50-100	5	5-3/3
N1200		0-10	7	5-2/2	10-20	6	5-3/2	20-30	4	5-5/8	30-50	6	5-3/4
N1300		0-20	6	5-3/3	20-40	5	5-4/8	40-50	6	5-2/1	50-85	5	5-3/6
O-100	C	0-20	7	7.5-2/2	20-60	5	5-2/2	60-100	4	5-5/8			
O0000	H	0-15	5	5-3/3	15-25	7	7.5-3/4	25-40	5	5-2/4	40-50	4	5-3/6
O0100	C	0-30	7	5-2/2	30-50	5	5-2/4	50-60	4	5-5/8	60-70	4	7.5-4/4
O0200	M	0-15	3	7.5-5/8	15-30	5	7.5-3/4	30-50	5	7.5-4/4	50-70	7	5-3/6
O0300	M	0-15	2	7.5-5/6	15-40	4	7.5-4/6	40-50	5	7.5-4/4	50-100	5	7.5-4/4
O0400	C	0-10	4	7.5-3/4	10-15	6	7.5-3/2	15-20	4	7.5-4/4	20-35	6	7.5-3/4
O0500	M	0-15	7	5-1.7/1	15-40	5	5-3/4	40-50	6	5-2/4	50-100	5	2.5-2/4
O0600	M	0-20	2	10-6/8	20-50	6	7.5-4/4	50-60	7	7.5-3/4	60-90	6	5-3/6
O0700	M	0-5	3	10-6/6	5-15	5	10-3/3	15-50	6	7.5-3/4	50-60	6	7.5-3/4
O0800	M	0-10	3	10-5/8	10-15	5	7.5-4/4	15-70	7	7.5-3/4	70-100	5	5-4/8
O0900	M	0-15	3	10-6/6	15-30	7	2.5-2/2	30-70	6	5-3/3	70-100	5	5-3/3
O1000	M	0-10	3	10-6/6	10-20	5	10-4/4	20-35	7	7.5-3/3	35-50	5	7.5-4/6
O1100	M	0-10	3	10-6/8	10-20	4	10-4/6	20-50	6	10-4/4	50-80	5	5-3/4
P0200	C	0-15	6	7.5-3/3	15-50	6	5-3/3	50-100	5	5-3/3			
P0300	M	0-20	7	5-2/2	20-50	5	5-3/4	50-100	5	5-3/4			
P0400	B	0-5	4	7.5-4/4	5-20	7	7.5-2/2	20-50	6	5-3/3	50-60	6	5-3/3
P0500	M	0-15	3	7.5-4/6	15-30	6	7.5-3/2	30-40	6	7.5-3/4	40-50	5	5-2/4
P0600	M	0-35	3	7.5-6/8	35-50	6	7.5-3/4	50-100	6	5-3/4			
P0700	M	0-35	3	10-5/8	35-50	6	7.5-3/3	50-100	6	7.5-3/3			
P0800	B	0-10	3	10-6/6	10-20	7	7.5-2/2	20-50	6	7.5-3/3	50-100	6	5-2/4
P0900	M	0-20	3	10-5/8	20-40	6	10-3/4	40-60	7	5-2/4	60-85	5	5-4/8
P1000		0-5	3	10-6/6	5-20	7	7.5-2/2	20-30	5	5-2/4	30-50	6	5-3/3
Q0200	H	0-20	7	7.5-2/3	20-50	5	5-2/4	50-60	5	5-2/4	60-75	6	5-2/4
Q0300	C	0-20	6	7.5-2/2	20-30	6	7.5-2/2	30-50	4	5-4/8	50-100	4	5-4/8
Q0400	H	0-10	7	7.5-2/3	10-20	6	7.5-3/3	20-35	5	5-2/3	35-50	4	5-4/8
Q0500	H	0-10	5	5-3/3	10-15	7	5-3/3	15-20	6	5-3/4	20-50	5	5-4/8
Q0600	H	0-10	4	7.5-4/4	10-20	6	7.5-4/4	20-50	5	7.5-4/6	50-70	6	5-2/4
Q0700		0-20	6	5-2/2	20-40	4	5-3/4	40-50	5	5-4/8	50-70	5	5-4/8
Q0800		0-15	5	7.5-4/4	15-40	6	7.5-3/4	40-50	4	7.5-5/8	50-80	6	5-3/6
Q0900		0-10	7	5-2/2	10-20	6	7.5-2/3	20-50	4	5-4/8	50-70	6	7.5-4/4
Q1000		0-25	7	5-2/4	25-50	4	5-3/6	50-60	4	5-3/6	60-75	6	5-2/4
R0600		0-5	4	7.5-4/6	5-10	7	5-4/3	10-25	7	7.5-3/3	25-55	6	7.5-3/4

	LAY5 H COL5	LAY6 H COL6	LAY7 H COL7	LAY8 H COL8
M-100	80-1007 5-3/3			
M0000	45-50 6 5-4/4	50-55 6 5-4/4	55-75 5 5-4/8	75-1005 5-2/4
M0100	65-70 5 5-4/6	70-1006 5-2/4		
M0200				
M0300	65-1007 7.5-4/6			
M0400	90-1007 7.5-3/4			
M0500				
M0600	50-1007 5-2/4			
M0700	50-60 5 5-4/6	60-75 6 5-2/3	75-1004 5-4/6	
M0800				
M0900				
M1000	65-1007 5-2/4			
M1100	70-90 4 7.5-4/6	90-1005 5-3/4		
M1200	50-80 5 5-3/2	80-1004 5-4/8		
M1300	50-60 5 7.5-3/4	60-80 6 7.5-3/3	80-90 5 7.5-3/3	90-1004 7.5-3/4
M1400	30-40 4 5-5/8	40-50 5 5-4/6	50-65 5 5-3/6	65-80 6 5-3/6
M1500	50-60 5 5-4/6	60-90 6 5-2/3	90-1005 2.5-3/2	
N-100	50-75 4 5-5/8	75-85 6 5-3/3	85-1004 5-3/4	
N0000				
N0100	50-70 5 2.5-2/4	70-80 4 5-4/8	80-1006 5-2/4	
N0200				
N0300	60-1006 5-2/4			
N0400	85-1007 5-4/8			
N0500				
N0600	50-75 5 5-3/6	75-1007 5-2/4		
N0700	65-80 4 5-4/8	80-1006 2.5-2/4		
N0800				
N0900	50-65 6 7.5-3/3	65-80 4 5-4/8	80-1007 2.5-2/4	
N1000	65-75 4 5-4/8	75-1007 5-2/4		
N1100				
N1200	50-80 5 5-3/6	80-1007 5-3/3		
N1300	85-1006 5-2/4			
O-100				
O0000	50-60 6 5-3/6	60-70 5 5-3/6	70-1007 5-2/4	
O0100	70-1006 5-2/4			
O0200	70-1005 2.5-3/4			
O0300				
O0400	35-50 5 5-3/6	50-60 5 5-3/6	60-85 6 7.5-4/4	85-1007 5-3/4
O0500				
O0600	90-1005 5-3/6			
O0700	60-80 4 5-4/8	80-90 5 2.5-2/4	none	
O0800				
O0900				
O1000	50-85 7 7.5-4/4	85-1007 2.5-3/3		
O1100	80-1006 5-3/4			
P0200				
P0300				
P0400	60-80 4 5-4/8	80-90 4 7.5-4/8	90-1--4 7.5-3/2	
P0500	50-1005 5-2/4			
P0600				
P0700				
P0800				
P0900	85-1007 5-2/2			
P1000	50-80 4 5-4/8	80-1005 5-4/8		
Q0200	75-1004 5-4/8			
Q0300				
Q0400	50-1004 5-4/8			
Q0500	50-60 7 7.5-4/4	60-80 5 5-4/6	80-1006 5-3/6	
Q0600	70-1005 5-3/6			
Q0700	70-1006 5-3/4			
Q0800	80-90 5 5-4/8	90-1005 5-4/8		
Q0900	70-80 5 7.5-5/8	80-1006 7.5-4/4		
Q1000	75-1004 5-3/6			
R0600	55-90 5 5-2/4	90-1004 5-4/8		

	LAY9	H	COL9	LAY10	H	COL10	LAY_X1	H	COL_X1	LAY_X2	H	COL_X2
M-100												
M0000												
M0100												
M0200												
M0300												
M0400							0-10	3	10-6/6			
M0500							5-15	3	7.5-2/2			
M0600							15-25	5	7.5-4/4			
M0700												
M0800							10-20	4	7.5-3/4			
M0900												
M1000							20-30	5	7.5-4/4			
M1100							0-10	2	10-6/6			
M1200												
M1300												
M1400	80-85	5	5-4/8	85-100	6	5-3/4						
M1500												
N-100							0-5	3	10-6/8	5-10	5	
N0000							0-5	3	10-6/6			
N0100							0-5	5	7.5-3/3			
N0200												
N0300							0-10	3	7.5-5/8			
N0400												
N0500												
N0600												
N0700												
N0800												
N0900												
N1000												
N1100												
N1200												
N1300												
O-100												
O0000												
O0100												
O0200												
O0300												
O0400												
O0500												
O0600												
O0700												
O0800												
O0900												
O1000												
O1100												
P0200												
P0300												
P0400												
P0500												
P0600												
P0700												
P0800												
P0900												
P1000												
Q0200												
Q0300												
Q0400												
Q0500												
Q0600												
Q0700												
Q0800												
Q0900												
Q1000												
R0600												

REMARKS

I0500	cutaway area
I0600	cutaway area
I0700	no drilling - too hard
I0800	dry area
I0900	drilling in wet hollow.

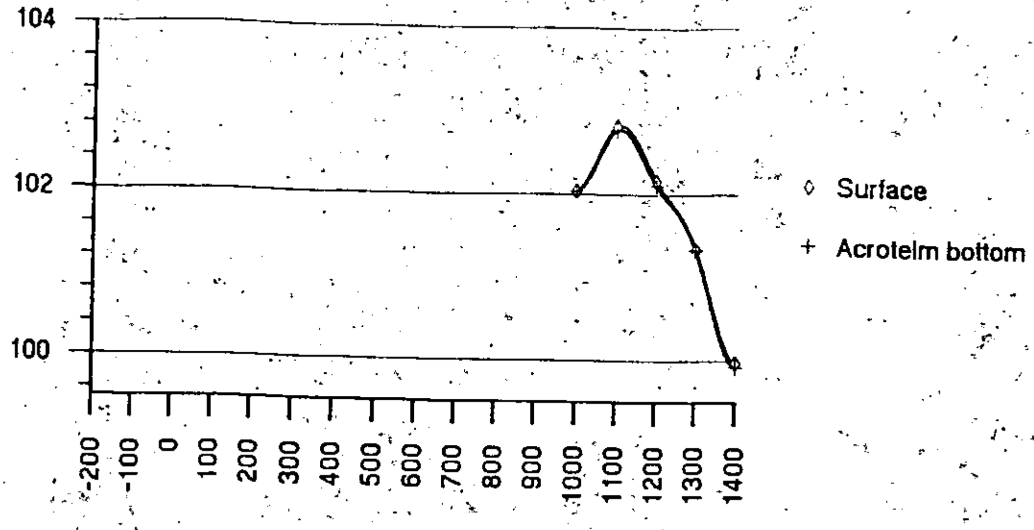
APPENDIX 13 DATA OF SUPPLEMENTARY ACROTELM MAPPING IN SPHAGNUM HOLES

COORD	LAY1	H	COL1	LAY2	H	COL2	LAY3	H	COL3
I1200	0-10	4	10-6/6						
J0	0-5	4	106/6						
J100	0-5	3	10-5/6	5-20	6	7.5-2/3			
J1000	0-8	3	10-5/6						
J1100	0-5	3		5-10	4				
J300	0-10	3	7.5-4/6	10-20	4	7.5-4/6	20-25	6	7.5-3/3
J600	0-10	4	10-5/4	10-30	6	7.5-2/1			
K0	0-10	4	7.5-4/3	10-30	7	7.5-2/2			
K100	0-10	3	10-6/6	10-20	7	10-2/1			
K1000	0-5	3		5-10	5				
K1200	0-5	3	10-6/4	5-15	5	10-6/4			
K200	0-60	3	10-5/8						
K300	0-5	3	10-6/6	5-30	4	10-4/6			
K400	0-15	3	10-5/8	15-25	5	10-4/3			
K500	0-30	4	10-6/6	30-40	5	10-3/4			
K600	0-10	3	10-5/6	10-20	5	7.5-3/4			
K800	0-10	2	10-6/8	10-20	6	7.5-2/3			
K900	0-30	3							
L1000	0-10	3	10-5/4						
L1300	0-5	3	10-6/4	5-10	5	7.5-2/3	10-20	3	10-5/6
L400	0-20	4	10-5/8						
L500	0-5	5	7.5-3/4	5-20	4	7.5-4/6			
N1000	0-5	2		5-10	3		10-15	5	
N1100	0-10	3							
N300	0-10	3	7.5-5/8						
N500	0-20	3	7.5-5/8						
O1100	0-10	3							

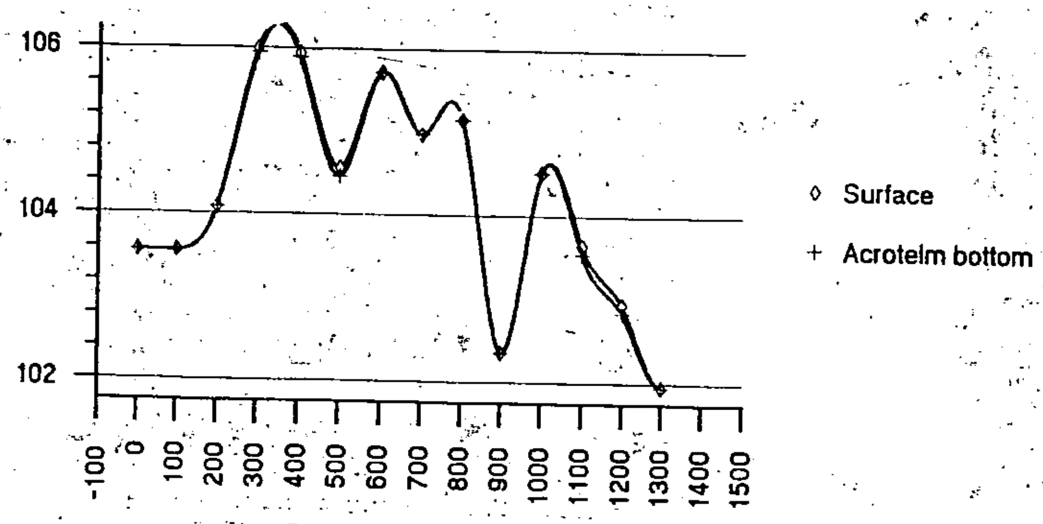
Explanation Appendix 12 and 13

coord = coordinate of the grid system of Raheenmore
lay1 = the first layer of the bog, the thickness is given in centimeters, the beginning end the end of the layer (vertical) is given
H = humification degree according to Von Post
Col1 = the colour of the first layer according to Munsell

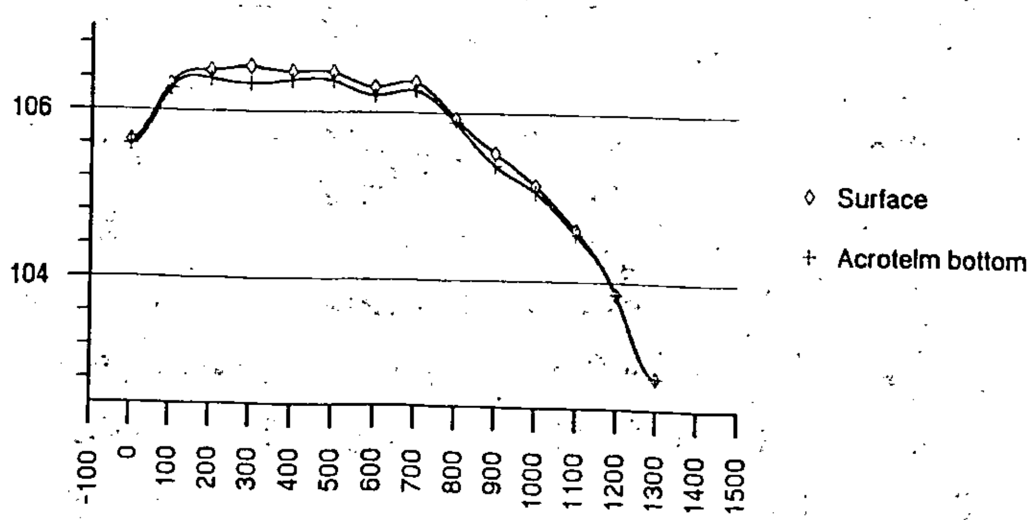
CROSS SECTIONS OF THE ACROTELM ON RAHEENMORE BOG



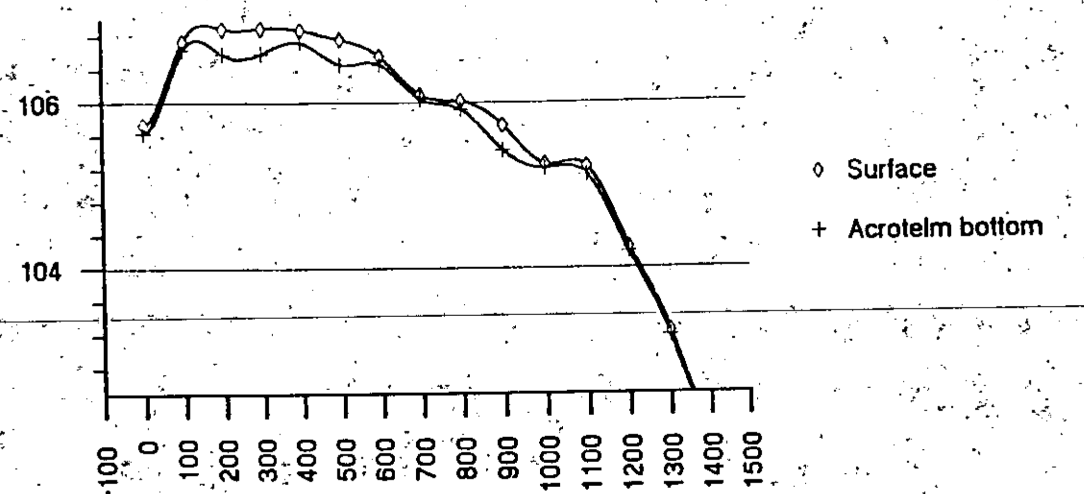
Acrotelm Raheenmore Bog, Transect H



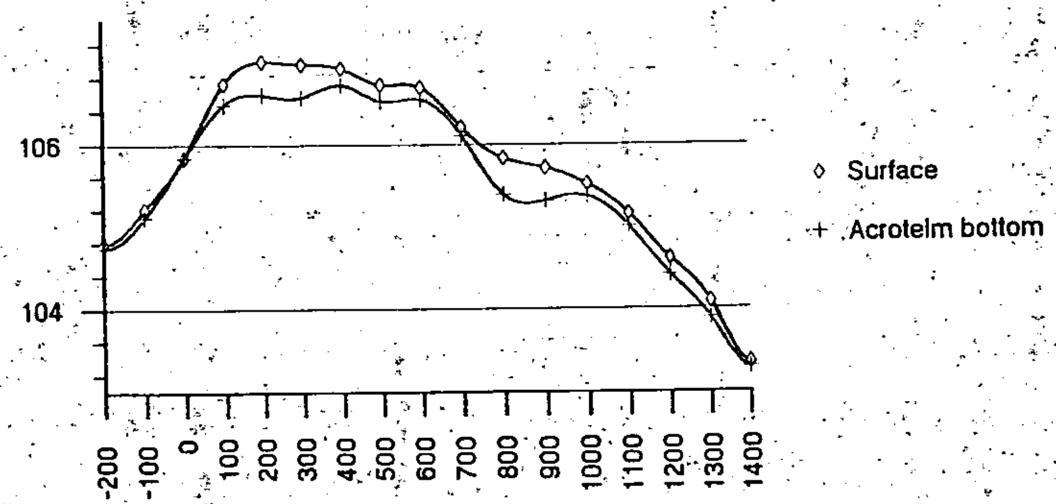
Acrotelm Raheenmore Bog, Transect I



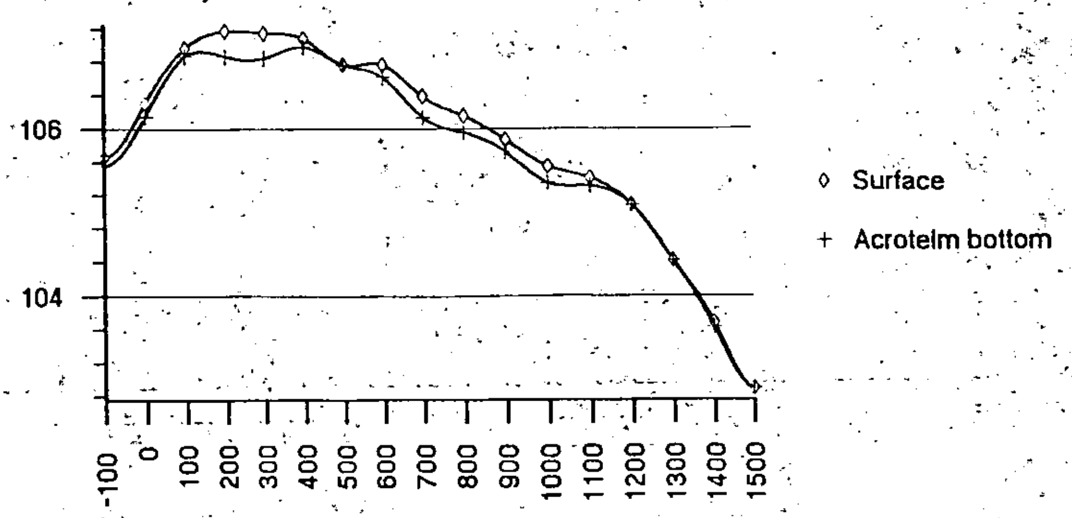
Acrotelm Raheenmore Bog, transect J



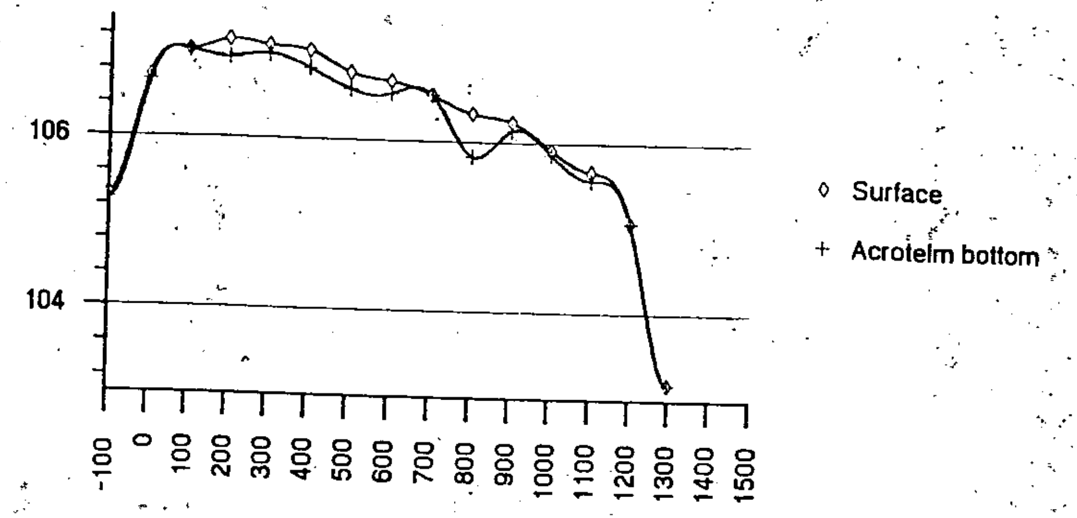
Acrotelm Raheenmore Bog, transect K



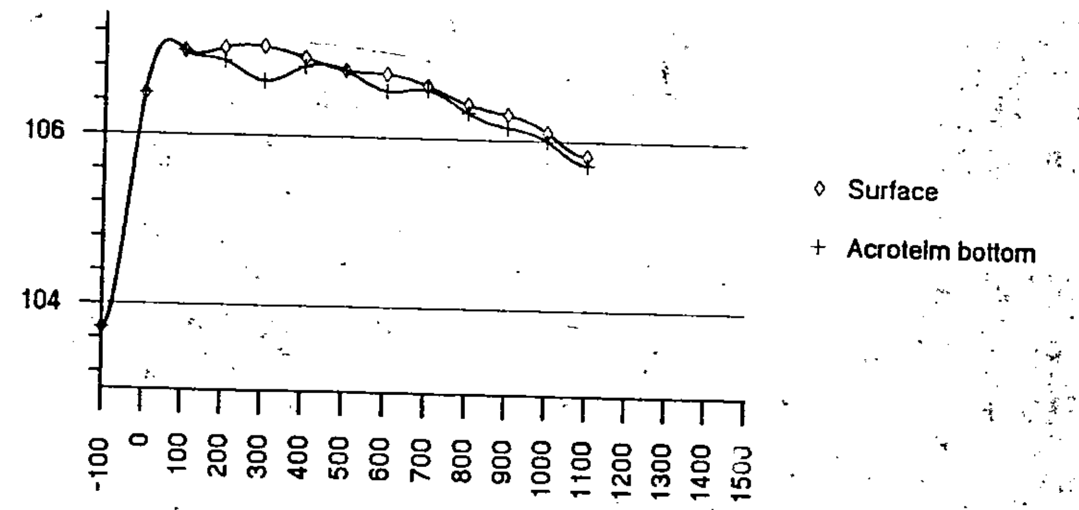
Acrotelm Raheenmore Bog, transect L



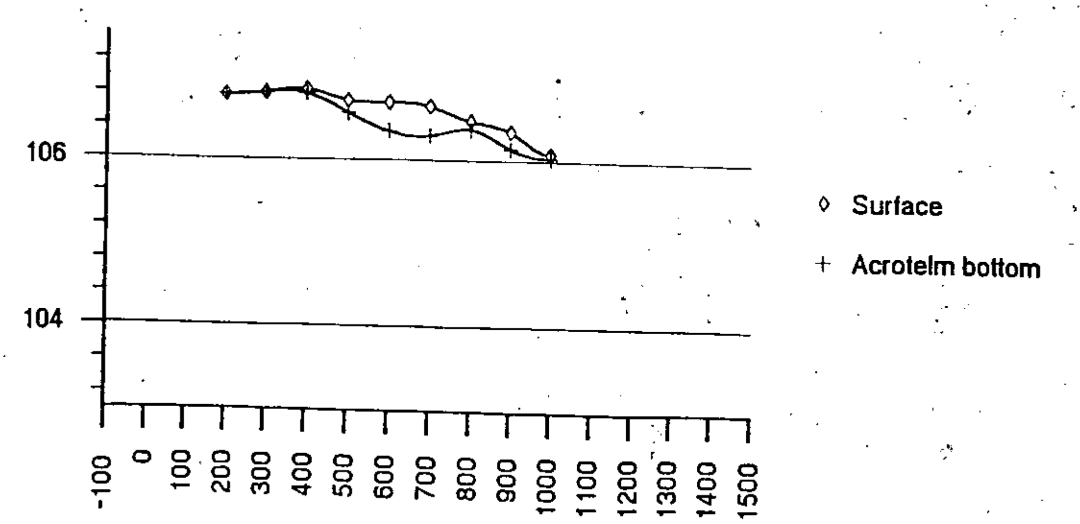
Acrotelm Raheenmore Bog, transect M



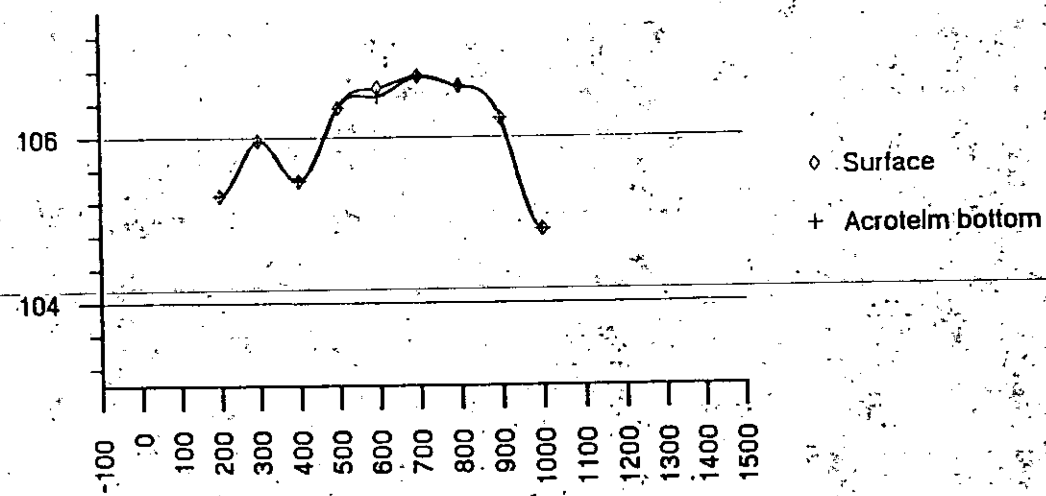
Acrotelm Raheenmore Bog, transect N



Acrotelm Raheenmore Bog, transect O



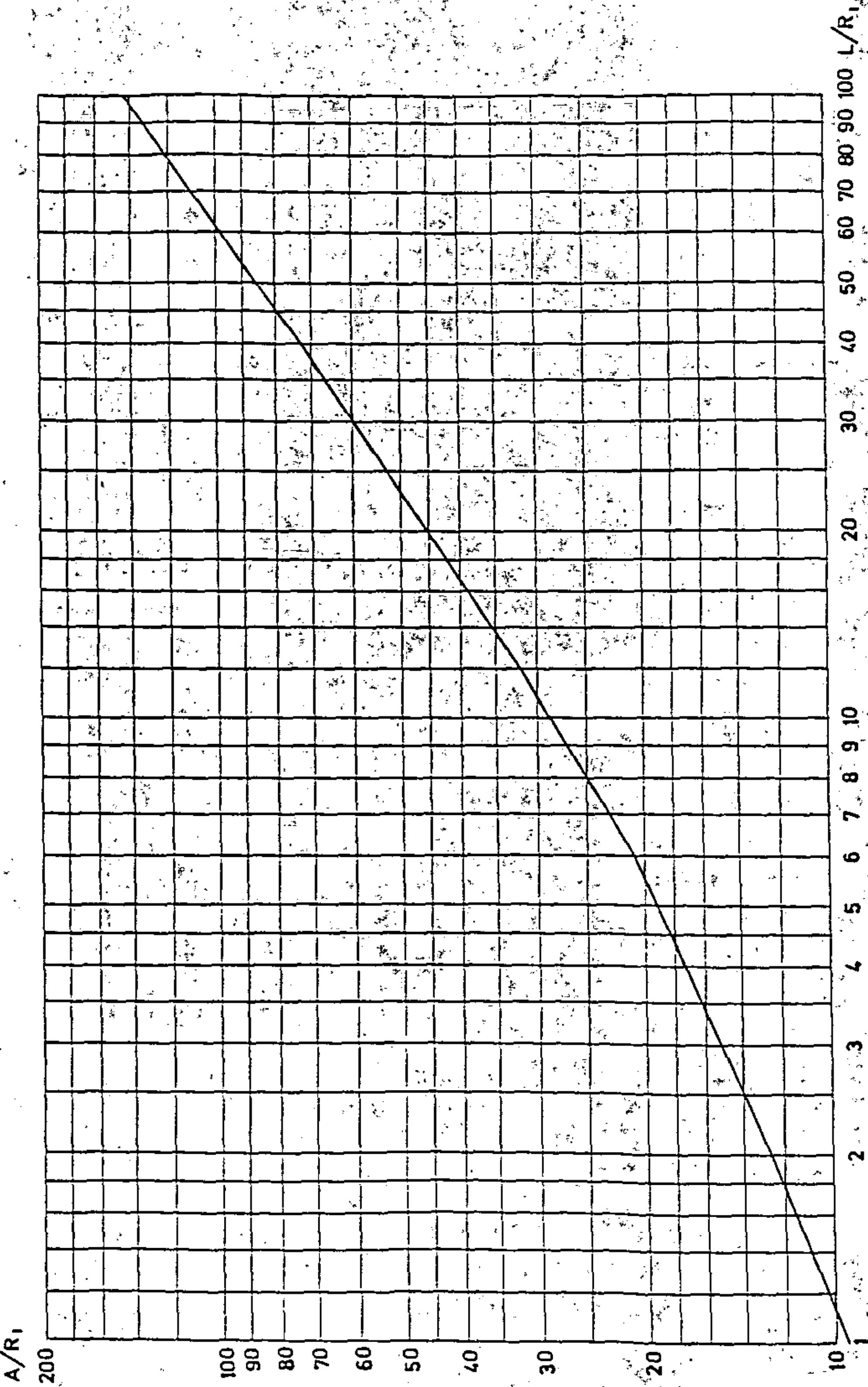
Acrotelm Raheenmore Bog, transect P



Acrotelm Raheenmore Bog, transect Q

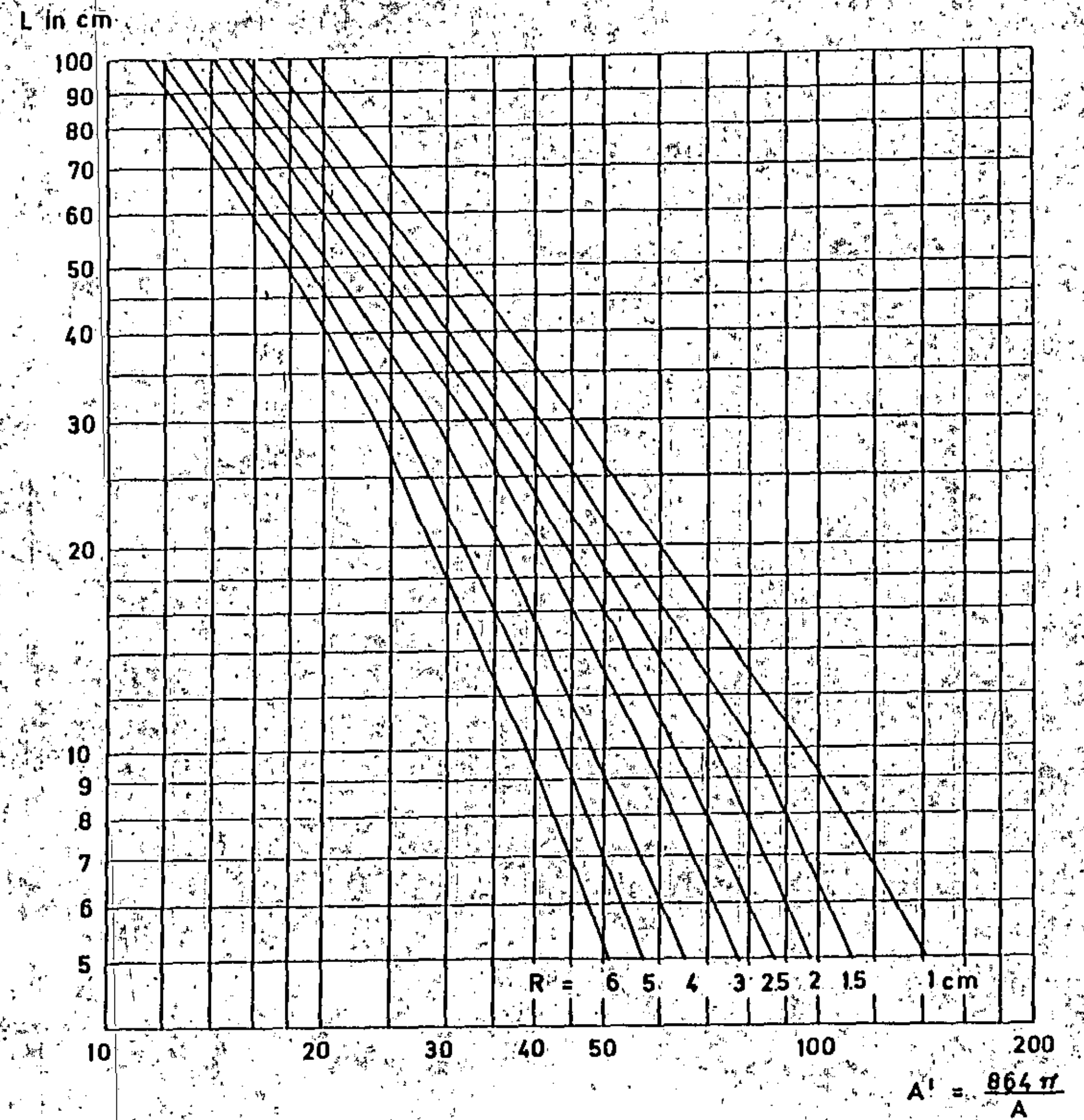
APPENDIX 15 NOMOGRAMS FOR THE DETERMINATION OF THE GEOMETRIC CONSTANTS IN THE FALLING AND RISING HEAD TEST

From Handleiding Veldpracticum Hydrologie (University Wageningen)



Graph 1. Relation between L/R_1 and A/R_1 for the piezometer method.

Graph 2. Relation between L, R_1 and A' for the piezometer method.



Ho - 244/4

APPENDIX 16 DATA, CALCULATIONS AND GRAPHS OF PIEZOMETER TEST 1

CONSTANT HEAD

date 17-4-1991 (numbers 1 to 4)
19-4-1991 (numbers 3 and 5 to 8)

location K1250 (near groundwaterrecorder)

tubenumber	1	2	3(1)	3(2)	4
filterlenght (m)	0.2	0.1	0.2	0.2	0.1
perforation percentage	10	10	20	20	20
imposed head y0 (m)	0.20	0.19	0.18	0.21	0.22
internal diameter (m)	0.021	0.021	0.021	0.021	0.021
shape factor S	0.31	0.16	0.31	0.31	0.16
watervolume vessel t1 (l)	9.4	9.4	9.5	7.7	9.1
watervolume vessel t2 (l)	9.0	9.0	9.2	7.1	8.7
time difference (min)	116	116	116	180	116
Q infin (lx10E-3(l/s))	0.057	0.057	0.043	0.056	0.050
hydr. conduc. k (m/day)	0.08	0.16	0.07	0.07	0.12

tubenumber	5	6	7	8
filterlenght (m)	0.2	0.1	0.2	0.1
perforation percentage	10	10	20	20
imposed head y0 (m)	0.20	0.19	0.19	0.16
internal diameter (m)	0.021	0.021	0.021	0.021
shape factor S	0.31	0.16	0.31	0.16
watervolume vessel t1 (l)	7.3	8.3	8.6	7.8
watervolume vessel t2 (l)	7.1	8.3	8.1	7.2
time difference (min)	180	180	180	180
Q infin (lx10E-3(l/s))	0.019	0.000	0.046	0.056
hydr. conduc. k (m/day)	0.03	0.00	0.07	0.20

RISING HEAD METHOD

DATA date: 13-3-91

tube	1	2	3	4	5	6	7	8
wat lev	78.1	82.8	83	82.4	78.4	75.5	75.7	71.2
time(s)	y' (cm)	y' (cm)	y' (cm)	y' (cm)	y' (cm)	y' (cm)	y' (cm)	y' (cm)
0	109.3	110.2	110	109	98	99.2	101.5	101.4
10	106.6	108.5	107.5	106.4	96.1	97.8	99.2	99.7
20	103.6	107.8	105.7	104.9	94.4	96.8	97.5	98
30	101.9	107.2	104.5	104	93.2	95.6	95.8	96.2
40	100.6	106.4	103.8	103.1	92.2	95	94.7	95.1
50	99.3	105.8	103	102.5	91.6	94.4	93.6	94
60	98.6	105.5	102.4	101.9	91.1	93.4	92.8	93.1
70	97.5	105.1	101.9	101.4	90.5	92.8	92	92.4
80	96.8	104.7	101.4	100.9	90.1	92.4	91.1	91.4
90	96.1	104.4	101	100.4	89.8	91.8	90.5	90.7
100	95.4	104.1	100.4	100.2	89.3	91.3	90	89.9
110	94.7	103.7	100.1	99.8	89	90.8	89.5	89.2
120	94.1	103.4	99.9	99.4	88.7	90.4	89.1	88.9
140	93.2	102.5	99.1	98.9	87.9	89.7	88.1	87.7
160	92.4	102.4	98.3	98.3	87.4	89.2	87.2	86.9
180	92.1	101.5	98	98	87.3	88.1	86.8	86.1
210	91.5	101	97.4	97.3	86.8	87.4	85.8	85
240	90.6	100.6	96.8	96.6	86.3	86.7	84.8	84
300	89.5	99.8	95.9	95.9	85.7	85.5	83.5	82.2
450	87.6	97.8	93.7	94.3	84.6	83.4	82.4	80
600	86.5	96	92.4	93.1	83.6	82.1	81	78.6
900	85	94	90.8	91.2	82.5	80.6	79.8	76.9
1200	83.8	92.8	89.5	90.6	81.9	79.7	79.1	76
1500	83.6	91.3	88.5	89.6	81.2	79	78.5	75.3
2100	82.7	90.2	87.5	87.9	80.7	77.7	77.7	74.6
2700	82.1	89.1	86.9	87.4	80.5	82.8	77.4	74.4
3600	81.8	87.8	85.8	86.5	66.5	80.7	77.4	73.7
5400	80.9	86.5	85	85.5	80.2	78.6	76.9	72.9
7200	80.4	85.5	84.7	94.9	80.2	77.7	76.8	72.2
9000	80.1	85.3	84.6	84.6	80	77.7		
10800	79.9	85	84.7	84.5	79.9			
12600	80	81.7	84.5					
14580	79.9	81.5						

CALCULATIONS

tube	1	2	3	4	5	6	7	8
perforat	1x20	1x10	2x20	2x10	1x20	1x10	2x20	2x10
r (cm)	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Lcav (cm	20	10	20	10	20	10	20	10
A	49	31	49	31	49	31	49	31
ln(y)/t	0.0048	0.00165	0.004	0.004	0.01	0.00412	0.00723	0.00404
k (m/d)	0.41546	0.22574	0.34622	0.54725	0.86554	0.56366	0.62579	0.55272

ln(y')/t 0,0037l 0,0025

98

FALLING HEAD METHOD

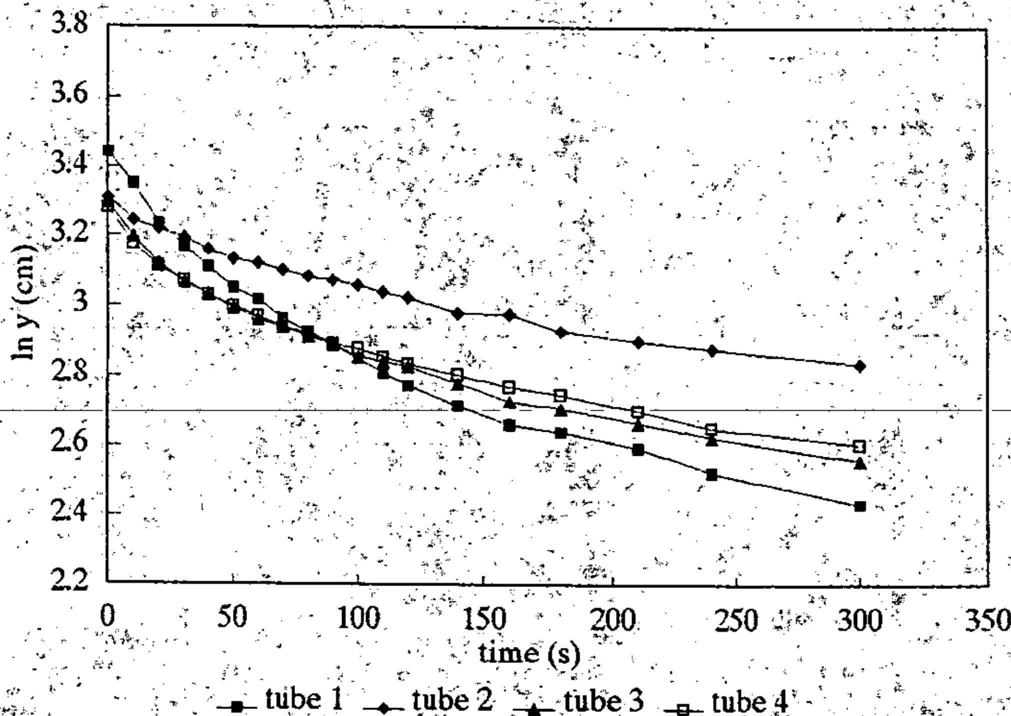
DATA (date 14-3-91)

tube	1	2	3	4	5	6	7	8
perforat	1x20	1x10	2x20	2x10	1x20	1x10	2x20	2x10
wat lev	79.1	83.8	83.9	83.1	79.1	76.2	75.8	71.2
time(s)	y' (cm)	y' (cm)	y' (cm)	y' (cm)	y' (cm)	y' (cm)	y' (cm)	y' (cm)
0	38.2	31	42.5	45	47.5	39.6	41	33
10	43	33.2	46.8	47.3	51.3	41.5	43.7	34.7
20	46.5	35.1	49	49	53.5	43.3	46.5	36.9
30	49.1	37	51.2	50.2	55	45.1	48.5	38.9
40	50.5	38.4	52.3	51.3	56.3	46.3	50.1	40.7
50	51.6	39.7	53.5	52.9	57.5	47.9	51.6	42.3
60	53.1	40.1	54.6	53.4	58.6	49	52.7	43.6
70	54.4	42	55.5	54.1	59.3	50.1	53.6	44.7
80	56.4	43.1	56.5	55.1	60.1	50.9	54.5	45.7
90	56.8	44.1	57.4	55.6	60.8	51.6	55.3	46.7
100	57.2	44.8	58.1	56.2	61.4	52.4	56	47.7
110	57.5	45.3	58.6	56.6	61.8	53.2	56.7	48.6
120	57.5	46.1	59	57.1	62.2	53.9	57.2	49.4
140	57.7	47.3	60	58.1	62.8	55	58	50.4
160	58.2	48.3	61	59.1	63.4	56.2	59	51.3
180	59	49.6	62	59.8	64	57.3	59.8	52.4
210	60	51	62.9	60.6	65	58.1	60.2	53.5
240	60.5	52.4	63.9	61.4	65.5	59.5	61.3	54.6
300	61.9	54.9	65.6	62.7	66.3	60.3	62.8	57
450	64.1	59.3	67.6	65.5	68.1	63.5	64.7	58.6
600	65.3	61.7	70.3	67.2	69.4	65.3	66.2	61.5
900	67.3	65.3	72.5	69.5	70.4	67.6	68.1	62.5
1200	69.2	68.1	74	71.3	72	69.1	69.4	63.5
1500	70.1	70	75.5	72.3	72.7	69.8	70.2	64.4
2100	71	72.6	77.5	74.2	74	71	71.6	65.5
2700	72.5	74.3	78.1	75.4	74.3	64.5	72.2	66.1
3600	73.6	76.5	79.2	76.7	74.8	67.9	73	66.9
5400	74.7	79	80.2	78.4	75.6	69.9		
7200	76	80	80.7	79.1				
9000	76.5	80.8	81.3					
10800	76.6							

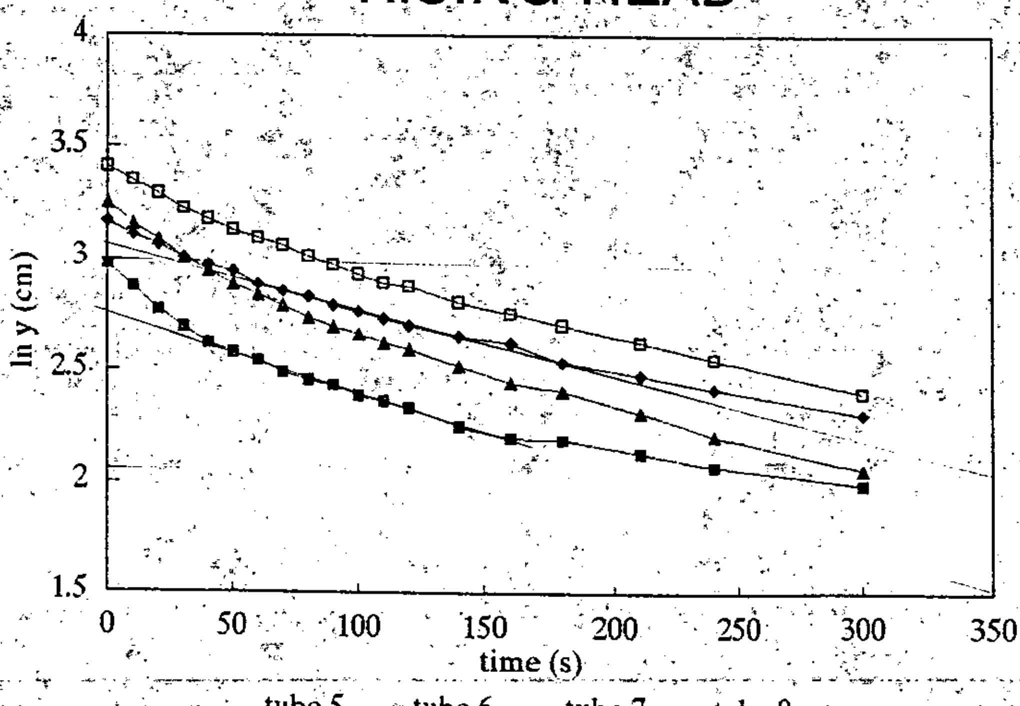
CALCULATIONS

tube	1	2	3	4	5	6	7	8
perforat	1x20	1x10	2x20	2x10	1x20	1x10	2x20	2x10
r (cm)	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Lcav (cm	20	10	20	10	20	10	20	10
shapef.	49	31	49	31	49	31	49	31
ln(y)/t	0.00143	0.00065	0.00175	0.00115	0.00497	0.00287	0.004	0.0033
k (m/d)	0.12377	0.08893	0.15147	0.15733	0.43017	0.39265	0.34622	0.45148

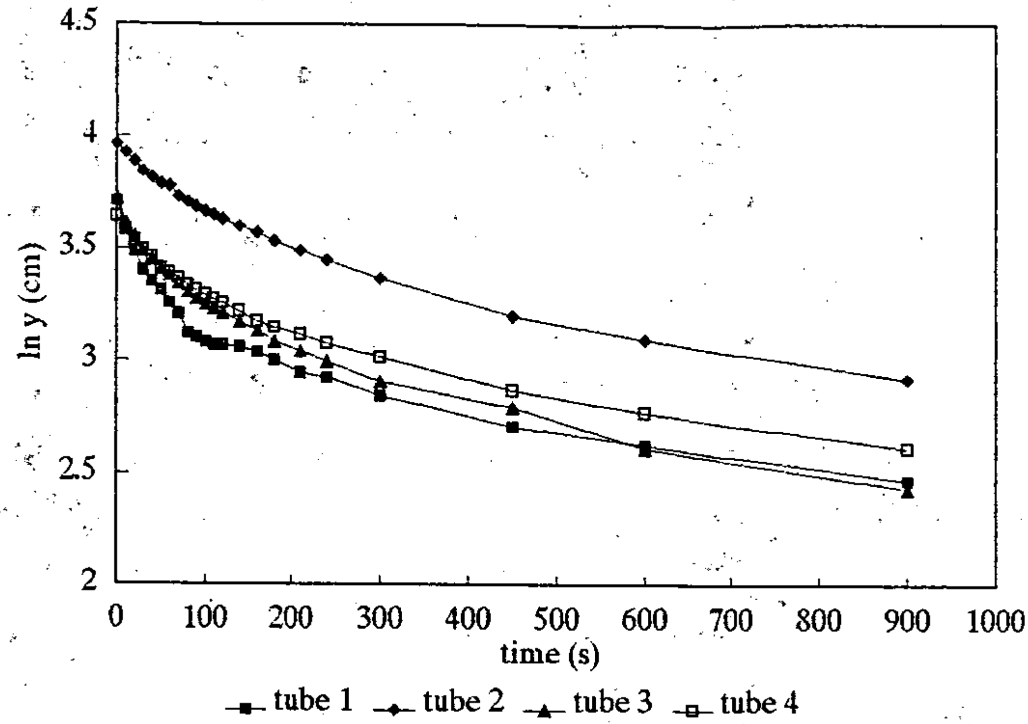
RISING HEAD



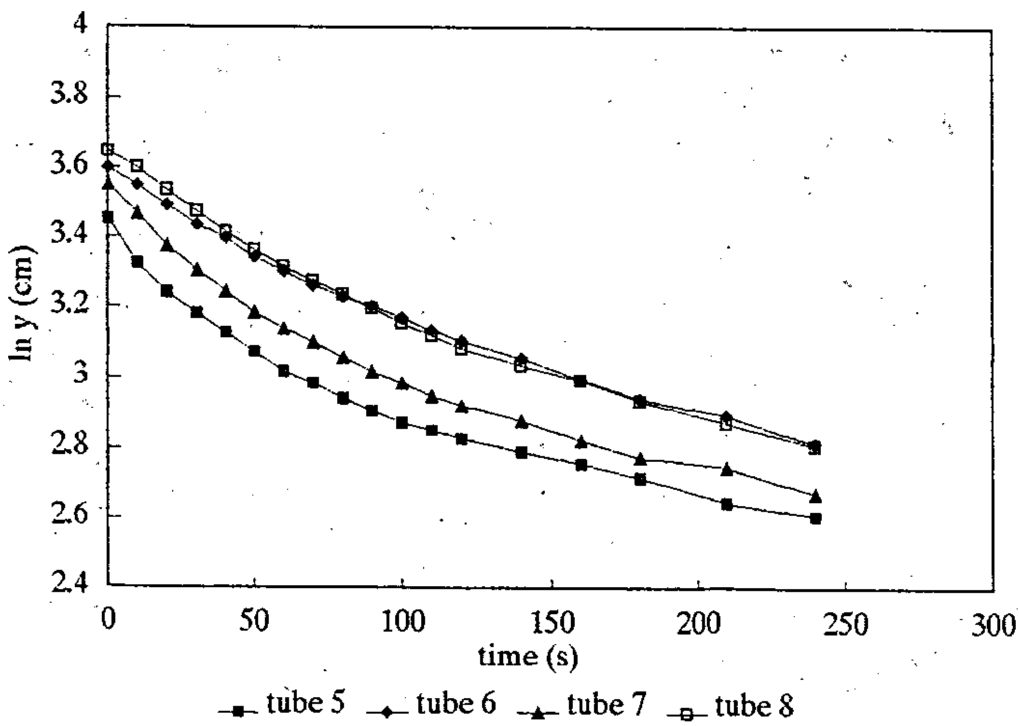
RISING HEAD



FALLING HEAD



FALLING HEAD



APPPENDIX 17 DATA, CALCULATIONS AND GRAPHS OF PIEZOMETER TEST 2

CONSTANT HEAD

date 03-05-91 (piezometers 2-9 to 2-12)
07-05-91 (piezometers 2-3 to 2-8)
08-05-91 (piezometers 2-1, 2-2 and 2-13 to

location K-900

number	2-1	2-2	2-3	2-4	2-5	2-6	2-7
filterlenght (m)	0.2	0.1	0.2	0.1	0.2	0.1	0.2
perforation percentage	10	10	20	20	10	10	20
imposed head y0 (m)	0.03	0.09	0.16	0.05	0.13	0.10	0.15
internal diameter (m)	0.021	0.021	0.021	0.021	0.021	0.021	0.021
shape factor S	0.31	0.16	0.31	0.16	0.31	0.16	0.31
waterlevel vessel t1 (cm)	17.4		18.8	16.8	19	21.2	19.3
waterlevel vessel t2 (cm)	16.9		15.3	11.3	18.2	19.2	15.5
time difference (min)	158		1088	1090	1090	1089	1089
Q infin (1x10E-3/s)	0.018		0.019	0.029	0.004	0.011	0.020
hydr. cond. k (m/day)	0.18		0.03	0.31	0.01	0.06	0.04

number	2-8	2-9	2-10	2-11	2-12	2-13	2-14
filterlenght (m)	0.1	0.2	0.1	0.2	0.1	0.2	0.1
perforation percentage	20	10	10	20	20	10	10
imposed head y0 (m)	0.11	0.12	0.16	0.11	0.10	0.09	0.05
internal diameter (m)	0.021	0.021	0.021	0.021	0.021	0.021	0.021
shape factor S	0.16	0.31	0.16	0.31	0.16	0.31	0.16
waterlevel vessel t1 (cm)	21.9	17.1	10	12.2	13.2	18.2	19.8
waterlevel vessel t2 (cm)	15.1	15.1	4.8	9.1	7.4	16.5	18.2
time difference (min)	1089	209	10	209	170	158	157
Q infin (1x10E-3/s)	0.036	0.056	3.033	0.087	0.199	0.063	0.059
hydr. cond. k (m/day)	0.18	0.13	10.13	0.21	1.06	0.19	0.71

number	2-15	2-16		2-12	2-13	2-14
filterlenght (m)	0.2	0.1		0.1	0.2	0.1
perforation percentage	20	20		20	10	10
imposed head y0 (m)	0.14	0.13		0.05	0.15	0.13
internal diameter (m)	0.021	0.021		0.021	0.021	0.021
shape factor S	0.31	0.16		0.16	0.31	0.16
waterlevel vessel t1 (cm)	22.6	19.4		18	15.8	13
waterlevel vessel t2 (cm)	22.6	18.8		16	12	8
time difference (min)	156	157		65	72	72
Q infin (1x10E-3/s)	0.000	0.022		0.179	0.308	0.405
hydr. cond. k (m/day)	0.00	0.09		1.95	0.58	1.70

RISING HEAD METHOD (1)

A' bij 20 cm filter	57
A' bij 10 cm filter	88

piezomete	2/1
start lev	36.4
time	level
0	111.5
167	106.5
405	101.5
730	96.5
977	93
1588	87
k(0-1588)	
dy/dt=	0.015
k=	0.024

piezomete	2/2
start lev	35.5
time	level
0	113.7
277	107.5
520	103.5
802	99.5
1036	96
1680	89.5
k(0-1680)	
dy/dt=	0.014
k=	0.032

piezomete	2/3
start lev	43.2
time	level
0	107.4
157	101
341	94.6
513	91
758	87
1115	83
1642	77.2
2224	72
k(0-513)	
dy/dt=	0.032
k=	0.055

piezomete	2/4
start lev	40.9
time	level
0	91
127	81
330	77.7
456	74.5
588	70.5
k(0-588)	
dy/dt=	0.035
k=	0.130

piezomete	2/5
start lev	41.7
time	level
0	113
265	102
533	90
946	80.4
1209	75
k(0-533)	
dy/dt=	0.043
k=	0.070

piezomete	2/6
start lev	41.7
time	level
0	0
377	377
577	954
349	1303
310	1613
k(0-1613)	
dy/dt=	0.024
k=	0.117

piezomete	2/7
start lev	43
time	level
0	86
283	63
446	56
k(0-446)	
dy/dt=	0.067
k=	0.231

piezomete	2/8
start lev	41.2
time	level
0	96
271	84
497	75.2
809	70.1
1154	64
k(0-497)	
dy/dt=	0.028
k=	0.143

piezomete	2/9
start lev	37.5
time	level
0	104.5
134	96
309	88
634	78
1002	72
1678	62.5
k(0-634)	
dy/dt=	0.042
k=	0.075

RISING HEAD METHOD (2)

piezomete	2/10
start lev	39.5
time	level
0	96
46	82
101	71
188	58
k(0-188)	
dy/dt=	0.202
k=	0.802

piezomete	2/13
start lev	45.5
time	level
0	93
126	74
184	69
310	63
k(0-184)	
dy/dt=	0.130
k=	0.387

piezomete	2/16
start lev	41.5
time	level
0	105
149	95
250	90.7
365	86.5
533	82
615	78.3
919	73
k(0-615)	
dy/dt=	0.043
k=	0.129

piezomete	2/11
start lev	44
time	level
0	105.8
128	99.5
286	93
973	78
1117	75
k(0-1117)	
dy/dt=	0.028
k=	0.057

piezomete	2/14
start lev	45.5
time	level
0	110
22	100
47	95
112	78
191	66
k(0-112)	
dy/dt=	0.286
k=	0.876

piezomete	2/12
start lev	40.7
time	level
0	90
103	74.8
282	61
k(0-282)	
dy/dt=	0.103
k=	0.439

piezomete	2/15
start lev	50
time	level
0	118
213	115
168	113
331	111
952	105.6
1109	100
1846	93.5
k(0-712)	
dy/dt=	0.010
k=	0.015

FALLING HEAD METHOD

A' bij 20 cm filter	57
A' bij 10 cm filter	88

piezomete	2/1
start lev	92.5
time	level
5	63
13	65
18	66
24	67
30	68
41	69
69	70
87	71
106	71.5
125	72
K(5-41)	
dy/dt=	0.167
k=	0.606

piezomete	2/2
start lev	88
time	level
0	52
6	54
17	56
31	58
63	60
80	61
108	62
150	63
199	64
253	65
339	66
k(0-63)	
dy/dt=	0.127
k=	0.590

piezomete	2/3
start lev	92.5
time	level
0	68
6	70
14	71
24.5	72
39.5	73
59	74
89	75
122	76
k(0-39.5)	
dy/dt=	0.127
k=	0.554

piezomete	2/4
start lev	90
time	level
0	64
5	65
10	66
24	67
41	68
60.5	69
94	70
136.5	71
193	72
269	73
k(0-60.5)	
dy/dt=	0.083
k=	0.523

piezomete	2/5
start lev	90
time	level
0	62
10	64
15	65
20	66
23.5	67
38	68
51	69
66	70
86	71
k(0-23.5)	
dy/dt=	0.213
k=	0.804

piezomete	2/6
start lev	93.3
time	level
5	71
12	72
21	73
33	74
51	75
72	76
102	77
k(0-51)	
dy/dt=	0.087
k=	0.637

piezomete	2/7
start lev	91
time	level
0	50
5	54
20	60
24	61
29	62
33	63
37	64
44	65
51	66
61	67
69	68
80	69
92	70
k(0-44)	
dy/dt=	0.341
k=	0.980

piezomete	2/8
start lev	92.5
time	level
0	64
5.5	65
13	66
24	67
38	68
53.5	69
77	70
110	71
k(0-53.5)	
dy/dt=	0.093
k=	0.535

piezomete	2/15
start lev	99.5
time	level
0	65
5	66
9.5	67
17	68
25	69
34	70
52	71
68	72
93	73
k(0-34)	
dy/dt=	0.147
k=	0.443

APPENDIX 18 STANDARD PAPER FOR THE RISING HEAD TEST

Piezometer Method

Location :

No :

Date :

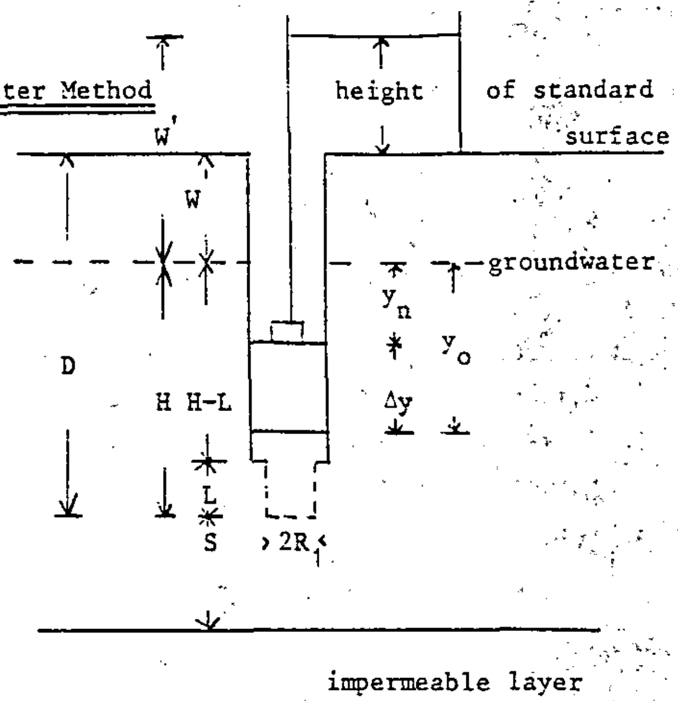
Observer :

Depth D : cm

Groundwater level W: cm

Layer measured : - cm

K :



W'	=	cm	D	=	cm
height	=	cm	W	=	cm
W	=	cm	H	=	cm
			L	=	cm

H - L = cm; H - L> L and S > L

---

time	water table after pumping	
t	y'_t	Δy_t

$y_o = y_o' - W' =$

$\Delta y = y_o' - y_n' =$

$\bar{y} = y_o - \frac{1}{2}\Delta y =$

L = cm

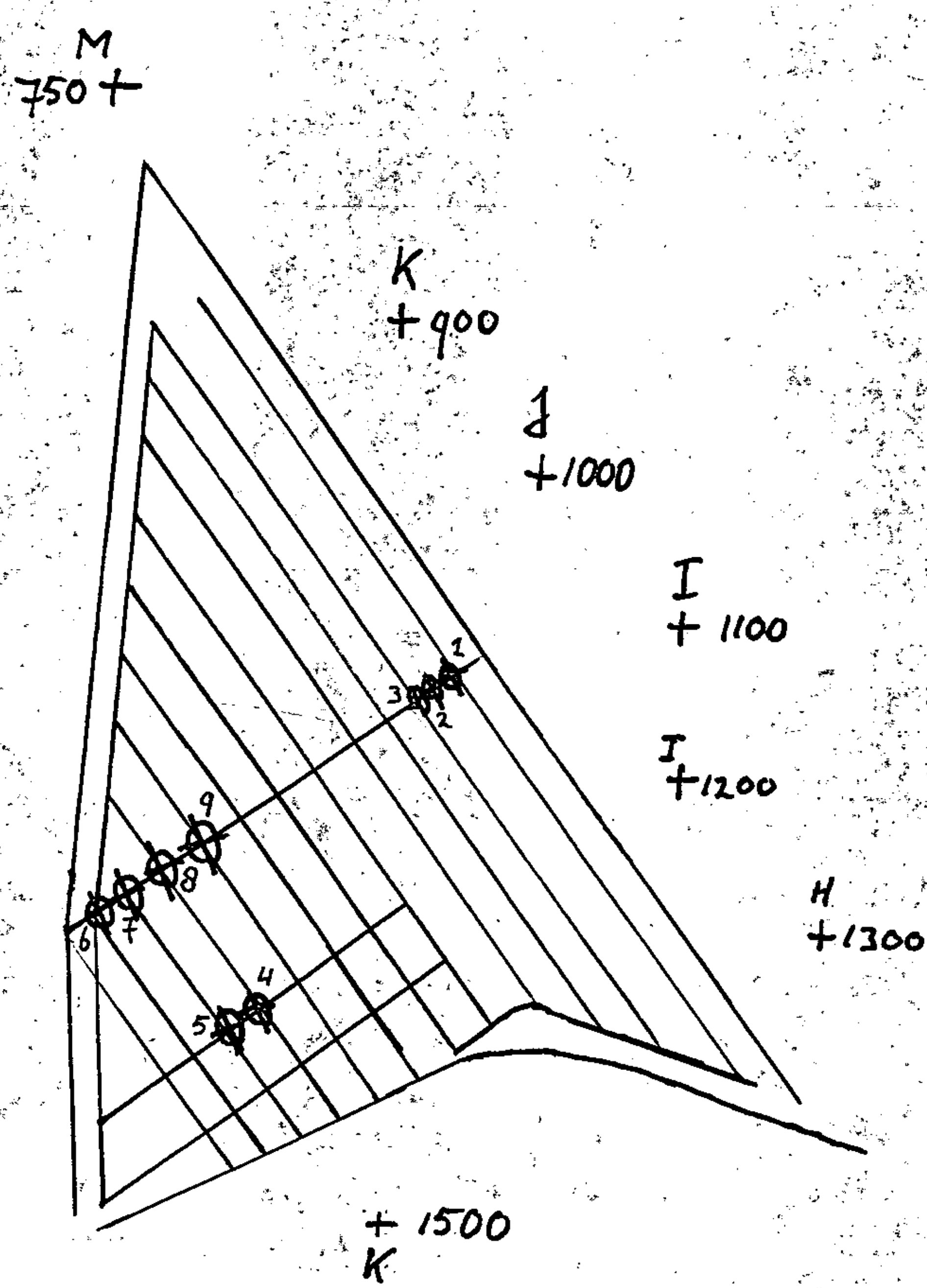
R_1 = cm A' = (from graph)

R_2 = cm

$\frac{\Delta y}{\Delta t} = \rule{2cm}{0.4pt} =$ cm/sec

$K = \frac{A' R_2^2}{\bar{y}} \times \frac{\Delta y}{\Delta t} = \quad \times \quad =$ m/day

APPENDIX 19 MAP OF DRAINS AND ADDITIONAL PIEZOMETERS ON RAHEENMORE



LEGEND

⌖ 1 PIEZOMETER 1

+ 1500 K GRID COORDINATE

——— DRAIN

For orientation of the drain see the grid of Raheenmore in APPENDIX 1