AUTOMATIC PROCESSING OF HYDROLOGICAL DATA

Errata

In het artikel van de heer B.A. Herfst (pag. 11 - 25) dient het woord "retrieval" vervangen te worden door "correction".

In the article of Mr. B.A. Herfst (page 11 - 25) the word "retrieval" has to replaced by "correction".

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INTRODUCTION

During recent years, water resources development in the Netherlands has become increasingly complex in nature. Two examples of large water resource undertakings are the Zuiderzee Works and the Delta Works. Both projects have had far reaching effects on the Dutch social and economic structure and on the problem supplying an adequate quantity of high quality water.

In order to effectively solve problems such as these it is evident that there is an increasing need for the collection, processing, and analysis of hydrological data.

Until a few decades ago hydrological data were collected by reading gauges, thus severely limiting the number of data available.

Since then, several rapid developments in various fields have had a considerable influence on the collection, processing, analysis, and storage of hydrological data.

The development of automatic registration instruments made it possible to closely follow the changes in water levels over a period of time.

The advances in computer techniques have enabled the hydrologist to process and analyse large numbers of data and to solve complex mathematical and statistical problems.

Concurrent with these developments, hydrology evolved more and more from an empirical art to a science based on mathematics and physics.

Although these new developments opened considerable possibilities, the speed of development resulted in a number of problems of a mathematical, technical, and economic nature. Many of these problems have not yet been solved or even fully recognized.

With this in mind, the Committee for Hydrological Research TNO decided to dedicate its 25th Technical Meeting to the subject of "Automatic Data Processing in Hydrology".

This meeting was held in february 1971 and the papers presented there dealt mainly with recent developments in this field which have taken place both in the Netherlands and abroad.

L. Horst

I. AUTOMATIC COLLECTING AND PROCESSING OF HYDROLOGIC DATA FROM CATCHMENT AREAS

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1. Introduction

For the Netherlands automatic collecting and processing of hydrologic data is a new development. Particularly with automatic processing of data much can be gained from the experience of the British, Americans and Australians and of international organizations like W.M.O. and UNESCO.

The symposium on hydrometry at Koblenz, 1970 showed that interest in automation is increasing fast, that there is a great supply of automatic recorders, but also that there is little known about automation in hydrology.

Automation in hydrology can be distinguished in three interdependent phases:
— collecting data
— processing data
— using data

Both processing and using data will make demands upon the way of collecting the data. Important for the processing is the method of registration (tapecode and format in which the data are to be collected).

The user will give criteria for the frequency of observation, the accuracy and the reliability of the data. This, of course, largely depends on the objective of his research, if it is e.g. a statistic or a deterministic analysis. See also § 4.2. The processing itself is in fact a transformation of the collected data in a form that meets the requirements of the user.

This article will mainly be restricted to the collection and processing of hydrologic data on punched papertape. Incidental attention will be paid to other forms of collection and processing.

2. Collecting data

2.1. *The readings*

An old technique is the reading of data by an observer. (Fig. 2.1. - 2.6.). Mostly the observer proves reliable and accurate. He is able to collect different types of data. His frequency of observation is relatively low but he is reasonably cheap. Processing of data, collected in this way is very time consuming.

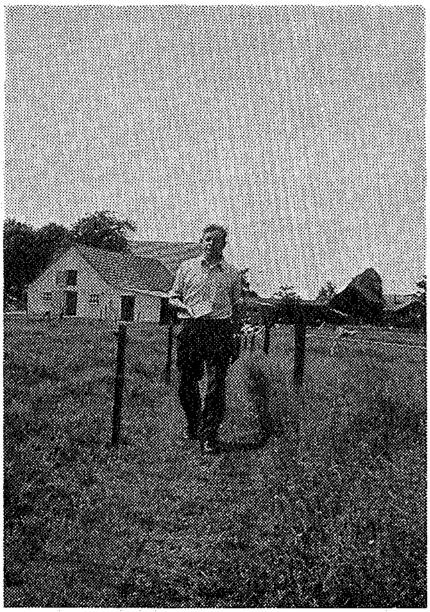
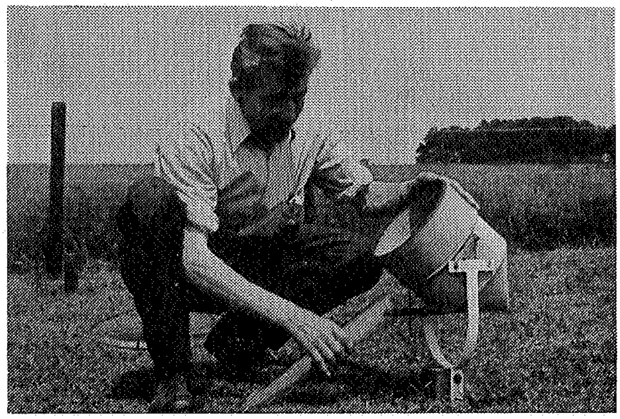


Fig. 2.1.



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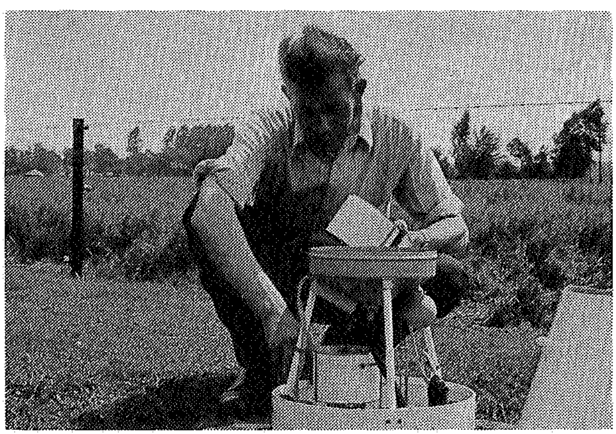

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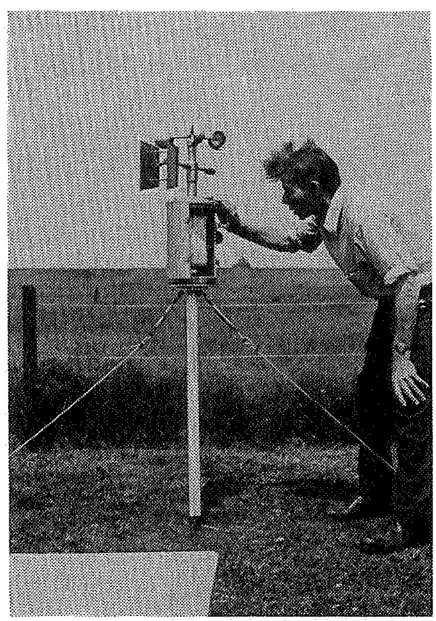

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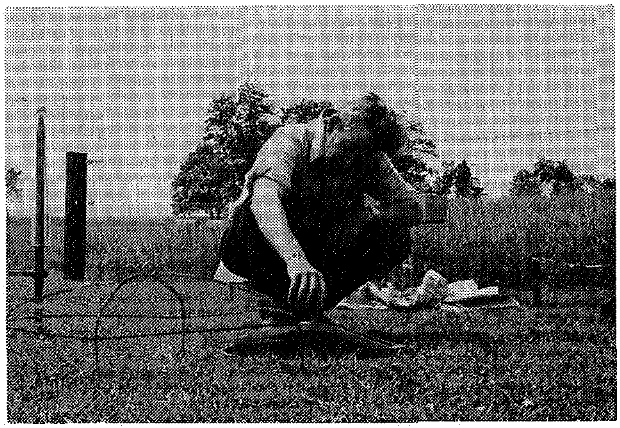

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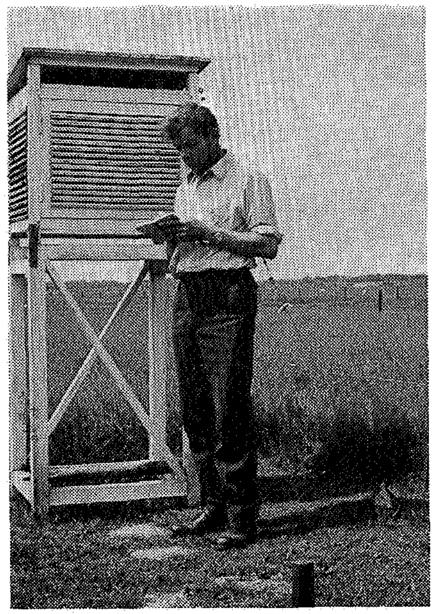

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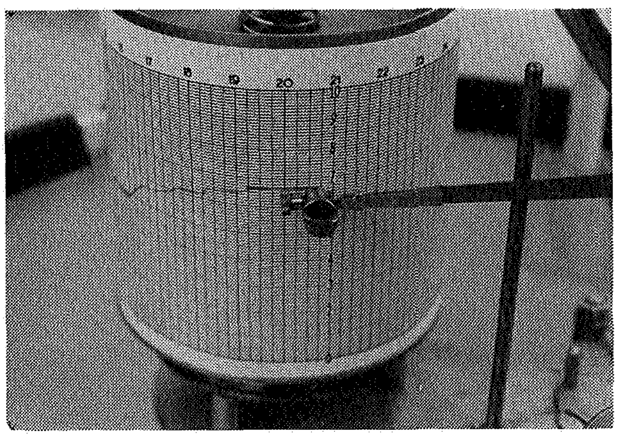


Fig. 2.7.

2.2. *Automatic recording*

By recording data automatically, the frequency of observation can be considerably increased, so that more detailed information is acquired.

Automatic recording is continuous or intermittent registration of process values by an instrument, connected by some means to a process value recorder.

Automatic recording can be separated into analogue and digital recording.

2.2.1. *Analogue recording*

Usually the process value is followed continuously and is recorded, for example, with a pen on a strip chart (Fig. 2.7). Most analogue recorders are reliable and accurate. In general one recorder can only register one datum. The processing of data collected this way is also time consuming.

2.2.2. *Digital recording*

The process value is registered at moments at regular intervals in digital form on punch papertape or on magnetic tape. In the second half of the sixties the first digital recorders for hydrologic use appeared in the Netherlands. Their number is growing fast. There is a great variety of tapes and tape-codes to choose from. (Fig. 2.8). The choice is hard for the hydrologist. He wants to acquire maximum information as cheaply as possible. But costs are determined by the price of the instrument and by the expense of computer processing the data. In particular with digital recording a good understanding between hydrologist and systems analyst (or computer programmer) is a necessity. The hydrologist, who works with digital computers, must know enough about computer science and programming to indicate how his tapes must be processed. Then he will be able to prevent the advantage of taperecording being nullified by an incorrect or ignorant processing. Usually the digital recorder is reliable and accurate. Its frequency of observation is adjustable, but lowering the frequency will increase costs per datum.

Without special provision one digital recorder can only register one datum. Because time-consuming preparatory work (the punching of cards or tapes) can be omitted, processing can be done quickly. The time saved can be used to increase observation frequency and therefore accuracy. However, a certain equilibrium has to be found between frequency and accuracy on one side and costs of recording and processing on the other. The objectives of the research must also be taken into account.

In Scheme 1 different registration techniques are compared under a number of headings. It can be clearly seen that the changes caused by digital recorders, are mainly in frequency of observation and computer compatible recording.

Directly computer compatible are the 5-, 7- and 8-hole punch tapes. The great variety of codes and formats necessitates alertness when processing and hampers the exchange of data as provision has to be made in the computerprogram for the different codes and formats. The 16-hole tape (Fischer and Porter) and many types of magnetic tape are not directly computer compatible. They first have to be translated to computer compatible tape.

Fig. 2.9 gives some idea of the many alternatives between registration and computer.

The essence of registration is that somehow a time series is recorded. The time series consists of process values y, dependent on the time t:

$$y=f(t) \tag{1}$$

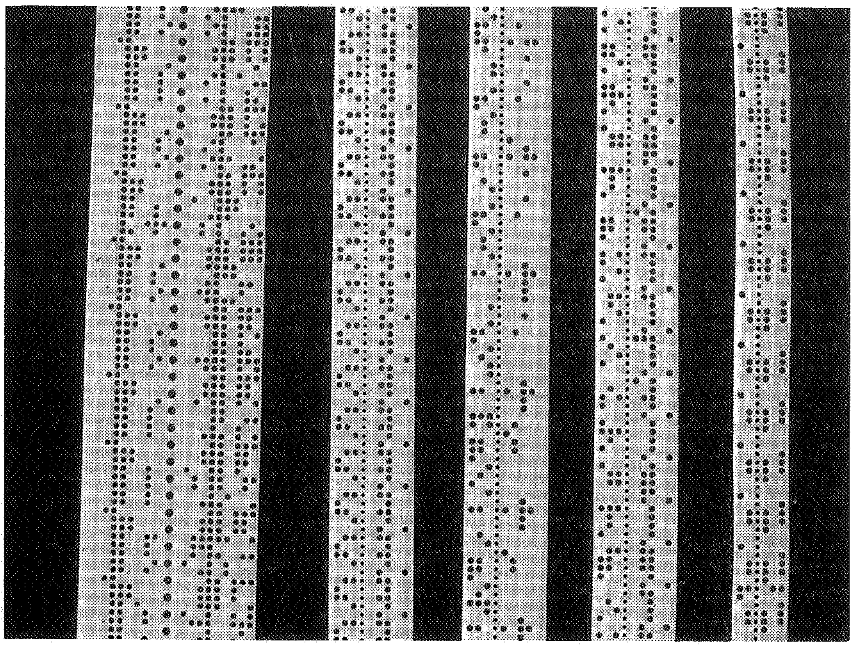


Fig. 2.8.

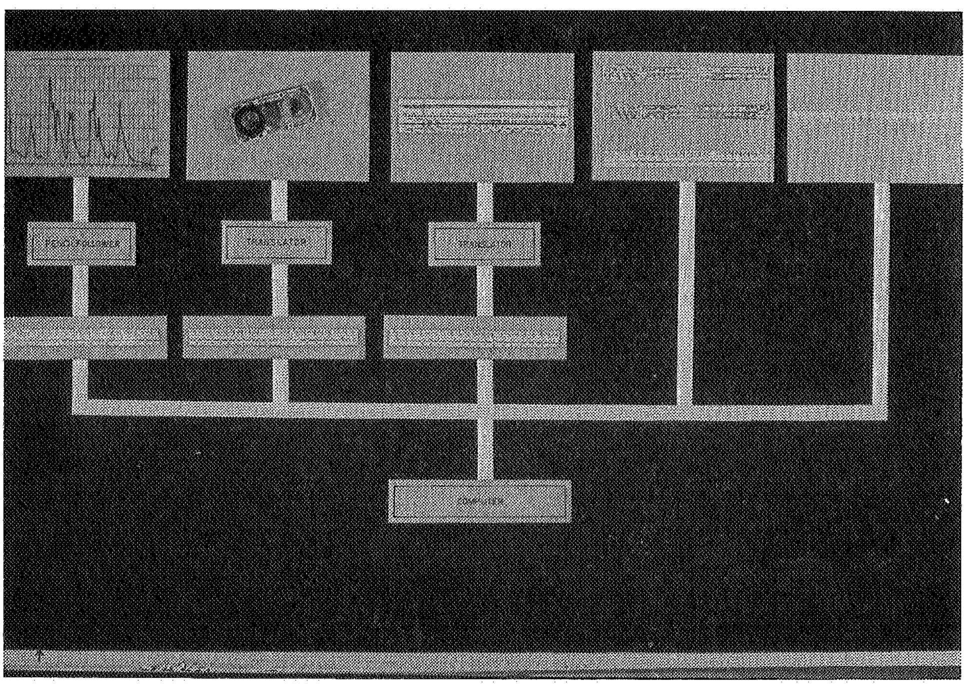


Fig. 2.9.

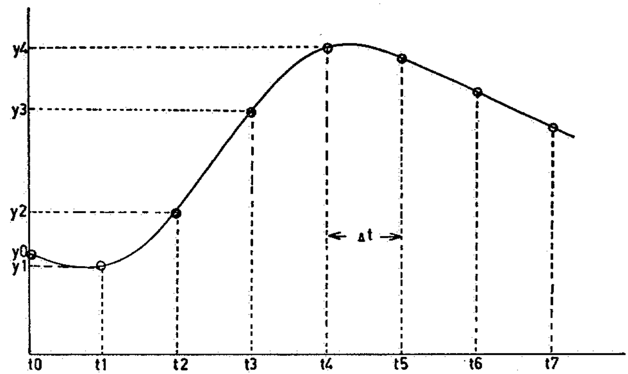


Fig. 2.10. Equidistant method.

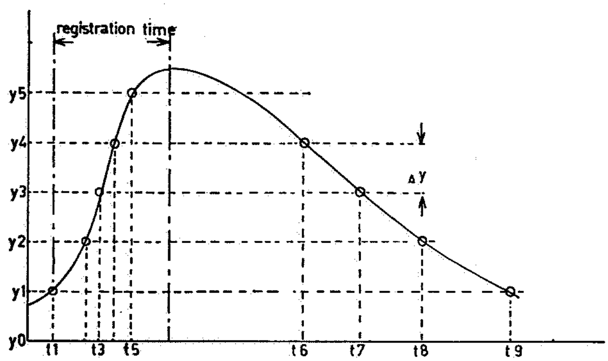


Fig. 2.11. Non-equidistant method.

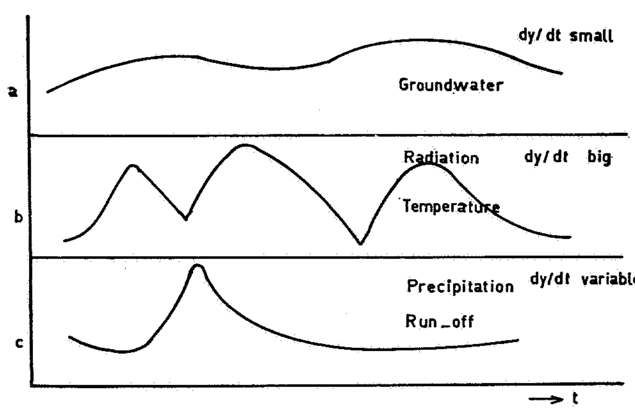


Fig. 2.12.

The moment of registration is either determined by a certain constant time interval, with the process value as the dependent variable, or by a certain constant change in the process value, with the time as the dependent variable.
In the first case the process values:

$$y(n) = f(t_0 + n.\Delta t) \quad n = 0, 1, \ldots\ldots N \qquad (2)$$

are recorded (Fig. 2.10). Usually the registration of t is omitted because $t \rightarrow y$ is single valued and Δt is a constant; however t_0 and t_N must be known. This method will hereafter be called equidistant method. In the Netherlands this method is used e.g. in the Hupselse Beek Catchment in the Eastern part of the country. In the second case registration takes place when the absolute value of the difference between the process value (y) and the latest recorded value is greater than a certain constant process value interval Δy (Fig. 2.11).

Because $y \rightarrow t$ is not single valued, both t and the sign of the change Δy(+ or —) must be recorded.

If occasionally the process value changes so rapidly that its value increases or decreases more than the chosen step Δy within the time interval needed for one registration (registration time) it will be necessary to record the process value itself instead of the sign (Fig. 2.11).

This method, hereafter called the non-equidistant method, was first applied in the Netherlands by the "Rijksdienst voor de IJsselmeerpolders" to an urban catchment in the city of Lelystad. (Lit. 1).

Which method to use, largely depends on the size of Δy and of Δt, which in turn depends on the nature of the process to be recorded.

2.3. *The nature of the process*

From the measuring point of view three types of processes can be distinguished: (Fig. 2.12 a-c):

a. Rate of change of process value is slow (dy/dt is predominantly small; e.g. deep groundwater).
b. Rate of change of process value is rapid (dy/dt is predominantly large; e.g. radiation, temperature).
c. Rate of change of process value is variable (sometimes slow, sometimes rapid) (dy/dt is variable; e.g. precipitation, run-off).

Clearly the non equidistant method is more suitable than the equidistant method for the third type of process as then the amount of collected data can be considerably reduced. (Tables 1 and 2). If the equidistant method is used in this type of process, information is lost if Δt is chosen too large. Another disadvantage is that a large amount of uninteresting data would be registered.

The equidistant method is more suitable for the two other processes and has the advantages of simple and relatively cheap instruments.

With the non equidistant method a minimum number of observations are required and rapid changes may be followed in the process value. Disadvantages are the expensive purchase costs and a less accurate recording of the real process because Δy has to be chosen so that in the process value independable fluctuations (e.g. wind) are smaller than Δy.

If neither of the methods provide for a separate recording of time it is often impossible afterwards to correct for interruptions in the recording. Processing is clearly different for the two methods, although for both the problems of processing are still considerable.

2.4. *Multiple point registration*

Multiple point registration is the recording of more than one process on one recorder. Such a recorder is often called a data-logger. Between the sensors and the tape recorder there is a scanner, which takes care of the right connections at the right moment. Process values in analogue form have to be digitized by an analogue-to-digital convertor before the signals can be recorded. There is only one clock for the data-logger, so synchronization problems with process values can easily be solved. Sometimes multiple point registration can decrease the costs per registration considerably, especially if the measuring points lie close to each other and if the sensors are of the same kind.

One speaks of telemetry when the sensors are at "some" distance from each other and from the data-logger. "Some" is not strictly defined. The transmission of data is through wires (telephone wires or special wires), or by radio-transmission. Instead of a tape-recorder, a small computer can be installed so that most of the processing can be done on the spot and different processes and their interactions can be analysed directly. Then malfunction of sensors can be immediately detected and repaired, so that hardly any valuable information will be lost.

Bussel and Jackson (Lit. 2) describe such a system, developed for the Dee and Clwyd River Authority.

3. Length of recording interval

At present the 15 minute interval is very popular (Fig. 3.1), although the choice of this interval is, in fact, arbitrary. Why the 15 minute interval is chosen is subjective. "You never know what use it might be" is the (powerful) argument. Objective is the calculation of the optimum interval. The optimum interval is the maximum possible interval, in which no important information will get lost. The length of the optimum interval depends on the kind and objective of the study, for which the data are collected.

In this chapter only precipitation and run-off will be considered. For both processes the effect of interval length on accuracy is different.

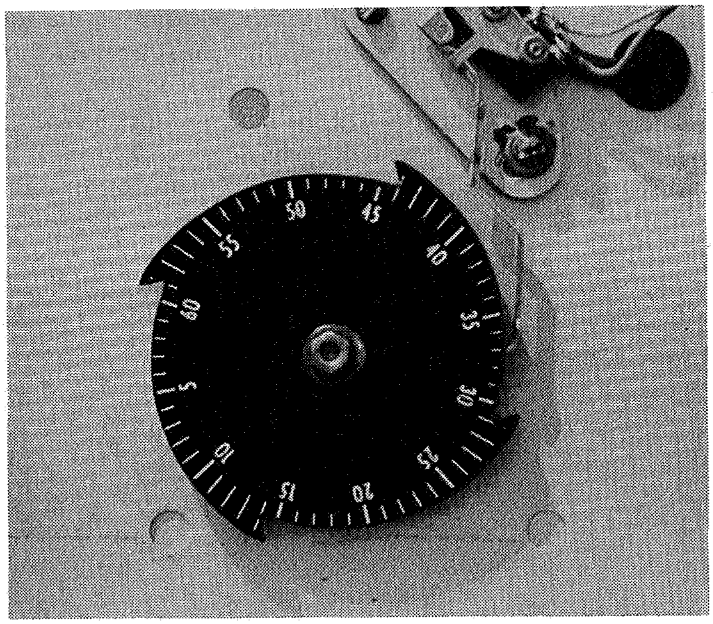


Fig. 3.1.

3.1. *Precipitation*

Fig. 3.2. shows for rainfall, the effect of lengthening the interval by a factor 10. The rainfall measuring system acts as an integrator over the interval Δt.

Therefore with an increase of Δt the high intensities will be smoothed. Of course the total amount of rain over a certain period does not change.

The rapid fluctuations in the rainfall intensities will never be completely ex-

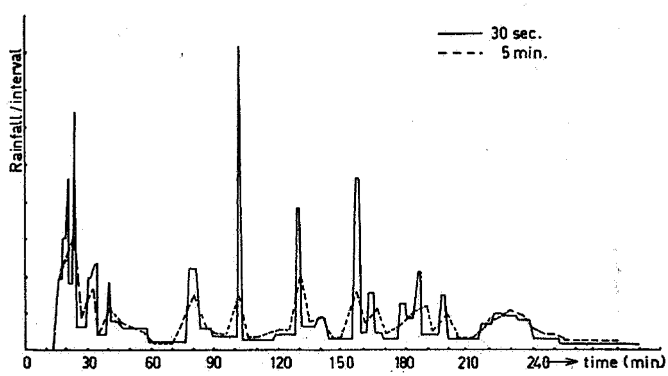


Fig. 3.2. Rainfall measured with different time intervals.

pressed in the fluctuations of the run-off intensities, because of the filtering effect of the system (the catchment) in which rainfall is transformed into run-off. This filter is a fixed datum.

In addition there is the filtering effect of the rain gauge. This filter is a function of Δt or Δy. The interval has to be chosen so that the filtering effect of the instrument is much smaller than the filtering effect of the system. The problem is how to find the right criterion for "much smaller". The interval has to be chosen so that the distribution of the rainfall within this interval is no source of extra information and thus does not have to be measured. This means that the distribution of the rainfall will have no influence on the shape of the output (the run-off). In general it can be stated, that the frequencies of the rainfall variations within the interval should be so high, that they cannot pass through the filter.

If the system is expressed in a linear mathematical model the filtering effect of the system can be determined by analysis of the spectrum of the model (Lit. 3). Both the type of mathematical model and its parameters determine the spectrum. From this spectrum the interval length can be derived. Interval length depends on both the type of mathematical model and the values of its parameters.

3.2. *Run-off*

In catchments the run-off measuring system does not act as an integrator. With certain time intervals the water level is recorded and by means of the local rating curve the run-off can be computed. On a graph the plotted process values are joined by straight lines. As the length of the interval increases, the measured run-off hydrograph will become a poorer representation of the real hydrograph so that the run-off peaks will become smoother. (Fig. 3.3.).

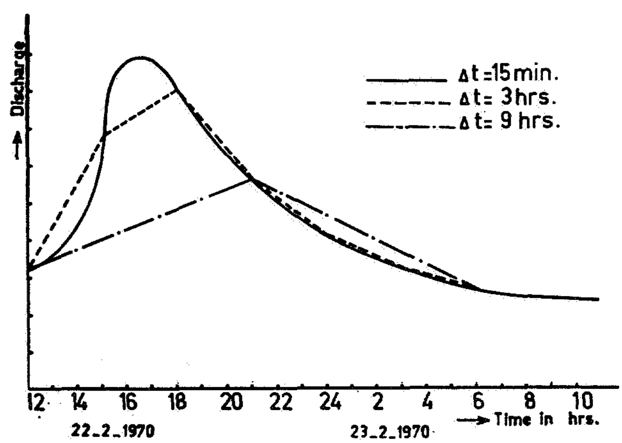


Fig. 3.3. Discharge measured with different time intervals.

The optimum interval length of run-off can be determined by taking a continuous registration (a strip chart) of a water level hydrograph. On the hydrograph points are taken at fixed distances Δt from each other. These points are joined by straight lines. The smaller Δt, the better the lines will fit the hydrograph. By fixing a tolerance it can be traced for what value of Δt this approach will still be acceptable.

Clearly the popular 15 minute interval is not applicable to all types and series of catchment areas. Even if the interval is chosen on the basis of a discrete approach of a continuous hydrograph or with the aid of the spectral analysis, a subjective factor, a tolerance or a criterion is introduced.

4. Processing data

4.1. *The quality check*

The quality of the data on the tape is checked by special computer programmes. First the quality will be provisionally checked with regards to

— number of recorded process values
— punch errors
— administrative errors

Whether a tape is acceptable or not will show up from criteria for usefullness. With quality of data there are many problems which should not be underestimated. From our research less than 50% of the tapes from the recorders were directly usable for processing.

Errors in data can often be noted. But retrieval is difficult and not always possible either because there is a single-valued relation between error and reality (the real value for the error is not known) or because sufficient information is lacking to retrieve the error in the right way.

The following example will clarify this:
The number of recorded process values n has to be equal to:

$$n = \frac{t_e - t_b}{\Delta t} + 1 \tag{3}$$

where
t_b = time of first recording
t_e = time of last recording
Δt = interval length

Suppose the number of process values in the tape is equal to m. In the correct case m has to equal n. If not, and this happens often there is an error.

Possible errors are:
— t_b and/or t_e are/is written down wrongly

— the clock of the recorder was slow or fast, so that Δt had the wrong value
— there was a temporary interruption in the recording
— the space punch, that separates the process values in the tape was off stroke, so that m was counted wrong.

Therefore there are a number of alternatives to choose from. Often it is not clear which is the true reason for the disagreement between duration and number of recordings.

So far only the number of recordings within a certain interval has been considered. Problems increase considerably as soon as the process value itself is included. Then every process value is checked for reliability, for which different methods are developed such as:

— the sequence of process values, plotted by the computer
— "double mass curve"
— exceedance of the physical limits of the process values

In spite of all these checks unreliable process values may still be used. The quality check does not reveal all possible errors. The best results can be achieved by the retrieval of punch errors.

4.2. *The actual processing*

Every processing has to start with the retrieval of errors in tape and/or in process values, so that as perfect a tape as possible can be handed over to the user. The actual processing is merely a transformation of the collected data in a form that meets the requirements of the user.

Unfortunately the range of requirements is many times larger than the range of possible registration codes and forms.

A small anthology with respect to rainfall will elucidate this:

— a printout per quarter, hour, day, decade, etc.
— a punchout per quarter, hour, day, decade, etc.
— number of storms in a tape bigger than x mm.
— different sorts of table.
— a plot of the rainfall pattern.
— an isohyetal map.
etcetera.

Already now users must choose and accept one standard tape code and say what formats are to be used, both for tape and output. Exchange of programmes and data will then become simplier. At the same time research must be done on how the flood of data can be reduced, without appreciable loss of accuracy, so that both storage accommodation and computer time can be kept down.

Abbott and co-workers (Lit. 4) describe, in their interesting paper, how much discrete, equidistant data — collected according to the equidistant method — can be reduced to a discrete, non equidistant series of much less data, without appreciable loss of information.

5. Final remarks

- Automatic collecting of data is indissolubly connected with automatic processing. When buying a tape recorder a computer programmer should be consulted.
- Collected data must be processed as quickly as possible. Then important indications can be obtained whether the sensor or tape recorder is functioning properly.
- The computer programmes for the processing must be available when automatic collection of data starts. The manufacturer of the recorder has to supply test tapes in advance.
- The method of registration also depends on the nature of the process to be recorded.
- An independent time indication in the tape is indispensable. This means that the clock mechanism has to be independent of the data collecting mechanism.
- Magnetic tapes are more vulnerable than paper tapes.
- Supply and quality of curve followers are on the increase, so analogue registration can more easily be digitized.
- What is gained in accuracy by frequent registration can be nullified by the use of inaccurate sensors and meters.
- In hydrology the use of computers has become indispensable. All hydrologic education must include computer science and programming.
- Automatic collecting and processing of hydrologic data will become an absolute necessity for the future management of our national water resources system.

6. Literature

1. "Data logger registreert hydrologie onderzoek"; Techniek en Toepassing, Philips Bedrijfsapparatuur. Nederland N.V., oktober 1968, nr. 31.
2. Bussell, R. B. & Jackson, E. "Telemetry for River Authorities"; Journal of the Institution of Water Engineers, Vol. 22, nr. 3, May 1968.
3. Van de Nes, Th. J. & Hendriks, M. H.; "Analysis of a linear distributed model of surface runoff"; Rapport 1, Laboratorium voor Hydraulica en Afvoerhydrologie, Wageningen, January 1971.
4. Abbott, M. B., Pardo Castro, E., Tas, P.; "On the optimum recording of a type of hydrological data"; Bulletin of the I.A.S.H., March 1967.

	observer	analogue registration	digital registration
reliability	observer dependable	instrument dependable	instrument dependable
accuracy	variable	variable	variable
frequency	low	infinite	high (1)
decision	logic	programmed (2)	programmed (2)
costs	low (3)	higher	highest
computer compatible registration	mostly no	no	mostly yes

1): low is possible, but increases the costs per recording
2): very expensive
3): increases with the wages

Scheme 1

Table 1. Number of registrations for 750 mm of rain, being the average annual rainfall in the Netherlands.

	Δt (min.)	Δy (mm.)	Number of registrations
Equidistant method	¼		2.102.400
	15		35.040
	60		8.760
	1440		365
	registration time (sec.)		
Non equidistant method	13	0,1	$\leqslant$ 7.500
	13	0,2	$\leqslant$ 3.750
	13	0,5	$\leqslant$ 1.500
	13	1,0	$\leqslant$ 750

Table 2. May 1969: discharge recording at the outlet of the Hupselse Beek; absolute movement of the float was 2400 mm.

	Δt (min.)	Δy (mm.)	number of registrations
Equidistant method	¼		178.560
	15		2.976
	60		744
	1440		31
	registration time (sec.)		
Non equidistant method	13	1	⩽ 2.400
	13	2	⩽ 1.200
	13	5	⩽ 480
	13	10	⩽ 240

II. HYDROLOGISTS AND THEIR COMPUTER CENTRES

W. F. VOLKER

Rijkswaterstaat

Computers can be used efficiently in hydrology and other sectors for many different purposes. Brief consideration of the way in which the word "computer" is translated in some of the main European languages illustrates this.

— The English word "computer" indicates a calculating machine which can handle all kinds of mathematical calculations, e.g. the solution of n equations with n unknowns, or the solution of differential equations.

— The French word "ordinateur" indicates a machine which establishes some orderly classification by taking logical decisions (provided it has the necessary programme), e.g. the alphabetical listing of names or the allocation of moorings to a group of ships with random but known dimensions in a lock-chamber so that the largest possible number of ships can be handled simultaneously.

— The German word "Rechenanlage" suggests a machine which works on a large scale with very great thoroughness and follows set instructions to solve problems and generate new ones.

— The Italian term "registratore elettronico" indicates that the computer is capable of accumulating, recording and storing large quantities of data.

— In the author's opinion, the Dutch word "rekentuig" is ambiguous. Is it formed by analogy with the word "vliegtuig" (flying machine, aeroplane) or is the word "tuig" (vermin) a reference to the human staff in a computer centre? Many users who are obliged to call upon outside specialists to programme their data for computer processing will detect a measure of truth in this etymological explanation, mainly because academically trained staff in computer centres often give the impression of wishing to concern themselves with other people's business. But the attitude and behavior of these experts are explained by more elevated motives than a simple desire to interfere. The aim of this lecture is to show this.

Four factors which are important in any computer project are the following:

1. Money, or economic viability.
2. The time required to carry through a project.
3. The need to strike a balance between the client's requirements and what is technically feasible.

4. Agreement on procedures during the project phase and once the system has been brought into service.

Strange as it may seem, the economic factor is rarely decisive. The client (in our case the hydrologist) must accept the fact that computer time costs at least 800 guilders per hour, while the charge for a large modern, high-speed computer will be between 2,000 and 5,000 guilders per hour. He must also realize that systems analysts and programmers are still more expensive to hire, so that the expenditure relating to the programming is almost always greater than the cost of renting computer time; sometimes it is many times higher than the actual computer rental charges. Whatever the immediately demonstrable costs may be, the advantages or drawbacks of automation are always of far more decisive importance.

As a general rule it will be noted that the cost of computerized calculations is low in relation to 1. the advantage of obtaining information more rapidly, 2. more sophisticated mathematical methods of processing the relevant data and 3. the benefit of obtaining results which are more reliable because they are based on fuller data which has been processed more thoroughly. Sometimes a combination of these three arguments may apply.

In addition to the question of economic viability, the time required to bring a system into service is also important, especially in the case of non-routine data-processing. In the light of past experience, clients therefore aim as far as possible at simple, uncomplicated computer programmes. Project managers in computer centres who have also learnt from past experience, should concentrate on a set-up which is comprehensive enough for the computer programme to handle all the complications which may be encountered.

Take a practical example: in calculating river currents, the presence of a small island in mid-stream may taken a substantial difference. Let us assume that a computer programme has been prepared which calculates river currents as a function of the water level. The programme has been checked against a convenient test case and found satisfactory; on the basis of this experience, the client promises a third party e.g. his boss that he will produce the required results within a specific time limit. When the input data is fed in, it is suddenly found that in the programme no allowance has been made for rivers with islands. We need not go into this example in any more detail to see that arguments will now arise between the client (i.e. the hydrologist) and the project manager in the computer centre. Obviously, a mistake has been made but who is to blame? The client will say to himself: those computer people knew perfectly well that... The project manager will think: if only I had risked the appearance of prying and asked him... The mathematician who is the project manager's assistant will phrase it more precisely: don't these duffers realize that domains which are not simply connected are quite different from... And the programmer will simply throw up his hands in resignation because he has been through all this many times before. He had better keep the rejected programme because it can still be used to test the new one. But this will merely create further problems because time is short and the client and project manager will decide to use a less accurate method of calculation for the new system and minor disparities will always appear when the two programmes are tested. The programmer will waste hours looking for a fault in the programme which does not in fact exist .

How then can successful cooperation be established between the client (the hydrologist) and the staff of the computer centre, and, more particularly, between a client who wants a calculation performed by a specific date and a computer centre which cannot write a separate programme for each calculation? Our example has shown that the client must give as much background information on the project as possible, while the project manager must consider whether the calculations appear logical; if they do not, there must be some aspect which he has not grasped properly. In striking a balance between the client's requirements and what is technically feasible in the available time, the following general rule will prove useful:

Start from the most universal method and use this method to develop the simplest possible system. In this way, the difficulties — often of a practical nature — inherent in the chosen method will be recognized in good time and everyone concerned will gain experience, so that the system can be extended as required and also made more accessible.

We have now arrived at the three basic rules of the game:
Programming (investment) costs are generally much higher than the cost of renting computer time on an annual basis. However, all these costs appear very small in comparison with the economic advantages of the automated system over the old processing system (or in comparison with the alternative of doing nothing at all).

It usually takes months to bring a system into service; projects should therefore be embarked upon at the earliest possible date. A project should only be set up after detailed discussion between the staff of the computer centre and the hydrologist (client). The persons involved on a project should exchange as much information as possible and they must explain to each other exactly what they are all doing. A practical example will show the importance of this rule: a systems analyst or scientific programmer who has watched a tug moor at an automatically recording staff gauge will be more likely to make allowance for the possibility that gauges may record incorrect values. A hydrologist who has seen the miles of tape handled in a computer centre will realize the necessity of labelling tapes.

Before examining how, in theory at least, a project should be prepared and designed, we shall first diagram the operations which are performed in an automated system.

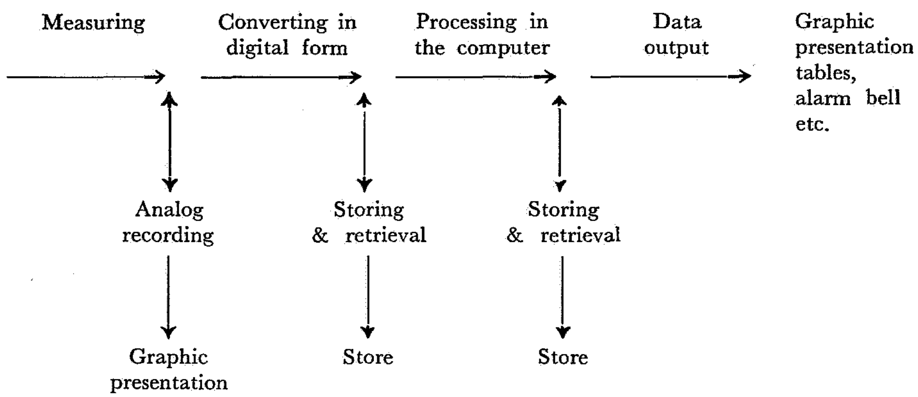


Fig. 1.

This figure can best be clarified by a practical example. After measurement of the water level at a given point by means of a float, the measured values are recorded in analog form by a level-indicating device. For further processing, the data must be converted into digital form so that it can be read by the computer. This digital data is then stored for subsequent use, i.e. other primarily administrative information will be added, after which the data is stored in such a way as to be readily retrievable later on. Such a store containing all kinds of different data is generally known as a data bank. Arguments about the desirability and advantages of data banks are generally heated because no one knows precisely why a data bank is kept. Under these circumstances a conscientious scientist would say that everything should be stored — irrespective of whether the data is correct or known to be wrong, complete or incomplete. In short the raw, unprocessed material is simply put on file in the "registratore elettronico". This explains why, in the above system, storage precedes the actual calculations made with the data; strictly speaking, however, this is not entirely true. Calculations in the computer are in fact preceded by the location and classification of new or existing data in the "ordinateur". The results are frequently stored for further processing but ultimately the aim is to present them in the clearest possible form. The output may take the form of statistics, tables, graphs, depth gauge charts, alarm signals etc.

Before considering how a successful data processing system should be designed it is useful to determine precisely what information a good system should provide. A good system supplies the data required for a specific purpose and eliminates superfluous information. Paradoxically, the less accurately we know what information we need, the more data we ask for. This paradox may also be expressed as follows: the computer centre which supplies a client with stacks of paper is a bad centre and/or the client is stupid and thinks he knows best; if the user receives thousands of figures in reply to a question, he will have to select the information which is useful for his purpose and disregard all the rest. But this selection ought to be effected by the computer itself.

To gain an impression of the difficulty of designing a system which will operate successfully, it is sufficient to consider the following facts. An expensive measuring instrument must be installed at a given point, perhaps in an inaccessible location where it cannot be supervised; it will be operated by the local "odd-job man" (e.g. the nearest farmer), while the instrument itself will frequently be serviced by an outside concern. This delicate equipment has often been on the market for too short a time to be completely debugged. And in addition it is expected to function precisely under the most extreme conditions, i.e. during severe drought or floods. The measured values are usually recorded on the spot in both analog and digital form. The digital information stored on tapes is usually meaningless to the person who operates the instrument. The recording tape is forwarded to a computer centre with additional information e.g. on the time and place of measurement, the instrument used, the measurement range to which the meter was set and other relevant details.

The next step, i.e. feeding the data into a computer for processing or storage, is carried out in a computer centre by staff who have no knowledge of hydrology.

To sum up, the following persons and services play a part in the operation of the system:

1. The hydrologist (client), often working in the research department of a government service.
2. The person responsible for daily maintenance, tape replacement etc. His main occupation is always quite different, e.g. farming, lock-keeping, highway maintenance.
3. The local contact man who also has a different main occupation, passes on instructions from the research department to the persons referred to in 2) and 4).
4. The technicians employed by the supplier of the measuring instrument and/or technicians from the responsible maintenance department.
5. Staff in the computer centre, including card or tape punchers, operators etc.
6. The computer centre contact man who is generally responsible for analyzing the faults in the system that come to his attention.
7. The last and most important figure remains in the background — the person for whose benefit the entire system has been set up, for whom it works and who ultimately foots the bill. He not only wants an answer to questions such as the quantity of drinking water which may be extracted from a given area; he also requires rapid and reliable information on the immediate situation. The analog equipment is primarily provided to meet his requirements (see Figure 1). The fact that this analog recording is gratefully used by the computer centre if faults

develop to check the digital equipment is often in itself reason enough to convert to analog recording. Such duplication costs money.

Proper, smooth operation of the system is also complicated by the fact that measurement errors are often only discovered weeks later by persons who are both literally and figuratively miles away from the point at which the measurements were taken.

When the system is set up, therefore, great attention should be paid to the indication and correction or prevention of faults. The fact that the whole data processing system from the measurement stage to the data output does not consist of independent parts each delivering a separate but complete intermediate product, leads to many organizational problems. It is therefore clear that both the manufacturer and the engineers responsible for maintenance of measuring instruments in the field must help in laying down standards to be met during processing in the computer centre. The computer specialists in turn will have their own demands to make of the measuring instruments.

Organizational problems which must be taken into account in designing a hydrological data-processing system include the functional and geographical decentralization of the persons involved and of the equipment used, and the requirement that some information must be made available very quickly, while other data can only be gathered over a more extended period.

To overcome these problems, a computer centre should make a contribution in the following areas when a data-processing system is automated:

1. Choice of initial project.
2. Choice of computing method.
3. Organization of the entire system in the form in which it will subsequently operate.
4. Method of detecting faults and rectifying them when necessary.
5. Method of storing data.

How can a project manager and his colleagues in a computer centre make a contribution in these five areas?

To obtain optimum results, the objectives of the project must be defined with the utmost care. After full discussion with all the persons concerned, these objectives should be carefully formulated by the client in such a way that the project heads know what is expected of them.

The objectives must clearly reflect the purpose of the project. There is no need to indicate the means by which it is felt these objectives should be achieved. The objectives in a project for automation of data processing, then, should precisely indicate the specific problems for which data is required. The question as to whether data should be processed by a digital computer is not a matter for inclusion in the objectives. It is a conclusion which will sometimes be self-evident but sometimes, on the contrary, it will require detailed study.

The following example will perhaps clarify the problem somewhat. If we wish to know how high a dike must be, the objective should not be formulated as: determination of the frequency of an excess reading on the gauge at point X. This would exclude the possibility of arriving at a satisfactory answer by a different method (the question as to whether the objective "how high must a dike be?" is the correct one is left aside here). There can of course be certain limitations on the objectives, such as the requirement that the proposed system must be operational in a given number of days. Once the objectives have been defined and willingly accepted by everyone concerned, the task or tasks to be performed in the light of them can then be determined and delegated to others. Many problems which arise in carrying out a project can be solved by examining them in the light of the objectives.

So much for the relationship between hydrologist, computer centre and other persons involved. It is worth summarizing some points to which the staff in a computer centre will have to give special attention. We have already mentioned the need to collect all kinds of data from the client/hydrologist and the manufacturer of the measuring instruments. They are the persons who can indicate possible sources of error which will not be immediately apparent to a computer expert but are nevertheless important. As an example, it may be necessary to know whether it is possible that a gauge is incorrectly callibrated. If so, how frequent is this type of error and how can it be detected? etc. All possible sources of error in a system must be analyzed, with cooperation between client and computer centre, with reference to the following criteria:

1. Can the fault be detected and if so, how?
2. How frequent is such a fault?
3. Do the consequences of the fault materially affect the results? (in the light of the objective?)
4. Can the fault be detected by a logical procedure? (For instance, if a float-driven recording gauge is jammed because the float wire is broken, this can be readily spotted, but detection of such a fault when nothing more than a tape with recorded readings is available is quite another matter).
5. Once the fault has been detected, can it be remedied automatically? Once measured value which is missing from a series can perhaps be reconstructed at least approximately — by interpolation; but this is rarely the case with a whole series of observations.
6. If the fault cannot be remedied through the programme, can it be corrected or repaired by making changes in the measuring instrument or by installing another instrument of the same kind?

Figure 2 illustrates a logical flowchart used to analyse and eliminate if possible the consequences of sources of error. The key to the whole procedure is the question of "logical detection". This term implies the possibility of designing the computer programme in such a way that it is possible to determine in the computer itself whether something is wrong. This can of course only be done if the data input contains more information than is strictly necessary. This "redundancy" may be of many different kinds, sometimes intentionally introduced into the system and sometimes inherent in the nature of the problem.

Duplication of equipment is a very simple example. Rather less obvious is the redundancy obtained by making use of the knowledge that a numerical value, e.g. representing a water level, is always made up of a fixed number of digits. The telephone number of a subscriber in The Hague beginning with a 0 or containing more or less than 6 digits is a logically detectable impossibility and a fault which cannot be put right by logic (it must of course be true that all telephone numbers in The Hague have six digits and never begin with 0).

The parity check which is normally used in digital equipment is an example of intentional redundancy. Knowledge of the physical process is a source of additional information and the necessary corrections can often be made on the basis of this knowledge; if the water level in a river is shown by the digital recording to be changing abnormally quickly, it can generally be assumed that there is something wrong with the equipment.

An exceptional value in a series of figures must usually be replaced by one which is more probable. What is abnormal (which means, in effect, what norm must be applied) is something which the hydrologist can generally say or which can be determined theoretically.

A properly run computer centre will try to show the hydrologist/client what is being done with the data supplied by him. The client must have a description of the automated part of a system, determined on the basis of its objectives. The following specific information must certainly be given:

— a physical and mathematical explanation;
— reasons for solution opted for;
— an explicit indication of the physical or mathematical limitations which may or may not be inherent in the solution opted for;
— faults which can be detected in series of observations;
— how this is done.

See Figure 2 for further details.

Good documentation will indicate whether certain faults can be repaired and if so, how; and also how it is shown in the output that a fault has in fact been repaired. In addition, the computer centre should draw up explanatory instruc-

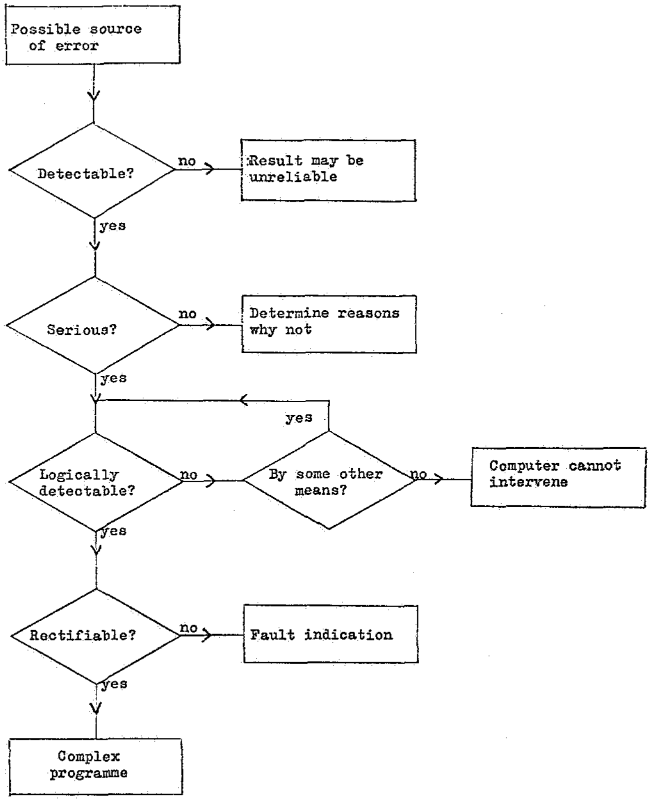


Fig. 2.

tions, together with an example, showing the input required by programmes and the output they can be expected to provide. A vital component of the whole automated system is the set of formulae and other aids by which further information is defined, such as the additional administration required for an automatically recorded series of measurements mentioned previously. Other formulae must be used to process information and generate the necessary data in the computer.

Additional documentation required by the centre will be a set of notes for the technical/scientific programmer, showing how the programme has been compiled, the significance of the symbols used and the storage of files in the secondary memories, etc.

The client must remember that all this documentation simply describes a part of the whole system. It is his job to ensure that a report is prepared on how the system as a whole operates, listing the instructions, tasks and terms of reference of each individual and also that everyone involved has an up-to-date copy of all this information.

Finally, a word about the division of functions (outlined above) between hydrologist, computer centre project manager and all the other persons involved. In some instances it will not be clear who is responsible for a particular task; the aim of this paper was simply to show the tasks which have to be performed. In practice, the accuracy of the division of tasks indicated above may be open to question, if only for the reason that it is not possible in a general report to make allowance for random factors such as the knowledge and experience of personnel, etc.

III. THE AUTOMATION OF THE ARCHIVES FOR GROUNDWATER LEVELS

C. GROENEWOUD and W. A. VISSER

Groundwater Survey TNO

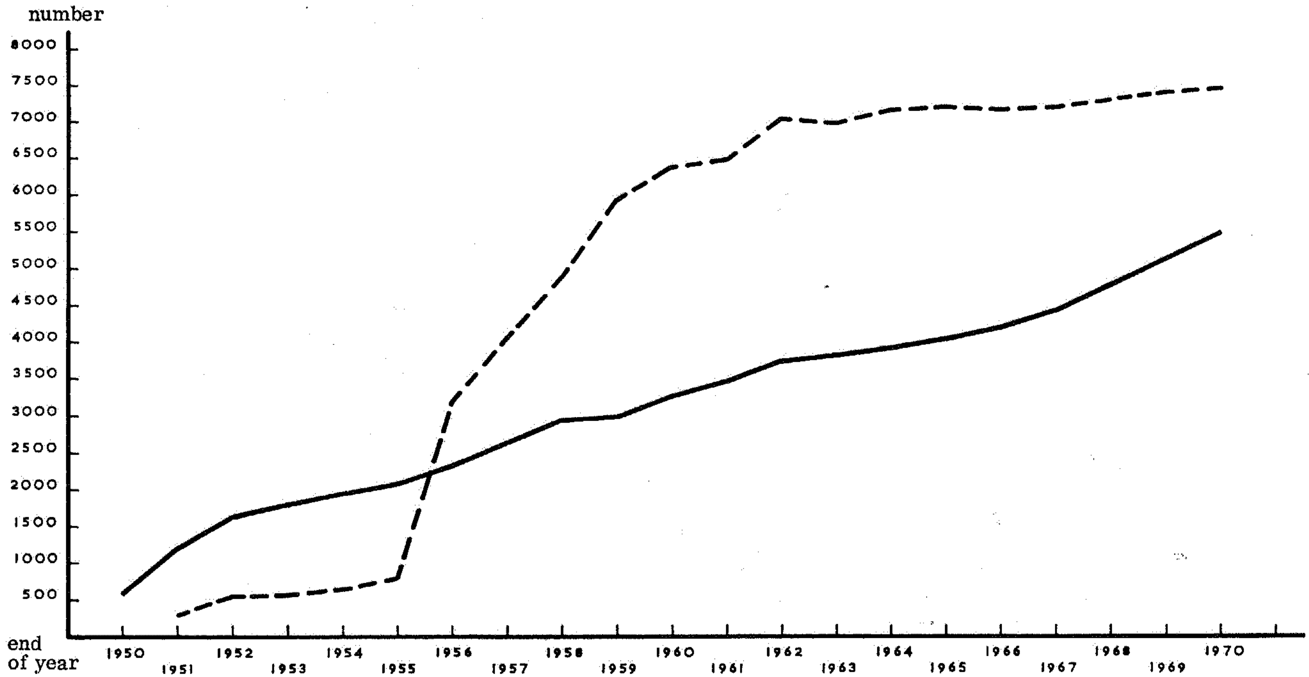
In the Netherlands the Archives for Groundwater Levels were founded in 1948 by the Committee for Hydrological Research TNO. Towards the end of 1967 the Archives were incorporated in the Groundwater Survey TNO, a newly established institution assigned to carry out the systematic collection of groundwater data and the compilation of geohydrological maps in the country (Lit. 6, 8, 9). The Survey includes a Geophysical Department (formerly the TNO Study Group for Geo-electrical Investigations, founded in 1956) and a newly formed Geohydrological Department.

Concerning the aims and working methods of the Archives, in 1957 a lecture was held for the 13th Technical Meeting of the Committee for Hydrological Research TNO by the conservator at that time, J. Kost (Lit. 7). While in 1957 a network consisting of 5,709 observation points was available, in the ensuing years their number has more than doubled to 12,876 at the end of 1970 (fig. 1).

At that date the network consisted of (fig. 2):

a. for confined, semi-confined and deep phreatic aquifers — cased boreholes of depths up to 350 m. Of these 1,389 wells were established for fire fighting purposes, in some cases the well screens extending over more than one aquifer. Further there are 4,044 boreholes, generally with more than one well screen and string of tubing completed in different aquifers to a total number of 8,718 separate well screens,
b. for phreatic aquifers — 7,362 shallow cased holes of depths up to 5 m and 81 water wells.

In more than half of the observation points groundwater levels are gauged fortnightly (on the 14th and 28th of each month), and in about 40% four times a year to obtain seasonal averages on April 28th, August 28th, October 14th and December 14th. The soundings are carried out voluntary and free of charge by 3,555 observers, among whom there are about 2,000 private persons and the remainder of which are employees of provincial and municipal institutions and private companies. Each observer sends the depth of the water table, gauged to a reference mark on tubing or casing, to the Archives by special postcard (fig. 8), and thus



—— for confined, semi-confined and deep phreatic aquifers
– – – for phreatic aquifers

Fig. 1. Number of observation points

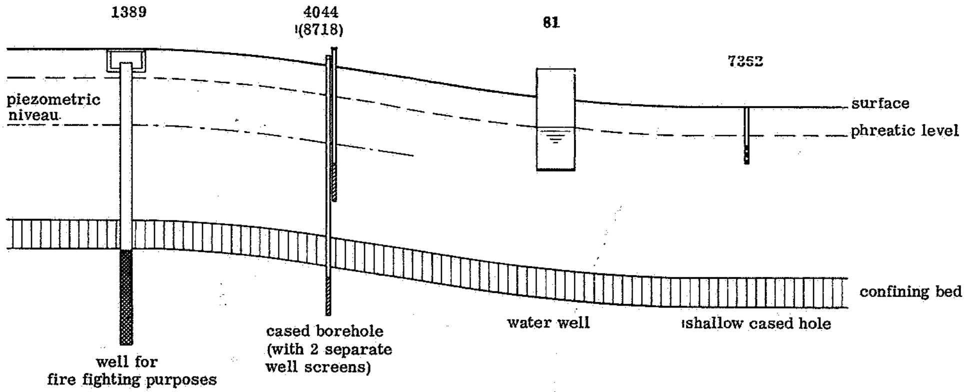


Fig. 2. Types and numbers of observation points.

twice a month some 2,800 postcards, several with more than one observation, are received to be checked and filed. In this way since 1948, during a 22 years period, more than 3,200,000 soundings were collected (fig. 3), spread all over the country at various depths. At present this number increases yearly with about 200,000 (fig. 4. The peak during 1952-1955 represents the observations made by the Committee for Research on Water Economy in Agriculture in the Netherlands — "COLN" — TNO). Maintenance and development of the network and levelling are carried out by the Archives as well.

Data on groundwater levels are supplied to applicants free of charge, either in the form of typed tables (fig. 5) or in graphs (fig. 6) and maps; yearly about 20,000 separate pieces of information are supplied. This procedure is time-consuming and costly, and often applicants have to wait longer than is considered desirable.

Another activity of the Archives was of a statistical nature. It was found that in certain areas a simple linear relationship exists between phreatic groundwater levels which are measured in various wells. This opened the possibility that from the data, obtained in a fortnightly observed well, the groundwater levels in wells in the surroundings could be computed, and accordingly a considerable reduction in the numbers of observations would ensue (Lit. 2, 4, 1). The hope, however, that the country could thus be subdivided in an easily manageable number of such "statistically homogeneous areas" was not fulfilled. Conditions in the free water table are complicated and due to external circumstances vary widely. As a consequence calculating the statistical relations by hand was found a too time-consuming procedure to warrant continuation, and, although of obvious hydrological significance, the search for such areas was terminated by 1964.

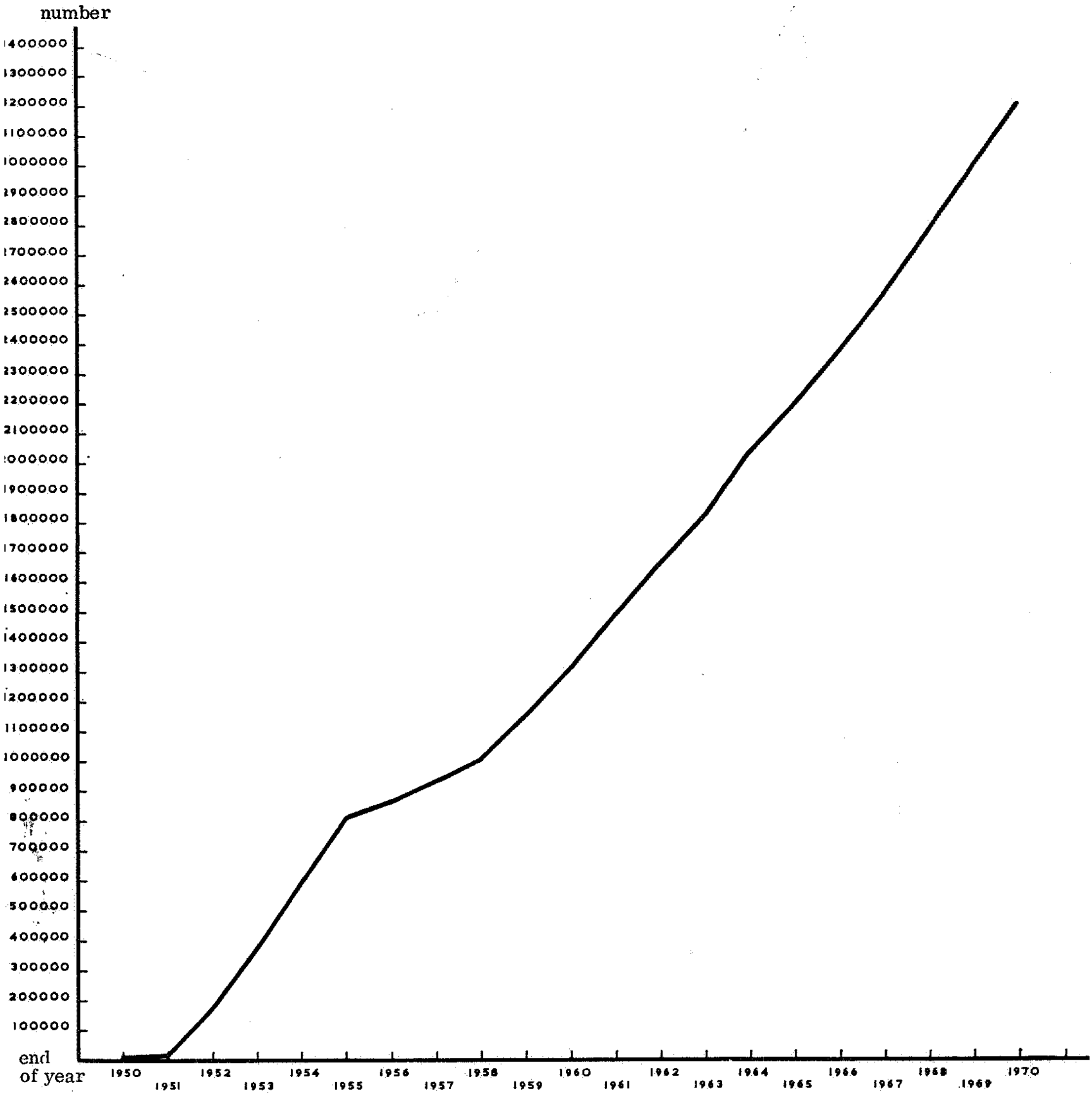


Fig. 3. Cumulative number of observations received.

Fig. 4. Yearly number of observation received.

DIENST GRONDWATERVERKENNING TNO
ARCHIEF VAN GRONDWATERSTANDEN

Kaartblad 38C Peilput 222 | Folionummer 1

Hoogte van het { meetpunt 107 cm+NAP; maaiveld 044 cm+NAP } | Provincie Zuid-Holland; Gemeente Zwijndrecht

Toestand van het grondwater

Filter { bovenkant 2056 cm−NAP; onderkant 2156 cm−NAP }

Gegevens van de grondwaterstand in cm

datum	− meet-punt	− NAP	datum	− meet-punt	− NAP	datum	− meet-punt	− NAP	datum	− meet-punt	− NAP
1960											
14 I	156	049									
28 I	105	+002									
15 II	148	041									
29 II	171	064									
14 III	119	012									
28 III	193	086									
14 IV	168	061									
28 IV	191	084									
14 V	126	019									
28 V	117	010									
14 VI	128	021									
28 VI	123	016									
14 VII	138	031									
28 VII	176	069									
15 VIII	107	000									
29 VIII	122	015									
14 IX	133	026									
28 IX	147	040									
14 X	133	026									
28 X	161	054									
14 XI	166	059									
28 XI	096	+011									
14 XII	175	068									
28 XII	167	060									

Bijzonderheden

DIENST GRONDWATERVERKENNING TNO
ARCHIEF VAN GRONDWATERSTANDEN

Kaartblad 38C Peilput 222 | Folionummer 1

Hoogte van het { meetpunt 097 cm+NAP; maaiveld 044 cm+NAP } | Provincie Zuid-Holland; Gemeente Zwijndrecht

Toestand van het grondwater

Filter { bovenkant 6356 cm−NAP; onderkant 6456 cm−NAP }

Gegevens van de grondwaterstand in cm

datum	− meet-punt	− NAP	datum	− meet-punt	− NAP	datum	− meet-punt	− NAP	datum	− meet-punt	− NAP
1960											
14 I	195	098									
28 I	175	078									
15 II	192	095									
29 II	200	103									
14 III	170	073									
28 III	209	112									
14 IV	207	110									
28 IV	211	114									
14 V	179	082									
28 V	174	077									
14 VI	174	077									
28 VI	176	079									
14 VII	178	081									
28 VII	203	106									
15 VIII	169	072									
29 VIII	172	075									
14 IX	178	081									
28 IX	176	079									
14 X	188	091									
28 X	191	094									
14 XI	192	095									
28 XI	160	063									
14 XII	191	094									
28 XII	194	097									

Bijzonderheden

Fig. 5. Table of fortnightly gauged groundwater levels in borehole ("peilput") 222 on topographic map sheet ("kaartblad") 38 C - two well screens ("filters") resp. 20.56 - 21.56 m and 63.56 - 64.56 m below ordnance level ("NAP") - observations are in cm relative a reference mark ("meetpunt") - "maaiveld" - surface elevation.

It will be clear that automation could be of help to a proper functioning of the Archives. However, collection and supply of soundings is only one aspect of the activities of the Archives. Another aspect that thusfar has hardly been touched will be the scientific analysis of the data collected, by means of which the behaviour of the groundwater under varying circumstances, such as climate, river levels and human influences in their widest sense, can be studied, and perhaps explained and forecasted. In The Netherlands we should be able scientifically to exploit the hoard of material available to the utmost. For the necessary statistic operations the basic information is available, however, in a difficult accessible and therefore costly form.

Early in 1968 on the request of the Groundwater Survey TNO a programme for the automation and an estimate of the costs were drawn up by the Institute TNO for Mathematics, Information processing and Statistics. At the end of 1969 the financial means were made available by the Central Organization TNO and by some interested institutions (the Provincial Departments of Public Works and two private companies, de "Koninklijke Nederlandsche Heidemaatschappij" and the "Grondverbetering- en Ontginningsmaatschappij N.V."). A beginning was made, as yet on a small scale, early in 1970. The aim is to complete the automation in 5 to 6 years' time. Through punched cards the data will be collected on magnetic discs. The use of punched tape has been considered, but it is thought that cards possess certain advantages. Reading the cards and correcting errors will be easy. Disadvantages are the large number of cards and their storage in a specially conditioned room. However, it may turn out to be unnecessary to keep the punched cards for any period of time. In December 1970 two Univac VP 1701 combined punching and control machines were installed.

Use will be made of discs rather than of magnetic tape. The disc has the greater capacity and quicker retrieval is possible, so that the higher costs may be compensated. The Institute TNO for Mathematics, Information processing and Statistics is equipped with a computer of the type Control Data 3200. Retrieval can be done by means of both, a line printer (for tables) and a plotter (for graphs and maps in different scales).

Of each observation point or separate well screen the following information will be stored on 3 types of punched cards (fig. 7):

I. Identity card:

1. the number of the topographic map sheet, scale 1 : 25,000
2. the type of the observation point (f.i. shallow hole, borehole)
3. the number of the observation point
4. top of the well screen in cm to ordnance level ("NAP": "Normaal Amsterdams Peil")

5. base of the well screen in cm to ordnance level ("NAP": "Normaal Amsterdams Peil")
6. the elevation in cm of the reference mark on well tubing or casing relative ordnance level
7. surface elevation relative ordnance level
8. the x co-ordinates of the Netherlands State Triangulation Survey to an accuracy of 10 m
9. the y co-ordinates of the Netherlands State Triangulation Survey to an accuracy of 10 m
10. the first day of observation
11. the number of screens in this well; if there is more than one separate screen, each will be recorded on a separate set of cards
12. open space reserved for last day of observation
13. type of card
14. project number of the Institute TNO for Mathematics, Information processing and Statistics.

II. Observations

Topographic map sheet, type of observation point, number, depth of well screen are repeated and followed by the complete sequence of observation dates and groundwater levels relative ordnance level. It will be realised that there is space for 5 entries only, so that sequences extending over a number of years require a large amount of punched cards.

III. Remarks

— changes in the observation point (e.g. shifts in the reference mark, cleaning, repairing, replacing the hole). Especially the shallow cased holes are liable to be damaged by external causes or to silting up. Repairs and cleaning operations may involve shifts in the reference marks or in the location of the hole.

At present (February, 1971) the Institute TNO for Mathematics, Information processing and Statistics is developing a programme to collect and continue the information stored in the punched cards on a magnetic disc.

Recording the complete sequences of groundwater levels will enable the Archives to retrieve easily and rapidly the information required by any applicant. Moreover, more involved requests than for simple print-outs and graphs may then be answered. The automation will greatly facilitate processing and accessibility:

1. Storage — the soundings as far as available in typed tables and further as received by postcard from the observers will be transferred via punched cards

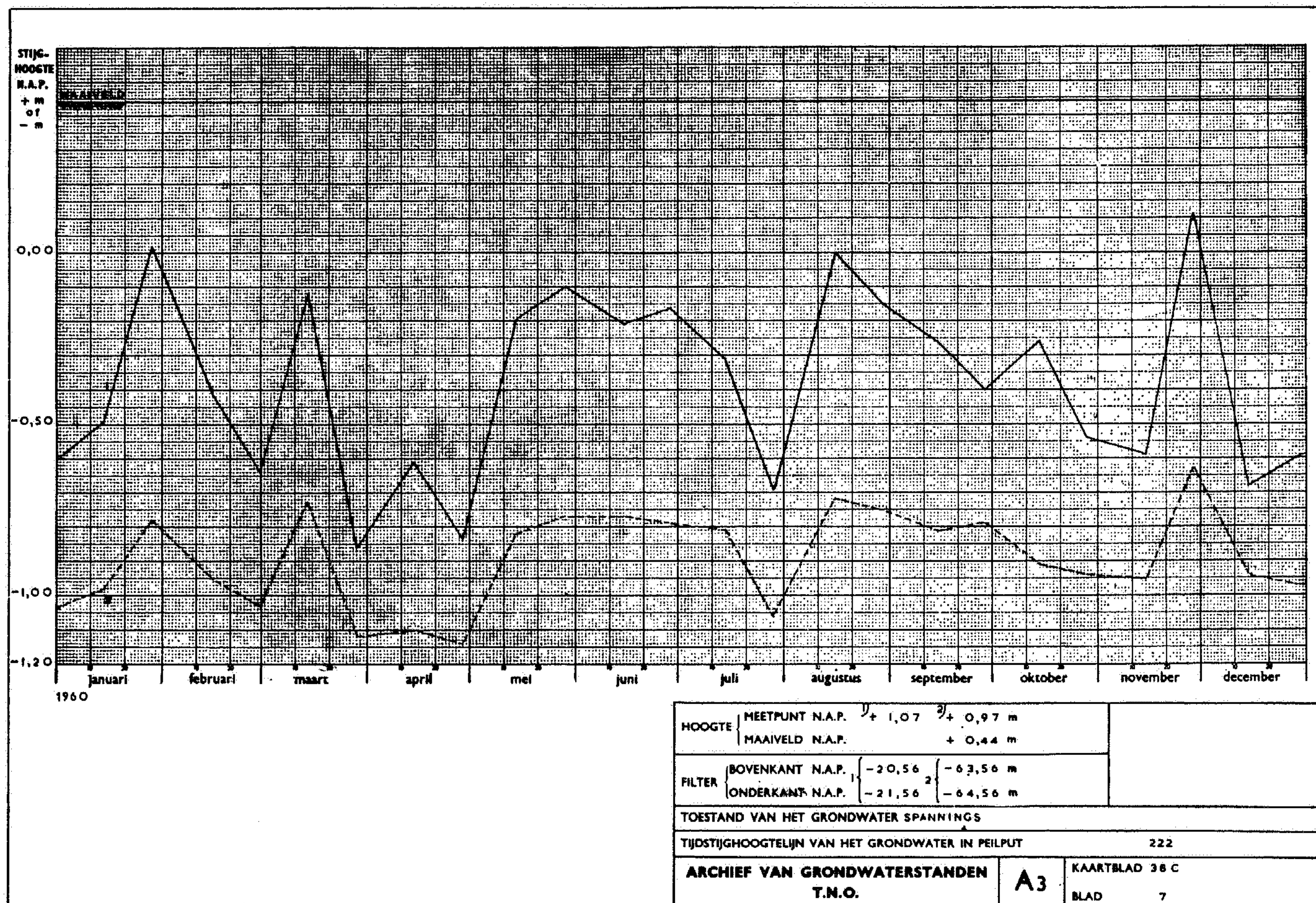


Fig. 6. Graph of groundwater levels observed in borehole 38C-222 during 1960 (see fig. 5).

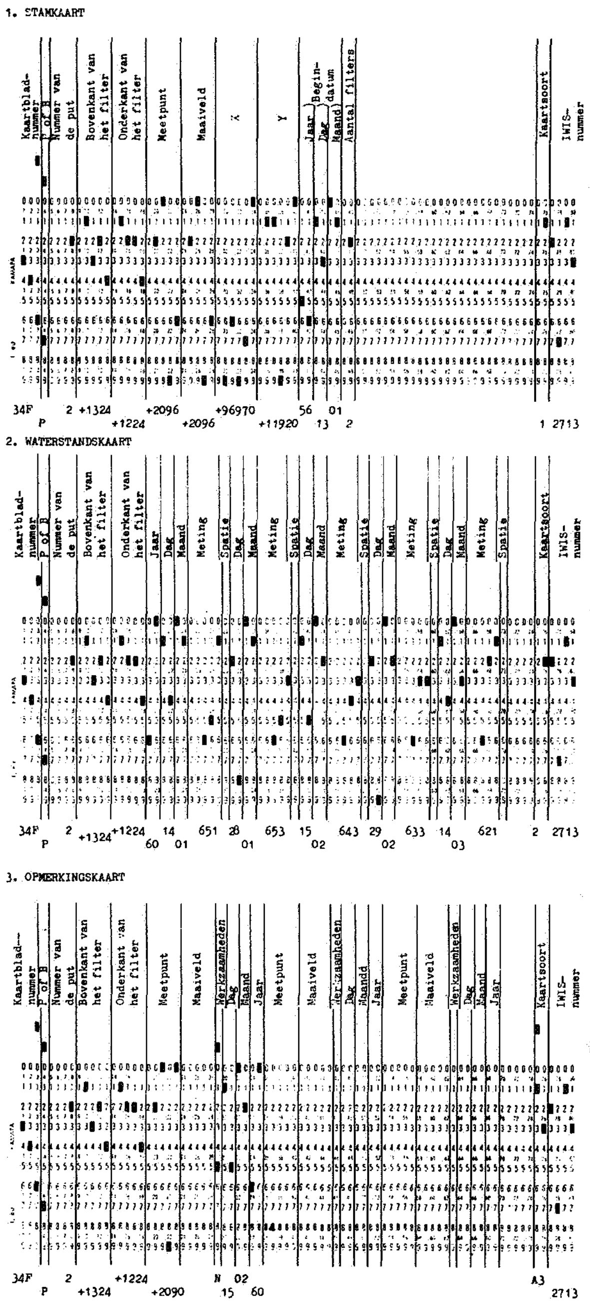
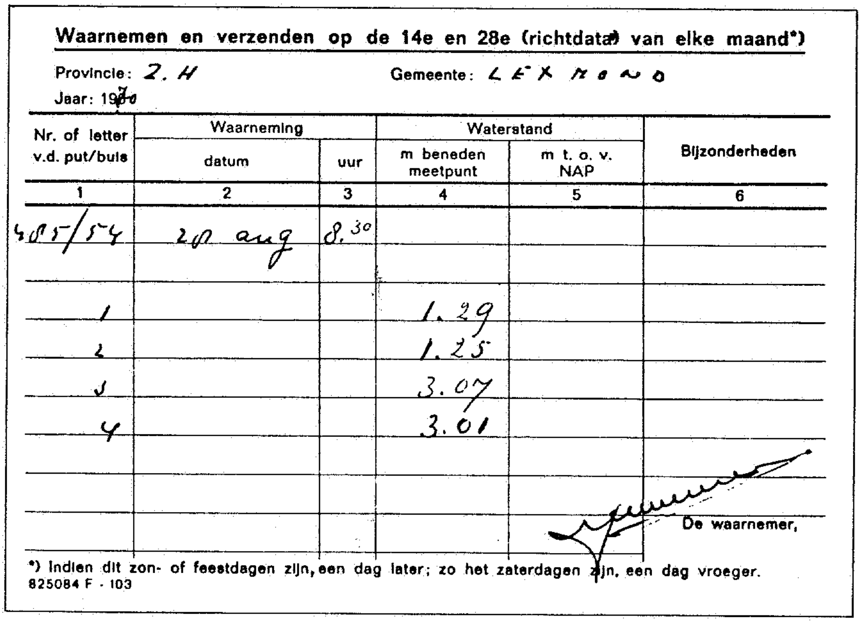


Fig. 7. Examples of punched cards: 1. identity card ("stamkaart") 2. observations ("waterstandskaart"), 3. remarks ("opmerkingskaart").



Waarnemen en verzenden op de 14e en 28e (richtdata) van elke maand*)

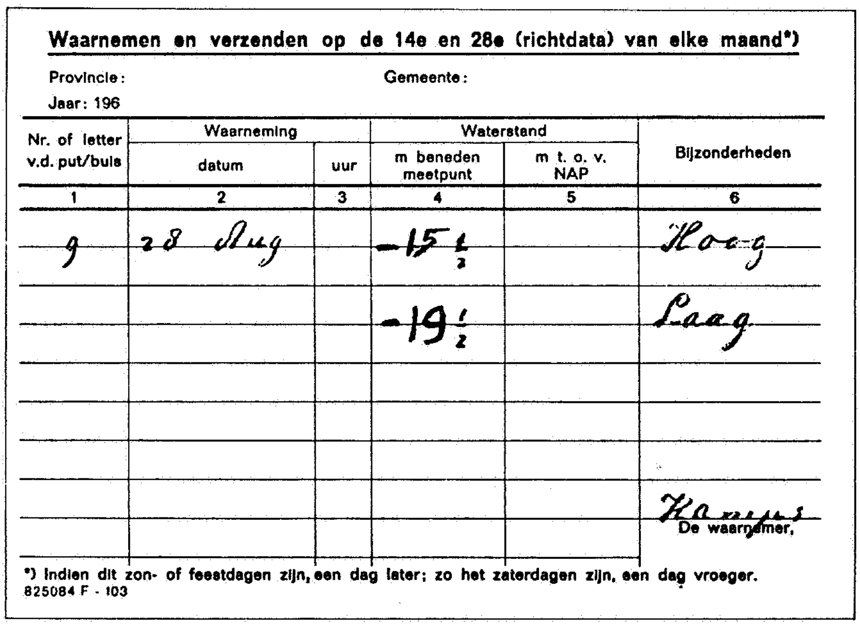
Provincie: Z. H   Gemeente: Lex mond

Jaar: 1960

Nr. of letter v.d. put/buis	Waarneming datum	Waarneming uur	Waterstand m beneden meetpunt	Waterstand m t. o. v. NAP	Bijzonderheden
1	2	3	4	5	6
405/54	28 aug	8.30			
1			1.29		
2			1.25		
3			3.07		
4			3.01		

De waarnemer,

*) Indien dit zon- of feestdagen zijn, een dag later; zo het zaterdagen zijn, een dag vroeger.
825084 F - 103



Waarnemen en verzenden op de 14e en 28e (richtdata) van elke maand*)

Provincie: Gemeente:

Jaar: 196

Nr. of letter v.d. put/buis	Waarneming datum	Waarneming uur	Waterstand m beneden meetpunt	Waterstand m t. o. v. NAP	Bijzonderheden
1	2	3	4	5	6
9	28 Aug		-15½		Hoog
			-19½		Laag

De waarnemer,

*) Indien dit zon- of feestdagen zijn, een dag later; zo het zaterdagen zijn, een dag vroeger.
825084 F - 103

Fig. 8. Observers' postcards. The example at the top is of a borehole with 4 well screens, numbered 1 to 4, and the card is properly filled in. The example at the bottom lacks identification; it concerns a borehole with 2 well screens ("hoog"-high and "laag"-low); soundings are in centimeters.

to a magnetic disc. In future typing the information in tables can be dispensed with. Conversion of sounding depths to surface and ordnance level, now done by hand, will be included in the computer programme.

2. Retrieval — information on groundwater levels will be supplied, either relative to ordnance level or to surface, in:
   — tables of levels in an observation point or well screen during any period required
   — graphs (time-level curves) of levels in an observation point or well screen during any period required on different scales
   — possibly piezometric maps at any date required or maps of averages and interpolated values during any period required on different scales, the depths of the screens and the locations of observation points in any area can be given in co-ordinates or on maps
   — information on observation periods and frequencies in any area or time interval.

3. Statistical analyses, for which simple programmes suffice or existing programmes can be adapted, under consideration are:
   — averages, for instance seasonal, yearly, decennial, and deviations from the averages, trends; highest and lowest levels; frequencies. Thus comparison and correlation will become feasible with precipitation, river levels, surface discharge, the influence of technical activities and of withdrawal
   — calculation of mean highest water level and mean lowest water level in order to derive classes of groundwater tables for soil mapping purposes (Lit. 5). Such maps are used for re-allottment of lands, recreation, town development and road building (Bekkink and Maessen, Soil Survey Institute, personal communication)
   — correlation in horizontal sense over groups of observation points in one aquifer and vertically in various aquifers. In this way the information available can be used quantitatively in order to characterize sub-surface conditions of water behaviour (Van Someren, "Commissie Grondwaterwet Waterleidingbedrijven", personal communication).

4. Derivation of reservoir properties and prognosis of the complex results of technical and agricultural activities through complicated calculating techniques for which the use of a computer programme is expedient (W. C. Visser, Institute for Water Management and Land Reclamation, personal communication). To develop such advanced hydrological programmes duplicates of the punched cards could be made available to specialised institutes.

In combination with other information a still wider scope can be attained. Combination and correlation of groundwater levels with those of surface waters and with meteorological and possibly hydrological, geological and hydrochemical data will become feasible. Extensive contacts with the Mathematical Physical Section of the State Public Works Department, the Royal Netherlands Meteorological Institute and others, for instance the State Institute for Water Supply and the State Geological Survey are of the utmost importance. Close co-operation is indispensable between the Institute TNO for Mathematics, Information processing and Statistics, the Archives of Groundwater Levels and other institutions. A good understanding between the users of the information and the computer centres is required.

It is, however, not our intention to include in our discs other data than groundwater levels. If required, retrieval of combined information is always possible. The identity cards, i.e. the particulars of the observation points, should, however, be similar in each system.

In other systems information on aquifers and confining beds and on the groundwater itself could be recorded. As yet the groundwater mapping is not sufficiently advanced to encode the various aquifers, while information on the transmissibility and other hydrological properties of the aquifers and other beds is too scattered to warrant automation. At present lithology and statigraphy are being dealt with by the State Geological Survey. From almost every well screen a chemical analysis of the groundwater is available or easily obtainable. Methods to automatize the latter have been developed elsewhere, and are at present being studied at the Geological Institute of the State University in Leiden (Lit. 3).

By way of experiment, in the course of 1970 the groundwater levels in shallow holes and deeper borings in and around the municipality of Ruurlo (province of Gelderland) have been recorded on punched cards. This area, where soil mapping is in progress for a land re-allottment project, was selected after consultation with the Institute for Water Management and Land Reclamation and the Soil Survey Institute.

A punching machine was made available by the Institute TNO for Mathematics, Information processing and Statistics. Duplicates of the punched cards were supplied to the Soil Survey Institute which in due course developed a programme and produced a print-out showing the observed groundwater levels and the calculated mean highest and lowest levels for each observation point. Here automation resulted in a considerable saving of time. As discussed in detail by Van Heesen (Lit. 5), the mean highest and lowest levels characterize the average seasonal fluctuations of the groundwater table, which, however, may vary considerably from place to place. Since the agricultural value of any tract of land in cartels determined by the groundwater level, information of groundwater levels is incorporated in soil maps. For mapping purposes a classification of fluctuations of groundwater levels was made, the seven classes of water tables being defined by the mean highest groundwater table or by a combination of the mean highest and the mean lowest ones.

In order to expedite the transfer of the observations to a magnetic disc, it is tempting to contemplate ways, by which the observers' postcards could be made suitable for mechanical reading. Often, however, the cards are filled-in in such a way that we doubt whether such a procedure is feasible (fig. 8). In the near future the Archives will design mechanical reading cards, in which experiment some institutional observers will be requested to co-operate.

REFERENCES:

1. BELTMAN, J. H. (1967) — The Archives for Groundwater levels in The Netherlands, in "Hydrological aspects of the utilization of water" IASH Gen. Ass. Bern, Sept.-Oct. 1967.
2. BELTMAN, J. H. en KOST, J. (1952) — Een onderzoek naar de veranderingen van de grondwaterstand in de gemeente Schoorl, Mededeling 1, Archief van Grondwaterstanden TNO (with summary in English).
3. CREUSOT, M. R. en GEIRNAERT, W. (1971) — Processing of water-quality data by digital computer, Geologie en Mijnbouw 50, 35-40.
4. GROENEWOUD, C. (1966) — Algemene opzet en werkwijze van het Archief van Grondwaterstanden TNO, Mededeling 2, Archief van Grondwaterstanden TNO.
5. HEESEN, H. C. VAN (1970) — Presentation of the seasonal fluctuation of the water table on maps, Geoderma 4, 257-278.
6. HEIDE, S. VAN DER (1968) — A Survey of the geohydrological and hydrological investigations in the Netherlands, Geologie en Mijnbouw, 47-4, 274-279.
7. KOST, J. (1960) — Inventarisatie van grondwaterstanden, Verslagen Technische Bijeenkomst 13-14, 82-89.
8. VISSER, W. A. (1968) — De Dienst Grondwaterverkenning TNO, TNO-Nieuws, 23, 207-209
9. VISSER, W. A. (1969) — New developments in groundwater studies in The Netherlands, Nature and Resources, V no. 3, 17-18.

IV. SOME INTERNATIONAL ACTIVITIES IN THE FIELD OF HYDROLOGIC INFORMATION SYSTEMS

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In 1967 the Co-ordinating Council of the International Hydrological Decade requested Unesco to establish a small Working Group to make a study on Systems for the Acquisition, Transmission and Processing of Hydrological Data (SAPHY-DATA) from which work the following is abstracted.
The study on Saphydata should include:

a. a report on the experiences of countries which use or have developed hydrologic information studies;
b. an assessment of possibilities and the practical value of installing various systems under different conditions;
c. an evaluation of the relations of hydrologic information systems with the World Weather Watch of the WMO and possible other global systems.

The Working Group consists of specialists from France, Hungary, the Soviet Union, the United States and Sweden, with the participation of WMO. The first meeting took place in 1968 and the report will most probably be published in 1972.

Hydrologic Information Systems are subdivided by the Working Group into three subsystems namely: Measurement systems, Transmission systems and Data Processing Systems; while hydrology includes, in this case, surface water, groundwater, water quality, rainfall, temperature, humidity, ice and snow.

The reasons for the establishment of this Working Group are: the necessity for co-ordination and exchange of data between countries especially in the fields of automation and electronic data processing, storage and retrieval and secondly, the necessity for conveying the experience and knowledge in the field of hydrologic information systems of the developed countries to the developing countries.

At the beginning especially expectations were high and many people thought that something similar to the World Weather Watch could be realized, that is, one global Saphydata system. In the beginning it is true, this would only encompass the developed part of the world but would gradually be extended by the joining of developing nations who would, in this activity, be assisted by the developed countries.

This idea has not been developed further, on the one hand because most of the developed nations do not have a comprehensive national system and on the other hand because of a fundamental difference between meteorology and hydrology. We have, for example, a need for own weather forecasts to know at several hours of the day what the atmospheric pressure is in Great Britain and France while we do not care very much about daily discharges of the Thames and the Seine rivers. There is thus a difference in necessity for meteorologic and hydrologic international information systems and thus a difference in willingness to put money in it. It is therefore not surprising that a Global Hydrological Information System did not come to life.

From several points of view, however, this is a pity, namely, because of the stimulating effects the working out of a global system would have had on the development of national systems, the exchange of information between countries with common hydrological units and/or problems and our knowledge of the world water balance.

It is certain that in future a closer collaboration has to come but it will start on an ad-hoc basis as is done already for instance by the Danube countries.

The WWW or World Weather Watch of the WMO is a World Meteorological Information System in development: precipitation data will be included but whether surface water data will get a place in this system will have to be seen. The World Weather Watch will, aside from communication satellites, make an extensive use of meteorological satellites, which will make day and night photographs of clouds and snow. Under the World Weather Watch Global Data Processing Centers which will be established there will be all modern facilities including large computers for the processing of meteorological and climatological data in order to arrive at better weather forecasts.

The four essential elements of the World Weather Watch are: the Global Observation System, the Global Data Processing System, the Global Telecommunication System and the scientific research of the atmosphere. The organizational build-up is from National via Regional to World Meteorological Centres. Melbourne, Moscow and Washington are world centres. Twenty regional centres are already operational which give additional climatological analyses and weather predictions on a regional scale.

A good functioning international meteorological communication system exists already but in order to make a big step forward in meteorological forecasting so many more data are necessary that the present system is becoming inadequate.

Simultaneously with the development of the World Weather Watch is WMO in collaboration with ICSU, that is the International Council of Scientific Unions busy with the development of a Global Atmospheric Research Programme (GARP). The purpose of this programme is to arrive at better weather forecasts through a more profound understanding of the physical processes of the atmosphere.

Better meteorological forecasts are of great interest for hydrologists. Weather forecasts are at the moment reasonably reliable for periods from some hours to one day. When the time comes that precipitation can be forecasted quantitatively some days ahead hydrological forecasts especially flood forecasts will improve enormously. The forecasts aimed at by the World Weather Watch are: short-time forecasts up till 36 hours ahead for precipitation (quantitative), wind direction and speed, maximum and minimum and dew-point temperatures, cloud-cover and radiation, week forecasts, monthly forecasts and seasonal forecasts. It may be expected that weather forecasts will improve so much in the seventies that they will become operational for hydrologists. Several institutes are now testing and improving mathematical atmospheric models and the computers in the world and regional meteorological centres will be so large that they will be able to handle these models. For instance the IBM computer which will be installed at the end of 1971 at the Meteorological Institute at Bracknell (UK) will be the largest computer in Western Europe.

As was already said above it has not yet been decided how much hydrological data which are not at the same time meteorological data will be included by the World Weather Watch. A work group of the Commission of Hydrometeorology of the WMO, the Working group hydrological aspects of the World Weather Watch, is studying the subject. It is already clear that although the World Weather Watch is a global system for meteorology it will not become a global hydrological system. It will be more likely that hydrologists will use the World Weather Watch as a tool, using the communication satellites for collection of data from automatic stations in remote areas, for the transmission and processing of data on/between neighbouring countries and on a regional scale and using the observation satellites for remote sensing of hydrological parameters.

There are pressure groups who would like hydrology to become a part of meteorology. With regard to the wide and good experience of meteorologists in data acquisition, transmission and processing systems, nationally and internationally there is something to say for the integration. On the other hand hydrology is such a broadsided activity that especially in developed regions it is not only a science dealing with water but more with water management, where there is a basic difference from meteorology. As long as we cannot speak of weather management we may ask if it would be optimal to let a service that has no experience with management problems take over hydrology.

In the United Nations system, if there is question of installing hydrological networks in developing countries the WMO is asked to be the executing agency for those projects.

There is a hydrometeorological service in most East European countries and in Sweden. In most countries, however, different services are under all possible ministeries.

Take the Netherlands, for example, where there are certainly over fifty services and institutions dealing with something hydrological. It is not at all necessary that those hydrological activities in the Netherlands come under he leadership of the Royal Netherlands Meteorological Service but hydrologists will have to profit from the experience of meteorological services and especially, in future, come to close co-operation because meteorology will get more and better possibilities in hydrology.

A system is an efficiently ordered coherent entity of together-belonging units and their parts. Thinking in systems has become necessary because of the insight that it is not optimal, as well economically as technically, to improve part by part without taking into account the performance of the entity. When looking at the Netherlands, for example, we can say that society needs hydrologic data of a certain quality and quantity. The problem is to get these data as cheaply as possible, and as cheaply as possible amounts here to minimal costs for the society as a whole and not the minimal costs for the different services. In fact this is only possible when every service only looks at the overall interest of society and when there is very good co-ordination. A good working system may bring us close to this ideal.

Another advantage of system-thinking is the necessity of formulating clearly what we in fact want the system to do for us. A first necessity for the acquisition of hydrological data could be as part of a general survey of natural resources of a region as a tool for making a development plan for this region. A second phase would be for the positioning of new residential and industrial areas and the dimensioning of hydraulic structures and a third phase would be for the development of a network to be constantly informed about changes in our water environment so that we can adjust ourselves quickly, for example, in case of floods and for navigation.

The last phase would be the forecasting network and even decision system. It is clear that each of these phases is successively more intricate and organizationally more demanding. As quickly as there is a question of a forecasting system it is necessary to use models, understanding here that a model is a schematized imitation on a small time and space scale of a hydrologic unit.

As physical models of hydraulic and hydrological systems have now been used for a long time as a tool for the design of all kinds of hydraulic works there has been over the last ten years an enormous development in mathematical models for surface water as well as groundwater studies. Analogue models clearly seem to lose ground. An advantage of mathematical models is that data are easily put in and changed. Secondly, a mathematical model does not ask for servicing, is non-destructible and does not take up much space. Thirdly, you can find computers nearly everywhere in the world. Fourthly, the connection between automatic stations and digital computers is simpler.

International co-operation becomes, by the increasing complexity of systems more necessary, intricate and expensive, even if only because of the different existing computer systems. At the moment an international programme for the exchange of computer programmes in the field of hydrology would be opportune. Many hydrological services have hundreds of computer programmes available but the services nationally and internationally do not know what the others are doing and so much effort and money is wasted in the development of programmes which other people somewhere else have already made operational.

I know only one example of a country that publicizes something in the field of computer programmes for the processing of hydrological measurements, namely the USA. The United States Geological Survey, who controls the largest part of all hydrological data activities in the USA publishes yearly a book called "Computer Programs for Processing Water Data". This publication contains summaries and output examples. Two years ago the number of programmes in this book was 250.

Unesco is studying ways and means to make an international exchange of computer programmes possible.

The planning of an operational information system demands, of course, an accurate knowledge of the kind of information, the resolution and quantity needed and the frequency with which the data have to be obtained.

To find the optimal system a number of alternative systems have to be put on paper and the cost benefit ratio of the different configurations have to be looked at. It is expected that lower entity-costs and an effective connection with hydrological problems will be obtained when independent systems are coupled and a certain unity in subsystems is obtained. A rigid scheme to measure effectivity does not, of course, exist but you could think in terms of performance, reliability and serviability.

General steps are: establish a number of objectives for hydrological data, establish a number of specifications for the acquisition of these data, establish a number of basic accuracy requirements and form a matrix that contains the different specifications. Such a matrix is for example developed by the USGS to measure the efficacity of the national hydrological networks. As an illustration of what exists in the world in the field of hydrologic information systems, a national system, a basin system and an example of international cooperation will be discussed.

The Hungarian National Water Authority

The National Water Authority is subordinated directly to the Council of Ministers. Its scope extends from river regulation, water supply and waste water, land reclamation and irrigation, establishment of fish ponds, harbours to training of technicians. The National Water Authority performs its task through twelve District Water Authorities and several large institutions among which the Research Institute for Water Resources Development is the most influential. The Institute employes about 800 people, of whom about 100 are university educated, most of them civil engineers.

The Institute runs a vast hydrological information service covering the whole country. Every morning it receives by telegraph reports from 70 stations in Hungary and reports from 110 foreign stations through radio, telegraph and telex. The international languages for this purpose are French and Russian. Also each morning, the service receives data on precipitation and temperature of all meteorological stations from the Central Meteorological Institute through a direct telephone line.

Every day a precipitation map is made of the Danube basin with the help of information from abroad obtained through international synoptic radio broadcasts.

Lastly, data on water temperature, navigation conditions and ice conditions are collected. These daily collected data are processed and published in a daily hydrologic map with annexes. Every morning at 3 a.m. this map is printed. In Budapest special messengers bring the map to all interested services while the people in the province receive the map the next day by post.

Since the big floods of the last years emphasis has been put on flood forecasting and a network of telerecording stations is in development that will continuously transmit the stage of rivers entering the country. Every month a groundwater map is made with data from an observation network of 2,000 stations consisting of wells that are exclusively used for observations which take place every three months.

The hydrological year book does not only contain stages and discharges but also information on groundwater levels, springs, sediment transport, navigation channels, water temperatures, ice conditions, precipitation, air temperatures, evaporation, sunshine etc. Since 1962 Hungary has published, as a result of the plan-economy, a water quantities yearbook in which information is founded on available and exploitable quantities of water, water extraction etc.

The above outlined organization has something attractive because of its simplicity. Certainly, outside the Research Institute for Water Resources Development there are other bodies dealing with hydrology such as the Academy of Sciences, the Universities and the Central Institute for Meteorology but the operational aspects are clearly in one hand.

The establishment of a strict complete system has been made possible here by a radical change in the organization of the state in the past.

At the moment the Hungarian Hydraulic Information System does not make use in an integrated way of electronic computers.

The Orsanco System

ORSANCO stands for Ohio River Valley Water Sanitation Commission. It is an Interstate compact organization. About 18 million people are living in the Ohio valley and the Commission in order to effectively control pollution has developed a rather complex information system.

This information system consists of three integrated components namely, a group of electronic analysers with a transmitter, a telemeter interrogator and receiver and a data logger and transcriber.

The analyser with transmitter is one unit that can be placed anywhere along the river. The instrument measures changes in water quality which are transformed into electric impulses which are relayed to Orsanco Headquarters through a leased telephone wire circuit. The telemeter interrogates each station at intervals of one hour. The received data are automatically typed and put on punched tapes which are fed to a computer for processing and evaluation. In 1965 the Orsanco observation network consisted of (a) 17 manual stations operated by municipal and private water supply companies on a voluntary basis (b) 11 manual stations operated by the United States Geological Survey on a contract basis (c) 13 robot stations installed and operated by Orsanco and (d) 15 sampling points for measurements that cannot be taken automatically, such as, radio-activity in water, sand and living organisms, under contract with a potamological institute.

The robot-monitors complement the manually operated stations. The robot-monitors have the advantage that continuous measurements can be taken in an economic way, but important matters such as, alkilinity, hardness, iron, manganese, etc. cannot be measured without human interference. The same holds for data on bacteriological conditions.

The number of data obtained by the robot-monitors is so large that data processing and presentation are becoming very important. The computer supplies tables per day and per station, which are from time to time bundled and published. A normal processing of all data would be impossible. It would take 150 man years to make summaries of data collected during one year — a work which is done by the computer for 4,500 dollars.

The Orsanco system is clearly a highly developed information system which enables the Government authorities to act quickly when necessary.

The Co-operation of the Scandinavian Countries

As long as nearly all Governments see national independence as the most important thing on earth it is not to be expected that real international hydrologic information systems will quickly emerge.

The Scandinavian countries have thought out procedures so that they come to a maximal integration without coming to a point where a supranational body would have any control over the national services. The co-ordination has the following objectives:

(a) co-ordination of hydrological networks;
(b) planning of new network activities;
(c) exchange of data in directly usable format for data processing as on magnetic tapes and punched cards and tapes;

(d) exchange of computer programmes and the harmonization of programmes;
(e) harmonization of publications;
(f) harmonization of measuring methods and computer systems as far as new material is concerned which is especially important for the processing of data from automized river gauging stations.

The harmonization of measuring methods is for instance done by way of a standardization of making water analysis. Standard solutions needed for calibration are for all five countries supplied by the Limnological Institute in Uppsala. Another example is the choice of one kind of neutron-meter for a standardized soil moisture measurement. The experiences of the Scandinavian co-operation are very instructive:

(a) Most successful was the harmonization of data acquisition and data exchange in directly usable format for processing.
(b) The Services and Institutes that measure, collect and store hydrological data cannot be forced to process their data automatically.
(c) Only a few computer programmes have been executed until now. The big differences between the several computer hard and soft ware systems make the adaption of "strange" programmes difficult, costly and time-consuming. The only programmes exchanged until now are those with a few technical algorithmes.
(d) There are no reasonable digital recorders on the market for a reasonable price so that standardization is not possible at the moment.

As a conclusion we may remark that international co-operation is not easy even when all possible goodwill is present.

Experiences and Progress in Other Countries

The development of hydrological information systems has scarcely started, even in the most developed countries. No reasonably developed integrated national system exists in the world let alone a continental system. Part systems have reached a highly developed level at certain places, much research is also dedicated to the development of hydrological information systems. The technology of highly developed telecommunication and computer systems is available. In fact, technically, we can do what we like, it is more a question of organization and money than a technical problem.

In the USA there are for several hydrological entities some highly developed hydrological information systems. In the Scandinavian countries also. France has also several, under control of the Electricité de France, very modern information and decision systems.

There are no general figures available, but in order to get an idea of what is available in several countries follow here the figures for automatic water quality stations.

Country	*Existing*	*Planned*	*Remarks*
Austria	1	—	
Belgium	1	1	
Czechoslovakia	3 experimental	50	
German Federal Republic	6 federal	4 federal	Some more local stations exist
Netherlands	29	11	10 in execution
Norway	—	—	
Poland	2	—	5 in execution
Spain	—	10	
Sweden	12	18	
Switzerland	2 experimental	7	
USA	205	1,000	
USSR	—	—	
UK	4 experimental	240	

It is not right to think that highly developed systems are only appropriate for highly developed countries. There are in the developing countries many conditions which only very modern highly developed systems could made work satisfactorily. For example, the data acquisition-transmission and forecasting system that is executed in the Pantanal, that is the Matto Grosso, by the Brazilian Government with the assistance of Unesco has highly developed automatic systems.

A description can be given under which a modern system will be optimal. Very modern systems are only optimal for large areas and in those cases when conventional systems can in no way whatever give the necessary information and services. This can be because of the geographical conditions, number of data or the speed with which the data have to be processed and transmitted in order to enable quick decisions.

V. HYDROMETEOROLOGICAL MEASUREMENTS IN THE NETHERLANDS

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1. Introduction

In recent years in the field of hydrologic research important changes took place in The Netherlands. Hydrologic studies are carried out on a more regional scale and more detailed data, according to spatial and temporal distribution are often needed. Therefore it is unlikely, that the hydrologic network, providing adequate data in former years, will do so any longer.

A discussion of the existing network seems also worthwhile at this moment, because the measuring and processing techniques have been improved considerably. Better facilities for data handling and storage are available now.

The discussions will be restricted to the measurement, processing and publication of the following hydrometeorological variables: rainfall, evaporation, discharge, groundwater levels and soil moisture. Some more general aspects will be mentioned first.

2. General aspects

The longest rainfall records in The Netherlands are measured at the station of Zwanenburg. This record starts in 1735. For the river Rhine and Waal records of water levels are available from the stations Arnhem and Nijmegen, starting resp. in 1772 and 1770; for the river IJssel (station Zutphen) the record starts in 1765. For the river Meuse (station Maastricht) the record is shorter and starts in 1820. Since 1900 the river stages of the main rivers and the sea levels of some coastal stations are published regularly by Rijkswaterstaat (1900 etc.). It is not the aim to give an inventory of all the available records, however. This small historical preamble was only used to put the question: "is it still worthwhile to give so much attention to the collection and processing of hydrometeorological data and even to spend a whole meeting on this subject". To my mind the answer on this question must be yes, although a relatively dense network exists in The Netherlands and the length of the records is sometimes quite considerable. However, in a densely populated and highly developed country as The Netherlands, the water problems must be studied in very minute detail.

For design purposes, based on small risk-factors only, accurate figures are acceptable. As stated before, the way of tackling the problems has also been changed. It must be stated that the calculation techniques, developed recently (e.g. various types of hydrological models), also need more accurate and detailed data.

Another important question which can be raised is: "are relatively short records still valuable from a hydrological point of view". Using short records for frequency studies will generally lead to wide confidence intervals. However, a short record of a certain station can often be used in combination with long records of other stations. In that case the long record must also cover the period of the short record. By comparing the frequency distributions of both stations for the same period the parameters of the long term frequency distribution of the first station can be estimated (Werkgroep Afvloeiingsfactoren, 1970). Short records of stations in different areas can also be used for a comparison of the hydrological characteristics of these areas. Especially runoff and groundwater level data are valuable in this respect.

Finally it must be mentioned that the parameters of e.g. rainfall-runoff models can be determined from short records. According to the foregoing it can be concluded that the measurement of hydrometeorological variables is not only still important, but even more so than in the past.

Another general aspect must be stressed briefly. The collection of hydrometeorological variables comprises not only the installation of an instrument and taking regular observations, but in fact various aspects must be considered together:

— the determination of the number of stations and the selection of suitable measuring sites (network design);
— the choice of the type of instrument and the recording interval;
— the regular control and periodic maintenance of the equipment;
— the possibilities of change of charts, punched tapes etc.;
— the control and checking of the data;
— the completion of the records;
— the presentation and publication of the data.

The selection of the most suitable instrument is closely related to the processing equipment available.

In case one or more of these factors are neglected, the results will not be optimal, and even a complete failure of the measurements must be feared.

3. Hydrometeorological observations

3.1 *Precipitation*

The main precipitation network in The Netherlands is run by the Royal Netherlands Meteorological Institute (KNMI). It comprises 310 stations. In most stations daily measurements are taken. In 6 stations the measurements are taken 3 times a day, while at 5 stations pluviographs have been installed. The distribution of the stations over the country is fairly irregular and the distance between two adjacent stations is sometimes considerable. This is partly due to the fact that nearly all the observers are volunteers. A frequency distribution of the Thiessen polygons is shown in fig. 1. This curve is prepared by using the Thiessen map compiled by the Rijkswaterstaat (1960).

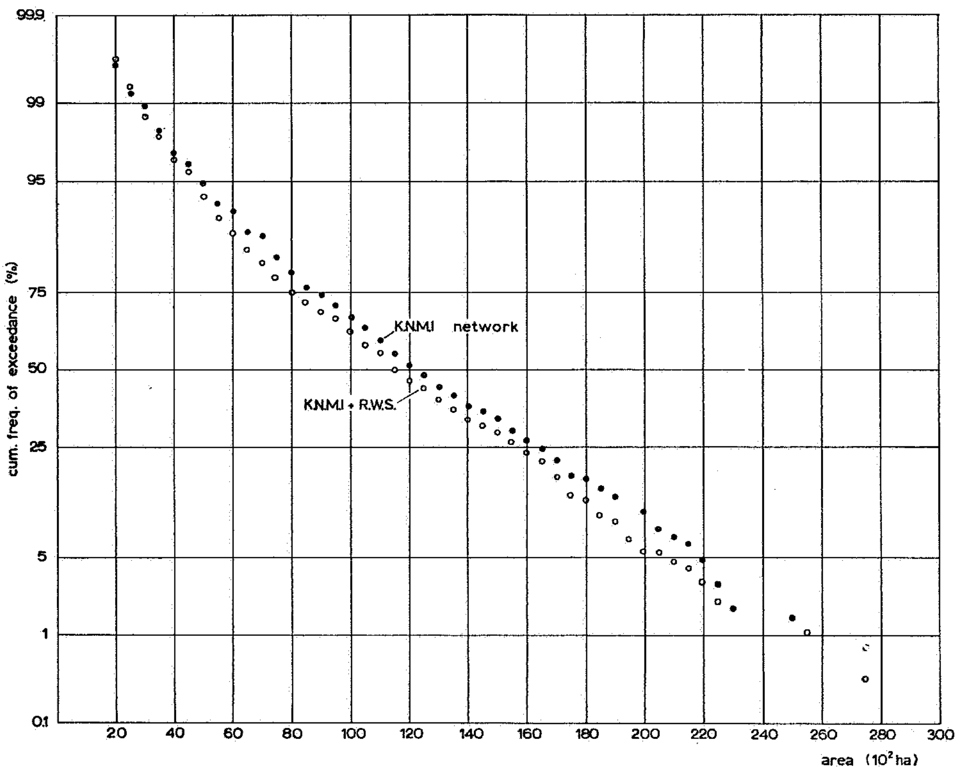

Fig. 1. The percentages of areas (determined according to Thiessen polygons) exceeding the given magnitudes.

The mean size of the polygons amounts to 12,000 ha, but 10% of the polygons exceeds 20,000 ha. The number of available stations is often insufficient to permit a detailed hydrologic study. Therefore the network density is increased by installing additional gauges. The network of Rijkswaterstaat (Service for Water Management) is the most important secondary network. It comprises about 60 stations, 20 of which have both a standard gauge and a pluviograph. At 10 stations a recording raingauge at ground level (ReCoVer) has been installed (Colenbrander en Verstraate, 1966). It is a disadvantage that in The Netherlands only very scarce information is available concerning the relation between network density and the accuracy of mean basin rainfall calculations. Stol (1971) has studied this aspect in the Eastern part of The Netherlands, and Colenbrander and Stol (1970) for the Leerinkbeek area.

Another aspect must be discussed briefly. It is well-known that the accuracy of rainfall measurements is affected e.g. by the shape of the collector, the exposure of the gauge, and the height of the rim of the gauge above land surface.

In case the conditions mentioned are not constant during the observation period, the records will not be homogeneous. Important changes in the height of the gauge of the KNMI-stations, took place in 1905 and 1947. At this moment the standard height of the raingauges is 40 cm above land surface. Even at this height the wind can reduce the catch measured with these gauges (de Zeeuw, 1963). Colenbrander and Stol (1970) present differences between standard and ground level gauges too.

It is obvious that during the observation period the exposure of most stations was not constant. It is worthwhile that the effect of the variation in gauge height and exposure will be studied especially with respect to the influence on the prepared frequency distribution of rainfall.

Collecting and processing of the observations of the KNMI-stations is standardized and very efficient. The data are also readily available, because each month the daily rainfall amounts of all stations are published, just like annual reviews. Very important are also the frequency distributions published for a number of stations. The processing and publication of the data of the secondary networks is less standardized, and the data are not published regularly. This is a disadvantage and it is important to stimulate the availability of these data. It is clear that a link between the archives of primary and secondary stations will be essential, for obtaining full information out of the networks.

3.2. *Evaporation*

In this section only the evaporation records of a free water surface will be discussed. Potential and actual evapotranspiration data of vegetated land are not available over long periods. Yet some institutes have lysimeter data, but these are mostly sampled for special experiments and not on a routine basis. At 16 KNMI-stations data are observed to calculate the evaporation of a free water surface according to Penman. The calculations are made on a monthly basis. The accuracy of the evaporation totals, however, is not known. This is due to the fact that not all the relevant figures are measured at each of the 16 stations. It is also unknown how the exposure of a station is affecting the measurements. In other words the question is: "are the calculated evaporation totals fairly representative".

Besides the KNMI-stations the Rijkswaterstaat (Service for Zuiderzee Works) also regularly publishes evaporation data, e.g. from some floating pans in Lake IJssel.

It is obvious that for various investigations more detailed data are desired. The most important aspects are:

— a better knowledge of the accuracy and representativeness of the available records;
— the relationship between the evaporation of a free water surface and the potential evatranspiration of various types of vegetated land;
— the availability of evatranspiration totals over shorter periods than a month (e.g. weekly or daily totals).

3.3 *Discharge*

The discharge records of small rivers will be discussed only. Most of these are from gauging stations, which belong to Rijkswaterstaat (Service for Water Management). In 1970 this service was responsible for 169 stations where water level observations were taken. At 116 sites this was done by staff gauges, at 40 sites by limnographs and at 13 sites by punched tape recorders.

At 150 out of the 169, discharge measurements are carried out regularly. Most gauging stations are situated in the small rivers in the higher parts of the country, where the excess rainfall is drained by gravity. In the low polder areas with mainly artificial drainage conditions only a few stations exist. In the polder areas observations are mostly carried out by the local water boards. Measuring stations have been installed by Provincial and local water boards, also in the water courses of the high catchment areas. A few discharge records of Rijkswaterstaat started in 1942, but the greatest number in the period 1950 - 1953.

In principal the full range of flow could be measured accurately but in practice, this was often only true for the high flows. The calculation of the low and medium flows is strongly affected by the aquatic vegetation. For most gauging sites the varying flow resistance, caused by this vegetation, is not well-known. This aspect is discussed in detail elsewhere (Colenbrander, 1967; Blok en Colenbrander, 1970).

It is certain that not only the peak flows are of interest, but also the medium and low flows. Therefore special attention must be given to this aspect in selecting streamflow stations.

As mentioned before, a number of stations belongs to other agencies. It is advisable that a better co-operation between Rijkswaterstaat and the other agencies arises and that all the available discharge data is being stored in one archive.

3.4. *Groundwater level*

It will not be necessary to repeat what is said in the report of Groenewoud and Visser elsewhere published in this volume.

The necessity of a complete and quick automation of the archives for groundwater levels may be stressed only. A close co-operation between this archive and the other archives of hydrometeorological data is needed too.

3.5. *Soil moisture*

From a few stations, only regularly attended, soil moisture data are available. The measurements are mostly done by Rijkswaterstaat (Service for Water Management). The records are mostly short and not published regularly.

For special investigations some institutes have also measured soil moisture contents. These measurements are mostly not taken in a systematic way and the length of the records varies greatly.

Regular measurements (e.g. weekly or bimonthly) of soil moisture content at some carefully selected sites, located in different parts of the country, will be very valuable for future hydrological research.

4. Conclusions

From the foregoing the following conclusions can be drawn:

— the existing number of rainfall and evaporation stations is not adequate to provide the data, needed for multipurpose hydrological investigations. The additional stations must be installed by the KNMI, or by other agencies in close contact with this institute;

— the number of groundwater raingauges must be increased;

— the effect of the inhomogeneity of the existing rainfall records, e.g. in relation with the frequency distributions, must be studied;

— the accuracy and representativeness of the available evaporation data must be considered;

— all available streamflow data should be stored in one archive;

— in selecting streamflow gauging stations it must be certain that, besides the peak flows, the medium and low flows can also be measured with reasonable accuracy;

— the complete and rapid automation of the archive for groundwater levels is very important;

— regular soil moisture measurements in a number of sites, distributed over the country, will be valuable;

— the last, but in the meantime the most important conclusion is that it is essential to create a better co-operation between the existing archives of hydrometeorological data. When new archives are set up (e.g. for water quality data), it is important to link them up with the existing archives.

It will be worthwhile to consider also the set up of a key-archive, comprising all information concerning the existing records (e.g. location of station, beginning and end of record, discontinuities, recording interval, etc.).

A number of examples of a fruitfull co-ordination of hydrometeorological archives are discussed by Verhoog elswhere in this volume. Other studies in this field are published, e.g. in Australia (Australian Water Resources Council, 1970) and the U.S.A. (Federal Interagency Water Data Handling Work Group, 1971).

Various of the above conclusions are anything but new. This is evident when I am quoting a question raised by Mr. Schijf during a meeting in December 1952 (!): "Because different agencies are collecting more or less the same type of data (i.c. flow data) it is advisable to store these data in one central archive. The most suitable agency to take the responsibility for this may be Rijkswaterstaat".

Mr. F. Volker, speaker at the meeting, fully agreed. During the same meeting Prof. Krul made the following statement:
"It is essential to co-ordinate the water level and discharge measurements with the observations of the groundwater table. This will facilitate studies concerning surface water and groundwater relationships. It seems to be just the right time (!) to start a co-operation between Rijkswaterstaat and the Archives for Groundwater Levels".
So far my quotations .

Finally I should like to make the following proposal: to set up a working group for the study of a better co-operation between the existing hydrometeorological archives, and to consider if it is worthwhile to store all information of the existing records in a special archive. To my mind the Committee for Hydrological Research TNO is the most suitable to take action in this field, and at the same time it is to be hoped for that such a working group study will not take another twenty years.

LITERATURE

AUSTRALIAN WATER RECOURCES COUNCIL — 1970. Standards for Interchange of Surface Hydrologic Data on Computer Media.

BLOK T. en H. J. COLENBRANDER — 1970. Afvoermetingen in kleine stroomgebieden (with English summary). In: Hydrologisch Onderzoek in het Leerinkbeekgebied; Sub Report 6.

COLENBRANDER, H. J. — 1967. De invloed van de begroeiing op de afvoercapaciteit van de beek. Cultuurtechn. Tijdschrift. 6,5.

COLENBRANDER, H. J. en J. M. I. VERSTRAATE — 1968. Een registrerende grondregenmeter, waarvan de gegevens automatisch kunnen worden verwerkt. Cultuurtechn. Tijdschr. 6,3.

COLENBRANDER, H. J. en Ph. Th. STOL — 1970. Neerslag en neerslagverdeling naar plaats en tijd (with English summary). In: Hydrologisch Onderzoek in het Leerinkbeekgebied; Sub Report 5.

FEDERAL INTERAGENCY WATER DATA HANDLING WORK GROUP — 1971. Design Characteristics for a National System to Store, Retrieve and Disseminate Water Data.

RIJKSWATERSTAAT — 1900 etc. Jaarboek der Waterhoogten. Directie Waterh. en Waterbew. Hydrometrische Afd.

RIJKSWATERSTAAT — 1960. Nederland, Overzichtskaart Neerslagstations (met Thiessen polygons). Directie Waterh. en Waterbew. Dienst v. d. Waterhuishouding.

STOL, Ph. Th. — 1971, in press. The relative efficiency of the density of raingauge networks.

WERKGROEP AFVLOEIINGSFAKTOREN — 1970. Tweede Interimrapport. Uitbreiding van korte waarnemingsreeksen. (par. 3.2.9.).

ZEEUW, J. W. de — 1963. Over de werkelijkheidsbenadering van gemeten neerslagen. Landb. Tijdschr. 75, 14.