# Studies on the water balance of a small natural catchment area in southern Sweden

By ULF HÖGSTRÖM, *Dept. of Meteorology, University of Uppsala*, and INGEMAR LARSSON, *Dept. of Physical Geography, University of Lund*

(Manuscript received July 4, 1967; revised November 24, 1967)

ABSTRACT

A water balance study is made on a small natural catchment area in flat sandy agricultural country in southern Sweden. Relevant simultaneous data concerning precipitation, evapotranspiration, surface run-off and ground moisture content are obtained from measurements over a period of at least six years. Complete balance between precipitation, evapotranspiration and surface run-off is obtained from the six-year period as a whole. The results show a significant and very pronounced pattern of seasonally influenced subsurface inflow and outflow. When represented as running 12-month means, the surface run-off and ground water level curves show a high degree of correlation to long term variations in precipitation. The ground water is found to lag 6 months behind the precipitation and the run-off 2 or 3 months. The running 12-month mean for evapotranspiration is found to vary only slightly and does not appear to be related to the precipitation.

## Introduction

Studies of experimental catchment areas have in recent years been in the focus of hydrological research work in most countries. In 1965, the first year of the International Hydrologic Decade (IHD), a symposium was arranged in Budapest by the International Association of Scientific Hydrology (IASH). The proceedings of this symposium (Int. Ass. Sci. Hydrol., Publ. No. 66) reveal the actual state of scientific hydrology in the field of water balance studies and research work in experimental areas and are an excellent literary review of this topic.

The problems of natural water balance appear to have mainly been considered in three different ways:

(*a*) By means of conventional methods (directly related to the equation of hydrological equilibrium).

(*b*) By experimental methods, such as lysimeter investigations and different types of model studies.

(*c*) By means of mathematical models.

The first method (*a*) is well known, and does not need further explanation here. The present state of lysimeter research work may be exemplified by two authors, Chardabellas (1965) and Supek (1965). Németh (1965) has used different types of scale models and has compared experimental results with parameters of full-scale basins (method *b*).

As a representative for the last-named approach (*c*) to water balance studies with mathematical models, Roche (1965) may be mentioned.

This study of water balance belongs to type (*a*), with the exception that hydrological data from other catchment areas have been included. However, owing to the small distances involved and uniform land type, cf. p. 636, these data are considered to be acceptable.

Todd (1959) gives the most general form of the equation of hydrological equilibrium, including all waters—surface and subsurface—entering and leaving a basin:

$$\left.\begin{array}{l}\text{Surface inflow + subsurface inflow + precipitation + imported water + decrease in surface}\\ \text{storage + decrease in ground water storage}\end{array}\right\} = \left\{\begin{array}{l}\text{Surface outflow + subsurface outflow + consumptive use + exported water + increase in}\\ \text{surface storage + increase in ground water storage}\end{array}\right. \quad (1)$$

Todd stated that there are many situations, in which it is possible to eliminate certain items from the equation because they are negligible

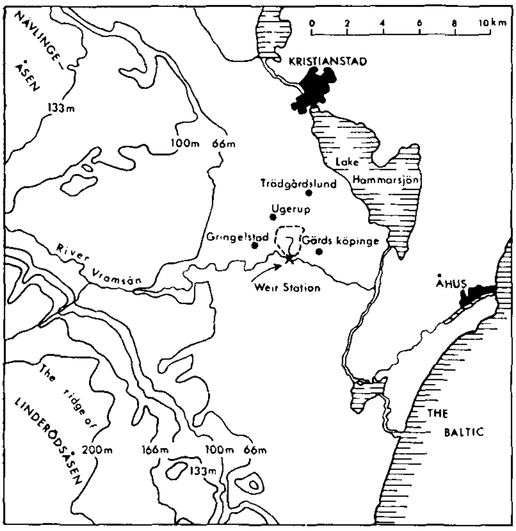


*Fig. 1.* Survey map of the experimental area, the Kristianstad plain, southern Sweden. The balance study applies to the small catchment area indicated. Ground water stations are situated at Trädgårdslund, Gärds Köpinge, Gringelstad and Ugerup. Other measurements were performed at Ugerup (cf. Fig. 2).

or because they do not effect the solution. Similar ideas are pointed out by Ubell (1965) who discusses the vertical moisture movements and finds that an experimental area should be selected where ground water inflow and outflow may, for all practical purposes be considered as zero, or where ground water inflow and outflow are identical (steady ground water flow), which implies that no change occurs in ground water resources. Thus Ubell states the water balance equation in the following form:

$$P - R_s = E \pm S_{gw} \pm S_m,$$

where

$P$ = precipitation,
$R_s$ = surface runoff,
$E$ = evapotranspiration,
$S_{gw}$ = ground water storage,
$S_m$ = soil moisture storage.

The aim of the present investigation has been to collect hydrological data from a small experimental area in southern Sweden and apply the balance equation. This has been made possible by the systematic hydrological research that has been carried out in this region during the period 1955–1964 by the Hydrology of the Kristianstad Region Cooperating Committee (SKH) (see Weijman-Hane (1961) for a summary of the project). The results of these investigations have been used in the present study.

## Experimental arrangements and hydrological base data

The experimental area was situated on the Kristianstad plain in southern Sweden. Ground water and precipitation were measured at a large number of stations, spread over the area shown in Fig. 1 (cf. Larsson (1962) and Ellesson & Persson (1961)). Stream flow was measured at one weir station, situated on a small stream named Bredakärrsbäcken (cf. Fig. 1). This recorded the run-off from a catchment area, the area of which was only 1.77 sq. km. Evapotranspiration and soil moisture content was also measured at only one station, Ugerup experimental farm, situated about 3 km north-west of the weir station, cf. Fig. 2.

For the water balance study, the following measurements were involved:

*Precipitation*, recorded by a normal type gauge at Ugerup (measurements performed by the Swedish meteorological and hydrological institute (SMHI), Ellesson).

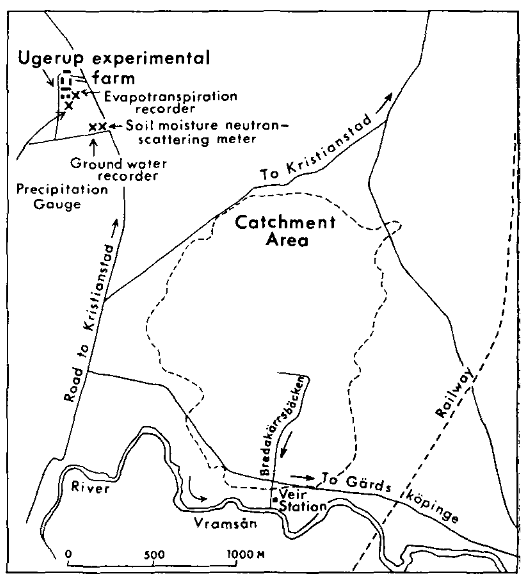


*Fig. 2.* The catchment area and its immediate surroundings. The area shown on the map is fairly flat, uniform, agricultural country.

*Evapotranspiration* at Ugerup (measurements performed by SMHI, Högström), according to the method described below.

*Streamflow* at Bredakärrsbäcken (measurements performed by SMHI, Tryselius).

*Ground water* in the quaternary deposits at four stations: Ugerup, Gringelstad, Trädgårdslund and Gärds Köpinge, see Fig. 1 (measurements performed by Dept. of Physical Geography, University of Lund, Larsson).

*Soil water* at Ugerup (Dept. of Land Improvement and Drainage, Royal Institute of Technology, Stockholm, Fleetwood). Measurements were performed with the aid of the neutron flux method from the surface down to a depth of 160 cm (cf. Larsson & Fleetwood (1967).

All the above-mentioned measurements, except that of evapotranspiration, are more or less standard and need not be described in detail. The evapotranspiration data, however, has been obtained in a rather complex way, with the aid of three entirely different methods:

1. The vertical water-vapour flux was measured at Ugerup with the eddy correlation technique on 45 occasions. The instrument was situated about 4 metres above ground-level. The instrument is described and the basic data tabulated in Högström (1967*a*). Each measurement period had a duration of about one hour. Simultaneously vertical profiles of humidity, temperature and wind were recorded. The eddy water vapour flux, $E$, and the vertical gradient of humidity, $\partial\bar{q}/\partial z$ could then be used to determine the exchange coefficient for water vapour, $K_w$, from the flux-gradient relationship:

$$E = -\varrho K_w \frac{\partial \bar{q}}{\partial z}.$$

The 45 recordings then formed the basis for an investigation of the relation between $K_w$ and atmospheric stability (Högström, 1967*b*). The result agrees well with findings from similar investigations in other places, performed during the last few years.

2. The findings from the eddy flux study were used to evaluate the vertical water vapour flux on a running hourly basis from continuous measurements of vertical water vapour pressure difference, vertical temperature difference, and wind speed at one level. The results of these recordings are available for the period March 1961–September 1963 (with the exception of July and August 1963). These data have been examined in detail in a separate paper (Högström, 1968).

3. Monthly means for the water vapour flux obtained with the method described above (called, in the following: "the profile method") were compared with values for the so-called "potential evapotranspiration", obtained with the methods of Penman and Thorntwaite. The quotient $E_p/E$ between the "Thorntwaite value", $E_p$, and "the profile value", $E$, was found for each month and plotted against the month. For the period April–October a remarkably consistent tendency was found: the quotient being close to one in spring, rising to about two in autumn. The reason for this behaviour is discussed in Högström (1967*c*). For the winter months an empirical relation between evapotranspiration and monthly mean temperature was obtained (Högström, l.c.). Thus with the aid of empirical relations approximate monthly values of actual evapotranspiration could be obtained from monthly mean temperature data only. Individual values, however, obtained in this way must be subject to a considerable scatter. In the following water balance study only running 12-month means, or, in another analysis, 6 values from different years, were used so the uncertainty of the evapotranspiration values used in the study is estimated not to exceed $\pm 10\%$ of the actual value.

## Adaption of the experimental data to the balance equation

We rewrite the hydrological balance equation in the following convenient form:

$$N - E - A - \Delta M - \varepsilon = 0, \qquad (2)$$

where

$N$ = precipitation,
$E$ = evapotranspiration,
$A$ = surface run off,
$\Delta M$ = change in moisture content of the ground,
$\varepsilon$ = net subsurface outflow (positive) or inflow (negative).

In order to apply the water balance equation (2) to the catchment area, depicted in Fig. 2, it is first necessary to consider the applicability of all recordings, with the exception of surface run-off, to this catchment.

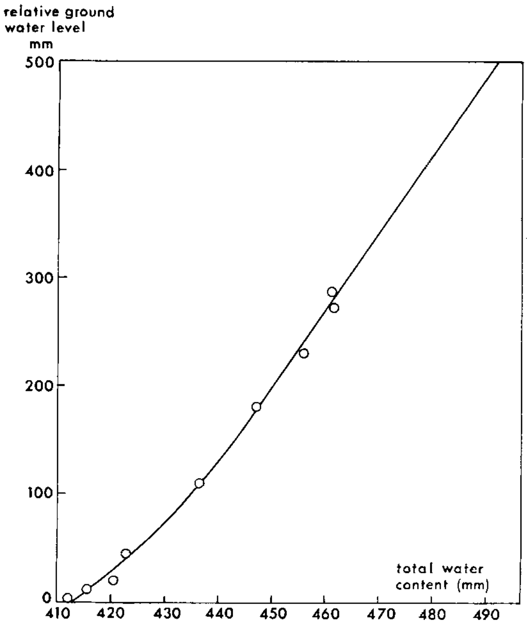


*Fig. 3.* Empirical relation between running 12-month means for total soil-water content (surface to 160 cm depth) and relative ground water level at Ugerup. The points on the graph are not entirely independent of each other, as they are derived from 21 successive monthly means. The curve is drawn to give the best fit in the points.

The catchment is situated in fairly wide, flat agricultural country. Ugerup experimental farm, where the evapotranspiration measurements, the soil moisture measurements and the precipitation measurements took place, is situated in the same area about two kilometers north–west of the centre of the catchment (cf. Fig. 2).

Elleson (1967) has analysed the detailed distribution of *precipitation* on the Kristianstad plane. From his maps it is clear that the precipitation over the catchment cannot significantly differ from that at Ugerup.

It can be shown (cf. Högström, 1968) that the data obtained with the "profile method" represents a mean of the *evapotranspiration* over an area in the order of square kilometers. This must also apply to the values obtained with the "modified Thorntwaite method", as this method is deduced empirically from the results obtained with the "profile method" (cf. p. 635). It can therefore be concluded that due to the uniform nature of the land type and the short distances involved, the data from Ugerup must be equally applicable to this catchment.

The *soil moisture measurements* at Ugerup are performed in sandy soil which, according to Nilsson (1966), covers most of the area (a small part is covered by till). The soil moisture measurements pertain to the uppermost 160 cm of the soil. Below this depth the changes in soil moisture are considered insignificant. Thus it seems reasonable to say that the measurements give the *total change in moisture content of the ground*, $\Delta M$, and that it is also representative for this particular catchment area. The soil moisture measurements at Ugerup, however, are available only for the period 23.7.1963–22.4.1965. To obtain values of $\Delta M$ for a more extended period the following analysis was performed:

In all, 53 soil moisture measurements were available for the 21-month period. For each month the mean value was found. These monthly soil water content means (down to a depth of 160 cm) varied between 370 mm and 520 mm. For the same months the mean ground water level was derived from the ground water station at Ugerup. A regression line with slope 0.15 and a correlation of 0.85 was obtained. In the analysis to follow running 12-month means have been used. Fig. 3 shows the relation obtained between total moisture content and relative ground water level derived on such a running 12-month basis. The rings, which represent the actual values, form a very consistent picture. It is, however, significant that the method used in deriving these values involves an interrelation between successive values, a process which tends to reduce the scatter considerably. Although the way of producing the diagram (Fig. 3) is open to question, is appears not unreasonable to use it as a tool for determining the change in moisture content from ground water level measurements during periods when soil moisture measurements are not available.

The *ground water* station at Ugerup was set up in July 1963, but, unfortunately, the extensive ground water net-work for the surrounding area ceased in December 1963. Three of the stations of that net-work, Gringelstad, Trädgårdslund and Gärds Köpinge, were selected as representative of the area under study. They are situated around this catchment at a distance of less than 3 km from its centre (cf. Fig. 1), and they are all in sandy soil. During the period

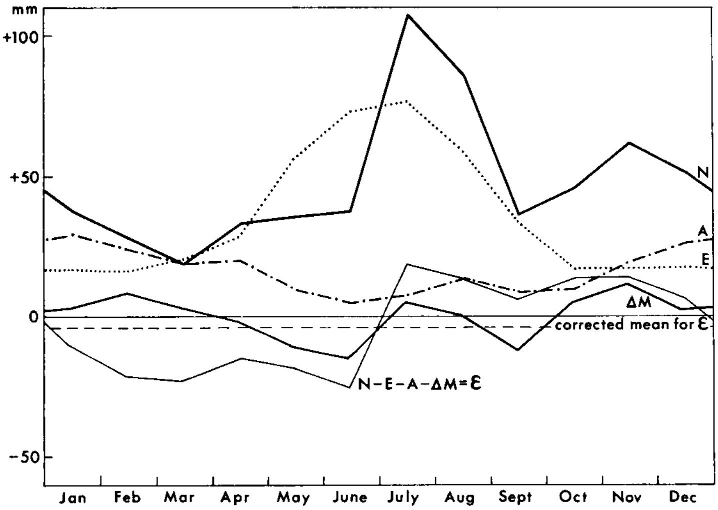


*Fig. 4.* Monthly means for the different components of the hydrological balance based on six-year data. Explanation of symbols: $N$, precipitation (thick full line); $A$, surface run-off (dash-dotted line); $E$, evapotranspiration (dotted line); $\Delta M$, change in total ground moisture content (medium thick full line); $\varepsilon$, subsurface inflow (negative sign) or outflow (positive sign) (thin line). "Corrected mean for $\varepsilon$" is the mean which is obtained if correction is made for the "precipitation gauge error".

when recordings overlap, the run of the Ugerup record can be compared to that of the mean of the other three stations. This comparison gives a satisfactory result, which means that the change in average ground water level at Gringelstad, Trädgårdslund and Gärds Köpinge can be used to determine the corresponding change in moisture content of the ground with the aid of Fig. 3.

Evidently, Ugerup experimental farm has a key position in this study: the evaporation measurements were performed there, and so were the soil moisture measurements and the precipitation measurement. It is the opinion of the authors that the data obtained at the Ugerup station are well representative of the catchment area. As mentioned earlier most of the catchment area is flat agricultural land, covered by sandy soil like the local Ugerup area. The station is situated 1 km outside the proper catchment area, it is true, but the land is uniform over extended areas.

From the above discussion, it is thus apparent that reasonable estimates are available for the components $N$, $E$, $A$ and $\Delta M$ of the balance equation (2) for this catchment. The remaining component $\varepsilon$ then comes out as a rest term.

## Results

For the period 1958–1963 all the components $N$, $E$, $A$ and $\Delta M$ are available at the same time. It is then possible to derive mean values for each of the components for the entire period. The following result is obtained (mm/year):

| Precipitation $N$ | Evapotranspiration $E$ | Run-off $A$ | $\Delta M$ | $\varepsilon$ |
|---|---|---|---|---|
| 575.7 | 430.2 | 191.3 | 0 | −45.8 |

It is a well known fact (see e.g. Andersson, 1964) that rain gauges systematically underestimate the actual precipitation by 5–10%, thus justifying an increase of 30–60 mm/year in this case. It is thus highly probable that the observed value −45.8 mm/year for $\varepsilon$ is entirely accounted for by the precipitation gauge effect. This means that *complete balance between N, E and A is obtained for the entire six-year period 1958–1963.*

The mean seasonal variation of the different components is displayed in Fig. 4, which is based on monthly means calculated from the 1958–1963 material. The *precipitation, N,* has a very pronounced maximum in July (107 mm) and a second high point in November (60 mm), and pronounced minima in March (20 mm) and September (36 mm). The *evapotranspiration*, $E$, describes a smooth curve with a maximum in July (76 mm) and a flat minimum in winter (*c*. 15 mm). The *run-off*, $A$, has a maximum in January (39 mm) and a minimum in July (5 mm). *The shape of the change in ground moisture content curve*, $\Delta M$, is somewhat confusing. Its integral, $M$, the total water *content* of the ground behaves as follows: from a maximum in the beginning of April, it decreases to its lowest in the beginning of July, shows a small increase as a result of the heavy rains in late summer, decreases during the early autumn until the beginning of October, whence it steadily increases again towards its maximum. The curve for "*the balance term*", $\varepsilon$, has a very pronounced shape. During February, March, April, May and June it remains on a constant level of about $-20$ mm. It then rises abruptly about 40 mm and remains on this higher level until November. During December and January the curve falls gradually. The amplitude of the curve (measured as the difference between its highest and lowest value) is about ten times greater than the "precipitation gauge correction". It is of interest that the seasonal variation in $\varepsilon$ that is revealed in the mean is also clearly discernible in the curves for the individual years. Fig. 4 shows clearly the improbability that systematic errors in the determination of any of the hydrological balance components can account for the seasonal variation in $\varepsilon$. The large June–July change in $\varepsilon$ can be taken as an example. The errors in $N$ and $A$ can obviously not be of the order of magnitude necessary to cause this change. If it is assumed that a fault lies in $\Delta M$, an error of 3 times the determined value is necessary to account for the observed change in $\varepsilon$. An error of this order seems highly improbable. A similar situation arises in the case of $E$. The June value of $E$ would then be 48 mm and the July value 94 mm, and there is no physical reason for this large difference between the values for these two months. The seasonal variation in $\varepsilon$ must therefore be accepted as a reality. Then during the first six months of the year a net inflow of ground water into the catchment area must take place and during the later half of the year there must be a corresponding net outflow. It is worth nothing in this connection that the first phase in the seasonal cycle of $\varepsilon$ is characterized by excessive water content of the ground (and maximum ground water level) and the second phase by deficit in water content (and minimum ground water level). It is also reasonable to assume that $\varepsilon$ for a given month is related to the precipitation. An analysis show this to be true for all months except January, February and March. The slope and the zero intersection, however, varies clearly and evenly from month to month. Thus precipitation values of 73 mm in July and 24 mm in October give $\varepsilon$ equal to zero. Precipitation in excess of these figures give positive value of $\varepsilon$.

For each of the components of the hydrological balance equation running 12-month means have been derived. They have been displayed in a time lapse diagram where a value representing the mean over the period from a time $t$ to $t+12$ months is plotted at $t+6$ months. In Fig. 5 the components $N$, $E$, $A$, $\Delta M$ and $\varepsilon$ are represented on the same scale but with different zero points. In addition, the diagram also gives the corresponding 12-month running mean curve for the average ground water level, $G$, for most of the period a mean for the stations Trädgårdslund, Gärds Köpinge and Gringelstad, reduced to a common datum, during 1964, for the station Ugerup only. It should be noted that the scale differs from that of the other curves of Fig. 5. The *precipitation* curve, $N$, of Fig. 5 has a pronounced component of several years' duration with large amplitude—the difference between the maximum and minimum value is approximately equal in magnitude to the mean value for he entire period. The *ground water level* curve, $G$, follows the long-term component of the precipitation, but with a lag of about 6 months. The dominating wave during the period studied approximates to a sine curve with a full period of about 8 years. The *run-off* curve, $A$, also follows the slow wave of the precipitation with a lag of two or three months, but here a pronounced hysteresis-effect is also discernible. The relation between precipitation and run-off can be studied in detail in Fig. 6. With precipitation as abscissa and run-off as ordinate, 12-month means have been plotted and successive points joined. The overall means for precipitation and run-off have been indicated by lines in the diagram. The hysteresis effect mentioned is clearly discernible in Fig. 6: when the precipi-

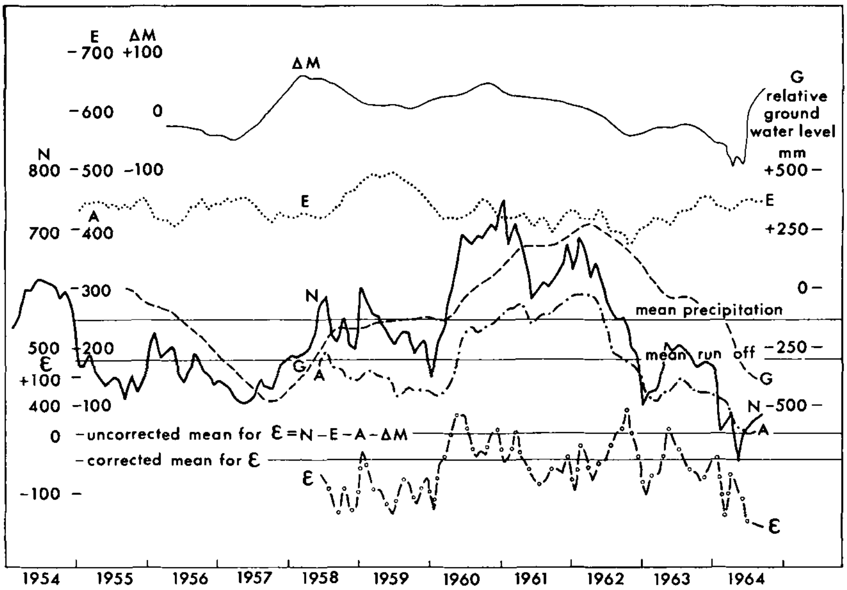


*Fig. 5.* Running 12-month means for the different components of the hydrological balance. A mean derived over a period of 12 months is plotted at the half-way point, i.e. mean of $t+12$ is plotted on $t+6$. Explanation of symbols: $\Delta M$, change in total ground water moisture content (thin line); $E$, evapotranspiration (dotted line); $N$, precipitation (thick full line); $G$, mean ground water level (broken line); $A$, surface run-off (dash-dotted line); $\varepsilon$, subsurface inflow (negative sign) or outflow (positive sign) (broken line with rings). The same scale (mm) is used for $\Delta M$, $E$, $N$, $A$ and $\varepsilon$, although with different zero points. The scale for $G$ (righ-hand side of the diagram) differs, however, from the other scales. "Corrected mean for $\varepsilon$" is that obtained when the "precipitation gauge error" is taken into account.

tation is rising, the run-off is generally appreciably smaller than when it is decreasing. Another noteworthy feature of Fig. 6 is the pronounced difference in the slope of the lines (that is of $dA/dN$) when the precipitation is above or below the mean. In the case of excessive precipitation $dA/dN$ is equal to 1.0, so that a given increase in precipitation gives an equal increase in run-off. When the precipitation is below normal, on the other hand, $dA/dN$ is only 0.4, so that only 40% of an increase in precipitation contributes to an increase in run-off.

To return to Fig. 5, *the change in ground moisture content curve*, $\Delta M$, is roughly in phase with the precipitation. The *evapotranspiration* curve, $E$, shows no correlation to precipitation. The amplitude of the curve is small—the difference between the largest and smallest 12-month mean is only about one quarter of the mean value for the whole period. The greatest evapotranspiration occurred during the year 1959, the summer of which was characterized by very high insolation. The curve for the *net subsurface outflow*, $\varepsilon$, follows the precipitation curve to some extent but the long-term wave in the precipitation curve is not reflected in the $\varepsilon$-curve. The amplitude of the $\varepsilon$-curve is of the same order of magnitude as the "precipitation gauge error", a correction for which is indicated in the figure.

## Conclusions

For a catchment area of about 2 sq. km, consisting of flat sandy, agricultural land in southern Sweden, long-term observations of the following hydrological parameters have been made: precipitation, evapotranspiration, surface run-off and soil water content. Under a period of six years complete balance is obtained between precipitation, evapotranspiration and surface run-off, if the "rain gauge error" is considered. On a seasonal basis, however, there is a pronounced and significant variation in both soil moisture content and subsurface outflow, particularly the latter. The subsurface outflow

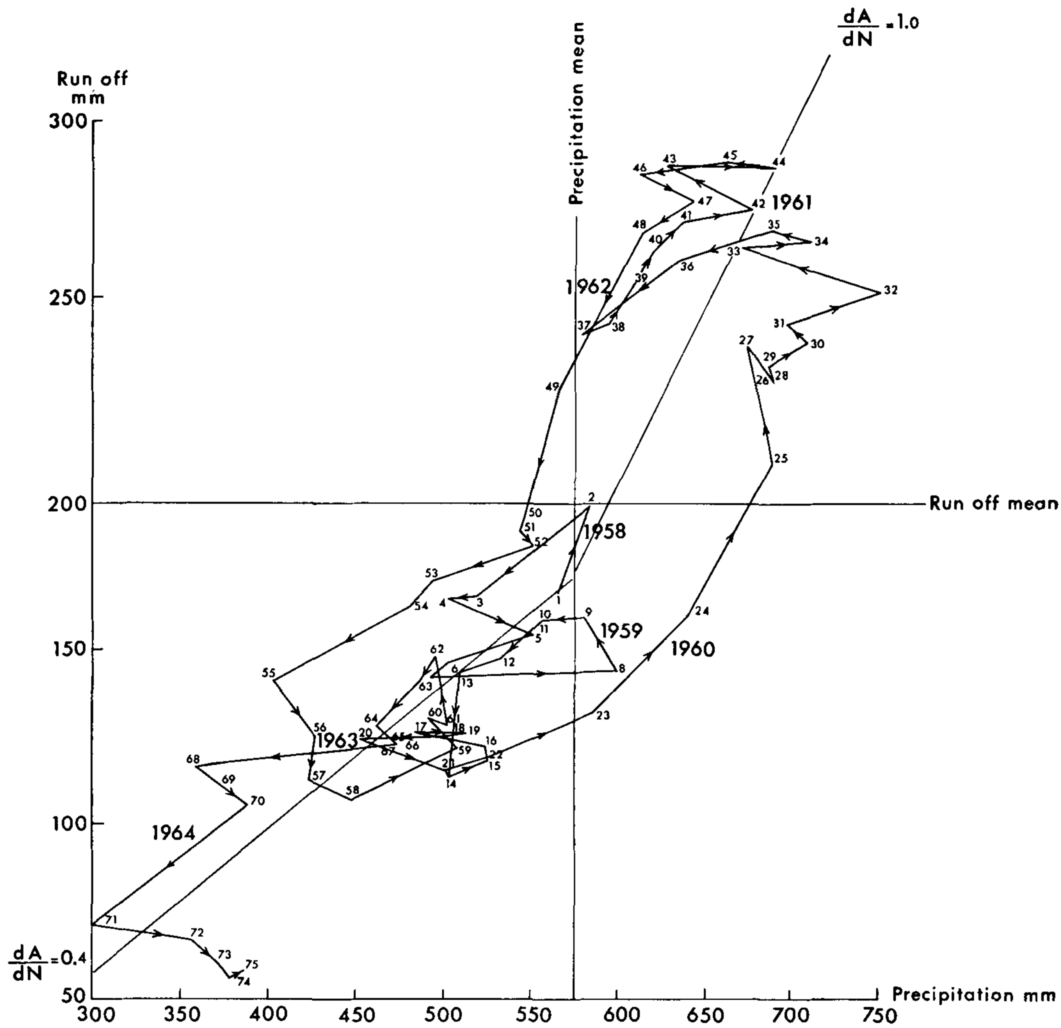


*Fig. 6.* The numbers indicate simultaneous running 12-month means of surface run-off and precipitation. The line joins successive values. Note the pronounced hysteresis effect and the difference in the slope ($dA/dN$) for precipitation values greater than and smaller than the normal.

is negative ( = flow *into* the area) and constant during the first six months of the year and positive ( = flow *out* of the area) and also constant during the latter half of the year. The magnitude of this flow, whether positive or negative, is about half the mean value of the precipitation. It has not been possible to investigate in any detail the mechanism of this phenomenon but there is no doubt it exists.

A presentation on *running 12-month basis* of all the hydrological components reveals: that there are long-term variations of large amplitude (an 8-year period in this case) in the precipitation which reflect distinctly in the run-off curve, the ground water level curve, and in the change of soil moisture content curve. This relation does not appear in the evapotranspiration curve or the subsurface outflow curve. In the latter curve, however, many of the short-term fluctuations of the precipitation curve are discernible. The ground water level curve lags about 6 months behind that of the precipitation, and the run-off curve 2 or 3 months. The evapotranspiration curve varies with less than one quarter of its mean value. In a plot of running 12-month means of run-off against precipitation a pronounced hysteresis effect is apparent. In addition, this diagram shows that if the total precipitation is greater than the normal, a further increase in precipitation leads to an equal increase in run-off. If the total precipitation is less than normal, on the other hand, a given increase in precipitation only gives rise to a 40% increase in run-off.

In a special study it is shown that the monthly mean soil moisture content is linearly related to the ground water level with a fairly high degree of significance.

The conclusions reached above are drawn from a study at one small catchment area, and no attempt is made here to judge their more general applications.

## Acknowledgements

The authors owe many thanks to all colleagues in the Hydrology of the Kristianstad region Cooperating Committee, especially to Prof. Yngve Gustafsson and civiling. Åke Fleetwood and fil. mag. Lars Nilsson for valuable help and cooperation.

## REFERENCES

Andersson, T. 1964. Further studies on the accuracy of rain measurements. *Arkiv för Geofysik 4*, 16.

Chardabellas, P. 1965. Evaluation du bilan de la régénération des eaux souterraines dans des bassins hydrogéologiques, à l'aide des cases lysimétriques situées dans des champs représentatifs des régions alimentaires. *Ass. Int. d'Hydrol. Sci.*, Publ. No. 66, Vol. 2, pp. 399–408.

Ellesson, J. 1967. Nederbörden på Kristianstadsslätten. Lunds Universitets Naturgeografiska Institution. Rapporter och notiser nr 1, Lund.

Ellesson, J. & Persson, R. 1961. Skyfallsartade regn över Skåne 1959–1960. *Svensk Geografisk Årsbok 37*. (With an English summary.)

Högström, U. 1967*a*. A new sensitive eddy flux instrumentation. *Tellus 19: 2*, 230.

Högström, U. 1967*b*. Turbulent water vapor transfer at different stability conditions. *The Physics of Fluids* (vol. 10, supplement).

Högström, U. 1968. Studies of the natural evaporation and energy balance. *Tellus 20: 1*, 65.

Larsson, I. 1962. Studies on ground water in the quaternary deposits of the Kristianstad plain. *Lunds Studies in Geography*, Ser. A, No. 19.

Larsson, I. & Fleetwood, Å. 1967. Relations between precipitation, soil moisture content and ground water storage in sandy soil in Southern Sweden. (To be published.)

Németh, E. 1965. Etude sur modèle réduit du ruissellement accomplissant dans un bassin versant. *Ass. Int. d'Hydrol. Sci.*, Publ. No. 66, Vol. 1, pp. 122–130.

Nilsson, K. 1966. Geological data from the Kristianstad plain, southern Sweden. *Sveriges Geol. Unders.*, Stockholm, Ser. C, No. 205.

Roche, M. 1965. Point de vue matricial sur un opérateur linéaire de transformations pluies-débits. *Ass. Int. d'Hydrol. Sci.*, Publ. No. 66, Vol. 1, pp. 234–246.

Supek, J. 1965. Experimental research on evapotranspiration using compensation lysimeters. *Ass. Int. d'Hydrol. Sci.*, Publ. No. 66, Vol. 2, pp. 550–555.

Todd, D. K. 1959. *Ground Water Hydrology*. New York and London.

Ubell, K. 1965. Investigations into ground water balance in experimental areas. *Ass. Int. d'Hydrol. Sci.*, Publ. No. 66, Vol. 2, pp. 388–398.

Weijman-Hane, G. 1961. *Undersökning av Kristianstadsslättens hydrologi*. Kungl. Väg- och vattenbyggn.styr. publ.serie, Stockholm Pu 8.1. (With an English summary.)

## ИЗУЧЕНИЕ ВОДНОГО БАЛАНСА НЕБОЛЬШОЙ ОБЛАСТИ ЕСТЕСТВЕННОГО ВОДОСБОРА В ЮЖНОЙ ШВЕЦИИ

Проведено изучение водного баланса небольшой области естественного водосбора в плоской песчаной сельскохозяйственной местности в Южной Швеции. Из измерений, проводиных и течение, по крайней мере, 6 лет, получены также одновременные данные по осадкам, эвапотранспирации, поверхностному стоку вод и содержанию влаги в почве. Получен полный баланс между осадками, эвапотранспирацией и поверхностным стоком для периода в 6 лет в целом.

Результаты указывают на существование значительного и хорошо выраженного подповерхностного притока и оттока вод, вызванного сезонными изменениями. Будучи представленными в виде скользящих 12-месячных средних, кривые поверхностного стока и уровня подземных вод проявляют высокую степень корреляции с долговременными изменениями осадков. Найдено, что подземные воды имеют запаздывание в 6 месяцев по сравнению с осадками, а сток — запаздывание в 2–3 месяца. Скользящее 12-месячное среднее значение для эвапотраспирации оказывается лишь слабо меняющимся и, повидимому, не-связанным с осадками.