551.482.215.3

# ON THE EFFECTS OF VARIOUS FACTORS ON THE DISCHARGE OF THE VANTAA RIVER REGION

by

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Abstract

Various factors which caused a severe flood in September 1962 have been studied and their effects on this discussed. In order to make short-period forecasts possible a unit hydrograph has been determined.

## 1. *Introduction*

The purpose of this paper is to study the various factors which caused a severe flood in the Vantaa river region in southern Finland during a storm period in September 1962. The data available were meteorological observations made in the area and in its neighbourhood, besides information on the daily discharges of the Vantaa river. With the aid of these fundamental data computations have been performed as well as comparisons between the various factors.

The area dealt with here is situated in southern Finland. The river flows in a practically due north-south direction and discharges into the Gulf of Finland close by Helsinki. The shape and situation of the basin are seen in Fig. 1. The area of the whole basin is 1680 km². This paper deals with a part of it, the area of which is 1235 km². The total lake area is only 2.8% of this. The terrain is rather flat; differences in height are not very great. About half of the area is cultivated, the other half consisting of forest and marsh. The soil consists of sediments, mostly clay, layered on base rock, the layer being only a few meters thick, leaving the base rock visible in many places. The river, about 90 km long, flows in a low-lying valley, the soil of which is clay. The flow is even; the difference in height, about 85 m, between the sea and the highest lakes is due to short rapids on the way.

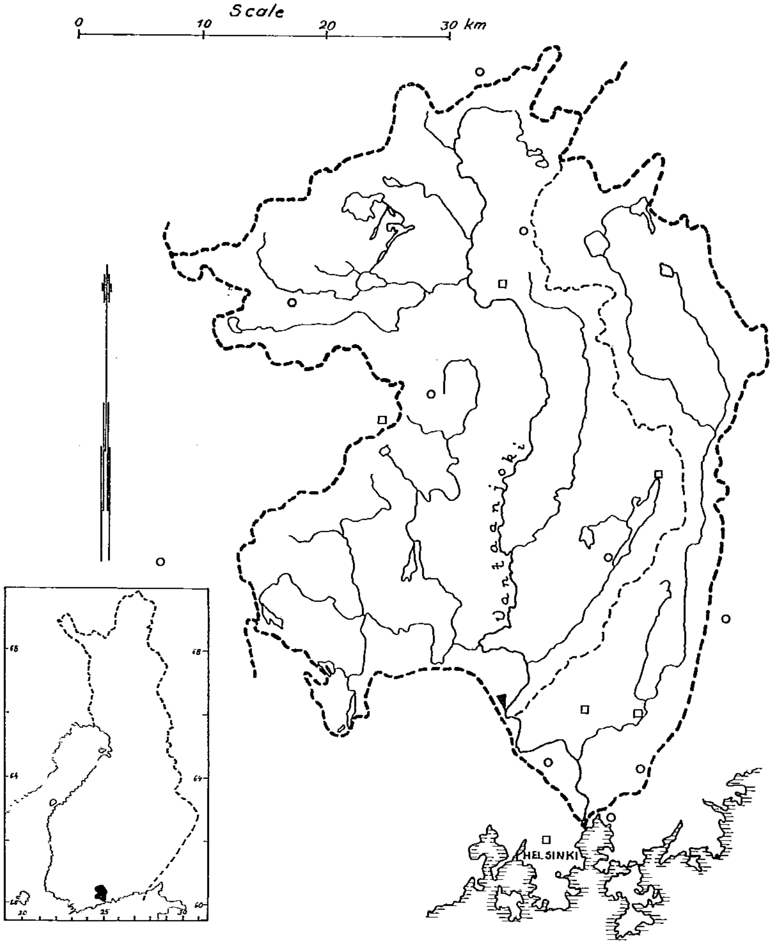


Fig. 1. The Vantaa river catchment area

Symbols

○ rain gauge

□ climatological observation station

▼ water level gauge and place of discharge measurement

--- watersheds

Since water level observations in the present measuring place were started as late as 1959, no long homogeneous series of observations is available. The number of discharge measurements is 25. The average deviation of the results of measurements from the rating curve is less than 0.4 $m^3$/sec. Daily discharges have been computed from water level observations with the aid of a rating curve. Water level readings once a day seem to be sufficient for the purpose, for, on account of the fairly large size of the area, the variations of the discharge are so slow that they appear clearly even in these observations.

## 2. *Methods of computation*

Precipitation data of the area and its neighbourhood have been obtained from 18 stations. Observations have been carried out once a day. The data have been entered on daily precipitation charts, and isohyets have been drawn. The areal precipitation value has been computed from these charts, using a planimeter for determining the precipitation value of the areas between the isohyets and then calculating the weighted mean. For checking the result another method has been used, too. The precipitation of 20 days at each station was summed up and put down on the map. The areal value of these sums has been computed in the same way as above. Comparison between the results showed a deviation of 2.5%, indicating that, with so dense a station network, the personal error was fairly small.

Evaporation has been calculated from the data of the climatic observation stations in the area (see Fig. 1). The computations are based on the Penman method [1]. In the computation work wind velocity measured at 2 m height is needed. As the daily wind observations are made considerably higher up, anemometer readings have been corrected by a logarithmic velocity distribution [2]*.

* Correction equation for wind velocities

$$u_2 = u_N \frac{\log \frac{2}{z_0}}{\log \frac{N}{z_0}}$$

where $N$ = anemometer height from ground level
$z_0$ = roughness parameter
$u$ = wind velocity

Storage was computed after the other factors had become known. From the data available, it was not possible to construct a diagram for determining storage as a function of rainfall and temperature.

For being able to utilize the discharge in the computation work, the total flow has first to be separated into surface and base flow. For further clarification some previous isolated storms and the discharges caused by them were studied. For this purpose storms followed by dry periods were chosen. When presented on semilogarithmic paper the discharge of these periods form recession curves consisting of two rectilinear parts of different slope. In Fig. 2 two typical curves are seen, both having the same character. The greater deviation of the observation points from the straight line in the second case is due to individual errors in gauge reading. Similar curves have been obtained elsewhere, too. The reasons previously suggested to account for the formation of a broken line do not apply in this case, however. It has been suggested [3] that the gently sloping end may be due to minor rains. In this case, however, the periods were so chosen that the areal value of the daily precipitation

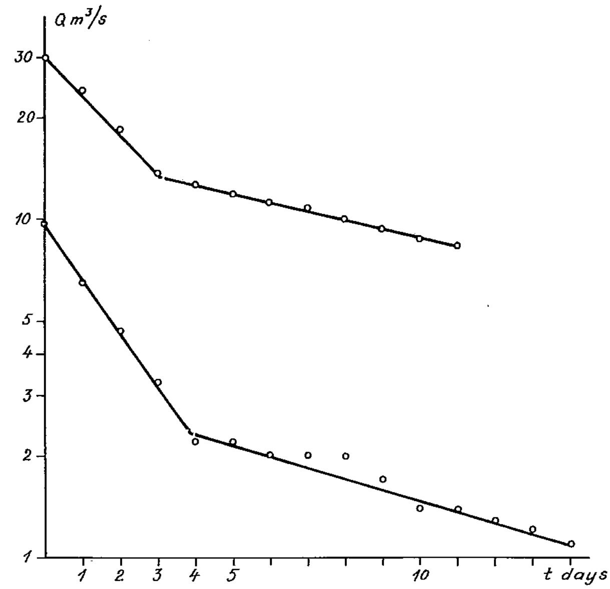


Fig. 2. Two typical depletion curves according to daily discharges presented on a semilogarithmic scale.

never exceeded 1 mm; hence, as the vegetation utilizes all such precipitation, there could be no runoff. If, however, the explanation of the broken line is assumed to be that the former part is caused by the sum of surface flow and base flow, and the latter part by base flow alone,

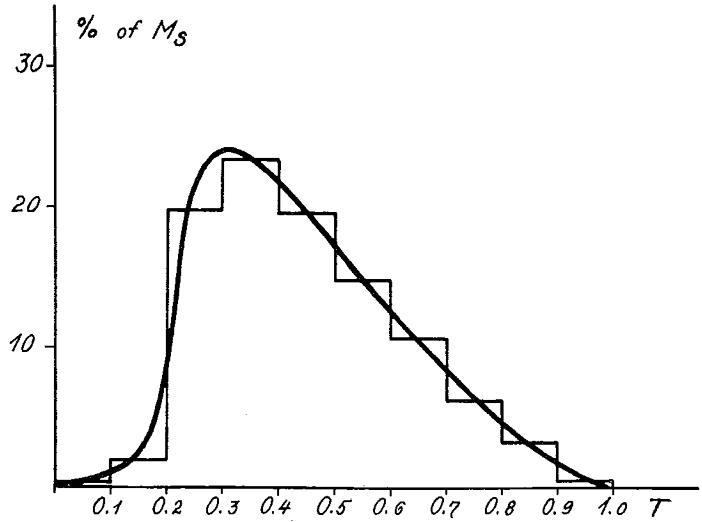


Fig. 3. Unit hydrograph for the Vantaa river, the period of surface flow (in tenths) as a variable.

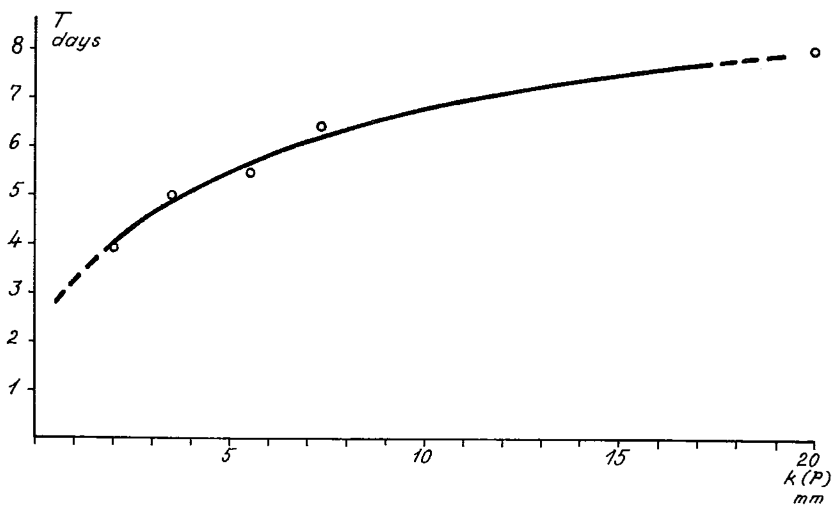


Fig. 4. Dependence of period $T$ on coefficient $k(P)$.

these two slopes are understandable. On this assumption it was possible to estimate the exact time of termination of the surface flow. This has been used in determining the duration of the surface flow as a function of the total amount of stream flow.

In the separation of the surface flow and base flow from the total flow, it was assumed that when ground reservoirs are filling, the flow caused by these increases linearly as a function of time. When the beginning and end of the surface flow can be determined as shown above, it is possible to compare different slopes of base flow increase during different rain periods. This comparison showed the slope to remain almost constant during the period between August and October. Making use of this knowledge it was possible to separate base flow and surface flow from the total flow during the rainy period that lasted 15 days in September 1962.

In order to discover the relation between discharge and the duration of flow, a unit hydrograph was determined, using some previous isolated storms. In this determination discharge $Q(t)$ is divided into two parts:

$$Q(t) = k(P)\, u(t)$$

where $k(P)$ = a coefficient depending on the runoff caused by precipitation
$u(t)$ = unit hydrograph

When, using this equation, account is taken of the fact that surface flow does not always last the same length of time, the duration is seen to vary according to the amount of surface flow. In order to get an unambiguous unit hydrograph, a tenth of the duration $T$ of the surface flow was used as a unit of time. Hence, $u(0) = u(T) = 0$, $u(t) > 0$ when $0 < t < T$. In Fig. 3 this function for the Vantaa river is seen, as well as the histogram used for numerical calculations. Further, the dependence of $T$ on the precipitation $P$ has been determined using the coefficient $k(P)$ as the variable. This is presented in Fig. 4. Using these functions the total volume of the surface runoff $M_s$ can be expressed by the equation

$$M_s = \int_0^{T(P)} k(P) u(t) dt$$

Insofar as the form of the unit hydrograph does not vary on account of the amount of precipitation, the determination of the volume of surface flow is reliable for periods shorter than $T$, too. When the base flow, assumed to increase linearly up to point $T$ and then to deplete exponentially, is added to this, the total flow at any moment of the period can be determined.

## 3. *The flood of September 1962*

By applying the methods described above to the discharge calculations of the period 6—20. 9. 1962, the effect of the period $T$, the duration of the surface flow, could be clearly seen. When the discharge was calculated in such a way that the duration of the surface flow was always the same ($T$ = constant) the result was a maximum flow which has hardly ever been exceeded here. This first approximation is seen in Fig. 5, curve $b$. The discharges observed are presented by curve $a$ in the same figure. When the unit hydrograph was used in such a way that the duration $T$ varied according to function in Fig. 4, the result was quite close to the actual conditions, as is seen in Fig. 5, curve $c$. The analogy

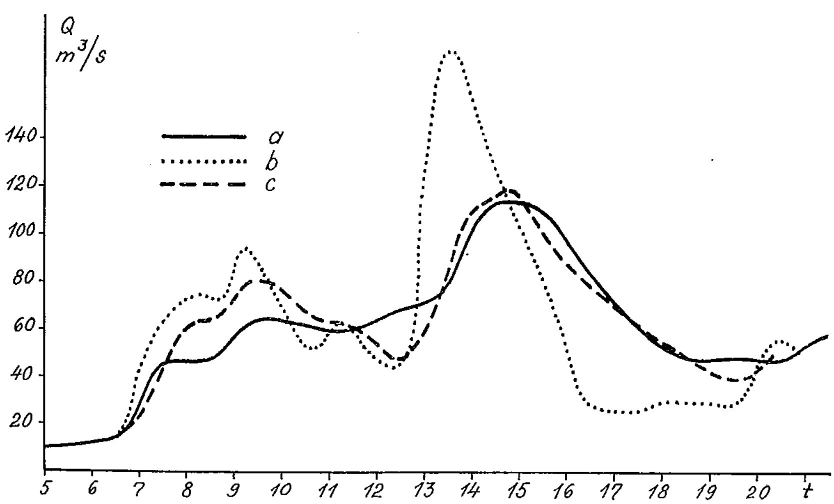


Fig. 5. Discharge from 5.9 to 20.9 1962 as a function of time.

curve $a$ = observed discharge

$b$ = discharge computed using unit hydrograph when $T$ is assumed to be constant

$c$ = computed discharge when $T$ varies according to function in Fig. 4.

obtained in curve *c* is fairly good, especially in view of the scanty data available. It will be possible to improve the result when more data on isolated storms are available.

With the aid of the computations made it is possible to compare the effects of various factors on the flood of September 1962. The most notable among them is the precipitation. During the period 1—20. 9. 1962 it amounted to 21% of the annual mean precipitation. As, moreover, the rainy period had started in the beginning of August, the capacity of the soil to store water was comparatively low. This is clearly seen in the table below. If the amount of precipitation during the period 1—20. 9. 1962 is taken as 100%, the following table is obtained:

| | Precipit. | Evaporat. | Discharge | | | Storage |
|---|---|---|---|---|---|---|
| | | | surface | base | total | |
| % | 100 | 14.7 | 38.2 | 16.4 | 54.6 | 30.7 |
| mm | 133.7 | 19.6 | 51.0 | 22.0 | 73.0 | 41.1 |

The amount of evaporation is quite normal, but the amount of water carried away by the river was at times greater than the capacity of the river, with resultant flooding in the low-lying valley. The fact that the soil was mostly clay having but a small coefficient of permeability, further added to the damage in the valleys.

The frequency of floods of this kind cannot be determined because of the short period of observation, but if these data are compared with the corresponding data from Lake Päijänne [4: Tabelle 2], a clear deviation from normal conditions can be seen. Although the catchment areas are not quite comparable, the latter being much larger, the comparison shows the extreme rarity of this kind of condition in the autumn season.

## 4. *Conclusions*

Some remarks on the computation methods can be made when the results are compared with the observations. The determination of areal values of precipitation is accurate enough as a basis for calculations. The differences in the values obtained in two ways are so small that the density of the station network can be considered sufficient. The calculated amounts of evaporation agree well with those observed. Some simplifying assumptions were made in the use of the unit hydrograph. On the basis of the data used it is difficult to say whether the form of the curve remains similar when the amount of precipitation varies, but the result indicates that it is possible to determine runoff from a single curve if the variation in the duration of surface flow is borne in mind. On account of the scanty data it was not possible to construct a diagram showing discharge as a function of precipitation and temperature. Where this is possible, the method can be used for making short-period forecasts even for extensive areas.

*Acknowledgements.* This work has been suggested and carried out under the guidance of Dr. H. Simojoki, Director of the Hydrological Office, to whom I am deeply indebted. Further, I am grateful to Mrs. Ethel Yli-Pohja for correcting the language.

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