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# SMALL WATER BEARING VALUES AND THEIR PERIODS IN THE RIVERS OF THE CZECH SOCIALIST REPUBLIC

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## SUMMARY

For the upper limit of small diurnal and monthly water bearing values the author used the discharge rate corespondly to 36 % of the long-term average discharge. This made it possible to recognice temporal as well as regional deviations of their average duration and the frequencies and probabilities of the occurrence of their periods of different lengths. They are conditioned by a different balance of water circulation in the river basins in which important element are characteristics of the basin determining the formation and exhaustion of ground water reserves.

## INTRODUCTION

For the purpose of temporal delimitation of small water bearing values discharges exceeded in average by 355 days in a year were used in our country until lately. But it appeared that this limit ceased to be suitable not only for water supply planning focussed on the utilization of rivers as water resources and economically advantageous ways of liquidation of waste but even for the study of the regime of small water bearing values. Their main disadvantage as a criterion of small discharges was that the substance of this discharge contradicted the different natural conditions of the Czech rivers affecting the magnitude and frequency of the small water bearing values. If the discharges mentioned above are used, the frequency of occurrence and the average duration of the small water bearing values would be absolutely equal not only in our rivers but in general in all streams of the world which contradicts the different conditions for river feeding and, accordingly, even for the runoff from the river basin.

The first task of research was to find a more suitable limit for the analysis of the small water bearing values of rivers be it judged according to the values of daily or monthly discharges. The task was tackled on the rivers of the Morava River basin and the results were published (Netopil 1976). In the publication the analysis was described of the frequency of occurrence and the distribution in time of small monthly water bearing values for which the monthly run-off corresponding to 3 % of the annual average run-off appeared to be suitable. It corresponds in substance to the discharge attaining 36 % of the long-term average discharge (normal). It has the following advantages:

1. It comports with the character of the small water bearing of rivers for it is mostly lower than the average of the series of discharges of the months of smallest water bearing values in the individual years.

2. It allows to find out the agreement or disagreement in the distribution in time of the periods of small water bearing values and with rivers with analogical natural and geological conditions in the river basin affecting the run-off and even the agreement or similarity in the duration of those periods.

3. In the case of rivers with diverse natural and geological conditions in the river basin it gives a true picture of the deviations caused by them both in the average duration and in the duration of the individual periods of the small water bearing values.

4. In rivers with very steady run-offs the monthly discharges do not fall to the limit of small water bearing values at all or only exceptionelly. This is in line with the properties of these streams in which even minimum discharges need not have the character of a small water bearing.

5. The possibility of a cartographical representation of the diverse features of the regime of small water bearing values of rivers of a larger territorial unit allows to reason about the relationships between the small run-off and the individual elements of the natural milieu.

6. An establishment of synchronous long periods of small water bearing values on a larger territory makes possible a judgement of the exceptionality of their occurrence according to precipitation conditions with respect to the conditions of replenishment and take-off of groundwater.

7. The chosen limit of small monthly water bearing values is adwantageous even for the determination of the effect of hydraulic structures (reservoirs) and its degree on the discharge regime.

8. The chosen discharge approaches the value of the average share of groundwater in river feeding attaining 30 up to 40 % of the average all-year run-off. In the periods of small water bearing values the rivers are fed exclusively from groundwater resources in the river basin.

9. It is in a certain sense a universal limit of small water bearing values for all rivers though very different as to their average water bearing. It can, accordingly, be of general validity. Its utilization, suitable even for analyses of small daily discharges, provides results widening the knowledge concerning small water bearing values of our rivers as well as the causes of their occurrence.

## Average Duration and Distribution in Time of Small Monthly Water Bearing Values

The application of the limit mentioned of small water bearing values has allowed to get a completely new idea of the considerable differences both in average duration and in the distribution in time of the small water bearing values, of their regional deviations and, accordingly, even to determinate the territorial units, in which the rivers are endangered by a distinct fall of discharges to a diverse extent and in a diverse time. The 40 years sequences of monthly discharges from 133 hydrometric stations and from 26 stations with at least 20 years sequences are certainly sufficient for objective conclusions both as to the regime of small water bearing values in our streams and as to possible effects of some properties of the natural milieu on the regime.

An analysis of the occurrence of small monthly water bearing values has shown that their average duration changes in the rivers of the Czech Socialist Republic from more than 4 months to less than 1 month with cases when the monthly discharges did not fall to the limit of the small water bearing values in the whole period at all or only sporadically. A sporadic or zero occurrence was established in rivers with basins on permeable sandstones of the Czech Plateau and in rivers below larger reservoirs with power generators and protective function. The first case is in line with the high natural equalizing ability of run-off in a permeable rock milieu in which groundwater resources originate, replenish and are equally taken-off appearing as an important resource of river feeding. The dissected relief of the sandstone plateaus contributes to a more intense exchange of groundwater resources. The fact that in the same Czech Plateau where outcrops of impermeable rocks occur (clays, claystones) the average duration of small water bearing values attains 4,7 months proves that the degree of permeability of the rock milieu is a first-rate factor for the frequency of occurrence of small water bearing values. In the second case water reserves in water basins controlled from the point of view of water supply are concerned the utilization of which according to plan causes considerable oscillations in discharge in the course of the day which do not manifest themselves in monthly run-off.

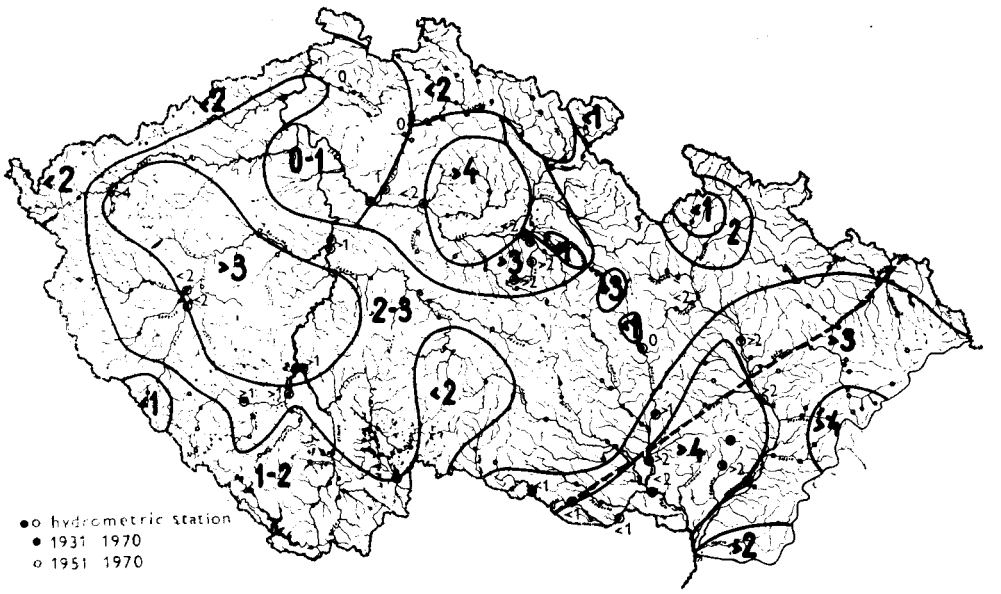



*Fig. 1.* Average duration of small monthly water bearing of streams (1, 2, 3, 4 = average duration expressed in months)

In the other rivers the average duration od small monthly water bearing values decreases with increasing altitude of the river basin above mean sea level sinking in the highest mountain chains below 1 month. But this conclusion is valid only for the rivers of the territory of the Czech Massif. In the Carpathian part of the Morava and Odra River basins the changes mentioned were not confirmed. Even this second law governing the spatial deviations of the average duration of small monthly water

bearing values is connected to a certain extent with the rate of the run-off of groundwater and its share in river feeding. In mountainous regions built of relatively less permeable rocks i.c. crystalline or diagenetically strongly consolidated sedimentary rocks numerous authors established a considerable underground run-off exceeding distinctly the same run-off in plains. This apparent paradox can be explained logically. In contradistinction to the flat territories of plains where important static groundwater reserves may occur but only small dynamic reserves decreasing and replenished in the course of the year only unsubstantially along the streams the considerable declivity of the terrain of the mountains makes possible a quicker running of groundwater in the zone of subsurface disjoining of rocks including the stony regolith and debris. Among the total groundwater reserves prevail dynamic ones with a yearly intense exchange in the whole space of fissure and percolation

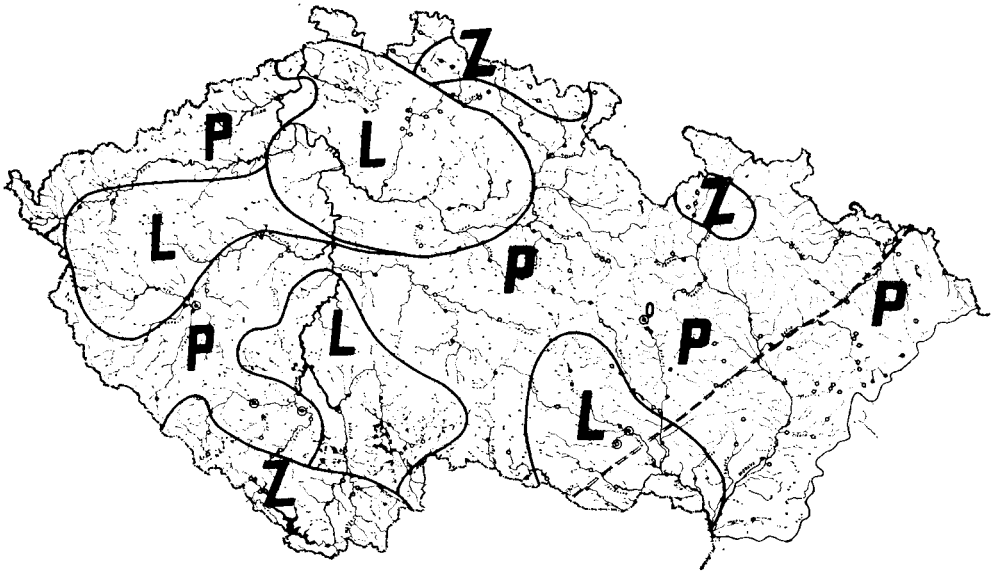



*Fig. 2.* Most frequent occurrence of small monthly water bearing of rivers in seasons (Z = Winter, L = Summer, P = Autumn)

water bearing bed. The mountain river basins are, besides, in comparison with lowland ones, climatically more favourable (higher precipitation more equally spread during the year, lower evapotranspiration) for the formation of replenishing grounwater reserves. The high values of subsurface run-off in the mountains were proved not only by hydrological but even by hydrogeological methods of the determination of subsurface run-off (Krásný and Kněžek 1977, Daňková et al. 1977, Brázda 1970) and they are mentioned even in publications abroad (e.g. Karrenberg and Weyer 1970). In the Carpathian part of the Czech Socialist Republic built of flysch rocks are the conditions for groundwater occurrence less favourable and the whole region is poor in groundwater (Hynie 1961). This is why in this rock type and the overlying weathered material and, in addition, in the mountain relief, thers are no favourable conditions for a more uniform feeding of rivers not even

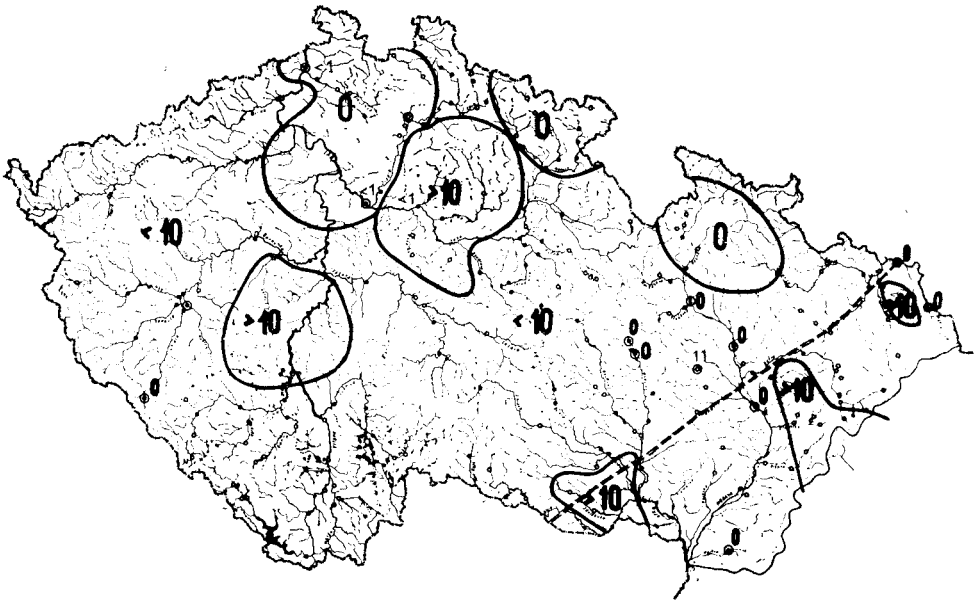
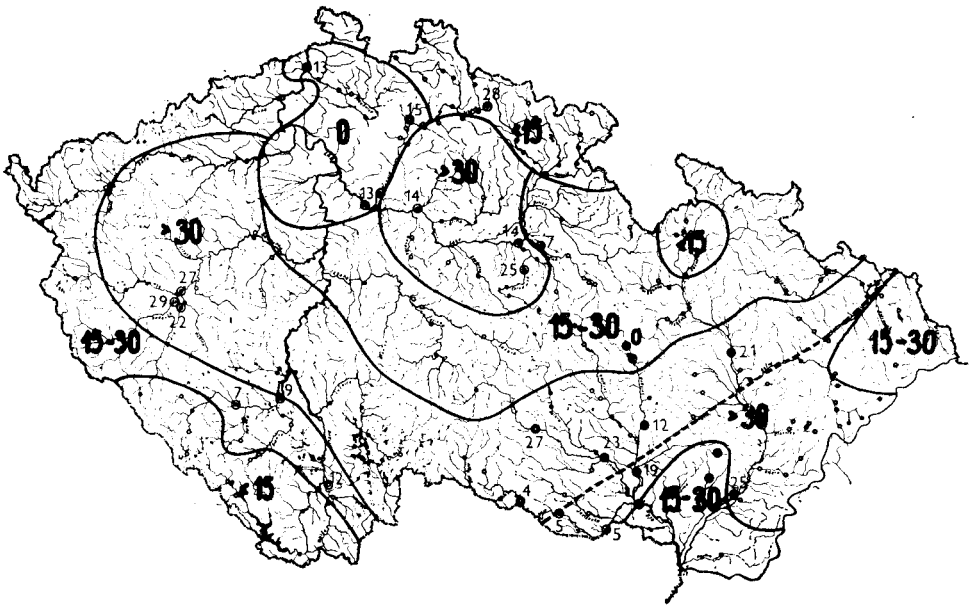



*Fig. 3*

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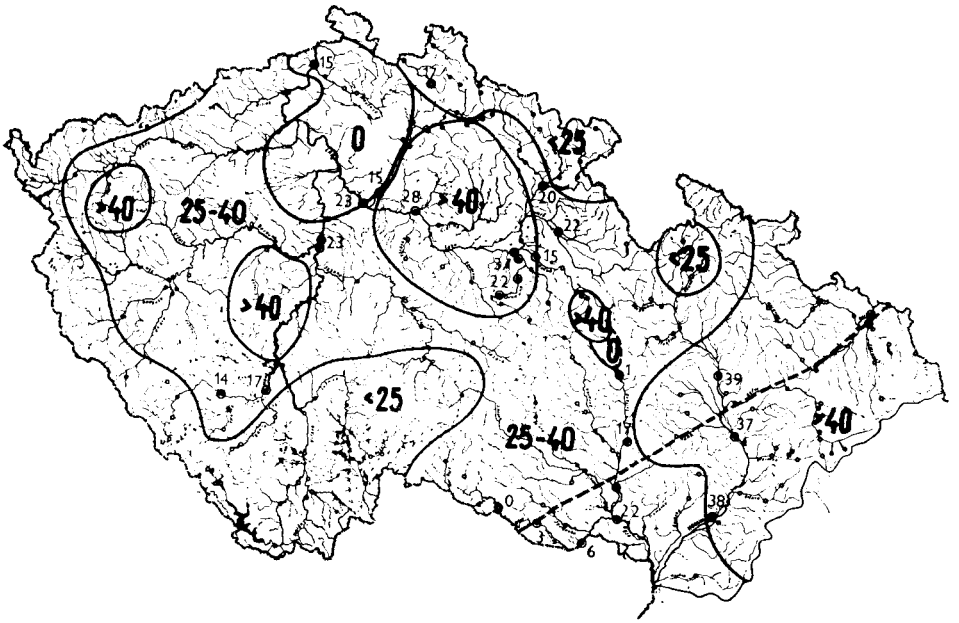


*Fig. 5*

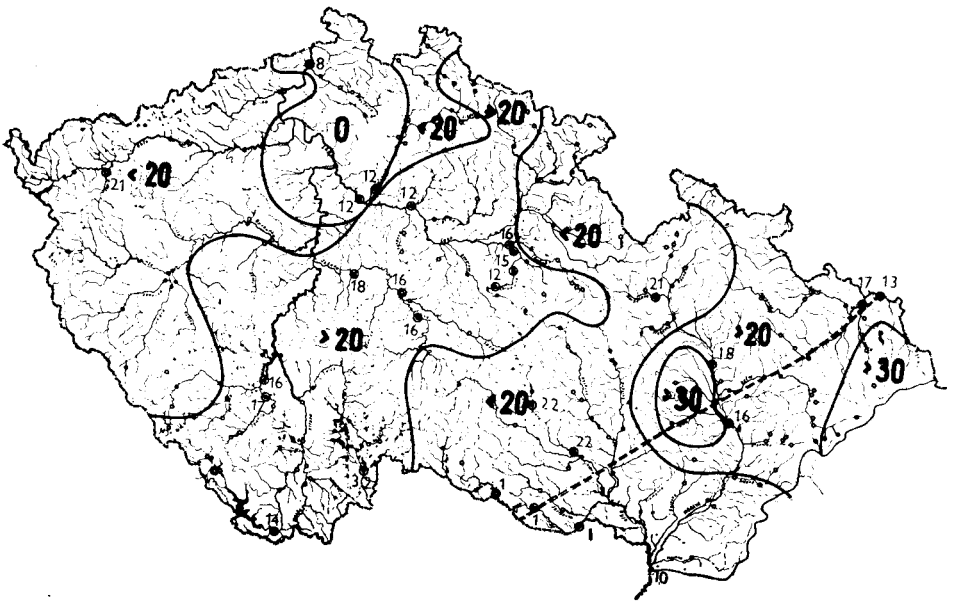


*Fig. 6*

*Fig. 3—6.* Probable occurrence (percentage) of small monthly water bearing values in seasons (3 — in spring, 4 — in summer, 5 — in autumn, 6 — in winter)

in climatically more favourable terrain (river basin in the summit zone of mountain ridges).

The pointed out properties of the natural milieu of the river basins manifest themselves even in the deviations of the distribution of the small monthly water bearing values in the course of the year. The following laws follow from their analysis:

1. In spring, the small monthly water bearing values are most seldom or were not established at all.

2. On the territory of the Czech Massif, the most frequent occurrence of small water bearing values is shifted with increasing altitude a.m.s.l. of the river basin from summer to winter the relatively most frequent occurrence in the winter period being linked up with the uppermost parts of the mountain river basins.

3. Their occurrence in the Carpathian part of the Czech Socialist Republic is in winter relatively less frequent than in autumn and summer but attains absolutely more than 30 % of its duration similarly as in the rivers of the Czech Massif.

Among the causes of regional deviations in the most frequent occurrence of small monthly water bearing values in the individual seasons belongs besides the rock properties even the different balance of water circulation in the individual seasons. In the balance it is necessary to take account not only of consumption by evapotranspiration but even of the replenishment of the soil moisture. In lower situated river basins the maximum part of winter precipitation is consumed for restoration of their reserves so that the increase of groundwater quantity is unsubstantial. In the mountains the greatest part of winter precipitation accumulates in the snow cover so that there the increase of the groundwater quantity is interrupted.

Following knowledge follows from the analysis of the regional deviations in the frequency of occurrence of small monthly water bearing values:

1. In spite of the differences in the relative duration of small water bearing values in winter their total occurrence in this season is similar in lowland as well as mountain rivers. The small water bearing values can last the whole winter once in three up to five years in average.

2. In spring, the frequency and even probability of the occurrence of small water bearing values decreases with the altitude a.m.s.l. of the river basins and in rivers flowing from the highest mountains their occurrence was established either not at all or isolatedly in March which has in such places rather properties of a winter month.

3. In summer, great regional deviations in the frequency of occurrence of small water bearing values were established. Rare cases show that they need not occur at all, in other rivers they can last in average every second year the whole summer. The frequency of their occurrence decreases with the increasing altitude a.m.s.l. But this rule is not valid in the Carpathian part of the Morava and Odra river basins.

4. In autumn, the regional deviations in the frequency of occurrence of small water bearing values decrease but the relationship between the frequency of their occurrence and the altitude a.m.s.l. of the river basin keeps preserved.

## Average Duration and Distribution in Time of Small Daily Water Bearing Values

A small daily water bearing values in considered a daily discharge equalling or lower than 36 % of the long-lasting mean discharge derived from the period

between 1931 and 1970. To determine the regional deviations in the average duration and distribution in time of small daily water bearing values the same criterion was used, therefore, as in the case of small monthly water bearing values of rivers. Their occurrence was studied between 1946 and 1970 by the students M. Kohút in the Labe River basin as far as the confluence with the Vltava River, M. Koželuh in the Vltava River basin and J. Procházka in the Morava River basin on the territory of the Czech Socialist Republik.

The average duration of the small daily water bearing values of rivers expressing the frequency of their occurrence ranged within a considerably wide space. In the rivers with basins on the sandstones of the Czech Plateau the daily discharges on the margin of small water bearing values did either not dropped at all or dropped only sporadically in individual days or only in several successive days. In the rivers with their basins on permeable rocks of other structures their average duration has not exceeded 30 days. A similar situation was even with the rivers below water reservoirs whose improving effect can be observed on a distinct decrease on the average duration of small water bearing values or the limitation of their occurrence to isolated cases even at a distance of tens of kilometres below the dams. In the mountain rivers of the Czech Massif the average duration of small water bearing values attains as many as 30 up to 90 days in dependence on altitude above sea level and the natural properties of the river basin affecting the filling up and drawing of groundwater reserves. These are improving with the altitude above sea level. In the rivers of highland and hilly lands it increases to 90 up to 150 days. In average, the longest durations of small water bearing values that is of even more than 190 days in a year occur in rivers with a plain catchment area on impermeable rocks but even in the mountain relief of the Western Carpathians with prevailing impermeable flysch rocks. From this knowledge it follows that the laws governing the regional deviations in the frequency of occurrence of small daily water bearing values are analogous to those of small monthly water bearing values. The duration of small daily water bearing values was in most of the 115 hydrometric stations in the period 1946—1970 longer than that of small monthly water bearing values transferred to the number of days (1 month = 30 days). This is obvious even from the arithmetical means of their progressions (average 97 and 75 days). But, in spite of the different deviations, the relation between the average duration of both these quantities is very close and highly significant which was shown by the correlation coefficient $r = 0{,}89$ and the result of $t$-distribution ($t$-test). The critical value $t = 21{,}15$ surpasses considerably the tabulated value for the degree of freedom of $v = n - 2$ and the level of significance of 0.05 (1.98) and 0.01 (2.61). The correlative association can be replaced by the functional association expressed by the straight line equation whose form for small daily water bearing values $d$ is as follows:

$$d = \frac{30\, m}{0.78}$$

and for small monthly water bearing values $m$

$$m = \frac{0.78\, d}{30}$$

The high degree of correlative association is another proof that the frequency of occurrence of small monthly water bearing values gives a sufficiently true picture of the characteristic features of small water bearing of streams.

The distribution of small daily water bearing values in a mediocre year according to their frequencies in the seasons conforms in substance with that of small monthly water bearing values.

## Periods of Small Monthly Water Bearing Values

By means of an analysis of the maximum duration and frequencies of the periods of small water bearing values of streams of a duration of three and more, six and more and nine and more months in the period between 1946 and 1970 in 144 hydrometric stations it was possible to determine their regional deviations as well as the causes of such deviations. The longest periods of small discharges established since 1931 conform almost in all hydrometric stations with those established between 1946 and 1970. In case they occured in rivers, their duration up to five months was established only in rivers with their drainage area on permeable sandstones, in river sections below reservoirs and in some mountain rivers. Periods of a duration of six up to eight months were most frequent, six- and seven-months periods being more frequent than eight-months periods. The distinctly decreasing number of rivers with the longest period of ten up to eleven months and the isolated cases of periods of a duration of twelve up to sixteen months are indicative of affecting of small discharges in smaller rivers by off-takes of water, accumulation in reservoirs and or other kinds of water management activities.

One set of longest periods of small water bearing of a most frequent duration of six and more months occurred in most rivers in the years 1953—1954 and 1947 when they were of regional character and in the years 1962—1963 and 1969—1970 when they occurred especially in the rivers of the Labe drainage area. Except 1947, these periods lasted from the second half of summer or since the autumn over winter and ended by increased run-off in the time of spring snow melting. They were connected with the exhaustion of groundwater reserves already in summer and with the lack of efficient precipitation in autumn and or in winter which kept lying in the form of snow. In 1947 the period of small water bearing was caused by a considerable lack of precipitation during whole spring and the beginning of summer but even by ineffective precipitation till the end of October. The occurrence of long periods of small water bearing during 1946—1970 indicates that it is possible to expect their repetition in average once in 6 up to 7 years with the exception of the rivers below reservoirs, with drainage areas on permeable rocks and the rivers of highest mountain ranges.

The frequency of the periods of a duration of three and more and six and more months points to the probability of their occurrence (in %) in every year. The smallest probability of occurrence of an at least three-months period is in rivers with the drainage area on permeable rocks where it does not surpass 10 %. The reservoirs decrease the probability of their occurrence to an extent depending not only on their volume and function but even on the distance from the dam. The system of the largest reservoirs on the Vltava River acts in this direction not only on the whole Vltava but even on the Labe River as far as the frontier. Such a period has either occurred not at all since filling-up of the reservoirs or did occur only sporadically. The probability of the occurrence of such periods decreases further even with the growth of the drainage areas of larger rivers. On rivers flowing from the highest mountain ranges of the Czech Massif the probability of their occurrence ranges between 20 and 30 %, in most favourable conditions between 10 and 20 %. With

decreasing altitude above sea level of the catchment area the probability of their occurrence increases attaining 50 up to 75 % in the rivers with their drainage areas on the hilly lands and plains of the Czech Massif and the Western Carpathians. Higher values were established only on analogous rivers in rain shadow and on the rivers of the Carpathian part of the Morava River drainage area where the mountain relief occurs on impermeable rocks of flysch, impermeable products of weathering

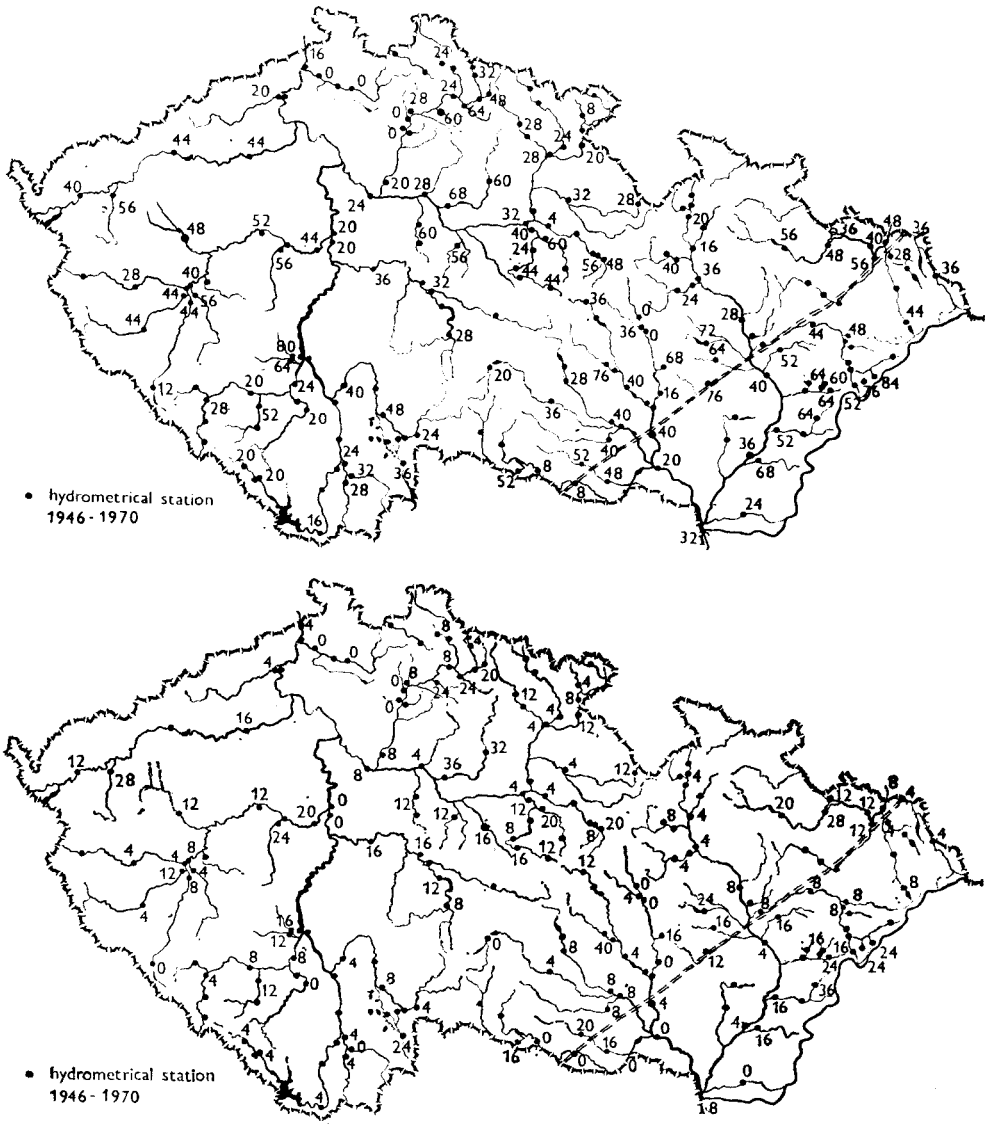


*Fig. 7—8.* Probable occurrence of periods of small monthly water bearing values in year (7 — periods ≧ 3 months, 8 — periods ≧ 6'months)

and soils. In the Bečva River basin on the small Kychová and Zděchovka Rivers on the watershed of the Vsetínské vrchy Mts. it attains the highest values of 76 % and 84 %.

Periods of small monthly water bearing of a duration of six and more months occurred on most rivers except some of the mountain streams. On most rivers with their catchment areas in mountains and higher highlands the probability of their occurrence does not exceed 10 %. It is higher — over 20 % up to 30 % — on rivers with their drainage areas on impermeable rocks irrespective of relief type. It increases even on the rivers whose catchment areas lie in rain shadow. On larger rivers it does not change substantially with the increase of the stream length from their effluence from the mountains. They did not occur at all on rivers below reservoirs except reservoirs for water supply where, quite on the contrary, their frequency increases.

Periods of small water bearing values of a duration of nine and more months occurred only on rivers with their catchment areas on lowland and hilly land relief on impermeable rocks or fine -grained products of weathering and in rain shadow zones. In the period between 1946 and 1970, they occurred only once or twice so that their probability of occurrence was lower every year and amounted to 10 %.

## CONCLUSION

In conclusion it is possible to say of the periods of small monthly water bearing of streams that their duration and probability of occurrence are conditioned in every year not only by precipitation conditions but, above all, by the properties of the rocks, products of weathering and soils determining the formation, exhaustion and filling-up of the groudwater reserves affected even by relief type. The same properties of the natural environment of drainage areas are accordingly involved which are decisive of the total frequency of the occcurrence of small water bearing values expressed by their average duration.

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